THE FEASIBILITY OF DOCUMENTING AND ESTIMATING ADULT FISH PASSAGE AT LARGE HYDROELECTIRC FACILITIES IN THE SNAKE RIVER USING VIDEO TECHNOLOGY

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ABSTRACT

A field study was conducted at Lower Granite Dam on the Snake River in 1992 to evaluate the feasibility of using time-lapse video technology to document and estimate fish ladder passage of chinook salmon *Oncorhynchus tshawytscha,* sockeye salmon *0. nerka,* and steelhead *0. mykiss* using time-lapse video technology.

High quality video images were produced with a time-lapse video system operating in 72 h mode from 1 May through 31 December, 1992 and fish were counted from 1 June through 15 December. From the video record we counted 15 sockeye salmon, 3,283 summer chinook salmon, 1,022 fall chinook salmon, and 125,599 steelhead.

The composite count of target species generated from the video record was similar ($p = 0.617$) to the estimate made by on-site counters during identical time periods indicating that the two methods were precise. Comparisons of 24 h video counts and on-site (10 and 16 h) counts showed that a significant ($p < 0.001$) proportion of target salmonids migrated during the nighttime when on-site counts are not typically made at Lower Granite Dam.

The mean sockeye salmon fork length measured from video images was 453 mm. Mean fork-lengths reported for Snake River sockeye salmon between 1953 and 1965 were much greater (♀ = 546 mm ♂ = 577 mm).

Cost comparisons showed that video costs were less than half those of on-site counting methods. The video method also included the collection of additional data.

A computer software demonstration program was developed that graphically illustrated the possibilities of a completely automated, computerized fish counting and identification system.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This project tests the feasibility of using video technology for estimating and evaluating fish passage at Lower Granite Dam on the lower Snake River. The Snake River is the largest tributary in the Columbia River Basin. Lower Granite Dam is a key fisheries monitoring location used by fisheries managers to assess the status of Snake River salmon stocks. Several of these stocks are in low abundance and have been listed as threatened or endangered under the federal Endangered Species Act (ESA 1973). Conventional fish counting procedures may not be adequate for accurate escapement estimation of these stocks.

The standardized fish counting method now used at all U.S. Army Corps of Engineers (COE) dams including Lower Granite is based on (on-site) visual observations of migrating adult salmon at viewing windows in hydroelectric dam fish ladders. Fish passage is monitored generally between 1 March and 15 December and, during this time period, fish are counted for 10 to 16 hours daily. Fish are counted for the first 50 minutes of each hour of fish monitoring. This 50 minute count is then expanded to estimate fish passage for the entire hour. Fish ladder passage estimates made using the standardized methods now employed are treated as absolute estimates. Because they are not repeatable, these estimates cannot be subjected to tests for accuracy, nor is independent

confirmation of species identification possible. The degree of confidence that may be placed in such estimates is impossible to estimate both for population and for individual specimen identification.

Time-lapse video systems have been used to record salmon passage at various fish viewing stations throughout the Columbia River Basin (Hatch and Schwartzberg 1991). This technique provides the opportunity to calculate variance and place confidence bounds on estimates. Video technology provides a permanent record of fish passage that can be reviewed multiple times by different readers to obtain accurate specimen and population abundance estimates. Time-lapse video also permits 24 h uninterrupted fish ladder passage monitoring. In one study of this methodology (Hatch and Schwartzberg 1991), a significant proportion (approximately 8.5%) of the entire sockeye and chinook salmon runs in the Wenatchee River, Washington, were found to have migrated during the eight hours of the day when fish counting is not typically conducted at COE hydroelectric projects. Video fish counting can also reduce data gathering costs by approximately 80% and increase the amount of data collected by 33% compared with on-site counting.

In most situations, time-lapse recorded video tapes of fish passage contain only a small percentage of frames of actual fish images. Most frames are only of background features and flowing water. However, a counter must

review all tape frames, no matter how many fish are present. To reduce reviewing time, especially during times of low fish passage, we developed a computerized system to edit video tapes, leaving only images of fish passage events (Wand and Hatch 1993). In this project, the system was modified to permit its application in an area of relatively high fish passage, such as Lower Granite Dam. We also initiated development of a completely automated fish counting system that performs fish counting and identification. Computerized image processing techniques have many potential applications for the analysis of fish passage. We believe that in the near future it may be possible for computers to count and speciate fish with speed and accuracy at least as good as human counters. Eventually, computers may even be trained to recognize more subtle characteristics, such as tags, fin clips, and injuries.

The goal of this project is to develop a method to assess adult salmonid passage at Lower Granite Dam that may be more accurate and economically efficient than current methods and one that provides a permanent record of fish passage events, particularly for sockeye *Oncorhynchus nerka* and chinook salmon *0. tshawytscha* stocks that have been listed as endangered or threatened under the Endangered Species Act. The specific objective of the project is to test the feasibility of using video technology to document adult fish passage at Lower Granite Dam. The seven tasks associated with this project are to:

1. Install a time-lapse video system to record adult fish passage at the fish counting station in Lower Granite Dam;

2. Document and calculate fish-ladder passage estimates (for sockeye and chinook salmon, and steelhead 0. *mykiss)* at Lower Granite Dam using time-lapse video technology;

3. Test the precision of fish counts generated from time-lapse video recordings relative to on-site counts;

4. Compare the costs of producing annual fish ladder passage estimates from on-site and video counting;

5. Confirm individual sockeye salmon identification;

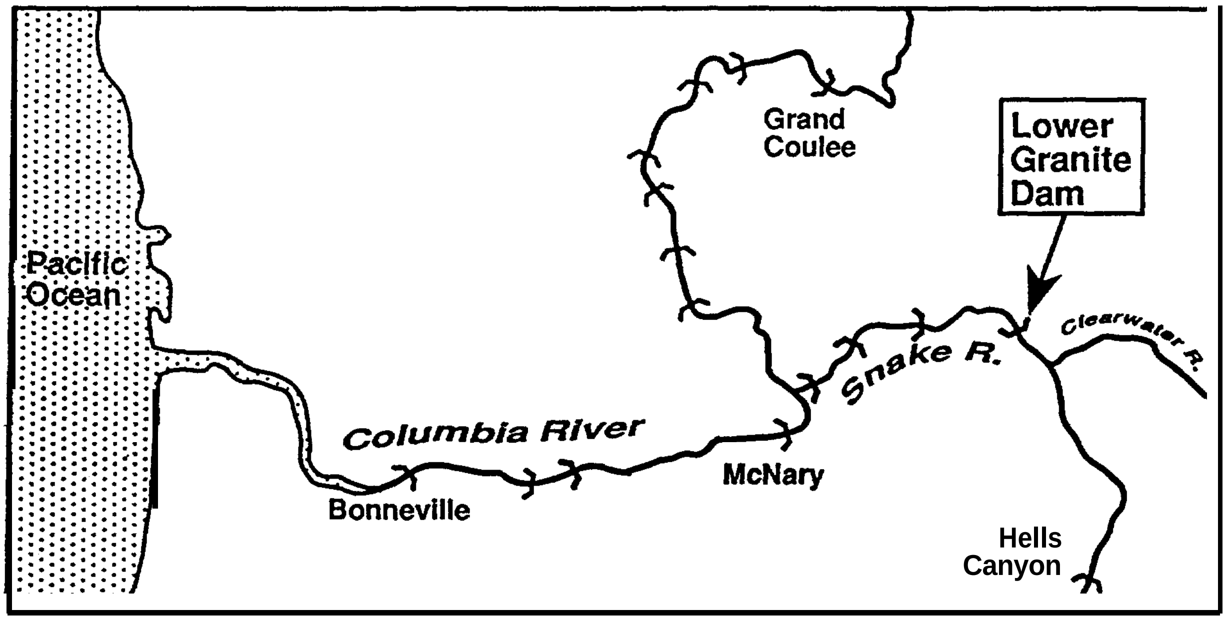
6. Adapt computerized video-tape analysis system for use at large hydroelectric projects; and,

7. Investigate image processing techniques that may permit computerized counting and species identification from video tape records.

DESCRIPTION OF PROJECT AREA

Lower Granite Dam is located at river kilometer (rkm) 107 on the Snake River, Washington (Figure 1). Completed in 1975, the dam is part of the Lower Snake River Project of the COE, and provides river navigation and electrical power generation throughout the year. It is 32 m high and 206 m long, and contains an adult fish passage facility. All upstream migrating fish must pass a single fish counting station (Figure 2). This station included a counting room, with a 116 by 122 mm glass viewing window separating the counting room from the fish ladder. An adjustable crowder varied the width of the counting slot in the fish ladder from 45.7 to 91.4 cm. Fluorescent bulbs behind a glass diffuser located on the crowder provided backlighting.

Figure 1. **Map showing the location of Lower Granite Dam.**



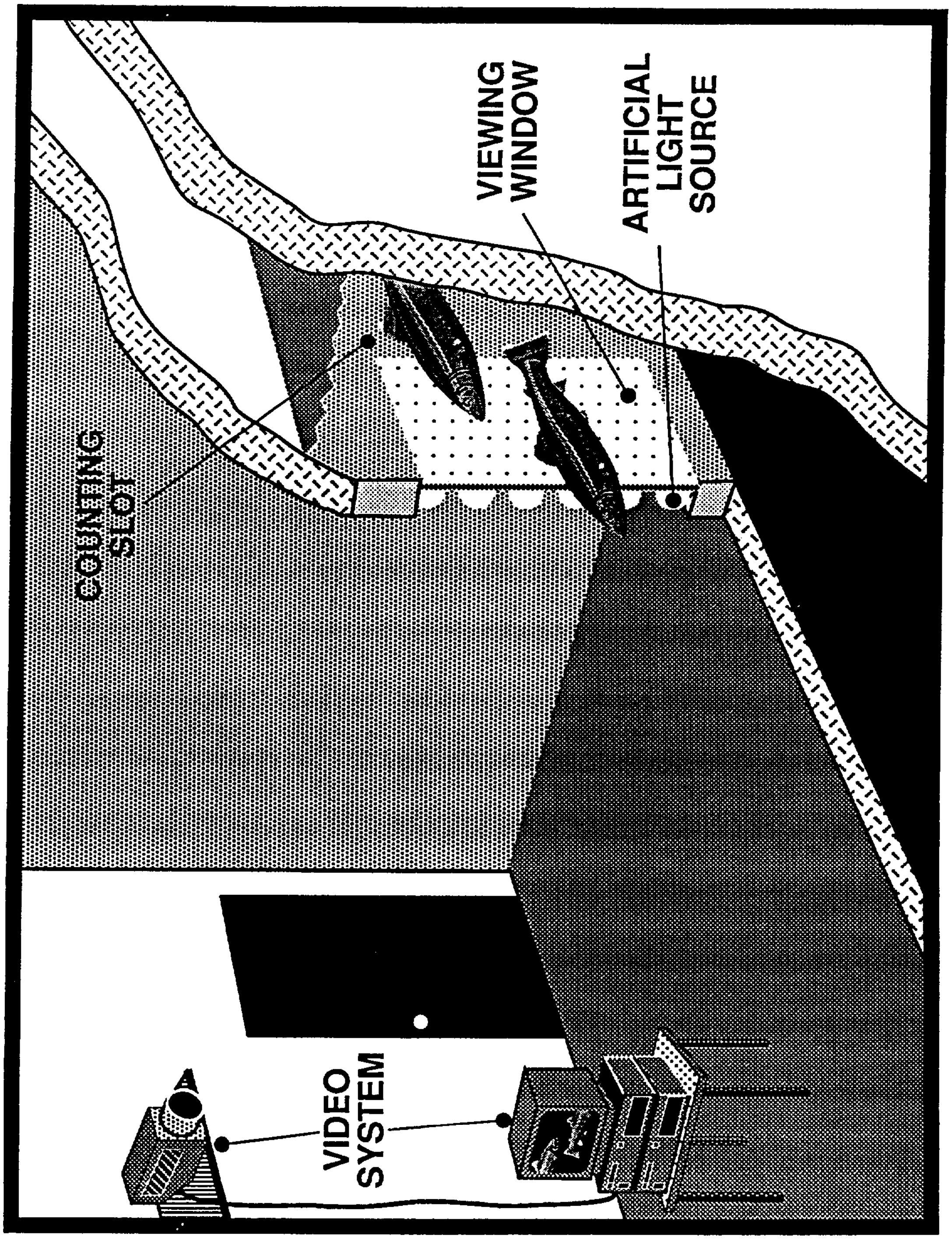
METHODS

Task 1. Recording Adult Fish Passage

A color charged coupling device (CCD) camera (Panasonic WV-D5100) was secured to the back wall of the counting room 2.24 m off the floor (Figure 2). The camera was aimed at the fish viewing window 3.30 m away. The camera was connected to a Panasonic AG-6720 time-lapse Super Video Home System (S-VHS) video tape recorder (VTR). Fish passage was recorded in 72 h time-lapse mode, a VTR setting that yields 1.66 video records per second. It has been determined that this recording speed maximizes the amount of fish passage that can be captured on a given video cassette without missing fish passage during VTR frame advance (Hatch and Schwartzberg 1990). During recording, the VTR imprinted the time and date on each frame of video tape, providing a record of the exact time each fish passed through the counting slot.

