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Video Monitoring of Adult Fish Ladder Modifications to Improve Pacific Lamprey Passage at the McNary Dam Oregon Shore Fishway, 2010.

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I. ABSTRACT

In this study underwater infrared cameras and remote video surveillance was used at three modified tilting weirs to assess whether the presence of newly constructed lamprey orifices impede passage of migrating salmon and steelhead, and to determine behavior of Pacific lamprey as they approach, enter, and pass through these orifices. To facilitate video analysis, an automated visual event detection and classification system (AVEDac) utilized by oceanographic videographers was also developed and evaluated for this specific video monitoring application.

Video images were collected between April and September 2010. Monitoring at lamprey orifices covered the early and peak portions of the spring, summer, and fall Chinook salmon, Sockeye salmon, steelhead, and American shad runs. Roughly 1% of the Oregon shore spring and summer Chinook salmon run was seen in the near vicinity of the lamprey orifices; only one spring Chinook observed on video attempted to pass an open orifice and the passage attempt did not result in any observable harm. On average, the time fish spent in view of the camera was less than two seconds. Fall Chinook salmon were never seen in view of the cameras. For Sockeye salmon, a total of seven fish attempted passage through the lamprey orifices, corresponding to less than 0.02% of the entire run passing at the Oregon shore fish ladder. These interactions typically lasted only several seconds and were characterized by fish nosing into the orifice then turning away. No passage attempts through lamprey orifices were recorded for steelhead, however 0.014% of the run at the Oregon shore fish ladder were seen in the near vicinity of the open orifices. No shad were seen in the vicinity of the lamprey orifices. In general, the lamprey orifices did not delay or otherwise harm migrating stocks of salmon, steelhead, or shad.

Lamprey behavior and passage at the orifices was recorded during both day and night. On average, roughly half of the lamprey seen passed successfully through the orifices. Specific behaviors of lamprey at orifices were characterized and quantified. Lamprey passed through orifices by either: (1) attachment to the substrate near the downstream-side of the orifice with subsequent burst swimming through the orifice; (2) burst swimming through the orifice with subsequent attachment near the upstream-side of the orifice; (3) attachment to the substrate near the downstream-side of the orifice, burst swimming through the orifice, and subsequent reattachment on the upstream-side of the orifice; or (4) burst swimming through the orifice with no attachment. The total number of lamprey observed during video monitoring (260) was considerably higher than the number counted at the fish counting window over the same time period (90), indicating that lamprey likely pass through the picketed leads and therefore are not counted at the count window.

Utilizing an eight-node computer cluster, AVEDac was developed to both mark salient video events and classify objects (salmon and lamprey) according to a neuromorphic selective attention algorithm. Sample video was successfully processed using the detection and tracking features of AVEDac, while further development of the classifier is needed to improve automated species recognition.

II. EXECUTIVE SUMMARY

Past telemetry studies involving tagging Pacific lamprey with radio transmitters have demonstrated that various locations within fish passage structures at hydropower projects on the Columbia and Snake rivers may delay passage. In 2010, to facilitate passage of Pacific lamprey through the tilting weir section of McNary Dam, the U.S. Army Corps of Engineers installed (i) 14 lamprey orifices to the stemwall of seven tilting weirs and (ii) metal plating at diffusers on the lower ladder. Through the months of April through September, underwater video monitoring was peformed to assess (i) whether the presence of these orifices delayed or otherwise harmed migrating stocks of salmon, steelhead, shad; (ii) whether lamprey utilized these new orifices (and plating); and (iii) lamprey behavior in passing the orifices.

Video was collected using low-light cameras and external infrared lighting (for nighttime lamprey viewing) and recorded to a standalone DVR. All video was transmitted to UCD campus through a satellite network connection. Within the tilting weir section, video quality was generally excellent with the exception of a short period of high turbidity and sporadic periods of high turbulence due to uneven water surface elevations between tilting weirs. Video collected at the diffuser plating was of very poor quality because of high tubulence and entrained air; no lamprey observations were possible at this location.

Of the total spring Chinook passing through the Oregon shore fish ladder, 26% passed during the video monitoring period. Lamprey orifices were evaluated in the closed and open configuration for the spring Chinook run, and more fish were observed in the vicinity of the closed orifice (5.3%) than at the open orifice (1.5%). Attempts to switch the status of the orifices (open to closed and closed to open) failed due to debris lodged in the open orifice. Regardless, spring Chinook were not delayed by the presence of the orifices; fish generally spent only a fraction of a second in the vicinity of an orifice. Diurnal variation of passage and presence at the orifices was investigated, and roughly 7% more fish were seen at the orifices in the morning than in the afternoon hours. Only one spring Chinook observed on video attempted to pass an open orifice; the passage attempt did not result in any observable harm.

Of the total summer Chinook passing through the Oregon shore fish ladder, 28.9% passed during the video monitoring period. Lamprey orifices were evaluated in the closed and open configuration for the summer Chinook run, and more fish were observed in the vicinity of the open orifice (1.7%) than the closed orifice (0.8%). When the status of the orifices was changed (open to closed and closed to open), fish still exhibited a preference for the same side of the ladder. No summer Chinook attempted orifice passage.

Video monitoring of Fall chinook encompassed nearly 40% of the entire run passing the Oregon shore fish ladder, and no fish were seen in the vicinity of the orifices. Similarly for shad, 34% of the run passing through the Oregon shore fish ladder passed during the video monitoring period and no shad were seen in the vicinity of the orifices. For steelhead, 22% of the entire run passing the Oregon shore fish ladder passed during the video monitoring period, and 0.01% were observed on video. Of the steelhead observed on video, none attempted orifice passage or were delayed by an open orifice.

The Sockeye run in 2010 was nearly 400% of the ten year average, and nearly 50% of the run passing the Oregon shore fish ladder passed during the video monitoring period. Of the Sockeye observed on video, seven attempted orifice passage, corresponding to 0.016% of the entire run. No fish were observed to be harmed by these passage attempts, and no significant delay was observed.

Video monitoring of lamprey initially occurred during nighttime hours. During this period (July 15-August 5), 119 lamprey were oberved with 42.9% successfully passing through the lamprey orifices. Roughly 92% of the lamprey passing through orifices attached to the channel prior to passage and 8% swam directly through the orifice without attachment. Due to increasing numbers of lamprey seen during daytime monitoring, video monitoring was switched to daytime from August 15 to the end of September. Collectively across the entire monitoring period (July 15 through the end of September), 260 lamprey were observed on video with an overall successful orifice passage rate of 50.4%. During this same period of time, 90 lamprey were observed by staff in the fish count window. Hence, significant numbers of lamprey are likely passing behind the picket leads and thus evading detection by fish count technicians.

To help facilitate processing large amounts of video data, an automated software system (AVEDac) was developed and applied to samples of video. This software system has the capability to automatically detect, track, identify, and count fish, and can process a 60 minute video in less than 20 minutes. The event classifier portion of AVEDac, wherein events are identified to the species-level, needs further refinement to accurately identify lamprey and salmonids. The accuracy of the current event classifier is roughly 78%. Use of alternative classifiers should increase accuracy to above 95% for fish species recognition.

III. TABLE OF CONTENTS

I. ABSTRACT i
II. EXECUTIVE SUMMARY ii
III. TABLE OF CONTENTS iv
IV. LIST OF FIGURES v
V. LIST OF TABLES vi
1.0 INTRODUCTION 1
2.0 METHODOLOGY 2
Video Camera Apparatus and Video Collection 2
Video Analyses 5
Statistical Analyses 6
AVEDac Processing 6
3.0 RESULTS 8
Spring Chinook Salmon 8
Summer Chinook Salmon 13
Fall Chinook Salmon 16
Sockeye Salmon 17
Steelhead 19
American Shad 21
Pacific Lamprey 22
Diffuser Plating Video 30
AVEDac Processing 30
4.0 DISCUSSION 32
5.0 CONCLUSIONS AND RECOMMENDATIONS 37
6.0 ACKNOWLEDGEMENTS 38
7.0 REFERENCES 38
8.0 APPENDICES 40

IV. LIST OF FIGURES

Figure	Title	Page

Figure 1: Video camera trolley system. Left photo shows the relationship of the I-Beam to the lamprey orifice on weir 336. The right photo shows the camera trolley with underwater IR video camera. The black weight also served as a mounting location for up to two external IR lights. 2
Figure 2: Typical field of view of the lamprey orifice using one SPECO CVC-320WP B/W infrared video camera. 3
Figure 3: Locations of video cameras within the tilting weir section of McNary Oregon shore upper fish ladder. Location of lower ladder and camera viewing diffuser plating is not shown. 4
Figure 4: Pmbarivision processing of raw video clips. Steps show the event detection and tracking algorithm. 7
Figure 5: Comparison of nighttime (a) and daytime (b) counts of lamprey by fish counting technicians at the fish count window and video at lamprey orifices. 23

V. LIST OF TABLES

Table	Title	Page

Table 1: Summary of recording dates and times at various locations at McNary Oregon shore fish ladder in 2010. 5
Table 2: Presence of spring Chinook salmon at the closed and open lamprey orifice at weir 336 during video monitoring. 10
Table 3: Presence of spring Chinook salmon at the closed and open lamprey orifice at weir 336 during morning and afternoon video monitoring. 11
Table 4: Time spent by spring Chinook salmon at the closed and open orifices at weir 336 during video monitoring. 12
Table 5: Passage attempt summary for spring Chinook salmon at the closed and open orifices at weir 336. 12
Table 6: Presence of summer Chinook salmon at the closed and open lamprey orifice at weir 336 during video monitoring. 14
Table 7: Presence of summer Chinook salmon at the closed (North side) and open (South side) lamprey orifice at weir 336 during video monitoring. 15
Table 8: Presence of summer Chinook salmon at the closed (South side) and open (North side) lamprey orifice at weir 336 during video monitoring. 15
Table 9: Time spent of summer Chinook salmon at the closed and open orifices at weir 336 during video monitoring. 16
Table 10: Presence and passage attempts of adult Sockeye salmon at the open lamprey orifice at weir 336 during video monitoring. 18
Table 11: Time spent of Sockeye salmon at the open orifices at weir 336 during video monitoring. 19
Table 12: Presence of adult steelhead at the open lamprey orifices at weir 337 during video monitoring. 20
Table 13: Time spent of steelhead at the open orifices at weir 337 during video monitoring. 21
Table 14: Presence of adult Pacific lamprey at orifices at weirs 336 and 337 during nighttime video monitoring. 25
Table 15: Presence of adult Pacific lamprey at orifices at weirs 336 and 337 during daytime video monitoring. 26
Table 16: Passage success of adult Pacific lamprey through orifices at weirs 336 and 337 during nighttime monitoring. 27
Table 17: Passage success of adult Pacific lamprey through orifices at weirs 336 and 337 during daytime monitoring. 27
Table 18: Behavior of lamprey successfully passing open orifices at weirs 336 and 337 during nighttime video monitoring. 28
Table 19: Behavior of lamprey not passing open orifices at weirs 336 and 337 during nighttime video monitoring. 28
Table 20: Behavior of lamprey successfully passing open orifices at weirs 336 and 337 during daytime video monitoring. 29
Table 21: Behavior of lamprey not passing open orifices at weirs 336 and 337 during daytime video monitoring. 30

Table 22: Modified pmbarivision command line parameters. 30
Table 23: Confusion matrix results from testing video containing lamprey and sucker fish. Lamprey and sucker fish classes used in training library..... 31
Table 24: Confusion matrix results from testing video containing only lamprey. Lamprey and sucker fish classes used in training library. 32

1.0 INTRODUCTION

Declining returns of pre-spawning adult Pacific lamprey *Lampetra tridentata* to the Columbia River highlight the need to document juvenile and adult passage at dams (Close et al. 1995; Jackson et al. 1996) as well as other factors that may be limiting lamprey productivity in the system. Pacific lamprey are anadromous and must pass up to nine dams Columbia River basin to reach upstream spawning areas. Impeding passage of lamprey below dams may subject them to increased predation pressure and other sources of mortality.

Beginning in 1996, radiotelemetry (RT) studies funded by the United States Army Corps of Engineers (USACE) have examined lamprey passage in the lower Columbia River, initially focused at Bonneville Dam (e.g., Moser et al. 2002a, 2002b, 2003, 2005) and later expanded to include The Dalles, John Day, McNary and Ice Harbor dams (Cummings et al. 2008; Boggs et al. 2008, 2009a, 2009b; Daigle et al. 2008; Keefer et al. 2009a, 2009b). Results indicated that Pacific lamprey did not readily pass dams and poor passage could represent a critical limitation to migration success (Close et al. 1995; Moser et al. 2002a). Specifically, Moser et al. (2002a, 2002b, 2003, 2005) found that fishway entrances, collection/transition areas, count stations, diffuser gratings, and serpentine weirs impeded adult Pacific lamprey dam passage at lower Columbia River dams.

In late 2009 the Walla Walla District USACE made modifications to the tilting weir and diffuser grating sections at McNary Dam in an effort to improve passage and reduce delay of lamprey. The tilting weir section is comprised of a series of tilting weirs with main fish passage orifices located several feet above the fishway floor. The purpose of these orifices is to allow passage of migrating salmon and steelhead, but their elevated location relative to the fishway floor may pose passage problems for migrating lamprey. Modifications to this area included installation of lamprey orifices (measuring 3 inches tall by 18 inches long) cut flush to the fishway floor to seven stemwalls supporting the tilting weirs; a total of 14 new lamprey orifices installed, two per tilting weir. These orifices are opened and closed with a sliding gate which is operated by a turnhandle located on the ladder walkway, and the orifices are lined with metal for hydraulic reasons and to also serve as lamprey attachment points. In addition to the lamprey orifices, metal plating was installed over the top of three diffuser gratings to aid in lamprey attachment and passage through the lower section of the ladder.

While installation of these orifices may improve lamprey passage, the orifices may also delay passage or otherwise harm migrating adult stocks of salmon, steelhead, and shad. The use of underwater video monitoring was proposed as a non-invasive means of studying the behavior of spring/summer/fall Chinook, steelhead, Sockeye, and shad. Additionally, using low-light video cameras for nighttime monitoring the behavior of lamprey as they approach, enter, and ultimately pass through the modified orifices and diffuser plating could also be studied.

Use of non-invasive means such as video monitoring at these various structures within fishways to study fish can quickly result in large amounts of video, creating an arduous task of manually reviewing and processing footage. As an alternative to human annotation, advanced software exists to perform automated video event detection and event classification such that long spans

of video may be scanned for objects of interest and identified using a computer cluster with little human input.

The primary objectives of this study were to 1) install seven infrared underwater video cameras to monitor fish and lamprey passage at the first three modified stem walls and associated tilting weirs and one diffuser plating; 2) determine whether new lamprey orifices pose a risk to migrating salmonids and assess lamprey behavior at orifices and diffuser plating, and; 3) determine suitability of automated event detection and classification software for video processing of salmonid and lamprey behavior within hydropower fish passage structures.

2.0 METHODOLOGY

Video Camera Apparatus and Video Collection

Camera tracks and trolleys: Three inch aluminum I-Beam sections were attached to the lateral aspect of the fish ladder channel with Hilti-bolts at the following locations: downstream of the south-side of weir 335 (video from this location was never analyzed due to the dissimilarity in the orifice on weir 335 from orifices on weirs 336 and 337); downstream of the north- and south-side of weir 336; downstream of the north- and south-side of weir 337; and the north-side of the diffuser plating (Diffuser 13) in lower ladder. The tracks were located approximately 2 feet from the orifice opening as shown in Figure 1. Camera trolleys which slide along the I-Beams were custom-fabricated and measure 18 in. x 6 in. x 2 in. and contained a 5 pound metal plate to keep the trolley stable on the fish floor (Figure 1). The camera trolleys allowed for the cameras to be pulled up by hand during the season for routine maintenance, cleaning, and repositioning of cameras.

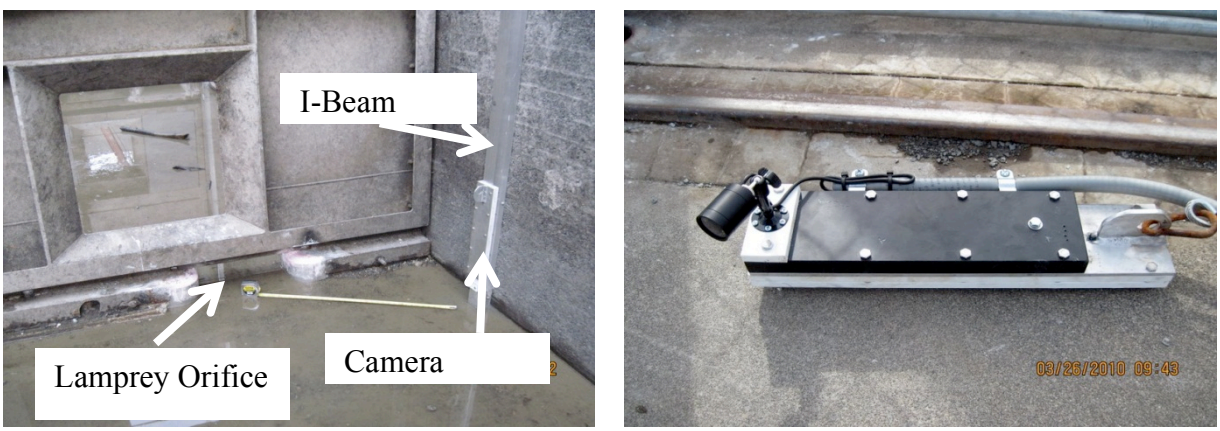

Figure 1: Video camera trolley system. Left photo shows the relationship of the I-Beam to the lamprey orifice on weir 336. The right photo shows the camera trolley with underwater IR video camera. The black weight also served as a mounting location for up to two external IR lights.

Underwater cameras and external infrared lighting: Selection of underwater IR video cameras was based on light sensitivity, cost, and video quality. The camera used (SPECO CVC-320WP B/W Waterproof Bullet) for all video observations has a light sensitivity of 0.02 lux and a resolution of 420 vertical TV lines. The field of view for this camera at 2 ft. from the orifice is approximately 2 ft. (vertical) by 2 ft. (horizontal), or 49° (see Figure 2). Prior to opening of all orifices, two cameras were used to view one lamprey orifice to increase the field of view. In the example provided in Figure 2, the second camera was positioned to allow the area to the left of the first camera to be visible, thus expanding the field of view to approximately 98°.

Figure 2: Typical field of view of the lamprey orifice using one SPECO CVC-320WP B/W infrared video camera.

During nighttime video monitoring of lamprey passage, external infrared lighting was needed to observe animals in complete darkness. An overall schematic of the general placement of cameras within the fish ladder is shown in Figure 3. One additional video camera was placed within the ladder to monitor the plating installed over the diffuser (Diffuser 13) in the lower section of ladder. This camera was lowered all the way down to the plating on the fish ladder floor, and the camera was oriented downstream to encompass as much of the plating as possible to observe lamprey migrating upstream.

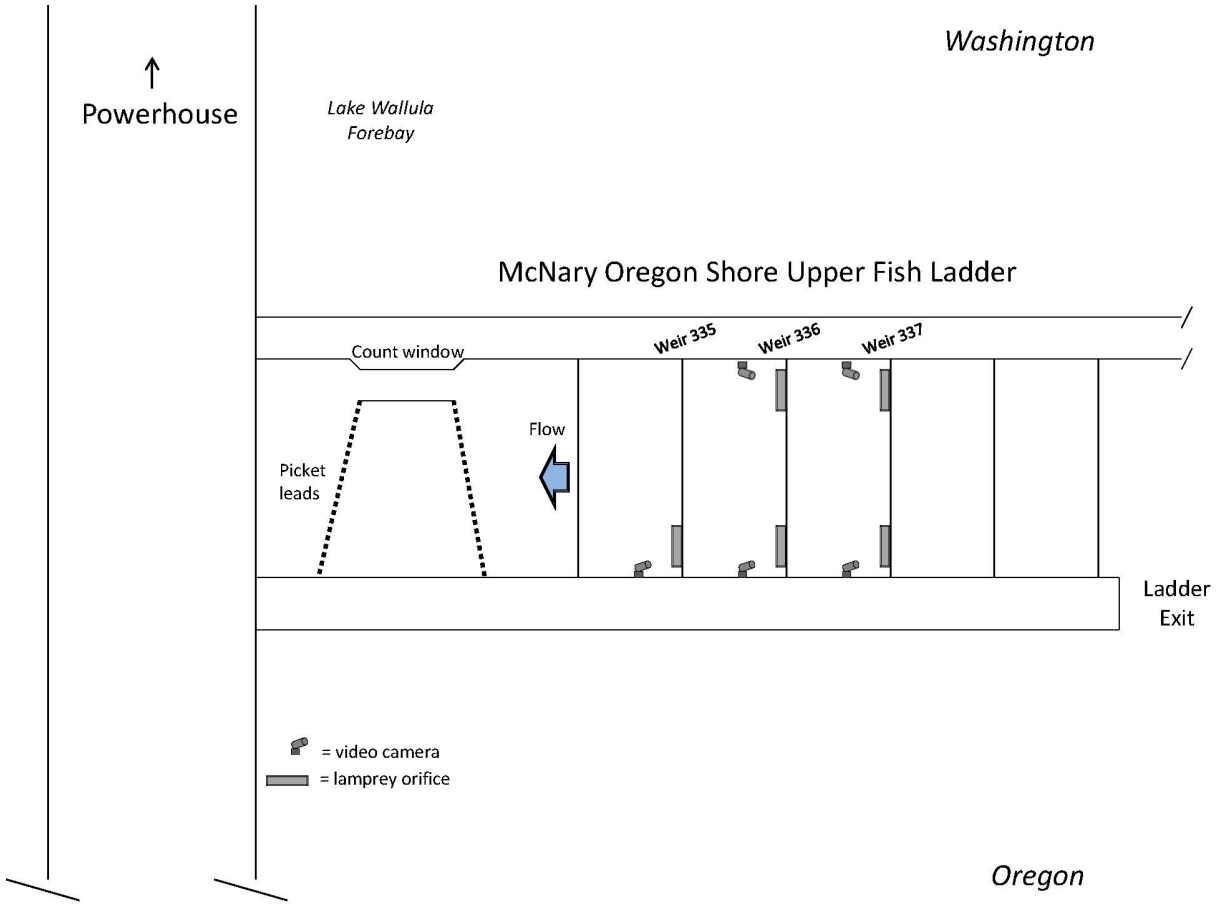

Figure 3: Locations of video cameras within the tilting weir section of McNary Oregon shore upper fish ladder. Location of lower ladder and camera viewing diffuser plating is not shown.

