Evaluation of Juvenile Salmonid Outmigration and Survival in the Lower Umatilla River Basin

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EVALUATION OF JUVENILE SALMONID OUTMIGRATION AND SURVIVAL IN THE LOWER UMATILLA RIVER BASIN

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EXECUTIVE SUMMARY

This is the fifth annual report of a multi-year project that monitors the outmigration and survival of hatchery and natural juvenile salmonids in the lower Umatilla River. This project supplements and complements ongoing or completed fisheries projects in the Umatilla River basin. Knowledge gained on outmigration and survival assists researchers and managers in adapting hatchery practices, flow enhancement strategies, canal and fish ladder operations, and supplementation and enhancement efforts for natural and restored fish populations.

Objectives and Tasks for FY 1999

Objective 1. Use PIT-tag technology to monitor tagged hatchery and natural juvenile salmonids emigrating from the Umatilla basin.

Task 1.1 Install a remote PIT-tag detection system at West Extension Canal.
Task 1.2 Initiate PIT- tagging and monitoring activities.
Task 1.3 Edit, send, and retrieve PIT-tag files.
Task 1.4 Develop tag interrogation capabilities at Westland Canal.

Objective 2. Determine migration performance and pattern, migrant abundance, and survival of PIT-tagged hatchery and natural juvenile salmonids in the lower Umatilla River.

Task 2.1 Determine trap collection efficiencies.
Task 2.2 Determine species composition, condition, and total weight of collected fish at Westland Canal during juvenile fish transport.
Task 2.3 Determine migration performance and pattern and migrant abundance of PIT-tagged hatchery spring and fall chinook salmon and summer steelhead in the lower Umatilla River.
Task 2.4 Determine migration performance and pattern, life history characteristics, and migrant abundance of tagged natural spring chinook salmon and summer steelhead and untagged fall chinook salmon within the lower Umatilla River.
Task 2.5 Estimate survival of PIT-tagged hatchery spring and fall chinook salmon and summer steelhead in the lower Umatilla River.
Task 2.6 Estimate survival of tagged naturally-produced juvenile salmonids in the lower Umatilla River.
Task 2.7 Estimate reach-specific survival and migration rate of PIT-tagged hatchery fish.
Task 2.8 Investigate effects of river and canal flow, water temperature, and other environmental variables on fish migration.

Objective 3. Participate in a pilot Radio Telemetry Study to validate survival estimates for summer steelhead from different release strategies.

Task 3.1 Assist with tagging of summer steelhead.
Task 3.2 Assist with receiver installation and monitoring of tagged fish.

Accomplishments and Findings for FY 1999

We achieved all three objectives and 12 of 14 tasks in FY 1999. We researched tag interrogation capabilities for Westland Canal and found that with current technology and cost, remote interrogation would not be feasible at this time. Although we did assist with monitoring in the pilot radio telemetry study, our overall involvement was limited. In addition to the required tasks, we observed and noted the presence of resident fish in our samples, avian predators near trap sites, and monitored the movement of juvenile Pacific lamprey.

We monitored juvenile migration at two locations in the lower river (RM 1.2 and 3.7) from early October 1998 through mid-July 1999. Throughout the rest of July until early August, we sampled at Westland Canal (RM 27.3) during juvenile fish transport operations. We did not monitor migration from early August through September due to low flows.

PIT Tagging and Interrogation

Monitoring of PIT-tagged fish at West Extension Canal was conducted 24 h/d, 25% through hand sampling and 75% through remote detection. The remote detection system consisted of a six-inch PVC pipe encased within a 400 kHz remote PIT-tag detector. Overall detection efficiency for the remote system was 96.8%.

Hatchery spring chinook salmon (March releases) and summer steelhead (late April small-grade release) were detected the least; yearling and subyearling fall chinook salmon were detected the most. Nearly 3% of the December-released spring chinook salmon were detected.

Tag groups of natural spring chinook salmon were detected proportional to tagged fish released upriver, but tag groups of natural summer steelhead were not. Tributary releases of tagged steelhead were detected proportionally less. Overall detections of species groups from the mainstem release site and within Meacham Creek were similar (11-17%). Lower river tagging of natural chinook salmon (792) and summer steelhead (1,891) supplemented upriver tribal tagging.

PIT-tag recoveries from island bird colonies were higher for summer steelhead than spring or subyearling fall chinook salmon; distinct colonies appeared to prey on each species.

Trap Efficiencies

At West Extension Canal, the mean of sub-pooled trap collection efficiency estimates was higher for races of hatchery and natural chinook salmon (32.7% - 45.3%) than for hatchery and natural summer steelhead (18.9% - 30.6%) and higher for natural fish than for hatchery fish. Most fish were detected within the first day or two after release, and all release groups had detections. Percent survival and tag retention for test fish during pre-test holding was greater than 90% in most tests.

Hatchery and natural chinook salmon released for trap efficiency tests showed similar patterns in diel detection, generally with peak detection the morning (0600 – 0700 hours) following an evening release. Detections of hatchery subyearling fall chinook salmon released both in the evening and mid-morning peaked shortly after release. Hatchery and natural summer steelhead detections increased in the morning.

Collection

Adjusted collection at the rotary-screw trap from 1 October through 8 March consisted mostly of hatchery spring chinook salmon (1,592) from a December release. Captures of natural salmonids (mostly spring chinook salmon) began in late November (spring chinook and coho salmon) and late December (summer steelhead).

Sampling at West Extension Canal was conducted from 8 March through 19 July. Collection totaled 100,651 salmonids, with hatchery fish comprising 97% of the collection. Over 3,000 natural fish were sampled, mostly summer steelhead (73%) and spring chinook salmon (25%).

Trap and Haul

During juvenile fish transport from 20 July to 5 August at Westland Canal, an estimated 11,573 salmonids were trapped and transported to the mouth of the Umatilla River. Hatchery subyearling fall chinook made up 94% of the collection. Natural salmonids included 55% chinook and 43% coho salmon.

Migration Parameters

For all hatchery species, PIT-tag detections revealed that migration duration decreased and mean travel speed to Three Mile Falls Dam increased the later the release date. Spring chinook salmon released in December were detected up to 141 d after release, but all other hatchery releases (salmon and steelhead) migrated within 47 d. Mean travel speed was highest for subyearling fall chinook salmon (5 mi/d) and lowest for summer steelhead (2 mi/d).

Migration of natural fish was longer in duration than the migration of hatchery fish, with natural spring chinook salmon and summer steelhead migrations lasting 74 d and 108 d, respectively. Natural spring chinook salmon migrated slower (2 mi/d) than hatchery spring chinook salmon (3.5 mi/d), except for the December hatchery release (0.8 mi/d). Natural summer steelhead migrated at 4.1 mi/d.

Mean travel speed increased the further upriver fish were released for all reach-specific survival test groups. Spring and subyearling fall chinook salmon reached West Extension Canal quickly, mostly within two weeks after release. Travel speed ranged from 1.34 – 8.39 mi/d and 0.93 – 5.43 mi/d, respectively. Large-grade summer steelhead tended to move steadily downriver for a month and a half following release (0.36 – 2.49 mi/d) and small-grade summer steelhead mostly reached West Extension Canal only a few weeks after release (0.56 – 2.89 mi/d). Mean travel speed from release site to John Day Dam on the Columbia River was similar for all groups, usually between 2 – 4 mi/d. Subyearling fall chinook salmon tagged for trap and haul evaluation at Westland Canal traveled twice as fast as all other test groups (8.93 mi/d) to John Day Dam.

Diel movements of most hatchery and natural salmonids passing West Extension Canal were similar. Most fish moved between sunrise and sunset, with peak movement at various times of the day. Generally, yearling chinook salmon were detected during mid-day and subyearling chinook salmon in the morning. Hatchery and natural summer steelhead peaked in movement during late afternoon and mid-morning, respectively.

Lengths and Weights

Hatchery salmonids showed a significantly larger mean fork length than natural conspecifics when tested monthly. Insufficient weight data was available for analysis.

Fin Clips

Percent recapture of hatchery yearling chinook salmon and summer steelhead with multiple fin clips was less than that for fish with a single fin clip or no fin clip at all. In addition, hatchery spring chinook, subyearling fall chinook, and coho salmon with single fin clips (AD) were recaptured less than those with no fin clips.

Fish Condition and Health

Of hatchery fish, subyearling fall chinook salmon were in best condition and summer steelhead were in poorest condition. Most hatchery and natural salmonids examined were undamaged (minimal scale loss). However, almost 50% of hatchery summer steelhead were partially descaled or descaled. Bird marks comprised >50% of the injuries on most hatchery fish. Natural fish exhibited few bird marks but were highly infested with parasites.

All of the natural chinook salmon and summer steelhead submitted for disease analysis tested positive for the presence of the Rs antigen (BKD), though ELISA values were mostly low to moderate. Hatchery spring chinook salmon analyzed also had low ELISA values when tested for the RS antigen. Visible evidence of disease was not present in any of the fish submitted.

Migrant Abundance and Survival

Survival was poorest for spring chinook salmon and best for yearling fall chinook salmon. April-released spring chinook salmon from out-of-basin hatcheries survived better (68.7%) than March-released fish (25.4%) from Umatilla and Little White Salmon Hatcheries. December-released fish survived at 49.5%. Conversely, yearling fall chinook salmon survived better when released in March (85.5%) than in April (70.8%). Of tagged subyearling fall chinook salmon released in June, 53.9% survived. Summer steelhead released in early April survived better (68.6%) than those released in late April (56.6%). Of the early releases, steelhead released at Minthorn survived best.

Survival was similar for tagged natural spring chinook salmon migrating from the upper Umatilla River and Meacham Creek. However, natural summer steelhead migrating directly from the upper Umatilla River survived better (57.0%) than those migrating from tributaries. Of the tributaries, steelhead from Meacham Creek had the highest overall survival (36.9%).

Reach-Specific Survival

Survival was determined for PIT-tagged release groups of different hatchery species released in the Umatilla River from RM 80 to RM 9. All groups generally exhibited an increasing trend in survival with lower reaches, especially summer steelhead. Exceptions were spring chinook salmon released at RM 80 (highest survival) and subyearling fall chinook salmon released at RM 9 (second lowest survival).

Mainstem detection trends showed progressively higher mean detection rates with successively lower releases for all species. Subyearling fall chinook transported from Westland Canal and released at RM 0 in July were detected the same as fish released at RM 48 in June.

Environmental Conditions and Bypass Operations

Flows peaked in the Umatilla River in late December and early January, reaching nearly 5,000 ft^3/s in the lower river. Flows were negatively correlated with Secchi depth and water temperature. Secchi depth ranged from less than 0.5 m to 2 m and water temperature ranged from 31 - 72 ^oF.

Correlations of fish passage with river flow and river temperature were variable based on detections at West Extension Canal. Detections of hatchery subyearling fall chinook salmon and both large- and small-grade hatchery summer steelhead were positively correlated with river flow. Hatchery spring and fall chinook salmon and natural summer steelhead showed a positive correlation with river temperature whereas large- and small-grade hatchery summer steelhead had negative correlations.

Correlations between travel speed and river flow provided variable results for hatchery fish released for production and reach-specific survival tests. A positive correlation was observed for spring chinook salmon released in December, as well as for all releases of subyearling fall chinook salmon and small-grade summer steelhead. Negative correlations were found for all other releases of spring chinook salmon, yearling fall chinook salmon, and most releases of large-grade summer steelhead. The exception was positive correlations for large-grade steelhead released for survival tests at two upriver sites.

Diversion rate at West Extension Canal influenced trapping efficiency of hatchery and natural chinook salmon but not summer steelhead. Phase I pump exchange generally curtailed collection. Subyearling fall chinook salmon peaked in their migration during water releases from McKay Reservoir.

Resident Fish and Avian Predators

Piscivorous resident fish captured included 182 juvenile bass and 79 northern pikeminnow. Sixty-eight bass and 4 northern pikeminnow were classified as predator-size fish. Juvenile Pacific lamprey were collected from November to April. Smolted lamprey were captured only in November and December; captures were positively correlated with river flow.

Primary avian predators included gulls, night herons, great blue herons, and cormorants. Gull activity was greatest during low flows and high fish abundance.

Management Implications and Recommendations

1. Upgrade to new ISO PIT tags and continue the use of PIT tags to monitor the outmigration patterns of hatchery and natural juvenile salmonids and to estimate their survival. PIT tags are an improvement over other marking methods used in the past (color marks and brands) because they provide more precise data and longer term “recoveries”.

2. Continue remote interrogation of PIT-tagged fish at West Extension Canal to provide in-basin information, reduce handling, and augment detections from mainstem dams. Upgrade to a 134 KHz detection system to correspond with mainstem changes and to accommodate the new ISO tags.

3. Continue transplanting adult fall chinook salmon from mid-Columbia hatcheries into the Umatilla River to enhance natural production. Although a low number of adult transplants in fall 1998 produced low numbers of juvenile migrants in 1999, successful natural production can result from the outplant strategy.

4. Consider releasing small-grade summer steelhead from the lower acclimation site at Minthorn and continue early volitional and forced releases of all other steelhead groups. This will provide additional information on the suitability of this release site for improving migration success. Research shows that fewer fish are detected from the late release at Bonifer.

5. Investigate the feasibility of a remote detection system (flat plate) at the east-bank ladder at Three Mile Falls Dam. A flat-plate detection system would allow monitoring of juvenile PIT-tagged fish at both dam passage routes, improving trap efficiency and abundance estimates, as well as provide for detection of returning adult PIT-tagged fish.

6. Continue release of stored water from McKay Reservoir through July to fully allow in-river migration of natural and hatchery salmonids. This will reduce the number of fish trapped at Westland Canal and transported to the river mouth and decrease the transport of rearing coho. Water releases can also temper stressful thermal conditions and provide improved rearing conditions for natural fish in the mid-reach section.

7. Provide and protect a minimum flow in the lower river from July through August by releasing stored McKay Reservoir water and activating Phase I pump exchange in the lower river. Having flow in the lower river during this critical period provides a passage corridor that permits expression of natural life histories and migration tendencies for both juvenile and adult salmonids.

8. Consider an expanded test to determine survival of in-river migrants in July, if flows are provided to allow such conditions. This will allow us to determine if in-river migrants survive better than transported fish.

9. Continue to rear yearling fall chinook salmon for the Umatilla program at Bonneville Hatchery. These fish show good migrant survival.

10. When sufficient flows are available, ensure that the east-bank fish ladder remains open during the summer. Closure of the ladder alters movement patterns of resident fish.

11. Operate the bypass facility at West Extension Canal with the river-return pipe open during Phase I exchange. This will aide in attraction of downstream migrants into the bypass system and alleviate holding and passage delay upstream of Three Mile Falls Dam.

12. Monitor movement of juvenile Pacific lamprey year round. This would provide important information on lamprey life history patterns and their relationship to environmental parameters.

13. Provide bird deterrents such as water cannons, rain bird sprinklers, mylar balloons or strips, noisemakers (i.e. firecrackers), or physical barriers at Three Mile Falls Dam and the bypass outfall. Avian predators are opportunistic and are abundant at Three Mile Falls Dam, particularly during times of low flow and high salmonid abundance. Deterrents may be a cost-effective way to discourage avian predation on juvenile salmonids.

INTRODUCTION

Large runs of salmon (*Oncorhynchus spp*.) and steelhead (*O. mykiss*) once supported productive Tribal and sport fisheries in the Umatilla River. By the 1920s, unscreened irrigation diversions, reduced in-stream flows, poor passage conditions, and habitat degradation had extirpated the salmon run and drastically reduced the summer steelhead run (CTUIR and ODFW 1989). Reintroduction of chinook salmon (*O. tshawytscha*) and coho salmon (*O. kisutch*) and enhancement of summer steelhead populations in the Umatilla River was initiated in the early and mid-1980s (CTUIR and ODFW 1989). Measures to rehabilitate the fishery and improve flows in the Umatilla River are addressed in the original Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (NPPC 1987). These include habitat enhancement, hatchery production, holding and acclimation facilities, flow enhancement, passage improvement, and natural production enhancement. Detailed scope and nature of the habitat, flow, passage, and natural production projects are in the Umatilla River basin fisheries restoration plans (CTUIR 1984; Boyce 1986). The Umatilla Hatchery Master Plan (CTUIR and ODFW 1990) provides the framework for hatchery production and evaluation activities. Many agencies cooperate, coordinate, and exchange information in the Umatilla basin to ensure successful implementation of rehabilitation projects, including the Oregon Department of Fish and Wildlife (ODFW), the U.S. Bureau of Reclamation (USBR), the Bonneville Power Administration (BPA), National Marine Fisheries Service (NMFS), Oregon Water Resources Department (OWRD), the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and local irrigation districts (West Extension, Hermiston, and Stanfield-Westland). The Umatilla River Operations Group and the Umatilla Management, Monitoring and Evaluation Oversight Committee coordinate river and fisheries management and research in the Umatilla River basin.

Monitoring and evaluation efforts to fine-tune specific restoration projects are ongoing or near completion. Evaluation of juvenile salmonid outmigration and survival in the lower Umatilla River basin is a necessary component for determining the success of these projects and the overall effectiveness of the rehabilitation plan. A critical uncertainty is whether juvenile salmonids are surviving and successfully migrating out of the Umatilla River basin. Potential factors determining survival of juvenile salmon in the Umatilla basin include loss through in-river predation, cumulative effects of passage through facilities at irrigation diversion dams, effects of poor river conditions and transport on fish health, and effects of hatchery rearing and release strategies. Smolt-to-adult survival is being assessed through the Umatilla Hatchery Monitoring and Evaluation Project (Keefe et al. 1993, 1994, Hayes et al. 1995, 1996, 1999a, 1999b, Focher et al. 1998, and Stonecypher et al. 2001), though results are broad in scope and reliant on long-term adult returns.

Information on migration success and performance of different rearing and release strategies for salmonid species within the Umatilla River supplement evaluation of specific practices at Umatilla Hatchery. Strategies for rearing at Umatilla Hatchery include use of standard Oregon raceways and oxygenated Michigan raceways and rearing at different fish densities. Some production groups released into the Umatilla River are also reared at other hatcheries. Release strategies include yearling versus subyearling production and varying release times for chinook salmon and graded summer steelhead (Appendix Table A-1).

In addition, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are investigating the natural production potential of each race or species of salmonid in the Umatilla River basin and the effects of hatchery supplementation on native steelhead (CTUIR 1994, Contor et al. 1996, 1997, 1998, 2000). Addressing these critical uncertainties has required the estimation and determination of survival, life history characteristics, distribution, composition, abundance, and production capacity of naturally-produced juvenile and adult salmonids in the Umatilla River basin. Monitoring in the lower river is crucial for determining movement patterns, migration timing, lower river abundance, and survival of naturally-produced salmonids originating in the upper river.

Previous outmigration monitoring of juvenile salmonids discerned different hatchery rearing groups through branded and color-marked fish (Knapp et al. 1996, 1998a, 1998b, 2000). The advent of PIT-tag detection at John Day Dam in 1998 prompted the initial use of PIT tags on hatchery fish in the Umatilla River basin.

Estimates of survival have been poor for some groups of fish in past years (Knapp et al. 1996, 1998a, 1998b, 2000). Release site (river mile distance) was thought to be a factor affecting survival. PIT tagging and monitoring in 1998 (Knapp et al. 2000) and again this year provided an opportunity to conduct reach-specific survival tests with PIT-tagged fish and gain a more detailed understanding of the effects of release site on survival.

Survival of juvenile salmonids can also be affected by poor conditions during their transport from Westland Canal (RM 27.3) to the lower Umatilla River. Juvenile salmon collected at Westland Canal undergo scale loss and stress during dip-net loading (Cameron et al. 1994) and crowding (Walters et al. 1994). The cumulative effect of collection, crowding, loading, and transport on the health of juvenile salmonids may result in poor survival after release. Testing the cumulative effects through treatment and control tests revealed greater injury and mortality of transported fish versus non-transported fish (Knapp et al. 1998a, 1998b). Detecting transported PIT-tagged fish at mainstem dams provides useful information on survival beyond the Umatilla River (Knapp et al. 2000).

A number of issues related to water use in the Umatilla River are associated with fisheries rehabilitation. Providing water for irrigators and anadromous fish is a desired goal of the Umatilla Basin Project (USBR 1988). An understanding of flow requirements for fish passage, rearing, and survival, and species-specific migration characteristics is critical to determine optimum canal operations, water release strategies, and flow enhancement strategies (USBR 1988, USBR and BPA 1989). Phase I pump exchange at West Extension Canal affects the efficiency of the bypass in routing fish past Three Mile Falls Dam (Knapp et al. 1996, 1998a, and 2000). Water releases from McKay Reservoir are important in allowing in-stream migration of juvenile migrants in late spring (Knapp et al. 1998a) and throughout summer (Knapp et al. 2000). Assessing these effects is done through monitoring at the bypass sampling facility and, in the past, partly through video monitoring at the east-bank ladder (Knapp et al. 1998b, 2000).

The most efficient methods of aiding fish passage and increasing survival in the Umatilla River are still unclear and require further evaluation.

The goal of the Outmigration and Survival Study is to evaluate the outmigration and estimate the survival of juvenile salmonids in the lower Umatilla River basin and investigate the various factors affecting migration and survival. General objectives for meeting this goal in the 1998-1999 project period were:

1. Use PIT-tag technology to monitor tagged hatchery and natural juvenile salmonids emigrating from the Umatilla basin.
2. Determine migration performance and pattern, migrant abundance, and survival of PIT-tagged hatchery and natural juvenile salmonids in the lower Umatilla River.
3. Participate in a pilot Radio Telemetry Study to validate survival estimates for summer steelhead from different release strategies.

In this report, we describe our fifth-year activities and findings for the Umatilla River Outmigration and Survival Study from 1 October 1998 to 30 September 1999. We present information from outmigration monitoring, including species, origin, and health of fish collected, lengths and weights, PIT-tag detections, migration patterns, and migration performance. We present trapping efficiencies, estimations of migrant abundance and survival, information on reach-specific survival and transport effects, and effects of environmental conditions. We also include observations of resident fish, anadromous lamprey, and avian predators.

STUDY SITES

We collected outmigration data from three sampling sites during 1998-1999. These sites included one in-river location below Three Mile Falls Dam and two irrigation canal screening facilities.

We collected data from below Three Mile Falls Dam using a 5-ft-diameter rotary-screw trap located below the I-82 bridge (RM 1.2; Figures 1 and 2). Descriptions of the rotary-screw trap and its deployment are included in Knapp et al. 1998a and 1998b. This site was used when operations at the West Extension Canal facility prevented trapping procedures there. We did not conduct trap efficiency tests for this site.

We collected data at the West Extension Canal bypass facility (RM 3.7) at Three Mile Falls Dam during the irrigation season from March to mid-July (Figure 2). Canal operations varied throughout the sampling season, affecting the degree of attraction flow guiding fish into the sampling facility. If canal diversion was reduced or eliminated, one of two methods was deployed to provide attraction flow. These methods included opening a 24-in pipe returning water to the river or turning on one or two pumpback pumps that circulate water through the bypass system. Further details on the operation of this canal and bypass facility can be found in Knapp et al. 1996. A remote PIT-tag detection system was added to the system for the 1998 - 1999 season (Figure 3). Releases for trap efficiency tests were made upriver at the Hermiston Waste Water Treatment Plant (RM 5.0; Figure 1).

We also subsampled at the Westland Canal screening facility (RM 27.3) during juvenile salmonid Trap and Haul operations in mid-summer. Descriptions of this facility are included in Knapp et al. 1996. We did not conduct trap efficiency tests at this site.

During low river flow, fish passage in the lower river is enhanced by pumping Columbia River water into West Extension Canal in lieu of diverting Umatilla River water (Phase I exchange). During full Phase I exchange, all canal flow is supplied by pumping, and water flowing through the bypass system is returned to the river. River flow is additionally augmented at times through releases of stored water from McKay Reservoir (Figure 1).

Tagging and holding of fish groups for reach-specific survival tests were conducted at Irrigon Fish Hatchery. Releases for reach-specific survival tests were made at various points further upriver near Hermiston (RM 8.8), Echo (RM 27.3), Rieth (RM 48.5), and specific acclimation sites above Pendleton (Figure 1).

METHODS

Outmigration Monitoring

PIT Tagging and Interrogation

We tagged fish of various species, races, and origins with 400 kHz Passive Integrated Transponder (PIT) tags for several purposes and tests. Hatchery fish were tagged for trap efficiency and reach-specific survival tests. Natural fish were tagged for trap efficiency tests and to provide augmented detection information at mainstem dams for Confederated Tribes of the Umatilla Indian Reservation (CTUIR) analysis. Tags for hatchery fish were obtained directly from the Pacific States Marine Fisheries Commission (PSMFC). Tags for natural fish were obtained from CTUIR.

Prior to tagging, we set up a tagging file in the PITAG.exe program on a laptop computer to record codes of implanted tags and to track the number of fish tagged. All fish were anesthetized with MS222 (tricaine methanosulfonate) and scanned for PIT tags prior to injection of a new tag. Fish were tagged according to standards outlined in the PIT Tag Marking Station Procedural Manual (PIT Tag Steering Committee, 1993). Immediately after tagging, fish were scanned with a 400 kHz tabletop detector to read and send the code directly to the tagging file. If length or weight data was taken, it was entered into the computer along with the tag code. If the laptop computer was not available, we scanned fish and stored tag codes directly to the reader and later downloaded those codes into a file. Codes and other fish data were also recorded on paper.

This was the first year that natural fish were PIT tagged in the upper Umatilla River by CTUIR. CTUIR selected natural fish for tagging based on size with the assumption that larger fish were actively migrating. Natural spring chinook salmon were collected, tagged and released at RM 80 of the Umatilla River and RM 2 of Meacham Creek. Natural summer steelhead were collected, tagged and released at the following locations in the upper Umatilla River basin: RM

80 of the Umatilla River, RM 2 of Meacham Creek, various locations in Squaw Creek, Buckaroo Creek, Pearson Creek, and Birch Creek, and the east and west forks of Birch Creek.

We used two methods to interrogate fish captured at lower river trapping sites for the presence of PIT tags - passive and active interrogation. Remote detection (passive interrogation) at West Extension Canal eliminated the need to sample 24 h per day. For passive interrogation, fish that entered the trap were diverted to a six-inch PVC pipe encased within a 400 kHz remote PIT-tag detector (Figure 3). Once fish passed the detector they were returned to the bypass downwell via another six-inch diameter PVC pipe. The remote detector was connected to a reader and laptop computer housed in a waterproof, metal case mounted above the sampling area approximately 6 feet from the detector. We used a Tunnel.exe program (Biomark, Boise, ID) to record tag codes of PIT-tagged fish and date and time of passage through the detector. Data was simultaneously recorded in an interrogation file on the hard and floppy drives of the laptop computer. We changed the floppy disk on a daily basis. A new interrogation file was created any time the floppy disk was changed and automatically at 2400 hours every evening. Interrogation files were transferred to a desktop hard drive at the office.

We conducted daily efficiency tests for the remote detector using a stick with an embedded known PIT-tag code. The 4-in-long x 1-in-diameter stick was attached to a secured string. The code stick was placed in the flume above the detector and allowed to float freely through the detector to simulate fish movement. On two occasions daily, two different test sticks were passed through the detector 3 times for a total of 6 runs. We recorded detection for each pass. We also recorded the level of the water flowing through the pipe (e.g., 50% full) to ascertain affects on detection efficiency.

During sampling at West Extension Canal and the rotary trap, we hand interrogated (active interrogation) all sampled fish for PIT tags (except coho salmon, which were not tagged). As in tagging, we scanned codes from PIT-tagged fish into a monitoring file using the PITTAG.exe program. Monitor files consisted of recaptured fish codes and codes from natural fish that were tagged and released. A new monitor file was created for each trap check period. If the laptop computer was not available, we stored codes on the reader and downloaded the data at the office. We collected length and weight data on most recaptured tagged fish. Fish were placed in a recovery tank after interrogation and released into the river when recovered.

Fish tagged for trap efficiency tests were scanned and codes were recorded into a tagging file. If we were tagging during sampling, tagging files included test fish codes and recapture fish codes. A new tagging file was created for each test and species. Files were transferred to a floppy disk and transported to the office where they were transferred to a desktop computer.

All tagging and monitoring files were edited and verified using the PITVAL2 program then sent to the PTAGIS database via the internet. Interrogation files were validated as they were created and were sent directly to PTAGIS.

Columbia River detection sites were operating by early April 1999. We downloaded tag information from the PTAGIS database to determine tag detections of our test fish at mainstem Columbia River dams (John Day and Bonneville dams) and in the Columbia River estuary, and for tag recoveries at Columbia River islands. Island tag recoveries reflected predation by birds.

We looked into the feasibility of installing a flat plate PIT-tag detection system at Westland Canal for use during the Trap and Haul Program. We conversed with experts in the PIT-tag field and reviewed schematics of the Westland Canal facility.

Trap Efficiencies

We used trap collection efficiencies to expand the detections of tagged fish for an estimate of tagged migrant abundance. Trap efficiency tests were conducted only at West Extension Canal, and test fish were tagged with PIT tags. Tests were species specific with both hatchery and natural fish. A final trap collection efficiency estimate was a multi-step process that involved determining the probability of survival of tagged fish released for trap efficiency tests and determining the detection efficiency of the remote detector (*see* **PIT Tagging and Interrogation**). We also determined tag retention efficiency, but this estimate was not used in adjusting the trap efficiency estimate. We assumed tag loss would be negligible after the 24 – 48-h holding period.

We determined trap collection efficiency at West Extension Canal by releasing a known number of tagged fish (M) upstream of the trap and detecting them at the trap (m) over the duration of the monitoring period. Releases were made 2-4 times each week for each species and rearing origin of fish. For each test group, we compared daily trap efficiencies using Chi^2 analysis and pooled the test data if the efficiency estimates were not significantly different at an alpha level of 0.05. If all daily estimates were not significantly different, a final pooled trap efficiency estimate was determined as the ratio of total fish detected to total fish released over the collection period (TE = m/M). On occasion, significant differences between days resulted in sub-pooling of trap efficiencies for specific periods. The final trap efficiency estimate was the weighted mean of the sub-pooled estimates. Furthermore, because we could determine when specific groups of fish were being detected, we computed a running average of the sub-pooled estimates for the period in which fish were present. We expanded the detection of tagged hatchery and natural fish by this estimate to derive an abundance estimate for tagged fish during that period.

We counted the number of fish that died during the 24-h holding period to assess the probability of survival (s) of remaining live fish released for trap efficiency tests. The number of live fish released (R) was adjusted for survival (s) to obtain the adjusted number of tagged fish available for detection (T; R(s) = T). As with the daily trap collection efficiencies, we compared daily survival estimates using Chi^2 analysis, and pooled the data if survival estimates were not significantly different. All detections were adjusted by the overall detection efficiency estimate.

For trap efficiency tests, we used healthy untagged hatchery and natural fish sampled at the collection facility. Species tagged included yearling chinook salmon, subyearling fall chinook salmon and summer steelhead; yearling hatchery chinook salmon could not be differentiated between spring and fall races. Of hatchery fish, we tagged only unclipped chinook salmon, but used AD- and ADLV-clipped summer steelhead to obtain sufficient numbers. We tagged test fish with 400 kHz PIT tags as described in **PIT Tagging and Interrogation**. In general, hatchery chinook salmon were tagged on the sampling day but natural fish and hatchery summer steelhead were accumulated over several days to obtain sufficient numbers for tagging. We tagged approximately 50 to 150 fish, depending on the availability of fish and current recapture estimates.

After tagging, fish were held in special net pens for 24 h to assess latent mortality and tag loss. These enclosed net pens incorporated a large-meshed false bottom to allow lost tags to fall to the small-meshed bottom of the pen. Net pens were held in a large circular tank supplied with inflow water from the canal. We measured water temperature at the start and end of holding. Before test release, we scanned the tag codes of dead fish and retrieved and scanned ejected tags. If a dead fish had no tag, an ejected tag was attributed to that fish. Tagged, live fish were transported to the release site at the Wastewater Treatment Plant (Figure 1) in an un-insulated, aerated, 300-gal slip tank. At the release site, dead fish and ejected tags in the transport load were retained and scanned for codes. Ejected and tagged dead fish tags were removed from the tagging file. Releases were generally made in the early evening, but subyearling chinook salmon were occasionally released in mid-morning.

Released fish were detected at West Extension Canal via the remote detector or during hand sampling. To determine if detected codes were from trap efficiency fish, we manually searched the tagging files for detected codes on a regular basis. This allowed us to keep abreast of tag recaptures and to make adjustments in future tagging numbers, if necessary.

Collection

Fish were collected to determine trends in species composition, to note the presence of natural fish, and to obtain fish for trap efficiency tests. The rotary-screw trap was generally checked once every one to three days, usually in the afternoon. Data collected at the rotary trap was expanded to account for times when the trap was not sampling (during trap checks) by dividing by the proportion of the time sampled. Data was expanded for species, race, origin, marks, and fin clips. We did not extrapolate data for days when the trap was not sampling (i.e. floods, ice). Sample data from the West Extension Canal facility was expanded to account for sampling rates less than 100%. Percent of time sampled was also determined, but in general, data was not expanded by non-sampled periods. Sampling was conducted periodically throughout the day (0600-2400 hours). Fish were routed through the remote PIT-tag detector when not being sampled.

Juvenile fish were anesthetized using a stock solution of MS222 before evaluation (40 mg/l). We identified and counted juvenile salmonids by species, race, and origin (hatchery or natural). Yearling hatchery spring and fall chinook salmon were primarily differentiated from natural fish by a clipped adipose fin (if coded-wire tagged), or by size and condition if not adipose-fin clipped. Hatchery fish were generally larger than natural fish and in poorer condition (scaling, fin erosion, deformities, etc.). Hatchery summer steelhead were differentiated from natural fish by the absence of an adipose fin on hatchery fish. Subyearling fall chinook salmon that were not adipose-fin clipped were differentiated from natural subyearlings by the presence of a blank-wire tag (all fall chinook salmon from Umatilla

Hatchery have a CWT or BWT). We used a tabletop metal detector to determine the presence of a wire tag. Coho salmon that were not adipose clipped were differentiated from natural fish based on size or time of year when captured. Generally, coho salmon <100 mm in fork length were considered naturally produced when both hatchery and natural fish were in the river early in the season. Larger fish may have also been considered of natural origin based on their excellent overall appearance and condition. However, all coho salmon collected at Westland Canal in July and August were considered natural origin.

We scanned all chinook salmon and summer steelhead for PIT tags (coho salmon were not PIT tagged). Length and condition data was collected on subsamples of hatchery fish and all natural fish throughout the field season. Scale samples were collected mostly from natural summer steelhead exhibiting smolt characteristics and were analyzed by CTUIR biologists for age and rearing information. Limited scale samples were also collected from other species to ascertain origin or race.

Trap and Haul

In conjunction with CTUIR, we examined fish collected at Westland Canal during Trap and Haul operations. We collected length and condition data on juvenile salmonids while CTUIR recorded species composition and fish per pound data (CTUIR and ODFW 1999). Fish were collected with dipnets from the juvenile fish holding pond at Westland Canal, anesthetized, counted, and identified to species. We scanned all chinook salmon and summer steelhead for the presence of PIT tags. We examined a subsample of salmonids for scale loss and measured fork length to the nearest millimeter.

We used species composition and fish per pound data to estimate the total number of fish by species collected at Westland Canal during Trap and Haul operations (CTUIR and ODFW 1999). We used estimates of number of salmonids per pound multiplied by the total number of pounds transported to estimate the number of salmonids collected each day. We then divided the estimated number of each species by the total estimated number of salmonids for the day to determine the species percent by day. Daily totals were summed to estimate total number of fish collected at Westland Canal. For days when fish were transported and no fish per pound data was collected, we averaged data collected from preceding and following dates on which sampling was conducted to interpolate missing data. Weight of non-salmonids was not subtracted from total transport weight.

Migration Parameters

We determined migration duration, pattern, and timing, identified dates of peak movement, and calculated mean travel speed for hatchery and natural salmonids using PIT-tag detections from lower river traps. Migration parameters were analyzed for production fish, reach-specific survival test fish, trap efficiency test fish, and natural fish. Migration duration was the length of time from initial to final detection. Migration timing was the cumulative percent detection of a fish species over time. Migration patterns and periods of peak movement were identified from a plot of daily detections through time. Median detection was the 50th percentile detection. Mean detection was the average of individual detections. We determined a weighted mean travel speed using the travel speeds (mi/d) of individual tagged fish. Travel speed was estimated using miles from release to detection site divided by days from release to detection. We determined diel movement of PIT-tagged fish by plotting the exact time when tags were detected at West Extension Canal.

We determined migration timing to John Day and Bonneville dams on the lower Columbia River for reach-survival test fish. We documented fish consumed by terns or gulls by subsequent tag retrieval from mainstem island colonies.

Lengths and Weights

We measured fork length (FL) to the nearest millimeter (mm) of all natural salmonids and a portion of hatchery salmonids. On a monthly basis, we estimated mean, minimum, and maximum fork length for each species and race of hatchery and natural fish. Spring chinook salmon were identified by date of capture (before fall chinook salmon were released), the presence of an ADLV fin clip, or PIT-tag verification. Yearling fall chinook salmon were identified only through PIT-tag verification. We used the t-test to test for significant differences between lengths of hatchery fish and lengths of natural conspecifics over the collection period. We took weights on a portion of natural salmonids when they were tagged and on a portion of tagged natural and hatchery salmonids recaptured at the rotary-screw trap and West Extension Canal. Weights were recorded to the nearest tenth of a gram (gm) using an OHAUS Portable Advanced scale and reported as mean, minimum, and maximum weights on a monthly basis.

Fin Clips

We examined each salmonid captured for fin clips. A portion of hatchery fish reared at Umatilla, Little White Salmon, and Carson hatcheries was given coded-wire tags (CWT) and marked with fin clips. Coded-wire tagged fish (spring chinook salmon) reared at Umatilla Hatchery were given an adipose fin clip (AD) and those reared at Little White Salmon and Carson hatcheries were marked with an adipose and left ventral fin clip (ADLV). Some yearling and subyearling fall chinook salmon were given a coded-wire tag and marked with an adipose fin clip while others were given a blank-wire tag (BWT) and no fin clip (NC). Coho salmon were either unmarked (no fin clip), or marked with an adipose clip if they had a coded-wire tag. All summer steelhead were adipose fin clipped. Those with a coded-wire tag were also left ventral fin clipped.

We determined the percent recovery of each clip by species to ascertain survival or collection differences between clips. For chinook salmon, races were combined due to similarities in fin clips (AD) and the failure to scan all fish for a wire tag. However, chinook salmon with an ADLV fin clip were known to be of spring origin. Percent recovery was determined using raw counts that were not expanded by sample rate or periods not sampled. We used the binomial test (Snedecor and Cochran 1989) to determine differences in recapture rates of fish with different clips.

Fish Condition and Health

Subsamples of hatchery and natural fish were examined for scale loss and other bodily injuries to determine fish condition. We categorized scale loss following criteria used by the Umatilla Hatchery Monitoring and Evaluation study (Keefe et al. 1994). We considered fish health "good" if cumulative scale loss on either side of the fish was less than 3%. We considered fish "partially descaled" if cumulative scale loss exceeded 3% but was less than 20% on either side of the body, and "descaled" if cumulative scale loss equaled or exceeded 20%. We determined the proportion each condition category comprised of total fish examined. We also examined fish for external parasites and other injuries to the head, eyes, operculum, body, and tail. We noted fungal infections on the body surface, indications of bacterial kidney disease (BKD), and bird marks. Symmetrical bruises on each side of the fish identified bird marks.

Fish mortalities were noted by species and identified as to whether they occurred prior to or during sampling. Sampling mortalities were omitted when computing percent mortality of collected fish. Percent mortality was determined from the total number of fish sampled, not just examined. All dead natural fish and some diseased and dead hatchery fish were examined by the ODFW Fish Pathology Lab to determine fish health status. Unusual marks or indications of disease on dead fish were also noted.

Abundance and Survival

Migrant Abundance and Survival

We estimated migrant abundance for each race or species of salmonid that was PIT tagged to estimate total outmigration and survival of tagged hatchery and natural fish. Migrant abundance was determined from data collected at the rotary trap and at the West Extension Canal facility. We also estimated abundance of non-tagged spring chinook salmon captured at the rotary trap and all natural species captured at both sites. We estimated migrant abundance (A) by multiplying the number of tagged fish detected (D) during the season at a specific trap site by the reciprocal of the efficiency estimate ($1/TE$) for the collection period ($A = D \times 1/TE$; Burnham et al. 1987; Dauble et al. 1993). The efficiency estimate was a running average of subpooled or singular estimates (see **Trap Efficiencies**). We summed subtotals of abundance at each trap site for a total abundance estimate over the collection period (October – July). We used the Bootstrap method (Efron and Tibshirani 1986; Thedinga et al. 1994) with 1,000 iterations to determine the variance of production abundance estimates. Variances for abundance subtotals were summed to derive an overall variance. Confidence intervals (95%) for the abundance estimate were calculated using the square root of the variance estimate ($CI = 1.96 \sqrt{V}$).

We estimated natural fish abundance (A) by relying on several expansion factors to extrapolate for missing data. Total abundance of tagged and untagged fish combined was determined on a monthly basis and summed for the season. At West Extension Canal, count of fish from hand sampling was expanded by the sample rate during the specific sampling period (*C*). We generally sampled within a block of time during the day, but some of the time was not sampled within this block. We adjusted *C* by the portion of time sampled (*T*) to account for unsampled hours within the block. Using the diel pattern of movement through the facility (from tag detections), we determined the proportion of the diel distribution that the sampling block encompassed (*D*) to make a final adjustment for number bypassed through the facility ($B = (C/T)/D$). Abundance (or total passage) was derived by expanding number bypassed (*B*) by the average trap efficiency estimate (*TE*) for that month ($A = B/TE$) for that species. For months where trap efficiencies were not available, we used estimates from hatchery conspecifics. If hatchery conspecific efficiencies were not available for that month, we used estimates from the month before or month after.