Recording took place continuously from 1 April, 1992, through 15 December, 1992. Video tapes were changed five times each week (Monday through Friday) and mailed to our laboratory in Portland, Oregon, for analysis. A few non-recorded time periods in the video record occurred, ranging from 10 minutes (6 September 1992) to 70 hours (8-l 1 May 1992). No data loss representing greater than 10 minutes occurred between 1 June and 15 December when the majority of the data analyzed in this report was collected.

Figure 2. The video fish passage counting system installed at Lower Granite Dam.



Estimates of fish passage during non-recording periods were made by interpolation using an average of the previous and following days' counts.

During this study, several modifications were made to the counting room to improve video tape images. At first, the tapes were of relatively poor quality because lighting was insufficient. On 17 May, six 90 watt halogen flood lights were placed around the viewing window inside the counting room. On 12 August, four more lights were added. In addition, strips of black velvet were affixed to the shelf around the viewing window to reduce incidental glare caused by this extra lighting. Backlighting was turned off, and the crowder was adjusted to narrow the width of the counting slot to 45.7 cm. These adjustments provided lighting conditions that produced good-quality video tape images and were compatible with on-site counting procedures.

The video camera was originally placed in its upright position, and captured a 115.6 by 78.6 cm section of the viewing window. This field of view encompassed the entire width of the window, but did not include the top 43.3 cm. In an attempt to reduce the area missed, the camera was readjusted on 9 July to capture a 115.6 by 86.1 cm section of the viewing window. The camera was readjusted on 12 August by orienting it vertically (turning it on its side) to eliminate the possibility of fish avoiding the upper limit of the camera's

field of view. This modification allowed the camera to capture the entire height of the viewing window and 86.4 cm of the window's width.

Task 2. Fish Ladder Passage Estimates Using Time-Lapse Video

Tapes were reviewed by an experienced fish counter using a special VTR (Panasonic AG-1960) equipped with a jog/shuttle dial. This dial allows precise control of tape movement, in forward or reverse, at speeds ranging from freeze frame to 7X normal speed. Steelhead, chinook adult and chinook jack (< 55.9 cm) salmon, and sockeye salmon counts were tallied for the first 50 min of each hour and for the entire hour. All hourly counts were summed to produce daily counts, which were distributed to several agencies within one week after recording.

The average dates of migratory timing and their associated standard deviations were calculated (Mundy 1982) for steelhead, sockeye, and chinook salmon at Lower Granite Dam.

Nighttime counts for each species were calculated. Nighttime hours were considered to be those hours when on-site counts were not made: 2100 to 0500 from (1 June to 24 October), 2000 to 0400 from (25 October to 31 October), and 1600 to 0600 from (1 November to 15 December).

Particular attention was paid to observations of sockeye salmon because of the importance placed by fishery managers on conservation of this stock and the relatively small number of fish in this population. Whenever a sockeye salmon was observed, its fork length was measured and recorded. Length was determined by measuring the fish image in each frame and using the maximum length. Measurements were calibrated to a standard of known length.

Task 3. Precision of Video Relative to On-Site Fish Counting

Three tests were performed to investigate the precision of video-based fish passage estimates relative to on-site fish counting. Paired Wilcoxon Tests (Conover 1980) were used to compare video-based and on-site fish counts. For all tests α, the probability of a Type I error, was set at 0.05. The first test compared daily fish passage estimates for chinook salmon, chinook salmon jacks, steelhead, and sockeye salmon. On-site counts were provided by the COE, whose estimates were made by counting for 50 min out of each hour for 10 or 16 hours per day. At the end of each day the counts were expanded by a factor of 1.2 to account for the 10 min break periods taken each hour by fish counters. Depending on the time of year, counts were made for either 10 or 16 hours in a given day. Our video-based fish counts were made for the entire 10 or 16 hour period corresponding to COE's counting-day length. The second test utilized the same COE data described above, but the video data consisted of 24 hour fish passage estimates.

To investigate the potential error that the 1.2 expansion factor, used to adjust 50 min counts to estimate hourly fish passage, had on fish passage estimates, we conducted a paired Wilcoxon Test on video data. We used daily fish passage estimates generated from 60 min counts compared with estimates generated from 50 min counts expanded by 1.2.

A potential source of counting error attributed to video counting is the possibility of a fish swimming past the viewing window at a velocity great enough to exclude the capture of the fish image on time-lapse video tape. To determine if it was possible for fish to pass the viewing window without being recorded on the tape, we conducted an experiment to calculate the average amount of time that fish spend in the viewing window. The video signal from the camera was routed to a second VTR recording simultaneously with the primary VTR used in this study. This second VTR recorded in 6 h time-lapse mode, a speed that generates 60 video records per second. In contrast, the primary VTR, recording in 72 h mode, generated 1.66 video records per second. The 6 h recordings were made on 7 randomly selected days. The number of frames were counted that each individual fish appeared on each 6 h tape. From these data the probability of a fish appearing in X number of 72 h time-lapse recorded video frames was calculated.

Task 4. Video and On-Site Counting Cost Comparisons

On-site counting costs were estimated by calculating the total number of hours during which counting was performed and multiplying by $12, the approximate wage of on-site fish counters. On-site counting generally takes place for 16 h/day (1 March to 15 December) or 10 h/day (1 November to 15 December), and is performed 7 days per week. No additional costs were taken into consideration.

Video-based counting, which provided counts for 24 h each day, required approximately 4 h of work per day, 5 days a week. In addition to salary costs: equipment , video tape, and mailing expenses were also taken into consideration. Equipment costs were amortized over a 3 year period, the estimated life span of the equipment.

Task 5. Confirm Individual Specimen Identification

The permanent video tape record was used several times throughout the season to verify the passage of individual sockeye salmon. The majority of the time that on-site counters observed a sockeye salmon, the time and date of passage was noted. Coincidence of observation between the two methods helped to verify individual specimen identification. On the occasions when on-site counters identified a sockeye salmon but video counting originally did not, the video record was further reviewed for confirmation. On the occasions

when sockeye salmon were identified by video counts but not by on-site counts, no further analysis could be made.

Task 6. Computerized Video Tape Editing System

The computerized video tape editing system was designed to reduce the amount of time required to review fish passage recordings. Previously developed in another project (Wand and Hatch 1993), this system edited tape records from areas with relatively low fish passage. For this project, the system was modified to permit operation with tapes recorded at Lower Granite Dam. The editing system is composed of a personal computer (HP Vectra 486/33T), a digital image processing frame grabber board (Sharp GPB-I), two computer-controlled VTRs (Panasonic AG-7350, NEC PV-S98A), and custom-written software. This system automatically scans recorded video tapes, and dubs those sections containing fish images onto another tape.

Task 7. Computerized Counting and Species Identification From Video Tape Records

Tardis Systems Inc., an image processing consulting group based in Los Alamos, New Mexico, was contracted to undertake a proof-of-principle study to examine computerized fish counting. A software demonstration program was created that uses a number of advanced image processing techniques to count and speciate fish on several digitized sequences of video frames.

The demonstration program performs five primary steps on the video tape frames being analyzed. These steps are to:

a. Determine whether a fish is present in the current frame;
b. Remove the background from the frame if a fish is present;
c. Locate each discrete object, or *blob,* and extract relevant features;
d. Analyze each blob to determine the number and species of fish present in the frame;
e. Count fish passage by keeping track of when fish enter and exit the counting slot.

a. Detecting the presence of fish

Each sequence to be analyzed begins with a *background frame,* or a frame containing no fish. Subsequent frames are compared to this background image to determine if fish are present. The *luminance,* or brightness, values of all the pixels in a frame are summed and divided by the number of pixels per frame, thereby giving the average luminance value of an entire frame. This value is compared to the average luminance value of the background image. It has been determined that if the two values differ by more than I%, a fish is usually present in the frame.

b. Background removal

If a fish is present in the frame being examined, background removal takes place. The object of this step is to remove all pixels that comprise the background, leaving only those pixels that make up the fish image. An averaging convolution is first performed on both the frame and the background image to filter out image noise. Next, each pixel in the current frame is

compared to the corresponding pixel in the background image. If the luminance values of the two pixels differ by more than a preset amount, that pixel is considered to be part of the foreground, and is retained. If the two luminance values are similar, the pixel is considered to be part of the background, and is removed (luminance is set to 0).

c. Blob segmentation

Once the background has been removed, all the remaining pixels make up discrete groups that must be processed. Each group of connected pixels is classified as a blob, and the following features are extracted:

- coordinates of the smallest rectangle encompassing the blob
- area of the blob
- coordinates of the blob's center of mass
- extent (ratio of width to height)
- radius measurements from the blob's center of mass

d. Blob analysis

Following segmentation, each blob is analyzed to determine how many fish it contains and to identify the species of each fish. First, several vertical lines are passed through each blob. The second derivative of the luminance values along each line is calculated. This statistical process locates sudden changes in luminance across the blob that indicate overlapping fish. Also, the edge profile of each blob is used to count the number of tails. Tails were one of the features used to determine the number of fish present. Speciation occurs by locating

the center of mass and several morphometric features (such as the tail and the dorsal fin) on each fish, and measuring distances among them. These measurements, that are different for each species, allow speciation of each fish.

e. Counting

The counting process utilizes a relatively simple algorithm. It works by increasing the count whenever the number of fish in a frame is greater than the number of fish in the previous frame (i.e. a fish entered the counting slot). If the number decreases, a fish presumably left the counting slot, but no action is taken since the fish was counted when it entered.

The demonstration program was tested on three different frame sequences. Sequence 1 contained five fish images on six frames. Sequence 2 contained 13 fish images on 10 frames. Sequence 3 contained 29 fish images on 14 frames.

RESULTS

Task 1. Recording Adult Fish Passage

A total of 123 video tapes were recorded, changed, and mailed during the period from 1 June to 15 December. One tape was lost in the mail and not received for review. Image quality was good to excellent, especially after lighting modifications were made (Figure 3).