Video data collection and uplink: Bayonet Neill-Concelman (BNC) cable ends from all video cameras were routed to an air-conditioned electrical enclosure (NEMA 4 rated) bolted to the wall underneath the south stairwell leading to tilting weir section of the fish ladder. The enclosure housed an eight channel standalone Digital Video Recorder (heavy duty power supply, DVR grade 8.0 terabyte SATA-2 storage, DVD-RW 24X drive dual layer, 4.0 gigabyte DDR2 RAM memory, Microsoft Windows XP PRO, 512 MB Nvidia PCI-x16 video card, H.264 video compression. DVR Systems, Ashtabula, OH), a Hughes Satellite modem, and a 2.0 terabyte backup drive (Buffalo model HD-W2.0TIU2/R1. Austin, TX).

Remote connectivity from the University of California Davis (UCD) facilities to the standalone DVR was achieved using a satellite dish (Model HN9000, Hughes Satellite, Germantown, MD) with an upload speed of at least 1 megabit per second (mps). Programming of recording settings and other commands controlling the DVR operation was performed remotely from UCD using a computer video server through a remote desktop software running Windows 7 operating system. Other commands sent from this video server include: 1) external drive backup, 2) modification of camera settings (e.g., image-collection time, frames-per-second

(FPS), and resolution), and 3) video file retrieval. Video recordings were saved to the DVR drive in a proprietary MP4 file format. Files were mannually backed up to the external terabyte drive. The MP4 files were transferred to the video server at UCD using a standard FTP network protocol. MP4 files were converted to .avi file format for viewing using a file converter (DVR Systems).

Video recording: Using the remote desktop feature in Windows 7, the standalone DVR was remotely programmed from a video server at UCD to collect video from assorted cameras at various times for weirs 336 and 337 (Table 1). Video from the sole camera at the diffuser plating (Diffuser 13) was connected directly to a standard DVR (Toshiba, Model DR430) and the video footage was recorded directly to a DVR disc.

Table 1: Summary of recording dates and times at various locations at McNary Oregon shore fish ladder in 2010.

Dates	Weir 336	Weir 337	Diffuser 13	Runs observed[b]
April 25 - May 10	0700-1200	0700-1200		1,4,5,6
May 11 - May 13	1200-1700	1200-1700		1,4,5,6
May 16 - May 25	0700-1700[a]	0700-1700		1,4,5,6
June 16 - July 7	0700-1700	0700-1700		2,4,5,6
July 14 - July 25	2200-0500	2200-0500		7
July 26 - Aug 9	0700-1200	0700-1200 [a]		4,5,6,7
Aug 15 - Sept 9	0700-1200	0700-1200		3,4,5,6,7
Sept 10 - Sept 30	0700-1200 [a]	0700-1200		3,4,5,7
Aug 13			1100-1400 [a]	
Aug 14			0700-0900 [a]	
Aug 15			1400-1600 [a]	
Aug 31			1700-2000 [a]	
Sept 1			1700-2000 [a]	
Sept 2			1300-1600 [a]	

[a] Excessive air entrainment- underwater video observations not possible.
[b] Runs: spring Chinook salmon (1), summer Chinook salmon (2), fall Chinook salmon (3), steelhead (4), Sockeye salmon (5) American shad (6), and Pacific lamprey (7).

Video Analyses

Salmon and steelhead runs: During the first phase of video monitoring, between April 18 and July 14, evaluations of salmon and steelhead interactions at lamprey orifices were based on videos captured by cameras providing an extended field of view of orifices (~98 degrees). After all lamprey orifices were opened on July 15, videos from four cameras pointed toward the orifices with a field of view of approximately 49 degrees were collected and analyzed (see Methods).

In general, the presence of fish other than Pacific lamprey at orifices was monitored to establish if salmon and/or steelhead were attracted to lamprey orifices. Specifically, presence of salmon and steelhead was recorded and analyzed to determine if there was a difference in 1) fish presence between open and closed orifices, 2) fish presence at orifices betweeen morning and afternoon hours, and 3) fish presence between orifices located at the North and South side of the fish ladder.

Videos were also used to track the time salmon and steelhead spent in the immediate vicinity of orifices. To evaluate if lamprey orifices attract fish other than lamprey for extended amounts of time, and thereby possibly prolong their migration time through the fish ladder, the average time spent at orifices for each species was determined. Furthermore, comparisons of time spent at open and closed orifices were performed to evaluate if the amount of time present at orifices is linked to the orifice status.

Finally, the risk of harm for fish species/runs of interest at lamprey orifices was assessed by monitoring passage attempts. Narrow orifices designed for lamprey may cause injury to salmon and steelhead trying to enter or pass through. For the purpose of this study, any behavior indicating a passing attempt, such as a surging acceleration towards the orifice with touching the weir or orifice steel inserts was interpreted as an attempt. Passage attempts were analyzed and presented as a fraction of the total count of the respective species during the monitoring period, the daily count, and the run total.

Pacific lamprey run: The number of lamprey observed on video were compared between orifices to evaluate potential preference between orifices located at the North or South side of the Oregon shore fish ladder. The extent of lamprey using the orifices was based on the number of successful passage attempts relative to the total number of lamprey observed on video. The extent of lamprey passing the picket leads was qualitatively assessed by comparing the total number of lamprey observed on video to observed numbers at the Oregon Shore fish count window. Behavior during successful and unsuccessful orifice passage was observed and classified. Comparison of classified behaviors was based on the average amount of time lamprey exhibited each behavior and the percent of overall lamprey observed on video that exhibited each type of behavior.

Statistical Analyses

Statistical analyses of presence differences between orifices (open or closed; North or South side; morning or afternoon) for salmon runs, steelhead, and lamprey were performed with a likelihood ratio test. Testing of the null hypothesis ($p=0.5$) was performed with a two-tailed Z test. Z-scores were used to calculate p-values, and the null hypothesis was rejected when $p \leq 0.05$. Depending on sample sizes, comparison of the average time spent at orifices was performed using the two-sample, two-sided t-test (sample size < 30) or the two-tailed Z-test (sample size > 30). The computer program Number Cruncher Statistical Systems (NCSS; Kaysville, Utah) was used to perform all analyses with a significance level, α, of 0.05.

AVEDac Processing

The Automated Visual Event Detection and Classification System (AVEDac) is a computer software package developed by Monterey Bay Aquarium Research Institute (MBARI), University of Southern California, and California Institute of Technology. AVEDac consists of three software programs: (1) aved-pmbarivision used for the detection and tracking of events in video; (2) aved-classifier used to classify (e.g., identify) events of interest; and (3) aved-ui which is a graphical user interface (GUI) that can be used in conjunction with aved-classifier.

All three programs that comprise AVEDac are feely available as source code through MBARI. The source code must then be compiled by a computer program on a particular computer to run the program; aved-pmbarivision is compiled by C++ and aved-classifier and aved-ui are compiled by Matlab.

In this study, aved-pmbarivision was installed on an eight-node rack 32 CPU Beowulf cluster (Quad-Core Opteron Twin Servers, Microway, Inc., Plymouth, MA) operating on a LINUX platform running Fedora 9 operating system. The management of cluster hardware was handled through the manufacturer's management software and communicated through a secure web-based graphical user interface (GUI). The specific tasks performed by aved-pmbarivision are graphically depicted in Figure 4 (Walther et al, 2004). Each video frame in the original file is processed using a neuromorphic selective attention algorithm (Walther et al, 2002), whereby candidate objects are flagged as interesting if tracked across successive video frames. Non-interesting objects (objects not tracked across successive video frames) are discarded through a "winner take all" voting process used in computer neural networks (Itti et al. 1998). Each video frame is processed to reduce associated noise and improve predictions regarding the objects movement using a linear Kalman filter. Two files are produced from aved-pmbarivision: (1) a .xml file of all detected events and (2) a .mpeg file containing the original video with flagged events of interest.

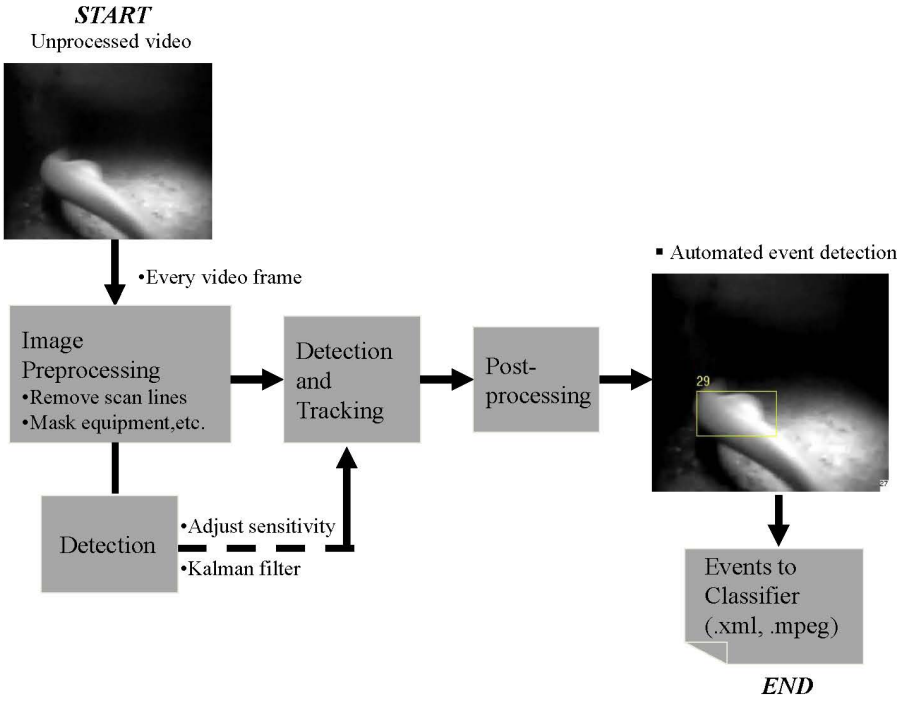

Figure 4: Pmbarivision processing of raw video clips. Steps show the event detection and tracking algorithm.

The event classifier (aved-classifier) and GUI (aved-ui) were installed on a Mac Pro 5.1 (2.8 GHz Quad Core Intel processor, 6 GB RAM, Mac OS 10.6.4). The software programs were run in Matlab containing Image Processing Toolkit. Once the processed files are opened in the event classifier the individual events detected by pmbarivision are shown as thumbnail images. Each event (or thumbnail image) includes detail of the size of the event (in pixels), the frame duration of the event (in seconds), and exactly when the event occurred in the video (time stamp). Selection of a particular thumbnail image will generate a video clip corresponding to the video in the original source file of that specific event.

In order for the event classifier to identify unknown events, training libraries were created using algorithms described previously (Ranzato et al, 2007). The basic steps were:

> *1) Class creation.* Each event in the thumbnail images is identified by the user by manually labeling each salient event. All objects in the video can be assigned to a class of any identity. In this study, we created classes that represented lamprey, suckerfish, perch, and miscellaneous. The miscellaneous class was reserved for artifacts in the video such as entrained air, sticks, rocks, and plant matter.
> *2) Library training.* During this phase the system is trained to distinguish features between the different classes. Training is established using a Bayesian classifier that models the training data as a mixture of Gaussians (Bishop, 2000). Libraries are user-selected and may consist of any combination and number of classes.
> *3) Test class.* In this study, ninety percent of the images contained within each class were used for library training and 10% of the images were used for testing the performance of each library. Performance of the training library was computed and reported in terms of recall and precision. Successful class and library creation was established using a probability threshold of 80%.
> *4) Run classifier.* Unknown events in the processed pmbarivision files were identified by applying a specific training library. Results from the classifer were presented in a table referred to as a "confusion matrix" which reports both actual (user labelled) and predicted (classifier labelled) events. For each class, both precision and recall values were reported.

3.0 RESULTS

Spring Chinook Salmon

<u>General spring Chinook salmon run statistics:</u> The 2010 adult spring Chinook salmon run, as reported by USACE, was expected to pass McNary Dam between April 01 and June 08. Hourly counts from the fish counting stations at the Oregon and Washington shore fish ladders recorded the passage of 153,500 adult spring Chinook salmon at McNary Dam. In comparison to the 10-year average for this cohort (93,083 for the years 2000 to 2009), the 2010 season was considerably higher (165% of normal). According to the counting stations, 42,734 (27.8%) passed McNary Dam at the Washington shore fish ladder, and 110,766 (72.2%) passed at the Oregon shore fish ladder.

Active video monitoring: Video monitoring of the open and the closed lamprey orifice at weir 336 was performed between April 18 and May 20 to cover early and peak passage of the adult spring Chinook salmon run. All orifices on other weirs were closed during the video monitoring period of spring Chinook salmon. Videos from each lamprey orifice were captured by two cameras, one focused on the orifice itself, and one providing an expanded field of view inclusive of an area downstream from the opening. Active monitoring started on Sunday, April 18, after less than 2,400 (2.1% of the total run) adult spring Chinook salmon had passed the Oregon shore fish ladder. Video surveillance concluded on Thursday, May 20 after 88,662 adult spring Chinook salmon or 80.0% of the total run had passed the Oregon shore fish ladder at McNary Dam.

Underwater video monitoring of the open and the closed lamprey orifice during the spring Chinook salmon run was generally performed five hours per day (7am to 12pm) five days a week (Sun-Thu) between April 18 and May 15, and was extended to ten hours per day five days per week between May 16 and May 20 (see Appendix A). Expanding video footage to 10 hours a day allowed the analysis of diurnal interaction differences at orifices.

For data analyses, hourly counts from the fish counting station at the Oregon shore fish ladder were obtained for all video monitoring periods. During video monitoring hours, 26.1% (28,962) of the total adult spring Chinook salmon run passed through the Oregon shore fish ladder (see Appendix A). Throughout the entire adult spring Chinook salmon run, the lamprey orifice at the North side of weir 336 remained closed while the orifice at the South side remained opened.

Lamprey orifice interactions of adult spring Chinook salmon: Evaluation of spring Chinook salmon interactions at open and closed lamprey orifices was based on videos captured by the two cameras providing the extended field of view of both orifices. In cases where fish identification or interaction with the orifices was difficult to interpret, video files from the cameras focused on the orifices themselves were relied upon.

Presence of adult spring Chinook salmon at the open and closed lamprey orifice:
Presence of adult spring Chinook salmon at lamprey orifices during monitoring hours differed considerably between days, and between the open and closed orifice (Table 2). The total number of fish present in the field of view of the two cameras monitoring the closed orifice (North side) was 1,545 or 5.3% of the total adult spring Chinook salmon passage during video observations. Daily presence varied between 0 and 612 or 0.0% and 42.2% of the visual counts taken during the daily video monitoring hours. At the open orifice (South side), 427 or 1.5% of the total adult spring Chinook salmon count were present during monitoring hours. The number of fish present in the field of view of cameras monitoring the open orifice varied between 0 and 123 or 0.0% and 21.6% of the visual counts taken during the daily video monitoring hours (Table 2). Out of the 24 days of active monitoring: (1) presence of adult spring Chinook salmon at the open and closed orifice did not differ statistically for eight days (Table 2); (2) presence of adult spring Chinook salmon was statistically greater at the closed orifice than at the open orifice for ten days; (3) presence of adult spring Chinook salmon was statistically greater at the open orifice than the closed orifice for three days; and (4) no fish were observed at either orifice for three days. The overall proportional presence of fish at the closed orifice was statistically greater than the open orifice (Table 2).

Table 2: Presence of spring Chinook salmon at the closed and open lamprey orifice at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence closed orifice	Presence open orifice	% at closed orifice[c]	% at open orifice[d]	p-value
April 18	0700-1000	181	0	0	0.0	0.0	1.0
April 20	0700-1200	380	**26**[e]	2	6.8	0.5	<0.001
April 21	0700-1200	1675	18	31	1.1	1.9	0.054
April 22	0700-1200	1769	6	12	0.3	0.7	0.134
April 25	0700-1200	2334	**169**	79	7.2	3.4	<0.001
April 26	0700-1200	662	2	**13**	0.3	2.0	<0.001
April 27	0700-1200	888	6	8	0.7	0.9	0.589
April 28	0700-1200	1294	42	47	3.2	3.6	0.596
April 29	0700-1200	599	33	22	5.5	3.7	0.130
May 02	0700-1200	553	**52**	5	9.4	0.9	<0.001
May 03	0700-1200	979	**6**	0	0.6	0.0	0.014
May 04	0700-1200	2922	**8**	2	0.3	0.1	0.018
May 05	0700-1200	1781	**64**	21	3.6	1.2	<0.001
May 06	0700-1200	1451	**612**	10	42.2	0.7	<0.001
May 09	0700-1200	1578	N.C.[b]	N.C.	N.C.	N.C.	-
May 10	0700-1200	1204	N.C.	N.C.	N.C.	N.C.	-
May 11	1200-1500	569	75	**123**	13.2	21.6	<0.001
May 12	0700-1200	1637	**5**	0	0.3	0.0	0.025
May 13	0700-1200	1105	N.C.	N.C.	N.C.	N.C.	-
May 16	0700-1700	884	4	6	0.5	0.7	0.519
May 17	0700-1700	989	4	**17**	0.4	1.7	<0.001
May 18	0700-1700	644	**6**	1	0.9	0.2	0.007
May 19	0700-1700	1841	**406**	24	22.1	1.3	<0.001
May 20	0700-1700	1043	1	4	0.1	0.4	0.094
Totals		28962	**1545**	427	5.3	1.5	<0.001

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during video monitoring hours.
[b] No fish were counted on this day due to extuating circumstances (e.g., elevated turbidity or entrained air bubbles) that prevented the collection of video images.
[c] Percent of fish observed on video at the closed orifice relative to the total number of fish observed visually at the count window in the Oregon shore fish ladder during video monitoring hours.
[d] Percent of fish observed on video at the open orifice relative to the total number of fish observed visually at the count window in the Oregon shore fish ladder during video monitoring hours.
[e] The bolded number is statistically greater than the corresponding non-bolded number.

Diurnal variation of adult spring Chinook salmon presence at lamprey orifices: Due to equipment maintenance and repair on May 11, video monitoring was performed during afternoon hours (Table 2). Analysis of video footage from that day indicated that presence of spring Chinook salmon at lamprey orifices may be higher during afternoon hours. To determine if fishway passage and behavior at lamprey orifices differed between morning and afternoon hours, video monitoring was extended to 10 hours per day during the following week (May 16 to 20; Table 3). During this time period, 5,401 spring Chinook salmon were recorded by the fish counting station, with 55% (2,954) passing during morning hours, and 2,447 (45%) during afternoon hours. Overall passage of spring Chinook salmon during this week was greater statistically during morning hours compared to afternoon hours (Table 3).

Presence of spring Chinook salmon during morning hours ranged from 0 to 344 fish or 0.0 to 24.2% between May 16 and May 20 (Table 3); the total number of fish present at the orifices during morning hours represented 12% of the visual counts during that period. Presence of fish

during afternoon hours varied between 2 and 86 fish or 0.5 and 20.4% between May 16 and May 20 (Table 3); the total number of fish present at the orifices during afternoon hours represented 4.8% of the visual counts during that period. Presence of spring Chinook salmon was significantly higher during afternoon hours in comparison to morning hours on May 17, while the opposite was true for May 19. Overall, spring Chinook salmon passed the fish count window at statistically higher numbers during morning hours from May 16 to 20; additionally the fraction of fish detected at the lamprey orifices on video was statistically higher between 7am and 12pm (Table 3).

Table 3: Presence of spring Chinook salmon at the closed and open lamprey orifice at weir 336 during morning and afternoon video monitoring.

Date	Visual counts[a]	Visual counts[b] 0700 – 1200 (% of total)	Presence[c] 0700-1200 (% of AM total)	Visual counts[b] 1200 – 1700 (% of total)	Presence[c] 1200-1700 (% of PM total)	p-value
May 16	884	329 (37)	4 (1.2)	556 (63)	6 (1.1)	0.519
May 17	989	436 (44)	0 (0.0)	553 (56)	**21** (3.8)[d]	<0.001
May 18	644	169 (26)	4 (2.4)	475 (74)	3 (0.6)	0.702
May 19	1841	1420 (77)	**344** (24.2)	421 (23)	86 (20.4)	<0.001
May 20	1043	601 (58)	3 (0.5)	442 (42)	2 (0.5)	0.648
Totals	5401	2954 (55**)**	**355 (12.0)**	2447 (45)	118 (4.8)	<0.001

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours extending from 0700 to 1700..

[b] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours between specified hours of visual detection.

[c] Fish detected on video at a lamprey orifice. Paranthetical percentages reflect the percent of fish visually passing the count window that were detected on video at a lamprey orifice.

[d] The bolded number is statistically greater than the corresponding non-bolded number.

Time spent by adult spring Chinook salmon at lamprey orifices: The time each spring Chinook salmon was present in the vicinity of the lamprey orifices was recorded. For observations that occurred less than 0.5 seconds, the obervation was recorded as 0.5 seconds. For observations that extended longer than 0.5 seconds, the exact time period of observation was recorded. The time periods individual spring Chinook salmon spent at the closed orifice ranged from 0.5 to 97 seconds, while those at the open orifice ranged from 0.5 to 122 seconds. For the vast majority of time only part of the fish (e.g. caudal fin) was observed in the field of view of the cameras and the observation occurred for a fraction of a second (e.g., less than 0.5 seconds). Individual observations of the time that spring Chinook salmon spent in front of either an open or closed orifice were averaged across all fish observations in a given day (Table 4). Seventy five percent of the average values for a given monitoring day extending from April 18 to May 20 were less than or equal to 0.5 seconds in front of the closed orifice. Seventy eight percent of the average values for a given monitoring day were less than 0.5 seconds in front of the open orifice. No statistically significant differences were found between the average amount of time that fish spent at the open orifice relative to the closed orifice, with the exception of the afternoon monitoring period on May 11. Analysis of videos from that day indicated that fish observed at the open orifice spent a statistically greater amount of time (22.5s) than those oberved at the closed orifice (6.7s) (Table 4). A comparison of the average amount of time fish spent in front of the open (6.7 seconds) and closed (0.9 seconds) orifices over the entire video monitoring period (April 18-May 20) resulted in a statistically significant difference ($p<0.001$) (Table 4).

However, when the May 11 data was excluded from this analysis, averages of the time spent at orifices did not differ statistically (p=0.127).

