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Evaluation of the Effects of Extended Length Submersible Bar Screens at McNary Dam on Migrating Juvenile Pacific Lamprey (Lampetra tridentata)

R.A. Moursund
R.P. Mueller
K.D. Ham
T.M. Degerman
M.E. Vucelick

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Battelle, Pacific Northwest Division
PO Box 999
Richland, Washington 99352

Executive Summary

In May and June of 2001 Battelle conducted a field study to ascertain the effects of extended-length submersible bar screens (ESBS) on juvenile Pacific lamprey (*Lampetra tridentata*) at McNary Dam. The focus of the project was two-fold. The first task consisted of a video evaluation of lamprey on the screen. Four small underwater video cameras were mounted to the brush bar mechanism, which traveled the face of an ESBS at unit 4B. We observed 12 juvenile lamprey contacting the screen face. These fish were either impinged or became wedged in the 1/8-in. opening of the bar screen. In addition, salmonid smolts were observed actively swimming against the flow and in some instances contacting or becoming impinged on the screen face.

A second task was to determine if juvenile lamprey could be successfully detected within the juvenile fish bypass system and, if so, to compare the travel times of juvenile lamprey released in the gatewell, the collection channel, and the immediate forebay of a turbine intake. Approximately 700 juvenile lamprey were obtained from the John Day Dam smolt monitoring facility, PIT tagged, and released at locations within and immediately upstream of McNary Dam. The detection efficiency for juvenile lamprey was 97%; this was within 1% of the detection rate for smolts when released immediately above the detector. Detection rates varied depending on the release location, but no significant difference was found in the travel time between locations of the lamprey releases. Five lamprey were also detected at John Day Dam, demonstrating that at least some of the tagged population continued their migration downriver (10, 12, 13, 17, and 28 day travel times). The methods developed for this study can be used to determine the efficacy of measures for mitigating any potentially adverse effects of ESBS on juvenile Pacific lamprey.

Acknowledgments

We sincerely acknowledge the cooperation, assistance, and hard work of the following:

Paul Ocker and Marvin Shutters of the U.S. Army Corps of Engineers, Walla Walla District, for project oversight.

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1.0 Introduction

Since the 1960s there has been a notable decline in numbers of Pacific lamprey, an anadromous species inhabiting the Columbia and Snake rivers. In May and June of 2001, Battelle conducted field studies of juvenile Pacific lamprey at McNary Dam. The research was conducted for the U.S. Army Corps of Engineers, Walla Walla District, under the Anadromous Fish Evaluation Program.

The primary goal of this project was to ascertain the effects of extended-length submerged bar screens (ESBS) on juvenile Pacific lamprey traveling downstream through McNary Dam. To accomplish this, underwater optical video cameras were used to record *in situ* observations within a fully operational turbine intake. A secondary goal was to determine whether field releases of PIT-tagged lamprey could be tracked through the juvenile bypass system. The goals were defined in two tasks:

- Task 1 – Document incidents of impingement, and determine the effect of the cleaning brush on juvenile lamprey encountering an ESBS at McNary Dam.

- Task 2 – Determine the detection rate of PIT-tagged juvenile lamprey in the bypass system of McNary Dam and compare the travel times of juvenile lamprey released in the forebay, gatewell, and collection channel.

1.1 Background

The Pacific lamprey (*Lampetra tridentata*) is the largest lamprey species in the Columbia River Basin. These anadromous fish have four primary life stages. Spawned in fresh water, filter-feeding larval lamprey, or "ammocoetes" inhabit the substrate of their natal streams for up to 7 years. They develop adult physiological and morphological characteristics in the juvenile stage during their emigration to the ocean. Parasitic in the adult stage, which may extend up to 5 years, they prey upon fish species such as rockfish, halibut and hake. Their return to fresh water marks the final stage, as they migrate upstream to spawn and die (Wydoski and Whitney 1979). The current distribution of Pacific lamprey in the mainstem Columbia and Snake rivers extends up to Chief Joseph Dam and Hell's Canyon Dam, respectively. Principal spawning and rearing habitats occur in tributary streams (Kan 1975), with limited use of the mainstem Columbia River corridor except during adult and juvenile migration periods.

A widespread decline in the numbers of Pacific lamprey has occurred since the 1960s, the period when most dam construction occurred in the lower Snake and Columbia rivers. This decline has been attributed to several causes, including habitat loss, water pollution, ocean conditions, and dam passage (Close et al. 1995). Operations at mainstem hydroelectric projects may be deleterious to juvenile lamprey migrating downstream. They have a higher potential for entrainment through turbines due to their tendency to swim lower in the water column than anadromous salmonids (Long 1968). Also, previous findings suggest that extended length bar screens pose a hazard to lamprey that encounter them. Some investigators reported large numbers of juvenile lamprey trapped between individual bars of the fixed bar screens at The Dalles and McNary dams (Hatch and Parker 1998).

Juvenile passage studies were conducted at McNary Dam in 2001. Located at river mile 292 of the Columbia River (Figure 1), McNary Dam is 7,365 ft long. The spillway is 1,310 ft long with a hydraulic capacity of 2200 kcfs from 22 bays. The powerhouse is 1422 ft long with a hydraulic capacity of 232 kcfs among 14 Kaplan turbine units. All of the turbine intakes are equipped with extended-length submerged bar screens (ESBS). The screens measure 18 ft wide by 40 ft long and are part of a juvenile bypass system that guides fish away from the turbines (Figure 2). Fish are guided by the screen into the gatewell, from which they enter the collection channel via submerged orifices. From the collection channel, they are transported laterally along the powerhouse to the smolt monitoring facility.

1.2 Summary of Previous Studies

In 1999 and 2000, Battelle studied the interaction of juvenile lamprey with turbine intake screens. The 1999 work consisted primarily of laboratory investigations into potential injury mechanisms and the effects of turbine bypass screens on lamprey behavior and survival. The results of these trials illustrated that the current fixed bar screens do not prevent juvenile lamprey impingement. Under laboratory conditions, with the bar screen perpendicular to flow, the progression of events from impinged to stuck was documented (Moursund et al. 2000). Also in 1999, Oregon State University investigated tag technologies and developed a tagging protocol for juvenile lamprey using passive integrated transponder (PIT) tags (Schreck et al. 1999). Battelle continued laboratory tests in 2000 focused on comparing screen materials with different mesh widths; findings indicated that a smaller gap impinged fewer lamprey. Battelle also conducted direct video observations of juvenile lamprey on an operating ESBS at McNary Dam that documented the progression from impinged to stuck under actual operating conditions (Moursund et al. 2001).

1.3 Study Site

The studies reported here were conducted at McNary Dam in May and June 2001. Located at river mile 292 of the Columbia River (Figure 1), McNary Dam is 7,365 ft long. The spillway is 1,310 ft long with a hydraulic capacity of 2,200 kcfs from 22 bays. The powerhouse is 1,422 ft long with a hydraulic capacity of 232 kcfs among 14 Kaplan turbine units. All of the turbine intakes are equipped with ESBS. The screens measure 18 ft wide by 40 ft long and are part of a juvenile bypass system that guides fish away from the turbines (Figure 2). Fish are guided by the screen into the gatewell, from which they enter the collection channel via submerged orifices. From the collection channel, they are transported laterally along the powerhouse to the smolt monitoring facility.

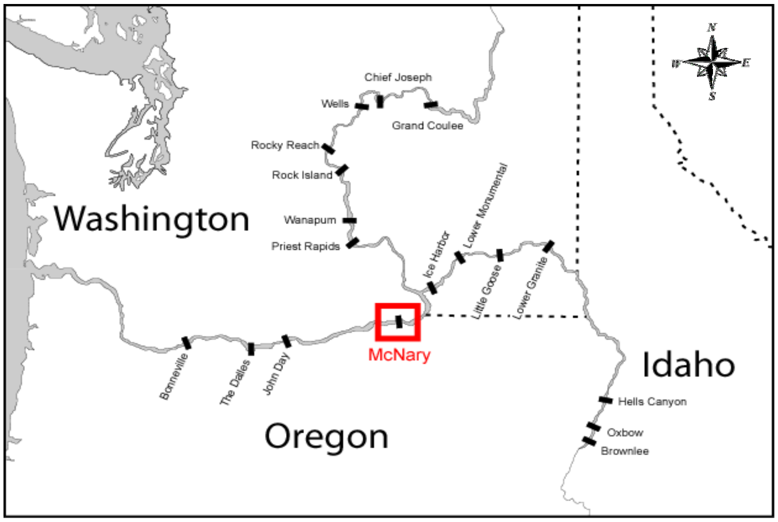

Figure 1. Physical location of McNary Dam at river mile 292 of the Columbia River.

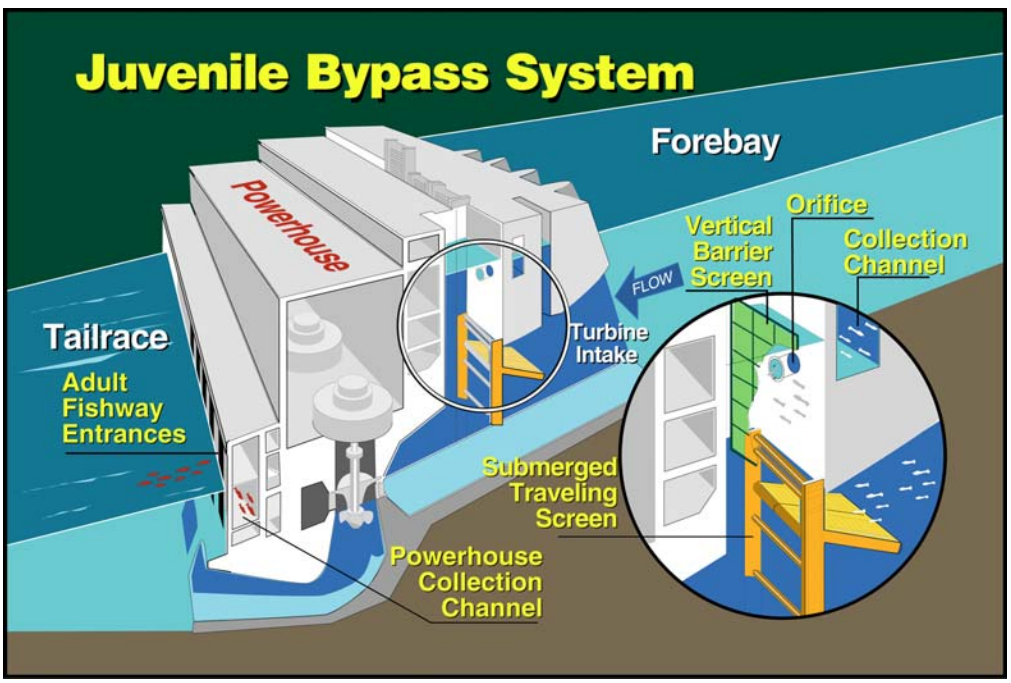

Figure 2. Cut-away view of a juvenile bypass system. The McNary dam ESBS are about twice the length of the STS shown above.

1.4 Overview of Report

Section 2 describes the methods and equipment used for the underwater video observations of lamprey encountering the screens, as well as the PIT tagging and release methods, data processing, and data analysis. Results of the field studies are presented in Section 3 and discussed in Section 4. Section 5 provides conclusions and recommendations. Section 6 contains references.

Appendix A lists release date, detection data, and travel times for each PIT-tagged lamprey. Appendix B provides graphs showing historical run timing data for juvenile lamprey at Lower Granite, Little Goose, McNary, John Day, and Bonneville dams. Appendix C lists equipment used in the studies.

2.0 Methods

The methods and equipment used for the underwater video observations are described in Section 2.1. The following subsections describe the PIT tagging procedure, release methodology, data processing and data analysis for the more than 600 juvenile Pacific lamprey tagged and released at McNary Dam.

2.1 Brush Bar-Mounted Optical Cameras

Video cameras were utilized to document the behavior of the juvenile lamprey as they interacted with the ESBS and cleaning brush mechanism. Four cameras were fastened to the brush bar of the unit 4B screen. All of the cameras were directed toward the screen face at a 30º angle. Two of these cameras pointed up toward the gatewell, while two faced down toward the intake floor (Figure 3). Two custom video/power cables were routed up the screen face, around the flow vane and up to the forebay deck. Two spring-activated cable reels with associated slip rings were used to take up slack in the cable as the brush bar moved up and down the screen.

During the recording period, the brush bar was operated using a portable manual control unit, which allowed us to stop the brush and observe lamprey when they appeared within camera range. The total coverage area, based on a 1-ft field of view along the entire screen, was 10% of the intake screen. The brush bar was operated on a normal 20-min cycle and stopped only if a fish on the screen was encountered. During non-recording periods, the brush was set for automatic cycling. All recordings were made on digital video format tapes.

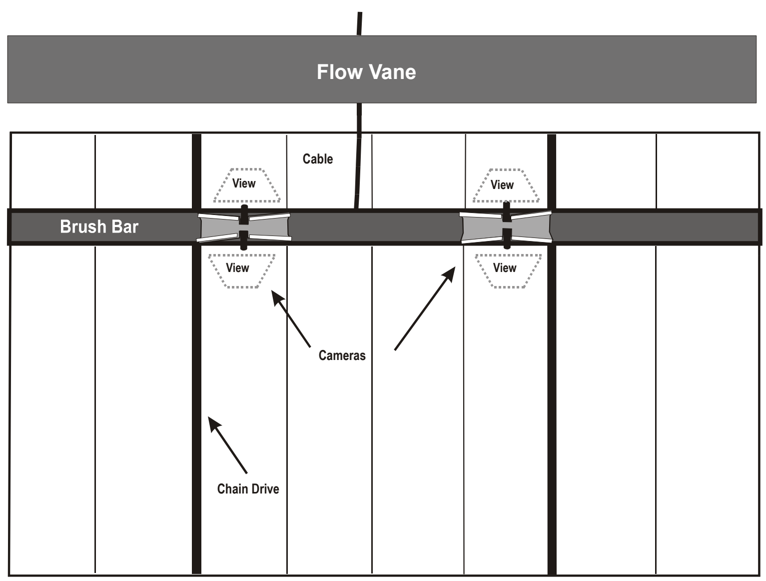

Figure 3. Diagram of the optical camera deployment and field-of-view relative to the entire screen.

The video recording period was scheduled from 2000 to 0200 h (six hours). This time frame corresponded with the majority of the lamprey sightings in an average 24-hr period (Moursund et al. 2001). Video recordings were started on May 25; however, due to an unexpected voltage drop due to the cable length and wire gauge, only the south up-looking camera was operational. Video recordings were made with this one camera from 2000 to 0200 h. The video system was inspected, repaired, and redeployed by May 30. A fault in the cabling system disabled the south up-looking camera during this sample period. Video recordings from the remaining three cameras continued through June 3 from 2000 to 0200 h.

2.2 PIT Tagging Procedure

Juvenile lamprey were acquired from the John Day Dam smolt monitoring facility from early April through mid May and transported to the PNNL aquatic laboratory in aerated coolers. The lamprey were approximately 130 mm in length and 5 to 8 mm in width. The lamprey were held in a circular holding tank at the PNNL aquatic laboratory in chilled well water (6 ºC). PIT tag retention and mortality observations were conducted in a 190-gal Living Stream™ tank and a trough supplied with ambient river water.

The lamprey were removed from the holding tank in lots of 15 to 20 and placed in an anesthetizing solution of MS-222 (250 mg/L, pH 7.0). When their activity level decreased and they could be easily handled, each lamprey was measured and placed on a wetted, closed-cell foam pad with the right side gill openings facing up, oriented at a 45° angle with the tail facing away. A 22-gauge hypodermic needle was used to puncture a small hole about 5 mm posterior of the gill pores. A tapered dissecting needle was then used to enlarge the opening slightly to allow for insertion of the PIT tag injector needle. The injector needle was inserted, bevel side up, until the needle opening was under the skin (Figure 4). With the lamprey body held steady, the PIT tag injector was turned with the beveled side pointed toward the lamprey body and the tag was injected into the cavity. The tagged lamprey were placed into a separate cage, supplied with an airstone, within the chilled holding tank. They were allowed a minimum of 48 hours to recover from the PIT tagging procedure before being transported to McNary Dam and released.

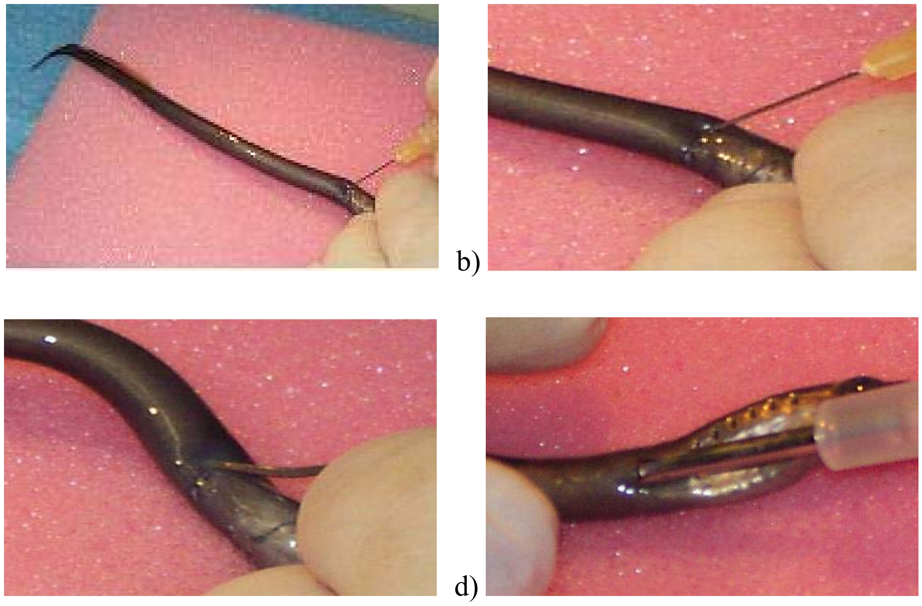

Figure 4. PIT tagging procedure. a) orientation; b) 22-gauge needle ; c) tapered dissecting needle; d) tag injected with 12-gauge PIT tag injector.

