US Army Corps of Engineers

King County

Seattle Public Utilities

FINAL REPORT

PIT Tagging of Juvenile Salmon Smolts in the Lake Washington Basin: Seventh and Eighth Year (2006-2007) Study Results

King County Water and Land Resources Division
U.S. Army Corps of Engineers, Seattle District
and
Seattle Public Utilities

Contract Numbers T02752T, W912DW-07-P-0249, and ROO-34-12

R2 Resource Consultants, Inc.

May 30, 2008

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Prepared for:

King County Water and Land Resources Division
U.S. Army Corps of Engineers, Seattle District
Seattle Public Utilities

Prepared by:

Paul DeVries, Ph.D., P.E.
R2 Resource Consultants, Inc.
Redmond, Washington

2006-2007 Study Collaborators:

Charles Ebel, Lynne Melder, Fred Goetz; U.S. Army Corps of Engineers, Seattle District
Greg Volkhardt, Kelly Kiyohara; Washington Department of Fish and Wildlife
Frank Leonetti, Hans Berge; King County Water and Land Resources Division
Julie Hall, Paul Faulds; Seattle Public Utilities

May 30, 2008

Funding and resources provided by:

- King County
- U.S. Army Corps of Engineers
- Seattle Public Utilities
- Washington Department of Fish and Wildlife

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ABSTRACT

This study continued the use of Passive Integrated Transponder (PIT) tag technology for monitoring smolt migration characteristics as they pass through the Lake Washington and Lake Washington Ship Canal (LWSC) system, including the Hiram M. Chittenden Locks (Locks). This document presents results of the seventh and eighth consecutive years of monitoring studies conducted as follow-up to the Lake Washington General Investigation Study.

Four smolt flumes and PIT tag detection devices (tunnel readers) were again installed over the spillway dam of the Locks to monitor outmigration during the spring of 2006 and 2007. Funding was limited in 2006, resulting in a reduced scope that year. A mix of tags were used in various studies conducted by (i) Washington Department of Fish and Wildlife (WDFW) in Bear Creek, the Cedar River, and the Issaquah Hatchery, (ii) the University of Washington (UW) hatchery, and (iii) the Northwest Fisheries Science Center, National Marine Fisheries Service (NMFS). Primarily juvenile Chinook and coho salmon were captured, tagged and released. A few steelhead juveniles and rainbow/cutthroat trout were also captured, tagged, and released. Hatchery Chinook and coho were tagged and released as part of individual experiments.

This report presents results primarily for fish tagged and released by WDFW; detection data were provided to the various other researchers conducting PIT tagging in the basin; they will present their results in separate reports. However, where relevant to describing passage characteristics through the LWSC and Locks, selected results are presented here that include the detection data for the other studies.

Tunnel reader calibration tests were performed in 2006 and 2007 using wooden sticks with tags to evaluate the detection efficiency of the tunnel readers. Detection efficiencies generally ranged between 90%-100%. Similar issues as previous years included structural features of the flumes reducing the detection efficiency of the tunnel readers, and the absence of complete coverage of PIT tagged fish passing the Locks through other routes.

Flume passage rates were reduced in 2004 compared with other years because of early warming of surface water temperatures in the LWSC and Lake Washington and reduced water availability, resulting in use of fewer flumes and reduced passage rates at the flumes.

The data continued to provide valuable, detailed biological information for seventh and eighth consecutive years on migration and passage behavior of salmon smolts originating from different parts of the Lake Washington basin and transitioning to adult life in saltwater. The information included seasonal and diurnal migration and passage timing, passage routes through the Locks,

and further evidence of repeat cycling through the Locks and residualism, both of which may be related to water temperatures in the LWSC and Lake Washington. *Water temperature in the LWSC and lunar phase appeared to interact in their influence on outmigration and passage characteristics, although temperature may have the stronger influence*. The information from these studies can be used for shaping spill timing and volume requirements at the Locks, and for evaluating causal mechanisms of decline.

Results of adult PIT tag monitoring in the fish ladder in 2006 and 2007 are also provided as a separate technical memorandum in an appendix. The adult detection data have provided information regarding both juvenile and adult migration and passage patterns and survival.

Implementation of PIT tagging is not assured in the future. The data have proven extremely useful for monitoring purposes and should continue to provide valuable insights into factors influencing salmon populations in the Lake Washington basin. Future activities will depend on a concerted funding commitment by stakeholders in the basin to continue PIT tagging as part of a longer term monitoring program.

ACKNOWLEDGEMENTS

This document reports the results of studies conducted as a continuation of efforts originally funded by Seattle Public Utilities, King County and the U.S. Army Corps of Engineers (USACE), Seattle District as part of the Lake Washington General Investigation (LWGI) Study. Project managers for the respective funding institutions are: Linda Smith, Project Manager, LWGI Section 1135 Study, and Chuck Ebel, PIT Tag Study Project Manager, USACE; Frank Leonetti and Hans Berge, King County Water and Land Resources Division; and Julie Hall and Paul Faulds, Seattle Public Utilities. A large number of persons contributed significantly to study implementation in 2006 and 2007, including: Greg Volkhardt, WDFW, team leader for the multi-year study of smolt trapping in Lake Washington tributaries; Kelly Kiyohara, WDFW, was responsible for tagging fish caught in the tributary screw traps and providing data for this analysis; and John Post, USACE, oversaw installation and implementation of smolt flume facilities and provided assistance in other aspects of the study. Hans Berge provided a helpful review.

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1. INTRODUCTION

The Hiram M. Chittenden Locks (Locks; also known as the Ballard Locks) were constructed by the Seattle District, U.S. Army Corps of Engineers (USACE) as part of the Lake Washington Ship Canal (LWSC) project between 1911 and 1916 to provide for navigation between Lake Washington and Puget Sound (Figure 1-1). The LWSC is approximately 14 km (8.6 miles) long and lies entirely within the boundaries of the city of Seattle. The project was authorized by Public Law 61-264, River and Harbor Act of 25 June 1910, in the First Session of the 60th Congress in accordance with a plan set forth in House Document 953. The Montlake Cut, which extends between Lake Washington and Lake Union, was the final link in the route and was completed in 1917. Official dedication of the Locks project occurred on July 4, 1917. Other concurrent, related activities included closure of the historic outflow of Lake Washington into the Black River in 1912 and concomitant rerouting of the Cedar River into the lake for flood control (Hanson 1957). Although the Locks have since undergone several structural modifications and improvements including construction of a saltwater intrusion barrier in 1966 and a new fish ladder in 1976, the entire LWSC project has effectively influenced anadromous fish passage and migration from the time it was constructed through to the present day.

The Washington Department of Fish and Wildlife (WFDW) and Muckleshoot Indian Tribe (MIT) initiated field research in 1994, in cooperation with the Environmental Resources Section of the Seattle District, regarding the effects of operation of the Locks on the survival and general well-being of anadromous salmonids utilizing the Lake Washington watershed for various parts of their life-cycle. Issues raised in the studies have included successful downstream passage of juvenile and adult outmigrants, loss of estuarine habitat and the effects of a relatively sudden freshwater-saltwater transition, intrusion of saltwater into Lake Washington, and upstream passage of adult migrants. These and other concerns are particularly germane now in light of listings under the federal Endangered Species Act (ESA) of Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*; listed in 1999 as "threatened"; 64 FR 14308) and bull trout (*Salvelinus confluentus*; listed in 1999 as "threatened"; 64 FR 58910), and potential listing of coho salmon (*O. kisutch*). Sockeye salmon (*O. nerka*) is also an important species in the basin for water and fisheries management. It is important that the influence of the LWSC project on salmonid survival and health be fully understood so that appropriate measures can be developed and enacted at the locks that minimize or eliminate adverse effects. In addition, it is important that migration behavior and survival be better understood in the Lake Washington basin to maximize effectiveness of restoration efforts and projects.

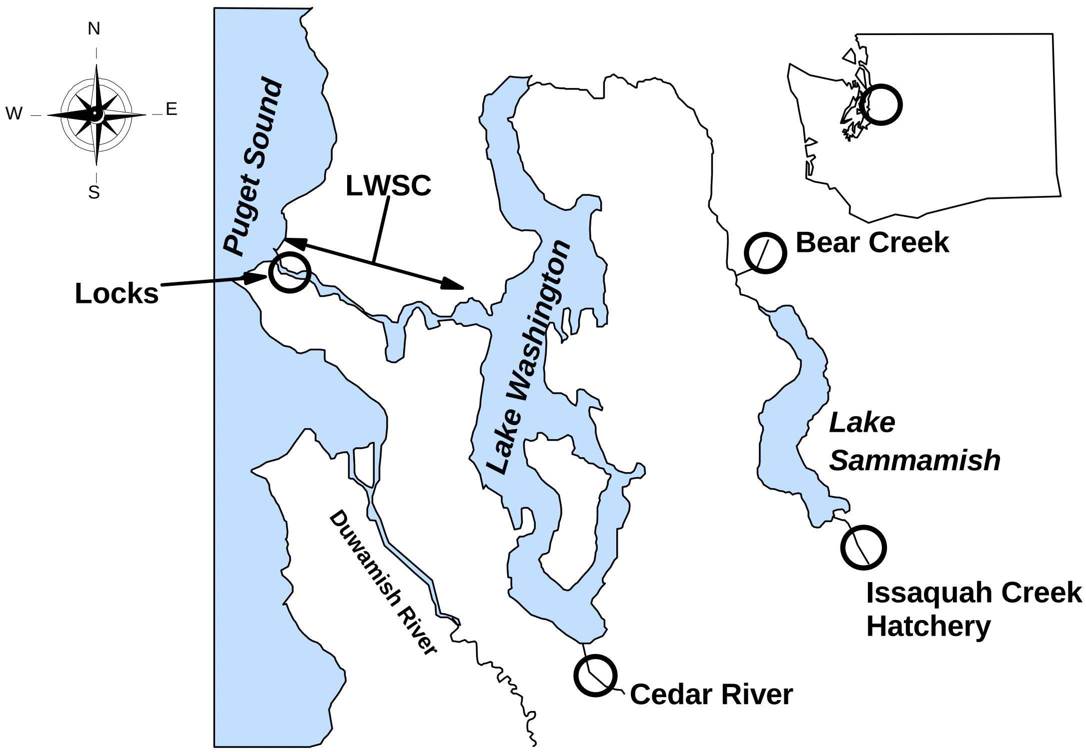

Figure 1-1. Locations of the Lake Washington Ship Canal (LWSC), Hiram M. Chittenden Locks, and long term PIT-tagged fish release locations in the Lake Washington.

This document details the results from seventh and eighth year studies of migration and passage behavior and survival using Passive Integrated Transponder (PIT) tag technology (Prentice et al. 1990a,b,c). The work builds on six years of work conducted as part of the greater Lake Washington General Ecosystem Restoration General Investigation (LWGI) Study conducted by the Seattle District of the USACE, with Seattle Public Utilities as a GI Study partner. King County was a study partner during the initial stages of the GI. This report and the data analyses presented herein were funded by King County's Water and Land Resources Division.

1.1 PHYSICAL LAYOUT, FEATURES, AND OPERATION OF THE LOCKS

The Locks consist of a large and small lock on the north side, a fish ladder on the south side, and a 71.6 m (235') long concrete gravity spillway dam extending between the small lock and the ladder (Figure 1-2). There is also a saltwater return system that consists of a drain leading to below the spillway dam and a pipe that runs along the bottom of the LWSC to the fish ladder. The pipe discharge is distributed to a number of steps where it mixes with the freshwater entering the head of the ladder.

The large lock is 24.4 m (80') wide and can accommodate ships with drafts up to 9.1 m (30'). It consists of three operating gates that divide the lock into two chambers, two 4.3 m (14') high by 2.6 m (8.5') wide culverts that run longitudinally along each side of the lock and pass lake water into the lock to fill it, filling valves, and dewatering facilities. During normal operations, either one or both chambers are used depending on the size and number of ships passing through the facility. The valves can be used to vary the rate at which the lock is filled. A saltwater barrier is located at the upstream end of the lock and can be raised to reduce the volume of saltwater intruding into the LWSC when the upper gate is opened. Relatively strong density currents can occur within the lock when the gate is opened, as surface freshwater enters the lock to replace the denser saltwater flowing out into the LWSC.

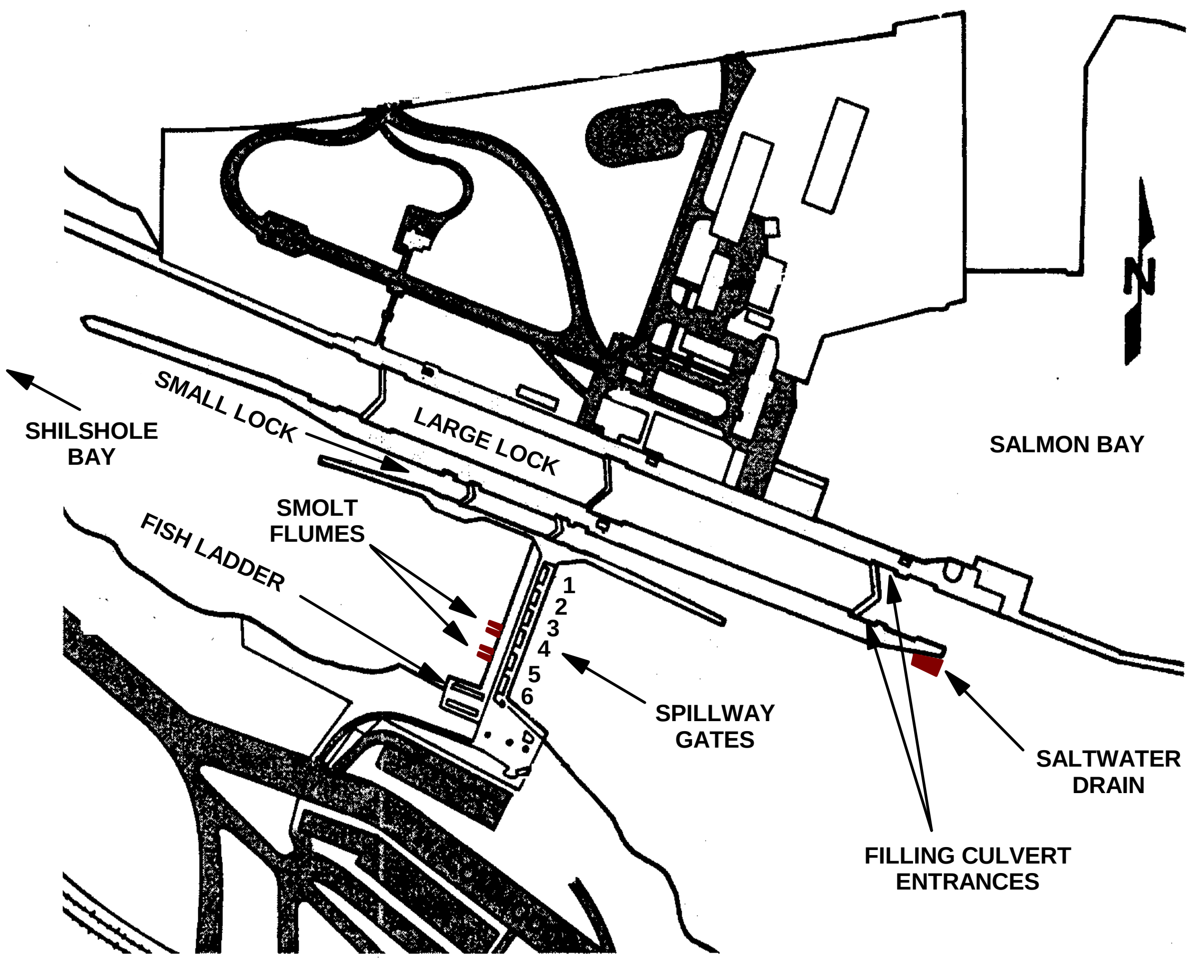

Figure 1-2. Plan view of the Hiram M. Chittenden Locks showing major structural features and location of smolt flumes and tunnel readers in spill bays 4 and 5.

The small lock is 9.1 m (30') wide and can accommodate smaller boats with drafts up to 4.9 m (16'). It consists of two operating gates, two 1.8 m (6') high by 2.6 m (8.5') wide culverts that run longitudinally along each side of the lock and pass lake water into the lock to fill it, filling valves, and dewatering facilities. The valves can be used to vary the rate at which the lock is filled.

Saltwater intrusion is an important concern, particularly with respect to managing water quality of Lake Washington and Lake Union where the resulting density stratification and water quality attributes of the lakes could transform their deeper areas into sterile, anaerobic waters. The Washington Department of Ecology has correspondingly set water quality standards, where the salinity in the LWSC at the University Bridge may not exceed 1 parts per thousand (ppt) at any point in the water column. The Locks are therefore managed to minimize intrusion as much as possible, which occurs with each lockage when a denser, more saline layer flows upstream under the less dense freshwater in the form of a density (or, gravity) current. The large lock is associated with approximately 25 times more saltwater intruding per lockage than the small lock, but the small lock is conversely used more frequently. A hinged barrier on the large lock bottom partly retards saltwater intrusion, but the main line of defense is the saltwater drain located immediately upstream. The saltwater drain has a discharge capacity of 300 cfs and returns water downstream, including through the fish ladder.

The spillway dam consists of six bays that are numbered sequentially as numbers 1 through 6, from North to South. Each bay is 9.8 m (32') wide and controlled by a 3.8 m (12.5') radius tainter gate that is driven by an independent electric motor. The spillway has a design head of 2.3 m (7.4'), a crest elevation of 4.2 m (13.75'), an ogee shape, and is capable of discharging up to 515 m^3/s (18,200 cfs) at the maximum regulated Lake Washington elevation of 6.7 m (22'). Beginning in May 2000, four seasonal smolt passage flumes (smolt flumes) have been installed in bays 4 and 5 with the goal of passing downstream migrating juvenile salmonids by the Locks (the flumes have been installed in April in each following year). These flumes replaced a prototype "smolt slide" that was installed initially in 1995 for the same purpose of passing smolts downstream of the Locks.

The Locks regulate the elevation of the water surface of Salmon Bay, Lake Union, and Lake Washington. Project authorization documents specify the normal operating levels to be between 6.1 m (20') and 6.7 m (22') above the USACE Project Datum. The Project Datum, established on 1 January 1919, is 2.08 m (6.82') below the National Geodetic Vertical Datum (NGVD) and 0.17 m (0.57') below the Seattle mean lower low water (MLLW) elevation. In constructing the

LWSC project, the level of Lake Washington was lowered about 2.7 m (9') from its historic elevation. The storage between the 6.1 m and 6.7 m levels has been used historically to augment LWSC inflows for use in operating the Locks, the saltwater return system, and the fish ladder facility. More recently, the storage is also used to provide flows to the smolt flumes during the spring outmigration period.

There are four seasonal periods of operation: the winter holding period (low pool), the spring refill period, the summer conservation holding period (full pool), and the fall drawdown period. The lake elevation is maintained at the minimum operating level (6.1 m) during winter months to allow for maintenance on docks, walls, etc. by businesses and lakeside residents, minimize wave and erosion damage during winter storms, and provide storage space for high inflows during flood events. The spring refill period begins February 15 and continues until generally the first week in May when the lake reaches 6.66 m (21.85'), which is slightly less than the full pool level (6.7 m; levels can reach this depending on water availability). The spillway gates (and also now the flumes when appropriate) are operated to keep the lake elevation near its maximum authorized normal level of 6.7 m. The upper limit is dictated by physical design restrictions of the spillway gates and requirements of lake-associated infrastructure. Water demands of the Locks, the saltwater drain, the fish ladder, and the flumes result in the lake elevation gradually lowering, beginning in late June to late July depending on water availability. The Water Conservation Plan that is in effect at the Locks attempts to maintain lake levels at or above the 6.1 m level as much as possible (70% historic reliability level). It is not always possible, however, to maintain this elevation during abnormally low water years and when higher than usual saltwater intrusion associated with lock openings requires additional flushing.

1.2 CONTEXT AND PURPOSE OF THE PIT TAG STUDY

PIT tag studies were originally implemented as part of the greater LWGI study, which was initiated in May 1999. The LWGI study is a USACE project with the City of Seattle (Seattle Public Utilities) and King County as local sponsors. In addition, funding has been provided for tag detection in the fish ladder by a King Conservation District grant. The purpose of the LWGI study is to develop a set of ecosystem restoration projects to provide benefits primarily to salmon in the Lake Washington basin. This includes evaluation of various projects that may contribute to restoration of ecological processes or functions within the Lake Washington basin, including projects that will improve passage of juvenile and adult salmon through the Locks. The LWGI study has included salmon studies at the Locks, in the Ship Canal, and in Lakes Washington and Sammamish and their tributaries since 2000. Activities have entailed studies that improve knowledge and understanding of the life history and ecology of native fish in the Lake

Washington basin. Relevant projects have included making fish passage improvements at the Locks and in the LWSC, and implementing water conservation measures to provide additional water for fish passage through the Locks. PIT tagging studies help address data needs associated with better understanding of salmon migration in the greater Lake Washington basin and relative survival of out-migrating juvenile salmon, and have been conducted every year of the GI Study. In addition, PIT tag monitoring of juveniles has complemented post-flume construction monitoring performed as part of the Lake Washington Ship Canal Smolt Passage, Section 1135 Restoration Project (USACE 1999). The studies have been funded variously by the USACE, SPU, and King County. This report and analyses were funded by King County.

Results presented in this report address the following overall objectives for using PIT tagging as a monitoring methodology:

- Continue documentation of the migration timing characteristics of naturally and hatchery reared salmon in the Lake Washington basin with emphasis on Chinook and coho salmon;
- Further focus the evaluation of mark and recapture of PIT-tagged fish as a means to evaluate factors influencing survival of outmigrating Chinook and coho salmon juveniles; and
- Evaluate hypotheses based on previous years' results with the 2006-2007 results.

In addressing the above objectives, the resulting data were intended for use in evaluating alternative operations and structural measures at the Locks and other restoration measures in the Lake Washington system, as well as building a longer term time series for analysis.

2. METHODS

Tagging efforts after 2004 have been reduced in scope compared with before, reflecting funding constraints. Primary goals of the 2006 and 2007 studies were to further evaluate the use of PIT tagging in the Lake Washington system and the influence on migration patterns of factors within and outside of the control of water management operations at the Locks. The overall study design involved tagging and release of natural and hatchery origin juvenile Chinook and coho salmon at multiple locations in the watershed, and detecting them at the Locks. Study design and methods are described below.

2.1 PIT TAG TECHNOLOGY

PIT tags are small, unobtrusive electronic devices that are implanted in the abdominal cavity of fish. The tags used in the 2006 study were 134.2 kHz Destron-Fearing TX1400BE, 14 character tags. WDFW switched to the use of Allflex tags in 2007 for fish caught in the Bear Creek and Cedar River screw traps. The tags do not appear to influence fish behavior or survival significantly when inserted properly (Prentice et al. 1990c). Delayed tagging mortalities generally do not exceed 1% based on extensive experience in the Columbia River (Muir et al., 2001a,b; Dare 2003). The tags consist of an antenna coil of coated copper wire that is connected to an integrated circuit chip, all encased in a glass tube that is approximately 12 mm long and 2.1 mm in diameter (Figure 2-1). The device works on the principle of induction of current in a coil as it passes through an electromagnetic field. As the tag passes through the field created by a detection device, the current that is induced in the coil powers the chip, which subsequently transmits a unique tag identification number code through the coil. The tag signal is received by a coil loop of the detection device and is decoded. Each PIT tag in this study had 10 unique characters that distinguished it from approximately 34×10^9 other possible code combinations (Prentice et al. 1990a,b,c).

The distance at which a PIT tag may be detected is relatively short because of power generation and dissipation concerns in a water medium. Consequently, the fish must either be made to pass through the coil of a detection apparatus that is fixed in position at a structure where passage can be controlled, or the tagged fish must be captured in the field and held near a portable ("hand-held") detector. In this study, four fixed detectors ("tunnel readers") were custom fabricated and installed in spillway bays 4 and 5 at the Locks, and hand-held detectors were used in the field for detecting tagged fish that were caught during various seining operations.

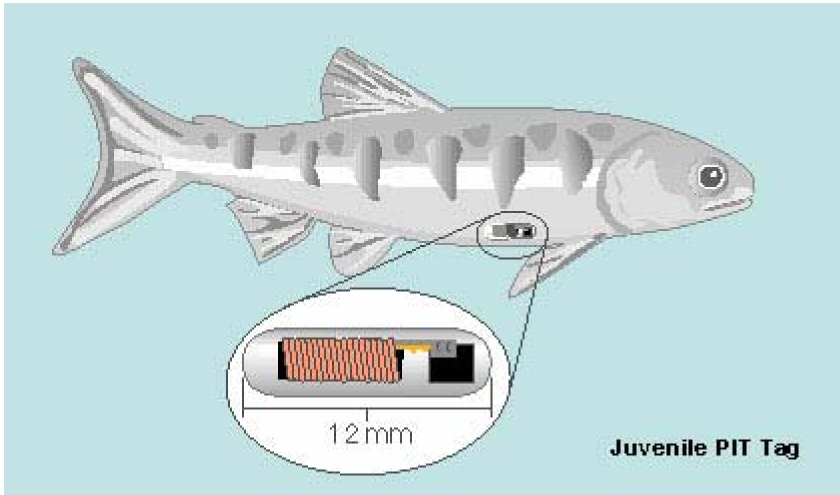

Figure 2-1. Schematic of a Passive Integrated Transponder (PIT) tag inside a juvenile salmonid.

2.2 INSTALLATION AND MONITORING OF TUNNEL READERS AT THE LOCKS

Spillway bays 4 and 5 were converted into smolt passage facilities by raising the radial gates and installing bulkheads with adjustable gates that controlled free surface water flow into four flumes, two located in each bay. Flumes were numbered according to spillway bay (4 or 5) and entrance size (A = 0.69 m (2.25') wide entrance; B = 1.8 m (6') wide entrance; C = 1.2 m (4') wide entrance). Flume number assignments were, from north to south, 4A, 4B, 5C, and 5B (or alternatively, numbers 1 through 4, respectively). Each flume was cantilevered out over the spillway face and led to a tunnel reader that was attached to its end (Figure 2-2). However, this configuration was associated with structural vibration problems in 2000 that led to reduced detection efficiencies. In response, the flumes were "stiffened" at the beginning of the 2001 study by using steel rods attached at one end to the flume and at the other end to the concrete spillway. Tension was applied to the rods by means of turn-buckles, which were adjusted until structural vibrations were minimized. Unfortunately, some residual vibrations remained that could not be corrected, and that were apparently associated with flume hydraulics. This was a greater problem in the two large flumes (4B and 5B).

The sidewalls and floor of each flume were constructed of stainless steel screen so that some of the water entering the flume passed through the screens, thereby reducing the amount of water entering the tunnel reader. A larger flow rate was needed at the entrance of the flume than could be passed through the tunnel reader to ensure (i) large attraction flows and (ii) water velocities that significantly exceeded the swimming capacity of the tagged fish as they passed through the flume and reader. Entrance flows to each flume at normal operating capacity were 1.4, 3.7, 2.5, and 3.7 m^3/s (50, 130, 90, and 130 cfs) for Flumes 4A, 4B, 5C, and 5B, respectively. Outflows were approximately 0.34, 0.42, 0.40, and 0.42 m^3/s (12, 15, 14, and 15 cfs), respectively. The difference between inflow and outflow is the amount that passed through the screen walls of the flumes.

The tunnel readers used were Destron-Fearing brand 134.2 kHz PIT tag monitors. Each tunnel reader contained two independent sets of coil and electronic components that detected and recorded PIT tags separately as they passed through the reader (Figure 2-3). The tag numbers were stored on two computers (one main, one backup) located in the fish ladder maintenance room. The Windows-based MINIMON computer program was used. This program automatically created a new file each day and stored a complete record of detections and self-testing logs for each coil. Relevant data included PIT tag numbers, identification number of the coil that detected the tag, and the time and date of detection. Coil identification numbers were reversed in order from previous years, however. In 2003 and earlier, coils 11 and 12 represented flume 4A, coils 21 and 22 flume 4B, coils 31 and 32 flume 5C, and coils 41 and 42 represented flume 5B. In 2004 and 2005, the order of coil numbers was reversed during flume installation, where coils 11 and 12 were for flume 5B, etc. The PIT tag information was extracted using a Fortran program written to filter out other information and pre-process the data prior to QA/QC checking and subsequent data analyses.

The flumes are installed each spring, and removed each fall. The flumes became operational on April 27, 2006 and April 16, 2007. A flow-related operational problem occurred irregularly when the lake level was relatively high, and involved periodic over-topping of the flumes. Supercritical flow standing waves appeared to move slowly through the readers, as manifest by pulses in the outfall water. The amount of water spilling over was relatively small, and occurred in pulses that may have been associated with the transient standing waves. Observation of the flumes and fish swimming behavior did not indicate fish were being ejected, suggesting that few if any fish bypassed the tunnel reader when the flume overtopped. Because the number of PIT tagged fish was small relative to the total number of fish passing the Locks, it is likely that if tagged fish were ejected, the number would have been negligible.

Figure 2-2. The smolt flumes and PIT tag funnel readers, in position and operating at the Locks during spring 2000. Flumes are numbered, from left to right (and north to south), 4A, 4B, 5C, and 5B. View is from walkway next to fish ladder.

Figure 2-3. A PIT tag tunnel reader, prior to its installation at the Locks. Note the two reader coil units. Flow is from left to right through the pipe. The mounting bolts on the left end are for attaching the reader to the flume.

2.3 TAGGING, HOLDING, AND RELEASE OF FISH

Juveniles of three anadromous salmonid species were tagged: Chinook salmon, coho salmon, and steelhead trout. A small number of assumed resident trout were also tagged in 2006. Groups tagging juvenile salmonids with PIT tags in the Lake Washington basin included Washington Department of Fish and Wildlife (WDFW), National Marine Fisheries Service Northwest Fisheries Science Center (NMFS), University of Washington (UW), King County, and U.S. Fish and Wildlife Service (USFWS), with support from the U.S. Army Corps of Engineers (USACE; contact: Chuck Ebel). PIT tagging was conducted for five main studies (see Section 3.1 for numbers tagged and released):

- Naturally-spawned Chinook salmon (both years) and coho salmon (2007 in Cedar River only) offspring were caught by WDFW personnel, tagged, and released at two different locations in the Lake Washington watershed to evaluate passage characteristics of fish using the smolt flumes. Capture, tagging and released occurred at WDFW juvenile outmigrant smolt screw traps (see, e.g., Thedinga et al. 1996 for a description of a screw trap). In 2006, fish were released upstream of the trap to also estimate trap efficiency (contact: Greg Volkhardt). Tagging dates encompassed the peak of the outmigration period for naturally-produced smolts. Release locations were (Figure 1-1):
  - Lower Bear Creek, below the railroad trestle, downstream of Redmond Way; 2007 only)
  - Lower Cedar River, just upstream from the Logan Street Bridge; both years

- Resident trout were tagged and released at various locations in late July/early August of 2006 and 2007 in the Cedar River by WDFW, King County, and USFWS; 1 steelhead juvenile was tagged in 2007 (contact: Brad Thompson);
- Experimental groups of Chinook (both years) and coho salmon (2006 only) were tagged and later released at the UW Hatchery (contact: Tom Quinn);
- An experimental group of coho salmon were tagged and later released at the Issaquah Hatchery in 2007 for a feed study (contact: Jed Varney);
- Coho salmon, steelhead trout, and resident cutthroat and rainbow trout were tagged and released by NMFS at various locations in the Cedar River watershed in both years (contact: George Pess);

Data for individual fish in the WDFW studies were collected using a data collection station (Biomark brand) equipped with Pacific States Marine Fisheries Commission (PSMFC) software

(PITTAG2.EXE). All tagging was conducted using methods described by Prentice et al. (1990c). Tagging operations involved insertion into the abdominal cavity using a large bore syringe. After tagging, the needles on the syringes were disinfected in an ethyl alcohol bath for a minimum of 10 minutes before being reloaded and reused. Fish were collected overnight in the screw traps. On each day of tagging, fish trapped the night before were transferred using sanctuary dip nets to 5 gallon buckets and then to a small tub containing MS-222. A PIT tag was inserted into the anaesthetized fish, which were then returned into a recovery bucket. Fish were allowed to recover fully from the anesthetic before they were released back directly into the river below the screw trap, usually within an hour after tagging. In general, all or nearly all Chinook and coho present in the trap that day were tagged, except for a few fish that were smaller than about 70 mm in length, which were too difficult to handle and for which the tag was large relative to the abdominal cavity size. Tests were not conducted of post tagging mortality and tag shed rates; results from previous years indicated that such rates were likely to have been negligible (DeVries et al. 2007). Fish tagged in Bear Creek and the Cedar River were exclusively naturally reared. The tagged Chinook were likely all sub-yearlings, whereas it is likely that most tagged coho were yearlings.

2.4 CALIBRATION TESTING OF THE TUNNEL READERS

“Fish sticks” were used six times in 2006 and four times in 2007 to monitor the detection efficiency of the tunnel readers. The sticks were constructed out of 30 cm lengths of 1.9 cm (sold as ¾") x 1.9 cm hemlock stock wood. A small hole was drilled and a PIT tag was inserted and sealed in. Two types of sticks were constructed: (1) where the tag was oriented parallel (0º) to the long axis of the stick, and (2) where the tag was oriented 45º to the long axis. Previous years’ results indicated the fish sticks provided a reasonable index of detection efficiency, and that averaging the results of the 0º and 45º stick tests approximated live fish results (DeVries et al. 2005). Tests involved the release of arrays of five sticks of a particular tag orientation, tied together approximately two feet apart on fishing line, into the flumes from the spillway walkway using a surf-casting rod and reel. Previous test results suggest that the five sticks have a similar probability of detection as five sticks dropped individually into the flumes and retrieved below with a boat (DeVries et al. 2007). Each stick array was released into each flume for a total of twenty sticks per flume for each tag orientation in 2006, and ten sticks per flume in 2007. The associated error in determining detection efficiency of a given tag orientation was therefore 5% in 2006 and 10% in 2007, with overall detection efficiency errors of ±2.5% and ±5% respectively. The number of fish sticks detected was determined from the file created by MINIMON. Detection efficiency was calculated as the ratio of number detected to number released in each flume, expressed as a percentage. Supertags were used in 2006 and 2007;

Allflex tags were also used in 2007 to evaluate their effectiveness for continued use by WDFW in the tributary studies.

2.5 DETECTION STRATEGY

The 2006 and 2007 studies relied primarily on releasing fish at various locations in the watershed and detecting them at the Locks. As in previous years, not all of the passage routes through the Locks were monitored. There were no detection facilities or sampling conducted in the small lock, the other spillway gates, the saltwater drain, or the fish ladder. An unknown proportion of tagged fish therefore passed downstream without being detected.

2.6 DATA ANALYSES

Data analyses generally followed those in previous years (DeVries et al. 2002, 2005, 2007), with the notable exception that survival to the Locks was not evaluated in 2006 and 2007 because of the limited number of release locations and reduced effort overall.

2.6.1 Physical Characteristics of the Fish

Other than general body condition at time of tagging, the only physical characteristic of the tagged fish that was measured was fork length at time of tagging, and whether the fish could be discerned to have been of hatchery origin. Almost all of the tagged fish were measured, with the exception of a small number whose lengths were inadvertently not recorded by the digitizing system. Information was not available regarding growth and length at time of passage at the Locks. Fish lengths at time of tagging were used primarily to compare potential size differences between the detected and undetected fish by means of frequency analysis using a Chi Square test of observed (=detected fish) and expected (=released fish) frequencies (Zar 1984). This was done for each group as a whole, irrespective of release date to identify potential fish size dependent effects suggested by the data that might influence survival of each stock to the Locks. The length data from the Cedar River and Bear Creek tagging operations were used to compute average lengths of tagged fish at different times at each location. The results were plotted against tagging date to identify temporal trends, if any, that might potentially influence size-dependent survival to the Locks, or suggest partitioning of the length frequency data by tagging date.

2.6.2 Migration Behavior

The dates of PIT tag detections at the Locks were used to identify patterns and differences in migration timing, total travel time until passage through the flumes, and average migration rate among the different test groups. Average migration rate was computed by dividing travel distance by the number of days between release and detection at the Locks. Travel distances were determined using the "Topo" software package (Wildflower productions) by tracing assumed migration routes five times on electronic topographic quad sheets and averaging the numbers calculated by the program. Routes in the LWSC were assumed to follow the mid-channel line on average. Routes through Lake Washington were assumed to follow the west shoreline from either the mouth of the Cedar River, or the mouth of the Sammamish River, where the path as traced ran within approximately 400 m (¼ mile) offshore (note, however, that some hatchery fish exiting the Sammamish River were determined during this study to have likely migrated along the eastern shore of Lake Washington; see Section 4.0). Traced routes through Lake Sammamish followed both west and east shorelines and an average was taken of the two.

2.6.3 Passage Behavior at the Locks

The dates and times of PIT tag detections at the Locks were used to identify patterns and differences in seasonal and daily passage timing among the different test groups at the Locks. Tag codes were also evaluated for recycling times through the Locks, based on repeated detections at the tunnel readers and/or in purse seine samples in the large lock.

Flume passage rates were also evaluated for their potential relation to small lock fillings over the course of the outmigration season. The same Fortran computer program used in previous years calculated the number of detections that occurred (i) while the small lock was filling and for five minutes thereafter ("fill" period), and (ii) until the time of the next fill sequence ("between-fill" period). Times of lock openings were determined from records maintained by the Lockmaster, and the time for each lock to fill was determined as a function of tide elevation and observations of fill times at different tide levels. A post-fill period of five minutes was selected arbitrarily (absent specific data), assuming that fish continued to swim about actively for a short period after the velocity field in the spillway dam forebay returned to approximately steady-state, non-fill conditions. The exact time for velocities to return to steady state has not been determined in recent measurements of velocity fields above the Locks, but appears to be less than five minutes based on available measurements (Johnson et al. 2001). Velocity transients associated with density currents when the upper gates are opened (Lingel 1997) were not considered. The two sets of counts were compared using a t-test to evaluate the hypothesis that transient changes in water currents in the vicinity of the Locks caused by lock filling operations were associated with increased passage through the flumes. The null hypothesis was that passage was not significantly different in pair-wise comparisons of sequential observations of numbers of fish passing through the flumes during and between fills.

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3. RESULTS

Figures 3-1 and 3-2 show the approximate times that the smolt flumes were open for the periods in which the majority of PIT tagged salmon passed during the 2006 and 2007 outmigration seasons, respectively, according to logs kept in the lock control tower. The first and last detections of PIT tagged salmon in 2006 occurred on May 8 and July 16, respectively. Three trout PIT tagged in 2006 in the Cedar River were detected passing through the flumes in April 2007; otherwise, the first and last detections of PIT tagged salmon in 2007 occurred on May 1 and July 8, respectively.

The smolt flumes were used as the primary means to spill water to control lake levels during the spring outmigration period. However, inflows into Lake Washington were relatively high during May and June of 2006 compared with 2007 and preceding PIT tag study years, whereas they were closer to average in July of 2006 and all three months of 2007 (USGS gage data; these are the months when the majority of PIT tagged fish are detected passing the Locks). Considerable additional spill occurred through gates 1-3 in May and June of 2006, but not in 2007 (Figure 3-1). The increased spill may have affected PIT tag detection rates in 2006, as described later in this report, by providing an additional, alternative passage route to the smolt flumes. Flumes were generally shut down at night in both years to conserve water, except when they were needed for spill management. These operating procedures were based on previous years' PIT tag study results showing that more than 95% of fish passage in the flumes occurred during daylight hours (DeVries et al. 2005). There were also periods during the study when the flumes were closed for maintenance. Consequently, the flume coverage for PIT tags was neither continuous nor consistent.

The flumes operated long enough that the coho salmon outmigration was essentially complete and the numbers of tagged Chinook salmon passing through the flumes had decreased substantially to near zero, consistent with previous years (DeVries et al. 2007). Behavioral patterns evident in the data were therefore unlikely to have been influenced significantly by systematic error related to length of season. These patterns relate to migration, passage, and the transition to saltwater, and provide significant insight into the basic biology of juvenile outmigrant salmonids in the Lake Washington system, as described in the remainder of this report.

This section focuses predominantly on results for 2006 and 2007, and in a few cases presents previous years' results for comparative purposes. The results are compared in greater depth with previous findings and hypotheses in Section 4.