Table 4: Time spent by spring Chinook salmon at the closed and open orifices at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence[c] closed orifice	Presence[c] open orifice	Avg. time[d] at closed orifice (s)	Avg. time[d] at open orifice (s)
April 18	0700-1000	181	0	0	N.A.	N.A.
April 20	0700-1200	380	26	2	0.5	0.5
April 21	0700-1200	1675	18	31	0.5	0.5
April 22	0700-1200	1769	6	12	0.5	0.5
April 25	0700-1200	2334	169	79	0.5	0.5
April 26	0700-1200	662	2	13	0.5	0.5
April 27	0700-1200	888	6	8	0.5	0.5
April 28	0700-1200	1294	42	47	0.5	0.5
April 29	0700-1200	599	33	22	0.5	0.5
May 02	0700-1200	553	52	5	0.5	0.5
May 03	0700-1200	979	6	0	0.5	N.A.
May 04	0700-1200	2922	8	2	0.5	0.5
May 05	0700-1200	1781	64	21	0.5	0.5
May 06	0700-1200	1451	612	10	0.5	0.5
May 09	0700-1200	1578	N.C.[b]	N.C.	N.A.	N.A.
May 10	0700-1200	1204	N.C.	N.C.	N.A.	N.A.
May 11	1200-1500	569	75	123	6.7	**22.5** (p<0.001)[e]
May 12	0700-1200	1637	5	0	0.5	N.A.
May 13	0700-1200	1105	N.C.	N.C.	N.A.	N.A.
May 16	0700-1700	884	4	6	4.7	0.7
May 17	0700-1700	989	4	17	0.5	0.5
May 18	0700-1700	644	6	1	1.2	2.0
May 19	0700-1700	1841	406	24	1.3	1.1
May 20	0700-1700	1043	1	4	2	0.5
Totals		28962	1545	427	0.9	**6.7** (p<0.001)

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours.
[b] No fish were counted on this day due to extuating circumstances (e.g., elevated turbidity or entrained air bubbles) that prevented the collection of video images.
[c] Fish detected on video at a lamprey orifice.
[d] Average time is calculated based on the total number of fish oberserved on video for a given day of monitoring.
[e] The bolded number is statistically greater than the corresponding non-bolded number.

<u>Adult spring Chinook salmon passage attempts:</u> One passage attempt by an adult spring Chinook salmon at the open orifice was observed during video monitoring (Table 5). The passage attempt was not successful and the salmon did not make contact with the weir or orifice.

Table 5: Passage attempt summary for spring Chinook salmon at the closed and open orifices at weir 336.

Date	Recording time	Visual counts[a]	# of attempts	% of visual count	% of run[b]
May 03	0700-1200	979	1	0.10	0.003

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours.
[b] The percent of total run reflects the number of fish observed at the orifice during video monitoring divided by the total number of fish enumerated at the Oregon shore fish count window for the entire duration of the seasonal run.

Summer Chinook Salmon

General summer Chinook salmon run statistics: The adult summer Chinook salmon run, as reported by USACE, passed McNary Dam from June 9 to August 8, 2010. Hourly counts from the fish counting stations at McNary Dam fish ladders recorded the passage of 66,526 adult summer Chinook salmon, with 38,138 (57.3%) passing the Washington shore, and 28,388 (42.7%) passing the Oregon shore. In comparison to the 10-year average of 62,885 established between 2000 and 2009, the 2010 run was slightly greater (106% of average).

Active video monitoring: Underwater video monitoring of the open and the closed lamprey orifice at weir 336 was performed by two cameras per orifice, one focused on the orifice itself, and one providing an expanded field of view inclusive of an area downstream from the opening. Videos were captured for selected periods of time during the summer Chinook salmon run to cover the early and peak passage periods (see Appendix B). During the first eleven days of video monitoring (June 9 to June 19), video data were difficult to interpret due to high turbidity following heavy rainfall. From June 20 to July 07, video monitoring of the open and closed lamprey orifices was performed for 10 hours per day (0700 to 1700) seven days a week. When video monitoring commenced on June 20, approximately 11,900 or 41.8% of the total adult summer Chinook salmon run had passed McNary through the Oregon shore fish ladder. After July 7 (18 days of monitoring), daytime video monitoring was terminated due to the installation of additional equipment for the following nighttime monitoring of lamprey. When daytime video monitoring ceased on July 7, approximately 23,918 adult summer Chinook salmon or 84.3% of the total run had passed the Oregon shore fish ladder at McNary Dam.

Hourly counts from the fish counting station at the Oregon shore fish ladder of McNary Dam were obtained for all video monitoring periods. During video monitoring hours (June 20 to July 7 from 0700 to 1700), 28.9% (8,198) of the total adult summer Chinook salmon run passed through the Oregon shore fish ladder (see Appendix B). For the first four days of video monitoring (June 20 through June 23), orifice status (open/closed) matched that of the spring Chinook run with the North side closed and the South side open. To evaluate if fish presence was linked to orifice status or the location of the orifice (North versus South side), the North side was intentionally opened after the first four days of monitoring and remained open for the duration of video monitoring (June 24 to July 7), and the South side was intentionally closed and remained closed for the duration of video monitoring.

Lamprey orifice interactions of adult summer Chinook salmon: Evaluation of summer Chinook salmon interactions at open and closed lamprey orifices was based on videos captured by the two cameras providing an extended field of view of both orifices. In cases where fish identification or interaction with the orifices was difficult to interpret, video files from the cameras focused on the orifices themselves were analyzed.

Presence of adult summer Chinook salmon at the open and closed lamprey orifice: Overall presence of adult summer Chinook salmon at the open and closed lamprey orifices did not differ statistically during video monitoring hours (Table 6). In general, presence of summer Chinook salmon at the two orifices was low, with 1.2% and 1.4% of the fish passing the visual count station at the Oregon shore fish ladder observed on video at the closed and open orifice,

respectively. The total number of fish present on video at the closed and open orifice was 101 and 112, respectively. Daily presence at the closed orifice varied between 0 and 32 fish or 0.0% and 5.3% of the visual counts taken during the daily video monitoring hours. Daily presence at the open orifice varied bewteen 0 and 25 fish or 0.0% and 5.5% of the visual counts taken during the daily video monitoring hours (Table 6). Out of the 18 days of active monitoring: (1) presence of adult summer Chinook salmon at the open and closed orifice did not differ statistically for 10 days; (2) presence of adult summer Chinook salmon was statistically greater at the closed orifice than at the open orifice for three days; and (3) presence of adult summer Chinook salmon was statistically greater at the open orifice than the closed orifice for five days (Table 6).

Table 6: Presence of summer Chinook salmon at the closed and open lamprey orifice at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence closed orifice	Presence open orifice	% at closed orifice[b]	% at open orifice[c]	p-value
June 20	0700-1700	426	**13**[d]	1	3.1	0.2	<0.001
June 21	0700-1700	445	**5**	0	1.1	0.0	0.025
June 22	0700-1700	464	2	3	0.4	0.6	0.648
June 23	0700-1700	608	**32**	4	5.3	0.7	<0.001
June 24	0700-1700	280	6	8	2.1	2.9	0.5892
June 25	0700-1700	442	5	**15**	1.1	3.4	0.001
June 26	0700-1700	456	9	**25**	2.0	5.5	0.002
June 27	0700-1700	428	3	**14**	0.7	3.3	<0.001
June 28	0700-1700	275	6	6	2.2	2.2	1.0
June 29	0700-1700	590	2	3	0.3	0.5	0.648
June 30	0700-1700	461	8	17	1.7	3.7	0.054
July 01	0700-1700	263	0	0	0.0	0.0	1.0
July 02	0700-1700	498	1	1	0.2	0.2	1.0
July 03	0700-1700	539	0	**4**	0.0	0.7	0.046
July 04	0700-1700	433	2	2	0.5	0.5	1.0
July 05	0700-1700	527	0	**6**	0.0	1.1	0.014
July 06	0700-1700	391	5	3	1.3	0.8	0.730
July 07	0700-1700	672	2	0	0.3	0.0	0.157
Totals		8198	101	112	1.2	1.4	0.450

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during video monitoring hours.
[b] Percent of fish observed on video at the closed orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[c] Percent of fish observed on video at the open orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[d] The bolded number is statistically greater than the corresponding non-bolded number.

<u>Location preference of summer Chinook salmon in the fishway:</u> Between June 20 and June 23, a statistically greater number of summer Chinook were observed at the closed orifice on the North side (2.7%) than at the open orifice on the South side (0.4%) (Table 7). Video monitoring data collected between June 20 and June 23 suggested a possible preference of summer Chinook salmon for the North side (closed) orifice relative to the South side (open) orifice. To evaluate if fish presence was linked to orifice status (open/closed) or the location of the orifice (North or South side), the closed North side was opened and the open South orifice was closed on June 24. Between June 24 and July 7, a statistically greater number of summer Chinook were observed at the open orifice on the North side (1.7%) than at the closed orifice on the South side

(0.8%) (Table 8). Hence, preference for the North side was likely related to factors other than the lamprey orifices.

Table 7: Presence of summer Chinook salmon at the closed (North side) and open (South side) lamprey orifice at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence North orifice	Presence South orifice	% at closed orifice[b]	% at open orifice[c]	p-value
June 20	0700-1700	426	**13**[d]	1	3.1	0.2	<0.001
June 21	0700-1700	445	**5**	0	1.1	0.0	0.025
June 22	0700-1700	464	2	3	0.4	0.6	0.648
June 23	0700-1700	608	**32**	4	5.3	0.7	<0.001
Totals		1943	**52**	**8**	2.7	0.4	<0.001

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during video monitoring hours.
[b] Percent of fish observed on video at the closed orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[c] Percent of fish observed on video at the open orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[d] The bolded number is statistically greater than the corresponding non-bolded number.

Table 8: Presence of summer Chinook salmon at the closed (South side) and open (North side) lamprey orifice at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence South orifice	Presence North orifice	% at closed orifice[b]	% at open orifice[c]	p-value
June 24	0700-1700	280	6	8	2.1	2.9	0.5892
June 25	0700-1700	442	5	**15**[d]	1.1	3.4	0.001
June 26	0700-1700	456	9	**25**	2.0	5.5	0.002
June 27	0700-1700	428	3	**14**	0.7	3.3	<0.001
June 28	0700-1700	275	6	6	2.2	2.2	1.0
June 29	0700-1700	590	2	3	0.3	0.5	0.648
June 30	0700-1700	461	8	17	1.7	3.7	0.054
July 01	0700-1700	263	0	0	0.0	0.0	1.0
July 02	0700-1700	498	1	1	0.2	0.2	1.0
July 03	0700-1700	539	0	**4**	0.0	0.7	0.046
July 04	0700-1700	433	2	2	0.5	0.5	1.0
July 05	0700-1700	527	0	**6**	0.0	1.1	0.014
July 06	0700-1700	391	5	3	1.3	0.8	0.730
July 07	0700-1700	672	2	0	0.3	0.0	0.157
Totals		6255	49	**104**	0.8	1.7	<0.001

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during video monitoring hours.
[b] Percent of fish observed on video at the closed orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[c] Percent of fish observed on video at the open orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[d] The bolded number is statistically greater than the corresponding non-bolded number.

<u>Time spent of adult summer Chinook salmon at lamprey orifices:</u> The time each summer Chinook salmon was present in the vicinity of the lamprey orifices was recorded. For observations that occurred less than 0.5 seconds, the obervation was recorded as 0.5 seconds. For observations that extended longer than 0.5 seconds, the exact time period of observation was recorded. The time periods individual summer Chinook salmon spent at the closed orifice

ranged from 1 to 13 seconds, while those at the open orifice ranged from 0.5 to 8 seconds. Individual observations of the time that summer Chinook salmon spent in front of either an open or closed orifice were averaged across all fish observations in a given day (Table 9). On any given monitoring day, no statistically significant differences were found between the average amount of time that fish spent at the open orifice relative to the closed orifice (Table 9). Additionally, over the course of the entire monitoring period, there was no statistical difference in the overall average amount of time that fish spent in front of a closed orifice (1.9 seconds) relative to an open orifice (1.8 seconds) (Table 9).

Table 9: Time spent of summer Chinook salmon at the closed and open orifices at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence[b] closed orifice	Presence[b] open orifice	Avg. time[c] at closed orifice (s)	Avg. time[c] at open orifice (s)
June 20	0700-1700	426	**13**[d]	1	1.6	2.0
June 21	0700-1700	445	5	0	1.2	N.A.
June 22	0700-1700	464	2	3	1.5	2.3
June 23	0700-1700	608	**32**	4	1.3	1.0
June 24	0700-1700	280	6	8	1.5	1.0
June 25	0700-1700	442	5	**15**	1.0	1.1
June 26	0700-1700	456	9	**25**	1.4	1.4
June 27	0700-1700	428	3	**14**	4.3	1.8
June 28	0700-1700	275	6	6	1.8	3.2
June 29	0700-1700	590	2	3	1.0	1.0
June 30	0700-1700	461	8	17	4.9	2.4
July 01	0700-1700	263	0	0	N.A.	N.A.
July 02	0700-1700	498	1	1	2.0	3.0
July 03	0700-1700	539	0	4	N.A.	1.8
July 04	0700-1700	433	2	2	4.0	4.0
July 05	0700-1700	527	0	6	N.A.	3.0
July 06	0700-1700	391	5	3	1.0	1.3
July 07	0700-1700	672	2	0	7.0	N.A.
Totals		8198	101	112	1.9	1.8

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours.
[b] Fish detected on video at a lamprey orifice.
[c] Average time is calculated based on the total number of fish oberserved on video for a given day of monitoring.
[d] The bolded number is statistically greater than the corresponding non-bolded number.

Adult summer Chinook salmon passage attempts: Passage of the lamprey orifices was not attempted by adult summer Chinook salmon during video monitoring.

Fall Chinook Salmon

General fall Chinook salmon run statistics: The adult fall Chinook salmon run, as reported by USACE, passed McNary Dam between August 9 and October 31, 2010. Hourly counts from the fish counting stations at McNary Dam fish ladders recorded the passage of 197,951 adult fall Chinook salmon, with 83,277 (42%) passing the Washington shore, and 114,674 (58%) passing the Oregon shore. The fall Chinook salmon run in 2010 was 171% of the 10-year average established between 2000 and 2009.

Active video monitoring: Underwater video monitoring was performed at the North and South side of the Oregon shore fish ladder. In contrast to earlier surveillance work for the spring and summer runs, all orifices were open during the fall run, and a total of four cameras captured video at both orifices of two consecutive weirs (weirs 336 and 337). Furthermore, the main purpose of the cameras was to evaluate lamprey passage success and behavior; hence single cameras were focused on single orifices and two cameras per orifice location were not used to provide a greater field of view as with video monitoring performed with the spring and summer run of Chinook salmon. Videos were captured for selected periods of time during the fall Chinook salmon run to cover the early and peak passage periods (see Appendix C). Video monitoring commenced August 15 and was performed five hours per day (0700 to 1200) five days a week (Sun-Thu) until September 30. When video monitoring commenced (August 15), 338 or 0.3% of the total adult fall Chinook salmon run had passed the Oregon shore fish ladder at McNary Dam. When video monitoring ceased September 30, 20,462 fish or 17.9% of the total run had passed the Oregon shore fish ladder at McNary Dam.

Hourly counts from the fish counting station at the Oregon shore fish ladder of McNary Dam were obtained for all video monitoring periods. During video monitoring hours (August 15 to September 30 from 0700 to 1200), 38.7% (44,310) of the total adult fall Chinook salmon run passed the Oregon shore fish ladder (see Appendix C).

Lamprey orifice interactions of adult fall Chinook salmon: Fall Chinook salmon were never observed at any of the four open lamprey orifices during the video monitoring period between August 15 and September 30. .

Sockeye Salmon

General Sockeye salmon run statistics: The Sockeye salmon run at McNary Dam began with the first sighting of a Sockeye salmon at the Washington shore fish ladder on May 28, 2010. The run peaked during the last week of June, and ended October 7 with the last fish counted at the Washington shore fish ladder. A total of 278,799 Sockeye salmon passed McNary Dam in 2010, 399% of the 10-year average of 69,820 established between 2000 and 2009. Three quarters of the 2010 Sockeye salmon run (209,180) passed McNary Dam through the Washington shore fish ladder, and the remaining 25% (69,619) passed through the Oregon shore fish ladder.

Active video monitoring: Underwater video monitoring of Sockeye salmon (Appendix D) was performed at specific locations and time periods coinciding with active video monitoring of the summer and fall Chinook salmon runs. During the summer Chinook salmon run, a total of four cameras captured expanded views of the open and closed orifices of weir 336 ten hours per day (0700 to 1700) seven days per week between June 20 and July 7. During the fall Chinook salmon run, four cameras captured video at both open orifices of two consecutive weirs (weirs 336 and 337) five hours per day (0700 to 1200) five days per week (Sun-Thu) between August 15 and September 30. No video was collected between July 8 and August 14.

Approximately 1,280 Sockeye salmon or 1.8% of the total Oregon shore fish ladder Sockeye run passed the ladder between the start of the run and the first day of video monitoring (June

20). An additional 36% (24,774) of the Sockeye run passed the Oregon shore fish ladder between the summer and fall Chinook salmon monitoring period (between July 7 and August 15). No Sockeye salmon passed the Oregon shore fish ladder after the completion of video monitoring (September 30). During video monitoring hours, close to 50% (34,127) of the total Sockeye salmon run passed the Oregon shore fish ladder (see Appendix D). Hourly counts from the fish counting station at the Oregon shore fish ladder at McNary Dam were obtained for all video monitoring periods.

Lamprey orifice interactions of adult Sockeye salmon: Between June 20 and July 7, evaluation of Sockeye salmon interactions at open and closed lamprey orifices was based on videos captured by the two cameras providing an extended field of view of both orifices at weir 336. In cases where fish identification or interaction with the orifices was difficult to interpret, video files from the cameras focused on the orifices themselves were analyzed. Between August 15 and September 30, evaluation of Sockeye salmon interactions of the four open orifices on weirs 336 and 337 were based on a single camera at each location directed at the orifice.

Presence of adult Sockeye salmon at the open lamprey orifice: Approximately 21,350 Sockeye salmon, nearly a third of the entire run passing the Oregon shore fish ladder, passed between June 2 and June 6. Nearly three quarters of these fish (16, 500) passed during the hours of video observation. During this 5-day period, no Sockeye salmon were observed on video at the closed orifice of weir 336. During this 5-day period, 7 Sockeye salmon were observed at the open orifice of weir 336, and all seven fish attempted to pass through the orifice (Table 10). The seven fish that attempted to pass the open orifice represented 0.04% of the total fish enumerated at the Oregon shore fish count window during the video monitoring period, 0.05% of the daily count, and 0.016% of the total seasonal run (Table 10).

Table 10: Presence and passage attempts of adult Sockeye salmon at the open lamprey orifice at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence open orifice	% at open orifice[b]	# of attempts	% of daily count[c]	% of run[d]
July 02	0700-1700	3247	1	0.03	1	0.04	0.002
July 03	0700-1700	2989	2	0.07	2	0.08	0.005
July 04	0700-1700	3406	1	0.03	1	0.04	0.002
July 05	0700-1700	3787	2	0.05	2	0.07	0.005
July 06	0700-1700	3071	1	0.03	1	0.04	0.002
Totals		16500	7	0.04	7	0.05	0.016

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during video monitoring hours.
[b] Percent of fish observed on video at the open orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[c] The percent of daily count reflects the number of fish observed at the orifice during video monitoring divided by the total number of fish enumerated at the Oregon shore fish count window for the given day.
[d] The percent of total run reflects the number of fish observed at the orifice during video monitoring divided by the total number of fish enumerated at the Oregon shore fish count window for the entire duration of the seasonal run.

Time spent of adult Sockeye salmon at lamprey orifices: The time each Sockeye salmon spent in the vicinity of the open lamprey orifice on weir 336 was recorded. Individual observations were averaged across all fish observed on a given day (Table 11). Daily average values ranged from 2.5 to 3.5 seconds, with the overall average between July 2 and July 6 of 3.0 seconds.

Table 11: Time spent of Sockeye salmon at the open orifices at weir 336 during video monitoring.

Date	Recording time	Visual counts[a]	Presence open orifice[b]	Avg. time[c] at open orifice (s)
July 02	0700-1700	3247	1	3.0
July 03	0700-1700	2989	2	2.5
July 04	0700-1700	3406	1	3.0
July 05	0700-1700	3787	2	3.5
July 06	0700-1700	3071	1	3.0
Totals		16500	7	3.0

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours.
[b] Fish detected on video at a lamprey orifice.
[c] Average time is calculated based on the total number of fish oberserved on video for a given day of monitoring.

Adult Sockeye salmon passage attempts: Passage attempts were made by all seven adult Sockeye salmon observed at the open orifice of weir 336 (Table 11). One passage attempt was successful, while the remaining salmon did not fully pass through the orifice. Passage attempts did not visually appear to negatively impact the fish.

Steelhead

General steelhead run statistics: The 2010 adult steelhead run at McNary Dam, as reported by USACE, started on April 1 and counting concluded October 31. Hourly counts from the fish counting stations at McNary Dam fish ladders recorded the passage of 262,513 adult steelhead at McNary Dam in 2010, with 59,754 (22.8% passing the Washington shore, and 202,759 (77.2%) passing the Oregon shore. Approximately 66% of the total run was clipped hatchery steelhead and 34% were unclipped wild steelhead. In comparison to the 10-year average of 257,489 established between 2000 and 2009, the 2010 run was slightly greater (102% of average).

Active video monitoring: Underwater video monitoring of steelhead (Appendix E) was performed at specific locations and time periods coinciding with active video monitoring of the spring, summer, and fall Chinook salmon runs. During the spring Chinook salmon run, a total of four cameras captured expanded views of the open and closed orifices of weir 336 five hours per day (0700 to 1200) five days per week (Sun-Thu) between April 18 and May 15, and ten hours per day five days per week between May 16 and May 20. During the summer Chinook salmon run, a total of four cameras captured expanded views of the open and closed orifices of weir 336 ten hours per day (0700 to 1700) seven days per week between June 20 and July 7. During the fall Chinook salmon run, four cameras captured video at both open orifices of two consecutive weirs (weirs 336 and 337) five hours per day (0700 to 1200) five days per week (Sun-Thu) between August 15 and September 30.

Approximately 1,444 steelhead or 0.7% of the total Oregon shore fish ladder steelhead run passed the ladder between the start of the run and the first day of video monitoring (April 18). An additional 0.3% (685) and 22.9% (46,391) of the steelhead run passed the Oregon shore fish ladder between the spring and summer Chinook salmon monitoring period (May 20 and June

20) and the summer and fall Chinook monitoring period (July 7 and August 15), respectively. After video surveillance was completed, 37,225 (18.4%) steelhead passed through the Oregon shore fish ladder. During video monitoring hours, 22.0% (44,569) of the total steelhead run passed the Oregon shore fish ladder (see Appendix E). Hourly counts from the fish counting station at the Oregon shore fish ladder at McNary Dam were obtained for all video monitoring periods.

Lamprey orifice interactions of steelhead: During the spring and summer Chinook monitoring periods (April 18 to May 20 and June 20 to July 7), adult steelhead interactions with lamprey orifices were based on videos captured by the two cameras providing the extended field of view of the open and closed orifices of weir 336. During the fall Chinook salmon monitoring period (August 15 to September 30), adult steelhead interactions with lamprey orifices were based on videos captured with a single camera located at each orifice on weirs 336 and 337.