Task 2. Fish Ladder Passage Estimates Using Time-Lapse Video

Adult chinook and jack salmon, steelhead, and sockeye salmon fish passage estimates derived from video tape records from 1 June through 15 December 1992 were 7,020, 666, 125,599, and 15; respectively (Appendix A, B, C). Summer chinook adult and jack counts were 2,924 and 359. Fall chinook salmon adult and jack counts were 858 and 164. The mean dates of passage at Lower Granite Dam were 28 July, 29 September, 7 October, and 22 July, for summer chinook, fall chinook, steelhead, and sockeye; respectively. The associated standard deviations were 7.1, 20.8, 20.2, and 21.4, for summer chinook, fall chinook, steelhead, and sockeye; respectively. Adult chinook salmon passage distribution showed a peak on 2 July and passage counts dropped to near zero from approximately 30 July through 3 September (Figure 4). Jack chinook salmon passage distribution generally followed that of adults (Figure 5). Steelhead passage generally showed a normal distribution

Figure 3. **Digitized images of fish passage from the video tape record. Clockwise from upper left: steelhead, sockeye, chinook jack, and chinook adult. The digitizing process has reduced actual video image quality.**

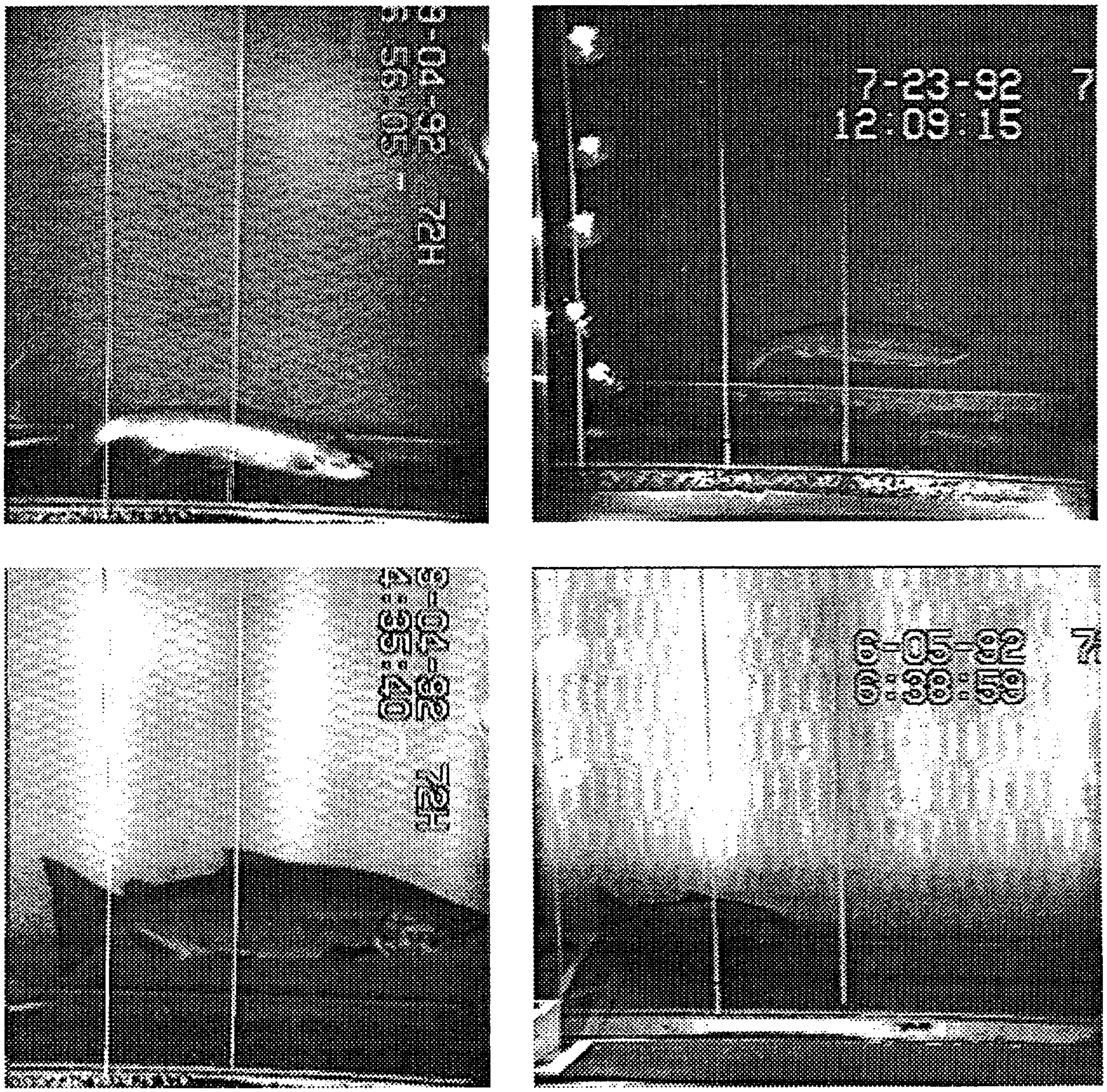


Figure 4. Snake River adult chinook salmon fish ladder passage counts made at Lower Granite Dam, using video technology, in 1992.

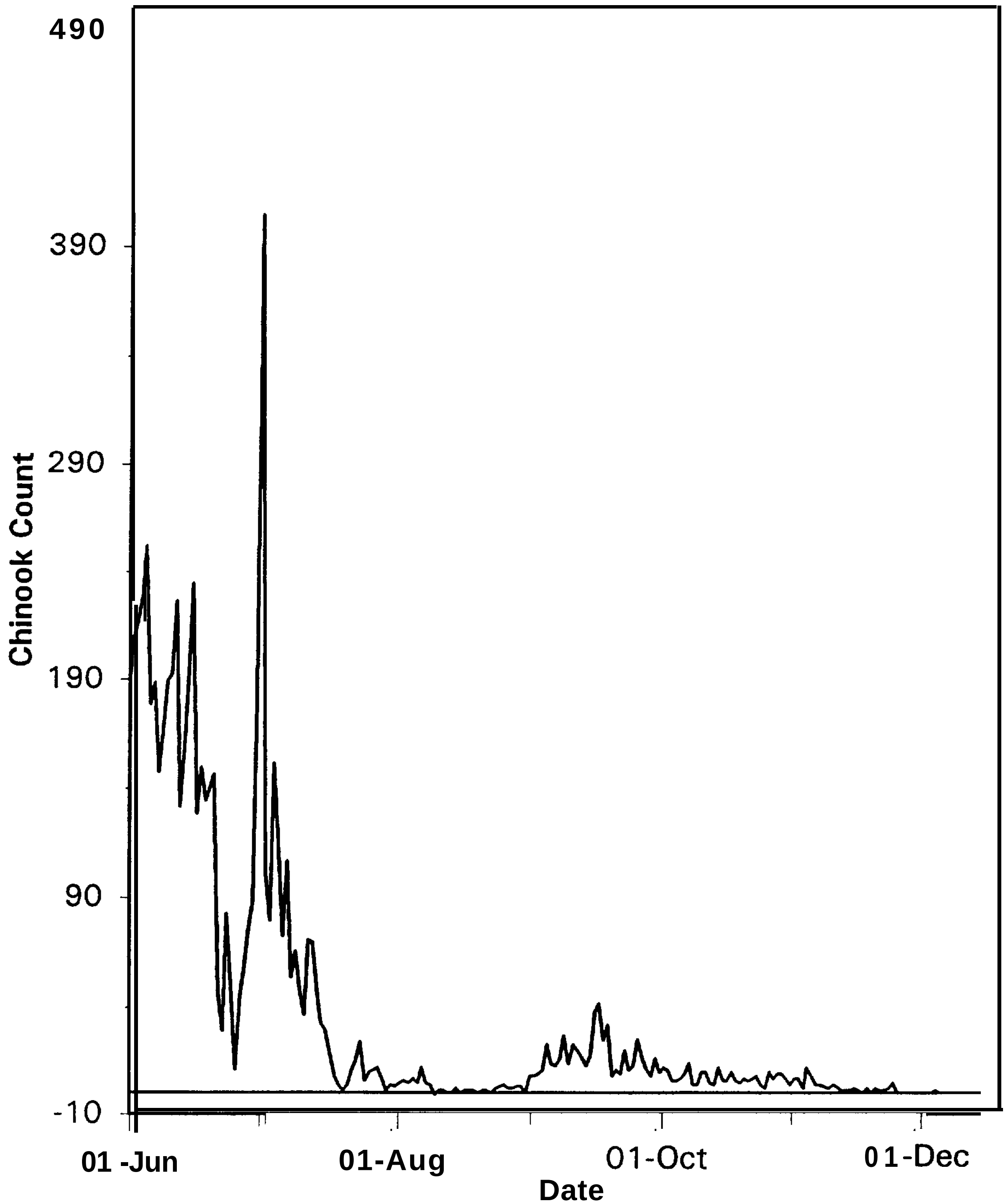
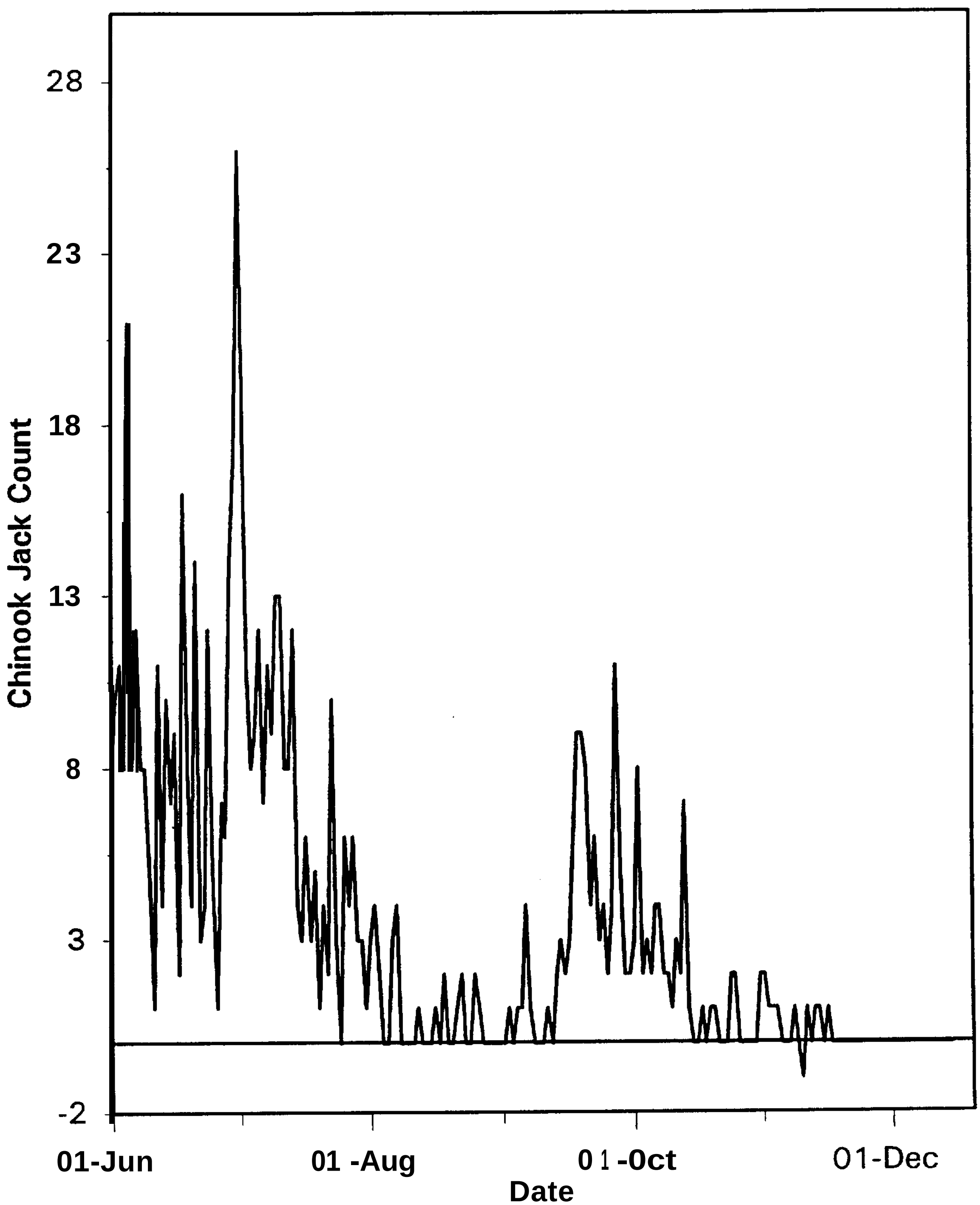


Figure 5. **Snake River jack chinook salmon fish ladder passage counts made at Lower Granite Dam, using video technology, in 1992.**



with the bulk of passage occurring between mid-September through October (Figure 6). The maximum daily count of sockeye salmon was two (Figure 7).