2.3 Release Procedures

Tests were conducted to determine the survival and tag retention of tagged lamprey and to determine detector efficiency, in addition to conducting the actual releases of tagged lamprey in the forebay, gatewell and collection channel of McNary Dam's juvenile bypass system. The methods used for all of these tests are described below.

2.3.1 Post-Tagging Survival and Tag Retention

A comparison was conducted using tagged and untagged lamprey to determine long-term survival and tag retention. The subjects were initially segregated into two groups (75 tagged and 75 untagged) in separate cages, and then held in chilled well water for a period of 40 days. After the 17th day, 30 tagged and 30 untagged lampreys (about half) were removed from the chilled water and acclimated to river water (19-23° C) over a 24-hr period. This was done to accelerate a possible decline in health from the tagging procedure and to exaggerate any differences between tagged and non-tagged lamprey in a compressed time period.

2.3.2 Detection Efficiency at a Single Detector

To determine detection efficiency, PIT-tagged lamprey were released in the juvenile bypass collection facility below the main fish separator into flume sections A and B (Figure 5). Initial concerns were that: 1) the orientation of the lamprey body as it passed through the detector would prevent the tag from working correctly, and 2) one or more lamprey might attach to the side of the detector tube. If the coil detector was occupied by a tagged lamprey, it would be unable to detect other tagged fish passing.

Lamprey were acclimated to river water temperature over a period of 24 hrs. They were removed from the transport container via dip net, scanned with a portable PIT tag reader, and individually released directly into the flume sections about 2 m above the primary coil detectors. Two groups (n=63 and n=40) of tagged lamprey were released on April 27 and May 8, respectively. Each release group was split evenly between the two flume channels A and B. On April 27, 33 tagged lamprey were released above the A-Separator gate and 30 above B-Separator gate. On May 8, 23 were released above the A-Separator gate and 17 above the B-Separator gate.

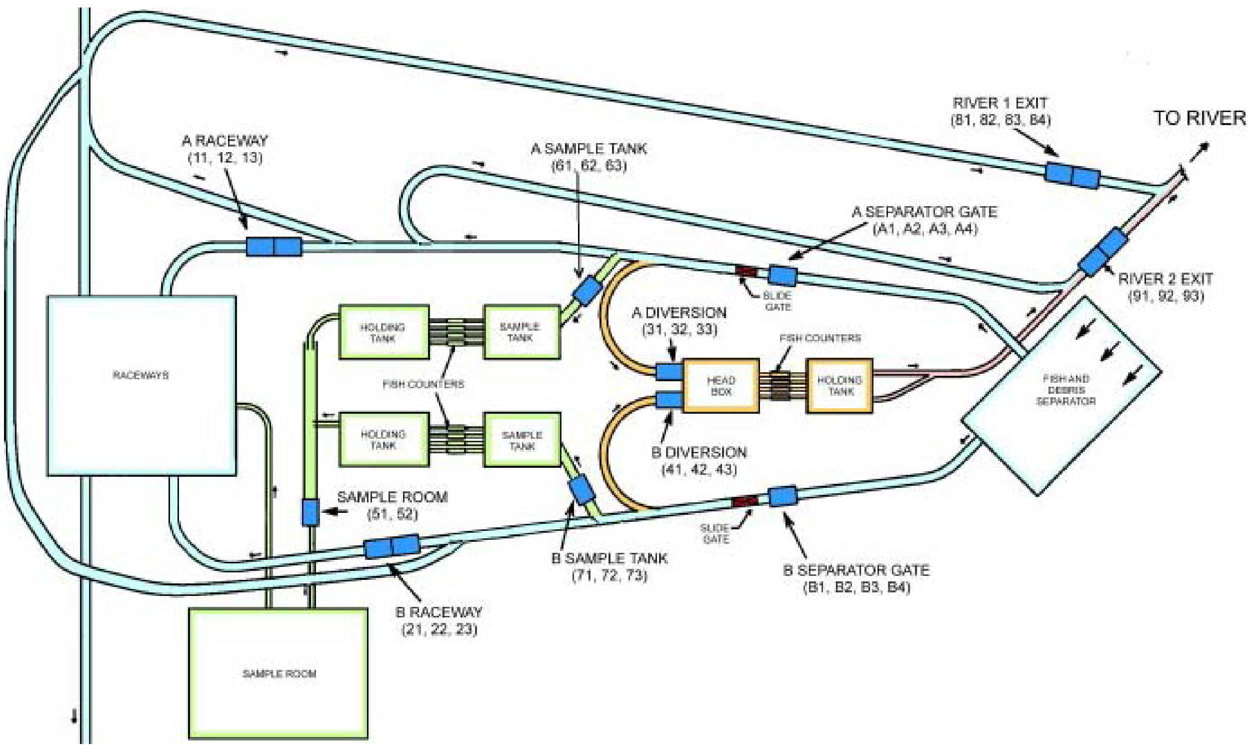

Figure 5. Plan view of the McNary Dam juvenile fish facility PIT tag detectors. Fish enter the system at the fish and debris separator and exit to the river.

2.3.3 McNary Dam Field Releases

Three release locations were selected to examine differences in passage rates through the juvenile bypass system: the forebay, the gatewell, and the collection channel. Each of these releases occurred within or in front of intake 4B (Figure 6). Unit 4 was chosen because it was near the center of a block of operating turbine units. Tagged lamprey were released on three dates at each of the three locations in groups of 30 to 50 (Table 1). Prior to being released, the groups were acclimated to river water over a period of 24-hr and scanned with the portable PIT tag reader. Release times were similar for all release dates, between 2000 and 2300h.

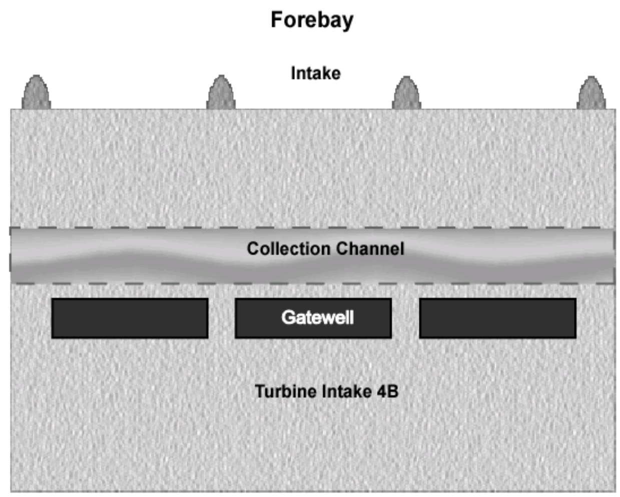

Figure 6. Plan view of turbine unit 4 at McNary Dam.

To conduct the forebay releases, tagged lamprey were ferried by motorboat to the area just upstream of the Unit 4B intake. The release vessel was a weighted wire cage (12 in. diameter × 18 in. length), which was lined with 1/8 in. nylon mesh material to prevent the lamprey from escaping through the wire mesh or attaching to it. Nylon mesh covers were attached to the ends of the cage using heavy-duty elastic bands that could be removed via attached nylon lines while the cage was held at depth. The lamprey were released using the following procedure: 1) the cage was placed into a 6-gal pail filled with water with the mesh cap attached to the bottom end; 2) the lamprey were placed inside the cage through the top end and its mesh cap was attached; 3) the pail containing the cage was placed in the river until submerged, then the cage was removed and lowered to the desired depth; 4) both mesh end caps were removed simultaneously by pulling the nylon lines, which allowed the lamprey to swim out. To evaluate whether detection varied with release depth, forebay release depths ranged from between the water surface to 30 ft (Table 1).

Within the gatewell, groups of tagged lamprey were released by lowering a 6-gal pail containing the lamprey into the gatewell slot. Upon reaching the water surface, the bucket was inverted using a nylon rope attached to its base, enabling the lamprey to swim out of their own volition. Releases into the collection channel were accomplished by lowering a 6-gal pail containing tagged lamprey into the channel near the 4B orifice outfall, inverting the bucket at the water surface using the rope attached to its base, and allowing the lamprey to swim out.

Table 1. Release schedule for PIT-tagged juvenile lamprey at McNary Dam in 2001.

Location	Date	Time	Depth (ft)	Number
Forebay	26-May	21:10	15	31
Forebay	26-May	21:40	15	30
Forebay	11-Jun	21:10	10	40
Forebay	11-Jun	21:25	Surface	40
Forebay	11-Jun	21:41	30	40
Forebay	18-Jun	20:29	5	45
Forebay	18-Jun	20:44	10	46
Forebay	18-Jun	20:58	15	45
Gatewell	26-May	20:25	Surface	33
Gatewell	26-May	22:07	Surface	30
Gatewell	11-Jun	22:10	Surface	35
Gatewell	18-Jun	21:23	Surface	47
Collection	26-May	20:40	Surface	33
Collection	26-May	22:19	Surface	31
Collection	11-Jun	22:25	Surface	47
Collection	18-Jun	21:35	Surface	46

2.4 Data Processing

The PTAGIS system (http://www.pittag.org) was used to obtain data on tag detections at McNary Dam and other projects downstream. The PIT tag detections were compiled in a database, and then summarized to correspond to each release group date and time of release (Appendix A). Video recordings were reviewed manually, and both lamprey and smolt occurrences were noted as to time, location, and duration of appearance.

2.5 Data Analysis

The methodologies used to analyze results of the detector efficiency test and the travel time data collected for travel through the juvenile bypass system and from McNary Dam to John Day are described below.

2.5.1 Optical Camera Observations

Summary statistics and video clips were used to summarize the optical video observations. No formal statistical tests were conducted for this portion of the study.

2.5.2 Detection Efficiency

Detection efficiencies were compared among release depths for the forebay releases. A log-linear analysis was conducted (GLZ module, Statistica) to test whether detection efficiencies differed among release depths. The null hypothesis is that detection efficiencies do not differ among release depths for the forebay release site. The maximum likelihood chi-square value was computed and statistical significance was judged relative to an alpha of 0.05. The null hypothesis is that detection efficiency, as a percentage of individuals released, does not differ among release sites.

2.5.3 Travel Times in the McNary Dam Juvenile Bypass System

Travel times from the release location to the first PIT tag detectors (separator A or B) within the McNary Dam juvenile fish facility were computed in minutes. Travel times were log transformed to better approximate a normal distribution. Log travel times were compared with ANOVA (GLM module, Statistica) among release depths for the forebay release site to evaluate whether they should be pooled for comparisons among release sites.

Log travel times were compared among release sites using ANOVA (GLM module, Statistica). The alpha level for hypothesis tests was set at 0.05. Travel times were compared among groups with a post-hoc multiple comparison test (Newman-Keuls test) to explore whether any two groups differed.

2.5.4 Travel Times from McNary Dam to John Day Dam

Mean travel times from McNary Dam to John Day Dam were compared with travel times of PIT tagged fall chinook salmon smolts (DART 2001). Travel times were log transformed to better approximate a normal distribution. Means were compared among lamprey and fall chinook salmon using a t-test of independent samples with alpha set at 0.05.

3.0 Results

Data on river discharge and dam operations and lamprey and salmonid run size and timing and results from the video observations are provided below in Sections 3.1, 3.2, and 3.3. Section 3.4 provides a detailed presentation of results of the survival comparison and detector performance tests, detection rates for PIT-tagged fish released from the three release locations, travel times in the juvenile bypass system, travel times through the smolt monitoring facility, and travel times from McNary to John Day Dam.

3.1 River Discharge and Dam Operations

During the video evaluation, Unit 4 loading was at or near 55 MW. This was a low flow year with the river discharge from 25-Apr to 18-Jun at 45% of the 10-yr average (DART 2001). Total daily project discharge ranged from 106 to 158 kcfs and nighttime spill, when it occurred, ranged from 7.2 to 7.6 kcfs (Figure 7). The hourly discharge data (Figure 8) shows the considerable diel variability of both the powerhouse and spillway operations. Water temperature ranged from 15.2 to 18.2° C.

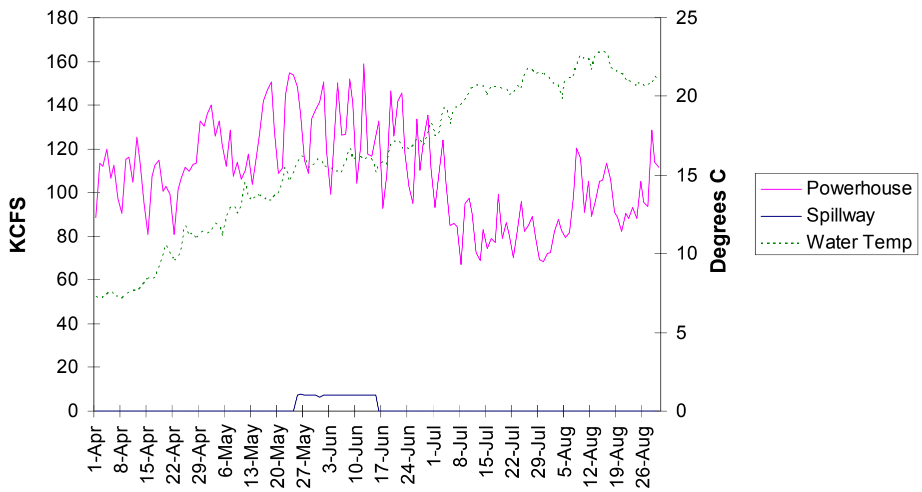

Figure 7. Average daily dam operations over the season.

Figure 8. Hourly dam operations during the study.

3.2 Run Timing

Run timing and size data for juvenile lamprey and salmonids are presented below.

3.2.1 Juvenile Lamprey

Based on data from the Smolt Monitoring Program, the estimated number of juvenile lamprey passing McNary Dam during 2001 was low (37,570) compared to the 1994 to 2000 average of 110,00 (Figure 9). The run was also slightly late compared to the 1994 to 2001 average (Figure 10) (DART 2001). Detailed historical data are presented in Appendix B.

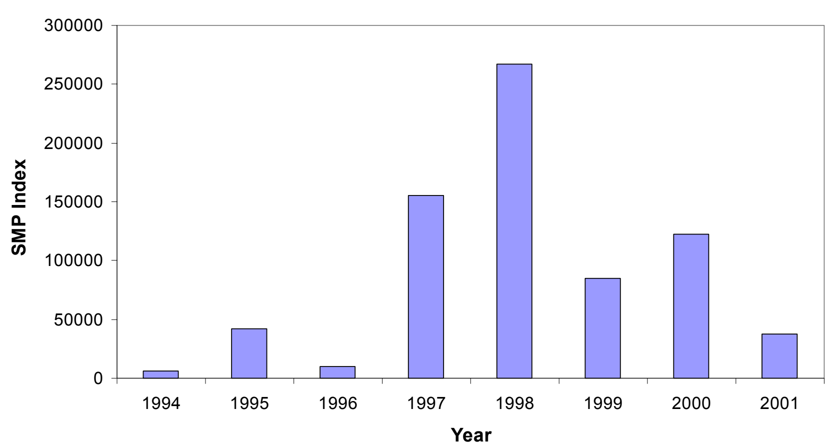

Figure 9. Historical run size for juvenile lamprey from 1994 to 2001 (through Oct 25 for each year) for comparison.

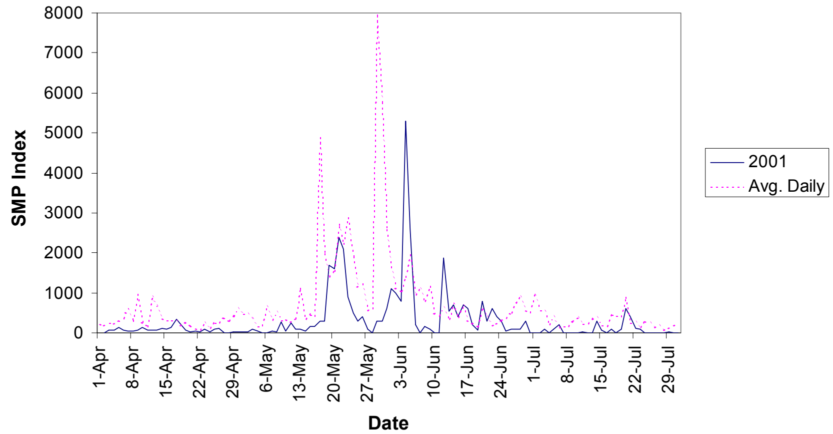

Figure 10. Juvenile lamprey run timing in 2001 with the 1994-2001 daily average shown.

3.2.2 Juvenile Salmonids

The *in situ* observation data collection occurred during the transition of the chinook salmon run from yearling to sub-yearling smolts (Figure 11). For the first half of the study period, the run consisted primarily of yearling chinook, but sub-yearlings became predominant during the second half (DART 2001). Species composition was 1-age chinook salmon (63%), 0-age chinook salmon (14%), sockeye (13%), steelhead (6%), and coho (4%).

