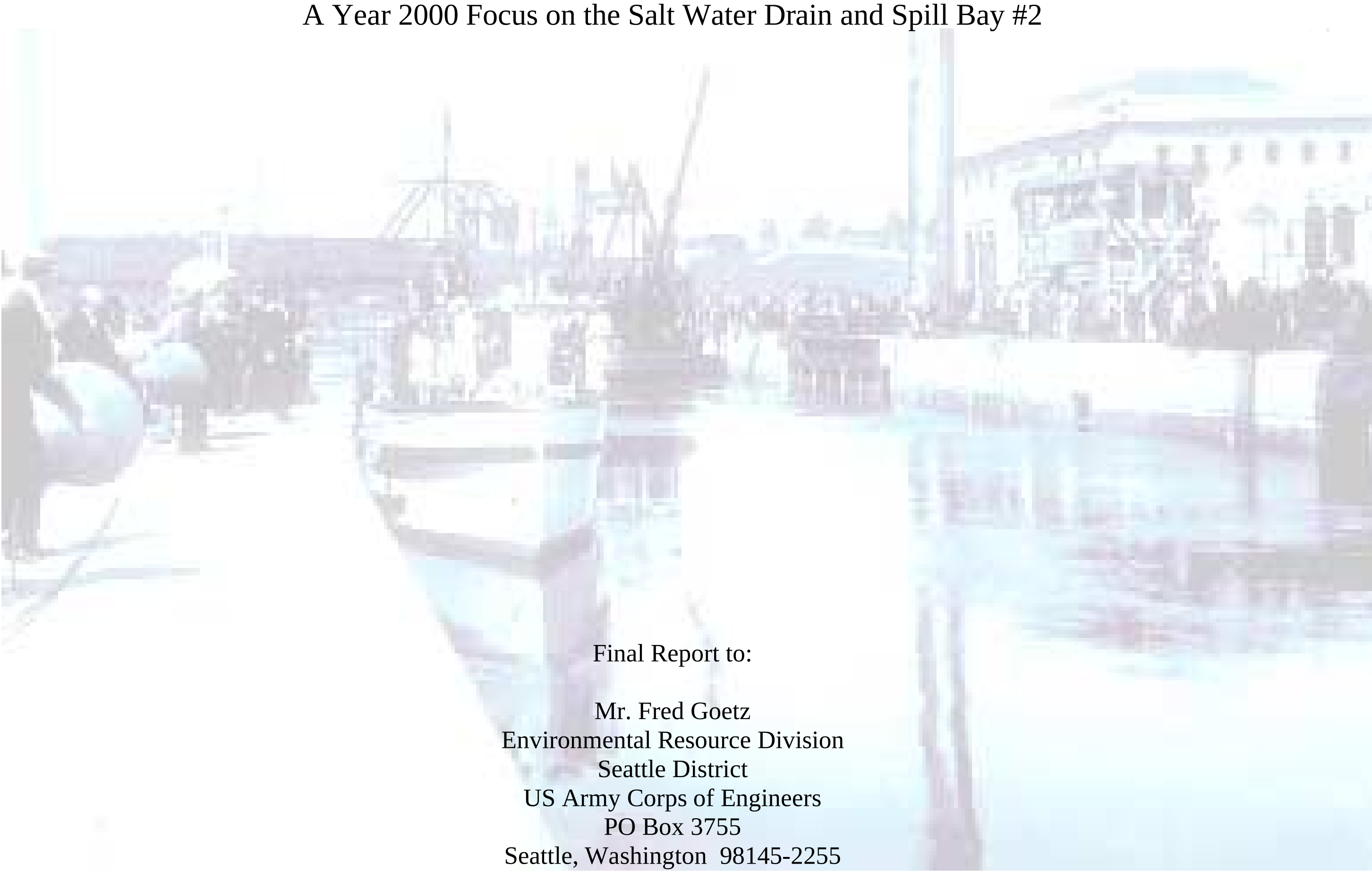
Acoustic and Video Measurements of Fish Passage at the Hiram M. Chittenden Locks:

A Year 2000 Focus on the Salt Water Drain and Spill Bay #2



Final Report to:

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Executive Summary

Scientific single-beam acoustic techniques were used to count fish passing under spill gate #2 from April 24th through June 22nd, 2000, with different gate height openings tested.

Scientific split-beam acoustic and underwater video techniques were used to monitor fish passing into the intake of the salt-water drain system from April 24th through September 30, 2000.

Flow velocity into the mouth of the salt-water drain was estimated at 1.5 feet per second at 300 cfs, and accelerates to an estimated 8 feet per second at the throat of the intake structure.

In general, fish passage through spill was higher when passage rates through the fish flumes were lower, and vice versa.

Based on visual observations of fish passing through the fish flumes and on schools in the forebay of the spill region at the locks, we believe that the majority of the fish counted at spill bay #2 were salmonid smolts.

It is hypothesized that the attractant flows from spill or fish flumes extend upstream a considerable distance due to shallow depth of the water.

Fish entrainment rates at the entrance to the salt-water drain were low from April 24th through the end of July. The rates before May 31st may have been low due to improper aiming of the transducer or to low fish detectability. Fish counts began to increase in mid-August and peaked at over 2500 fish per day. Counts dropped sharply in the first week of September, and then increased steadily through the end of the study to over 1000 fish per day.

The underwater video camera located at the intake mouth showed many species holding in the current flowing into the mouth of the drain. Most of the observations consisted of marine species (herring, shiner perch).

Adult Chinook salmon were observed holding at the intake mouth starting in mid-July. Video and acoustic data both showed adults being carried into the drain intake and swimming back out, producing a saw tooth pattern on the sonar.

Introduction

The Lake Washington (LW) Ecosystem Restoration General Investigation (GI) Study was initiated in July 1999. The co-sponsors of this study include the City of Seattle and King County. The purpose of the study is to evaluate various projects that may contribute to 1) restoration of ecological processes or functions within the Lake Washington Basin. This includes fish passage improvements at the Hiram M. Chittenden Locks ("The Locks") and in the Lake Washington Ship Canal ("Ship Canal"); and 2) water conversation in the Ship Canal to provide additional water for fish passage. Under the LW GI study, environmental monitoring will be conducted in 2000, 2001, and 2002. Monitoring of juvenile salmonids will complement post-construction monitoring performed under the Lake Washington Ship Canal Smolt Passage, Section 1135 Restoration Project.

The Hiram M. Chittenden Locks and spillway dam are used to regulate the elevation of the water surfaces of Salmon Bay, Lake Union, Lake Washington, and the Ship Canal. The 235-foot long concrete gravity spillway dam is located between the small lock and the fish ladder on the south shore. The spillway consists of six 32-foot wide bays, each controlled by 12.5-foot radius tainter gates. The spillway is capable of discharging up to 18,200 cubic feet per second (cfs) at a maximum regulated Lake Washington elevation of 22 feet. Spillway bays are numbered 1 through 6, from north to south respectively.

The facility provides for vessel lockage into and out of the Lake Washington drainage, with large numbers of commercial and recreational vessels pass through the locks each week. The facility contains one large lock measuring 80 feet wide and 825 feet long, and a smaller lock measuring 28 feet wide by 150 feet long. Located in Ballard (Figures 1 and 2), the facility is a favorite tourist spot.

During lockage of vessels, the difference in elevation between the upstream fresh water and the downstream marine water is 4-24 feet, depending on tide. As a result, salt water migrates upstream through the locks into the fresh water environment. A salt-water return system is installed to siphon saline water in the environment upstream of the structure to a downstream location. This system consists of an underwater intake structure, a water transport pipe that branches into two sections, control valves and two exits. The first exit, known as the "old salt water drain", falls over a small spillway at the north end of the spillway structure. The second pipe and exit was added to the salt-water drain in 1976. This branch, known as the fish attraction diffuser pipe, routes flow southward and exits in a diffuser structure in the fish ladder. This 160 cfs flow combines with the 23 cfs flow through the fish ladder to provide additional flow at the exit of fish ladder to attract adult salmon.

The Locks provides the only passage route into and out of the Lake Washington drainage for several species of salmon and steelhead. Adults enter the system through the fish ladder on the south bank or pass through the navigation locks. Smolts that have been rearing or released in the system must pass through the structure on their migration to the sea. There are 12 different routes that smolts can use to pass into the marine environment: 1) the fish ladder; 2) one of 6 spillway gates; 3) prototype smolt slide (up to 1999) or four smolt passage flumes (beginning in 2000); 4) the old salt water drain and over the spillway at the north end; 5) the salt water drain through the fish ladder auxiliary water supply; 6) entrainment into the small lock filling culverts; 7) volitional migration through the small lock miter gates and downstream as boats; 8) entrainment into the small culverts (2 x 4 ft. side portals) during down lockage in the small lock; 9) entrainment into the large lock filling culvert intakes and into the upper lock chamber; 10) entrainment into the large lock filling culverts and into the full lock chamber; 11) entrainment into the small (2 x 4 foot) culverts during down lock (of the upper or full lock chambers); and 12) volitional migration through the large lock miter gates and down lock as boats. Data from previous studies indicate that both smolts and adults may pass through the structure multiple times. Figure 3 and 4 present diagrams modeling the potential paths that salmonid smolts might take through the project.

A wide variety of measurement techniques have been deployed in the past to assess how salmonids pass through the structure and determine any deleterious effects. The scope of these studies was expanded in 2000. Scientific acoustic techniques coupled with underwater video observations were proposed for monitoring passage of fish into the Salt Water Drain intake located off the end of the pier between the two locks. Scientific acoustic techniques were also used to observe fish passage at Spill Bay #2. This report documents the methodology and findings of the year 2000 studies.

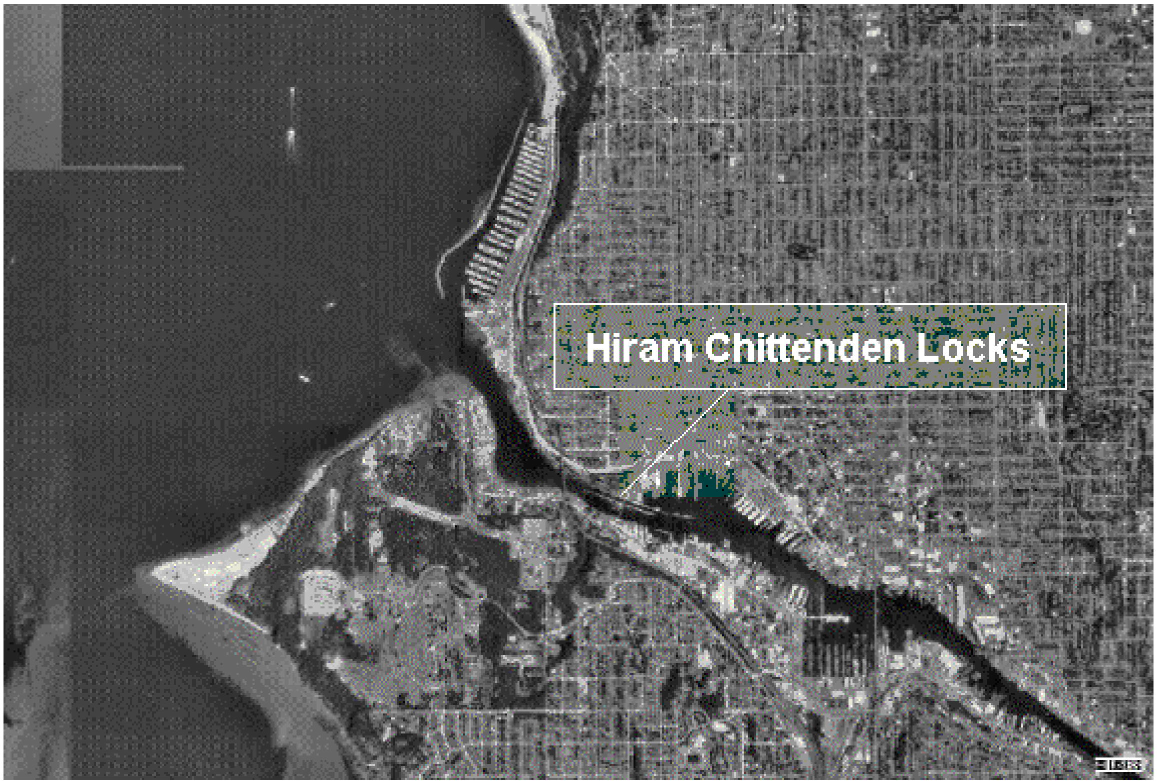


Figure 1. Hiram M. Chittenden Locks located in North Seattle.

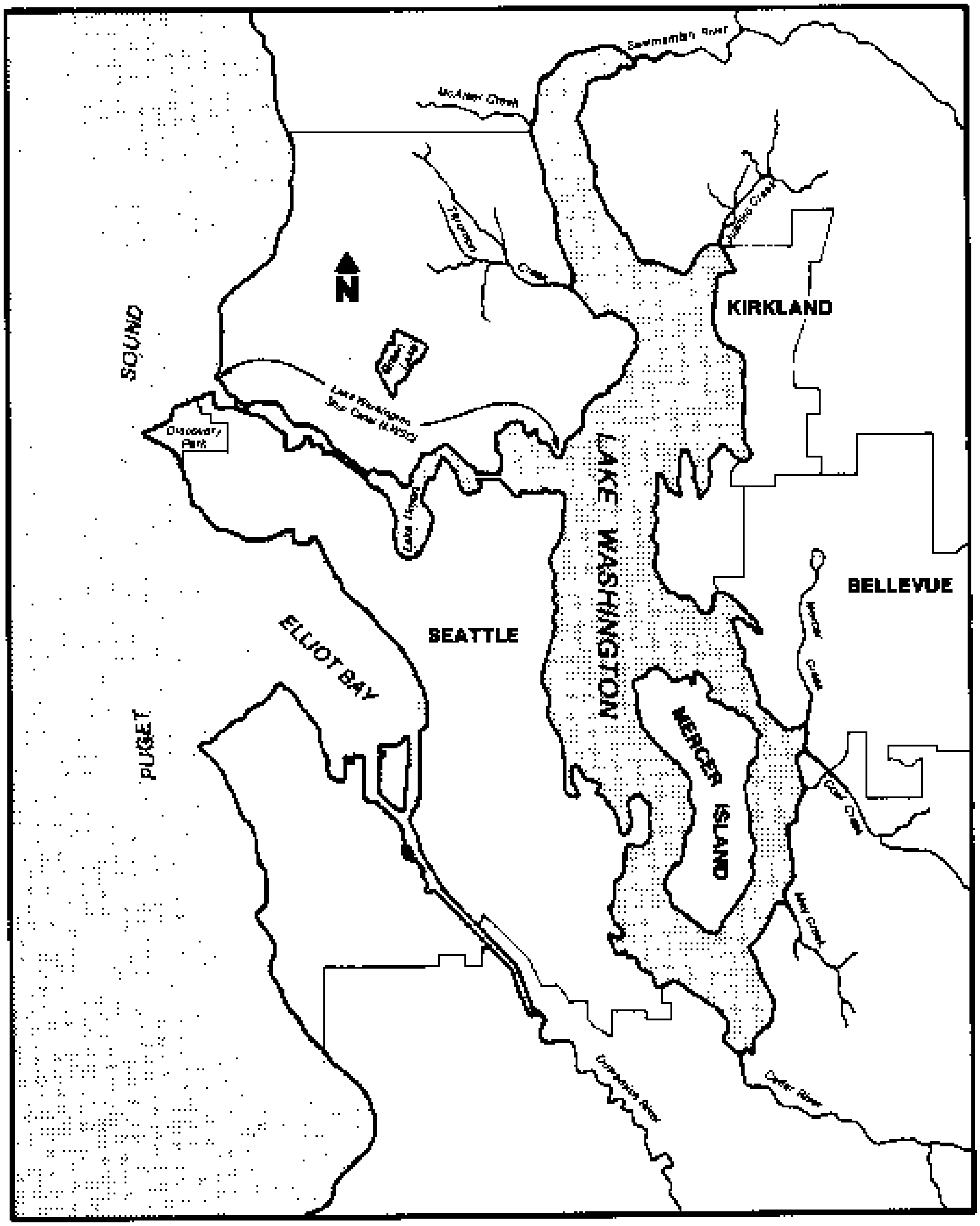


Figure 2. Western half of the Lake Washington Ship Canal and the Hiram M. Chittenden Locks

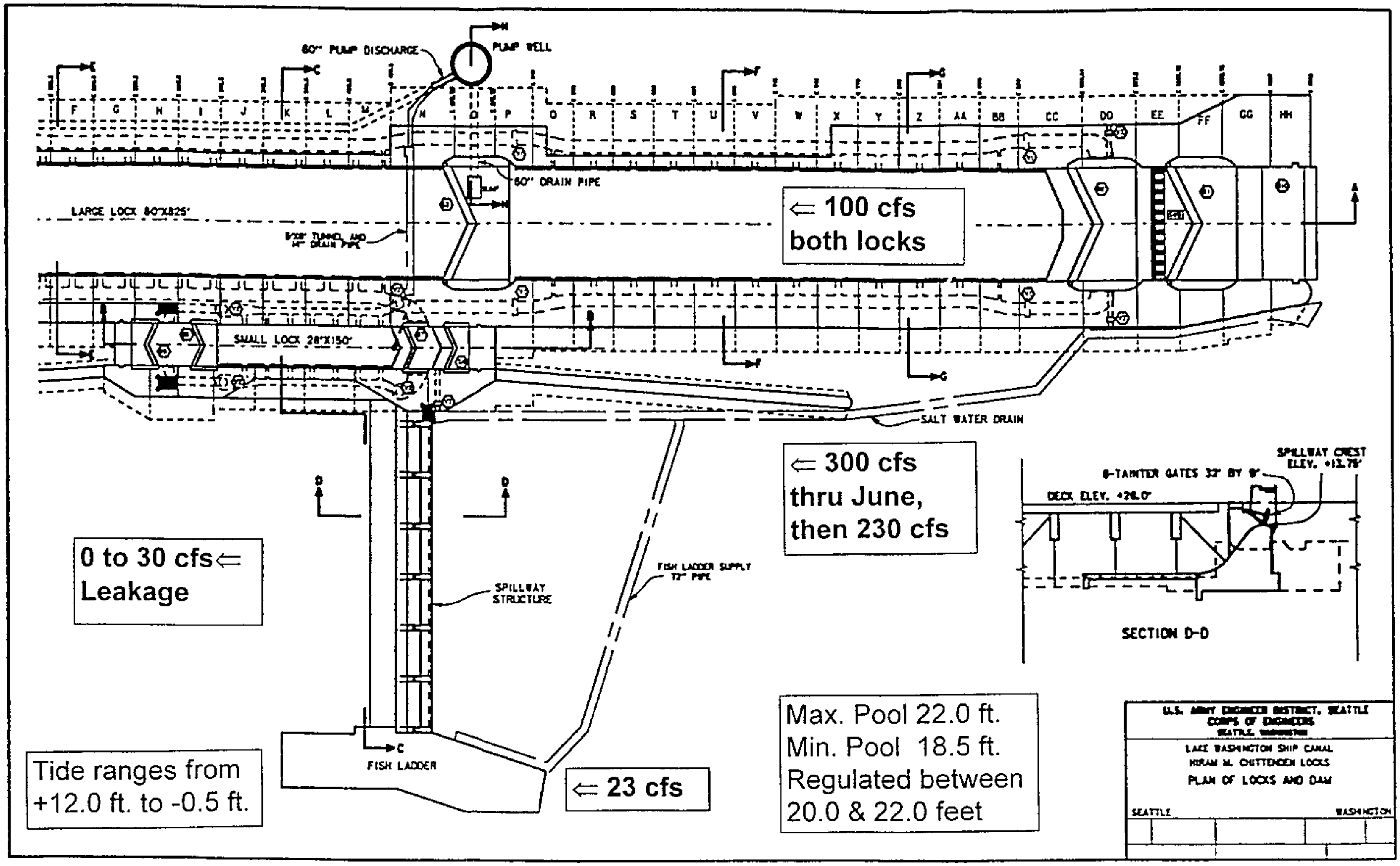


Figure 3. Plan view of the Locks including low flow volumes per outlet (from Fred Goetz, USACE)

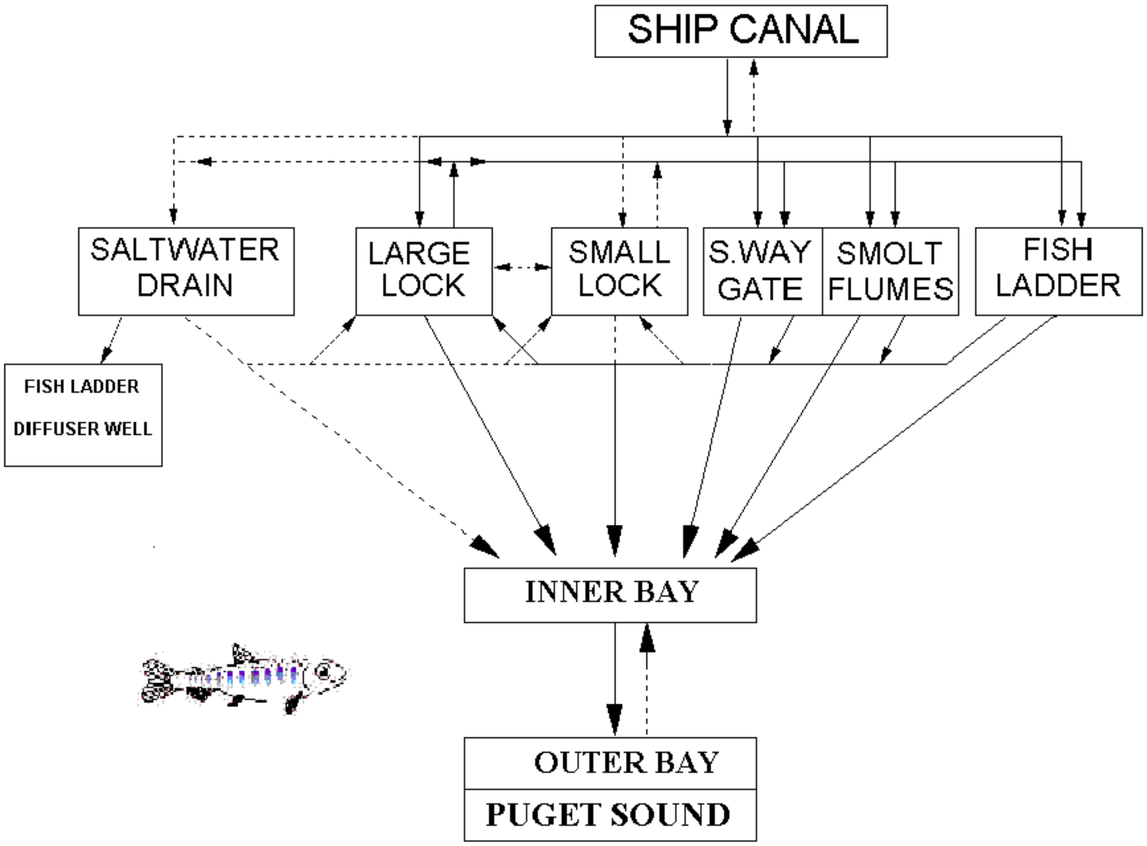


Figure 4. Conceptual model of observed (solid line) and possible (dashed line) downstream passage routes for juvenile salmon at the Hiram M. Chittenden Locks (from Fred Goetz, USACE).