To estimate abundance of hatchery or natural fish at the rotary-screw trap, capture number was adjusted by the proportion of time sampled, the retention efficiency of the trap for that species, and a trap efficiency estimate. Retention and trapping efficiency for natural fish was based on estimates for hatchery conspecifics. Retention and trapping efficiency for hatchery fish were based on 1998 estimates (Knapp et al. 2000). Since no retention efficiency estimates were available for natural or hatchery steelhead, we assumed a 50% retention efficiency based on a 77% efficiency estimate for spring chinook salmon in 1998. Similarly, since no trap efficiency estimates were available for natural or hatchery steelhead, we used a trap efficiency estimate of 1%, assuming the efficiency for natural summer steelhead would probably be around half that of yearling spring and fall chinook salmon (2.1 - 3.7%; Knapp et al. 2000) due to their ability to avoid the trap.

Survival estimates ($S = A/R$) for hatchery and natural fish were based on the migrant abundance method (Burnham et al. 1987; Dauble et al. 1993) where survival (*S*) was estimated as the proportion of tagged migrants passing the sampling site (*Abundance* = *A*) to the number of tagged fish released at upriver sites (*R*). We used this method to estimate survival of all PIT-tagged fish groups. The binomial test was used to test for significant differences in survival between production release groups.

We assisted in a pilot radio telemetry study conducted by Umatilla Hatchery Monitoring and Evaluation personnel to determine emigration success of hatchery steelhead (Stonecypher et al. 2001). Using a Lotek SRX-400 mobile tracking receiver, we assisted in tracking 20 small-grade summer steelhead released at Bonifer Springs (RM 79) on 5 May 1999. Mobile tracking was performed from two miles above Bonifer Springs down to Stanfield Dam (RM 32.4). Mobile tracking occurred biweekly and extended through the 44-d battery life.

Reach-Specific Survival

Reach-specific survival tests were conducted for hatchery spring chinook salmon, summer steelhead, and subyearling fall chinook salmon. To determine reach survival, these fish were released at three lower river locations (RM 42 or 48, RM 27, and RM 9 or 11) in addition to the standard release site at the respective acclimation facilities (RMs 80, 79, 74, and 64). After PIT tagging, test fish groups were held separately at the hatchery in indoor circular tanks until time of release; therefore, test fish were not acclimated upriver. Mortality was recorded on a daily basis. Tag loss was determined at the end of holding. Consumption of tags was discovered during tag scanning prior to release.

Test groups included three groups of spring chinook salmon (250 fish/group), seven groups of summer steelhead (250 fish/group), and three groups of subyearling fall chinook salmon (500 fish/group). The seven summer steelhead groups were separated into four large-grade steelhead groups and three small-grade steelhead groups released in April and May, respectively. For each species, test-group releases were split into three consecutive-day releases (replicates), immediately following the normal production release from the acclimation facility. On the day of release, fish were scanned for a PIT-tag code and measured (FL), placed in site-specific 30-gal containers with lids, and transported in an aerated 300-gal slip tank to each release site. Fish were released either by hauling the entire container down to the river or loading batches of fish in five-gal buckets for release.

Fish were interrogated in the lower river at West Extension Canal, either through the remote detector or during hand sampling. To determine if detected codes were from reach survival tests, we manually searched the tagging files for detected codes on a regular basis. This allowed us to keep abreast of tag recaptures. Final detections were derived from the PTAGIS database.

Estimates of survival were computed by various methods. For detection in the Umatilla River (West Extension Canal), we expanded detections of each replicate release group by corresponding trap efficiencies to derive an estimate of abundance and mean survival for the entire group. We determined significant differences in survival among sites using ANOVA with untransformed data, followed by Duncans multiple comparison test when ANOVA results were significant. We also derived a relative survival index (mean percent detection for each release site) using all non-duplicate tag detections within the Umatilla and Columbia rivers, including tag recoveries at island bird colonies. We similarly used ANOVA to test for differences among sites. Variances of the means were used to compute 95% confidence intervals. Tag detections within the Columbia River were downloaded from the PTAGIS database.

A separate test was conducted at Westland Canal (RM 27.3) in late July during Trap and Haul operations to determine relative survival to John Day Dam of transported fish. In this test, three groups of about 166 PIT-tagged subyearling fall chinook salmon were released into the holding pond at Westland Canal immediately prior to loading and transport to the mouth. These fish were tagged and held at the hatchery and transported to the canal several days prior to the first test release. Prior to transport from the hatchery, fish were scanned for tag codes and separated into three release groups. At Westland, fish were held in separate net pens in the canal for 4 to 10 d to acclimate them to ambient water temperatures. On the day of transport to the river mouth, and after fish samples were collected for species composition sampling, one net pen of test fish was released into the pond to be collected for transport. Net pen mortalities were usually counted on the day of release. Tag detections within the Columbia River were downloaded from the PTAGIS database. We compared these detections with mainstem detections of fish released at reach sites in June.

We also tagged a small group (57) of subyearling fall chinook salmon directly at Westland Canal that were collected at the canal in late July. This procedure was a test to determine if on-site tagging was feasible for future transport tests.

Environmental Conditions and Bypass Operations

We conducted daily monitoring of physical river and environmental conditions at each lower river trap site to characterize conditions in the Umatilla River and assess their relationship to fish migration. At the rotary-screw trap, we recorded air and water temperatures (^{o}F), debris level, water color, water clarity, and river elevation once daily at the time of check, usually in the afternoon. We also recorded cone rotations per minute before and after debris removal. At West Extension Canal, we recorded air and water temperatures (^{o}F), water clarity, and bypass operations once daily at 1200 hours. Bypass operation information included when pumpback pumps were on and off, when the river-return pipe was open or closed, and the opening on each of three headgates. River conditions at the bypass facility (as stated for the rotary trap) were measured at approximately six-hour intervals, beginning at 0200 hours and ending at 2000 hours.

At both trap sites, we measured daily maximum and minimum water and air temperatures using a Taylor Max-Min thermometer. In addition, daily thermograph data (mean temperature) from Three Mile Falls Dam was provided by CTUIR and was plotted against river flow (RM 3.7) and percent detection of each species. We categorized debris level as low, moderate, or high, and water color from clear to dark brown. Water clarity was measured to the nearest 0.05 m using a 7-in-diameter Secchi disk attached to a PVC pipe; we averaged the depth at which the disk disappeared from sight as it was lowered and reappeared in sight as it was raised to obtain a mean Secchi depth. At the rotary-screw trap, we recorded river elevation to the nearest 0.05 ft on a staff gauge, and at West Extension Canal, river and canal elevations were recorded to the nearest 0.10 ft above sea level.

We obtained river flow data (ft^3/s) recorded below Three Mile Falls Dam (UMAO gauging station, RM 2.1) from the U.S. Geological Survey. Flow data from other upriver gauging stations for Water Year 1999 was obtained from the U.S. Bureau of Reclamation's (USBR) HYDROMET (hydrological-meteorological) data acquisition system. These gauging stations are located near Stanfield (UMDO, RM 24.4), Yoakum (YOKO, RM 37.6), McKay Creek (MCKO, RM 52), and Pendleton (PDTO, RM 55.3). The USBR also provided canal flow data for West Extension Canal and information on water releases from McKay Reservoir. Diversion into West Extension Canal was calculated by subtracting the Phase I exchange amount (WEPO gauging station) from canal flow measured at the WEIO gauging station located below the pumped inflow. When the canal checkgates were closed during Phase I water exchange, the diversion amount was adjusted to be at least 5 ft^3/s (when the river return pipe was closed) or 20 ft^3/s

(when the river return pipe was open) to account for flow running through the bypass channel. Flow at the dam (RM 3.7) was calculated by adding the UMAO flow data and the unadjusted canal diversion flow data (UMAO data includes bypass flow that has been returned to the river). Diversion rate was calculated by dividing the diversion amount by the sum of the diversion amount and flow at the dam. The relationships between diversion rate and trap efficiencies for each test group were then determined using correlation analysis.

The linear relationship between mean river flow and fish travel speed was assessed through correlation analysis using SAS and Excel. Travel speed (mi/d) was calculated from the river mile of release to Three Mile Falls Dam (RM 3.7) for all detected salmonids. Mean flow for the river corridor was derived from recordings at all Bureau of Reclamation HYDROMET gauging stations below the release point.

Resident Fish and Avian Predators

All resident fish captured during the sampling season were identified and their presence noted. We counted northern pikeminnow (*Ptychocheilus oregonensis*), bass (*Micropterus spp.*) and Pacific lamprey (*Lampetra tridentata*) at each trap check. All other species were noted but not enumerated. We identified lamprey with silvery coloration and visible eyes as metamorphosed juveniles (smolted) and lamprey with brown coloration and unidentified eyes and mouth as larvae (non-smolted). We measured fork lengths of northern pikeminnow and bass and total lengths of Pacific lamprey to the nearest millimeter (mm). We calculated overall mean lengths for smolted and non-smolted lamprey. We developed length-frequency distributions for northern pikeminnow, bass, and Pacific lamprey. We also plotted river flow (ft^3/s) against number of lamprey captured over time and used correlation analysis to determine a linear relationship.

Avian predators were noted at both trap sites on an intermittent basis. We recorded species and number of each avian predator and the date and time observed. Dividing the number of observed predators by the number of times observations were made standardized the number of avian predators observed per day. We plotted the number of gulls observed with river flow (ft^3/s) above Three Mile Falls Dam and with the number of fish detected over time.

Statistical Analyses

We used linear correlation (Pearson Correlation) to examine relationships between environmental variables and fish detection data, canal diversion rate and fish collection efficiencies, and detection efficiency and bypass flume water level.

We used Chi^2 tests of independence to determine significant differences between daily trap efficiency estimates and daily survival probabilities. Differences in the proportion of PIT-tagged fish detected or fin-clipped production fish recovered were tested with the Binomial test (Snedacor and Cochran 1989). We used t-tests to determine significant differences in fork lengths between hatchery and natural fish and to test water temperature between years. We used

Analysis of Variance (ANOVA) and Duncans multiple range test to test survival or relative detection differences among reach sites. Proportional data was not transformed. We used SAS (Statistical Analysis Systems) for personal computers (SAS Institute 1990), MS Excel, and hand calculations to conduct our analyses. All tests were performed at a significance level of alpha = 0.05.

RESULTS

Outmigration Monitoring

PIT Tagging and Interrogation

We created 240 interrogation files from remote detection from 9 March to 9 July 1999 (123 days sampling). We created 198 monitor files from 6 December 1998 to 13 July 1999 (219 days sampling). Ninety-one trap efficiency files were created from 10 March to 3 July (116 days sampling). We interrogated the PTAGIS database in December 1999 and January 2000 to retrieve tag data. Most PTAGIS reports were finalized by February 2000.

We conducted detection efficiency tests for the remote detection system from 10 March to 8 July 1999. Overall detection efficiency was 96.8% (Appendix Table A-2). The pipe was charged with water from 25 – 100% full during tests and detection efficiency ranged from 67 - 100%. There was no correlation between detection efficiency and water level (r = -0.09).

We PIT tagged 792 natural chinook salmon from December 1998 to May 1999 and 1,891 natural summer steelhead from December 1998 to June 1999 (Table 1). Most fish were tagged at West Extension Canal during peak movement. Detections of these fish at mainstem dams were later analyzed by CTUIR's Natural Production M & E Study (Contor et al., In Preparation).

Most PIT-tagged fish of hatchery and natural origin were detected by the remote detection system at West Extension Canal (91%; Table 2). Only 5 tagged hatchery spring chinook salmon were detected at the rotary trap in January, and one subyearling fall chinook salmon was detected at Westland Canal in July. Of hatchery species, yearling and subyearling fall chinook salmon were detected in similar proportions overall, as were spring chinook salmon and summer steelhead. A larger number of spring chinook salmon and summer steelhead were detected by hand than subyearling fall chinook salmon because of increased subsampling effort during their peak migration. We were unable to track one PIT-tagged hatchery chinook salmon to its original release group because the code was not recorded in any of our tagging files. Of natural species, percent detection of tagged natural chinook salmon was nearly twice the percent detection of tagged summer steelhead (Table 2). Of the total number detected for both species, 84% (spring chinook) and 88% (summer steelhead) were detected remotely.

The proportion each tag group of natural spring chinook salmon comprised at release at the Meacham Creek (RM 79) and mainstem Umatilla River (RM 80) sites was similar to the proportion each tag group comprised total detection in the lower river (Table 3). In addition, approximately 16% of each tag group was detected. However, proportion of tagged summer steelhead detected was not similar to the proportion of tagged fish released upriver at various mainstem and tributary sites. Relative detections from releases at smaller tributary sites were less and detections from the mainstem site (RM 80) and Meacham Creek were more than the tagged proportions at release (Table 3). Detections of natural steelhead tagged and released at Buckaroo, Squaw, and Birch creeks ranged from 2.2-5.2%. Detections of tagged steelhead released in Meacham Creek and at RM 80 were near 11% and 17%, respectively.

March releases of spring chinook salmon from Umatilla and Little White Salmon hatcheries had fewer detections than April releases from Little White Salmon and Carson hatcheries (Table 4). The 2.9% detection for hatchery spring chinook salmon released in December included 5 fish detected at the rotary trap and 9 fish detected later at West Extension Canal. Percent detection of the March and April releases of yearling fall chinook salmon from Bonneville Hatchery were similar to each other and to the April releases of spring chinook salmon from Little White and Carson hatcheries. Percent detection of summer steelhead reared at Umatilla Hatchery was slightly less for small-grade fish released in late April than for large-grade fish released in early April. Percent detections of spring chinook salmon from different rearing strategies (Oregon vs. Michigan) at Umatilla Hatchery and released in March were similar, as were detections for subyearling fall chinook salmon reared at different densities and released in June (Table 4). Percent detection for spring chinook salmon reared in Oregon raceways and released in December was lower than the March release, but ice up at the rotary-screw trap prevented sampling for 10 days in late December and early January. These fish were being reared at Imeques acclimation facility and were emergency released in December due to ice at the facility.

PIT-tag recoveries from islands in the mainstem Columbia River where bird colonies exist ranged from 0.80 - 3.61% for fish tagged for reach-specific survival tests (Appendix Table A-3). Large-grade summer steelhead released in April suffered the highest mortality; 69% of the mortality was from the Rice Island rookery (RM 21). However, the highest mortality for subyearling fall chinook salmon (42%) was from the mid-Columbia River rookery on Three Mile Canyon Island (RM 256).

We discontinued our effort at designing a PIT-tag interrogation system for Westland Canal during juvenile trap and haul operations. We concluded the cost was too high for the minimal data that would be provided, and the technology had not advanced to a usable form for the required situation.

Trap Efficiencies

All trap efficiency tests were conducted at the West Extension Canal trap (RM 3.7). We tagged 103 hatchery spring chinook salmon, 1,611 combined spring and fall chinook salmon, 1,708 subyearling fall chinook salmon, and 1,571 summer steelhead for trap efficiency tests (Table 5). We also tagged 560 natural chinook salmon and 1,608 natural steelhead. Percent survival and tag retention during holding was greater than 90% in most tests. On occasion, unusually high tag loss (>20%) was observed for hatchery chinook salmon and summer steelhead; stressful tagging conditions caused a 17% loss of natural steelhead in late May. There were no significant differences in survival during holding tests within each hatchery and natural species. Therefore, data was pooled to derive an overall survival estimate for trap efficiency-released fish. Estimated pooled survival for hatchery and natural species ranged from 97.8 – 99.4%.

Significant differences were found among daily trap efficiency estimates for all groups; therefore, subpooling was required (Table 6). Mean pooled estimates ranged between 18.9 – 44.0% for hatchery fish and 30.6 – 45.3% for natural fish, with the lower estimates representing steelhead. Trap efficiency estimates for hatchery subyearling and natural yearling chinook salmon were remarkably similar (Table 6).

Eighteen releases were made for hatchery chinook salmon from mid-March to mid-May, including one release of strictly spring chinook salmon (Table 6). Fish were detected from all releases from 1 to 53 d after release. Most fish were detected within the first day or two after release. Mean travel time from release to detection was longest for the first two releases in March (> 9 d) and progressively shortened by April and May (2 – 6 d).

Fifteen releases were made for hatchery subyearling fall chinook salmon from early June to early July (Table 6). Fish were detected from all releases from 1 to 8 d after release. Most fish were detected within the first day after release. Mean travel time was short, generally less than 1 d.

Eighteen releases were made for hatchery summer steelhead from late April to early June (Table 6). Fish were detected from all releases from 1 to 29 d after release. Most fish were detected within the first day after release. Mean travel time progressively shortened with time, from near 8 d in late April to less than 1 d in late May.

Nine releases were made for natural chinook salmon from early April to late May (Table 6). Fish were detected from all releases from 1 to 14 d after release. Most fish were detected within the first day after release. Mean travel time was generally between 1 to 2 d.

Nineteen releases were made for natural summer steelhead from early April to early June (Table 6). Fish were detected from all releases from 1 to 21 d after release. Most fish were detected within the first day after release. Mean travel time progressively shortened with time, from near 4 d in late April to less than 1 d in late May.

Diel detections of fish released in trap efficiency tests are presented in Figures 4 and 5. Both hatchery and natural chinook salmon exhibited similar diel patterns of movement after release (Figure 4). Fish releases made in the evening were followed by a gradual rise in detections through the night, with peak detection the next morning (0600 – 0700 hours). Hatchery and natural summer steelhead movements were not as similar. After release, hatchery fish detections decreased until the following early morning, then gradually increased. Natural steelhead detections increased slightly after releases, decreased between 0100 – 0500 hours, and then peaked between 0600 – 0700 hours.

Time of release for subyearling fall chinook salmon influenced their movement (Figure 5). Evening releases were followed by peak detection shortly after, with detections continuing into the next day. Mid-morning releases were followed by a sharp peak in detections by mid-afternoon and no further detections after 2200 hours.

Collection

We monitored the outmigration of juvenile salmonids from 1 October 1998 to 8 March 1999 at the rotary-screw trap (RM 1.2). The trap did not operate from 20 – 26 December 1998, 30 December 1998 - 2 January 1999, and 1 – 4 March 1999 due to ice and high flows. We collected 1,596 fish at the rotary trap that expanded to 1,764 fish when adjusted for unsampled hours during sampling periods (Table 7). Ninety percent of the collected fish were hatchery spring chinook salmon. A total of 172 natural salmonids were caught at the rotary trap; 74% of these were natural spring chinook salmon. Most natural spring chinook salmon were sampled in early to mid-January and again in early March. Natural spring chinook salmon were first captured on 22 November, natural coho salmon on 28 November, and natural summer steelhead on 29 December 1998. Two adult hatchery coho salmon were captured in the rotary trap, one in late November (unknown sex and length) and the other in early December (female, 660 mm FL).

We monitored at West Extension Canal (RM 3.7) from 8 March - 19 July 1999 and sampled 100,651 fish (Table 7). Expanded by sample rate, 202,749 hatchery and natural salmonids passed through the sampling facility within the specified sampling hours. We began 24 h sampling at 100% on 12 July and continued until 19 July when the West Extension Canal trap was shut down. All fish sampled from 12-19 July were transported to the mouth of the Umatilla River due to limited return flow. Sampling at West Extension Canal ended on 19 July because of the high capture of resident fish. On average, we sampled fish 6 hours per day for a total of 792 hours, or 25% of the monitoring period. Ninety-seven percent of the fish sampled at West Extension Canal were hatchery salmonids (97,575 fish). Of the number of hatchery fish sampled, 48% were yearling chinook salmon, 13% were subyearling fall chinook salmon, 37% were coho salmon, and 2% were summer steelhead. Number of natural juvenile salmonids sampled totaled 3,076 fish, primarily summer steelhead (73%) and spring chinook salmon (25%). Number of natural subyearling fall chinook (1%) and coho (1%) salmon sampled was low.

Yearling hatchery chinook salmon dominated samples from March to early May (Figure 6). Similarly, yearling natural chinook salmon were predominate from March to mid-April (Figure 6). Subyearling natural chinook salmon were found in samples in late June to mid-July, analogous to hatchery subyearling fall chinook salmon (Figure 6). Hatchery coho salmon dominated samples through most of May, while natural coho salmon were present in small numbers throughout the sampling period (Figure 6). Most hatchery steelhead were sampled in May, but their natural counterparts were the dominant species collected in early and late March, from mid-April to mid June, and in mid-July (Figure 6).

Two adult summer steelhead were captured at the canal trap on 21 April 1999. One was a hatchery female (565 mm FL) and the other a natural male (559 mm FL).

A total of 113 scale samples were collected from juvenile salmonids from November 1998 to May 1999 (Table 8). Eighty-one percent of these samples were from smolted natural summer steelhead and 15% from natural chinook salmon. Scales from several coho salmon were also collected to determine their origin.

Trap and Haul

We sampled a total of 867 juvenile salmonids at Westland Canal during trap and haul operations from 20 July to 5 August 1999. Eighty-seven percent of all salmonids sampled were hatchery subyearling fall chinook salmon (Table 7). Of the natural salmonids sampled, 55% were chinook salmon and 43% were coho salmon. Although hatchery subyearling fall chinook salmon were the dominant salmonid species sampled, natural chinook and coho salmon appeared consistently throughout trapping operations (Table 9). Resident fish were present from the beginning of trapping operations and gradually became the dominant group by the end (Table 9).

A total of 710 pounds of fish (salmonids and resident species) were trapped at the canal and transported to the mouth of the Umatilla River (Table 9). An estimated 11,573 of 13,591 fish transported were live hatchery and natural juvenile salmonids. For these salmonids, 76% were transported on the first two days of trapping, 20 - 21 July. Salmonids suffered 6.8% mortality from handling during trap and haul procedures. Ninety-eight percent of the mortalities were hatchery subyearling fall chinook salmon.

Once juvenile transport ended, we did not monitor or sample fish for the rest of the season. Minimal flows in the lower river and the prevalence of resident fish hindered sampling.

Migration Parameters

Production Fish: Hatchery spring chinook salmon transferred to Imeques acclimation pond (RM 80) in November were emergency released on 20 December 1998 because of ice problems at the site. These fish were first collected at the rotary trap 9 days after release, and tagged fish were first detected 16 days after release (Figure 7; Table 10). A cumulative detection of 36% for tagged fish from the December release was achieved by 11 January at the rotary trap (Figure 7). Tagged fish from this release group were not detected again until 7 April at West Extension Canal; detection continued through the end of May. Even though these fish were released about 2.5 months earlier than fish released in March, mean detection dates in April were similar (Table 10). No peak detection was noted for tagged fish because overall detections were low (N = 14). However, un-tagged fish peaked on 5 January (Figure 7). Tagged hatchery spring chinook salmon released on 8 March and 14 April were detected within 2 days of their releases (Table 10). Many March-released fish migrated quickly after release (30% cumulative detection in 4 days), but most fish were detected in the first three weeks of April (40 - 90 % cumulative detection; Figure 8). Many April-released fish migrated immediately as well, but most fish were not detected until the first two weeks of May (42 – 97% cumulative detection). Mean and peak detection dates for April-released fish were within one day of each other and within three weeks of release (Table 10). Peak detection of March-released fish was one day after release, whereas mean detection was 4 - 5 weeks later. For all releases of spring chinook salmon, duration of migration decreased and mean travel speed increased with later releases (Table 10).

Tagged hatchery yearling fall chinook salmon released on 11 March and 15 April were detected at West Extension Canal within 6 and 2 days of their releases (Figure 8; Table 10). A cumulative detection of 95% for tagged fish was reached in 34 days for the March release (Figure 8). April-released fish migrated faster, with a cumulative detection of 95% 23 days after release. Mean detection for the March release was nearly one month after release compared to two weeks for the April release (Table 10). These fish migrated steadily with no substantial peak, though high detections on 1 May were more than double any other day's detections (Figure 8; Table 10). Similar to spring chinook salmon, duration of migration decreased and mean travel speed increased with the later release.

Tagged hatchery subyearling fall chinook salmon released on 3 June reached West Extension Canal within 3 days of release (Figure 9; Table 10). Mean and peak detections for subyearlings were within 2 weeks of release with an increase in cumulative detection (18% to 70%) from 13 June to 19 June, coinciding with a change in canal operations (Figure 9; Table 10). There were as many as 163 PIT-tag detections per day during peak movement in mid-June. Migration duration for tagged fish was similar to hatchery spring and fall chinook salmon, but subyearlings had the highest mean travel speed. On 26 June, tag detections substantially increased again with an 8% increase in cumulative percent detection (Figure 9).

Tagged hatchery summer steelhead (large-grade) volitionally released on 5 April at Bonifer and 6 April at Minthorn were detected at West Extension Canal in 5 - 10 days (Figure 10; Table 10). Small-grade fish from the 27 April volitional release at Bonifer took 12 days to reach the canal. Cumulative detection in mid-May increased from 32-76% for the 6 April release and 10-55% for the 5 April release in 3 days. Cumulative detection for the 27 April release increased from 10-75% within 10 days. Although the release of small-grade fish was 3 weeks later than the large-grade releases, mean and peak detection dates for all groups were within a period of 6 days in late May (Table 10). Migration duration was shortest and mean travel speed highest for the April 27 release. Most fish from all three releases moved to the lower river in mid-May (Figure 10).

Natural Fish: Tagging of natural fish by CTUIR began in late January (RM 80) and continued to late April. Tagged natural spring chinook salmon yearlings were first detected at lower river trapping sites in mid-March (Table 10). Natural fish migrated steadily throughout April and May (Figure 11). Four fish tagged and released at RM 80 in mid-February were detected on 19 May. Mean detection date of natural spring chinook salmon in early May was similar to that for hatchery spring chinook salmon released in mid-April. Migration duration was longer and mean travel speed slower for natural chinook salmon than all hatchery chinook releases except for the 20 December release. No natural subyearling chinook salmon were tagged by CTUIR.

Tagging of natural summer steelhead began in late January (RM 80) and continued to early June. Tagged natural summer steelhead were first detected on 9 March (Table 10). Most natural summer steelhead moved to the lower river in mid- to late May when detections peaked (Figure 11). These detections included fish tagged in all tributary creeks (Buckaroo Creek, Squaw Creek, east and west forks of Birch Creek, and Pearson Creek). Therefore, regardless of when and where fish were tagged, they tended to move to the lower river within the month of May. Some natural steelhead tagged in late May moved to the lower river within one week. However, most late-tagged fish were generally detected in mid- to late June. Mean detection for natural steelhead in late May was similar to that of their hatchery counterparts, whereas, migration duration was longer and mean travel speed faster.

Reach Survival Fish: Hatchery spring chinook salmon tagged for reach-survival tests were released from 9-11 March. Fish from the Cottonwood, Echo, and Rieth (RMs 11, 27, and 48) test groups were initially detected at West Extension Canal on 10 March, 1 d after the first release (Figure 12). Cumulative detections for all release groups ranged from 69-83% within 2 weeks of their initial release. Peak detections for these test groups were on 12 March, but the Imeques group (RM 80) did not peak until 18 March. Tagged fish from Imeques were first detected on 13 March, 3 d later than the other groups. Similar to hatchery spring chinook salmon tagged for production, most fish from all test groups moved out quickly. Mean travel speed to West Extension Canal was incrementally faster for fish released farther upriver (1.34-8.39 mi/d; Appendix Table A-4). However, all tag groups traveled similarly (2 mi/d) from West Extension Canal to John Day Dam on the Columbia River (76.4 RMs). Fish from the Echo test group were the first (1 April) and last (5 May) fish to be detected at John Day Dam (Figure 12). The Imeques release was the only group to have a peak in detections at John Day Dam (22 April; 28%). Ninety percent of the Echo group and 100% of the Cottonwood, Rieth, and Imeques groups passed John Day Dam in a 3-week period, 8 April to 30 April.

Hatchery subyearling fall chinook salmon tagged for reach-survival tests were released from 3-5 June. Fish from the Steelhead Park (RM 9) release group were first detected in peak numbers at West Extension Canal on 4 June, 1 d after the first release (Figure 13). Fish from Echo, Rieth, and Imeques were initially detected 5 June, 2 d after the first release. These three groups peaked on 15 June, the same day as hatchery subyearling fall chinook salmon tagged for production. Cumulative detections were > 83% for the lowest three releases and 57% for the Imeques release within 2 weeks of the first release date. Mean travel speed for tagged subyearlings was similar to spring chinook salmon test groups. The further fish were released upriver, the faster their travel speed (0.93-5.43 mi/d) to West Extension Canal (Appendix Table A-4). All groups traveled at about 4 mi/d from West Extension Canal to John Day Dam. Fish from the Steelhead Park release were the first (11 June) and last (16 July) fish to be detected at John Day Dam with most detections from 17-22 June (Figure 13). Peak detections at John Day Dam for Echo, Rieth and Imeques fish were on 19 and 20 June. All groups reached a cumulative detection of > 50% by 22 June and > 90% by 1 July at John Day Dam.

Hatchery subyearling fall chinook salmon tagged for trap and haul evaluation and first released at Westland Canal on 20 July were first detected at John Day Dam on 24 July. Peak detection (N = 5) was one day after the final release on 27 July. These fish moved down river quickly with 85% passing John Day Dam within two weeks and traveling an average of 8.93 mi/d, more than twice that of in-river test groups released in June (Appendix Table A-4).

Large-grade hatchery summer steelhead tagged for reach-survival tests were released from 12-15 April. Fish from Steelhead Park and Echo releases were initially detected at West Extension Canal on 13 April, one day after the first release (Figure 14). Fish from Minthorn

(RM 64.5), Rieth, and Bonifer (RM 2 of Meacham Creek) were initially detected on 15, 16, and 17 April. The Steelhead Park test group was the only one with a substantial peak (14 - 15 April); the other test groups moved steadily downriver until the end of May. Cumulative detections for the lowest three test groups ranged from 74-79% by 13 May. However, the Minthorn and Bonifer test groups did not reach this range until 22 May, 9 days later. Mean travel speed for tagged steelhead to West Extension Canal was similar to spring and fall chinook salmon, with incremental increases corresponding to upriver releases (Appendix Table A-4). However, the difference in travel speed between sites was not as large as with the salmon test groups. Mean travel speed from West Extension Canal to John Day Dam was also similar to salmon test groups; all steelhead groups traveled at about 2-3 mi/d. Fish from the Steelhead Park and Echo releases were the first to be detected at John Day Dam (19 April); fish from the Bonifer release were the last (13 June; Figure 14). Fish from all groups passed John Day Dam steadily from mid-April to the end of May with 1-6 detections in a day for each group. Detections were low, but peaked on 7 May for the Steelhead Park release and 23 May for the Echo and Minthorn releases. There were no peak detection dates for fish from Rieth or Bonifer. The lowest three test groups (Steelhead Park, Echo, and Rieth) reached 50% cumulative detection by 9 May, but the Minthorn and Bonifer groups did not reach 50% cumulative detection until 22 May, 13 days later.

Small-grade hatchery summer steelhead tagged for reach-survival tests were released from 4-7 May. Fish from the Steelhead Park and Echo test groups were initially detected at West Extension Canal on 5 May, 1 d after the first release (Figure 15). Fish from Minthorn were detected 3 d later and fish from Bonifer did not reach the trap until 18 May, two weeks after the first release. Peak detection for each summer steelhead test group varied. Detection of fish from Steelhead Park peaked on 6 May before the final test group was released. Echo and Rieth tests groups peaked in late May, and the Bonifer test group did not have a peak date. Most fish from all groups passed the trap in the latter part of May. Mean travel speed to West Extension Canal for small-grade steelhead was similar to large-grade fish, with incremental increases in speed with upriver releases (Appendix Table A-4). Travel speed from West Extension Canal to John Day Dam was also similar among groups (3-4 mi/d). Fish from Steelhead Park test groups were the first to be detected (9 May) at John Day Dam and fish from Echo and Rieth were detected a few days later (11 and 13 May; Figure 15). However, first detection from the Bonifer group was on 23 May. Bonifer was the last group detected at John Day Dam (18 June). Detections ranged from 1-4 fish in a day for each group, therefore peak detections were not substantial. All four groups of small-grade summer steelhead reached a cumulative percent detection of about 50% within 6 days of each other in late May; ≥ 80% of the fish detected passed John Day Dam by 6 June.

Diel movement: Remote PIT-tag detection at West Extension Canal allowed tracking of diel movement of tagged salmonids without 24-h sampling. Most tagged hatchery and natural salmonids passed West Extension Canal between sunrise and sunset except hatchery spring chinook salmon detected in March (Figures 16 - 18). Most of these fish moved before 0800 hours and after 1800 hours, with peak detection at 0700 hours (N = 9).

Peak detection of hatchery spring chinook salmon in April (N =14) and May (N = 13) was in the middle of the day at 1300 hours (Figure 16). Detections of natural chinook salmon in April peaked at 1500 and 1800 hours (N = 3; Figure 16). Peak detection of natural spring chinook salmon in May (N = 5) was close to their hatchery counterparts at 1500 hours.

Peak movement of tagged hatchery yearling fall chinook salmon in April (N = 9) and May (N = 7) was at 1200 hours and 1300 hours, similar to hatchery spring chinook salmon (Figure 17). Detections of fall chinook salmon in March were low, so no peak was discerned. Peak detections for hatchery subyearling fall chinook salmon occurred at 0800 hours (N = 90) and 1100 hours (N = 89) in June (Figure 17), and were earlier in the day than peaks for hatchery yearling and natural chinook salmon.

Peak movement of hatchery summer steelhead was from 1500-1800 hours in May, but many fish moved around 0700 hours and 0900 hours as well (Figure 18). Movement of natural summer steelhead in May was similar to hatchery fish, with peak detections in the morning at 0900 hours and additional fish movement in the afternoon at 1500 and 1700 hours (Figure 18).

Lengths and Weights

Mean lengths of natural and hatchery juvenile salmonids are presented seasonally in Table 11. By month, hatchery salmonids captured showed a significantly larger mean fork length ($P < 0.04$) than natural salmonids of the same species. July was the exception for coho salmon and summer steelhead due to low sample size.

Natural chinook salmon were determined to be mostly yearling and subyearling spring chinook salmon, but smaller mean lengths in June, July, and August represented the subyearling fall chinook portion of the species (Table 11). Natural coho salmon fry (< 50 mm) were captured in March and April at West Extension Canal (RM 3.7). Larger natural coho were captured in July and August at Westland Canal (RM 27.3). Mean lengths of natural summer steelhead were similar from March through June as most fish emigrated. The smaller natural steelhead captured at Westland Canal in July were parr (72 mm mean FL, N = 3).

The higher mean fork length of hatchery chinook salmon at West Extension Canal in July represented captures of four mini-jacks. For known hatchery spring chinook salmon, mean lengths gradually increased from January through April, representing releases made in December, March, and April. Hatchery fall chinook salmon (identified through PIT tags) had similar fork lengths from March through May. Mean lengths of hatchery subyearling fall chinook salmon increased by 13 mm over the 2-month collection period at West Extension Canal. Captures of hatchery subyearling fall chinook salmon at Westland Canal in August were nearly 40 mm larger than June-sampled fish. Mean fork lengths of hatchery coho salmon increased by 20 mm from their March release to final capture in July. Hatchery coho exhibited a wide range in lengths overall. Mean fork lengths of hatchery summer steelhead were similar in April, May, and June. Fish sampled in April represented the “larges” release group only.

Insufficient weight data was available for analysis in 1998-99 (Table 12). An increase in weight was observed for hatchery spring and fall chinook salmon, though few weights were taken for these races. Data for all other species showed no clear trends.

Fin Clips

Percent recapture of differently clipped fish at all trap sites is presented in Table 13. Percent recapture between AD and NC subyearling fall chinook and coho salmon was only slightly different (0.17% and 0.18%, respectively), whereas the absolute difference between AD and NC yearling chinook salmon was 1.36% (Table 13). However, all comparisons were significant. In addition, AD-clipped and non-clipped chinook salmon were recaptured approximately five times more than ADLV-clipped fish, both a significant difference. Percent recapture of AD-clipped summer steelhead was also significantly higher than those with ADLV clips.

Fish Condition and Health

Of hatchery fish collected at the two lower sites, we examined for condition 5,713 yearling chinook salmon, 2,790 subyearling fall chinook salmon, 3,049 coho salmon, and 1,755 summer steelhead. All species, except steelhead, were near 80% undamaged or with minimal scale loss (Table 14). Only 42% of sampled steelhead were undamaged; near 50% were partially descaled and descaled. Subyearling fall chinook salmon were in best condition overall, with minimal mortality. Mortality was relatively low (<1%) for all species. Handling or trap-caused mortality ranged from 0.5 – 1.5% for hatchery fish.

Of the natural fish collected, we examined for condition 725 chinook salmon, 37 coho salmon, and 1,639 summer steelhead. All species, except steelhead, had > 90% minimal scale loss (Table 14). Near 73% of natural steelhead were undamaged and 27% were partially descaled and descaled. Handling or trap-caused mortality ranged from 1.2-2.1% for natural fish. The only natural mortalities observed were two steelhead. As with hatchery steelhead, natural steelhead stranded themselves during trap escapes.

We examined 156 hatchery fish (all were subyearling fall chinook salmon) and 43 natural fish at Westland Canal during Trap and Haul operations in late July and August. For the hatchery subyearlings, 64% were undamaged, and the remaining 36% were partially descaled or descaled. Only two dead fish were sampled. We examined mostly natural coho salmon, in which 81% were undamaged.

Other types of injuries were evident on fish, including damage to eyes, head, operculum, or body, torn caudal fins, bird marks, and other predator marks (Table 15). We also observed fungal infections, external parasites, and signs of bacterial kidney disease (BKD). A large proportion (≥ 50%) of the injuries on most hatchery species were bird marks. External parasites included leeches and the metacercaria from black spot disease (*Neascus metacercariae*). Many yearling chinook salmon exhibited signs of BKD. Natural fish exhibited few bird marks but were highly infested with parasites (Table 15).

We submitted 24 natural chinook salmon, 68 natural summer steelhead, and 3 hatchery spring chinook salmon to ODFW pathology for disease examination. All fish were collected dead or they died at West Extension Canal. Of the natural chinook salmon, all fish were positive for the presence of the Rs antigen (BKD), but ELISA values were low to moderate. There was no evidence of internal or external disease. Of the summer steelhead, no systemic bacteria were detected in the 14 fish analyzed and none of the 68 fish showed evidence of external or internal disease. Technically, all fish were positive for the presence of the Rs antigen, but most ELISA values were low to moderate. One fish had a high moderate value. The hatchery chinook salmon had very low positive values for the Rs antigen and no diseases were evident.

Abundance and Survival

Migrant Abundance and Survival

Abundance and survival estimates were determined for tagged natural and hatchery juvenile salmonids detected at the rotary trap and at West Extension Canal (Tables 16 and 17). Hatchery fish were from various rearing hatcheries and released at various times (Table 16). Natural fish were tagged and released at various upper Umatilla River and tributary locations (Table 17).

Production releases of spring chinook salmon from Umatilla Hatchery were split between fish released in December from Imeques (cold-water rearing) and the standard release in March. Of these, the December-released group had better survival, although total number detected was small and confidence intervals were large (Table 16). Based on recovery and abundance of untagged spring chinook salmon, 49.5% of cold-water reared fish successfully migrated out of the basin. Survival estimates for March-released spring chinook salmon ranged from 18.2% to 32.5% for the different pond groups, with an overall survival estimate of 25.4% (± 4.8%). Fish reared at Little White Salmon Hatchery and released in March were also detected in the same proportion as tagged Umatilla Hatchery fish and had a similar survival estimate (24.6%). However, spring chinook salmon reared at Little White Salmon and Carson hatcheries and released in April had significantly improved and similar survival estimates (68.7% overall, ± 10.7%; $P < 0.001$). Overall survival for all spring chinook salmon release groups was 37.0% (± 6.7%).

Yearling fall chinook salmon reared at Bonneville Hatchery and released in the Umatilla River in March and April exhibited highest survival, with March-released fish surviving significantly better than April-released fish ($P < 0.001$; Table 16). Overall, 78.3% of the tagged fish from these two release groups survived to the lower Umatilla River (± 12.6%).

Survival estimates for tagged subyearling fall chinook salmon reared at Umatilla Hatchery and released in early June ranged from 45.3% (pond M4A) to 61.6% (pond M2A) for the 6 pond groups. Survival for A-pass fish (54.2% ± 4.3%) was not significantly different from B-pass fish (53.5% ± 4.3%). Overall survival of tagged fish from all ponds was 53.9% (± 3.1%).

Two groups of summer steelhead were released from Umatilla Hatchery, beginning with a volitional release and ending with a forced release one week later. One group (larges) was released in early April at the Bonifer and Minthorn acclimation sites. The second group (smalls) was released in late April at Bonifer. Of the two early releases, the Minthorn release group had a significantly higher survival by 10 points (*P* = 0.029; Table 16). Overall survival for the early release groups was 68.6% (± 17.2%). The late-April release group had the poorest survival (56.6%), which was significantly different from the combined early release groups *(P* < 0.001.*)*. Overall survival for all steelhead release groups was 63.6% (± 13.2%)

Survival was similar between natural spring chinook tagged and released in the Umatilla River (RM 80) and at Meacham Creek (RM 79; Table 17). Overall percent detection was 16.0% and survival was 35.3%.

Survival was significantly greater (*P* <0.001) for tagged natural steelhead released at RM 80 on the Umatilla River than for fish released at RM 2 in Meacham Creek (Table 17). Steelhead tagged and released in the east and west forks of Birch Creek had lower but similar survival estimates; no fish were detected from the mainstem Birch Creek release. Similar survival estimates for steelhead tagged and released in Squaw Creek, Pearson Creek, and Buckaroo Creek were lower than Birch Creek fork estimates, but these streams are higher in the system. Overall percent detection of tagged natural steelhead was 9.6% and estimated survival was 31.2%.

We estimated 3,490 natural chinook salmon emigrated past the rotary trap and 16,661 chinook salmon emigrated past the canal trap site. Combined with the 418 subyearling salmon collected at Westland Canal (Table 7), an estimated 20,569 yearling and subyearling chinook salmon migrated from the basin. Separating between spring chinook (October - May) and fall (June - August) chinook salmon yielded 19,414 spring chinook and 1,155 fall chinook salmon migrants (Appendix Table A-5). The crude estimate of natural steelhead abundance at the rotary trap was 6,400 fish. We further estimated 39,104 natural steelhead emigrated past the canal trap site and 9 steelhead were trapped at Westland Canal (Table 7) for a total estimate of 45,513 natural steelhead migrants in 1999 (Appendix Table A-5). Similarly, an estimated 517 natural coho salmon emigrated past the rotary-screw trap, 1,923 coho emigrated past the canal site, and 268 coho were trapped at Westland Canal (Table 7), for a total estimate of 2,708 natural coho migrants (Appendix Table A-5).