Presence of adult steelhead at the open lamprey orifices: All video observations of steelhead occurred during September, the month in which almost 50% (99,165) of the Oregon shore run passed the fish ladder. A total of six adult fish were observed during three days in September (Table 12). Fish were observed at the open orifices on both sides of weir 337 at approximately equal presence: approximately four steelhead at the North side orifice and two steelhead at the South side orifice (Table 12).

Table 12: Presence of adult steelhead at the open lamprey orifices at weir 337 during video monitoring.

Date	Recording time	Visual counts[a]	Presence North side orifice	Presence South side orifice	% North side orifice[b]	% South side orifice[c]	% of daily count[d]	% of run[e]
Sep 15	0700-1200	1158	3	1	0.26	0.09	0.52	0.006
Sep 19	0700-1200	1072	0	1	0	0.09	0.15	0.002
Sep 30	0700-1200	812	1	0	0.12	0	0.21	0.002
Totals		3042	4	2	0.20	0.09	0.31	0.009

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during video monitoring hours.
[b] Percent of fish observed on video at the North side orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[c] Percent of fish observed on video at the South side orifice relative to the total number of fish observed visually at the count window in the Oregon Shore fish ladder during video monitoring hours.
[d] The percent of daily count reflects the number of fish observed at the orifice during video monitoring divided by the total number of fish enumerated at the Oregon shore fish count window for the given day.
[e] The percent of total run reflects the number of fish observed at the orifice during video monitoring divided by the total number of fish enumerated at the Oregon shore fish count window for the entire duration of the seasonal run.

Time spent of adult steelhead at lamprey orifices: The time each steelhead spent in the vicinity of lamprey orifices was recorded. Individual observations were averaged across all fish observed on a given day (Table 13). Daily average values were 2.7 and 4.0 seconds on the North side orifice, and 3.0 and 41.0 seconds on the South side orifice (Table 13).

Table 13: Time spent of steelhead at the open orifices at weir 337 during video monitoring.

Date	Recording time	Visual counts[a]	Presence North side orifice[b]	Avg. time[c] at North side orifice (s)	Presence South side orifice[b]	Avg. time[c] at South side orifice (s)
Sep 15	0700-1200	1158	3	2.7	1	41
Sep 19	0700-1200	1072	0	N.A.	1	3
Sep 30	0700-1200	812	1	4.0	0	N.A.
Totals		3042	4	3.0	2	22.0

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours.
[b] Fish detected on video at a lamprey orifice.
[c] Average time is calculated based on the total number of fish oberserved on video for a given day of monitoring.

Adult steelhead passage attempts: Passage of the lamprey orifices was not attempted by adult steelhead during video monitoring.

American Shad

General shad run statistics: The majority of adult American shad run, as reported by USACE, passed McNary Dam in 2010 between May 16 and August 31. Counts from the fish counting stations at McNary Dam fish ladders recorded the passage of 276,673 American shad, with 240,579 (87%) passing the Oregon shore, and 36,094 (13%) passing the Washington shore. The number of American shad passing McNary Dam in 2010 was considerably less than the 10-year average established between 2000 and 2009.

Active video monitoring: Underwater video monitoring of American shad (Appendix F) was performed at specific locations and time periods coinciding with active video monitoring of the spring, summer, and fall Chinook salmon runs. During the spring Chinook salmon run, a total of four cameras captured expanded views of the open and closed orifices of weir 336 five hours per day (0700 to 1200) five days per week (Sun-Thu) between April 18 and May 15, and ten hours per day five days per week between May 16 and May 20. During the summer Chinook salmon run, a total of four cameras captured expanded views of the open and closed orifices of weir 336 ten hours per day (0700 to 1700) seven days per week between June 20 and July 7. During the fall Chinook salmon run, four cameras captured video at both open orifices of two consecutive weirs (weirs 336 and 337) five hours per day (0700 to 1200) five days per week (Sun-Thu) between August 15 and September 30.

No shad passed the Oregon shore fish ladder before the start of video monitoring (April 18). Approximately 10.3% (26,058) and 25.3% (60,750) of the American shad run passed the Oregon shore fish ladder between the spring and summer Chinook salmon monitorying period (May 20 and June 20) and the summer and fall Chinook monitoring period (July 7 and August 15), respectively. During video monitoring hours, 33.7% (80,926) of the total American shad run passed the Oregon shore fish ladder (see Appendix F). Hourly counts from the fish counting station at the Oregon shore fish ladder at McNary Dam were obtained for all video monitoring periods.

Lamprey orifice interactions of American shad: During the spring and summer Chinook monitoring periods (April 18 to May 20 and June 20 to July 7), American shad interactions with lamprey orifices were based on videos captured by the two cameras providing the extended field of view of the open and closed orifices of weir 336. During the fall Chinook salmon monitoring period (August 15 to September 30), American shad interactions with lamprey orifices were based on videos captured with a single camera located at each orifice on weirs 336 and 337. American shad were never observed at any of the lamprey orifices during the video monitoring period, despite the fact that monitoring period covered more than a third of the shad run through the Oregon shore fishway at McNary Dam.

Pacific Lamprey

General Pacific lamprey run statistics: Hourly daytime counts from the fish counting stations at McNary Dam fish ladders recorded the passage of 825 adult lamprey between May 1 and September 30, 2010, with 83.0 % (685) passing the Oregon shore fish ladder and 17.0% passing the Washington shore fish ladder. In comparison to the 10-year average of 4,658, established between 2000 and 2009, the 2010 run was considerably smaller (17.7% of average). For the second year in a row, USACE also performed nighttime video counting at the fish count windows of lamprey passing McNary Dam between July 1 and September 30. A total of 345 lamprey were recorded during nighttime counting, again with a greater percentage passing the Oregon shore fish ladder (72.8%) than the Washington shore fish ladder (27.2%). The number of lamprey passing McNary Dam at night in 2010 (345) was roughly half the number that passed at night in 2009 (666).

Active video monitoring: Hourly counts from the fish counting station at the Oregon shore fish ladder of McNary Dam were obtained for all video monitoring periods at lamprey orifices. Underwater video monitoring was performed at the North and South side of the Oregon shore fish ladder. All orifices were opened on July 15, and a total of four cameras were in place at both orifices of two consecutive weirs (weirs 336 and 337). The main purpose of the cameras was to evaluate lamprey passage success and behavior; hence single cameras were focused on single orifices and two cameras per orifice location were not used to provide a greater field of view as with video monitoring performed with the spring and summer run of Chinook salmon. Videos were captured for selected periods of time during the lamprey run to cover the early and peak passage periods (Appendix G and H). On July 8, the first lamprey of the seasonal run in the Oregon shore fish ladder was observed at the fish count window. At the start of video monitoring on July 15, 3.2% (22 lamprey) of the total seasonal run of lamprey had been observed at the fish count window. From July 15 to August 5, video monitoring at lamprey orifices was performed six to seven hours per night (2200 – 0400 or 0500) seven days per week (Figure 5a). Between August 15 and September 30, video monitoring of lamprey orifices was performed five hours per day (0700 to 1200) five days per week (Figure 5b). Monitoring was terminated September 30 because of greatly diminished numbers of lamprey passing through the McNary Dam fish ladders. Only three adult lamprey (0.4% of the total run) were observed at the Oregon shore fish count window after September 30.

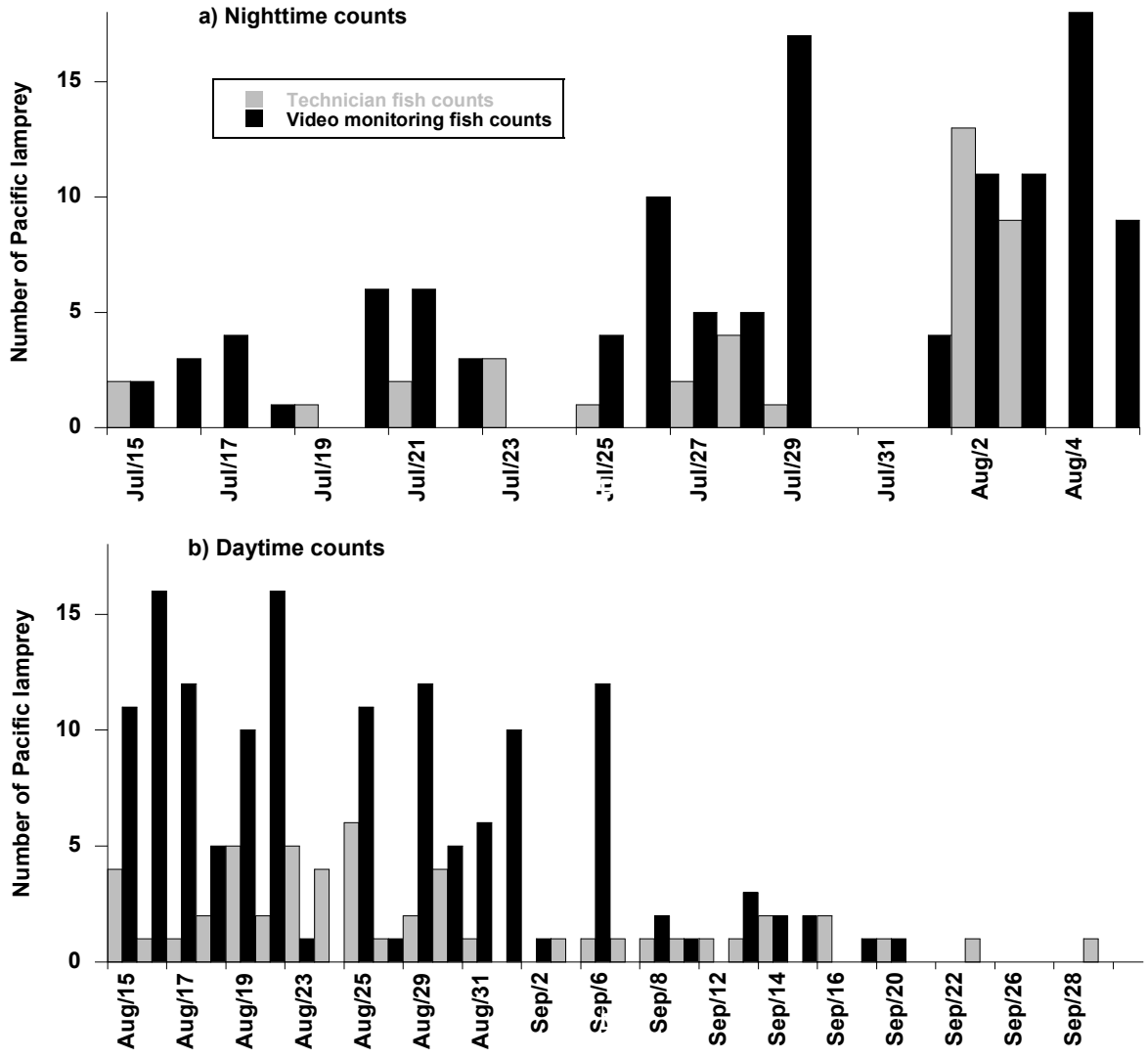

Figure 5: Comparison of nighttime (a) and daytime (b) counts of lamprey by fish counting technicians at the fish count window and video at lamprey orifices.

During daytime video monitoring hours at lamprey orifices (Figure 5b), a total of 141 lamprey were observed in the vicinity of the lamprey orifices; over a similar duration of time, 52 lamprey were observed passing the fish count window. During nighttime video monitoring hours at lamprey orifices (Figure 5a), a total of 119 lamprey were observed in the vicinity of the lamprey orifices; over a similar duration of time, 38 lamprey were observed passing the fish count window. Overall, a much higher number of lamprey were observed in the vicinity of the lamprey orifices than were observed at the fish count window.

Lamprey orifice interactions of adult Pacific lamprey: Evaluation of lamprey interactions with the four orifices on weirs 336 and 337 were based on videos captured by individual cameras focused on each orifice. Videos were analyzed for presence, passage attempts and success rates, time duration, and behavior at open orifices.

Presence of adult Pacific lamprey at open orifices: In 2009, 49.6% of the seasonal lamprey run in the Oregon shore ladder passed the fish count window at night. Therefore, in 2010 the lamprey orifice video monitoring system was initially designed and operated for nightime underwater viewing. Several technical issues arose immediately that were addressed as part of this study. Specifically, the infrared light built into each camera proved inadequate to illuminate each lamprey orifice. Four external infrared lights were purchased and a single light was installed with each camera. A single external light mounted with a camera proved inadequate to illuminate each lamrey orifice. Two external infrared lights were then added to a camera which provided adequate illumination of the lamprey orifice. However, once the lighting issue was resolved, there was inadequate time to purchase four additional lights given the timing of the lamprey run. Therefore, during nighttime video monitoring of lamprey orifices, only two of the four open orifices had adquate lighting. The lighting systems were cycled between the four cameras on roughly a semi-weekly basis over the duration video monitoring. During nights when no lights were on a specific camera, results for that camera were presented as 'not counted' (N.C.) in Table 14. Additionally, missing visual counts from the fish count technician occurred during five nights and were also identified as 'not counted' (Table 14).

During nights when video data was available for orifices located on opposite sites of the same weir, observed lamprey numbers were compared statistically to determine if fish preferred the North side or South side orifice. These orifice preference comparisons were made for four days between July 16 and 19 for weir 336, and for a total of seven days between July 28 and August 5 for weir 337 (Table 14). Presence of lamprey at orifices of weir 336 did not differ significantly on a nightly basis. Presence at the North side orifice of weir 337 was significantly greater than presence at the South side during two out of seven nights (Table 14). In addition to the statistical comparison of lamprey presence at opposite orifices of a specific weir on an individual night basis, lamprey presence totals for the 4-day and 7-day periods for weir 336 and 337, respectively, were compared statistically. Over the monitoring period, lamprey presence at the North side orifice of weir 337 was greater statistically than presence at the South side orifice. Presence at the lamprey orifices of 336 did not differ significantly over the monitoring period.

During daytime video monitoring of lamprey orifices, several time periods were characterized by large amounts of entrained air that prevented the collection of video. During these periods of time, results from a given camera are presented as 'not counted' (N.C.) in Table 15. Comparisons of lamprey presence at the South and North side orifices were performed for orifices of a single weir. Statistical comparisons of lamprey presence at weir 336 were possible for 27 days during the monitoring period between August 15 and September 30, and 29 days for weir 337. Presence of lamprey at the North and South side orifice did not differ significantly on a daily for weir 336. A significantly greater number of lamprey were observed at the South side orifice of weir 337 during one day (August 16). In addition to the statistical comparison of lamprey presence at opposite orifices of a specific weir on a daily basis, lamprey presence totals for the entire period of video monitoring were compared statistically. Over the video monitoring period, the total number of lamprey did not differ significantly between the North and South side of either weir 336 or 337.

Table 14: Presence of adult Pacific lamprey at orifices at weirs 336 and 337 during nighttime video monitoring.

Date	Recording time	Visual counts[a]	Presence North side orifice 336	Presence South side orifice 336	Presence North side orifice 337	Presence South side orifice 337
July 15	2200-0500	2	1	N.C.[b]	N.C.	1
July 16	2200-0500	0	2	1	N.C.	N.C.
July 17	2200-0500	0	2	2	N.C.	N.C.
July 18	2200-0500	0	0	1	N.C.	N.C.
July 19	2200-0500	1	0	0	N.C.	N.C.
July 20	2200-0500	0	N.C.	3	N.C.	3
July 21	2200-0500	2	N.C.	4	N.C.	2
July 22	2200-2400	0	N.C.	0	N.C.	3
July 23	2200-0400	3	N.C.	N.C.	N.C.	N.C.
July 24	2200-0400	0	N.C.	N.C.	N.C.	N.C.
July 25	2200-0400	1	N.C.	2	N.C.	2
July 26	2200-0400	0	N.C.	7	N.C.	3
July 27	2200-0400	2	N.C.	4	N.C.	1
July 28	2200-0400	4	N.C.	N.C.	3	2
July 29	2200-0400	1	N.C.	N.C.	8	9
July 30	2200-0400	N.C.	N.C.	N.C.	N.C.	N.C.
July 31	2200-0400	N.C.	N.C.	N.C.	N.C.	N.C.
Aug 1	2200-0400	N.C.	N.C.	N.C.	4	0
Aug 2	2200-0400	13	N.C.	N.C.	7	4
Aug 3	2200-0400	9	N.C.	N.C.	**9 (p=0.006)**	2
Aug 4	2200-0400	N.C.	N.C.	N.C.	**13 (p=0.035)**	5
Aug 5	2200-0400	N.C.	N.C.	N.C.	6	3
Totals		**38**	**5**	**24**	**50**	**40**

[a] Numbers established by fish count technicians at the Oregon shore fish ladder using video taken during monitoring hours.

[b] During nights when no lights were on a specific camera, results for that camera were presented as 'not counted' (N.C.).

Table 15: Presence of adult Pacific lamprey at orifices at weirs 336 and 337 during daytime video monitoring.

Date	Recording time	Visual counts[a]	Presence North side orifice 336	Presence South side orifice 336	Presence North side orifice 337	Presence South side orifice 337
Aug 15	0700-1200	4	5	2	2	2
Aug 16	0700-1200	1	N.C.[b]	7	2	**7** (p=0.045)[c]
Aug 17	0700-1200	1	2	2	5	3
Aug 18	0700-1200	2	1	3	0	1
Aug 19	0700-1200	5	1	2	4	3
Aug 22	0700-1200	2	6	3	3	4
Aug 23	0700-1200	5	1	0	0	0
Aug 24	0700-1200	4	0	0	N.C.	N.C.
Aug 25	0700-1200	6	5	3	1	2
Aug 26	0700-1200	1	1	0	N.C.	N.C.
Aug 29	0700-1200	2	2	1	5	4
Aug 30	0700-1200	4	0	0	2	3
Aug 31	0700-1200	1	2	1	3	0
Sep 1	0700-1200	0	2	4	1	3
Sep 2	0700-1200	0	1	0	0	0
Sep 5	0700-1200	1	N.C.	N.C.	N.C.	N.C.
Sep 6	0700-1200	1	4	6	0	2
Sep 7	0700-1200	1	N.C.	N.C.	N.C.	N.C.
Sep 8	0700-1200	1	2	N.C.	N.C.	N.C.
Sep 9	0700-1200	1	N.C.	N.C.	N.C.	1
Sep 12	0700-1200	1	N.C.	N.C.	0	0
Sep 13	0700-1200	1	1	0	2	0
Sep 14	0700-1200	2	N.C.	N.C.	0	2
Sep 15	0700-1200	0	1	0	1	0
Sep 16	0700-1200	2	N.C.	N.C.	0	0
Sep 19	0700-1200	0	0	0	0	1
Sep 20	0700-1200	1	0	0	1	0
Sep 21	0700-1200	0	0	0	0	0
Sep 22	0700-1200	0	0	0	0	0
Sep 23	0700-1200	1	0	0	0	0
Sep 26	0700-1200	0	0	0	0	0
Sep 27	0700-1200	0	0	0	0	0
Sep 28	0700-1200	0	0	0	0	0
Sep 29	0700-1200	1	0	0	0	0
Sep 30	0700-1200	0	0	0	0	0
Totals		52	37	34	32	38

[a] Numbers established by fish count technicians at the Oregon shore fish ladder during monitoring hours.
[b] No fish were counted on this day due to extuating circumstances (e.g., elevated turbidity or entrained air bubbles) that prevented the collection of video images.
[c] The bolded number is statistically greater than the corresponding non-bolded number.

Passage success of adult Pacific lamprey at orifices: Of all 260 lamprey observed during night- and daytime monitoring, 50.4% passed the orifices successfully. Of all lamprey observed during nighttime monitoring, 42.9% (51 fish) passed orifices successfully, 10% (12 fish) attempted but failed orifice passage, and 47.1% (56 fish) swam away from the orifice without a passage attempt (Table 16). The fraction of successful attempts at orifice passage was not

statistically different than the fraction of failed attempts at orifice passage for any of the orifices on weirs 336 and 337.

Table 16: Passage success of adult Pacific lamprey through orifices at weirs 336 and 337 during nighttime monitoring.

North side orifice 336			South side orifice 336			North side orifice 337			South side orifice 337		
Total	Pass	No Pass	Total	Pass	No Pass	Total	Pass	No Pass	Total	Pass	No Pass
5	1	4	24	10	14	50	20	30	40	20	20

During daytime monitoring, 56.7% (80 fish) of all individuals observed at the four orifices passed successfully, 9.2% (13 fish) attempted but failed orifice passage, and 34.1% (48 fish) swam away from the orifice without a passage attempt (Table 17). The fraction of failed attempts on the South side of weir 336 was statistically greater than the fraction of successful attempts at orifice passage. The fraction of failed attempts on the North side of weir 336 was not statistically different than the fraction of successful attempts at orifice passage. The fraction of successful attempts at passage of both orifices on weir 337 was statistically greater than the fraction of failed attempts at passage of either orifice

Table 17: Passage success of adult Pacific lamprey through orifices at weirs 336 and 337 during daytime monitoring.

North side orifice 336			South side orifice 336			North side orifice 337			South side orifice 337		
Total	Pass	No Pass	Total	Pass	No Pass	Total	Pass	No Pass	Total	Pass	No Pass
37	16	21	34	8	26	32	30	2	38	26	12

<u>Passage behavior of adult Pacific lamprey at orifices during nighttime monitoring</u>: The majority of lamprey observed in the vicinity of lamprey orifices during nighttime monitoring displayed one of the following behaviors:

a) Direct passage without attachment to substrate;
b) Attachment in front or directly in the orifice (position 1), followed by burst swimming through the orifice;
c) Orifice passage and attachment upstream of the orifice with tail/caudal fin still visible in the orifice (position 2);
d) Both positions 1 and 2.

All other behaviors observed during video monitoring (e.g., simply swimming through the camera's field of view) were classified as 'other'. While all lamprey with successful passage displayed one or behavior listed above (a-d), behavior categorized as 'other' was only displayed by lamprey with failed passage attempts or without passage attempts.

A total of 51 lamprey successfully passed through open orifices during nighttime video monitoring. Only four fish (7.8%) swam directly through the orifice without attaching in front of, directly in, or upstream of the orifice. In contrast, 41.2% of the lamprey that successfully passed orifices exhibited both position 1 and position 2 (Table 18). More than a third of the lamprey that successfully passed orifices swam through the orifice and then subsequently attached to substrate (35.3% in position 2), while 15.7% attached in front or directly in the orifice (position 1).

Lamprey with successful orifice passage during nighttime monitoring spent on average 72.7 seconds in the camera's field of view (StDev: 103.4). Lamprey swimming directly through the

orifice spent, on average, the shortest amount of time in the camera's field of view (9.0 s). Fish observed in both position 1 and 2 during passage spent the greatest amount of time in the camera's field of view (108.7 s). Lamprey attaching in front of or in the orifice (position 1) spent an average of 43.6 seconds in view and those attaching upstream after passage (position 2) spent an average of 57.7 seconds in view (Table 18).

Table 18: Behavior of lamprey successfully passing open orifices at weirs 336 and 337 during nighttime video monitoring.