Methods

Video Techniques

Description of System

A Sony Model CVX-V18NS VersaCam color video camera with 0.7 lux sensitivity was installed inside a waterproof ABS housing. Features of the camera included high resolution (470,000 pixels – 500+ lines) with remote zoom and shutter control. The camera cable was routed back to a Sony Model SVT-LC300 videocassette recorder. The recorder was operated in time-lapse mode, allowing 24 hours of images to be recorded onto single T-160 VHS videotapes. A small video monitor was attached to the recorder to monitor the quality of the images being recorded.

Deployment

The camera housing was clamped to a pipe mount attached at mid-height of one of the vertical stainless steel bars at the mouth of the salt-water drain. The camera depth was about 47 feet below the surface. We decided to use no auxiliary lighting to insure that the measurement equipment did not affect fish behavior. The mount location and approximate field of view are shown in Figure 5. The zoom lens was adjusted to the widest field of view and the focus was set to infinity.

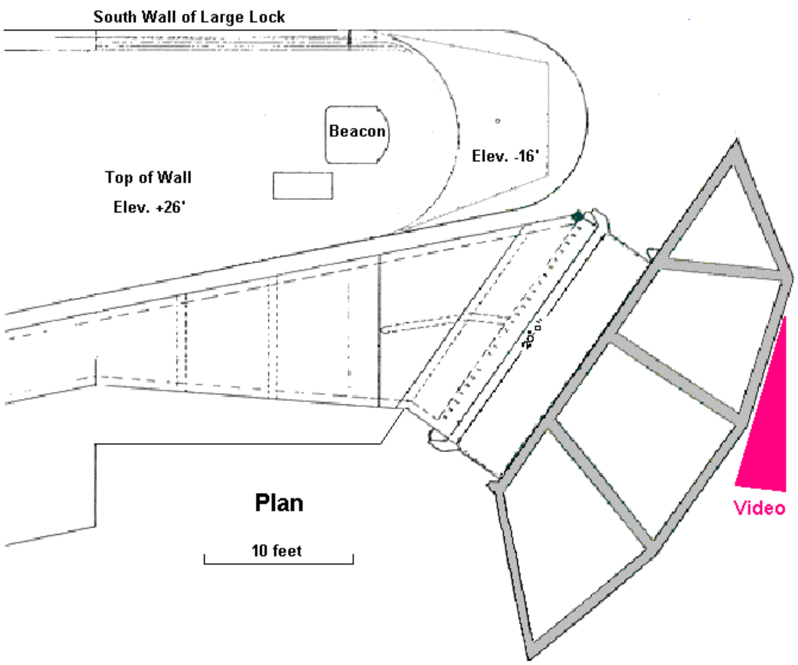


Figure 5. Plan view of salt-water drain intake showing location of video camera mount and approximate field of view.

We observed that the clarity of the video image began to degrade several weeks after deployment of the video camera. Macrophyte growth on the camera lens was the cause. We utilized divers to clean the lens on May 31 and on August 30. Water clarity improved throughout the study period. Under optimal conditions, the camera gave a clear view to a range of about 8 feet, based on the distance from the camera to identifiable structures. The vertical frame at far range extended from the intake floor to the ceiling.

Data Collection

Video images were recorded in time-lapse fashion to VHS videocassettes. The time-lapse function allowed recording of 24 hours of video images onto a single 8-hour videocassette. The cassettes were changed each day, typically after lunch. Tapes were numbered sequentially, and labeled with the start date and time.

Data Analysis

Videotapes were delivered to Peter Johnson, a Senior Research Scientist with MEVATEC Corp. Peter supervised Gina White and Patricia Pearson, students from Shoreline Community College, who analyzed samples of the video data. Tapes were initially scanned to determine hours of viewable data. For each tape hour that was defined as viewable, three 5-minute sub-samples were randomly chosen for processing. Observations included tape number, date, sample hour and minute, quality of overall image, and description of observations. Several tapes were processed in their entirety.

Acoustic Techniques

Salt Water Drain

Site Description

Because salt water is denser than fresh water, a certain volume is locked upstream during each vessel lockage. At the large lock, a barrier can be raised to block the upstream movement of some of this volume. In spite of operational procedures and structural modifications, some salt water continues to move into the aquatic environment. In years past, salt water has entered Lake Union, producing a region of anoxic water near bottom and resulting in the production of hydrogen sulfide gas.

The primary system for minimizing salt-water intrusion involves the use of a settling basin immediately east of the large lock and a siphon system to return the salt water to the marine environment. The intake of this system is located to the southeast of the end of the pier, between the large and small locks, at a depth of 50 feet. A fan-shaped intake structure (Figures 6-7) houses 4 openings 12 feet across and 4 feet high. The intake structure is constructed of concrete. Vertical bars of 1x3 inch stainless steel are spaced at 2-foot intervals to block the entrance of large objects. The floor of the structure is lined with bags of concrete. Considerable scouring has jumbled the bags and scoured underneath the northern sidewall. The dimensions of the structure decrease to 2 feet high by 20 feet across at the innermost part of the structure, at which point the flow is vectored upward into a manifold that transitions to the shape of a pipe (Figure 8).

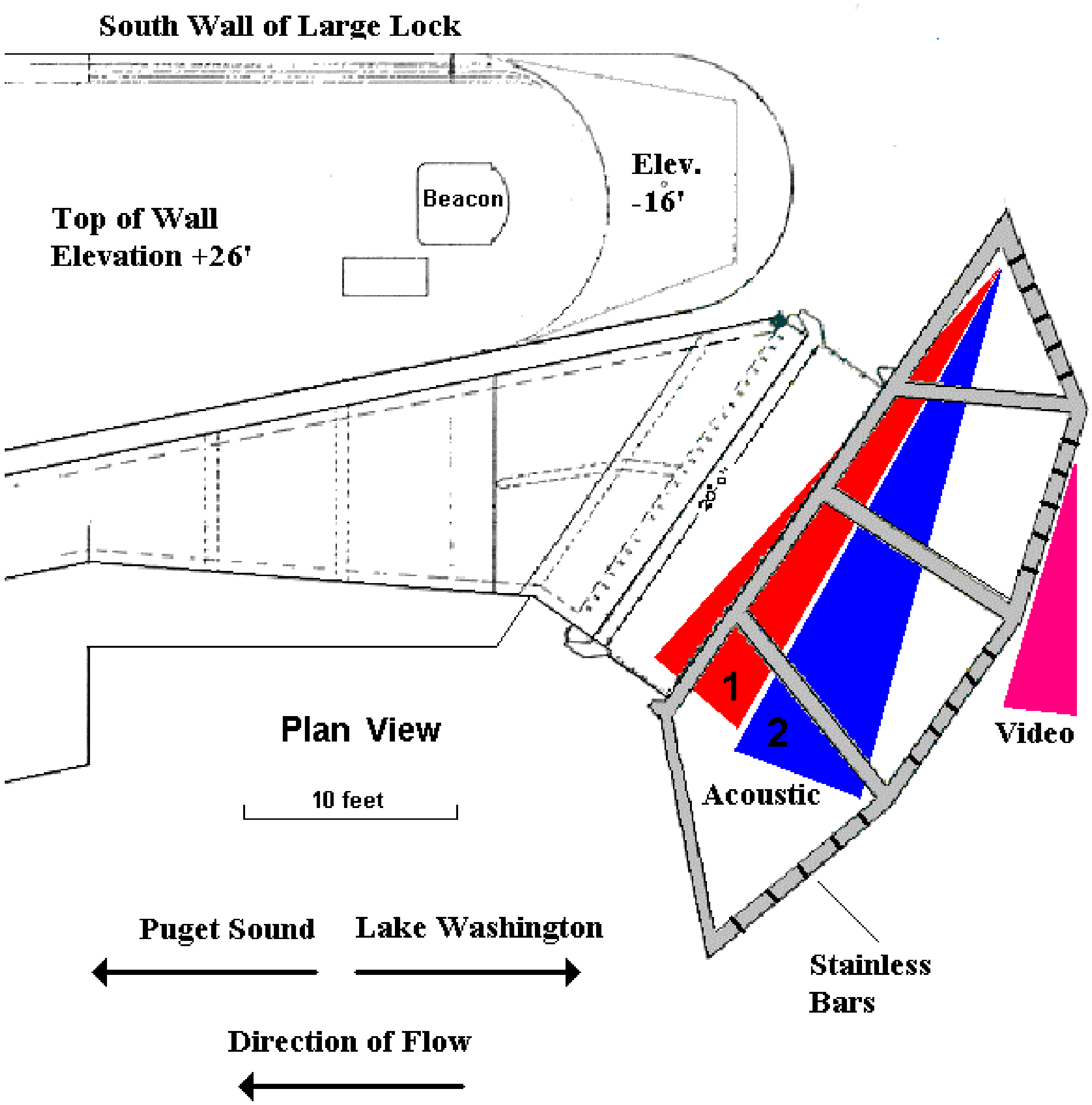


Figure 6. Plan view of salt-water drain intake (with roof transparent) showing position relative to pier between large and small locks.

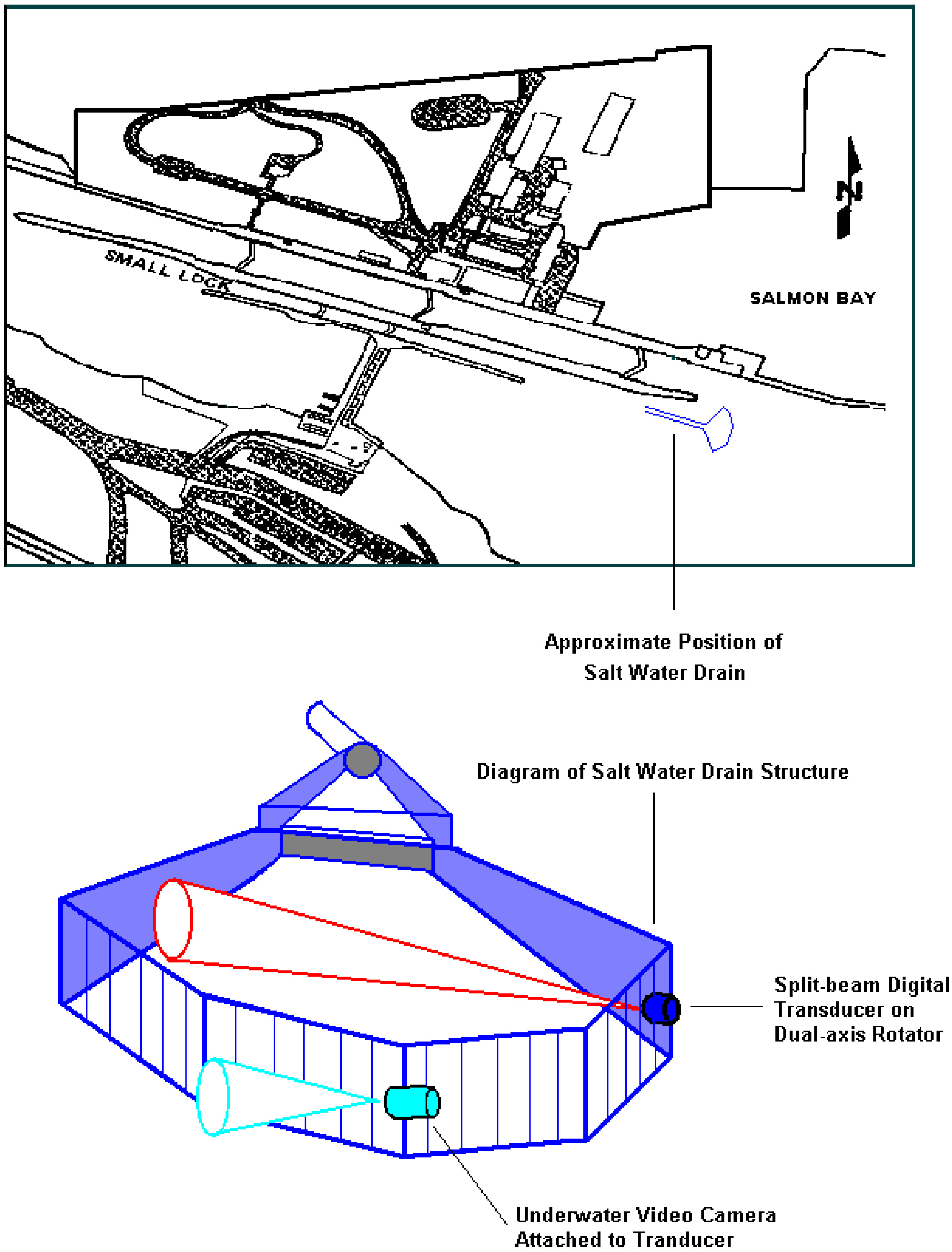


Figure 7. Isometric representation of salt-water intake.

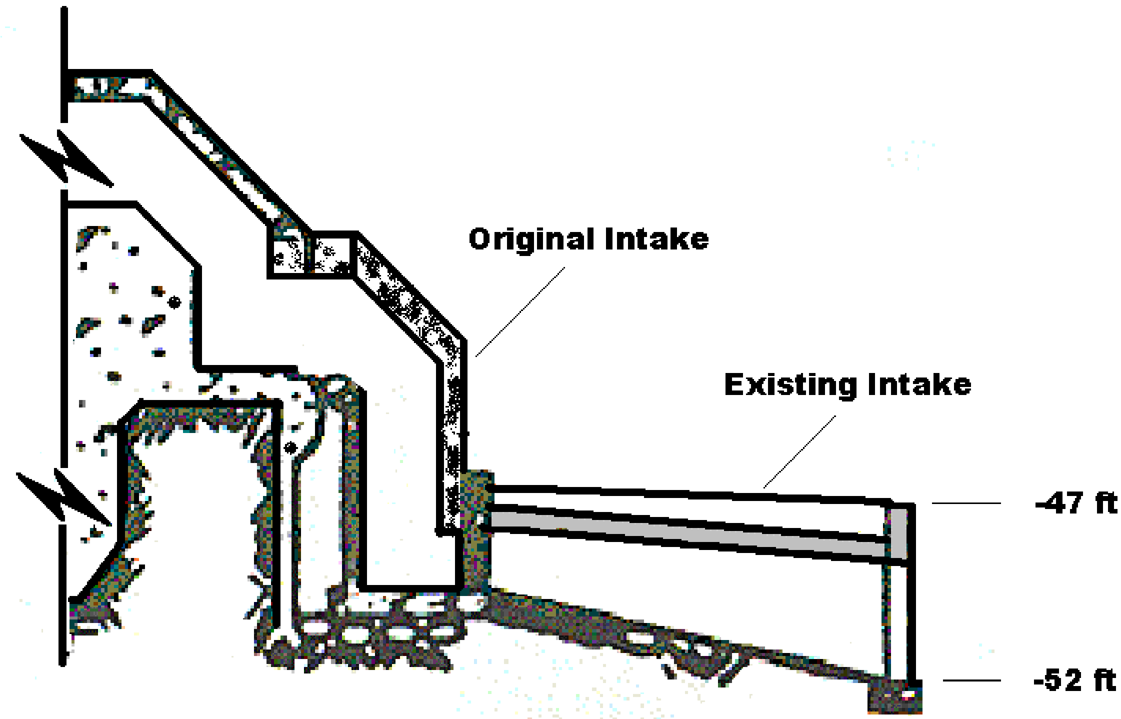


Figure 8. Cross Sectional View Through the Salt Water Drain Intake Structure

The flow through the salt water drain system is driven by gravity and flows through pipes to two locations; one flows into a diffuser system in the fish ladder, while the second passes through a chute at the north end of the spill bay section. The flow through the diffuser is 160 cfs, and the flow through the chute is 140 cfs. When both paths are opened, the velocity at the mouth of the salt-water drain is approximately 1.5 feet per second (assuming a mouth opening of 192 square feet and a flow of 300 cfs). The water accelerates as it arrives at the back of the structure, where drawings indicate an opening 2 feet high and 20 feet across. 300 cfs passing through a 40 square foot opening would produce velocities approaching 8 feet per second. Before studies commenced, divers rearranged the concrete bags to form a relatively level and smooth floor of the drain structure. Divers observed and removed considerable debris, primarily ropes, plastic sheets, and tarps, that were wound around the vertical stainless steel bars.

Deployment

During creation of the study design, it was anticipated that targets detected inside the salt-water drain would be single targets, as opposed to schools or aggregates of fish. Therefore, a split-beam echo sounder was assigned the task of detecting targets inside the drain. If suitable signal to noise conditions exist, the split-beam system is able to measure both the target strength (acoustic size) and the direction of travel of each individual fish target.

A DT6000 200 kHz split-beam scientific echo sounder manufactured by BioSonics was used to detect fish inside the intake structure. The echo sounder used a 6-degree nominal beam angle circular transducer. The transducer was mounted on a dual-axis rotator attached to the northernmost stainless steel vertical bar (see Figure 6). The assembly was mounted such that the transducer was about 3.5 feet from the floor of the intake gallery. The horizontal and vertical aiming angles were controlled remotely. From April 24 through May 31, the transducer was aimed toward the transition point at the rear of the structure (see aiming angle #1 in Figure 6). No fish were observed by the sonar system in this configuration, either due to shadowing by the rear wall or to reduced fish detectability associated with high passage velocity. On June 1st, the transducer was rotated upstream and aimed across the intake opening as shown by aiming angle #2 in Figure 6. The vertical angle was minutely adjusted to maximize sonar detection range and minimize returns from the bags of concrete forming the floor of the intake.

The specific position of the transducer mount was dictated in part by the physical dimensions of the salt-water drain intake, and also by the logistical constraints of using divers to mount equipment in enclosed regions. Our intent was to aim the expanding volume of the beam in a direction to maximize the fish detection range. Interference from the ceiling and floor of the intake structure would result from rotating the beam in toward the throat of the intake, while diminished sample volume and detection range would result from rotating the beam out toward the mouth of the intake. Additionally, an outward rotation would locate the beam outside of the intake mouth and in regions of ambiguous fish behavior. Although mounting the transducer further into the salt water drain structure would assign a higher probability of entrainment to the passage estimates, acoustic conditions would not allow this placement.

Data Collection

The echo sounder operated at a pulse rate of 10 pulses per second, and a pulse width of 0.3 ms was used. Signals were thresholded at an acoustic level corresponding to an on axis value of –60 dB. This level was the lowest possible value over which data could be collected inside the salt-water drain with the available deployment position. Acoustic sample data were saved into 30-minute files and recorded to hard disk. A high-resolution color echogram was provided in real time to assist in aiming the rotator and for diagnostic purposes. Data files were downloaded periodically via SCSI card to a 2 gigabyte Iomega Jaz drive and brought to the office for analysis and archiving. All sonar data were archived onto CD's. The echo sounder was shut down only during data backup periods, and collected data continuously from April 24th to October 13th, 2000.

Data Preview

During the early part of the season, many of the data files contained no fish detections. Analysis of empty files would take considerable time, so we implemented a scheme to preview data files. This approach created a high-resolution color echogram for each data file and stored it to a bitmap file. The 48 daily pictures were viewed with a graphics program, and files with fish traces were transferred to a working subdirectory for further analysis.

Data Processing and Analysis

The echo sounder saved thresholded digital samples to file. A "Trace Formation" program called VTRACK written by BioSonics was used to process these files. The program's first step was to form fish echoes from these samples. The program then implemented a three dimensional tracking algorithm to assemble spatially correlated fish echoes into fish traces. Finally, the software used a variety of filters to select true fish traces and reject traces formed from noise. An operator entered a series of parameters to define each of these processes. The values are summarized in Table 1. Fish counts were written by VTRACK to database files, which were exported to a spreadsheet for summarization and graphics.

One critical parameter listed in Table 1 is fish velocity. This parameter is used to create a search sphere in the tracking algorithm. Although fish are not traveling this fast, interference and noise detected by the echo sounder confound the split-beam algorithm and resulting positional estimates. The apparently high value of fish velocity is required to accommodate the increased variability in positional estimates, which produces a correspondingly high variability in the acoustic estimate of fish velocity. This process of calculating a search sphere is independent of range.

Table 1. Analysis parameters used in the Trace Formation software

VTRACK Data Processing Parameters		
Chittenden Locks, 2000		
Echo Location Parameters		
General Parameters		
Maximum Echoes per Ping	100	echoes
Shape Correlation	0.9	
Pulse Width Measurement Level	-12	dB
Echo Strength Parameters		
Minimum Target Strength	-60	dB
Maximum Target Strength	-20	dB
Spatial Parameters		
Minimum Range	1	m
Maximum Range	10	m
Minimum Pulse Width	75	%
Maximum Pulse Width	150	%
Angular Parameters		
Minimum X Angle	-6	degrees
Maximum X Angle	6	degrees
Minimum Y Angle	-6	degrees
Maximum Y Angle	6	degrees
St. Deviation of X Angle	2	degrees
St. Deviation of Y Angle	2	degrees
Trace Formation Parameters		
Minimum Echo Separation	0.01	m
Projected Fish Velocity	3	m/s
Ping Gap	7	pings
Trace Filters		
Minimum Echoes per Trace	10	Echoes
Maximum Echoes per Trace	200	Echoes
Minimum Trace Target Strength	-55	dB
Maximum Trace Target Strength	-20	dB
Minimum Ping Concentration	50	%
Maximum Ping Concentration	100	%

The target strength of each fish was calculated from the mean of the target strength of the echoes composing a fish trace. The echo target strengths were calculated using the split-beam technique to correct for position in beam effects.

Target strength (TS) is a measure of the acoustic size of a fish, or better, its reflectivity. Target strength is related to the density of the fish, the fish size, and the fish aspect. The dorsal aspect formula used by Love (1971) is provided as a frame of reference below:

$TS = 19.1 \log(L) - 0.9 \text{Log}(f) - 62$, where

L = fish length (cm)
f = frequency (kHz)

Example conversions between fish length and target strength are provided below in Table 2.

Table 2. Sample conversions between fish length and target strength

Length (cm)	TS (dorsal)
1	-64.07093
2	-58.32125
5	-50.7206
10	-44.97093
20	-39.22125
50	-31.6206

Target strength is a highly variable parameter due to the complex reflective nature of the fish as well as irregularities in the transmitting medium (water).

Spatial Extrapolation

Spatial extrapolation is required when the acoustic beam does not sample the total cross sectional area of an intake. Fish detected by the acoustic system are expanded based on the ratio of the effective beam angle to the width of the intake. The effective beam angle is usually derived from a detectability model, which relates echo detection threshold, fish trajectory, fish target strength, fish velocity, and other parameters to an "expected number of echoes threshold" to estimate the effective beam angle of the transducer. Fish with fewer echoes are then excluded.

The current generation of detectability models assumes a constant flow through the beam at any specific range. This assumption is not valid inside the salt-water drain intake structure since the water is accelerating as it passes through the acoustic beam. An additional difficulty in applying a classic detectability model is that the echo sounder was aimed horizontally. As a result, fish may have been sampled head-on or side-on. The variety of fish sizes, detection aspects, and body morphologies produced a widely varying target strength distribution, which in turn modifies the effective beam angle. Finally, little was known on whether fish were uniformly distributed across the mouth of the intake or whether they oriented to the walls of the structure. Due to these difficulties, we decided to assume a nominal beam angle (6 degrees) and spatially extrapolate based on the ratio of the beam cross section to the intake cross-section. Based on the beam angle, aiming geometry, cross-sectional area of the opening of the drain intake structure, and the decreasing height inside the structure, the percent of the total area that was sampled was estimated at 25%. A spatial extrapolation of 4 was applied to each fish to expand observed counts into un-sampled flow. This extrapolation assumes a uniform horizontal distribution across the mouth of the intake.