From 1 June through 15 December a total of 133,300 fish of target species (chinook salmon, steelhead, and sockeye salmon) were counted. Of these 133,300 fish, 8,555 (6.4%) were counted during the nighttime. The nighttime is that period of time when COE fish counting was not conducted. Video counts of nighttime fish passage were 244 (3.5%), 27 (4.1%), 3 (20.0%), and 8,281 (6.6%), for adult chinook salmon, jack chinook salmon, sockeye salmon, and steelhead; respectively (Figure 8).

The sockeye salmon length frequency ranged from 356 mm to 539 mm. The average estimated length of sockeye salmon was 453 mm (Figure 9).

Task 3. Precision of Video Relative to On-Site Fish Counting

In Test 1, comparison of video and on-site daily fish counts (16 hr or 10 hr days) revealed that there was a nonsignificant ($p = 0.617$) difference in the composite count of target species (chinook, steelhead, and sockeye). Paired Wilcoxon Tests also resulted in nonsignificant differences between the two methods using sockeye salmon ($p = 0.096$) and steelhead counts ($p = 0.305$). Video counts of chinook salmon were significantly less than on-site counts for

Figure 6. **Snake River steelhead fish ladder passage counts made at Lower Granite Dam, using video technology, in 1992.**

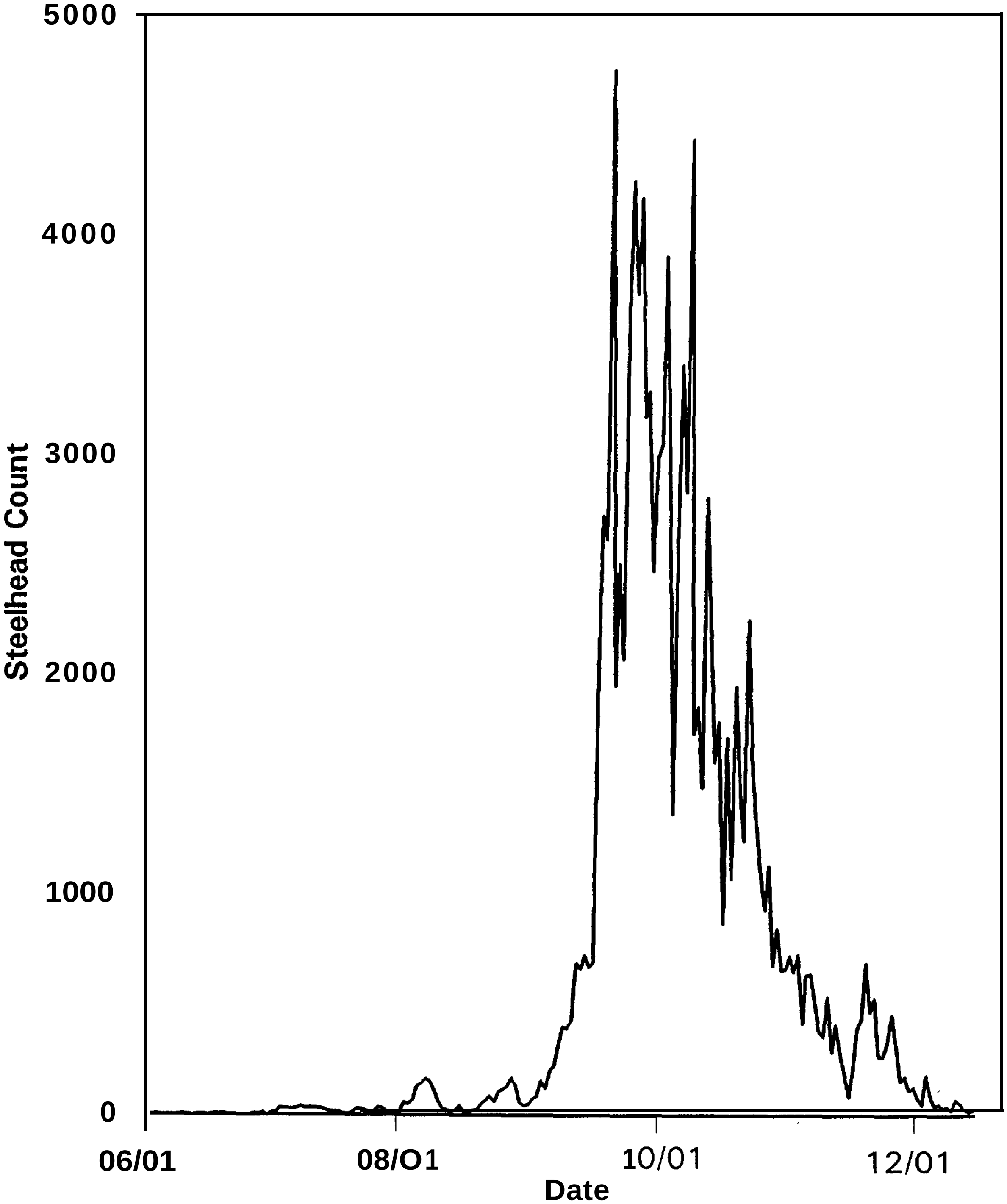


Figure 7. Snake River sockeye salmon fish ladder passage counts made at Lower Granite Dam, using video technology, in 1992.

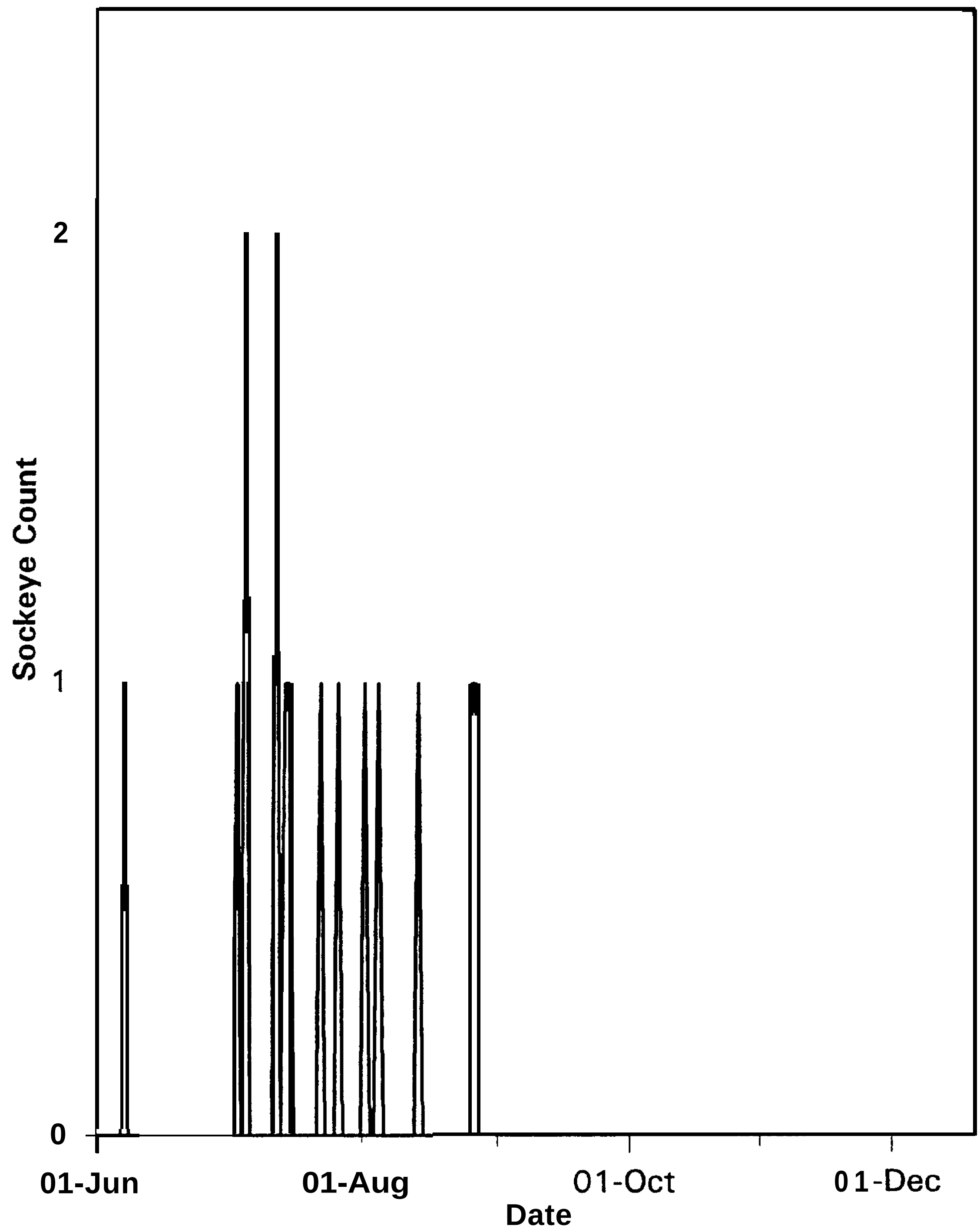


Figure 8. Steelhead, chinook, and sockeye salmon fish ladder passage counts as a function of time of day recorded at Lower Granite Dam in 1992.