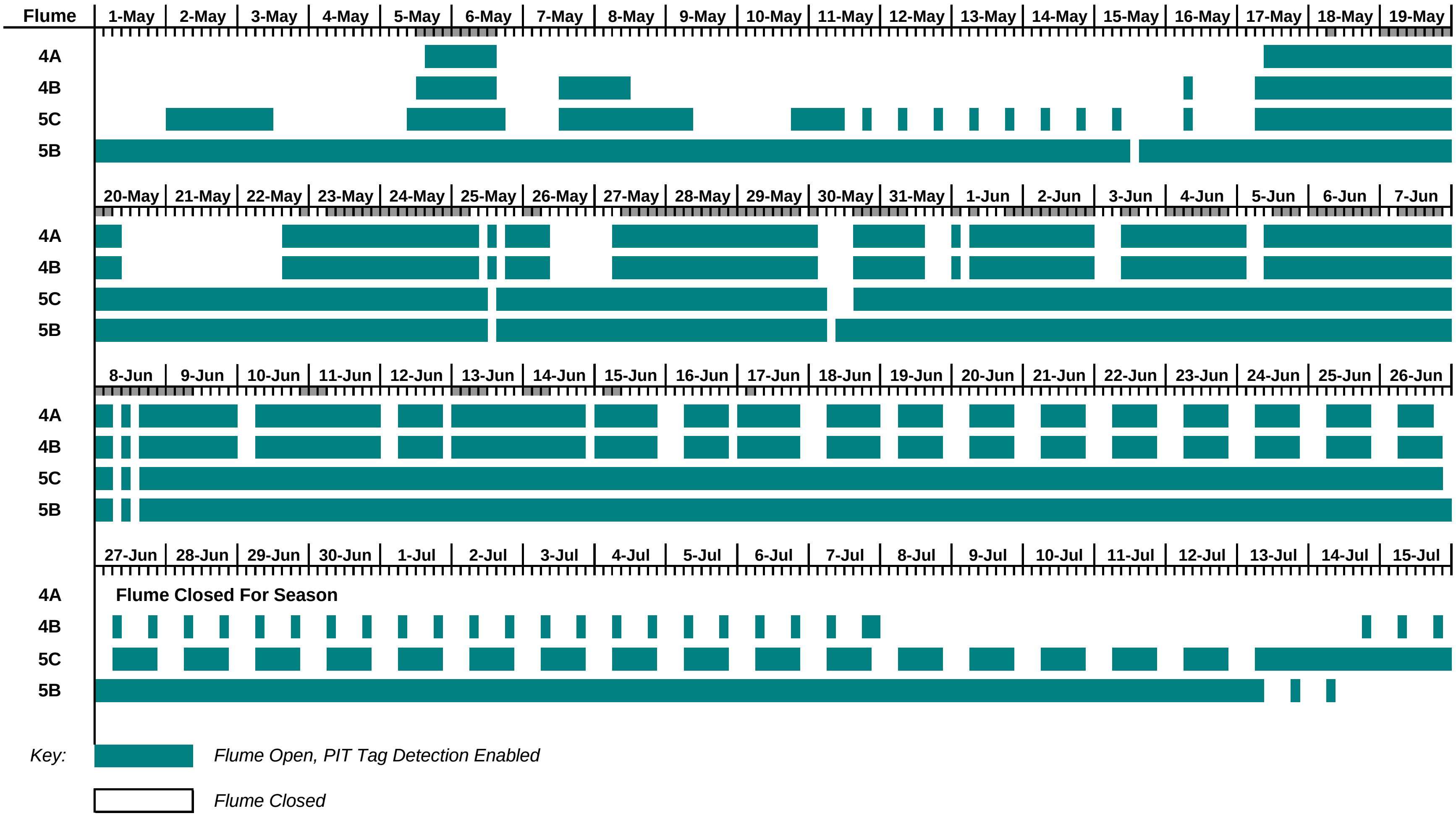


Figure 3-1. Times that the smolt flumes were open at the Locks during the 2006 PIT tag study until tunnel reader detections had essentially ceased. Periods of spill through gates 1-3 are indicated by the thin horizontal bar located immediately beneath the date.

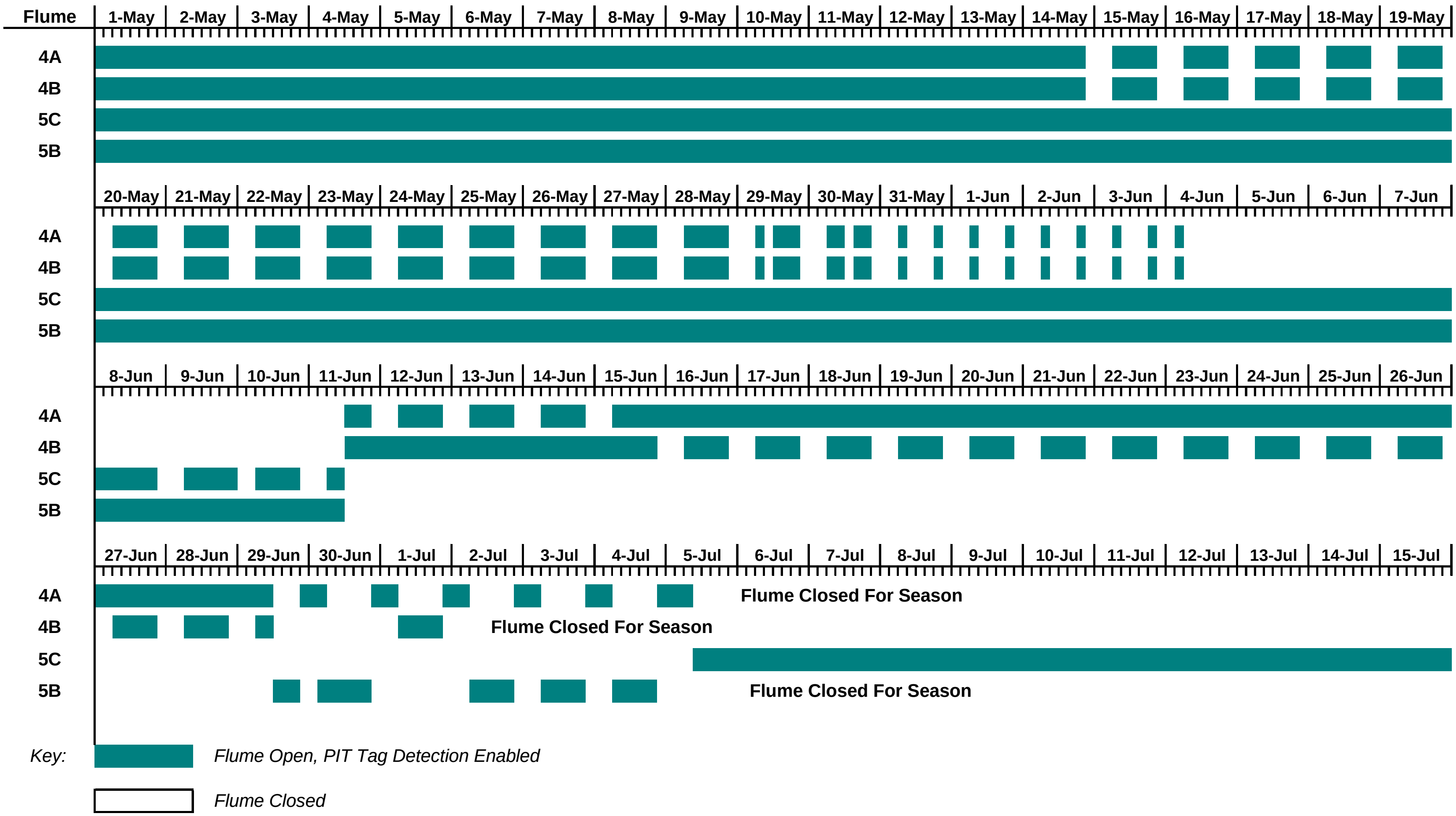


Figure 3-2. Times that the smolt flumes were open at the Locks during the 2007 PIT tag study until tunnel reader detections had essentially ceased.

3.1 PIT TAG DATA SUMMARIES

Table 3-1 summarizes numbers of fish and the locations at which they were tagged and released. The estimated numbers passing through the flumes reflect corrections based on average detection efficiencies determined for each flume in the calibration tests. Figures 3-3 through 3-5 depict the cumulative numbers and dates of tagging for each Chinook and coho group and screw trap release location. The numbers and dates of release of each species at each location, and the corresponding numbers detected in each flume are also presented in tabular form in Appendix A. Chinook were initially captured in low numbers in the Cedar River in 2007, but then numbers increased substantially around the same time that the decision was made to begin tagging coho salmon to make up for low tagging numbers overall; the increase in Chinook numbers and initiation of tagging of coho appeared to be coincidental (Kelly Kiyohara, WDFW, personal communication).

Table 3-1. Summary of 2006 and 2007 PIT tag release and recapture numbers at the screw trap sites and Issaquah Hatchery, Lake Washington PIT tag studies.

Species (Year)	Origin	Issaquah Creek Hatchery	Bear Creek	Cedar River
		Total Numbers Tagged and Released:		
Chinook (2006)	Natural	--	--	573
Chinook (2007)	Natural	--	2694	734
	Hatchery	--	--	1
Coho (2007)	Natural	--	--	75
	Hatchery	1178	--	--
		Total Numbers Detected in Smolt Flumes:		
Chinook (2006)	Natural	--	--	191
Chinook (2007)	Natural	--	713	60
	Hatchery	--	--	0
Coho (2007)	Natural	--	--	3
		449	--	--
		Estimated Total Numbers Passing Through Smolt Flumes:		
Chinook (2006)	Natural	--	--	191
Chinook (2007)	Natural	--	826	69
	Hatchery	--	--	0
Coho (2007)	Natural	--	--	3
	Hatchery	529	--	--

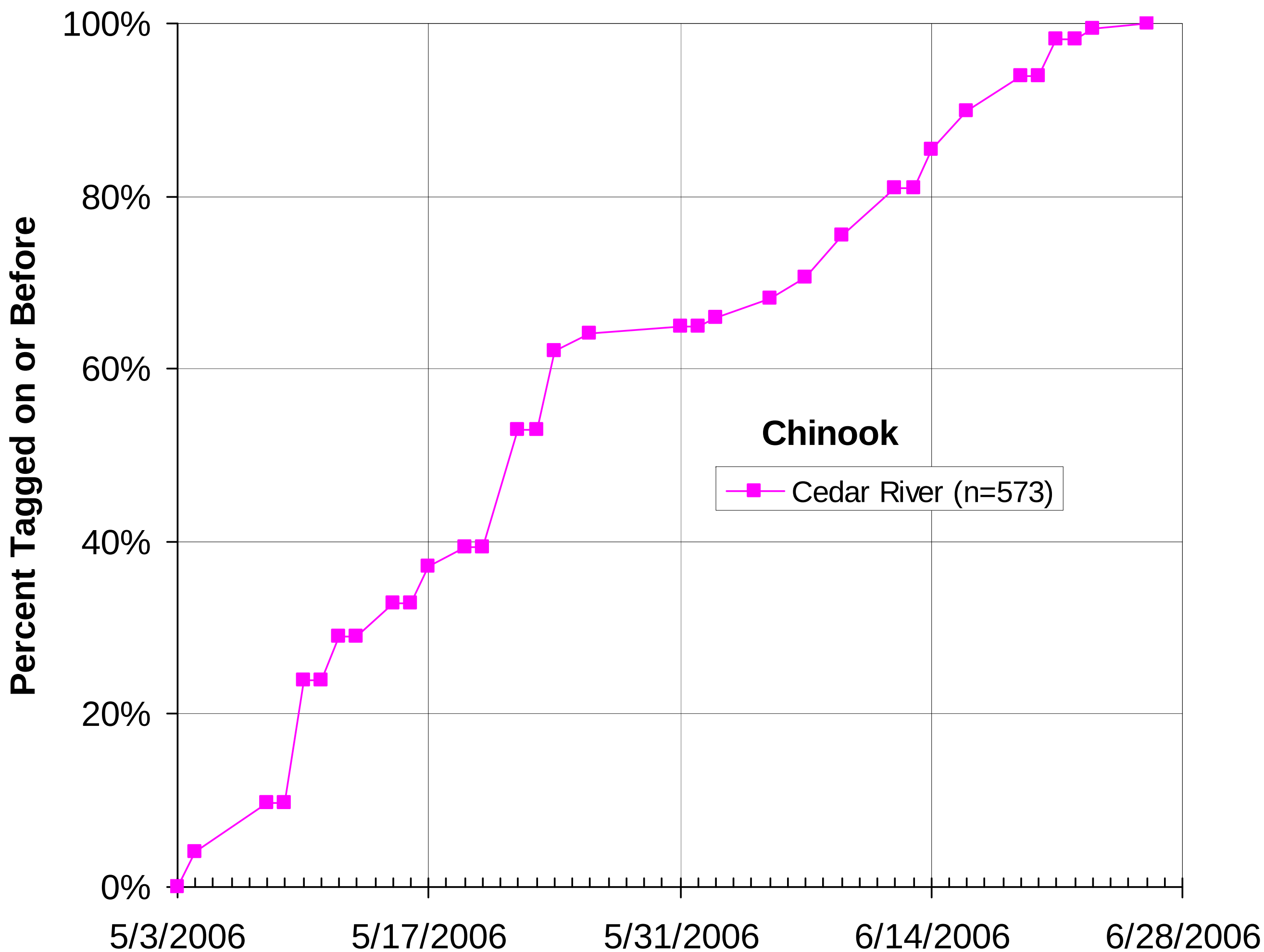


Figure 3-3. Cumulative frequency distributions of juvenile natural origin Chinook salmon PIT tagging numbers in the Cedar River by date, 2006 Lake Washington PIT Tagging study.

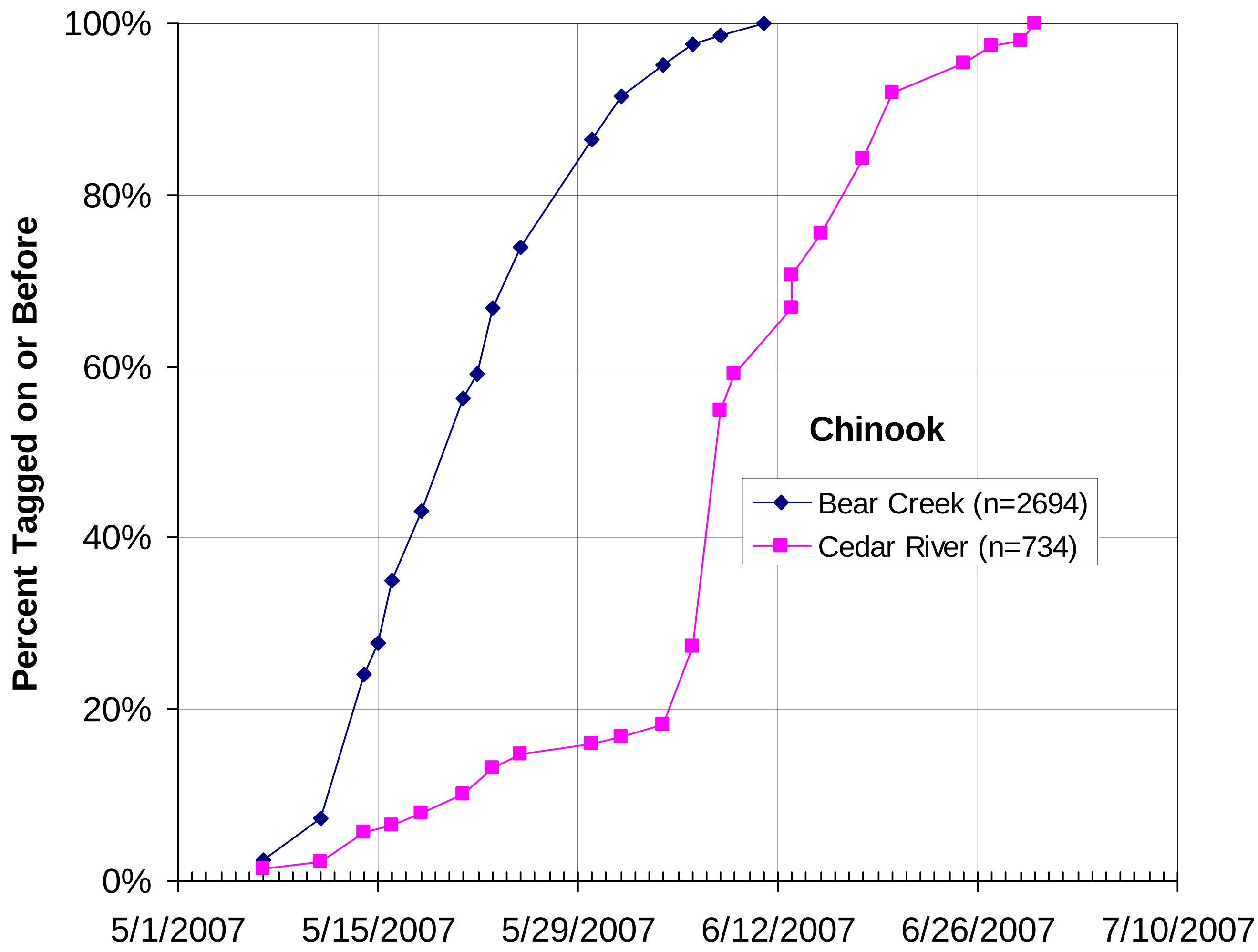


Figure 3-4. Cumulative frequency distributions of juvenile natural origin Chinook salmon PIT tagging numbers by date and location, 2007 Lake Washington PIT Tagging study.

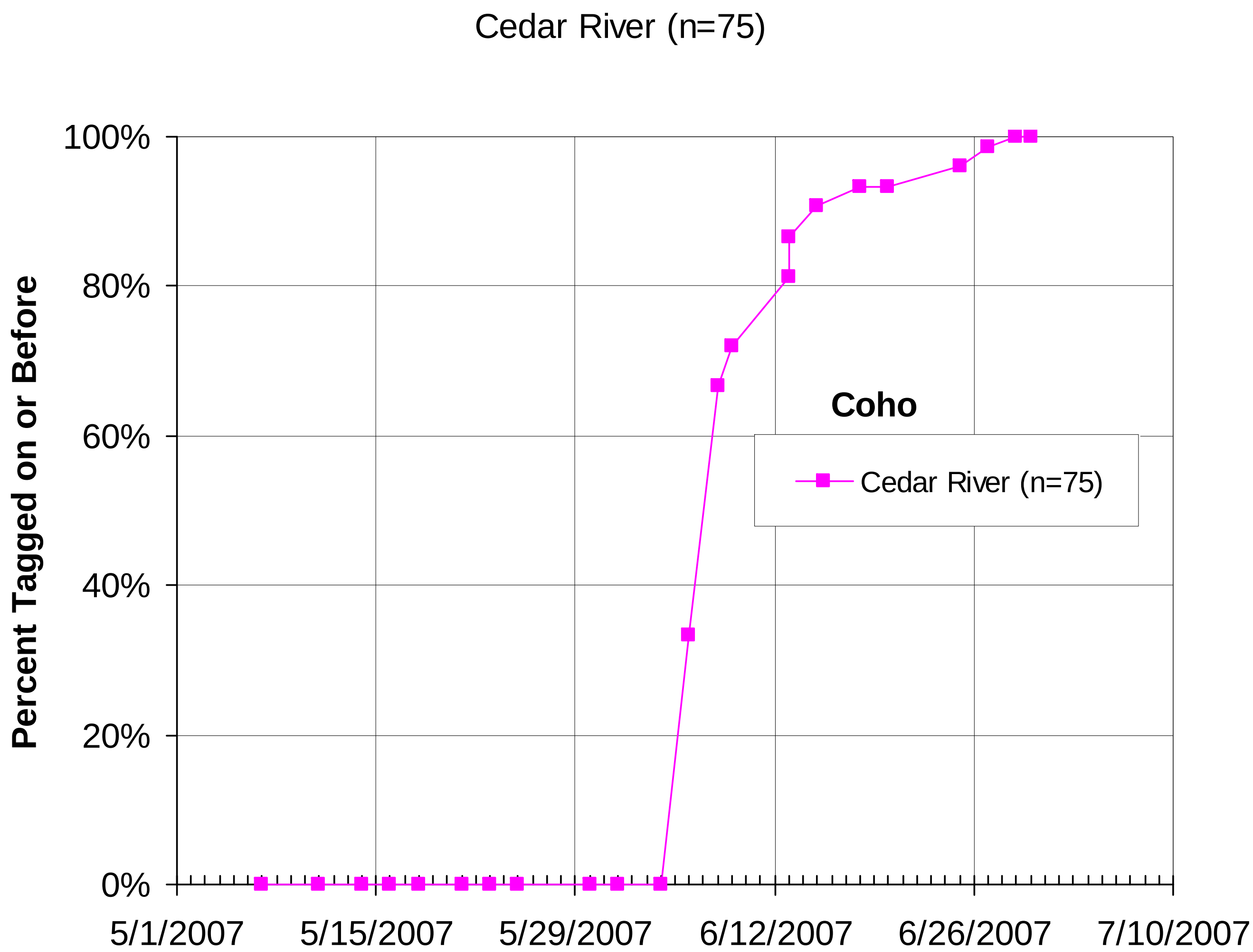


Figure 3-5. Cumulative frequency distributions of juvenile natural origin coho salmon PIT tagging numbers in the Cedar River by date, 2007 Lake Washington PIT tagging study.

There were a total of 20 mystery tags detected in the flumes in 2006, the origins of which were unknown (Table 3-2). They either represent tags that were not recorded during tagging in the system, or were part of another unreported study either in the basin or elsewhere (in which case the fish would have moved upstream through the lock chambers first). Each year, there are a few such mystery tags that apparently did not get recorded during tagging.

There was a tagging equipment problem in 2007 that led to losing data for 31 Chinook in Bear Creek and 9 Chinook in the Cedar River on May 9, 2007 (K. Kiyohara, WDFW, personal communication). It was not possible to identify which location or species of fish they were inserted at/in. There were correspondingly 11 mystery tags detected at the Locks, all with the Allflex tag ID (Table 3-2). These fish may have been tagged on May 9, 2007, or on other dates and not recorded during tagging.

3.2 TUNNEL READER CALIBRATION TESTING

Although the tunnel readers were monitored less frequently than in most previous years because of insufficient funding, the results indicated that the readers were generally operating satisfactorily. Average detection efficiencies for the spring outmigration period in each year were:

- 2006, Supertags: Flume 4A = 100% (0º and 45º); Flume 4B = 96% (0º) and 94% (45º); Flume 5C = 98% (0º) and 100% (45º); and Flume 5B = 98% (0º and 45º). Flume 4B performed the worst overall (Figure 3-6).
- 2007, Supertags: Flume 4A = 93% (0º) and 100% (45º); Flume 4B = 90% (0º) and 100% (45º); Flume 5C = 93% (0º) and 100% (45º); and Flume 5B = 90% (0º) and 78% (45º). Flume 5B performed the worst overall (Figure 3-7).
- 2007, Allflex: Flume 4A = 86% (0º) and 80% (45º); Flume 4B = 95% (0º and 45º); Flume 5C = 86% (0º) and 90% (45º); and Flume 5B = 88% (0º) and 89% (45º). Flume 4A performed the worst overall (Figure 3-7).

These levels were generally consistent with previous detection efficiencies. Flume 4A has been regularly associated with efficiencies at or near 100% in previous years (DeVries et al. 2007). Flumes 4B and 5B vary from year to year as to which flume has a higher detection efficiency. Guidelines for the Columbia River require a minimum detection efficiency of 95% with four coils operating, and most systems there operate in the 98-100 percent efficiency range (D. Park, Biomark, personal communication). The mean detection efficiency estimates were used to estimate the total numbers of PIT-tagged fish passing through the flumes by dividing the number detected from each release group in a flume by that flume's detection efficiency.

Detection efficiencies were higher in 2007 for the Destron-Fearing supertags compared with the Allflex tags (Figure 3-7). Allflex tags are consequently not recommended for future use in the system in studies relying on detection data from the Locks.

Table 3-2. PIT tags detected in the flumes in 2006 and 2007 with unconfirmed origin.

Tag No.	Detection		
	Flume	Date	Time
3D9.1BF26BEA55	4A	5/11/2006	19:09:46
3D9.1BF26BF302	4A	5/14/2006	7:52:30
3D9.1BF26BEEBF	4A	5/16/2006	11:26:50
3D9.1BF26BC6CB	4A	5/17/2006	7:12:32
3D9.1BF26B60CE	4A	5/22/2006	16:46:14
3D9.1BF26BFDE9	4A	5/25/2006	7:07:45
3D9.1BF26BFCE6	4A	5/27/2006	12:36:10
3D9.1BF26BC017	4A	5/29/2006	14:05:01
3D9.1BF26BE7A8	4A	5/31/2006	14:26:29
3D9.1BF18C2750	4A	6/1/2006	6:37:17
3D9.1BF26BAB2F	4A	6/12/2006	16:19:14
3D9.1BF26C01E2	4A	6/20/2006	6:07:57
3D9.1BF18C621B	4A	6/20/2006	10:46:47
3D9.1BF26BF7DD	4A	7/4/2006	9:04:04
3D9.1BF18D4792	4B	5/12/2006	6:16:30
3D9.1BF26BFDDA	4B	5/18/2006	19:36:06
3D9.1BF26BF1D2	4B	5/23/2006	3:22:44
3D9.1BF18C2D69	5C	5/17/2006	5:46:52
3D9.1BF26BBBA0	5C	5/18/2006	10:25:11
3D9.1BF26BDC9E	5C	5/24/2006	7:11:29
3D6.021EBC3023	5C	5/25/2007	5:09:22
3D6.021EBC3C9E	4A	5/25/2007	13:36:24
3D6.021EBC0B13	4A	5/25/2007	19:23:44
3D6.021EBD5B74	4B	5/26/2007	5:05:44
3D6.021EBBFDD6	4B	5/26/2007	19:08:45
3D6.021EBC244E	5B	5/28/2007	6:15:41
3D6.021EBC2133	5C	5/29/2007	6:06:07
3D6.021EBC44AA	4B	5/30/2007	7:03:45
3D6.021EBD4571	4B	6/2/2007	16:14:58
3D6.021EBC6E5A	4B	6/9/2007	5:38:21
3D6.021EBC2999	5B	6/12/2007	9:01:09

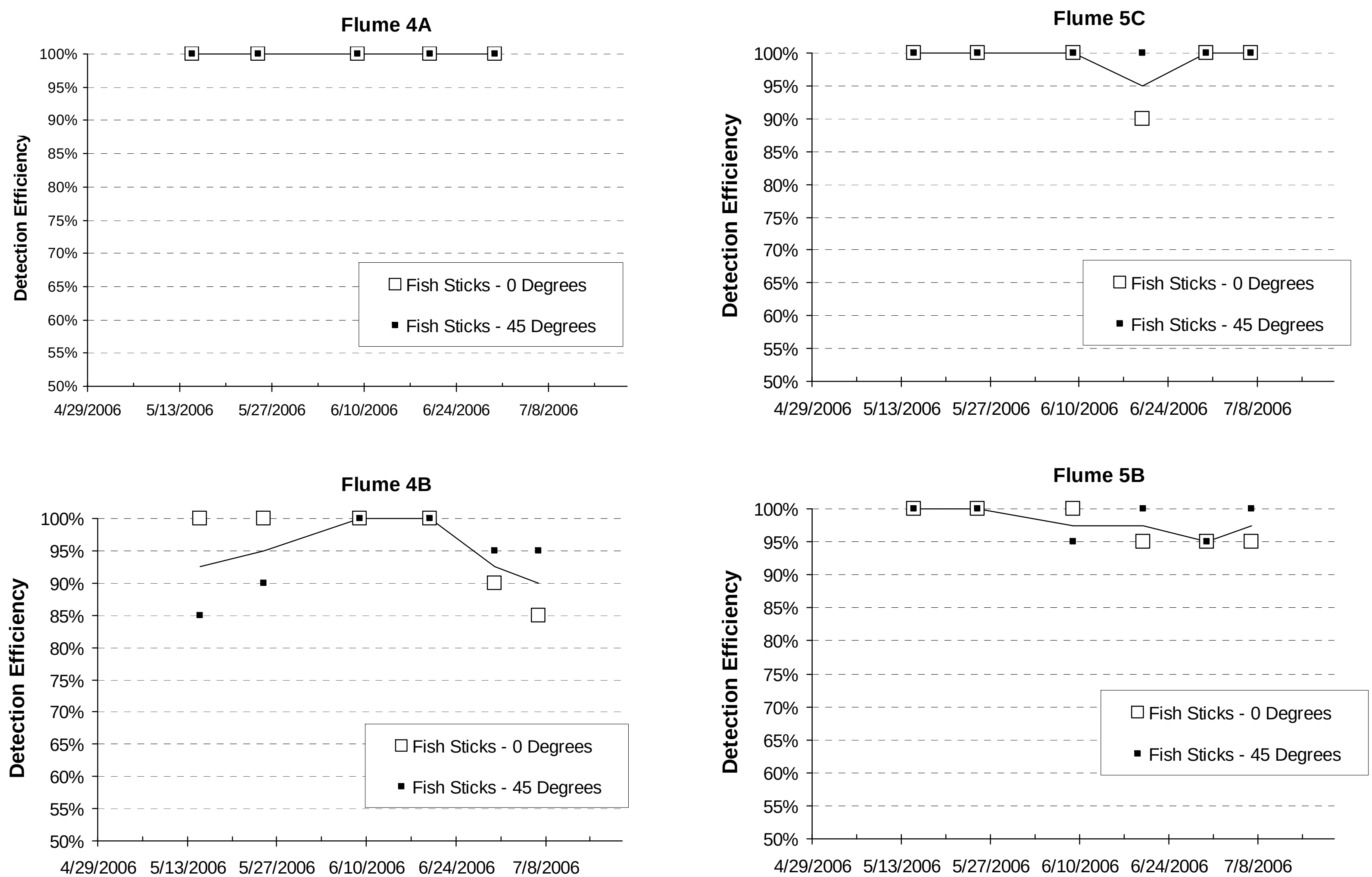


Figure 3-6. Results of calibration tests of tunnel detector efficiency at the Locks using fish sticks released directly into each flume, 2006 PIT tag study.

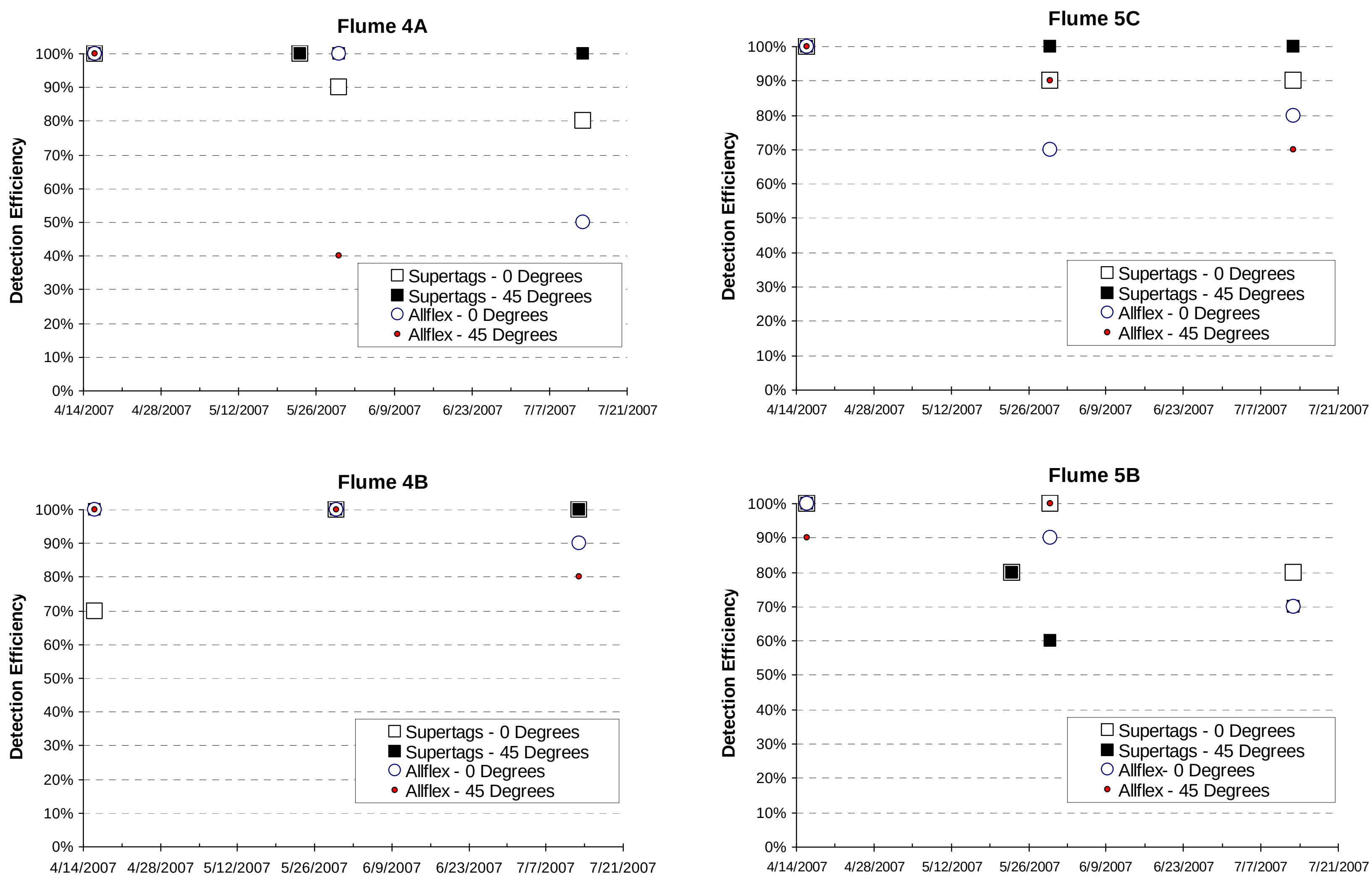


Figure 3-7. Results of calibration tests of tunnel detector efficiency at the Locks using fish sticks released directly into each flume, 2007 PIT tag study.

3.3 FISH LENGTH CHARACTERISTICS

Fish lengths were determined primarily at the time of tagging and should not be used to infer size at time of passage at the Locks. Figures 3-8 through 3-11 depict the range and frequency distributions of lengths of the fish that were tagged in each group, and compares the distributions with those of the fish that were detected at the Locks. The figures also depict the change in mean length of fish at the tributary locations where tagging continued over the passage season.

In general, there was limited evidence of a consistent effect of fish size overall on detection rate at the Locks, indicating that tagged Chinook and coho smolts of all sizes generally had an equal probability of passing through the flumes. The exception was for Chinook salmon tagged and released in the Cedar River in 2007, where fish detected at the Locks were significantly smaller than all fish released over the season (5% significance level, Chi-Square test of expected frequencies; Locks = observed, tagging = expected; Figure 3-9). This result may reflect the fact that relatively fewer, smaller fish were tagged early in the season compared with more, larger fish tagged later in the season (Figure 3-4), and that detection rates for the later migrating fish were lower than for the earlier migrants (see Section 3.5.2)

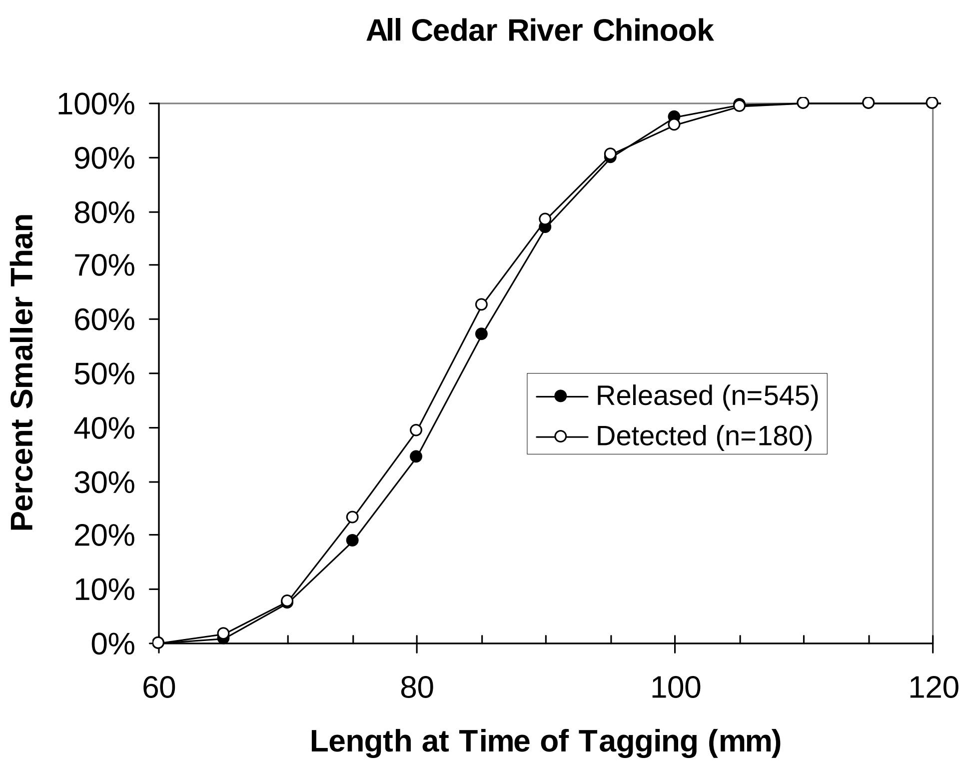
Mean lengths of Chinook juveniles in the Cedar River generally increased over the outmigration season in both 2006 and 2007, reflecting growth (Figures 3-8 and 3-9). In contrast, mean lengths of Chinook in Bear Creek did not increase substantially in 2007 (Figure 3-10). As in previous years, mean lengths of coho salmon smolts in the Cedar River remained relatively constant in 2007 (Figure 3-11). It was not possible to test for significant differences in size distributions of released and detected coho overall because only three fish were detected at the Locks.

3.4 MIGRATION BEHAVIOR

The PIT tag data provided valuable information on arrival date and travel rate to the Locks from the different release locations, and residualism in Lake Washington.

3.4.1 Migration Timing

The majority of coho salmon tagged by NMFS in the Cedar River basin in early 2006 passed through the locks before the majority of Chinook tagged by WDFW n the screw trap (Figure 3-12). Passage timing distributions were more similar for the two species in 2007 (Figure 3-12). Similar to previous years, Cedar River Chinook passed slightly later in the 2007 season overall than Bear Creek fish (Figure 3-13). There was greater variation in passage timing distributions for coho tagged at different locations in the Cedar River basin in 2006 than in 2007, and Issaquah Hatchery coho released in 2007 exhibited a similar passage timing distribution to natural origin fish tagged and released in the Cedar River basin (Figure 3-14).



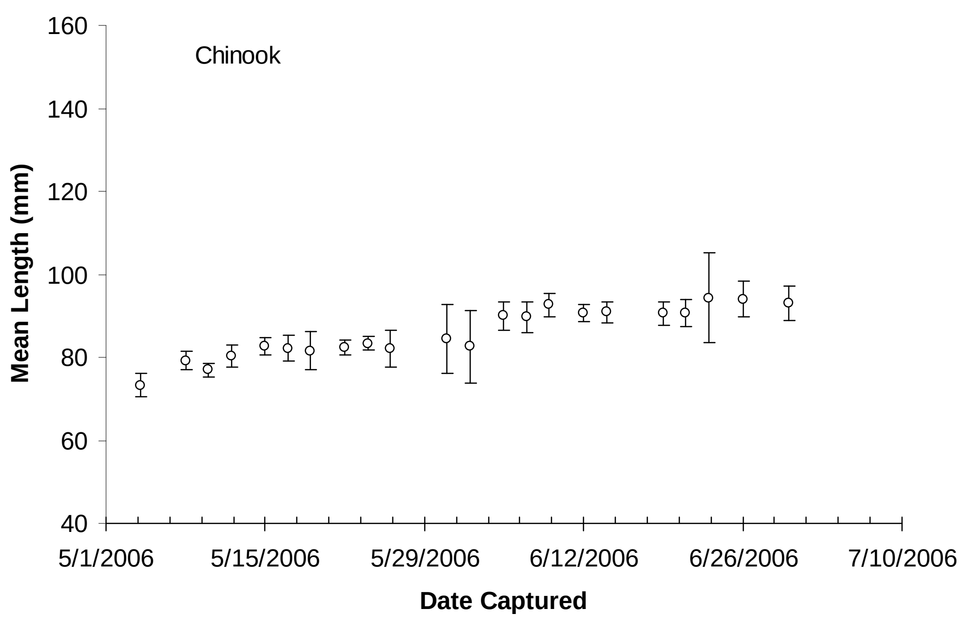
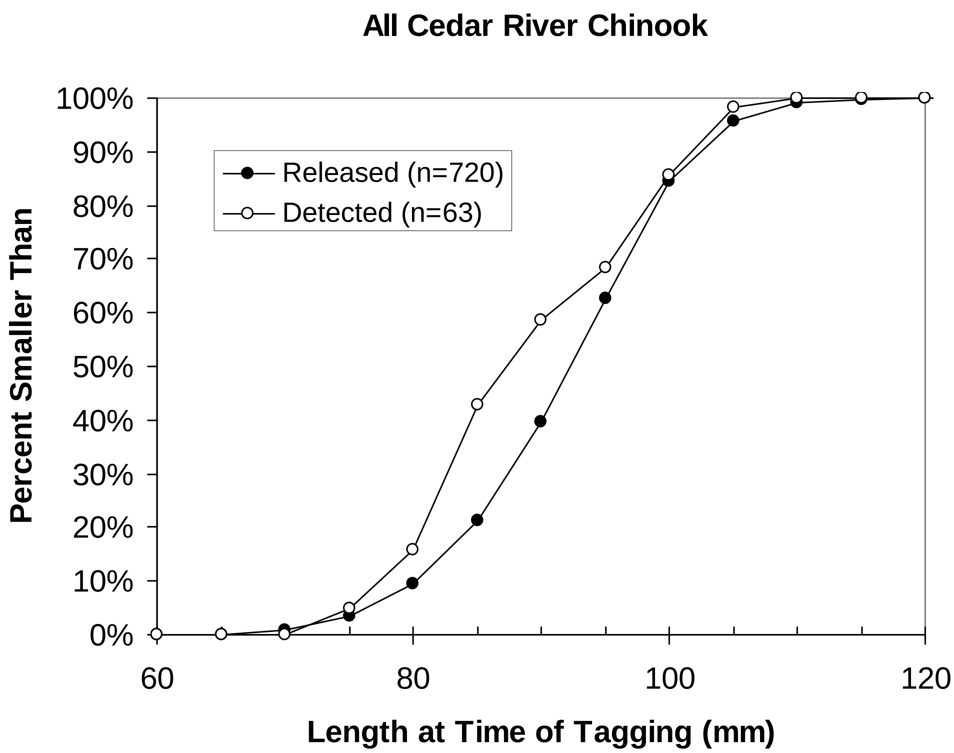


Figure 3-8. Cumulative frequency distributions of lengths of tagged and detected Chinook salmon caught in the Cedar River (top), and temporal variation in the mean length and 95% CI of the different release groups (bottom), 2006 Lake Washington PIT tag study.