Results of radio telemetry work with juvenile summer steelhead (small-grade) can be found in Stonecypher et al. 2001. In general, only a few fish were detected exiting the river while some remained near the release site at Bonifer pond.

Reach-Specific Survival

Replicate groups of tagged spring chinook salmon, subyearling fall chinook salmon, and summer steelhead from Umatilla Hatchery were released for reach-specific survival tests (Table 18). Mean in-basin survival estimates for spring chinook salmon from the four release sites ranged from 20.2% at RM 48 to 27.4% at RM 80. No increasing trend in percent detection or survival with lower reaches was evident. ANOVA testing indicated no significant difference in survival among sites.

Tagged subyearling fall chinook salmon released at four sites exhibited incrementally higher survival from RM 80 to RM 27 (41.4 – 57.7%; Table 18). Survival for the last group released at RM 9 was reduced and similar to the uppermost survival estimate. Based on ANOVA, there was no significant difference in survival among the four sites.

Large-grade summer steelhead released in mid-April exhibited incrementally improved survival from RM 79 (51.7%) to RM 9 (139.8%; Table 18), with similar survival estimated for the two upper sites (Bonifer and Minthorn). ANOVA testing indicated significant differences in survival among sites ($P < 0.001$; Table 18). Multiple comparison testing indicated releases at RM 79 and RM 65 were not significantly different from each other, but they were from the lower release sites (Table 18). Survival of fish released at RM 27 was not significantly different from the RM 48 or RM 9 releases, which were significantly different from each other.

Small-grade summer steelhead released in early May exhibited the same pattern of increasing survival with lower river releases (Table 18). Survival of fish from the uppermost release site (Bonifer) was nearly 3 times less than survival at the next lower release site (RM 48). Whereas, survival of fish from RM 48 and RM 27 was different by only 8 points. ANOVA testing indicated significant differences among sites ($P < 0.001$; Table 18). Multiple comparison testing indicated releases at RM 48 and RM 27 were not significantly different from each other, but they were from the uppermost and lowermost release sites.

A similar pattern emerged with mainstem detections and all detections combined (Table 19). Although detection differences for spring chinook salmon within the mainstem were near significance ($P = 0.073$), differences were not significant with combined total (non-duplicative) detections. For subyearling fall chinook salmon, the trend in total detections (Table 19) was similar to the in-basin survival trend (Table 18) where survival for fish released at RM 9 was reduced. However, mean percent detection was not significantly different among sites. Mean percent detection of fish released at RM 0 is from fish trapped at Westland Canal (RM 27) and transported to the mouth of the Umatilla River. This detection was similar to mainstem detections of fish released at RM 27 in June and allowed to migrate in river (pseudo control).

Mean detections within the mainstem for large-grade and small-grade steelhead were not significantly different among release sites, although a pattern of increased detection was evident (Table 19). Survival indices from total detections were similar to in-basin reach survival estimates (Table 18) and ANOVA tests were significant ($P < 0.001$). Multiple comparison tests with large-grade steelhead indicated the significance lay between the uppermost site (RM 79), the mid-reach site at RM 48, and the lower sites (RMs 27 and 9). Mean detection from Minthorn releases (RM 65) was similar to adjacent sites. For small-grade steelhead, multiple comparison tests indicated the significance lay mostly between the uppermost site (RM 79), the mid-reach sites (RMs 48 and 27), and the lowermost site (RM 9). Mean detections at RM 48 and RM 27 were similar. In addition, detection of small-grade summer steelhead was less than large-grade steelhead for every site.

Tag loss for fish held at the hatchery prior to test releases varied from 2.5% for subyearling fall chinook salmon to 16.4% for large-grade steelhead. Tag loss for small-grade steelhead (7.8%) and spring chinook salmon (10.0%) was similar. All but one fish from the test group of subyearling fall chinook salmon tagged on site at Westland Canal died due to an intolerable water temperature during tagging (near 68 °F).

Environmental Conditions and Bypass Operations

Environmental Conditions

River flows at all main HYDROMET gauging stations during the project period are presented as stacked flows in Figure 19. Flows peaked in late December and early January, reaching nearly 5,000 ft^3/s at RM 2.1. Flows were also high in mid-January (2,410 ft^3/s), early and late March (3,570 ft^3/s and 2,430 ft^3/s, respectively), and mid-April (2,150 ft^3/s). Flows were lowest from October through late November 1998 and from June through September 1999.

Secchi depth was negatively correlated with river flow (r = -0.716, P = 0.0001, N = 196; Figure 20). Water clarity reached 2 m during low flow periods and decreased to less than 0.5 m during higher flow periods. Water clarity was minimal just after a release of hatchery spring chinook salmon in December 1998 and when juvenile salmonids were migrating in March and April. Water clarity decreased greatly on 27 June following an increase in flow from McKay Reservoir (38 ft^3/s). Subyearling fall chinook salmon were migrating during this time.

Water temperatures in the lower Umatilla River ranged from a low of 31 ^oF in December to a high of 72 ^oF in July (Figure 21, Appendix Table A-6; Appendix Table A-7). Although temperatures progressively increased throughout spring and into summer, slight decreases were observed when river flows increased. Mean water temperature was negatively correlated with river flow at RM 3.7 (r = -0.488, P = 0.0001, N = 355).

Natural Fish: Daily detections of natural salmonids were compared with river flow and water temperature (Table 20). Natural chinook salmon and summer steelhead detections were not correlated with river flow, although steelhead did appear to migrate as flows were decreasing in late May and early June (Figure 22). Natural chinook detections were not correlated with temperature. However, detections of natural summer steelhead were correlated in a positive manner. Temperatures increased by almost 20 ^oF during the peak detection period from mid-April through mid-June; detections greatly diminished by the temperature peak in mid-June.

Production Fish: Daily detections of hatchery salmonids were also compared with river flow and water temperature (Table 20). Detections of hatchery spring and fall chinook salmon were not correlated with river flow but were positively correlated with temperature (Table 20; Figure 23). Most spring and fall chinook salmon were detected from March through May, a time when overall temperatures increased by almost 20 ^{o}F. Although no correlation was determined, periods of decreased detections for both spring and fall races were observed with increases in flow (late March and late April). Detections of hatchery subyearling fall chinook salmon, on the other hand, were positively correlated with river flow. Flows during the peak subyearling detection period were fairly stable (Min. = 161 ft^3/s, Max. = 212 ft^3/s, Mean = 200 ft^3/s). Detections also peaked with a rise in temperature, although there was no correlation. A positive correlation was observed between daily detections of hatchery summer steelhead and river flow for both large- and small-size releases (Figure 24). Detections in April (corresponding to the forced releases on 13-14 April) peaked prior to the mid-month freshet. Flows were relatively stable in May during most detections of steelhead, but slight increases in flow did coincide with increased detections. Temperature was negatively correlated with daily detections of both large- and small-size summer steelhead.

In addition, detections of production fish were analyzed to determine relationships between river flow and travel speed (Table 21; Appendix Figures A-1 – A-5). Detections of December-released spring chinook salmon showed a strong positive correlation between river flow and travel speed, although the maximum travel speed was only 4.7 mi/d (Table 21). Travel speeds of spring chinook salmon released in March and April showed a negative correlation with river flow. Travel speeds of yearling fall chinook salmon released in March were negatively correlated with river flow as well, but no correlation was observed for April releases. Subyearling fall chinook salmon (released in June) showed a strong positive correlation between river flow and travel speed. Large-sized summer steelhead released at Minthorn and Bonifer in mid-April had strong negative correlations between river flow and their travel speed. Travel speed of small-sized summer steelhead released at Bonifer in late April was positively correlated with river flow.

Reach Survival Fish: Detections of fish from reach-specific survival tests were also analyzed to determine relationships between river flow and travel speed (Table 21; Appendix Figures A-6 – A-9). Travel speeds of most spring chinook salmon release groups were negatively correlated with river flow. Imeques-released fish had the strongest negative correlation, followed by Echo-released fish. Travel speeds of fish released at Cottonwood and Rieth were not correlated with river flow. Release groups of subyearling fall chinook salmon had travel speeds that were positively correlated with river flow. Imeques-, Steelhead Park-, and Echo-released fish showed the strongest correlations, but Rieth-released fish also had a good correlation. Positive correlations between river flow and travel speed were observed for large-sized summer steelhead released at Bonifer and Rieth whereas negative correlations were observed for releases at Steelhead Park and Echo. Minthorn release groups had no correlation. Small-sized summer steelhead release groups showed a positive correlation between river flow and their travel speed, with the Echo group being the exception with no correlation.

Bypass Operations

Diversion of water at West Extension Canal varied throughout the season (Figure 25). At times, irrigators were reliant on Phase I exchange pumping as flows decreased in the river to near or below 250 ft^3/s. Operations at West Extension Canal appeared to influence movement and detections of various species of hatchery and natural juvenile salmonids. In general, most yearling hatchery salmonids were detected at the canal from March through late May when the canal was withdrawing from 30 – 130 ft^3/s. When Phase I pumping was first initiated on 31 May and diversion curtailed, detections of hatchery fish greatly diminished (Figure 25). Subyearling fall chinook salmon were released and detections peaked at West Extension Canal during Phase I pumping. All hatchery fish detections had diminished when diversion was reinitiated on 12 July.

Efficiency estimates of the juvenile bypass facility trap were compared with West Extension Canal diversion rates (Table 22). Trap efficiency estimates for hatchery yearling and subyearling chinook salmon were positively correlated with diversion rate ($r = 0.692$, $P = 0.001$, $N = 18$ and $r = 0.653$, $P = 0.008$, $N = 15$, respectively). However, trap efficiencies of hatchery summer steelhead were not correlated with diversion rate.

Trap efficiencies for natural spring chinook salmon had a positive correlation with diversion rate ($r = 0.752$, $P = 0.019$, $N = 9$). There was no correlation for natural summer steelhead.

Water was released from McKay Reservoir in early June through July to improve fish passage (Figure 25). Subyearling fall chinook salmon detections peaked during this period (15 June). In mid-July, when salmonid detections declined, McKay reservoir releases decreased, Phase I pumping was discontinued, and canal diversion was re-instated. Lower river flows at this time prompted juvenile transport to be initiated past Westland Canal (19 July) to aid passage of late migrants.

Resident Fish and Avian Predators

Resident fish species were collected at West Extension Canal throughout the season (Table 23). Of special concern were juvenile salmonid predators (bass and northern pikeminnow) and Pacific lamprey. During July, an increased number of sucker, chiselmouth, and catfish captures coincided with the closure of the east-bank fish ladder and prompted the shut down of the sampling facility at West Extension Canal.

We captured 182 juvenile bass (120 mm mean FL, N = 162) from November 1998 to July 1999 (Figure 26). The smallest bass (51 mm FL) was captured in March and the largest bass (174 mm FL) was captured in May. Sixty-eight bass captured at RM 3.7 were predator-size fish (> 128 mm FL; Vigg et al. 1988). Mean fork lengths of bass captured increased over three-month periods from 77 mm (November to January) to 107 mm (February to April) to 133 mm (May to July). Larger-sized bass were captured at West Extension Canal.

Seventy-nine northern pikeminnow were captured from November 1998 to May 1999 with a mean fork length of 164 mm (Figure 27). Four fish (captured in December, January, and March) were over 250 mm in fork length and therefore considered predator-size fish (Vigg et al. 1988). The largest fish (459 mm FL) was captured in January. Most smaller fish were captured in November and December (N = 8); the smallest pikeminnow captured was 67 mm FL.

Pacific lamprey collected from November 1998 to April 1999 were all juveniles (100 - 175 mm TL; Figure 28). Of the 274 juvenile lamprey captured, 76 were smolted (148 mm TL, N = 71) and 197 were non-smolted (148 mm TL, N = 188). Smolted lamprey were only captured in November and December; capture was positively correlated with river flow (r = 0.565, P = 0.044, N = 13; Figure 29). Although captures of non-smolted juvenile lamprey appeared to increase with river flow, there was no linear correlation.

Avian predators were also observed at the trap sites (Table 24). Sightings included 287 gulls (*Larus spp*.), 30 night herons (*Nycticorax nycticorax*), 11 great blue herons (*Ardea herodias*), 6 cormorants (*Phalacrocorax spp.*), and incidental sightings of kingfishers (*Ceryle alcyon*) and common mergansers (*Mergus merganser*). Gulls were observed from late November to late June; peak sightings were in June. Gull observations coincided with high salmonid abundance in the river during June (Figure 30). Gulls were observed mainly during flows < 500 ft^3/s (Figure 30) and were either flying, on the dam sill at Three Mile Falls Dam, or in the river below the dam. Night herons were mostly observed at the fish bypass outfall from late April to early June, with peak sightings in May and June. Great blue herons, seen mostly in the river, were sighted from November to early June. Cormorants were observed near the dam in mid-March and late June.

DISCUSSION

Outmigration Monitoring

PIT-tagging of juvenile salmonids this year proved to be a superior method of marking and obtaining data compared to the color marking technique used in 1998 (Knapp et al. 2000). Maintenance of color marking equipment was high, whereas minimal problems were experienced with PIT-tagging equipment. Color mark quality was dependent on the technique of the person marking, mark color, fish size, species marked, and location of the mark (Knapp et al. 2000), whereas PIT-tag quality was dependant on retention of the tag, usually a factor of tagging technique and fish species (size). Color marking also required additional handling of fish to visually detect the mark, accurate identification of marks, and intensive sampling to collect marked fish. With PIT tags and a remote detection system, we were able to “sample” 24 h/d, which eliminated the need for data expansion. Monitoring with PIT tags permitted passive monitoring, eliminating the need to actively sample and handle large numbers of fish. In addition, detection capabilities allowed us to obtain migration and survival information from mainstem Columbia River dams and the Columbia River estuary. We recommend the continued use of PIT tags and a remote detection system for monitoring outmigration and survival of salmonids in the Umatilla River to decrease the amount of handling needed to monitor fish and decrease errors associated with expansion estimates. We will pursue upgrading to a 134-kHz detection system in 2000 to accommodate the ISO tags that will be used basinwide.

We did experience one drawback with the use of PIT tags, however. Because larger fish (> 130 mm) tended to consume tags lost by other fish during holding, we were unable to account for all tags. Tag accountability proved to be a critical factor. As a result of tag consumption, number of validly tagged fish available for tests could be miscalculated. Two or more tags in a fish would also jam the reader and cause a tag "no read". These fish could not be used in tests. We will need to modify holding conditions for larger fish (e.g., summer steelhead and spring chinook salmon) to minimize tag consumption and associated problems with tag accountability.

PIT tagging of fish also proved ideal for testing trap efficiencies and as a result, trap efficiency estimates for each species were greater this year than in past years. Although such influencing factors as river flow and canal withdrawals vary among years, the greatest difference in 1999 was the use of a remote PIT-tag detection system. Tagged fish were detected from all test releases, which therefore improved the estimates. Furthermore, no expansions were required to extrapolate for missing data. We consider this year's estimates of trap efficiency to be the best we have obtained, which translates to improved abundance and survival estimates.

As in past years, the larger the fish, the smaller the efficiency estimate. This is probably due to behavioral differences and stronger swimming capabilities between smaller and larger fish. Hatchery and natural summer steelhead had the lowest trap efficiency estimates and the smaller-sized hatchery subyearlings and natural chinook salmon had the highest. Steelhead are more apt to evade the bypass facility, whereas chinook salmon are readily collected. This behavior is corroborated through correlations between trap efficiency estimates and diversion rate, where no correlation existed for summer steelhead.

Migrational behaviors were also elucidated in trap efficiency tests that corresponded with behaviors exhibited by run-of-the-river fish. Most noteworthy was the speed at which the smaller chinook salmon migrated and the short duration of their detection. We also observed slower movement from March and April test releases than from releases made in May, particularly for spring chinook salmon and summer steelhead. Migrational cues such as water temperature, flow, sun orientation, turbidity, or smolt status differ among months and may be the causative factors in these differences. Findings from trap efficiency tests offer another venue for understanding migrational patterns and behaviors.

Fish collection at West Extension Canal was much lower than previous years because we were able to monitor fish passively with the new remote PIT-tag detection system. Fish were bypassed 75% of the time this year (through the remote detection system) compared to 4% in 1998 when most fish were sampled (Knapp et al. 2000).

Collection of larger-sized hatchery chinook salmon (> 200 mm) in July was an anomaly. These fish were considered spring chinook mini-jacks (< 400 mm) returning from early spring releases. Because supplemental river flows were extended this year, these mini-jacks had the opportunity to ascend the Umatilla River and were trapped at and released above the east-bank ladder at Three Mile Falls Dam. When the ladder was shut down in mid-July, a number of these fish moved back downriver through the bypass system. It is unknown if this early return is a normal life history trait that was expressed with the provision of supplemental flow, or if a hatchery rearing strategy is promoting this trait that may be undesirable. To gain a better understanding of the mini-jack life history, Umatilla Hatchery Monitoring and Evaluation personnel collected and sent otolith samples from some of these fish to the University of Washington for analysis. Otoliths were examined for ratios of Strontium (Sr) and Calcium (Ca). The Sr/Ca ratio is typically greater in seawater than in freshwater, so analysis of Sr/Ca ratios across the otolith of a fish can describe the migrational history of that fish (personal communication, Chris Zimmerman, University of Washington, Seattle, WA). The analysis on these mini-jacks is not yet complete, but it is known from otolith analysis that these fish traveled as far as the saltwater wedge on the Columbia River near Quincy, OR (~RM 50).

Transport of juvenile salmonids from Westland Canal in 1999 was delayed until 20 July (2 weeks later than 1998) as a result of an ongoing strategy to enhance summer flows for in-river rearing or migration of natural and hatchery juvenile salmonids. This two-week delay in transport was possible due to the extended release of water from McKay Reservoir. As a result, total number of hatchery subyearling fall chinook salmon transported in 1999 (0.6% of fish released) was less than in 1998 (1%; Knapp et al. 2000), 1997 (2%; Knapp et al. 1998b), 1996 (13%; Knapp et al. 1998a), and 1995 (4%; Knapp et al. 1996). Since most fish (76%) were transported in the first two days, it would be beneficial to extend water releases and delay transport for a few days to one week. This would greatly reduce the number of fish transported. In the last three years of transport operations, substantially fewer hatchery salmonids were collected by the third week of July (CTUIR and ODFW 1997, 1998, and 1999).

If water availability can provide suitable passage flows throughout July, we recommend the total elimination of mid-summer transport operations. Although tagged transported hatchery subyearlings were similarly detected at mainstem sites as test in-river release groups in June, the trapping and handling of fragile subyearlings in 74 °F water temperatures is stressful. In future years, we recommend an expanded test to determine survival of in-river migrants in July, if flows are provided to allow such conditions.

Species composition of fish sampled at Westland Canal was different from 1998 in that hatchery subyearling fall chinook salmon dominated samples throughout transport and a fair percentage of fish sampled were resident species (similar to transport in 1997; Knapp et al. 1998b). In 1998, natural subyearling chinook salmon were predominant after the first week of transport because of high production (Knapp et al. 2000). In all years, natural fall chinook salmon are the dominant natural species collected and transported, although the presence of natural coho salmon is on the rise as a result of improved natural production. However, collection of this species confounds transport efforts, as most juveniles are rearing and are not active migrants. This is further reason to eliminate transport.

We observed similar migration behavior in the hatchery spring chinook salmon released in December as in later releases, with fish moving to the lower river quickly after release. The small portion remaining in the basin until the following spring were apparently not smolted sufficiently or ready to migrate. We also observed migrational similarities between tagged hatchery and natural spring chinook salmon, with most fish of each origin emigrating from April to mid-May. Spring chinook salmon produced at Umatilla Hatchery were from broodstock collected at Three Mile Falls Dam in 1997, the first year Umatilla broodstock were collected.

Since natural and hatchery smolts had the same parentage (41% of the detected smolts were from Umatilla Hatchery), we would expect to see similar life history expressions.

Mean and peak detection of hatchery subyearling fall chinook salmon was later this year than in 1998, primarily due to a difference in canal operations in combination with Phase I pump exchange, which replaces canal diversion. In 1999, less water (ft^3/s) was pulled into the bypass trap during Phase I exchange because the river-return pipe (the primarily water draw) was closed until June 13th. In 1998, the river-return pipe remained open during Phase I exchange. Closure of the river-return pipe when canal diversion is reduced creates a pooling effect in the headworks of the facility, diminishing attraction for fish. It is important to ensure that during Phase I pump exchange, the river-return pipe is open to create attraction flow and facilitate passage through the bypass system.

Hatchery and natural steelhead were both delayed in peak movement until late May. In the past, we typically observed peak movement of summer steelhead in late April to mid-May with hatchery and natural summer steelhead having similar migration patterns during all years of monitoring. The delay in 1999 may have been due to cooler water temperatures upriver due to a cooler spring. Water temperatures at Yoakum (RM 37.6) were significantly cooler ($P = 0.039$) in 1999 than in 1998 from March through June (USBR HYDROMET data). This is the period most steelhead migrate. Detections of natural summer steelhead this year were positively correlated with water temperature (Table 20).

It has been noted that steelhead smolts appear to rely on size as a migratory cue (Bell 1986). This may account for the plasticity in summer steelhead life history patterns in the Umatilla River. During the peak migration of natural steelhead (March through June), lengths of steelhead approximated the migratory size of 152 – 203 mm FL (Bell 1986). These fish were primarily age-2 fish, which is the dominant age class for migrants in the Umatilla River (Knapp et al. 2000). The larger-sized steelhead captured this year (age 3- and 4-year old fish) may have been smaller sized at age 2, requiring additional years to obtain the optimal length for migration. Data from 1998 scale analysis shows that natural steelhead over 255 mm FL were 3- and 4-year old fish (CTUIR, unpublished data).

PIT-tag detections for hatchery spring chinook salmon and hatchery and natural summer steelhead were lower overall than all other species in 1999. Operations and flows at West Extension Canal may have influenced the detection rate of spring chinook salmon released in early March. Umatilla River water was not being diverted into West Extension Canal until 15 March of 1999. The diversion of river water into the canal provides an attraction for fish to enter the trapping facility and increases trapping efficiencies. Once water was diverted to the canal, flows increased from 600 –2,000 ft^3/s within one week and remained above 1,000 ft^3/s until the end of March. Therefore, trap operations and flows probably decreased the detection rate for spring chinook salmon released in March.

Summer steelhead typically have lower detection rates and trap efficiencies, possibly due to behavioral differences such as trap avoidance. Fish may be using the east-bank adult ladder, which does not have a remote PIT-tag detection system. With the installation of a detection system (flat-plate detector) at the adult trapping facility, fish could be monitored at both passageways of the dam, improving detections and subsequently, abundance estimates.

Upriver releases of reach-survival test fish traveled faster than lower river releases. Increased travel speed with upriver releases was apparent with all species, but was most prominent with yearling spring and subyearling fall chinook salmon. Once fish passed Three Mile Falls Dam, all groups within a species had similar travel speeds to John Day Dam. Water velocity may be uniform in the mainstem Columbia River, whereas water velocity in the Umatilla River is influenced by reach gradients.

Diel patterns of movement for PIT-tagged salmonids in 1999 emulated movement of fish collected and counted hourly in 1995 and 1996 for all species (Knapp et al. 1996 and 1998a). Movement was primarily between sunrise and sunset for all species, with the exception of PIT-tagged hatchery spring chinook salmon detected in March (no fish detected from 1100 – 1700 hours). The similarity in diel movement of PIT-tagged fish remotely detected in 1999 and those hand sampled (collected 24-h per day) in past years at West Extension Canal substantiates the finding that daytime movement of salmonids through the facility is different from in-river movement, which is primarily at night. Daytime movement at West Extension Canal is also in contrast to passage data collected at John Day Dam, where greater than 78% of the salmon and steelhead pass at night between 2000-0600 hours (Martinson et al. 1995). Daytime movement patterns for fish through the West Extension Canal bypass facility may be associated with the pooling effect of the dam or with the facility structure itself. Fish may be holding up in shaded "sanctuary areas" created by facility structures and moving out as the angles of sunlight change and eliminate shaded sanctuaries. Daytime operational changes at the canal also affect movement of fish through the sampling facility. For instance, when more water is pulled into the canal for irrigation purposes, flow is increased and fish are more attracted into the facility.

Fin clip data present in our collection this year may be incomplete. It is possible that observations of any or all clips may not have been consistent between samplers or even between days of the same sampler. Even so, recoveries of fin-clipped salmonids confirmed findings that fish with multiple clips have a higher survival disadvantage over non-clipped or single-clipped fish (Blankenship, unpublished data; Vincent-Lang 1993). Although it was decided that ventral-fin clips would be discontinued for chinook salmon, spring chinook salmon from Little White Salmon Hatchery were mistakenly ADLV-fin clipped this year. Proportionately, this group of smolts was recaptured much less than their counterparts with only AD clips or no clip at all. Summer steelhead with ADLV clips were also captured far less than fish with only an adipose clip. The slight difference in recapture of AD-clipped and non-clipped coho salmon may be due to the minimal effect of adipose fin clips and coded-wire tags on survival (Vincent-Lang 1993). The same may hold true for AD-clipped and non-clipped subyearling fall chinook salmon.

As in previous years, hatchery fish were in worse condition than natural fish in terms of scale loss, especially summer steelhead. However, BKD was not as evident in hatchery fish this year as last, mortality was low, and scale loss was generally minimal. By July, condition was deteriorating for subyearling salmon that were collected at Westland Canal. Water quality was probably a primary factor, as water temperatures were beyond the chinook thermal threshold (68 °F).

Water quality may also be a factor in the high prevalence of black spot disease in natural fish. Black spot disease is actually the embedded and encysted metacercaria in the final life history stages of a parasitic intestinal trematode found in reptiles, birds, and mammals (Noble and Noble 1971). These trematodes are believed to primarily exist in areas of poor water quality. The infestation rate in 1999 was more than twice that observed in 1998 (Knapp et al. 2000).

Abundance and Survival

PIT-tag information this year provided more accurate estimates of abundance and survival than in previous years because all tagged fish moving through the bypass facility were accounted for, either by remote detection or hand interrogation. This included tagged fish used in trap efficiency tests, which provided improved estimates. In past years, numbers of marked fish in the sample were expanded by various factors, introducing the potential for large error in estimates. PIT tags also allowed the tracking of specific groups of fish, based on tag codes. The results were interesting and informative.

Spring chinook salmon from Umatilla and Little White Salmon hatcheries survived poorer than other hatchery groups released one month later. Conversely, fall chinook salmon from Bonneville Hatchery released in the same month as Umatilla fish survived well, in fact, better than any other release group. Therefore, March survival estimates are not poor for all species, just spring chinook salmon, which are predominantly from Umatilla Hatchery. Poorer survival for fish from Little White Salmon Hatchery may be due to bacterial kidney disease as 20% of the pre-liberation samples showed signs indicative of BKD (Onjukka et al. 2001). It is noteworthy that bacterial kidney disease was not evident in fish reared at Umatilla Hatchery, progeny of 97 brood year adults from the Umatilla River that were very “clean” in terms of BKD (Onjukka et al. 2001).

However, evidence is building to support the theory that Umatilla Hatchery spring chinook salmon are at a survival disadvantage in another aspect. As postulated in past reports, rearing conditions are probably not amenable to good survival. Water temperatures are too high for a yearling rearing strategy. Poor survival for Umatilla spring chinook salmon is further corroborated by results from reach survival tests and from previous years’ work. Whereas 1999 estimates of survival for production fish ranged from 18.2 – 32.5%, the reach survival estimate was 27.4% for fish similarly released at RM 80. In 1996, Umatilla spring chinook survival was estimated at 34% (Appendix Table A-5). This estimate was for March-released fish captured at the rotary trap. Brand recoveries in 1995 showed that 19.4% of the branded spring chinook salmon from Umatilla Hatchery survived (Knapp et al. 1996).

Because the overall survival estimate for spring chinook salmon from all hatcheries in 1998 was 73% (fish could not be differentiated by hatchery), it was believed that changes in rearing practices at Umatilla Hatchery to reduce growth and an earlier release date may have contributed to improved survival (Knapp et al. 2000). However, the overall survival estimate of 37% in

1999 indicates that although improved practices at Umatilla Hatchery may be beneficial, water temperatures probably still play a major role in reduced survival.

Early cold-water rearing at the Imeques acclimation pond appears to be advantageous for spring chinook salmon. This practice was instigated in 1999 for a group of spring chinook salmon to test the benefit of rearing throughout the winter in cold water (Stonecypher et al. 2001). Although this group of fish was emergency released two months prior to their scheduled release date in March, nearly 50% migrated successfully out of the basin. We recommend the continuation of this cold-water rearing strategy and the hatchery strategies used to retard growth. This will allow another year of in-basin monitoring to determine the efficacy and benefits of these changed strategies to spring chinook survival. Improved survival for April-released spring chinook salmon from Little White Salmon and Carson hatcheries continues to indicate improved rearing conditions at these hatcheries (colder water), although fish health is poorer.

Bonneville-reared fall chinook salmon have done well in the Umatilla River. Survival estimates were similar in 1999 (78%) and 1998 (70%; Appendix Table A-5). Earlier estimates were either representative of both spring and fall chinook salmon (1997, 71%) or included releases from both Umatilla and Bonneville hatcheries (1996, 40%; Appendix Table A-5). These fish should continue to be reared at Bonneville Hatchery to provide optimum potential for good migrant survival and adult returns.

Survival is progressively improving for subyearling fall chinook salmon reared at Umatilla Hatchery, primarily due to improved passage conditions in the migration corridor. This is the third year (1997 – 1999) that enhanced flows from McKay Reservoir were provided through June for juvenile migrants. Discounting overestimated survival in 1996 and 1998, survival improved from 18% in 1995 (when enhanced flows ended in early June) to 35% in 1997 and to near 54% in 1999 (Appendix Table A-6). Reach-survival tests in 1999 also indicated similar survival (52%) for subyearling chinook released at RM 80. Providing passage flows throughout June appears beneficial and should be continued or even extended.

Survival estimates for Umatilla-reared steelhead in 1999 continue to support the pattern of poorer survival for Bonifer-released fish, especially for small-grade steelhead released in late April. Radio telemetry work with tagged summer steelhead in the Umatilla River indicated some fish remained in the release-site area (Bonifer) and only a few fish exited the river (Stonecypher et al. 2001). In late May 1999, we also detected a holdover large-grade steelhead from an April 1998 release made at Bonifer, as part of our reach-survival tests. Based on survival estimates from production releases and reach survival tests, better survival is apparent for fish released at the Minthorn site, 15 miles lower in the river. We recommend an experimental release of small-grade steelhead from the Minthorn acclimation facility in 2000. This will provide additional information on the suitability of this release site for improving migration success.

For a second year, reach-specific survival tests indicated improved fish survival with successively lower releases. Translating this into adaptive management could result in lower release sites for specific groups of production fish, as indicated for summer steelhead. Improved survival for subyearling fall chinook salmon might be accomplished if fish were released below the McKay Creek confluence at RM 52, where cooler water enters the Umatilla River. Reduced survival for fish released at RM 9 is perplexing as it was expected to be the highest. It is apparent from travel speed analysis that these fish travel the slowest and may be subjected to increased predation when directly released at this site. Imagery from forward-looking infrared radiometry (CTUIR, unpublished data) indicates an intrusion of cooler spring water within this reach (Minnehaha Spring at RM 10.3), which should be beneficial to fish survival.

PIT-tag recoveries from islands in the mainstem Columbia River where bird colonies exist continue to be a source of mortality for Umatilla fish, especially summer steelhead. In both 1998 and 1999, summer steelhead from our reach survival tests suffered greater mortality from bird predation in the lower Columbia River than chinook salmon, which may be related to release timing. Umatilla summer steelhead were released in mid-April and mid-May which corresponds with timing of brood site selection by Caspian terns in the lower Columbia River (http://www.columbiabirdresearch.org/). Rice Island (RM 21) was the main source of bird predation in the mainstem Columbia River for summer steelhead in both 1998 (89%; Knapp et al. 2000) and 1999 (73%). A study is currently in progress to relocate nesting pairs from Rice Island to East Sand Island (RM 5) where marine food sources are available to nesting birds, which may reduce consumption of migrating juvenile salmonids (http://www.columbiabirdresearch.org/).

Because handling was considerably reduced, estimates of natural production were more difficult to obtain. It was evident, however, that collection of natural fall chinook salmon was much lower this year than in 1998 when nearly 5,000 natural subyearlings were sampled (Knapp et al. 2000). During our limited sampling in 1999, only 34 natural subyearling fall chinook salmon were collected and a similarly low abundance was estimated. Although mean daily river flows (near or below 1,000 ft^3/s) were conducive to incubation and rearing of the juvenile life stage, the number of adults outplanted in fall 1998 for spawning escapement was low (N= 403, 19% females; CTUIR and ODFW 1999) compared to 1997 (N=1,113 adults, 46% females; CTUIR and ODFW 1998). Outplanted fish are those from mid-Columbia hatcheries that are surplus to their broodstock needs. Outplanted fish are the only source of natural production for fall chinook salmon in the Umatilla River because all returning hatchery adults are used for Umatilla broodstock.

However, we collected many natural spring chinook salmon in 1999, which were determined to be mostly age one fish through length analysis. Estimated total abundance of 19,414 fish was similar to the estimated abundance in 1998 (18,724 fish; Appendix Table A-5). Good escapement in 1996 (2,216 spawners) and 1997 (1,540 spawners) and favorable river conditions resulted in good production. However, poor escapement in 1998 (216 spawners) could result in low production of yearling chinook salmon in 2000. Higher escapement in 1999 (1,264 spawners) may produce high numbers of subyearling spring chinook salmon in 2000 and yearlings in 2001.

Collection of natural summer steelhead was the highest among natural species. And the estimate of abundance in 1999 (45,513 fish) was similar to 1998 (53,854 fish; Appendix A-6). Escapement of hatchery and natural steelhead in 1997 (2,477) and 1996 (2,081), which produced the age-2 migrants in 1999 and 1998, was also similar (Stonecypher et al. 2001). These estimates for natural spring chinook salmon and summer steelhead migrants in 1999 possibly portend a good return of natural adults in 2001 and 2002.

Although natural production of summer steelhead appears to be fairly consistent over the years, production of spring chinook salmon has varied widely. This is most probably due to river conditions, flow events during incubation and rearing, and spawning escapement. With stable and adequate flows and sufficient spawners, spring chinook salmon can successfully produce in the Umatilla River, especially in the upper headwaters where habitat is most suitable. However, the question remains whether natural progeny produced can successfully return as adults. For natural summer steelhead, the consistent pattern in production (Appendix Table A-5) may indicate a system that is seeded to capacity given current habitat conditions. Future improvement in and expansion of habitat areas for spawning and rearing may allow for increased production.

Natural production of coho salmon (mostly yearlings) has remained within 1,000 to 3,000 fish since 1997 (Appendix Table A-5). Adult escapement between 1995 and 1997 has also been similar (618-946 fish; Stonecypher et al. 2001). With the adult return of 3,081 coho salmon in 1999, good production should result in 2001.

Estimates of survival for spring chinook salmon based on natural fish tagged in the upper river (35.3%) was remarkably similar to the overall survival estimate for hatchery production fish (37%). It can be assumed that tagged fish were active migrants, as most natural spring chinook migrate as yearlings. Survival variability of tagged natural steelhead is most likely a result of variability in age of migration and in tagging sites. Although most natural steelhead migrate at age 2, steelhead also migrate at age 1, 3 and 4. In addition, those fish tagged in tributary systems may still be in their rearing phase and not ready to migrate. The difference in proportion tagged to proportion detected from tributary sites suggests this thought. Thus, all tagged steelhead might not be true migrants and survival estimates might not be true estimates of survival.

Environmental Conditions and Bypass Operations

For the 1999 water year (October 1998 through September 1999), the Umatilla River produced a few high flow periods but lacked any major flood events. Moderate flows in the river were favorable for incubation, rearing, and outmigration of natural juvenile salmonids.

Variability in river flow throughout the sampling season affected water clarity. Rapid rises in river flow increased suspended sediment loads, causing water clarity to decrease. Both Pacific lamprey and hatchery and natural salmonid movements did not appear to be altered by turbidity but rather influenced by the associated river flow.

As in the past several years, rises in water temperature in 1999 coincided with low river flow (Knapp et al. 1998a, 1998b, 2000). High water temperatures exist in the Umatilla River during the summer months as a consequence of minimal water flow and high ambient air temperature. Even with the influx of flow (and cooler water) through enhancement strategies

(McKay Reservoir releases), conditions can be intolerable for juvenile salmonids and may affect their survival. In fact, river temperatures neared a lethal limit of 75 °F (Brett 1952) at RM 3.7 several times in June and July and temperatures at RM 37.6 were near and above 60 °F. In addition, the forward-looking infared radiometry (FLIR) profile compiled and released by CTUIR for the Umatilla River in August 1998 showed large fluctuations in river temperatures below Pendleton, which might alter or delay migration or stress fish. McKay Creek, for example, immediately cools the Umatilla River by more than 15 ^{o}F before it gradually warms again. Intermittent contributions from groundwater intrusion, canal seepage, and springs cool the heated water only temporarily.

A critical period for flow enhancement is during the outmigration of summer migrants, particularly natural and hatchery subyearling fall chinook salmon. Water releases from McKay Reservoir during June are a requisite for aiding outmigration and increasing survival of these migrants. Reservoir releases comprised 96% of the total water volume in June. This additional water allows more fish to move out in-river (versus transport from Westland Canal) and gives them a better chance for survival. Limiting thermally-induced and flow-associated stress can increase outmigration success in the Umatilla River. Connor et al. (1998) stated that flow releases into the Snake River from Dworshak Reservoir are highly beneficial to the survival of Snake River stock of subyearling fall chinook salmon because, in addition to increased flow, water temperature remains cooler for longer periods. Increased summer flows (and the associated thermal benefits) in the Umatilla River are important in optimizing conditions for mid- and late summer migrants. Continued water releases throughout the summer may also provide a suitable thermal profile for rearing of naturally produced fish in mid-river locations.

In addition, subyearling fall chinook salmon, both natural and hatchery, arrive at Three Mile Falls Dam in early summer and are faced with facility-related challenges that do not exist for species that arrive earlier. With minimal flow spilling over the dam, these fish must either pass through the west-bank canal bypass facility or the east-bank fish ladder. At this time, degree of diversion is important in attracting fish to the canal bypass facility in order to minimize any delay in migration. Termination of canal diversion with the onset of Phase I pump exchange appeared to affect attraction and bypass efficiency, particularly for subyearling fall chinook salmon. A definite decrease in fish detections was observed this year when the opening of the river-return pipe was delayed until well after diversion was curtailed. However, detections of subyearling fall chinook salmon peaked immediately after the pipe was re-opened in mid-June. When the bypass facility is in sampling mode, it is vital that the river-return pipe be open during Phase I pump exchange to provide an attraction flow into the bypass system. (The river-return pipe was closed due to the concern that discharge would falsely attract adult spring chinook salmon during low river flow.)

Hatchery and natural chinook salmon (both yearling and subyearling) were captured more efficiently with a higher diversion rate. However, diversion rate had no effect on the efficiency of capturing hatchery and natural summer steelhead. The ability of steelhead to hold in currents may be a behavioral characteristic for which their large size and strong swimming capabilities allow. Results were similar in 1998, except for spring chinook salmon, which showed no correlation to degree of diversion (Knapp et al. 2000).

The magnitude of resident fish using the dam passage facilities also underscores the importance of ensuring that operations at both facilities are providing efficient and effective passage. This is especially true during low summer flows when the bypass facility is in sampling mode; during this period, the ladder and bypass are the only means of navigating past Three Mile Falls Dam. Closure of the east-bank fish ladder in July eliminated the main migration route and subsequently caused a large influx of resident fish to pass through the juvenile bypass system. Operational changes at the dam affected movement patterns of resident fish and it is, therefore, important to have both systems running properly to accommodate all fish passage needs.

The relationship between travel speed and mean river flow is believed to be positive (Skalski et al. 1996). However, hatchery fish released into the Umatilla River produced mixed results. It is hard to determine if movement of hatchery fish exhibits a true relationship with river flow conditions due to the confounding effects of being "released". This year, as in the past, most species of hatchery fish tended to move out immediately after release, regardless of environmental conditions (Knapp et al. 1998b, 2000). In addition, movement of natural fish may be more related to temperature than to flow.

Travel speeds of spring chinook salmon released in March and April for both production and reach-survival tests were inversely related to mean flow in the river corridor. The scatter plots for these releases mostly showed an initial cluster of data points immediately following release, with flows between 400 and 700 ft^3/s (Appendix Figures A-1 and A-6). Remaining fish moved out when flows approached 1,000 ft^3/s. However, spring chinook salmon released in December only emigrated when flows were above 1,000 ft^3/s. Travel speeds increased for the few remaining fish as flows increased toward 1,500 ft^3/s. The scatter plots of hatchery-released fall chinook salmon showed a similar pattern to spring-released spring chinook salmon, with a few fish moving out immediately after release, but the majority moving when flows reached 1,100 ft^3/s (Appendix Figure A-2). It appears that higher flows were a requisite to the final stimulation of movement for spring and fall chinook salmon, though other factors such as level of smoltification at time of release may have played a part in delaying their outmigration (Kindley 1991).

Travel speeds of subyearling fall chinook salmon (both production and reach-survival fish), on the other hand, were all strongly related to increasing flow (Appendix Figures A-3 and A-7). Although flow was relatively stable during their outmigration, the strong correlation suggests that even the slightest increase in flow is beneficial for these summer migrants. Thus, flow enhancement appears to offer a benefit to these later migrants and should continue throughout the summer months.

Relationships between travel speed and mean river flow for summer steelhead were variable between release sites in production and reach-survival releases. For the most part, travel speeds were positively correlated with river flow. Exceptions were the large-sized production releases in early April (Bonifer and Minthorn) and the Echo and Steelhead Park reach-specific survival releases; these releases showed an inverse relationship. Removing a few outliers from these exceptions, however, shifted most results to the expected positive correlation; the correlation for reach-survival test fish released at Steelhead Park remained negative. It is possible that Steelhead Park may experience a pooling effect from Three Mile Falls Dam, minimizing the effect of flow through this area on these larger fish. A scatter plot of steelhead released in early April for both production and reach-survival tests showed concentrated data points mostly when flows approached or exceeded 1,000 ft^3/s (Appendix Figures A-4 and A-8). Although flows during release were at this level, much of the migration was delayed until late May. Earlier we speculated that cooler temperatures may have delayed movement for both hatchery and natural steelhead. In addition, Kindley (1991) found that when juvenile chinook salmon were not physiologically developed, flow had little influence on travel speed. Similarly, smoltification of large-grade steelhead may not have been adequate for migration at the time of release in early April.