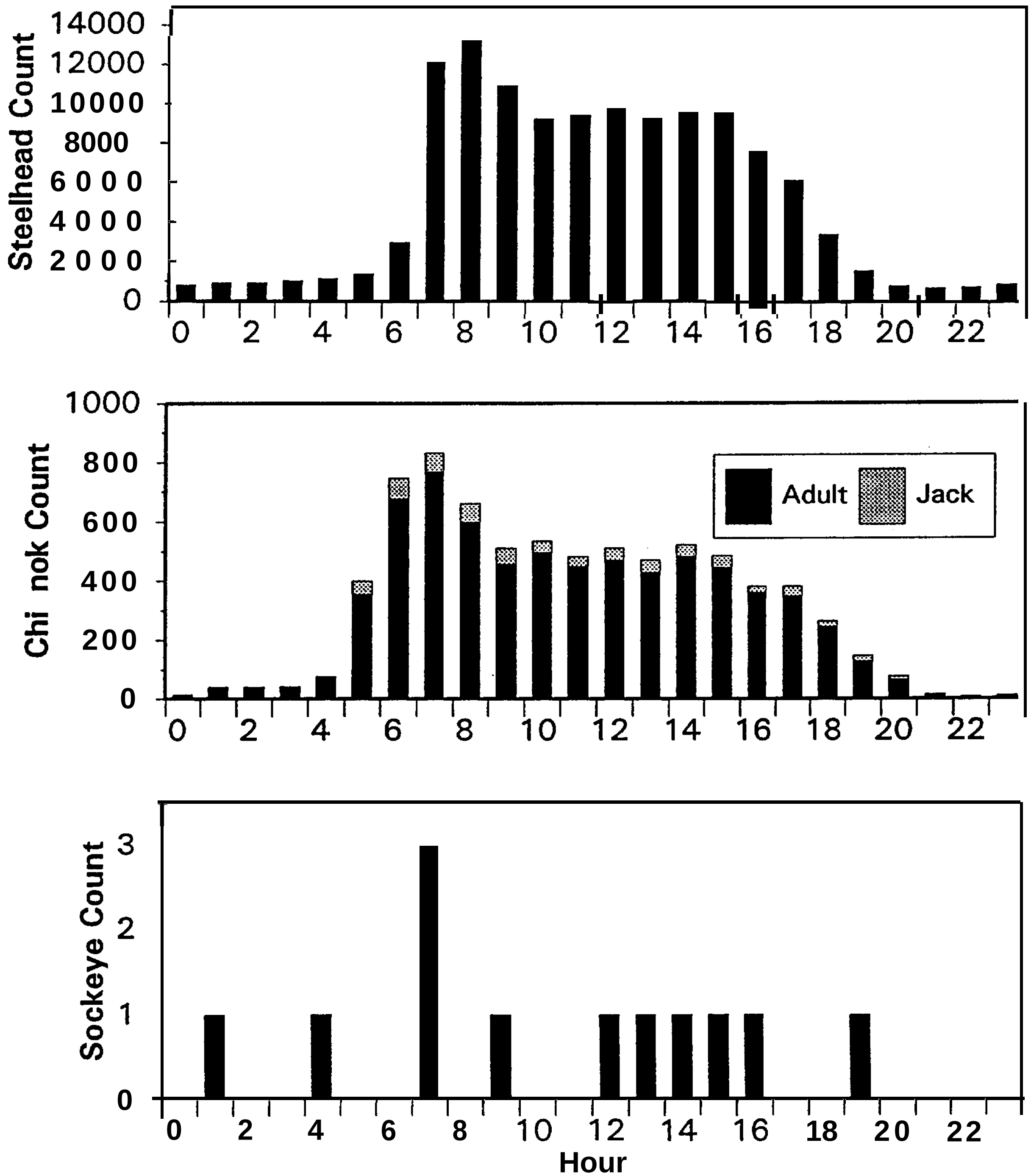
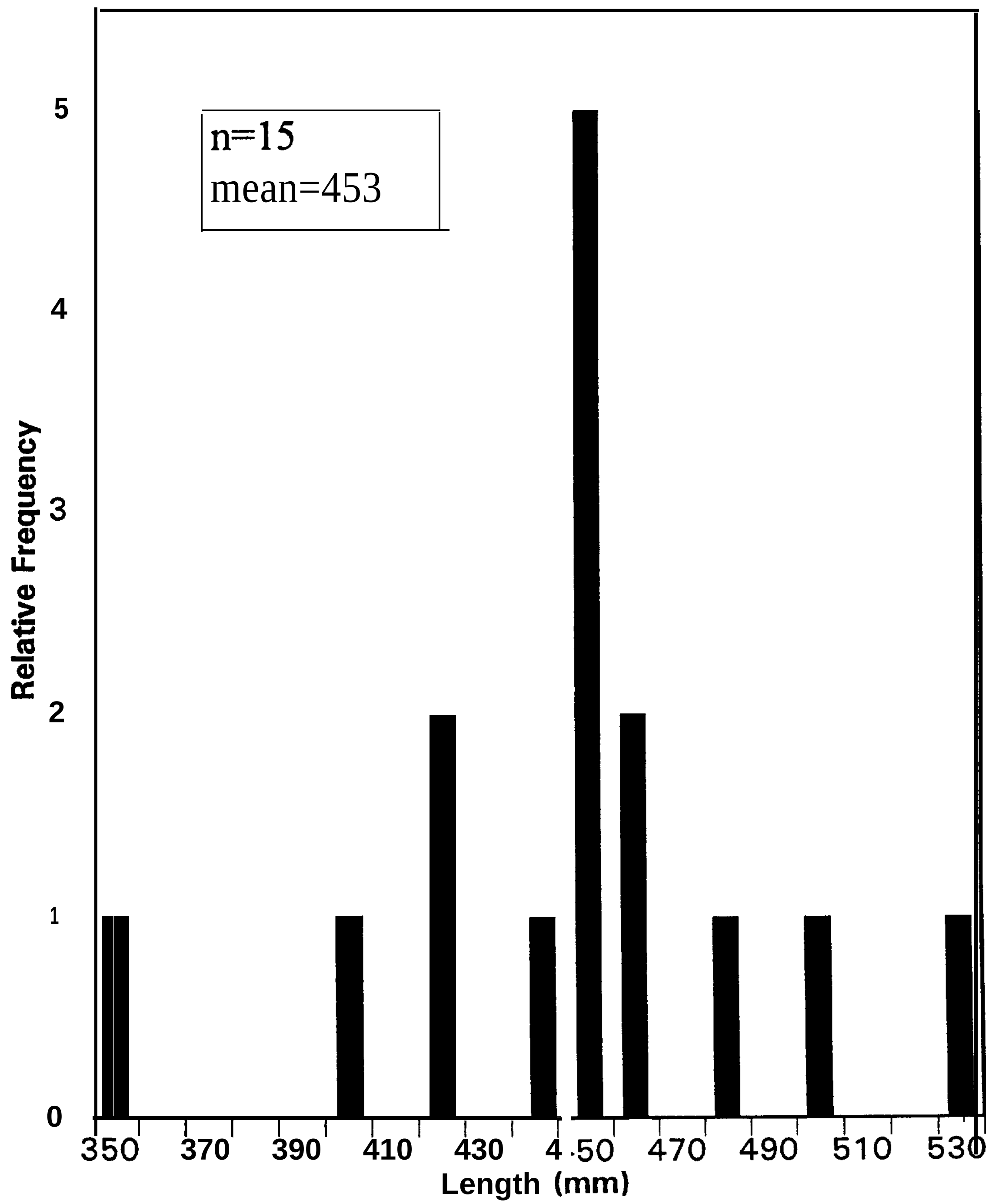


Figure 9. Sockeye salmon length frequency measured from video images recorded at Lower Granite Dam, in 1992.



adults and jacks combined ($p < 0.001$), and for separate adult ($p < 0.001$) and jack ($p < 0.001$) counts.

In Test 2, the comparison of daily on-site fish counts (16 h or 10 h) to daily video counts (24 h) revealed a significant ($p < 0.001$) difference in the composite count of target species (chinook, steelhead, and sockeye). Steelhead, chinook adult, and chinook jack counts were also significantly different ($p < 0.001$, $p = 0.042$, and $p = 0.001$; respectively). Paired Wilcoxon tests utilizing sockeye and combined chinook adult and jack counts revealed nonsignificant differences ($p = 0.564$ and $p = 0.992$, respectively).

In Test 3, we found that the COE practice of counting fish for 50 min and expanding that count by a factor of 1.2 to represent hourly fish passage had no effect on estimates. Using 50 min expanded data and complete 60 min daily counts derived for video tape, we determined that there was no significant difference for counts of chinook adults, chinook jacks, steelhead, and sockeye ($p = 0.441$, $p = 0.114$, $p = 0.628$, and $p = 1.00$; respectively).

The average and minimum amount of time that individual fish spent within the viewing window was 5.48 and 2.77 sec for chinook salmon jacks, 4.49 and 1.70 sec for chinook salmon adults, and 3.20 and 0.93 sec for steelhead. These calculations were based on sample sizes of 22, 90, and 92;

for chinook salmon jacks, chinook salmon adults, and steelhead; respectively. Each of the three fish categories had a 100% probability of being seen in at least two video frames (Table 1).

Task 4. Video and On-Site Counting Cost Comparisons

On-site counting took place for 3,874 h during 1992. Assuming an hourly wage of $12.00 for a counter, the cost for the 1992 season would be $46,488. This does not include indirect, equipment, or administrative costs.

Over the same period, video-based counting would cost approximately $12,566/year. A video tape counter would spend approximately 740 h reviewing tapes ($12.00/h) for a total cost of $8,880. The 185 video tapes used each year cost approximately $8.50 each, and mailing fees are $2.90 per tape. Since tapes are changed and mailed five times per week, the total expenditure for tapes and mailing fees would be $2,109. Video equipment costs are summarized below:

1 Panasonic AG-6720 Time Lapse VTR	1,698
1 Panasonic AG-1960 VTR	967
1 Panasonic WV-D5100 Color CCD Camera	1,060
1 Panasonic WV-LZ14/8AF Zoom Lens	420
1 Panasonic WV-3203B Power Supply	72
1 Panasonic WV-CA1 0 Power/Camera Cable	25
2 Panasonic CT-l 382Y monitors	498
Total Equipment Cost	$4,731
Total Amortized Annual (3 yrs) Equipment Cost	$1,577

Table 1. The probability of an individual fish of the target species appearing in X number of video frames in 72 h time-lapse recordings.

Species	n	1 frame	2 frames	3 frames	4 frames	5 frames
Chinook	90	1.00	1.00	1.00	0.93	0.86
Chinook jack	22	1.00	1.00	1.00	1.00	0.98
Steelhead	92	1.00	1.00	0.98	0.90	0.80
Weighted mean	204	1.00	1.00	0.98	0.90	0.80

Using the same salary rate and equipment costs, extending video-based counting to 50 weeks per year would increase the total project cost to $16,427/year.

Task 5. Confirm Individual Specimen Identification

Fifteen sockeye salmon were reported by on-site counters. Of these, twelve were positively confirmed using video tape. The remaining three sockeye salmon reported by on-site counters could not be found in the video record, even though the approximate time of passage was known (Appendix C). We did note that fish of sizes and shapes similar to sockeye were present at the times two of the three unconfirmed on-site observations were made. However, careful analysis of video images revealed that these fish were different species (Appendix D, E). The third observation could not be corroborated with the presence of any fish on video tape. Additionally, three sockeye salmon were counted during the nighttime with video.

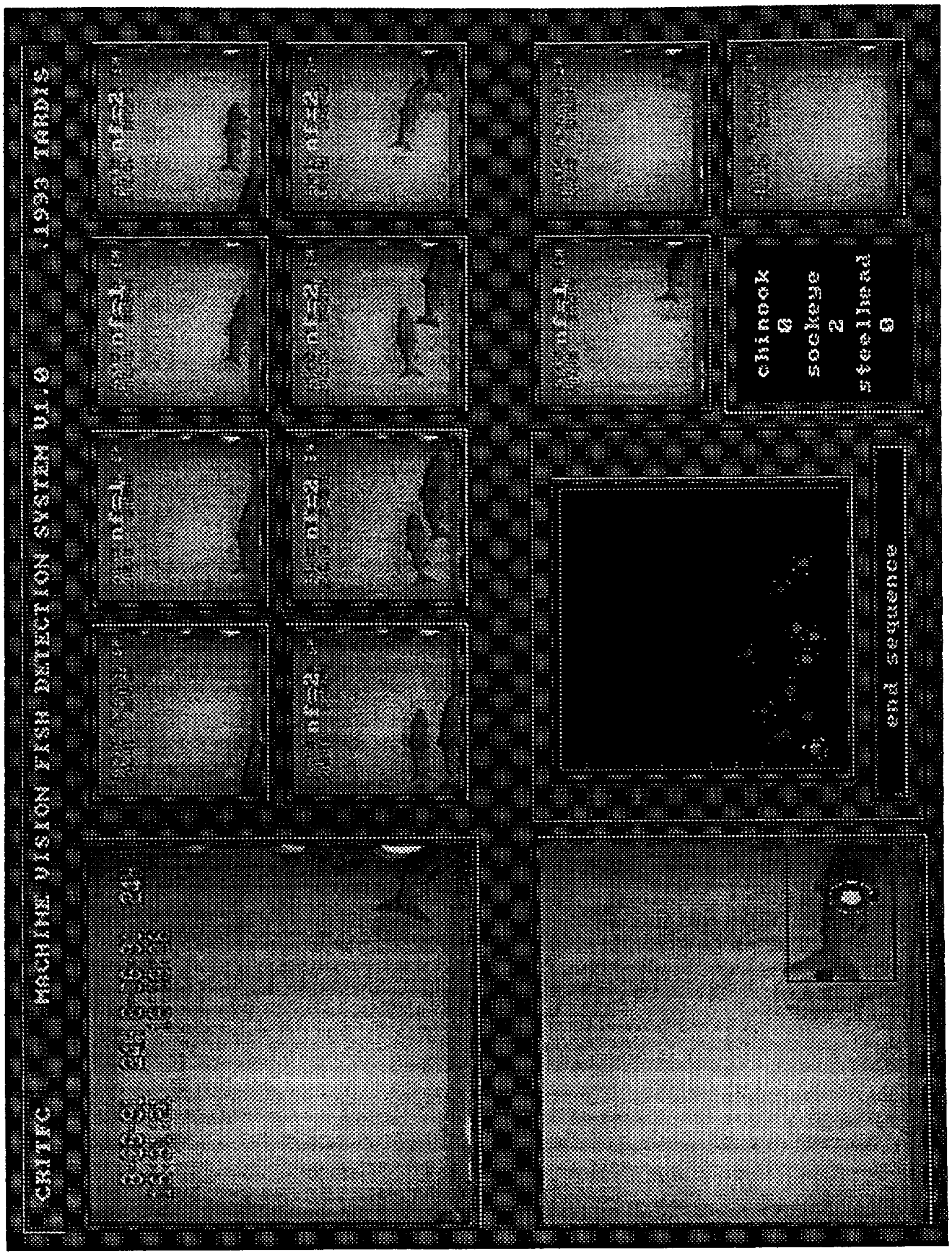
Task 6. Computerized Video Tape Editing System