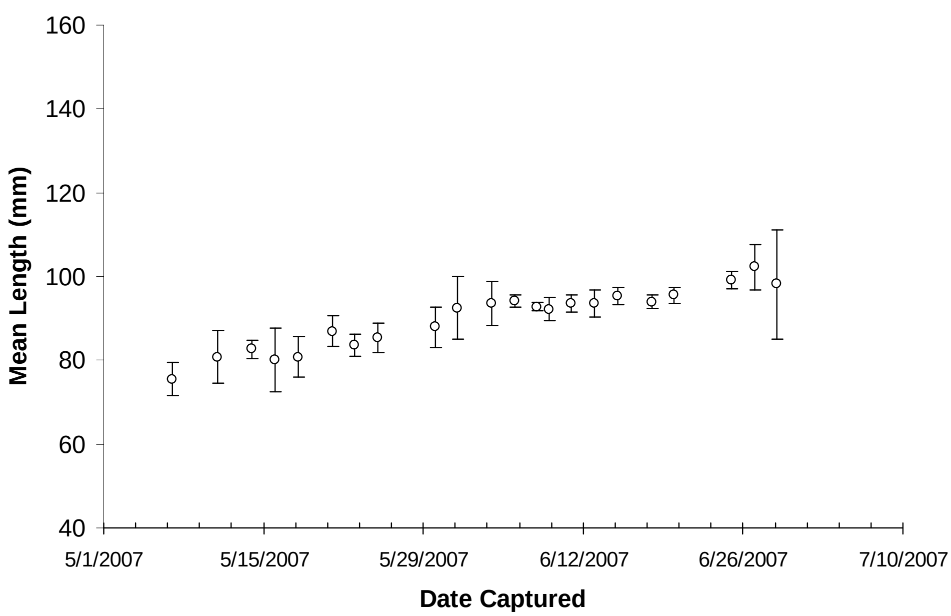


Figure 3-9. Cumulative frequency distributions of lengths of tagged and detected Chinook salmon caught in the Cedar River (top), and temporal variation in the mean length and 95% CI of the different release groups (bottom), 2007 Lake Washington PIT tag study.

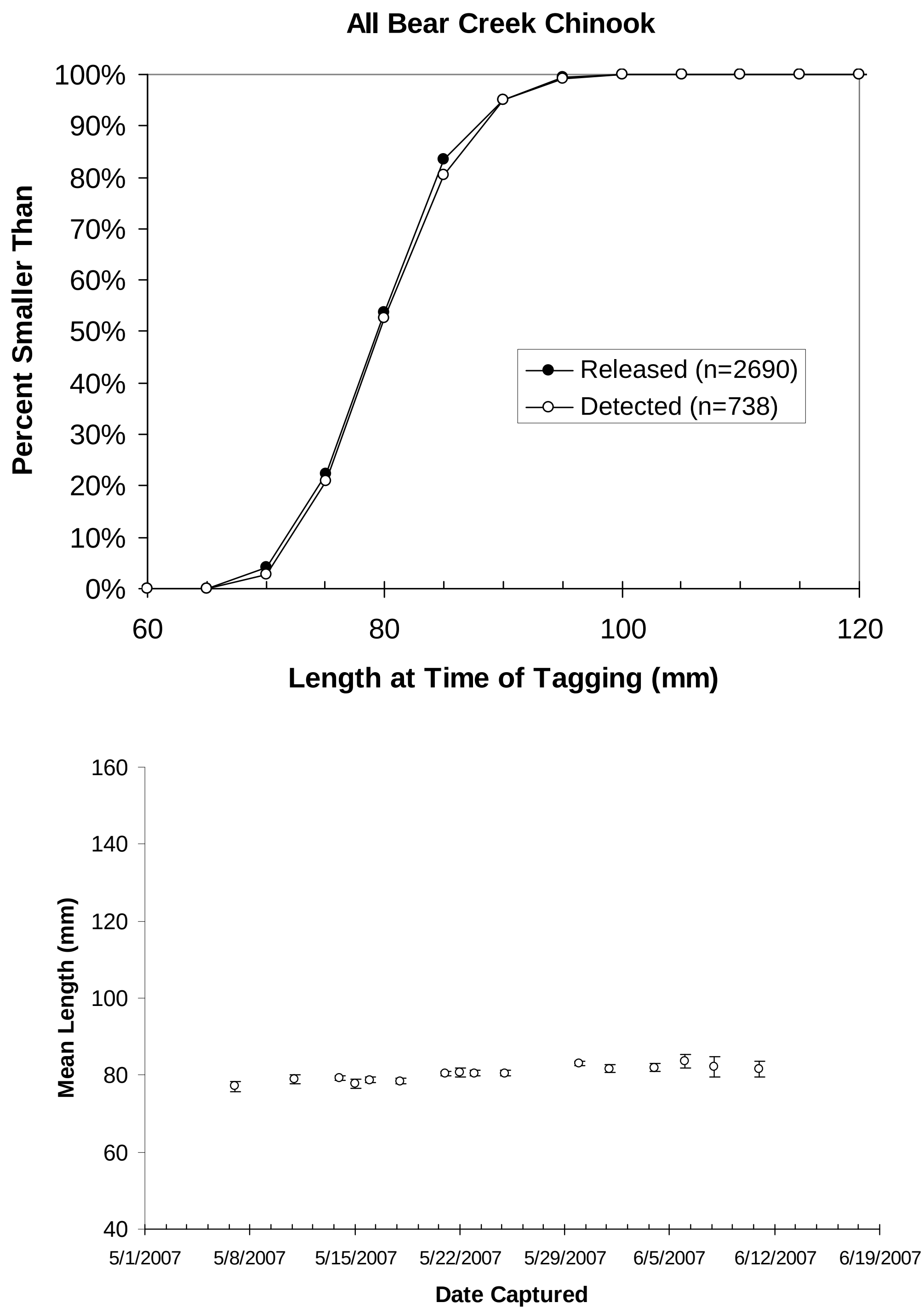


Figure 3-10. Cumulative frequency distributions of lengths of tagged and detected Chinook salmon caught in Bear Creek (top), and temporal variation in the mean length and 95% CI of the different release groups (bottom), 2007 Lake Washington PIT tag.

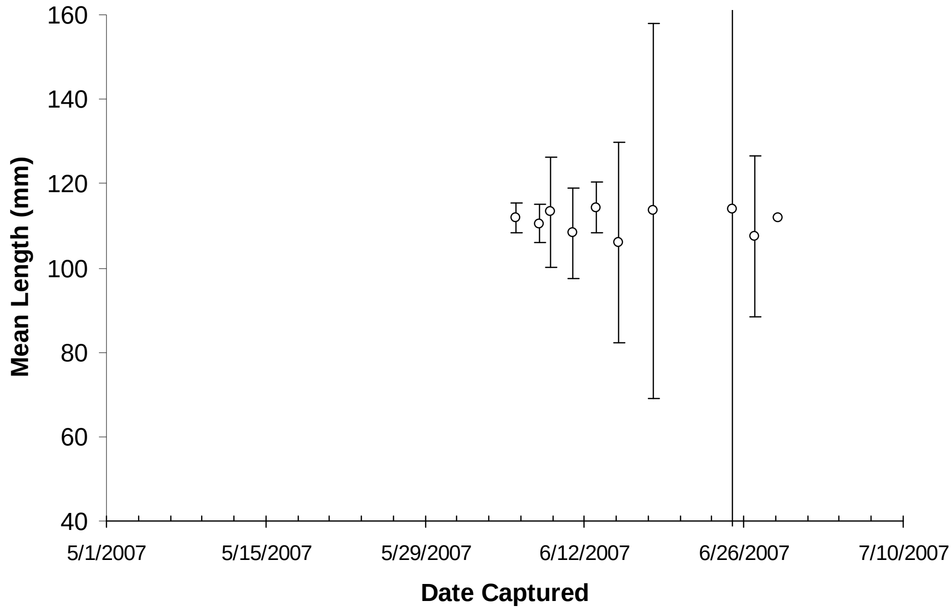


Figure 3-11. Temporal variation in the mean length and 95% CI of coho salmon tagged and released in the Cedar River, 2007 Lake Washington PIT tag study. Only three fish were detected at the Locks.

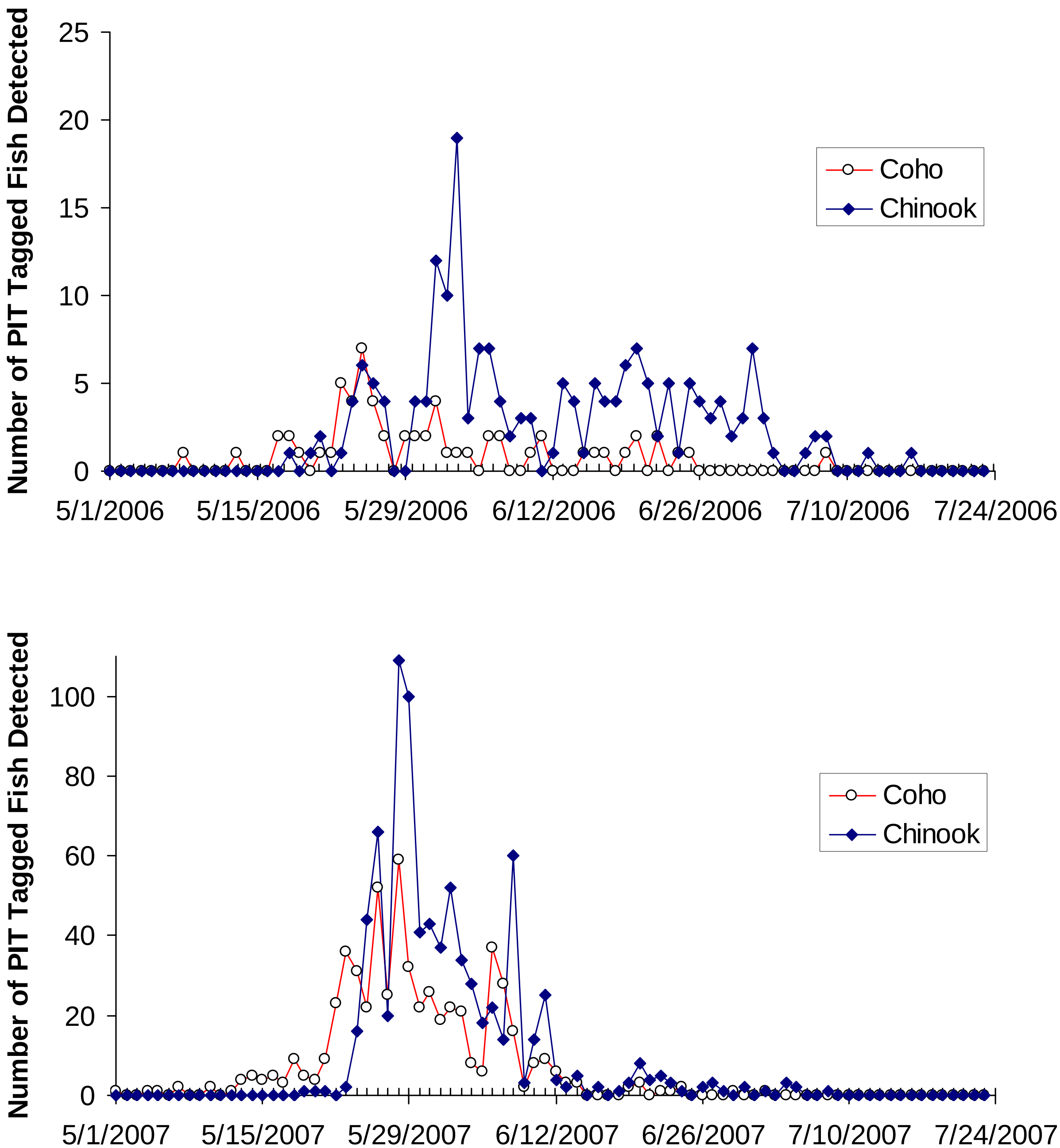


Figure 3-12. Seasonal frequencies of detections at the Locks of Coho and Chinook salmon PIT tagged at Issaquah Hatchery, Bear Creek, and Cedar River, 2006 (top) and 2007 (bottom) Lake Washington PIT tag study.

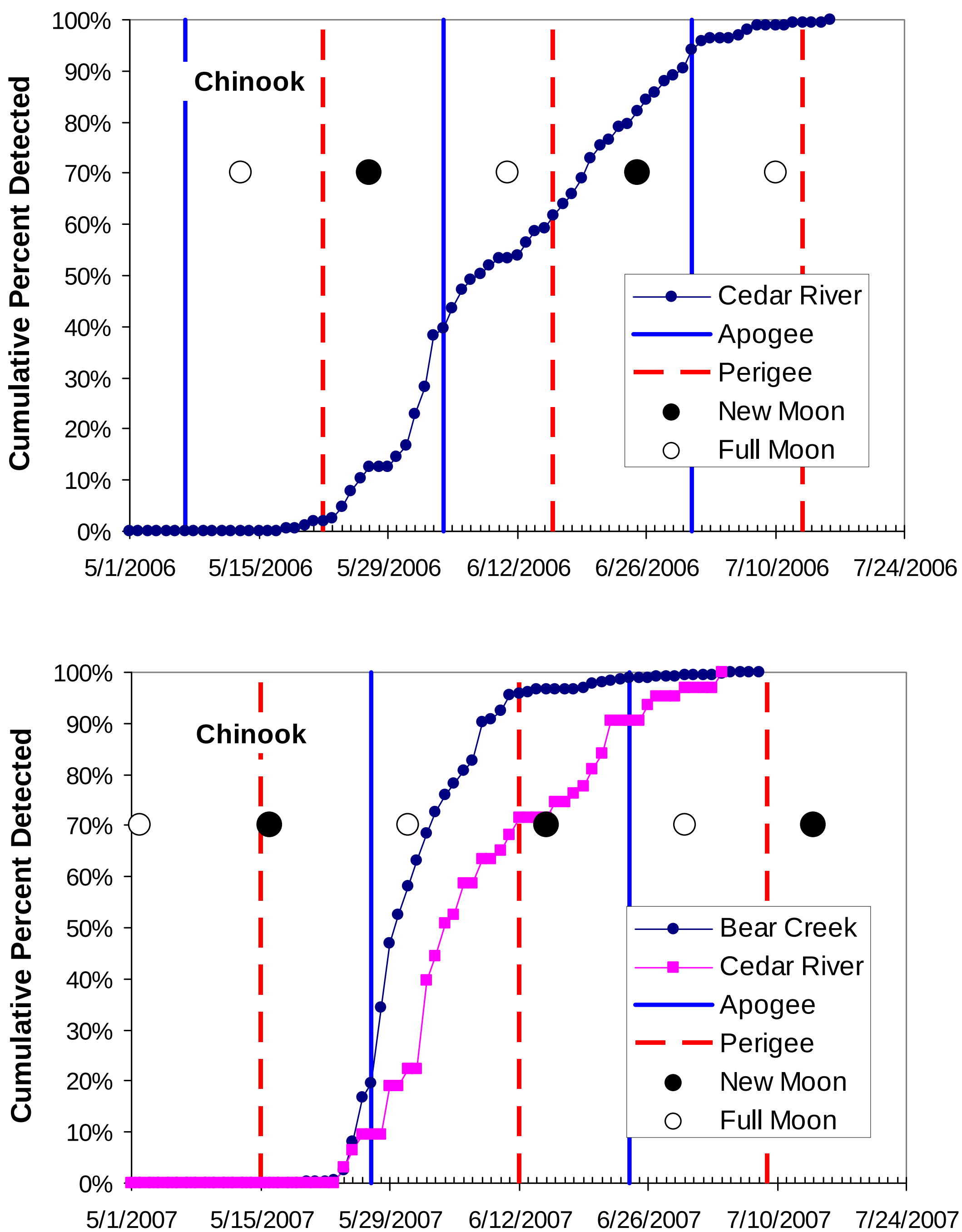
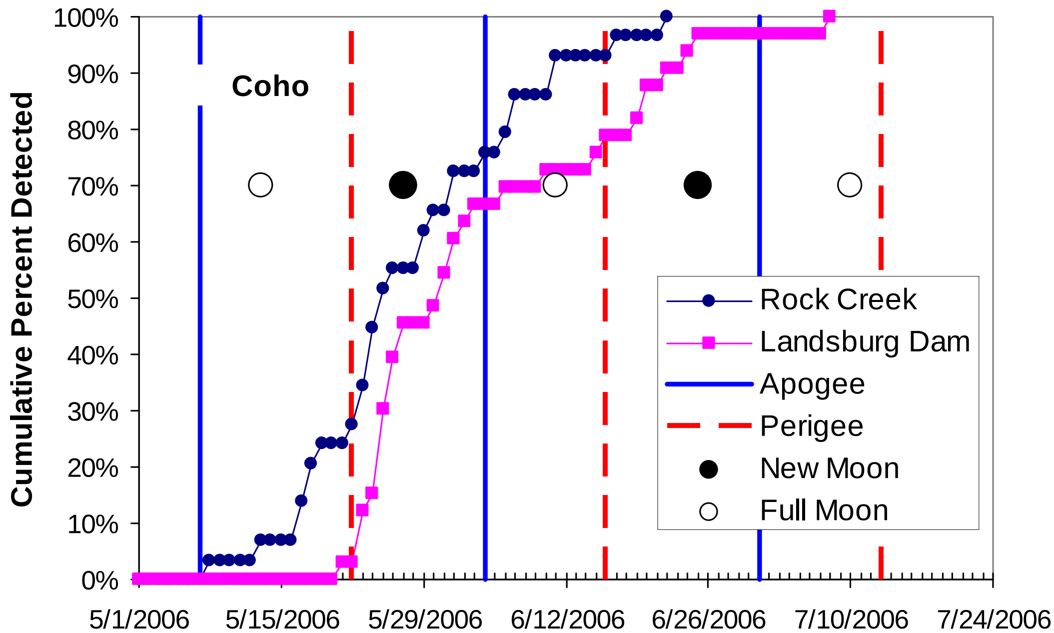


Figure 3-13. Cumulative frequency distributions of the numbers of PIT tagged juvenile Chinook salmon that were detected, as they passed the smolt flumes at the Locks, by date and release location, 2006 (top) and 2007 (bottom) Lake Washington PIT tag studies. The dates when the moon was at apogee (farthest from Earth) and perigee (closest to Earth) are indicated by the vertical lines.



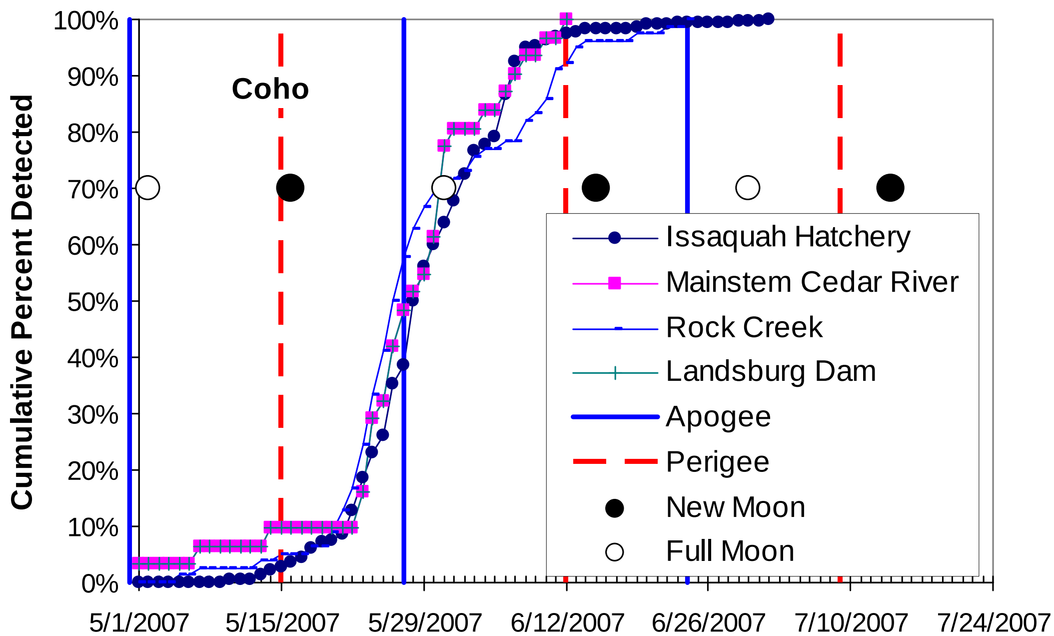


Figure 3-14. Cumulative frequency distributions of the numbers of PIT tagged juvenile coho salmon that were detected, as they passed the smolt flumes at the Locks, by date and release location, 2006 (top) and 2007 (bottom) Lake Washington PIT tag studies. The dates when the moon was at apogee (farthest from Earth) and perigee (closest to Earth) are indicated by the vertical lines.

A comparison of the passage timing data with lunar data indicated Chinook smolt passage timing was less strongly related to the date of apogee in 2006 than has been observed in previous years with the exception of 2005 (Figure 3-13; DeVries et al. 2007). Conversely, a stronger relation was again observed in 2007 (Figure 3-13). Passage timing of Cedar River Chinook was earlier in 2006 than in 2002 when apogee occurred around the same date, and was similar to passage timing in 2007 (Figure 3-15). Coho tagged in the Cedar River basin generally exhibited similar passage timing as in 2002, whereas passage timing in 2003 was earlier (Figure 3-16).

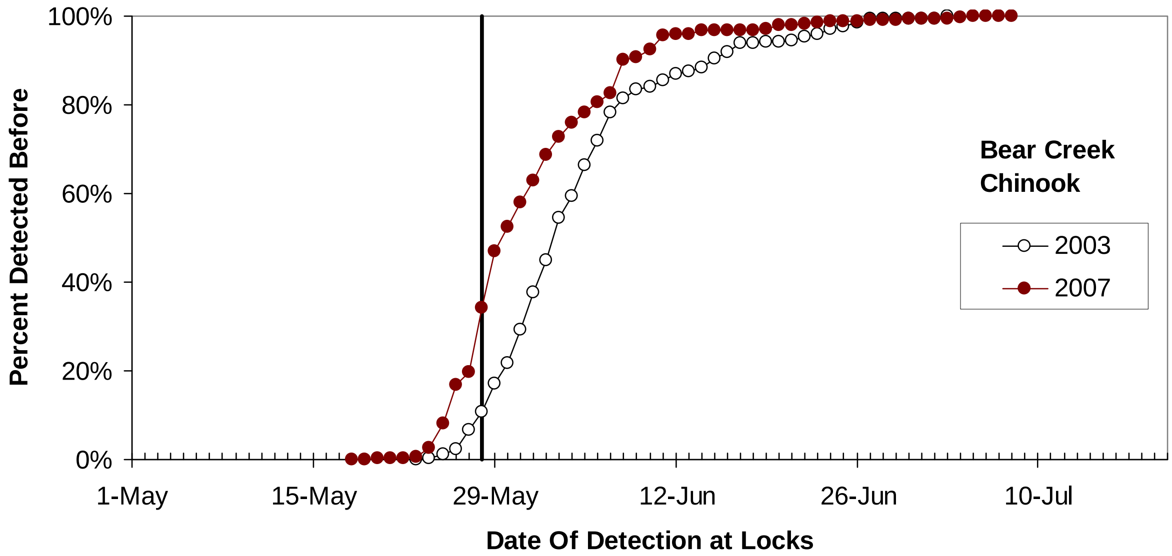
3.4.2 Migration Rate

Average migration rates varied between the tributary screw trap release groups. Table 3-3 lists the estimated minimum travel distances between the different release locations and the Locks, excluding possible detours, where the Cedar River site is closest to the Locks and the Issaquah Hatchery is farthest. As in previous years, average migration rates appeared to be proportional to travel distance in 2007. Chinook smolts from Bear Creek took about the same amount of time and thus migrated faster on average than fish from the Cedar River (Figure 3-17). Cedar River Chinook migrated faster in 2007 than 2006 (Figure 3-17). It must be noted that the average migration rates reported here are all subject to uncertainty regarding the length of time spent in the vicinity of the Locks before passing through the flumes. For example, if tagged fish spend more than a few days near the Locks, their actual migration rate to the Locks would be faster than the rates estimated here.

Table 3-3. Approximate minimum travel distances between release locations of PIT tagged fish and the Locks (see Section 2.6.2 for details on how distances were determined).

Release Location	Distance to Locks (km)
Cedar River	39
Bear Creek	56

Figure 3-18 indicates that migration rates of individual Chinook salmon juveniles exhibited an increasing trend with time over the course of the outmigration season in 2006 and 2007, a pattern observed in most years (DeVries et al. 2007). The results suggest further that juvenile salmon in the Lake Washington system speed up their migration as the end of the passage season approaches, and that early migrants may have a greater tendency to hold for a period before passing the Locks.



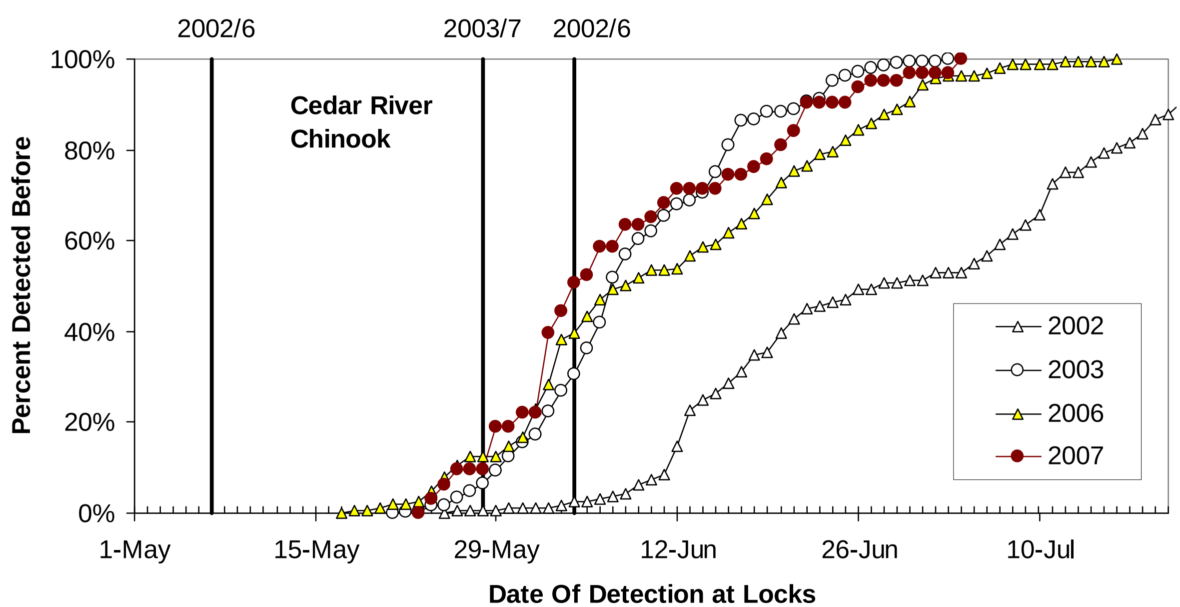


Figure 3-15. Comparison of passage timing of Chinook salmon smolts originating from Bear Creek (top) and the Cedar River (bottom) in 2006 and 2007 with previous years when lunar apogee occurred around the same dates. The vertical line denotes the occurrence of apogee for each pair of years.

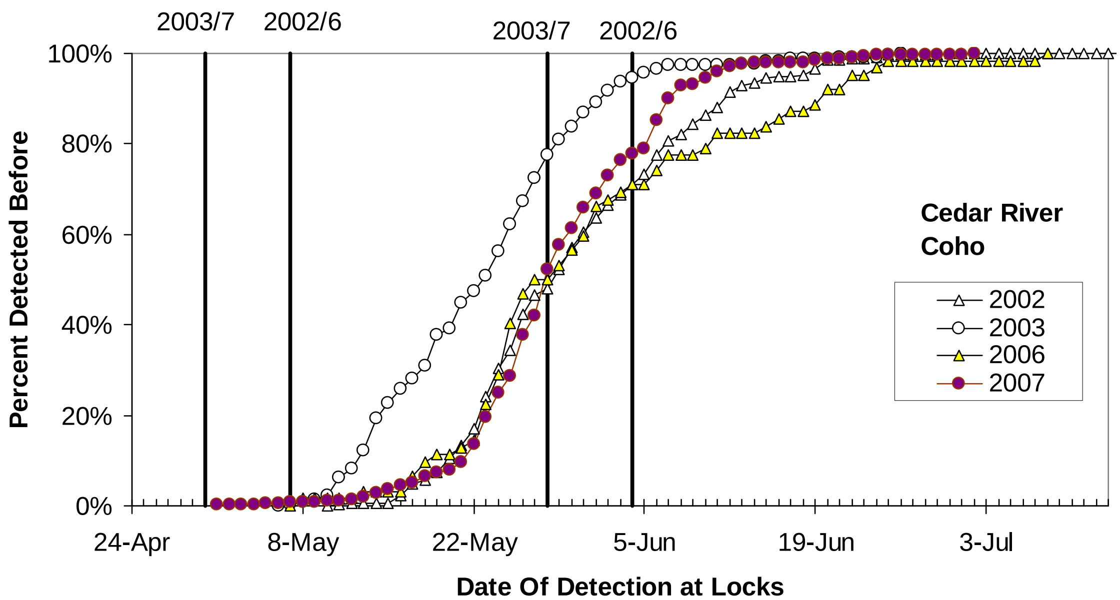


Figure 3-16. Comparison of passage timing of coho salmon smolts originating from the Cedar River in 2006 and 2007 with previous years when lunar apogee occurred around the same dates. The vertical line denotes the occurrence of apogee for each pair of years.

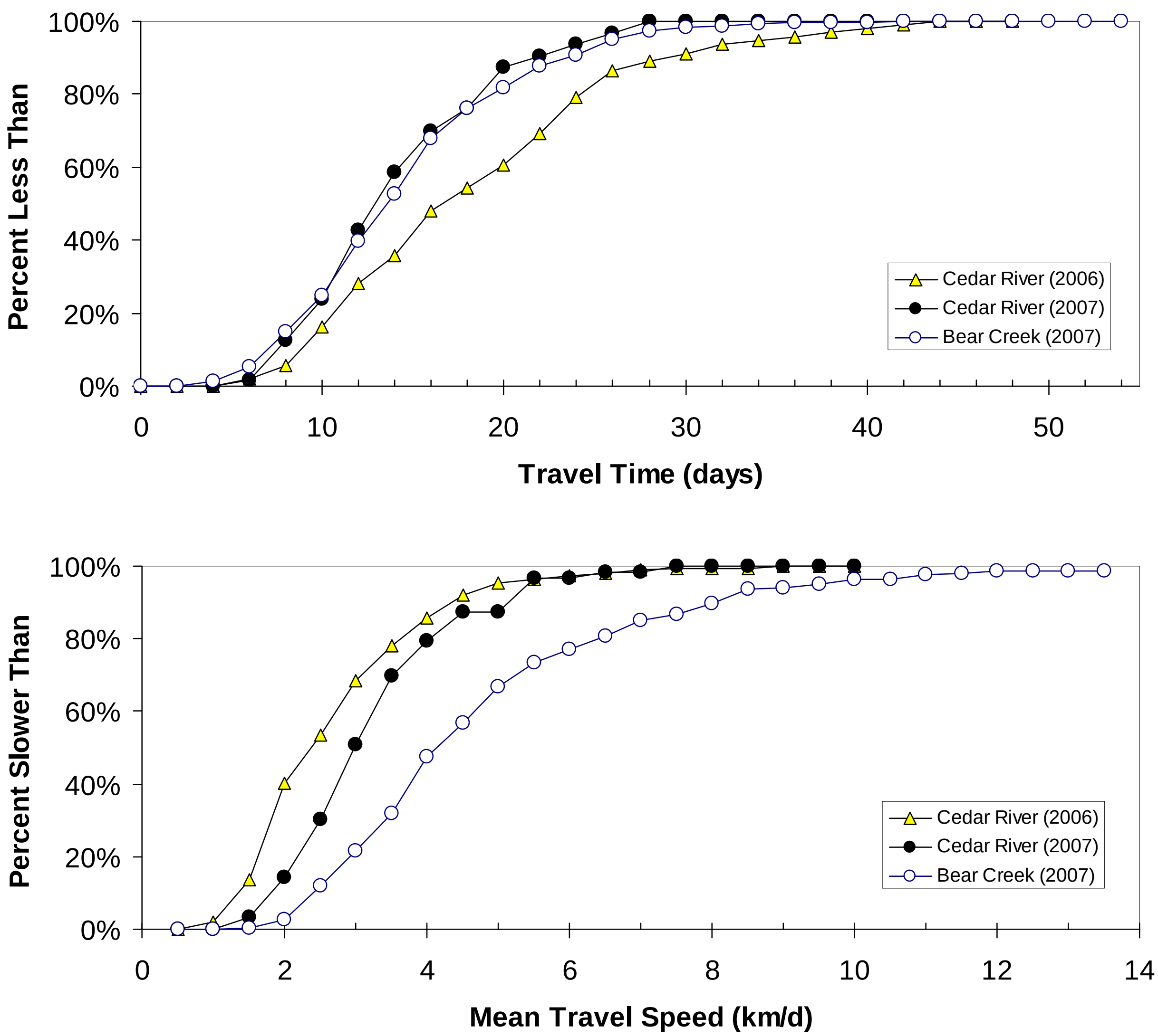


Figure 3-17. Cumulative frequency distributions of average travel time (top) and speed (bottom) of juvenile Chinook and coho salmon PIT tagged at the tributary screw traps and Issaquah Hatchery and detected in the smolt flumes at the Locks in 2006 (left) and 2007 (right) Lake Washington PIT tag studies.

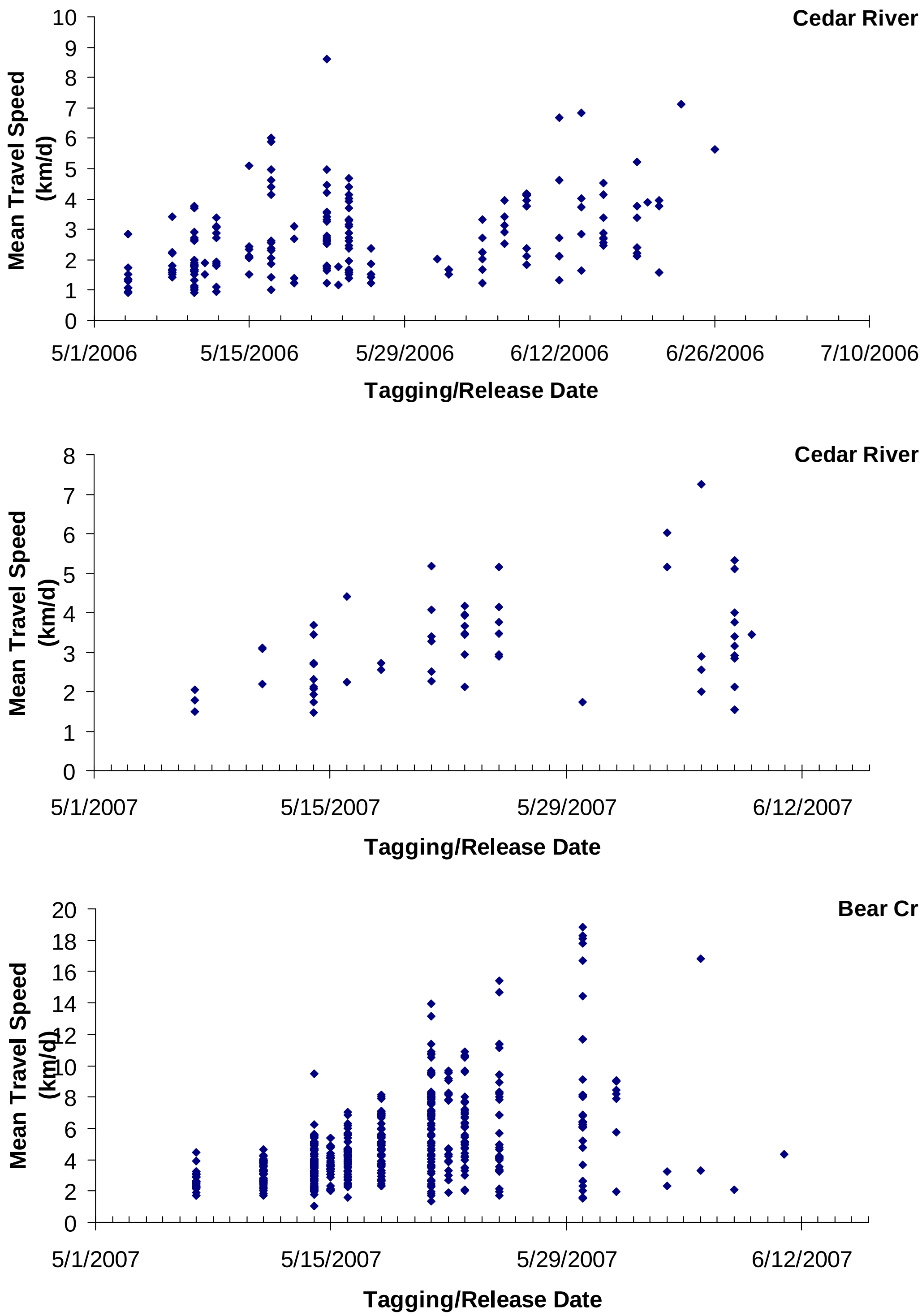


Figure 3-18. Scatterplots of mean travel speed of individual juvenile Chinook salmon PIT tagged at the tributary screw traps and detected as they passed the smolt flumes at the Locks, 2006 and 2007 Lake Washington PIT tag studies.

The cumulative frequency distributions of numbers of juvenile salmon tagged and detected at the flumes can also be used to describe travel times for the different release groups (Figure 3-19). In general, the distributions indicate that Chinook salmon originating in the Cedar River in 2006 took on the order of two weeks to reach and pass the smolt flumes, and on the order of 10 days for Chinook originating in Bear Creek in 2007. Results are inconclusive for Chinook salmon from the Cedar River screw trap in 2007 because a large fraction of fish were tagged later in the season, when detection rates were falling (see Section 3.5.2). Detection numbers were too small (n=3) for coho salmon from the Cedar River in 2007.

3.4.3 Tags From Other Studies

Tags were detected passing through the smolt flumes that had been inserted in fish as part of the four other independent studies being conducted in the basin:

- **WDFW Cedar River Trout Studies:** 23 trout (3.8%) tagged in 2006 were detected passing through the Locks during the spring outmigration season of 2007 (Figure 3-20). The data were forwarded to Brad Thompson.
- **UW Hatchery Studies:** In 2006, 40% of tagged Chinook and 4% of tagged coho were detected passing through the smolt flumes. One Chinook was detected returning as a jack through the fish ladder in September 2007. In 2007, 77% of tagged Chinook were detected passing through the flumes. The data were forwarded to Tom Quinn and Jon Wittouck.
- **Issaquah Hatchery Coho Feed Study:** In 2007, 36.4% and 38.2% of control and treatment fish were detected passing through the flumes. Of these, 3.0% and 2.4% recycled through the locks, respectively. There did not appear to be a significant effect ($p<0.05$) of diet on survival to, or passage behavior at, the Locks. The detection data were forwarded to Jed Varney (WDFW) and Chuck Ebel (USACE).
- **NMFS/UW Cedar River Studies:** In 2006, 62 coho and one steelhead were detected passing through the flumes. In 2007, 116 coho and 2 steelhead were detected. The detection data were forwarded to G. Pess, NMFS Northwest Fisheries Science Center.

These studies are anticipated to produce respective data analysis reports at a later date.

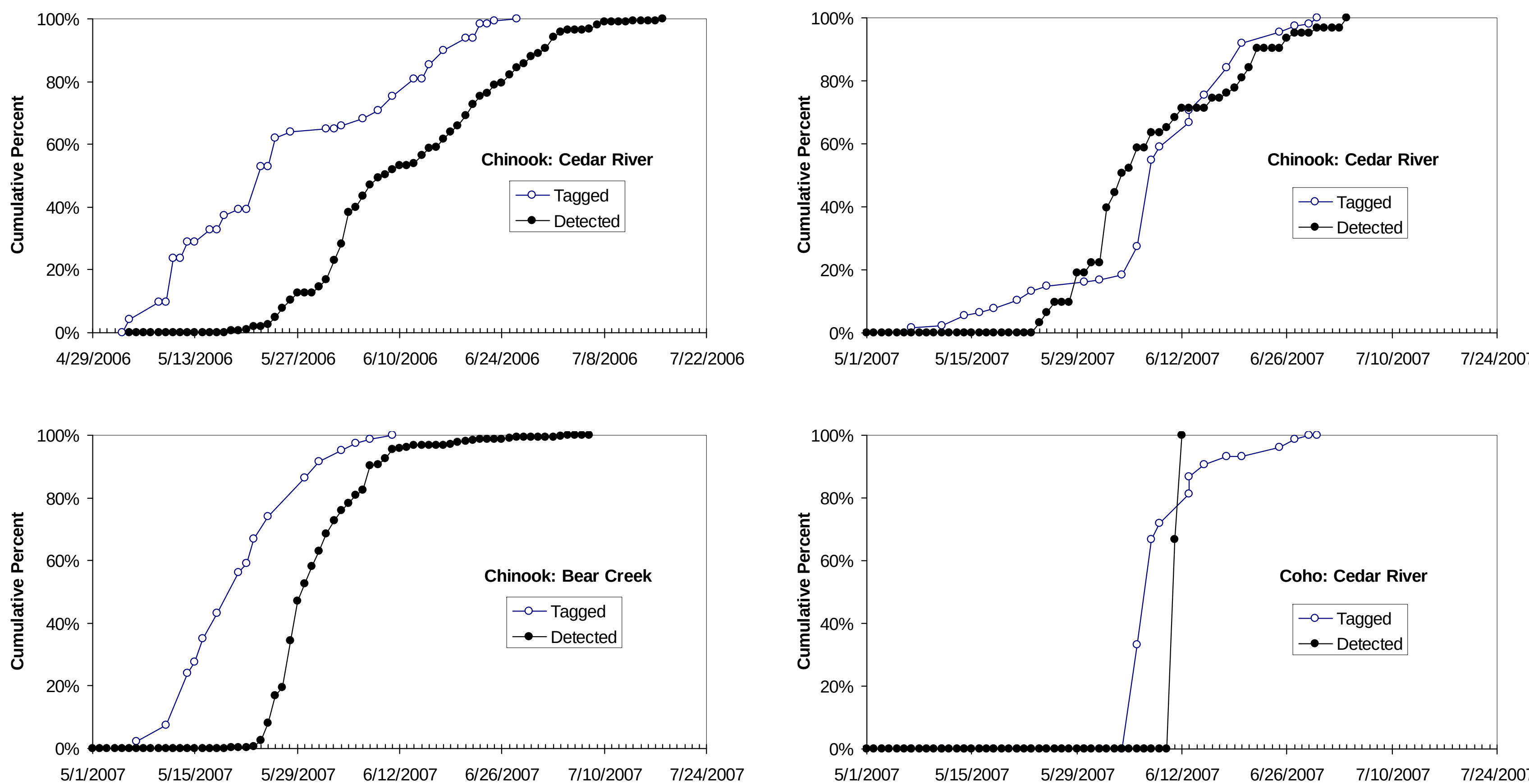


Figure 3-19. Cumulative frequency distributions of the numbers of PIT tagged juvenile Chinook and coho salmon that were tagged at the tributary screw traps and detected as they passed the smolt flumes at the Locks, by date and release location, 2006 and 2007 Lake Washington PIT tag studies. The horizontal difference between the two curves in each plot reflects the average time taken by all fish from a release location to travel to the Locks and pass through the smolt flumes.