Small-sized steelhead released later (late April for production and early May for reach-survival tests) exhibited travel speeds that were directly related to increasing flows, with most data points associated with flows between 500 ft^3/s and 850 ft^3/s (mid-May; Appendix Figures A-5 and A-9). Mean travel speeds for these fish were faster than for fish released earlier in April, possibly an attribute of advanced smoltification. In another study on the Wallowa River, summer steelhead smolts released from Wallowa Fish Hatchery also migrated much faster the later they were released (April versus May releases; Flesher and Whitesel 1999).

Resident Fish and Predators

Resident fish were captured in unusually high numbers in July. These fish may move down the Umatilla River towards the Columbia River naturally during the summer months in search of better river conditions or subsequent to spawning. Largescale suckers in Lake Washington, for example, move to the mouths of tributaries during the summer months seeking deeper, cooler water (Wydoski and Whitney 1979). The large influx of resident fish at West Extension Canal this year coincided with the closure of the east-bank fish ladder, indicating that the ladder is an important migration route. Flow enhancement in the lower river throughout summer, coupled with passage facility operations, would have value for resident fish in allowing expression of their natural life history strategies.

Higher numbers of larger-sized bass were captured this year than past years at West Extension Canal (Knapp et al. 1996, 1998a, and 2000). An increase in bass populations has been suspected in the lower Umatilla River in recent years, especially near RM 10, but no research has been conducted to verify this increase or its consequences (personal communication, J. Germond, ODFW, Pendleton, OR). Bass are a major predator on juvenile salmonids in rearing areas such as this when bass and salmonid habitats overlap (Tabor et al. 1993). Although all bass spp. captured were juveniles (< age 3), 68 of the 162 measured had mean fork lengths above 128 mm. According to Vigg et al. (1988), smallmouth bass between the lengths of 128 - 314 mm have the highest consumption of fish in their diet with roughly 1 - 7% of that diet comprising salmonids. Therefore, the bass population rearing in the lower Umatilla River may negatively affect the survival of juvenile salmonids. Reach survival tests with subyearling fall chinook salmon showed a decrease in their survival at the RM 9 release site.

Northern pikeminnow was another pisciverous predator of concern captured in 1999. Although we captured only four pikeminnows of predator size (> 250 mm FL, Collis et al. 1995), these fish were captured in December and January, a time when the small, early-released (20 December) spring chinook salmon were in the river. An additional fifteen fish over 200 mm FL were also captured in January and may have been potential predators as well. Past data shows that captures of larger-sized northern pikeminnows coincided with the outmigration of smaller salmonids such as subyearling fall chinook salmon (Knapp et al. 1998a), but captures in 1997 were in January when few hatchery juvenile salmonids were in the river but many resident juveniles were (Knapp et al. 1998b). As in past years, captures at West Extension Canal this year were relatively low (79), but high numbers of northern pikeminnows were seen at the east-bank fish ladder (Knapp et al. 1998a, 2000; CTUIR and ODFW 1999). The east-bank ladder may be the primary migration route for northern pikeminnows, leaving low capture data from West Extension Canal to be misleading as to their abundance in the lower river. In one instance (October 2000), however, over 600 northern pikeminnows were captured in a single day at the bypass facility during an increase in flow (ODFW, unpublished data). The presence of northern pikeminnow at the ladder and bypass indicates their presence in the forebay of Three Mile Falls Dam, an area where juvenile salmonids are vulnerable to predation.

Juvenile Pacific lampreys were captured in the lower Umatilla River from November through April. Most lamprey captured in 1999 were larvae (non-smolted), and as in recent years, captures appeared to coincide with an increase in river flow (Knapp et al. 1998b, 2000). These larvae were not migrating, but rather washed out of their burrows during the higher flows (Close et al. 1995). Non-smolted lamprey were similar in length to smolted lamprey, which is not consistent with 1998 data in which smolted lamprey were smaller in size than non-smolted lamprey (Knapp et al. 2000). Typically, lamprey decrease in size as they undergo metamorphosis (personal communication, D. Close, CTUIR, Mission, OR). Metamorphosed (smolted) lampreys were captured in late November and throughout December. Because smolted juvenile lampreys are known to migrate to the ocean between late fall and spring (Close et al. 1995; van de Wetering 1998), smolted lampreys captured in the Umatilla River were thought to be actively migrating. It has also been observed that lamprey smolts migrate more actively during the rise and fall of river flow, not necessarily the peak of the flow (Knapp et al. 2000; van de Wetering 1998); most smolts were captured in the Umatilla River this year during a rise in flow. Year-round monitoring is needed to determine when lampreys undergo metamorphosis in the Umatilla River and to determine their annual abundance and habitat requirements. The Confederated Tribes of the Umatilla Indian Reservation’s Lamprey Restoration Plan (Close, In Preparation) intends to supplement in-basin lamprey populations and gain an in-depth understanding of this species and its needs in the Umatilla River. Our monitoring of lamprey juvenile life stages assists in this effort.

It has been noted since this study began that avian predators pose a serious threat to juvenile salmonids (Knapp et al. 1996, 1998a, 1998b, 2000). Although few avian predators were observed during sampling at the rotary-screw trap, numbers were prevalent while sampling at West Extension Canal from April through June. Fish are more visible near the dam as they approach and spill over, pass into the canal headworks, or surface in turbulent waters below the dam, making them more vulnerable to avian predation. Gulls were the dominant avian predator observed this year, although cormorants, great blue herons, and night herons were also present. Gulls and other pisciverous birds are opportunistic feeders and are often most active during periods of major fish movements or after fish stockings (Modde et al. 1996, Ruggerone 1986).

Highest observations in May and June coincided with the presence of hatchery fish in the river, low river flows, and high water clarity. A few gulls were observed during November and December while flow was still relatively low and the water was clear. Because there were no hatchery fish and few natural salmonids in the river at this time, these gulls may have been feeding on resident fish or Pacific lamprey. Historically, lampreys have been known to constitute as much as 71% of the diet of gulls (Close et al. 1995). Observations of avian predators in May coincided with several upriver hatchery releases in April of spring chinook salmon, yearling fall chinook salmon, and summer steelhead (Appendix Table A-1). The June observations corresponded with releases of hatchery subyearling fall chinook salmon. Cormorants, great blue herons, and night herons were also observed at high numbers during May and June. All four species (gulls, cormorants, great blue herons, and night herons) were feeding mostly near the dam, some with a distinct niche. Using a niche different from other predators minimizes competition and therefore maximizes the benefits for each individual species. Most great blue herons were seen standing in the river below the dam for feeding. Night herons were observed usually at the bypass outfall at higher river flows, feeding on bypassed juveniles.

Although feeding habits of these avian predators was not the main focus of this study, the effect on salmonid survival was a concern. Of the fish that were captured with visible injuries, bird marks were present on all species (Table 15). Fifty percent or greater of injured hatchery chinook salmon, coho salmon, and summer steelhead possessed bird marks. Only one hatchery subyearling fall chinook salmon captured was observed with bird marks, though gull activity was highest during their outmigration (Figure 30). This may indicate that these smaller fish are not escaping or surviving predatory attacks.

From these results, it can be suggested that avian predation on salmonids is an ongoing problem. It is recommended that efforts to decrease bird predation be focused on the area surrounding Three Mile Falls Dam where fish are most vulnerable. Bird deterrents such as water cannons, rain bird sprinklers, mylar balloons or strips, or noisemakers (i.e. firecrackers) are needed at the dam to discourage avian predators from feeding on salmonids. A barrier blocking entrance to the outfall may be the best option to prevent night herons from preying at this site.

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LITERATURE CITED

Beamish, R.J. 1980. Adult biology of the river lamprey (*Lampetra ayersi*) and the Pacific lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences 37:1906-1923.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fish Passage Development and Evaluation Program, Corps of Engineers, North Pacific Division, Portland, Oregon.

Blankenship, H.L., S. Olhausen, and D.A. Thompson. Differential survival of ventral fin and adipose fin clips in fall chinook salmon (*Oncorhynchus tschawytscha*). Internal Report, Washington Department of Fish and Wildlife, Olympia, Washington.

Boyce, R.R. 1986. A comprehensive plan for rehabilitation of anadromous fish stocks in the Umatilla River basin. Final report of Oregon Department of Fish and Wildlife to the Bonneville Power Administration, Portland, Oregon.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. Journal of the Fisheries Research Board of Canada, 9: 265-323.

Burnham, K.P., D.R. Anderson, G.C. White, C. Brownie, and K.H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5: 1-437.

Cameron, W.A., S.M. Knapp, and B.P. Schrank. 1994. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. 1993 annual progress report to Bonneville Power Administration, Portland, Oregon.

Clarke, W.C. and R.J. Beamish. 1988. Response of recently metamorphosed anadromous parasitic lamprey (*Lampetra tridentata*) to confinement in fresh water. Canadian Journal of Fisheries and Aquatic Sciences 45:42-47.

Close, D.A. In Preparation. Restoration plan for Pacific lampreys (*Lampetra tridentata*) in the Umatilla River, Oregon. Report to Bonneville Power Administration, Portland, Oregon.

Close, D., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of the Pacific Lamprey (*Lampetra tridentata*) in the Columbia River Basin. Report to Bonneville Power Administration, Portland, Oregon.

Collis, K., R.E. Beaty, B. Ashe, B. Parker, K. McRae, and G. Lee. 1995. Report E *in* C. Willis and D. Ward, editors. Development of a systemwide predator control program: Stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River basin. Volume 1-Implementation. 1993 annual progress report to Bonneville Power Administration, Portland, Oregon.

Conner, W.P., H.L. Burge, and D.H. Bennett. 1998. Detection of PIT-tagged subyearling chinook salmon at a Snake River Dam: Implications for summer flow augmentation. North American Journal of Fisheries Management, Vol. 18: 530–536.

Contor, C.R., E. Hoverson, P. Kissner, and J. Volkman. 1996. Umatilla basin natural production monitoring and evaluation. Annual progress report 1994-1995 to Bonneville Power Administration, Portland, Oregon.

Contor, C.R., E. Hoverson, P. Kissner, and J. Volkman. 1997. Umatilla basin natural production monitoring and evaluation. Annual progress report 1995-1996 to Bonneville Power Administration, Portland, Oregon.

Contor, C.R., E. Hoverson, and P. Kissner. 1998. Umatilla basin natural production monitoring and evaluation. Annual progress report 1996-1997 to Bonneville Power Administration, Portland, Oregon.

Contor, C.R. and P. Kissner. 2000. Umatilla basin natural production monitoring and evaluation. Annual progress report 1997-1998 to Bonneville Power Administration, Portland, Oregon.

Contor, C.R. and P. Kissner. In Preparation. Umatilla basin natural production monitoring and evaluation. Annual progress report 1998-1999 to Bonneville Power Administration, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation). 1984. Umatilla basin recommended salmon and steelhead habitat (hatchery and passage) improvement measures. Mission, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation). 1994. Umatilla basin natural production monitoring and evaluation. Annual progress report 1992-1993 to Bonneville Power Administration, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1989. Umatilla River subbasin – salmon and steelhead plan. Prepared for the Northwest Power Planning Council for Columbia Basin system planning.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1990. Umatilla hatchery master plan. Prepared for the Northwest Power Planning Council, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1997. Trapping and transportation of adult and juvenile salmon in the lower Umatilla River in northeast Oregon, Annual progress report 1996-1997 to Bonneville Power Administration, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1998. Trapping and transportation of adult and juvenile salmon in the lower Umatilla River in northeast Oregon, Annual progress report 1997-1998 to Bonneville Power Administration, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1998. Fish passage operations in the Umatilla River, Annual progress report 1998-1999 to Bonneville Power Administration, Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation) and ODFW (Oregon Department of Fish and Wildlife). 1999. Umatilla River passage operations program. Annual progress report 1998 – 1999 to Bonneville Power Administration, Portland, Oregon.

Dauble, D.D., J. Skalski, A. Hoffman, and A. E. Giorgi. 1993. Evaluation and application of statistical methods for estimating smolt survival. Report to the Bonneville Power Administration, Portland, Oregon.

Efron, B. and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1(1): 54-77.

Flesher M.W. and T.A. Whitesel. 1999. Volitional releases of summer steelhead in NE Oregon: smolt performance and adult survival. Poster presented at the Northwest Fish Culture Conference, 7-9 December 1999, Seattle, Washington.

Focher, S.M., R.W. Carmichael, M.C. Hayes, and R.W. Stonecypher, Jr. 1998. Umatilla Hatchery monitoring and evaluation. 1996 annual progress report to Bonneville Power Administration, Portland, Oregon.

Hayes, M.C., R.W. Carmichael, S.M. Focher, M.L. Keefe, and G.W. Love. 1995. Umatilla Hatchery monitoring and evaluation. 1994 annual progress report to the Bonneville Power Administration, Portland, Oregon.

Hayes, M.C., R.W. Carmichael, S.M. Focher, and R.W. Stonecypher, Jr. 1996. Umatilla Hatchery monitoring and evaluation. 1995 annual progress report to Bonneville Power Administration, Portland, Oregon.

Hayes, M.C., R.W. Carmichael, S.M. Focher, and R.W. Stonecypher, Jr. 1999a. Umatilla Hatchery monitoring and evaluation. 1997 annual progress report to the Bonneville Power Administration, Portland, Oregon.

Hayes, M.C., W.A. Cameron, R.W. Stonecypher, Jr., and R.W. Carmichael. 1999b. Umatilla Hatchery monitoring and evaluation. 1998 annual progress report to the Bonneville Power Administration, Portland, Oregon.

Kindley, R. 1991. The flow/survival/travel time relationship: review and analysis of supporting information and rationale for flows for juvenile spring chinook salmon and summer chinook migrations. Pacific Northwest Utilities Conference Committee, Portland, Oregon.

Keefe, M.L., R.W. Carmichael, R.A. French, W.J. Groberg, and M.C. Hayes. 1993. Fish research project – Oregon. Umatilla Hatchery monitoring and evaluation. 1992 annual progress report to Bonneville Power Administration, Portland, Oregon.

Keefe, M.L., R.W. Carmichael, S.M. Focher, W.J. Groberg, and M.C. Hayes. 1994. Umatilla Hatchery monitoring and evaluation. 1993 annual progress report to Bonneville Power Administration, Portland, Oregon.

Knapp, S.M., J.C. Kern, W.A. Cameron, S.L. Shapleigh, and R.W. Carmichael. 1996. Evaluation of juvenile salmonid outmigration and survival in the lower Umatilla River basin. Annual progress report 1994-1995 to Bonneville Power Administration, Portland, Oregon.

Knapp, S.M., J.C. Kern, W.A. Cameron, S.M. Snedaker, and R.W. Carmichael. 1998a. Evaluation of juvenile salmonid outmigration and survival in the lower Umatilla River basin. Annual progress report 1995-1996 to Bonneville Power Administration, Portland, Oregon.

Knapp, S.M., W.A. Cameron, J.C. Kern, and R.W. Carmichael. 1998b. Evaluation of juvenile salmonid outmigration and survival in the lower Umatilla River basin. Annual progress report 1996-1997 to Bonneville Power Administration, Portland, Oregon.

Knapp, S.M., R.W. Carmichael, D.L. Ehlers, S.M. Focher, T.A. Jones, and J.C. Kern. 2000. Evaluation of juvenile salmonid outmigration and survival in the lower Umatilla River basin. Annual progress report 1997-1998 to Bonneville Power Administration, Portland, Oregon.

Knapp, S.M., R.W. Carmichael, D.L. Ehlers, S.M. Jewett. In Progress. Evaluation of juvenile salmonid outmigration and survival in the lower Umatilla River basin. Annual progress report 1999-2000 to Bonneville Power Administration, Portland, Oregon.

Martinson, R.D., R.J. Graves, M.J. Langeslay, L.A. Wood, and S.D. Killins. 1995. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities. 1994 annual progress report to Bonneville Power Administration, Portland, Oregon.

Noble, E.R., and G.A. Noble. 1971. Parasitology, the Biology of Animal Parasites. Lea & Febiger, Philadelphia, Pennsylvania.

NPPC (Northwest Power Planning Council). 1987. Columbia River basin fish and wildlife program (as amended). Northwest Power Planning Council, Portland, Oregon.

Onjukka, S.T., G.M. Claire, W.J. Groberg, Jr., B.M. Farman and K.A. Brown. 2001. Fish health monitoring and evaluation (Report B). *in* R.W. Stonecypher, Jr., editor. Umatilla Hatchery monitoring and evaluation. 1999 annual report to Bonneville Power Administration, Portland, Oregon.

PIT Tag Steering Committee. 1993. PIT-tag marking station procedural manual. Version 1.0.

SAS Institute, Inc. 1990. SAS language: reference, version 6.12. Cary, North Carolina.

Stonecypher, R.W., Jr., W.A. Cameron, M.C. Hayes, and R.W. Carmichael. 2001. Umatilla Hatchery monitoring and evaluation. 1999 annual report to the Bonneville Power Administration, Portland, Oregon.

Skalaski, J.R., R.L. Townsend, R.F. Donnelly, and R.W. Hilborn. 1996. The relationship between survival of Columbia River fall chinook salmon and inriver environmental factors. Analysis of historic data for juvenile and adult salmonid production: Phase II. Final report to Bonneville Power Administration, Portland, Oregon.

Snedecor, G.W. and W.G. Cochran. 1989. Statistical Methods. 8th Edition. Iowa State University Press, Ames, Iowa.

Tabor, R.A., R.S. Shively, and T.P. Poe. 1993. Predation on juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13: 831-838.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

USBR (U.S. Bureau of Reclamation). 1988. Umatilla basin project – planning report and final environmental impact statement. Statement Number FES 88-4, filed February 12, 1988.

USBR (U.S. Bureau of Reclamation) and BPA (Bonneville Power Administration). 1989. Umatilla basin project. Initial project workplan presented to the Northwest Power Planning Council, May 1989.

van de Wetering, S.J. 1998. Aspects of Life History Characteristics and Physiological Processes in Smolting Pacific Lamprey, *Lampetra tridentata*, in a Central Oregon Coast Stream. A thesis submitted to Oregon State University, Corvallis, Oregon.

Vigg, S., T.P. Poe, L.A. Pendergast, and H.C. Hansel. 1988. Predation by resident fish on juvenile salmonids in a mainstem Columbia River reservoir: Part II. Consumption rates of northern squawfish, walleye, smallmouth bass, and channel catfish. *In* T.P. Poe and B.E. Rieman, editors. Predation by resident fish on juvenile salmonids in John Day

Reservoir, 1983 - 86. Final report (Contracts DE-AI79 -82BP34796 and DE-AI79-82BP35097) to Bonneville Power Administration, Portland, Oregon.

Vincent-Lange, D. 1993. Relative survival of unmarked and fin-clipped coho salmon from Bear Lake, Alaska. The Progressive Fish Culturist 55(3): 141-148.

Walters, T.R., R.D. Ewing, M.A. Lewis, R.W. Carmichael, and M.L. Keefe. 1994. Evaluation effects of transporting juvenile salmonids in the Umatilla River at high temperatures. Pages 117-130 *in* S.M. Knapp, editor. Evaluation of juvenile fish bypass and adult fish passage facilities at water diversions in the Umatilla River. Annual progress report 1992 – 1993 to Bonneville Power Administration, Portland, OR.

Wydoski, R.S. and R.R. Whitney. 1979. Inland Fishes of Washington. University of Washington Press, Seattle, Washington.

Table 1. Number of natural salmonids PIT tagged at trap sites and released live into the lower Umatilla River, December 1998 – June 1999.

Month tagged	Year	Number tagged: Spring chinook	Number tagged: Summer steelhead
		Rotary Trap (RM 1.2)	
December	1998	12	2
January	1999	77	10
February	1999	1	1
March	1999	19	1
Total		*109*	*14*
		West Extension Canal (RM 3.7)	
March	1999	181	88
April	1999	345	251
May	1999	157	1,475
June	1999	0	63
Total		*683*	*1,877*

Table 2. Number detected and percent detection of PIT-tagged hatchery and natural salmonids interrogated remotely and by hand at lower river trapping sites on the Umatilla River, January – July 1999.

Species[a]	Location[b]	Detection type	Number detected	Number released[c]	Percent detected
		Hatchery			
CHS	RST	hand	5		
	WEID	hand	47		
	WEID	remote	186		
		Total	*238*	*2,151*	*11.1*
CHF	WEID	hand	29		
	WEID	remote	96		
		Total	*125*	*484*	*25.8*
CH[d]	WEID	hand	1	-	-
CHF0	WEID	hand	8		
	WEID	remote	819		
	Westland	hand	1		
		Total	*828*	*3,489*	*23.7*
STS	WEID	hand	12		
	WEID	remote	71		
		Total	*83*	*696*	*11.9*
		Natural			
CH	WEID	hand	7		
	WEID	remote	37		
		Total	*44*	*275*	*16.0*
STS	WEID	hand	23		
	WEID	remote	169		
		Total	*192*	*2,010*	*9.6*

[a] *CHS = spring chinook salmon, CHF = fall chinook salmon, CHF0 = subyearling fall chinook salmon, STS = summer steelhead, and CH = chinook salmon.*

[b] *RST = rotary trap at RM 1.2, WEID = West Extension Canal at RM 3.7, and Westland = Westland Canal at RM 27.3.*

[c] *Number tagged was adjusted by tag loss and mortality prior to release.*

[d] *One PIT-tag code of unknown origin was detected in a chinook salmon so the race could not be determined.*

Table 3. Natural fish PIT tagged by CTUIR, released at upper Umatilla River sites, and detected at RM 3.7, Umatilla River, January – June 1999.

Release site[a]	Release date	Number tagged	Number detected	Percent detected
		Spring Chinook Salmon		
Meacham Creek	1/22	5	0	0.0
(RM 79)	2/17	3	0	0.0
	2/19	2	0	0.0
	2/27	1	1	100.0
	3/16	5	1	20.0
	3/19	19	3	15.8
	3/23	5	1	20.0
	3/30	3	1	33.3
	4/13	3	1	33.3
	4/17	1	0	0.0
	4/20	1	0	0.0
Total		*48*	*8*	*16.7*
Umatilla River	1/21	32	3	9.4
(RM 80)	1/30	14	1	7.1
	2/17	14	3	21.4
	2/19	45	10	22.2
	2/27	50	7	14.0
	3/5	24	3	12.5
	3/16	12	1	8.3
	3/19	1	0	0.0
	3/23	16	1	6.3
	3/30	1	0	0.0
	4/13	6	1	17.7
	4/15	3	1	33.3
	4/16	1	0	0.0
	4/17	4	2	50.0
	4/22	4	3	75.0
Total		*227*	*36*	*15.9*
		Summer Steelhead		
Buckaroo Creek	3/25	128	4	3.1
(RM 73)	4/1	55	0	0.0
Total		*183*	*4*	*2.2*

[a] *Release site RM is where the mouth of the creek enters the Umatilla River or where the trap is located on the Umatilla River.*

Table 3. Continued.

Release site[a]	Release date	Number tagged	Number detected	Percent detected
		Summer Steelhead (cont'd)		
Squaw Creek (RM 77)	3/18	39	1	2.6
Birch Creek (RM 48)	3/19	16	0	0.0
	3/16[b]	43	0	0.0
	4/5[b]	97	8	8.2
	3/19[c]	52	2	3.8
	4/7[c]	120	7	5.8
	4/8[c]	114	7	6.1
	3/16[d]	39	1	2.6
Total		*481*	*25*	*5.2*
Meacham Creek (RM 79)	1/22	8	1	12.5
	3/16	7	1	14.3
	3/19	44	3	6.8
	3/23	59	4	6.8
	3/30	18	0	0.0
	4/2	29	2	6.9
	4/13	68	6	8.8
	4/17	49	6	12.2
	4/20	316	55	17.4
	4/22	14	3	21.4
	4/28	57	6	10.5
	4/30	11	2	18.2
	5/6	13	3	23.1
	5/12	46	4	8.7
	5/14	56	4	7.1
	5/15	17	3	17.6
	5/18	22	2	9.1
	5/20	34	4	11.8
	5/21	53	7	13.2
	5/25	49	2	4.1
	5/26	45	2	4.4
	5/28	47	0	0.0
	6/3	10	1	10.0
Total		*1,072*	*121*	*11.3*

[b] *Released in East Fork of Birch Creek.*
[c] *Released in West Fork of Birch Creek.*
[d] *Released in Pearson Creek, a tributary to Birch Creek.*

Table 3. Continued.

Release site[a]	Release date	Number tagged	Number detected	Percent detected
		Summer Steelhead (cont'd)		
Umatilla River	1/30	3	0	0.0
(RM 80)	2/19	1	0	0.0
	2/27	3	0	0.0
	3/5	4	2	50.0
	3/16	1	0	0.0
	3/19	2	0	0.0
	3/23	15	1	6.7
	3/30	34	4	11.8
	4/13	11	2	18.2
	4/15	7	2	28.6
	4/16	3	0	0.0
	4/22	74	17	23.0
	4/28	21	3	14.3
	5/6	5	1	20.0
	5/8	13	5	38.5
	5/14	4	1	25.0
	5/15	3	0	0.0
	5/18	4	0	0.0
	5/20	11	2	18.2
	5/21	2	1	50.0
	5/24	5	0	0.0
	5/25	3	0	0.0
	5/28	6	0	0.0
Total		*235*	*41*	*17.4*

Table 4. PIT-tagged fish from different hatcheries and hatchery rearing strategies detected in the lower Umatilla River at RM 1.2, RM 3.7, and RM 27.3, October 1998 - August 1999.

Hatchery	Rearing strategy[a]	Raceway section	Number released	Release date[b]	Number detected[c]	Percent detection	Total detection
			Spring Chinook Salmon				
Umatilla	Oregon	A	243	12/20	8	3.3	
	Oregon	B	240	12/20	6	2.5	2.9
	Michigan	A	240	3/8	15	6.3	
	Michigan	B	247	3/8	14	5.7	
	Michigan	C	240	3/8	19	7.9	6.6
	Oregon	A	241	3/8	17	7.1	
	Oregon	B	233	3/8	18	7.7	7.4
Little White	Standard		248	3/8	20	8.1	8.1
Salmon	Standard		219	4/14	58	26.5	26.5
Carson	Standard		248	4/14	63	25.4	25.4
			Fall Chinook Salmon				
Bonneville	Standard		248	3/11	62	25.0	25.0
	Standard		236	4/15	63	26.7	26.7
			Subyearling Fall Chinook Salmon				
Umatilla	Low density	A	590	6/3	118	20.0	
	Low density	B	585	6/3	141	24.1	22.0
	Med. density	A	583	6/3	144	24.7	
	Med. density	B	582	6/3	144	24.7	24.7
	High density	A	564	6/3	153	27.1	
	High density	B	585	6/3	128	21.9	24.5
			Summer Steelhead				
Umatilla	Large grade	C	198[d]	4/5[e]	25	12.6	12.6
	Large grade	B	210[f]	4/6[e]	29	13.8	13.8
	Small grade	A	288[d]	4/27[e]	29	10.1	10.1

[a] *Oregon = reared in standard raceway, Michigan = reared in oxygenated raceway, low density = reared at 200K, medium density = reared at 300K, and high density = reared at 400K.*

[b] *Spring chinook salmon released at RM 80, yearling and subyearling fall chinook salmon released at RM 73.5, and summer steelhead released at RM 64.5 and 79.*

[c] *Number detected does not include fish that lost tags or tagged fish that could not be assigned to a tag file.*

[d] *Released at Bonifer Springs, RM 2 of Meacham Creek at RM 79 of the Umatilla River.*

[e] *Volitional release dates.*

[f] *Released at Minthorn Springs, RM 64.5.*

Table 5. Holding survival and tag retention of tagged hatchery and natural juvenile salmonids used in trap efficiency tests at West Extension Canal (RM 3.7), Umatilla River, spring 1999.

Mark date	Number tagged	Mean temperature[a]	Hours held	Number mortalities	Number of lost tags	Percent survival[b]	Percent tag retention
Hatchery							
Spring Chinook Salmon							
3/10	103	9.5	25.8	4	1	96.1	99.0
Chinook Salmon							
3/12	102	14.8	18.0	0	8	100.0	92.2
3/15	105	9.8	27.6	1	1	99.0	99.0
3/17	103	8.0	31.6	0	21	100.0	79.6
3/19	106	9.3	32.4	0	29	100.0	72.6
3/24	110	9.8	27.8	7	1	93.6	99.1
3/26	110	8.3	31.1	4	0	96.4	100.0
3/29	109	8.0	46.2	3	0	97.2	100.0
4/7	80	9.5	29.8	0	0	100.0	100.0
4/16	85	12.5	29.4	1	1	98.8	98.8
4/19	98	11.0	27.8	3	0	96.9	100.0
4/22	101	11.0	29.0	0	0	100.0	100.0
4/25	87	12.0	31.7	4	0	95.4	100.0
4/28	88	12.0	54.3	0	0	100.0	100.0
5/1	83	13.0	24.3	0	0	100.0	100.0
5/4	74	12.9	27.8	0	0	100.0	100.0
5/8	84	11.3	31.2	2	0	97.6	100.0
5/13	86	12.0	30.0	0	0	100.0	100.0
					Overall	*98.5*	*96.4*
Subyearling Fall Chinook Salmon							
6/6	100	16.3	28.5	1	0	99.0	100.0
6/7	98	16.0	--	0	0	100.0	100.0
6/8	99	16.5	29.5	0	0	100.0	100.0
6/9	99	18.0	--	7	1	92.9	99.0
6/10	150	19.0	20.0	2	1	98.7	99.3
6/11	149	19.0	28.2	0	0	100.0	100.0
6/12	150	19.5	28.0	0	0	100.0	100.0
6/13	150	20.5	27.7	1	0	99.3	100.0
6/14	151	21.3	52.8	6	0	96.0	100.0

[a] *Average of temperature in °C at beginning and end of holding period.*

[b] *Percent survival is based on holding mortalities only and is the expected survival of fish after test release.*

Table 5. Continued.

Mark date	Number tagged	Mean temperature [a]	Hours held	Number mortalities	Number of lost tags	Percent survival[b]	Percent tag retention
			Subyearling Fall Chinook Salmon (cont'd)				
6/16	100	21.0	26.4	3	0	97.0	100.0
6/18	103	20.8	27.8	0	0	100.0	100.0
6/20	98	19.5	24.8	4	0	95.9	100.0
6/22	95	19.5	20.6	0	0	100.0	100.0
6/24	60	19.0	46.5	3	1	95.0	98.3
6/30	54	19.5	24.7	2	0	96.3	100.0
7/3	52	18.3	54.2	8	1	84.6	98.1
					Overall	*97.8*	*99.8*
			Summer Steelhead				
4/18	97	11.8	44.1	0	2	100.0	97.9
4/27	88	10.8	21.9	0	0	100.0	100.0
5/1	67	13.0	29.5	0	1	100.0	98.5
5/5	74	13.5	20.4	1	0	98.6	100.0
5/8	102	11.8	19.5	2	0	98.0	100.0
5/9	59	11.8	21.0	0	0	100.0	100.0
5/12	83	12.8	20.8	0	5	100.0	94.0
5/14	81	11.5	29.8	0	0	100.0	100.0
5/16	93	14.3	24.6	2	0	97.80	100.0
5/18	98	15.3	20.3	1	7	99.0	92.9
5/20	87	14.0	33.0	1	0	98.9	100.0
5/21	81	15.5	22.0	0	0	100.0	100.0
5/23	100	18.5	24.0	0	0	100.0	100.0
5/25	92	18.0	20.9	1	9	98.9	90.2
5/26	102	17.3	20.2	1	10	99.0	90.2
5/28	99	17.8	33.8	0	0	100.0	100.0
5/30	84	18.3	31.6	0	0	100.0	100.0
6/1	84	15.8	30.4	0	19	100.0	77.4
					Overall	*99.4*	*96.6*
			Natural Chinook Salmon				
3/31	59	9.0	29.1	2	0	96.6	100.0
4/4	101	8.8	31.5	0	0	100.0	100.0
4/9	55	10.3	30.3	0	0	100.0	100.0
4/15	51	12.0	23.3	0	0	100.0	100.0
4/20	74	12.0	104.4	0	0	100.0	100.0

Table 5. Continued.

Mark date	Number tagged	Mean temperature[a]	Hours held	Number mortalities	Number of lost tags	Percent survival[b]	Percent tag retention
			Chinook Salmon (cont'd)				
4/29	64	13.0	20.7	0	0	100.0	100.0
5/7	53	13.0	23.6	0	0	100.0	100.0
5/13	56	12.3	21.0	0	0	100.0	100.0
5/24	47	19.3	21.2	2	0	95.7	100.0
					Overall	*99.3*	*100.0*
			Summer Steelhead				
4/9	20	10.3	29.1	0	0	100.0	100.0
4/19	69	11.5	20.9	0	0	100.0	100.0
4/26	75	10.5	30.3	0	2	100.0	97.3
4/29	87	13.0	23.6	0	0	100.0	100.0
5/3	65	12.0	22.8	0	0	100.0	100.0
5/7	58	12.3	29.1	0	5	100.0	91.4
5/8	81	12.0	20.0	1	0	98.8	100.0
5/9	62	11.8	22.0	0	0	100.0	100.0
5/11	88	12.8	24.2	2	0	97.7	100.0
5/14	130	11.8	18.3	0	6	100.0	95.4
5/16	83	14.3	23.1	0	1	100.0	98.8
5/18	104	15.3	21.8	1	2	99.0	98.1
5/20	110	14.0	30.5	4	0	96.4	100.0
5/21	133	15.5	20.5	1	0	99.2	100.0
5/23	104	18.5	23.3	18	1	82.7	99.0
5/25	88	18.0	19.2	1	4	98.9	95.5
5/27	90	18.3	27.0	0	0	100.0	100.0
5/29	85	18.8	28.5	0	0	100.0	100.0
5/31	76	16.8	27.8	1	1	98.7	98.7
					Overall	*98.2*	*98.6*

Table 6. Release and detection of hatchery and natural juvenile salmonids, trap efficiency estimates, and mean travel times for tagged fish, West Extension Canal (RM 3.7), spring 1999.

Release date	Number released[a]	Number detected[b] (days after release)	Trap efficiency (TE)	Pooled TE[c]	Mean travel time (days)[d]
		Hatchery			
		Yearling Chinook Salmon			
3/11[e]	99	5(1) 1(10) 2(30)	0.084	0.131	8.9
3/13	94	3(1) 4(2) 1(3) 1(4) 1(5) 1(9) 1(11) 1(25) 1(30) 1(43) 1(53)	0.179	0.131	11.5
3/16	103	36(1) 3(3) 1(4) 1(6) 1(17) 2(21) 1(22) 1(24) 1(26) 1(27) 1(28) 1(29) 1(31) 1(32)	0.531	0.506	5.9
3/18	82	22(1) 7(2) 2(3) 1(13) 1(15) 1(17) 1(19) 1(25) 1(26)	0.474	0.506	3.7
3/20	77	6(1) 1(2) 1(12) 1(30)	0.123	0.123	5.2
3/25	102	1(1) 1(13)	0.021	0.040	6.8
3/26	106	1(2) 1(4) 1(5) 1(7) 1 (12) 1(25)	0.059	0.040	8.6
3/31	106	33(1) 6(2) 5(3) 5(4) 1(5) 3(7) 1(14) 1(16)	0.555	0.514	1.9
4/8	80	4(1) 10(2) 8(3) 4(4) 2(5) 2(6) 3(7) 1(9) 1(11)	0.460	0.514	3.2
4/17	83	2(1) 3(2) 1(5)	0.076	0.094	1.9
4/20	95	4(1) 1(2) 1(4) 1(5) 1(9) 2(13)	0.111	0.094	4.3
4/23	101	13(1) 5(2) 1(3) 2(7) 2(8) 1(10) 5(11) 2(13) 1(14) 1(16)	0.343	0.386	5.0
4/26	84	6(1) 10(2) 3(3) 3(5) 1(6) 2(7) 1(9) 2(10) 2(11) 1(12) 1(13) 1(20) 2(22)	0.438	0.386	5.6
4/30	88	21(1) 7(2) 3(3) 2(5) 3(6) 7(7) 2(8) 3(9) 1(12) 2(13) 1(14) 1(16) 1(25)	0.645	0.485	4.5
5/2	83	8(1) 4(2) 8(3) 1(4) 5(5) 3(6) 2(11) 1(12) 1(14) 4(15) 2(16) 1(18) 1(23)	0.519	0.485	6.3
5/5	73	7(1) 6(2) 9(3) 1(4) 3(5) 1(8) 1(13) 1(15)	0.418	0.485	3.2
5/9	82	10(1) 2(2) 2(3) 3(4) 2(5) 4(7) 1(8) 1(9) 3(10)	0.359	0.485	3.9
5/14	86	10(1) 11(2) 2(3) 8(4) 5(5) 1(6) 1(8)	0.464	0.485	2.6
			Mean pooled = 0.327 (SD = 0.196)		

[a] *Number released was adjusted by the expected survival of test fish.*
[b] *Number detected was adjusted by efficiency of the remote detector and includes remote and hand interrogations.*
[c] *Pooled TE was based on results of Chi^2 tests. Mean pooled TE was based on the mean of sub-pooled estimates.*
[d] *Mean travel time was determined from individual travel times of PIT-tagged fish.*
[e] *This release group was solely hatchery spring chinook salmon.*

Table 6. Continued.

Release date	Number released[a]	Number detected[b] (days after release)	Trap efficiency (TE)	Pooled TE[c]	Mean travel time (days)[d]
		Subyearling Fall Chinook Salmon			
6/7	99	22(1) 1(2)	0.245	0.245	0.59
6/8	98	6(1) 2(2) 1(3) 1(6)	0.108	0.109	1.44
6/9	99	10(1) 1(2) 2(5)	0.139	0.109	1.44
6/10	91	1(1) 1(2) 2(3) 1(5)	0.058	0.109	2.43
6/11	146	3(1) 5(2) 5(3) 2(4) 1(5) 1(6)	0.123	0.109	2.44
6/12	149	46(1) 6(2)	0.369	0.369	0.70
6/13	150	96(1) 3(2) 1(8)	0.704	0.669	0.38
6/16	145	70(1) 1(3)	0.517	0.669	0.31
6/17	97	70(1) 1(4)	0.773	0.669	0.26
6/19	103	69(1) 1(2) 1(3)	0.728	0.669	0.23
6/21	94	59(1) 2(2) 1(3)	0.697	0.669	0.19
6/23	95	59(1)	0.656	0.669	0.15
6/26	56	40(1)	0.754	0.669	0.13
7/1	52	28(1)	0.569	0.669	0.15
7/5	43	7(1) 1(2)	0.196	0.196	0.49
			Mean pooled = 0.440 (SD =0.262)		
		Summer Steelhead			
4/20	95	5(1) 1(2) 1(11) 2(12) 1(16) 1(29)	0.120	0.120	7.35
4/28	88	10(1) 1(10) 2(11) 1(17) 1(18) 3(20) 2(21) 1(22) 1(27)	0.260	0.205	9.85
5/2	66	3(1) 1(2) 1(3) 1(6) 1(7) 2(11) 1(17) 1(19)	0.173	0.205	6.58
5/6	73	5(1) 1(3) 1(5) 1(11) 3(12) 1(13) 1(14) 1(15) 1(24)	0.213	0.205	7.95
5/9	100	6(1) 5(2) 1(4) 1(8) 2(10) 1(11) 1(13) 1(15) 1(16)	0.197	0.205	4.95
5/10	59	1(1) 1(2) 3(4) 1(5) 3(7) 2(8) 1(10) 1(11) 1(14)	0.247	0.205	6.31
5/13	78	4(1) 1(2) 1(3) 1(4) 1(5) 2(6) 1(7) 1(12) 1(14)	0.173	0.205	4.42
5/15	81	5(1) 1(2) 7(3) 4(4) 1(15)	0.231	0.205	2.96
5/17	91	7(1) 6(2) 1(3) 1(4) 1(7) 1(8) 1(9) 1(10) 1(15)	0.228	0.205	3.27
5/19	90	5(1) 2(2) 1(4) 2(5) 1(12)	0.127	0.205	2.70
5/21	86	3(1) 1(2) 2(3) 2(4) 1(5) 1(7) 1(16)	0.133	0.205	3.93
5/22	81	7(1) 3(2) 3(3) 1(4) 1(9)	0.192	0.205	1.93
5/24	100	13(1) 1(2) 3(3) 1(6) 1(7)	0.197	0.205	1.64
5/26	82	11(1) 1(3) 1(4) 1(5)	0.177	0.205	1.28

Table 6. Continued.

Release date	Number released[b]	Number detected[b] (days after release)	Trap efficiency (TE)	Pooled TE[c]	Mean travel time (days)[d]
		Summer Steelhead (cont'd)			
5/27	91	15(1) 3(2) 2(3) 1(4)	0.240	0.205	0.94
5/29	99	21(1) 5(2)	0.273	0.205	0.75
5/31	84	6(1)	0.074	0.105	0.51
6/2	65	9(1)	0.144	0.105	0.41
			Mean pooled = 0.189 (SD = 0.036)		
		Natural Spring Chinook Salmon			
4/1	57	13(1) 6(3) 1(7)	0.365	0.454	1.28
4/5	101	37(1) 8(2) 1(3) 3(5) 2(10)	0.526	0.454	1.13
4/10	55	9(1) 7(2) 4(3) 1(4) 1(7)	0.416	0.454	1.70
4/16	51	10(1) 2(3)	0.245	0.291	0.93
4/24	74	11(1) 9(2) 1(3) 1(5) 1(11)	0.323	0.291	1.56
4/30	64	17(1) 7(2) 4(3) 4(4) 1(5) 2(7) 1(8) 1(14)	0.602	0.602	2.50
5/8	53	11(1) 2(5)	0.255	0.255	1.14
5/14	56	17(1) 3(2) 5(3) 3(4) 1(5) 1(6)	0.558	0.639	1.63
5/25	45	31(1) 1(2)	0.740	0.639	0.45
			Mean pooled = 0.453 (SD = 0.151)		
		Summer Steelhead			
4/10	20	7(1) 1(2) 1(8)	0.473	0.473	1.26
4/20	69	7(1)	0.107	0.107	0.19
4/27	73	15(1) 4(2) 2(3) 1(4) 1(5) 2(11) 1(16) 2(21)	0.404	0.308	3.64
4/30	87	13(1) 3(2) 1(3) 1(4) 1(5) 1(6) 2(7) 3(8) 1(13) 1(15) 1(18) 1(19)	0.351	0.308	4.30
5/4	65	18(1) 2(2) 1(3) 1(4) 1(13) 1(16)	0.389	0.308	1.74
5/8	53	14(1) 1(2) 1(7) 1(8) 1(11) 1(18)	0.377	0.308	2.50
5/9	80	9(1) 2(2) 3(4) 1(5) 1(6) 1(8) 3(10) 1(11)	0.276	0.308	3.60
5/10	62	7(1) 1(2) 1(3) 2(4) 1(5) 1(7)	0.221	0.308	1.89
5/12	86	10(1) 6(2) 1(4) 1(6) 4(7)	0.269	0.308	2.29
5/14	124	14(1) 1(2) 2(3) 4(4) 4(5) 2(6)	0.229	0.308	2.17
5/17	82	13(1) 8(2) 3(3) 2(7)	0.334	0.308	1.48
5/19	101	19(1) 2(2) 2(5) 1(6) 1(8) 1(10)	0.271	0.308	1.70
5/21	106	28(1) 5(2) 7(3) 1(4) 1(5)	0.417	0.308	1.14

Table 6. Continued.

