WENATCHEE RIVER SALMON ESCAPEMENT ESTIMATES USING VIDEO TAPE TECHNOLOGY IN 1990

Technical Report 91-3

Douglas R. Hatch
Matthew Schwartzberg

May 31, 1991

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ABSTRACT

Time-lapse VHS video tape equipment was used to record salmon passage at the fish ladder viewing window in Tumwater Dam on the Wenatchee River, Washington, in 1990. Salmon passage was recorded continuously from 15 May through 30 September. Using video recordings, escapement estimates were made for sockeye salmon *Oncorhynchus nerka*, chinook salmon *O. tshawytscha*, and steelhead trout *O. mykiss*. Tests of estimation accuracy and tape reviewer precision were conducted.

Video based escapement estimates were within 2% of inter-dam based visual fish ladder counts derived by subtracting counts for each species made at two mainstem Columbia River dams. Analysis of variance showed no significant difference among five different tape reviewers using fish counts of three species—chinook salmon (P=1.00), sockeye salmon (P=1.00), and steelhead trout (P=0.052). A significant amount of fish passage was observed between 2100 and 0500 hours. This time period generally represents a time when mainstem Columbia River counting stations do not operate because significant passage is not believed to occur.

The use of time-lapse video technology appears to be an effective method for Pacific salmon escapement estimation. In many applications, this method has advantages over the escapement estimation system now in use in the Columbia Basin based on in-person visual fish counts at hydroelectric dams. Video based methods are more cost effective in areas with low escapement and provide a permanent and independently verifiable passage record. Tape analysis may be automated by using a computerized image processing system.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Over the past five years, video tape technology has become a very common tool for research in the biological sciences. Time-lapse video recording of biological phenomena is a technique that generally offers many advantages over traditional methods of observation. Besides being very economical, video monitoring creates a permanent record of events that may be re-examined and subjected to a variety of analyses. Additionally, analysis of video records may be automated using the newly developing methodologies of video image processing (Brown et al. 1989; Dazzo and Petersen 1989; Stutte 1990). The greatest number of applications of this technology in the biological sciences may be found in the field of microbiology, where video microscopy (Commare 1989; Inoue 1989) has been used for studies of cellular and microorganismic growth, change, and function (Tatsuka et al. 1989; Lanotte and Rioux 1990; Lowy et al. 1990). Another common area of scientific application has been in zoological research, both invertebrate (Breen et al. 1987; Kamykowski et al. 1989; Browman et al. 1989; Matczak and MacKay 1990; Tobler and Stalder 1988) and vertebrate (Danchin 1988; McLeod 1990; Lagarde and Trivedi 1990; Van Scheik and Buttler 1986).

Applications in the aquatic and marine sciences have been less common because of many difficulties related to underwater video system operation in field rather than in laboratory settings. Studies have been made using underwater video systems to survey the ocean bottom (Ballard 1984; Smith et al. 1984; Theroux 1984). Underwater video technology has also been used to assess and verify other oceanographic sampling methods (Bennett 1984; Twohig and Smolowitz 1984; Bouma and Rappeport 1984). Fish behavioral studies using video technology have been made (Gilat and Gelman 1984). In one of the few reported freshwater field applications of video technology, Bergstedt and Anderson (1990) evaluated the usefulness of this methodology in determining the densities of stationary objects located on shallow lake bottoms.

Studies using time-lapse video systems to monitor and estimate migratory fish escapement are almost non-existent in the literature. However, we know of several installations where this technology is being used experimentally to count Pacific salmon. These include: winter-time counting at Bonneville Dam on the Columbia River, Oregon (Dan Rawding, Washington Department of Wildlife, personal communication), at Rock

Island Dam on the Columbia River, Washington (Steve Hays, Chelan County Public Utility District Number 1, Wenatchee, Washington, personal communication), at Three Mile Dam on the Umatilla River, Oregon (Kutchins 1990), at Tumwater Dam on the Wenatchee River, Washington (Hatch and Schwartzberg 1990), at Willamette Falls on the Willamette River, Oregon (Bennett and Foster 1990), and at Prossor Dam on the Yakima River, Washington (Joel Hubel, Confederated Tribes and Bands of the Yakima Indian Nation, Yakima, Washington, personal communication). The methodology is also being tested with Atlantic salmon in New England (Kevin Friedland, National Marine Fisheries Service, Woods Hole, Massachusetts, personal communication) and in Newfoundland, Canada (John Pipie, Department of Fisheries and Oceans, St. Johns, Newfoundland, personal communication). Among the above mentioned studies, Hatch and Schwartzberg (1990) tested fish count accuracy between two time-lapse recording speed modes.

This study, the Wenatchee River Salmon Escapement Estimation Project, was conducted by the Columbia River Inter-Tribal Fish Commission (CRITFC) and is a part of the U.S.-Canada Pacific Salmon Treaty spawning escapement monitoring program (Pacific Salmon Treaty 1985). The purpose of this study is to refine the technique of monitoring and estimating migratory salmon passage at Tumwater Dam on the Wenatchee River, Washington using a video camera and time-lapse video tape recorders. Multiple readings of the video tape record permits a variance and confidence bound to be placed on the escapement estimate. Bounded estimates are not typically generated from the more traditional one-time visual fish counts made at many count stations in the Columbia Basin.

In addition to estimating escapement at Tumwater Dam for spring and summer chinook salmon *Oncorhynchus tshawytscha*, sockeye salmon *0. nerka*, and steelhead trout *0. mykiss*, specific objectives of the 1990 research were to determine diurnal migration and among-reader error in video tape analysis.