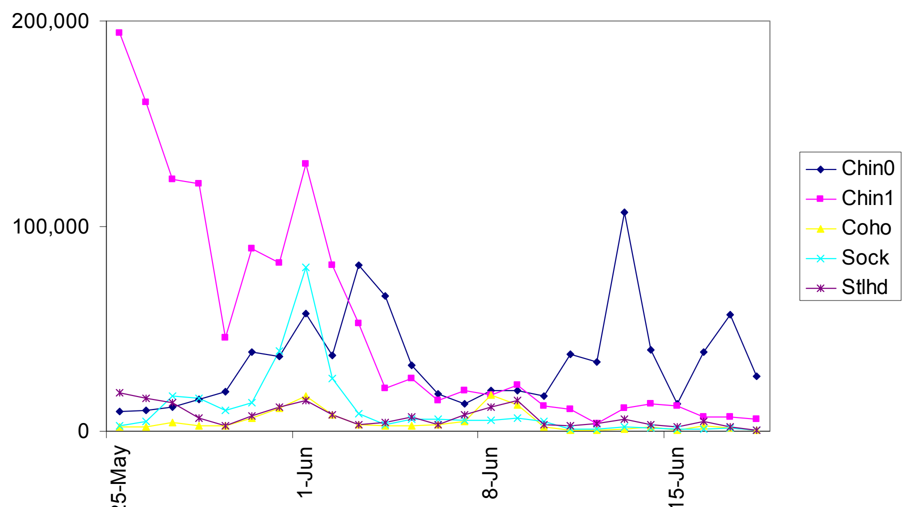

Figure 11. Salmonid species composition and run timing during the study period.

3.3 Optical Camera Observations

During the 42 hours of video recording, we observed 12 lamprey, 58 smolts, and 3 unidentifiable fish. The majority of smolt observations occurred between 2000 and 2300 h and were characterized by fish having periodic contact with the screen with their tails while actively swimming up or away from the screen. Lamprey sightings were dispersed throughout most of the recording period. Water clarity was good during the study, which contributed to adequate conditions for video observation. Turbidity at the dam varied between 4.2 and 4.8 secchi disk ft.

We sampled at the peak passage hours for lamprey and salmonids (Figure 12). Lamprey passage peaked at 2300 h while salmonid passage peaked slightly earlier at 2200 h. Of the observed lamprey, seven were detected on the north up-looking camera, two on the north down-looking camera, and three on the south down-looking camera. Since the south up-looking camera was non-functional, there was nothing to suggest that one side of the screen saw more lamprey than the other. The same was true for camera detections of the juvenile salmonids (Table 2).

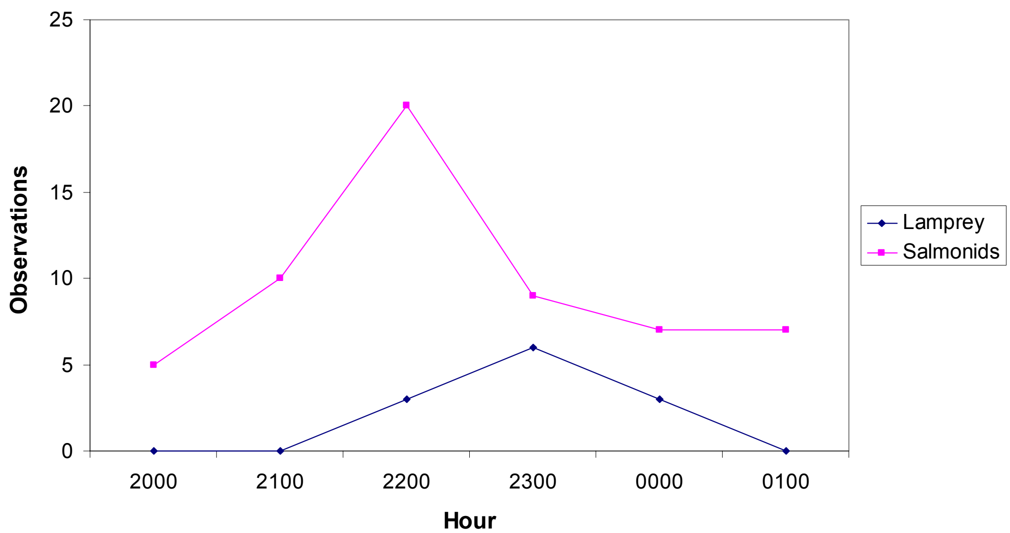

Figure 12. Total number of observations for all species (hour 2000 is the time from 2000 to 2059).

Table 2. Lateral camera detection comparison based on the down-looking cameras. Since the south up-looking camera malfunctioned, the up-looking cameras were not included in this comparison.

	North Cameras	South Cameras
Juvenile Lamprey	2	3
Juvenile Salmonid	12	11
Combined	14	14

3.3.1 Juvenile Lamprey

We observed 12 juvenile lamprey contacting the screen face. These observations included several fish at various stages of impingement and those wedged into the 1/8" (3.175 mm) bar screen openings. Seven of the lamprey were seen impinged but still moving when the bar was parked at the bottom of the screen. In one instance, approximately 10 ft from the bottom of the screen, a lamprey became stuck to the point where only its mouthparts were visible above the screen face (Figure 13). It slid back and forth in the slot between the horizontal support bars. This stuck lamprey was not observed again after the brush bar moved over the area where it was located.

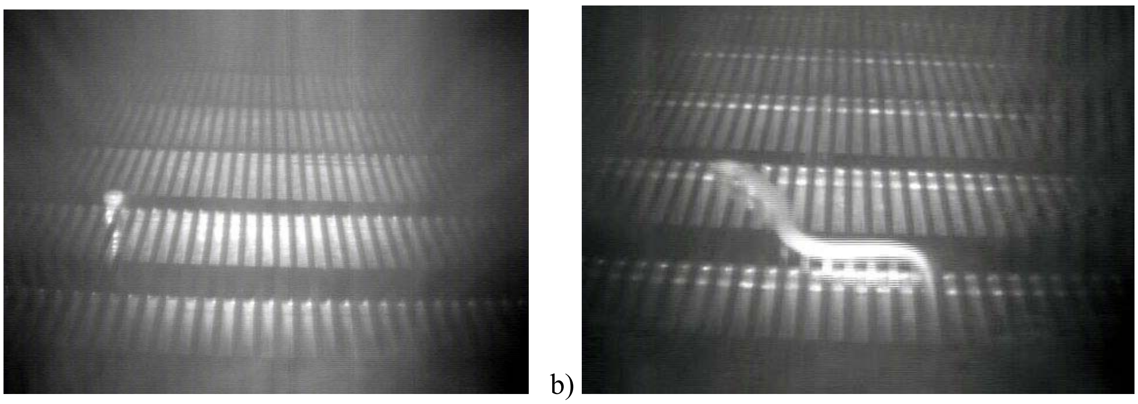
a) b)

Figure 13. a) Juvenile lamprey that has become stuck within the bar screen. b) Juvenile lamprey that is impinged, but actively swimming on the screen face.

3.3.2 Juvenile Salmonids

In addition to lamprey, we documented 58 juvenile fish (presumed to be salmonids) actively swimming against the flow and in some instances contacting or becoming impinged on the screen face. Some of the fish became temporarily impinged and were later able to free themselves from the screen face, while others were immobile on the screen with only the limited movement of the operculum visible. The body lengths of the three juvenile salmon that were temporarily impinged on the screen were estimated to be 40, 160, and 60 mm (Figure 14).

a) b)

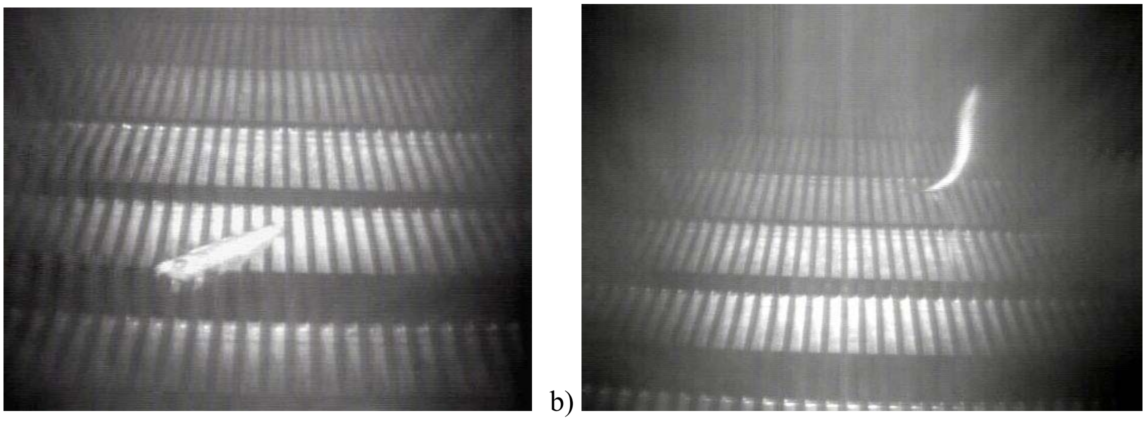

Figure 14. a) Salmonid sub-yearling that is impinged. b) Smolt swimming above the screen.

3.4 PIT Tagging

Results of the PIT tagging survival comparison and detector performance tests are provided below followed by descriptions of PIT tag detection rates and lamprey travel times.

3.4.1 PIT Tagging Survival and Retention

We found little difference in cumulative mortality rates between tagged and control groups; however, the cumulative mortality of both the tagged and untagged groups increased dramatically when held in ambient river water (Figure 15). Mortality for the lamprey held in chilled well water was 2% over the entire 40-day period. Over the same period 2.6% of the lamprey shed their PIT tags.

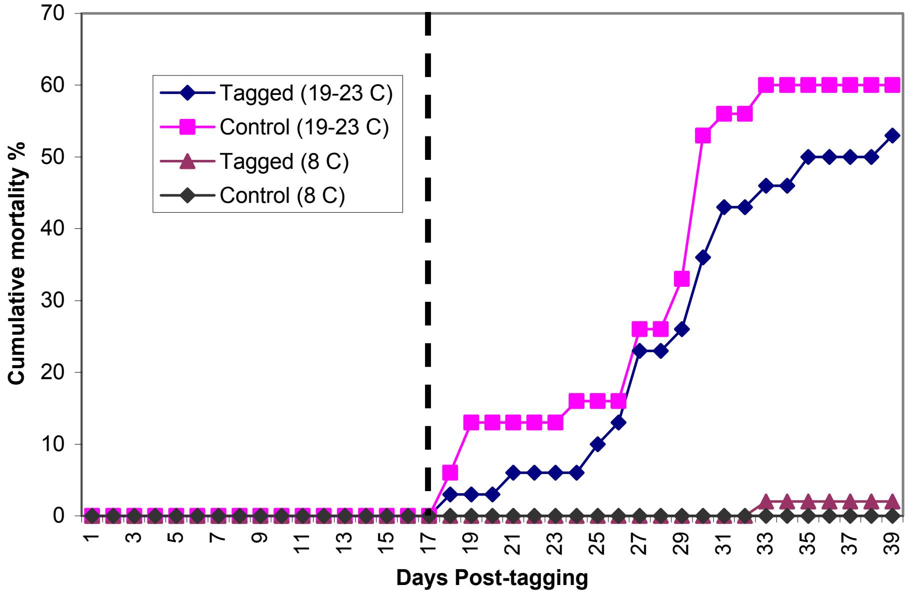

Figure 15. Post-tagging mortality for juvenile lamprey (120-155 mm). The tagged and untagged groups were split into ambient river water and chilled well water groups on Day 17.

Following the 40-day mortality test, the incision from the tagging procedure was completely healed and there were no signs of infection. Approximately 45 days after the procedure, we dissected several lamprey to determine whether any obvious abnormalities were apparent within the body cavity where the PIT tag was located. There was a small amount of scar tissue surrounding the tag, but no other signs of disease or hemorrhaging were observed (Figure 16).

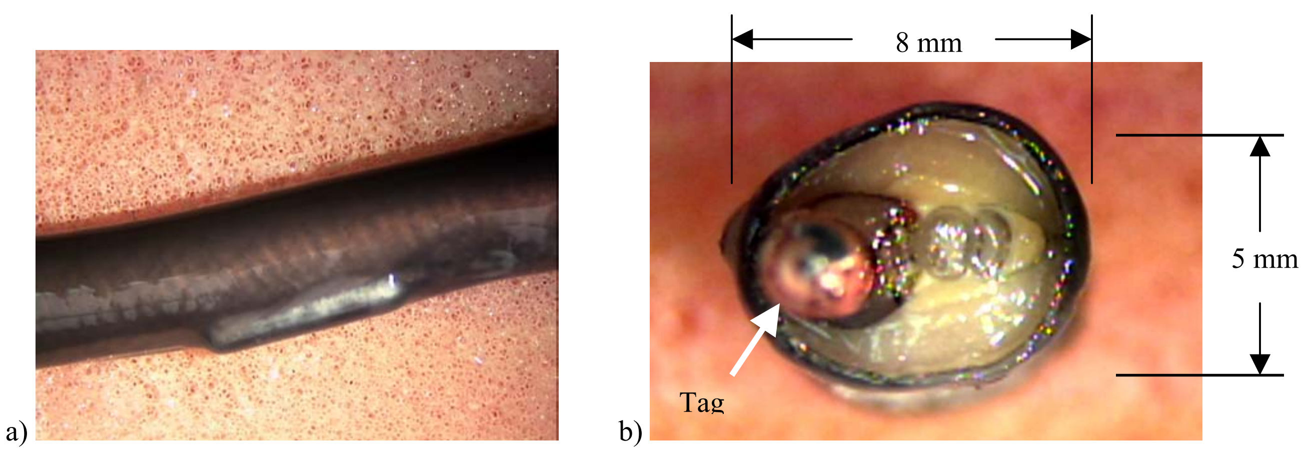

Figure 16. a) Tag under the skin, with the healed tag insertion wound anterior (right) of the tag itself, b) Cross section of a 160-mm-long lamprey showing the PIT tag location in relation to body cavity size

3.4.2 Detector Performance

Interrogation of the first release groups just above the first set of primary coils of the McNary Dam smolt monitoring facility showed an average detection efficiency of 97% for both A and B Separator coils (Table 3). Average performance for smolt detection overall at McNary Dam was 97.83% according to the 2000 Final System Tests and Performance Analysis, with an average A-Separator efficiency of 97.12% and an average B-Separator efficiency of 98.18% (Rowan and Carter 2000).

Table 3. PIT tag single detector counts at the primary coils.

Date	Number Released at Flume A	Number Released at Flume B	Percent Detected at A-Separator	Percent Detected at B-Separator
April 27	33	30	98.2%	95.7%
May 8	23	17	100%	100%

3.4.3 McNary Dam PIT Tag Detection Rates

Juvenile lamprey (115-178 mm) were PIT tagged and released in groups of 30 to 50 at various locations within and in front of McNary Dam. Detection percentage varied among release groups, with the most obvious differences evident among release sites (Table 4). Detection rates at the gatewell and collection channel were similar, ranging from 44 to 91% and 49 to 94%, respectively. The detection rates from the forebay releases were lower, ranging from 0 to 38%. Appendix A contains the raw PIT tag data.

In the case of forebay releases, percent detections appeared to decrease with release depth (Figure 17), but differences were not statistically significant (Chi-square, $p=0.35$). The null hypothesis, that detection efficiencies do not differ among release depths for the forebay release site, could not be refuted and forebay releases were pooled across release depth for further analysis of percent detections.

The lowest proportion of lamprey detected was from the forebay release site, while the gatewell release site produced the highest percentage of detections (Figure 18). Only 21.6% of forebay lamprey were detected at the primary separator coils A and B, while 72% of gatewell and 66.9% of collection channel lamprey were detected. Percent detection was statistically different (Chi-square, $p<0.001$) among release sites.

Table 4. Number, location, and detection rate of PIT-tagged lamprey released at the forebay, gatewell, and collection channel.

Location	Date	Depth (ft)	Number Released	Percent Detected
Forebay	26-May	15	31	0%
Forebay	26-May	15	30	10%
Forebay	11-Jun	10	40	13%
Forebay	11-Jun	Surface	40	30%
Forebay	11-Jun	30	40	18%
Forebay	18-Jun	5	45	31%
Forebay	18-Jun	10	46	24%
Forebay	18-Jun	15	45	38%
Gatewell	26-May	Surface	33	91%
Gatewell	26-May	Surface	30	67%
Gatewell	11-Jun	Surface	35	44%
Gatewell	18-Jun	Surface	47	82%
Collection	26-May	Surface	33	82%
Collection	26-May	Surface	31	94%
Collection	11-Jun	Surface	47	49%
Collection	18-Jun	Surface	46	57%

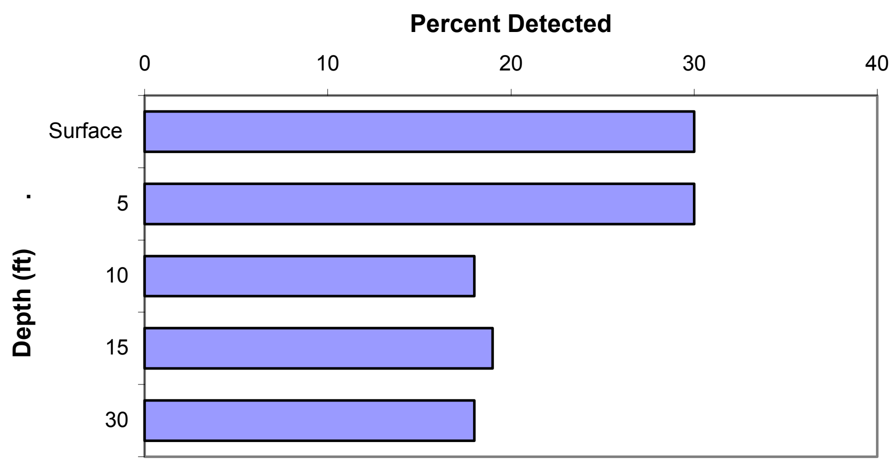

Figure 17. Percent of lamprey detected at the primary coils for forebay release groups in relation to water depth.