Behavior	North side orifice 336 (%)	South side orifice 336 (%)	North side orifice 337 (%)	South side orifice 337 (%)	All orifices combined (%)	Avg. time (s) spent in view (StDev)
Direct passage	0	0	15.0	5.0	7.8	9.0 (12.7)
Position 1	0	0	25.0	15.0	15.7	43.6 (20.6)
Position 2	0	20.0	40.0	40.0	35.3	57.7 (44.7)
Position 1 and 2	100	80.0	20.0	40.0	41.2	108.7 (148.8)

A total of 68 lamprey either failed their passage attempt or swam out of the camera's field of view without a passage attempt during nighttime video monitoring. Over 80% of these fish displayed behavior categorized as 'other', indicating that these lamprey did not attach in front of, directly in, or upstream of the orifice but instead oriented themselves towards the fishway sidewall before swimming upward along the weir (Table 19). Of the lamprey attaching to substrate and subsequently failing to pass through the lamprey orifice, 10.3% exhibited position 1, 4.4% exhibited position 2, and 2.9% exhibited both positions 1 and 2 (Table 19). Lamprey not passing the orifice after being observed in position 1 did not attempt passage or were pushed downstream by the current when attempting passage. Those observed in position 2 or in both positions 1 and 2 passed through the orifice from the downstream to upstream direction, and then were pushed back through the same orifice in the opposite direction.

Lamprey not attempting passage or with failed passage during nighttime monitoring spent on average 29.1 seconds in the camera's field of view (StDev: 50.9). Lamprey that simply swam through the camera's field of view or attached to the side walls spent, on average, 25.4 seconds in the camera's field of view (Table 19). Lamprey attaching in front of or in the orifice (position 1) spent an average of 36.6 seconds in view. Those attaching upstream after orifice passage (position 2) before being pushed downstream through the orifice spent an average of 71.7 seconds in view (Table 19). Fish observed in both position 1 and 2 before being pushed downstream by the current spent an average of 40 seconds in the camera's field of view.

Table 19: Behavior of lamprey not passing open orifices at weirs 336 and 337 during nighttime video monitoring.

Behavior	North side orifice 336 (%)	South side orifice 336 (%)	North side orifice 337 (%)	South side orifice 337 (%)	All orifices combined (%)	Avg. time (s) spent in view (StDev)
Position 1	0	0	16.7	10.0	10.3	36.6 (54.7)
Position 2	0	0	10.0	0	4.4	71.7 (71.5)
Position 1 and 2	0	0	6.7	0	2.9	40.0 (0.0)
Other	100	100	66.7	90.0	82.4	25.4 (50.2)

Passage behavior of adult Pacific lamprey at orifices during daytime monitoring: Lamprey monitored at orifices during daytime displayed similar behaviors observed during nighttime video monitoring. Among the 80 lamprey successfully passing through open orifices during daytime video monitoring, 5% swam directly through the orifice without attaching in front of, directly in, or upstream of the orifice. A little less than a third of the lamprey that successfully passed orifices attached in front of or directly in the orifice (30.0% in position 1), 33.8% swam through the orifice and then subsequently attached to substrate (position 2), and 31.2% exhibited both positions 1 and 2 (Table 20).

Lamprey with successful orifice passage spent an average of 70.2 seconds in the camera's field of view (Stdev: 74.2). Lamprey swimming directly through the orifice spent, on average, the shortest amount of time in the camera's field of view (6.2 s). Fish observed in both position 1 and 2 during passage spent the greatest amount of time in the camera's field of view (88.9 s). Lamprey attaching in front of or in the orifice (position 1) spent an average of 42.8 seconds in view and those attaching upstream after passage (position 2) spent an average of 86.6 seconds in view (Table 20).

Table 20: Behavior of lamprey successfully passing open orifices at weirs 336 and 337 during daytime video monitoring.

Behavior	North side orifice 336 (%)	South side orifice 336 (%)	North side orifice 337 (%)	South side orifice 337 (%)	All orifices combined (%)	Avg. time (s) spent in view (StDev)
Direct passage	6.2	12.5	6.7	0	5.0	6.2 (3.0)
Position 1	12.5	25.0	33.3	61.538.5	30.0	42.8 (45.6)
Position 2	56.3	37.5	16.7	38.5	33.8	86.6 (99.0)
Position 1 and 2	25.0	25.0	43.3	23.1	31.2	88.9 (58.7)

A total of 61 lamprey either failed their passage attempt or swam out of the camera's field of view without a passage attempt during daytime video monitoring. Roughly 80% of these fish displayed behavior categorized as 'other', indicating that these fish did not attach in front of, directly in, or upstream of the orifice but instead oriented themselves towards the fishway sidewall before swimming upward along the weir (Table 21). Of the lamprey attaching to substrate and subsequently failing to pass through the lamprey orifice, 9.8% exhibited position 1, 4.9% exhibited position 2, and 6.6% exhibited both positions 1 and 2 (Table 21). Lamprey not passing the orifice after being observed in position 1 did not attempt passage or were pushed downstream by the current when attempting passage. Those observed in position 2 or in both positions 1 and 2 passed through the orifice from the downstream to upstream direction, and then were pushed back through the same orifice in the opposite direction.

Lamprey not attempting passage or with failed passage during daytime monitoring spent on average 167.5 seconds in the camera's field of view (StDev: 426.4). Lamprey that simply swam through the camera's field of view or attached to the side walls spent, on average, 143.7 seconds in the camera's field of view (Table 21). Lamprey attaching in front of or in the orifice (position 1) spent an average of 48.0 seconds in view. Those attaching upstream after passage (position 2) and before being pushed downstream through the orifice spent an average of 646.3 seconds in

view (Table 21). Fish observed in both position 1 and 2 before being pushed downstream by the current spent an average of 272.3 seconds in the camera's field of view.

Table 21: Behavior of lamprey not passing open orifices at weirs 336 and 337 during daytime video monitoring.

Behavior	North side orifice 336 (%)	South side orifice 336 (%)	North side orifice 337 (%)	South side orifice 337 (%)	All orifices combined (%)	Avg. time (s) spent in view (StDev)
Position 1	9.5	15.4	0	0	9.8	48.0 (41.8)
Position 2	9.5	3.8	0	0	4.9	646.3 (455.5)
Position 1 and 2	9.5	7.7	0	0	6.6	272.3 (375.8)
Other	71.4	73.1	100	100	78.7	143.7 (450.5)

Diffuser Plating Video

One camera was positioned to monitor the steel plating at Diffuser 13. Unfortunately, video observations in this area were completely obscured from entrained air. As listed in Table 1, different time points during the day and throughout the lamprey season were recorded and video reviewed to determine if hydraulic conditions in this area lessened to a degree where observations were possible. Despite these efforts, video observations of lamprey at this location were not possible at any point during the season.

AVEDac Processing

Pmbarivision- event detection and tracking: Initial set-up of Beowulf cluster and pmbarivision code involved technology transfer, installation, and AVEDac and training library support from MBARI to the UCD research group. The Beowulf cluster was procured and installed at UCD and all AVEDac code and supporting documentation was made publicly available through Google code at http://avedac.googlecode.com. Following installation, troubleshooting, and debugging of pmbarivision software, the system was tested on multiple 60 minute clips of lamprey orifice video. Pmbarivision processing time for a 60 minute video (recorded at 6 fps) was 20 minutes using command line parameters described in detail at http://code.google.com/p/avedac/wiki/MbarivisionOptions. Many of the command line parameters were used at the default level. Table 22 summarizes the specific commands that were modified from the default settings to maximize detection and properly track all lamprey and fish within the video.

Table 22: Modified pmbarivision command line parameters.

Command and parameter	Description
mbari-cache-size=3	Number of frames used to compute the running average
mbari-min-event-area=1000	Minimum area an event must be to be candidate
mbari-max-event-area=50000	Maximum area an event can be, to be candidate
mbari-min-event-frames=3	Minimum number of frames an event must be to be candidate
mbari-saliency-dist=1	Number of frames to delay between saliency map computations
mbari-max-WTA-points=1	Maximum number of winner-take-all points to find in each frame

Event classification: Using subsamples of pmbarivision processed video, classes of fish species corresponding to lamprey and sucker fish were created. The lamprey and sucker fish classes consisted of 3,019 and 1,114 images of lamprey and sucker fish, respectively.

The classifier was initially evaluated with: (1) a 60 minute video, of a lamprey orifice, that contained both lamprey and sucker fish, and (2) the training library containing images of both lamprey and sucker fish (Table 23). A total of 199 (38+5+156=199) actual lamprey events were present in the 60 minute video (Table 23). Thirty eight of the actual lamprey events were classified as unknown; 5 actual lamprey events were classified correctly; and 156 actual lamprey events were classified as sucker fish. The precision of the classifier, defined as the fraction of the total number of lamprey events classified correctly, was 0.03 (5/199). A total of 23 (6+14+3) actual sucker fish events were present in the 60 minute video (Table 23). Six of the actual sucker fish events were classified as unknow; 14 actual sucker fish events were classified as lamprey; and 3 actual sucker fish events were classified correctly. In total, the classifier predicted 19 lamprey events (5+14), 5 of which were correctly classified. The recall of lamprey, defined as the faction of total predicted lamprey events classified correctly, was 0.26 (5/19). The precision and recall of the classifier related to sucker fish was 0.13 (3/23) and 0.02 (3/159), respectively.

The classifier was further evaluated with: (1) a 60 minute video, of a lamprey orifice, that contained only lamprey, and (2) the training library containing images of both lamprey and sucker fish (Table 24). A total of 67 (15+52=67) actual lamprey events were present in the 60 minute video (Table 24). Fifteen of the actual lamprey events were classified as unknown; 52 actual lamprey events were classified correctly; and 0 actual lamprey events were classified as sucker fish. The precision of the classifier, defined as the fraction of the total number of lamprey events classified correctly, was 0.78 (52/67). The recall of lamprey, defined as the faction of total predicted lamprey events classified correctly, was 1.0 (52/52).

Table 23: Confusion matrix results from testing video containing lamprey and sucker fish. Lamprey and sucker fish classes used in training library.

PREDICTED →	↓ ACTUAL		
	Unknown	Lamprey	Sucker
Unknown[a]	0	38	6
Lamprey[b]	0	5	14
Sucker[c]	0	156	3
Recall	0	0.26	0.02
Precision	0	0.03	0.13

[a] The AVEDac classifier predicted 0 actual unknown events as unknown, 38 actual lamprey events as unknown, and 6 actual sucker fish events as unknown.

[b] The AVEDac classifier predicted 0 actual unknown events as unknown, 5 actual lamprey events as lamprey, and 14 actual sucker fish events as lamprey.

[c] The AVEDac classifier predicted 0 actual unknown events as sucker fish, 156 actual lamprey events as sucker fish, and 3 actual sucker fish events as sucker fish.

Table 24: Confusion matrix results from testing video containing only lamprey. Lamprey and sucker fish classes used in training library.

PREDICTED →	↓ ACTUAL		
	Unknown	Lamprey	Sucker
Unknown[a]	0	15	0
Lamprey[b]	0	52	0
Sucker[c]	0	0	0
Recall	0	1.0	0
Precision	0	0.78	0

[a] The AVEDac classifier predicted 0 actual unknown events as unknown, 15 actual lamprey events as unknown, and 0 actual sucker fish events as unknown.

[b] The AVEDac classifier predicted 0 actual unknown events as unknown, 52 actual lamprey events as lamprey, and 0 actual sucker fish events as lamprey.

[c] The AVEDac classifier predicted 0 actual unknown events as sucker fish, 0 actual lamprey events as sucker fish, and 0 actual sucker fish events as sucker fish.

4.0 DISCUSSION

Salmonids, Steelhead, and Shad

Prior to the 2010 salmon migration season, all lamprey orifices were closed with the exception of one for the purposes of evaluating whether the open orifices negatively affected salmonid passage through the fish ladder. Video cameras were initially set up to capture the widest field of view possible, and these camera orientations were kept in place for the entire spring run and part of the summer run of Chinook salmon. Also during this time period, two additional cameras were oriented on the two main fish passage orifices of weir 336 to observe salmon usage; these main fish passage orifices are the intended routes of fish passage. Following the open/closed evaluation period, cameras were oriented directly on only lamprey orifices for lamprey viewing and to also capture behavior of subsequent runs of fall Chinook, steelhead, and shad. Throughout the entire study, no outages of video were experienced due to power or equipment failure, or from loss of network connectivity. The only period of time in which video was not collected (10 days) was due to extremely high turbidity levels resulting from heavy rainfall. Additionally, some periods during video recording were partly to completely obscured because of entrained air. Investigation into the cause of the entrained air revealed that the tilting weir section of the stemwalls was not operated in a manner resulting in a consistent elevation drop from one weir to the next in the fish ladder. The tilting weirs operate in response to elevation changes in the forebay and are automatically adjusted; if underwater video monitoring in the future is to occur at these locations then efforts by USACE should be made to operate the weirs in a consistent prescribed manner.

For the spring Chinook run, only one fish out of 88,662 fish that passed through the ladder during the video observation period was observed interacting with the orifice. Spring Chinook were observed utilizing the main fish passage orifice as a means to pass the weirs as would be

expected. Nearly all the fish seen using this route displayed highly directed and forceful swimming through the main orifice without delay. The presence of the lamprey orifices appeared to have little affect in terms of delaying their migration. In general, the fish were seen only for a fraction of a second at either closed or open lamprey orifice, and those fish spending more time than this displayed this behavior on only one day (May 11, 2010) for unknown reasons. To investigate whether diurnal pattern affected behavior of spring Chinook at the orifices we extended the video recording to encompass daily 10 hour periods. During this period of daily 10-hour monitoring of video, roughly 10% more fish passed the ladder in the hours between 0700 and 1200 than from 1200 to 1700, and 7% more fish were seen in the vicinity of the lamprey orifices during the morning hours. Collectively, these results suggest that video monitoring of the orifices in the morning hours for possible salmonid interactions is preferable to monitoring in the afternoon.

To address whether the closed or open lamprey orifices had an effect on salmonid behavior, the relative presence of the spring and summer run Chinook at the closed and open orifices was compared. For the spring run, significantly more fish were observed at the closed (WA) orifice. Attempts were made to open the closed orifice and close the open orifice during the spring run to determine whether this behavior was a function of lamprey orifice flow or some other attribute within the ladder fishway. Unfortunately, a large piece of wood was lodged in the open lamprey orifice and attempts to remove it with a pike pole proved unsuccessful even during orifice flow-only configuration (tilting weirs standing perpindicular to flow). For the summer Chinook run, again more fish were observed in the vicinity of the closed (North) side orifice of weir 336. When the orifice status was changed on this weir the fish still exhibited a preference for the same side of the ladder (North), although now the lamprey orifice was in the open position. These data suggested that salmon were not appreciably attracted to flow as a result of the open lamprey orifice, and all lamprey orifices were then opened by USACE in preparation for adult lamprey migration.

For the fall Chinook run, all orifices were opened and video observations were collected on two consecutive weirs (336 and 337) with two orifices per weir. Despite video monitoring that covered nearly 40% of the seasonal run, no fish were seen in the vicinity of the lamprey orifices. As with the spring Chinook run, fall Chinook utilized the main passage orifices within weirs and did so in a directed manner without being delayed by the presence of the lamprey orifices. American shad likewise were never seen in view of any of the cameras monitoring the lamprey orifices even though nearly 34% of the season run, on the Oregon shore, passed the ladder during video monitoring. Shad typically travel over the tops of weirs during ladder passage and hence would not be expected to be seen near lamprey orifices. Passage of steelhead ocurred throughout the periods of video monitoring from April to September, and as expected a large proportion of steelhead passed the Oregon shore fish ladder in the month of September (nearly 50% of the seasonal run). Correspondingly, all observations of steelhead near lamprey orifices were recorded during this month, but their overall presence within the camera field of view of the orifices was small (0.009% of the total seasonal run). No steelhead were observed interacting or trying to pass the lamprey orifices.

The Sockeye run in 2010 in the Columbia River was the largest on record since counting began, and the run at McNary Dam was nearly 400% of the ten year average established between 2000

and 2009. Due to extended video monitoring covering 10 hours per day, nearly 50% of the run passing the Oregon shore fish ladder occurred during video monitoring. During the video monitoring period, a total of seven Sockeye salmon corresponding to only 0.016% of the entire run at the Oregon shore attempted orifice passage. Each attempt was characterized by the fish turning sideways and attempting to pass through the lamprey orifice. One fish was successful at passing completely through the orifice, and did so in a few seconds. It is likely that because of their relatively small size some Sockeye salmon see the lamprey opening as a means of passage or they are attracted to the flow from the opening or a combination of these and other unknown factors. However, no Sockeye were seen at closed lamprey orifices, and although the majority of fish passed during periods when all orifices were open, their presence at only open orifices indicates that a very small number may cue to the flow pattern in the near vicinity of the orifices.

Pacific lamprey

The 2010 Pacific lamprey run at McNary Dam was the lowest since counting began. 2010 was only the second year in which lamprey were counted at night by technicians at the fish counting window. In 2009, 49.6% of the seasonal lamprey run in the Oregon shore ladder passed the fish count window at night. Therefore, in 2010 the video monitoring system was initially set up and designed for nightime underwater viewing which presented some technical issues that were satisfactorily resolved during this study. Specifically, these issues involved proper placement of underwater external infrared lights with respect to the lamprey orifices and also providing enough illumination since infrared light is strongly attenuated in water. Although the infrared cameras had built-in lighting, this lighting was too weak and the net effect was to illuminate small bubbles and detritus in the water several inches in front of the camera. The internal camera lighting was disabled, and two external, high power infrared lights were used in conjunction with each camera; an arrangement which was sufficient to view the entirety of the lamprey.

Video observations of lamprey at the diffuser plating were not possible due to entrained air which completely obscured the field of view of the camera. Various time points during the day and over the season were recorded to determine if any period was suitable for underwater viewing at this location, however conditions never improved and video recording was suspended at the diffuser.

The early and peak portions of the lamprey run at McNary south fish ladder were covered during video monitoring, with night monitoring occurring from July 15 to August 5. Of the 119 lamprey observed in video during nighttime monitoring, 42.9% passed through the orifices, while the remaining fraction either failed their passage attempt or swam out of the camera's field of view without a passage attempt. The behavior of lamprey as they attempted passage, day or night, was characterized by either: (1) attachment to the substrate near the downstream-side of the orifice with subsequent burst swimming through the orifice; (2) burst swimming through the orifice with subsequent attachment near the upstream-side of the orifice; (3) attachment to the substrate near the downstream-side of the orifice, burst swimming through the orifice, and subsequent reattachment on the upstream-side of the orifice; or (4) burst swimming through the orifice with no attachment. The majority of lamprey attached to the substrate during

orifice passage; less than 8% of lamprey were able to swim through the orifice without prior attachment. The length of time for lamprey orifice passage using the attachment mode was similar for day and night monitoring and was on average 70 seconds. Lamprey that swam through the orifice without substrate attachment did so in less than 10 seconds. Interestingly, lamprey did not stay attached to any sort of surface (substrate, fishway sidewall, weir stemwall) for any extended length of time. The longest period of attachment was slightly over 16 minutes for one lamprey with an unsuccessful orifice passage. Lamprey appeared to move through the weirs methodically and either passed through the orifice, swam out of view laterally, or moved up above the lamprey orifice to the tilting weir stemwall, where they likely passed through the main fish orifice which was just out of view of the cameras.

Daytime monitoring of lamprey began August 15, 2010, and continued to September 30. The transition from nightime to daytime video monitoring of lamprey orifices occurred for two reasons: (1) increased numbers of lamprey observed passing lamprey orifices during daytime monitoring of the spring Chinook run; and (2) increased numbers of lamprey observed passing the fish count window during daytime hours. Collectively during day- and nighttimes, 260 lamprey were observed during video monitoring of lamprey orifices while only 90 lamprey were recorded by fish count technicians at the the count window over the same time period. While it is possible that some lamprey were counted more than once during video monitoring of lamprey orifices, analysis of time-stamped video from multiple cameras on successive weirs casts doubt on this supposition. In cases where a lamprey was seen (not passing) at an orifice, the orifice on the opposite side of the weir was examined to see if lamprey appeared within a 30 minute time frame. Lamprey appearing within this time frame were discounted from counts, as were lamprey appearing at successive weirs (e.g. first at weir 336, then weir 337) within the same 30 minute period. Although this 30 minute time frame is arbitrary, based on the short length of time lamprey were observed at the orifices and the fact that they attached and held position for no more than a few minutes, this time period is a conservative estimate.

Significant differences between video monitoring and fish count technicians indicate that lamprey may be passing through the picket leads rather than through the fish count window. Lamprey using picket leads as a means of passing this section of ladder are thus not counted and possibly underestimate the true lamprey ladder escapement values by an appreciable amount, at least at the McNary Oregon shore fish ladder. More comprehensive placement of video cameras to monitor all points of possible lamprey passage (e.g. at main orifices on weirs) and a monitoring schedule that could account for varying passage frequency (diel, seasonal) would provide accurate means of establishing lamprey ladder escapement rates and whether counts at the window are a reliable means of continuing to enumerate lamprey at these fish passage structures.

AVEDac processing

The motivation for implementating AVEDac was to explore the capability of a software system previously used in marine video studies to facilitate automated detection and identification of fish species in underwater video collected at hydropower projects. For the system to be useful, it must be able to reduce the time spent by human annotators looking through large amounts of video, and ideally also have the capability to perform automated image recognition.

For the automated detection, the Beowulf cluster running pmbarivision was adapted to this specific application and was able to process video of various duration and quality using relatively few changes in command language. Fish were accurately detected and tracked following an interative process of command line modifications. Using the modified commands in pmbarivision, the system could analyze a 60 minute video in approximately 20 minutes. More importantly, aside from loading video files to the cluster (a several minute process), the system operates automatically and without human input, thus reducing labor costs associated with video annotators. Furthermore, with additional programming, multiple video files of any length may be queued up and run through the cluster and the whole process of loading, running, and saving results can be automated. While the time savings are evident, future modifications to pmbarivision commands should further increase speed of analysis. The majority of time was spent installing, debugging, and adapting the system for our application and relatively less time spent optimizing pmbarivision command language for event detection using our video format.

For the final step of AVEDac processing, the event classifier, classes of fish were created and training libraries established. The results from the classifier were reported using a confusion matrix, which is a tool used to visualize classifier performance (Fawcett, 2003). Although our video differed significantly from that used by MBARI in terms of frame rate (6 fps vs. 30 fps) and color scale (black and white vs. color) we were able to adapt the classifier to create classes and training libraries. However, the performance of the classifier in terms of predicting the identity of lamprey from sucker fish was poor. When video contained footage of both lamprey and sucker fish, classifier predictive power was far less than when video was analyzed wherein only lamprey were present. When considering video containing a mixture of species, the classifier had significantly better recall at predicting lamprey than sucker fish, or put another way, the classifier had far fewer false negative predictions for lamprey than sucker fish. By testing the same classifier library (using sucker and lamprey classes) on video containing only lamprey, recall was perfect and the precision increased to nearly 80%. This iterative manner of testing different combinations provided information as to why the classifier worked well in certain predictive scenarios and not so well in others. Performance was relatively high for predicting features of a lamprey, and clearly did not mistake lamprey for sucker fish until sucker were introduced into the video. This problem was tied not to the classes used for the training libraries, but lies in the specific classifer used in the training library to make the predictions..