Interpretation

The video system mounted in front of the salt-water drain intake observed fish swimming in the incoming flow, and typically resisting entrainment for long time periods. Fish observed by the video camera did appear in the upper half of the observed field. In addition, the flow entering appeared to have about a 30° downward angle from horizontal as it approached and entered the mouth of the salt-water drain. The echo sounder sound field was located further back in the intake, where flow was accelerating. Patterns observed by the acoustic system showed fish being carried with the current, then exhibiting a burst of swimming speed to move back toward the opening. This behavior created "saw tooth" type patterns on the echo sounder (Figure 9). Often fish would leave the beam while they were being entrained; other times they would exit the beam while swimming toward the mouth. For the purposes of entrainment estimation, we assumed that all fish observed by the echo sounder were eventually entrained. We do not have data to test the validity of this assumption. Because fish may have been carried through the sonar beam, swam out at a slightly different depth or location, and then been carried again through the sonar beam, we believe that the entrainment estimates presented in this report represent either maximum values or perhaps overestimates. However, since only the center portion of the flow was sampled, biases operating in the opposite direction could occur if fish were oriented to the sidewalls of the intake structure. The study design was not configured to test these assumptions.

Figure 9. Echogram showing large targets resisting entrainment flow.

Spill Gate #2

Description

Six spill bays are located to the south of the small lock (Figure 10,11). The bays are numbered from the north or lock end.

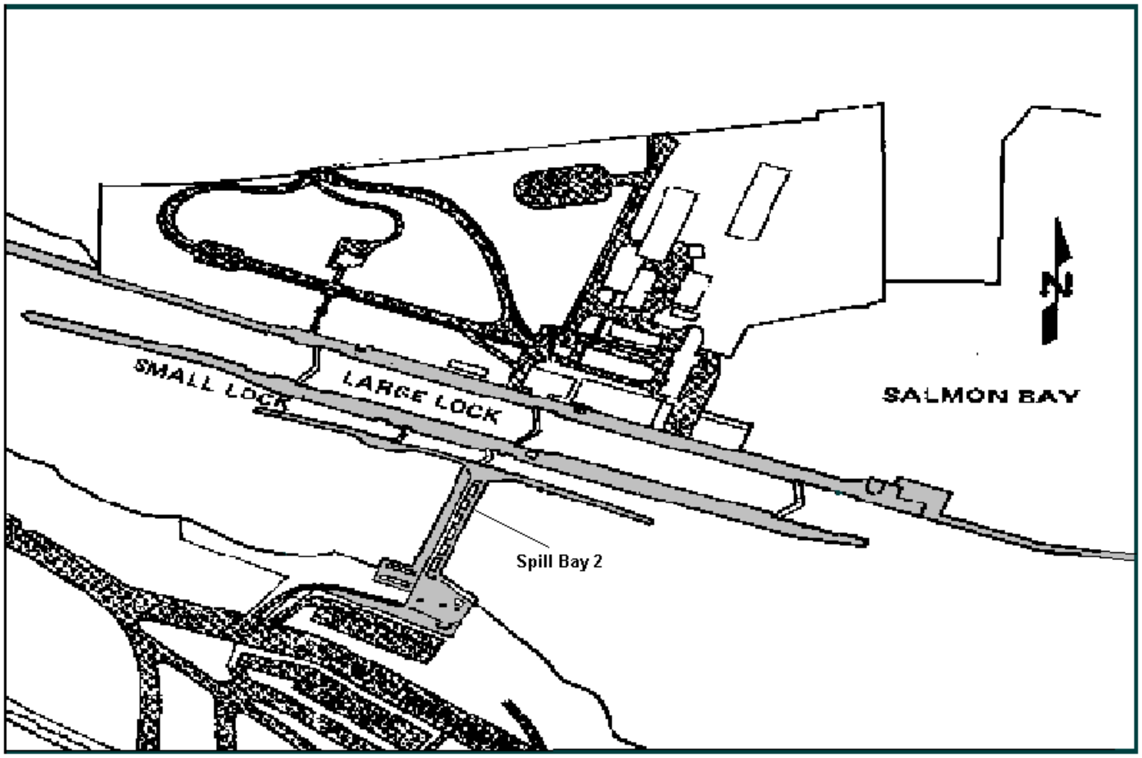


Figure 10. **Plan view of the Hiram M. Chittenden Locks and surrounding structures.**

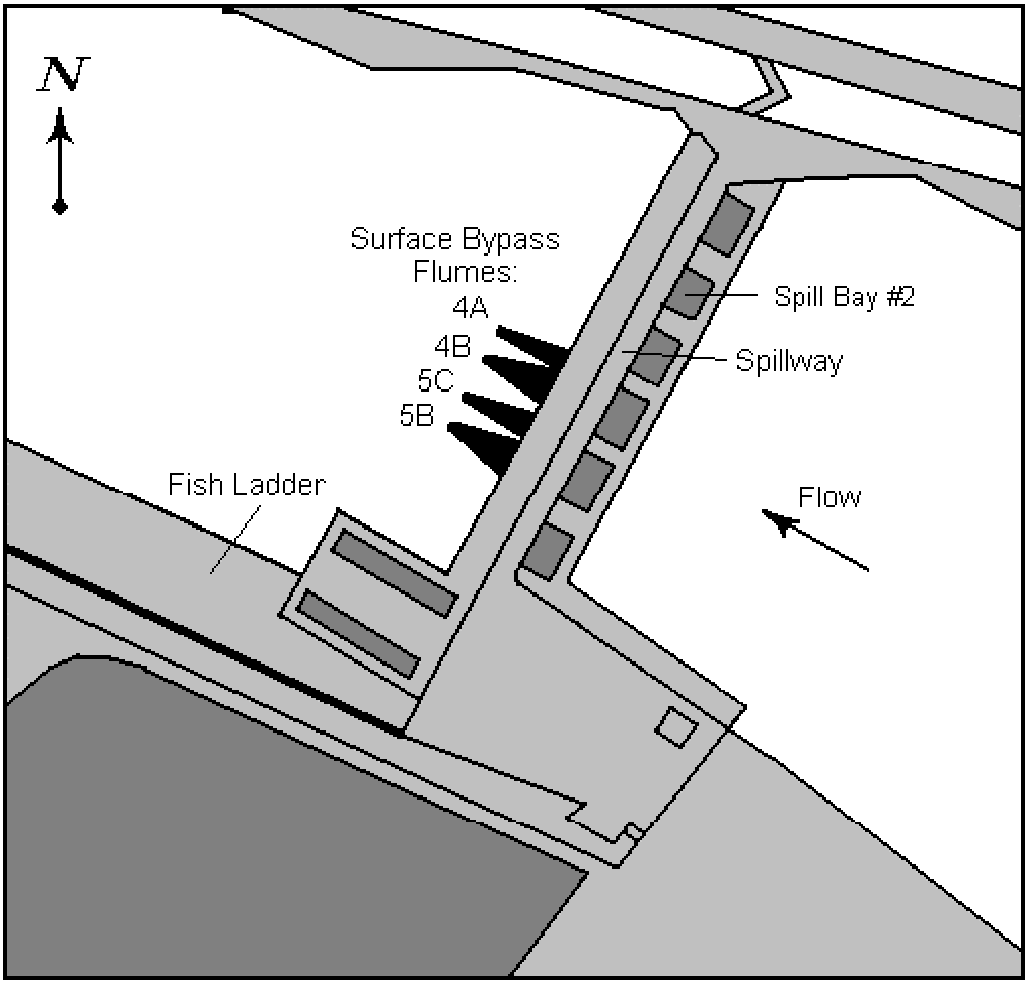


Figure 11. Plan view of spillway showing the location of the experimental flumes and spillway bay numbers.

Deployment

Each gate is a tainter gate, which is lifted to pass water. Single-beam 6 degree transducers were installed on each side of Spill Bay 2 at an elevation of 16 feet and aimed horizontally across at the opposite pier nose (Figures 12,13). Gate #2 was selected because it was forecast to have a continuous operating schedule and was physically separated from the installation of the fish flumes at gates 4 and 5. The transducers were initially oriented parallel to the front of the tainter gate, then rotated toward the gate as far as possible before interference from the gate was observed. This aiming procedure placed the sound fields as close to the bottom of the gate as acoustically possible.

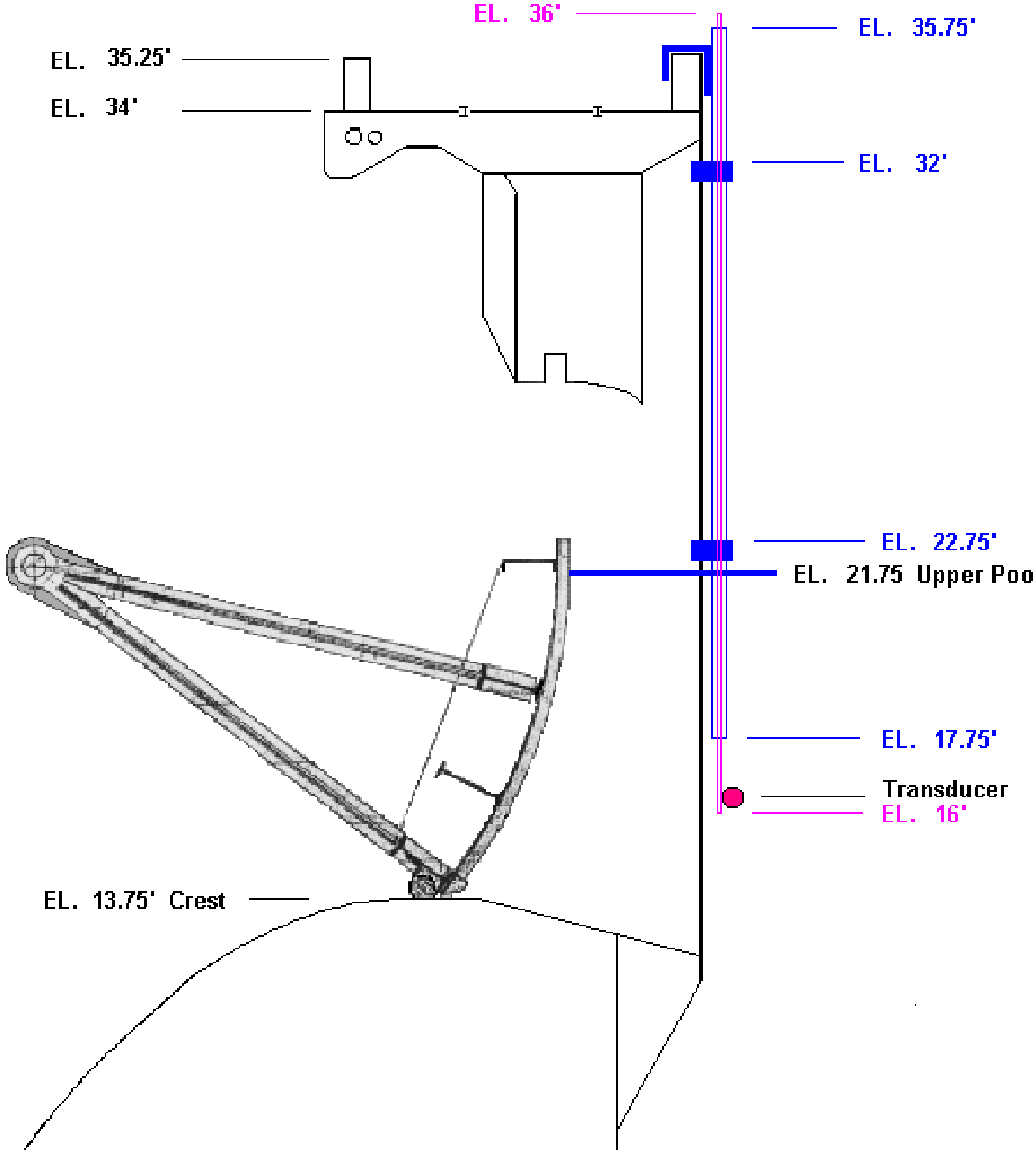
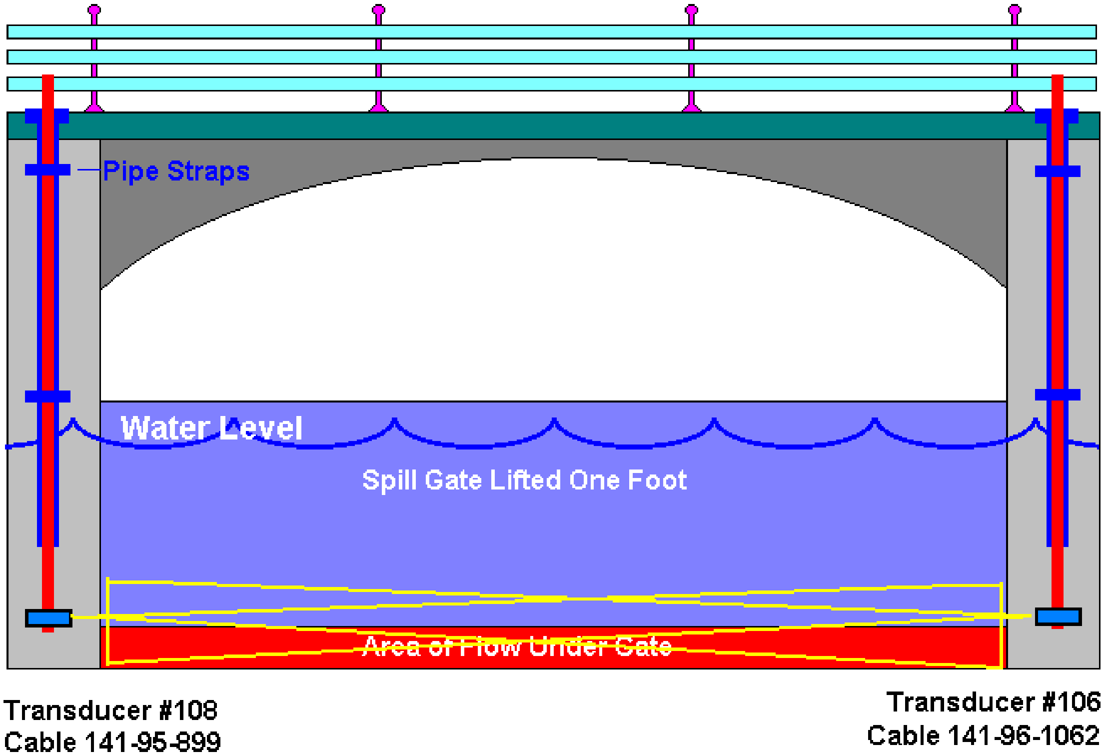


Figure 12. Spill Bay # 2 showing tainter gate and acoustic transducer deployment.



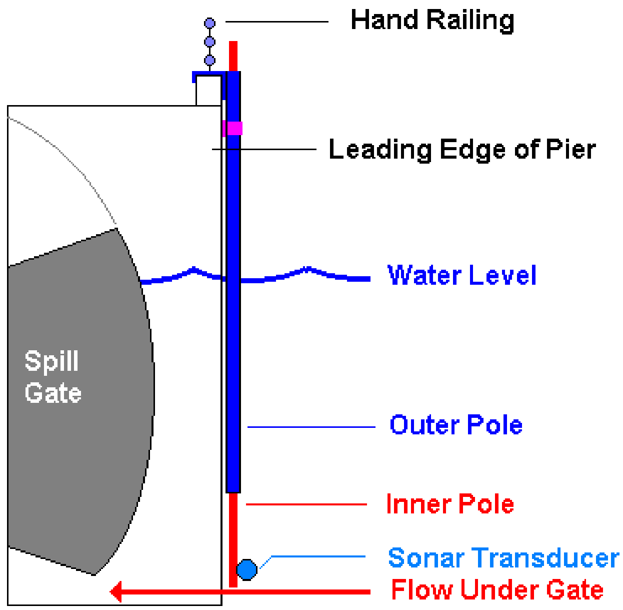


Figure 13. View of Spill Bay #2 from upstream showing transducer aiming geometry. Lower panel provides a cross-sectional view.

Data Collection

The sampling environment near the opening to Spill Bay #2 has many characteristics that are different from the salt-water drain. First, the opening under the tainter gate is about 8 feet below the surface, while the opening to the salt water drain is 50 feet deep. Because of this difference, each location is probably exposed to different fish communities. Second, velocities immediately upstream of the gate are expected to be much higher than those near the opening to the salt-water drain. Finally, the relatively shallow forebay in front of the spill bays is geographically removed from the deeper partially marine environment at the entrance to the salt-water drain. Several factors were involved in the choice of a single-beam system to sample at Spill Bay #2. We hypothesized that the population in this region would be comprised primarily of salmon smolts. By placing the sonar beams as close as possible to the gate opening, we believed that directional information was not critical, as most fish would be entrained. Finally, the use of two single-beam transducers provided a lower cost alternative to a split-beam system.

A 420 kHz ES2000 scientific echo sounder manufactured by BioSonics was used to interrogate the two six degree single-beam transducers at Spill Bay #2. Transducers were place on both sides to provide the maximum sample volume. If a single transducer had been used, the sample volume at close ranges would have not been adequate. A pulse length of 0.4 ms was used, and an overall pulse rate of 20 pulses per second was divided between the two transducers in fast multiplex mode to achieve a pulse rate of 10 pulses per second for each transducer. This high pulse rate was selected to insure adequate fish detectability in the high velocity flows near the gate opening. A threshold value of –60 dB was originally planned for this location, but the acoustic conditions encountered at Spill Bay #2 mandated the use of a –55 dB threshold. Fish echo detections were collected to hourly files. Data collection began on April 24th at 1500 hours and continued through October 1st at 1125 hours. Data were periodically downloaded through a parallel port SCSI adaptor into a 2 gigabyte Iomega Jaz drive.

The analog signals from the ES2000 echo sounder were routed into an ESP Model 281 Echo Signal Processor (ESP), which digitized the signals in real time, isolated fish echoes, and wrote echoes to binary data files on the PC hard drive. All acoustic equipment for monitoring spill bay 2 was placed in a portable environmental case and located on the walkway above the spills.

Study Design

Fish passage rates have correlated with flow through spill gates at some projects. To test this hypothesis, a block design was used to test passage versus flow at two gate heights – 6 inches and 12 inches. These two gate openings provide significantly different attractant flow. The proposed gate height schedule is documented in Table 3. On occasion, the spill gate was not set in the position specified by the block design. On other occasions, power failures to the acoustic system at Spill Bay #2 caused loss of data. These conditions are documented by color-coding in the passage tables located in the results section.

Table 3. Proposed and Actual Block Operational Design, Spill Bay #2

	Treatment Block							
	0600-1000		1000-1400		1400-1800		1800-2200	
Date	Proposed Gate Setting	Actual Gate Setting	Proposed Gate Setting	Actual Gate Setting	Proposed Gate Setting	Actual Gate Setting	Proposed Gate Setting	Actual Gate Setting
22-Apr	12 "		6 "	12"	6 "	12"	12 "	
23-Apr	12 "		6 "		12 "		6 "	
24-Apr	6"		12 "		12 "	CL 1400-1630	6 "	
25-Apr	6 "		12 "	CL 1200-1400	6 "	CL 1400-1600	12 "	
26-Apr	12 "		6 "		6 "		12 "	CL 1830-2000 6" 2000-2130
27-Apr	6 "		12 "		12 "		6 "	
28-Apr	6 "	CL 0930-1000	12 "	CL	12 "	CL	6 "	CL 1800-1930
29-Apr	12 "		6 "		6 "		12 "	
30-Apr	12 "		6 "	12"	6 "	12"	12 "	
1-May	6 "		12 "		12 "		6 "	
2-May	6 "		12 "		6 "		12 "	
3-May	12 "		6 "	12" 1000-1100	6 "		12 "	
4-May	12 "		6 "		12 "		6 "	
5-May	6 "		12 "		6 "		12 "	
6-May	12 "		6 "		12 "		6 "	
7-May		CL		CL		CL		6"
8-May	12 "	6" 0700-0800 CL 0800-1000	6 "	CL 1000-1230 12" 1230-1400	6 "		12 "	
9-May	12 "	CL 0700-1000	6 "	CL 1130-1400	12 "		6 "	
10-May	6"		12 "		12 "		6 "	
11-May	12 "		6 "	CL 1000-1100		6"		12"
12-May		12" CL 0900-1000		12" CL 1000-1030 CL 1200-1300 6" 1300-1400				

Data Preview

The ESP created hourly data files stored in a binary form. If a data file is empty, it has a fixed file size. We were able to select data files with no fish and exclude them from the analysis based on file size, thereby saving considerable analysis time. Additionally, the binary files were examined with the ESP_ECHO program, which displays the data in the form of an echogram. A series of data files collected on May 18th at 23:00 to May 19th at 08:00 were collected during a period when Spill Gate #2 was opened 4.5 feet. The preview of these files showed that the high acoustic noise generated by the flow obscured any possible fish detections. These files were not analyzed. On dates when no spill occurred, no data were analyzed, as reflected in the output tables.

Data Analysis

After preview of the data files, we observed that fish passed in large aggregations. Fish trace formation algorithms do not perform well in these densities. We therefore utilized an algorithm developed by the Bendix Company for counting high densities of sockeye salmon in Alaska Rivers. This "Bendix Algorithm" is a modification of the "duration in beam" method developed several decades ago. The algorithm counts total echoes, and divides this sum by the "number of echoes per fish". The Bendix algorithm relies on oscilloscope observations to determine the average number of echoes per fish. We estimated this parameter by counting echoes inside single fish traces that were discernible in the data files. We estimated an average of 22 echoes per fish trace.

The number of echoes per fish is related to the velocity of the fish through the beam, the pulse rate of the echo sounder, transducer beam width, and the angle or trajectory of the fish relative to the acoustic axis. A fish traveling normal to this axis will have the smallest number of echoes. We initially planned to estimate an echoes per fish parameter for each gate height to reflect a perceived change in fish velocity. During our data preview, we observed that the angle of fish approach to the spill gate was not constant between different gate heights. If fish approach angles vary, then velocity changes due to different gate openings do not provide linear changes in the echoes per fish parameter. We therefore chose to use an average "echoes per fish" value for scaling all echo counts.

Spatial Extrapolation

We incorporated the far half range of acoustic detections from each transducer into the fish passage estimates, that is, 16 to 32 feet in range. The nominal beam dimensions at these ranges were greater in vertical extent than the gate height openings used during all of the block design study. We observed high numbers of echoes in traces that could be identified as coming from a single fish. Due to the high number of detections and the full vertical coverage, we did not attempt to utilize a detectability model to estimate the effective beam width. We assumed full coverage of the opening and did not apply any spatial extrapolation.

Results and Discussion

Operations Data

Interpretation of the video and acoustic data is facilitated by an inspection of the operational records of the project. Table 4 provides flow data (in cfs) for all passages through the structure. Values are presented as daily totals.