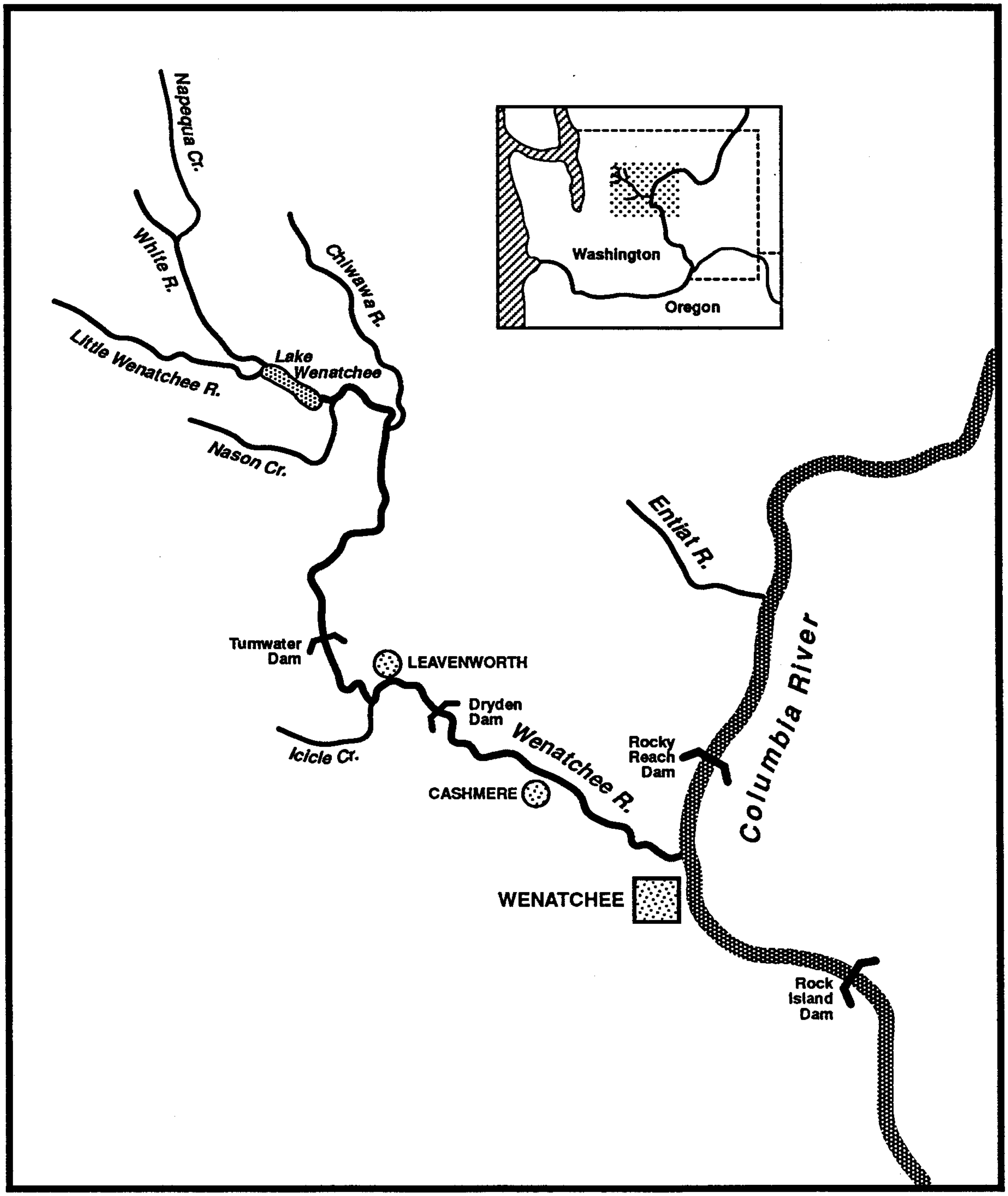
METHODS

Study Area

Tumwater Dam is located at river kilometer (rkm) 52 on the Wenatchee River, Washington (Figure 1). Tumwater Dam is 7 m high and 122 m long and was built by the Great Northern Railroad in 1907. It was the first hydroelectric dam constructed in the Pacific Northwest and was built to provide electric power for railroad locomotives passing through the 4.4 km Old Cascade Tunnel. The project originally included a fish ladder permitting adult salmon passage over the dam. Puget Sound Power and Light leased the dam in 1929 and Public Utility District Number 1 of Chelan County (Chelan PUD) purchased the facility in 1957. Diesel locomotives replaced the electric locomotives in the 1950s and, by 1956, Tumwater Dam hydroelectric generating facilities were dismantled. Fish passage facilities were redesigned in 1987 and included a single pool-and-weir fish ladder and a 2.3 x 1.8 m fish viewing window. Tumwater Dam is otherwise impassable to upstream salmon migration. In 1988, a fish trap was also constructed.

In the Wenatchee River Salmon Escapement Estimation Project at Tumwater Dam, a video camera was placed on a tripod and aimed at the fish ladder viewing window. Ten 150 watt flood lights were placed around the window to provide illumination for the camera. Two time-lapse VHS video tape recorders (VTRs) were installed and set to record in 72 hour time-lapse mode. The VTRs were connected to the camera in a way that allowed the first VTR to record images from the camera until its tape ended, at which time the second VTR began recording. This automatic switching mechanism provided a seven day period between tape changes. The camera and VTRs were operated continuously from 10 May, 1990 through 30 September, 1990. Four gaps in the video record occurred because of equipment malfunctions. These gaps were: 14-16 May; 21-23 May; 28-29 May; and 10-11 July. Limited fish passage occurred on days adjacent to the tape record gaps. Therefore, no attempt was made to account for passage which may have occurred during the equipment malfunctions. Tapes were changed in both VTRs at least weekly. The entire recording system was attached to a battery backup unit designed to supply power to the system during potential power failures. Appendix 1 contains a complete equipment list.

Figure 1. Map of the Wenatchee River Basin showing location of Tumwater and Dryden dams.



Escapement Estimation

Video Based Estimate

Video tapes were reviewed to determine fish counts by species. Viewing of tapes was done with a 33 cm color monitor connected to an editing VTR equipped with jog and shuttle controls that permitted frame-by-frame viewing. Each frame of video tape was marked by the recording VTR with the date and time of the recording. This tape frame coding system allowed enumeration of counts by time. Fish images were identified by species and hourly counts recorded. Hourly counts were summed to provide daily totals and cumulative counts for chinook and sockeye salmon for the entire migratory period. Steelhead trout counts were made concurrently with salmon counts but were not complete escapement estimates due to run timing differences between steelhead trout and salmon in the Wenatchee River. Migratory timing, mean passage date, and standard deviation were estimated for each species (Mundy 1982).

The fish trapping facilities at Tumwater Dam were used in several independent research projects in 1990. With the fish trap in use, the fish viewing window was by-passed. In 1990, sockeye, summer chinook salmon, and steelhead trout trapped at Tumwater Dam were not recorded by video. Consequently, records of trapping operations were obtained and used to augment daily video totals.

Inter-dam Based Estimate

An attempt to compare and possibly validate video-based escapement estimates was made by using a second, independent method of estimation. The second escapement estimation method involved subtraction of fish ladder counts for each species at Rock Island Dam (rkm 730) from counts made at Rocky Reach Dam (rkm 762), both on the mainstem Columbia River (CRITFC 1990). The Wenatchee River is the only major Columbia River tributary located between these two dams (Figure 1). The *inter-dam* escapement estimate for sockeye salmon was made by subtracting counts made at the two dams.