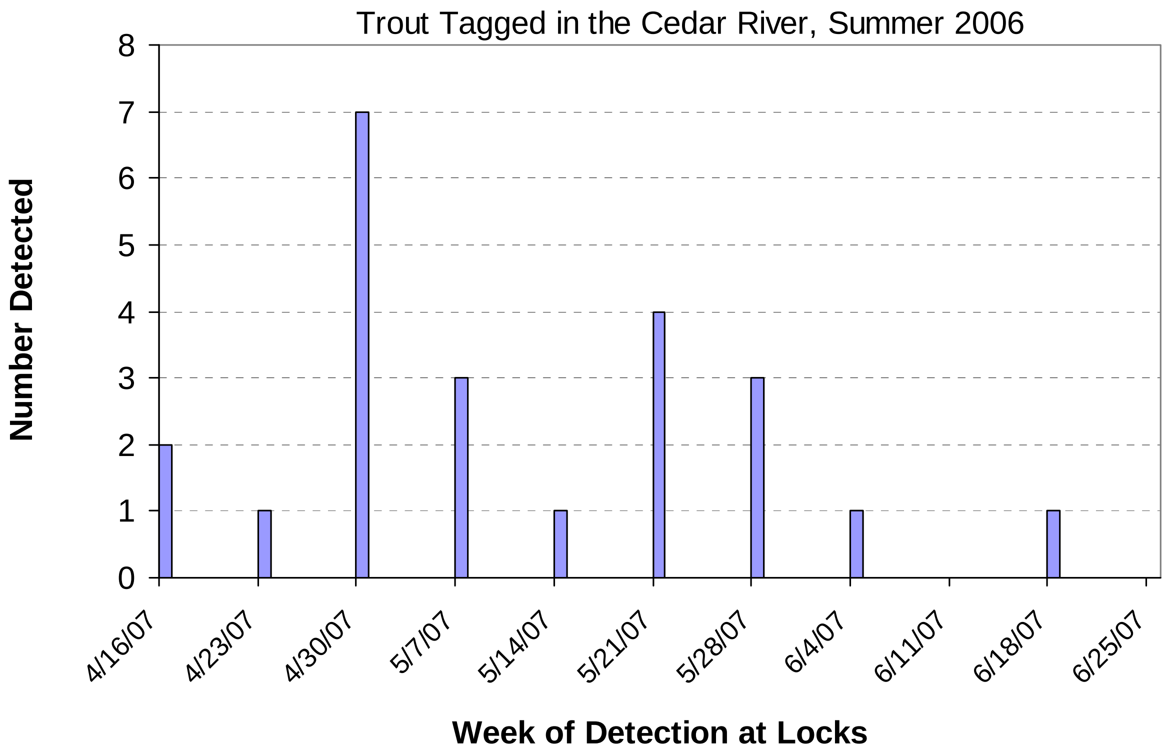


Figure 3-20. Temporal pattern of detection of trout (species not specified) PIT tagged in the Cedar River in 2006 and detected passing through the smolt flumes in 2007.

3.4.4 Residualism in the Lake Washington System

In contrast to previous years, there were no fish detected in 2006 and 2007 that had been tagged in previous years.

3.5 PASSAGE BEHAVIOR AT LOCKS

The PIT tag data again provided valuable information on passage behavior and possible influences of lock operations.

3.5.1 Diurnal Variation in Passage Timing

Previous years' results have led to shutting off the flumes at night if necessary to conserve water because most passage occurs during daylight hours. Flows were sufficient in 2006 that at least one flume was open all night during most of the outmigration season and a diurnal passage timing distribution was observed consistent with previous findings (Figures 3-1, 3-21; DeVries et al. 2007). The flumes were usually shut off at night to conserve water in 2007, thus the passage timing distributions from that year cannot be used to further corroborate the diurnal passage behavior hypothesis (Figure 3-2). Chinook smolt passage timing distributions in both years were sharply peaked and skewed with greatest passage occurring in the morning (Figure 3-21). There was a secondary peak in the evening in 2006 but not 2007. In 2007, the Chinook passage timing distribution was more sharply peaked (Figure 3-21), which likely reflected more frequent closing of flumes at night. Passage timing of coho salmon tagged by NMFS in the Cedar River basin was more uniformly distributed over daylight hours in both years (Figure 3-22).

3.5.2 Routes Through the Locks

Figure 3-23 depicts the possible passage routes through the Locks. As in previous years, the PIT tag data indicated that recycling occurred through the Locks in 2006 and 2007, where fish were observed to pass two or more times through the flumes. The seasonal patterns and recycling interval times were generally comparable to previous years' data (with the exception of hatchery Chinook released directly in the flumes as part of calibration testing in previous years, many of which took up to four weeks or more between consecutive passage events).

Recycling was rare in 2006. Only one (2.3% of detections) UW hatchery coho recycled in 2006. Natural origin Chinook and coho tagged at various locations in the Cedar River did not recycle in 2006. Recycling was more prevalent in 2007. As in previous years, the number of days between passage events decreased as the 2007 outmigration season progressed (Figure 3-24). Approximately 2.7% and 5.9% of Issaquah Hatchery coho and UW Hatchery Chinook detected in the flumes recycled, respectively. Approximately 5.0% and 3.9% of Cedar River and Bear Creek Chinook detected in the flumes recycled, respectively. Approximately7.8% and 6.9% of Rock Creek and Landsburg Dam coho detected in the flumes recycled, respectively. As in 2001 (DeVries et al. 2002), UW Hatchery Chinook exhibited a greater propensity to recycle multiple times: two fish each went through the flumes seven times in 2007. In general, the 2007 recycling rates listed above were an order of magnitude higher than in the previous years studied (excluding Issaquah Hatchery Chinook released directly into the flumes for calibration testing in previous years). Recycling rates in 2001, 2002, 2003, 2004 and 2005 were 0.39%, 0.71%, 0.07%, 0.18% and 0.11%, respectively, for Chinook detected from the Cedar River, Bear Creek, and Issaquah Hatchery combined. Recycling rates in 2001, 2002, 2003 and 2005 were 0.70%, 0.50%, 0.06%, and 0.33%, respectively, for coho detected in the flumes.

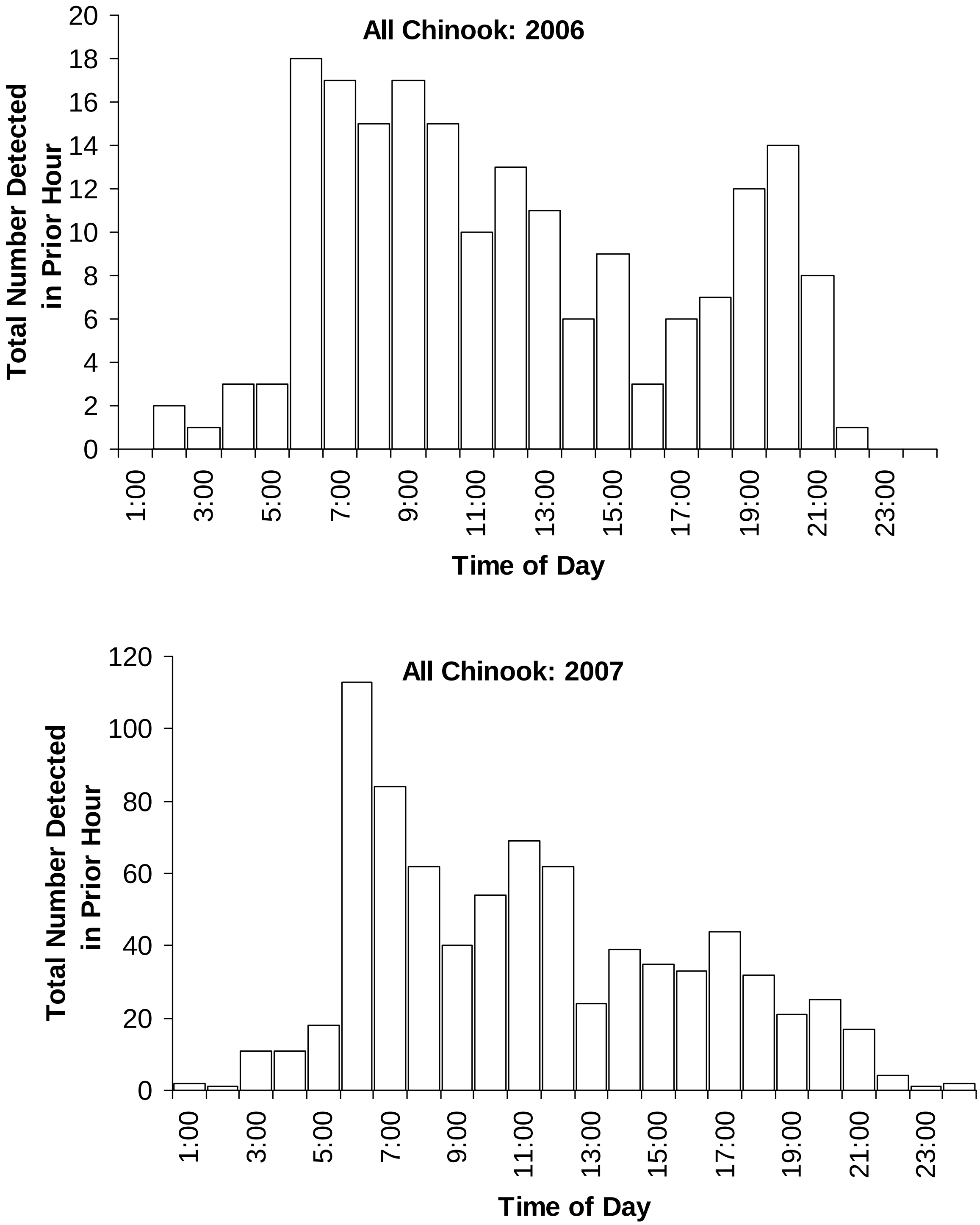


Figure 3-21. Diurnal variation in time of passage through the smolt flumes at the Locks by PIT tagged juvenile Chinook salmon, 2006 and 2007 Lake Washington PIT tag studies.

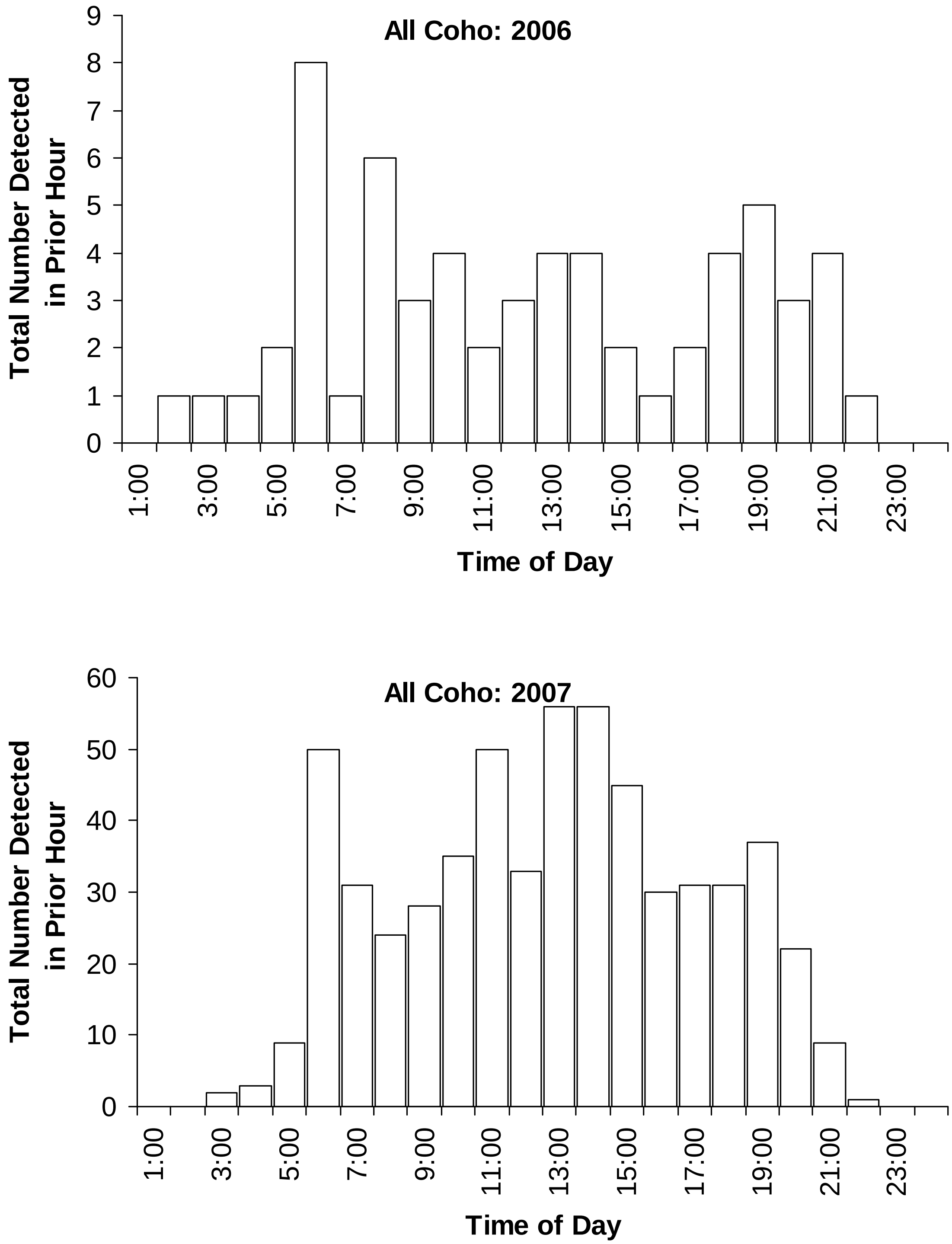


Figure 3-22. Diurnal variation in time of passage through the smolt flumes at the Locks by PIT tagged juvenile coho salmon, NMFS 2006 and 2007 Cedar River basin PIT tag studies.

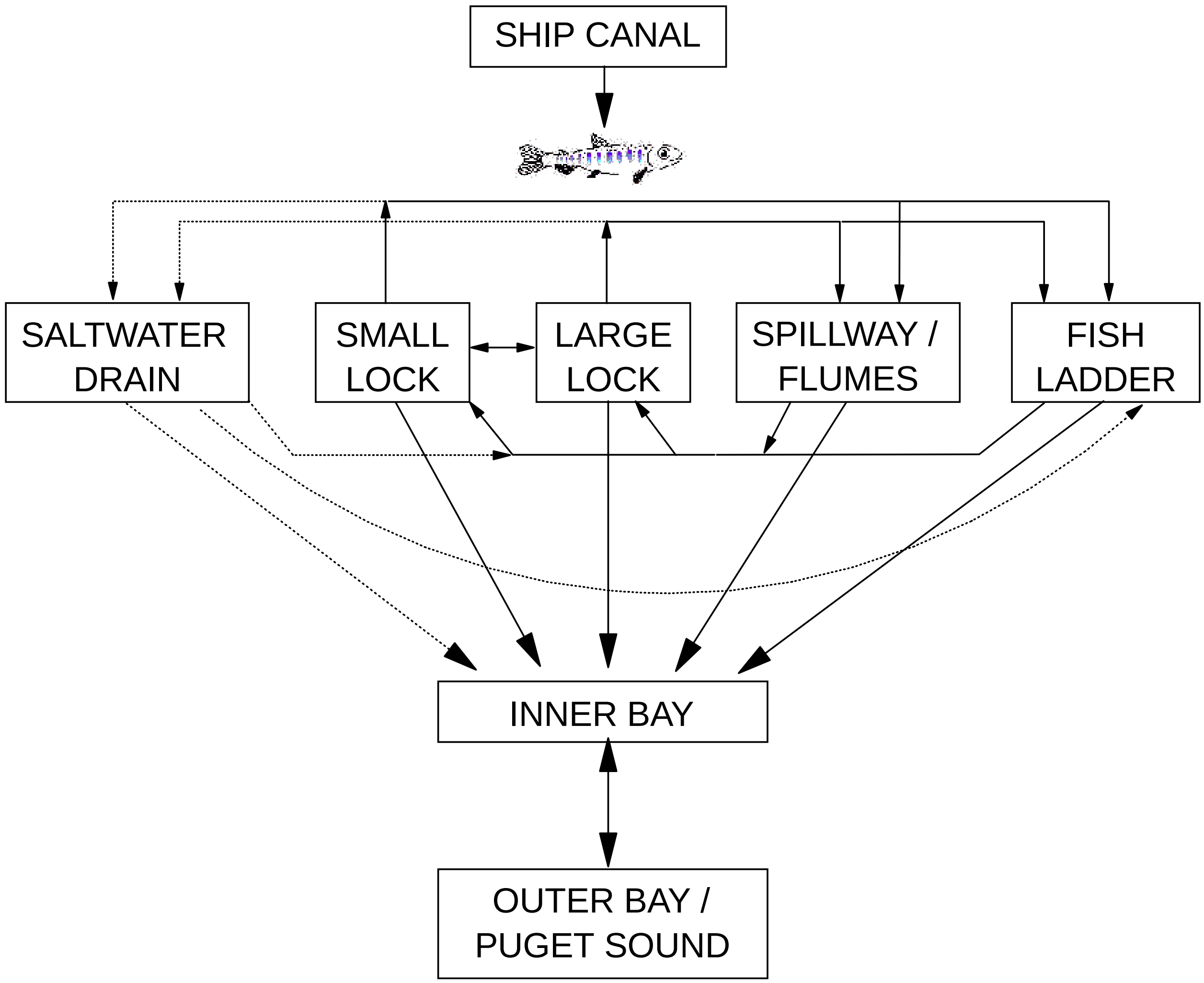


Figure 3-23. Possible migration routes of juvenile salmon through the Hiram M. Chittenden Locks to the Puget Sound. The routes are indicated for fish after they have first encountered the Locks and have entered one of the five structural facilities indicated. For example, a fish entering the smolt flumes may subsequently move back upstream through either the small or large lock, and return downstream through any of the five routes. Alternatively, the fish may migrate directly to saltwater. The route through the saltwater drain is thought to be of lesser importance to smolt passage than the other four routes and is thus indicated by the dashed lines.

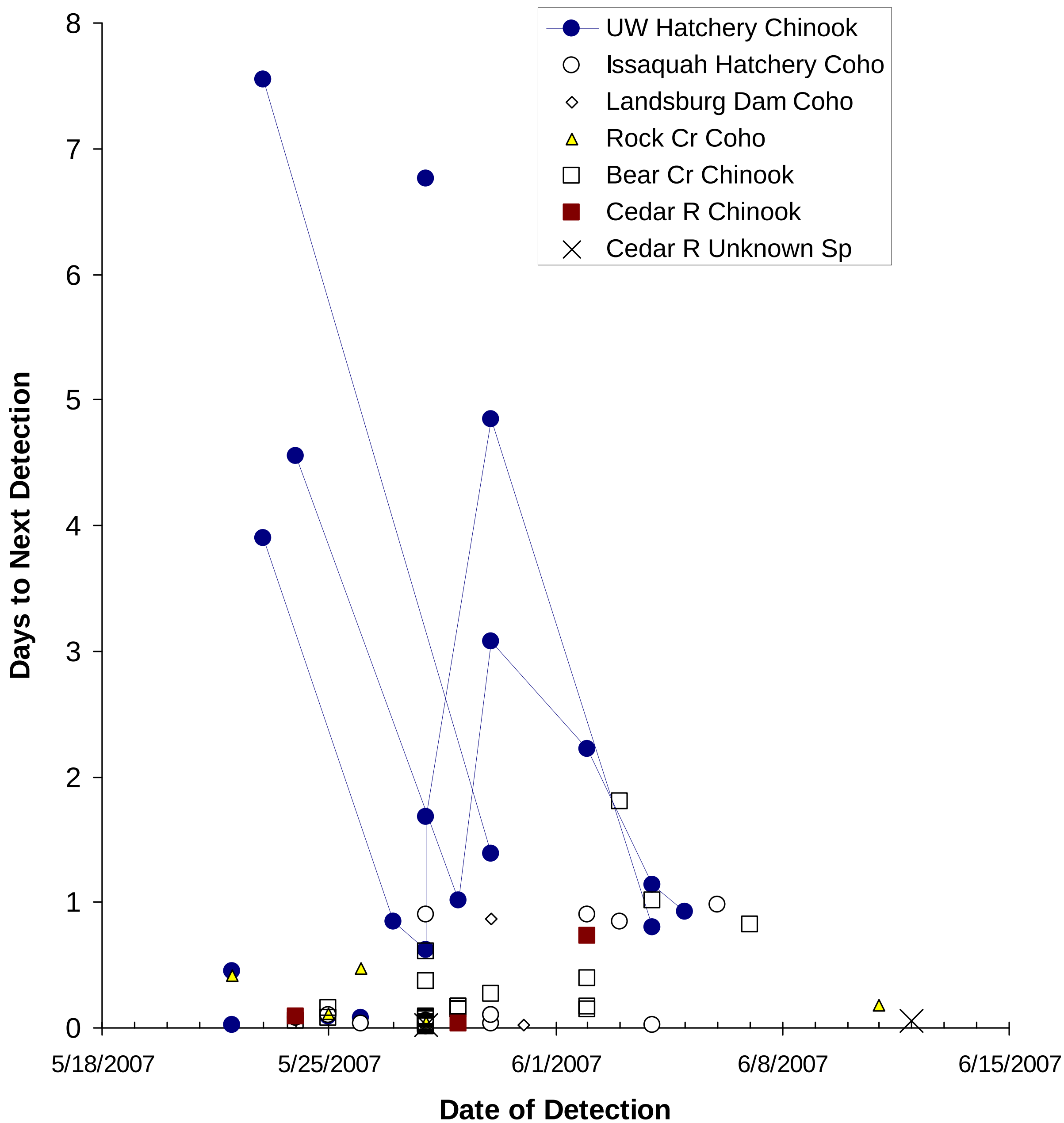
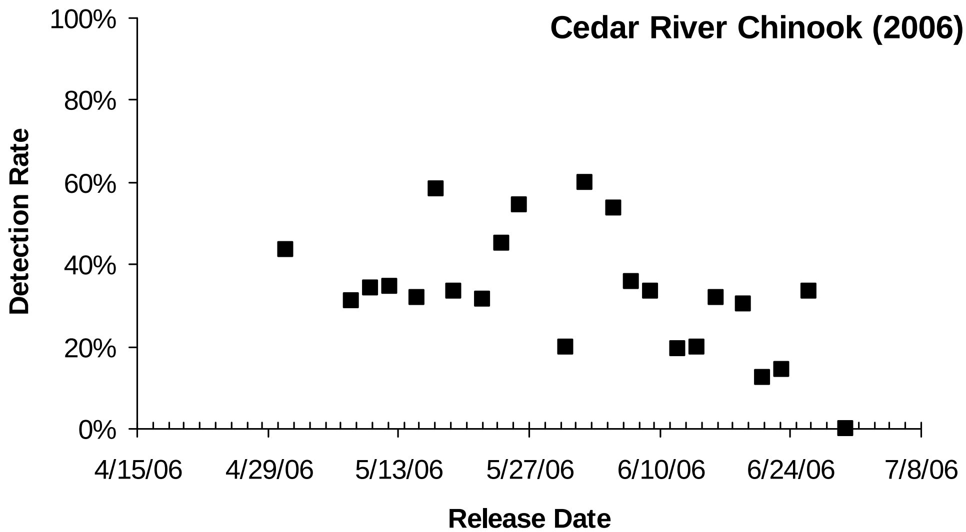


Figure 3-24. Recycling times of PIT tagged juvenile Chinook and coho salmon passing downstream two or more times through the smolt flumes at the Locks, 2007 Lake Washington PIT tag studies. The lines connect multiple recycling occurrences for the same fish.

The PIT tag data were used to evaluate seasonal variation in detection rates at the smolt flumes. The detection rate (number detected at Locks and adjusted for detection efficiency, divided by the number released on a given date) appears to reflect the proportion using the flumes overall (DeVries et al. 2005). Previous years' PIT tag data indicated that the proportion using the flumes dropped off during the course of the season. This phenomenon was observed again in 2006 and 2007 and was consistent for Bear Creek and Cedar River Chinook (Figures 3-25, 3-26). Average weekly detection rates for Chinook released in the Cedar River in May 2006 were on the order of 40% (Figure 3-25). Average weekly detection rates for Chinook released in both Bear Creek and the Cedar River through mid-May 2007 were around 30%-45%, and then dropped to near zero for fish released around the first week of June (Figure 3-26). Detection rates for Chinook tagged in the Cedar River in 2006 were higher later in the outmigration season than in most other years (Figure 3-27). Detection rates for Chinook tagged in both Bear Creek and the Cedar River fell within the center of the data scatter from previous years (Figure 3-27).

3.5.3 Influence of Lock Operations on Passage Through Flumes

Previous years' results have suggested that passage rates through the flumes are correlated with small lock filling operations. Figures 3-28 and 3-29 similarly indicate that there was again a tendency for PIT tagged fish to pass through the flumes at a higher rate during the small lock fill period than during the between-fill period in 2006 and 2007. To evaluate this statistically, the data in the figures were filtered and cases identified where fish were detected during consecutive fill and between-fill periods. A ratio was calculated of the passage rate during fill to the passage rate during the subsequent between-fill period. Results were similar to previous years, where two-tailed t-tests of the ratio indicated that it was significantly greater than 1.0 on average in both 2006 and 2007 ($p<0.05$). The numbers detected per unit time during fill in 2006 and 2007 were approximately 5.9 and 2.5 times, respectively, the number between fills on average. The average for 2007 is similar to values calculated in previous years. The sample size for 2006 was much smaller than in other years. The 2007 results corroborate the general observation from previous years' PIT studies that mean passage rates through the flumes are roughly double to triple while the small lock is filling than when they are not filling.



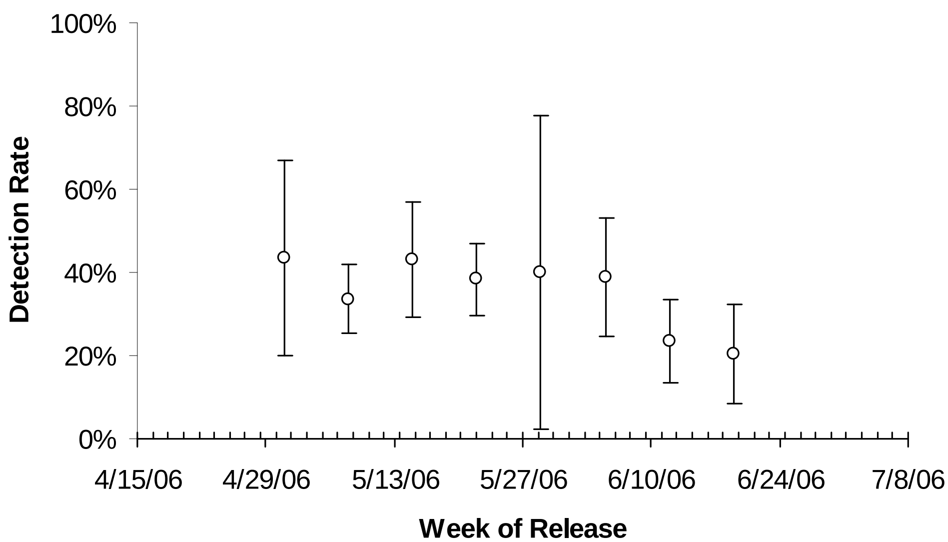


Figure 3-25. Daily and weekly variation of detection rate at the smolt flumes of PIT tagged juvenile Chinook salmon originating in the Cedar River by release date, 2006 Lake Washington PIT tag study. Each data point was calculated by dividing the number released in a group into the number subsequently detected at the Locks, adjusted for detection efficiency.

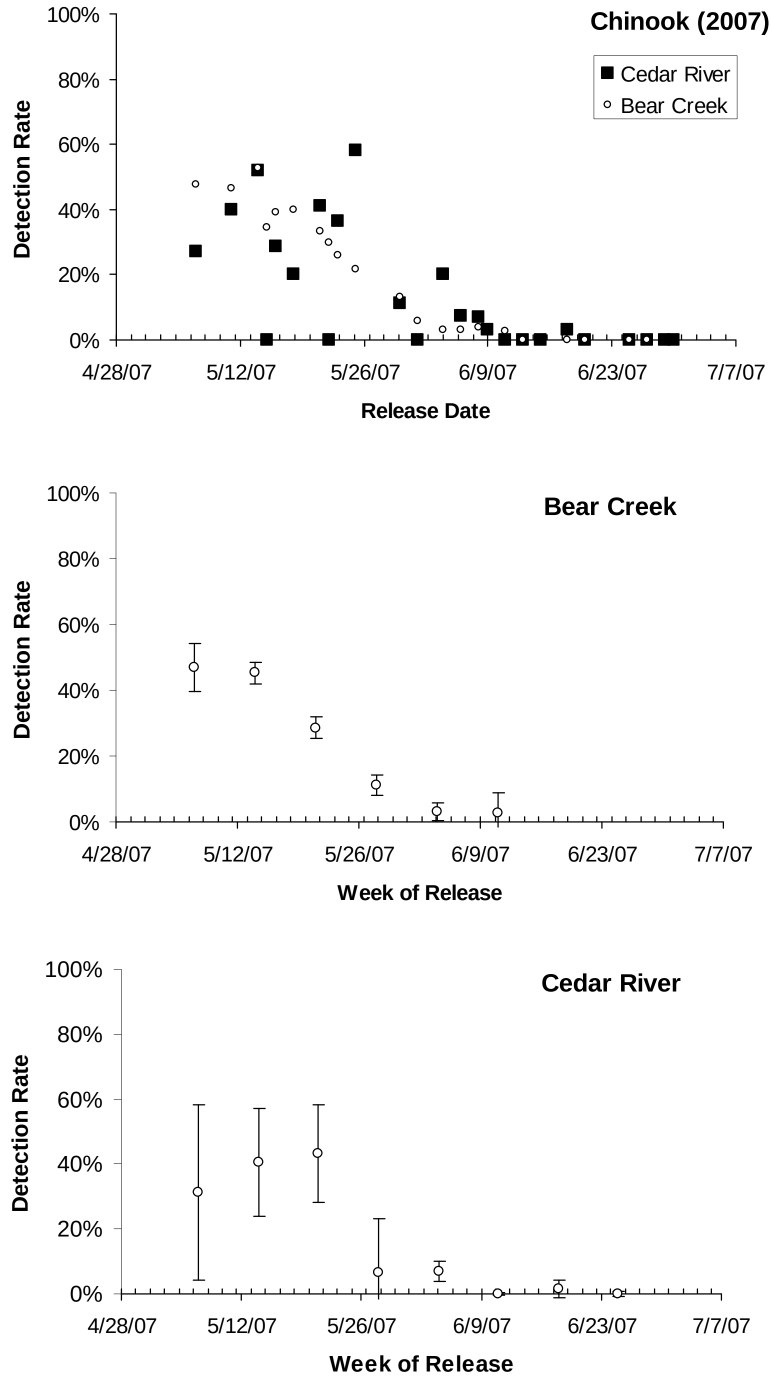
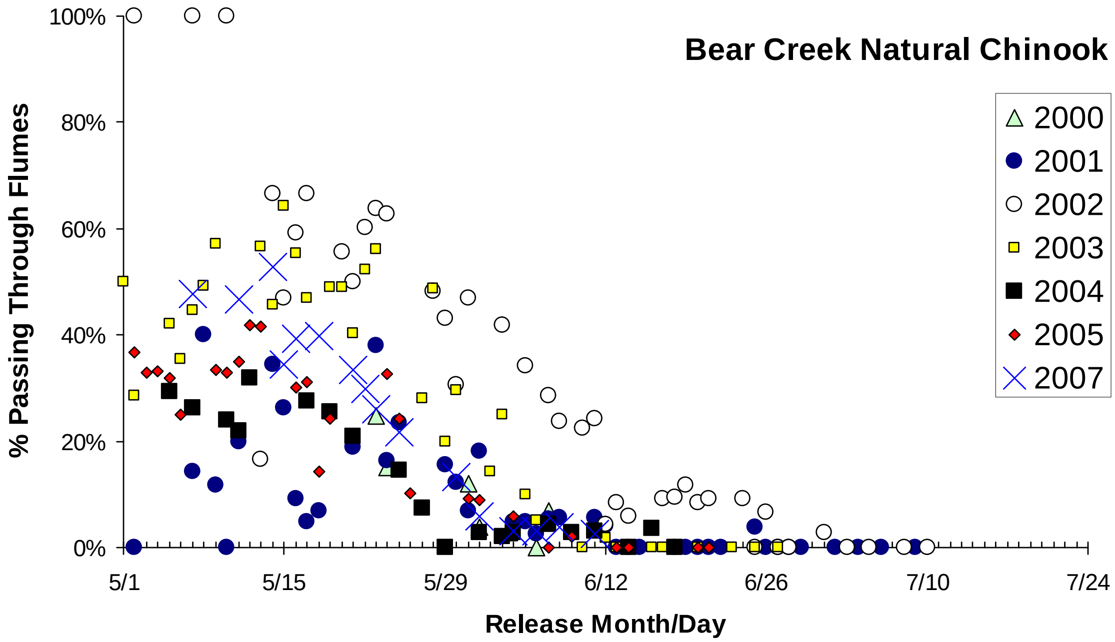


Figure 3-26. Daily and weekly variation of detection rate at the smolt flumes of PIT tagged juvenile Chinook salmon originating in Bear Creek and the Cedar River by release date, 2007 Lake Washington PIT tag study. Each data point was calculated by dividing the number released in a group into the number subsequently detected at the Locks, adjusted for detection efficiency.



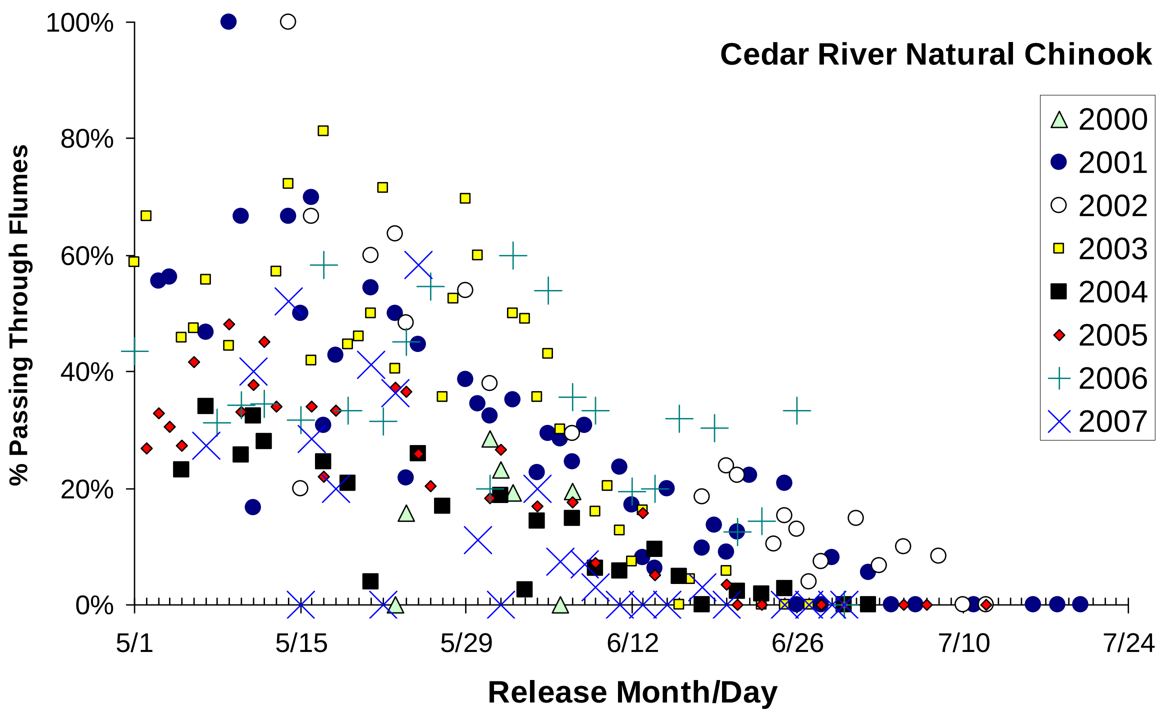
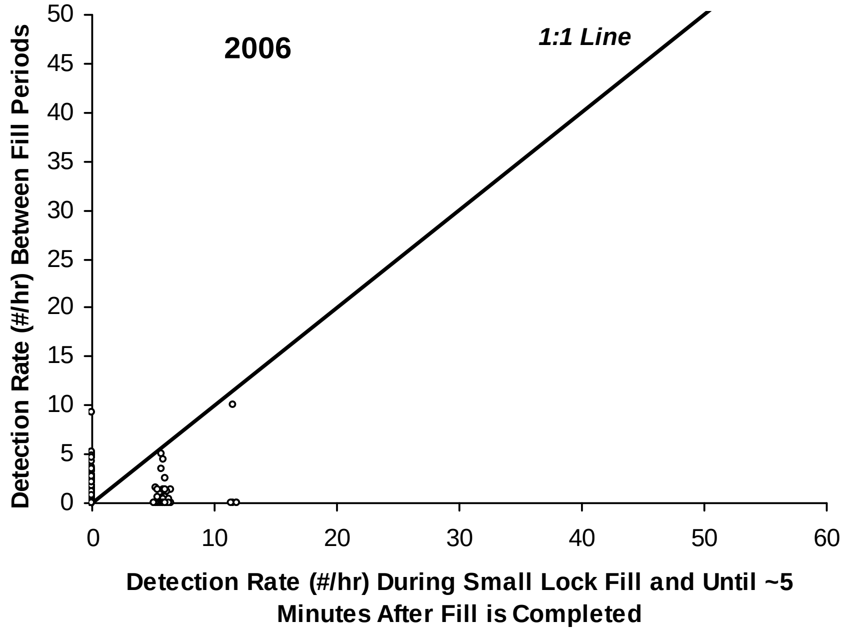


Figure 3-27. Comparison of daily release group detection rates at the smolt flumes of PIT tagged juvenile Chinook salmon originating in Bear Creek and the Cedar River by release location, 2000-2007Lake Washington PIT tag studies.