Table 4. Operational Data for the Hiram M. Chittenden Locks, April 1 to September 30, 2000

	Flume Hours of Operation				Flume Flow (cfs)					Total Spill Bay	Fish	Saltwater	Small	Large	Total Project
Date	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**Total**	**Flow (cfs)**	**Ladder**	**Drain**	**Lock**	**Lock**	**Flow (cfs)**
1-Apr-00	0	0	0	0	0	0	0	0	0	877.23	23	221.89	15.38	73.88	***1211.38***
2-Apr-00	0	0	0	0	0	0	0	0	0	227.49	23	230.4	10.26	54.73	***545.88***
3-Apr-00	0	0	0	0	0	0	0	0	0	566.92	23	193.85	18.35	36.17	***838.29***
4-Apr-00	0	0	0	0	0	0	0	0	0	1196.92	23	205.17	12.48	79.41	***1516.98***
5-Apr-00	0	0	0	0	0	0	0	0	0	874.87	23	250.51	13.24	44.32	***1205.94***
6-Apr-00	0	0	0	0	0	0	0	0	0	421.06	23	222.28	11.77	83.27	***761.38***
7-Apr-00	0	0	0	0	0	0	0	0	0	921.47	23	202.54	15.48	71.85	***1234.34***
8-Apr-00	0	0	0	0	0	0	0	0	0	907.79	23	222.44	22.86	56.57	***1232.66***
9-Apr-00	0	0	0	0	0	0	0	0	0	450.68	23	219.71	15.51	52.12	***761.02***
10-Apr-00	0	0	0	0	0	0	0	0	0	450.99	23	219.76	18.48	52.92	***765.15***
11-Apr-00	0	0	0	0	0	0	0	0	0	542.5	23	217.02	14.06	57.31	***853.89***
12-Apr-00	0	0	0	0	0	0	0	0	0	451.91	23	205.65	15.55	64.15	***760.26***
13-Apr-00	0	0	0	0	0	0	0	0	0	529.22	23	222.88	17.06	59.3	***851.46***
14-Apr-00	0	0	0	0	0	0	0	0	0	1747.31	23	228.66	18.55	36.03	***2053.55***
15-Apr-00	0	0	0	0	0	0	0	0	0	644.93	23	231.65	17.84	37.88	***955.3***
16-Apr-00	0	0	0	0	0	0	0	0	0	506.63	23	225.97	16.36	54.8	***826.76***
17-Apr-00	0	0	0	0	0	0	0	0	0	1340.9	23	228.96	15.64	53.5	***1662***
18-Apr-00	0	0	0	0	0	0	0	0	0	686.27	23	177.27	17.9	49.49	***953.93***
19-Apr-00	0	0	0	0	0	0	0	0	0	947.25	23	183.05	14.93	72.49	***1240.72***
20-Apr-00	0	0	0	0	0	0	0	0	0	794.12	23	223.43	16.43	77.89	***1134.87***
21-Apr-00	0	0	0	0	0	0	0	0	0	983.16	23	226.43	17.95	71.14	***1321.68***
22-Apr-00	0	0	0	0	0	0	0	0	0	1035.12	23	209.14	15.72	37.47	***1320.45***
23-Apr-00	0	0	0	0	0	0	0	0	0	545.82	23	238.19	14.24	55.53	***876.78***
24-Apr-00	0	0	0	0	0	0	0	0	0	659.71	23	220.87	21	59.58	***984.16***
25-Apr-00	0	0	0	0	0	0	0	0	0	1000.07	23	220.97	12.02	75.3	***1331.36***
26-Apr-00	0	0	0	0	0	0	0	0	0	1284.37	23	221.02	9.77	63.53	***1601.69***
27-Apr-00	0	0	0	0	0	0	0	0	0	1656.27	23	194.93	15.8	75.93	***1965.93***
28-Apr-00	0	0	0	0	0	0	0	0	0	345.95	23	203.7	20.33	80.27	***673.25***
29-Apr-00	0	0	0	0	0	0	0	0	0	327.92	23	235.88	21.12	69.05	***676.97***
30-Apr-00	0	0	0	0	0	0	0	0	0	518.61	23	238.86	18.87	50.21	***849.55***
1-May-00	0	0	0	0	0	0	0	0	0	424.31	23	221.34	18.87	63.53	***751.05***
2-May-00	0	0	0	0	0	0	0	0	0	443.17	23	192.13	21.88	38.59	***718.77***
3-May-00	0	0	0	0	0	0	0	0	0	644.39	23	174.6	18.11	57.82	***917.92***
4-May-00	0	0	0	0	0	0	0	0	0	791.16	23	215.5	16.6	87.92	***1134.18***
5-May-00	0	0	0	0	0	0	0	0	0	615.71	23	218.42	18.87	101.97	***977.97***
6-May-00	0	0	0	0	0	0	0	0	0	521.11	23	221.34	18.87	63.24	***847.56***
7-May-00	0	0	0	0	0	0	0	0	0	595.3	23	235.94	16.6	86.54	***957.38***
8-May-00	0	0	0	0	0	0	0	0	0	748.69	23	206.73	18.87	73.28	***1070.57***
9-May-00	0	0	0	0	0	0	0	0	0	725.11	23	192.13	15.85	76.68	***1032.77***
10-May-00	0	0	0	0	0	0	0	0	0	1481.98	23	203.81	18.11	62.65	***1789.55***
11-May-00	0	0	0	0	0	0	0	0	0	1233.56	23	204.45	13.58	72.09	***1546.68***
12-May-00	0	0	0	0	0	0	0	0	0	752.44	23	227.18	20.38	84.53	***1107.53***
13-May-00	0	0	0	0	0	0	0	0	0	0	23	227.18	19.62	80.95	***350.75***
14-May-00	0	0	0	0	0	0	0	0	0	0	23	224.26	15.85	61.34	***324.45***
15-May-00	0	0	0	0	0	0	0	0	0	0	23	218.42	20.38	52.71	***314.51***
16-May-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	0	23	212.57	21.13	51.34	***695.54***
17-May-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	0	23	212.57	21.13	64.65	***708.85***
18-May-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	276.23	23	224.26	21.88	81.37	***1014.24***
19-May-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	1147.9	23	212.57	23.39	61.96	***1856.32***
20-May-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	0	23	224.26	22.64	36.76	***694.16***
21-May-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	0	23	206.73	20.38	60.2	***697.81***
22-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	23	212.57	21.13	58.39	***653.53***
23-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	23	215.5	21.13	57.59	***655.66***
24-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	460.15	23	235.94	18.11	88.58	***1164.22***
25-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	38.35	23	215.5	19.62	96.07	***730.98***

Table 4 (continued)

Date	Flume Hours of Operation				Flume Flow (cfs)					Total Spill Bay Flow (cfs)	Fish Ladder	Saltwater Drain	Small Lock	Large Lock	Total Project Flow (cfs)
	4A	4B	5B	5C	4A	4B	5B	5C	Total						
26-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	95.87	23	221.34	23.39	91.38	***793.42***
27-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	23	247.63	20.38	37.71	***667.16***
28-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	210.9	23	233.02	21.88	41.74	***868.98***
29-May-00	0	24	24	24	0	127.5	127.5	83.44	338.44	329.13	23	233.02	21.88	82.86	***1028.33***
30-May-00	0	21.5	9	21.5	0	114.22	47.81	74.75	236.78	28.76	10	130.51	20.38	68.2	***494.63***
31-May-00	0	7.5	13	20.5	0	39.84	69.06	71.27	180.17	153.38	0	216.12	22.64	67.99	***640.3***
1-Jun-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	134.21	0	249.97	24.15	73.21	***869.04***
2-Jun-00	24	24	24	24	49.06	127.5	127.5	83.44	387.5	134.21	0	249.97	20.38	73.49	***865.55***
3-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	0	249.97	24.15	86.01	***698.57***
4-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	0	249.97	18.87	70.78	***678.06***
5-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	0	119.78	18.87	75.56	***552.65***
6-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	12	130.48	19.62	74.85	***575.39***
7-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	23	206.73	18.87	88.91	***675.95***
8-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	23	215.5	18.87	86.17	***681.98***
9-Jun-00	0	20.5	20.5	20.5	0	108.91	108.91	71.27	289.09	0	23	182.57	20.38	93.06	***608.1***
10-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	23	233.02	21.13	62.19	***677.78***
11-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	0	23	215.5	20.38	34.78	***632.1***
12-Jun-00	0	24	24	24	0	130	130	85	345	1923	23	218.67	18.17	64.97	***2592.81***
13-Jun-00	0	24	24	24	0	125	125	81.87	331.87	661.15	23	218.17	20.3	69.26	***1323.75***
14-Jun-00	0	24	24	24	0	125	125	81.87	331.87	76.44	23	212.35	20.3	82.29	***746.25***
15-Jun-00	0	24	24	24	0	130	130	85	345	501.47	23	209.87	20.45	76.86	***1176.65***
16-Jun-00	0	24	24	24	0	130	130	85	345	0	23	245.07	18.17	85.73	***716.97***
17-Jun-00	0	24	24	24	0	130	130	85	345	465.73	23	206.93	24.23	63.6	***1128.49***
18-Jun-00	0	24	24	24	0	130	130	85	345	931.22	23	206.93	27.26	65.1	***1598.51***
19-Jun-00	0	24	24	24	0	130	130	85	345	338.81	23	204	21.96	99.85	***1032.62***
20-Jun-00	0	24	24	24	0	130	130	85	345	0	23	204	21.2	95.71	***688.91***
21-Jun-00	0	24	24	24	0	130	130	85	345	1131.12	23	212.8	21.2	113.21	***1846.33***
22-Jun-00	0	24	24	24	0	127.5	127.5	83.44	338.44	830.56	23	238.86	23.39	76.9	***1531.15***
23-Jun-00	0	24	24	24	0	125	125	81.87	331.87	0	23	215.26	23.31	50.27	***643.71***
24-Jun-00	0	24	24	24	0	125	125	81.87	331.87	0	23	232.71	23.31	53.83	***664.72***
25-Jun-00	0	24	24	24	0	125	125	81.87	331.87	0	23	218.17	21.06	79.75	***673.85***
26-Jun-00	0	24	24	24	0	122.5	122.5	80.31	325.31	0	23	206.33	20.23	80.69	***655.56***
27-Jun-00	0	24	24	24	0	120	120	78.75	318.75	0	23	200.37	25.39	80.3	***647.81***
28-Jun-00	0	24	24	24	0	120	120	78.75	318.75	0	23	168.65	23.15	84.16	***617.71***
29-Jun-00	0	17	24	18	0	84.29	119	58.59	261.88	0	23	160	17.9	58.24	***521.02***
30-Jun-00	0	0	24	9	0	0	120	29.53	149.53	0	23	177.3	24.65	93.08	***467.56***
1-Jul-00	0	0	24	0	0	0	120	0	120	0	23	211.9	25.39	52.54	***432.83***
2-Jul-00	0	0	24	0	0	0	120	0	120	0	23	211.9	23.9	81.95	***460.75***
3-Jul-00	0	0	12	12	0	0	59	38.75	97.75	0	23	194.48	19.36	34.02	***368.61***
4-Jul-00	0	0	0	24	0	0	0	78.75	78.75	0	23	160	24.65	58.14	***344.54***
5-Jul-00	0	0	0	19	0	0	0	62.34	62.34	0	23	160	28.38	64.87	***338.59***
6-Jul-00	0	0	0	13	0	0	0	42.66	42.66	0	23	160	16.43	55.9	***297.99***
7-Jul-00	0	0	0	13	0	0	0	43.16	43.16	0	23	160	24.7	75.62	***326.48***
8-Jul-00	0	0	0	13	0	0	0	42.66	42.66	0	23	160	30.62	21.57	***277.85***
9-Jul-00	0	0	0	13	0	0	0	42.66	42.66	0	23	160	27.63	65.75	***319.04***
10-Jul-00	0	0	0	3	0	0	0	9.84	9.84	0	23	160	22.4	43.32	***258.56***
11-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	23.15	53.29	***259.44***
12-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	20.16	51.04	***254.2***
13-Jul-00	0	3	3	3	0	15	15	9.84	39.84	0	23	176.02	20.91	85.98	***345.75***
14-Jul-00	0	0	3.84	0	0	0	19.2	0	19.2	0	23	176.02	23.15	69.47	***310.84***
15-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	26.14	72.93	***282.07***
16-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	29.13	60.31	***272.44***
17-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	22.34	62.19	***267.53***
18-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	20.16	109.81	***312.97***
19-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	19.36	69.76	***272.12***
20-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	20.11	53.55	***256.66***
21-Jul-00	0	0	0	0	0	0	0	0	0	0	23	177.19	23.04	71.58	***294.81***
22-Jul-00	0	0	0	0	0	0	0	0	0	0	23	211.59	23.04	88.17	***345.8***
23-Jul-00	0	0	0	0	0	0	0	0	0	0	23	211.68	22.33	54.6	***311.61***

Table 4 (continued)

Date	Flume Hours of Operation				Flume Flow (cfs)					Total Spill Bay	Fish	Saltwater	Small	Large	Total Project
	4A	4B	5B	5C	4A	4B	5B	5C	Total	Flow (cfs)	Ladder	Drain	Lock	Lock	Flow (cfs)
24-Jul-00	0	0	0	0	0	0	0	0	0	0	23	194.45	23.82	42.55	***283.82***
25-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	16.38	62.66	***262.04***
26-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	23.77	65.67	***272.44***
27-Jul-00	0	0	0	0	0	0	0	0	0	0	23	160	20.04	36.7	***239.74***
28-Jul-00	0	0	0	0	0	0	0	0	0	0	23	177.15	24.47	75.03	***299.65***
29-Jul-00	0	0	0	0	0	0	0	0	0	0	23	211.45	25.22	49.69	***309.36***
30-Jul-00	0	0	0	0	0	0	0	0	0	0	23	211.45	24.47	65.56	***324.48***
31-Jul-00	0	0	0	0	0	0	0	0	0	0	23	194.3	20.02	49.5	***286.82***
1-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	21.46	55.63	***260.09***
2-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	22.91	67.57	***273.48***
3-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	22.17	79.36	***284.53***
4-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	25.04	93.33	***301.37***
5-Aug-00	0	0	0	0	0	0	0	0	0	0	23	228	25.77	58.51	***335.28***
6-Aug-00	0	0	0	0	0	0	0	0	0	0	23	193.91	28.66	56.27	***301.84***
7-Aug-00	0	0	0	0	0	0	0	0	0	0	23	227.7	23.48	76.64	***350.82***
8-Aug-00	0	0	0	0	0	0	0	0	0	0	23	227.52	21.24	76.13	***347.89***
9-Aug-00	0	0	0	0	0	0	0	0	0	0	23	227.4	19.01	47	***316.41***
10-Aug-00	0	0	0	0	0	0	0	0	0	0	23	227.4	20.47	55.44	***326.31***
11-Aug-00	0	0	0	0	0	0	0	0	0	0	23	227.22	18.24	66.75	***335.21***
12-Aug-00	0	0	0	0	0	0	0	0	0	0	23	227.1	27.69	58.88	***336.67***
13-Aug-00	0	0	0	0	0	0	0	0	0	0	23	226.98	24.74	58.11	***332.83***
14-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	22.52	77.95	***283.47***
15-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	21.02	107.43	***311.45***
16-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	20.98	67.1	***271.08***
17-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	22.43	66.72	***272.15***
18-Aug-00	0	0	0	0	0	0	0	0	0	0	23	165.53	16.61	94.03	***299.17***
19-Aug-00	0	0	0	0	0	0	0	0	0	0	23	209.74	23.82	75.09	***331.65***
20-Aug-00	0	0	0	0	0	0	0	0	0	0	23	193.1	24.51	54.05	***294.66***
21-Aug-00	0	0	0	0	0	0	0	0	0	0	23	193.1	22.34	80.83	***319.27***
22-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	20.86	56.95	***260.81***
23-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	24.44	48.15	***255.59***
24-Aug-00	0	0	0	0	0	0	0	0	0	0	23	160	22.98	63.82	***269.8***
25-Aug-00	0	0	0	0	0	0	0	0	0	0	23	176.41	21.48	33.84	***254.73***
26-Aug-00	0	0	0	0	0	0	0	0	0	0	23	209.25	24.35	68.39	***324.99***
27-Aug-00	0	0	0	0	0	0	0	0	0	0	23	209.2	23.61	92.6	***348.41***
28-Aug-00	0	0	0	0	0	0	0	0	0	0	23	192.68	22.83	80.71	***319.22***
29-Aug-00	0	0	0	0	0	0	0	0	0	0	23	176.32	22.82	76.39	***298.53***
30-Aug-00	0	0	0	0	0	0	0	0	0	0	23	208.88	21.36	77.79	***331.03***
31-Aug-00	0	0	0	0	0	0	0	0	0	0	23	208.84	19.92	56.78	***308.54***
1-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.79	24.88	68.83	***325.5***
2-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.75	22.02	46.95	***300.72***
3-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.57	22.67	52.55	***306.79***
4-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.62	22.68	63.71	***318.01***
5-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.53	18.4	51.95	***301.88***
6-Sep-00	0	0	0	0	0	0	0	0	0	0	23	160	21.23	47.39	***251.62***
7-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.39	21.89	43.55	***296.83***
8-Sep-00	0	0	0	0	0	0	0	0	0	0	23	197.57	18.33	53.62	***292.52***
9-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.3	21.86	59.28	***312.44***
10-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.3	20.45	69.6	***321.35***

Table 4 (continued)

Date	Flume Hours of Operation				Flume Flow (cfs)					Total Spill Bay	Fish	Saltwater	Small	Large	Total Project
	4A	4B	5B	5C	4A	4B	5B	5C	Total	Flow (cfs)	Ladder	Drain	Lock	Lock	Flow (cfs)
11-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.48	19.1	58.79	***309.37***
12-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.53	21.23	58.48	***311.24***
13-Sep-00	0	0	0	0	0	0	0	0	0	0	23	197.85	19.86	71.3	***312.01***
14-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.57	22.67	52.26	***306.5***
15-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.62	22.68	60.6	***314.9***
16-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.57	19.83	56.67	***308.07***
17-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.53	23.36	69.03	***323.92***
18-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.53	18.4	71.7	***321.63***
19-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.48	16.97	54.12	***302.57***
20-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.57	20.54	45.76	***297.87***
21-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.53	19.82	58.16	***309.51***
22-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.53	19.82	57.11	***308.46***
23-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.39	22.6	70.53	***324.52***
24-Sep-00	0	0	0	0	0	0	0	0	0	0	23	208.3	23.27	74.21	***328.78***
25-Sep-00	0	0	0	0	0	0	0	0	0	22.85	23	208.35	18.35	72.32	***344.87***
26-Sep-00	0	0	0	0	0	0	0	0	0	54.73	23	208.21	17.6	82.4	***385.94***
27-Sep-00	0	0	0	0	0	0	0	0	0	54.73	23	208.21	20.42	33.94	***340.3***
28-Sep-00	0	0	0	0	0	0	0	0	0	54.73	23	208.21	19.72	84.07	***389.73***
29-Sep-00	0	0	0	0	0	0	0	0	0	154.83	23	208.12	18.28	89.59	***493.82***
30-Sep-00	0	0	0	0	0	0	0	0	0	54.81	23	208.3	18.33	91.02	***395.46***

Video Data

A summary of the video logs created by technicians viewing samples of the video data is presented in Table 5. Since no artificial light source was used, video images from nighttime samples provided no data. Video images were also degraded during cloudy days and occasionally by algal cover of the lens. The predominant species observed included marine perch, salmon smolts, starry flounder, candlefish, sculpin, crab, pipefish, unidentified minnow species, and adult salmon. The general pattern of fish behavior was described by fish holding directly in front of the video camera in the flow entering the salt-water drain structure. Occasionally, fish would disappear into the structure and not reappear. Adult salmon first appeared on July 21st.

159 videotapes were collected during the study. 148 tapes were analyzed - 55 fully viewed and 93 tapes sub-sampled. The entire study period lasted 160 days or 3,840 hours. From the video analysis, salmon smolts were observed in 113 sample hours, and shiner perch/surf smelt were observed in 583 sample hours. When smolts were observed, they represented observations of solitary fish, while perch observations represented aggregates of 10 or more individuals. These numbers of observations may be put into context by comparing them with visual fish counts through fish flumes 4b, 5b, and 5c. The visual measurements were made by Peter Johnson and his staff between May 23rd and June 23rd. Of the possible 468 hours during this time period, they sampled 213 hours or almost 28% of the time. All samples were collected during daylight hours. A total of 197394 fish were counted passing through the flumes, representing a rate of 927 fish per hour. Additionally, the purse seine sampling by WDF caught 27,772 salmon smolts in 83 sets, for an average of 339 fish per haul.

The video data observed 176 smolts, 14 of which were reported as entrained. A coarse estimate of the cross section of the intake covered by the video is 1/16th of the area. If all observed smolts were entrained, rather than the number reported, the spatially expanded entrainment total would be 2816 fish. These data suggest that the passage of smolts through the salt-water drain is at least an order of magnitude lower than the numbers passing through the smolt flumes or through the large locks.

Table 5. Summary of Observations from the Underwater Video Camera at the Mouth of the Salt Water Drain.