The system has been modified, but has not yet been used to edit tapes from Lower Granite Dam. Most of 1992 was spent testing video equipment.

Task 7. Computerized Counting and Species Identification From Video Tape Records

The demonstration counting and speciation program correctly located and identified 46 out of 47 different fish images on three different video sequences consisting of a total of 30 frames (Figure 10).

Figure 10. Screen capture of computerized fish counting demonstration program.



DISCUSSION

We were able to record fish passage at an established fish counting station by using current video technology. This information provided 24 h counts from 1 June, 1992, through 31 December, 1992. Good-quality video images were produced, enabling a reviewer to count and identify fish. We recommend that several relatively inexpensive modifications be made to the Lower Granite Dam fish counting facility to improve future image quality and enhance on-site counting conditions.

There is a small semi-circular trough in the floor of the counting slot. Although designed to accommodate the brush that cleans the viewing window, the brush is larger than the trough, thereby allowing the lower 7 cm of the viewing window to accumulate algae and dirt. We recommend that a ramp be added to the floor of the counting slot to direct fish off the floor and into the center of the viewing window.

The artificial lights used in this study were aimed at the viewing window. Reflected light sometimes caused problems with on-site counting, and to a lesser degree with video counting. We recommend that lights be enclosed in a cabinet to reduce glare from the viewing window. The cabinets should be lined with reflective material to increase light transmission. The existing backlighting creates

shadows and poor image quality and should be replaced with a white background. This would provide a uniform surface to diffuse light and increase contrast between fish and background features.

The mean fork length of sockeye salmon was 453 mm measured from video recordings at Lower Granite Dam. Bjornn et al. (1968) reported that the Snake River sockeye salmon females and males averaged 546 and 577 mm during the period 1953 through 1965. The minimum fork length reported by Bjornn during this period was 483 mm. Only two of the sockeye salmon that we measured exceeded this minimum size.

Interest has been paid recently by fisheries managers and others to conservation of Snake River sockeye salmon stocks. One important question that has been repeatedly raised is whether the few sockeye salmon remaining in the Snake River are the same stock as the one historically present. Another debated question is whether fish passing Lower Granite Dam today are anadromous sockeye, resident kokanee, or the anadromous progeny of kokanee. Our length measurements of Snake River sockeye salmon suggest some differences between historic and present day stocks. A possible explanation for this difference is that the mean length of Snake River sockeye has changed in the last 28 years. It is also possible that the fish we observed at Lower Granite Dam represented a different 0. *nerka* stock.

From the video record, we were able to successfully verify twelve sockeye salmon that were reported by on-site counters. We also believe that two of the 15 sockeye salmon that were reported by on-site counters were misclassified. By using the time of passage that on-site counters reported to us, on one occasion we located a 330 mm shad (Appendix D) and on the other a 508 mm steelhead (Appendix E). The lengths of the fish reported by on-site counters for these passage times were also 330 mm and 508 mm. When we inspected the video record for the third unverified sockeye salmon reported by on-site counters we were unable to locate any fish other than shad. Since the time of passage for this fish was reported only to the nearest hour, we reviewed several nearby hours of the video record.

By replacing the current mechanical talliers that the on-site counters use for fish enumeration with an electronic tallier that would record the exact time of passage of each fish, individual specimen identification would be much more precise. The time recorded by the electronic tallier could be synchronized with the VTR.

Composite fish counts (all target species combined) were found to be similar when comparing daily on-site (10 and 16 h) fish passage counts to video based methods. This indicates that video counting is precise relative to on-site methodology. Results of tests using steelhead and sockeye salmon counts were

also similar. However, results showed differences in counts for total chinook salmon, as well as those of adults and jacks tested separately. There are at least two possible explanations for the differences in chinook counts.

First, there may have been a classification error by either video-based or on-site counters. The video-based counter may have classified some chinook salmon as steelhead. On-site counters may have classified some steelhead as chinook salmon. This is possible, since the average daily chinook total counts were higher for on-site than video based estimates. Also, average daily on-site steelhead counts were lower (although not statistically significantly) than video-based estimates. Recounts of some periods of the video record were made, and preliminary results indicated that video counters were classifying chinook salmon and steelhead correctly. We plan to further investigate the accuracy of species classification from video records next year. Unfortunately, since on-site counting is not repeatable the same tests can not be applied to that method.

Second, theoretically, fish passage could have occurred simultaneously as the VTR advanced to the next frame. Consequently, the fish image would not have been captured on video tape. We believe that this is not possible, particularly with chinook salmon, based on the results from our test of the probability of a fish appearing in a given number of video frames (Table 1). This test showed that there was a 100% probability that adult and jack chinook salmon would appear in

at least three video frames when recording in 72 h time-lapse. Further, all target species had a 100% probability of being captured in at least two video frames when recording in 72 h time-lapse. In addition, composite counts were similar using the two methods.

When comparing daily fish passage counts between video-based (24 h) and on-site (10 to 16 h) methods, composite counts were significantly different, indicating the importance of nighttime fish passage. The composite nighttime passage comprised 6.42% of the total run. Tests using only sockeye salmon counts were nonsignificant, but this is a result of the small number of sockeye observed by either method. However, nighttime sockeye salmon passage was substantial, comprising 20.0% of the run. This compares with nighttime passage estimates for sockeye salmon of 6.3% recorded on the Wenatchee River (Hatch et al. 1992), and a range of 5.0% to 13.9% recorded at Bonneville, The Dalles, and John Day dams in 1973 and 1974 (Calvin 1975). Tests using chinook salmon adult and jack and steelhead counts were all significant. Nighttime passage for chinook salmon was 3.5%. This compares to estimates of 14.6% recorded on the Wenatchee River (Hatch et al. 1992) and a range of 1.9% to 14.2% recorded at Bonneville, The Dalles, and John Day dams in 1973 and 1974 (Calvin 1975). Tests using combined chinook adult and jack counts were nonsignificant. This result is confounded by Test 1, in which a difference was found.

The mean daily video-based combined chinook count was lower than the on-site count in Test 1 and then in Test 2 the video-based mean was increased because of nighttime passage while the on-site mean remained the same. This could be a result of misclassification of jack and adult chinook. The mean daily video-based adult estimate was lower than the on-site estimate and the jack estimate was higher than on-site estimates. It is probable that video-based counters were better at classifying jacks because the video allowed the counter to freeze individual frames and measure images. On-site counters were not able to measure individual fish but made a judgement of size relative to lines placed on the viewing window. Tests using steelhead were significantly different between video-based and on-site estimates. This is attributed to nighttime passage, estimated to be 6.6% of the run. This estimate is lower than the 17.9% recorded on the Wenatchee River (Hatch et al. 1992) and in the middle of the range of 1.9% to 14.2% recorded at Bonneville, The Dalles, and John Day dams in 1973 and 1974 (Calvin 1975).

Tests on the effect to passage estimates that expanding daily counts by a factor of 1.2 to account for "break" periods were all nonsignificant. This indicates that the overall distribution of fish passage is normal (Hays 1988).

We have shown that operating costs of video-based counting are only 27% of on-site counting costs. If video-based counting were implemented throughout

the entire year (counting 50 weeks, 2 weeks dewatered), the total cost would be 35% of current estimated on-site method. These savings mainly result from lower personnel costs associated with video-based counting. While on-site counting typically occurs 16 hours per day, a counter using a video-based system can review a full day's records (24 hours) in 4 hours, a personnel savings of 75%.

In addition to a significant cost reduction, video-based counting has the added benefit of generating complete counts. While on-site counts are based on 50 min of each hour and typically 16 hours a day, video-based counts were made 60 min of each hour and 24 hours a day. Although there was no significant difference between 60 min and expanded 50 min counts, we have shown that a significant amount of fish passage occurs during the nighttime hours when COE counting is not conducted.

On-site counts are generally available to fishery managers within 24 to 48 h of actual passage. In contrast, video based counts from this project took 3 to 7 days to generate. Most of the delay was a result of the time required to mail tapes from Lower Granite Dam to our laboratory in Portland, Oregon. If video-based counting had been performed on location, counts could have been produced with a delay of less than one day.

Speeding up the tape review process by using a computerized editing system to reduce the volume of video tape that an individual must inspect could enhance the utility of the counting method. We intend to fully test and implement such a system at Lower Granite Dam in 1993.

We believe that the fish counting program described in this report demonstrates that it is possible to fully automate video fish counting and accurately count and identify fish using existing technology and current image processing techniques. Such a system would run in real-time (30 frames/sec), and be capable of counting under a variety of conditions. Based on our study and those of others (McCarthy 1988, Irvine et al. 1991) a working system could be implemented at a selected location as early as next year.

For a system to count and speciate fish, a huge amount of information must be processed for each frame. Much of this information could be transformed into useful fisheries management data. For example, the system could measure and record lengths of individual fish and other morphometric measurements with minimal additional processing.

Once computerized fish counting has been implemented at a site, it would be relatively simple to automate other aspects of the fish passage monitoring process. For instance, hourly counts could be automatically uploaded to an

electronic bulletin board, such as the Columbia River Operational Hydro Management System (CROHMS) to give all interested agencies immediate access to data. The system could also be programmed to upload images to the bulletin board when certain conditions are met, such as when a sockeye salmon enters the fish counting slot at Lower Granite Dam. This feature would, in effect, allow any agency with a computer and a modem to monitor the site. The counting system could also be trained to notify people, by telephone, if problems arise. If the fish counting slot becomes blocked with debris, or water turbidity is extremely high, the system could call officials and play a recorded message explaining the problem. Finally, the system could be given a large degree of control over its environment. It could automatically focus the video camera, modify lighting conditions to maximize image quality, and clean the viewing window when necessary.

SUMMARY

1. A time-lapse video recording system was installed and operated continuously in the fish counting room at Lower Granite Dam from 1 May through 31 December, 1992.

2. Fish ladder passage was documented on video tape and 15 sockeye salmon, 3,283 summer chinook salmon, 1,022 fall chinook salmon, and 125,599 steelhead were counted from 1 June through 15 December, 1992.