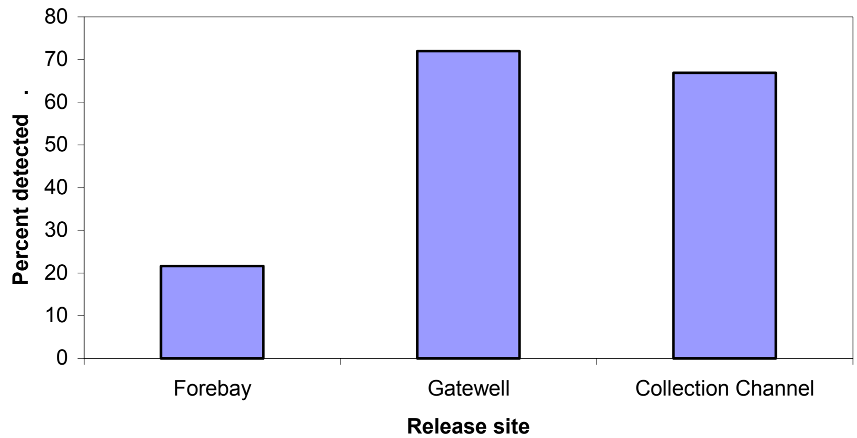

Figure 18. Percent of lamprey detected at the primary coils for each release site.

3.4.4 Travel Times in the McNary Dam Juvenile Bypass System

Mean log travel times did not differ among forebay release depths (ANOVA, p=0.62). The null hypothesis, that travel times do not differ among release depths for the forebay release site, could not be refuted and forebay releases were pooled for comparison of travel times among release sites. Geometric mean travel times were: forebay (492 min), gatewell (323 min), and collection channel (245 min). Because of the high variability among individuals, mean log travel times did not differ significantly (ANOVA, p=0.32) among release sites. The result does not refute the null hypothesis that travel times to the first PIT tag detector do not differ among release sites. Travel times were further compared among groups with the Newman-Keuls multiple comparison procedure (Table 5). Log travel times did not differ among release sites, and the null hypothesis, that travel times do not differ between any two groups, was not refuted.

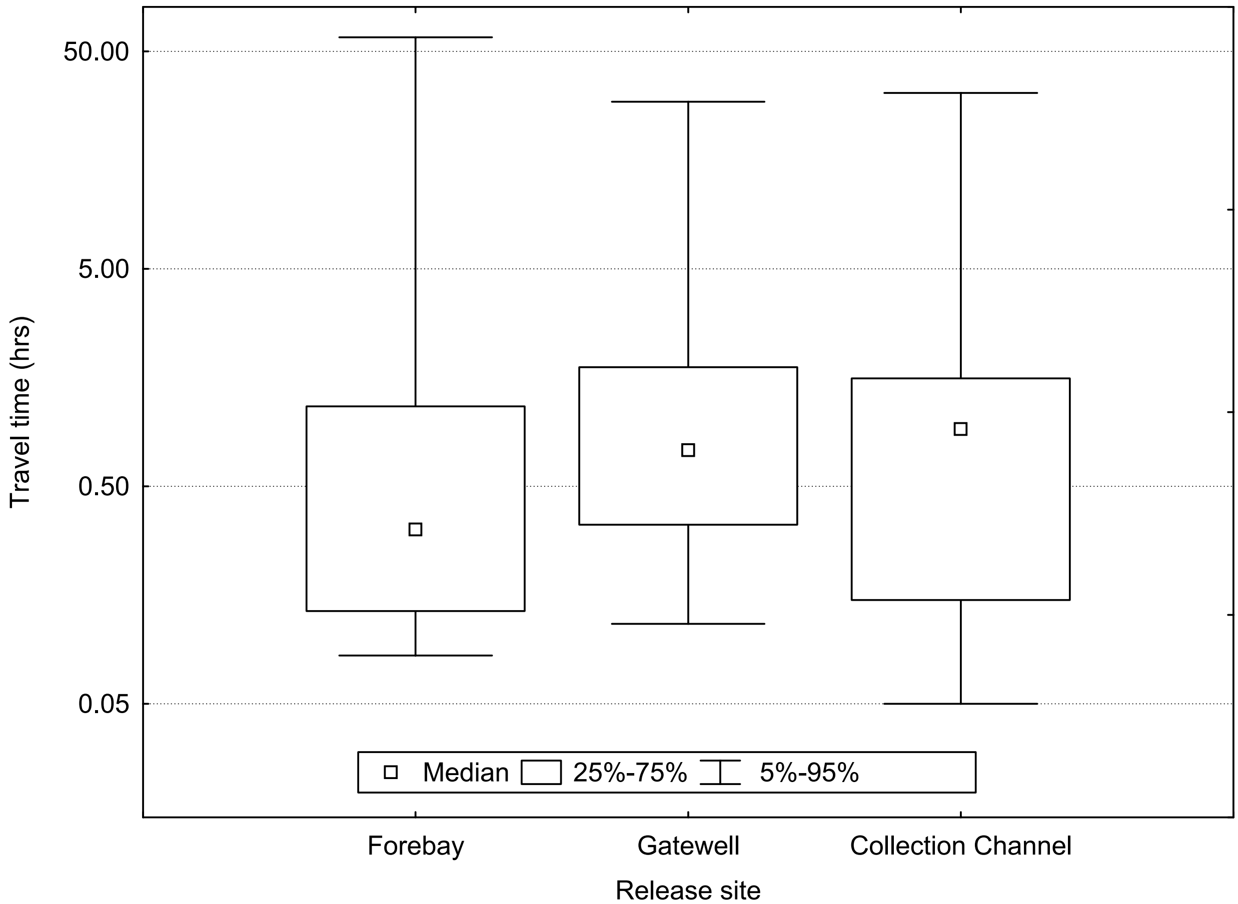

Figure 19. Median travel times for lamprey released in the forebay, gatewell, and collection channel to travel to the primary detectors at the juvenile facility.

Table 5. Median travel time for each site and Newman-Keuls test p-values (*italics*) for pairwise comparisons among release sites.

	Forebay	**Gatewell**	**Collection Channel**
Median travel time (hrs)	8.19	5.40	4.08
Forebay		*0.21*	*0.30*
Gatewell			*0.83*

The majority (>75%) of lamprey detected at the smolt monitoring facility reached a detector within the first 2 hours post release (Figure 20). Total percent detections differed among release sites (Figure 18), but over 90% of fish detected from each release site arrived within 24 hours. Travel times of up to 256 hours were recorded, but less than 3% of individuals exceeded 60 hours travel time for any release site.

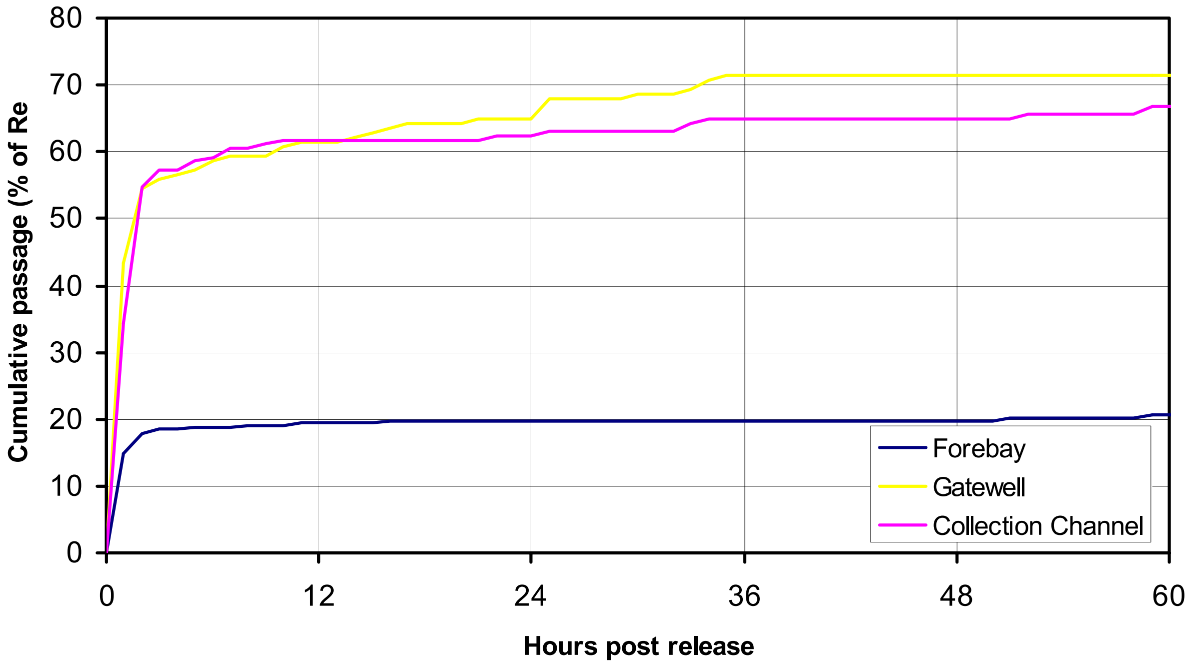

Figure 20. Cumulative detection through time as a percentage of release numbers.

3.4.5 Travel Times through the Smolt Monitoring Facility

The juvenile lamprey we released took various routes through the smolt monitoring facility, some of which incurred variable amounts of holding time. For instance, some were diverted into the sample room and held, and others were directed into a holding raceway. Because of these variations in holding by route, travel time through the entire facility could not be compared among groups. Instead, we analyzed sections of straight flume between PIT tag detectors that comprised the overall route. Also since the A-side and B-side flumes differed in length (Figure 5), each was analyzed separately.

The majority of fish traveled the Separator to Diversion section (Figure 21). Within this relatively short section, lamprey and smolt behaved differently, with smolts actually having a longer travel time. Sample sizes for the remaining travel times were lower but show a trend of increasing as the distance between coils increases. The data from these other routes show travel time distributions where lamprey held within the flume section for extended periods.

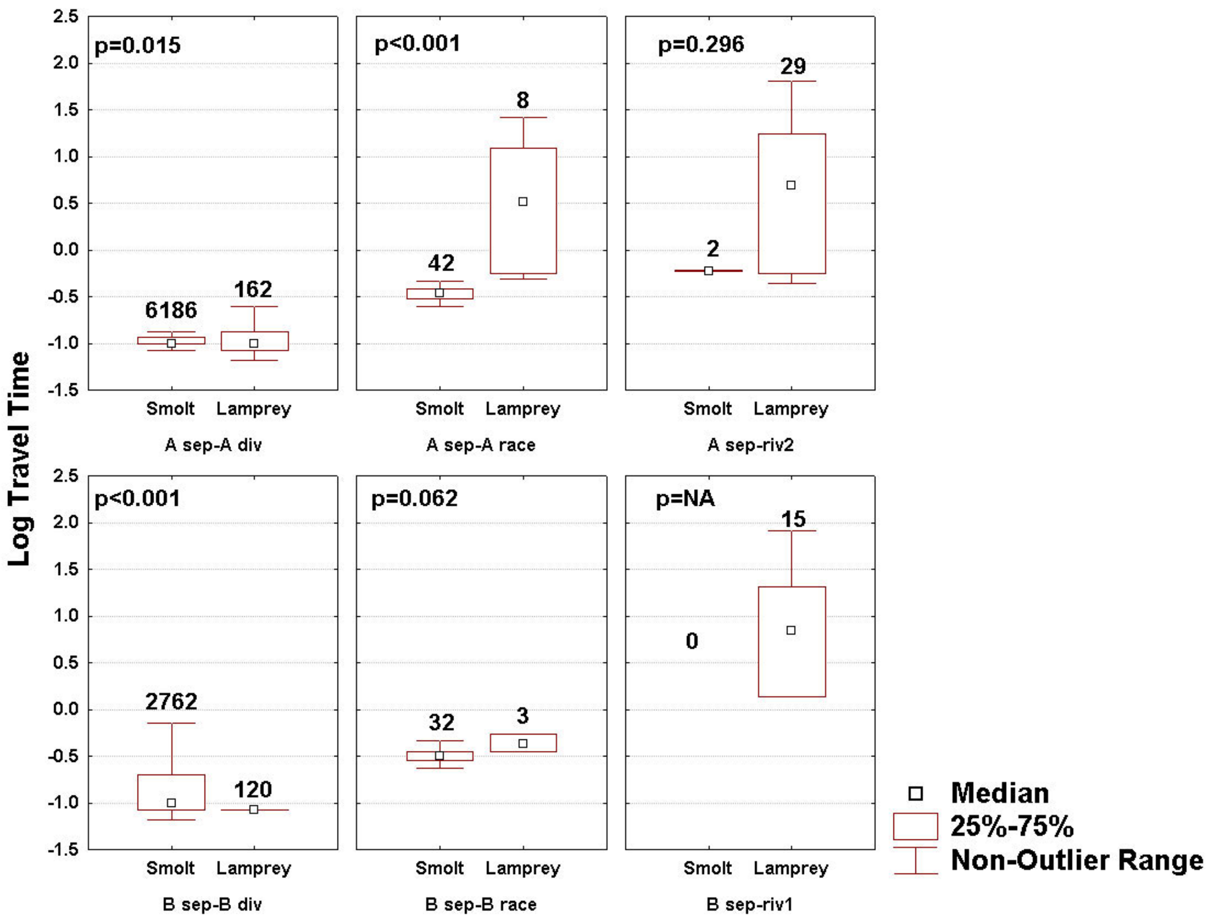

Figure 21. Distribution of travel times through the McNary Dam smolt monitoring facility. P-value results from Mann-Whitney tests are shown, as are sample sizes of each group. Smolts were fall chinook salmon.

3.4.6 Travel Times from McNary Dam to John Day Dam

Five juvenile lamprey were detected at John Day Dam at intervals ranging from 10 to 28 days from the release date. There were no detections recorded at the Bonneville Dam detectors. The travel times of the five lamprey between McNary Dam and John Day Dam did not differ significantly (t-test of independent samples, $p=0.60$) from travel times for fall chinook salmon ($n=2240$) passing McNary in the same general time period (DART 2001). The results do not refute the null hypothesis that travel times from McNary Dam to John Day Dam do not differ between lamprey and fall chinook salmon. The power of the test to detect differences, however, was limited because of the low sample size for the lamprey.

4.0 Discussion

Discussions of the video observations and PIT tagging survival, detection, and travel times are discussed below.

4.1 Direct Observations

As in the 2000 study at McNary Dam, we were able to use video cameras mounted to the brush bar of an ESBS to document the behavior of migrating juvenile lamprey when they came in contact with the screen. Although only a small number of lamprey were actually observed, the fact that one lamprey was observed stuck in the screen up to its head, unable to free itself, validated laboratory tests conducted in 2000 (Moursund et al. 2001). None of the lamprey observed were able, or necessarily attempted to, swim against the flows encountered on the screen face. Juvenile lamprey have not exhibited any obvious rheotactic response to barriers in the field or in the laboratory under flows likely to be encountered near the screen.

A stuck lamprey was observed near the center portion of the screen, approximately 10 ft from the bottom. Based on field measurements at the prototype ESBS at John Day Dam, the velocity in this region is about 3 ft/s with flows perpendicular to the bar screen (Weiland and Escher 2001). While this is the nadir of the overall velocity magnitude, this part of the screen has no sweeping velocity. In contrast, sweeping velocities, longitudinal to the screen, can reach 8 ft/s at the top. It is unknown whether this part of the bar screen impinges more lamprey. This particular stuck lamprey was not seen again after the brush bar passed over the area where it was observed.

Laboratory studies conducted by Battelle in 2000 (Moursund et al. 2001) demonstrated that the primary factors causing lamprey to become stuck are a combination of water velocity and time in contact with the screen. These studies also demonstrated that juvenile lamprey were likely to become stuck in 1/8-in. (3.175-mm) bar screen when approach velocities exceed 3 ft/s. If we draw a conceptual model of impingement based on the laboratory data (Figure 22a), it suggests that we observed lamprey *in situ* that are being impinged and occasionally becoming stuck. The sweeping velocities encountered in the intake, which were not possible to replicate in the laboratory, probably push this curve to the right (Figure 22b). The video footage made of lamprey that were impinged but actively swimming across the screen face, similar to behavior observed in 1999 and 2000, supports this conclusion.

A number of juvenile salmonids were also documented by the video cameras. Of the 58 smolts observed, 3 were impinged on the screen and were unable to swim against the velocity present near the screen face. Smolts were either actively swimming to keep from contacting the screen or they were sliding along the screen face. This demonstrated how the brush bar camera deployment may be used to document the *in situ* behavior of any fish species that comes within close proximity of the screen face.

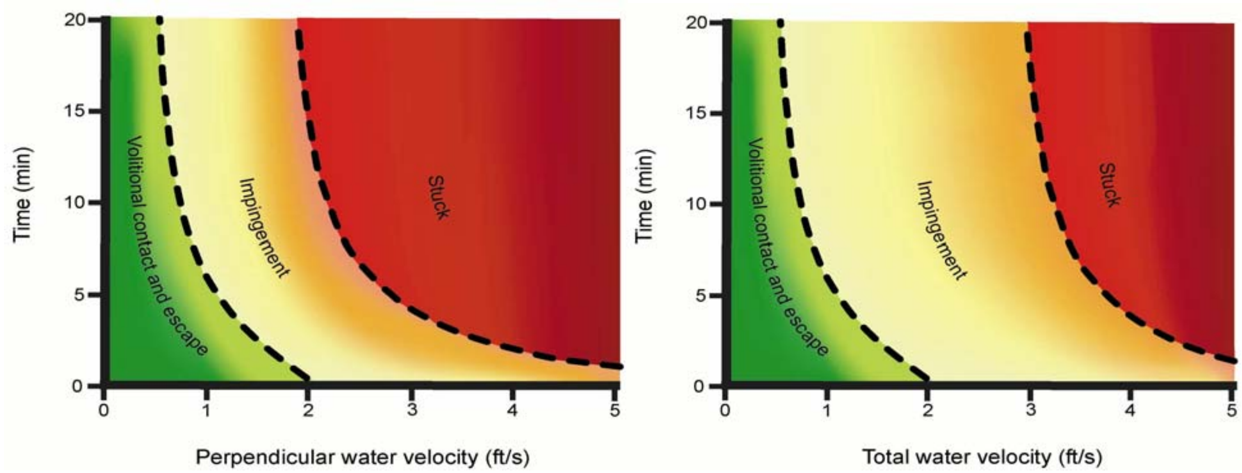

Figure 22. Conceptual diagram summarizing the relationship between lamprey behavior and water velocity on 1/8-in. bar screen with a) flows perpendicular to the screen (left), and b) total water velocity to factor in the influence of sweeping velocities encountered *in situ* (right).