Release date	Number released[a]	Number detected[b] (days after release)	Trap efficiency (TE)	Pooled TE[c]	Mean travel time (days)[d]
		Natural Summer Steelhead (cont'd)			
5/22	132	29(1) 15(2) 3(3) 1(4) 1(5)	0.319	0.308	1.31
5/24	85	22(1) 1(2) 1(4)	0.297	0.308	0.65
5/26	83	22(1) 1(2) 1(3)	0.304	0.308	0.56
5/28	90	22(1) 2(2) 3(3)	0.316	0.308	0.81
5/30	85	13(1) 3(2)	0.198	0.308	0.78
6/1	74	20(1) 1(2)	0.299	0.308	0.54
			Mean pooled = 0.306 (SD = 0.061)		

Table 7. Adjusted collection of hatchery and natural juvenile salmonids at RM 1.2 and RM 3.7 and fish sampled at Westland Canal (RM 27.3), Umatilla River, October 1998 - August 1999. Mean fork length is in millimeters.

Site, Species[a]	Age	Mean FL (SE)	Number sampled	Adjusted number collected[b]	Number released	Release date	Percent recapture[c]
Rotary - Screw Trap at RM 1.2 (10/1/98 - 3/8/99)							
HCHS	1+	123 (2.36)	1,456	1,592	114,370	12/20/98	1.4
NCHS	1+	101 (1.08)	112	128	--	--	--
NCOH	0+	109 (5.49)	12	12	--	--	--
NSTS	1+	147 (11.52)	16	32	--	--	--
West Extension Canal at RM 3.7 (3/8/99 - 7/19/99)							
HCH	1+	153 (0.23)	46,832	130,373	1,109,175	3/8 + 3/11, 4/14 + 4/15	4.2
HCHF	0+	100 (0.18)	12,240	17,457	1,842,666	6/3/99	0.7
HCOH	1+	141 (0.21)	36,246	47,240	1,475,922	3/22-24, 3/26, + 3/30-4/2	2.5
HSTS	1+	223 (0.49)	2,257	2,571	121,633	4/13-14 + 5/4[d]	1.9
NCH	0 - 1+	103 (0.42)	801	1,788	--	--	--
FRY	0+	38	1	1	--	--	--
NCOH	0+	92 (5.03)	38	85	--	--	--
NSTS	0 - 3+	181 (0.53)	2,236	3,234	--	--	--
Westland Canal at RM 27.3 (7/20/99 - 8/5/99)[e]							
HCHF	0+	134 (1.27)	756	10,855	1,842,666	6/3/99	0.6
HSTS	1+	-	1	23	121,633	4/13-14 + 5/4[d]	< 0.1
NCH	0+	95 (1.69)	61	418	--	--	--
NCOH	0 - 1+	125 (3.26)	47	268	--	--	--
NSTS	1+	72 (5.84)	2	9	--	--	--

[a] *HCHS = hatchery spring chinook salmon, HCHF = hatchery fall chinook salmon, HCH = hatchery spring and fall chinook salmon, HCOH = hatchery coho salmon, HSTS = hatchery summer steelhead, NCHS = natural spring chinook salmon, NCOH = natural coho salmon, NSTS = natural summer steelhead, and NCH = natural chinook salmon.*

[b] *Adjusted number collected is number sampled adjusted by time not sampled at RST, by sample rate at West Extension Canal only during sampling periods and by pounds hauled at Westland Canal.*

[c] *Percent recapture at rotary-screw trap and Westland Canal are based on adjusted number collected and on number sampled at West Extension Canal.*

[d] *Volitional release dates for summer steelhead were 4/5-6, and 4/27/99.*

[e] *Sample data collected by CTUIR; length data obtained by ODFW.*

Table 8. Scale samples from hatchery and natural juvenile salmonids collected at RM 1.2 and RM 3.7 on the Umatilla River, November 1998 – June 1999.

Species [a]	Number	Fork Length (mm) Min	Fork Length (mm) Max	Dates collected
HSTS	3	250	308	5/3/99 - 5/27/99
NCHS	17	84	117	11/24/98 - 3/1/99
COH	1	116	116	11/30/98
NSTS	92	145	302	1/12/99 - 5/19/99

[a] *HSTS = hatchery summer steelhead, NCHS = natural spring chinook salmon, COH = coho salmon of unknown origin, and NSTS = natural summer steelhead.*

Table 9. Estimated number of hatchery and natural juvenile salmonids and other resident fish species collected at Westland Canal (RM 27.3) and transported to the lower Umatilla River, 20 July - 5 August 1999. Results are based on CTUIR sample data.

	Species[a]												
	HCHF0		HSTS		NCHF0		NCOH		NSTS		Resident Fish		Pounds
Date	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	hauled
7/20	5,469	90.8	0	0.0	120	2.0	48	0.8	0	0.0	384	6.4	261
7/21[b]	3,070	83.8	18	0.5	73	2.0	37	1.0	0	0.0	465	12.7	185
7/23	535	72.9	5	0.7	14	1.9	10	1.4	0	0.0	170	23.1	44
7/26	663	72.1	0	0.0	25	2.7	36	3.9	6	0.7	190	20.7	54
7/28	240	43.2	0	0.0	9	1.6	46	8.3	0	0.0	126	22.7	31
7/30	277	57.7	0	0.0	54	11.3	17	3.5	3	0.6	129	26.9	31
8/3	452	55.5	0	0.0	74	9.1	63	7.7	0	0.0	226	27.7	56
8/5	149	27.7	0	0.0	49	9.1	11	2.0	0	0.0	328	61.1	48
Total	10,855	79.9	23	0.2	418	3.1	268	2.0	9	0.1	2,018	14.8	710

[a] *HCHF0 = hatchery subyearling fall chinook salmon, HSTS = hatchery summer steelhead, NCHF0 = natural subyearling fall chinook, NCOH = natural coho salmon, and NSTS = natural summer steelhead.*

[b] *Data for 7/21 was derived by averaging sample data from 7/20 and 7/23.*

Table 10. Migration parameters of PIT-tagged hatchery and natural juvenile salmonids captured at lower river trapping sites (RM 1.2, 3.7, and 27.3), Umatilla River, 1 October 1998 - 5 August 1999.

Species[a] Hatchery[b] Rearing[c]	Release Date	Release RM	Detection at lower river N	First (date)	Mean (date)	Last (date)	Peak (date)	Duration (d)	Mean travel speed (mi/d)[d]
				Hatchery					
CHS									
UFH									
Oregon	12/20/98	80	14	1/5	4/11	5/25	-[e]	141	0.8
Oregon	3/8/99	80	29	3/9	4/5	5/3	3/10	55	3.5
Michigan	3/8/99	80	54	3/9	4/1	5/6	3/10	58	3.5
LWS	3/8/99	80	20	3/10	4/15	5/23	-[e]	74	2.1
CAR	4/14/99	80	63	4/16	5/5	5/17	5/6	32	4.5
LWS	4/14/99	80	58	4/16	5/5	5/3	5/6	18	3.7
CHF									
BON	3/11/99	73.5	62	3/17	4/7	4/27	4/1	42	2.6
BON	4/15/99	73.5	63	4/17	4/30	5/17	5/1	31	4.4
CHF0									
UFH									
Low	6/3/99	80	259	6/6	6/16	7/20	6/15	45	5.0
Medium	6/3/99	80	288	6/6	6/16	7/8	6/15	33	4.8
High	6/3/99	80	281	6/6	6/16	7/6	6/17	31	4.8
STS									
UFH	4/5/99[f]	79[g]	25	4/15	5/19	5/27	5/20	43	1.3
UFH	4/6/99[f]	64.5	29	4/11	5/20	6/6	5/26	57	1.9
UFH	4/27/99[f]	79[g]	29	5/9	5/25	6/6	5/26	29	2.8

[a] *CHS = spring chinook salmon, CHF = fall chinook salmon, CHF0 = subyearling fall chinook salmon, and STS = summer steelhead.*

[b] *UFH = Umatilla Fish Hatchery, LWS = Little White Salmon Fish Hatchery, CAR = Carson Fish Hatchery, and BON = Bonneville Fish Hatchery.*

[c] *Oregon = reared in standard raceway, Michigan = reared in oxygenated raceway, low = reared at density of 200K, high = reared at density of 300K, and high = reared at density of 400K.*

[d] *Weighted mean travel speed calculated from point of release to lower river trap sites.*

[e] *No peak in detections was observed.*

[f] *Forced release dates for volitional release on 4/5, 4/6, and 4/27 were on 4/13, 4/14, and 5/4, respectively.*

[g] *Bonifer holding pond at RM 2 of Meacham Creek (RM 79 of Umatilla River).*

Table 10. Continued.

Species[a] Hatchery[b] Rearing[c]	Release		Detection at lower river						Mean travel speed (mi/d)[d]
	Date	RM	N	First (date)	Mean (date)	Last (date)	Peak (date)	Duration (d)	
				Natural					
CHS	1/20–4/29	79[h] & 80	44	3/17	5/4	5/29	5/19	74	2.4
STS	1/21–7/2	48 – 80[i]	192	3/9	5/24	6/24	5/26	108	4.1

[h] *Trap site on Meacham Creek (RM 79 of Umatilla River).*
[i] *Various release sites at river miles 48, 64, 73, 75, 77, and 80.*

Table 11. Maximum, minimum, and mean fork lengths (mm) of natural and hatchery juvenile salmonids, lower Umatilla River, November 1998 - August 1999.

		Month									
Species[a]		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
NCH	N	3	12	72	2	199	369	171	17	11	1
	MAX	166	117	118	107	134	120	124	102	100	93
	MIN	100	87	82	98	81	36	82	65	72	93
	MEAN	123	101	97	102	100	101	106	88	87	93
NCOH	N	1	6	2	0	10	19	4	2	31	13
	MAX	116	144	101		139	129	125	81	160	151
	MIN	116	94	81		39	31	65	77	70	85
	MEAN	116	117	91		99	85	106	79	124	126
NSTS	N	0	2	9	1	90	249	1,406	108	8	0
	MAX		149	216	259	294	305	302	262	221	
	MIN		101	89	259	109	125	125	143	60	
	MEAN		125	140	259	177	182	180	186	162	
HCH	N	0	0	0	0	757	3,800	1,298	10	4	0
	MAX					197	207	205	180	205	
	MIN					91	104	110	134	195	
	MEAN					153	154	151	161	202	
HCHS	N	0	0	9	1	21	63	52	0	0	0
	MAX			137	124	163	188	187			
	MIN			110	124	115	100	127			
	MEAN			123	124	138	145	144			
HCHF	N	0	0	0	0	3	11	5	0	0	0
	MAX					168	173	170			
	MIN					134	144	130			
	MEAN					157	159	156			

[a] *NCH = natural chinook salmon, NCOH = natural coho salmon, NSTS = natural summer steelhead, HCH = hatchery chinook salmon, HCHS = hatchery spring chinook salmon, and HCHF = hatchery fall chinook salmon.*

Table 11. Continued.

Species[a]		Month									
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
HCHF0	N	0	0	0	0	0	0	0	2,092	849	88
	MAX								121	150	163
	MIN								70	85	93
	MEAN								97	110	135
HCOH	N	0	0	0	0	320	1,121	1,553	203	3	0
	MAX					173	200	202	185	182	
	MIN					106	83	110	97	139	
	MEAN					136	139	142	147	156	
HSTS	N	0	0	0	0	0	198	1,337	179	2	0
	MAX						276	308	287	216	
	MIN						123	143	100	191	
	MEAN						221	223	223	203	

[a] *HCHF0 = hatchery subyearling fall chinook salmon, HCOH = hatchery coho salmon, and HSTS = hatchery summer steelhead.*

Table 12. Maximum, minimum, and mean weights (g) of natural and hatchery juvenile salmonids, lower Umatilla River, December 1998 - June 1999.

		Month					
Species[a]		December	January	March	April	May	June
NCH	N	1		140	260	142	
	MAX	8.2		30.9	60.5	23.8	
	MIN	8.2		5.5	0.7	8.3	
	MEAN	8.2		11.7	19	13.8	
NCOH	N			8	6	1	
	MAX			26.5	42.2	13.5	
	MIN			0.6	10.9	13.5	
	MEAN			13.4	22.1	13.5	
NSTS	N	1		81	196	859	2
	MAX	33.5		163.2	294.6	208.1	45.7
	MIN	33.5		13.3	16.8	4.4	38.6
	MEAN	33.5		56.3	82.3	57.7	42.1
HCHS	N		5	9		1	
	MAX		30.9	52		37	
	MIN		20.9	23.6		37	
	MEAN		25	33		37	
HCHF	N			2	1		
	MAX			52.2	68.3		
	MIN			24.1	68.3		
	MEAN			38.1	68.3		
HCOH	N				2		
	MAX				39.3		
	MIN				5.6		
	MEAN				22.5		
HSTS	N				1	11	1
	MAX				63.6	137.8	70.4
	MIN				63.6	45.7	70.4
	MEAN				63.6	81.3	70.4

[a] *NCH = natural chinook salmon, NCOH = natural coho salmon, NSTS = natural summer steelhead, HCHS = hatchery spring chinook salmon, HCHF = hatchery fall chinook salmon, HCOH = hatchery coho salmon, and HSTS = hatchery summer steelhead.*

Table 13. Fin clips on juvenile salmonids collected at lower river trapping sites (RM 1.2, 3.7, and 27.3), Umatilla River, October 1998 - August 1999. Binomial probabilities are given for the difference in recapture proportions of differently-clipped fish.

Species[a] Clip[b]	Number by trap site RM 1.2	RM 3.7	RM 27.3	Total number recaptured	Total number released[c]	Percent recapture	*P*
HCH							
AD	515	5,610		6,125	204,084	3.00	< 0.001[d]
ADLV		330		330	60,049	0.55	
NC	941	40,892		41,833	959,412	4.36	
HCHF0							
AD		2,103	159	2,262	393,471	0.57	< 0.001
NC		10,135	659	10,794	1,449,195	0.74	
HCOH							
AD		1,836		1,836	80,178	2.29	0.002
NC		34,410		34,410	1,395,733	2.47	
HSTS							
AD		1,411	1	1,412	59,213	2.38	< 0.001
ADLV		639		639	62,420	1.02	

[a] *HCH = hatchery chinook salmon (spring and fall races), HCHF0 = hatchery subyearling fall chinook salmon, HCOH = hatchery coho salmon, and HSTS = hatchery summer steelhead.*
[b] *AD = adipose fin clip, NC = no fin clip, and LV = left ventral fin clip.*
[c] *Totals include fin-clipped fish with and without coded-wire tags.*
[d] *Binomial probabilities for all tests (AD/NC, ADLV/NC and AD/ADLV) are P < 0.001.*

Table 14. Summary of scale loss and mortality of hatchery and natural juvenile salmonids collected at RM 1.2 and RM 3.7, Umatilla River, December 1998 - July 1999.

	Condition[a]							
	Good		Partial		Descaled		Mortality[c]	
Species[b]	Number	Percent	Number	Percent	Number	Percent	Number	Percent
				Hatchery				
CH	4,561	80.7	963	17.0	127	2.2	62	0.8
CHF0	2,341	84.0	298	10.7	147	5.3	4	0.1
COH	2,413	79.3	569	18.7	60	2.0	7	0.2
STS	741	42.3	609	34.8	401	22.9	4	0.2
				Natural				
CH[d]	657	90.6	60	8.3	8	1.1	0	0.0
COH	34	91.9	2	5.4	1	2.7	0	0.0
STS	1,191	72.8	370	22.6	76	4.6	2	0.1

[a] *Condition refers to the extent of scale loss on live fish captured and fish mortalities. Good = scale loss < 3%; Partial = scale loss >3% and < 20%; Descaled = scale loss > 20%.*

[b] *CH = spring and fall chinook salmon, CHF0 = subyearling fall chinook salmon, COH = coho salmon, STS = summer steelhead.*

[c] *Mortality does not include handling or facility mortality.*

[d] *CH = natural chinook salmon includes yearling and subyearling age groups.*

Table 15. Summary of injuries, parasites, and diseases on hatchery and natural juvenile salmonids collected at RM 1.2 and RM 3.7, Umatilla River, December 1998 - July 1999.

	Condition[a]							
	Bird marks		Injuries		Parasites		BKD[c]	
Species[b]	Number	Percent	Number	Percent	Number	Percent	Number	Percent
				Hatchery				
CH	190	53.2	63	17.6	32	9.0	72	20.2
CHF0	1	20.0	4	80.0	0	0.0	0	0.0
COH	48	52.2	22	23.9	15	16.3	7	7.6
STS	42	50.0	40	47.6	2	2.4	0	0.0
				Natural				
CH[d]	12	5.7	10	4.7	189	89.6	0	0.0
COH	1	8.3	0	0.0	11	91.7	0	0.0
STS	24	13.3	17	9.4	140	77.3	2	0.1

[a] *Condition refers to the presence of bird marks, body injuries, and external parasites, and signs of bacterial kidney disease. Body injuries include damaged eyes, operculum, head, body, and fins and presence of fungus. Parasites include leeches and nematode metacercaria. Some fish with bird marks, parasites, and BKD also had body injuries.*

[b] *CH = spring and fall chinook salmon, CHF0 = subyearling fall chinook salmon, COH = coho salmon, STS = summer steelhead.*

[c] *BKD = Bacterial kidney disease*

[d] *CH = natural chinook salmon, including yearling and subyearling age groups.*

Table 16. Detection, abundance, and survival of PIT-tagged production fish released into the upper Umatilla River and detected in the lower river, December 1998 – July 1999.

Hatchery[a]	Pond	Release date	Release site	Release number	RM 1.2	RM 3.7	Percent detection	Abundance[b]	Percent survival (95% C.I.)
				Spring Chinook Salmon					
UFH	O4A	12/20/98[c]	RM 80	243	3	5	3.3	120	49.4 (± 44.0)
UFH	O4B	12/20/98[c]	RM 80	240	2	4	2.5	81	33.8 (± 36.3)
UFH	O5A	3/8/99	RM 80	241	0	17	7.0	57	23.7 (± 9.5)
UFH	O5B	3/8/99	RM 80	233	0	18	7.7	67	28.8 (± 11.5)
UFH	M2A	3/8/99	RM 80	240	0	15	6.3	58	24.2 (± 10.8)
UFH	M2B	3/8/99	RM 80	247	0	14	5.7	45	18.2 (± 8.3)
UFH	M2C	3/8/99	RM 80	240	0	19	7.9	78	32.5 (± 13.5)
LWSH	LWS-1	3/8/99	RM 80	248	0	20	8.1	61	24.6 (± 9.4)
LWSH	LWS-2	4/14/99	RM 80	219	0	58	26.5	154	70.4 (± 16.0)
Carson	Carson	4/14/99	RM 80	248	0	63	25.4	167	67.5 (± 14.6)
Overall					0			*888*	*37.0*
95% C. I.									*(30.3 – 43.7%)*
				Yearling Fall Chinook Salmon					
BFH	BFH	3/11/99	RM 73	248	0	62	25.0	212	85.5 (± 19.8)
BFH	BFH	4/15/99	RM 73	236	0	63	26.7	167	70.8 (± 15.3)
Overall								*379*	*78.3*
95% C.I.									*(65.7 – 90.9%)*
				Subyearling Fall Chinook Salmon					
UFH	M2A	6/3/99	RM 80	590	0	118	20.0	267	45.3 (± 6.6)
UFH	M2B	6/3/99	RM 80	585	0	141	24.1	320	54.7 (± 7.3)
UFH	M3A	6/3/99	RM 80	583	0	144	24.7	327	56.1 (± 7.5)
UFH	M3B	6/3/99	RM 80	582	0	144	24.7	327	56.2 (± 7.5)
UFH	M4A	6/3/99	RM 80	564	0	153	27.1	348	61.6 (± 8.2)
UFH	M4B	6/3/99	RM 80	585	0	128	21.9	291	49.7 (± 7.2)
Overall								*1.879*	*53.9*
95% C.I.									*(50.8 – 56.9%)*
				Summer Steelhead					
UFH	M8C	4/5/99[d]	RM 79[e]	0	198	25	12.6	126	63.6 (± 22.7)
UFH	M8B	4/6/99[d]	RM 65	0	210	29	13.8	154	73.3 (± 25.7)
UFH	M8A	4/27/99[d]	RM 79[e]	0	288	29	10.1	163	56.6 (± 20.8)
Overall								*443*	*63.6*
95% C.I.									*(50.4 – 76.8%)*

[a] *UFH = Umatilla Fish Hatchery, LWSH = Little White Salmon Hatchery, Carson = Carson National Fish Hatchery, BFH = Bonneville Fish Hatchery.*

[b] *Abundance was estimated from number of detections and the trap efficiency estimate (running average) for the period in which fish were detected.*

[c] *Fish were emergency released from the acclimation pond due to ice.*

[d] *Beginning of volitional release for summer steelhead.*

[e] *Rivermile 2 of Meacham Creek at rivermile 79 of Umatilla River.*

Table 17. Detection, abundance, and survival of PIT-tagged natural fish released into the upper Umatilla River and tributaries and detected in the lower river, March – June 1999.

Release site[a]	Release number	Number detected	Percent detection	Abundance[b]	Percent survival
		Spring Chinook Salmon			
Umatilla River	48	8	16.7	18	37.5
Meacham Creek	227	36	15.9	79	34.8
Total	*275*	*44*	*16.0*	*97*	*35.3*
		Summer Steelhead			
Umatilla River	235	41	17.4	134	57.0
Meacham Creek	1,072	121	11.3	396	36.9
Birch Creek	16	0	0	0	0
East Fork Birch Creek	140	8	5.7	26	18.6
West Fork Birch Creek	286	16	5.6	52	18.2
Pearson Creek	39	1	2.6	3	7.7
Squaw Creek	39	1	2.6	3	7.7
Buckaroo Creek	183	4	2.2	13	7.1
Total	*2,010*	*192*	*9.6*	*627*	*31.2*

[a] *Umatilla River = RM 80, Meacham Creek = RM 2, Birch Creek = RM 48, East Fork Birch Creek = RM 16, West Fork Birch Creek = RM 16, Pearson Creek = RM 11, Squaw Creek = RM 77, Buckaroo Creek = RM 73.*

[b] *Abundance was estimated from number of detections and the trap efficiency estimate (running average) for the period in which fish were detected.*

Table 18. Mean percent detection and survival of PIT-tagged fish released for reach-specific survival tests and interrogated in the lower Umatilla River (RM 3.7), March - July 1999.

Species[a]	Release dates	Release site	Release number	Number detected	Mean % detection (95% C.I.)	Abun-dance[b]	Mean % survival[c] (95% C.I.)
CHS	3/9 – 3/11	RM 80	252	16	6.2(±4.6)	70	27.4 (± 14.1)$_{A}$
CHS	3/9 – 3/11	RM 48	250	13	5.3(±2.5)	49	20.2 (± 10.9)$_{A}$
CHS	3/9 – 3/11	RM 27	257	12	4.8(±3.1)	63	24.5 (± 5.5)$_{A}$
CHS	3/9 – 3/11	RM 11	246	12	4.9(±0.9)	64	25.5 (± 14.6)$_{A}$
CHF0	6/3 – 6/5	RM 80	498	99	19.9(±3.4)	206	41.4(± 11.9)$_{A}$
CHF0	6/3 – 6/5	RM 48	477	117	24.6(±1.2)	258	54.3 (± 3.8)$_{A}$
CHF0	6/3 – 6/5	RM 27	482	122	25.2(±4.6)	279	57.7 (± 9.6)$_{A}$
CHF0	6/3 – 6/5	RM 9	537	87	15.9(±7.9)	235	42.7 (± 18.8)$_{A}$
STS[d]	4/12 – 4/15	RM 79[e]	187	19	10.1(±3.6)	97	51.7 (± 20.6)$_{A}$
STS[d]	4/12 – 4/15	RM 65	224	25	11.6(±3.4)	125	58.0 (± 18.2)$_{A}$
STS[d]	4/12 – 4/15	RM 48	220	38	16.9(±3.1)	199	89.1 (± 14.4)$_{B}$
STS[d]	4/12 – 4/15	RM 27	219	48	21.9(±2.7)	245	111.8 (± 14.2)$_{BC}$
STS[d]	4/12 – 4/15	RM 9	229	65	27.7(±3.1)	328	139.8 (± 16.1)$_{C}$
STS[f]	5/4 – 5/7	RM 79[e]	238	10	4.2(±1.7)	62	25.8 (± 8.9)$_{A}$
STS[f]	5/4 – 5/7	RM 48	242	33	13.6(±5.0)	174	71.5 (± 25.3)$_{B}$
STS[f]	5/4 – 5/7	RM 27	245	41	16.4(±3.7)	200	79.9 (± 18.2)$_{B}$
STS[f]	5/4 – 5/7	RM 9	243	64	26.2(±4.3)	338	138.3 (± 24.1)$_{C}$

[a] *CHS = yearling spring chinook salmon, CHF0 = subyearling fall chinook salmon, STS = summer steelhead.*

[b] *Abundance was estimated from number of detections and the trap efficiency estimate (running average) for the period in which fish were detected.*

[c] *Means with the same letter are not significantly different.*

[d] *Comprised of large-grade and medium-grade steelhead.*

[e] *Rivermile 2 of Meacham Creek at rivermile 79 of Umatilla River.*

[f] *Comprised of small-grade steelhead.*

Table 19. Mean percent detection of PIT-tagged fish released for reach-specific survival tests and detected at Columbia River interrogation sites, April - July 1999. Means with the same letter are not significantly different.

Species[a]	Release dates	Release site	Release number	Mainstem number detected[b]	Mean % detection (95% C.I.)	Total detection[c]	Mean % detection (95% C.I.)
CHS	3/9 – 3/11	RM 80	252	18	7.2(±2.2)A	34	13.4(±2.7)A
CHS	3/9 – 3/11	RM 48	250	20	8.1(±1.6)A	33	13.4(±4.0)A
CHS	3/9 – 3/11	RM 27	257	30	12.0(±5.7)AB	42	16.8(±5.4)A
CHS	3/9 – 3/11	RM 11	246	43	17.3(±4.9) B	55	22.2(±5.8)A
CHF0	6/3 – 6/5	RM 80	498	43	8.6(±4.3)A	142	28.5(±7.2)A
CHF0	6/3 – 6/5	RM 48	477	43	9.1(±1.1)A	160	33.7(±2.1)A
CHF0	6/3 – 6/5	RM 27	482	52	10.8(±2.9)A	174	36.0(±2.0)A
CHF0	6/3 – 6/5	RM 9	537	63	11.8(±1.3)A	150	27.6(±6.7)A
CHF0	7/20 – 7/26	RM 0[d]	428	41	9.7(±3.2)A	--	--
STS[e]	4/12 – 4/15	RM 79[f]	187	13	6.9(±4.7)A	32	17.0(±5.0)A
STS[e]	4/12 – 4/15	RM 65	224	27	12.2(±2.9)A	52	23.7(±6.0)AB
STS[e]	4/12 – 4/15	RM 48	220	25	11.6(±4.0)A	63	28.5(±4.9)B
STS[e]	4/12 – 4/15	RM 27	219	32	15.5(±4.2)A	80	37.4(±5.1)C
STS[e]	4/12 – 4/15	RM 9	229	35	16.2(±4.4)A	100	43.9(±1.6)C
STS[g]	5/4 – 5/7	RM 79[f]	238	8	3.4(±1.1)A	18	7.6(±0.7)A
STS[g]	5/4 – 5/7	RM 48	242	14	5.7(±1.4)A	47	19.2(±5.6)B
STS[g]	5/4 – 5/7	RM 27	245	15	6.0(±1.9)A	56	22.4(±4.0)B
STS[g]	5/4 – 5/7	RM 9	243	20	8.6(±4.8)A	84	34.8(±4.3)C

[a] *CHS = yearling spring chinook salmon, CHF0 = subyearling fall chinook salmon, STS = summer steelhead.*

[b] *Interrogation sites in the mainstem Columbia River included John Day and Bonneville dams and the Columbia River estuary. Tags were also recovered within island bird colonies.*

[c] *Total detection included Umatilla River and mainstem detections and island recoveries.*

[d] *Test fish were collected from the holding pond at Westland Canal at RM 27.3 and transported to the mouth of the Umatilla River.*

[e] *Comprised of large-grade and medium-grade steelhead.*

[f] *Rivemile 2 of Meacham Creek at rivermile 79 of the Umatilla River.*

[g] *Comprised of small-grade steelhead.*

Table 20. Correlations of daily detections with river flow (ft^3/s) and temperature (^oF), lower Umatilla River, March - July 1999. * indicates a significant correlation.

	Flow			Temperature		
Species[a]	r	*P*	N	r	*P*	N
HCHS	-0.067	0.425	142	0.286	<0.001*	142
HCHF	-0.146	0.255	63	0.243	0.055*	63
HCHF0	0.279	0.052*	49	0.166	0.261	48
HSTS (large)	0.385	0.001*	68	-0.270	0.026*	68
HSTS (small)	0.656	<0.001*	55	-0.263	0.052*	55
NCH	0.092	0.434	74	0.170	0.148	74
NSTS	-0.131	0.175	108	0.313	0.001*	107

[a] *HCHS = hatchery spring chinook salmon, HCHF = hatchery fall chinook salmon, HCHF0 = hatchery subyearling fall chinook salmon, HSTS (large) = large-grade hatchery summer steelhead, HSTS (small) = small-grade hatchery summer steelhead, NCH = natural chinook salmon, and NSTS = natural summer steelhead.*

Table 21. Correlations between travel speed (mi/d) and river flow (ft^3/s) based on daily detections of hatchery fish. The r-value is presented with the N-value in parenthesis for significant results ($P < 0.05$).

	Species[a]				
	CHS	CHF	CHF0	STS (large)	STS (small)
Release site (reach-specific test fish)					
Imeques (RM 80)	-0.829 (16)		0.822 (99)		
Bonifer (RM 79)				0.754 (10)	0.754 (10)
Minthorn (RM 65)				*[b]	
Rieth (RM 48)	*		0.574 (117)	0.384 (38)	0.639 (33)
Echo (RM 27)	-0.586 (12)		0.716 (122)	-0.280 (48)	*
Cottonwood (RM 11)	*				
Steelhead Park (RM 9)			0.784 (87)	-0.370 (66)	0.542 (64)
Release date and RM (production fish)					
20 December (RM 80)	0.982 (14)				
8 March (RM 80)	-0.735 (103)				
11 March (RM 73)		-0.792 (62)			
5 April (RM 79)				-0.607 (25)	
6 April (RM 65)				-0.763 (29)	
14 April (RM 80)	-0.323 (120)				
15 April (RM 80)		*			
27 April (RM 79)					0.812 (29)
3 June (RM 80)			0.954 (828)		

[a] *CHS = spring chinook salmon, CHF = fall chinook salmon, CHF0 = subyearling fall chinook salmon, and STS = summer steelhead.*

[b] ** represents no correlation.*

Table 22. Correlations by species between diversion rate and trap efficiency estimates at West Extension Canal, lower Umatilla River, March - July 1999.

Species[a]	r	*P*	N
HCH	0.692	0.001*	18
HCHF0	0.653	0.008*	15
HSTS	0.012	0.963	18
NCHS	0.752	0.019*	9
NSTS	0.69	0.129	6

[a] *HCH = hatchery chinook salmon, HCHF0 = hatchery subyearling fall chinook salmon, HSTS = hatchery summer steelhead, NCNS = natural spring chinook salmon, and NSTS = natural summer steelhead.*

Table 23. Number and length range (mm) of resident fish species captured at the rotary-screw trap (RM 1.2) and West Extension Canal (RM 3.7), lower Umatilla River, October 1998 - July 1999.

Family Common name (*Genus species*)	Number captured[a]	Length range (mm)[b]
Catostomidae		
Unidentified sucker (*Catostomus spp.*)		--
Centrarchidae		
Bluegill (*Lepomis macrochirus*)	--	--
Unidentified bass (*Micropterus spp.*)	182	51-174
Unidentified crappie (*Pomoxis spp.*)	--	--
Cyprinidae		
Chiselmouth (*Acrocheilus alutaceus*)		--
Common carp (*Cyprinus carpio*)	--	--
Northern pikeminnow (*Ptychoceilus oregonensis*)	79	67-459[c]
Redside shiner (*Richarsonius balteatus*)	--	--
Unidentified dace (*Rhinichthys spp.*)	--	--
Ictaluridae		
Unidentified catfish (*Ictalurus spp.*)		--
Percidae		
Yellow perch (*Perca flavescens*)	--	--
Petromyzontidae		
Pacific lamprey (*Lampetra tridentata*)	274	100-175

[a] *Only northern pikeminnow, bass, and Pacific lamprey were counted on a regular basis.*
[b] *Pacific lamprey were measured to total length; northern pikeminnow and bass were measured to fork length.*
[c] *One adult northern pikeminnow measured 459 mm; all other lengths ranged from 67 - 270 mm.*

Table 24. Avian predators observed during sampling at the rotary-screw trap (RM 1.2) and West Extension Canal (RM 3.7), lower Umatilla River, November 1998 - June 1999.

Month[a]	Species	Actual No. observed	Standardized No. observed[b]	Location
November	Seagull	7	0.37	flying
	Great Blue Heron	1	0.05	river
December	Seagull	1	0.05	river
	Merganser	1	0.05	flying
February	Great Blue Heron	1	0.06	river
March	Seagull	1	0.01	
	Great Blue Heron	2	0.03	
	Cormorant	2	0.03	
	Kingfisher	2	0.03	
April	Great Blue Heron	3	0.01	
	Night Heron	1	0.02	outfall
May	Seagull	44	0.37	flying (21), dam (19)
	Great Blue Heron	4	0.03	dam (1), flying (1), river (1)
	Night Heron	19	0.16	fish ladder (1), dam (4), river (3), flying (1), outfall (10)
June	Seagull	234	3.6	dam (61), outfall (2), forebay (4)
	Great Blue Heron	2	0.03	river (1)
	Night Heron	8	0.12	outfall (2), river (4), canal (1)
	Cormorant	4	0.06	dam

[a] *November through February observations were made at the rotary-screw trap (RM 1.2); March through June observations were made at West Extension Canal (RM 3.7).*

[b] *Standardized observations are the monthly total of avian predators observed per monthly total of observations.*

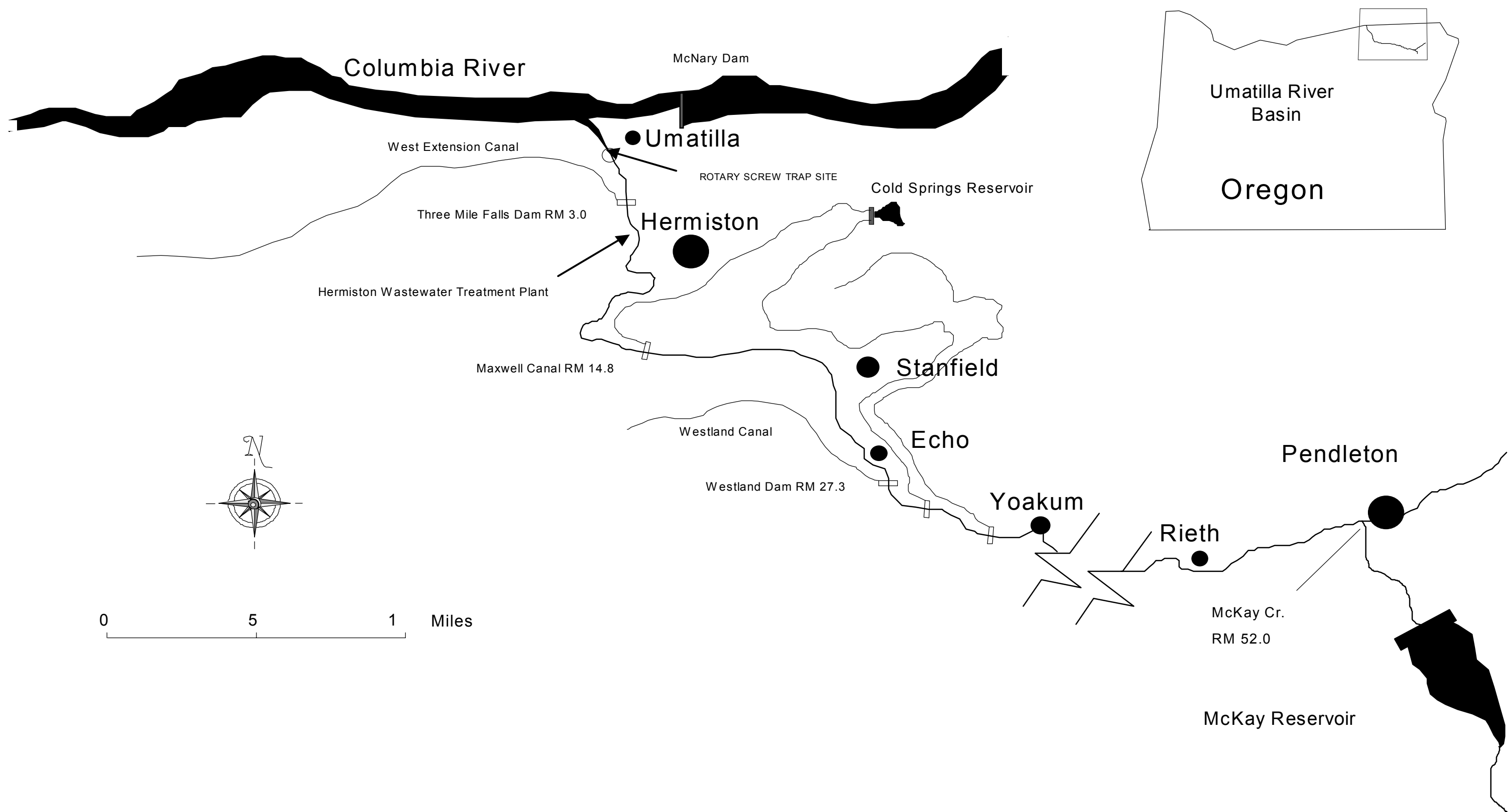


Figure 1. Study and activity sites on the lower Umatilla River, October 1998 – September 1999.

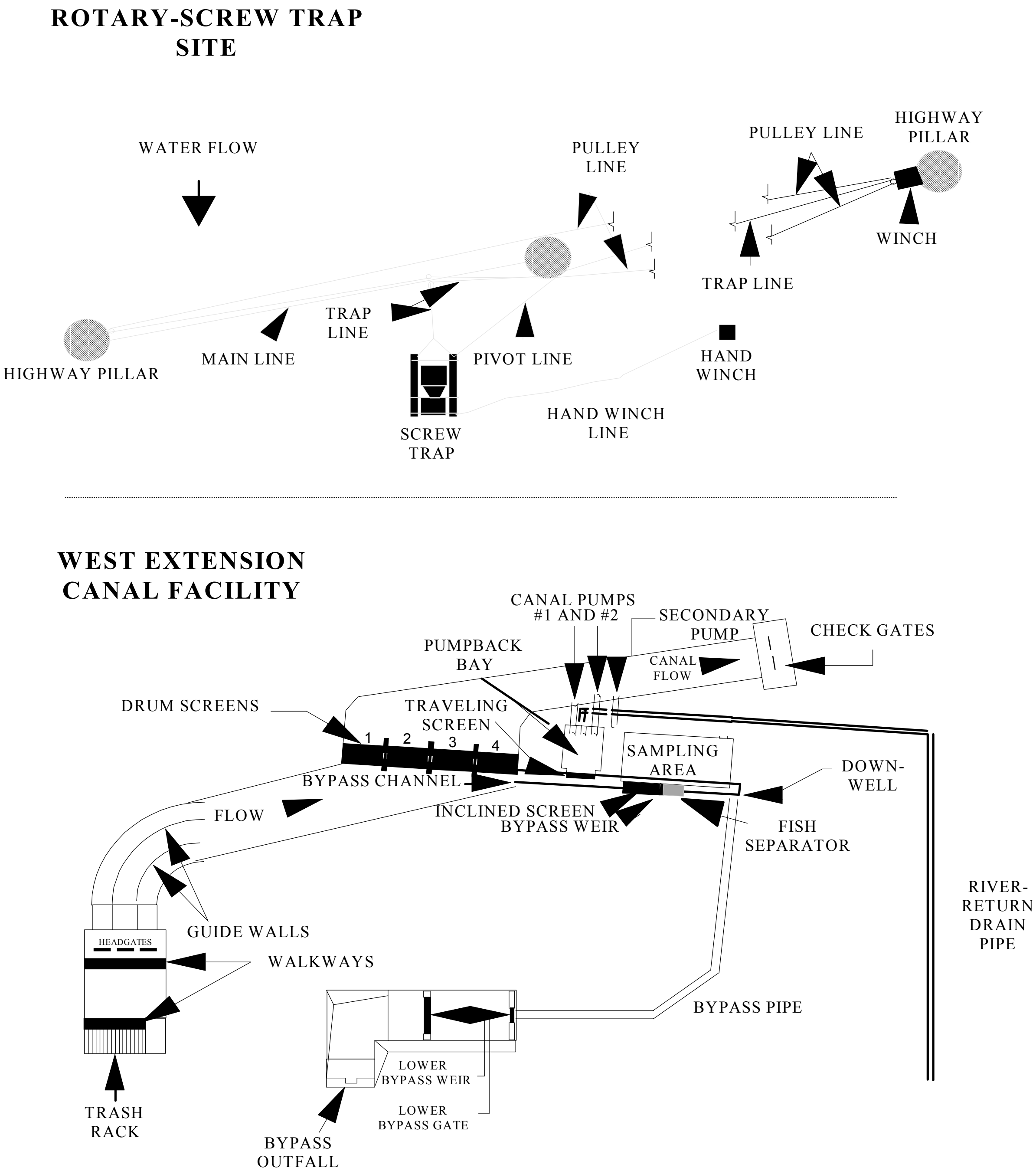


Figure 2. Schematic of the rotary-screw trap with anchoring system and the West Extension Canal screening/bypass facility, lower Umatilla River.