This specific classifer uses a modelling approach (a mixture of Gaussians) that performs at a very high level when identifying marine benthic organisms (Cline, et al. 2007), typically achieving precision and recall rates at or above 95%, reaching the performance level of professional human marine annotators. Future work to improve the classifier for this application involve systematically testing alternative classifiers to determine which one will discriminate between salmonid and lamprey at a minimum, and at best identify various fish to the species level. The classes of fish (sucker, lamprey, etc) already developed in AVEDac can be tested using a suite of statistical and open-source data mining tools to find the classifier which has the appropriate modelling algorithm and achieve precision and recall rates of at least 95%.

5.0 CONCLUSIONS AND RECOMMENDATIONS

- Collection of large amounts of video data at hydropower projects by means of a networked standalone DVR is an efficient means of transmitting data and requires little maintenance or human input. The system of low-light underwater cameras and high-power external infrared lighting was suitable for night video observation of orifices.

- Underwater video monitoring is not possible in locations with entrained air (e.g. diffuser plating). Future placement of video cameras to observe fish behavior should avoid such areas, or if possible, the operation of hydraulic structures should be modified to reduce the entrainment of air.

- Migrating stocks of adult salmon, steelhead, and shad were not delayed or otherwise harmed by the presence of lamprey orifices. Of all monitored species, Sockeye were most likely to attempt lamprey orifice passage, but at a very low frequency (0.016% of entire run).

- Roughly half of the lamprey observed in the vicinity of a lamprey orifice successfully passed through the orifice. The majority of successful passages involved substrate attachment followed by burst swimming through the lamprey orifice. Lamprey moved relatively quickly through the orifices in a matter of a few minutes and did not spend appreciable time in the vicinity of the orifices.

- Overall day and night video counts of lamprey near lamprey orifices were higher (by a factor of nearly three) than those counted by technicians at the fish count window. Passage of lamprey behind picket leads at the fish count window may lead to substantial underestimation of lamprey ladder at the Oregon shore fish ladder.

- Diel patterns of lamprey passage can vary significantly from year to year. In 2010, the majority of lamprey passed the ladder during daylight hours. Video monitoring aimed at determining true lamprey ladder escapement must capture this temporal variation by recording 24-hours of continuous video.

- Future video work to determine lamprey ladder escapment should involve careful placement of cameras to capture all points of possible lamprey passage as they move through ladder structures.

- AVEDac was successfully adapted to detect and track fish in video of fish ladder structures, and future improvements in the classifier are needed to increase accuracy of species image recognition. The system has potential to automate the analysis of large amounts of video data.

6.0 ACKNOWLEDGEMENTS

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8.0 APPENDICES

Appendix A: Hourly count of adult spring Chinook salmon at the Oregon shore fish-ladder (ladder 7) of McNary Dam during the 2010 season. Hour 1 starts at 5am DST and hour 16 ends at 8:50pm DST. Hourly counts represent fish passage during 50 minute per hour. For full hour estimates, 50 minute counts were multiplied by 1.2. Dark background indicates hours during which video monitoring occurred.

Date	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16
01-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
02-Apr-10	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	1
03-Apr-10	0	0	1	0	0	0	2	5	1	1	1	0	1	0	0	0
04-Apr-10	0	0	0	0	0	1	3	0	2	1	0	0	0	0	0	0
05-Apr-10	0	0	0	0	0	2	1	0	0	0	1	0	1	1	0	0
06-Apr-10	0	-1	0	1	0	0	0	0	1	0	0	0	1	0	0	0
07-Apr-10	0	0	0	0	0	0	0	1	4	2	1	0	0	3	0	0
08-Apr-10	0	0	0	0	0	0	0	0	5	4	-1	1	3	1	0	0
09-Apr-10	0	0	0	0	0	1	0	1	5	1	0	1	6	3	0	0
10-Apr-10	0	1	2	2	1	4	1	4	4	3	3	7	1	2	3	1
11-Apr-10	0	0	3	1	0	2	1	5	3	3	8	1	0	1	5	1
12-Apr-10	0	0	0	0	1	0	0	4	2	5	3	6	16	6	10	1
13-Apr-10	0	1	3	1	5	3	0	0	0	6	15	11	22	21	7	0
14-Apr-10	0	1	19	3	21	30	20	21	26	13	2	8	43	14	1	0
15-Apr-10	0	1	10	10	7	35	40	44	11	74	41	50	98	83	22	3
16-Apr-10	0	4	25	4	16	10	54	56	38	38	53	48	86	30	23	11
17-Apr-10	0	18	11	12	30	52	41	30	33	54	64	17	14	18	27	1
18-Apr-10	0	19	27	22	102	91	119	63	65	80	35	38	21	16	12	3
19-Apr-10	0	3	12	12	66	50	91	59	91	138	103	54	56	58	23	6
20-Apr-10	0	18	17	24	41	89	146	98	93	123	76	66	66	62	13	3
21-Apr-10	0	28	120	N.C[a]	396	452	428	36	178	177	131	137	120	98	21	9
22-Apr-10	0	31	52	123	396	518	385	25	180	280	88	38	36	52	20	5
23-Apr-10	0	18	22	58	192	266	277	12	79	76	74	37	67	127	63	11
24-Apr-10	0	49	109	120	333	363	311	29	145	137	119	96	126	93	79	41
25-Apr-10	3	14	166	368	534	494	383	25	128	176	123	58	83	77	52	14
26-Apr-10	0	55	69	22	120	226	115	86	172	198	216	62	13	28	10	7
27-Apr-10	0	40	55	61	148	198	278	30	260	82	104	140	145	129	49	13
28-Apr-10	0	44	68	69	145	309	487	48	303	318	322	344	479	283	106	23
29-Apr-10	3	63	78	38	48	107	228	24	238	283	143	118	162	173	48	13
30-Apr-10	0	20	11	12	53	98	162	25	264	318	218	137	185	252	108	57
01-May-10	8	67	54	9	59	120	61	61	152	150	114	154	214	134	63	32
02-May-10	4	92	42	30	115	143	131	12	176	217	200	290	254	161	153	71
03-May-10	12	14	103	133	170	229	181	23	179	242	184	240	264	177	115	26
04-May-10	4	17	122	525	732	591	465	24	134	198	169	139	132	101	39	9
05-May-10	36	19	219	494	402	278	91	53	134	231	212	213	260	140	45	13
06-May-10	51	12	141	198	344	280	246	10	241	119	182	122	168	222	40	30
07-May-10	200	27	326	863	851	624	600	50	432	248	228	151	127	102	55	44
08-May-10	59	14	86	305	313	270	261	25	256	175	178	238	267	203	148	79
09-May-10	86	13	123	286	253	300	353	17	149	269	129	121	187	179	131	58
10-May-10	31	20	90	73	207	273	360	39	306	263	187	226	121	109	43	1
11-May-10	168	19	102	397	347	273	8	10	132	332	225	232	177	166	34	11
12-May-10	67	59	80	466	422	291	105	60	36	15	16	51	146	139	37	12
13-May-10	84	27	109	237	274	139	162	11	78	140	14	96	155	87	15	13
14-May-10	100	79	68	227	198	189	291	20	117	84	101	50	81	59	9	2
15-May-10	36	41	51	48	58	66	59	45	52	16	15	45	57	57	30	3

16-May-10	11	30	19	46	25	44	140	11	98	100	72	83	111	127	79	50
17-May-10	41	52	33	53	109	58	110	11	113	83	62	89	110	49	13	4
18-May-10	10	18	11	48	20	31	31	79	87	16	62	152	321	270	84	78
19-May-10	136	76	221	416	220	197	129	74	68	80	56	73	52	43	12	12
20-May-10	62	48	92	73	34	106	196	10	88	68	62	49	38	88	25	7
21-May-10	12	13	40	98	97	177	196	14	142	120	24	62	64	145	157	89
22-May-10	75	26	78	167	124	111	186	84	45	42	32	16	54	66	42	32
23-May-10	41	18	15	26	31	76	32	35	27	36	19	48	50	53	64	12
24-May-10	14	12	15	21	30	42	27	16	39	26	28	9	29	30	18	6
25-May-10	29	17	15	32	46	35	30	17	33	19	32	42	47	43	17	9
26-May-10	7	21	8	10	13	20	26	62	19	11	43	12	1	0	N.C[a]	6
27-May-10	146	47	16	35	47	60	94	49	37	20	50	44	15	11	4	10
28-May-10	31	34	20	60	95	73	86	71	61	30	65	30	39	31	34	27
29-May-10	87	23	15	31	57	45	34	48	70	53	87	68	46	35	36	38
30-May-10	65	15	42	79	81	127	60	22	45	40	32	39	28	9	14	12
31-May-10	27	28	4	37	51	60	48	26	41	28	20	38	27	34	24	20
01-Jun-10	48	12	40	27	63	40	77	64	37	26	21	37	21	20	6	3
02-Jun-10	33	51	54	102	89	69	84	78	89	65	67	93	79	43	6	13
03-Jun-10	54	24	38	61	140	90	49	39	0	1	36	87	118	64	12	16
04-Jun-10	27	19	22	58	46	14	305	21	225	168	161	82	120	100	123	125
05-Jun-10	34	68	193	210	255	202	109	64	98	79	56	84	148	139	111	62
06-Jun-10	27	43	41	99	122	145	132	17	137	174	111	114	89	81	76	58
07-Jun-10	70	63	57	79	125	56	77	90	93	86	126	98	94	89	18	24
08-Jun-10	21	45	36	88	176	195	151	12	165	167	153	60	81	49	26	21

[a] Not counted. Missing data from fish count technicians.

Appendix B: Hourly count of adult summer Chinook salmon at the Oregon shore fish-ladder (ladder 7) of McNary Dam during the 2010 season. Hour 1 starts at 5am DST and hour 16 ends at 8:50pm DST. Hourly counts represent fish passage during 50 minute per hour. For full hour estimates, 50 minute counts were multiplied by 1.2. Dark background indicates hours during which video monitoring occurred.

Date	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16
09-Jun-10	17	19	31	79	98	132	108	92	115	131	134	82	179	112	61	73
10-Jun-10	13	12	20	21	30	40	80	41	124	102	40	78	176	97	74	55
11-Jun-10	20	26	20	25	86	90	77	111	84	84	69	124	132	135	107	44
12-Jun-10	20	29	11	41	44	42	115	71	114	81	46	92	82	144	73	134
13-Jun-10	37	21	9	50	79	88	88	88	61	104	58	58	42	73	73	72
14-Jun-10	42	23	17	16	40	36	32	50	72	105	58	39	75	41	28	21
15-Jun-10	9	8	6	11	10	20	41	28	95	37	54	48	40	41	40	25
16-Jun-10	33	28	55	85	128	188	184	117	145	69	121	72	75	45	11	19
17-Jun-10	38	41	51	72	97	80	76	53	31	55	50	17	16	25	18	7
18-Jun-10	30	18	12	34	30	19	41	30	16	18	17	20	15	18	17	4
19-Jun-10	22	19	3	28	56	31	50	49	34	16	15	13	29	22	9	11
20-Jun-10	16	14	48	48	37	34	46	37	19	28	21	37	25	36	9	14
21-Jun-10	55	24	18	52	42	63	53	31	20	21	31	40	47	33	12	16
22-Jun-10	25	22	22	53	75	64	85	22	12	20	19	15	28	25	16	24
23-Jun-10	17	7	13	24	71	87	100	74	39	32	25	42	44	38	28	10
24-Jun-10	18	7	8	33	51	14	28	31	23	9	20	16	28	25	25	20
25-Jun-10	33	19	13	32	42	55	28	20	25	40	67	46	21	46	51	31
26-Jun-10	27	21	18	27	47	49	37	43	46	27	48	38	22	38	35	33
27-Jun-10	17	25	35	26	37	31	30	21	39	50	31	57	51	42	42	12
28-Jun-10	34	33	19	24	29	18	12	21	25	30	32	19	30	41	28	23
29-Jun-10	34	34	30	40	60	58	72	51	24	28	16	113	85	71	43	14
30-Jun-10	19	22	39	61	80	55	46	30	22	23	11	17	25	30	19	12
01-Jul-10	25	11	9	27	29	37	33	30	14	14	15	11	11	32	21	21
02-Jul-10	24	31	14	29	42	67	49	37	30	25	66	56	65	63	72	33
03-Jul-10	47	33	16	26	49	83	59	54	40	38	29	55	56	54	22	27
04-Jul-10	22	32	14	32	35	63	73	48	37	15	25	19	39	32	31	29
05-Jul-10	71	39	31	38	28	65	121	60	14	31	34	17	41	33	14	42
06-Jul-10	42	42	27	18	60	30	74	76	18	9	5	9	8	11	15	12
07-Jul-10	41	22	15	40	130	119	105	72	25	14	11	29	22	13	21	11
08-Jul-10	19	13	14	27	20	25	6	15	7	2	17	15	11	16	13	2
09-Jul-10	9	8	17	7	20	33	50	29	22	1	15	17	11	22	26	18
10-Jul-10	29	19	13	17	19	36	41	32	39	41	22	13	8	9	30	8
11-Jul-10	11	14	9	16	23	13	21	38	8	13	5	22	14	19	23	7
12-Jul-10	22	13	24	5	24	25	8	19	4	14	24	21	22	22	30	32
13-Jul-10	50	24	25	31	24	36	17	21	18	21	34	21	9	11	10	0
14-Jul-10	10	16	17	7	18	48	42	26	4	10	22	19	20	14	3	11
15-Jul-10	61	38	27	26	12	20	33	32	9	3	16	19	3	12	6	2
16-Jul-10	10	1	5	4	11	25	19	10	11	3	8	2	10	7	5	9
17-Jul-10	12	1	14	4	3	5	6	4	8	3	4	6	7	2	2	2
18-Jul-10	5	0	0	3	3	5	12	10	12	5	9	5	8	2	3	5
19-Jul-10	0	0	6	2	3	13	5	8	5	2	2	3	3	7	4	0
20-Jul-10	3	4	3	1	7	5	13	5	7	7	3	6	5	0	0	1
21-Jul-10	1	1	3	0	4	4	3	5	3	10	4	4	8	6	7	1
22-Jul-10	1	0	0	2	1	2	2	2	5	6	1	3	5	4	0	7
23-Jul-10	4	3	5	2	4	6	9	8	3	4	1	1	2	2	4	4
24-Jul-10	6	6	4	9	9	7	13	10	2	6	11	2	2	4	0	3
25-Jul-10	17	3	6	10	15	13	15	6	3	4	2	1	2	2	7	2

26-Jul-10	3	1	4	0	2	2	10	0	7	0	4	5	1	2	3	0
27-Jul-10	0	1	0	5	5	9	1	7	0	4	0	1	1	0	0	0
28-Jul-10	1	0	3	3	3	2	0	1	0	4	2	0	3	3	1	2
29-Jul-10	1	0	1	4	4	5	6	4	5	1	3	4	0	2	1	1
30-Jul-10	8	3	6	2	6	2	2	9	2	2	5	4	3	7	2	0
31-Jul-10	0	0	0	2	7	2	2	5	6	2	2	1	2	2	2	1
01-Aug-10	0	0	1	4	4	0	6	3	5	2	2	2	0	0	1	0
02-Aug-10	0	1	0	0	3	0	1	2	2	2	4	2	3	1	4	4
03-Aug-10	1	1	0	2	1	1	1	1	1	1	0	1	0	1	0	0
04-Aug-10	N.C[a]	N.C[a]	N.C[a]	11	15	8	8	7	0	0	0	0	0	0	0	0
05-Aug-10	1	0	3	3	4	6	1	1	0	0	1	5	1	1	0	0
06-Aug-10	1	0	2	0	1	1	0	1	1	2	2	2	1	0	0	1
07-Aug-10	0	0	1	0	1	3	0	0	2	1	2	1	0	0	0	0
08-Aug-10	1	1	3	1	2	1	15	15	9	5	5	0	4	2	1	1

[a] Not counted. Missing data from fish count technicians.

Appendix C: Hourly count of adult fall Chinook salmon at the Oregon shore fish-ladder (ladder 7) of McNary Dam during the 2010 season. Hour 1 starts at 5am DST and hour 16 ends at 8:50pm DST. Hourly counts represent fish passage during 50 minute per hour. For full hour estimates, 50 minute counts were multiplied by 1.2. Dark background indicates hours during which video monitoring occurred.

Date	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16
09-Aug-10	1	5	0	4	1	1	0	4	4	5	3	0	3	3	0	1
10-Aug-10	0	1	0	1	1	3	3	3	9	2	0	0	1	2	1	1
11-Aug-10	1	1	0	1	0	1	1	4	3	5	1	4	6	4	6	6
12-Aug-10	0	2	2	2	6	8	11	7	6	4	6	4	3	2	1	1
13-Aug-10	0	4	3	1	5	3	2	4	1	0	2	1	6	1	1	9
14-Aug-10	0	2	7	8	6	14	10	8	2	4	2	2	0	0	1	0
15-Aug-10	1	6	3	3	6	11	8	6	6	5	3	8	11	6	2	5
16-Aug-10	0	1	1	3	6	6	10	5	2	6	0	1	4	3	2	1
17-Aug-10	0	2	1	2	2	5	2	9	0	1	0	0	1	0	0	1
18-Aug-10	0	0	0	1	0	3	2	1	5	5	0	1	0	0	0	0
19-Aug-10	1	1	0	1	1	0	2	5	6	4	2	3	1	0	5	0
20-Aug-10	0	2	1	6	2	4	2	2	0	3	3	0	0	0	1	0
21-Aug-10	0	6	2	7	10	12	8	13	8	6	4	6	4	1	0	0
22-Aug-10	0	1	3	2	5	4	3	7	5	1	1	3	0	4	1	0
23-Aug-10	0	6	8	3	2	2	7	5	4	0	1	5	1	1	0	0
24-Aug-10	0	3	13	23	79	41	39	52	24	33	19	22	18	13	10	6
25-Aug-10	1	24	15	16	30	25	12	8	11	14	13	8	6	2	0	0
26-Aug-10	0	4	13	13	22	60	36	36	27	13	11	22	25	10	9	2
27-Aug-10	0	9	12	24	41	50	52	45	49	26	14	30	29	19	19	7
28-Aug-10	0	16	10	16	24	62	90	94	87	63	33	54	35	19	18	3
29-Aug-10	2	13	18	24	69	160	146	141	149	139	87	48	43	28	12	3
30-Aug-10	0	7	8	14	13	20	43	23	16	17	19	21	15	5	1	0
31-Aug-10	2	4	12	74	224	455	360	236	159	153	69	75	81	25	27	4
01-Sep-10	2	15	9	26	107	126	64	48	29	21	13	19	78	29	9	0
02-Sep-10	0	2	3	90	280	264	271	209	175	73	42	66	85	43	10	1
03-Sep-10	1	7	9	56	214	230	245	219	192	164	178	114	46	32	47	14
04-Sep-10	4	16	7	138	206	214	228	238	237	218	191	146	172	185	125	41
05-Sep-10	12	12	53	321	549	480	529	444	380	319	172	111	200	135	112	20
06-Sep-10	5	49	42	249	534	400	329	298	268	150	83	85	97	35	50	13
07-Sep-10	1	25	36	298	776	563	365	159	197	119	112	105	36	45	15	2
08-Sep-10	1	17	16	290	667	253	601	480	315	238	184	93	119	41	27	3
09-Sep-10	3	42	30	41	170	188	267	287	181	184	211	189	285	139	23	11
10-Sep-10	3	64	57	219	384	280	264	115	158	171	121	87	143	118	74	7
11-Sep-10	0	51	54	61	82	78	64	114	170	92	105	173	96	79	61	3
12-Sep-10	3	34	4	73	334	308	205	137	175	182	113	137	111	70	50	5
13-Sep-10	1	81	36	31	278	216	284	335	164	114	67	117	307	274	45	1
14-Sep-10	0	40	42	31	178	182	282	175	64	72	30	30	32	31	8	0
15-Sep-10	2	18	13	58	70	51	27	74	72	40	64	74	34	14	-1	0
16-Sep-10	0	7	5	6	6	10	16	19	33	32	14	23	27	7	0	0
17-Sep-10	0	7	14	8	18	18	18	23	47	27	20	22	9	5	1	0
18-Sep-10	1	4	6	1	54	38	68	178	187	138	122	150	140	102	33	2
19-Sep-10	2	31	22	466	673	295	282	261	279	275	192	117	92	97	67	15
20-Sep-10	0	53	28	151	454	259	210	302	292	536	359	157	278	197	25	3
21-Sep-10	0	22	53	610	207	682	356	222	306	159	157	121	120	174	94	15
22-Sep-10	N.C[a]	N.C	608	172	N.C[a]	107	570	269	256	217	176	77	77	65	14	3
23-Sep-10	0	17	82	543	125	477	386	289	165	91	51	91	67	75	13	15
24-Sep-10	5	33	93	399	706	350	179	84	60	78	49	72	83	67	24	2
25-Sep-10	2	17	41	456	106	650	375	272	97	73	121	87	82	62	11	1
26-Sep-10	2	23	79	339	107	550	262	180	129	274	51	67	77	45	13	1

27-Sep-10	6	21	60	276	119	550	287	131	157	114	97	62	93	43	19	0
28-Sep-10	1	14	51	380	137	876	419	275	223	178	132	72	48	52	2	1
29-Sep-10	1	1	18	27	85	128	69	122	104	55	104	152	193	126	26	2
30-Sep-10	1	37	70	115	403	401	274	204	248	183	24	128	30	13	0	3
01-Oct-10	0	10	21	30	237	237	63	111	94	133	100	75	76	29	1	1
02-Oct-10	0	12	7	238	954	628	313	302	259	263	101	174	71	54	24	5
03-Oct-10	2	17	31	89	391	436	412	369	167	178	152	126	88	71	25	-1
04-Oct-10	1	21	42	85	236	203	153	97	152	108	45	104	41	41	3	0
05-Oct-10	0	17	19	27	210	110	163	40	50	47	44	34	31	19	2	1
06-Oct-10	0	8	18	32	66	60	61	49	40	44	67	34	67	33	6	0
07-Oct-10	0	0	19	37	82	143	53	80	36	39	50	30	12	9	1	0
08-Oct-10	0	3	35	49	121	134	157	54	41	45	22	28	26	19	-1	0
09-Oct-10	0	4	77	17	93	133	91	120	44	59	43	32	28	25	5	0
10-Oct-10	1	0	45	20	97	96	142	52	65	47	14	40	24	24	2	1
11-Oct-10	0	0	49	95	163	235	157	44	29	37	42	41	39	30	3	1
12-Oct-10	0	2	16	8	24	20	45	27	N.C[a]	N.C[a]	N.C[a]	N.C[a]	N.C[a]	N.C[a]	110	2
13-Oct-10	0	0	6	32	16	19	50	10	10	13	21	13	30	21	4	0
14-Oct-10	1	0	8	4	23	28	21	26	23	24	18	27	23	23	1	1
15-Oct-10	2	1	9	20	28	40	53	38	39	53	26	30	28	18	5	8
16-Oct-10	0	2	16	33	71	67	60	33	18	8	15	19	22	21	4	4
17-Oct-10	1	0	32	11	28	22	20	14	28	13	17	17	26	5	7	0
18-Oct-10	0	2	21	13	10	15	32	19	29	70	31	20	15	10	1	0
19-Oct-10	0	0	6	1	14	25	21	10	41	9	13	21	10	3	2	1
20-Oct-10	2	0	6	12	18	19	30	22	9	13	11	8	8	3	0	0
21-Oct-10	1	0	14	7	9	20	14	9	4	6	4	12	8	1	2	0
22-Oct-10	2	0	12	19	23	11	17	7	4	9	5	8	10	6	1	0
23-Oct-10	0	1	10	18	24	28	26	17	4	16	2	13	4	0	0	1
24-Oct-10	3	2	7	12	25	10	3	12	6	0	4	4	3	1	0	0
25-Oct-10	0	1	7	14	5	16	21	13	14	11	13	11	7	3	0	0
26-Oct-10	3	0	7	10	10	26	16	23	7	13	4	3	1	0	0	0
27-Oct-10	0	1	5	5	7	13	9	0	4	7	3	10	2	3	0	0
28-Oct-10	1	1	2	5	6	6	3	0	5	2	0	4	0	0	0	0
29-Oct-10	2	0	3	4	2	3	2	2	4	5	10	4	6	4	4	1
30-Oct-10	0	0	2	9	4	4	3	3	3	3	6	12	4	0	0	1
31-Oct-10	0	1	0	1	2	1	6	3	5	6	3	2	2	0	0	0

[a] Not counted. Missing data from fish count technicians.