4.2 PIT Tagging

We PIT tagged juvenile lamprey ranging between 115 and 178 mm in length with minimal mortality and tag shedding in the laboratory. We modified the surgical implantation method (Shreck et al. 1999) to one that was less time consuming and had a lower overall mortality rate. The post cumulative mortality for the procedure was 2% after 40 days for fish held in a Living Stream™ tank supplied with 8º C well water.

The detection efficiency for juvenile lamprey was similar to the 97% detection rate for smolts (Rowan and Carter 2000) when released immediately above the detector. There is no evidence that the gatewell or orifice passage presented problems for juvenile lamprey based on the lack of a difference in travel time between the gatewell and collection channel releases. The skewed travel time distribution of juvenile lamprey through the longer sections of flume and their poor swim capacity (Moursund et al. 2000) suggests that they are attaching to the smooth surfaces of the flume with their oral disc. Thus, juvenile lamprey passage times through the juvenile bypass system were different than those of smolts. There was no evidence that travel time through John Day Reservoir was different than that of fall chinook smolts.

The low returns of tagged lamprey from all the powerhouse releases remains unexplained. One explanation is that excessive tag shedding occurred under strenuous field conditions not present in the laboratory. For example, the need for strenuous swimming or physical impacts with surrounding structures may have forced the tags out of their insertion cavities. Another possibility is that lamprey escaped through holes, cracks, or seams in the upper juvenile bypass system. In the laboratory, juvenile lamprey demonstrated an ability to escape through remarkably small openings.

5.0 Conclusions and Recommendations

Collectively, the results of our studies provide the Corps with information that can be used to mitigate any potentially adverse effects of ESBS on juvenile Pacific lamprey. By showing the mechanisms leading to lamprey impingement, steps can be taken to prevent or reduce this phenomenon. Once a solution is implemented, the methods developed here can be used to test their efficacy. This information is generally applicable for all hydroelectric projects that employ intake submerged bar screens or other situations in which bar screens of similar size are used.

Our video observations at McNary Dam have illustrated that lamprey *in situ* behave in a manner similar to that observed in previous laboratory studies. Juvenile lamprey are poor swimmers and cannot swim faster than the water velocities found at the screen face. As a result they experience an almost instantaneous impingment on the screen. Most are able to move along the screen face; however, some become stuck in the 1/8-in. (3.175 mm) spacing between the bars.

This study also demonstrated that juvenile lamprey can be effectively PIT tagged and enumerated, if they are diverted by the turbine intake screens to fish collection facilities. Travel time distributions within the juvenile bypass system were different for lamprey than for fall chinook smolts of the same year, and apparently demonstrate the lamprey's ability to adhere to smooth surfaces present in the system. In addition, the detection of five lamprey at John Day Dam demonstrated that at least some of the tagged population continued their migration downriver.

We recommend that future field studies of ESBS screens deploy the upward facing brush bar cameras. These cameras have the best opportunity to view stuck lamprey as the bar travels up the screen, and because the process of impingement for juvenile lamprey is a function of both time and velocity the brush bar should be operated within normal parameters in order to reflect the typical intake environment. We recommend that the effects of the PIT tagging procedure be quantified by using swim performance measures developed from prior laboratory studies. We also recommend that, if possible, PIT-tagged lamprey be released in conjunction with in-turbine fyke net studies. Examination of the gap net catch could answer whether juvenile lamprey are more susceptible to passage through the screen gap. Also multiple release sites within a juvenile bypass system could localize areas of loss and suggest solutions. Lastly, we recommend that a single suture should be added to the PIT tagging procedure to reduce the possibility of tag expulsion.

6.0 References

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Appendix A

PIT tag Data

For the File_ID field: DW = Collection channel, GT = Gatewell, and FB = Forebay releases.

File_ID	Release_Date	Tag_ID	First_Obs_Date	First_Monitor_Name	Last_Monitor_Name	First_Coil	Travel_Time (min)
DW1	5/26/01 20:40	3D9.1BF111DC37	5/26/01 20:47	A-SEPARATOR GATE	RIVER-2 EXIT	A1	7
DW1	5/26/01 20:40	3D9.1BF1131643	5/26/01 20:50	B-SEPARATOR GATE	RIVER-2 EXIT	B1	10
DW1	5/26/01 20:40	3D9.1BF11313E5	5/26/01 20:43	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW1	5/26/01 20:40	3D9.1BF11E73A2	5/26/01 20:47	B-SEPARATOR GATE	RIVER-2 EXIT	B1	7
DW1	5/26/01 20:40	3D9.1BF111E78C	5/26/01 20:43	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW1	5/26/01 20:40	3D9.1BF11E8739	5/26/01 20:44	B-SEPARATOR GATE	RIVER-2 EXIT	B1	4
DW1	5/26/01 20:40	3D9.1BF112CDA7	5/26/01 20:43	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3
DW1	5/26/01 20:40	3D9.1BF11E924A	5/26/01 21:09	A-SEPARATOR GATE	RIVER-2 EXIT	A1	29
DW1	5/26/01 20:40	3D9.1BF11E77A9	5/26/01 20:43	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW1	5/26/01 20:40	3D9.1BF11E631D	5/26/01 20:49	A-SEPARATOR GATE	RIVER-2 EXIT	A1	9
DW1	5/26/01 20:40	3D9.1BF11E7F4B	5/26/01 20:49	A-SEPARATOR GATE	RIVER-2 EXIT	A1	9
DW1	5/26/01 20:40	3D9.1BF11E8E23	5/26/01 21:23	A-SEPARATOR GATE	RIVER-2 EXIT	A1	43
DW1	5/26/01 20:40	3D9.1BF11244E3	5/28/01 4:54	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1934
DW1	5/26/01 20:40	3D9.1BF11E78EF	5/26/01 22:12	A-SEPARATOR GATE	RIVER-2 EXIT	A1	92
DW1	5/26/01 20:40	3D9.1BF11E6FA2	5/26/01 20:43	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3
DW1	5/26/01 20:40	3D9.1BF111D818	5/26/01 21:19	A-SEPARATOR GATE	RIVER-2 EXIT	A1	39
DW1	5/26/01 20:40	3D9.1BF111E232	5/27/01 17:52	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1272
DW1	5/26/01 20:40	3D9.1BF11E8F77	5/26/01 21:15	A-SEPARATOR GATE	RIVER-2 EXIT	A1	35
DW1	5/26/01 20:40	3D9.1BF11E83E7	5/26/01 20:55	A-SEPARATOR GATE	RIVER-2 EXIT	A1	15
DW1	5/26/01 20:40	3D9.1BF111DD87	5/26/01 20:43	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3
DW1	5/26/01 20:40	3D9.1BF11E8359	5/26/01 21:26	A-SEPARATOR GATE	RIVER-2 EXIT	A1	46
DW1	5/26/01 20:40	3D9.1BF11E7CA3	5/26/01 21:49	B-SEPARATOR GATE	RIVER-2 EXIT	B1	69
DW1	5/26/01 20:40	3D9.1BF11E7986	5/26/01 20:46	B-SEPARATOR GATE	RIVER-2 EXIT	B1	6
DW1	5/26/01 20:40	3D9.1BF111C927	5/26/01 20:43	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3
DW1	5/26/01 20:40	3D9.1BF111CAF2	5/26/01 20:48	B-SEPARATOR GATE	RIVER-2 EXIT	B1	8
DW1	5/26/01 20:40	3D9.1BF111DC37	5/26/01 20:47	A-SEPARATOR GATE	RIVER-2 EXIT	A1	7
DW1	5/26/01 20:40	3D9.1BF111FE48	5/26/01 21:35	A-SEPARATOR GATE	RIVER-2 EXIT	A1	55

DW2	5/26/01 22:19	3D9.1BF11E7FDE	5/28/01 7:04	B-SEPARATOR GATE	RIVER-1 EXIT	B1	2025
DW2	5/26/01 22:19	3D9.1BF1132E8A	5/26/01 22:37	A-SEPARATOR GATE	RIVER-2 EXIT	A1	78
DW2	5/26/01 22:19	3D9.1BF11E7202	5/26/01 22:49	B-SEPARATOR GATE	RIVER-2 EXIT	B1	90
DW2	5/26/01 22:19	3D9.1BF111E3BC	5/26/01 22:23	A-SEPARATOR GATE	RIVER-2 EXIT	A1	64
DW2	5/26/01 22:19	3D9.1BF111E028	5/26/01 22:29	B-SEPARATOR GATE	RIVER-2 EXIT	B1	70
DW2	5/26/01 22:19	3D9.1BF11E5F88	5/26/01 22:59	A-SEPARATOR GATE	RIVER-2 EXIT	A1	100
DW2	5/26/01 22:19	3D9.1BF1132923	5/26/01 23:17	A-SEPARATOR GATE	RIVER-2 EXIT	A1	118
DW2	5/26/01 22:19	3D9.1BF111DCCB	5/26/01 22:52	A-SEPARATOR GATE	RIVER-2 EXIT	A1	93
DW2	5/26/01 22:19	3D9.1BF11E82C2	5/26/01 23:00	B-SEPARATOR GATE	RIVER-2 EXIT	B1	101
DW2	5/26/01 22:19	3D9.1BF1124B7F	5/27/01 22:13	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1494
DW2	5/26/01 22:19	3D9.1BF1124660	5/26/01 22:30	A-SEPARATOR GATE	RIVER-2 EXIT	A1	71
DW2	5/26/01 22:19	3D9.1BF111E137	5/26/01 22:50	A-SEPARATOR GATE	RIVER-2 EXIT	A1	91
DW2	5/26/01 22:19	3D9.1BF11E8F04	5/28/01 6:11	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1972
DW2	5/26/01 22:19	3D9.1BF111D4AB	5/26/01 23:59	A-SEPARATOR GATE	RIVER-2 EXIT	A1	160
DW2	5/26/01 22:19	3D9.1BF111F9E1	5/29/01 7:28	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3489
DW2	5/26/01 22:19	3D9.1BF112A503	5/26/01 22:37	B-SEPARATOR GATE	RIVER-2 EXIT	B1	78
DW2	5/26/01 22:19	3D9.1BF1129074	5/26/01 22:45	B-SEPARATOR GATE	RIVER-2 EXIT	B1	86
DW2	5/26/01 22:19	3D9.1BF11E805B	5/26/01 22:38	A-SEPARATOR GATE	RIVER-2 EXIT	A1	79
DW2	5/26/01 22:19	3D9.1BF11E7729	5/26/01 22:23	B-SEPARATOR GATE	RIVER-2 EXIT	B1	64
DW2	5/26/01 22:19	3D9.1BF11E734A	5/26/01 2:05	B-SEPARATOR GATE	RIVER-2 EXIT	B1	286
DW2	5/26/01 22:19	3D9.1BF1123740	5/26/01 22:30	A-SEPARATOR GATE	RIVER-2 EXIT	A2	71
DW2	5/26/01 22:19	3D9.1BF1133116	5/26/01 23:09	A-SEPARATOR GATE	RIVER-2 EXIT	A1	110
DW2	5/26/01 22:19	3D9.1BF111D952	5/26/01 23:08	A-SEPARATOR GATE	RIVER-2 EXIT	A1	109
DW2	5/26/01 22:19	3D9.1BF11E8080	5/26/01 22:34	A-SEPARATOR GATE	RIVER-2 EXIT	A2	75
DW2	5/26/01 22:19	3D9.1BF111D129	5/26/01 22:37	A-SEPARATOR GATE	RIVER-2 EXIT	A1	78
DW2	5/26/01 22:19	3D9.1BF112317E	5/26/01 23:03	A-SEPARATOR GATE	RIVER-2 EXIT	A1	104
DW2	5/26/01 22:19	3D9.1BF1132C29	5/27/01 3:37	A-SEPARATOR GATE	RIVER-2 EXIT	A1	378
DW2	5/26/01 22:19	3D9.1BF1132C1E	5/27/01 2:26	A-SEPARATOR GATE	RIVER-2 EXIT	A1	307
DW2	5/26/01 22:19	3D9.1BF11329D9	5/26/01 22:23	A-SEPARATOR GATE	RIVER-2 EXIT	A2	64
DW3	6/11/01 22:25	3D9.1BF11200F3	6/11/01 22:33	A-SEPARATOR GATE	RIVER-2 EXIT	A1	8
DW3	6/11/01 22:25	3D9.1BF111D8A2	6/11/01 22:28	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW3	6/11/01 22:25	3D9.1BF1122466	6/11/01 22:28	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW3	6/11/01 22:25	3D9.1BF1131A67	6/11/01 22:29	B-SEPARATOR GATE	RIVER-2 EXIT	B1	4
DW3	6/11/01 22:25	3D9.1BF1126078	6/11/01 22:46	B-SEPARATOR GATE	RIVER-2 EXIT	B1	21
DW3	6/11/01 22:25	3D9.1BF111E1FA	6/11/01 22:28	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW3	6/11/01 22:25	3D9.1BF1125845	6/11/01 22:52	A-SEPARATOR GATE	RIVER-2 EXIT	A1	27
DW3	6/11/01 22:25	3D9.1BF11E7F8B	6/11/01 22:46	B-SEPARATOR GATE	RIVER-2 EXIT	B1	21
DW3	6/11/01 22:25	3D9.1BF1132BB5	6/11/01 23:05	A-SEPARATOR GATE	RIVER-2 EXIT	A1	40
DW3	6/11/01 22:25	3D9.1BF1122219	6/11/01 23:46	A-SEPARATOR GATE	RIVER-2 EXIT	A1	81

DW3	6/11/01 22:25	3D9.1BF11E6204	6/11/01 23:35	A-SEPARATOR GATE	RIVER-2 EXIT	A1	70
DW3	6/11/01 22:25	3D9.1BF1125122	6/11/01 23:33	A-SEPARATOR GATE	RIVER-2 EXIT	A1	68
DW3	6/11/01 22:25	3D9.1BF111F76D	6/11/01 23:00	A-SEPARATOR GATE	RIVER-2 EXIT	A1	35
DW3	6/11/01 22:25	3D9.1BF1132280	6/11/01 22:46	B-SEPARATOR GATE	RIVER-2 EXIT	B2	21
DW3	6/11/01 22:25	3D9.1BF1125C1B	6/11/01 22:54	B-SEPARATOR GATE	RIVER-2 EXIT	B1	29
DW3	6/11/01 22:25	3D9.1BF11E7FB6	6/11/01 22:28	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW3	6/11/01 22:25	3D9.1BF11E7A06	6/11/01 22:37	B-SEPARATOR GATE	RIVER-2 EXIT	B1	12
DW3	6/11/01 22:25	3D9.1BF111FD59	6/11/01 22:28	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW3	6/11/01 22:25	3D9.1BF112259E	6/11/01 22:49	A-SEPARATOR GATE	RIVER-2 EXIT	A1	24
DW3	6/11/01 22:25	3D9.1BF11E6F1C	6/11/01 22:32	B-SEPARATOR GATE	RIVER-2 EXIT	B1	7
DW3	6/11/01 22:25	3D9.1BF111E1E7	6/11/01 22:36	B-SEPARATOR GATE	RIVER-2 EXIT	B1	11
DW3	6/11/01 22:25	3D9.1BF11E63CE	6/11/01 22:28	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW3	6/11/01 22:25	3D9.1BF1122434	6/11/01 22:28	B-SEPARATOR GATE	RIVER-2 EXIT	B1	3
DW4	6/18/01 21:35	3D9.1BF1122221	6/19/01 2:02	A-SEPARATOR GATE	A-RACEWAY	A1	267
DW4	6/18/01 21:35	3D9.1BF1122D1D	6/18/01 21:57	B-SEPARATOR GATE	B-RACEWAY	B1	22
DW4	6/18/01 21:35	3D9.1BF11E2D11	6/19/01 6:33	A-SEPARATOR GATE	SAMPLE ROOM	A1	538
DW4	6/18/01 21:35	3D9.1BF11E7277	6/18/01 22:27	B-SEPARATOR GATE	B-SUBSAMPLE	B1	52
DW4	6/18/01 21:35	3D9.1BF1120307	6/18/01 23:09	B-SEPARATOR GATE	B-SUBSAMPLE	B1	94
DW4	6/18/01 21:35	3D9.1BF11E2E57	6/18/01 23:33	B-SEPARATOR GATE	B-SUBSAMPLE	B1	118
DW4	6/18/01 21:35	3D9.1BF11225B6	6/18/01 21:40	A-SEPARATOR GATE	RIVER-2 EXIT	A1	5
DW4	6/18/01 21:35	3D9.1BF1122650	6/21/01 1:03	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3088
DW4	6/18/01 21:35	3D9.1BF1122BA7	6/18/01 22:57	B-SEPARATOR GATE	RIVER-2 EXIT	B1	82
DW4	6/18/01 21:35	3D9.1BF11200B9	6/19/01 0:16	A-SEPARATOR GATE	RIVER-2 EXIT	A1	161
DW4	6/18/01 21:35	3D9.1BF11E2F73	6/19/01 4:30	A-SEPARATOR GATE	RIVER-2 EXIT	A1	415
DW4	6/18/01 21:35	3D9.1BF1125B8B	6/18/01 21:48	B-SEPARATOR GATE	RIVER-2 EXIT	B1	13
DW4	6/18/01 21:35	3D9.1BF11E8F40	6/18/01 22:32	B-SEPARATOR GATE	RIVER-2 EXIT	B1	57
DW4	6/18/01 21:35	3D9.1BF1121E0B	6/21/01 7:39	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3484
DW4	6/18/01 21:35	3D9.1BF11E8D69	6/19/01 6:55	A-SEPARATOR GATE	RIVER-2 EXIT	A1	560
DW4	6/18/01 21:35	3D9.1BF11E7BE1	6/18/01 22:23	A-SEPARATOR GATE	RIVER-2 EXIT	A1	48
DW4	6/18/01 21:35	3D9.1BF11E721F	6/19/01 0:20	A-SEPARATOR GATE	RIVER-2 EXIT	A1	165
DW4	6/18/01 21:35	3D9.1BF112148D	6/18/01 21:40	B-SEPARATOR GATE	RIVER-2 EXIT	B1	5
DW4	6/18/01 21:35	3D9.1BF11E6CFE	6/18/01 23:50	A-SEPARATOR GATE	RIVER-2 EXIT	A1	135
DW4	6/18/01 21:35	3D9.1BF11E333B	6/18/01 21:54	B-SEPARATOR GATE	RIVER-2 EXIT	B1	19
DW4	6/18/01 21:35	3D9.1BF112256D	6/18/01 23:08	B-SEPARATOR GATE	RIVER-2 EXIT	B1	93
DW4	6/18/01 21:35	3D9.1BF11E2F1A	6/18/01 22:43	B-SEPARATOR GATE	RIVER-2 EXIT	B1	68
DW4	6/18/01 21:35	3D9.1BF111FA53	6/18/01 22:01	B-SEPARATOR GATE	RIVER-2 EXIT	B1	26
DW4	6/18/01 21:35	3D9.1BF1120458	6/18/01 21:54	B-SEPARATOR GATE	RIVER-2 EXIT	B1	19
DW4	6/18/01 21:35	3D9.1BF112238D	6/18/01 21:48	A-SEPARATOR GATE	RIVER-2 EXIT	A1	13
DW4	6/18/01 21:35	3D9.1BF11E2D7D	6/18/01 22:40	B-SEPARATOR GATE	RIVER-2 EXIT	B1	65