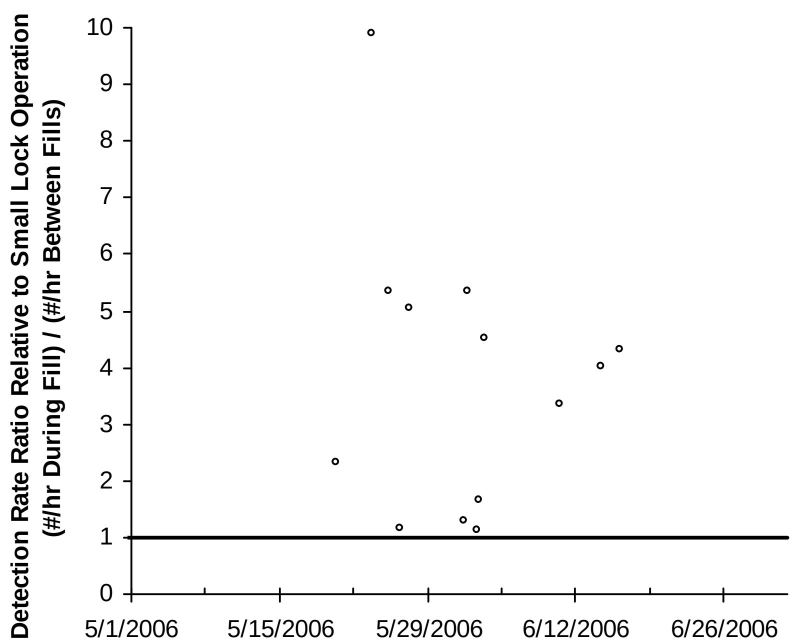
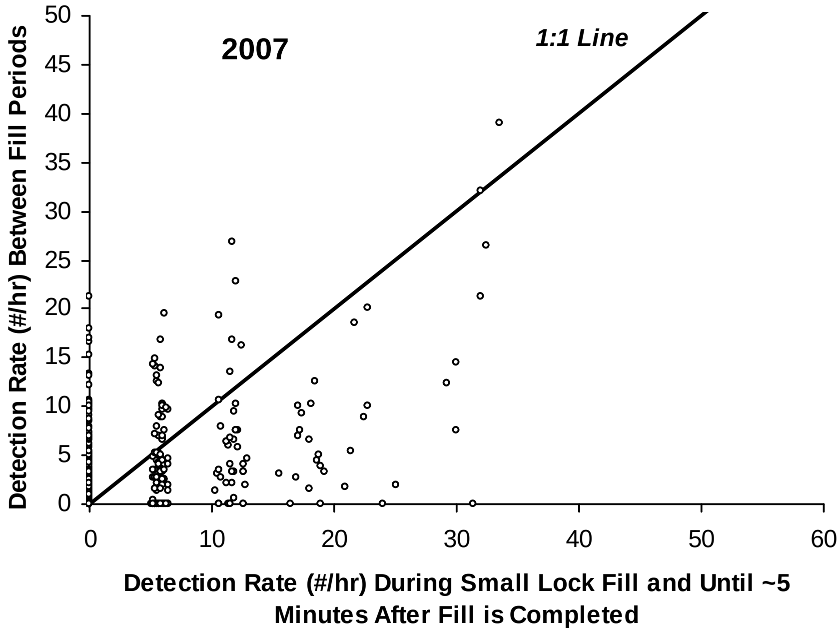


Figure 3-28. Comparison of passage rates of PIT tagged juvenile salmon (all species) through the smolt flumes at the Locks during filling of the small lock and until the next fill, 2006 Lake Washington PIT tag study. The bottom plot shows the ratio of the two passage rates over time. The line of equality is indicated by the solid diagonal (top) and horizontal (bottom) line.



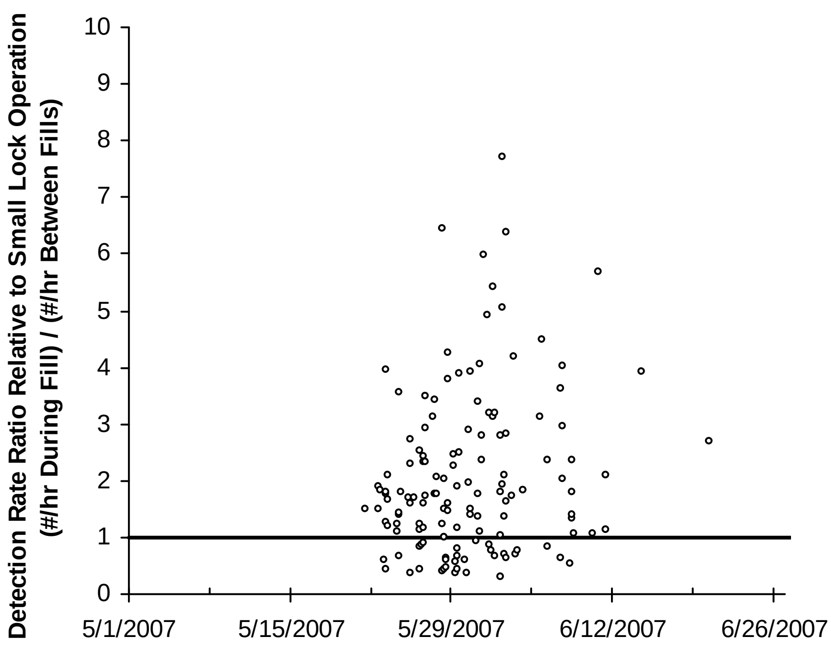


Figure 3-29. Comparison of passage rates of PIT tagged juvenile salmon (all species) through the smolt flumes at the Locks during filling of the small lock and until the next fill, 2007 Lake Washington PIT tag study. The bottom plot shows the ratio of the two passage rates over time. The line of equality is indicated by the solid diagonal (top) and horizontal (bottom) line.

4. DISCUSSION OF 2006-2007 RESULTS AND COMPARISON WITH SYNOPSIS OF 2000-2005 FINDINGS

The results of the 2006 and 2007 studies generally provided data corroborating insights obtained in previous years' PIT tagging studies as described in DeVries et al. (2005, 2007) regarding migration and passage characteristics of tagged fish in the Lake Washington and LWSC system. This section is an update of Chapter 4 in DeVries et al. (2007), incorporating the 2006 and 2007 results. In whole, the data continue to indicate that PIT tagging is a useful and important tool for evaluating outmigration characteristics and the effects of the Locks on juvenile salmon. The results permit further evaluation of the relation between Locks operations and downstream passage by salmon smolts, identification of potential changes to operations that may reduce the effects or help conserve water in a benign manner, and identifying future studies that may be designed to obtain more complete information on smolt behavior in the system. These issues are discussed below. Selected results are also compared with findings from previous years to refine or further support hypothesized trends in migration behavior, environmental conditions, and Locks operations.

Tagging efforts in 2006 and 2007 will also be useful in future years for interpreting adult return data as PIT tagged fish are detected in the fish ladder. There have been two years of returns monitored to date, with results presented in Appendix B that further demonstrate the importance of continued PIT tagging in the basin towards salmon management. A separate study was also undertaken in August and September 2006 in which groups of adult Chinook and sockeye salmon were tagged below the Locks by the USACE and WDFW to evaluate the proportion using the ladder and recycling characteristics. The results from that study, which also involved inserting acoustic tags, are forthcoming pending compilation and evaluation of out-of-basin detection data (F. Goetz, USACE, personal communication).

Detection efficiencies of the tunnel readers in 2006 and 2007 were generally comparable to efficiencies in previous years. The large tunnel readers were still sometimes operating below the desired minimum detection efficiency of 95%. Detection efficiencies were worse in 2007 when there was reduced monitoring of tunnel reader performance, but were still sufficiently high that the results reported for Chinook and coho salmon juveniles in both were likely representative of non-tagged fish.

The Allflex tags used by WDFW in 2007 had a worse performance than the "super tags," and are not recommended for use in future years.

4.1 COMPARISON BETWEEN HATCHERY AND NATURAL ORIGIN FISH

There were insufficient fish tagged at the Issaquah Hatchery to evaluate the use of hatchery Chinook juveniles for migration survival studies in lieu of natural origin fish. Data collected up through 2005 had indicated that the behavior of Issaquah Hatchery fish was reasonably similar to that of natural origin fish (DeVries et al. 2007). University of Washington hatchery Chinook continued to exhibit notably different passage behavior compared with natural origin fish, in which the hatchery fish exhibited a greater tendency to recycle multiple times through the flumes and lock chambers.

4.2 POSSIBLE INFLUENCE OF WATER TEMPERATURE ON SURVIVAL AND PASSAGE

The proportion of tagged Chinook smolts using the flumes remained higher for longer in 2006 compared with other years for the Cedar River release groups (Figure 3-27). Proportions in 2007 were closer to the midrange of all years for both Bear Creek and Cedar River Chinook release groups (Figure 3-27). However, overall proportions for Cedar River Chinook and coho were much lower in 2007 compared with other years (Table 4-1). This result probably reflected the majority of fish being tagged later in the season than usual (Figures 3-4, 3-5), probably in response to increasing near surface water temperatures. Detection rates have consistently decreased each year since 2000 as water temperatures increased and this trend was again observed in 2006 and 2007 (Figures 3-27, 4-1, 4-2). As described below, decreasing detection rates may reflect effects of elevated water temperatures on survival to the locks and/or on migration and passage behavior (DeVries et al. 2005, 2007). These phenomena in turn lead to hypotheses regarding trends in species abundance.

4.2.1 Survival and Predation

Survival of outmigrants to the locks may be adversely affected by elevated temperatures because of effects on predation rates. The overall rate at which juvenile Chinook, coho, and sockeye salmon are consumed will depend on when predator-prey habitats overlap spatially and vertically in the water column, abundance of prey relative to predators, and when water temperatures are near optimal levels for predator feeding rates (Tabor et al. 1993; Petersen and Ward 1999). Primary predators in the LWSC appear to be smallmouth (*Micropterus dolomieui*) and largemouth (*M. salmoides*) bass, and northern pikeminnow (*Ptychocheilus oregonensis*; Tabor et al. 2004). Studies in other Washington rivers indicate that smallmouth bass eat primarily subyearling Chinook, whereas northern pikeminnow also eat larger lifestages (Poe et al. 1991; Fritts and Pearsons 2004). Juvenile salmon consumption rates in the Columbia River have been

Table 4-1. Summary of Releases and Detections of PIT tagged Chinook and coho salmon smolts[1] for long term study release locations, 2000-2007 Lake Washington GI PIT Tag Studies

			Issaquah Creek		Bear Creek		Cedar River	
Quantity	**Species**	**Year**	**Natural**	**Hatchery**	**Natural**	**Hatchery**	**Natural**	**Hatchery**
Number Released	Chinook	2000	226	122	525	--	273	--
		2001	--	4676	2132	--	1550	67
		2002	--	4024	2309	--	814	--
		2003	--	992	2305	--	1726	6
		2004	--	--	1512	--	2185	6
		2005	--	409	1424	--	2075	63
		2006	--	--	--	--	573	--
		2007	--	--	2694	--	734	1
	Coho	2001	--	--	1011	12	1235	--
		2002	--	--	2661	--	1038	--
		2003	--	--	2044	--	1027	--
		2005	--	--	1207	--	1265	--
		2007	--	1178	--	--	75	--
Fraction Detected in Flumes[2]	Chinook	2000	0.004	0.008	0.1	--	0.19	--
		2001	--	0.38	0.13	--	0.29	0.06
		2002	--	0.39	0.32	--	0.21	--
		2003	--	0.28	0.35	--	0.30	0.17
		2004	--	--	0.15	--	0.15	0
		2005	--	0.14	0.24	--	0.27	0.03
		2006	--	--	--	--	0.33	--
		2007	--	--	0.31	--	0.09	0
	Coho	2001	--	--	0.47	0	0.49	--
		2002	--	--	0.65	--	0.59	--
		2003	--	--	0.72	--	0.66	--
		2005	--	--	0.56	--	0.50	--
		2007	--	0.45	--	--	0.04	--

[1] - Insufficient data for sockeye salmon or steelhead trout

[2] - Adjusted for detection efficiency

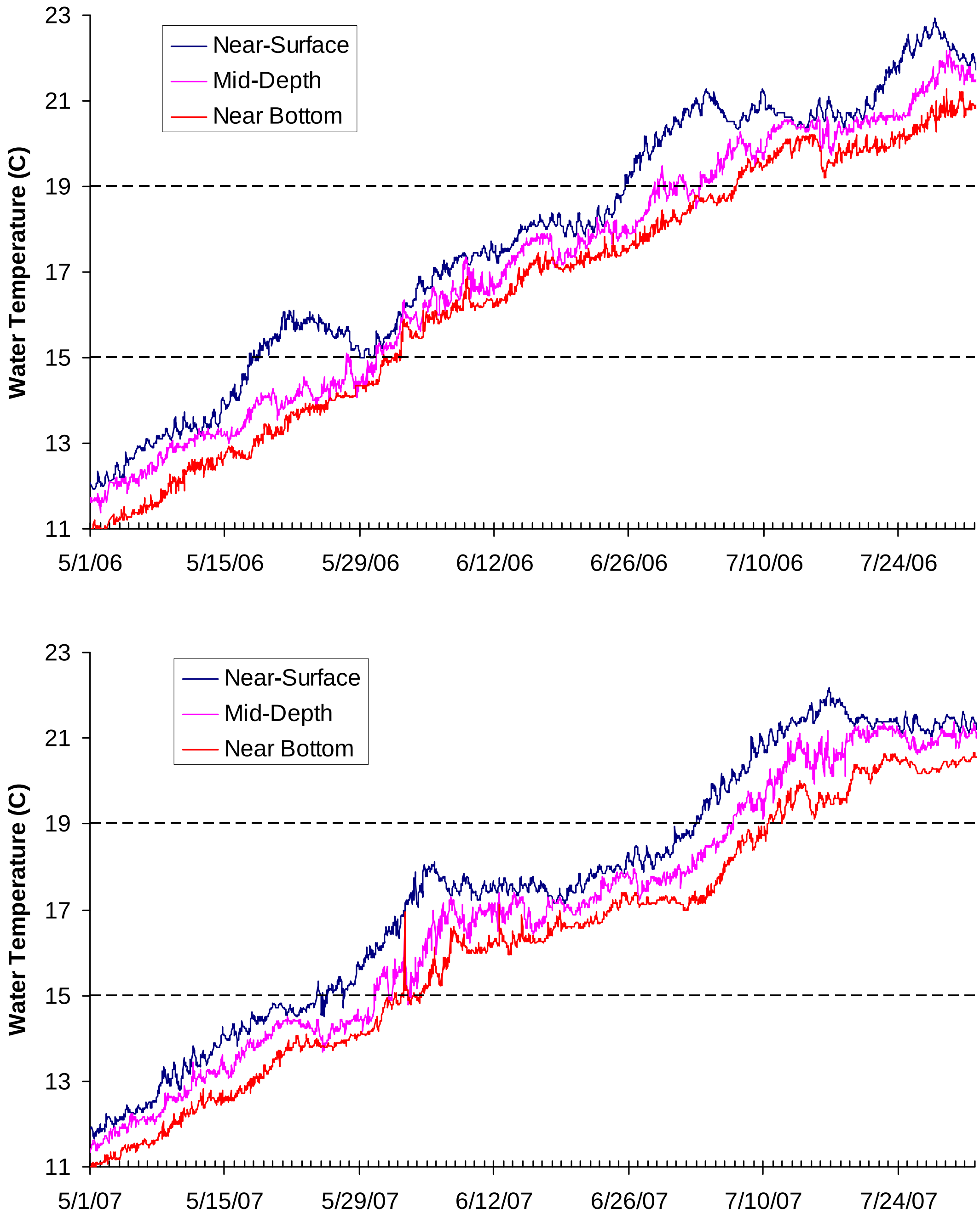


Figure 4-1. Temporal variation in water temperatures measured in the LWSC at the Ballard Bridge during the 2006 (top) and 2007 (bottom) Lake Washington PIT tag studies. The horizontal lines indicate approximate threshold criteria for optimal juvenile salmon growth (15°C) and avoidance and feeding inhibition (19°C).

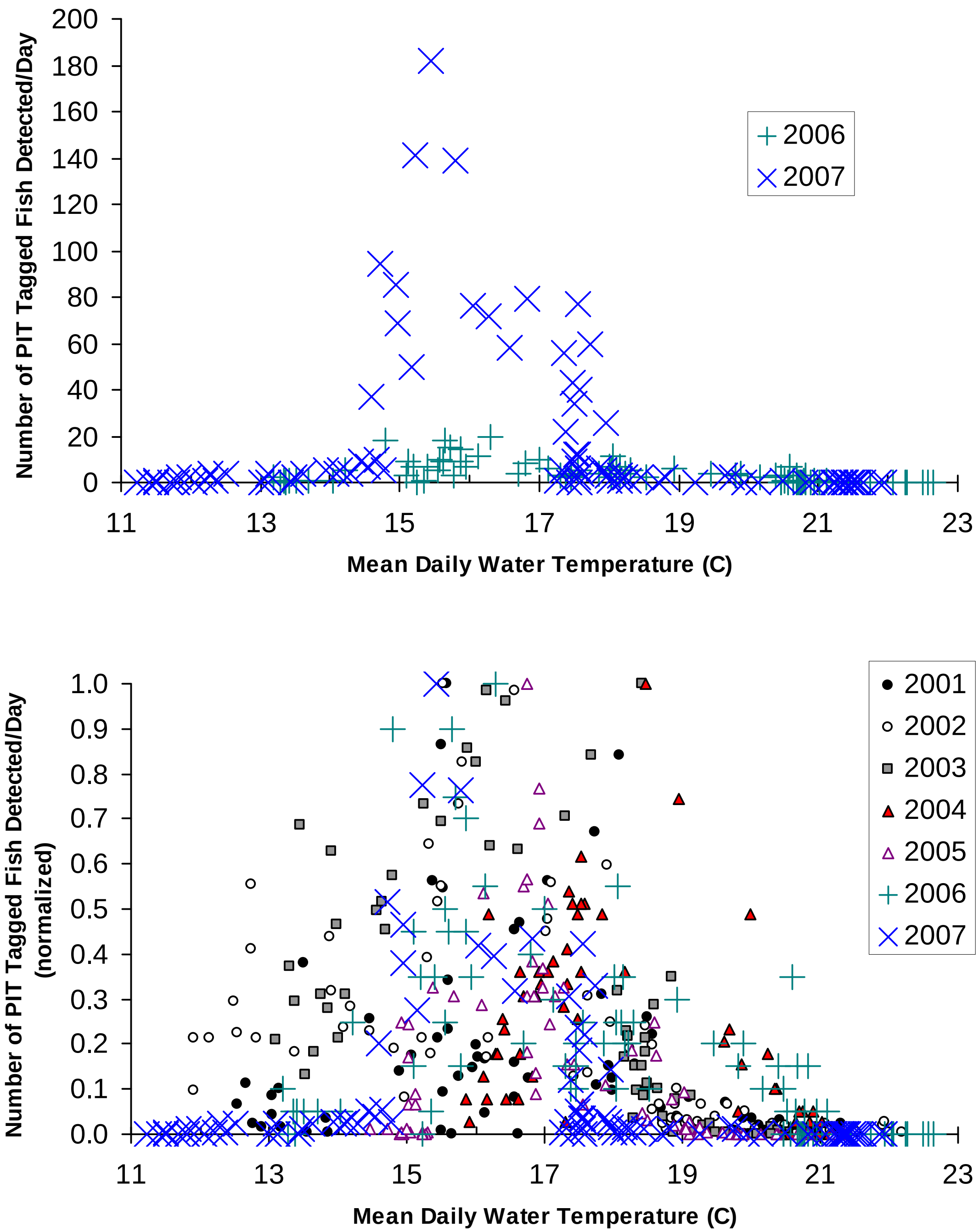


Figure 4-2. Variation in daily detection numbers in the smolt flumes with mean daily surface water temperature in the LWSC. Each data point represents the total number of PIT tagged fish detected over 24 hours, and the corresponding temperature for that day. Top graph: absolute detection numbers for 2006-7; bottom graph: numbers for 20001-2007 normalized with respect to the maximum daily number for each year.

found to be highest when water temperatures were highest (Vigg et al. 1991). Available information indicates the following influences of temperature on predation rates:

- Smallmouth bass prefer temperatures above about 20-21ºC and begin to feed more substantially when temperatures exceed 10ºC (Wydoski and Whitney 2003). They feed more actively at temperatures above 15ºC (Carlander 1977, cited in Naughton et al. 2004), and most actively around 20ºC (Wydoski and Whitney 2003). Moyle (2002) noted that preferred and optimal temperatures for growth and feeding are higher when food is abundant, and suggested that this species may seek out cooler water in part if that is where prey is found. Naughton et al. (2004) noted roughly five times higher predation rates on juvenile salmonids by smallmouth bass in the Columbia River in one year when temperature was around 20.6ºC compared with the previous year when temperature was around 16.7ºC, although the increase may have also partly reflected increased prey abundance.
- Largemouth bass exhibit temperature ranges for preference and growth similar to that of smallmouth bass (Wydoski and Whitney 2003; Moyle 2002).
- Northern pikeminnow in the Columbia River have been determined to feed more effectively at temperatures above about 15ºC, with optimal temperatures ranging between 20.1 and 22.7ºC (Petersen and Ward 1999), or around 21.5ºC (Vigg and Burley 1991). Consumption and growth rates drop rapidly with temperatures below about 15ºC (Petersen and Ward 1999). They have been noted to have been collected in Lake Washington in areas with highest temperatures ranging between 20-23ºC (Wydoski and Whitney 2003).

Since 2000, near-surface water temperatures in the LWSC have generally reached 15ºC at some time during the month of May (Figure 4-3). Temperatures have generally exceeded 20ºC between the end of the third week in June and middle of July. Timing of temperature increases may limit the overall effect of predation mortality on outmigrating smolts in the LWSC because temperatures do not favor higher predation rates until later in the outmigration season. Smolts may also seek cooler water than bass later in the outmigration season. Releases of coho and Chinook smolts from the University of Washington hatchery may provide a major source of salmonid prey to bass and pikeminnow earlier in the migration season (Tabor et al. 2004), where smolts from elsewhere in the basin may benefit by being targeted less. Nonetheless, the reduced detection rates at the Locks later in the outmigration season could reflect in part the effect of temperature on predation rate.

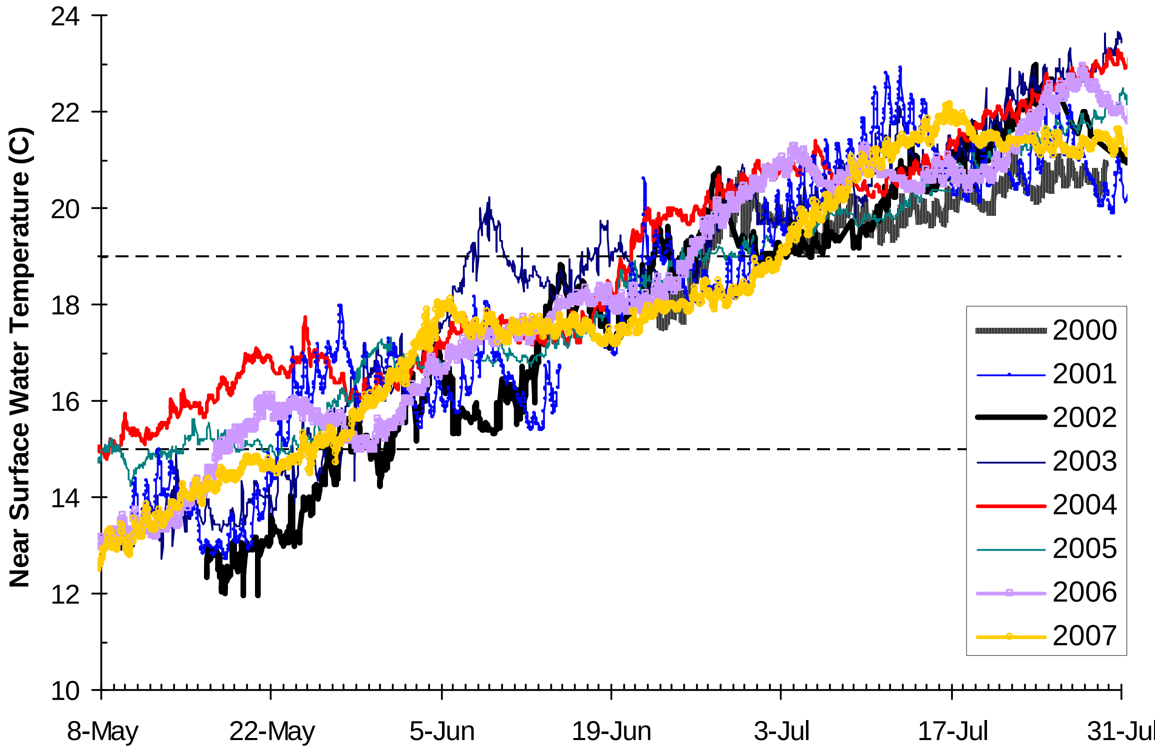


Figure 4-3. Between-year variation in near-surface water temperatures in the LWSC, 2001-2007 (USACE data).

4.2.2 Migration and Passage Depth

Surface water temperatures in the LWSC reach adverse levels sooner in the outmigration season than near-bottom temperatures. One hypothesis is that the decrease in detection rates over time could reflect a shift in passage behavior where the outmigrants gradually seek deeper routes through the LWSC and Locks. This hypothesis has not been fully tested using hydroacoustic data, but is being evaluated more directly using microacoustic tag data collected in 2006 and 2007 (Roger Tabor, USFWS personal communication). Passage later in the season could occur via the large lock and its filling culverts, with a sill elevation 20 feet below that of the small lock on the lake side and approximately 36 feet below the flume entrances. In most locations, the mid-column water temperature was approximately 1-2ºC cooler than the surface temperature (Figure 4-1). Water temperatures below the Locks are also much cooler. Salt water wedges intruding upstream through the large and small locks result in cooler, brackish water near the bottom that the smolts may be attracted to as the surface water warms in the LWSC.

Near-surface water temperatures reached 15ºC in mid-May, and 19ºC near the end of June in 2006 (Figure 4-1). In 2007, temperatures reached 15ºC and 19ºC around the end of May and beginning of July, respectively. These temperatures are of significance because they respectively approximate the limit to optimal juvenile salmon growth, and the approximate onset of feeding inhibition and avoidance during migration (ODEQ 1995; McCullough 1999). Temperature preference has been correlated with optimal growth temperature, and the general preference of juvenile salmonids appears to be for temperatures that are about 15ºC and lower (McCullough 1999). By comparison, detection rates of tagged Bear Creek and Cedar River Chinook salmon began dropping for groups released around the middle of June in 2006 (Figure 3-25) and around the third week of May in 2007 (Figure 3-26). By the median time those fish had reached the Locks (around 13-16 days later), near-surface water temperatures in the LWSC had reached approximately 19ºC in 2006 and 17ºC in 2007 (Figure 4-1). Detection rates approached zero for groups released around the end and middle of June in 2006 and 2007, respectively. By the median time those fish had reached the smolt flumes, surface temperatures had exceeded 20ºC in 2006 and approached 19ºC in 2007. From 2001-2005, total daily detection rates and numbers began to drop off as surface water temperatures in the LWSC exceeded 15ºC and leveled off at very low numbers when the near surface mean daily temperature exceeded approximately 19-20ºC (DeVries et al. 2007). Diurnal variation in LWSC surface temperature is generally less than 0.5ºC, so similar results are seen for daily minimum and maximum temperatures.

Elevated water temperatures in the LWSC have the potential to affect a substantial number of Chinook smolts in this manner. A comparison of the median travel times of Chinook smolts tagged in 2006 and 2007 (~13 and 16 days, respectively; Figure 3-17) with the dates near-surface water temperatures reached 19ºC at the Ballard Bridge (Figure 4-1) suggest that smolts leaving each stream after about June 12, 2006 and June 18, 2007 were more likely to experience adverse near-surface water temperatures in the LWSC than not. This amounts to approximately 19% of Cedar River smolts tagged in 2006, and 0% of Bear Creek Chinook and 16% of Cedar River smolts tagged in 2007, respectively.

The 2006 and 2007 data were inconclusive regarding the possible influence of spill on the hypothesized temperature-flume proportion relationship. DeVries et al. (2007) discussed a corollary hypothesis that the proportion using the flumes is inversely related to the amount of spill through other gates, other factors being equal, because spill through the other gates presents an alternate passage route. There were numerous days with spill through other gates in 2006 and none in 2007 during the first half of the outmigration season (Figures 3-1, 3-2), yet the proportions of PIT tagged Chinook release groups detected in the flumes in both years were comparable over the same period (Figure 3-27). However, this also corresponds to the period when temperature does not appear to affect passage behavior. More focused studies would be needed to determine the interaction between surface water temperature and spill on passage rates through the flumes.

Another potential factor influencing the hypothesized temperature-flume proportion relationship is acclimation occurring during warmer springs such that the proportion using the flumes drops off later in the season because the fish can withstand warmer temperatures (cf. McCullough 1999). Acclimation could allow proportionally more outmigrant Chinook to migrate closer to the surface with more fish able to pass through the flumes. This hypothesis has implications to water management, where a threshold temperature has been suggested by previous years' data for determining when to shut down the flumes for the summer to conserve water (DeVries et al. 2005). There was evidence of this phenomenon in 2004 (DeVries et al. 2007). Detection rates in most years have generally dropped off precipitously when surface water temperatures reached 19-20ºC, except in 2004, when the apparent threshold was around 20-21ºC (lower graph in Figure 4-2). The 2006 data indicated an extended period of higher detection rates later in the spring similar to 2004 (Figures 3-27), and not dropping to near zero until temperatures approach 20-21ºC (Figure 4-2). However, water temperatures in April and May of 2006 were not substantially different from years other than 2004. Thus the possibility raised in DeVries et al. (2007) that a higher threshold temperature may be applicable in years when water temperatures in April and May are with well above average compared with other years requires more focused and detailed study and analysis.

Nonetheless, the results collectively suggest that use of the smolt flumes may have little benefit for smolt passage as some upper temperature threshold is approached in surface waters of the LWSC, and could be closed until the next spring for purposes of saving water for the saltwater drain, lockages, and the fish ladder instead. What level that threshold temperature should be remains to be determined, and will likely balance water availability, water use, water quality, and fish passage objectives. The highest mean daily temperatures in 2006 and 2007 at which flume passage of PIT tagged Chinook occurred were approximately 20.9°C (1 fish/day) and 20.5°C (1 fish/day), respectively. Previous years showed flume passage, albeit in small numbers (1-9 fish/day), at mean daily surface water temperatures as high as 21.3°C in 2001, 22.0°C in 2002, 20.5°C in 2003, 21.0°C in 2004, and 20.8°C in 2005 (Figure 4-2).

4.2.3 Residualism in Lake Washington

No salmon smolts were detected at the Locks in 2006 and 2007 that had been tagged in previous years. Previous years have observed small numbers passing the Locks that residualized in the Lake Washington system (DeVries et al. 2007). This behavior is thought to reflect the influence of rising water temperatures during the spring outmigration, and the possible existence of thermal barriers to outmigrants posed by the LWSC and Sammamish River in late spring and early summer. In the case of the Montlake and Fremont Cut entrances, it is hypothesized that thermal barriers may develop during the outmigration when near surface water temperatures rise above general smolt preference (~15°C) and tolerance (~ 19°C) limits (ODEQ 1995; McCullough 1999). The critical temperature at which a thermal barrier becomes significant has not been established directly, but appears to be somewhere within this range. DeVries et al. (2007) discuss this phenomenon and its implications in greater detail. In summary, the range of dates at which 10 m depth water temperatures exceed 15°C correspond roughly to the range of tagging group release dates for which PIT tag detection rates begin to decline. Thermal bottlenecks or barriers potentially posed by the Montlake and Fremont cuts are important in the sense that they may cause residualization in Lake Washington until the following spring, through avoidance behavior and/or adverse effects to the smolting process (McCullough 1999). An extended year of lake residency could also lead to increased risk of predation.

4.2.4 Possible Implications for Anadromous Salmonid Species Composition in the Lake Washington Basin

The data indicate that water temperatures in Lake Washington and the LWSC generally warm over the outmigration season. There is also evidence that temperatures in the system have been warming over the long term (e.g., Arhonditsis et al. 2004; Winder and Schindler 2004). Larger bodied sockeye, coho, and Chinook yearlings outmigrate and pass the Locks earlier in the spring than smaller, young of year sockeye and Chinook. Sockeye and coho yearlings appear to have the largest saltwater survivals and run sizes returning to the LWB based on the limited amount of adult PIT tag detection data available to date (DeVries et al. 2007). As described above and in DeVries et al. (2005), detection rates, and thus potentially survival to the Locks, decline as water temperatures increase over the outmigration season to levels that are above various preference, tolerance, and saltwater adaptability criteria.

In addition, because predation risk increases with water temperature, survival to the Locks may decrease as water temperatures increase over the spring outmigration period. This interaction could potentially affect later migrating species and cohorts more adversely than earlier migrating ones. Greatest impacts of predation as related to water temperature would therefore be expected for later migrating Chinook and young of year sockeye smolts, and fewest impacts would be expected for larger bodied, earlier migrating sockeye and coho smolts.

It is thus reasonable to hypothesize that sockeye and coho salmon smolts may have an adaptive advantage over Chinook salmon smolts based on interactions between body size, outmigration timing, and water temperature patterns. The greater proclivity of steelhead to exhibit reverse smoltification at elevated temperatures (Wedemeyer et al. 1980) also leads to a hypothesis that gradual long term warming of the system could help explain the decline seen in this species' population. Additional study appears warranted to evaluate these hypotheses.

4.3 INFLUENCE OF LOCK OPERATIONS ON PASSAGE AND ESTUARINE TRANSITION

The 2006 and 2007 PIT tag data further corroborate findings from previous years that suggest there are several features of lock construction or operation that may also influence downstream passage and the transition to saltwater. These include seasonal and diurnal environmental and operational features that may result in changes in passage behavior, and are evaluated below.

4.3.1 Influence on Juveniles Located Above the Locks

4.3.1.1 Influence of Lock Fillings

The preceding PIT tag studies indicated that operation of the small lock may have a stronger influence on passage rates in the flumes than the large lock (DeVries et al. 2007). The mechanism is hypothesized to be that lock filling operations influence flume passage rates through transient changes in velocity patterns occurring in the forebay area. Juveniles may be induced to swim more actively in the forebay area in response to unsteady flows when local currents increase temporarily while the small lock is filling. Increased swimming activity may increase the probability that outmigrants encounter the smolt flume entrances, with increased probability of passage. In corroboration, passage rates during fills of either lock were more than twice passage rates between successive fills in 2006 and 2007, consistent with previous years' results. The differences were significant at the 95% confidence level in both years. However, the relation between small lock fillings and passage rates does not appear to reflect diurnal variation in small lock fillings (Figure 4-4), but more likely sounding of smolts to deeper water at night such that they are effectively unavailable to pass through the flumes (Johnson et al. 2004; DeVries et al. 2007).

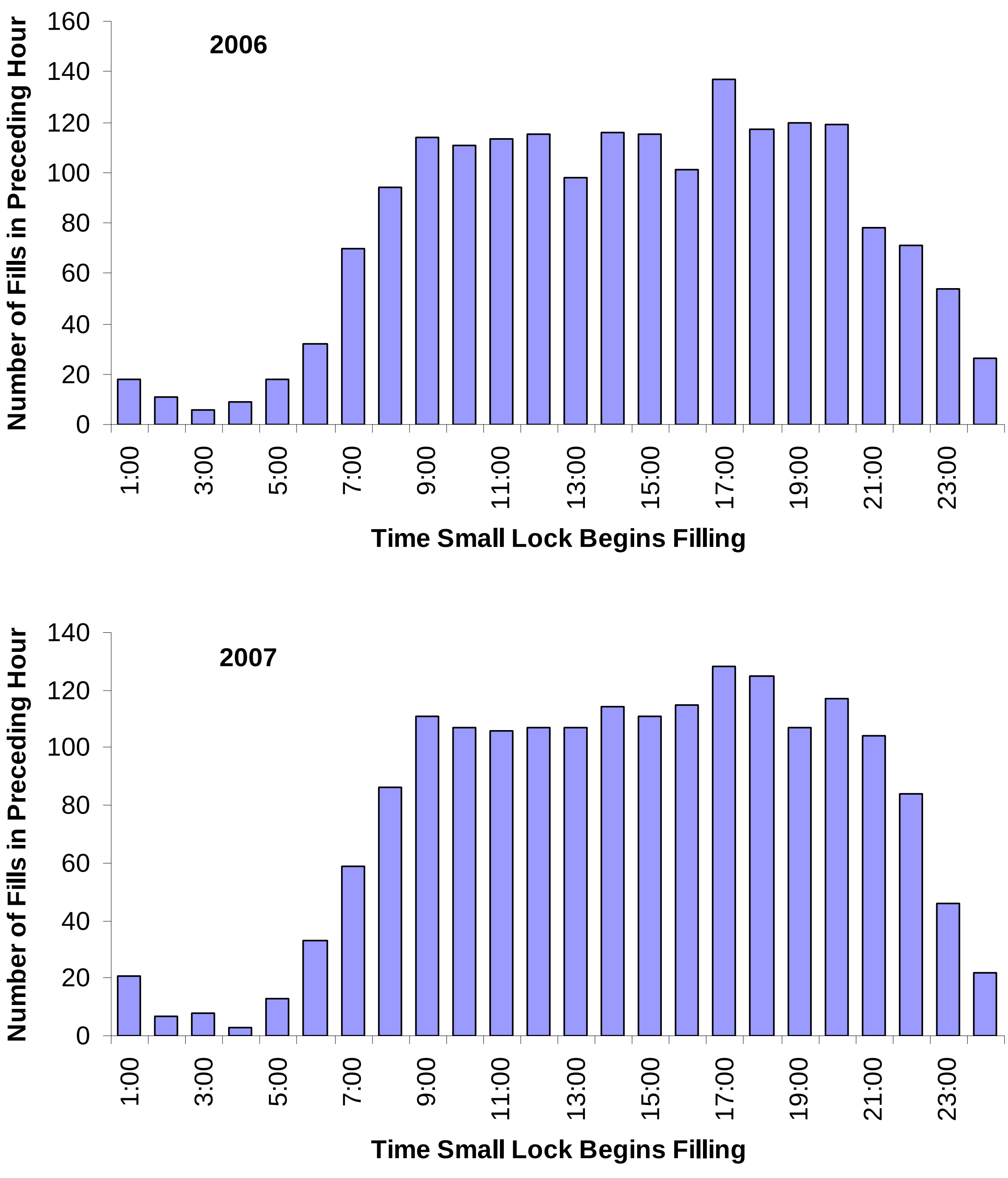


Figure 4-4. Diurnal variation in times at which the small lock began to fill during the 2006 (top) and 2007 (bottom) Lake Washington PIT tag study periods May1-July 15, 2006 and 2007.

4.3.1.2 Influence of Flume Flow Rate

A direct relationship between flume flow and passage numbers has been suggested by previous years' results to occur before water temperature affects passage behavior (DeVries et al. 2007). The relation of passage rate with flume flow was addressed for the 2004 data by DeVries and Hendrix (2005) and is thus not repeated in detail here. That work systematically evaluated the relation between flume flow and entrainment rates in the large lock filling culvert, relying on PIT tagging, observer count, and hydroacoustic data. A key finding of that analysis with respect to Locks operations and involving the PIT tag data was that maximum flume passage numbers appeared to increase with total flume flow rate. There was no apparent flume flow rate above which passage numbers decreased asymptotically. There was also some evidence that the flume flow-passage rate relation may have been stronger within a week or two after apogee occurred (DeVries and Hendrix 2005). The collective results suggest that additional flumes could be opened or substituted (e.g., both large flumes instead of one large and the medium-sized flume) as needed and feasible to maximize flume passage rates until water temperatures begin to affect migration depth as hypothesized, and detection rates decline.

The flume with greatest passage rate per unit discharge of water has varied over the years, but in general the two larger flumes (4B and 5B) have been most effective (DeVries et al. 2007). The results for 2006 and 2007 were different, however, in that this time the two smaller flumes (4A and 5C) appeared to have passed more fish per unit discharge on days when all four flumes were effectively open simultaneously during daylight hours (Figure 4-5). The reason for this difference compared with previous years is not clear given that detection efficiencies were not substantially different across all four flumes each year (Figures 3-6, 3-7).

4.3.2 Influence of Locks on Juveniles Located Below the Locks

As in previous years, the 2007 data indicate that some Chinook and coho salmon smolts recycled through the Locks (Figure 3-24). As discussed in DeVries et al. (2005, 2007), it is unknown whether this was because (i) fish were entrained during lock openings and became disoriented, (ii) some fish that passed through the flumes were not completely smolt-ready and thus actively avoided more saline water by swimming upstream through the Locks in the less saline lens, or (iii) fish were swimming about in pseudo-random movements that were directed on average in the upstream direction. Similar to 2004 and 2005, most occurrences of recycling occurred within 24 hours. The behavior was observed in fish originating from different locations in the basin. Of particular note, University of Washington Hatchery Chinook again recycled most prolifically, similar to results from 2001 (DeVries et al. 2002) further indicating that these fish behave differently from natural origin Chinook.

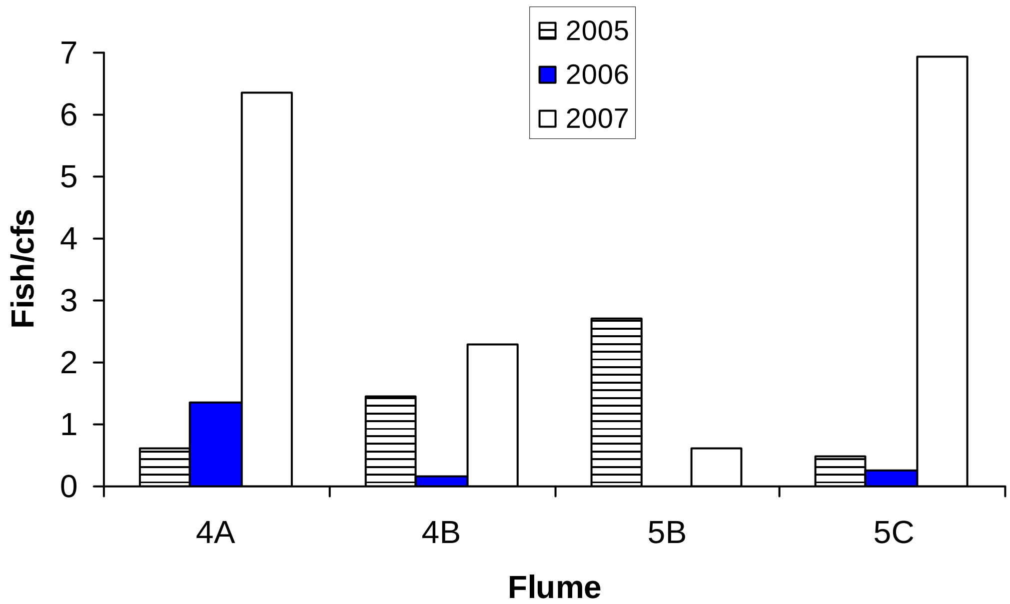


Figure 4-5. Number of all PIT tagged Chinook and coho salmon passing through each flume on days when all four flumes were open during daylight hours, normalized to unit discharge during the 2005-2007 Lake Washington PIT tag studies.