Month	Day	# Hours smolts observed	# Smolts Observed	# Smolts Entrained	# Hours Perch Observed	#Hours Adult Salmon Observed	#Adults Observed	Notes
April	24							
April	25							
April	26							
April	27							
April	28							
April	29							
April	30							
May	1							
May	2							
May	3							
May	4							
May	5							
May	6							
May	7							
May	8							
May	9							
May	10							
May	11							
May	12							
May	13							
May	14							
May	15							
May	16							
May	17							
May	18							
May	19							
May	20							
May	21							
May	22							
May	23							
May	24							
May	25							
May	26							
May	27							
May	28							
May	29							
May	30							
May	31							
June	1	-	-	-	-			Tape too dark
June	2	-	-	-	-			Tape too dark
June	3	-	-	-	-			Tape too dark
June	4	-	-	-	-			Tape too dark
June	5	-	-	-	-			Tape too dark
June	6	-	-	-	-			Tape too dark
June	7	-	-	-	-			Tape too dark
June	8	-	-	-	-			Tape too dark
June	9	-	-	-	-			Tape too dark
June	10	-	-	-	-			Tape too dark
June	11	-	-	-	-			Tape too dark
June	12	-	-	-	2			Tape dark
June	13	-	-	-	-			Tape too dark
June	14	-	-	-	1			Tape dark
June	15	-	-	-	-			Tape too dark
June	16	2	6	1	5			
June	17	0	0	0	2			
June	18	0	0	0	1			Tape dark
June	19	1	1	0	5			
June	20	0	0	0	7			

Table 5 (continued)

Month	Day	# Hours smolts observed	# Smolts Observed	# Smolts Entrained	# Hours Perch Observed	#Hours Adult Salmon Observed	#Adults Observed	Notes
June	21	0	0	0	5			
June	22	0	0	0	2			
June	23	1	1	0	5			
June	24	2	2	0	5			
June	25	3	3	0	10			
June	26	2	3	0	2			
June	27	0	0	0	3			
June	28	0	0	0	8			
June	29	4	6	1	8			
June	30	0	0	0	9			
July	1	3	3	0	6			
July	2	2	2	0	13			
July	3	0	0	0	13			
July	4	1	0	0	7			
July	5	4	4	0	8			
July	6	1	1	0	14			
July	7	7	12	0	9			
July	8	6	15	2	5+			
July	9	4	5	2	14			
July	10	4	5	0	14			
July	11	2	3	0	9			
July	12	2	23	0	15			
July	13	2	4	1	6			
July	14	4	6	0	12			
July	15	1	1	0	10			
July	16	0	0	0	13			
July	17	3	6	1	6			
July	18	2	5	2	10			
July	19	1	1	0	8			
July	20	4	5	0	12			
July	21	2	2	0	11	1	3	
July	22	1	1	0	8			
July	23	3	6	0	9	1	1	
July	24	2	1	0	11	2	3	
July	25	2	3	1	6	3	4	
July	26	1	1	0	6	4	8+	
July	27	3	4	0	8	3	5+	
July	28	1	1	0	13	7	8	
July	29	1	1	0	13	8	10+	
July	30	0	0	0	12	3	5	
July	31	0	0	0	6	3	6	
August	1	2	3	1	11	11	26	
August	2				12	7	29	
August	3				13	7	23	
August	4				4	4	1	
August	5	2	2			9	1	
August	6							
August	7	2	2		5	5	7	
August	8				3	3	1	
August	9							
August	10				7	2	6	
August	11				3	1	5	
August	12				12			
August	13	1	1		8	1	5	
August	14				1	6	8	
August	15				9			
August	16				3			
August	17				15	2	3	
August	18				5			
August	19				3			
August	20				6			

Table 5 (continued)

Month	Day	# Hours smolts observed	# Smolts Observed	# Smolts Entrained	# Hours Perch Observed	#Hours Adult Salmon Observed	#Adults Observed	Notes
August	21				3			
August	22				6	2	2	
August	23				3			
August	24				2	1	1	
August	25				4	1	1	
August	26				5	3	3	
August	27				9	5	5	
August	28	2	2		5	3	4	
August	29				2	3	3	
August	30	3	3		6	2	6	
August	31	3	4		3	6	16	
September	1	3	3	0	3	6	9	Also 3 schools of minnows, Pipefish
September	2	6	8	0	5	8	14	Also Starry flounder, Sculpin
September	3	3	3	1	3	7	14	Also Several schools of minnows, Sculpin
September	4	0	0	0	1	2	5	Also Starry flounder,
September	5							
September	6							
September	7							
September	8							
September	9							
September	10							
September	11							
September	12							
September	13							
September	14	0	0	0	2	7	136?	Image dark, high turbidity, ID questionable
September	15	0	0	0	2	6	65?	Image dark, high turbidity, ID questionable
September	16	0	0	0	2	8	179?	Image dark, high turbidity, ID questionable
September	17	1	1	1	2	8	297?	Image dark, high turbidity, ID questionable
September	18	0	0	0	2	6	150?	Image dark, high turbidity, ID questionable
September	19	0	0	0	1	7	168?	Image dark, high turbidity, ID questionable
September	20	0	0	0	2	7	467?	Image dark, high turbidity, ID questionable
September	21	0	0	0	6	6	>54?	Image dark, high turbidity, ID questionable
September	22	0	0	0	0	0	0	Image dark, high turbidity, ID questionable
September	23	1	1	0	0	10	?	Image dark, high turbidity, ID questionable
September	24	0	0	0	1	6	310?	Image dark, high turbidity, ID questionable
September	25	0	0	0	1	3	345?	Image dark, high turbidity, ID questionable
September	26							
September	27							
September	28							
September	29							
September	30							

Acoustic Data at the Salt Water Drain

Hourly fish entrainment estimates are presented for June through September 2000, in Tables 6-9 respectively. Horizontal and vertical sums are shown to characterize daily passage and monthly diel periodicity. No fish were observed by the acoustic system prior to the adjustment in the horizontal aiming angle on May 31st. Although fish counts were low until mid-August, we believe that the transducer orientation prior to May 31st may have had reduced acoustic detectability due to the accelerated flow near the rear of the salt-water drain.

The entrainment estimates in these tables are further summarized in Figure 14, which depicts the daily entrainment rate over the last four months of the study. The diel passage pattern of fish detected at the mouth of the salt-water drain structure for April 24th through September 30th, 2000, is given in Figure 15. Diel passage patterns for June, July, August, and September 2000 at the salt-water drain are shown in Figures 16 – 19. Sample sizes for individual months are tabled later in the report under the section describing the results of the target strength analysis. Daylight passage patterns are clearly established for the months of August and September.

We looked at the species composition from the WDFG purse seine data to put the acoustic counts into context. The catch data are characterized by extremely high variability, both in total catch and in percent of smolts. For example, approximately 1300 salmon smolts were captured on May 25th from 4 sets. On May 31st, about 12,300 smolts were caught in 3 sets. In terms of species variability, an estimated 10,000 herring were caught in two sets on May 11th, while none were caught the day before. The seine data suggest a patchy distribution, both of smolts and non-smolts

Table 6. Entrainment Estimates for June 2000, at the Salt Water Drain Based on Expanded Counts

	DAY														
HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	0	0	0	0	0	0	0	4	16	0	0	0	0	0

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	**SUM**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	20
0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	24
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	68

Table 7. Entrainment Estimates for July 2000, at the Salt Water Drain Based on Expanded Counts

	DAY															
HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
18	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	8	4	0	0	0	0	0	0	0	0	0	0	0	0	4

HOUR	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	**SUM**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	8
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	8
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	8
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	8	12	0	0	0	4	0	0	0	0	0	8	0	0	4	52

Table 8. Entrainment Estimates for August 2000, at the Salt Water Drain Based on Expanded Counts

HOUR	DAY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0
7	0	0	0	0	0	0	0	12	0	0	0	0	0	16	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
17	0	20	0	0	0	0	0	88	0	0	0	0	0	0	0	12
18	0	0	4	0	0	0	0	0	0	0	0	8	0	0	4	12
19	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	20
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
21	0	0	0	0	8	0	0	0	0	0	20	0	0	0	8	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	20	4	0	8	4	0	100	0	0	36	8	0	64	20	64

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	**SUM**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	4	32	8	4	0	64	8	0	8	176
0	12	0	0	8	12	28	40	76	36	64	100	36	20	12	472
0	0	0	0	0	4	24	12	12	8	36	32	12	112	12	264
0	0	0	0	0	0	0	0	0	4	20	12	20	92	12	160
0	8	8	0	0	8	4	0	8	0	68	24	24	40	104	300
0	12	16	0	24	4	0	0	16	28	0	24	8	116	168	416
0	0	4	4	20	0	8	0	0	48	4	12	0	48	332	480
0	0	0	44	0	8	0	0	12	20	4	0	0	388	228	704
0	0	0	48	16	4	0	0	0	0	20	4	28	116	204	440
4	4	16	44	12	12	12	0	0	12	20	12	20	32	20	220
0	20	4	48	24	12	0	4	0	36	40	8	28	0	24	268
0	16	8	24	0	0	0	16	0	28	68	12	24	4	100	420
0	0	12	24	0	0	8	0	48	0	56	44	40	20	80	360
0	0	0	12	0	0	0	0	44	24	36	28	28	24	40	268
0	0	0	0	0	0	0	16	4	0	0	0	0	0	0	28
0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	44
0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	8
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	72	68	248	104	64	88	128	228	248	436	384	276	1012	1344	5032

Table 9. Entrainment Estimates for September 2000, at the Salt Water Drain Based on Expanded Counts

HOUR	DAY 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	8	0	0	0	0	0	0	20	0	0	4	0	20
7	8	0	0	0	4	12	0	0	40	12	12	0	36	12	8
8	28	4	0	0	60	0	0	0	0	8	28	20	12	32	32
9	0	56	0	0	40	0	0	16	0	16	12	16	72	60	24
10	260	164	176	0	12	0	0	128	20	8	8	16	40	36	4
11	316	300	48	100	100	0	0	88	4	0	20	20	28	36	0
12	240	316	184	0	72	0	4	48	8	0	0	12	12	112	40
13	488	272	80	80	184	0	44	52	4	0	16	4	44	32	4
14	536	364	124	188	84	0	0	0	0	0	40	0	4	44	40
15	168	228	344	252	136	0	16	0	0	0	0	0	28	16	52
16	252	124	268	120	112	0	12	0	0	0	0	12	0	0	32
17	252	184	108	200	72	0	0	0	0	0	0	16	0	8	20
18	52	48	156	88	76	0	0	0	0	8	0	0	0	4	32
19	0	28	4	40	36	0	12	0	0	0	0	0	8	0	4
20	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	2600	2088	1500	1068	988	12	88	332	76	72	140	120	288	392	312

HOUR	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	**SUM**
0	0	0	0	0	0	0	0	0	0	0	8	12	32	0	20	72
1	0	0	0	0	0	0	0	0	0	0	8	8	0	12	16	44
2	0	0	0	4	0	0	0	0	0	0	4	16	12	12	12	60
3	8	0	0	0	0	0	0	0	0	8	4	24	16	0	0	60
4	0	0	4	0	0	12	0	0	0	0	0	8	4	0	0	28
5	8	0	0	0	0	0	0	0	0	0	8	0	12	0	8	36
6	8	0	32	16	0	40	36	80	20	64	32	4	16	8	36	444
7	16	0	16	40	36	220	56	32	100	208	48	160	52	100	68	1296
8	12	0	0	16	0	44	20	32	40	44	28	12	124	124	16	736
9	20	8	0	0	0	20	48	20	124	0	76	32	92	52	88	892
10	40	20	0	20	20	0	52	8	24	44	144	72	128	44	72	1560
11	36	44	8	0	0	8	0	24	12	92	60	148	148	64	32	1736
12	48	20	36	0	0	4	8	76	20	52	24	32	100	40	80	1588
13	36	32	0	24	0	4	4	0	20	44	52	8	120	72	120	1840
14	12	68	24	4	28	12	4	0	0	48	24	16	52	20	96	1832
15	4	60	0	64	24	12	0	0	0	40	4	56	72	12	136	1724
16	8	32	20	36	32	28	0	0	0	48	8	24	52	20	60	1300
17	32	4	52	12	0	12	44	28	0	56	152	20	36	28	80	1416
18	20	8	24	28	20	76	28	48	48	80	52	8	84	84	140	1212
19	12	8	4	8	64	72	68	0	80	28	56	8	20	12	44	616
20	0	0	0	0	0	0	4	0	0	0	0	12	48	4	12	88
21	0	0	0	0	4	0	0	0	0	8	20	16	0	8	52	108
22	0	0	0	0	0	0	0	0	0	12	20	0	4	4	0	40
23	0	0	0	0	16	0	0	0	0	4	0	4	0	12	12	48
SUM	320	304	220	272	244	564	372	348	488	880	832	700	1224	732	1200	18776

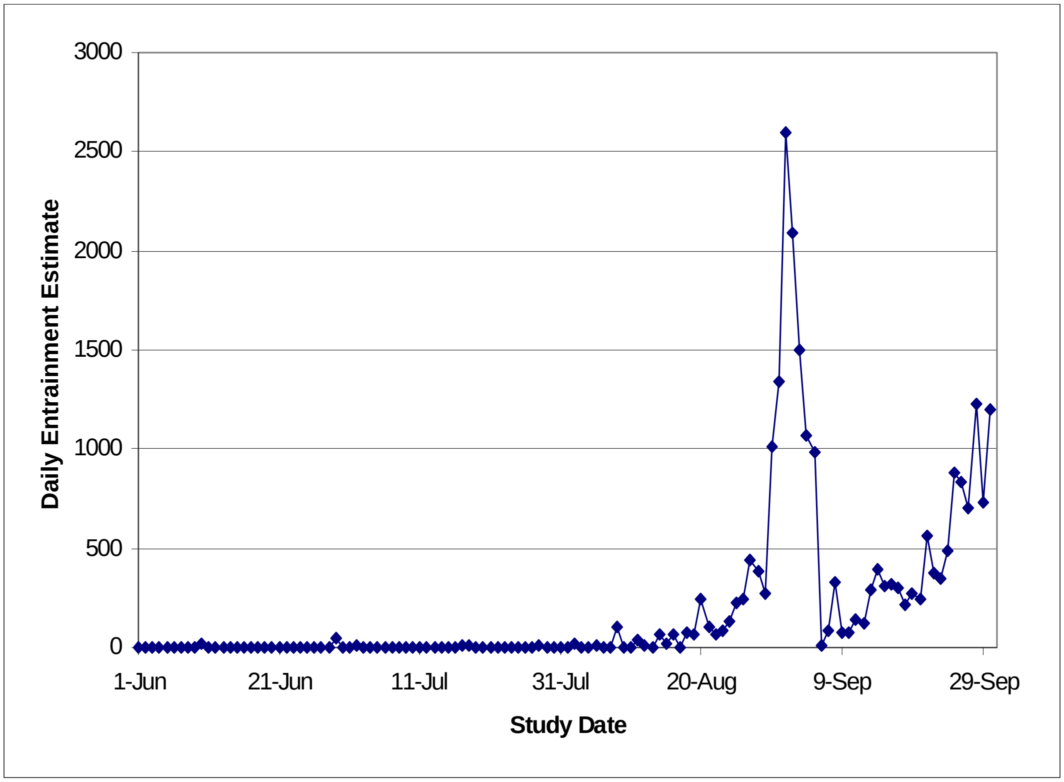


Figure 14. Seasonal Fish Entrainment Pattern at the Salt Water Drain

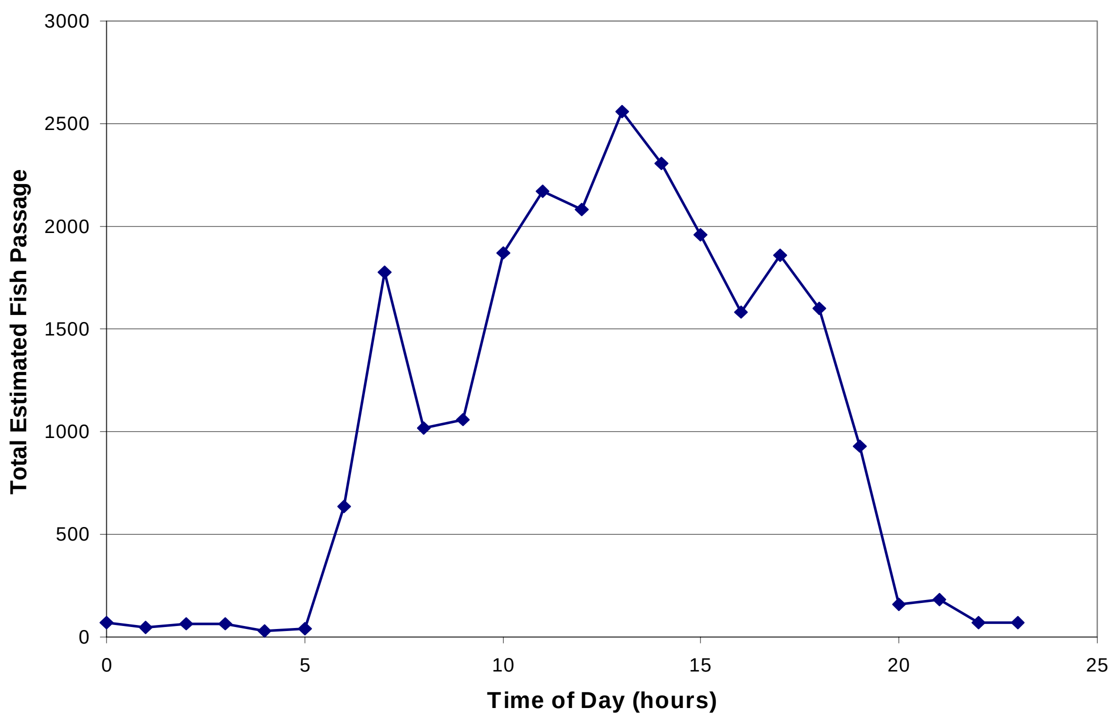


Figure 15. Diel Fish Passage Pattern, Salt Water Drain Intake, April 24th through September 30th, 2000

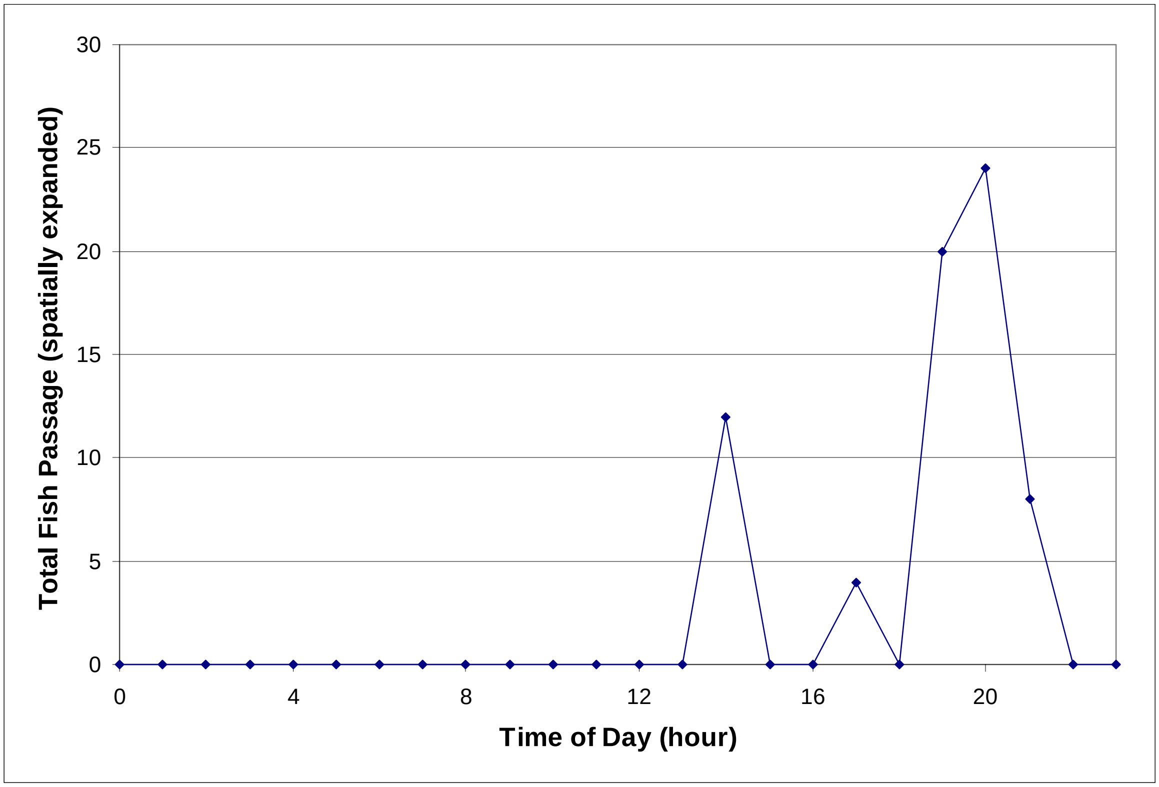


Figure 16. Diel Passage into the Salt Water Drain During June 2000

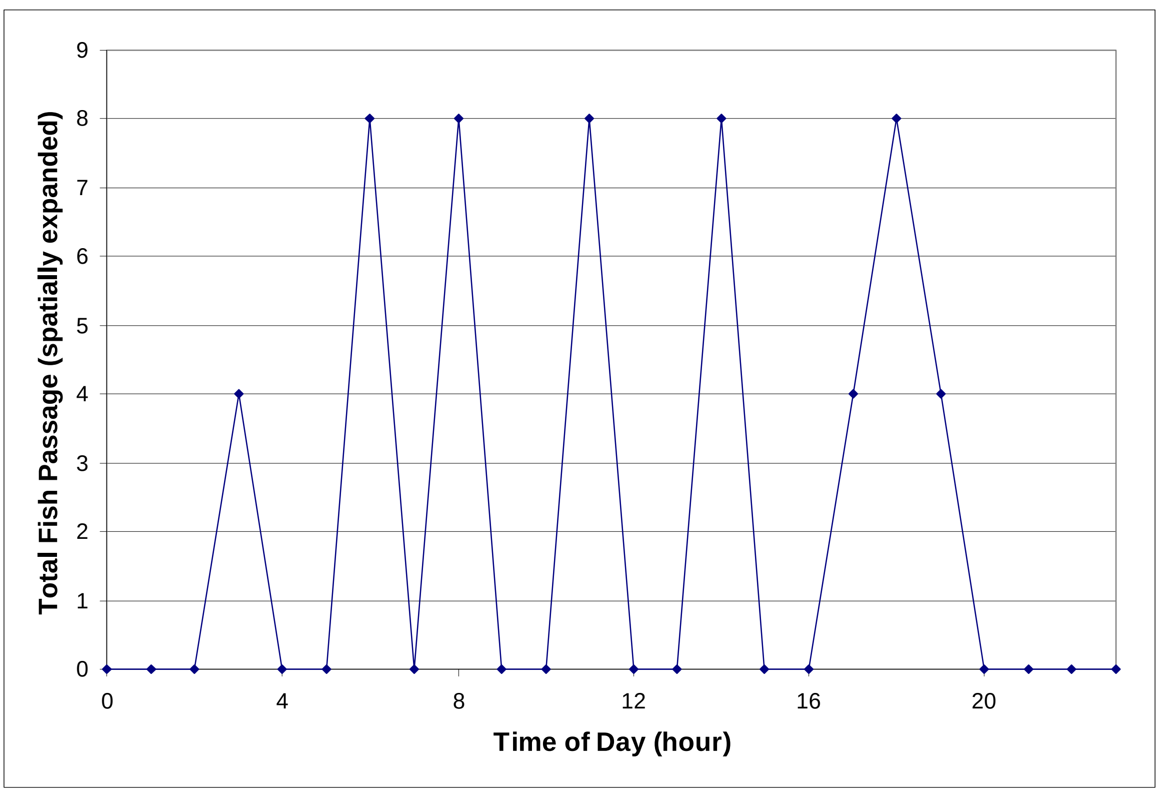


Figure 17. Diel Passage into the Salt Water Drain During July 2000.