3. The composite count of target species generated from the video record was similar to the estimate made by on-site counters during identical time periods.

4. Comparisons of 24 h video counts and on-site (10 and 16 h) counts showed that a significant proportion of target salmonids migrated during the nighttime when on-site counts are not typically made at Lower Granite Dam.

5. The mean sockeye salmon fork-length measured from video images was 453 mm. Mean fork-lengths reported for Snake River sockeye salmon between 1953 and 1965 were much greater.

6. Cost comparisons showed that video costs were less than half those of on-site counting methods. The video method also included collection of additional data.

7. A computer software demonstration program was developed that graphically illustrated the possibilities of a completely automated, computerized fish counting and identification system.

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Appendix A. Daily and annual total chinook salmon passage estimates at Lower Granite Dam in 1992.

	Chinook Adult				Chinook Jack			
Date	WDW	Video Total	Video Day	Video Night	WDW	Video Total	Video Day	Video Night
06/01	198	189	186	3	6	8	8	0
06/02	185	210	203	7	11	10	10	0
06/03	178	218	211	7	8	11	11	0
06/04	229	229	221	8	4	8	7	1
06/05	275	252	250	2	10	21	21	0
06/06	163	179	173	6	8	8	8	0
06/07	188	189	188	1	10	12	12	0
06/08	131	148	147	1	6	8	7	1
06/09	190	165	157	8	8	8	8	0
06/10	215	190	189	1	4	5	5	0
06/11	229	193	189	4	2	1	1	0
06/12	272	227	226	1	8	11	11	0
06/13	178	132	126	6	1	4	4	0
06/14	190	159	157	2	7	10	10	0
06/15	212	194	184	10	7	7	7	0
06/16	248	235	236	-1	10	9	9	0
06/17	156	129	130	-1	2	2	2	0
06/18	148	150	139	11	11	16	16	0
06/19	146	135	130	5	5	8	8	0
06/20	127	140	134	6	1	4	3	1
06/21	151	147	148	-1	12	14	14	0
06/22	49	47	44	3	4	3	2	1
06/23	41	29	30	-1	6	4	4	0
06/24	83	83	83	0	8	12	12	0
06/25	62	50	49	1	2	5	5	0
06/26	22	11	13	-2	1	1	1	0
06/27	43	46	45	1	7	7	7	0
06/28	74	56	56	0	7	6	6	0
06/29	107	76	73	3	14	14	15	-1
06/30	90	89	88	1	13	17	17	0
07/01	163	182	161	21	19	26	24	2
07/02	404	405	399	6	22	19	19	0
07/03	115	102	100	2	6	11	9	2
07/04	77	80	77	3	8	8	7	1
07/05	157	152	152	0	4	9	9	0
07/06	114	116	116	0	11	12	12	0
07/07	85	73	72	1	5	7	7	0

Appendix A. continued.

	Chinook Adult				Chinook Jack			
Date	WDW	Video Total	Video Day	Video Night	WDW	Video Total	Video Day	Video Niaht
07/08	118	107	105	2	8	11	11	0
07/09	61	54	54	0	6	9	9	0
07/10	60	66	64	2	10	13	13	0
07/11	52	48	49	-1	12	13	13	0
07/12	41	37	37	0	8	8	7	1
07/13	55	71	68	3	8	8	7	1
07/14	54	70	69	1	11	12	11	1
07/15	44	48	49	-1	6	4	4	0
07/16	40	33	30	3	0	3	3	0
07/17	34	30	30	0	7	6	6	0
07/18	18	18	18	0	5	3	3	0
07/19	6	8	8	0	2	5	5	0
07/20	2	4	4	0	2	1	1	0
07/21	1	1	1	0	2	4	4	0
07/22	5	4	4	0	1	2	2	0
07/23	13	11	11	0	11	10	10	0
07/24	14	15	15	0	4	3	3	0
07/25	20	24	24	0	0	0	0	0
07/26	6	6	6	0	6	6	6	0
07/27	10	10	9	1	4	4	3	1
07/28	12	11	9	2	7	6	6	0
07/29	11	12	12	0	2	3	3	0
07/30	7	7	7	0	2	3	3	0
07/31	0	1	1	0	0	1	1	0
08/01	2	4	4	0	1	3	3	0
08/02	1	3	3	0	4	4	4	0
08/03	5	5	5	0	2	2	2	0
08/04	7	6	5	1	0	0	0	0
08/05	8	5	4	1	0	0	0	0
08/06	11	7	6	1	0	3	2	1
08/07	7	5	5	0	1	4	4	0
08/08	18	12	12	0	0	0	0	0
08/09	6	5	4	1	0	0	0	0
08/10	4	4	3	1	0	0	0	0
08/11	0	-1	-1	0	0	0	0	0
08/12	0	1	1	0	0	1	1	0
08/13	1	1	1	0	0	0	0	0

Appendix A. continued.

	Chinook Adult				Chinook Jack			
Date	WDW	Video Total	Video Day	Video Night	WDW	Video Total	Video Day	Video Night
08/14	0	0	0	0	0	0	0	0
08/15	0	0	0	0	0	0	0	0
08/16	2	2	2	0	0	1	1	0
08/17	0	0	0	0	0	0	0	0
08/18	4	1	1	0	0	2	2	0
08/19	1	1	1	0	0	0	0	0
08/20	0	1	1	0	0	1	1	0
08/21	0	0	0	0	0	0	0	0
08/22	1	1	1	0	0	2	2	0
08/23	1	1	1	0	0	1	1	0
08/24	0	0	0	0	0	0	0	0
08/25	6	2	2	0	1	0	0	0
08/26	0	3	3	0	0	1	1	0
08/27	5	4	4	0	0	0	0	0
08/28	4	2	2	0	0	0	0	0
08/29	4	2	2	0	0	0	0	0
08/30	1	3	3	0	0	0	0	0
08/31	2	3	3	0	0	0	0	0
09/01	0	0	0	0	0	0	0	0
09/02	7	8	7	1	1	1	1	0
09/03	8	8	7	1	0	0	0	0
09/04	11	9	9	0	0	1	1	0
09/05	10	11	10	1	1	1	1	0
09/06	29	23	23	0	1	4	4	0
09/07	16	14	14	0	1	1	1	0
09/08	13	13	9	4	0	0	0	0
09/09	18	16	16	0	0	0	0	0
09/10	24	27	24	3	0	0	0	0
09/11	12	14	12	2	0	1	1	0
09/12	17	23	23	0	0	0	0	0
09/13	16	20	18	2	1	2	2	0
09/14	23	17	16	1	0	3	2	1
09/15	17	13	13	0	2	2	2	0
09/16	19	18	15	3	0	3	3	0
09/17	41	38	37	1	2	6	5	1
09/18	43	42	41	1	4	9	8	1
09/19	28	25	23	2	4	9	8	1

Appendix A. continued.

	Chinook Adult				Chinook Jack			
Date	WDW	Video Total	Video Day	Video Night	WDW	Video Total	Video Day	Video Night
09/20	34	32	28	4	7	8	8	0
09/21	7	8	7	1	4	4	4	0
09/22	8	11	9	2	1	6	6	0
09/23	8	9	8	1	1	3	2	1
09/24	19	20	20	0	1	4	4	0
09/25	12	11	11	0	1	2	2	0
09/26	18	13	13	0	4	4	4	0
09/27	34	25	25	0	6	11	11	0
09/28	22	17	14	3	1	5	5	0
09/29	11	12	11	1	0	2	1	1
09/30	7	8	6	2	1	2	2	0
10/01	18	16	16	0	4	3	3	0
10/02	12	10	10	0	6	8	8	0
10/03	10	12	12	0	4	2	2	0
10/04	12	11	11	0	1	3	2	1
10/05	5	6	5	1	2	2	2	0
10/06	5	6	6	0	5	4	4	0
10/07	12	7	7	0	5	4	4	0
10/08	8	9	9	0	1	2	2	0
10/09	13	14	10	4	6	2	2	0
10/10	4	4	4	0	0	1	1	0
10/11	4	4	3	1	0	3	2	1
10/12	8	10	9	1	1	2	2	0
10/13	16	10	10	0	4	7	6	1
10/14	6	5	5	0	2	1	1	0
10/15	2	4	3	1	0	0	0	0
10/16	10	12	10	2	0	0	0	0
10/17	5	6	4	2	1	1	1	0
10/18	4	6	5	1	0	0	0	0
10/19	10	10	9	1	1	1	1	0
10/20	6	6	5	1	1	1	1	0
10/21	5	5	5	0	0	0	0	0
10/22	5	7	5	2	0	0	0	0
10/23	6	6	4	2	0	0	0	0
10/24	8	7	7	0	2	2	2	0
10/25	20	8	8	0	2	2	1	1
10/26	4	4	4	0	1	0	0	0

Appendix A. continued.

	Chinook Adult				Chinook Jack			
Date	WDW	Video Total	Video Day	Video Night	WDW	Video Total	Video Day	Video Night
10/27	4	2	2	0	0	0	0	0
10/28	10	10	8	2	0	0	0	0
10/29	4	7	3	4	0	0	0	0
10/30	7	9	8	1	1	0	0	0
10/31	6	9	8	1	1	2	2	0
11/01	6	7	5	2	0	2	1	1
11/02	4	4	2	2	0	1	0	1
11/03	1	7	1	6	0	1	1	0
11/04	7	7	6	1	1	1	1	0
11/05	4	2	2	0	0	0	0	0
11/06	10	12	9	3	0	0	0	0
11/07	6	8	4	4	0	0	0	0
11/08	2	4	3	1	0	1	0	1
11/09	0	4	1	3	1	0	0	0
11/10	0	3	0	3	0	-1	-1	0
11/11	2	2	2	0	2	1	1	0
11/12	2	4	2	2	0	0	0	0
11/13	1	3	1	2	0	1	1	0
11/14	1	1	1	0	0	1	1	0
11/15	0	1	0	1	0	0	0	0
11/16	0	1	0	1	0	1	0	1
11/17	6	2	2	0	0	0	0	0
11/18	0	1	1	0	1	0	0	0
11/19	0	0	0	0	0	0	0	0
11/20	0	2	0	2	0	0	0	0
11/21	1	0	0	0	0	0	0	0
11/22	1	2	0	2	0	0	0	0
11/23	0	1	0	1	0	0	0	0
11/24	0	1	0	1	0	0	0	0
11/25	1	2	2	0	0	0	0	0
11/26	0	5	4	1	0	0	0	0
11/27	0	0	0	0	0	0	0	0
11/28	0	0	0	0	0	0	0	0
11/29	0	0	0	0	0	0	0	0
11/30	0	0	0	0	0	0	0	0
12/01	0	0	0	0	0	0	0	0
12/02	0	0	0	0	0	0	0	0

Appendix A. continued.