4.3.3 Suggested Changes in Operations

Two changes to flume operations are suggested:

- Shutting off the flumes at night; and
- Shutting off the flumes when some temperature threshold is reached in the LWSC.

The collective evidence through 2007 is that smolts pass through the flumes primarily during daylight hours. Shutting the flumes down at night helps address water conservation needs for improving smolt passage at the Locks, a significant problem identified by USACE (1998), by allowing storage of water in the lake system to keep the flumes open for longer in the outmigration season.

The evidence also supports shutting down the flumes for the season when surface water temperatures in the LWSC in the vicinity of the Locks reach somewhere between 19-21ºC

(DeVries et al. 2007). Smolts are hypothesized to shift to deeper passage route alternatives, with few fish using the flumes after that temperature threshold is reached. There is limited evidence that the threshold could potentially be higher in years when water temperatures are warmer in April and May than normal if smolts can be shown to have acclimated to some extent. This effect needs to be studied in greater depth if management decisions are to be made accordingly.

4.4 SYNOPSIS OF OTHER BEHAVIORAL CHARACTERISTICS

4.4.1 Size-Dependent Influences

Lengths of natural origin Chinook generally increased in the smolt trap catches as the 2006 and 2007 migration seasons progressed in the Cedar River (Figures 3-8, 3-9), but not Bear Creek in 2007 (Figure 3-10). Mean lengths were generally within the middle to lower range of previous years' data in both Bear Creek and the Cedar River (Figure 4-6). The slower growth rate in Bear Creek may reflect the moderating effect of cool groundwater, especially in the Cottage Lake Creek sub-basin.

4.4.2 Lunar Phase and Passage Timing

As noted in Section 3.4, the relation between lunar phase and the initiation of the main passage period for Chinook was not as strong in 2005 and 2006 as in previous years when passage at the Locks became substantial within a few days of the date that the moon was at apogee (farthest from the earth; DeVries et al. 2004). Cedar River Chinook passage timing was later in 2006 than in 2002 when apogee occurred around the same dates (Figure 3-15). This suggested that the apparent connection between moon location relative to the earth and passage timing of Chinook salmon may have been influenced by other environmental factors that year, although given the small size of fish (Figure 4-6) and the hypothesis that smaller bodied smolts exhibit a stronger response (DeVries et al. 2004), a lunar influence would have been more likely to have been observed in 2006. The relation was stronger again in 2007 for Chinook from Bear Creek and the Cedar River (Figure 3-15), consistent with data from 2000-2004.

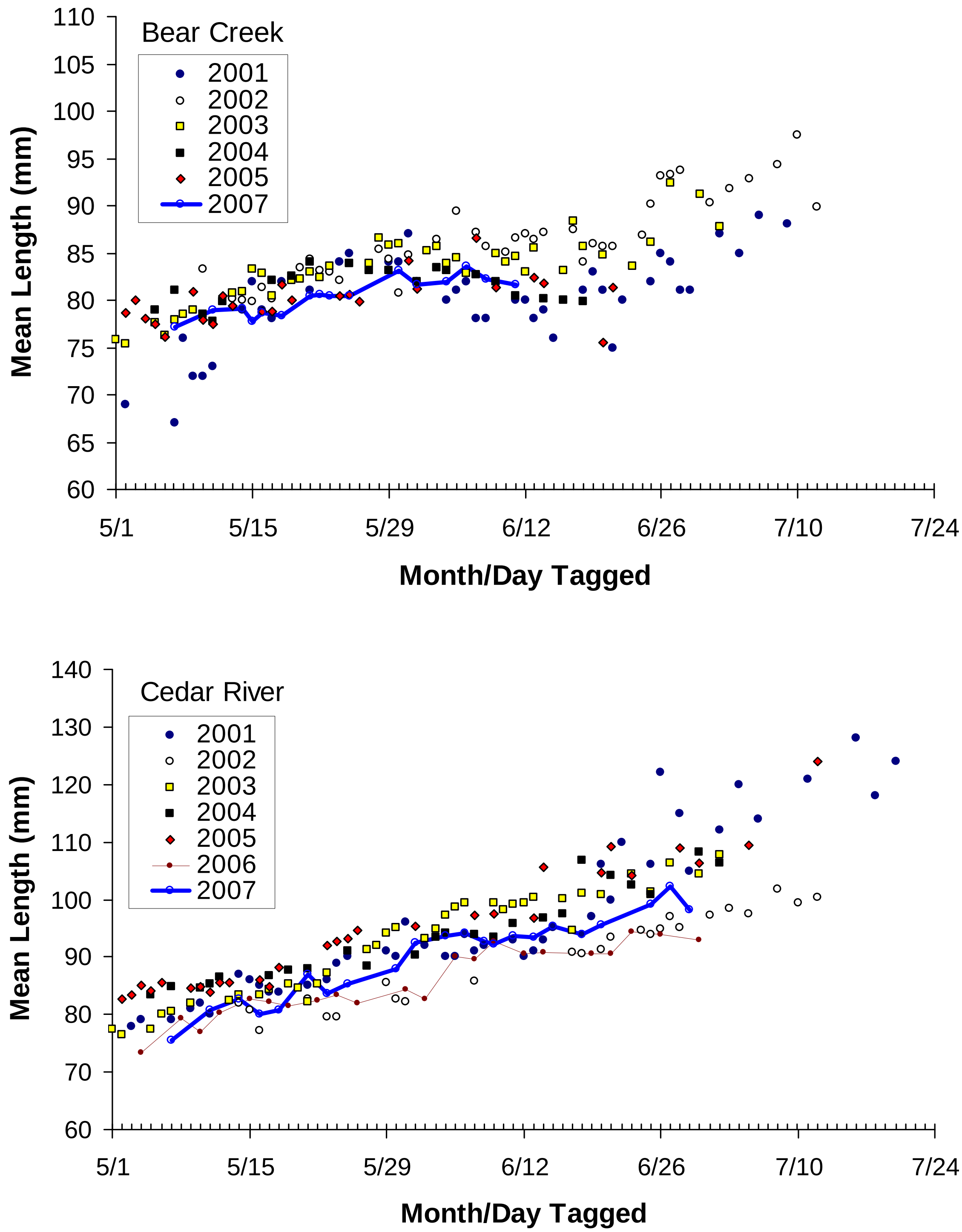


Figure 4-6. Temporal variation in mean lengths of Chinook caught, PIT tagged, and released in Bear Creek and the Cedar River, 2001-2005 Lake Washington PIT tag studies.

4.4.3 Travel Times to the Locks

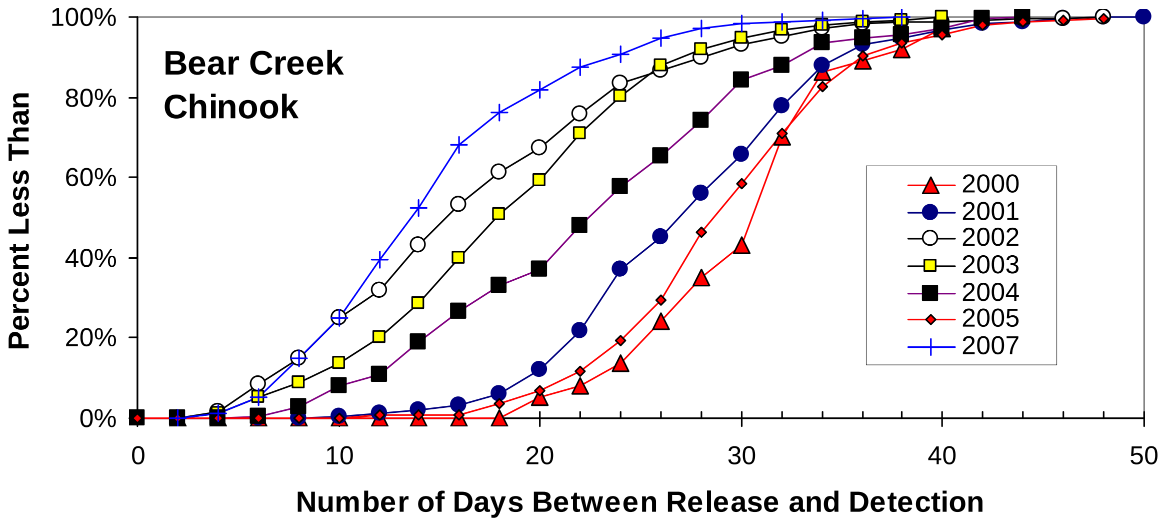
It was seen in DeVries et al. (2007) that migration rates for each species varied between stocks and years, where travel time did not consistently reflect travel distance, water temperatures, or location. Travel time distributions in 2006 and 2007 generally reflected faster migrations than in most other years (Figure 4-7). As discussed in DeVries et al. (2007), the variation seen in travel times and migration rates over the eight years of study may reflect a complicated interaction between many environmental cues and other factors including water temperature, flow, lunar phase, and release location.

4.4.4 Shoreline Affinity Behavior

It was not possible to assess shoreline affinity behavior conclusively in 2006 and 2007. Only one hatchery Chinook smolt was caught and PIT tagged in the Cedar River, on June 13, 2007. Smolts were released from the Issaquah Hatchery into Issaquah Creek on five separate occasions from May 17 through June 17, 2007; none were PIT tagged. Assuming a median travel speed similar to that for Bear Creek Chinook PIT tagged in 2007 (~4 km/day; Figure 3-17) and an approximate distance following the eastern shoreline of Lake Washington (~88 km), fish would be expected on average to arrive at the trap location about 22 days after release. Fish released on May 23, 2007 (the second group) would be expected to arrive on or about June 12, 2007. While not conclusive, the result may be consistent with a shoreline affinity hypothesis supported by previous years' results (DeVries et al. 2007), corresponding to fish that turned left instead of right at the mouth of the Sammamish River.

4.5 SUMMARY

The following primary observations or hypotheses were made based on the 2000-2007 PIT tag study results presented here and in DeVries et al. (2005, 2007). They represent a concise recap of the best available information to date. The summary based on 2000-2005 data and as reported in DeVries et al. (2007) is repeated below. Modifications and additions based on the additional 2006 and 2007 results are presented in italics. The observations below do not represent all findings based on the PIT tag data but may be the most noteworthy and provide guidance for focusing future questions. Specific, supporting details and other observations may be found in the series of PIT tagging reports produced as part of the Lake Washington GI and published on the Seattle District website (http://www.nws.usace.army.mil/PublicMenu/Doc_list.cfm?sitename=ERS&pagename=MONITORING).



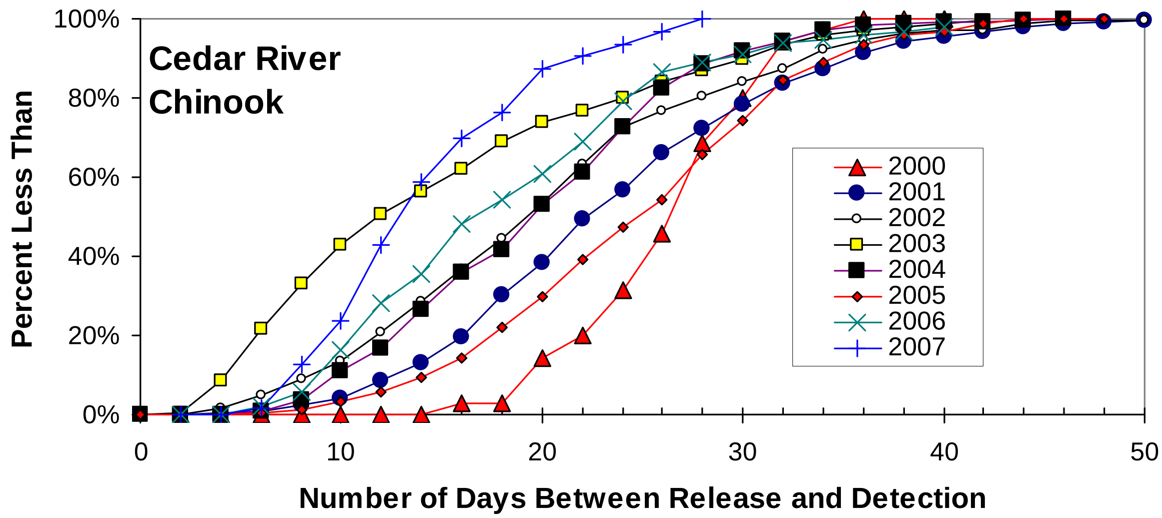


Figure 4-7. Between-year variation in travel time of tributary and hatchery Chinook salmon as they migrate through the Lake Washington system to the Locks, 2000-2007 Lake Washington PIT tag studies.

4.5.1 Survival Estimation

- Survival of Chinook smolts appears to be high (probably close to 100%) in the LWSC during most of the outmigration season, but may decrease when water temperatures exceed somewhere above about 15-19ºC.
- Survival estimates in most cases have been of low precision (most 95% confidence intervals spanned more than one quarter of the estimate in magnitude, and many were as big as the estimate itself), and have been complicated by warming water temperatures later in the season.
- PIT tag survival estimates were influenced, at minimum, by proportion using flumes, travel time distributions, residualism, and various sources of natural mortality.
- There is subtle but inconclusive evidence of a potential effect of fish size on detection rate at the Locks later in the outmigration season, where larger Chinook smolts may have a slightly greater probability of passing through the flumes than smaller smolts; however, differences in length frequency distributions of all fish tagged vs. all fish detected were not significantly different in a consistent manner for all Chinook stocks.

4.5.2 Migration Behavior in Freshwater

- Average migration rates vary spatially, seasonally, and annually. Travel times to the Locks generally, but not consistently, reflect travel distance and vary within (annually) and between (spatially) stocks.
- Migration rates do not consistently reflect the influence of any one environmental variable. Water temperature, stream flow, lunar phase, and release location may all interact in their effect on distributions of travel time to the Locks.
- Average Chinook smolt migration rates tend to increase as the outmigration season progresses; coho rates are steadier.
- Chinook smolts appear to move along lake shorelines while outmigrating.
- Chinook smolts may mix cross-channel in the LWSC in the Montlake Cut, Fremont Cut, and Locks forebay area.
- Sockeye smolts spend least time in the LWSC (in general, most within one week), Chinook smolts the most (most within three to four weeks); coho are intermediate (most within two weeks).

- Sockeye salmon smolts passing the Locks represent two age classes (young of year and yearlings).
- Yearlings of all three salmon species and University of Washington young of year Chinook generally pass through the Locks earlier than young of year Chinook and sockeye smolts; the distinction may reflect fish size.
- Chinook and coho salmon smolts have also been found to residualize in the system, with rates ranging between 0.09% and 0.45%. Residualization of Chinook smolts appears to be greater in years with warmer temperatures during the outmigration season, and may be greater for Bear Creek than Cedar River Chinook. It is possible a larger fraction residualizes where these percentages inherently reflect mortality rates for juveniles remaining an extra year or two in the system.
- Smolts may have a higher probability of residualizing in Lake Washington as the outmigration season progresses and surface water temperatures warm. The Montlake Cut and Sammamish River may pose thermal barriers later in the season. Residualized fish tend to be later migrants, and are among the first to pass the Locks the following year(s).
- The effects of temperature seen for PIT tagged salmon migration behavior suggests that long term, earlier warming of Lake Washington and the LWSC might be partially linked to increasing residualization of steelhead, and decreases in adult returns.

4.5.3 Passage at the Locks and Lock Operations

- The proportion of fish using the flumes relative to other routes through the Locks is initially approximately steady, can be on the order of 40%-80% when all four flumes are open, and then decreases over time. In years with warmer water temperatures, the proportion using the flumes can initially be on the order of 20%-40%, although this may also reflect reduced water availability and number of flumes being open. The seasonal decrease appears to reflect warming surface water temperatures in the LWSC, decreasing flume flow rate, and a hypothesized vertical shift by outmigrants to deeper, cooler water. However, the PIT tag data cannot be used to discern the relative importance of temperature effects on migration depth (avoidance) vs. growth rate and smoltification (residualization).
- Late in the outmigration season, Chinook smolts would be more likely to pass through the deeper, large lock.

- Relatively few smolts pass through the flumes during the night; the greatest passage rates generally occur near dawn, which may reflect an accumulation of smolts arriving overnight.
- Passage rates through the flumes increase during small and large lock fillings compared with between-fill periods.
- Diurnal patterns in passage rates through the flumes may reflect daily vertical migrations in the water column, not frequency of small lock operations. Smolts may move to deeper water during night-time hours where they would not be available to pass through the flumes. Hence, there appears to be a biological basis for shutting off the flumes at night to conserve water that can then be used to extend the overall period the flumes are operational as well as provide water for other beneficial uses such as the saltwater drain.
- The number of PIT tagged smolts passing through the flumes increases with total flow rate through the flumes, on average, when water temperature is not influencing passage behavior.
- *In most years, the large flumes (4B, 5B) tend to pass more fish per unit volume of water when all four flumes are open simultaneously. However, in 2006 and 2007, the small (4A) and mid-sized (5C) flumes passed more fish per unit volume of water.*
- The small flume (4A) generally passes small numbers of smolts when operated alone in Gate 4.
- Passage rates may increase in a flume (other than the small flume) when its companion flume in the gate is shut off (i.e., a compensatory passage rate effect may exist).
- Water savings can most likely be achieved by (i) turning off the flumes at night, and (ii) shutting down the flumes when surface water temperatures regularly exceed some (to be determined) threshold value between 19-21°C, when flume passage rates become minor (e.g., less than 5 PIT tagged fish/day). The magnitude of the threshold temperature may be a degree or so higher in years with warmer early spring water temperatures than in other years, reflecting possible earlier acclimation to some extent by Chinook smolts.
- Some Chinook and coho smolts recycle upstream through the large or small lock with observed rates *prior to 2006* ranging between 0.06% and 0.70% of detections for fish originating in tributaries; no sockeye smolts have been observed to recycle. *Recycling rates in 2007 were an order of magnitude higher, ranging between 3.9%-5.0% of Chinook detections and 6.9%-7.8% of coho detections.* The time between repeat passage decreases as the outmigration season progresses, and may be shorter overall in years with warmer spring water temperatures.

- Chinook released into the LWSC from the University of Washington Hatchery and the Issaquah Hatchery exhibit the strongest recycling behavior.
- Passage timing of Issaquah Hatchery Chinook appears to be fairly similar to that of Bear Creek Chinook. Cedar River Chinook passage timing may differ from the other two stocks' behavior, however.
- Passage/estuarine entry of young of year Chinook and sockeye smolts appears to be initiated in response to lunar apogee or quarter moon. This phenomenon may be moderated by warmer water temperatures occurring early in the spring. *2005 and 2006 were years with weaker behavior.*

4.5.4 Estuarine Transition

- Smolts may spend little time (e.g., less than an hour) in the freshwater lens immediately below the locks.
- Sockeye smolts appear to spend least time in the inner bay, Chinook smolts the most; coho may be intermediate.
- Hatchery Chinook may reside longer in the inner bay below the Locks than natural origin Chinook, possibly reflecting an abundant food supply from the LWSC.

4.6 FUTURE STUDY RECOMMENDATIONS

The following possible changes to study design are suggested on the basis of the data collected the last three years, and accompanying justifications are given (Italics are again used to denote modifications based on the 2006 and 2007 results):

- Structural vibration and surging problems continue to result in decreased detection efficiency in the large flumes (4B and 5B). It is important to continue working toward increasing the detection efficiency to above 95% as much as possible to reduce this source of variation to a negligible level. One possibility is to experiment with hydraulics within the flumes to reduce pulsing and smooth out the water surface within the tunnel readers and the flume flow lines. The use of supertags appears to compensate for this problem somewhat where detection efficiency in the two large flumes is increased substantially.
- Calibration testing should continue with both tagged fish and the "fish sticks" to further evaluate stick performance relative to using live fish because results to date indicate large

variability remains when using fish sticks, but use of live fish is more expensive. Stick tests should be done frequently to identify the potential need for retuning of selected tunnel reader coils. Additional tests would be useful comparing the use of a string of sticks introduced to the flumes from the walkway and recovered at the outlet using rod and reel and a long gaff. If effective, the method would eliminate the need for a boat to recover sticks downstream, thereby reducing effort and cost of calibration testing.

- Limited calibration test results in 2002 and 2003 indicate that live, tagged, hatchery fish can be introduced into each flume from the spillway walkway by flushing them through a large diameter PVC pipe using buckets of water, rather than through the more time consuming hand-feeding into the face of the flume from the bow of a boat. Recycling of large numbers of calibration test fish in 2003 indicate that the method may not result in significant harm to the specimens. Ideally, fish should be flushed individually and in groups to simulate a range of observed passage patterns. However, considering tag cost and holding facility limitations, at minimum the fish should be flushed down the pipe one at a time to maximize detection probability (it is unlikely based on the four years of data that more than one PIT tagged fish arriving from upstream passes through a flume at any moment in time and precludes detection of another tag).

- Future tag purchases should be of the newer "supertag" type only, given their greater detection rates at the flumes than of standard tags. *The use of Allflex tags is not recommended because of their lower apparent detection rate.*

- Fish should be held at the King County Environmental Laboratory primarily for calibration testing and releases at that location. Holding capacity could be increased in the future (F. Sweeney, King County personal communication). Other objectives should rely on other sources of fish. Holding of Chinook at the UW hatchery is not recommended for future PIT tag studies because of stress and disease problems experienced in previous years as water temperatures warm in the LWSC.

- Future tagging of fish at the Issaquah Hatchery is recommended only if fish can be released in smaller groups over the course of the migration season to better evaluate survival, migration, and passage characteristics of fish originating in Issaquah Creek. The one-time release at the hatchery each year in 2001-2003 and 2005 has proven useful, but it is unlikely extensive, additional, useful information can be derived from future such releases beyond identifying long term trends.

- Efforts in 2003 indicated that transporting hatchery fish from Issaquah Hatchery to different release locations in Lake Washington tributaries and tagging them onsite prior to release was a difficult endeavor as water temperatures warmed (see report in Appendix A), so continued tagging of fish at the location of capture remains recommended as the most direct means for addressing survival, migration, and passage characteristics.

Ideally, PIT tagging should occur at a number of locations along the migration route to evaluate differential survival at different locations, but only when Lake Washington and LWSC water temperatures are forecasted to be average or cooler in the month of June. Future studies should be set up with the contingency that if the spring water temperatures are predicted to be high, that the study be postponed until the following year(s) when water temperature are more conducive to post-tagging survival in June. Such information would be valuable for identifying measures at specific locations intended to increase overall survival. At minimum, purse seining could be continued in Lake Union and in the vicinity of the Montlake Cut to evaluate survival in the LWSC. In contrast to 2000 when there were disease problems, and 2003 when there were likely water temperature-related post-tagging mortality problems, the 2001 and 2002 data suggest minor mortality occurred in the LWSC. Further study would be useful for evaluating factors of decline, particularly upstream of the LWSC.

- Beach seining below the Locks to recapture PIT tagged fish is not recommended at this time for purposes of estimating proportions using the flumes. Significant mortality and injury could be expected.
- Sampling could conceivably be conducted in the large lock and small lock to determine the proportion of PIT tagged fish passing through each, as well as provide better information on recycling patterns through the Locks. Because less water is used to fill the small lock than the large lock, it is possible that relatively less effort could be expended in the former. However, the data would mostly re-confirm that recycling takes place, which appears to be determined more thoroughly based on the tunnel reader detections. Considerable sampling effort would likely be needed if the data from the two locks were to be used to determine the proportion of tagged fish using that route.
- Recently installed adult PIT tag readers in the fish ladder will make it possible in future years to scan for PIT tagged smolts, to determine the proportion of fish using that route. *See Appendix B for the 2006 and 2007 data report.* Continued, long term monitoring involving juvenile PIT tagging would provide valuable data based on adult returns.
- If tagging is performed in the LWSC, each day's collection of tagged fish should be divided in two and each group released near the north and south shorelines, to continue evaluating shoreline affinity and proportion using the smolt flumes. Alternatively, hatchery Chinook could be held at the King County Environmental Laboratory and released at that location at a minimum. Doing this over the passage season would facilitate an evaluation of seasonal changes in the proportion using the smolt flumes, and thus an improved appreciation of the temporal variation in survival or residualization of outmigrants in the Lake Washington system.

- The influence of small lock operations on passage rates should continue to be investigated by alternating between a normal daily lock opening pattern, when each lock is opened more frequently during the day than the night, and a uniform distribution where the frequency of lock openings is similar during both day and nighttime hours. This additional testing is needed to further evaluate the hypothesis that daily vertical migrations of smolts in the forebay are the cause of diurnal passage behavior in the flumes.

- The blood of subsamples of PIT tagged fish passing through the flumes could be tested for stress and signs of osmotic change or smolt readiness. This information is important for evaluating the effects of the Locks with respect to the relatively sudden transition to saltwater. Both smolt readiness (e.g., gill ATP-ase, sodium levels) and stress (e.g., plasma cortisol) measures would be required to determine if the fish caught in beach seine samples were experiencing stress from rapid transition to saltwater because they were not completely ready to do.

- Other studies that would be informative and potentially lead to specific recovery-related actions include:

  - Determining proportion of fish migrating left or right upon exiting the Sammamish and Cedar rivers. This could be accomplished by standard capture-recapture techniques.
  - Evaluation of the hypothesis that migration depth changes in both Lake Washington and the LWSC with increasing water temperature over the course of the migration season. This would help identify more conclusively the relations between water temperature, habitat use during the outmigration, residualization, survival, and passage routes. In addition the results could be evaluated in the context of predator depth and feeding intensity to determine if there is habitat segregation and when predation effects are greater. Migration depth of natural Chinook could conceivably be addressed either by using smaller microacoustic tags than are currently available, or by experimental designs involving diving surveys. Research is currently underway using microacoustic tags that may shed light on this (R. Tabor, USFWS, and J. Hall, Seattle Public Utilities, personal communication).

- A small number of tagged fish were detected at the Locks each year that were not in the tagging files. Most appeared to have been missed during scanning at time of tagging. It was possible to resolve where and when they were tagged in most cases by noting tag packaging identification numbers during tagging, and identifying the bag that a tag originated from. However, there were also a small number of tags with numbers not part of the study sequence. Some were identifiable in the PTAGIS database and appeared to have been leftover tags from the Columbia River and were assumed to have been used inadvertently by NMFS in this study during 2000 or 2001. Others were not in the database and were not part of the tag sequence from the GI study; they were considered "mystery" tags, and may have been from another study. These occurrences are mentioned mainly to alert researchers using PIT tags of the possibility for missed tags in any study, and to recommend that they register their tags with the PTAGIS database in Portland, Oregon.

- As long as funding is available to run the Bear Creek and Cedar River screw traps, they could continue to be used to tag fish if tags are made available (G. Volkhardt, WDFW, personal communication). However, future funding is uncertain, especially for Bear Creek. Future funding is also uncertain for connecting, calibrating, and maintaining the tunnel readers in the smolt flumes. A commitment would need to be made by the WRIA 8 (Lake Washington basin) water and fisheries management community to continue supporting PIT tagging efforts. Benefits include an improved understanding of the various results and conclusions reported here, which will lead to improved water management, Locks operations, and provide an improved understanding of the magnitude and ramifications of environmental factors including the water temperature problem in particular.

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APPENDIX A

2006 and 2007 PIT Tagging
Release and Detection Summary Tables

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Table A-1. Summary of smolt tagging numbers, 2006-7 Lake Washington PIT tag studies.

Release Location	Date	Time	Numbers Released: Chinook Hatchery	Chinook Natural	Coho Hatchery	Coho Natural	Steelhead Natural	TAGGING FILE
Issaquah Hatchery	4/18/07		0	0	1178	0	0	JSV07057.ISQ
Bear Creek	5/7/07	7:00	0	63	0	0	0	FAG07127.brc
	5/11/07	10:00	0	135	0	0	0	FAG07131.brc
	5/14/07	9:00	0	451	0	0	0	FAG07134.brc
	5/15/07	1:00	0	96	0	0	0	FAG07135.brc
	5/16/07	9:00	0	201	0	0	0	FAG07136.brc
	5/18/07	9:00	0	213	0	0	0	FAG07138.brc
	5/21/07	9:00	0	358	0	0	0	FAG07141.brc
	5/22/07	9:00	0	77	0	0	0	FAG07142.brc
	5/23/07	10:00	0	204	0	0	0	FAG07143.brc
	5/25/07	11:00	0	193	0	0	0	FAG07145.brc
	5/30/07	11:00	0	338	0	0	0	FAG07150.brc
	6/1/07	11:00	0	134	0	0	0	FAG07152.brc
	6/4/07	11:00	0	102	0	0	0	FAG07155.brc
	6/6/07	10:00	0	63	0	0	0	FAG07157.brc
	6/8/07	11:30	0	27	0	0	0	FAG07159.brc
	6/11/07	9:00	0	39	0	0	0	FAG07162.brc
Cedar River Screw Trap	5/4/06	20:45	0	23	0	0	0	FAG06124.CDR
	5/8/06	21:00	0	32	0	0	0	FAG06128.CDR
	5/9/06	8:00	0	0	0	0	0	FAG06129.CDR[1]
	5/10/06	21:30	0	79	0	0	0	FAG06130.CDR
	5/11/06	8:30	0	0	0	0	0	FAG06131.CDR[1]
	5/12/06	20:45	0	29	0	0	0	FAG06132.CDR
	5/13/06	10:30	0	0	0	0	0	FAG06133.CDR[1]
	5/15/06	20:45	0	22	0	0	0	FAG06135.CDR
	6/16/06	7:30	0	0	0	0	0	FAG06136.CDR[1]
	5/17/06	22:00	0	24	0	0	0	FAG06137.CDR
	5/19/06	20:00	0	12	0	0	0	FAG06139.CDR
	5/20/06	7:30	0	0	0	0	0	FAG06140.CDR[1]
	5/22/06	21:00	0	77	0	0	0	FAG06142.CDR
	5/23/06	8:00	0	0	0	0	0	FAG06143.CDR[1]

Table A-1. Summary of smolt tagging numbers, 2006-7 Lake Washington PIT tag studies.

Release Location	Date	Time	Numbers Released: Chinook		Coho		Steelhead	TAGGING FILE
			Hatchery	Natural	Hatchery	Natural	Natural	
Cedar River Screw Trap	5/24/06	21:00	0	51	0	0	0	FAG06144.CDR
	5/26/06	22:00	0	11	0	0	0	FAG06146.CDR
	5/31/06	22:00	0	5	0	0	0	FAG06151.CDR
	6/1/06	9:30	0	0	0	0	0	FAG06152.CDR[1]
	6/2/06	22:00	0	5	0	0	0	FAG06153.CDR
	6/5/06	22:00	0	13	0	0	0	FAG06156.CDR
	6/7/06	22:00	0	14	0	0	0	FAG06158.CDR
	6/9/06	22:00	0	27	0	0	0	FAG06160.CDR
	6/12/06	22:00	0	31	0	0	0	FAG06163.CDR
	6/13/06	8:00	0	0	0	0	0	FAG06164.CDR[1]
	8/14/06	22:00	0	25	0	0	0	FAG06165.CDR
	6/16/06	22:00	0	25	0	0	0	FAG06167.CDR
	6/19/06	22:00	0	23	0	0	0	FAG06170.CDR
	6/20/06	7:30	0	0	0	0	0	FAG06171.CDR[1]
	6/21/06	22:00	0	24	0	0	0	FAG06172.CDR
	6/22/06	8:30	0	0	0	0	0	FAG06173.CDR[1]
	6/23/06	22:00	0	7	0	0	0	FAG06174.CDR
	6/26/06	22:00	0	3	0	0	0	FAG06177.CDR
	6/30/06	22:00	0	11	0	0	0	FAG06181.CDR
	7/1/06	8:30	0	0	0	0	0	FAG06182.CDR[1]
	5/7/07	7:00	0	11	0	0	0	FAG07127.CDR
	5/11/07	22:00	0	5	0	0	0	FAG07131.CDR
	5/14/07	22:00	0	25	0	0	0	FAG07134.CDR
	5/16/07	22:00	0	7	0	0	0	FAG07136.CDR
	5/18/07	22:00	0	10	0	0	0	FAG07138.CDR
	5/21/07	22:00	0	17	0	0	0	FAG07141.CDR
	5/23/07	22:00	0	22	0	0	0	FAG07143.CDR
	5/25/07	22:00	0	12	0	0	0	FAG07145.CDR
	5/30/07	22:00	0	9	0	0	0	FAG07150.CDR
	6/1/07	22:00	0	6	0	0	0	FAG07152.CDR
	6/4/07	22:00	0	10	0	0	0	FAG07155.CDR

Table A-1. Summary of smolt tagging numbers, 2006-7 Lake Washington PIT tag studies.

Release Location	Date	Time	Numbers Released: Chinook Hatchery	Chinook Natural	Coho Hatchery	Coho Natural	Steelhead Natural	TAGGING FILE
Cedar River Screw Trap	6/6/07	22:00	0	67	0	25	0	FAG07157.CDR
	6/8/07	22:00	0	201	0	25	0	FAG07159.CDR
	6/9/07	22:00	0	32	0	4	0	FAG07160.CDR
	6/11/07	22:00	0	56	0	7	0	FAG07162.CDR
	6/13/07	22:00	1	29	0	4	0	FAG07164.CDR
	6/15/07	22:00	0	35	0	3	0	FAG07166.CDR
	6/18/07	22:00	0	64	0	2	0	FAG07169.CDR
	6/20/07	22:00	0	57	0	0	0	FAG07171.CDR
	6/25/07	22:00	0	25	0	2	0	FAG07176.CDR
	6/27/07	22:00	0	14	0	2	0	FAG07178.CDR
	6/29/07	22:00	0	5	0	1	0	FAG07180.CDR
	6/30/07	22:00	0	15	0	0	0	FAG07181.CDR
Cedar River Various	7/30/07	12:00	0	0	0	0	1[2]	GCV07211.GCV
Cedar R at Landsburg	5/16/06		0	10	0	296	62	grp06134.RA1
	9/25/06		0	0	0	1	0	grp06266.RA1
	10/2/06		0	0	0	1	0	grp06273.RA1
	10/5/06		0	0	0	1	0	grp06276.RA1
	10/8/06		0	0	0	1	0	grp06279.RA1
	10/9/06		0	0	0	2	0	grp06280.RA1
	10/10/06		0	0	0	2	0	grp06281.RA1
	10/11/06		0	0	0	1	0	grp06282.RA1
	10/12/06		0	0	0	1	0	grp06283.RA1
	10/15/06		0	0	0	2	0	grp06286.RA1
	10/18/06		0	0	0	6	0	grp06289.RA1
	10/20/06		0	0	0	1	0	grp06291.RA1
	10/23/06		0	0	0	0	0	grp06294.RA1
	10/24/06		0	0	0	1	0	grp06295.RA1
	10/25/06		0	0	0	3	0	grp06296.RA1
	10/29/06		0	0	0	2	0	grp06300.RA1
	10/30/06		0	0	0	1	0	grp06302.RA1
	11/4/06		0	0	0	8	0	grp06307.RA1

Table A-1. Summary of smolt tagging numbers, 2006-7 Lake Washington PIT tag studies.

Release Location	Date	Time	Numbers Released					TAGGING FILE
			Chinook		Coho		Steelhead	
			Hatchery	Natural	Hatchery	Natural	Natural	
Cedar R at Landsburg	11/5/06		0	0	0	5	0	grp06308.RA1
	11/6/06		0	0	0	7	0	grp06309.RA1
	11/15/06		0	0	0	3	0	grp06318.RA1
	11/17/06		0	0	0	6	0	grp06320.RA1
	11/18/06		0	0	0	4	0	grp06321.RA1
	11/21/06		0	0	0	4	0	grp06324.RA1
	11/22/06		0	0	0	2	0	grp06325.RA1
	11/29/06		0	0	0	2	0	grp06332.RA1
	12/3/06		0	0	0	2	0	grp06336.RA1
	12/4/06		0	0	0	1	0	grp06337.RA1
	12/5/06		0	0	0	2	0	grp06338.RA1
	12/9/06		0	0	0	4	0	grp06342.RA1
	12/10/06		0	0	0	1	0	grp06343.RA1
	12/11/06		0	0	0	6	0	grp06344.RA1
	12/12/06		0	0	0	3	0	grp06345.RA1
	12/13/06		0	0	0	3	0	grp06346.RA1
	12/14/06		0	0	0	7	0	grp06347.RA1
	12/16/06		0	0	0	13	0	grp06349.RA1
	5/15/07		0	0	0	77	111	grp07133.RA1
Cedar R above Landsburg	7/12/06		0	0	0	47	0	grp06191.RA1
	6/20/07		0	0	0	9	5	grp07169.RA1
	6/21/07		0	0	0	21	11	grp07170.RA1
	7/17/07		0	0	0	117	20	grp07196.RA1
	7/18/07		0	0	0	28	20	grp07197.RA1
	7/19/07		0	0	0	40	25	grp07198.RA1
	7/23/07		0	0	0	0	16	grp07202.RA1
	8/20/07		0	0	0	64	11	grp07230.RA1
	8/21/07		0	0	0	0	11	grp07231.RA1
	8/23/07		0	0	0	0	7	grp07233.RA1
	8/30/07		0	0	0	31	11	grp07240.RA1

Table A-1. Summary of smolt tagging numbers, 2006-7 Lake Washington PIT tag studies.

Release Location	Date	Time	Numbers Released					TAGGING FILE
			Chinook		Coho		Steelhead	
			Hatchery	Natural	Hatchery	Natural	Natural	
Rock Cr above Landsburg	8/9/05		0	0	0	15	0	grp05219.RA1
	8/10/05		0	0	0	16	0	grp05220.RA1
	8/11/05		0	0	0	7	0	grp05221.RA1
	8/18/05		0	0	0	2	0	grp05228.RA1
	9/21/05		0	0	0	6	2	grp05262.RA1
	10/20/05		0	0	0	39	16	grp05291.RA1
	10/25/05		0	0	0	55	15	grp05296.RA1
	10/27/05		0	0	0	22	8	grp05298.RA1
	2/14/06		0	0	0	13	2	grp06044.RA1
	2/21/06		0	0	0	7	0	grp06051.RA1
	7/10/06		0	0	0	82	3	grp06189.RA1
	7/11/06		0	0	0	17	0	grp06190.RA1
	9/25/06		0	0	0	47	0	grp06266.RA2
	9/26/06		0	0	0	97	19	grp06267.RA1
	9/27/06		0	0	0	22	12	grp06268.RA1
	9/28/06		0	0	0	56	0	grp06269.RA1
	3/7/07		0	0	0	42	1	grp07065.RA1
	3/8/07		0	0	0	16	2	grp07066.RA1
	7/24/07		0	0	0	30	2	grp07203.RA1
	7/25/07		0	0	0	35	9	grp07204.RA1
	7/26/07		0	0	0	26	0	grp07205.RA1
	7/27/07		0	0	0	68	1	grp07206.RA1
UW Hatchery	5/6/06		100	0	100	0	0	JWW06125.U1B
	5/25/07		200	0	0	0	0	JWW07134.U1B

[1] – Dates when only fish PIT tagged the day before were recaptured in the screwtrap.

[2] – "Trout" were targets for tagging in 2006 and 2007, this is only date a steelhead was identified specifically in tagging file; see text.

Table A-2. Summary of Chinook salmon smolt recapture numbers, 2006-2007 Lake Washington PIT tag studies (adjusted for recyclers).

			Number of Fish Detected at Locks in Each Flume								
	Release		**Hatchery Produced**				**Naturally Produced**				
Tagging File	**Location**	**Date**	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**FL**
FAG07127.brc	Bear Creek	5/7/07	0	0	0	0	4	6	4	13	0
FAG07131.brc		5/11/07	0	0	0	0	12	11	0	31	0
FAG07134.brc		5/14/07	0	0	0	0	43	47	9	105	0
FAG07135.brc		5/15/07	0	0	0	0	5	9	0	15	0
FAG07136.brc		5/16/07	0	0	0	0	19	18	3	28	0
FAG07138.brc		5/18/07	0	0	0	0	13	11	3	45	0
FAG07141.brc		5/21/07	0	0	0	0	24	21	10	48	0
FAG07142.brc		5/22/07	0	0	0	0	4	4	0	12	0
FAG07143.brc		5/23/07	0	0	0	0	8	14	1	23	0
FAG07145.brc		5/25/07	0	0	0	0	6	17	1	13	0
FAG07150.brc		5/30/07	0	0	0	0	7	20	1	12	0
FAG07152.brc		6/1/07	0	0	0	0	0	4	0	3	0
FAG07155.brc		6/4/07	0	0	0	0	2	0	0	0	0
FAG07157.brc		6/6/07	0	0	0	0	1	1	0	0	0
FAG07159.brc		6/8/07	0	0	0	0	0	1	0	0	0
FAG07162.brc		6/11/07	0	0	0	0	1	0	0	0	0
FAG06124.CDR	Cedar River Screw Trap	5/4/06	0	0	0	0	7	1	1	1	0
FAG06128.CDR		5/8/06	0	0	0	0	6	1	3	0	0
FAG06129.CDR		5/9/06	0	0	0	0	0	0	0	0	0
FAG06130.CDR		5/10/06	0	0	0	0	19	3	5	0	0
FAG06131.CDR		5/11/06	0	0	0	0	1	0	1	0	0
FAG06132.CDR		5/12/06	0	0	0	0	5	2	3	0	0
FAG06133.CDR		5/13/06	0	0	0	0	0	0	0	0	0
FAG06135.CDR		5/15/06	0	0	0	0	5	1	1	0	0
FAG06136.CDR		6/16/06	0	0	0	0	0	0	0	0	0
FAG06137.CDR		5/17/06	0	0	0	0	9	1	4	0	0
FAG06139.CDR		5/19/06	0	0	0	0	4	0	0	0	0
FAG06140.CDR		5/20/06	0	0	0	0	0	0	0	0	0
FAG06142.CDR		5/22/06	0	0	0	0	17	2	4	1	0
FAG06143.CDR		5/23/06	0	0	0	0	1	0	1	0	0
FAG06144.CDR		5/24/06	0	0	0	0	17	2	4	0	0

Table A-2. Summary of Chinook salmon smolt recapture numbers, 2006-2007 Lake Washington PIT tag studies (adjusted for recyclers).