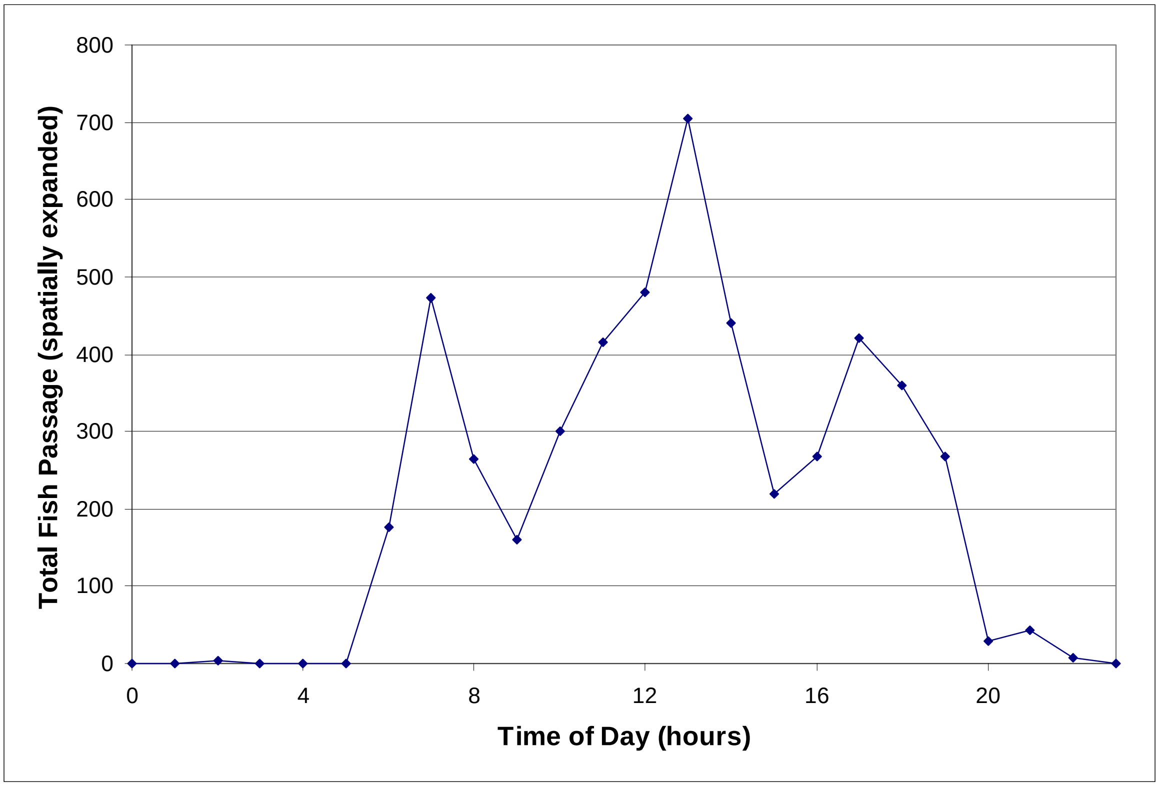


Figure 18. **Diel Passage into the Salt Water Drain During August 2000**

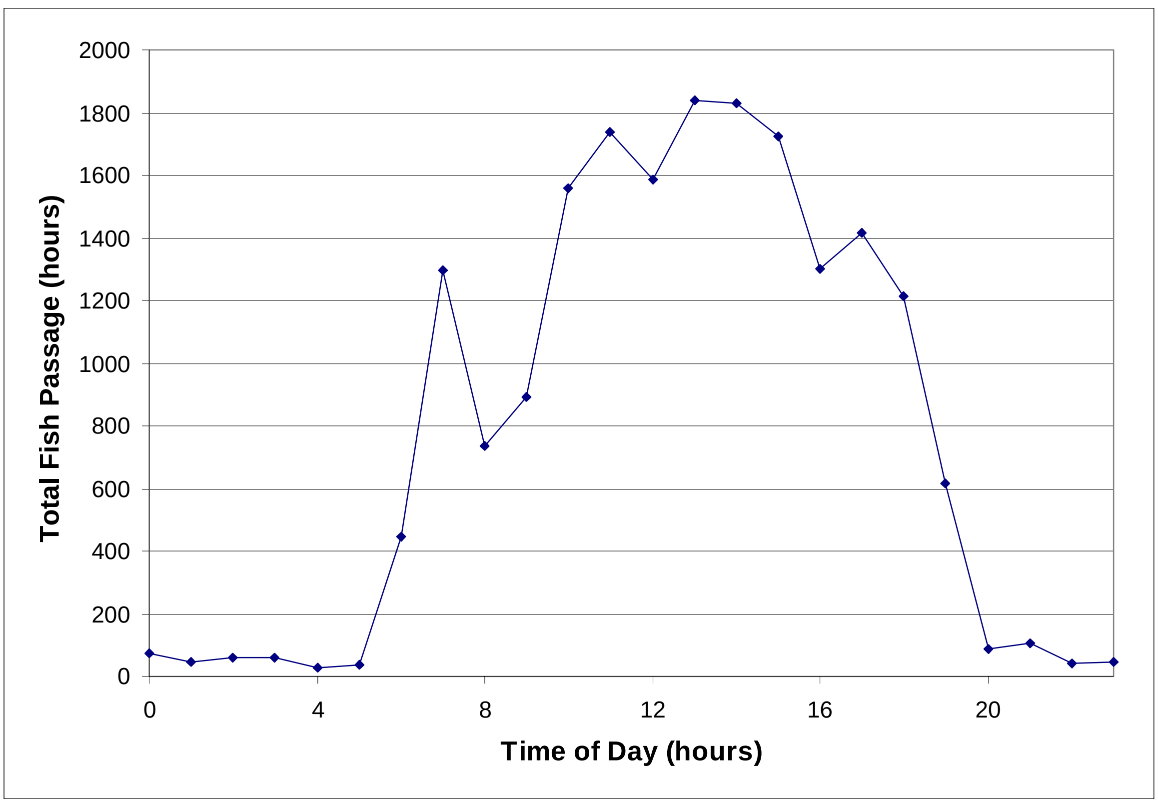


Figure 19. **Diel Passage into the Salt Water Drain During September 2000**

Target Strength Data

Target Strength is a measure of the acoustic size of a fish, and is roughly correlated to the physical size. Sample sizes were too low in June and July to create distributions. Table 10 provides the monthly mean target strength estimate of fish at the salt-water drain, along with the sample size (before spatial extrapolation), for June through September 2000. The target strength distributions for August and September are given in Figures 20 and 21.

The arrival of adult salmon at the salt-water drain in September is reflected by the bimodal target strength distribution. We interpret the high number (several hundreds) of observations in the large size mode of Figure 21 to be caused by adults being carried into the entrance and through the acoustic sensor, then resisting and swimming back upstream. Observations from both the video and acoustic systems suggest that the adult salmon may be more successful at swimming back out of the salt water drain once they are partially entrained than are the smaller marine species. A pattern of movement into and out of the entrance of the salt-water drain was documented by the acoustic system and shown earlier in Figure 9. We observed this behavior in most of the large targets entrained. While many of these fish may successfully leave the salt-water drain intake after their battle with the inward flow, many are clearly at risk of entrainment if they are carried too far into the structure to resist the rapidly accelerating flow.

Table 10. Monthly Mean Target Strength and Sample Size Values

Month	Average Target Strength	Sample Size
April	-	0
May	-	0
June	-40.0	17
July	-48.9	13
August	-37.3	1258
September	-35.6	4694

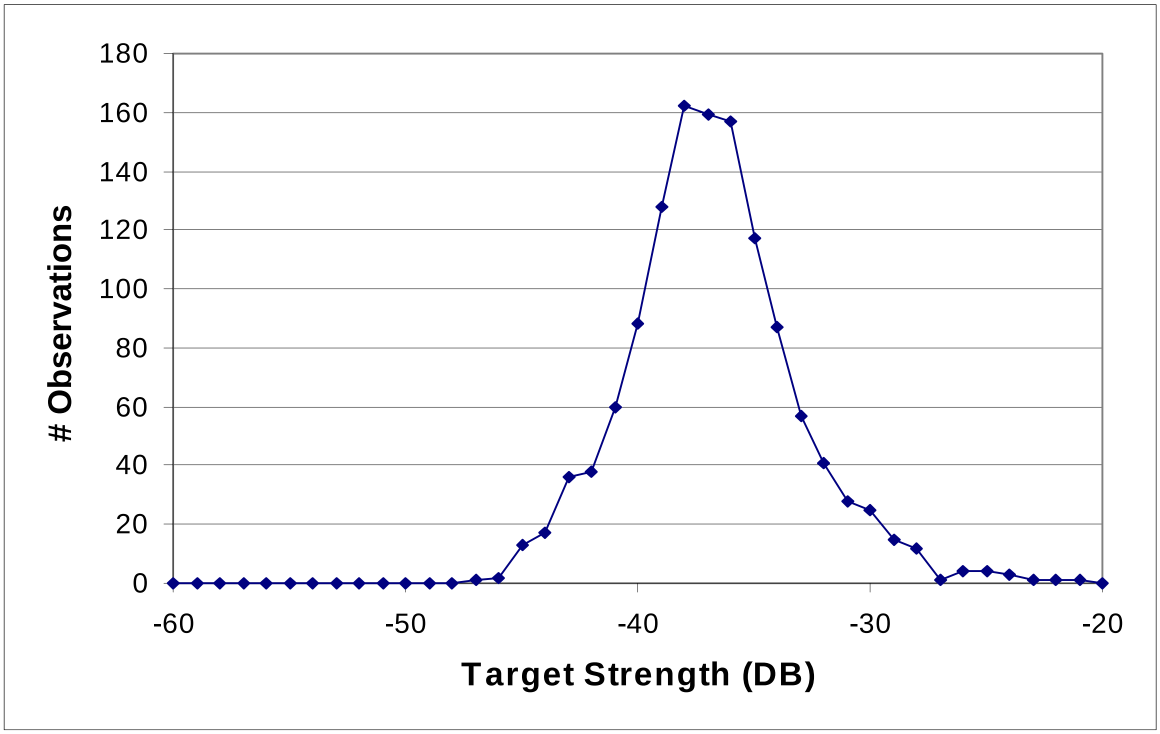


Figure 20. Target Strength Distribution of Fish Observed at the Salt Water Drain, August 2000

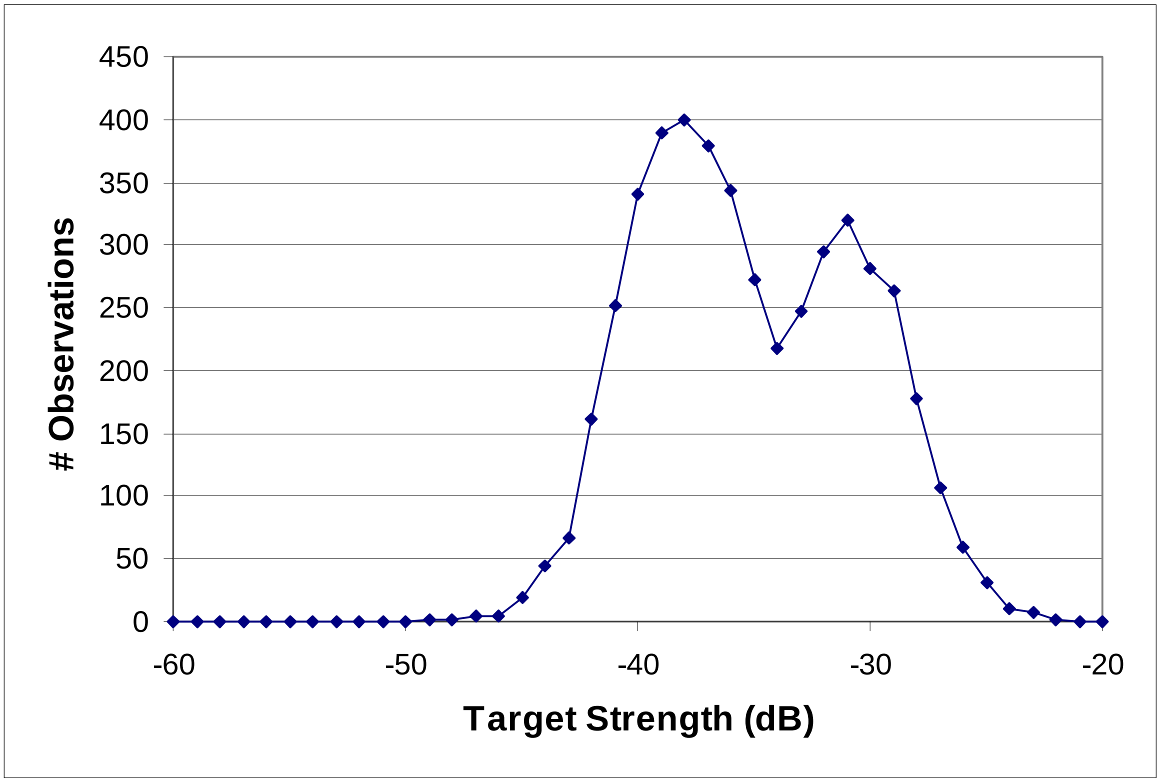


Figure 21. Target Strength Distribution of Fish Observed at the Salt Water Drain, September 2000

Acoustic Data at Spill Bay #2

For convenience, the fish passage estimates through Spill Bay #2 are grouped into four time periods: April 24-30, May 1-12, May 18-31, and June 1-22. The passage estimates for these periods are presented in Tables 11-14 respectively. Passage estimates are listed by hour in the first column for each date, while a code representing the number of spill gates open that hour is listed to the right. A value of (23) indicates that spill gates 2 and 3 were open for that hour. A code of (1234b5bc) indicates that spill gates 1-3 were open, as were fish flumes 4b, 5b, and 5c. These operational data were extracted from the daily logs maintained by the USACE.

Hourly passage estimates were summed to calculate daily totals. These sums reflect passage only when the spill gate is open, and therefore do not reflect an accurate estimate of run timing. The timing of fish passage through Spill Bay #2 is provided in Figure 22. Count data representing mean hourly passage rates through the fish flumes are superimposed on this figure.

Table 11. Hourly fish passage estimates through Spill Gate #2, April 24-30, 2000

	24-Apr		25-Apr		26-Apr		27-Apr		28-Apr		29-Apr		30-Apr	
0:00	0		7	(123)	27	(123)	197	(123)	0		0		37	(23)
1:00	0		2	(123)	61	(123)	145	(123)	38	(23)	0		47	(23)
2:00	0		33	(123)	88	(123)	297	(123)	19	(23)	0		16	(23)
3:00	0		12	(123)	58	(123)	161	(123)	17	(23)	0		17	(23)
4:00	0		48	(123)	39	(123)	73	(123)	41	(23)	0		11	(23)
5:00	0		29	(123)	130	(123)	97	(123)	104	(123)	0		85	(23)
6:00	0		92	(2)	38	(2)	37	(2)	81	(2)	0		56	(2)
7:00	0		9	(2)	33	(2)	8	(2)	120	(2)	0		40	(2)
8:00	0		4	(2)	11	(2)	7	(2)	58	(2)	0		327	(2)
9:00	0		50	(2)	48	(2)	4	(2)	0		0		439	(2)
10:00	0		153	(2)	87	(2)	4	(2)	0		0		430	(2)
11:00	0		95	(2)	118	(2)	14	(2)	0		0		580	(2)
12:00	0		0		178	(2)	5	(2)	0		0		676	(2)
13:00	0		0		236	(2)	3	(2)	0		197	(2)	846	(2)
14:00	0		0		150	(2)	7	(2)	0		122	(2)	911	(2)
15:00	0		0		57	(2)	4	(2)	0		49	(2)	392	(2)
16:00	0		70	(2)	39	(2)	16	(2)	0		5	(2)	241	(2)
17:00	0		57	(2)	34	(2)	93	(2)	0		4	(2)	36	(2)
18:00	72	(2)	133	(2)	10	(2)	22	(2)	0		12	(2)	102	(2)
19:00	6	(2)	27	(2)	0		16	(2)	0		18	(2)	76	(2)
20:00	11	(2)	8	(2)	8	(2)	9	(2)	0		54	(2)	58	(2)
21:00	10	(2)	3	(2)	7	(2)	11	(2)	0		22	(2)	36	(2)
22:00	1	(2)	21	(123)	26	(2)	0		0		0		0	
23:00	7	(12)	37	(123)	40	(123)	0		0		0		0	

Prior to start of study

Spill Bay #2 Closed

Power Failure, Echo sounder off

Table 12. Hourly fish passage estimates through Spill Gate #2, May 1-12, 2000

	1-May		2-May		3-May		4-May		5-May		6-May		7-May		8-May		9-May		10-May		11-May		12-May	
0:00	6	(23)	7	(23)	0		4	(123)	0	(23)	0		0		2	(123)	0		0		11	(123)	2	(123)
1:00	11	(23)	13	(23)	0		3	(123)	1	(123)	0		0		6	(123)	0		0		16	(123)	1	(123)
2:00	20	(23)	35	(23)	0		3	(123)	10	(123)	1	(123)	0		6	(123)	0		0		47	(123)	2	(123)
3:00	14	(23)	12	(23)	0		10	(123)	7	(123)	1	(123)	0		4	(123)	0		0		45	(123)	1	(123)
4:00	8	(23)	8	(23)	0		19	(123)	12	(123)	0	(123)	0		8	(123)	0		0		38	(123)	3	(123)
5:00	54	(23)	107	(23)	0		170	(123)	86	(123)	25	(123)	0		32	(123)	0		0		84	(123)	51	(123)
6:00	149	(2)	98	(2)	0		112	(2)	304	(2)	188	(2)	0		106	(123)	0		0		186	(2)	200	(123)
7:00	98	(2)	129	(2)	0		372	(2)	517	(2)	126	(2)	0		48	(123)	0		0		479	(2)	176	(123)
8:00	119	(2)	239	(2)	0		555	(2)	254	(2)	279	(2)	0		0		0		0		808	(2)	232	(123)
9:00	215	(2)	568	(2)	0		666	(2)	187	(2)	75	(2)	0		0		0		0		405	(2)	0	
10:00	624	(2)	1141	(2)	0		128	(2)	769	(2)	11	(2)	0		0		0		0		0		8	(123)
11:00	1199	(2)	2409	(2)	0		138	(2)	1029	(2)	21	(2)	0		0		0		0		41	(2)	140	(123)
12:00	1377	(2)	2584	(2)	0		118	(2)	1108	(2)	136	(2)	0		0		0		347	(2)	138	(2)	0	
13:00	1027	(2)	581	(2)	57	(2)	58	(2)	941	(2)	163	(2)	0		0		0		934	(2)	220	(2)	74	(23)
14:00	367	(2)	88	(2)	272	(2)	418	(2)	534	(2)	554	(2)	0		0		0		1300	(2)	75	(2)	0	
15:00	522	(2)	36	(2)	118	(2)	732	(2)	66	(2)	545	(2)	0		0		0		1168	(2)	7	(2)	0	
16:00	737	(2)	81	(2)	276	(2)	194	(2)	89	(2)	352	(2)	0		0		0		1160	(2)	8	(2)	0	
17:00	1212	(2)	23	(2)	404	(2)	51	(2)	12	(2)	530	(2)	0		0		0		858	(2)	9	(2)	0	
18:00	416	(2)	0	(2)	140	(2)	1	(2)	90	(2)	147	(2)	0		0		0		491	(2)	76	(2)	0	
19:00	22	(2)	0		27	(2)	23	(2)	109	(2)	48	(2)	9	(123)	0		0		4	(2)	25	(2)	0	
20:00	17	(2)	0		0	(2)	23	(2)	38	(2)	3	(2)	6	(123)	0		0		0	(2)	17	(2)	0	
21:00	13	(2)	0		0	(2)	0	(2)	3	(2)	0	(2)	0	(123)	0		0		0	(2)	4	(2)	0	
22:00	24	(2)	0		0		0		0		0		0	(123)	0		0		1	(2)	1	(2)	0	
23:00	8	(2)	0		0		0		0		0		1	(123)	0		0		1	(2)	1	(2)	0	

Spill Bay Closed

Power Failure, Echo sounder off

Table 13. Hourly fish passage estimates through Spill Gate #2, May 18-31, 2000

	18-May		19-May		24-May		25-May		26-May		28-May		29-May		30-May		31-May	
0:00	0		0	(234ab5bc)	5	(24b5bc)	6	(24b5bc)	0		9	(24b5bc)	9	(24b5bc)	0		43	(24b5c)
1:00	0		0	(234ab5bc)	2	(24b5bc)	1	(24b5bc)	13	(24b5bc)	38	(24b5bc)	12	(24b5bc)	0		54	(24b5c)
2:00	0		0	(234ab5bc)	10	(24b5bc)	0		21	(24b5bc)	68	(24b5bc)	21	(24b5bc)	0		84	(24b5c)
3:00	0		0	(234ab5bc)	12	(24b5bc)	0		37	(24b5bc)	59	(24b5bc)	81	(24b5bc)	0		85	(24b5c)
4:00	0		0	(234ab5bc)	95	(24b5bc)	0		58	(24b5bc)	105	(24b5bc)	194	(24b5bc)	0		120	(24b5c)
5:00	0		0	(234ab5bc)	606	(24b5bc)	0		349	(24b5bc)	250	(24b5bc)	1117	(24b5bc)	0		105	(24b5c)
6:00	0		0	(234ab5bc)	431	(24b5bc)	0		0		201	(24b5bc)	249	(24b5bc)	0		24	(24b5c)
7:00	0		0	(234ab5bc)	908	(24b5bc)	0		0		158	(24b5bc)	375	(24b5bc)	0		0	
8:00	0		0	(234ab5bc)	1283	(24b5bc)	0		0		73	(24b5bc)	1068	(24b5bc)	0		0	
9:00	0		0		1857	(24b5bc)	0		0		68	(24b5bc)	608	(24b5bc)	0		0	
10:00	0		0		1612	(24b5bc)	0		0		89	(24b5bc)	0		0		0	
11:00	0		0		1412	(24b5bc)	0		0		0		0		0		0	
12:00	0		0		1111	(24b5bc)	0		0		0		0		0		0	
13:00	0		0		728	(24b5bc)	0		0		0		0		0		0	
14:00	0		0		169	(24b5bc)	0		0		0		0		0		0	
15:00	0		0		169	(24b5bc)	0		0		0		0		0		0	
16:00	0		0		239	(24b5bc)	0		0		0		0		0		0	
17:00	0		0		228	(24b5bc)	0		0		0		0		0		0	
18:00	3	(24ab5bc)	0		341	(24b5bc)	0		0		0		0		0		0	
19:00	2	(24ab5bc)	0		294	(24b5bc)	0		0		0		0		0		0	
20:00	13	(24ab5bc)	0		75	(24b5bc)	0		0		0		0		0		0	
21:00	11	(24ab5bc)	0		85	(24b5bc)	0		0		0		0		0		0	
22:00	27	(24ab5bc)	0		4	(24b5bc)	0		0		0		0		9	(24b5c)	0	
23:00	0	(234ab5bc)	0		3	(24b5bc)	0		0		0		0		31	(24b5c)	6	(25bc)