Chinook salmon inter-dam escapement estimates had to be adjusted prior to comparison with video based estimates to account for harvest and escapement in Wenatchee River areas downstream of Tumwater Dam. These adjustments included the number of fish caught in the Icicle Creek spring chinook salmon fishery and the Leavenworth National Fish Hatchery escapement (LaVoy 1990), and both spring and summer chinook salmon natural escapement to areas between the Wenatchee River mouth and Tumwater Dam (Fast 1988). To calculate the adjusted inter-dam estimate for spring chinook salmon (AID_{sp}) the following equation was used:

$$AID_{sp} = ID_{sp} - H - NS - HS$$

where:

ID_{sp} = spring chinook salmon count at Rocky Reach Dam minus the spring chinook salmon count at Rock Island Dam,
H = lower Wenatchee River harvest,
NS = natural spawning below Tumwater Dam,
HS = fish spawned at Leavenworth Hatchery.

The following equation was used for summer chinook salmon (AID_{su}):

$$AID_{su} = ID_{su} - (ID_{su} \times NS)$$

where:

ID_{su} = summer chinook salmon count at Rocky Reach Dam minus the summer chinook salmon count at Rock Island Dam,
NS = estimated proportion of summer chinook salmon that spawn below Tumwater Dam.

Spring and summer chinook salmon were not distinguishable at Tumwater Dam (French and Wahle 1959). Only a combined chinook count could be used for comparing video to inter-dam counts. The adjusted inter-dam spring and summer chinook salmon estimates (AID_{sp} and AID_{su}) were therefore combined and used for comparison with the (already combined) Tumwater Dam video chinook escapement estimate.

Among-Reader Differences

Variability among readers of the video tape records was tested using analysis of variance (ANOVA). A randomized complete block experimental design was used (Kirk 1982). The experiment utilized five readers and five blocks. Over the entire test, 20 one-hour video tape segments were analyzed by each reader. Each reader's individual species count and composite species count (for every one hour video tape segment) made up the response variables. The blocking variable was levels of fish density (fish/hour). These densities were determined previously during the escapement estimation phase of the study. Fish density levels for each block were: 1 to 10, 11 to 100, 101 to 200, 201 to 300, and > 300. Within each block, four one-hour video tape segments were randomly selected. The total tape segment population consisted of 2,181 segments. The probability of a type I error (α) was set at 0.05 for all among-reader tests.

Night Migration

Estimates of night passage (fish passage between 2100 and 0500 hours) were made for sockeye and chinook salmon and steelhead trout at Tumwater Dam. Total counts for each species made between 2100 and 0500 hours were divided by their respective escapement estimates to calculate the percentage of the total count for each species that represented nighttime migration.

Potential Flow Barrier to Migration

Biologists have long considered that a water velocity barrier in Tumwater Canyon, located approximately 6 km downstream of Tumwater Dam, may prohibit salmon migration (Allen and Meekin 1980; Mullan 1986). The suggested velocity barrier threshold is 6,000 cfs for both sockeye and, to a lesser degree, chinook salmon. The existence of a velocity barrier was investigated by plotting Wenatchee River discharge, measured at Monitor Bridge (rkm 14), with daily sockeye and chinook salmon video counts made at Tumwater Dam in 1989 and 1990.

RESULTS

Sockeye Salmon Escapement

Video tape analysis provided a partial escapement estimate of 32,033 sockeye salmon at Tumwater Dam in 1990. Sockeye salmon trapped at Tumwater Dam and not enumerated in video records included 2,130 fish. Thus, the combination of counts produced a minimum 1990 Wenatchee River sockeye salmon escapement estimate of 34,163. The majority of passage (97%) occurred between 21 July and 12 August, 1990 (Figure 2; Appendix 2). The mean passage date was 29 July, 1990 with a standard deviation of 6.2 days. The inter-dam sockeye salmon escapement estimate was 34,846.

Chinook Salmon Escapement

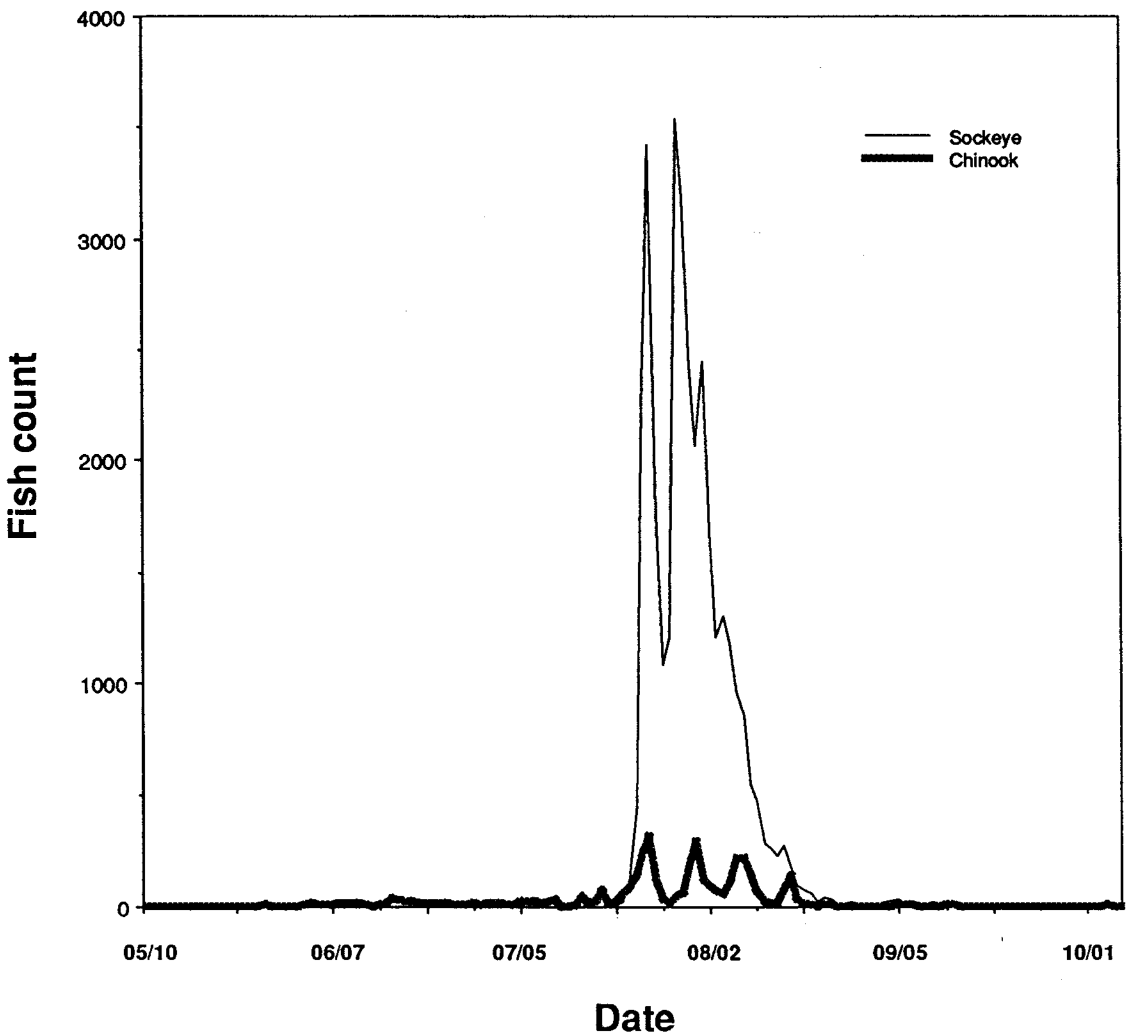
Video tape analysis provided a partial escapement estimate of 3,704 adult chinook salmon at Tumwater Dam in 1990. Chinook salmon trapped at Tumwater Dam and not enumerated in video records included 66 fish. Thus, the combination of counts produced a minimum 1990 Wenatchee River adult chinook salmon escapement estimate of 3,770. The majority of passage (74%) occurred between 21 July, and 13 August, 1990 (Figure 2; Appendix 2). The mean passage date was 24 July, 1990 with a standard deviation of 16.9 days.