FB2	5/26/01 21:40	3D9.1BF11E696E	5/26/01 21:46	B-SEPARATOR GATE	RIVER-2 EXIT	B1	6
FB2	5/26/01 21:40	3D9.1BF111E26D	5/27/01 8:38	A-SEPARATOR GATE	RIVER-2 EXIT	A1	658
FB2	5/26/01 21:40	3D9.1BF112489B	5/26/01 21:59	A-SEPARATOR GATE	RIVER-2 EXIT	A1	19
FB3	6/11/01 21:10	3D9.1BF111E045	6/11/01 21:18	B-SEPARATOR GATE	RIVER-2 EXIT	B1	8
FB3	6/11/01 21:10	3D9.1BF111FEB3	6/11/01 21:20	B-SEPARATOR GATE	RIVER-2 EXIT	B1	10
FB3	6/11/01 21:10	3D9.1BF11E7C54	6/11/01 21:23	B-SEPARATOR GATE	RIVER-2 EXIT	B1	13
FB3	6/11/01 21:10	3D9.1BF111FAB2	6/11/01 21:29	A-SEPARATOR GATE	RIVER-2 EXIT	A1	19
FB3	6/11/01 21:10	3D9.1BF11E5E96	6/11/01 21:21	B-SEPARATOR GATE	RIVER-2 EXIT	B1	11
FB4	6/11/01 21:25	3D9.1BF11E8BC0	6/11/01 21:34	B-SEPARATOR GATE	B-SUBSAMPLE	B1	9
FB4	6/11/01 21:25	3D9.1BF11E8B8A	6/11/01 21:45	B-SEPARATOR GATE	RIVER-2 EXIT	B1	20
FB4	6/11/01 21:25	3D9.1BF111D19D	6/11/01 21:41	B-SEPARATOR GATE	RIVER-2 EXIT	B2	16
FB4	6/11/01 21:25	3D9.1BF1132929	6/11/01 21:35	B-SEPARATOR GATE	RIVER-2 EXIT	B1	10
FB4	6/11/01 21:25	3D9.1BF111DA6A	6/11/01 21:34	A-SEPARATOR GATE	RIVER-2 EXIT	A1	9
FB4	6/11/01 21:25	3D9.1BF11E6932	6/11/01 21:40	B-SEPARATOR GATE	RIVER-2 EXIT	B1	15
FB4	6/11/01 21:25	3D9.1BF1139DCD	6/11/01 21:30	B-SEPARATOR GATE	RIVER-2 EXIT	B1	5
FB4	6/11/01 21:25	3D9.1BF11E9008	6/11/01 21:42	A-SEPARATOR GATE	RIVER-2 EXIT	A1	17
FB4	6/11/01 21:25	3D9.1BF111FC2C	6/11/01 22:35	A-SEPARATOR GATE	RIVER-2 EXIT	A1	70
FB4	6/11/01 21:25	3D9.1BF113331F	6/11/01 21:35	B-SEPARATOR GATE	RIVER-2 EXIT	B1	10
FB4	6/11/01 21:25	3D9.1BF11E8DB0	6/11/01 22:42	B-SEPARATOR GATE	RIVER-2 EXIT	B1	77
FB4	6/11/01 21:25	3D9.1BF11E7D9C	6/11/01 21:31	B-SEPARATOR GATE	RIVER-2 EXIT	B1	6
FB5	6/11/01 21:41	3D9.1BF11E80C5	6/11/01 23:33	A-SEPARATOR GATE	RIVER-2 EXIT	A1	112
FB5	6/11/01 21:41	3D9.1BF111EC7C	6/11/01 21:50	B-SEPARATOR GATE	RIVER-2 EXIT	B1	9
FB5	6/11/01 21:41	3D9.1BF1127FA4	6/11/01 22:09	B-SEPARATOR GATE	RIVER-2 EXIT	B1	28
FB5	6/11/01 21:41	3D9.1BF11E83C5	6/11/01 22:32	A-SEPARATOR GATE	RIVER-2 EXIT	A1	51
FB5	6/11/01 21:41	3D9.1BF11E895D	6/11/01 22:45	A-SEPARATOR GATE	RIVER-2 EXIT	A1	64
FB5	6/11/01 21:41	3D9.1BF111D8E1	6/11/01 22:33	A-SEPARATOR GATE	RIVER-2 EXIT	A1	52
FB5	6/11/01 21:41	3D9.1BF111E158	6/11/01 23:11	A-SEPARATOR GATE	RIVER-2 EXIT	A1	90
FB6	6/18/01 20:29	3D9.1BF1121F4C	6/18/01 21:39	B-SEPARATOR GATE	B-SUBSAMPLE	B1	70
FB6	6/18/01 20:29	3D9.1BF11217DD	6/21/01 7:04	A-SEPARATOR GATE	RIVER-1 EXIT	A1	3515
FB6	6/18/01 20:29	3D9.1BF11E7573	6/18/01 20:34	A-SEPARATOR GATE	RIVER-2 EXIT	A1	5
FB6	6/18/01 20:29	3D9.1BF11E65A1	6/18/01 20:35	A-SEPARATOR GATE	RIVER-2 EXIT	A1	6
FB6	6/18/01 20:29	3D9.1BF112016C	6/18/01 20:49	B-SEPARATOR GATE	RIVER-2 EXIT	B1	20
FB6	6/18/01 20:29	3D9.1BF111ED99	6/18/01 20:35	B-SEPARATOR GATE	RIVER-2 EXIT	B1	6
FB6	6/18/01 20:29	3D9.1BF111F765	6/20/01 22:40	A-SEPARATOR GATE	RIVER-2 EXIT	A1	3011
FB6	6/18/01 20:29	3D9.1BF11E7860	6/18/01 22:33	A-SEPARATOR GATE	RIVER-2 EXIT	A1	124
FB6	6/18/01 20:29	3D9.1BF111F961	6/18/01 21:07	B-SEPARATOR GATE	RIVER-2 EXIT	B1	38
FB6	6/18/01 20:29	3D9.1BF11216A6	6/18/01 20:49	A-SEPARATOR GATE	RIVER-2 EXIT	A1	20
FB6	6/18/01 20:29	3D9.1BF11E5E26	6/18/01 20:37	B-SEPARATOR GATE	RIVER-2 EXIT	B1	8
FB6	6/18/01 20:29	3D9.1BF1121FEA	6/29/01 12:13	A-SEPARATOR GATE	RIVER-2 EXIT	A1	15344

FB6	6/18/01 20:29	3D9.1BF111FEC5	6/18/01 20:42	B-SEPARATOR GATE	RIVER-2 EXIT	B1	13
FB6	6/18/01 20:29	3D9.1BF1121F5C	6/18/01 20:40	B-SEPARATOR GATE	RIVER-2 EXIT	B1	11
FB7	6/18/01 20:44	3D9.1BF11E78D6	6/21/01 22:46	A-SEPARATOR GATE	A-RACEWAY	A1	4442
FB7	6/18/01 20:44	3D9.1BF11E825D	6/18/01 20:51	A-SEPARATOR GATE	SAMPLE ROOM	A1	7
FB7	6/18/01 20:44	3D9.1BF11E7C60	6/18/01 20:52	A-SEPARATOR GATE	SAMPLE ROOM	A1	8
FB7	6/18/01 20:44	3D9.1BF11E8299	6/18/01 20:51	B-SEPARATOR GATE	B-SUBSAMPLE	B1	7
FB7	6/18/01 20:44	3D9.1BF11E8D65	6/18/01 21:23	A-SEPARATOR GATE	RIVER-2 EXIT	A1	39
FB7	6/18/01 20:44	3D9.1BF11E7E14	6/18/01 21:47	A-SEPARATOR GATE	RIVER-2 EXIT	A1	63
FB7	6/18/01 20:44	3D9.1BF1122732	6/18/01 20:50	A-SEPARATOR GATE	RIVER-2 EXIT	A1	6
FB7	6/18/01 20:44	3D9.1BF11E7D3C	6/18/01 23:20	B-SEPARATOR GATE	RIVER-2 EXIT	B1	156
FB7	6/18/01 20:44	3D9.1BF11201C1	6/18/01 20:49	A-SEPARATOR GATE	RIVER-2 EXIT	A1	5
FB7	6/18/01 20:44	3D9.1BF1121B93	6/18/01 20:53	B-SEPARATOR GATE	RIVER-2 EXIT	B1	9
FB7	6/18/01 20:44	3D9.1BF11E81EF	6/18/01 20:52	A-SEPARATOR GATE	RIVER-2 EXIT	A1	8
FB8	6/18/01 20:58	3D9.1BF11227CF	6/21/01 7:02	B-SEPARATOR GATE	B-RACEWAY	B1	3484
FB8	6/18/01 20:58	3D9.1BF1121F03	6/18/01 21:10	A-SEPARATOR GATE	SAMPLE ROOM	A1	12
FB8	6/18/01 20:58	3D9.1BF11225D2	6/18/01 21:03	A-SEPARATOR GATE	SAMPLE ROOM	A1	5
FB8	6/18/01 20:58	3D9.1BF1120020	6/18/01 21:02	B-SEPARATOR GATE	SAMPLE ROOM	B1	4
FB8	6/18/01 20:58	3D9.1BF11E7569	6/18/01 21:22	A-SEPARATOR GATE	SAMPLE ROOM	A1	24
FB8	6/18/01 20:58	3D9.1BF11E6A39	6/18/01 21:46	A-SEPARATOR GATE	SAMPLE ROOM	A1	48
FB8	6/18/01 20:58	3D9.1BF1122C61	6/18/01 21:17	B-SEPARATOR GATE	RIVER-2 EXIT	B1	19
FB8	6/18/01 20:58	3D9.1BF111F61D	6/18/01 21:05	A-SEPARATOR GATE	RIVER-2 EXIT	A1	7
FB8	6/18/01 20:58	3D9.1BF11E63F7	6/19/01 1:42	B-SEPARATOR GATE	RIVER-2 EXIT	B1	284
FB8	6/18/01 20:58	3D9.1BF11E2F09	6/18/01 21:37	A-SEPARATOR GATE	RIVER-2 EXIT	A1	39
FB8	6/18/01 20:58	3D9.1BF111FD08	6/19/01 4:19	A-SEPARATOR GATE	RIVER-2 EXIT	A1	441
FB8	6/18/01 20:58	3D9.1BF111FBF2	6/18/01 22:06	B-SEPARATOR GATE	RIVER-2 EXIT	B1	68
FB8	6/18/01 20:58	3D9.1BF111FE15	6/18/01 21:08	A-SEPARATOR GATE	RIVER-2 EXIT	A1	10
FB8	6/18/01 20:58	3D9.1BF11E2D80	6/19/01 12:57	A-SEPARATOR GATE	RIVER-2 EXIT	A1	959
FB8	6/18/01 20:58	3D9.1BF111FDE5	6/18/01 22:39	B-SEPARATOR GATE	RIVER-2 EXIT	B1	101
FB8	6/18/01 20:58	3D9.1BF111F979	6/18/01 20:41	A-SEPARATOR GATE	RIVER-2 EXIT	A1	-17
FB8	6/18/01 20:58	3D9.1BF11E874A	6/18/01 22:13	A-SEPARATOR GATE	RIVER-2 EXIT	A1	75
GT1	5/26/01 20:25	3D9.1BF1129078	5/28/01 7:18	A-SEPARATOR GATE	A-RACEWAY	A1	2093
GT1	5/26/01 20:25	3D9.1BF11E682B	5/26/01 21:19	B-SEPARATOR GATE	RIVER-2 EXIT	B1	54
GT1	5/26/01 20:25	3D9.1BF1123B7F	5/26/01 21:17	B-SEPARATOR GATE	RIVER-2 EXIT	B1	52
GT1	5/26/01 20:25	3D9.1BF1127D2A	5/26/01 20:39	A-SEPARATOR GATE	RIVER-2 EXIT	A1	14
GT1	5/26/01 20:25	3D9.1BF11E60DB	5/26/01 21:05	A-SEPARATOR GATE	RIVER-2 EXIT	A1	40
GT1	5/26/01 20:25	3D9.1BF11337AE	5/27/01 16:25	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1200
GT1	5/26/01 20:25	3D9.1BF1132043	5/26/01 22:40	B-SEPARATOR GATE	RIVER-2 EXIT	B1	135
GT1	5/26/01 20:25	3D9.1BF11E9143	5/26/01 20:45	B-SEPARATOR GATE	RIVER-2 EXIT	B3	20
GT1	5/26/01 20:25	3D9.1BF111DA85	5/26/01 21:28	A-SEPARATOR GATE	RIVER-2 EXIT	A1	63