			Number of Fish Detected at Locks in Each Flume								
	Release		Hatchery Produced				Naturally Produced				
Tagging File	**Location**	**Date**	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**FL**
FAG06146.CDR	Cedar River Screw Trap	5/26/06	0	0	0	0	4	1	1	0	0
FAG06151.CDR		5/31/06	0	0	0	0	1	0	0	0	0
FAG06152.CDR		6/1/06	0	0	0	0	1	0	0	0	0
FAG06153.CDR		6/2/06	0	0	0	0	3	0	0	0	0
FAG06156.CDR		6/5/06	0	0	0	0	5	0	2	0	0
FAG06158.CDR		6/7/06	0	0	0	0	3	0	1	1	0
FAG06160.CDR		6/9/06	0	0	0	0	7	1	1	0	0
FAG06163.CDR		6/12/06	0	0	0	0	2	2	2	0	0
FAG06164.CDR		6/13/06	0	0	0	0	0	0	0	0	0
FAG06165.CDR		8/14/06	0	0	0	0	5	0	0	0	0
FAG06167.CDR		6/16/06	0	0	0	0	6	0	2	0	0
FAG06170.CDR		6/19/06	0	0	0	0	2	3	2	0	0
FAG06171.CDR		6/20/06	0	0	0	0	0	0	1	0	0
FAG06172.CDR		6/21/06	0	0	0	0	1	0	2	0	0
FAG06173.CDR		6/22/06	0	0	0	0	0	0	0	0	0
FAG06174.CDR		6/23/06	0	0	0	0	1	0	0	0	0
FAG06177.CDR		6/26/06	0	0	0	0	1	0	0	0	0
FAG06181.CDR		6/30/06	0	0	0	0	0	0	0	0	0
FAG06182.CDR		7/1/06	0	0	0	0	0	0	0	0	0
FAG07127.CDR		5/7/07	0	0	0	0	1	0	0	2	0
FAG07131.CDR		5/11/07	0	0	0	0	1	0	1	0	0
FAG07134.CDR		5/14/07	0	0	0	0	3	4	1	3	0
FAG07136.CDR		5/16/07	0	0	0	0	0	0	0	2	0
FAG07138.CDR		5/18/07	0	0	0	0	0	0	0	2	0
FAG07141.CDR		5/21/07	0	0	0	0	1	2	0	3	0
FAG07143.CDR		5/23/07	0	0	0	0	1	2	0	4	0
FAG07145.CDR		5/25/07	0	0	0	0	0	3	0	3	0
FAG07150.CDR		5/30/07	0	0	0	0	0	0	1	0	0
FAG07152.CDR		6/1/07	0	0	0	0	0	0	0	0	0
FAG07155.CDR		6/4/07	0	0	0	0	1	1	0	0	0
FAG07157.CDR		6/6/07	0	0	0	0	5	0	0	1	0

Table A-2. Summary of Chinook salmon smolt recapture numbers, 2006-2007 Lake Washington PIT tag studies (adjusted for recyclers).

	Release		Number of Fish Detected at Locks in Each Flume								
			Hatchery Produced				Naturally Produced				
Tagging File	**Location**	**Date**	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**FL**
FAG07159.CDR	Cedar River Screw Trap	6/8/07	0	0	0	0	10	0	0	2	0
FAG07160.CDR		6/9/07	0	0	0	0	1	0	0	0	0
FAG07162.CDR		6/11/07	0	0	0	0	0	0	0	0	0
FAG07164.CDR		6/13/07	0	0	0	0	0	0	0	0	0
FAG07166.CDR		6/15/07	0	0	0	0	0	0	0	0	0
FAG07169.CDR		6/18/07	0	0	0	0	0	0	2	0	0
FAG07171.CDR		6/20/07	0	0	0	0	0	0	0	0	0
FAG07176.CDR		6/25/07	0	0	0	0	0	0	0	0	0
FAG07178.CDR		6/27/07	0	0	0	0	0	0	0	0	0
FAG07180.CDR		6/29/07	0	0	0	0	0	0	0	0	0
FAG07181.CDR		6/30/07	0	0	0	0	0	0	0	0	0
JWW06125.U1B	UW Hatchery	5/6/06	22	8	0	10	0	0	0	0	0
JWW07134.U1B		5/25/07	40	24	5	84	0	0	0	0	0

Table A-3. Summary of coho salmon smolt recapture numbers, 2006-2007 Lake Washington PIT tag studies (adjusted for recyclers).

			Number of Fish Detected at Locks in Each Flume								
	Release		Hatchery Produced				Naturally Produced				
Tagging File	**Location**	**Date**	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**FL**
JSV07057.ISQ	Issaquah Hatchery	4/18/07	135	111	11	193	0	0	0	0	0
FAG07127.CDR	Cedar River Screw Trap	5/7/07	0	0	0	0	0	0	0	0	0
FAG07131.CDR		5/11/07	0	0	0	0	0	0	0	0	0
FAG07134.CDR		5/14/07	0	0	0	0	0	0	0	0	0
FAG07136.CDR		5/16/07	0	0	0	0	0	0	0	0	0
FAG07138.CDR		5/18/07	0	0	0	0	0	0	0	0	0
FAG07141.CDR		5/21/07	0	0	0	0	0	0	0	0	0
FAG07143.CDR		5/23/07	0	0	0	0	0	0	0	0	0
FAG07145.CDR		5/25/07	0	0	0	0	0	0	0	0	0
FAG07150.CDR		5/30/07	0	0	0	0	0	0	0	0	0
FAG07152.CDR		6/1/07	0	0	0	0	0	0	0	0	0
FAG07155.CDR		6/4/07	0	0	0	0	0	0	0	0	0
FAG07157.CDR		6/6/07	0	0	0	0	1	0	0	1	0
FAG07159.CDR		6/8/07	0	0	0	0	1	0	0	0	0
FAG07160.CDR		6/9/07	0	0	0	0	0	0	0	0	0
FAG07162.CDR		6/11/07	0	0	0	0	0	0	0	0	0
FAG07164.CDR		6/13/07	0	0	0	0	0	0	0	0	0
FAG07166.CDR		6/15/07	0	0	0	0	0	0	0	0	0
FAG07169.CDR		6/18/07	0	0	0	0	0	0	0	0	0
FAG07171.CDR		6/20/07	0	0	0	0	0	0	0	0	0
FAG07176.CDR		6/25/07	0	0	0	0	0	0	0	0	0
FAG07178.CDR		6/27/07	0	0	0	0	0	0	0	0	0
FAG07180.CDR		6/29/07	0	0	0	0	0	0	0	0	0
FAG07181.CDR		6/30/07	0	0	0	0	0	0	0	0	0
JWW06125.U1B	UW Hatchery	5/6/06	4	0	0	0	0	0	0	0	0
grp06134.RA1	Cedar R at Landsburg	5/16/06	0	0	0	0	22/2[1]	4/0	0/0	6/4	0
grp06266.RA1		9/25/06	0	0	0	0	0	0	0	0	0
grp06273.RA1		10/2/06	0	0	0	0	0	0	0	0	0
grp06276.RA1		10/5/06	0	0	0	0	0	0	0	0	0
grp06279.RA1		10/8/06	0	0	0	0	0	0	0	0	0
grp06280.RA1		10/9/06	0	0	0	0	0	0	0	0	0
grp06281.RA1		10/10/06	0	0	0	0	0	0	0	0	0

Table A-3. Summary of coho salmon smolt recapture numbers, 2006-2007 Lake Washington PIT tag studies (adjusted for recyclers).

			Number of Fish Detected at Locks in Each Flume								
	Release		**Hatchery Produced**				**Naturally Produced**				
Tagging File	**Location**	**Date**	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**FL**
grp06282.RA1	Cedar R at Landsburg	10/11/06	0	0	0	0	0	0	0	0	0
grp06283.RA1		10/12/06	0	0	0	0	0	0	0	0	0
grp06286.RA1		10/15/06	0	0	0	0	0	0	0	0	0
grp06289.RA1		10/18/06	0	0	0	0	0	0	0	0	0
grp06291.RA1		10/20/06	0	0	0	0	0	0	0	0	0
grp06294.RA1		10/23/06	0	0	0	0	0	0	0	0	0
grp06295.RA1		10/24/06	0	0	0	0	0	0	0	0	0
grp06296.RA1		10/25/06	0	0	0	0	0	0	0	0	0
grp06300.RA1		10/29/06	0	0	0	0	0	0	0	0	0
grp06302.RA1		10/30/06	0	0	0	0	0	0	0	0	0
grp06307.RA1		11/4/06	0	0	0	0	0	0	0	0	0
grp06308.RA1		11/5/06	0	0	0	0	0	0	0	0	0
grp06309.RA1		11/6/06	0	0	0	0	0	0	0	0	0
grp06318.RA1		11/15/06	0	0	0	0	0	0	0	0	0
grp06320.RA1		11/17/06	0	0	0	0	0	0	0	0	0
grp06321.RA1		11/18/06	0	0	0	0	0	0	0	0	0
grp06324.RA1		11/21/06	0	0	0	0	0	0	0	0	0
grp06325.RA1		11/22/06	0	0	0	0	0	0	0	0	0
grp06332.RA1		11/29/06	0	0	0	0	0	0	0	0	0
grp06336.RA1		12/3/06	0	0	0	0	0	0	0	0	0
grp06337.RA1		12/4/06	0	0	0	0	0	0	0	0	0
grp06338.RA1		12/5/06	0	0	0	0	0	0	0	0	0
grp06342.RA1		12/9/06	0	0	0	0	0	0	0	0	0
grp06343.RA1		12/10/06	0	0	0	0	0	0	0	0	0
grp06344.RA1		12/11/06	0	0	0	0	0	0	0	0	0
grp06345.RA1		12/12/06	0	0	0	0	0	0	0	0	0
grp06346.RA1		12/13/06	0	0	0	0	0	0	0	0	0
grp06347.RA1		12/14/06	0	0	0	0	0	0	0	0	0
grp06349.RA1		12/16/06	0	0	0	0	0	0	0	0	0
grp07133.RA1		5/15/07	0	0	0	0	6	6	1	10	0
grp06191.RA1	Cedar R above Landsburg	7/12/06	0	0	0	0	5	1	0	4	0
grp07169.RA1		6/20/07	0	0	0	0	0	0	0	0	0
grp07170.RA1		6/21/07	0	0	0	0	0	0	0	0	0

Table A-3. Summary of coho salmon smolt recapture numbers, 2006-2007 Lake Washington PIT tag studies (adjusted for recyclers).

			Number of Fish Detected at Locks in Each Flume								
	Release		Hatchery Produced				Naturally Produced				
Tagging File	**Location**	**Date**	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**FL**
grp07196.RA1	Cedar R above Landsburg	7/17/07	0	0	0	0	0	0	0	0	0
grp07197.RA1		7/18/07	0	0	0	0	0	0	0	0	0
grp07198.RA1		7/19/07	0	0	0	0	0	0	0	0	0
grp07230.RA1		8/20/07	0	0	0	0	0	0	0	0	0
grp07240.RA1		8/30/07	0	0	0	0	0	0	0	0	0
grp05219.RA1	Rock Cr above Landsburg	8/9/05	0	0	0	0	2	1	0	0	0
grp05220.RA1		8/10/05	0	0	0	0	3	0	0	1	0
grp05221.RA1		8/11/05	0	0	0	0	1	0	0	0	0
grp05228.RA1		8/18/05	0	0	0	0	0	0	0	0	0
grp05262.RA1		9/21/05	0	0	0	0	0	0	0	0	0
grp05291.RA1		10/20/05	0	0	0	0	7	0	0	0	0
grp05296.RA1		10/25/05	0	0	0	0	3	3	0	0	0
grp05298.RA1		10/27/05	0	0	0	0	1	3	0	1	0
grp06044.RA1		2/14/06	0	0	0	0	3	0	0	0	0
grp06051.RA1		2/21/06	0	0	0	0	2	0	0	0	0
grp06189.RA1		7/10/06	0	0	0	0	0/3[1]	0/0	0/0	0/3	0
grp06190.RA1		7/11/06	0	0	0	0	0/0	0/1	0/0	0/2	0
grp06266.RA2		9/25/06	0	0	0	0	3	0	0	2	0
grp06267.RA1		9/26/06	0	0	0	0	5	5	3	15	0
grp06268.RA1		9/27/06	0	0	0	0	1	0	1	3	0
grp06269.RA1		9/28/06	0	0	0	0	3	3	1	8	0
grp07065.RA1		3/7/07	0	0	0	0	7	2	0	5	0
grp07066.RA1		3/8/07	0	0	0	0	0	2	0	0	0
grp07203.RA1		7/24/07	0	0	0	0	0	0	0	0	0
grp07204.RA1		7/25/07	0	0	0	0	0	0	0	0	0
grp07205.RA1		7/26/07	0	0	0	0	0	0	0	0	0
grp07206.RA1		7/27/07	0	0	0	0	0	0	0	0	0

[1] – X/Y = X detected in 2006, Y detected in 2007; otherwise, coho were detected the first spring outmigration season after tagging.

Table A-4. Summary of steelhead smolt recapture numbers, 2006-2007 Lake Washington PIT tag studies (adjusted for recyclers).

			Number of Fish Detected at Locks in Each Flume								
	Release		Hatchery Produced				Naturally Produced				
Tagging File	**Location**	**Date**	**4A**	**4B**	**5B**	**5C**	**4A**	**4B**	**5B**	**5C**	**FL**
grp06134.RA1	Cedar R at Landsburg	5/16/06	0	0	0	0	0/1[1]	0	0	0	0
grp05298.RA1	Rock Cr above Landsburg	10/27/05	0	0	0	0	0	0	0	1/1	0

[1] – X/Y = X detected in 2006, Y detected in 2007.

APPENDIX B

2006-2007 Adult PIT Tag Reader Data Report

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R2 Resource Consultants, Inc.
15250 NE 95th Street
Redmond, WA 98052-2518
Phone: (425) 556-1288
Fax: (425) 556-1290
E-mail: mail@R2usa.com

Technical Memorandum

Date: November 9, 2007   Project Number: 1662.01/MM101

To: Chuck Ebel (USACE, Seattle District)

cc: Frank Leonetti (King County); Julie Hall (SPU); Fred Goetz (USACE); Greg Volkhardt (WDFW), George Pess (NMFS), Kurt Fresh (NMFS)

From: Paul DeVries

Subject: Adult PIT Tag Reader Detection Summary for 2006-2007 (as of October 23, 2007), Hiram M. Chittenden Locks Fish Ladder

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TABLES

1. BACKGROUND

This technical memorandum summarizes detection and release characteristics of PIT tagged fish passing upstream from Puget Sound to the Lake Washington Ship Canal (LWSC) through the Hiram M. Chittenden Locks fish ladder in 2006 and 2007, as of October 23, 2007. This memorandum focuses on returning adult salmon that were PIT tagged as part of the Lake Washington General Investigation (LWGI) juvenile salmon outmigration studies, although data are presented for additional studies where they exist. Their tagging and downstream passage history, as determined by detection data for the smolt flumes, are evaluated in the context of downstream passage behavior at the Locks, and in terms of adult return rates.

A 2nd-year pilot experiment was also conducted by the USACE, WDFW, and R2 Resource Consultants in August 2006 where adult Chinook (*Oncorhynchus tshawytscha*) salmon were caught in the large lock, PIT tagged, and released near the railroad bridge pilings at Commodore Park. Fred Goetz, USACE was in charge of that study, the results of which will be summarized in a separate report once additional retrieval and tracking data have been analyzed; selected results are also presented here, however.

Four sets of antennae and PIT tag readers were first installed in the fish ladder in early June 2004. The readers were connected to the same data collection computers as the tunnel readers installed in the four smolt flumes in gates 4 and 5 of the Locks spillway. Two of the four antennae surround the orifice and weir of the first step ("upper," #1), located at the downstream end of the fish viewing chamber, and the remaining two surround the orifice and weir of the fourth step ("lower," #4) downstream. The upstream coils monitor the same portals through which fish are counted by observers in the fish viewing room. The numbering system used in recording data is as follows: coil 01 is the overflow weir and coil 02 the orifice on the upper step; coil 03 is the overflow weir and coil 04 the orifice on the lower step. Fish moving upstream or downstream through the ladder could therefore not avoid passing through a monitored location. Fish had the potential to be detected twice, which would have indicated the direction of movement and whether passage was likely to have been successful. Sampling in 2004 indicated that the detection efficiency was 100 percent, which influenced interpretation of passage movements. For example, if a fish was detected only at the lower step and not at the upper step, it was inferred that the fish was not successful at passing. All salient information is nonetheless provided in Table 1 so that the reader can make his or her own interpretation if desired. It should also be noted that returning adults may pass upstream undetected through the small and large lock chambers.

2. GENERAL OBSERVATIONS ON DETECTION DATA FOR 2006, 2007

Tables 1 and 2 summarize the detection and tagging history of each fish returning through the fish ladder in 2006 and 2007, respectively, that had been tagged as part of the LWGI and continued juvenile outmigration studies.

The following characteristics were noted in the detection data:

- No coho salmon juveniles were PIT tagged in the Cedar River screw trap in 2006, and thus the only adults detected returning in 2007 included:
  - Fish tagged by G. Pess higher up in the Cedar River watershed, which were detected in the ladder in both 2006 and 2007.
  - A fish that had been tagged and released in the spring of 2007 at Issaquah hatchery as part of a feed study returned in the fall of 2007 and was detected moving upstream in the ladder, presumably as a jack.
- No adult sockeye salmon (*O. nerka*) were detected in 2006 or 2007. The most recent year that sockeye juveniles were PIT tagged in the basin in sufficient numbers to have a reasonable chance of being detected in the fish ladder was in 2003.
- Returning Chinook from 2003, 2004 and 2005 were detected in both 2006 and 2007.
- As in 2004 and 2005, more Chinook and coho in 2006 and 2007 passed upstream through the orifices than the weirs.
- Three tags identified in the fish ladder in 2006 were noted in the PTAGIS database as having been implanted in juvenile Chinook salmon in the Columbia River in early spring of 2006 (Table 1). This is the first time PIT tagged fish from the Columbia River have been confirmed to pass through the Locks. The tags were associated with three different studies:
  - 3D9.1BF24A08A0 – disease susceptibility study;
  - 3D9.1BF25C7A44 – spring/summer Chinook study; and
  - 3D9.1BF237EFCE – barge release study.

3. REPEAT USE OF THE FISH LADDER IN 2006 AND 2007 (RECYCLING FISH)

Tables 3 and 4 present a summary of the number of fish using the fish ladder one or more times in 2006 and 2007, respectively. These data (along with data from 2004 and 2005) can be used to estimate correction factors that account for recycling-induced bias in fish ladder counts. Recycling rates were greater overall in 2006 (~12% of fish; 24% of all passage events) than 2007 (~7% of fish; 13% of all events). Tables 1 and 2 indicate recycling times for Chinook ranging from 1-8 days in 2006 and from 25-30 days in 2007, and for coho ranging from 3-11 days in 2006.

The one Chinook that recycled four times in 2006 was detected at the upper orifice about a month after its last confirmed upstream passage (Table 1), and thus may have either held in the viewing chamber for that duration (more likely) or passed upstream without being detected at the lower step (less likely given previous detection efficiency data).

The date of passage for each fish is depicted in Figure 1 with water temperature time series for the Lake Washington Ship Canal (USACE data are presented for the Ballard Bridge location, supplemented in fall 2006 with data from the Fremont Cut). As in 2005, recycling occurred when water temperature upstream of the Locks exceeded Department of Ecology's recommended upper limit for adult migration (between 16°-17°C; Hicks 2002), although other factors may also be related to this behavior.

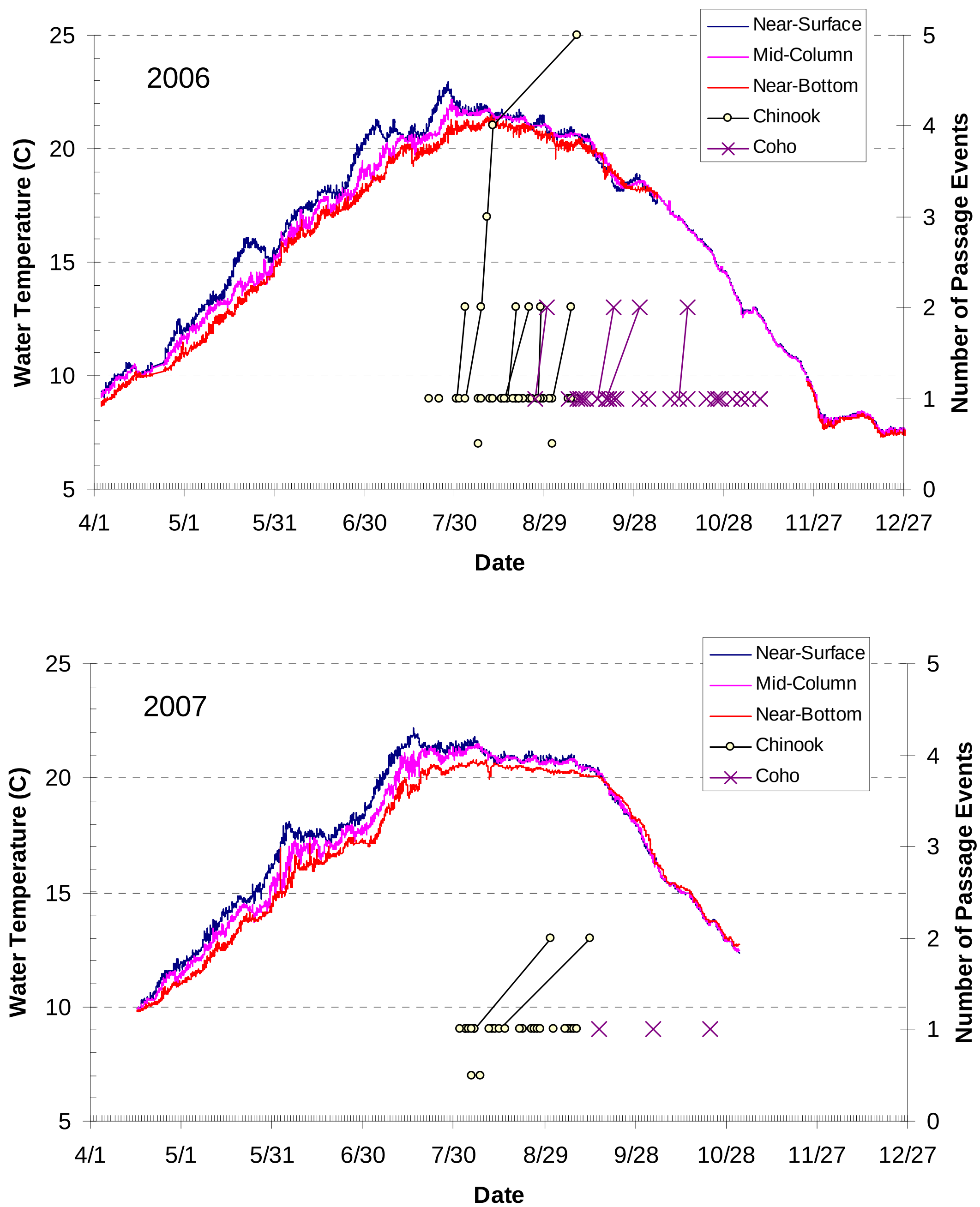

Figure 1. Water temperature time series for the Lake Washington Ship Canal and number of times and dates each returning PIT tagged adult salmon was detected in the fish ladder at the Hiram M. Chittenden Locks in 2006 (top) and 2007 (bottom). Aborted attempts are depicted as 0.5 values on the right axis; the lines depict the recycling behavior of individual fish.

4. PROPORTION OF DOWNSTREAM MIGRANTS USING THE FLUMES

Tables 5 and 6 summarize the numbers of returning adults detected in the fish ladder and the numbers that were detected outmigrating through the flumes as juveniles for 2006 and 2007, respectively. Such information can be used to estimate the overall proportion using the flumes as smolts. Table 7 is an update from previous data memoranda (DeVries 2004; DeVries and Hendrix 2005), and summarizes estimates of the proportion for each species' release group from Bear Creek, the Cedar River, and Issaquah Hatchery in terms of adult and juvenile detection numbers. The following observations are drawn from Tables 5-7:

- Proportions estimated for each daily release group with the largest returning adult sample sizes in Table 7 generally fall within the higher range observed for detection rates for smolt groups released in May and June (Figure 2). For each stock and brood year overall, the proportion of outmigrants detected in the flumes tends to be greater than the estimate of the proportion using the flumes based on the adult return data (Figure 3). A regression through the origin of the data in Figure 3 indicates a slope ≈ 67% (slope is significantly less than 1.0; $p<0.05$). These results may reflect juvenile detection numbers declining later in the spring, and an under-representation of Chinook adults returning from groups of smolts tagged and released later in the outmigration season.
- The numbers of adults for each release group in Table 7 are too low for assessing seasonal declines in the proportion using the flumes to a reasonable level of precision. Power analyses would be needed to identify suitable sample sizes of juvenile release groups for determining flume use proportions based on adult return data, as described by DeVries and Hendrix (2005). For example, PIT tag release groups in May would need to be composed of at least 5000 juveniles to yield an estimated 60% using the flumes with a 95% confidence interval of +/- 20%, assuming survival of tagged juveniles to the Locks is 100%, the SAR rate equals 1%, and 50% of adults use the fish ladder.
- Proportionally fewer adult Chinook appear to return for release groups from which proportionally fewer fish were detected in the flumes (Figure 4). The patterns depicted in Figure 4 suggest that release groups exhibiting a proportion using the flumes less than about 25% also have a lower probability of returning as adults than groups with a higher percentage detected in the flumes. Given that the proportion using the flumes decreases over time (Figure 2), this result suggests that later migrating Chinook smolts exhibit lower survival than earlier migrants, where natural origin juveniles released in Bear Creek and the Cedar River around early-June and later (cf. Figure 2 and dates in Table 7) have a lower probability of returning as adults than juvenile Chinook tagged and released earlier. Possible reasons include differential lake survival and reduced saltwater fitness of later migrating smolts, possibly in response to increased water temperature later in the season (Tabor et al. 2004; DeVries et al. 2005, 2007).

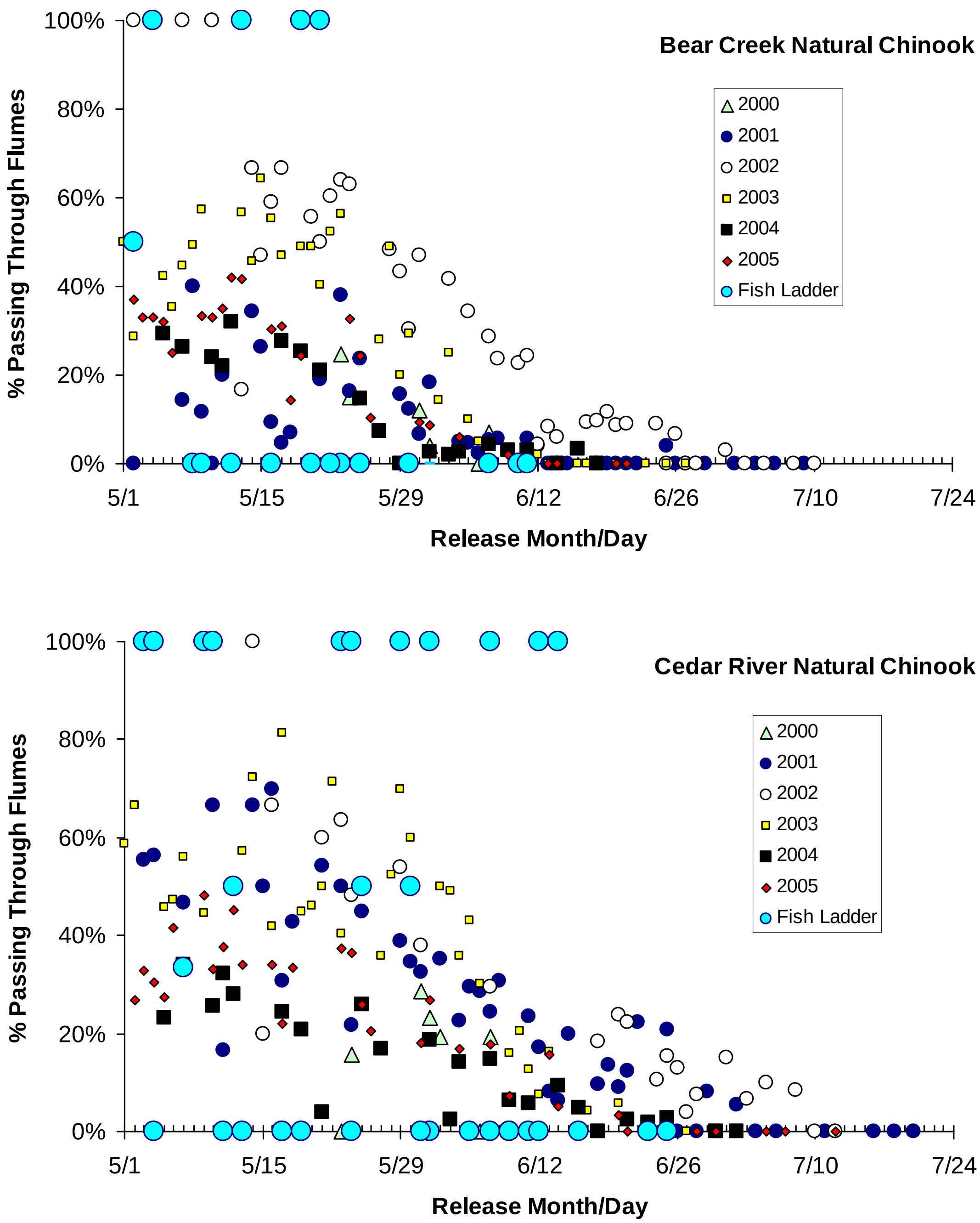

Figure 2. Comparison of observed detection rates in the flumes with estimated proportion using the flumes based on adult return data from the fish ladder, for groups of Chinook smolts tagged and released in Bear Creek (top) and the Cedar River (bottom) on a given date. Values of 0% and 100% are based on small samples and have wide 95% confidence intervals (not depicted for clarity).

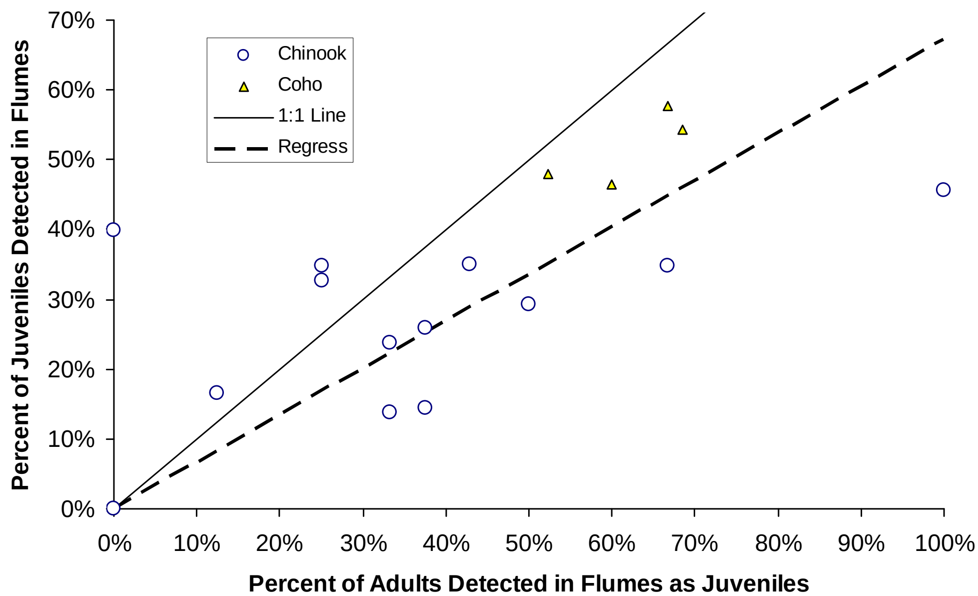

Figure 3. Comparison of smolt detection rates observed in flumes with estimated proportion using flumes based on adult ladder detection data. The dashed line is the regression through the origin. Data points are for specific brood year and stock in Table 7.

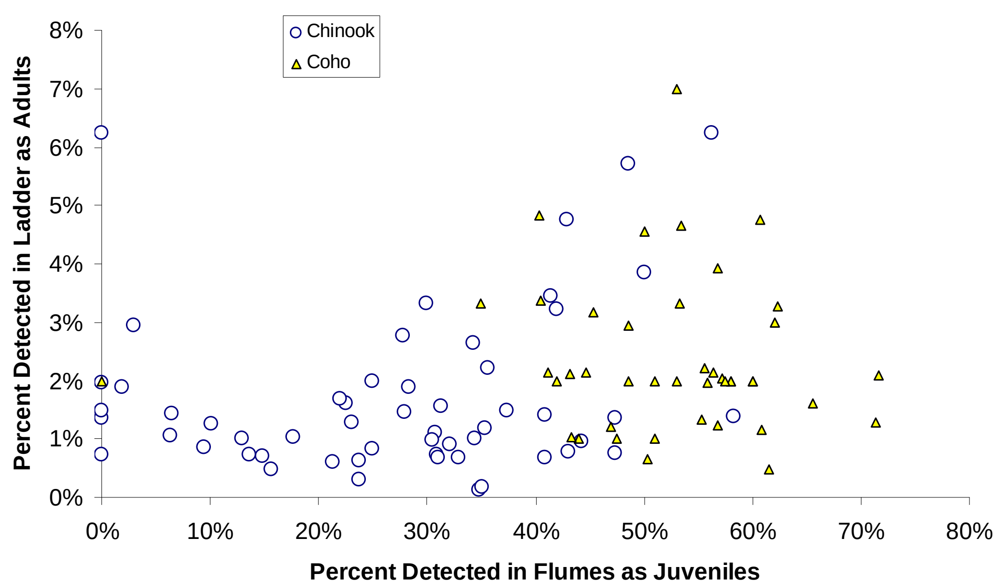

Figure 4. Comparison of percent of PIT tagged release groups detected in the fish ladder as returning adults and in the flumes as outmigrants. Data are pooled from all 2004-2007 fish ladder detections.

5. DIFFERENCES IN ANNUAL AND BROOD YEAR ADULT DETECTION RATES

Tables 7 and 8 indicate that there were fewer returning adults detected for Chinook tagged as smolts in both Bear Creek and the Cedar River in 2002 and 2004 compared with smolts tagged in 2003 and 2005. Return detection rates were highest for the 2005 Chinook outmigrating year class (table 8; the rates may be higher after next year as older fish return). Returns were generally lowest for Bear Creek Chinook tagged in 2002 and 2004, followed by Issaquah Hatchery Chinook tagged in 2001 and 2002, and for Cedar River Chinook tagged in 2002.

There are several possible sources of variation for differential detection rates in the tables: (1) differential detection rates of smolts through the flumes reflecting water temperature and/or freshwater survival effects, (2) differential survival from smolt to adult in saltwater, and (3) differential upstream passage rates through the fish ladder possibly in response to annual variation in water quality in the LWSC.

In the first case, there is no clear indication in water temperature in the LWSC or mean fish length data presented in DeVries et al. (2007) as to why 2002 and 2004 had lowest suggested returns. For example, May water temperatures in the LWSC were generally warmest in 2004 and coolest in 2002 (Figure 5). Earlier migrants released in May have generally been associated with greater detection rates in the smolt flumes (e.g., Figure 2), yet both Chinook outmigrating year classes exhibited low return rates based on total detections in the ladder.

In the second case, more detailed analysis would be required to develop hypotheses for the return trends observed in terms of possible influences of conditions in Puget Sound and the Pacific Ocean.

The third case appears likely. A hypothesis is that warmer years would be associated with a greater proportion of adults returning through the lock chambers as opposed to the fish ladder. Figure 5 indicates that water temperatures in August, when most of the returning Chinook were detected in the ladder, may indeed be related to upstream passage route selection. Table 9 summarizes ladder detection numbers by outmigration year and detection year. Detections in the fish ladder were generally greater in 2006 and 2007 than in 2004 and 2005. Correspondingly, near surface water temperatures in the LWSC were warmer in 2004 and 2005 than in 2006 and 2007. There appears to be a strong relation between upstream passage numbers in the fish ladder and water temperature in the LWSC.

This phenomenon could affect the accuracy of escapement estimates based on ladder counts, where numbers would be biased higher in cooler, and lower in warmer August periods. A controlled multi-year study involving PIT tagged adult Chinook could be designed to address this question.

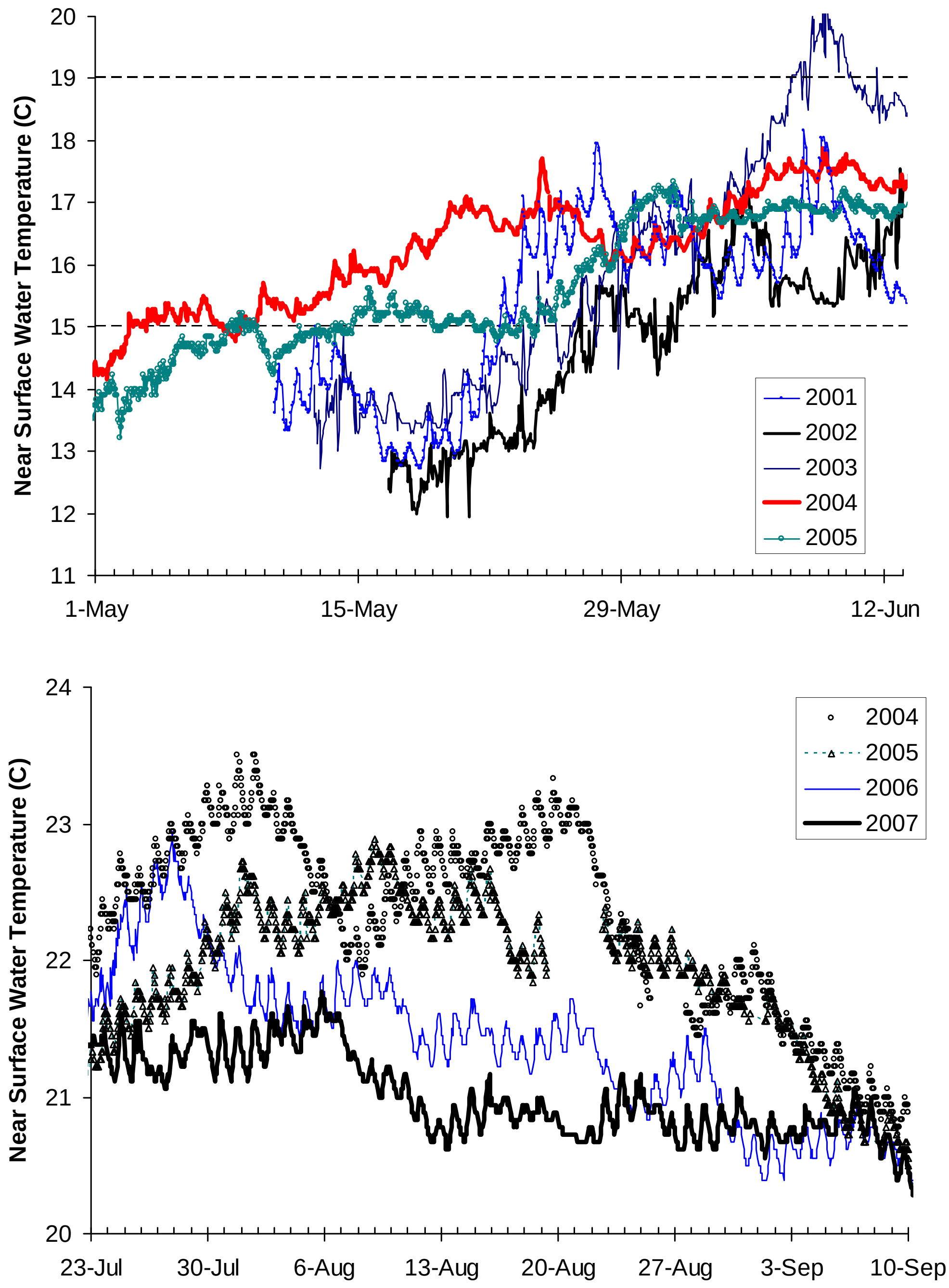

Figure 5. Near-surface water temperature time series in the LWSC, during the May/early June spring outmigration (top) and primary Chinook upstream passage (bottom) periods.