The chinook salmon (the combination of spring and summer stock counts) adjusted inter-dam count for 1990 was 3,842. The spring chinook salmon escapement estimate made from inter-dam analyses was 1,179. This excluded 1,850 harvested fish (1,025 sport plus 825 tribal fisheries) and 2,698 fish which escaped (2,578 to Leavenworth Hatchery plus 120 natural spawners, Larrie LaVoy 1990). The summer chinook salmon escapement estimate made from inter-dam analyses was 2,663. Three chinook salmon jacks were counted from video tape and none were trapped in 1990.

Steelhead Trout Escapement

Video tape analysis provided a partial escapement estimate of 245 adult

Figure 2. Wenatchee River sockeye and chinook salmon escapement in 1990 estimated by video tape count and additional fish trapped at Tumwater Dam.



steelhead trout at Tumwater Dam in 1990. Steelhead trout trapped at Tumwater Dam and not enumerated in video records included 5 fish. Thus, the combination of counts produced a minimum summer 1990 Wenatchee River adult steelhead trout escapement estimate of 248. Steelhead trout migrated over Tumwater Dam between 10 May and 30 September, 1989. The mean passage date was 14 August, 1990 with a standard deviation of 26.2 days. However, this estimate does not represent total escapement of steelhead trout because they generally migrate through the Wenatchee River between November and March during times when the video counting station is not activated (Larry Brown, Washington Department of Wildlife, personal communication).

The summer steelhead trout count was comprised of 5.6% hatchery and 94.4% non-hatchery origin fish, based on detection of an adipose fin on video images. It was also possible to determine the sex of some steelhead trout based on sexual dimorphism.

Among-Reader Differences

Among-reader variation in video tape counts was relatively low. This was indicated by results from ANOVA showing no significant differences among five readers for different species and for a composite of combined species counts (Figure 3; Table 1). Among-reader tests using sockeye, chinook salmon, and composite counts as the response variables were highly nonsignificant ($P = 1.000$). Tests using steelhead trout counts as the response variable were also nonsignificant ($P = 0.052$). The blocking variable, fish density, yielded strength of association estimates of 0.977, 0.694, 0.419, 0.981 for sockeye, chinook salmon, steelhead trout, and composite counts, respectively.

Night Migration

Over the entire 1990 migratory period, 2,242 sockeye salmon were video recorded migrating passed Tumwater Dam between 2100 and 0500 hours. (Figure 4). This represents 6.6% of the total Wenatchee River sockeye salmon escapement estimate. Night migration was also observed for chinook salmon and steelhead trout with 7.7% and 15.3%, respectively, migrating over Tumwater Dam between 2100 and 0500 hours (Figure 4).

Figure 3. Variation in fish counts from video tape segments enumerated by five different readers.