Appendix D: Hourly count of adult Sockeye salmon at the Oregon shore fish-ladder (ladder 7) of McNary Dam during the 2010 season. Hour 1 starts at 5am DST and hour 16 ends at 8:50pm DST. Hourly counts represent fish passage during 50 minute per hour. For full hour estimates, 50 minute counts were multiplied by 1.2. Dark background indicates hours during which video monitoring occurred.

Date	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16
28-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
30-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-Jun-10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
02-Jun-10	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0
03-Jun-10	0	0	0	0	3	0	1	0	0	0	0	0	0	1	0	1
04-Jun-10	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
05-Jun-10	0	0	0	0	0	0	2	2	0	3	4	2	3	2	2	0
06-Jun-10	0	0	0	0	0	1	2	2	3	4	3	1	1	3	1	0
07-Jun-10	1	5	0	0	2	2	2	3	0	4	8	4	3	4	1	0
08-Jun-10	1	3	1	1	0	1	1	4	2	2	1	1	5	2	1	3
09-Jun-10	1	1	0	0	4	2	0	0	4	9	3	3	3	2	0	2
10-Jun-10	1	1	4	0	4	3	0	2	0	1	1	0	2	0	0	1
11-Jun-10	0	0	1	0	2	1	3	3	0	1	1	0	2	7	1	1
12-Jun-10	2	2	0	0	0	0	1	3	2	4	7	4	4	5	0	0
13-Jun-10	3	2	1	4	2	2	1	2	0	3	7	3	8	7	0	2
14-Jun-10	5	1	2	3	2	6	4	6	5	3	0	6	9	5	2	1
15-Jun-10	0	2	3	0	3	2	7	13	4	2	14	27	11	1	6	3
16-Jun-10	11	9	8	10	8	12	12	16	18	17	11	15	10	6	4	1
17-Jun-10	7	5	5	9	6	12	24	35	13	9	14	6	13	12	6	3
18-Jun-10	6	2	8	3	9	12	23	16	10	7	12	8	8	10	10	7
19-Jun-10	5	1	1	9	8	21	14	15	10	1	13	7	4	11	5	3
20-Jun-10	6	8	5	23	36	17	14	13	19	17	27	32	19	39	26	30
21-Jun-10	15	8	7	48	35	19	35	47	51	59	32	35	53	38	27	31
22-Jun-10	23	16	24	61	88	123	100	42	86	88	33	36	47	53	46	33
23-Jun-10	26	18	16	88	142	124	131	115	137	91	81	79	72	59	39	37
24-Jun-10	20	24	65	164	116	52	73	51	53	49	52	74	60	54	37	47
25-Jun-10	59	47	105	223	246	185	99	145	110	93	164	84	75	51	57	51
26-Jun-10	31	49	24	147	132	209	192	106	93	65	69	79	100	146	88	91
27-Jun-10	41	47	81	125	130	81	118	70	73	44	37	34	32	37	17	28
28-Jun-10	44	40	40	107	142	172	119	90	93	92	60	45	40	35	18	22
29-Jun-10	21	40	63	75	135	173	199	135	73	80	29	70	64	59	31	26
30-Jun-10	16	22	100	156	248	275	214	197	169	159	65	66	94	60	60	40
01-Jul-10	31	12	112	179	240	65	167	102	85	56	37	41	62	45	30	36
02-Jul-10	54	41	68	141	241	332	392	284	387	221	331	309	304	224	204	109
03-Jul-10	174	145	341	463	396	349	309	258	125	76	47	127	104	86	41	105
04-Jul-10	160	103	285	431	545	467	348	249	169	109	101	134	123	99	57	93
05-Jul-10	179	228	305	427	541	584	432	307	178	157	165	60	196	120	66	67
06-Jul-10	148	116	204	340	527	513	385	297	67	92	52	82	201	215	92	191
07-Jul-10	154	169	422	599	563	464	408	319	325	119	186	188	146	131	115	89
08-Jul-10	154	153	292	444	374	344	334	209	113	114	105	100	130	148	96	85
09-Jul-10	130	108	209	235	266	251	226	127	105	97	110	111	180	200	166	90
10-Jul-10	137	119	175	302	202	296	261	137	149	169	105	80	116	123	128	85
11-Jul-10	110	86	102	202	178	105	145	135	53	68	21	86	79	87	87	52
12-Jul-10	177	88	80	132	101	93	82	60	73	94	76	140	161	150	141	148
13-Jul-10	135	110	136	168	61	97	56	93	128	97	135	131	118	111	65	73
14-Jul-10	43	121	157	175	210	310	199	123	84	82	69	72	86	73	50	48

15-Jul-10	0	74	73	191	275	239	221	109	106	53	63	83	61	47	21	23
16-Jul-10	13	67	62	45	72	62	53	63	53	27	26	25	41	49	43	34
17-Jul-10	37	26	42	34	40	30	60	30	24	17	29	32	38	31	20	30
18-Jul-10	30	13	26	44	34	38	49	35	22	24	17	14	30	27	23	33
19-Jul-10	14	21	30	28	34	50	42	33	22	13	22	26	33	18	19	31
20-Jul-10	17	28	29	36	33	38	48	48	9	18	9	20	9	5	13	6
21-Jul-10	11	14	12	14	17	28	33	19	12	11	18	20	5	12	8	14
22-Jul-10	5	5	9	30	19	8	14	14	8	4	2	2	12	9	4	7
23-Jul-10	5	7	7	14	18	14	20	8	2	6	2	11	9	2	6	3
24-Jul-10	6	4	9	9	14	10	16	14	7	3	7	1	1	5	3	4
25-Jul-10	1	5	3	8	7	6	3	6	3	3	1	3	9	7	4	5
26-Jul-10	2	1	4	6	7	15	6	4	3	6	4	6	5	3	2	1
27-Jul-10	0	1	1	9	6	10	8	5	5	7	1	4	0	6	2	0
28-Jul-10	2	2	7	2	5	5	2	3	3	4	5	1	4	2	3	1
29-Jul-10	2	2	2	3	3	2	5	4	2	1	1	4	4	3	3	2
30-Jul-10	1	0	3	3	4	2	3	2	3	3	1	2	2	3	0	1
31-Jul-10	0	1	2	1	2	2	2	7	2	1	4	2	1	0	2	1
01-Aug-10	0	1	2	1	0	2	1	1	1	4	0	2	3	3	1	0
02-Aug-10	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0
03-Aug-10	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	1
04-Aug-10	N.C[a]	N.C[a]	N.C[a]	1	1	1	2	1	0	0	0	0	0	0	0	0
05-Aug-10	1	0	0	1	2	0	0	0	0	0	0	1	0	0	2	0
06-Aug-10	0	1	1	2	1	1	4	1	0	0	0	0	0	0	0	0
07-Aug-10	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0
08-Aug-10	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
09-Aug-10	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0
10-Aug-10	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
11-Aug-10	0	0	0	0	0	1	0	0	0	0	0	-1	0	0	0	0
12-Aug-10	0	0	0	0	1	1	1	0	0	1	1	1	0	0	0	0
13-Aug-10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
14-Aug-10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Aug-10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
16-Aug-10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
17-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Aug-10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
19-Aug-10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
20-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
23-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
25-Aug-10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
26-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Aug-10	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0
28-Aug-10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
29-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
30-Aug-10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
31-Aug-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-Sep-10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
07-Sep-10	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
08-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

09-Sep-10	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
10-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Sep-10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
16-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Sep-10	0	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0
22-Sep-10	N.C[a]	N.C[a]	0	0	N.C[a]	0	0	0	0	0	0	0	0	0	0	0
23-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-Oct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Oct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Oct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-Oct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-Oct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-Oct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-Oct-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[a] Not counted. Missing data from fish count technicians.

Appendix E: Hourly count of adult steelhead trout at the Oregon shore fish-ladder (ladder 7) of McNary Dam during the 2010 season. Hour 1 starts at 5am DST and hour 16 ends at 8:50pm DST. Hourly counts represent fish passage during 50 minute per hour. For full hour estimates, 50 minute counts were multiplied by 1.2. Dark background indicates hours during which video monitoring occurred.

Date	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16
01-Apr-10	3	5	12	10	2	11	8	6	2	6	4	4	9	7	5	1
02-Apr-10	4	4	13	3	6	11	7	15	6	7	10	7	5	14	6	4
03-Apr-10	1	3	7	13	2	2	8	8	9	3	4	7	6	6	6	2
04-Apr-10	0	5	2	9	3	4	6	4	11	7	7	3	7	4	5	1
05-Apr-10	0	1	4	8	0	2	2	1	5	1	1	1	3	2	2	1
06-Apr-10	0	0	6	3	2	0	2	5	4	1	4	1	1	1	7	4
07-Apr-10	2	3	8	2	7	3	6	6	9	13	11	5	9	8	3	2
08-Apr-10	0	2	7	1	4	10	5	6	18	4	8	0	9	3	3	0
09-Apr-10	1	1	5	5	0	8	-2	4	7	11	7	2	5	9	10	0
10-Apr-10	-4	-2	9	1	4	6	6	6	7	4	4	4	3	5	3	3
11-Apr-10	1	3	2	5	4	2	4	3	2	1	3	2	1	1	3	0
12-Apr-10	0	3	4	-1	2	2	2	4	6	7	4	8	7	5	4	0
13-Apr-10	0	2	10	4	7	5	2	0	1	10	3	8	5	11	4	2
14-Apr-10	1	6	9	5	12	10	6	9	11	6	1	4	6	2	0	3
15-Apr-10	0	0	2	-1	3	2	5	4	3	6	6	5	9	3	2	1
16-Apr-10	1	2	7	3	3	7	4	2	3	5	2	4	9	2	1	1
17-Apr-10	2	5	5	5	8	2	3	2	5	2	9	4	9	5	4	2
18-Apr-10	0	11	7	6	11	8	4	7	8	4	3	4	4	0	1	6
19-Apr-10	0	2	5	5	10	7	4	2	7	1	6	3	2	6	2	1
20-Apr-10	1	1	2	5	1	2	3	6	3	2	3	4	1	4	1	1
21-Apr-10	1	13	4	N.C[a]	6	6	6	7	3	6	2	4	5	3	-1	1
22-Apr-10	1	1	6	5	7	1	2	1	3	1	1	3	3	1	0	1
23-Apr-10	1	4	2	6	5	4	3	2	4	0	2	2	2	1	4	2
24-Apr-10	1	3	5	4	2	1	8	1	5	4	2	3	2	2	4	0
25-Apr-10	0	4	4	2	4	2	1	3	3	9	1	1	3	4	4	4
26-Apr-10	0	5	3	1	1	4	1	2	1	3	3	0	0	0	1	0
27-Apr-10	0	2	0	1	0	0	1	1	0	2	0	0	1	0	0	0
28-Apr-10	0	1	3	0	2	3	0	2	1	0	1	1	3	2	0	1
29-Apr-10	1	0	1	1	2	3	0	2	2	1	0	2	1	0	0	0
30-Apr-10	0	1	0	2	1	3	2	1	1	1	0	0	0	2	0	0
01-May-10	2	0	1	2	0	1	0	2	0	1	1	0	0	2	0	0
02-May-10	0	0	1	1	5	2	0	0	0	1	0	0	0	0	0	0
03-May-10	0	0	1	1	1	2	0	0	1	0	0	1	0	0	0	0
04-May-10	0	0	0	2	1	1	2	1	0	0	1	2	0	0	1	0
05-May-10	1	0	0	1	0	0	0	0	0	0	1	4	0	2	0	0
06-May-10	0	0	1	0	0	0	1	1	3	0	1	0	1	0	0	0
07-May-10	0	0	1	1	2	0	0	0	0	0	0	0	1	0	0	0
08-May-10	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1
09-May-10	1	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0
10-May-10	0	0	0	0	1	0	0	1	2	0	0	2	0	0	0	0
11-May-10	1	0	0	1	0	0	0	0	1	3	2	1	1	0	0	0
12-May-10	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
13-May-10	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
14-May-10	1	0	0	1	0	1	0	0	0	0	2	0	0	0	0	0
15-May-10	0	2	0	1	1	0	1	0	1	0	0	1	2	1	0	0
16-May-10	3	1	1	1	0	0	0	1	0	0	0	0	0	0	1	2
17-May-10	0	2	1	1	1	0	2	0	1	4	1	2	1	0	0	1
18-May-10	0	0	0	0	1	0	0	1	0	0	1	2	3	0	0	1
19-May-10	2	0	1	1	1	0	1	1	0	0	3	0	1	0	0	1

20-May-10	0	1	1	0	0	0	0	0	1	1	0	0	1	0	0	0
21-May-10	0	0	0	1	1	0	1	0	1	1	0	0	1	0	0	0
22-May-10	0	0	0	0	3	-1	0	2	0	1	0	3	0	0	0	1
23-May-10	0	0	0	1	1	1	0	0	0	0	0	0	1	2	0	0
24-May-10	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1
25-May-10	1	1	-3	1	0	1	0	-1	2	1	1	3	0	1	0	0
26-May-10	0	0	0	0	0	0	0	0	0	0	0	2	1	1	N.C[a]	0
27-May-10	1	0	0	0	0	0	0	0	0	0	0	2	1	0	1	1
28-May-10	2	2	3	0	1	0	0	2	0	0	2	1	0	1	1	0
29-May-10	0	0	0	0	1	0	0	2	1	2	1	0	0	0	0	1
30-May-10	0	0	2	0	1	0	0	-1	1	0	2	0	0	1	0	0
31-May-10	1	1	0	1	0	0	0	1	0	0	3	1	0	0	0	0
01-Jun-10	0	1	0	0	2	1	1	0	0	0	1	0	0	0	0	1
02-Jun-10	2	1	0	0	1	0	3	0	1	1	0	0	1	0	1	1
03-Jun-10	0	0	1	0	1	0	2	0	0	1	0	1	1	1	0	0
04-Jun-10	0	0	0	1	0	0	2	1	0	0	0	0	1	5	2	0
05-Jun-10	0	0	3	0	1	1	0	2	1	0	0	2	1	2	0	1
06-Jun-10	2	0	3	2	3	1	3	0	0	0	0	1	1	1	0	2
07-Jun-10	0	0	2	0	3	0	1	0	1	1	0	0	0	2	1	0
08-Jun-10	0	1	1	2	5	5	1	1	2	0	1	2	0	2	0	1
09-Jun-10	1	2	3	2	1	1	2	1	3	2	1	2	0	3	3	2
10-Jun-10	2	0	1	0	0	0	2	1	1	1	0	1	4	0	0	3
11-Jun-10	0	0	1	2	3	5	2	3	0	1	6	3	3	0	4	2
12-Jun-10	2	2	1	1	3	2	3	1	1	4	1	2	1	0	0	0
13-Jun-10	0	0	0	3	3	1	2	3	0	0	1	1	4	2	0	1
14-Jun-10	1	1	0	2	0	1	5	3	3	2	1	1	5	0	2	0
15-Jun-10	0	0	1	4	3	1	5	4	0	1	0	0	1	1	0	3
16-Jun-10	2	4	3	2	4	2	7	9	3	1	5	0	2	2	1	4
17-Jun-10	1	4	2	3	4	4	4	5	2	2	9	2	4	4	7	2
18-Jun-10	0	3	2	2	7	8	2	4	3	1	2	0	2	1	4	2
19-Jun-10	2	1	3	7	1	7	4	3	5	4	3	5	1	7	1	1
20-Jun-10	2	4	1	4	14	3	2	2	6	9	4	5	5	8	5	4
21-Jun-10	4	4	1	2	2	2	2	3	4	1	3	4	3	7	3	0
22-Jun-10	4	1	5	7	6	5	6	1	3	3	3	2	2	1	0	1
23-Jun-10	0	1	1	7	1	6	4	5	2	1	2	6	1	1	0	3
24-Jun-10	4	4	5	8	6	4	4	10	0	4	2	5	8	2	3	3
25-Jun-10	4	5	3	13	14	7	2	15	4	9	8	7	7	9	5	6
26-Jun-10	9	8	1	9	13	18	23	8	15	12	5	5	14	15	20	9
27-Jun-10	7	7	24	13	13	1	13	7	12	6	13	7	7	13	10	5
28-Jun-10	12	4	20	16	10	18	10	3	4	11	8	5	13	16	14	14
29-Jun-10	20	14	19	18	28	26	23	7	8	10	12	13	14	43	20	32
30-Jun-10	15	16	31	62	47	30	29	25	16	14	14	15	26	21	6	14
01-Jul-10	28	6	21	19	21	30	14	10	9	8	3	12	9	9	18	9
02-Jul-10	21	15	19	37	36	24	19	6	26	14	25	29	46	29	15	20
03-Jul-10	27	11	26	29	30	31	17	26	18	16	15	32	27	28	9	24
04-Jul-10	16	14	22	38	38	43	31	26	20	21	23	24	35	19	6	22
05-Jul-10	54	22	12	25	16	33	42	27	17	26	21	11	25	20	28	21
06-Jul-10	40	18	34	24	47	44	52	52	31	15	23	6	22	15	8	14
07-Jul-10	24	16	30	61	81	65	64	56	38	10	21	52	24	24	30	15
08-Jul-10	33	32	40	69	23	56	25	51	35	9	20	17	18	20	14	11
09-Jul-10	10	10	16	39	44	64	50	57	28	5	47	27	37	38	33	23
10-Jul-10	26	29	41	49	64	74	57	39	51	39	27	38	29	31	35	27
11-Jul-10	42	20	19	51	72	45	77	60	33	17	5	45	40	33	37	8
12-Jul-10	60	19	48	73	82	93	63	36	24	41	23	47	40	47	39	42
13-Jul-10	68	44	73	109	71	64	36	83	57	58	89	65	72	70	25	0
14-Jul-10	21	45	58	67	116	120	99	81	14	41	83	81	48	62	12	19

15-Jul-10	71	35	33	55	101	104	118	90	76	25	79	68	49	52	11	15
16-Jul-10	17	19	44	25	75	82	57	65	59	49	50	34	73	75	40	20
17-Jul-10	65	21	29	40	74	94	74	66	72	95	81	101	119	90	52	38
18-Jul-10	47	9	19	48	55	80	120	108	89	95	64	76	87	109	43	18
19-Jul-10	78	4	24	28	96	149	140	128	81	100	96	91	86	88	46	29
20-Jul-10	39	32	25	93	110	131	182	147	113	90	77	67	94	64	30	11
21-Jul-10	49	27	25	22	75	82	126	89	74	79	142	164	137	124	59	31
22-Jul-10	41	13	8	50	32	54	53	91	81	93	48	59	96	100	12	38
23-Jul-10	95	48	40	44	90	108	113	121	71	51	59	129	149	108	91	42
24-Jul-10	187	65	34	38	62	72	118	100	30	94	136	41	54	69	50	64
25-Jul-10	231	53	29	47	159	125	202	155	62	153	115	79	147	98	77	47
26-Jul-10	272	56	28	22	22	74	97	123	92	103	89	86	135	90	27	10
27-Jul-10	15	8	5	23	48	76	71	196	138	109	54	51	36	52	40	16
28-Jul-10	23	17	32	18	78	81	123	73	81	98	95	98	108	72	44	44
29-Jul-10	92	41	25	56	131	153	199	174	146	88	122	110	52	81	28	14
30-Jul-10	122	30	28	17	162	63	58	105	69	79	82	180	88	110	56	18
31-Jul-10	69	22	4	48	91	115	145	287	129	188	155	90	90	68	69	57
01-Aug-10	37	12	7	34	73	98	183	190	117	109	101	125	181	197	103	55
02-Aug-10	159	77	41	53	94	58	152	191	159	134	127	169	178	135	137	41
03-Aug-10	83	41	32	56	94	96	186	121	58	55	47	55	69	79	31	15
04-Aug-10	N.C[a]	N.C[a]	N.C[a]	129	199	201	170	119	39	25	47	95	106	80	26	14
05-Aug-10	36	22	13	81	158	93	57	68	47	43	35	55	89	49	17	13
06-Aug-10	29	35	39	25	97	129	116	114	101	56	35	36	49	37	49	33
07-Aug-10	12	28	36	44	46	59	63	69	61	77	54	65	58	37	38	36
08-Aug-10	65	41	27	31	38	119	135	145	85	61	70	55	53	55	38	18
09-Aug-10	43	65	32	29	36	40	54	46	88	98	72	21	75	50	41	22
10-Aug-10	38	32	25	40	43	76	69	56	48	15	42	34	30	39	31	25
11-Aug-10	4	7	4	9	1	27	14	37	40	33	38	27	48	49	23	18
12-Aug-10	15	30	15	20	31	44	45	22	24	17	31	23	41	18	10	13
13-Aug-10	2	24	24	34	24	36	40	60	22	24	9	30	58	32	41	22
14-Aug-10	1	42	21	50	48	71	83	52	29	23	28	16	49	41	22	15
15-Aug-10	13	35	15	24	24	35	52	30	14	13	34	21	57	51	40	18
16-Aug-10	18	34	19	31	26	40	28	17	33	29	17	32	25	28	16	8
17-Aug-10	3	21	7	14	21	32	30	29	27	14	10	24	20	8	3	1
18-Aug-10	6	3	5	17	19	22	19	26	35	27	12	17	9	14	3	4
19-Aug-10	3	4	7	18	23	17	18	22	27	15	15	26	22	13	11	3
20-Aug-10	5	15	8	24	27	18	21	19	16	11	21	14	14	11	6	3
21-Aug-10	1	32	11	8	20	19	35	20	26	17	9	28	12	12	7	2
22-Aug-10	5	17	11	5	27	15	26	16	11	13	6	12	19	14	2	1
23-Aug-10	3	28	6	6	12	13	11	8	7	4	7	8	7	9	2	3
24-Aug-10	2	7	12	27	31	39	37	42	27	24	13	19	25	16	15	14
25-Aug-10	12	47	22	31	25	30	38	18	18	18	14	25	11	8	7	2
26-Aug-10	12	8	51	56	70	98	62	49	37	31	31	46	20	27	19	12
27-Aug-10	10	47	26	48	91	105	87	80	75	61	80	74	73	36	48	19
28-Aug-10	26	82	63	98	98	136	142	105	73	57	46	37	46	42	22	13
29-Aug-10	5	38	42	58	83	101	78	59	51	72	40	66	66	60	34	17
30-Aug-10	19	97	56	94	118	101	159	147	136	132	116	145	89	59	24	5
31-Aug-10	20	77	118	150	135	200	138	127	124	66	71	133	110	29	85	22
01-Sep-10	10	114	83	237	231	180	104	62	100	66	63	67	129	15	7	4
02-Sep-10	21	63	88	324	282	255	169	125	55	68	33	110	67	33	18	12
03-Sep-10	5	102	84	276	218	153	133	101	89	59	81	30	18	46	53	12
04-Sep-10	3	68	76	243	204	176	116	70	77	52	51	29	18	48	53	26
05-Sep-10	18	139	105	299	291	223	215	199	121	153	136	77	179	123	85	28
06-Sep-10	50	237	323	630	454	382	317	233	133	254	276	168	165	135	138	28
07-Sep-10	39	278	326	543	553	328	301	185	271	195	217	174	144	88	29	8
08-Sep-10	20	84	109	637	684	315	453	292	263	183	187	140	103	63	61	10