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Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	**Species**	**Origin**	**Date**	**Location**	**Length (mm)**	**Date**	**Time**	**Flume**	**Date**	**Time**	**Location**	
3D9.1BF1446273	Chinook	H	5/19/2003	Issaquah Hatchery	73			ND	7/25/2006	11:36:20	Lower Orifice	Upstream
									7/25/2006	11:36:47	Upper Orifice	
3D9.1BF1581551	Chinook	H	5/19/2003	Issaquah Hatchery	63			ND	9/1/2006	7:25:21	Lower Weir	Upstream
									9/1/2006	7:49:51	Upper Weir	
									9/7/2006	7:16:29	Lower Weir	Upstream
									9/7/2006	7:16:40	Upper Weir	
3D9.1BF1578981	Chinook	H	5/16/2005	Issaquah Hatchery	72	6/20/2005	5:27:03	4B	8/20/2006	14:12:35	Lower Weir	Upstream
									8/20/2006	14:41:38	Upper Weir	
3D9.1BF1106B65	Chinook	H	5/16/2005	Issaquah Hatchery	76			ND	8/31/2006	17:19:06	Lower Weir	Upstream
									8/31/2006	17:37:58	Upper Weir	
3D9.1BF14494A9	Chinook	H	6/12/2003	Smolt Flumes	63			ND	8/7/2006	15:28:23	Lower Orifice	Aborted
3D9.1BF18B66FB	Chinook	H	5/12/2003	Smolt Flumes	67			ND	8/11/2006	14:27:30	Lower Orifice	Upstream
									8/11/2006	15:10:35	Upper Orifice	Upstream Attempt
									8/11/2006	15:42:16	Lower Orifice	Downstream
3D9.1BF18B5182	Chinook	H	5/12/2003	Smolt	63			ND	8/21/2006	17:14:25	Lower Weir	Upstream

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
				Flumes								Attempt
									8/21/2006	17:31:19	Lower Orifice	Upstream Attempt
									8/21/2006	17:55:05	Lower Weir	Upstream Attempt
									8/21/2006	18:05:03	Lower Orifice	Upstream
									8/21/2006	18:08:04	Upper Orifice	
3D9.1BF17F776F	Chinook	H	5/30/2003	Kenmore	82			ND	8/7/2006	10:26:17	Lower Orifice	Upstream
									8/7/2006	10:27:56	Upper Orifice	
3D9.1BF185047B	Chinook	H	5/13/2003	Kenmore	84	5/28/2003	5:07:15	5B	8/20/2006	6:30:15	Lower Orifice	Upstream
									8/20/2006	6:36:31	Upper Orifice	
3D9.1BF10D958A	Chinook	W	6/11/2003	Bear Creek	92			ND	9/9/2006	19:35:18	Lower Weir	Upstream
									9/9/2006	19:37:07	Upper Orifice	
3D9.1BF15AF39B	Chinook	W	5/21/2003	Bear Creek	84	6/2/2003	6:39:22	4B	8/12/2006	17:49:38	Lower Weir	Upstream
									8/12/2006	19:13:50	Upper Weir	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF17DAB28	Chinook	W	5/20/2003	Bear Creek	72			ND	8/29/2006	11:11:45	Lower Orifice	Upstream
									8/29/2006	11:22:05	Upper Orifice	
3D9.1BF17E7881	Chinook	W	5/9/2003	Bear Creek	75			ND	7/31/2006	19:12:50	Lower Orifice	Upstream
									7/31/2006	19:13:21	Upper Orifice	
									8/3/2006	20:39:17	Lower Orifice	Upstream
									8/3/2006	20:39:39	Upper Orifice	
3D9.1BF17EEB65	Chinook	W	5/22/2003	Bear Creek	74			ND	7/31/2006	14:14:18	Lower Weir	Upstream
									7/31/2006	14:32:51	Lower Orifice	
3D9.1BF1856D8D	Chinook	W	5/8/2003	Bear Creek	74			ND	8/21/2006	13:45:01	Lower Orifice	Upstream
									8/21/2006	13:45:47	Upper Orifice	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	**Species**	**Origin**	**Date**	**Location**	**Length (mm)**	**Date**	**Time**	**Flume**	**Date**	**Time**	**Location**	
3D9.1BF1FF728A	Chinook	W	5/4/2005	Bear Creek	73	6/26/2005	7:23:45	4B	8/17/2006	15:54:12	Lower Orifice	Upstream
									8/17/2006	16:24:25	Upper Orifice	
									8/20/2006	18:19:59	Lower Weir	Upstream
									8/20/2006	18:33:37	Upper Orifice	
3D9.1BF18BAA48	Chinook	W	5/2/2005	Bear Creek	76	6/2/2005	8:59:41	4B	8/24/2006	17:11:20	Lower Orifice	Upstream
									8/24/2006	17:21:34	Upper Orifice	
3D9.1BF18E106C	Chinook	W	5/12/2005	Bear Creek	82			ND	8/27/2006	12:00:13	Lower Orifice	Upstream
									8/27/2006	12:38:04	Upper Orifice	
									8/27/2006	16:54:19	Upper Orifice	Downstream
									8/27/2006	17:03:20	Lower Orifice	
									8/28/2006	13:43:22	Lower Orifice	Upstream
									8/28/2006	13:58:11	Upper Orifice	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	**Species**	**Origin**	**Date**	**Location**	**Length (mm)**	**Date**	**Time**	**Flume**	**Date**	**Time**	**Location**	
3D9.1BF18DEB8C	Chinook	W	5/16/2005	Bear Creek	79			ND	9/1/2006	18:38:54	Lower Weir	Aborted
3D9.1BF18BA3F3	Coho	W	5/17/2005	Bear Creek	117			ND	8/26/2006	6:34:21	Lower Weir	Upstream
									8/26/2006	6:48:26	Upper Weir	
									8/30/2006	15:13:36	Lower Weir	Upstream
									8/30/2006	15:18:56	Upper Weir	
3D9.1BF207BB42	Coho	W	5/9/2005	Bear Creek	140			ND	9/6/2006	13:10:11	Lower Orifice	Upstream
									9/6/2006	13:11:16	Upper Orifice	
3D9.1BF1FF6AC0	Coho	W	5/5/2005	Bear Creek	121	5/25/2005	14:06:26	5B	9/9/2006	13:05:53	Lower Orifice	Upstream
									9/9/2006	13:07:37	Upper Orifice	
3D9.1BF18BCB15	Coho	W	5/2/2005	Bear Creek	110			ND	9/10/2006	16:07:43	Lower Weir	Upstream
									9/10/2006	16:08:31	Upper Orifice	
3D9.1BF1FF5473	Coho	W	5/12/2005	Bear Creek	106	5/31/2005	14:48:41	5C	9/10/2006	14:52:31	Lower Weir	Upstream Attempt
									9/10/2006	15:00:29	Lower Orifice	Upstream
									9/10/2006	15:17:00	Upper	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
											Orifice	
3D9.1BF2074ADD	Coho	W	5/6/2005	Bear Creek	91	6/2/2005	15:20:02	5B	9/10/2006	7:42:48	Lower Weir	Upstream
									9/10/2006	8:13:59	Upper Orifice	
3D9.1BF207441B	Coho	W	5/6/2005	Bear Creek	117	5/25/2005	12:49:44	5B	9/11/2006	15:10:15	Lower Orifice	Upstream
									9/11/2006	15:15:47	Upper Orifice	
3D9.1BF18D198E	Coho	W	5/18/2005	Bear Creek				ND	9/16/2006	13:50:28	Lower Weir	Upstream
									9/16/2006	13:51:11	Upper Weir	
3D9.1BF1FF72AC	Coho	W	5/5/2005	Bear Creek	116			ND	9/16/2006	14:09:05	Lower Weir	Upstream
									9/16/2006	14:12:40	Upper Orifice	
3D9.1BF207FF38	Coho	W	5/9/2005	Bear Creek	118	5/25/2005	11:55:47	5B	9/16/2006	11:05:05	Lower Orifice	Upstream
									9/16/2006	11:38:55	Upper Orifice	
									9/21/2006	15:34:01	Lower Orifice	Upstream
									9/21/2006	15:36:21	Upper Orifice	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	Inferred Direction of Movement
3D9.1BF207F9C9	Coho	W	5/6/2005	Bear Creek	113	5/28/2005	18:29:14	5C	9/19/2006	16:06:08	Lower Weir	Upstream
									9/19/2006	16:06:41	Upper Orifice	
3D9.1BF18D7511	Coho	W	5/24/2005	Bear Creek	110	6/11/2005	12:55:17	5B	9/20/2006	2:30:42	Lower Orifice	Upstream
									9/20/2006	2:40:14	Upper Orifice	
3D9.1BF1FF4E26	Coho	W	5/12/2005	Bear Creek	106	5/30/2005	8:27:01	5C	9/21/2006	11:23:08	Lower Orifice	Upstream
									9/21/2006	11:39:29	Upper Weir	
3D9.1BF207F706	Coho	W	5/9/2005	Bear Creek	115			ND	10/3/2006	13:21:34	Lower Weir	Upstream
									10/3/2006	13:22:17	Upper Weir	
3D9.1BF1FF4C89	Coho	W	5/13/2005	Bear Creek	142	5/25/2005	17:29:23	5B	10/13/2006	9:27:12	Lower Orifice	Upstream
									10/13/2006	9:34:24	Upper Orifice	
									10/16/2006	17:04:50	Lower Orifice	Upstream
									10/16/2006	17:13:08	Upper Orifice	
3D9.1BF17DA317	Chinook	W	5/19/2003	Cedar River	84			ND	7/22/2006	15:20:07	Lower Orifice	Upstream

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
									7/22/2006	15:20:27	Upper Orifice	
3D9.1BF10CFF06	Chinook	W	6/11/2003	Cedar River	102			ND	8/1/2006	17:59:35	Lower Orifice	Upstream
									8/1/2006	18:00:20	Upper Orifice	
3D9.1BF1BBF46A	Chinook	W	6/16/2003	Cedar River	103			ND	8/15/2006	18:41:55	Lower Weir	Upstream
									8/15/2006	18:42:05	Upper Weir	
3D9.1BF1BC3518	Chinook	W	6/25/2003	Cedar River	102			ND	8/19/2006	14:39:35	Lower Weir	Upstream
									8/19/2006	20:32:58	Upper Weir	Upstream Attempt
									8/20/2006	14:35:59	Upper Orifice	Upstream
3D9.1BF12773D8	Chinook	W	5/30/2003	Cedar River	92	6/7/2003	6:59:55	4B	8/22/2006	19:22:02	Lower Orifice	Upstream
									8/22/2006	19:46:34	Upper Weir	
3D9.1BF11396FE	Chinook	W	6/9/2003	Cedar River	99			ND	8/28/2006	17:35:50	Upper Weir	Upstream?

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF18019AC	Chinook	W	5/7/2004	Cedar River	79	5/27/2004	14:57:49	5B	8/3/2006	14:00:28	Lower Orifice	Upstream
									8/3/2006	14:01:08	Upper Orifice	
									8/8/2006	15:02:59	Lower Orifice	Upstream
									8/8/2006	15:03:20	Upper Orifice	
									8/10/2006	13:34:22	Lower Orifice	Upstream
									8/10/2006	13:41:13	Upper Orifice	
									8/12/2006	17:38:30	Lower Orifice	Upstream
									8/12/2006	17:38:52	Upper Orifice	
									9/9/2006	15:25:54	Upper Orifice	Held in Chamber?
3D9.1BF1D04E15	Chinook	W	6/1/2004	Cedar River	94	6/26/2004	11:09:34	5B	8/15/2006	15:49:30	Lower Orifice	Upstream
									8/15/2006	15:49:54	Upper Orifice	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF1802337	Chinook	W	5/7/2004	Cedar River	90			ND	8/21/2006	15:06:05	Lower Orifice	Upstream
									8/21/2006	15:06:52	Upper Orifice	
3D9.1BF18BAF40	Chinook	W	5/3/2005	Cedar River	90	5/22/2005	9:35:31	5B	8/8/2006	16:58:54	Lower Weir	Upstream
									8/8/2006	17:00:47	Upper Orifice	
3D9.1BF18C5C14	Chinook	W	6/7/2005	Cedar River	97	6/20/2005	5:34:14	4B	8/16/2006	20:07:45	Lower Weir	Upstream
									8/16/2006	20:09:25	Upper Orifice	
									8/24/2006	17:23:04	Lower Orifice	Upstream
									8/24/2006	17:32:47	Upper Orifice	
3D9.1BF18D5AF9	Chinook	W	5/17/2005	Cedar River	86			ND	8/25/2006	19:53:20	Lower Orifice	Upstream
									8/25/2006	20:16:47	Upper Orifice	
									8/26/2006	2:35:55	Upper Orifice	Downstream
									8/26/2006	2:49:55	Lower Orifice	
3D9.1BF18D4974	Chinook	W	6/1/2005	Cedar	81			ND	8/28/2006	9:20:57	Lower	Upstream

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
				River							Orifice	
									8/28/2006	9:37:14	Upper Orifice	
3D9.1BF18DF9A1	Chinook	W	5/12/2005	Cedar River	74			ND	9/6/2006	14:56:58	Lower Weir	Upstream
									9/6/2006	15:16:22	Upper Orifice	
3D9.1BF1FF6C10	Coho	W	5/3/2005	Cedar River	122	5/28/2005	12:32:38	5B	9/12/2006	13:20:55	Lower Orifice	Upstream
									9/12/2006	13:46:38	Upper Orifice	
3D9.1BF1FF59B3	Coho	W	5/5/2005	Cedar River	121	5/21/2005	13:34:17	4B	9/19/2006	12:04:45	Lower Orifice	Upstream
									9/19/2006	12:07:37	Upper Weir	
3D9.1BF18D5464	Coho	W	5/24/2005	Cedar River	114	6/13/2005	6:58:54	5B	9/19/2006	18:44:56	Lower Orifice	Upstream
									9/19/2006	18:47:59	Upper Orifice	
3D9.1BF18DF79F	Coho	W	5/12/2005	Cedar River	113			ND	9/19/2006	18:52:42	Lower Weir	Upstream
									9/19/2006	18:53:46	Upper Weir	
									9/30/2006	15:19:09	Lower Weir	Upstream
									9/30/2006	15:19:40	Upper Weir	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF1FF69A6	Coho	W	5/3/2005	Cedar River	112			ND	9/20/2006	20:24:13	Lower Orifice	Upstream
									9/20/2006	21:04:32	Upper Orifice	
3D9.1BF207FF01	Coho	W	5/9/2005	Cedar River	102	5/28/2005	9:52:04	5C	9/22/2006	12:46:14	Lower Weir	Upstream
									9/22/2006	12:58:36	Upper Weir	
3D9.1BF2074BBC	Coho	W	5/11/2005	Cedar River	105	5/30/2005	6:19:28	5B	9/30/2006	15:36:24	Lower Orifice	Upstream
									9/30/2006	15:43:30	Upper Orifice	
3D9.1BF18E1B18	Coho	W	5/16/2005	Cedar River	92			ND	10/10/2006	17:26:55	Lower Orifice	Upstream
									10/10/2006	17:34:04	Upper Orifice	
3D9.1BF18BA4B8	Coho	W	5/2/2005	Cedar River	120			ND	10/16/2006	6:06:44	Lower Orifice	Upstream
									10/16/2006	6:47:29	Upper Orifice	
3D9.1BF18D4DDE	Coho	W	5/31/2005	Cedar River	106	6/14/2005	10:50:14	5B	10/22/2006	16:58:40	Lower Orifice	Upstream
									10/22/2006	16:58:56	Upper Orifice	
3D9.1BF18D2AFA	Coho	W	5/17/2005	Cedar	104	6/9/2005	14:32:56	5B	10/25/2006	7:19:28	Lower	Upstream

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
				River							Orifice	
									10/25/2006	7:24:36	Upper Weir	
3D9.1BF1FF5C79	Coho	W	5/13/2005	Cedar River	112	6/5/2005	11:42:22	5C	10/26/2006	10:27:50	Lower Weir	Upstream
									10/26/2006	10:28:03	Upper Weir	
3D9.1BF2078D03	Coho	W	5/9/2005	Cedar River	110	6/2/2005	16:42:42	5B	10/27/2006	15:33:24	Lower Orifice	Upstream
									10/27/2006	15:33:44	Upper Orifice	
3D9.1BF207F2E6	Coho	W	5/10/2005	Cedar River	106			ND	10/31/2006	10:48:29	Lower Orifice	Upstream
									10/31/2006	10:49:22	Upper Orifice	
3D9.1BF1FF546C	Coho	W	5/16/2005	Cedar River	116			ND	11/3/2006	9:29:05	Lower Orifice	Upstream
									11/3/2006	9:42:04	Upper Orifice	
3D9.1BF208245B	Coho	W	5/5/2005	Cedar River	121			ND	11/5/2006	9:27:19	Lower Orifice	Upstream
									11/5/2006	9:58:02	Upper Orifice	
3D9.1BF1FF5C98	Coho	W	5/13/2005	Cedar River	96	6/5/2005	14:34:25	5B	11/9/2006	14:05:45	Lower Orifice	Upstream
									11/9/2006	14:12:16	Upper	

Table 1. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2006.

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
											Orifice	
3D9.1BF20751CD	Coho	W	5/10/2005	Cedar River	112	5/28/2005	14:47:07	5B	11/9/2006	16:20:35	Lower Orifice	Upstream
									11/9/2006	16:26:47	Upper Orifice	
3D9.1BF23B52BC	Coho	W	2/14/2006	Rock Creek	75			ND	11/3/2006	20:26:14	Lower Orifice	Upstream
									11/3/2006	21:01:00	Upper Orifice	
3D9.1BF24A08A0	Chinook	H	3/18/2006	Rapid River Hatchery		Columbia River Release			7/25/2006	10:21:08	Lower Weir	Upstream
									7/25/2006	13:19:13	Upper Weir	
3D9.1BF25C7A44	Chinook	H	3/21/2006	Knox Bridge		Columbia River Release			8/27/2006	12:29:39	Lower Weir	Upstream Attempt
									8/27/2006	12:39:13	Lower Weir	Upstream
									8/27/2006	13:21:35	Upper Weir	
3D9.1BF237EFCE	Chinook	H	4/25/2006	Lower Granite Dam		Columbia River Release			9/7/2006	0:38:46	Lower Orifice	Upstream
									9/7/2006	1:05:19	Upper Orifice	

Table 2. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2007 (updated through October 23).

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF1453DC8	Chinook	H	5/16/2005	Issaquah Hatchery	74			ND	8/12/2007	14:56:28	Lower Weir	Upstream
										14:56:44	Upper Weir	
3D9.1BF26C08DC	Coho	H	4/18/2007	Issaquah Hatchery	130	5/26/2007	11:04:16	5C	9/16/2007	16:26:56	Lower Weir	Upstream
										16:31:38	Upper Weir	
3D9.257C665C94	Chinook	H	5/6/2006	UW Hatchery	114			ND	9/7/2007	14:46:31	Lower Weir	Upstream
										14:49:17	Upper Weir	
3D9.1BF1447154	Chinook	H	6/19/2003	Smolt Flumes	73	6/19/2003	16:18:44	4A	8/6/2007	12:11:03	Lower Orifice	Upstream
										12:11:47	Upper Orifice	
									8/31/2007	16:05:28	Lower Orifice	Upstream
										16:15:15	Upper Weir	
3D9.1BF1D0D51B	Chinook	W	6/1/2004	Bear Creek	83			ND	8/8/2007	19:22:54	Lower Weir	Upstream Attempt
3D9.1BF18DE316	Chinook	W	5/25/2005	Bear Creek	87			ND	8/3/2007	12:50:08	Lower Orifice	Upstream
										13:04:11	Upper Weir	

Table 2. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2007 (updated through October 23).

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF18D44E0	Chinook	W	5/19/2005	Bear Creek	79	6/13/2005	14:08:14	5C	8/3/2007	18:06:10	Lower Weir	Upstream
										18:06:20	Upper Weir	
3D9.1BF18CC6BD	Chinook	W	6/7/2005	Bear Creek	82			ND	8/13/2007	18:57:21	Lower Orifice	Upstream
										18:57:44	Upper Orifice	
3D9.1BF18BE0F3	Chinook	W	5/2/2005	Bear Creek	70			ND	9/6/2007	5:35:32	Lower Orifice	Upstream
										5:48:33	Upper Orifice	
3D9.1BF1BB8B22	Chinook	W	6/12/2003	Cedar River	100			ND	8/4/2007	18:33:55	Lower Orifice	Upstream
										18:40:07	Upper Orifice	
3D9.1BF1C984C5	Chinook	W	6/7/2004	Cedar River	99			ND	8/6/2007	20:46:42	Lower Weir	Upstream
										20:46:57	Upper Weir	

Table 2. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2007 (updated through October 23).

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	**Species**	**Origin**	**Date**	**Location**	**Length (mm)**	**Date**	**Time**	**Flume**	**Date**	**Time**	**Location**	
3D9.1BF1D0D9DD	Chinook	W	5/17/2004	Cedar River	73			ND	8/14/2007	16:52:44	Lower Orifice	Upstream
										17:11:53	Upper Orifice	
									9/13/2007	15:19:23	Lower Orifice	Upstream
										15:27:30	Upper Orifice	
3D9.1BF15757CE	Chinook	W	6/23/2004	Cedar River	100			ND	8/22/2007	17:32:48	Lower Orifice	Upstream
										17:33:44	Upper Orifice	
3D9.1BF17E99B7	Chinook	W	5/7/2004	Cedar River	87			ND	9/5/2007	20:33:21	Lower Orifice	Upstream
										20:33:49	Upper Orifice	
3D9.1BF20820F0	Chinook	W	5/4/2005	Cedar River	97	5/21/2005	10:39:53	4B	8/1/2007	8:45:55	Lower Orifice	Upstream
										9:03:12	Upper Orifice	

Table 2. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2007 (updated through October 23).

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF1FF69D1	Chinook	W	5/23/2005	Cedar River	99	6/7/2005	8:26:04	4B	8/5/2007	10:38:30	Lower Orifice	Upstream
										10:38:59	Upper Orifice	
3D9.1BF18D3AA9	Chinook	W	5/25/2005	Cedar River	93	6/10/2005	19:16:54	5B	8/5/2007	14:33:15	Lower Orifice	Upstream Attempt
3D9.1BF1FF5C0B	Chinook	W	5/13/2005	Cedar River	96			ND	8/11/2007	10:40:55	Lower Orifice	Upstream
										11:19:14	Upper Orifice	
3D9.1BF18D3711	Chinook	W	5/25/2005	Cedar River	91			ND	8/16/2007	7:58:57	Lower Weir	Upstream
										7:59:11	Upper Weir	
3D9.1BF1FF3C25	Chinook	W	5/12/2005	Cedar River	90	6/3/2005	14:15:28	5B	8/21/2007	14:58:48	Lower Weir	Upstream
										15:52:56	Lower Orifice	
3D9.1BF2074EBF	Chinook	W	5/9/2005	Cedar River	87	6/1/2005	18:10:55	4B	8/25/2007	13:14:10	Lower Weir	Upstream Attempt
									8/26/2007	8:33:21	Lower Orifice	Upstream
										8:43:10	Upper Orifice	

Table 2. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2007 (updated through October 23).

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	Species	Origin	Date	Location	Length (mm)	Date	Time	Flume	Date	Time	Location	
3D9.1BF1FF41B6	Chinook	W	5/10/2005	Cedar River	87	6/9/2005	9:02:22	5B	8/26/2007	16:17:27	Lower Orifice	Upstream
										16:18:56	Upper Orifice	
3D9.1BF18D9C5F	Chinook	W	6/9/2005	Cedar River	105			ND	8/27/2007	17:37:09	Lower Orifice	Upstream
										17:40:04	Upper Orifice	
3D9.1BF1FF7302	Chinook	W	5/24/2005	Cedar River	93			ND	8/28/2007	14:50:22	Lower Weir	Upstream
										14:50:53	Upper Weir	
3D9.1BF1FF5D1D	Chinook	W	5/10/2005	Cedar River	92	6/8/2005	12:57:34	5C	9/1/2007	8:02:52	Lower Orifice	Upstream
										8:03:06	Upper Orifice	
3D9.1BF18E3178	Chinook	W	5/11/2005	Cedar River	79			ND	9/8/2007	10:25:00	Lower Orifice	Upstream
										10:26:09	Upper Orifice	
3D9.1BF18DA445	Chinook	W	6/9/2005	Cedar River	83			ND	9/9/2007	14:56:38	Lower Orifice	Upstream
										15:00:45	Upper Orifice	

Table 2. Tagging and detection information available for each returning adult with a PIT tag detected in the Hiram M. Chittenden Locks fish ladder in 2007 (updated through October 23).

			Smolt Life Stage						Adult Life Stage			
			Tagging/Release			Detection in Flumes			Detection in Ladder			Inferred Direction of Movement
Tag Number	**Species**	**Origin**	**Date**	**Location**	**Length (mm)**	**Date**	**Time**	**Flume**	**Date**	**Time**	**Location**	
3D9.1BF24CBE11	Coho	W	5/16/2006	Landsburg Dam	134	5/21/2006	18:43:38	4A	10/4/2007	17:32:34	Lower Orifice	Upstream
										17:43:01	Upper Orifice	
3D9.1BF24CEB6E	Coho	W	5/16/2006	Landsburg Dam	118			ND	10/23/2007	13:06:06	Lower Orifice	Upstream
										13:16:26	Upper Orifice	

Table 3. Adult Fish Ladder Return Summary Fall 2006.

Species	Release Year	Location	Origin	Number Detected in Ladder					Number Detected in Flumes as Smolts
				Once	**Twice**	**Thrice**	**Four Times**	**Total**	
Chinook	2003	Issaquah Hatchery	Hatchery	1	1			2	0
		Bear Creek	Natural	5	1			6	1
		Cedar River	Natural	6				6	1
		Kenmore	Hatchery	2				2	1
		Smolt Flumes	Hatchery	3				3	3
	2004	Cedar River	Natural	2			1	3	2
	2005	Issaquah Hatchery	Hatchery	2				2	1
		Bear Creek	Natural	2	2			4	2
		Cedar River	Natural	5				5	2
	2006	August Test Adults	Unknown	18	2	1		21	*na*
		Columbia River	Hatchery	3				3	*na*
Coho	2005	Bear Creek	Natural	13	2			15	9
		Cedar River	Natural	17	1			18	11
	2006	Rock Creek	Natural	1				1	0

Table 4. Adult Fish Ladder Return Summary Fall 2007.

Species	Release Year	Location	Origin	Number Detected in Ladder: Once	Twice	Thrice	Four Times	Total	Number Detected in Flumes as Smolts
Chinook	2003	Cedar River	Natural	1				1	0
		Smolt Flumes	Hatchery		1			1	1
	2004	Bear Creek	Natural	1				1	0
		Cedar River	Natural	3	1			4	0
	2005	Issaquah Hatchery	Hatchery	1				1	0
		Bear Creek	Natural	4				4	1
		Cedar River	Natural	13				13	7
	2006	UW Hatchery	Hatchery	1				1	0
Coho	2006	Landsburg Dam	Natural	2				2	1
	2007	Issaquah Hatchery	Hatchery	1				1	1

Table 5. Summary of 2006 Adult PIT Tag Detection Data in Fish Ladder by Release Group.

		Release		Number of Adults Detected		
Species	**Origin**	**Location**	**Date**	**In Ladder**	**And As Smolts in Flumes**	**Percent of Release Group Detected in Ladder**
Chinook	Natural	Bear Creek	5/8/2003	1	0	1.4%
			5/9/2003	1	0	0.8%
			5/20/2003	1	0	0.7%
			5/21/2003	1	1	0.7%
			5/22/2003	1	0	0.8%
			6/11/2003	1	0	2.9%
			5/2/2005	1	1	1.3%
			5/4/2005	1	1	0.7%
			5/12/2005	1	0	3.2%
			5/16/2005	1	0	1.9%
	Natural	Cedar River	5/19/2003	1	0	1.5%
			5/30/2003	1	1	2.9%
			6/9/2003	1	0	1.0%
			6/11/2003	1	0	1.3%
			6/16/2003	1	0	2.0%
			6/25/2003	1	0	6.3%
			5/7/2004	2	1	2.2%
			6/1/2004	1	1	0.7%
			5/3/2005	1	1	1.6%
			5/12/2005	1	0	2.4%
			5/17/2005	1	0	1.7%
			6/1/2005	1	0	0.8%
			6/7/2005	1	1	1.0%
	Hatchery	Issaquah H	5/19/2003	2	0	0.2%
			5/16/2005	2	1	0.5%
		Kenmore	5/13/2003	1	1	0.3%
			5/30/2003	1	0	0.2%
Coho	Natural	Bear Creek	5/2/2005	1	0	1.0%
			5/5/2005	2	1	2.0%

Table 5. Summary of 2006 Adult PIT Tag Detection Data in Fish Ladder by Release Group.

Species	Origin	Release Location	Release Date	Number of Adults Detected In Ladder	Number of Adults Detected And As Smolts in Flumes	Percent of Release Group Detected in Ladder
			5/6/2005	3	3	3.0%
			5/9/2005	3	1	3.2%
			5/12/2005	2	2	3.9%
			5/13/2005	1	1	2.0%
			5/17/2005	1	0	2.0%
			5/18/2005	1	0	2.0%
			5/24/2005	1	1	2.1%
		Cedar River	5/2/2005	1	0	1.0%
			5/3/2005	2	1	4.7%
			5/5/2005	2	1	1.4%
			5/9/2005	2	2	3.3%
			5/10/2005	2	1	2.0%
			5/11/2005	1	1	1.5%
			5/12/2005	1	0	1.2%
			5/13/2005	2	2	2.2%
			5/16/2005	2	0	2.0%
			5/17/2005	1	1	1.2%
			5/24/2005	1	1	3.3%
			5/31/2005	1	1	4.5%
		Rock Cr	2/14/2006	1	0	8.3%
Chinook	Hatchery	Columbia R	Spring 2006	3	*na*	*na*

Table 6. Summary of 2007 Adult PIT Tag Detection Data in Fish Ladder by Release Group.

Species	Origin	Release Location	Release Date	Number of Adults Detected: In Ladder	Number of Adults Detected: And As Smolts in Flumes	Percent of Release Group Detected in Ladder
Chinook	Natural	Bear Creek	6/1/2004	1	0	1.4%
			5/2/2005	1	0	1.3%
			5/19/2005	1	1	1.6%
			5/25/2005	1	0	1.3%
			6/7/2005	1	0	1.5%
	Natural	Cedar River	6/12/2003	1	0	1.1%
			5/7/2004	1	0	1.1%
			5/17/2004	1	0	1.1%
			6/7/2004	1	0	0.7%
			6/23/2004	1	0	1.9%
			5/4/2005	1	1	2.8%
			5/9/2005	1	1	1.0%
			5/10/2005	2	2	1.0%
			5/11/2005	1	0	2.2%
			5/12/2005	1	1	2.4%
			5/13/2005	1	0	0.9%
			5/23/2005	1	1	1.0%
			5/24/2005	1	0	1.2%
			5/25/2005	2	1	2.0%
			6/9/2005	2	0	1.4%
	Hatchery	Issaquah H	5/16/2005	1	0	0.2%
		Univ WA H	5/6/2006	1	0	1.0%
Coho	Natural	Landsburg Dam	5/16/2006	2	1	0.7%
	Hatchery	Issaquah	4/18/2007	1	1	0.1%

[1] *- not adjusted for detection efficiency of tunnel readers*

Table 7. Proportions of returning PIT-tagged salmon adults detected in the flumes as juveniles from primary study sites, 2004-2007 ladder data combined.

		Release		Smolts			Number of Adults Detected		Estimate of % of Outmigrants Using Flumes
Species	Origin	Location	Date	Released	Detected in Flumes [1]	% Detected	In Ladder	And As Smolts in Flumes	
Chinook	Natural	Bear Creek	5/23/2002	72	42	58%	1	0	0%
			6/10/2002	164	35	21%	1	0	0%
			5/8/2003	71	29	41%	1	0	0%
			5/9/2003	131	62	47%	1	0	0%
			5/13/2003	74	35	47%	1	1	100%
			5/20/2003	149	61	41%	1	0	0%
			5/21/2003	146	48	33%	1	1	100%
			5/22/2003	128	55	43%	1	0	0%
			5/30/2003	156	37	24%	1	0	0%
			6/11/2003	34	1	3%	1	0	0%
				76	26				
			6/1/2004	74	0	0%	1	0	0%
			5/2/2005	76	26	34%	2	1	50%
			5/4/2005	136	42	31%	1	1	100%
			5/12/2005	31	13	42%	1	0	0%
			5/16/2005	53	15	28%	1	0	0%
			5/19/2005	62	14	23%	1	1	100%
			5/25/2005	78	18	23%	1	0	0%
			6/7/2005	67	0	0%	1	0	0%

Table 7. Proportions of returning PIT-tagged salmon adults detected in the flumes as juveniles from primary study sites, 2004-2007 ladder data combined.

		Release		Smolts			Number of Adults Detected		Estimate of % of Outmigrants Using Flumes
Species	Origin	Location	Date	Released	Detected in Flumes [1]	% Detected	In Ladder	And As Smolts in Flumes	
Chinook	Natural	Cedar River	5/4/2001	16	9	56%	1	0	0%
			5/31/2001	145	45	31%	1	0	0%
			6/5/2001	68	19	28%	1	0	0%
			6/12/2001	204	32	16%	1	1	100%
			5/24/2002	29	12	41%	1	1	100%
			5/29/2002	26	13	50%	1	1	100%
			5/19/2003	67	25	37%	1	0	0%
			5/30/2003	35	17	49%	2	1	50%
			6/9/2003	100	13	13%	1	0	0%
			6/11/2003	79	8	10%	1	0	0%
			6/12/2003	94	6	6%	1	0	0%
			6/16/2003	51	0	0%	1	0	0%
			6/25/2003	16	0	0%	1	0	0%
			5/7/2004	90	27	30%	3	1	33%
			5/17/2004	91	28	31%	1	0	0%
			6/1/2004	139	0	0%	1	1	100%
			6/7/2004	142	21	15%	1	0	0%
			6/14/2004	116	11	9%	1	1	100%
			6/23/2004	53	1	2%	1	0	0%

Table 7. Proportions of returning PIT-tagged salmon adults detected in the flumes as juveniles from primary study sites, 2004-2007 ladder data combined.

		Release		Smolts			Number of Adults Detected		Estimate of % of Outmigrants Using Flumes
Species	Origin	Location	Date	Released	Detected in Flumes [1]	% Detected	In Ladder	And As Smolts in Flumes	
Chinook	Natural	Cedar River	5/3/2005	64	20	31%	1	1	100%
			5/4/2005	36	10	28%	1	1	100%
			5/9/2005	104	46	44%	1	1	100%
			5/10/2005	203	62	31%	2	2	100%
			5/11/2005	45	16	36%	1	0	0%
			5/12/2005	42	18	43%	2	1	50%
			5/13/2005	109	35	32%	1	0	0%
			5/17/2005	59	13	22%	1	0	0%
			5/23/2005	99	34	34%	1	1	100%
			5/24/2005	85	30	35%	1	0	0%
			5/25/2005	100	25	25%	2	1	50%
			6/1/2005	120	30	25%	1	0	0%
			6/7/2005	96	17	18%	1	1	100%
			6/9/2005	139	9	6%	2	0	0%
	Hatchery	Issaquah	5/15/2001	4676	1630	35%	6	4	67%
			5/31/2002	4024	1411	35%	7	3	43%
			5/19/2003	992	236	24%	3	1	33%
			5/16/2005	409	56	14%	3	1	33%
Coho	Natural	Bear Creek	4/29/2003	347	211	61%	4	2	50%
			4/30/2003	240	172	72%	5	5	100%
			5/1/2003	157	112	71%	2	2	100%
			5/2/2003	250	164	66%	4	0	0%
Coho	Natural	Bear Creek	5/5/2003	205	126	61%	1	1	100%

Table 7. Proportions of returning PIT-tagged salmon adults detected in the flumes as juveniles from primary study sites, 2004-2007 ladder data combined.

		Release		Smolts			Number of Adults Detected		Estimate of % of Outmigrants Using Flumes
Species	Origin	Location	Date	Released	Detected in Flumes [1]	% Detected	In Ladder	And As Smolts in Flumes	
			5/6/2003	100	60	60%	2	2	100%
			5/7/2003	100	51	51%	1	1	100%
			5/9/2003	100	60	60%	2	1	50%
			5/13/2003	95	41	43%	2	1	50%
			5/14/2003	100	53	53%	7	4	57%
			5/16/2003	100	53	53%	2	2	100%
			5/20/2003	50	21	42%	1	1	100%
			5/2/2005	100	44	44%	1	0	0%
			5/5/2005	100	51	51%	2	1	50%
			5/6/2005	100	62	62%	3	3	100%
			5/9/2005	95	43	45%	3	1	33%
			5/12/2005	51	29	57%	2	2	100%
			5/13/2005	50	0	0%	1	1	100%
			5/17/2005	50	29	58%	1	0	0%
			5/18/2005	49	28	57%	1	0	0%
			5/24/2005	47	21	45%	1	1	100%
		Cedar River	4/29/2003	50	29	58%	1	1	100%
			4/30/2003	102	57	56%	2	1	50%
			5/1/2003	62	25	40%	3	1	33%
			5/2/2003	84	51	61%	4	4	100%
Coho	Natural	Cedar River	5/5/2003	61	38	62%	2	2	100%
			5/6/2003	150	83	55%	2	1	50%

Table 7. Proportions of returning PIT-tagged salmon adults detected in the flumes as juveniles from primary study sites, 2004-2007 ladder data combined.

		Release		Smolts			Number of Adults Detected		Estimate of % of Outmigrants Using Flumes
Species	Origin	Location	Date	Released	Detected in Flumes [1]	% Detected	In Ladder	And As Smolts in Flumes	
			5/7/2003	94	53	56%	2	1	50%
			5/9/2003	99	47	47%	1	1	100%
			5/15/2003	45	25	56%	1	0	0%
			5/16/2003	155	78	50%	1	1	100%
			5/2/2005	97	42	43%	1	0	0%
			5/3/2005	43	23	53%	2	1	50%
			5/5/2005	141	58	41%	3	1	33%
			5/9/2005	60	21	35%	2	2	100%
			5/10/2005	101	58	57%	2	1	50%
			5/11/2005	68	33	49%	2	1	50%
			5/12/2005	81	46	57%	1	0	0%
			5/13/2005	89	36	40%	3	2	67%
			5/16/2005	101	49	49%	2	0	0%
			5/17/2005	83	39	47%	1	1	100%
			5/24/2005	30	16	53%	1	1	100%
			5/31/2005	22	11	50%	1	1	100%

Table 8. Proportion of PIT Tagged Smolts Detected as Adults in the Fish Ladder (data pooled from 2004-7 detections).

Species	Release Year	Location	Origin	Total Number of Smolts Tagged	Number Detected in Ladder as Adults	Percent Detected in Ladder as Adults
Chinook	2001	Issaquah Hatchery	Hatchery	4676	6	0.13%
		Cedar River	Natural	1550	3	0.19%
	2002	Issaquah Hatchery	Hatchery	4024	7	0.17%
		Bear Creek	Natural	2309	2	0.09%
	2003	Issaquah Hatchery	Hatchery	992	3	0.30%
		Bear Creek	Natural	2305	8	0.35%
		Cedar River	Natural	1726	8	0.46%
		Kenmore	Hatchery	853	2	0.23%
	2004	Bear Creek	Natural	1512	1	0.07%
		Cedar River	Natural	2185	8	0.37%
	2005	Issaquah Hatchery	Hatchery	409	3	0.73%
		Bear Creek	Natural	1424	8	0.56%
		Cedar River	Natural	2075	18	0.87%
Coho	2003	Bear Creek	Natural	2044	33	1.61%
		Cedar River	Natural	555	19	3.42%
	2005	Bear Creek	Natural	1207	15	1.24%
		Cedar River	Natural	1265	18	1.42%

Table 9. Summary of migratory-year adult return data, 2004-2007 ladder data combined. Diagonal sums equal number detected in ladder (e.g., shading = Bear Creek Chinook in 2007).

				In Year J		Number of Returning Adults Detected in Ladder				
Site	Species	Migratory Year J	Origin	Number of Smolts Released	Fraction Detected in Flumes [1]	Year J	Year J+1	Year J+2	Year J+3	Year J+4
Bear Cr	Chinook	2000	W	525	7%	--	--	--	--	0
Bear Cr	Chinook	2001	W	2132	13%	--	--	--	0	0
Bear Cr	Chinook	2002	W	2309	32%	--	--	0	2	0
Bear Cr	Chinook	2003	W	2305	35%	--	0	2	6	0
Bear Cr	Chinook	2004	W	1512	15%	0	0	0	1	--
Bear Cr	Chinook	2005	W	1424	24%	0	4	4	--	--
Bear Cr	Coho	2002	W	2661	65%	--	--	0	--	--
Bear Cr	Coho	2003	W	2044	72%	--	33	0	--	--
Bear Cr	Coho	2004	W	0	--	--	--	--	--	--
Bear Cr	Coho	2005	W	1207	56%	0	15	0	--	--
Cedar R	Chinook	2000	W	273	13%	--	--	--	--	0
Cedar R	Chinook	2001	W	1550	29%	--	--	--	3	1
Cedar R	Chinook	2002	W	814	21%	--	--	0	2	0
Cedar R	Chinook	2003	W	1726	30%	--	1	0	6	1
Cedar R	Chinook	2004	W	2192	15%	0	1	3	4	--
Cedar R	Chinook	2005	W	2075	27%	0	5	13	--	--

Table 9. Summary of migratory-year adult return data, 2004-2007 ladder data combined. Diagonal sums equal number detected in ladder (e.g., shading = Bear Creek Chinook in 2007).

				In Year J		Number of Returning Adults Detected in Ladder				
Site	Species	Migratory Year J	Origin	Number of Smolts Released	Fraction Detected in Flumes [1]	Year J	Year J+1	Year J+2	Year J+3	Year J+4
Cedar R	Coho	2002	W	1038	59%	--	--	0	--	--
Cedar R	Coho	2003	W	1027	66%	--	19	0	--	--
Cedar R	Coho	2004	W	0	--	--	--	--	--	--
Cedar R	Coho	2005	W	1265	50%	3	18	0	--	--
Issaquah	Chinook	2000	H	122	1%	--	--	--	--	0
Issaquah	Chinook	2001	H	4676	38%	--	--	--	4	2
Issaquah	Chinook	2002	H	4024	39%	--	--	2	5	0
Issaquah	Chinook	2003	H	992	28%	--	1	0	2	0
Issaquah	Chinook	2004	H	0	--	--	--	--	--	--
Issaquah	Chinook	2005	H	409	14%	0	2	1	--	--