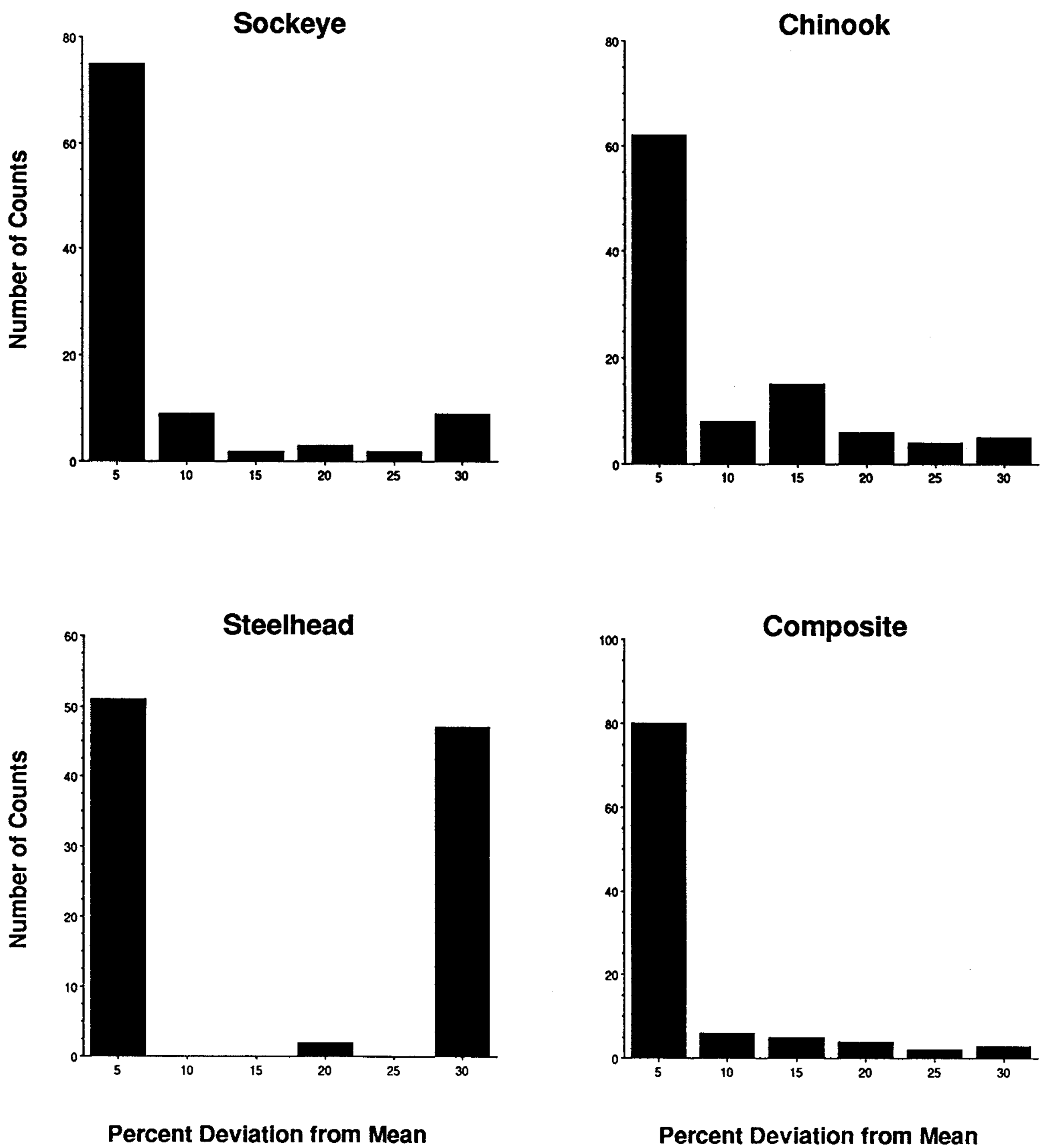
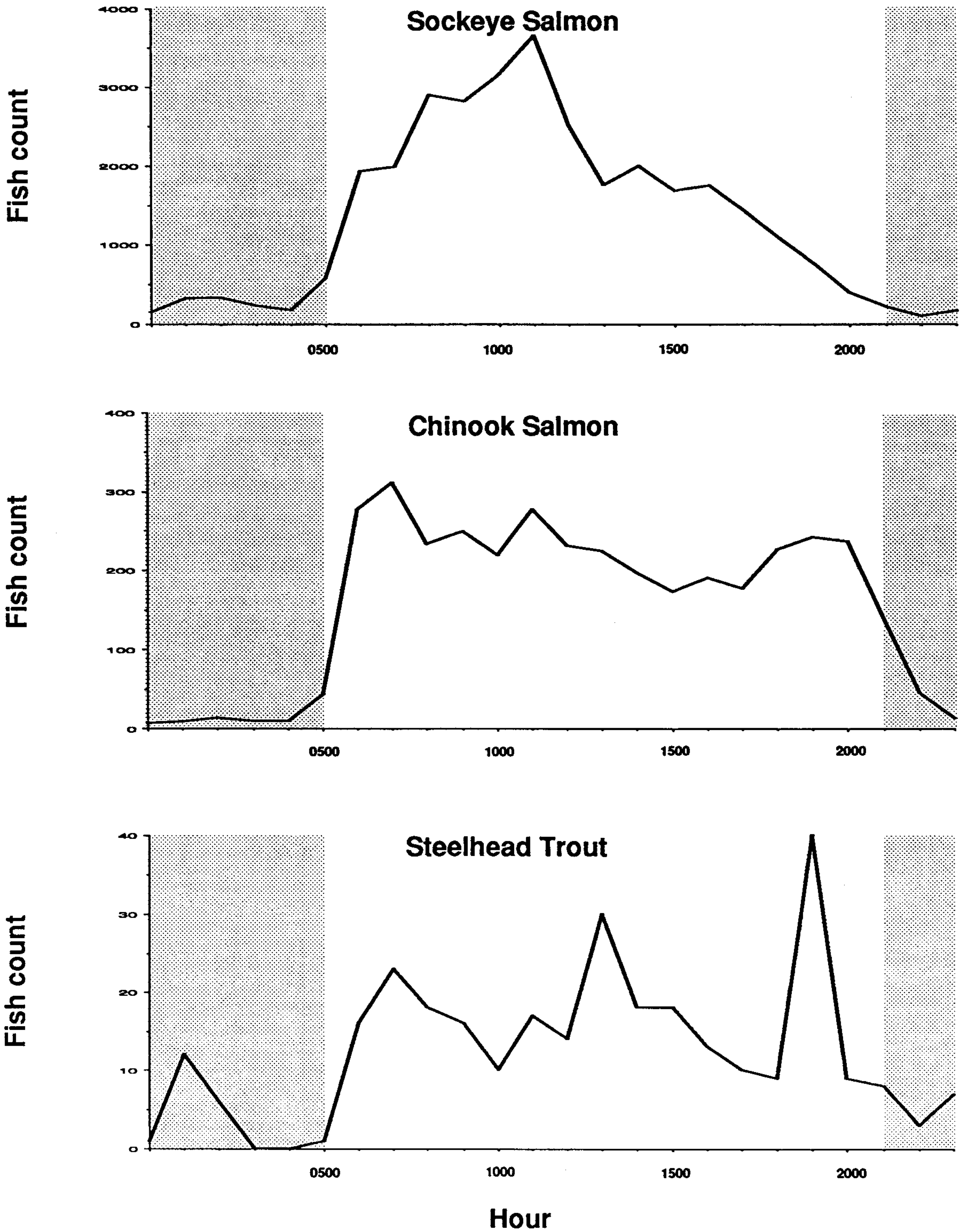


Table 1. Mean and standard deviation of video tape fish counts made by five different individuals using 20 one-hour tape segments.

Hour	Sockeye		Chinook		Steelhead		Composite	
		SD		SD		SD		SD
1	0.4	0.89	2.6	0.89	0.4	0.55	3.4	0.55
2	320.2	5.17	31.8	1.30	3.0	1.87	355.0	3.81
3	89.8	24.30	1.6	0.55	1.0	0.71	92.4	23.63
4	178.0	5.39	6.0	0.71	1.8	4.02	185.8	1.64
5	133.2	1.64	18.2	0.45	0.2	0.45	151.6	1.14
6	205.6	4.83	17.4	0.55	0.6	0.89	223.6	5.27
7	245.0	8.40	5.8	1.79	1.4	2.61	252.2	9.91
8	31.2	1.10	1.0	0.00	1.2	0.84	33.4	1.52
9	589.8	10.71	5.6	0.89	1.0	0.00	596.4	11.15
10	38.6	1.14	16.2	0.84	1.0	0.71	55.8	1.10
11	361.6	7.44	1.8	0.45	2.0	0.00	365.4	7.57
12	111.4	0.55	7.0	0.71	0.6	0.55	119.0	1.22
13	0.0	0.00	2.0	0.00	0.0	0.00	2.0	0.00
14	143.2	3.56	5.8	0.45	1.0	0.00	150.0	4.0
15	75.8	4.49	0.0	0.00	0.0	0.00	75.8	4.49
16	204.8	4.97	17.4	1.14	0.0	0.00	222.2	5.12
17	3.4	1.14	1.0	0.00	0.0	0.00	4.4	1.14
18	3.8	0.45	0.0	0.00	1.0	0.00	4.8	0.45
19	358.0	5.34	7.2	0.45	1.0	0.00	366.2	5.63
20	240.6	7.44	15.8	0.84	0.2	0.45	256.6	7.57

Figure 4. Composite sockeye, chinook salmon, and steelhead trout counts as a function of time of day with approximate hours of darkness shaded[1], recorded at Tumwater Dam in 1990.