09-Sep-10	16	86	115	282	632	562	393	292	186	245	211	216	230	95	21	24
10-Sep-10	35	90	217	578	571	434	418	137	307	333	246	255	325	266	150	35
11-Sep-10	10	141	142	270	300	207	155	223	246	242	251	266	276	242	143	19
12-Sep-10	14	125	46	201	405	236	269	130	156	145	146	178	112	92	80	17
13-Sep-10	11	171	127	99	298	318	303	233	120	149	182	275	317	218	23	10
14-Sep-10	16	144	127	245	651	371	412	231	184	190	210	206	189	146	24	7
15-Sep-10	8	49	102	310	287	153	113	143	146	106	222	208	103	89	20	2
16-Sep-10	2	61	29	52	108	137	143	173	209	185	112	152	160	72	9	6
17-Sep-10	7	65	87	156	298	184	298	296	296	221	154	197	113	67	42	8
18-Sep-10	5	63	129	89	442	335	241	282	213	185	175	174	169	113	42	18
19-Sep-10	7	86	136	208	320	136	93	109	121	120	122	82	114	112	49	19
20-Sep-10	20	127	41	110	241	139	162	148	119	117	111	104	196	141	18	8
21-Sep-10	31	166	249	419	952	517	396	456	506	371	188	313	239	313	104	73
22-Sep-10	N.C[a]	N.C[a]	960	124	N.C[a]	109	621	539	416	337	276	356	249	281	43	23
23-Sep-10	21	125	206	505	696	375	432	381	249	168	109	175	121	121	26	45
24-Sep-10	61	134	292	420	522	320	334	230	307	455	331	276	347	155	88	30
25-Sep-10	60	153	193	407	539	518	397	265	144	94	181	163	166	125	92	33
26-Sep-10	11	82	114	132	215	133	130	129	95	157	40	140	80	88	26	11
27-Sep-10	10	70	82	82	193	139	135	86	84	68	80	122	101	81	29	3
28-Sep-10	2	62	146	202	384	278	179	174	125	97	95	164	117	57	4	6
29-Sep-10	1	32	83	70	140	146	125	133	101	64	53	101	132	63	16	6
30-Sep-10	3	35	61	112	224	157	123	99	123	99	30	107	46	47	14	2
01-Oct-10	5	37	39	82	135	179	34	50	84	97	62	79	54	25	4	4
02-Oct-10	6	28	42	162	396	259	144	104	110	116	82	117	52	31	29	7
03-Oct-10	8	45	59	205	289	168	172	83	148	124	111	89	79	75	24	4
04-Oct-10	11	7	67	50	335	136	79	162	228	152	131	154	131	96	1	1
05-Oct-10	3	23	72	53	315	132	105	121	134	153	148	129	153	86	8	2
06-Oct-10	4	35	75	93	93	176	155	81	36	49	82	110	104	99	8	3
07-Oct-10	1	22	62	94	150	123	122	113	73	84	60	60	15	48	3	6
08-Oct-10	9	47	76	150	179	228	212	132	167	126	117	106	117	57	18	7
09-Oct-10	6	64	123	85	178	205	206	159	83	101	99	70	60	63	13	11
10-Oct-10	8	4	51	65	116	106	170	63	61	75	48	66	21	32	12	4
11-Oct-10	10	6	108	148	133	176	140	65	75	108	145	89	83	61	15	8
12-Oct-10	13	41	99	67	56	68	138	123	N.C[a]	N.C[a]	N.C[a]	N.C[a]	N.C[a]	N.C[a]	572	5
13-Oct-10	12	9	66	86	66	91	106	51	61	43	36	38	78	35	2	2
14-Oct-10	5	8	43	24	81	70	49	51	41	75	44	82	66	19	4	3
15-Oct-10	6	8	43	82	128	112	113	122	114	97	69	119	73	50	26	20
16-Oct-10	35	31	158	200	228	288	273	184	88	61	90	99	208	171	74	32
17-Oct-10	9	35	190	201	205	160	148	38	71	61	36	67	140	55	16	7
18-Oct-10	6	35	128	93	179	106	162	69	75	41	64	109	121	70	9	4
19-Oct-10	4	9	99	57	97	107	112	93	85	63	51	49	58	48	3	5
20-Oct-10	15	12	92	82	136	148	149	95	37	30	39	38	54	19	4	5
21-Oct-10	4	4	58	38	64	62	95	76	63	34	6	20	34	4	1	4
22-Oct-10	5	2	29	30	52	81	73	39	65	63	50	44	36	16	1	8
23-Oct-10	7	5	78	48	49	58	86	58	26	34	21	32	22	14	14	10
24-Oct-10	3	10	67	49	37	57	31	35	20	29	16	16	12	6	0	7
25-Oct-10	1	2	21	14	17	22	20	31	31	29	42	43	40	6	1	1
26-Oct-10	8	2	37	29	50	88	84	75	56	66	56	44	44	8	3	0
27-Oct-10	5	3	34	34	47	46	49	19	12	47	83	69	67	36	5	2
28-Oct-10	4	5	30	32	26	43	31	4	9	33	18	24	11	5	3	3
29-Oct-10	4	2	32	13	12	45	27	16	34	32	25	56	30	29	4	8
30-Oct-10	3	0	18	25	31	19	34	24	21	20	22	22	8	10	12	3
31-Oct-10	3	4	19	29	24	40	45	18	22	28	21	17	20	17	6	2

[a] Not counted. Missing data from fish count technicians.

Appendix F: Hourly count of adult American shad at the Oregon shore fish-ladder (ladder 7) of McNary Dam during the 2010 season. Hour 1 starts at 5am DST and hour 16 ends at 8:50pm DST. Hourly counts represent fish passage during 50 minute per hour. For full hour estimates, 50 minute counts were multiplied by 1.2. Dark background indicates hours during which video monitoring occurred.

Date	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16
01-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Apr-10	0	0	0	N.C[a]	0	0	0	0	0	0	0	0	0	0	0	0
22-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-May-10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
17-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

20-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
22-May-10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
23-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-May-10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
26-May-10	0	0	0	0	0	0	1	0	0	0	0	1	0	3	N.C[a]	2
27-May-10	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
28-May-10	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	2
29-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
30-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
31-May-10	0	0	0	0	2	0	0	0	0	0	1	0	2	1	2	0
01-Jun-10	0	0	0	0	0	2	0	0	0	1	1	1	0	3	5	0
02-Jun-10	3	0	0	1	1	3	1	2	5	9	4	3	11	0	1	6
03-Jun-10	1	0	2	1	1	0	9	2	1	9	18	7	15	11	10	10
04-Jun-10	0	0	0	1	0	1	8	0	0	0	2	3	2	13	11	4
05-Jun-10	0	3	1	0	0	0	0	4	17	19	22	42	55	74	49	26
06-Jun-10	3	5	2	9	2	9	14	42	43	69	122	109	135	193	148	77
07-Jun-10	68	25	21	13	15	21	56	26	8	-4	43	74	140	136	76	36
08-Jun-10	24	1	15	5	9	12	15	16	45	164	64	80	173	183	132	151
09-Jun-10	67	46	25	27	35	38	18	25	8	39	20	26	34	93	92	75
10-Jun-10	54	6	1	0	12	17	0	31	9	4	18	4	7	0	3	1
11-Jun-10	0	0	2	0	3	1	1	0	0	7	5	2	3	7	5	6
12-Jun-10	12	2	1	3	0	1	0	0	1	1	2	6	14	16	5	9
13-Jun-10	3	1	0	6	5	3	1	1	2	7	6	29	94	134	23	70
14-Jun-10	45	52	22	9	16	23	20	19	105	55	88	239	570	324	350	120
15-Jun-10	50	49	16	23	28	56	29	10	16	24	59	56	236	178	139	121
16-Jun-10	32	14	17	25	32	14	5	39	72	97	209	109	224	139	65	107
17-Jun-10	19	15	3	7	4	10	10	26	8	113	91	73	134	51	103	5
18-Jun-10	15	6	15	10	13	7	19	12	10	43	83	290	747	833	896	626
19-Jun-10	131	34	47	93	51	254	275	394	720	747	833	790	1027	1153	1082	730
20-Jun-10	169	153	93	245	482	564	603	626	140	1045	1344	1339	1244	1122	876	527
21-Jun-10	85	29	34	129	133	102	296	575	100	804	925	806	863	719	641	424
22-Jun-10	55	15	65	85	71	74	63	16	119	183	336	452	907	690	512	325
23-Jun-10	51	14	31	62	131	95	131	165	201	394	500	906	1432	1225	920	810
24-Jun-10	160	145	211	169	187	193	260	656	551	647	832	962	1226	1182	893	527
25-Jun-10	94	70	88	142	240	409	457	777	779	773	874	983	1565	1376	848	572
26-Jun-10	137	84	115	71	217	274	336	339	638	814	1122	1916	2723	2516	1376	1089
27-Jun-10	181	36	206	97	115	212	180	230	396	464	636	967	1621	1618	902	584
28-Jun-10	180	125	35	148	280	113	157	171	319	500	874	1163	1504	1189	630	476
29-Jun-10	105	139	192	222	202	158	364	334	288	571	450	1264	1419	1361	759	431
30-Jun-10	247	24	73	89	112	63	95	264	386	615	566	641	942	729	622	586
01-Jul-10	115	49	73	189	222	137	653	776	791	928	847	572	989	405	341	293
02-Jul-10	101	42	56	39	127	89	133	148	254	228	415	704	1150	603	416	248
03-Jul-10	36	14	16	18	25	56	112	109	96	111	128	213	410	349	159	225
04-Jul-10	24	15	33	52	130	161	202	157	251	224	191	288	510	306	292	278
05-Jul-10	44	7	26	35	99	58	121	173	225	212	218	294	762	473	361	312
06-Jul-10	84	85	115	151	170	233	519	573	579	504	752	555	466	480	322	292
07-Jul-10	71	77	227	317	253	334	527	507	668	617	722	828	732	482	452	218
08-Jul-10	58	95	157	203	288	370	366	661	751	669	575	442	374	229	226	160
09-Jul-10	26	18	50	46	51	73	89	174	241	527	299	212	186	187	170	167
10-Jul-10	28	14	10	37	97	264	449	489	793	1118	1212	1360	905	913	635	341
11-Jul-10	31	5	31	47	91	79	157	196	169	190	34	290	178	178	161	51
12-Jul-10	11	19	49	86	130	199	248	222	221	195	458	396	427	452	295	198
13-Jul-10	49	59	181	175	71	118	127	228	269	188	268	264	227	251	221	217
14-Jul-10	18	6	17	41	61	139	225	216	208	130	175	266	454	441	243	164

15-Jul-10	24	11	10	10	46	194	343	266	284	162	69	82	50	34	28	36
16-Jul-10	6	2	6	16	30	30	29	51	67	74	85	59	51	44	42	37
17-Jul-10	9	1	16	21	35	23	28	34	73	80	52	95	111	88	34	38
18-Jul-10	18	0	10	19	57	37	60	80	98	27	62	167	237	127	79	78
19-Jul-10	37	10	12	20	31	68	120	73	87	84	114	52	76	103	113	97
20-Jul-10	27	11	18	64	67	51	142	173	195	154	135	319	200	162	281	195
21-Jul-10	189	25	51	65	116	108	251	120	250	243	153	343	192	300	439	385
22-Jul-10	99	51	49	176	179	93	99	201	224	141	108	54	301	435	180	172
23-Jul-10	50	8	13	69	59	62	105	86	66	64	41	133	124	121	117	71
24-Jul-10	36	16	35	19	47	73	166	103	167	298	167	213	198	87	73	118
25-Jul-10	43	9	12	16	27	40	74	92	32	50	37	45	74	64	57	53
26-Jul-10	27	1	8	14	22	39	76	50	66	67	28	21	61	92	59	54
27-Jul-10	47	26	4	19	17	23	43	69	44	84	33	85	66	63	54	62
28-Jul-10	36	-1	4	8	24	29	59	27	62	57	48	81	53	12	82	55
29-Jul-10	52	3	13	33	37	51	58	52	56	48	34	49	40	82	59	46
30-Jul-10	22	6	11	8	32	19	85	26	40	63	51	40	50	46	39	49
31-Jul-10	20	3	4	2	38	9	23	21	28	33	8	21	17	11	15	25
01-Aug-10	1	0	0	1	8	22	10	22	40	35	12	40	16	29	33	26
02-Aug-10	5	1	0	3	7	10	19	20	69	17	10	28	33	32	26	31
03-Aug-10	16	3	0	6	8	8	16	10	14	5	14	9	7	18	11	8
04-Aug-10	N.C[a]	N.C[a]	N.C[a]	10	30	6	22	20	9	3	4	16	5	14	5	7
05-Aug-10	7	0	6	2	7	9	8	12	3	4	5	3	9	14	12	12
06-Aug-10	5	6	0	3	16	3	16	19	16	11	7	19	10	10	14	12
07-Aug-10	1	0	5	3	25	6	13	5	11	10	15	7	11	16	11	6
08-Aug-10	0	0	0	0	1	6	20	4	2	4	17	1	2	6	4	4
09-Aug-10	0	0	4	3	7	5	9	2	5	11	4	2	3	5	7	7
10-Aug-10	5	0	2	9	16	31	10	3	16	2	0	1	3	3	7	2
11-Aug-10	0	0	11	2	1	14	35	1	5	2	7	9	5	3	4	4
12-Aug-10	1	2	1	4	14	4	5	6	11	3	8	3	3	12	4	8
13-Aug-10	2	3	3	4	2	0	11	29	5	17	8	9	34	4	1	7
14-Aug-10	0	1	0	5	8	14	13	7	1	5	5	2	0	1	3	0
15-Aug-10	2	1	0	1	5	15	11	6	3	4	1	4	2	0	7	10
16-Aug-10	3	0	6	2	9	9	5	1	9	10	6	15	0	5	0	5
17-Aug-10	2	1	0	3	5	3	5	4	1	3	32	2	12	13	3	4
18-Aug-10	1	3	3	1	4	6	9	4	4	5	1	1	1	6	2	1
19-Aug-10	0	0	6	9	6	14	9	3	12	9	0	1	0	4	2	3
20-Aug-10	0	0	1	1	2	3	7	8	9	5	3	5	1	5	0	0
21-Aug-10	0	3	2	4	9	7	5	3	0	12	2	6	3	2	2	2
22-Aug-10	1	0	0	0	5	13	6	0	4	1	2	5	3	0	8	1
23-Aug-10	1	0	3	1	2	15	4	9	6	1	4	0	-1	2	1	3
24-Aug-10	1	0	0	2	0	5	1	0	3	12	0	7	0	4	1	11
25-Aug-10	0	0	0	0	2	0	1	6	25	8	11	1	3	6	8	16
26-Aug-10	0	0	2	1	1	3	4	1	0	1	3	6	0	7	6	0
27-Aug-10	1	1	0	0	0	2	1	3	1	0	3	3	4	2	0	0
28-Aug-10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Aug-10	0	0	0	0	0	4	2	0	0	2	0	1	0	0	1	0
30-Aug-10	0	0	0	0	0	0	0	4	2	1	1	2	0	3	1	1
31-Aug-10	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0

[a] Not counted. Missing data from fish count technicians.

Appendix G: Hourly daytime counts of adult Pacific lamprey at the Oregon shore fish-ladder (ladder 7) of McNary Dam during the 2010 season. Hour 1 starts at 5am DST and hour 16 ends at 8:50pm DST. Hourly counts represent fish passage during 50 minute per hour. For full hour estimates, 50 minute counts were multiplied by 1.2. Dark background indicates hours during which video monitoring occurred.

Date	hr1	hr2	hr3	hr4	hr5	hr6	hr7	hr8	hr9	hr10	hr11	hr12	hr13	hr14	hr15	hr16
01-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Apr-10	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
22-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Apr-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

20-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N.C[a]	0
27-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31-May-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Jun-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-Jul-10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
09-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Jul-10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
11-Jul-10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Jul-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Jul-10	0	2	1	2	0	0	0	0	0	0	0	0	0	1	0	0
14-Jul-10	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0

15-Jul-10	0	0	1	2	1	0	0	0	1	1	0	0	0	0	0	0
16-Jul-10	3	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
17-Jul-10	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0
18-Jul-10	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0
19-Jul-10	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
20-Jul-10	0	3	3	1	0	0	0	0	0	0	0	1	1	1	0	0
21-Jul-10	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
22-Jul-10	1	2	3	0	1	2	0	0	1	1	0	0	0	0	0	0
23-Jul-10	5	3	3	1	0	0	0	0	0	0	0	0	-1	0	0	0
24-Jul-10	6	2	2	0	0	0	0	0	1	0	1	0	0	0	0	0
25-Jul-10	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Jul-10	3	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
27-Jul-10	3	6	1	0	0	0	0	0	0	2	0	0	0	0	0	0
28-Jul-10	3	1	0	2	0	1	0	0	0	0	1	0	2	1	1	0
29-Jul-10	3	0	0	3	0	0	0	2	0	0	0	1	0	0	0	0
30-Jul-10	5	3	0	3	1	0	0	0	0	0	2	1	0	2	1	2
31-Jul-10	3	5	1	1	2	0	0	0	1	0	1	0	1	1	0	1
01-Aug-10	8	6	1	1	0	0	1	1	0	0	0	1	0	0	0	4
02-Aug-10	7	5	4	1	1	0	0	0	0	1	0	1	0	0	1	0
03-Aug-10	5	3	3	4	0	0	2	0	0	2	0	0	0	0	0	1
04-Aug-10	N.C[a]	N.C[a]	N.C[a]	9	0	0	0	0	0	0	2	0	0	0	1	0
05-Aug-10	5	1	1	3	3	0	1	0	1	2	0	0	1	0	0	1
06-Aug-10	7	4	1	3	1	0	0	1	1	0	1	0	0	1	0	0
07-Aug-10	2	8	3	0	1	0	0	0	0	0	0	0	0	0	0	1
08-Aug-10	4	2	2	4	3	1	0	0	0	2	0	2	0	0	0	0
09-Aug-10	9	5	6	2	2	2	0	0	0	0	0	0	1	0	0	0
10-Aug-10	7	5	0	2	2	2	0	0	0	0	1	0	0	0	0	0
11-Aug-10	3	0	1	1	0	3	0	2	0	0	0	0	1	0	1	0
12-Aug-10	0	6	0	1	1	0	0	0	0	0	0	0	1	1	2	0
13-Aug-10	1	3	2	3	0	-1	0	0	0	0	0	1	0	0	0	0
14-Aug-10	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0
15-Aug-10	2	7	1	1	0	1	0	0	0	0	0	0	0	0	0	0
16-Aug-10	1	4	0	0	0	0	1	0	0	0	0	3	0	0	0	1
17-Aug-10	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
18-Aug-10	3	1	0	0	2	0	0	0	0	0	0	0	0	1	1	0
19-Aug-10	4	2	1	0	2	0	1	0	0	0	1	1	1	0	0	0
20-Aug-10	3	2	3	1	1	0	0	0	0	0	0	2	0	0	0	-1
21-Aug-10	2	3	1	1	2	0	0	0	1	0	0	0	0	0	0	0
22-Aug-10	4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Aug-10	2	0	2	1	0	1	0	0	0	0	0	0	2	0	1	0
24-Aug-10	0	1	1	2	0	0	0	0	0	1	0	0	0	0	0	0
25-Aug-10	3	3	1	2	0	1	1	0	0	0	0	0	0	0	1	0
26-Aug-10	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
27-Aug-10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
28-Aug-10	1	0	0	2	1	1	0	1	0	0	0	0	0	0	0	0
29-Aug-10	1	1	1	0	0	1	0	1	1	0	0	1	0	0	0	1
30-Aug-10	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
31-Aug-10	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0
01-Sep-10	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Sep-10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-Sep-10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
04-Sep-10	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
05-Sep-10	0	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0
06-Sep-10	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
07-Sep-10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
08-Sep-10	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

09-Sep-10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
10-Sep-10	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
11-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
12-Sep-10	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
13-Sep-10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
14-Sep-10	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
15-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Sep-10	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
17-Sep-10	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Sep-10	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
19-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-Sep-10	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
21-Sep-10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Sep-10	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
24-Sep-10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
25-Sep-10	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
26-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Sep-10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
28-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Sep-10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Sep-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[a] Not counted. Missing data from fish count technicians.