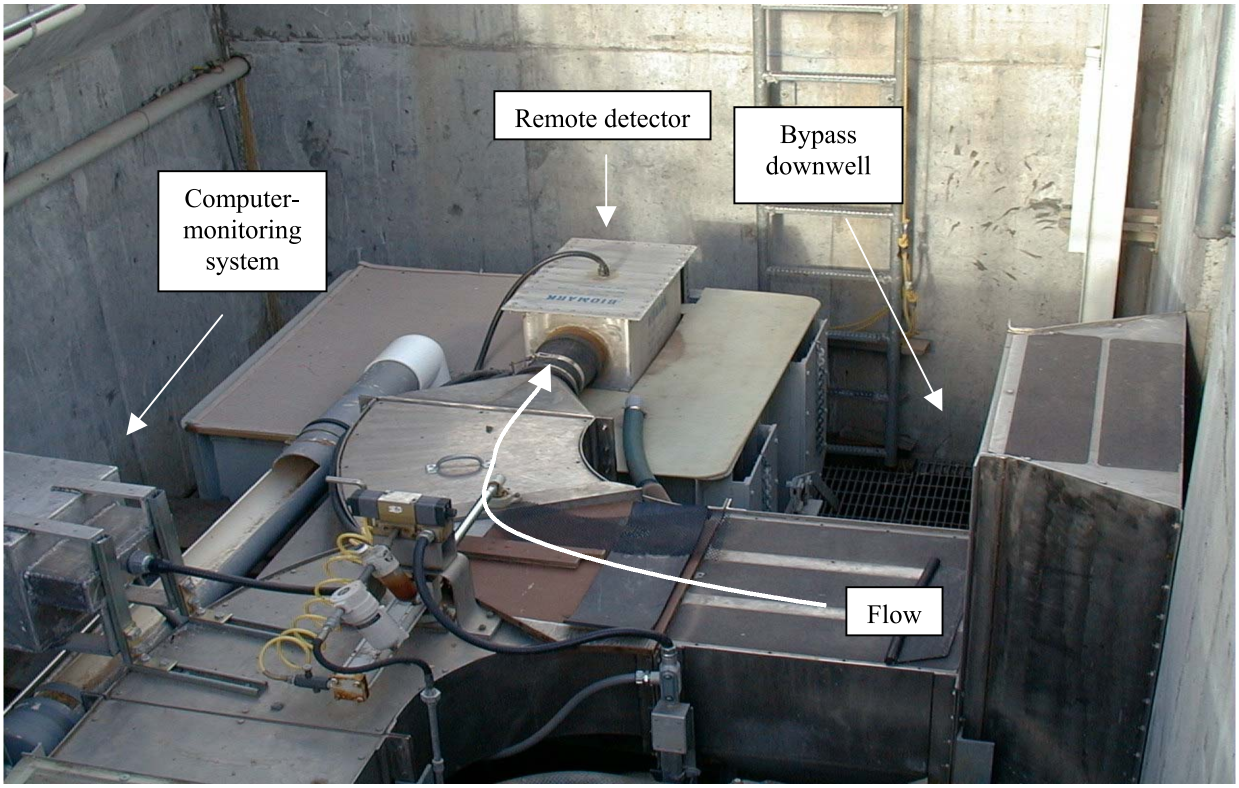
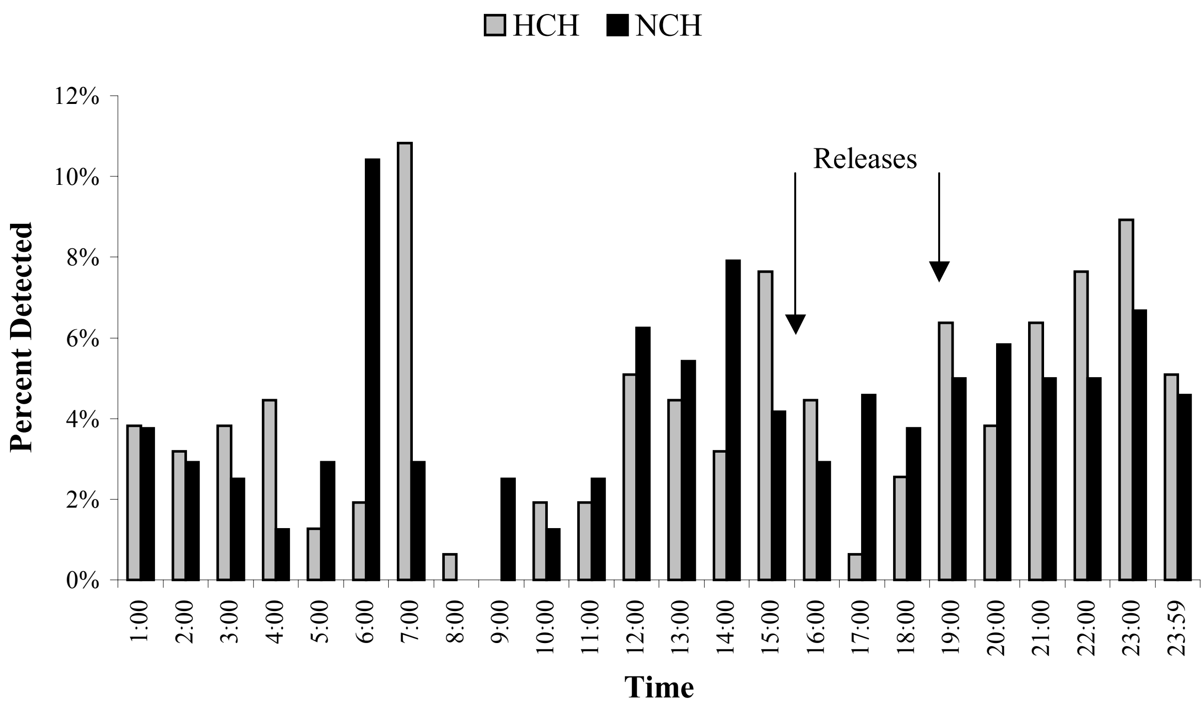


Figure 3. Remote detector (400 kHz) at the West Extension Canal sampling facility. A pipe extended from the backside of the detector to lead fish to the bypass downwell.



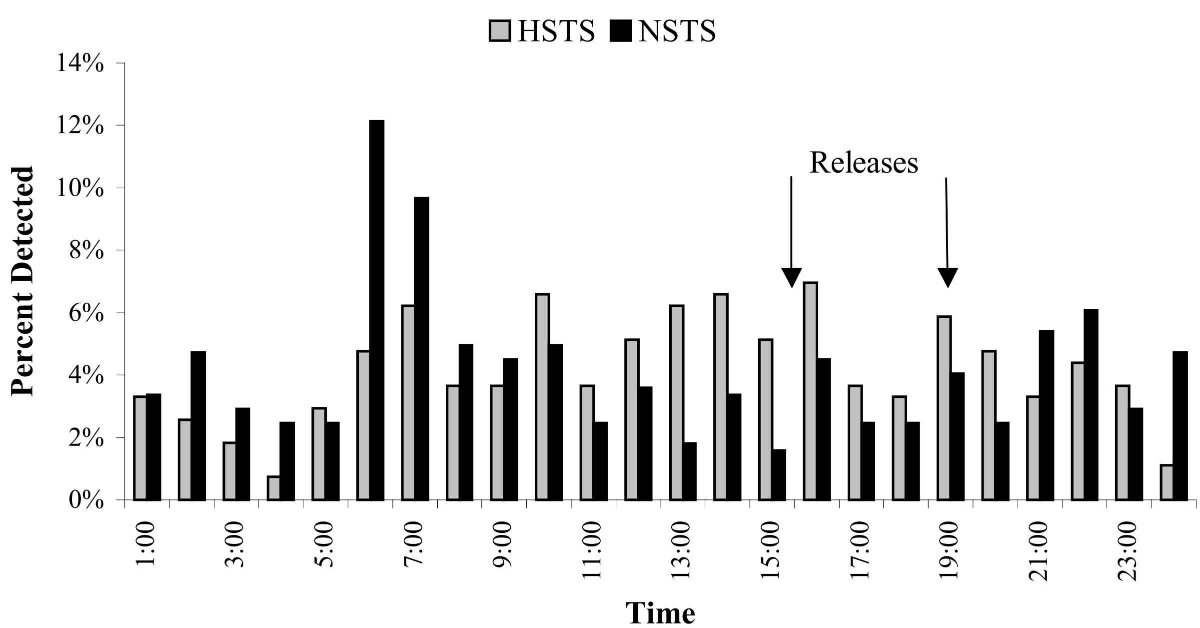


Figure 4. Diel detections of hatchery and natural chinook salmon and summer steelhead used in trap efficiency tests at West Extension Canal (RM 3.7), lower Umatilla River, April - June 1999.

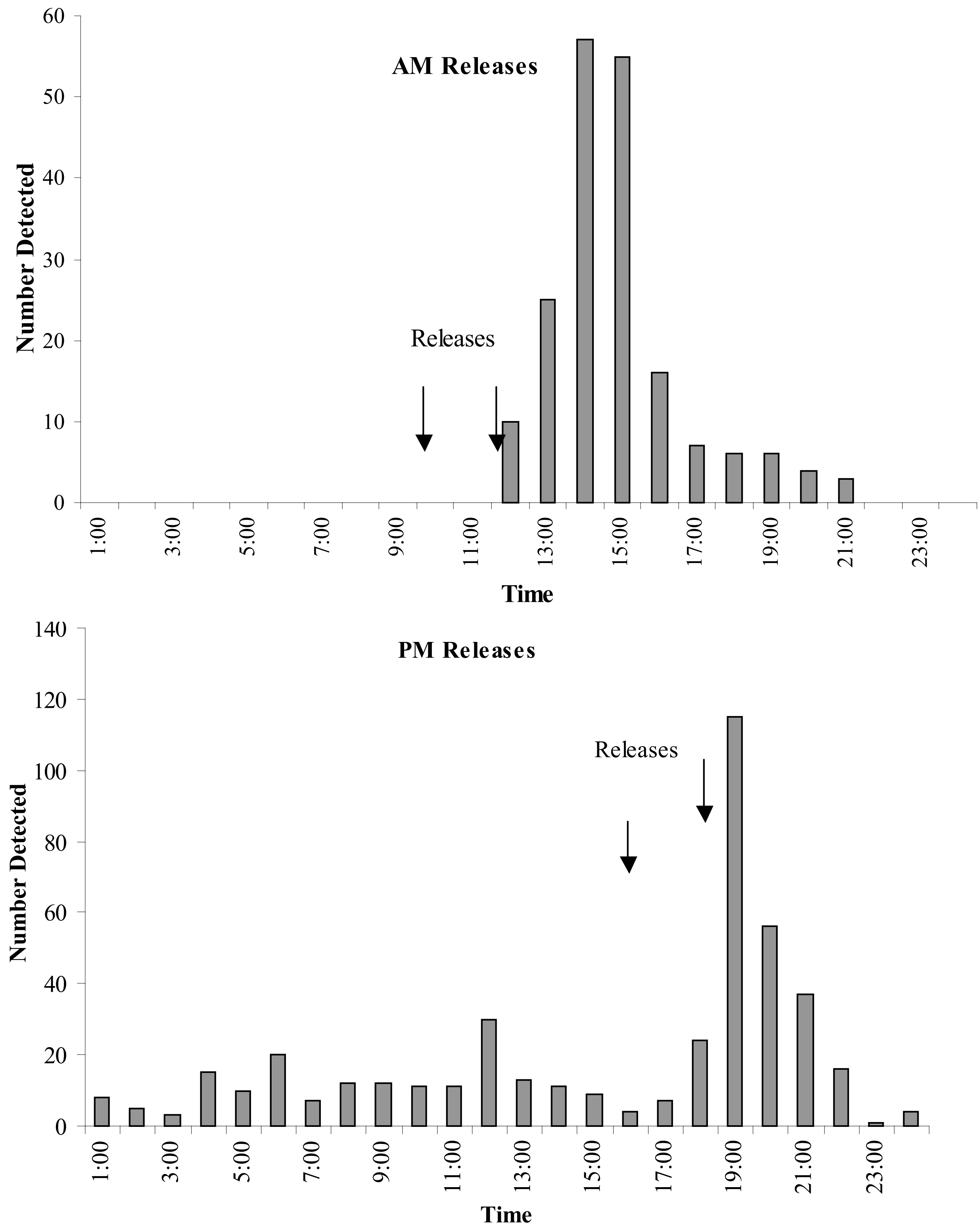


Figure 5. Diel detections of hatchery subyearling fall chinook salmon used in trap efficiency tests at West Extension Canal (RM 3.7), lower Umatilla River, June - July 1999. Releases were made in the AM and PM.

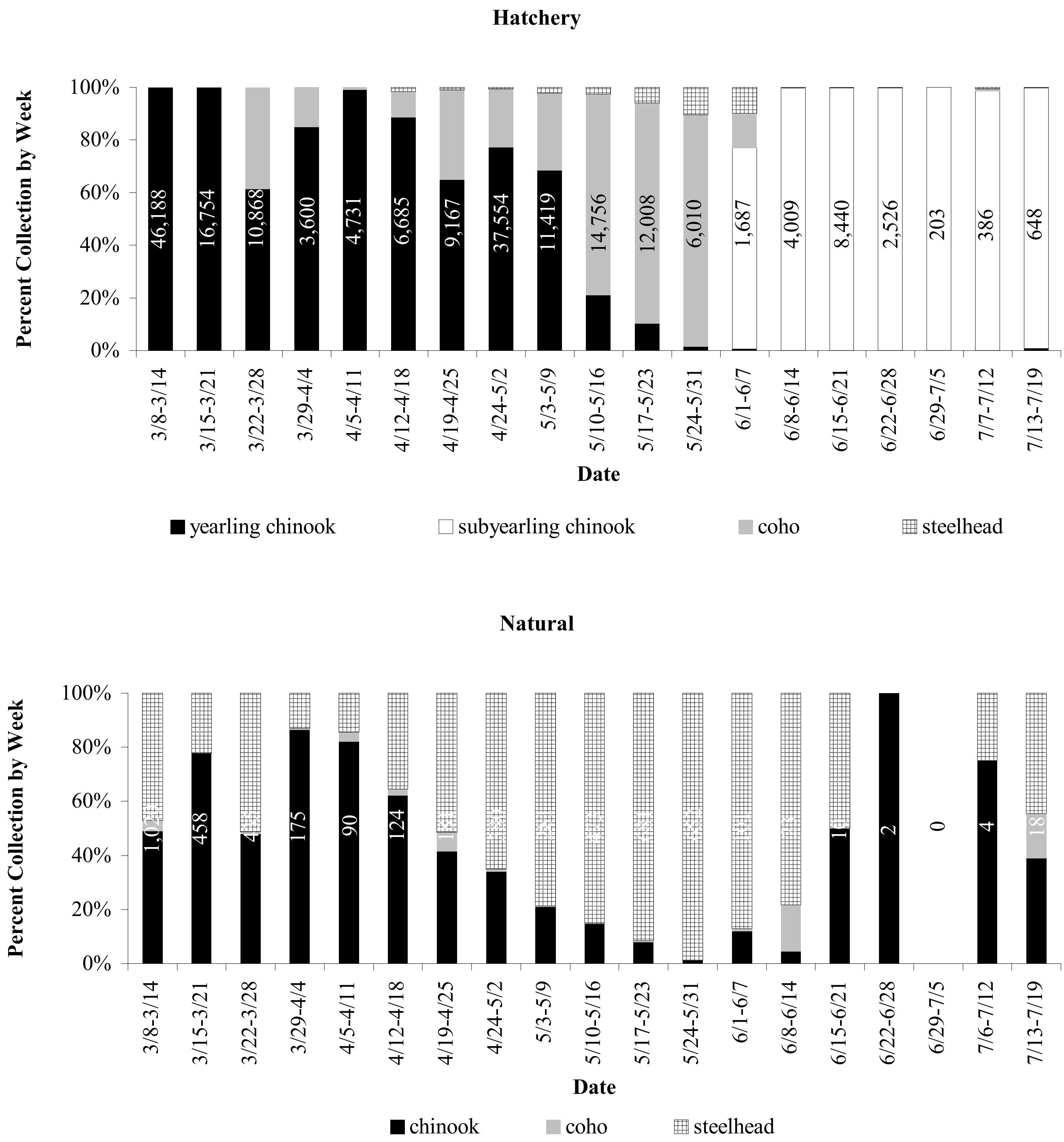


Figure 6. Weekly species composition of hatchery and natural juvenile salmonids sampled at West Extension Canal (RM 3.7), lower Umatilla River, March – July 1999. Numbers shown in bars are total number of fish captured per week.

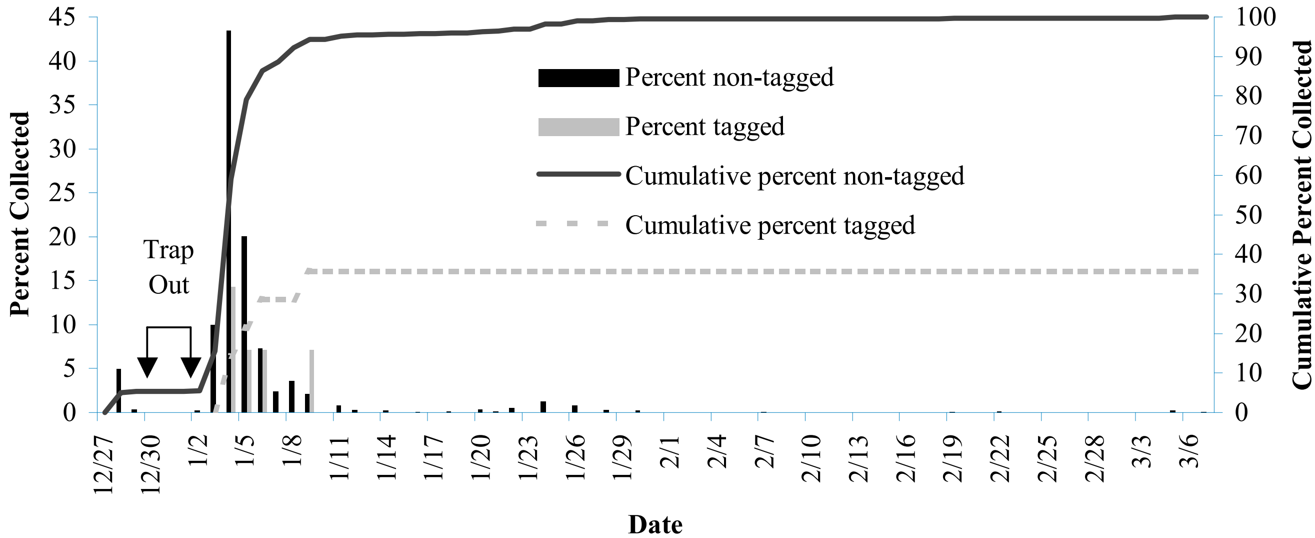


Figure 7. Percent and cumulative percent collection of tagged and non-tagged hatchery spring chinook salmon released on 20 December 1998 and collected at the rotary-screw trap (RM 1.2), Umatilla River, December 1998 – March 1999.

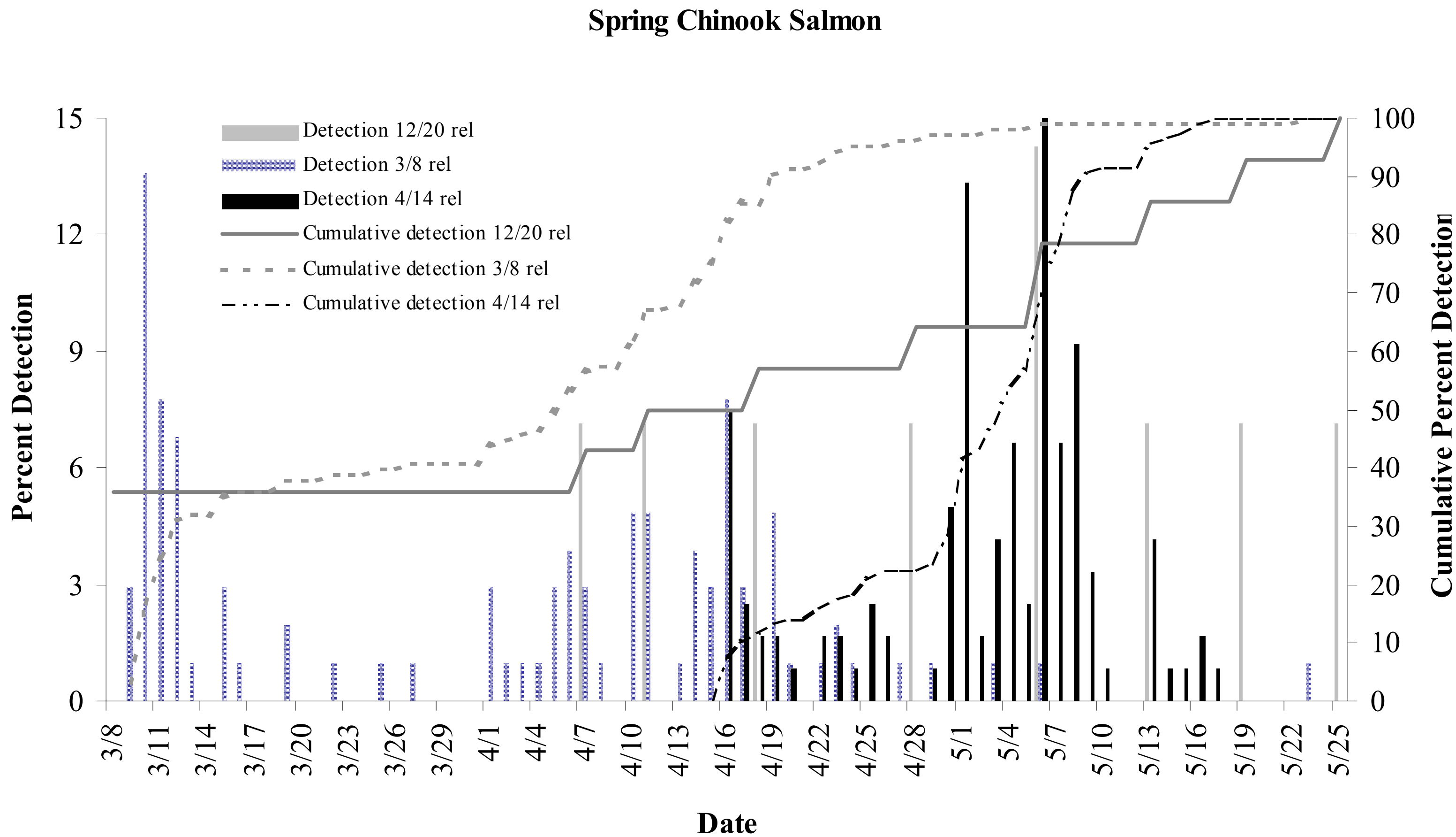
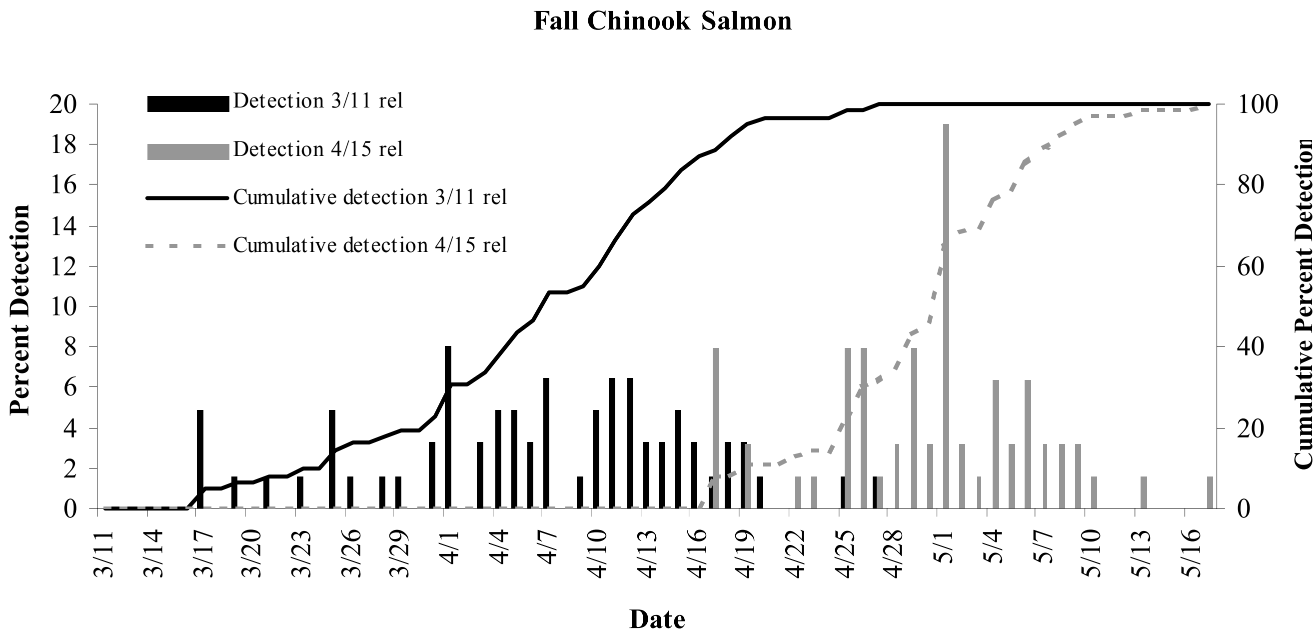


Figure 8. Percent and cumulative percent detection of PIT-tagged hatchery yearling spring chinook salmon at West Extension Canal (RM 3.7), Umatilla River, March – May 1999. Earlier detection (December – February) of December–released spring chinook salmon is not shown.



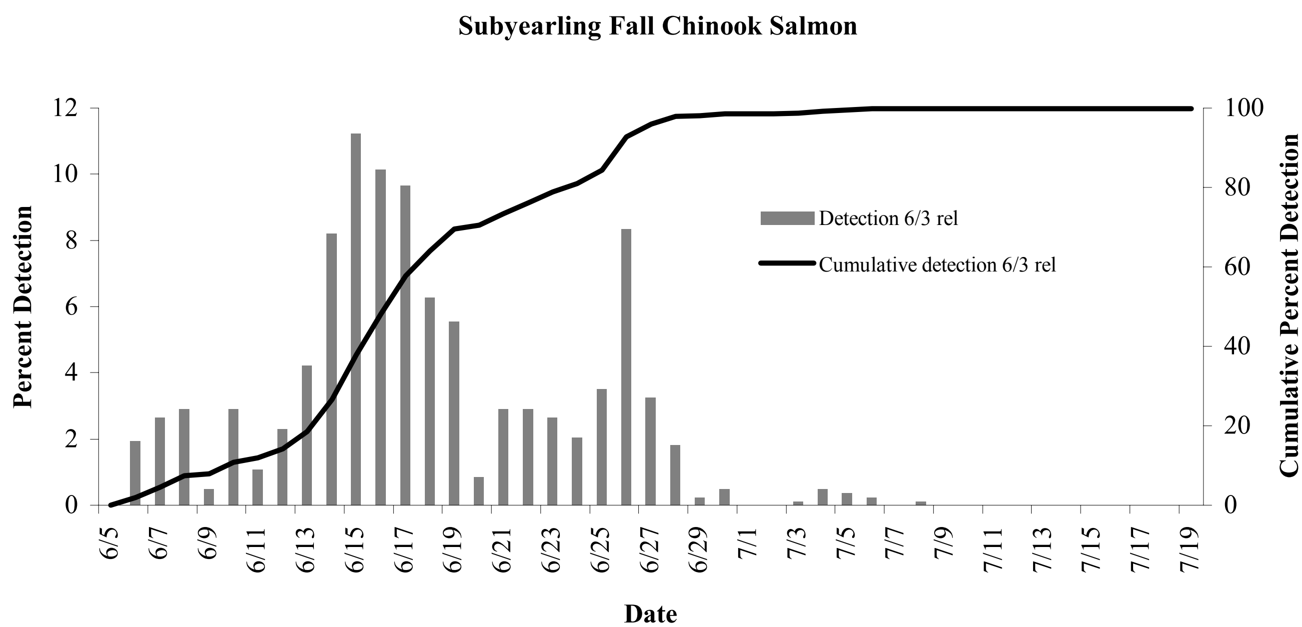


Figure 9. Percent and cumulative percent detection of PIT-tagged hatchery yearling and subyearling fall chinook salmon at West Extension Canal (RM 3.7), Umatilla River, March – July 1999.

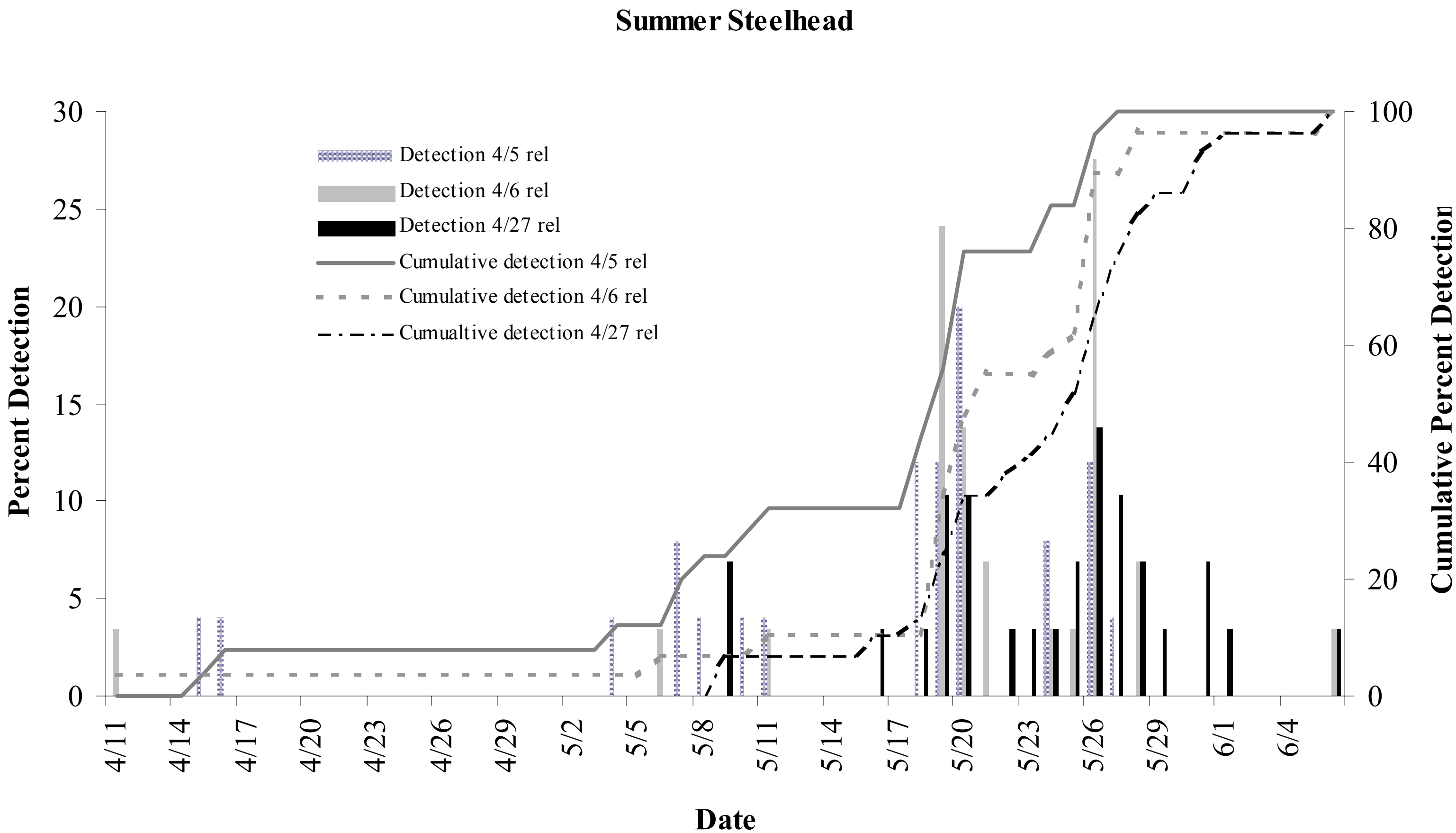
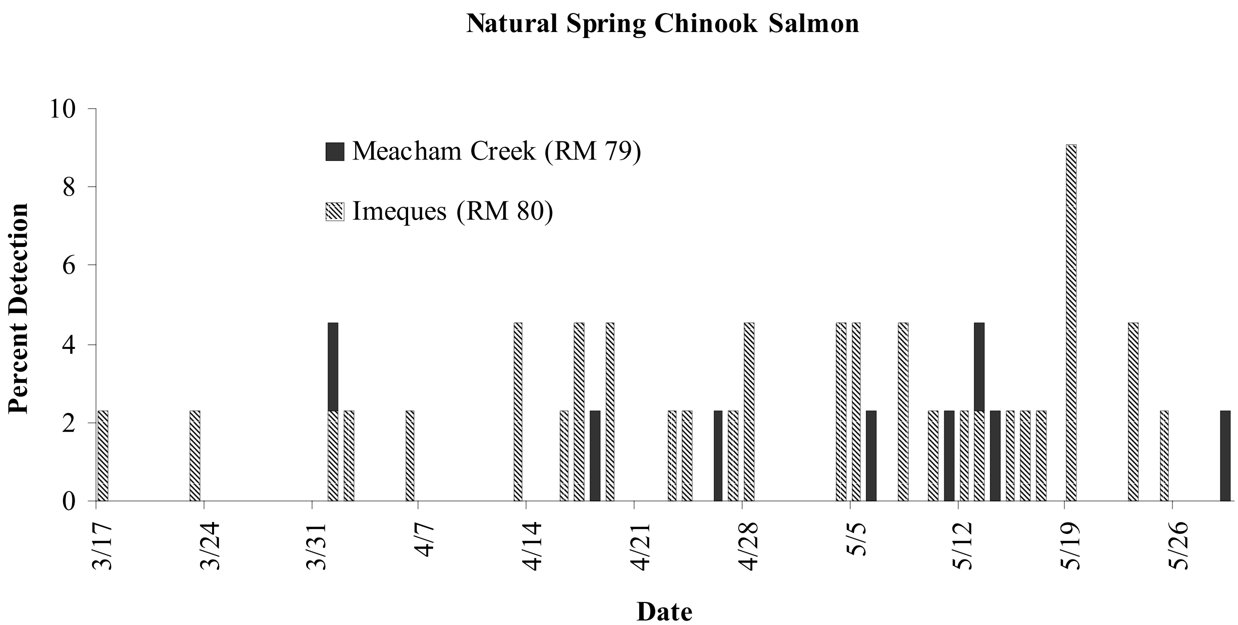


Figure 10. Percent and cumulative percent detection of PIT-tagged hatchery summer steelhead at West Extension Canal (RM 3.7), lower Umatilla River, April – June 1999. Release dates are volitional dates.



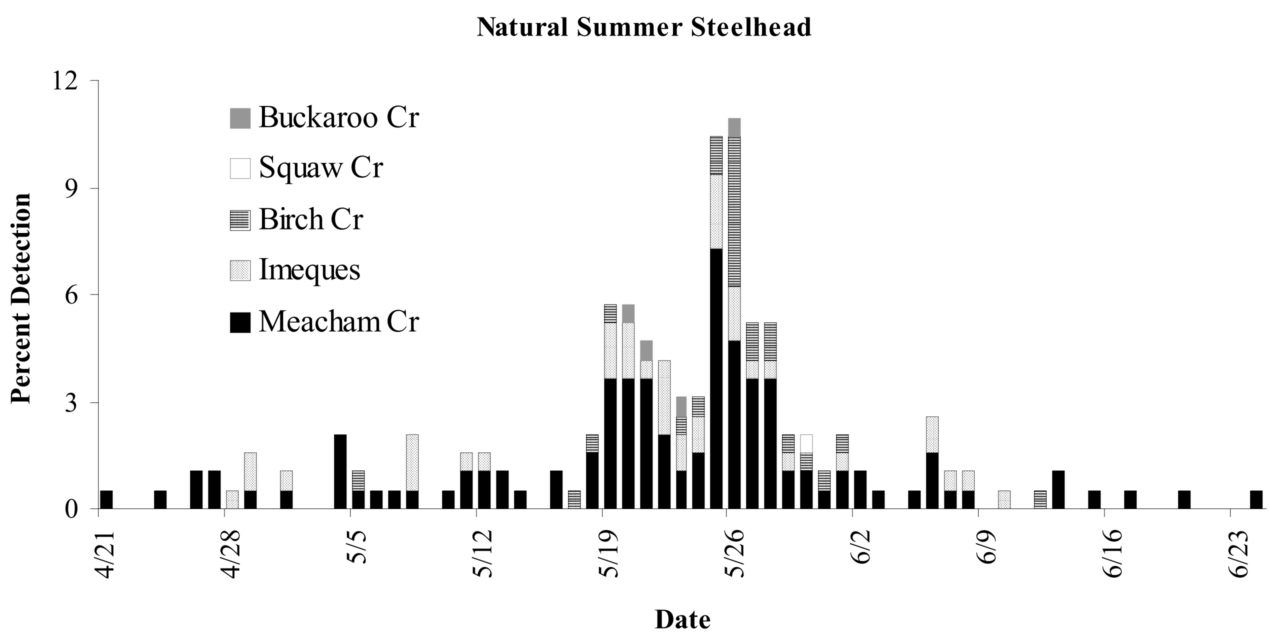


Figure 11. Percent detection of PIT-tagged natural chinook salmon and summer steelhead at West Extension Canal (RM 3.7), Umatilla River, March – June 1999. Sites indicated are where fish were released after being tagged.

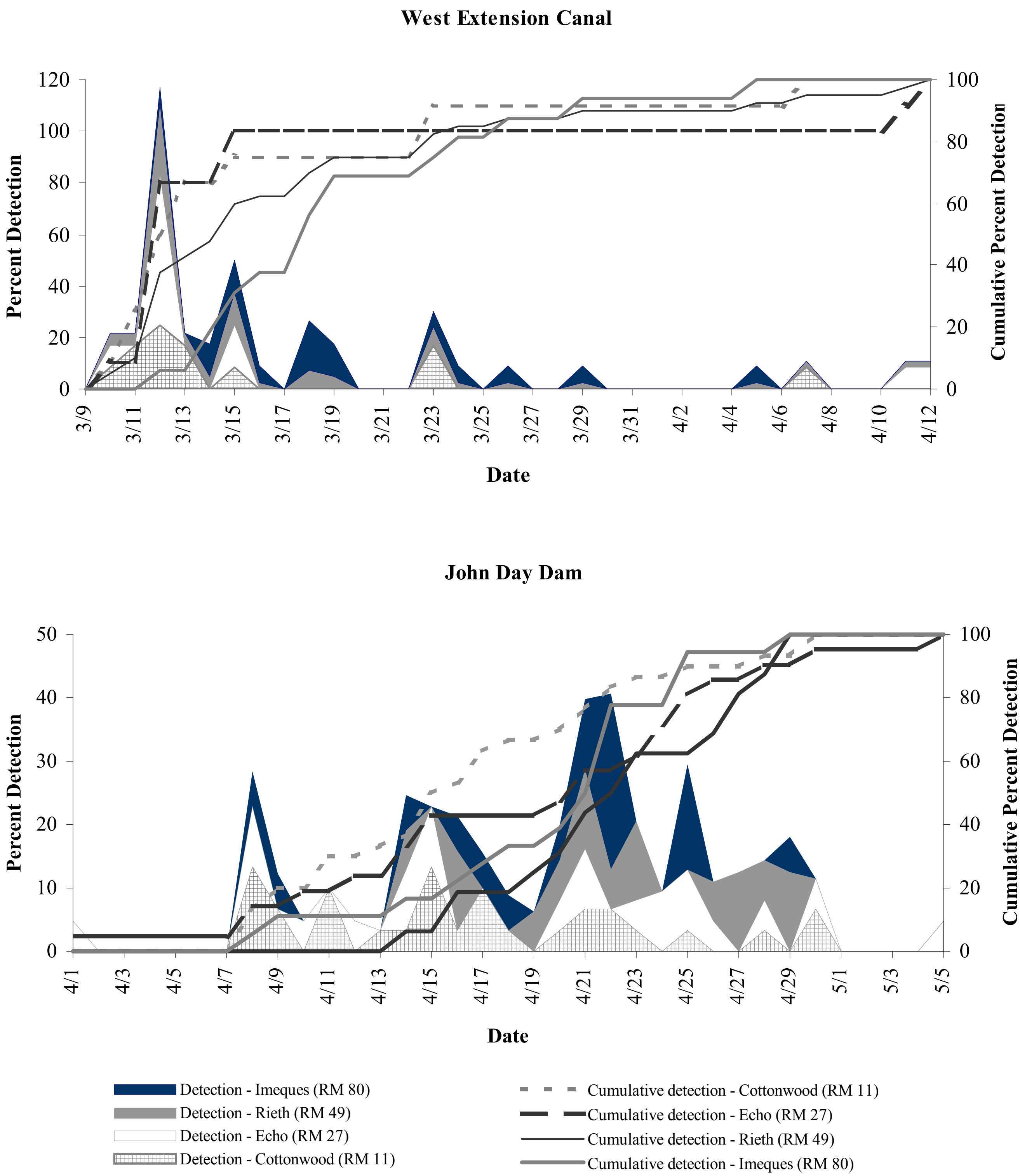
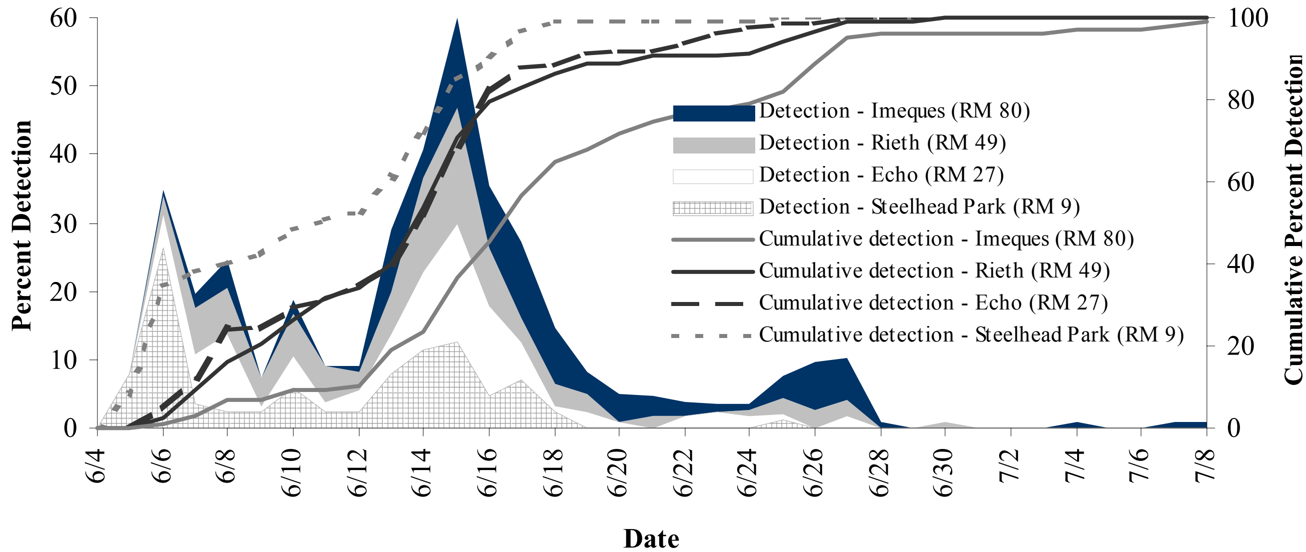


Figure 12. Percent and cumulative percent detection of hatchery spring chinook salmon PIT tagged for reach survival tests and detected at West Extension Canal (RM 3.7), lower Umatilla River, and John Day Dam, Columbia River, March – May 1999.