Spill Bay Closed

Spill Gate at 4.5 feet, file obliterated by noise

Table 14. Hourly fish passage estimates through Spill Gate #2, June 1-22, 2000

	1-Jun		2-Jun		12-Jun		13-Jun		14-Jun		15-Jun		17-Jun		18-Jun		19-Jun		21-Jun		22-Jun	
0:00	16	(24ab5bc)	0		0		1	(1234b5bc)	0		7	(24b5bc)	2	(24b5bc)	1	(24b5bc)	9	(24b5bc)	0		2	(234b5bc)
1:00	23	(24ab5bc)	1	(24ab5bc)	0		1	(1234b5bc)	0		8	(24b5bc)	0	(24b5bc)	1	(24b5bc)	9	(24b5bc)	0		1	(234b5bc)
2:00	29	(24ab5bc)	5	(24ab5bc)	0		1	(1234b5bc)	4	(24b5bc)	5	(24b5bc)	1	(24b5bc)	2	(24b5bc)	8	(24b5bc)	13	(24b5bc)	1	(234b5bc)
3:00	36	(24ab5bc)	10	(24ab5bc)	0		13	(1234b5bc)	10	(24b5bc)	11	(24b5bc)	1	(24b5bc)	4	(24b5bc)	7	(24b5bc)	18	(24b5bc)	2	(234b5bc)
4:00	85	(24ab5bc)	11	(24ab5bc)	0		49	(1234b5bc)	67	(24b5bc)	32	(234b5bc)	14	(24b5bc)	7	(24b5bc)	14	(24b5bc)	52	(24b5bc)	14	(234b5bc)
5:00	159	(24ab5bc)	12	(24ab5bc)	0		131	(234b5bc)	613	(24b5bc)	165	(1234b5bc)	124	(24b5bc)	84	(24b5bc)	67	(24b5bc)	296	(24b5bc)	87	(234b5bc)
6:00	71	(24ab5bc)	0	(24ab5bc)	0		0		0		0		0		63	(24b5bc)	0		94	(24b5bc)	45	(234b5bc)
7:00	0		25	(24ab5bc)	0		0		0		0		0		52	(24b5bc)	0		31	(24b5bc)	0	
8:00	0		0		0		0		0		0		0		44	(24b5bc)	0		36	(24b5bc)	0	
9:00	0		0		0		0		0		0		0		27	(24b5bc)	0		9	(24b5bc)	0	
10:00	0		0		0		0		0		0		0		57	(24b5bc)	0		7	(24b5bc)	0	
11:00	0		0		0		0		0		0		0		19	(24b5bc)	0		1	(24b5bc)	0	
12:00	0		0		0		0		0		0		50	(24b5bc)	26	(24b5bc)	0		0		0	
13:00	0		0		110	(1234b5bc)	0		0		0		394	(24b5bc)	43	(24b5bc)	0		0		0	
14:00	0		0		30	(1234b5bc)	0		0		0		116	(24b5bc)	50	(24b5bc)	0		0		0	
15:00	0		0		27	(1234b5bc)	0		0		0		24	(24b5bc)	109	(24b5bc)	0		4	(24b5bc)	0	
16:00	0		0		105	(1234b5bc)	0		0		0		97	(24b5bc)	212	(24b5bc)	0		60	(24b5bc)	0	
17:00	0		0		43	(1234b5bc)	0		0		0		55	(24b5bc)	133	(24b5bc)	0		112	(24b5bc)	0	
18:00	0		0		44	(1234b5bc)	0		0		0		62	(24b5bc)	151	(24b5bc)	0		16	(24b5bc)	0	
19:00	0		0		3	(1234b5bc)	0		0		0		130	(24b5bc)	81	(24b5bc)	0		11	(24b5bc)	0	
20:00	0		0		3	(1234b5bc)	0		0		0		199	(24b5bc)	79	(24b5bc)	0		19	(24b5bc)	0	
21:00	0		0		1	(1234b5bc)	0		0		0		24	(24b5bc)	24	(24b5bc)	0		7	(24b5bc)	0	
22:00	0		0		1	(1234b5bc)	0		0		0		4	(24b5bc)	1	(24b5bc)	0		2	(234b5bc)	0	
23:00	0		0		1	(1234b5bc)	0		0		0		2	(24b5bc)	2	(24b5bc)	0		0	(234b5bc)	0	

Spill Bay Closed

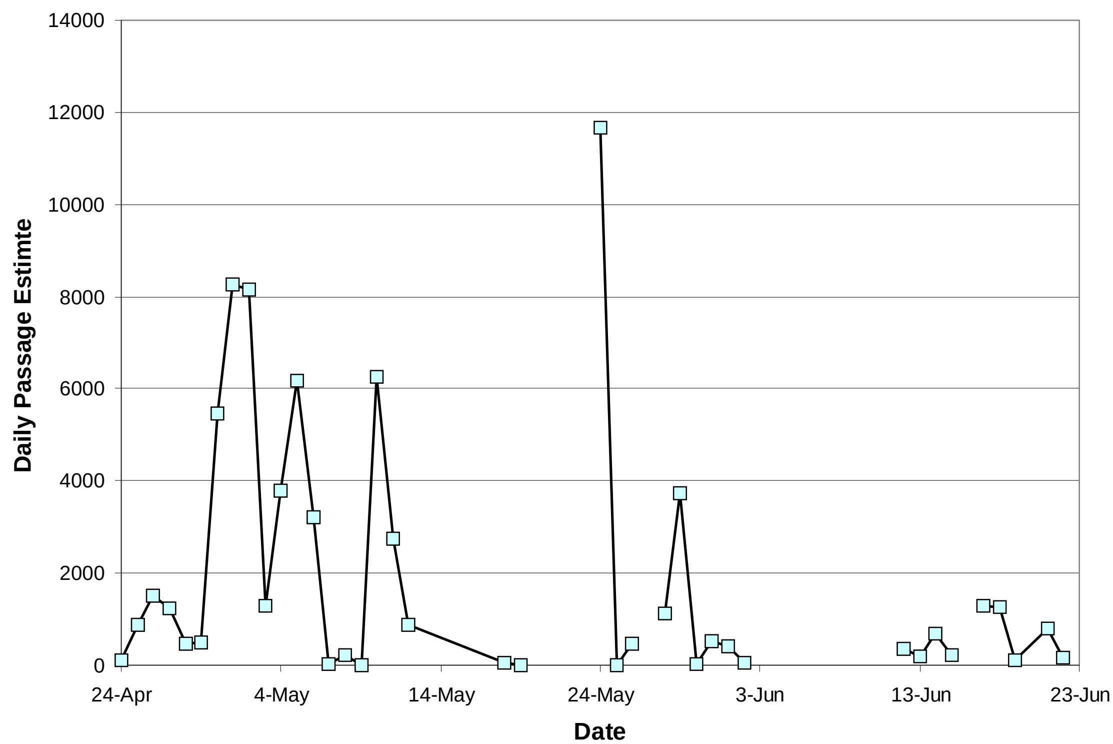


Figure 22. Fish Passage Numbers Through Spill Bay #2 for the Entire Study Period

The diel pattern of fish passing through Spill Bay #2 for April 24th through June 22nd is given in Figure 23. Diel passage patterns are presented by week in Figures 24-31. Figure 24 provides values for April 24-April 29, and Figure 25 contains data for April 30 – May 6th. In Figure 26, data are present for May 7th through May 12th. The fourth week contains data only from May 18-19th, as presented in Figure 27. Data from May 24 – 26 are displayed in Figure 28, and data from May 28 through June 2 are represented in Figure 29. No data were analyzed between June 2nd and June 12th. In Figure 30, data are presented for June 12th through June 15th, skips June 16th, and includes June 17th. Results from the final study week are presented in Figure 31, and include data from June 18, 19, 21, and 22. In each of these figures, the gate may be open some or all of the time for the days included in the plot. The percent of days that the gate is open each hour is plotted along with the fish passage rate.

Diel passage patterns were not observed until the last day of April (Table 11). Starting on April 30th, significant increases in passage rate through Spill Bay #2 were observed at dawn. During most of the subsequent sample days, this pattern was observed. For example, a significant diel passage pattern is observed on May 5th, where a sharp increase in passage rate corresponds with daybreak. After a drop in passage rates around 0800 hours, rates again are high from 1000 through about 1400 hours. On May 24th, the increase in fish passage rates through the spill bay again corresponds with the onset of daylight. Passage rates decrease by 1400 hours but remain quite high through 1900 hours. The remaining figures also show a strong increase in passage rate at daybreak, while passage peaks are seen later in the day during the last half of June. In general, passage is significantly reduced at night through Spill Bay #2.

The operational data documenting available routes for fish passage at the spill region of the structure were inserted into the fish passage tables to look for interactive effects, such as decreases in spill gate passage as fish flumes were opened. Flow through the fish flumes began on May 16th. The effect of operational effects on fish passage estimates, such as adjacent gates or fish flumes opened or closed, could not properly be evaluated since operational changes were typically made just at dawn and cannot be separated from diel effects. An operational suggestion based on these observations is to spill excess project water between about 0300 and 0800 hours each day to take advantage of the daytime mobility of the fish.

The acoustic fish passage data through Spill Bay #2 have no video or target strength data to indicate species. However, confidence is high that the visual observations of fish passing through fish flumes are salmonids. This observation suggests that salmonid smolts are drawn towards the spill region by flow as they migrate downstream. This flow can be provided either by smolt flumes or by open spill gates. The fish passage data through Spill Bay #2 are re-plotted against selected flow curves in Figure 32.

No target strength data were collected at Spill Bay #2, first because single beam transducers were used, and second, because we anticipated that fish might pass in schools. Single fish targets are required for TS estimation.

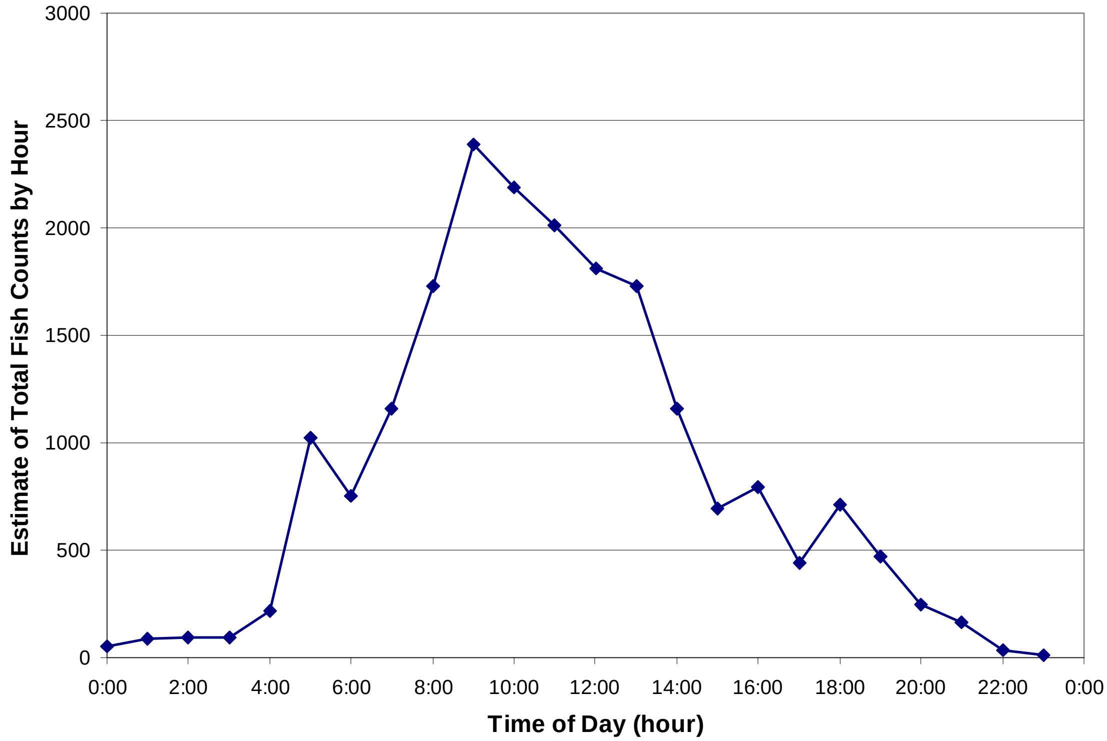


Figure 23 . Seasonal Diel Passage Pattern Through Spill Bay #2

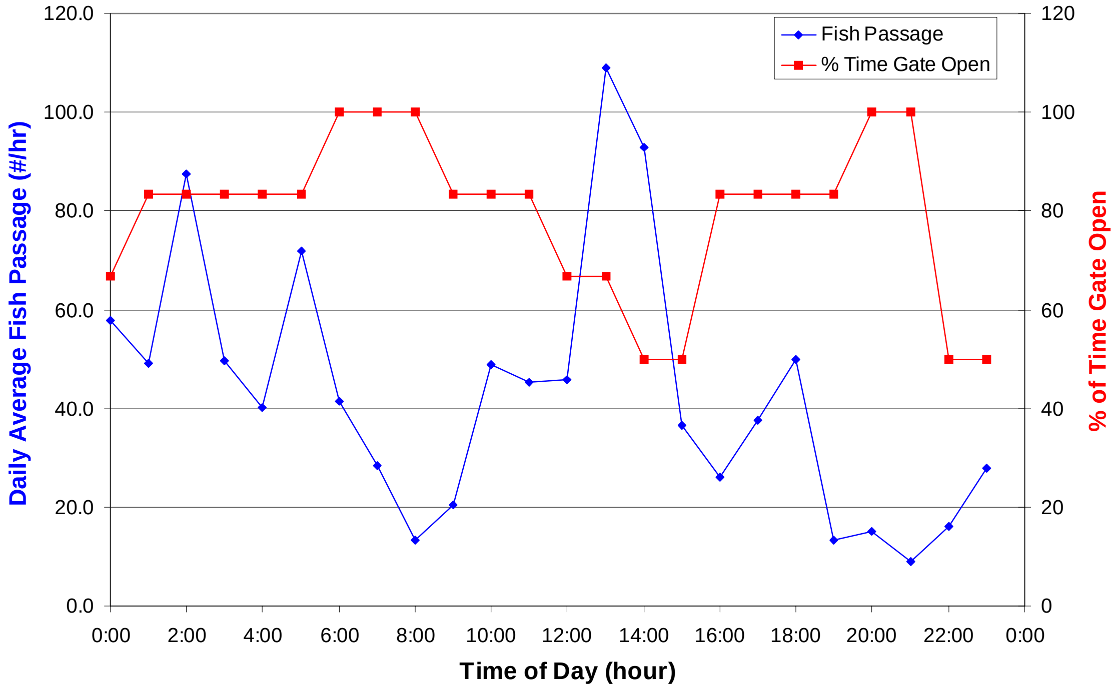


Figure 24. Diel Passage Pattern Through Spill Bay #2 for April 24-29, 2000.

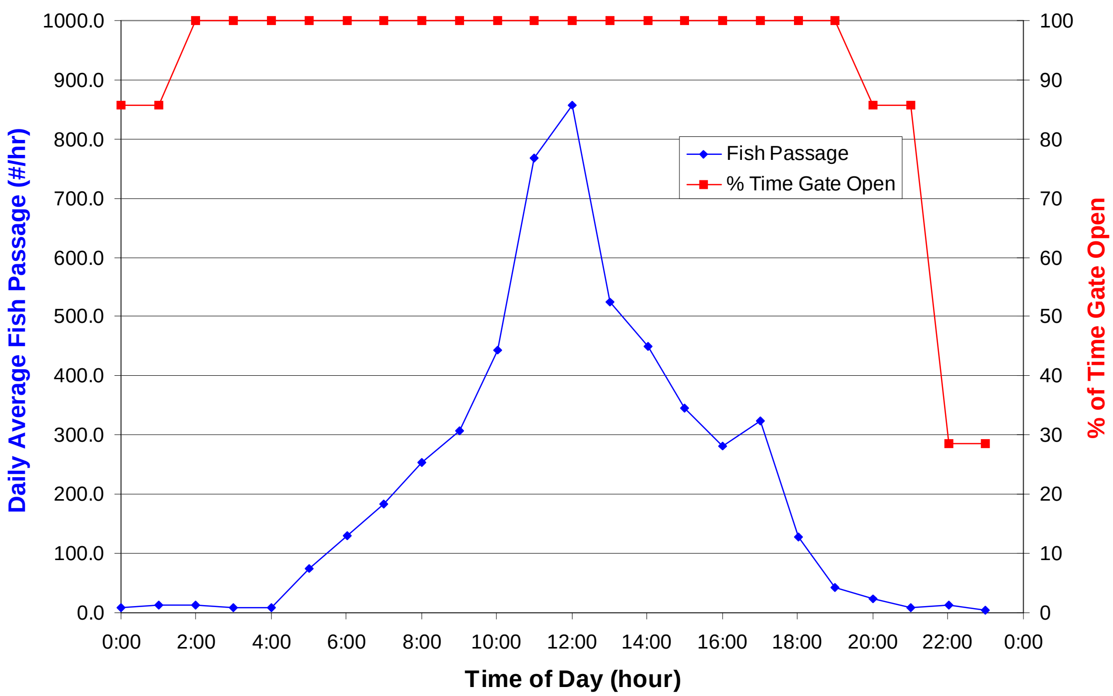


Figure 25. Diel Passage Pattern Through Spill Bay #2 for April 30 – May 6th, 2000.

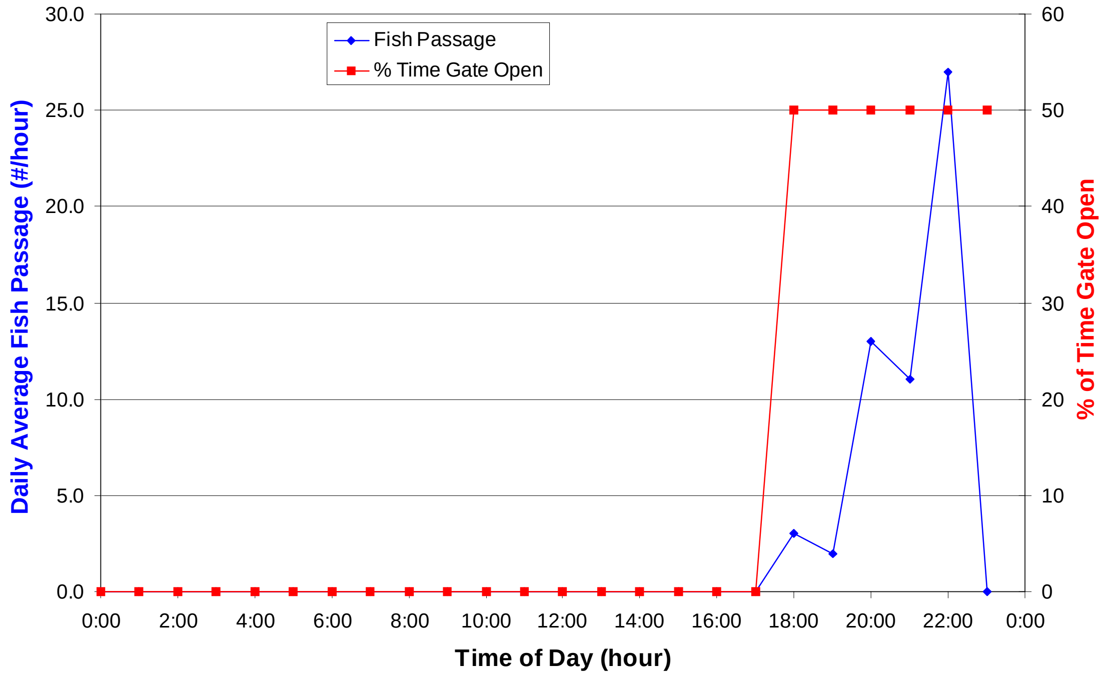


Figure 26. **Diel Passage Pattern Through Spill Bay #2 During May 7-12, 2000**

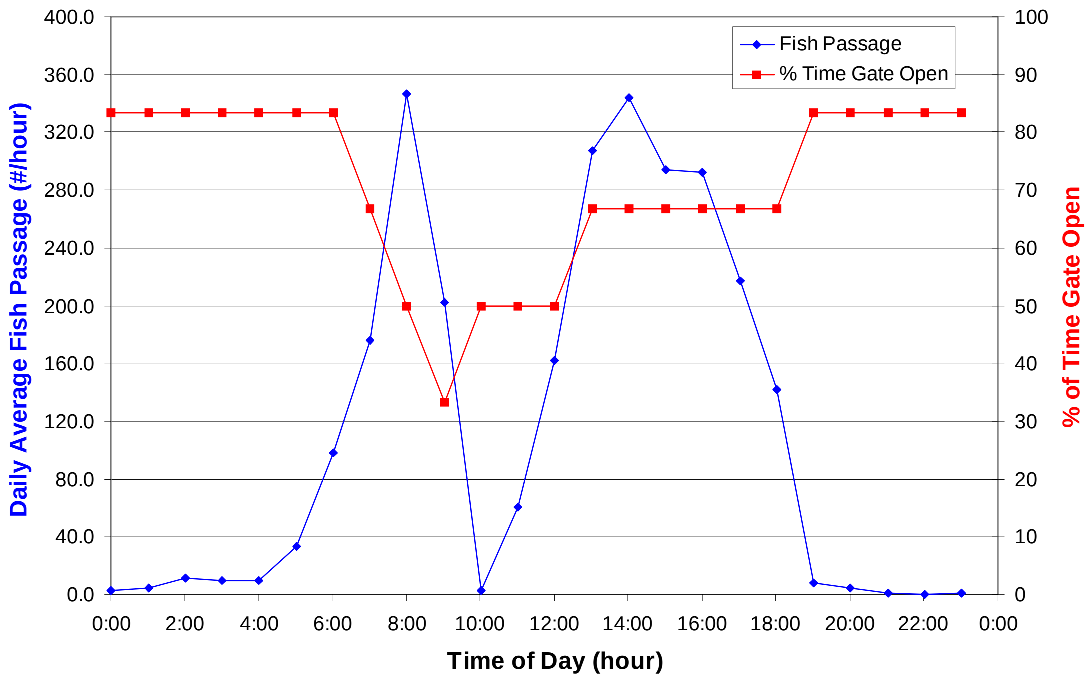


Figure 27. **Diel passage pattern through spill bay #2 during May 18-19, 2000.**

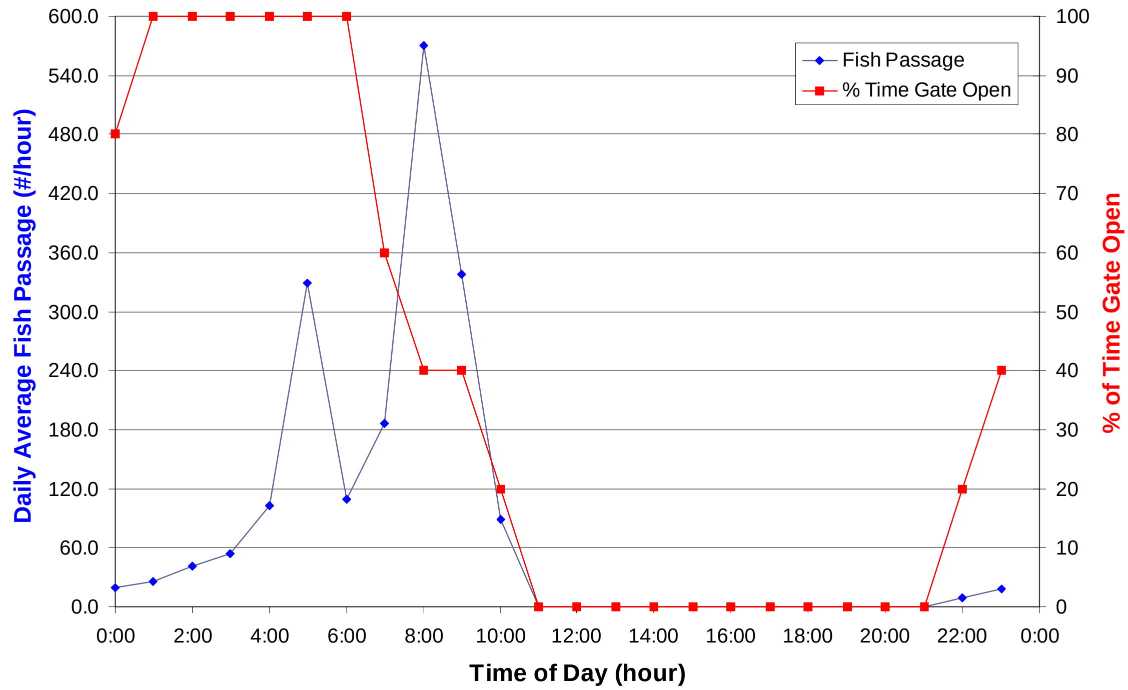


Figure 28. **Diel Passage Pattern Through Spill Bay #2 During May 24-27, 2000.**

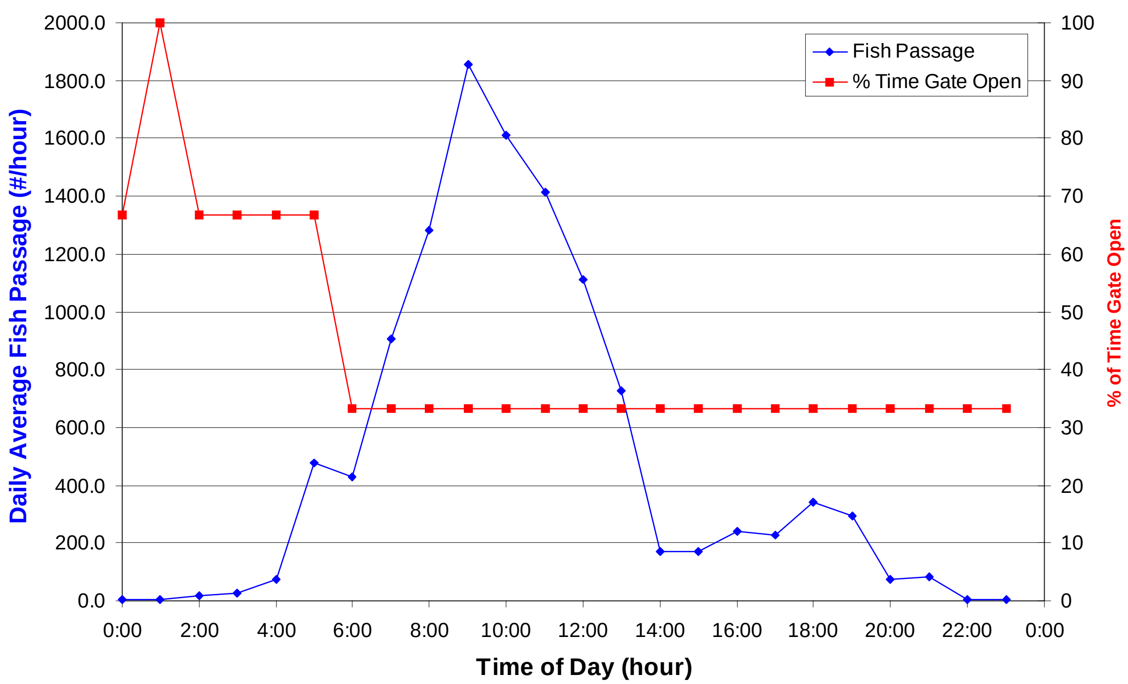


Figure 29. Diel Passage Pattern Through Spill Bay #2 During May 28 – June 2, 2000.