GT1	5/26/01 20:25	3D9.1BF1131ADB	5/26/01 20:38	B-SEPARATOR GATE	RIVER-2 EXIT	B1	13
GT1	5/26/01 20:25	3D9.1BF11E81C5	5/26/01 21:03	A-SEPARATOR GATE	RIVER-2 EXIT	A1	38
GT1	5/26/01 20:25	3D9.1BF11E782E	5/27/01 20:53	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1468
GT1	5/26/01 20:25	3D9.1BF111E39D	5/27/01 13:01	A-SEPARATOR GATE	RIVER-2 EXIT	A1	996
GT1	5/26/01 20:25	3D9.1BF11E6219	5/26/01 20:31	A-SEPARATOR GATE	RIVER-2 EXIT	A1	6
GT1	5/26/01 20:25	3D9.1BF111DFFB	5/26/01 21:08	B-SEPARATOR GATE	RIVER-2 EXIT	B1	43
GT1	5/26/01 20:25	3D9.1BF1131230	5/26/01 20:59	A-SEPARATOR GATE	RIVER-2 EXIT	A1	34
GT1	5/26/01 20:25	3D9.1BF11315AE	5/27/01 20:41	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1456
GT1	5/26/01 20:25	3D9.1BF11E82BA	5/26/01 21:05	B-SEPARATOR GATE	RIVER-2 EXIT	B1	40
GT1	5/26/01 20:25	3D9.1BF11E822D	5/26/01 23:51	B-SEPARATOR GATE	RIVER-2 EXIT	B2	206
GT1	5/26/01 20:25	3D9.1BF11E7D55	5/26/01 21:05	A-SEPARATOR GATE	RIVER-2 EXIT	A1	40
GT1	5/26/01 20:25	3D9.1BF11238B5	5/26/01 20:47	B-SEPARATOR GATE	RIVER-2 EXIT	B1	22
GT1	5/26/01 20:25	3D9.1BF11E7CA6	5/26/01 21:43	A-SEPARATOR GATE	RIVER-2 EXIT	A1	78
GT1	5/26/01 20:25	3D9.1BF11294C6	5/26/01 20:50	B-SEPARATOR GATE	RIVER-2 EXIT	B1	25
GT1	5/26/01 20:25	3D9.1BF1128B80	5/26/01 21:50	A-SEPARATOR GATE	RIVER-2 EXIT	A1	85
GT1	5/26/01 20:25	3D9.1BF11E7270	5/26/01 22:39	A-SEPARATOR GATE	RIVER-2 EXIT	A1	134
GT1	5/26/01 20:25	3D9.1BF1125A4F	5/26/01 22:07	A-SEPARATOR GATE	RIVER-2 EXIT	A1	102
GT1	5/26/01 20:25	3D9.1BF1145806	5/26/01 21:31	A-SEPARATOR GATE	RIVER-2 EXIT	A1	66
GT1	5/26/01 20:25	3D9.1BF111DDAD	5/26/01 21:11	A-SEPARATOR GATE	RIVER-2 EXIT	A1	46
GT1	5/26/01 20:25	3D9.1BF111E19B	5/26/01 20:59	B-SEPARATOR GATE	RIVER-2 EXIT	B2	34
GT1	5/26/01 20:25	3D9.1BF1124B85	5/26/01 20:45	A-SEPARATOR GATE	RIVER-2 EXIT	A1	20
GT2	5/26/01 22:07	3D9.1BF111E0AD	5/28/01 7:17	A-SEPARATOR GATE	A-RACEWAY	A1	1990
GT2	5/26/01 22:07	3D9.1BF11E6325	5/27/01 8:17	B-SEPARATOR GATE	RIVER-1 EXIT	B1	610
GT2	5/26/01 22:07	3D9.1BF1127145	5/27/01 22:40	B-SEPARATOR GATE	RIVER-1 EXIT	B1	1473
GT2	5/26/01 22:07	3D9.1BF11259D7	5/27/01 22:37	B-SEPARATOR GATE	RIVER-1 EXIT	B1	1470
GT2	5/26/01 22:07	3D9.1BF11295A4	5/26/01 22:38	A-SEPARATOR GATE	RIVER-2 EXIT	A1	31
GT2	5/26/01 22:07	3D9.1BF111DAFE	5/26/01 23:10	A-SEPARATOR GATE	RIVER-2 EXIT	A1	63
GT2	5/26/01 22:07	3D9.1BF1132B02	5/26/01 22:54	A-SEPARATOR GATE	RIVER-2 EXIT	A1	47
GT2	5/26/01 22:07	3D9.1BF112C2DA	5/26/01 22:29	A-SEPARATOR GATE	RIVER-2 EXIT	A1	22
GT2	5/26/01 22:07	3D9.1BF11E8F91	5/27/01 4:52	A-SEPARATOR GATE	RIVER-2 EXIT	A1	405
GT2	5/26/01 22:07	3D9.1BF11E5FAD	5/26/01 22:36	B-SEPARATOR GATE	RIVER-2 EXIT	B1	29
GT2	5/26/01 22:07	3D9.1BF11E61C9	5/26/01 22:28	A-SEPARATOR GATE	RIVER-2 EXIT	A1	21
GT2	5/26/01 22:07	3D9.1BF111DEDA	5/26/01 23:04	A-SEPARATOR GATE	RIVER-2 EXIT	A1	57
GT2	5/26/01 22:07	3D9.1BF111EC75	5/26/01 23:39	B-SEPARATOR GATE	RIVER-2 EXIT	B1	92
GT2	5/26/01 22:07	3D9.1BF11324DE	5/27/01 12:33	A-SEPARATOR GATE	RIVER-2 EXIT	A1	866
GT2	5/26/01 22:07	3D9.1BF111E257	5/27/01 13:14	A-SEPARATOR GATE	RIVER-2 EXIT	A1	907
GT2	5/26/01 22:07	3D9.1BF111DA8B	5/26/01 23:18	B-SEPARATOR GATE	RIVER-2 EXIT	B1	71
GT2	5/26/01 22:07	3D9.1BF11E8AB9	5/26/01 23:41	A-SEPARATOR GATE	RIVER-2 EXIT	A1	94
GT2	5/26/01 22:07	3D9.1BF1127F82	5/27/01 3:20	A-SEPARATOR GATE	RIVER-2 EXIT	A1	313

GT2	5/26/01 22:07	3D9.1BF11E82C8	5/26/01 22:51	A-SEPARATOR GATE	RIVER-2 EXIT	A1	44
GT2	5/26/01 22:07	3D9.1BF11E6C1F	5/26/01 22:40	A-SEPARATOR GATE	RIVER-2 EXIT	A1	33
GT3	6/11/01 22:10	3D9.1BF11E81BC	6/11/01 23:48	A-SEPARATOR GATE	RIVER-2 EXIT	A1	98
GT3	6/11/01 22:10	3D9.1BF113189C	6/11/01 22:53	A-SEPARATOR GATE	RIVER-2 EXIT	A1	43
GT3	6/11/01 22:10	3D9.1BF11324E2	6/11/01 22:21	A-SEPARATOR GATE	RIVER-2 EXIT	A1	11
GT3	6/11/01 22:10	3D9.1BF11E857F	6/11/01 22:18	A-SEPARATOR GATE	RIVER-2 EXIT	A1	8
GT3	6/11/01 22:10	3D9.1BF11E2ECA	6/11/01 23:32	B-SEPARATOR GATE	RIVER-2 EXIT	B1	82
GT3	6/11/01 22:10	3D9.1BF1131521	6/11/01 23:06	B-SEPARATOR GATE	RIVER-2 EXIT	B1	56
GT3	6/11/01 22:10	3D9.1BF11E8E0C	6/11/01 22:55	B-SEPARATOR GATE	RIVER-2 EXIT	B1	45
GT3	6/11/01 22:10	3D9.1BF1132567	6/11/01 22:30	A-SEPARATOR GATE	RIVER-2 EXIT	A1	20
GT3	6/11/01 22:10	3D9.1BF11E8AF7	6/11/01 23:54	B-SEPARATOR GATE	RIVER-2 EXIT	B1	104
GT3	6/11/01 22:10	3D9.1BF11E8978	6/11/01 22:18	A-SEPARATOR GATE	RIVER-2 EXIT	A1	8
GT3	6/11/01 22:10	3D9.1BF11225DB	6/11/01 22:31	A-SEPARATOR GATE	RIVER-2 EXIT	A2	21
GT3	6/11/01 22:10	3D9.1BF11E7017	6/11/01 23:26	A-SEPARATOR GATE	RIVER-2 EXIT	A1	76
GT3	6/11/01 22:10	3D9.1BF11E2F50	6/11/01 22:26	B-SEPARATOR GATE	RIVER-2 EXIT	B1	16
GT3	6/11/01 22:10	3D9.1BF111D24B	6/11/01 22:15	B-SEPARATOR GATE	RIVER-2 EXIT	B1	5
GT3	6/11/01 22:10	3D9.1BF11223A2	6/11/01 22:53	A-SEPARATOR GATE	RIVER-2 EXIT	A1	43
GT3	6/11/01 22:10	3D9.1BF11332A2	6/11/01 23:24	B-SEPARATOR GATE	RIVER-2 EXIT	B1	74
GT4	6/18/01 21:23	3D9.1BF11E637E	6/19/01 7:09	A-SEPARATOR GATE	A-RACEWAY	A3	586
GT4	6/18/01 21:23	3D9.1BF11E28C7	6/19/01 3:10	A-SEPARATOR GATE	A-RACEWAY	A1	347
GT4	6/18/01 21:23	3D9.1BF11E7AEF	6/19/01 7:09	A-SEPARATOR GATE	A-RACEWAY	A1	586
GT4	6/18/01 21:23	3D9.1BF11E6409	6/23/01 5:43	A-SEPARATOR GATE	A-DIVERSION	A1	6260
GT4	6/18/01 21:23	3D9.1BF1121F01	6/18/01 21:40	A-SEPARATOR GATE	SAMPLE ROOM	A1	17
GT4	6/18/01 21:23	3D9.1BF1120705	6/18/01 21:38	B-SEPARATOR GATE	B-SUBSAMPLE	B1	15
GT4	6/18/01 21:23	3D9.1BF11222E0	6/18/01 22:09	B-SEPARATOR GATE	B-SUBSAMPLE	B3	46
GT4	6/18/01 21:23	3D9.1BF11E6F31	6/18/01 21:56	B-SEPARATOR GATE	B-SUBSAMPLE	B1	33
GT4	6/18/01 21:23	3D9.1BF112143E	6/18/01 23:09	B-SEPARATOR GATE	B-SUBSAMPLE	B1	106
GT4	6/18/01 21:23	3D9.1BF11E6A41	6/18/01 21:42	A-SEPARATOR GATE	RIVER-2 EXIT	A1	19
GT4	6/18/01 21:23	3D9.1BF11E7413	6/18/01 21:58	A-SEPARATOR GATE	RIVER-2 EXIT	A1	35
GT4	6/18/01 21:23	3D9.1BF1121B52	6/18/01 21:34	B-SEPARATOR GATE	RIVER-2 EXIT	B1	11
GT4	6/18/01 21:23	3D9.1BF1123473	6/20/01 7:08	A-SEPARATOR GATE	RIVER-2 EXIT	A1	2025
GT4	6/18/01 21:23	3D9.1BF11E8A47	6/18/01 21:53	B-SEPARATOR GATE	RIVER-2 EXIT	B1	30
GT4	6/18/01 21:23	3D9.1BF11E8B3C	6/18/01 22:25	A-SEPARATOR GATE	RIVER-2 EXIT	A1	62
GT4	6/18/01 21:23	3D9.1BF11E8218	6/18/01 21:37	A-SEPARATOR GATE	RIVER-2 EXIT	A1	14
GT4	6/18/01 21:23	3D9.1BF11222EE	6/18/01 22:10	A-SEPARATOR GATE	RIVER-2 EXIT	A1	47
GT4	6/18/01 21:23	3D9.1BF11E6367	6/18/01 21:30	B-SEPARATOR GATE	RIVER-2 EXIT	B1	7
GT4	6/18/01 21:23	3D9.1BF11220ED	6/20/01 6:09	A-SEPARATOR GATE	RIVER-2 EXIT	A1	1966
GT4	6/18/01 21:23	3D9.1BF11E2D3C	6/18/01 21:36	A-SEPARATOR GATE	RIVER-2 EXIT	A1	13
GT4	6/18/01 21:23	3D9.1BF11E9047	6/18/01 21:43	B-SEPARATOR GATE	RIVER-2 EXIT	B1	20

GT4	6/18/01 21:23	3D9.1BF11E877D	6/18/01 21:43	A-SEPARATOR GATE	RIVER-2 EXIT	A2	20
GT4	6/18/01 21:23	3D9.1BF111FDD9	6/18/01 21:54	A-SEPARATOR GATE	RIVER-2 EXIT	A1	31
GT4	6/18/01 21:23	3D9.1BF11227D4	6/19/01 2:01	B-SEPARATOR GATE	RIVER-2 EXIT	B1	278
GT4	6/18/01 21:23	3D9.1BF1122581	6/18/01 21:37	A-SEPARATOR GATE	RIVER-2 EXIT	A1	14
GT4	6/18/01 21:23	3D9.1BF1122535	6/18/01 21:53	B-SEPARATOR GATE	RIVER-2 EXIT	B1	30
GT4	6/18/01 21:23	3D9.1BF11200BF	6/18/01 21:27	A-SEPARATOR GATE	RIVER-2 EXIT	A1	4
GT4	6/18/01 21:23	3D9.1BF11E66A9	6/19/01 10:59	A-SEPARATOR GATE	RIVER-2 EXIT	A1	816
GT4	6/18/01 21:23	3D9.1BF11E640B	6/18/01 21:35	B-SEPARATOR GATE	RIVER-2 EXIT	B1	12
GT4	6/18/01 21:23	3D9.1BF11E61EA	6/18/01 21:54	B-SEPARATOR GATE	RIVER-2 EXIT	B1	31
GT4	6/18/01 21:23	3D9.1BF11E2F5E	6/18/01 21:57	A-SEPARATOR GATE	RIVER-2 EXIT	A1	34
GT4	6/18/01 21:23	3D9.1BF11220D9	6/18/01 21:43	B-SEPARATOR GATE	RIVER-2 EXIT	B1	20
GT4	6/18/01 21:23	3D9.1BF11E2E07	6/18/01 21:28	A-SEPARATOR GATE	RIVER-2 EXIT	A1	5
GT4	6/18/01 21:23	3D9.1BF112200A	6/18/01 22:12	A-SEPARATOR GATE	RIVER-2 EXIT	A1	49
GT4	6/18/01 21:23	3D9.1BF1120024	6/20/01 2:44	B-SEPARATOR GATE	RIVER-2 EXIT	B1	1761
GT4	6/18/01 21:23	3D9.1BF1120133	6/18/01 21:29	A-SEPARATOR GATE	RIVER-2 EXIT	A1	6
GT4	6/18/01 21:23	3D9.1BF11E7D4C	6/18/01 21:54	A-SEPARATOR GATE	RIVER-2 EXIT	A1	31

Appendix B

Historical Run Timing

The following figures represent collection estimates based on a daily average sample rate; the same sampling procedures are followed at each of the dams listed.