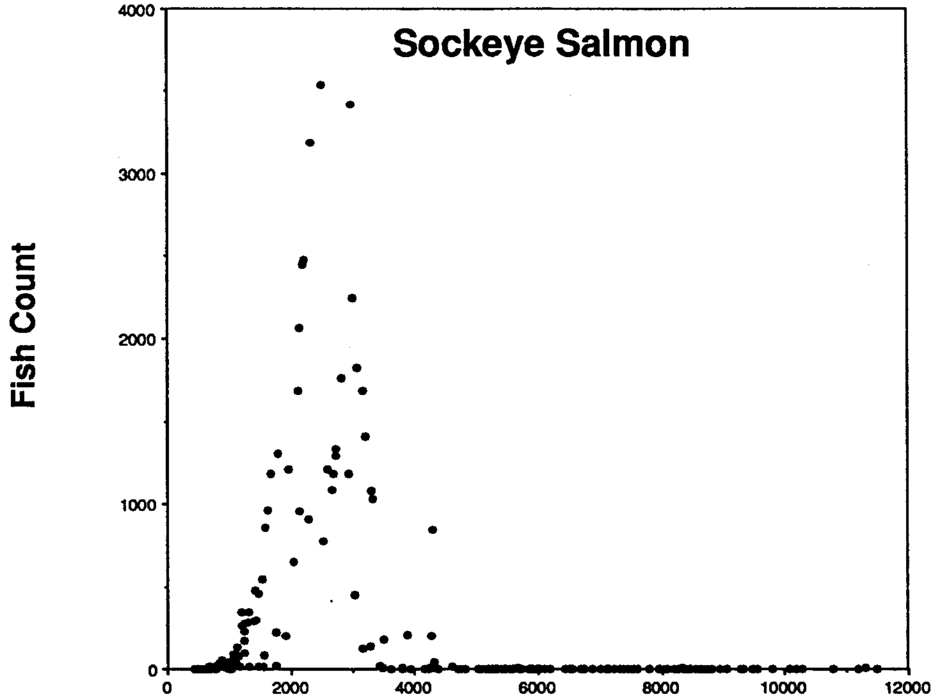


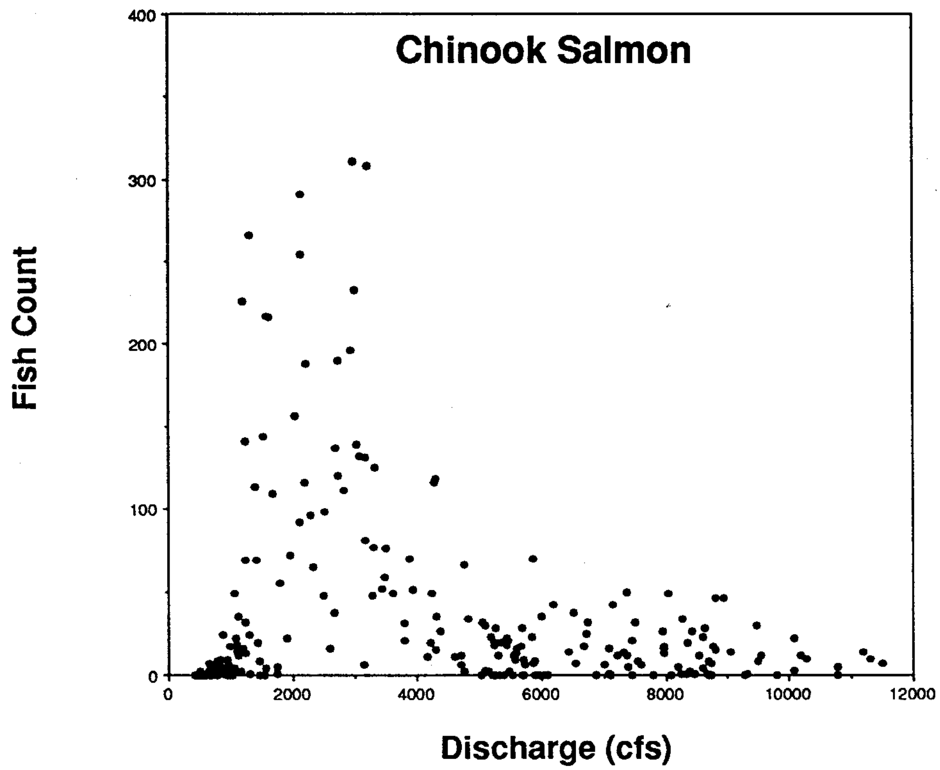
1. Shaded hours (2100 through 0500) correspond to times when in-person counts are not made at mainstem Columbia River hydroelectric projects.

Potential Flow Barrier to Migration

Plots of Wenatchee River discharge with Tumwater Dam sockeye and chinook salmon counts indicated that the majority migrated past Tumwater Dam when discharge was approximately 3,000 cfs (Figure 5). However, significant chinook salmon migration occurred during periods when discharge exceeded 8,000 cfs.

Figure 5. Relationship between Wenatchee River discharge at Monitor Bridge and Tumwater Dam salmon counts in 1989 and 1990.





DISCUSSION

Sockeye Salmon Escapement

The 1990 sockeye salmon escapement estimate based on video tape analysis was within 2% of the inter-dam based estimate. This indicates that the video method is relatively accurate. However, a test pairing video based and in-person counting should be conducted in the future to evaluate the two techniques. The estimated Wenatchee River sockeye salmon escapement increased 35% from the 1989 count of 22,057 based on video recordings and trapping records (Hatch and Schwartzberg 1990).

The mean date of passage over Tumwater Dam for sockeye salmon was 21 July in 1990 compared to 25 July in 1989. Both of these mean passage dates are earlier than any of the 14 (nonconsecutive) years of counts, from 1935-73, at Tumwater Dam (Mullan 1986). It is possible, therefore, that current migratory timing has changed from historic periods. However, it is also possible that inaccuracies exist in the historic record (Steve Hays, Chelan PUD, personal communication).

Chinook Salmon Escapement

The 1990 chinook salmon escapement estimate based on video tape analysis was within 2% of the inter-dam based estimate. This indicates that the video method is relatively accurate. However, a test pairing video based and in-person counting should be conducted in the future to evaluate the two techniques. The estimated Wenatchee River chinook salmon escapement decreased 23% from the 1989 count of 4,914 based on video recordings and trapping records (Hatch and Schwartzberg 1990).