	Chinook Adult				Chinook Jack			
Date	WDW	Video Total	Video Day	Video Niaht	WDW	Video Total	Video Day	Video Night
12/03	0	0	0	0	0	0	0	0
12/04	0	0	0	0	0	0	0	0
12/05	0	0	0	0	0	0	0	0
12/06	0	0	0	1	0	0	0	0
12/07	0	0	0	0	0	0	0	0
12/08	0	0	0	0	0	0	0	0
12/09	0	0	0	0	0	0	0	0
12/10	0	0	0	0	0	0	0	0
12/11	0	0	0	0	0	0	0	0
12/12	0	0	0	0	0	0	0	0
12/13	0	0	0	0	0	0	0	0
12/14	0	0	0	0	0	0	0	0
12/15	0	0	0	0	0	0	0	0
Total	7316	7020	6776	244	511	666	639	27

Appendix B. **Daily and annual total steelhead passage estimates at Lower Granite Dam in 1992.**

Date	WDW	video total	video day	video night
06/01	1	0	0	0
06/02	0	1	0	1
06/03	1	1	1	0
06/04	0	1	1	0
06/05	0	0	0	0
06/06	2	5	5	0
06/07	2	3	3	0
06/08	0	0	0	0
06/09	0	0	0	1
06/10	1	2	2	0
06/11	0	0	0	0
06/12	4	4	4	0
06/13	1	5	5	0
06/14	1	1	1	0
06/15	1	0	0	0
06/16	7	6	6	0
06/17	2	5	5	0
06/18	1	1	1	0
06/19	5	5	5	0
06/20	4	6	5	1
06/21	6	5	5	0
06/22	6	10	9	1
06/23	2	3	3	0
06/24	2	3	3	0
06/25	2	0	2	-2
06/26	1	1	1	0
06/27	5	3	3	0
06/28	4	2	2	0
06/29	10	10	9	1
06/30	5	5	3	2
07/01	16	12	12	0
07/02	5	3	4	-1
07/03	18	12	12	0
07/04	14	13	13	0
07/05	34	33	32	1
07/06	42	30	30	0
07/07	30	28	26	2
07/08	43	30	30	0
07/09	37	31	32	-1

Appendix B. continued.

Date	WDW	video total	video day	video night
07/10	31	38	36	2
07/11	25	33	32	1
07/12	31	37	37	0
07/13	35	31	30	1
07/14	30	31	30	1
07/15	23	28	26	2
07/16	22	23	21	2
07/17	14	18	17	1
07/18	16	17	16	1
07/19	17	15	15	0
07/20	5	5	3	2
07/21	7	4	4	0
07/22	16	16	16	0
07/23	23	28	25	3
07/24	34	30	28	2
07/25	23	23	23	0
07/26	16	17	17	0
07/27	19	19	16	3
07/28	32	35	33	2
07/29	32	32	32	0
07/30	23	18	17	1
07/31	12	8	9	-1
08/01	11	8	8	0
08/02	11	15	12	3
08/03	53	56	46	10
08/04	48	49	47	2
08/05	64	68	52	16
08/06	127	134	118	16
08/07	144	144	128	16
08/08	145	166	149	17
08/09	145	156	151	5
08/10	101	112	105	7
08/11	48	58	53	5
08/12	37	29	29	0
08/13	22	21	21	0
08/14	18	19	19	0
08/15	22	21	20	1
08/16	40	43	42	1
08/17	23	19	19	0

Appendix B. continued.

Date	WDW	video total	video day	video niaht
08/18	11	11	10	1
08/19	20	23	22	1
08/20	14	23	19	4
08/21	40	51	47	4
08/22	48	66	56	10
08/23	59	83	75	8
08/24	42	59	42	17
08/25	98	104	92	12
08/26	109	120	107	13
08/27	113	129	122	7
08/28	169	172	163	9
08/29	132	135	132	3
08/30	59	56	55	1
08/31	36	43	43	0
09/01	41	49	43	6
09/02	72	73	62	11
09/03	73	83	73	10
09/04	148	158	150	8
09/05	132	120	109	11
09/06	188	207	178	29
09/07	211	224	193	31
09/08	266	323	268	55
09/09	342	401	357	44
09/10	358	393	340	53
09/11	342	431	374	57
09/12	553	686	641	45
09/13	524	667	552	115
09/14	605	724	632	92
09/15	607	673	589	84
09/16	581	695	619	76
09/17	1901	2015	1888	127
09/18	2692	2727	2644	83
09/19	2384	2618	2465	153
09/20	4594	4763	4577	186
09/21	1950	1954	1869	85
09/22	2370	2508	2430	78
09/23	2012	2072	1963	109
09/24	3508	3666	3620	46
09/25	4206	4257	4224	33

Appendix B. continued.

Date	WDW	video total	video day	video niaht
09/26	3629	3740	3644	96
09/27	4208	4182	4117	65
09/28	3000	3180	3028	152
09/29	3127	3297	3145	152
09/30	2341	2476	2367	109
10/01	2879	2993	2904	89
10/02	2572	3053	2949	104
10/03	3797	3911	3849	62
10/04	2590	2855	2767	88
10/05	1279	1371	1293	78
10/06	2603	2716	2460	256
10/07	3104	3416	3093	323
10/08	2510	2837	2568	269
10/09	4346	4452	4283	169
10/10	1678	1733	1561	172
10/11	1703	1858	1723	135
10/12	1339	1493	1324	169
10/13	2664	2810	2623	187
10/14	2179	2234	2099	135
10/15	1459	1605	1515	90
10/16	1639	1788	1650	138
10/17	796	874	775	99
10/18	1747	1715	1634	81
10/19	962	1077	951	126
10/20	1897	1952	1884	68
10/21	1375	1468	1370	98
10/22	1146	1247	1179	68
10/23	2017	2254	2171	83
10/24	1613	1566	1522	44
10/25	1286	1336	1285	51
10/26	1048	1113	1069	44
10/27	849	931	884	47
10/28	1115	1134	1081	53
10/29	670	682	630	52
10/30	794	849	793	56
10/31	618	658	598	60
11/01	388	668	519	149
11/02	575	723	621	102
11/03	539	654	520	134

Appendix B. continued.

Date	WDW	video total	video day	video niaht
11/04	622	730	616	114
11/05	286	417	293	124
11/06	574	635	557	78
11/07	494	642	550	92
11/08	440	506	467	39
11/09	289	385	317	68
11/10	312	359	316	43
11/11	470	535	494	41
11/12	245	295	235	60
11/13	372	416	373	43
11/14	264	286	253	33
11/15	166	188	163	25
11/16	52	86	56	30
11/17	169	220	173	47
11/18	283	390	299	91
11/19	289	445	340	105
11/20	557	692	558	134
11/21	370	469	375	94
11/22	427	528	439	89
11/23	192	271	233	38
11/24	187	269	200	69
11/25	226	333	276	57
11/26	154	455	308	147
11/27	286	315	263	52
11/28	136	156	136	20
11/29	154	179	157	22
11/30	97	115	86	29
12/01	88	125	93	32
12/02	55	82	49	33
12/03	30	48	36	12
12/04	142	185	137	48
12/05	60	83	73	10
12/06	29	43	32	11
12/07	47	50	47	3
12/08	23	34	27	7
12/09	38	41	37	4
12/10	8	21	16	5
12/11	59	72	57	15
12/12	46	54	47	7

Appendix B. continued.

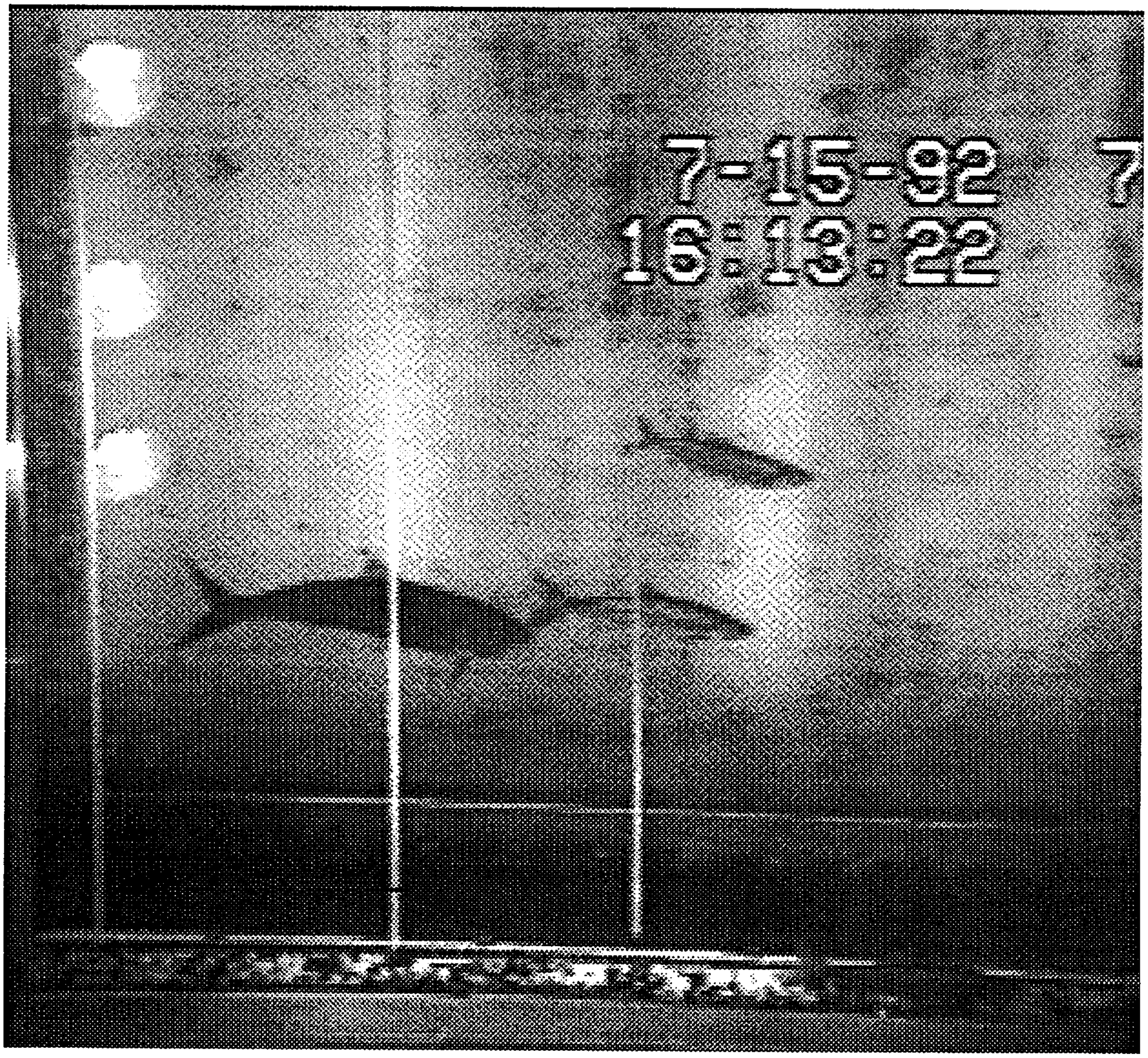
Date	WDW	video total	video day	video night
12/13	28	30	24	6
12/14	13	19	16	3
12/15	74	37	74	3
Total	116354	125599	117318	8281

Appendix C. Dates and times of recorded sockeye salmon passage at Lower Granite Dam in 1992.

COE	Video[1]
06/08, 15:00-15:50	06/08, 16:07:25
07/04, 18:00-18:50	07/04, 19:34:19
07/06, 06:00-06:50	07/06, 07:36:00
07/06, 08:00-08:50	07/06, 09:24:10
07/13, 06:42	07/13, 07:41:50
07/13, 13:42	07/13, 14:31:25
07/15, 14:45	07/15, 15:33:49
07/15, 15:25	
	07/16, 00:01:00
07/23, 11:10	07/23, 12:09:14
	07/27, 01:20:24
	08/02, 04:16:11
08/05, 15:24	08/05, 16:24:00
08/14, 06:26	08/14, 7:25:22
08/16, 19:00-19:50	
08/26, 12:40	08/26, 13:37:17
08/27, 12:05	08/27, 13:05:16
08/30, '10:32	

[1]Passage is recorded in Daylight Savings Time, which is one hour ahead of Pacific Standard Time, used by WDW and the COE.

Appendix D. **Digitized image of the video tape record showing the fish that was most likely classified as a sockeye salmon by COE on 7/15/92 at 1525 hours PST.**



Appendix E. **Digitized image of the video tape record showing the fish that** was **most likely classified as a sockeye salmon by COE on** 8/30/92 at 1032 **hours PST.**