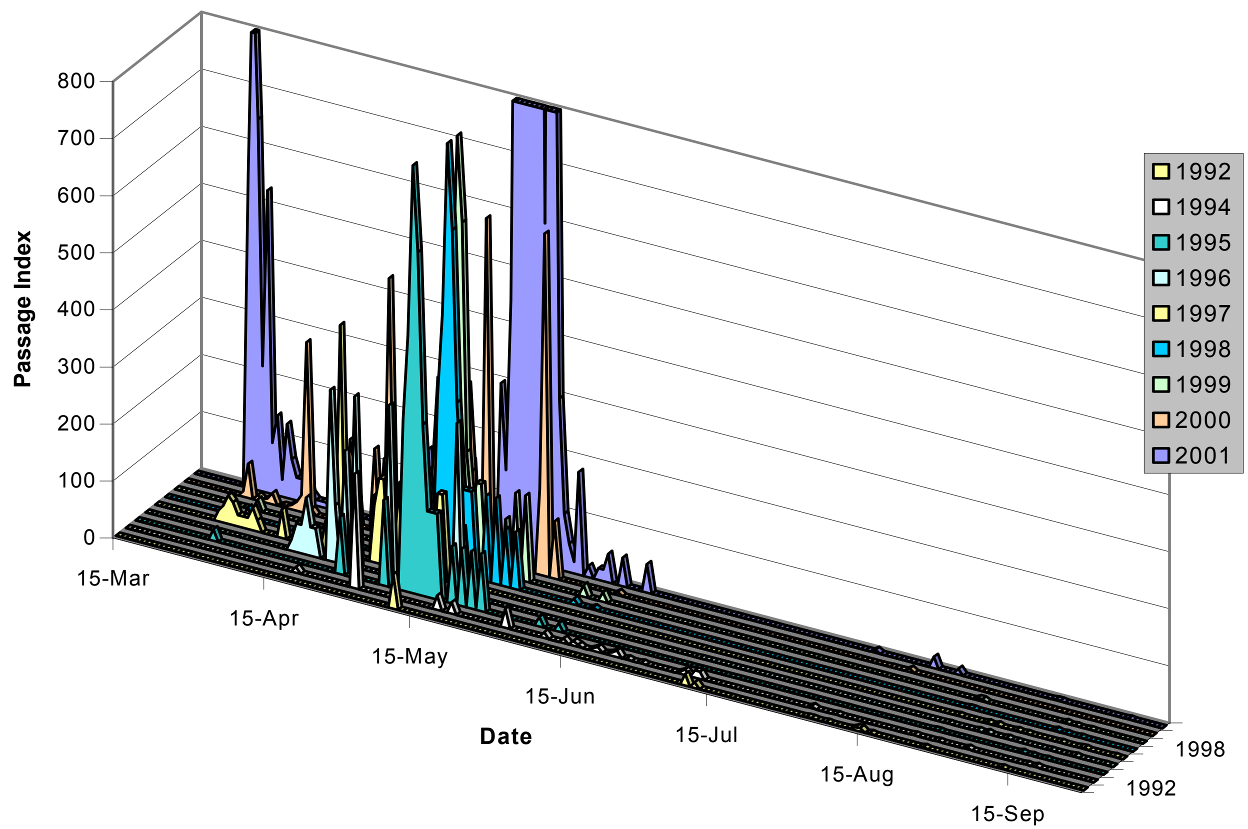

Figure B.1. Historical run timing of juvenile lamprey at Lower Granite Dam

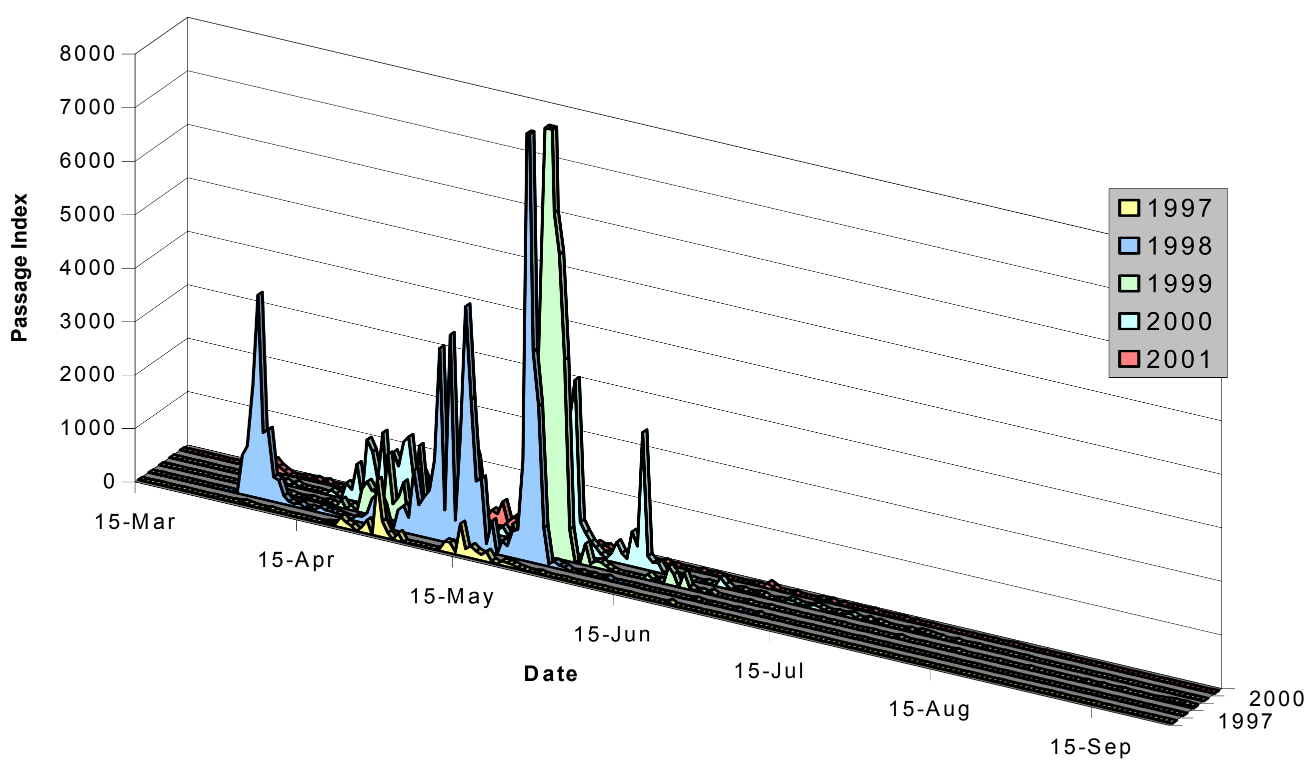

Figure B.2. Historical run timing of juvenile lamprey at Little Goose Dam

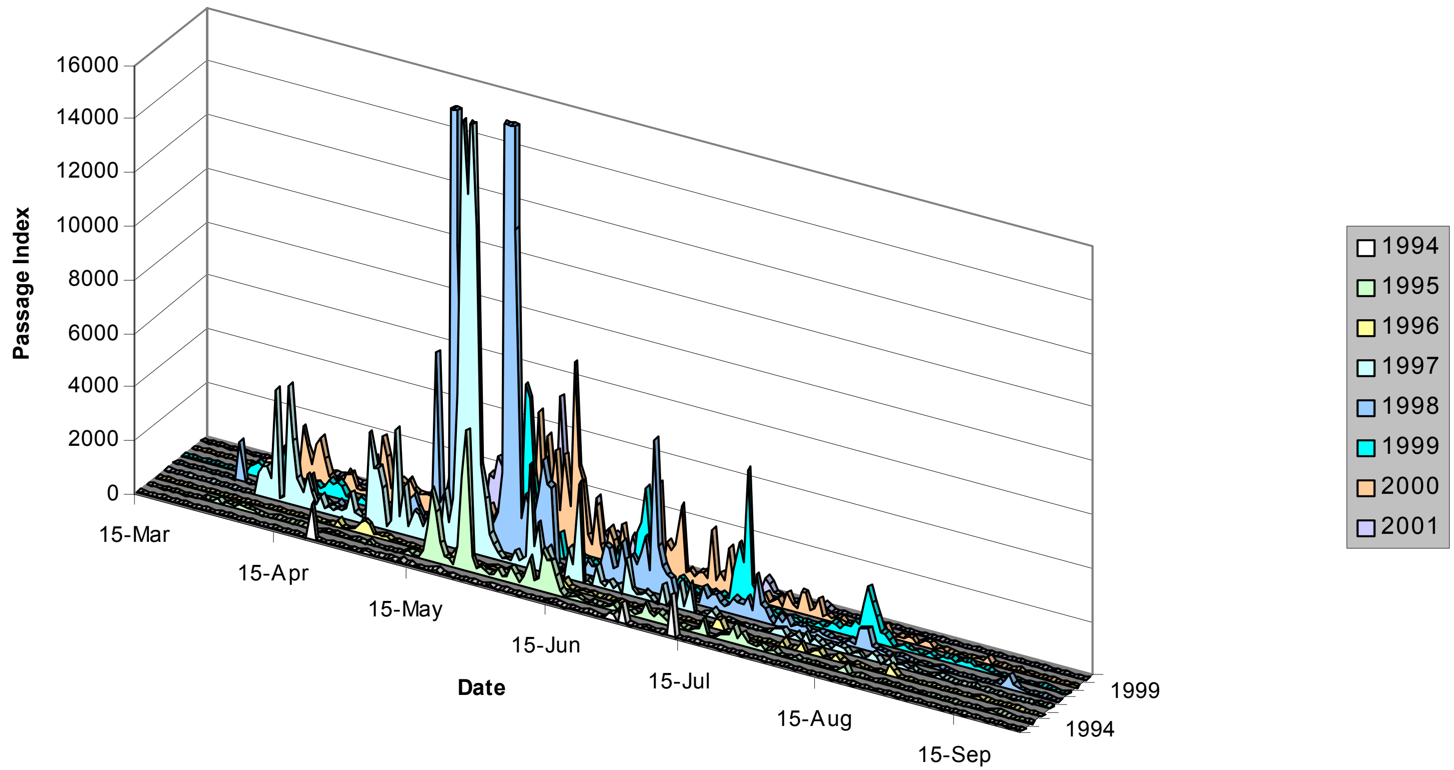

Figure B.3. Historical run timing of juvenile lamprey at McNary Dam

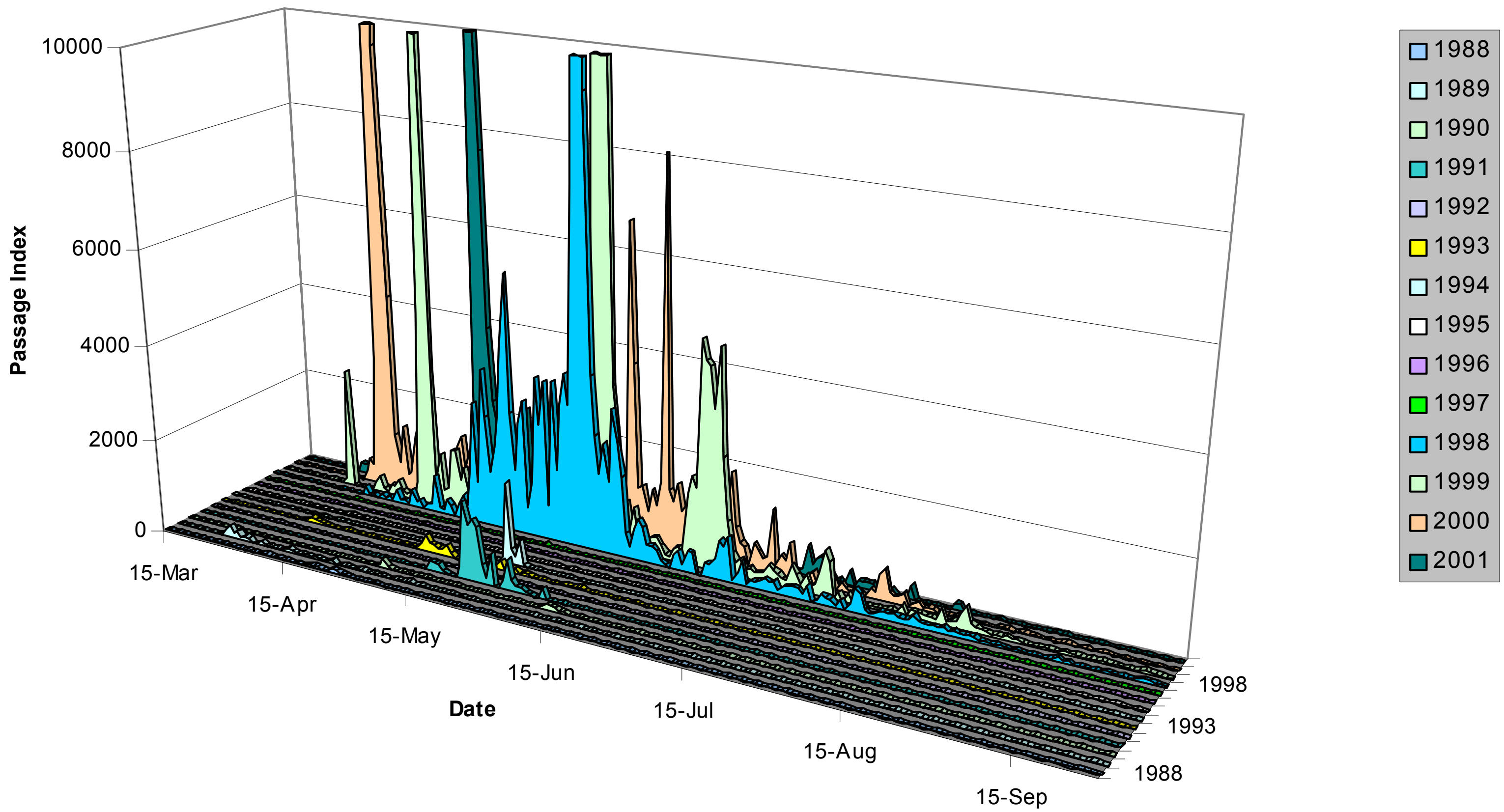

Figure B.4. Historical run timing of juvenile lamprey at John Day Dam

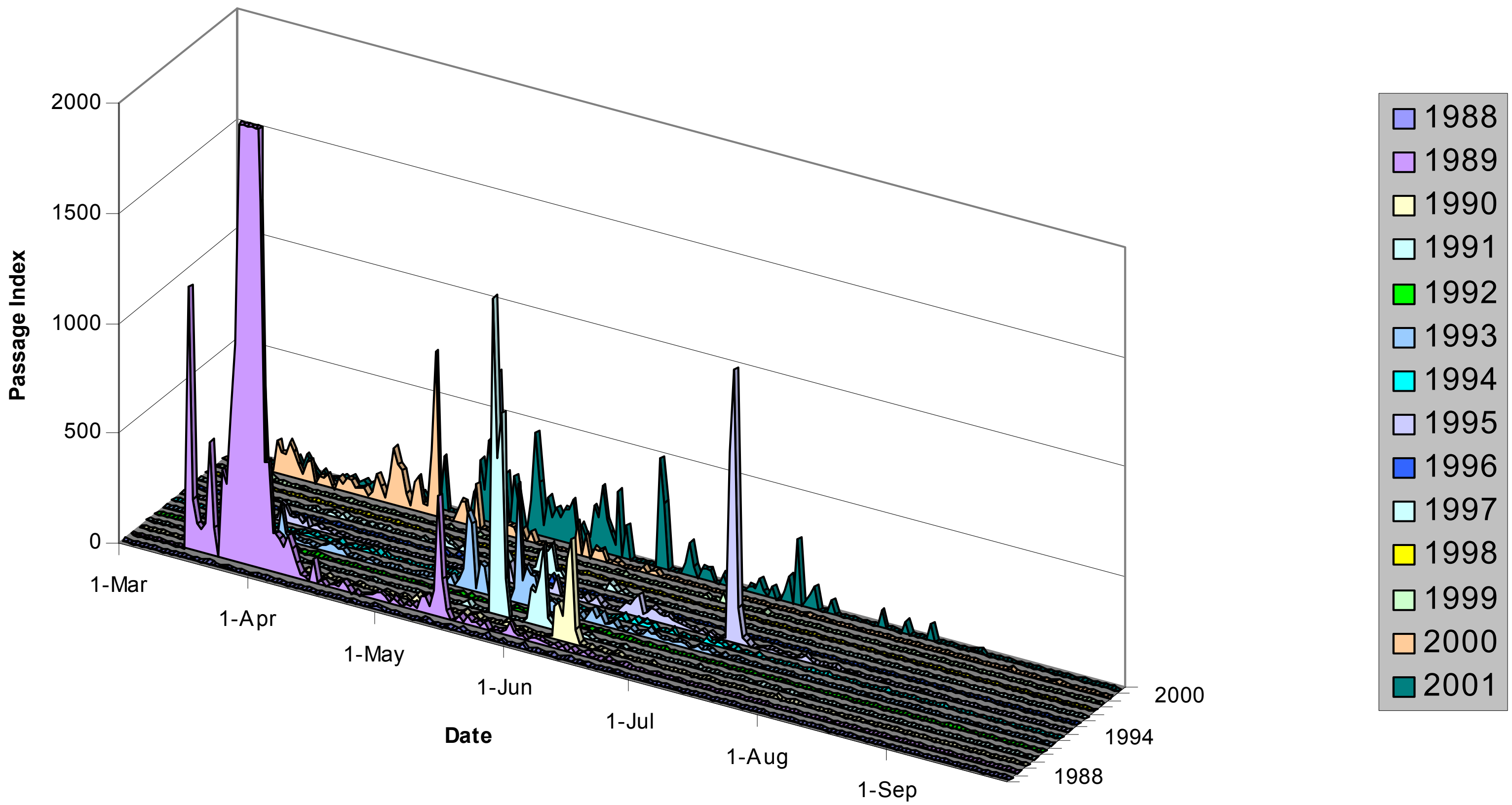

Figure B.5. Historical run timing of juvenile lamprey at Bonneville Dam

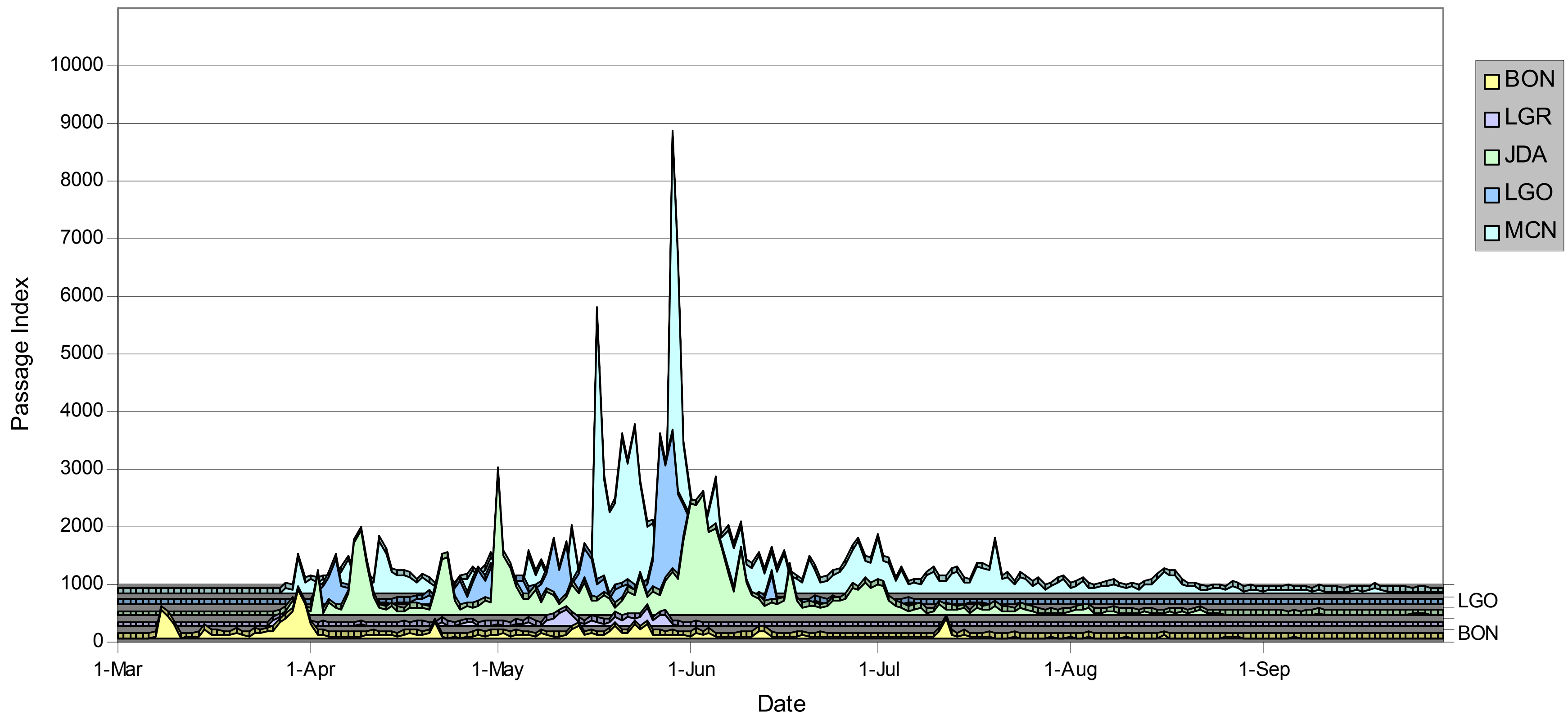

Figure B.6. Historical run timing of five dams on the lower Columbia and Snake Rivers

Appendix C

Equipment Specifications

The following equipment was used for the PIT tagging portions of this study:

Manufacturer and Model	Quantity
Biomark® handheld portable FS2001FR PIT tag reader	1
Biomark® TX1400L ISO 134.2 kHz PIT tags	900
Biomark® MK6 PIT tag injectors	1

The following equipment was used for the optical camera deployments:

Manufacturer and Model	Quantity
Deep Sea Power & Light 1065 Multi-SeaCam®	4
Gleason S21-1003-63-17-A-3 heavy duty cable reel	2
Falmat video/power cable, 18awg shielded pair with min coax and 2000 lb kevlar strength member	1
Sony GV D800 Digital 8mm video recorders	4
Sony HMP Hi 8mm tape	60
Tenma 72-6153 DC power supply, 0-18VDC, 0-10A	2
Tripp-lite LC-1800 line voltage regulater	2