West Extension Canal



John Day Dam

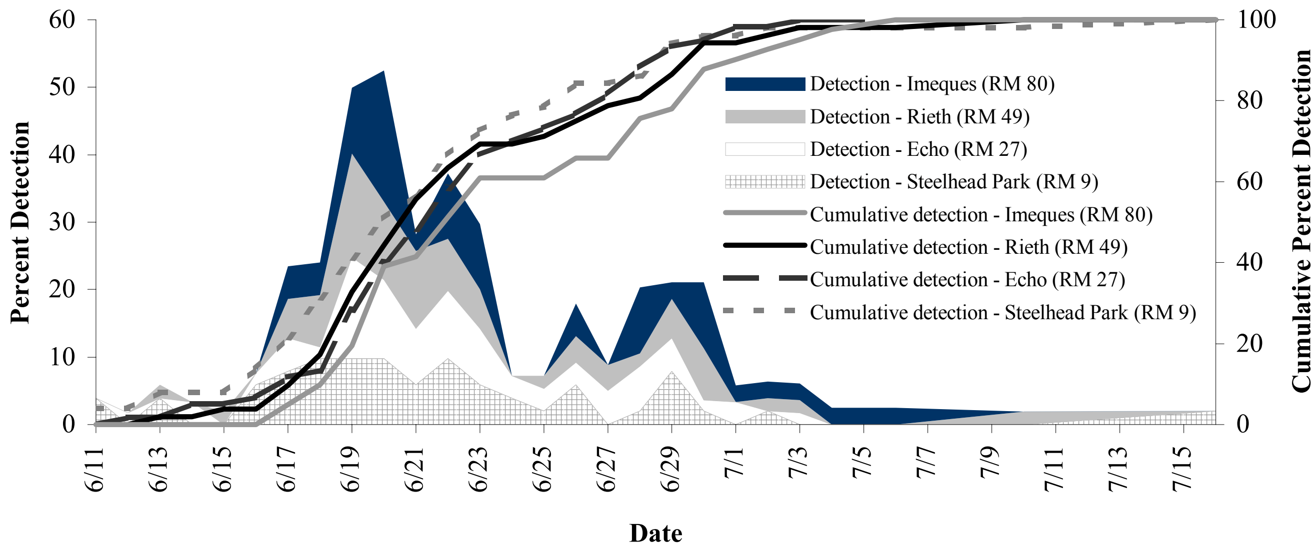


Figure 13. Percent and cumulative percent detection of hatchery subyearling fall chinook salmon PIT tagged for reach survival tests and detected at West Extension Canal (RM 3.7), lower Umatilla River, and John Day Dam, Columbia River, June – July 1999.

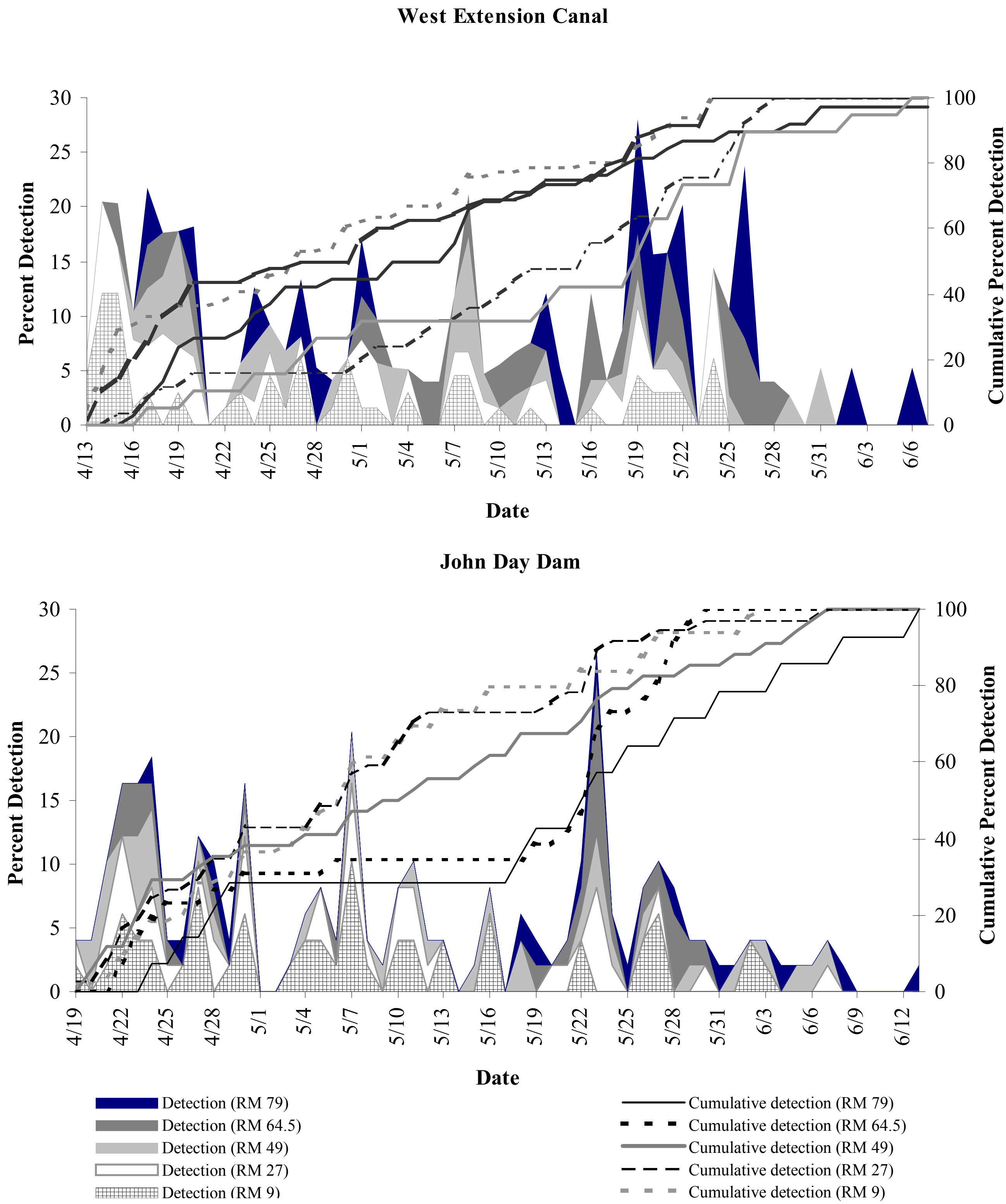


Figure 14. Percent and cumulative percent detection of large-grade hatchery summer steelhead PIT tagged for reach survival tests and detected at West Extension Canal (RM 3.7), lower Umatilla River, and John Day Dam, Columbia River, April – June 1999.

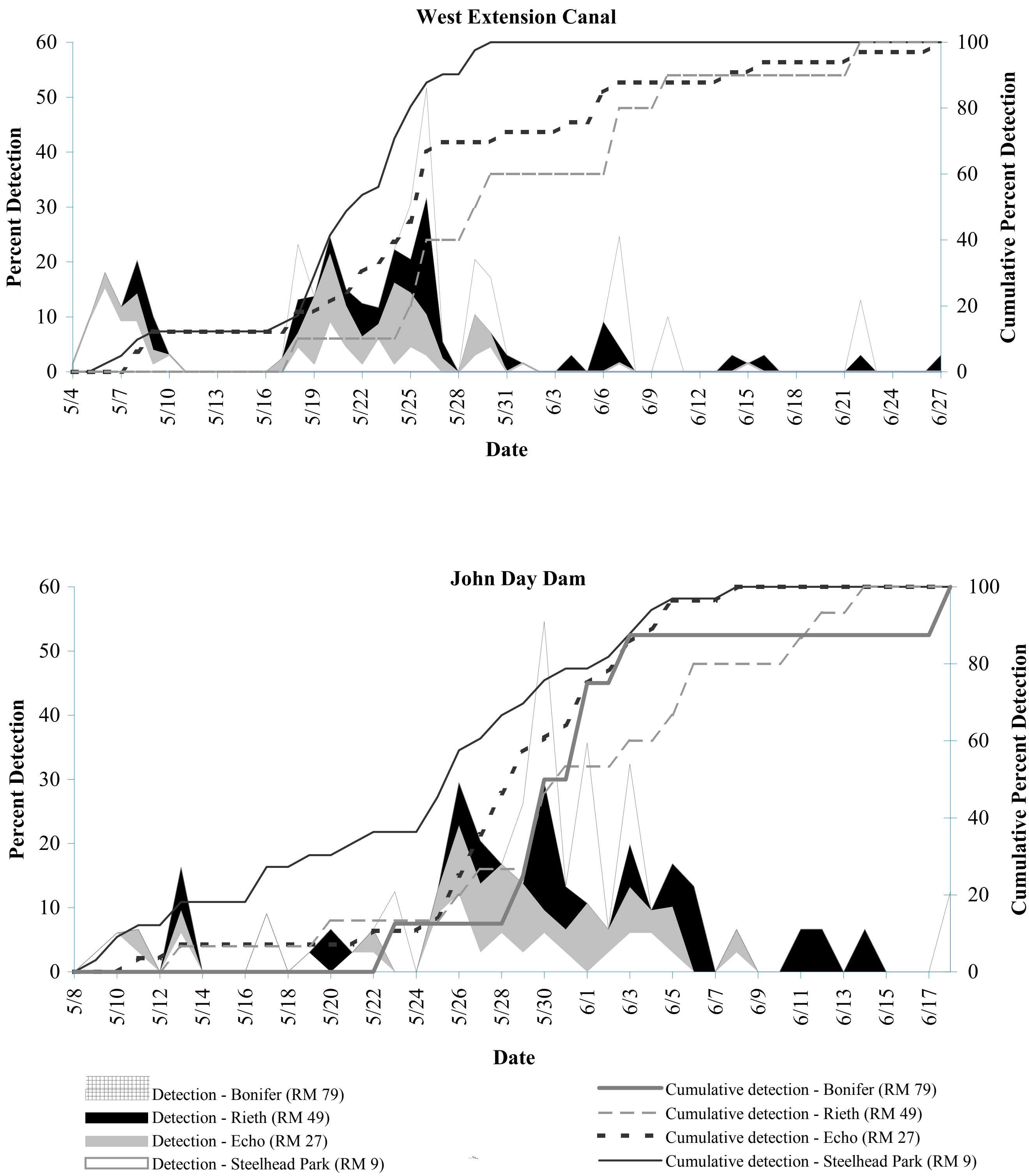
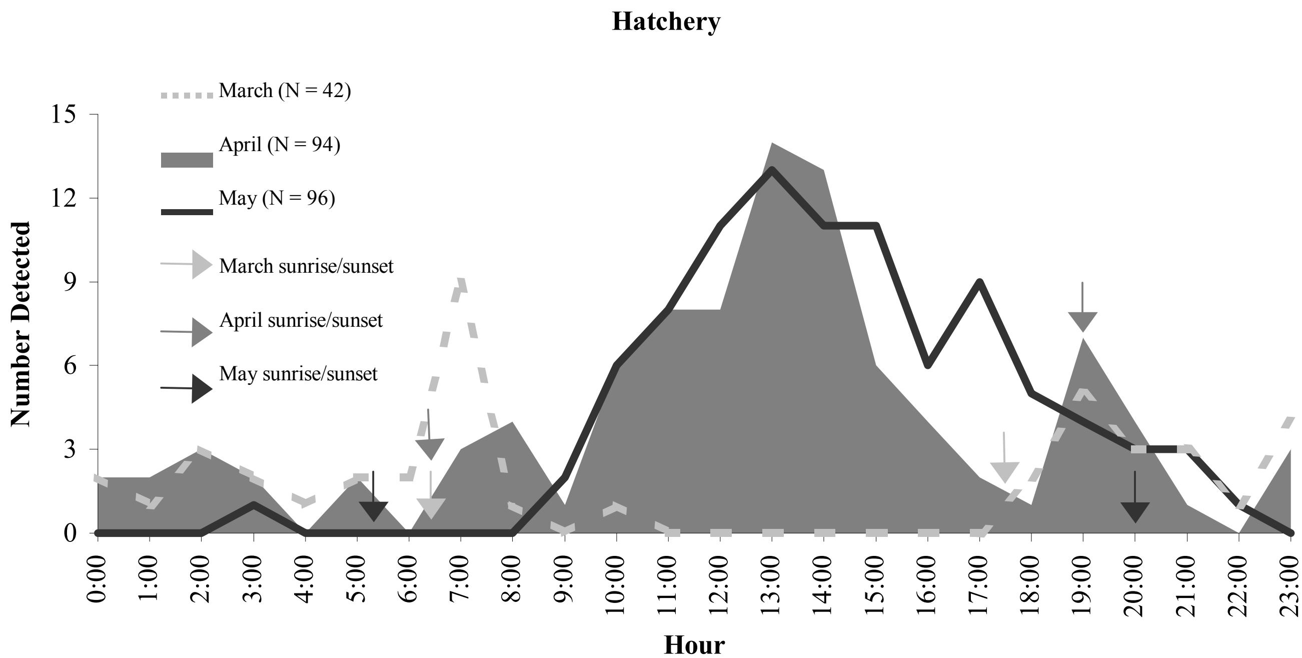


Figure 15. Percent and cumulative percent detection of small-grade hatchery summer steelhead PIT tagged for reach survival tests and detected at West Extension Canal (RM 3.7), lower Umatilla River, and John Day Dam, Columbia River, May – June 1999.



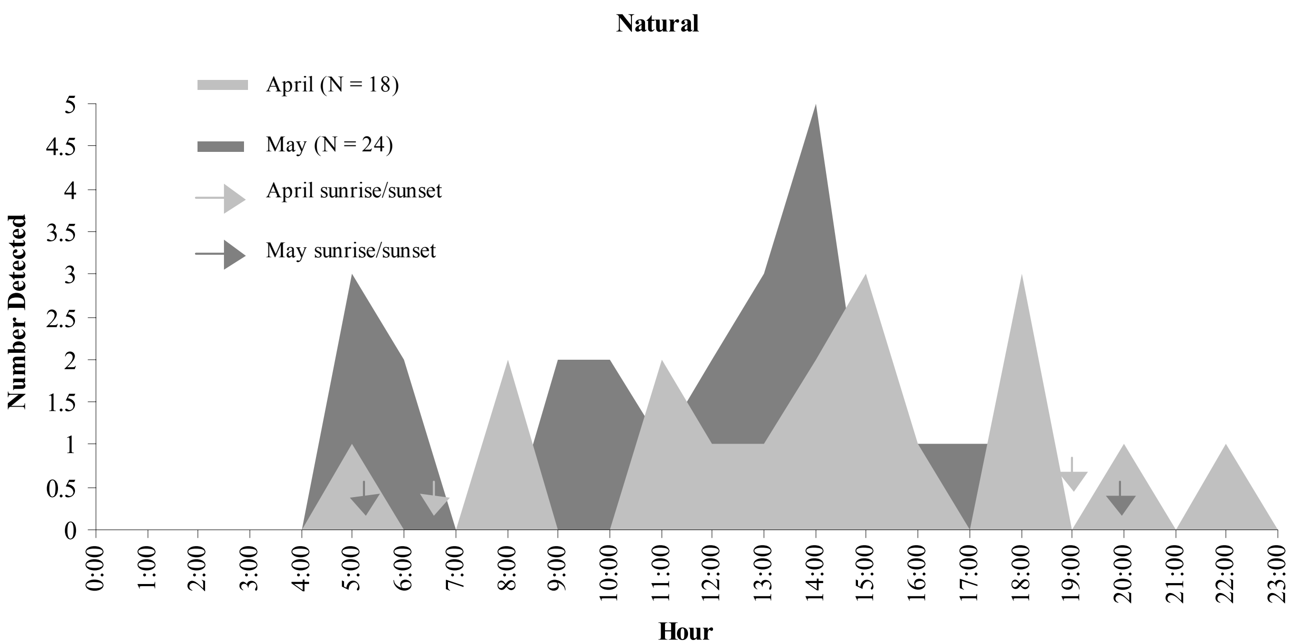
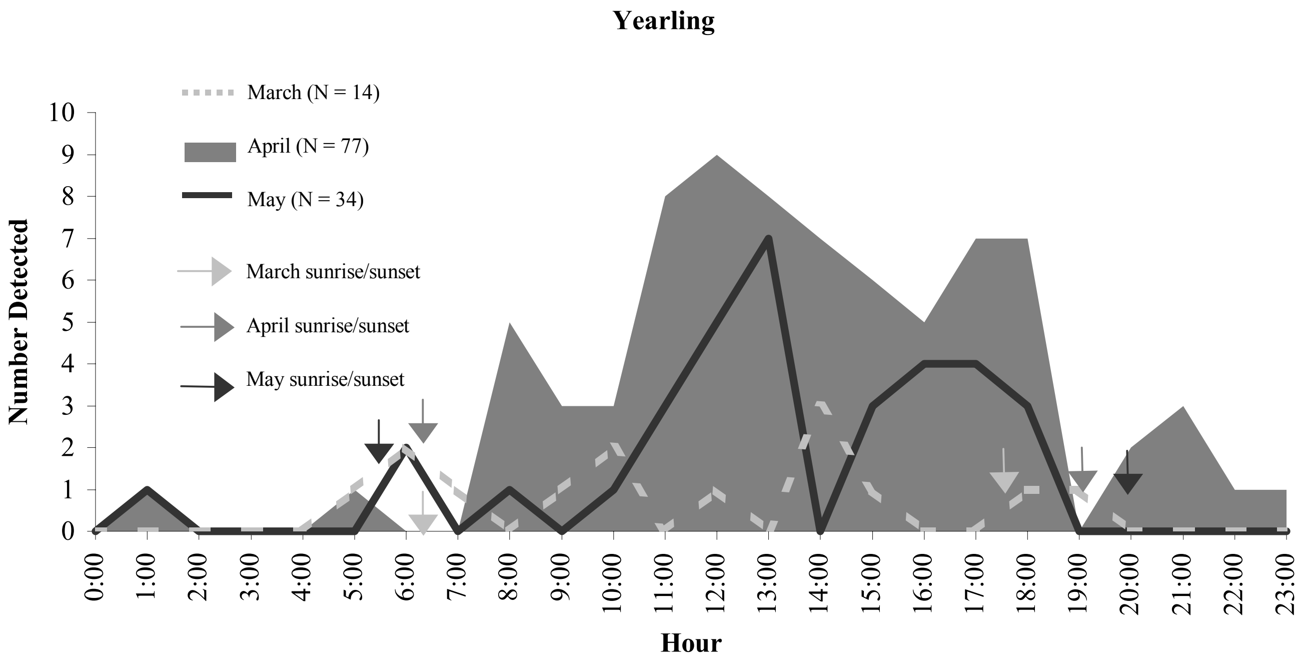


Figure 16. Diel detection of PIT-tagged hatchery and natural spring chinook salmon at West Extension Canal (RM 3.7), Umatilla River, March – May 1999.



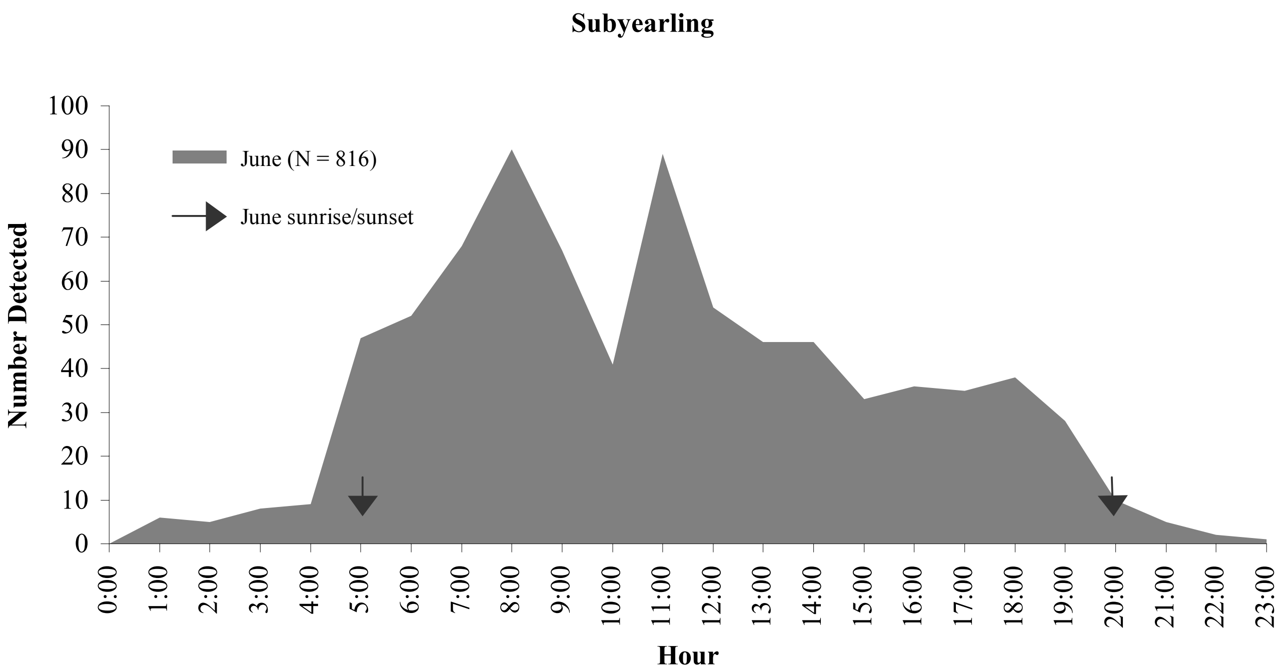
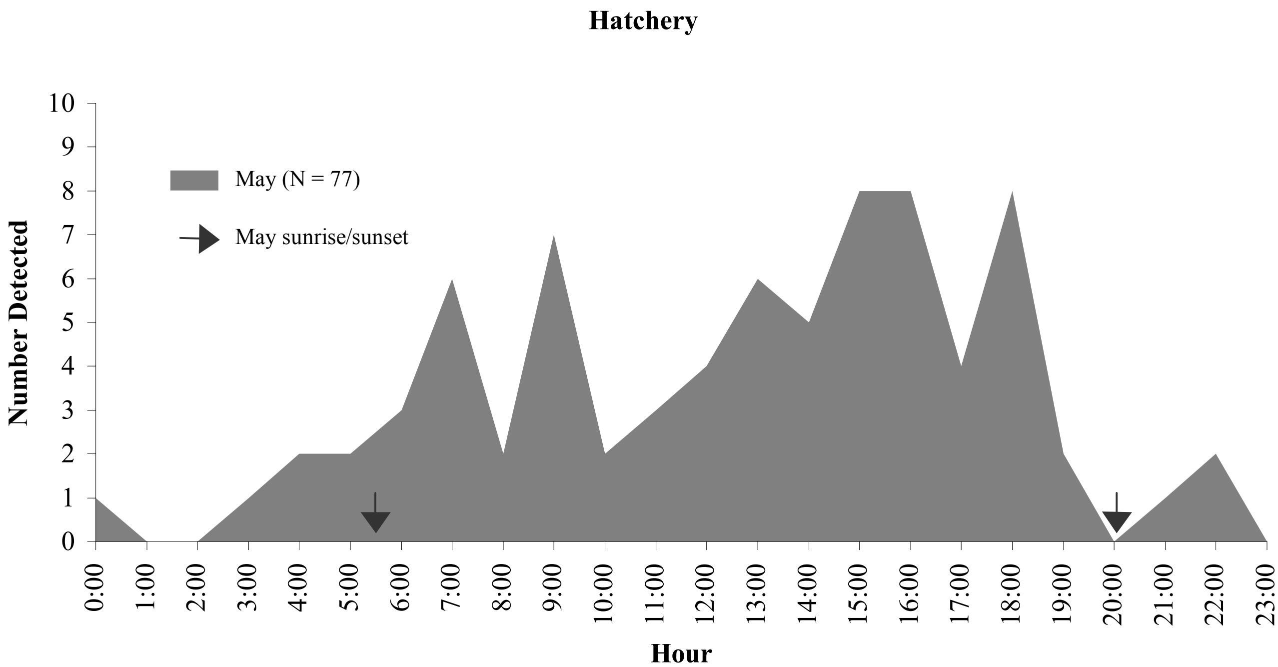


Figure 17. Diel detection of PIT-tagged hatchery yearling and subyearling fall chinook salmon at West Extension Canal (RM 3.7), Umatilla River, March – June 1999.



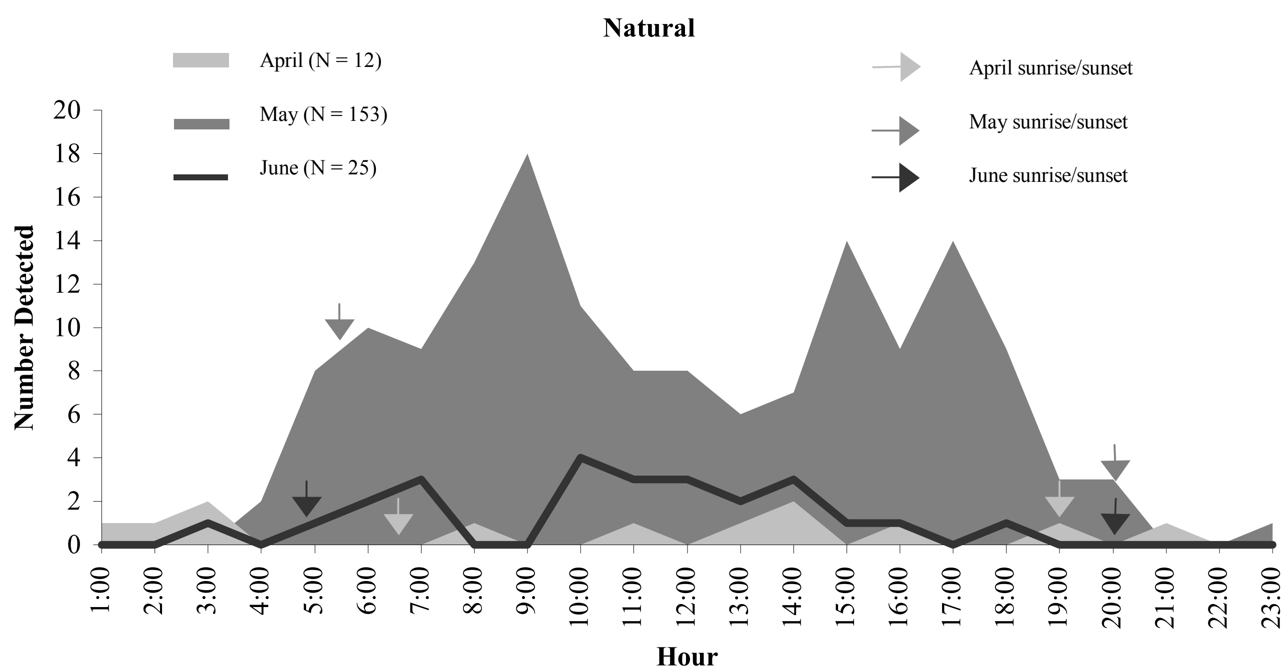


Figure 18. Diel detection of PIT-tagged hatchery and natural summer steelhead at West Extension Canal (RM 3.7), Umatilla River, April - June 1999.

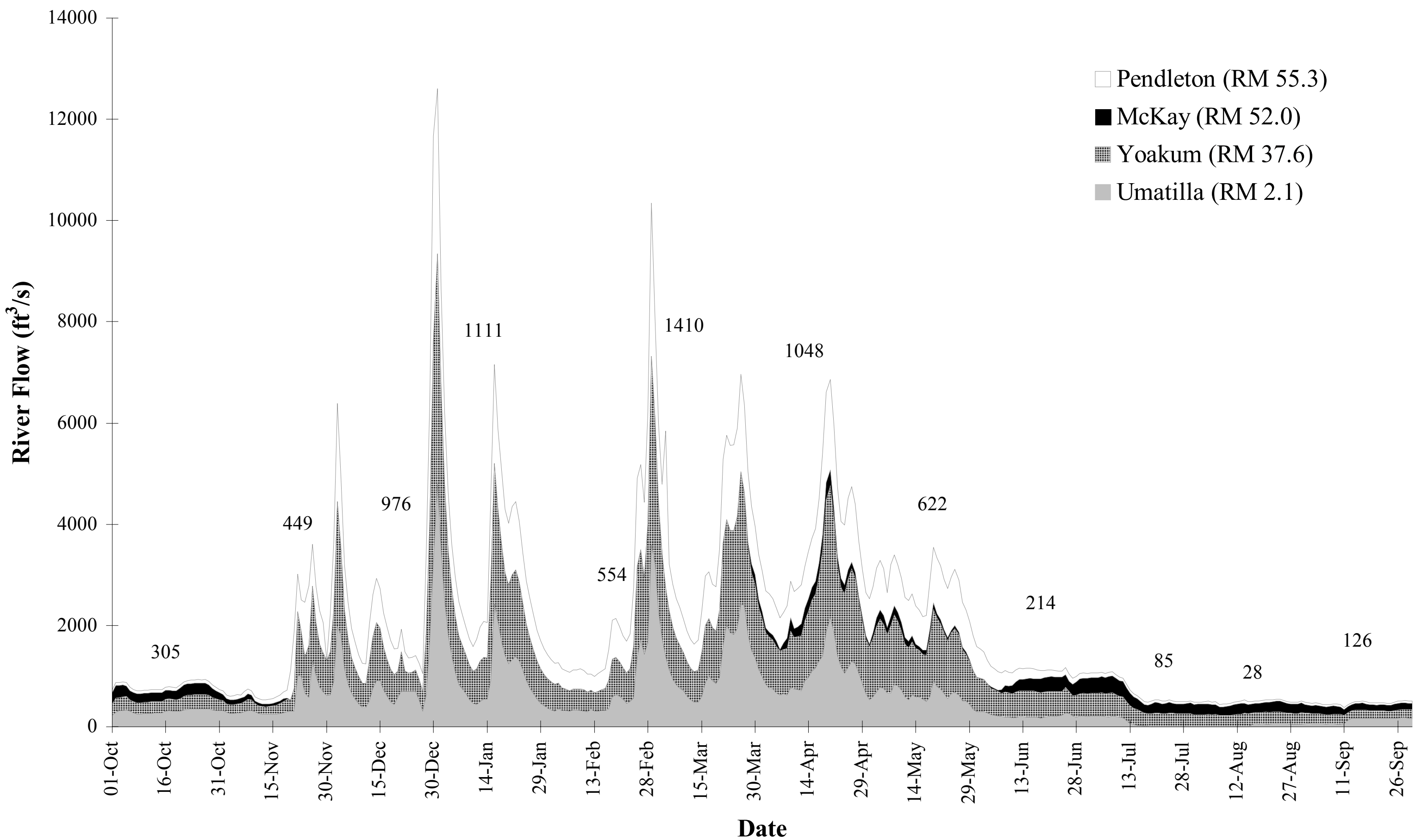


Figure 19. Mean daily river flows (ft^3/s) recorded at four gauging stations on the Umatilla River, October 1998 - September 1999. Numbers shown are monthly means at the UMAO gauging station (RM 2.1).

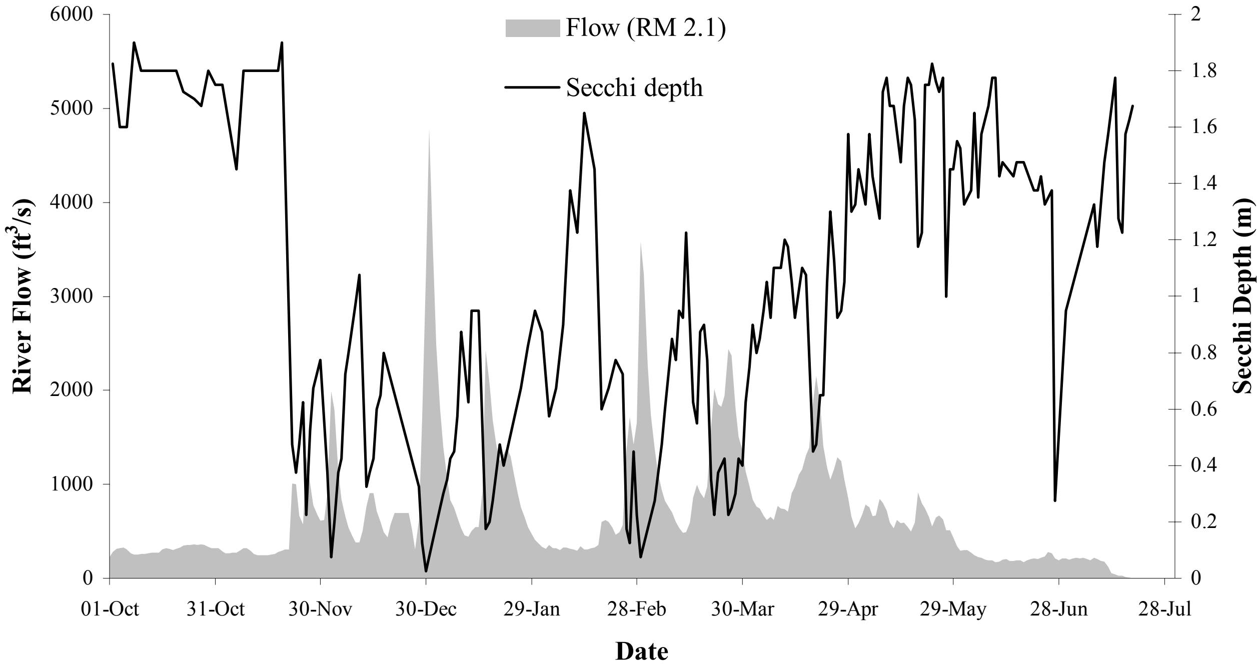


Figure 20. Mean daily river flow (ft^3/s) at RM 2.1 plotted against mean Secchi depth (m) at RM 1.2 or 3.7, lower Umatilla River, October 1998 - July 1999.

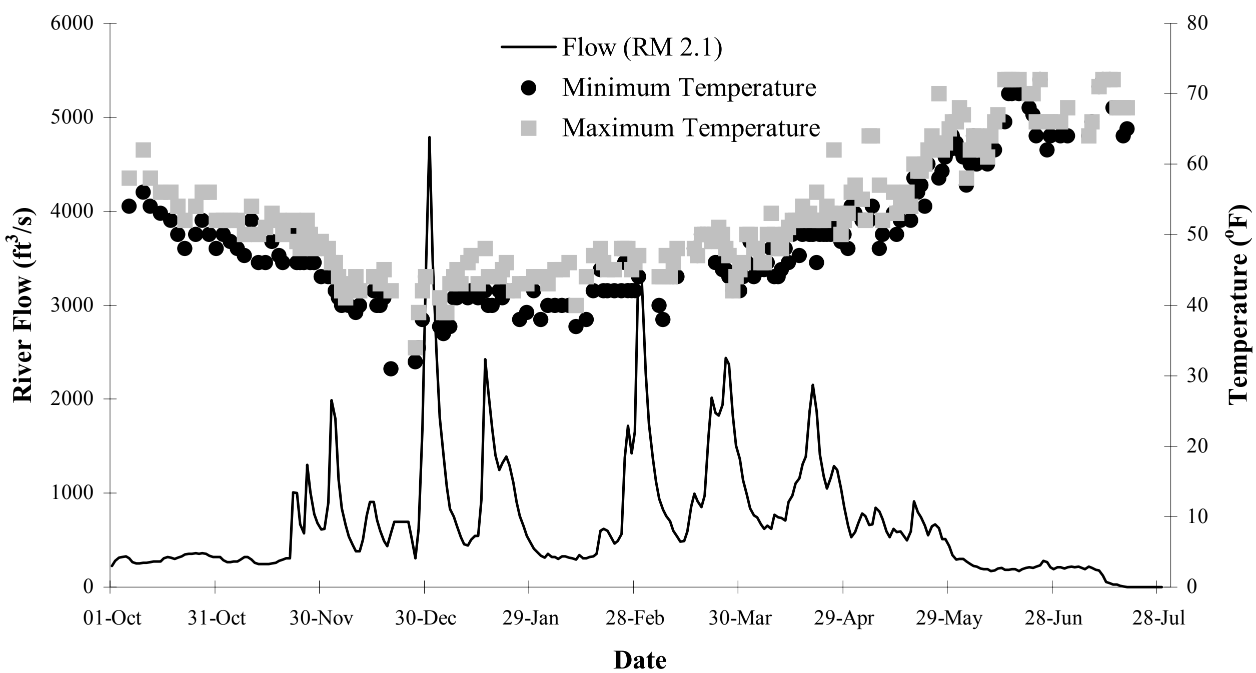
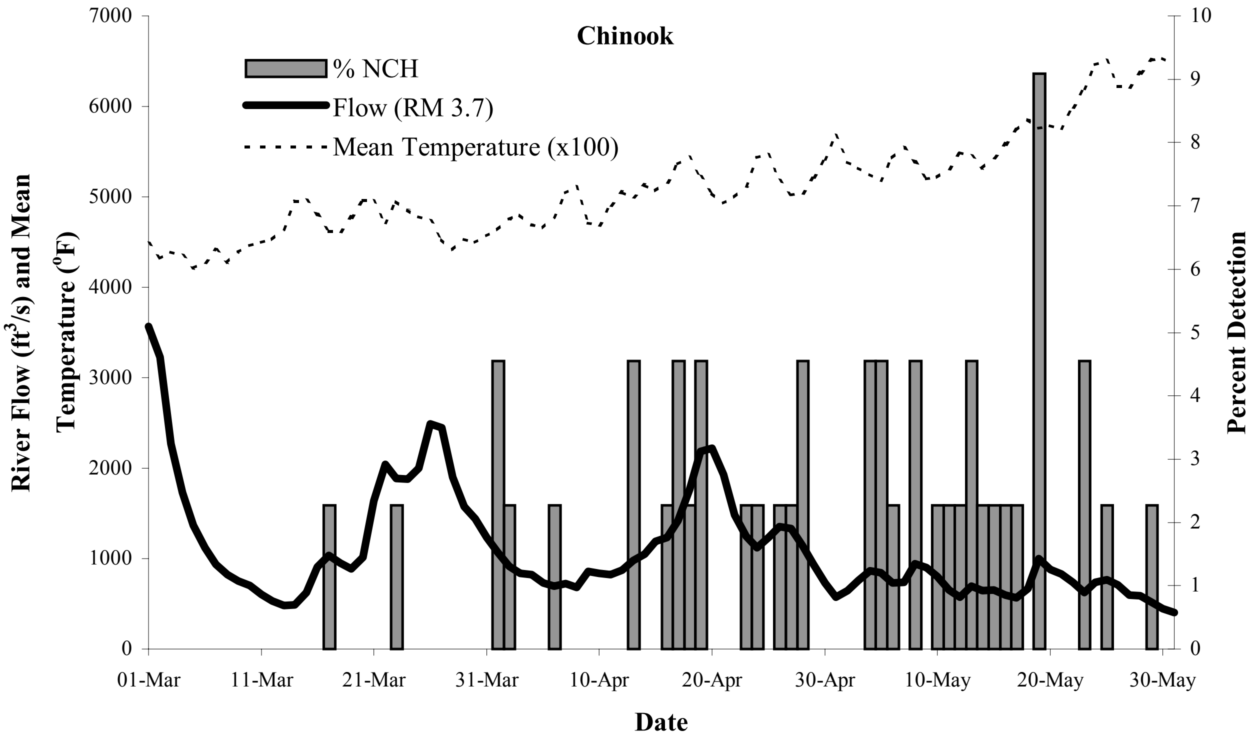


Figure 21. Maximum and minimum water temperatures (^{o}F) plotted against river flow (ft^3/s), lower Umatilla River, October 1998 - July 1999.