The mean date of passage over Tumwater Dam for chinook salmon in 1990 was 24 July compared to 18 July in 1989 (Hatch and Schwartzberg 1990). The only historic Tumwater Dam chinook salmon migratory timing data available is from French and Wahle (1959) who reported only migratory peaks. Unfortunately, these data are of little comparative use (Mundy 1982). We will attempt to correlate migratory timing with biotic and abiotic factors in the future as the database produced by our studies is developed.

Steelhead Trout Escapement

The steelhead trout count produced from time-lapse video records at Tumwater Dam represented only a portion of the Wenatchee River steelhead trout run because the majority of the migration occurs between November and March (Larry Brown Washington Department of Wildlife, personal communication) when video recordings were not made. Approximately twice as many steelhead trout were counted at Tumwater Dam in 1990 than in 1989 based on video estimations.

Among-Reader Differences

The among-reader error test found no significant difference in reader counts of fish images on video tape for each species or for all species combined. All individuals who analyzed video tapes were experienced in identifying the three Pacific salmon species recorded on the tapes. However, only two of the readers were experienced with using the video tape reviewing equipment and with identifying Pacific salmon images on video tape. The effect of different readers on counts of sockeye and chinook salmon and of a composite count of all species combined (Figure 3) was highly nonsignificant ($P = 1.000$). The effect of different readers on steelhead counts (Figure 3) was also nonsignificant, although not to the same degree ($P = 0.052$). Because daily steelhead counts were relatively low, the test was very sensitive to small among-reader differences for this stock. In addition, differences in steelhead counts were mostly attributable to one counter who tallied higher steelhead counts than did the other readers. Learning appeared to play an important part in reader accuracy as this reader's counts were similar to those of other readers over the latter 12 hours of tape reading. Nevertheless, these analyses indicate that several counters of video tape records may be used without a significant negative effect on escapement estimates.

Night Migration

Noticeable amounts of nighttime fish passage occurred at Tumwater Dam during 1989 as well as 1990 studies. Video records from 1989 and 1990 indicated that the two-year mean percentage of escapement for each species represented by nighttime passage was 13.9%, SD = 2.1; 8.2%, SD = 0.6; and 6.7%, SD = 0.07 for steelhead trout, chinook, and sockeye salmon, respectively. Currently, escapement estimates made at mainstem Columbia River dams assume that no night passage occurs and, therefore, fish are not generally counted in these programs (U.S. Army Corps of Engineers 1989) between 2100 and 0500 hours (hours differ from dam to dam). Video technology could be used to record night passage at these sites for improvements in escapement estimation accuracies. All methods to improve the accuracy of counts at Columbia and Snake river dams should be explored given the low abundance of some Columbia Basin salmon populations and the importance of accurate escapement estimates for these and other stocks.

Potential Flow Barrier to Migration

Plots of daily discharge, measured at the Monitor Bridge USGS gauging station, with daily escapement show that some chinook salmon passage occurred at discharges greater than 10,000 cfs (Figure 5). The highest discharge in which sockeye salmon counts were recorded was approximately 4,500 cfs (Figure 5). We believe the reason that sockeye salmon are not passing Tumwater Dam during high discharge periods is because they have not yet reached the Wenatchee River at the time when higher flows are typical. When sockeye salmon are in the Wenatchee River, discharge has usually decreased to levels below 6,000 cfs. As our database grows, we will investigate this question further by calculating the number of days en route between Rock Island and Tumwater Dam for chinook and sockeye salmon and correlate this with Wenatchee River discharge.

Video Taping as an Effective Method for Escapement Estimation

Time-lapse video taping of salmon passage appears to be an effective escapement estimation technique. Good quality fish images can be produced using professional equipment and adequate lighting (Figure 6). Video taping has advantages over in-person counting in that video taping produces a 24 hour escapement record and is less expensive. It is also possible to produce bounded escapement estimates using video tape records. Multiple readings of the entire video tape record or single readings of a representative sample of the video tape record may be used to achieve this estimate. With further development, video technology may provide a means to estimate individual fish length and sex.

Figure 6. **Black and white rendering of computer captured time-lapse video recorded image of chinook and sockeye salmon.**

Protocol for the mainstem Columbia Basin dam fish-counting system now in use includes individuals counting 50 minutes out of each hour during 8 to 16 hour per day intervals (depending on time of year). Video systems could be used to augment this procedure by recording passage during the ten minute per hour periods when it is not now recorded. Escapement estimates based on the in-person counts are currently adjusted to account for this gap. However, this may be not be an adequate procedure for stocks that are in very low abundance and that may be considered for listing under the federal Endangered Species Act (ESA 1973). Two stocks now under consideration for ESA listing, Snake River sockeye and fall chinook salmon, had estimated 1990 escapement of fewer than 100 individuals each (CRITFC 1990). Video technology is especially well suited for estimating escapement for stocks such as these.

Video technology can also be utilitized to obtain terminal area escapement estimates for naturally spawning stocks of Pacific Salmon. Video systems similar to the one tested in this study can be designed to operate underwater in low light conditions and can be incorporated into temporary weirs for application in remote areas. Fish counting cylinders that operate by sensing the difference in conductivity as a fish passes through them are another method for enumerating fish in terminal areas. However, this method cannot distinguish among species, making it much less useful for mixed stocks. These cylinders are further restrictive because they are generally built with a maximum diameter of 30 cm. Video taping fish passage is clearly a better method of natural stock escapement estimation than redd counting (single or multiple survey), a method used extensively in the Columbia River Basin. To estimate escapement with redd counting, many assumptions must be made that are frequently difficult to support. These include the number of spawners per redd, inclusion of all spawning areas in the sampling frame, representativeness of sample areas, and that all redds in a sample area are counted only once.

In certain cases, the use of time-lapse video technology in salmon escapement estimation does present potential difficulties that must be considered. This is especially true with remote area installations. Mechanical breakdown is always a concern, particularly with water being in close proximity to the electronic equipment. Theft and vandalism are potential risks in remote field locations. Potential for human error in system operation also exists. For example, improper system programming and failure to change tapes when necessary can cause data losses. In video equipped weir installations, electric power must be available for lights, camera, and recorders. This requirement may be reduced by using a battery powered camcorder type system designed to operate in low light conditions.

Even in 72 hour time-lapse mode, the amount of tape generated in one field season can be quite lengthy. Over a six month period, approximately 50 tapes will be produced at each counting station. Most of the recorded frames of tape, particularly for terminal area naturally spawning stock escapement estimation, will not contain fish images. In settings such as these, tape analysis is slow and tedious. Currently, we are developing a computerized system to eliminate empty tape frames and consequently speed the tape review process. This technology may eventually lead to a fully automated video tape analysis system permitting computerized species identification and counting, as well as determination of individual fish lengths.