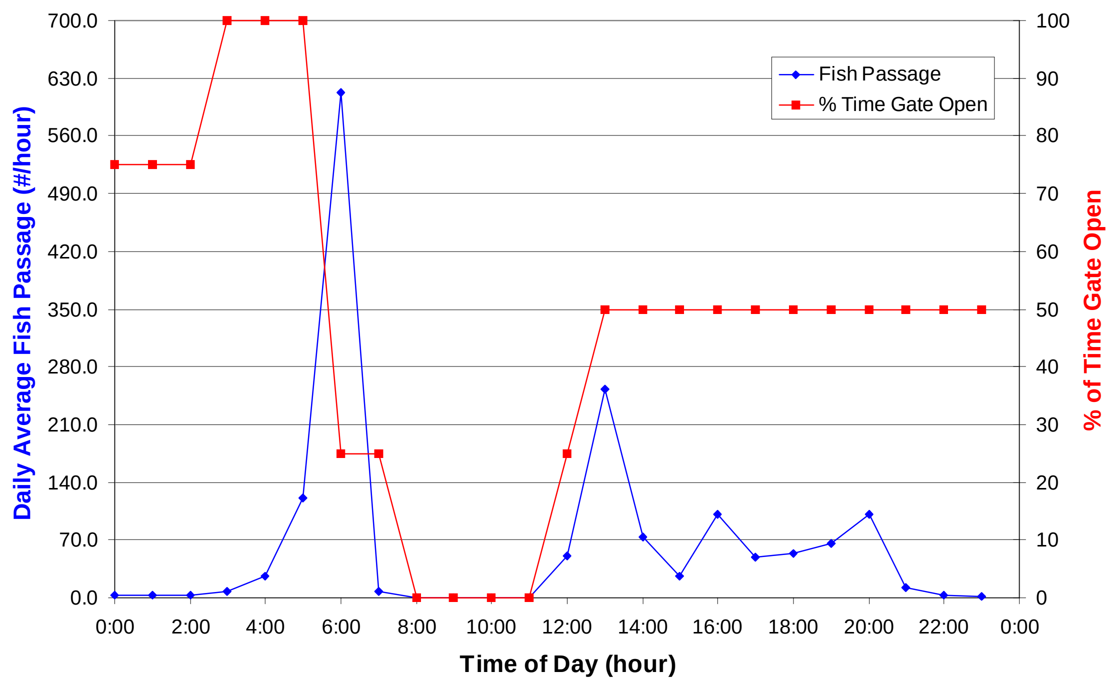


Figure 30. Diel Passage Pattern Through Spill Bay #2 During June 12-15, 17, 2000.

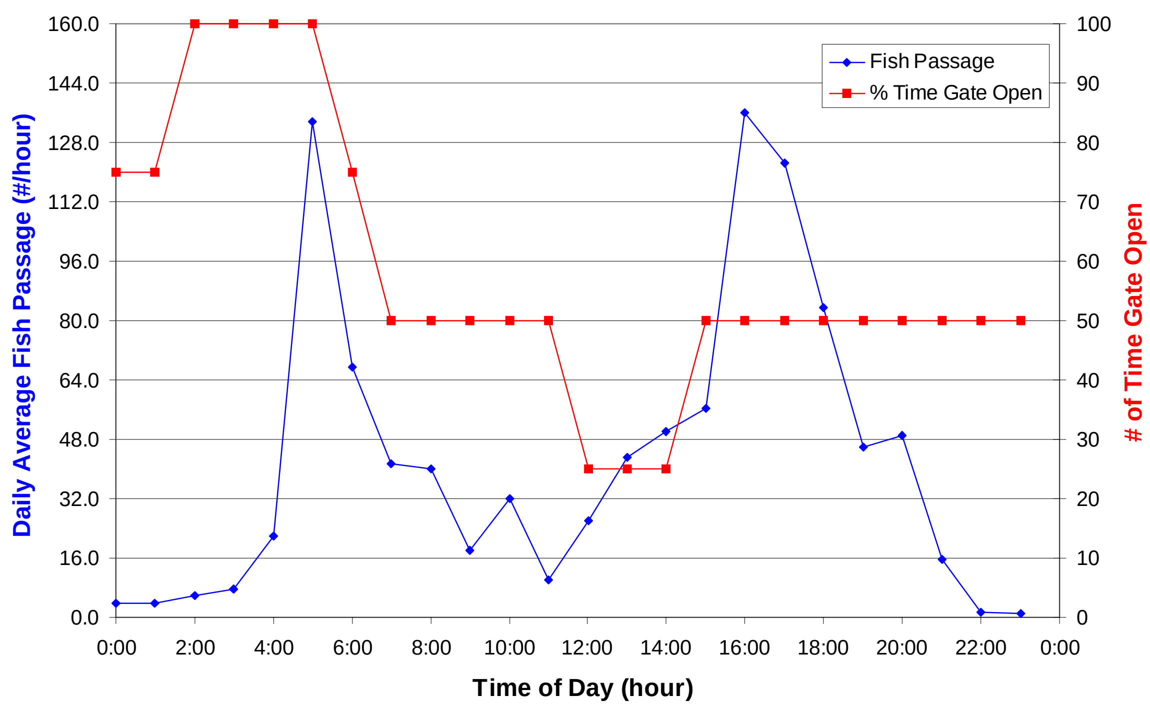


Figure 31. Diel Passage Pattern Through Spill Bay #2, June 18-19, 21-22, 2000.

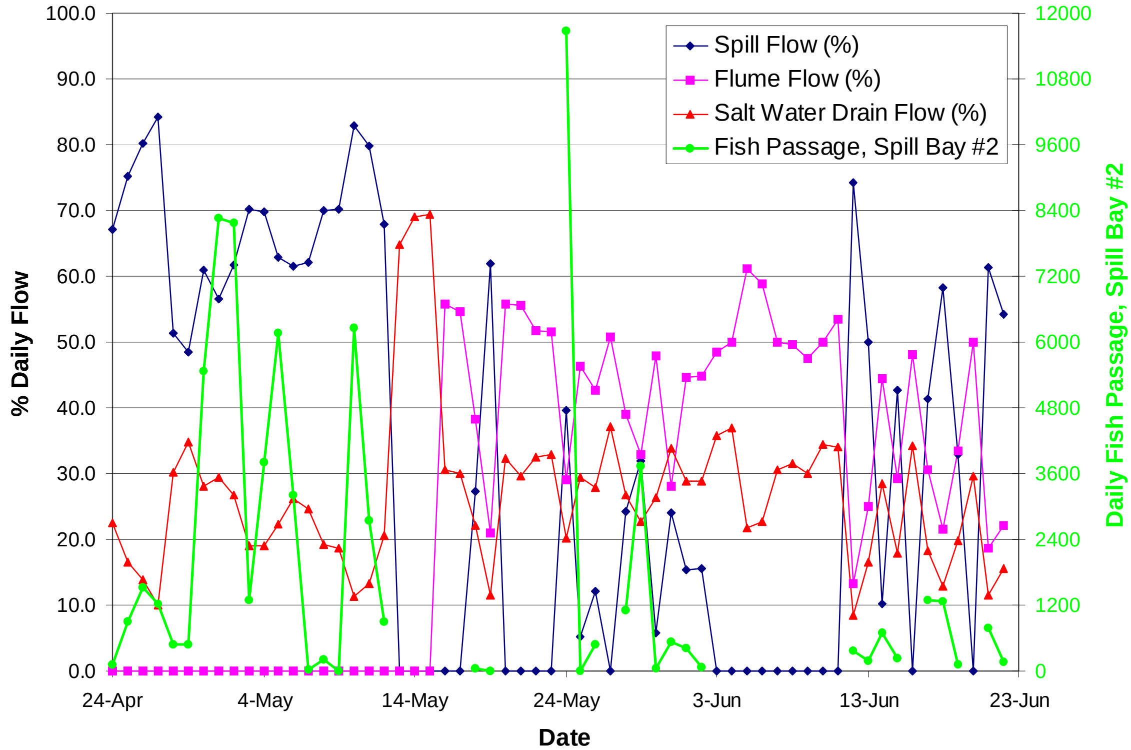


Figure 32. Fish Passage Through Spill Bay #2 with Daily Flow Through Selected Routes.

High fish passage rates were observed through Spill Bay #2 until late May, at which time the smolt flumes were activated (Figure 33). A few remaining passage peaks always corresponded with reduced flume operation. Although the flumes provide surface flow, the spill gate opening is only about 7 feet below surface. It seems reasonable to conclude that either flumes or spill gates can supply attractant flow to draw fish from other regions of the project because the spill forebay is quite shallow. Since no data on species identification of fish passing through spill are available, and since salmonids dominated the visual observations through the flumes, we are assuming that salmonids also dominate the acoustic counts of fish passing through Spill Bay #2.

In 1998, a single fish flume was positioned above Spill Gate #4. Mobile survey data indicated that the horizontal distribution of fish density in the spill forebay was quite variable. Moderate to high density patches of fish were typically observed along either the first transect line, which was about 25 m from the gates, or along the second line, which was about 59 m from the gates. Patches typically were localized to a single gate, but on occasion were large enough to overlap 2-3 gates. Patches were not seen as often during dawn and nighttime transects. Patches of fish were seen most often in front of Spill Bays 2-4. These observations do not incorporate operational data.

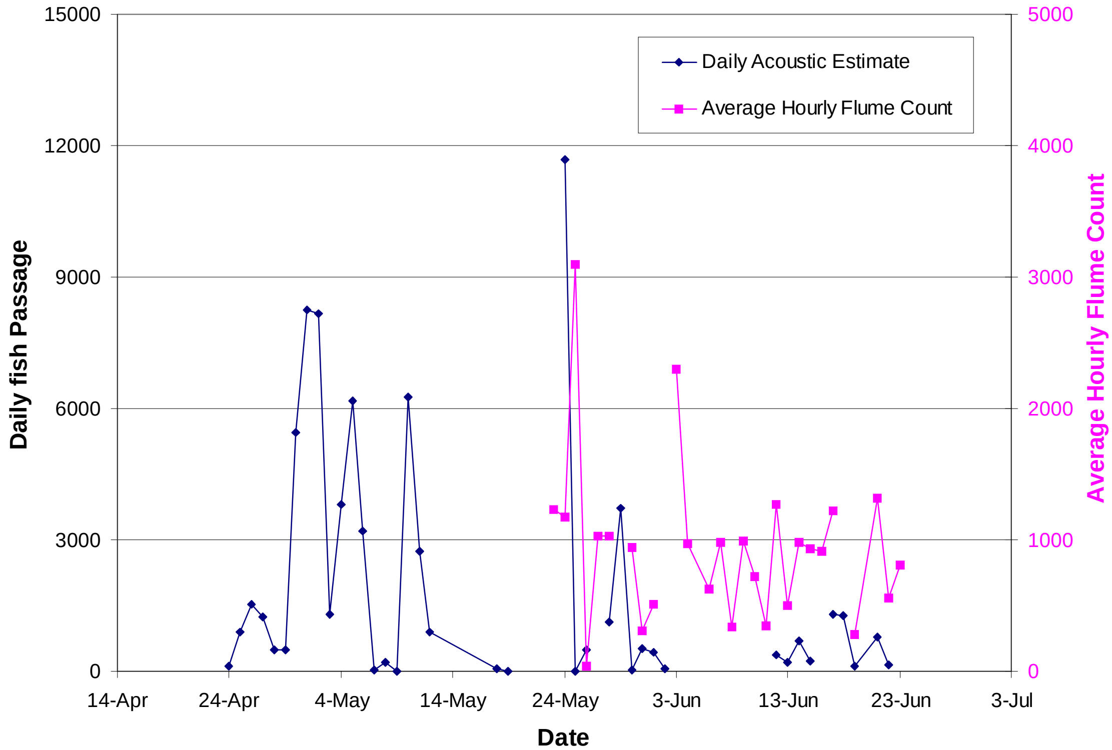


Figure 33. Total Daily Fish Passage Estimates through Spill Bay #2 from Acoustics with Average Hourly Flume Counts Overlaid

Effects of Spill Gate Opening

After removing hourly points representing gate settings not specified by the block design and points corresponding to down time on the acoustic system, the hourly passage estimates were plotted for the 6 inch and 12 inch gate openings in Figure 34. Sample sizes are provided at each gate setting. Other data points that were not originally in the block design are included in Figure 35.

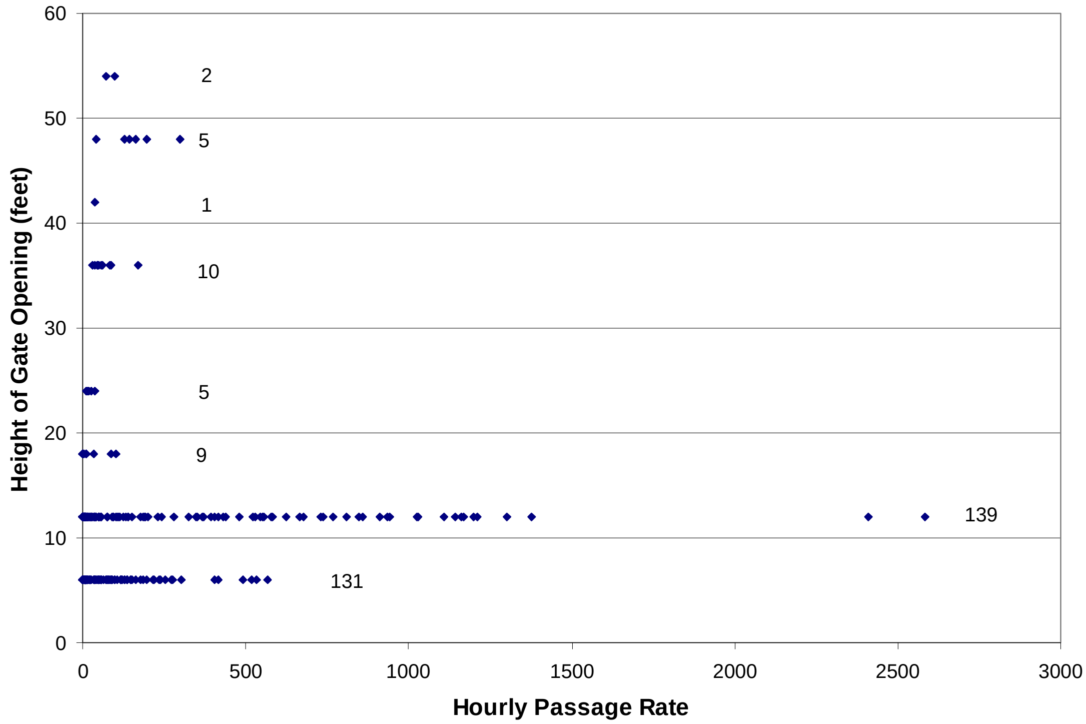


Figure 34. Scatter plot of hourly passage rate samples in the block design as a function of height of gate opening.

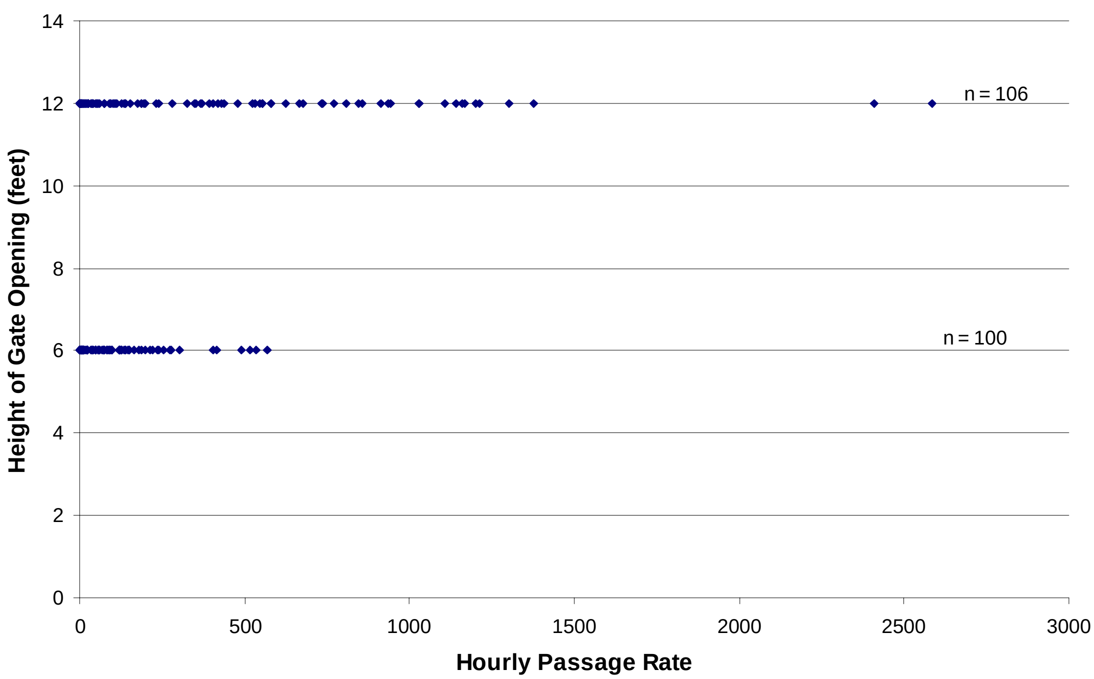


Figure 35. Scatter plot of all hourly passage rate samples as a function of height of gate opening.

The estimates of fish passage suggest increased passage at a 12-inch gate height. At the 6-inch height, only 7 points are higher than 300 fish per hour. When the gate is 12 inches high, 42 samples are over 300 fish per hour, and 12 samples are over 1000 fish per hour. The low sample size at any gate height greater than 12 inches precludes any conclusion of beneficial or detrimental effects on passage rate. The high variability at each level is characteristic of the patchy nature of the fish density as schools of various sizes approach and pass through the spill bay. A proposed causal mechanism for the difference in passage effectiveness with gate opening is that a 1-foot gate opening might provide velocities that extend to the surface-and capture surface-oriented fish, while the velocities produced by the 0.5-foot gate opening might not extend far enough.

Summary Discussions

By July 14th, the only paths available to downstream migrating salmon smolts included the fish ladder, the salt-water drain, and the large and small locks. The number of smolts observed by the video camera at the mouth of the salt-water drain began to increase on July 7th. This increase corresponds with the decreased flow through the fish flumes (less than 50 cfs total flow) and the end of flow through the spill gates. Although few smolt entrainment events at the salt-water drain were observed on the video system, the data suggest that the risk of smolt entrainment through the salt-water drain increases as alternate paths are removed. When flumes and spill gates are shut, the picture of what route smolts use to pass the project is less clear.

The observations gathered during this study suggest a hypothesis of fish passage and distribution, which we offer as follows. We propose that smolt distribution is controlled by both bathymetry and by a natural surface orientation. The forebay of the spill section of the project is quite shallow. As a result, flow created by spill or fish flumes will provide an attractive stimulus further upstream and over a wider geographical extent. Visual observations above the spill bays and of passage through the flumes, as well as acoustic passage estimates through Spill Bay #2 indicate that fish passage through this region is very favorable if suitable routes are provided. During the study, we observed vast schools of smolts holding in the forebay above the spill section of the Locks structures. Spill gates create a significant attractive flow quite some distance upstream from the project. When fish are drawn to the spill region by spill flow, they would prefer to pass through a surface opening, but will pass through spill gates since there opening s are typically about 7 feet deep.

We hypothesize that smolts migrating downstream are surface oriented. The number of smolts observed at the surface or passing through surface flow devices was much higher than numbers of smolts observed at a depth of 50 feet by the underwater video camera. The surface orientation is consistent with observed behavior of salmon smolts near Columbia and Snake River Dams. Based on this preference, we believe that smolts near the filling culverts resist entrainment since this flow draws them deeper than their preferred depth. If they remain in the vicinity of the filling culverts or if no alternate surface passage route is provided, we expect that salmon smolts will eventually be entrained into the locks during fill events.

We suggest a somewhat inverted hypothesis for adult Chinook salmon. When these fish exit the fish ladder, they hold in the deep-water basin in the cooler more saline waters. Both tag data and acoustic and video data showed adult Chinook holding in the flow at the mouth of the salt-water drain. They have no difficulty holding position for some time, and are often drawn deep into the center of the salt water drain intake structure, usually to fight their way back out to the slower flow outside. Some are carried too far in and cannot escape entrainment. The adult Chinook hold in the deeper water until one or more conditions change: if surface waters cool, the salmon may be able to move upstream from the structure; at some point in time, the salmon apparently have an inner compulsion to migrate that is stronger than the environmentally imposed forces; or the salmon are entrained into the salt water drain and pass either below the spillway or into the diffuser in the fish ladder.

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Dennis Erickson and Pat MacDonald of the U.S. Army Corps of Engineers for supervising safety issues on all underwater activities

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