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Appendix 1. Specifications of equipment used in the Wenatchee River Salmon Escapement Estimation Project.

Item	Number	Make	Model
Camera	1	Panasonic	WV-D5100
Tripod	1	Bogen	3046
Time-lapse VTR	2	Panasonic	AG-6720
Viewing VTR	1	Panasonic	AG-1960
Monitor	1	Sony	PMV1340
Video Tape	140	Panasonic	NV-T160
Battery Backup	1	Tripp-lite	SB-200a
Lighting	8	Phillips	150 watt flood

Appendix 2. Daily fish passage estimates at Tumwater Dam, using video tape counts and additional counts from fish trapped in 1990.

Date	Sockeye	Adult Chinook	Jack Chinook	Steelhead	Resident
05/10/90	0	0	0	2	0
05/11/90	0	0	0	1	0
05/12/90	0	0	0	0	0
05/13/90	0	0	0	0	0
05/14/90	0	0	0	0	0
05/15/90	0	0	0	0	0
05/16/90	0	0	0	0	0
05/17/90	0	2	0	0	0
05/18/90	0	0	0	0	0
05/19/90	0	0	0	0	0
05/20/90	0	0	0	0	0
05/21/90	0	0	0	0	0
05/22/90	0	0	0	0	0
05/23/90	0	0	0	0	0
05/24/90	0	2	0	0	0
05/25/90	0	3	0	0	0
05/26/90	0	2	0	0	0
05/27/90	0	6	0	0	0
05/28/90	0	0	0	0	0
05/29/90	0	0	0	0	0
05/30/90	0	1	0	0	0
05/31/90	0	0	0	0	0
06/01/90	0	1	0	0	0
06/02/90	0	5	0	0	0
06/03/90	0	12	0	0	0
06/04/90	0	7	0	0	0
06/05/90	0	5	0	0	0
06/06/90	0	8	0	0	0
06/07/90	0	13	0	0	0
06/08/90	0	17	0	0	0
06/09/90	0	16	0	1	0
06/10/90	0	15	0	0	0
06/11/90	0	8	0	0	0
06/12/90	0	0	0	0	0
06/13/90	0	6	0	0	0
06/14/90	0	14	0	1	0
06/15/90	1	32	0	0	0
06/16/90	0	26	0	0	0
06/17/90	0	19	1	0	0
06/18/90	0	23	1	0	0
06/19/90	0	17	0	0	0
06/20/90	0	14	0	0	0
06/21/90	0	12	0	0	0
06/22/90	0	12	0	1	0
06/23/90	0	14	0	1	0
06/24/90	0	7	0	0	0
06/25/90	0	5	0	1	0
06/26/90	0	8	0	0	0
06/27/90	0	12	0	1	0
06/28/90	0	6	0	0	0
06/29/90	0	16	0	1	0
06/30/90	1	12	0	2	0
07/01/90	0	14	0	3	0
07/02/90	2	7	0	0	0
07/03/90	2	7	0	2	0
07/04/90	3	18	0	2	0
07/05/90	0	21	0	1	0
07/06/90	2	23	0	0	0
07/07/90	1	13	0	0	0
07/08/90	1	18	0	2	0
07/09/90	2	28	0	1	0
07/10/90	0	0	0	0	0
07/11/90	0	0	0	0	0
07/12/90	1	8	0	0	0
07/13/90	1	42	0	0	0
07/14/90	4	17	0	0	0
07/15/90	1	30	0	1	0
07/16/90	3	66	0	2	0
07/17/90	8	15	0	1	0
07/18/90	10	21	0	2	0
07/19/90	18	52	0	1	0

Appendix 2. Continued.

Date	Sockeye	Adult Chinook	Jack Chinook	Steelhead	Resident
07/20/90	127	81	0	3	0
07/21/90	450	139	0	3	1
07/22/90	2248	233	0	3	0
07/23/90	3423	311	0	7	0
07/24/90	1761	111	0	0	0
07/25/90	1085	37	0	2	0
07/26/90	1212	16	0	2	0
07/27/90	3534	48	0	7	0
07/28/90	3187	65	0	3	0
07/29/90	2475	188	0	2	1
07/30/90	2065	291	0	1	0
07/31/90	2445	116	0	4	0
08/01/90	1689	92	0	6	0
08/02/90	1208	72	0	3	0
08/03/90	1303	55	0	3	0
08/04/90	1181	109	0	3	0
08/05/90	959	216	0	3	0
08/06/90	860	217	0	2	0
08/07/90	544	144	0	6	0
08/08/90	474	69	0	2	0
08/09/90	281	24	0	7	0
08/10/90	261	16	0	3	0
08/11/90	230	13	0	5	1
08/12/90	278	69	0	0	0
08/13/90	173	141	0	6	0
08/14/90	98	32	0	9	0
08/15/90	77	15	0	3	0
08/16/90	59	4	0	4	0
08/17/90	21	0	0	2	1
08/18/90	39	6	0	5	0
08/19/90	33	4	0	5	0
08/20/90	16	1	0	2	0
08/21/90	15	0	0	3	0
08/22/90	22	1	0	2	0
08/23/90	17	0	0	4	0
08/24/90	17	1	0	6	0
08/25/90	16	2	0	4	0
08/26/90	17	2	0	2	0
08/27/90	21	0	0	4	0
08/28/90	28	1	0	5	0
08/29/90	33	5	0	7	0
08/30/90	12	4	0	6	0
08/31/90	5	4	0	2	0
09/01/90	7	0	0	1	0
09/02/90	12	0	0	4	0
09/03/90	24	2	0	3	0
09/04/90	14	3	0	3	0
09/05/90	11	4	0	2	0
09/06/90	13	5	0	5	0
09/07/90	4	0	0	1	0
09/08/90	2	0	0	2	0
09/09/90	1	2	0	1	1
09/10/90	7	2	0	2	0
09/11/90	4	2	1	2	0
09/12/90	0	0	0	0	1
09/13/90	1	0	0	1	0
09/14/90	0	0	0	3	0
09/15/90	0	0	0	0	0
09/16/90	0	0	0	0	0
09/17/90	0	0	0	0	0
09/18/90	0	0	0	0	0
09/19/90	0	0	0	0	0
09/20/90	0	0	0	0	0
09/21/90	0	0	0	0	0
09/22/90	0	0	0	0	0
09/23/90	2	0	0	4	0
09/24/90	0	2	0	3	0
09/25/90	0	2	0	2	0
09/26/90	1	3	0	5	0
09/27/90	0	0	0	3	0
09/28/90	0	2	0	2	1
09/29/90	0	5	0	4	0
09/30/90	0	3	0	4	0
10/01/90	0	0	0	0	0