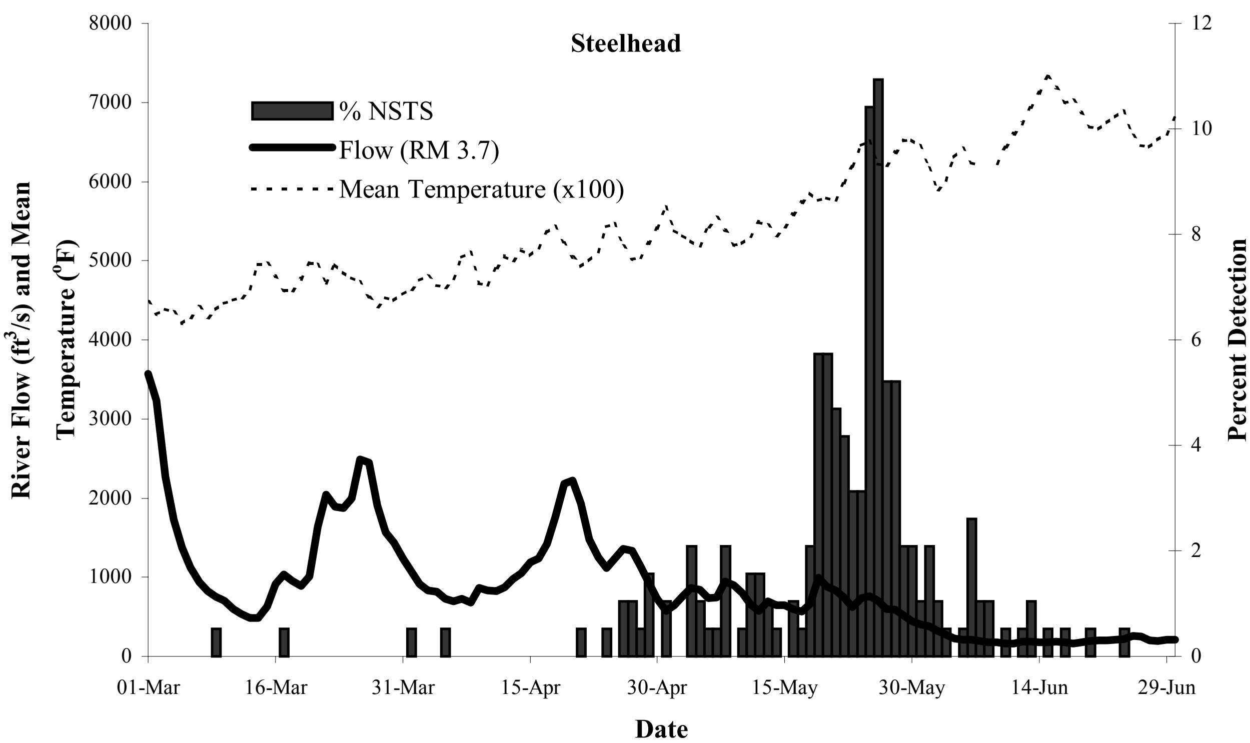


Figure 22. Daily river flow (ft^3/s), daily mean temperature (^{o}F), and percent detection of natural chinook salmon (NCH) and summer steelhead (NSTS) at West Extension Canal (RM 3.7), lower Umatilla River, March - June 1999.

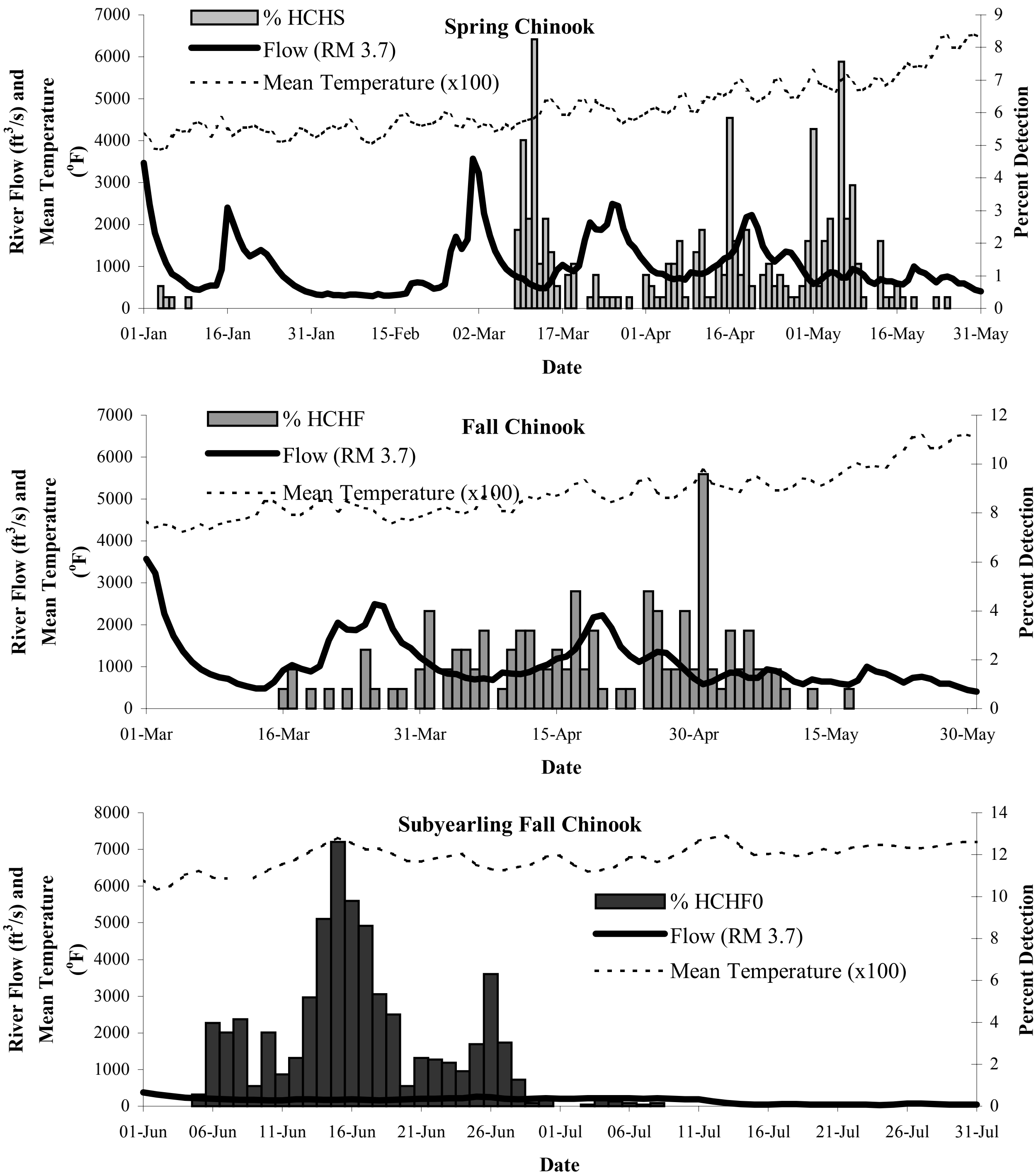
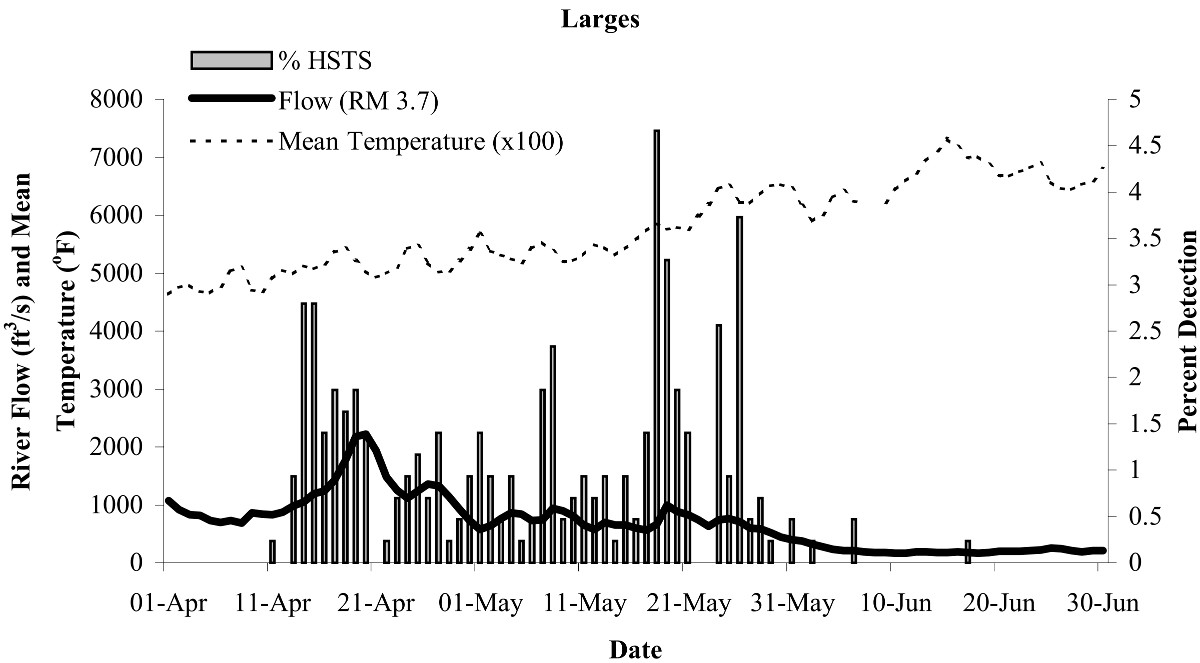


Figure 23. Daily river flow (ft^3/s), daily mean temperature (^{o}F), and percent detection of hatchery spring (HCHS), fall (HCHF), and subyearling fall chinook salmon (HCHF0) at West Extension Canal (RM 3.7), lower Umatilla River, March - May 1999.



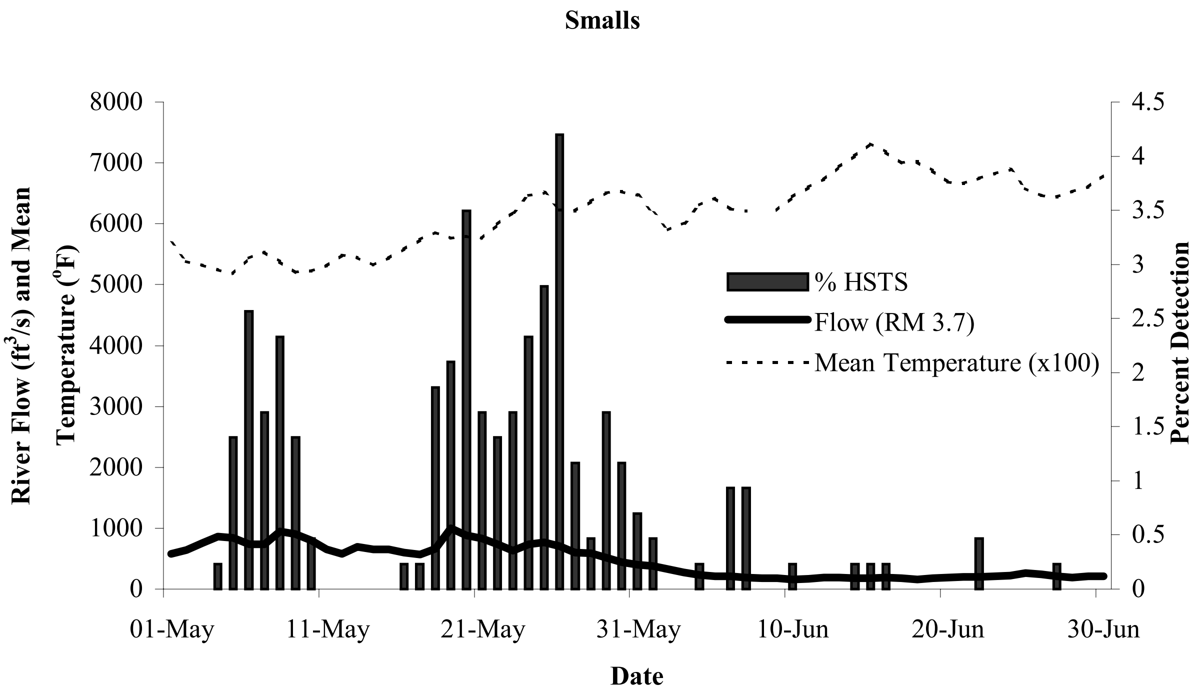


Figure 24. Daily river flow (ft^3/s), daily mean temperature (^oF), and percent detection of large- and small-grade hatchery summer steelhead (HSTS) at West Extension Canal (RM 3.7), lower Umatilla River, April - June 1999.

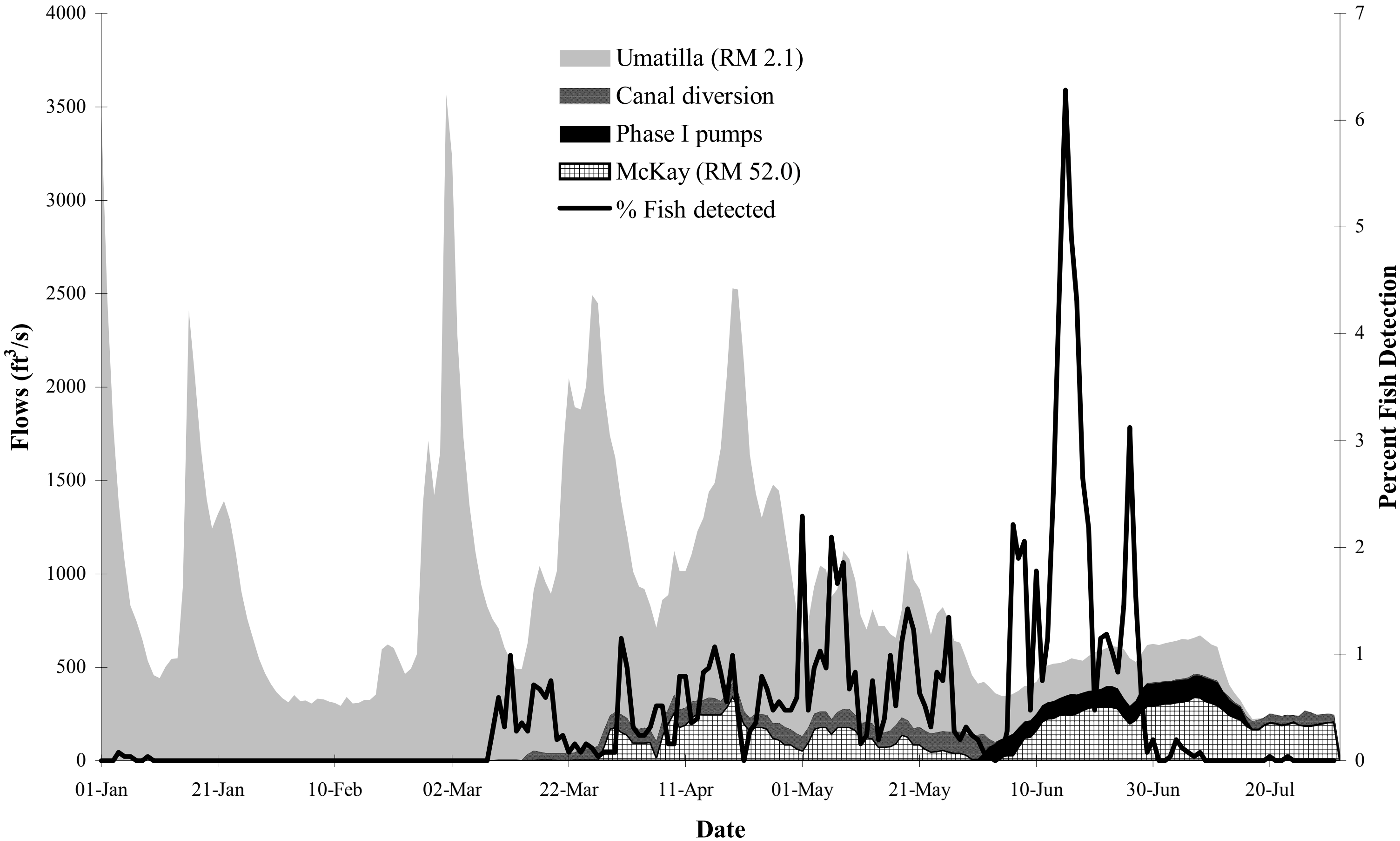


Figure 25. Mean daily flows (ft^3/s) for river discharge at UMAO gauging station (RM 2.1), Phase I exchange pumping, McKay Reservoir water releases, and canal diversion at West Extension Canal (RM 3.7) plotted with total percent detection of hatchery fish, lower Umatilla River, January - July 1999.

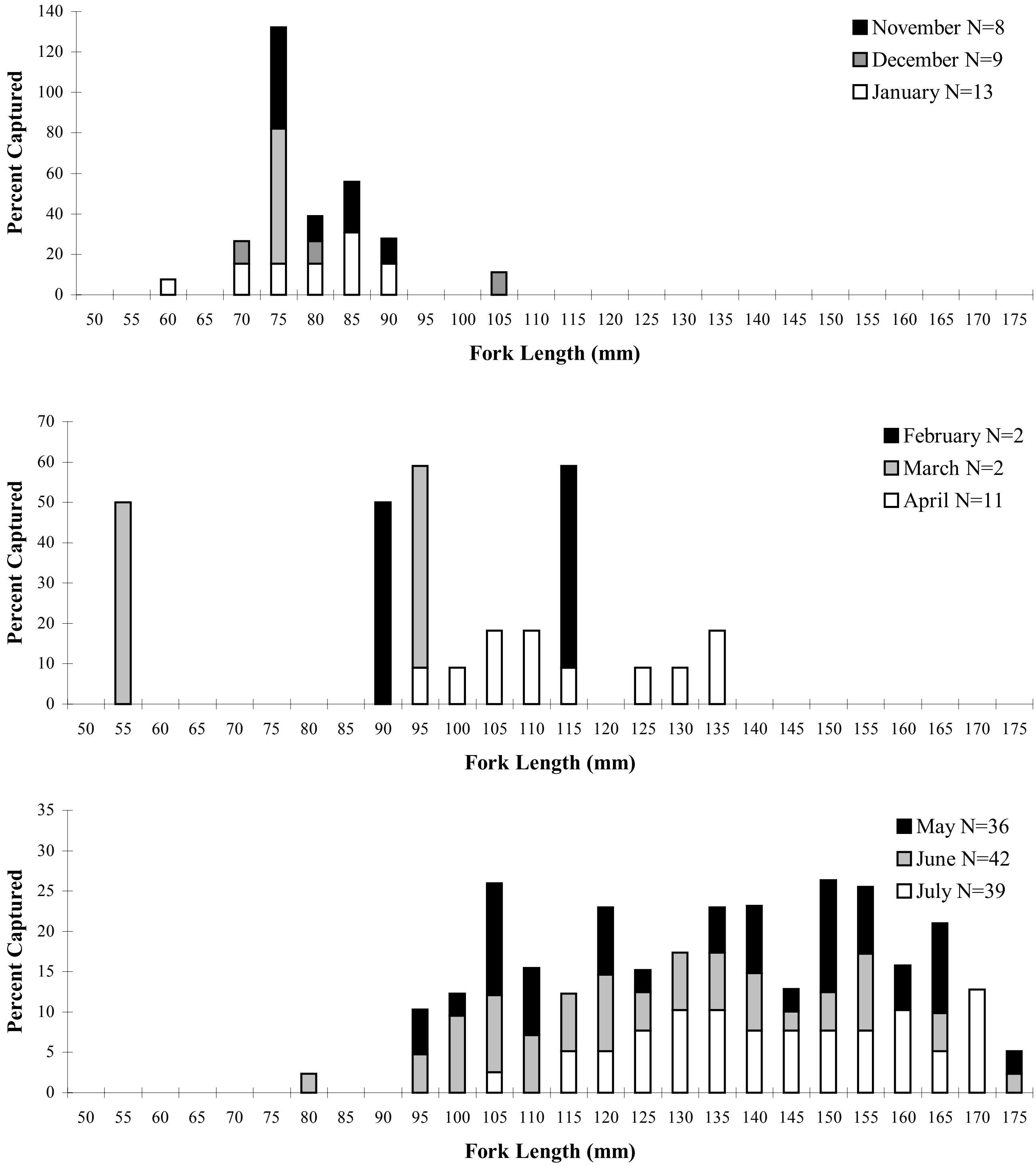


Figure 26. Length-frequency distribution of juvenile bass, lower Umatilla River, November 1998 - July 1999. Data represents captures at RM 1.2 (November through February) and RM 3.7 (March through July). Distributions are in 5-mm increments.

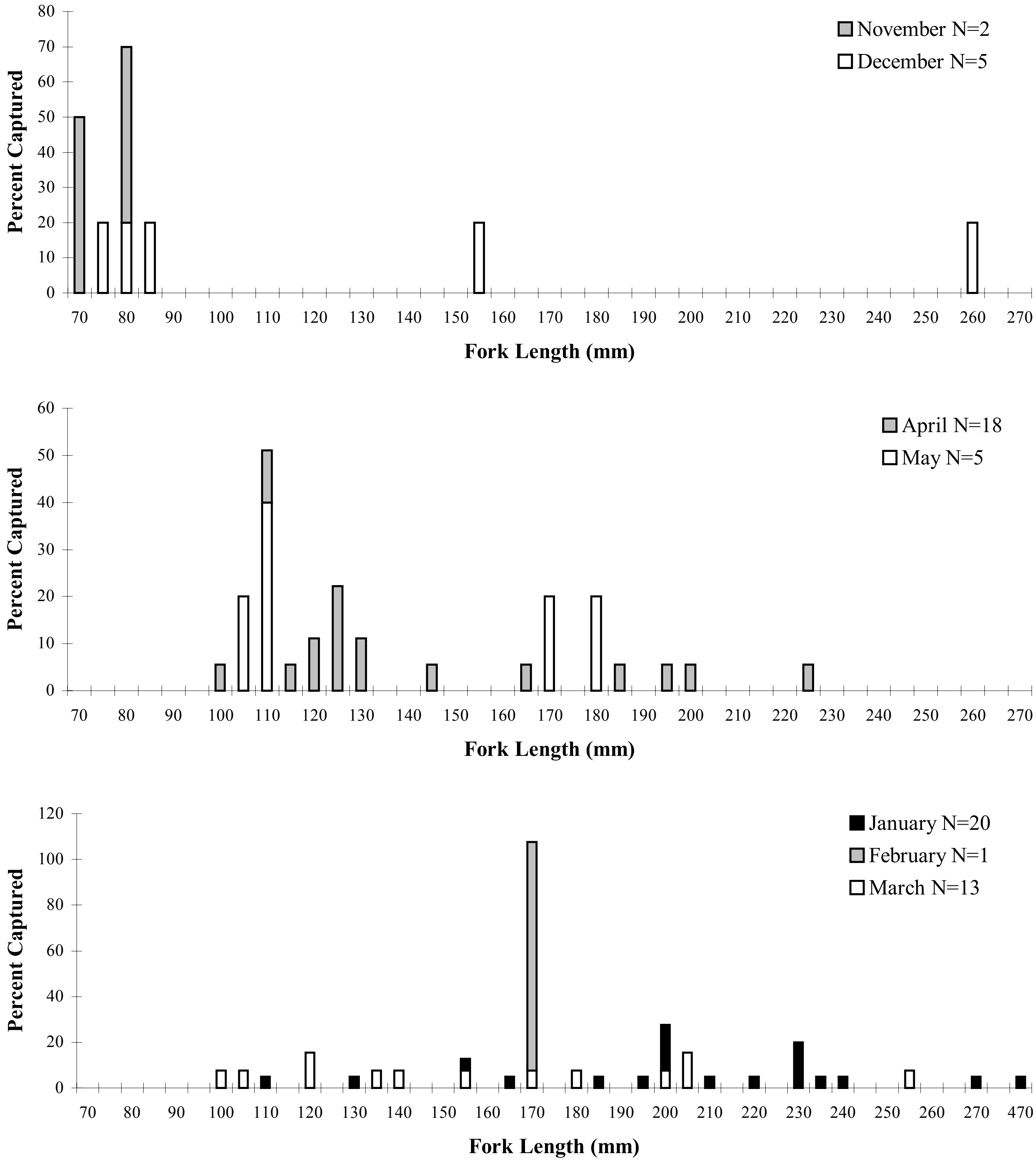


Figure 27. Length-frequency distribution by month of northern pikeminnow, lower Umatilla River, November 1998 - May 1999. Data represents captures at RM 1.2 (November through February) and RM 3.7 (March through May). Distributions are in 5-mm increments.

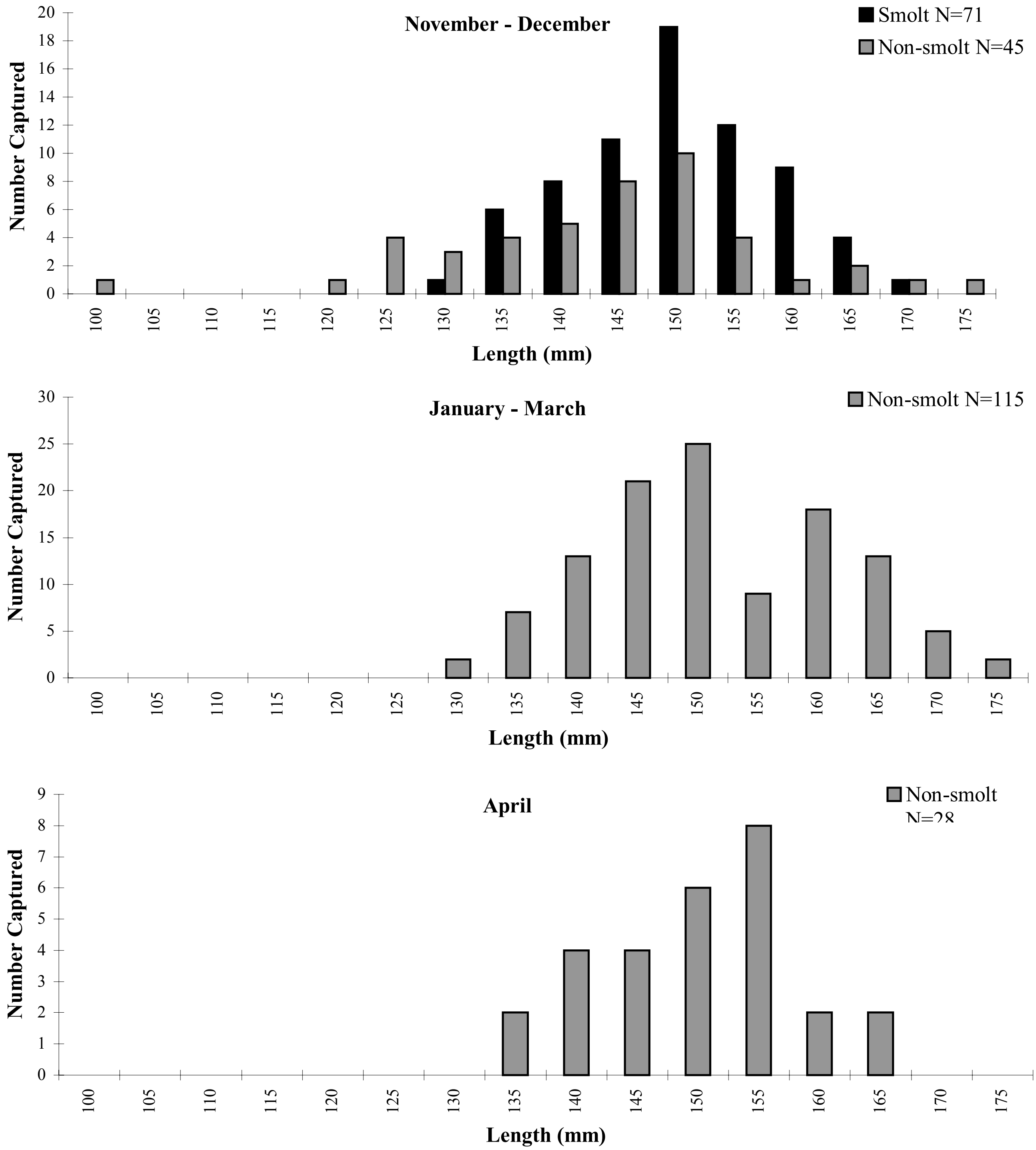


Figure 28. Length-frequency distribution by calendar quarter of juvenile Pacific lamprey, lower Umatilla River, November 1998 - April 1999. Data represents captures at RM 1.2 (November through February) and RM 3.7 (March through May). Distributions are in 5-mm increments.

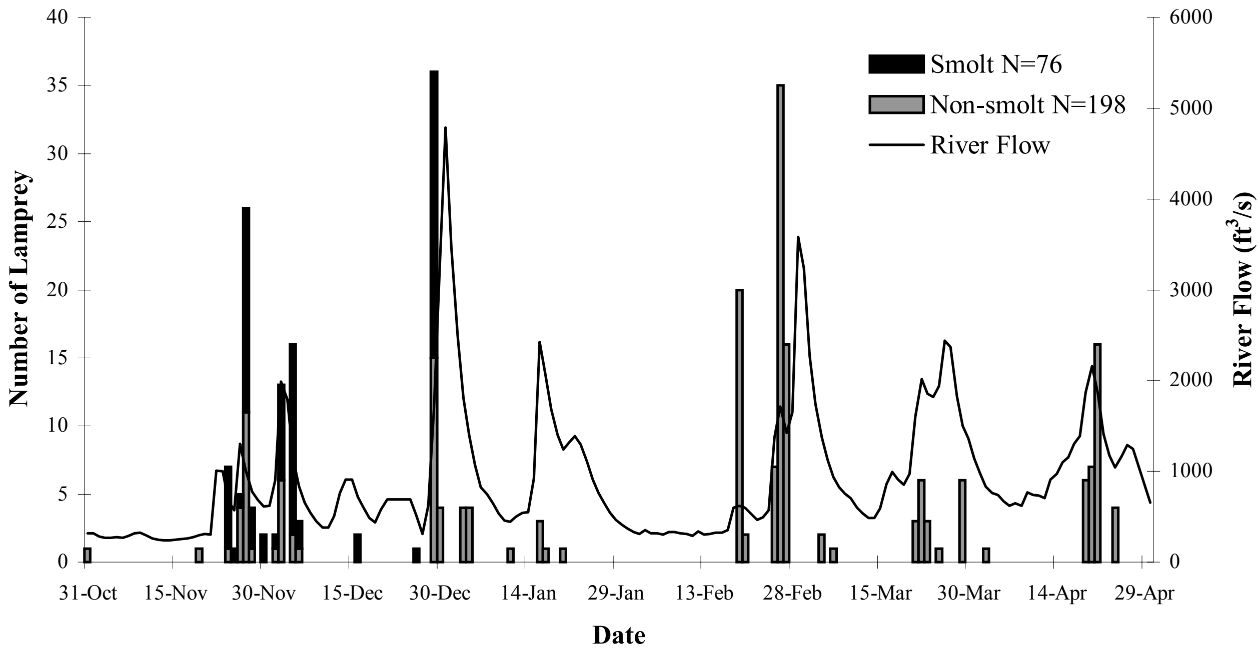


Figure 29. River flow (ft^3/s) recorded at the UMAO gauging station (RM 2.1) and number of juvenile Pacific lamprey captured at the rotary-screw trap (RM 1.2) and West Extension Canal (RM 3.7), Umatilla River, October 1998 - April 1999.

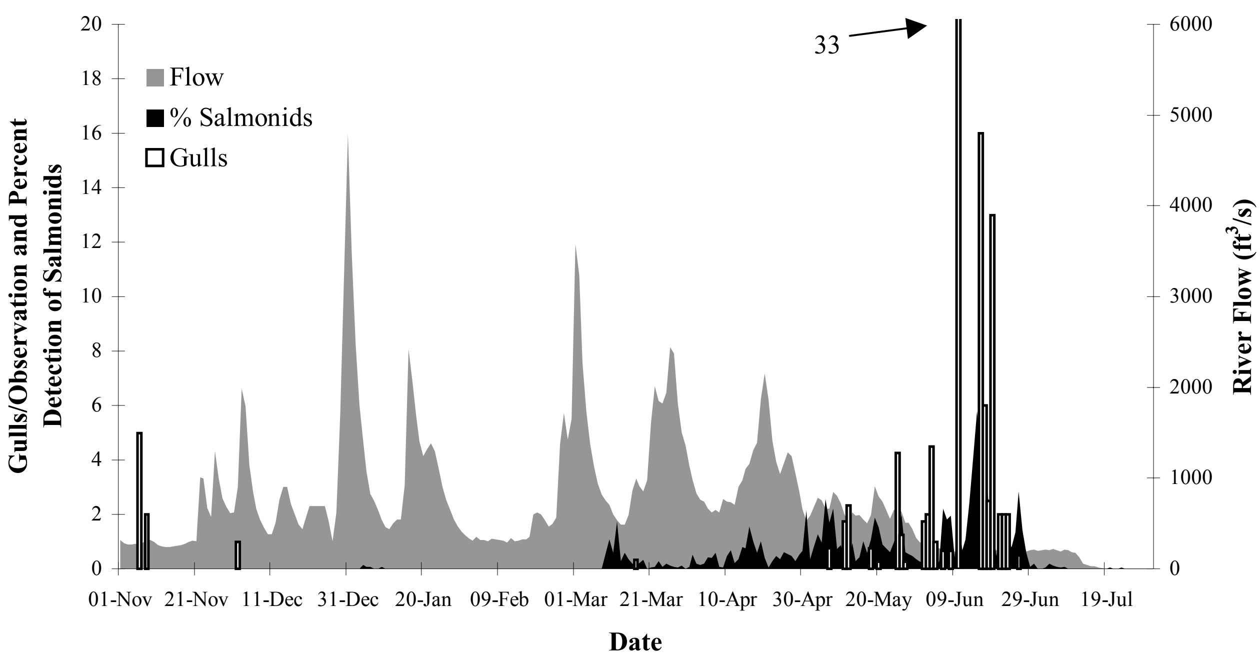


Figure 30. Number of gulls per observation and percent detection of salmonids plotted against river flow (ft^3/s), lower Umatilla River, November 1998 - July 1999.

APPENDIX A

Ancillary Information from Outmigration Studies

Appendix Table A-1. Releases of hatchery chinook salmon, coho salmon, and summer steelhead in the Umatilla River, December 1998 - June 1999.

Species[a]	Age	Hatchery origin	Release date(s)	Release location	River mile	Number released	Number CWT[b]
CHS	1+	Umatilla	12/20/98	Imeques	80.0	114,370	43,764
CHS	1+	LWSH[c]	3/8/99	Imeques	80.0	177,655	17,707
CHS	1+	Umatilla	3/8/99	Imeques	80.0	253,831	107,748
CHS	1+	Carson	4/14/99	Imeques	80.0	103,761	19,593
CHS	1+	LWSH	4/14/99	Imeques	80.0	124,360	17,993
					Total	***773,977***	***206,805***
CHF	1+	Bonneville	3/11/99	Thornhollow	73.5	233,861	24,693
CHF	1+	Bonneville	4/15/99	Thornhollow	73.5	215,707	24,918
					Total	***449,568***[d]	***49,611***
CHF	0+	Umatilla	6/3/99	Imeques	80.0	***1,842,666***[d]	***386,941***
COH	1+	LHCH[c]	3/22/99 - 3/24/99	Pendleton	52.0	465,314	26,537
COH	1+	Cascade	3/26/99 & 3/30/99 - 4/2/99	Pendleton	52.0	1,010,608	80,966
					Total	***1,475,922***	***107,503***
STS	1+	Umatilla	4/13/99[e]	Bonifer	79.0[f]	44,226	20,450
STS	1+	Umatilla	4/14/99[e]	Minthorn	64.5	41,843	20,787
STS	1+	Umatilla	5/4/99[e]	Bonifer	79.0[f]	35,564	19,088
					Total	***121,633***	***60,325***

[a] *CHS = spring chinook salmon, CHF = fall chinook salmon, COH = coho salmon, STS = summer steelhead.*
[b] *CWT = coded-wire tagged; number is adjusted for tag loss and non-recognizable fin clips.*
[c] *LWSH = Little White Salmon Hatchery, LHCH = Lower Herman Creek Hatchery.*
[d] *All CHF (1+ and 0+) not coded-wire tagged received a blank-wire tag.*
[e] *Dates of volitional releases began on 4/5/99, 4/6/99, and 4/27/99 for forced release dates of 4/13/99, 4/14/99, and 5/4/99, respectively.*
[f] *River mile 2 of Meacham Creek at river mile 79.0 on the Umatilla River*

Appendix Table A-2. Detection efficiency of remote detection system at West Extension Canal (RM 3.7), Umatilla River, March - July 1999.

Date	Water level - 1	Percent efficiency - 1	Water level - 2	Percent efficiency - 2	Total daily percent efficiency
3/10		100.00			100.00
3/15		100.00			100.00
3/17		100.00		100.00	100.00
3/18		100.00	0.50	100.00	100.00
3/19	0.50	100.00			100.00
3/20	0.75	100.00			100.00
3/21	0.50	100.00			100.00
3/22	0.25	100.00			100.00
3/24	0.50	100.00			100.00
3/25		100.00			100.00
3/26	0.75	100.00	0.50	100.00	100.00
3/27	1.00	75.00			75.00
3/28	1.00	100.00			100.00
3/29	1.00	83.33			83.33
3/30	0.75	100.00			100.00
3/31	1.00	100.00			100.00
4/1	0.75	75.00			75.00
4/2	0.75	66.67	0.75	83.33	75.00
4/3	0.75	100.00	0.50	100.00	100.00
4/4		100.00	0.75	100.00	100.00
4/5		100.00	0.75	100.00	100.00
4/6		100.00	0.90	83.33	91.67
4/7		100.00	0.80	100.00	100.00
4/8	0.95	100.00			100.00
4/9	0.75	100.00	0.80	100.00	100.00
4/10	0.75	100.00	1.00	100.00	100.00
4/11	0.50	100.00	0.75	100.00	100.00
4/12	0.50	100.00			100.00
4/13	0.50	100.00	0.50	100.00	100.00
4/14	0.50	100.00			100.00
4/15	0.75	100.00	0.75	100.00	100.00
4/16	1.00	100.00		83.33	91.67
4/17	0.95	100.00		100.00	100.00
4/18	0.95	100.00			100.00
4/19	0.80	100.00	0.75	100.00	100.00
4/20	0.80	100.00	0.90	100.00	100.00
4/21	1.00	100.00	1.00	66.67	83.33
4/22	0.90	100.00	0.50	100.00	100.00

Appendix Table A-2. Continued.

Date	Water level - 1	Percent efficiency - 1	Water level - 2	Percent efficiency - 2	Total daily percent efficiency
4/23	0.90	83.33		100.00	91.67
4/24	0.50	100.00		100.00	100.00
4/25	0.90	100.00	1.00	100.00	100.00
4/26	0.75	100.00	1.00	100.00	100.00
4/27	1.00	100.00			100.00
4/28		100.00	0.75	100.00	100.00
4/29	0.50	100.00	1.00	100.00	100.00
4/30	0.90	83.33			83.33
5/1		100.00	0.98	100.00	100.00
5/2		100.00	1.00	100.00	100.00
5/3	0.95	100.00			100.00
5/4	0.70	83.33			83.33
5/5	0.50	100.00			100.00
5/6	0.50	100.00		83.33	91.67
5/7	0.75	100.00	0.75	100.00	100.00
5/8	1.00	83.33			83.33
5/9	1.00	100.00			100.00
5/10	0.75	100.00			100.00
5/11	0.33	83.33	1.00	100.00	91.67
5/12	0.75	100.00	0.25	100.00	100.00
5/13	0.75	100.00			100.00
5/14		100.00	1.00	100.00	100.00
5/15	1.00	100.00			100.00
5/16		83.33	0.80	100.00	91.67
5/17	1.00	100.00	1.00	100.00	100.00
5/18	0.50	66.67	0.75	83.33	75.00
5/19	0.66	100.00			100.00
5/20	0.75	100.00	0.75	100.00	100.00
5/21	0.80	100.00		100.00	100.00
5/22	0.85	100.00	0.75	100.00	100.00
5/23	0.80	83.33	0.93	100.00	91.67
5/24	0.75	100.00	0.75	100.00	100.00
5/25	0.75	100.00	0.50	100.00	100.00
5/26	0.50	100.00	0.75	100.00	100.00
5/27	1.00	100.00	1.00	83.33	91.67
5/28	1.00	100.00	1.00	100.00	100.00
5/29	1.00	100.00	1.00	100.00	100.00
5/30	0.66	100.00	0.75	100.00	100.00
5/31	0.50	100.00	0.66	100.00	100.00

Appendix Table A-2. Continued.

Date	Water level - 1	Percent efficiency - 1	Water level - 2	Percent efficiency - 2	Total daily percent efficiency
6/1	0.66	100.00	0.66	100.00	100.00
6/2	1.00	100.00			100.00
6/3	1.00	83.33	0.50	100.00	91.67
6/4	0.35	100.00			100.00
6/5	0.25	100.00			100.00
6/6	0.80	66.67			66.67
6/7	0.75	66.67		100.00	88.89
6/8	0.70	100.00		100.00	100.00
6/9	0.75	100.00		100.00	100.00
6/10	0.75	100.00	0.66	83.33	91.67
6/11	0.68	100.00			100.00
6/12	0.50	100.00			100.00
6/13	0.50	100.00	0.50	100.00	100.00
614	0.50	100.00			100.00
6/15	0.50	83.33			83.33
6/16	0.50	100.00			100.00
6/17	0.50	100.00			100.00
6/18	0.50	100.00			100.00
6/19		100.00			100.00
6/20	0.50	100.00			100.00
6/21	0.50	83.33			83.33
6/23		100.00			100.00
6/24		100.00			100.00
6/26		100.00			100.00
6/27		100.00			100.00
6/29	0.66	100.00			100.00
6/30	0.66	100.00			100.00
7/1		100.00			100.00
7/7	0.66	100.00			100.00
7/8	0.66	100.00			100.00
Overall mean efficiency					***96.8***

Appendix Table A-3. PIT-tag recoveries at mainstem Columbia River islands from hatchery juvenile salmonids released for reach-specific survival tests in the Umatilla River, 1999. Islands are sites of bird colonies.

				Recovery site[b] (date)							
Species[a]	Release site	Release date	Number released	COLR (9/8/99)	ESANIS (9/27/99)	RICEIS (9/7/99)	3MILIS (8/17/99)	CRESIS (8/9/99)	RICHIS (8/23/99)	Total recovery	Percent recovery
CHS	RM 11	3/9-3/11	246			1				1	0.41
	RM 27	3/9-3/11	257		1	2				3	1.17
	RM 48	3/9-3/11	250	1	1	1				3	1.20
	RM 80	3/9-3/11	252		1					1	0.40
									Total	*8*	*0.80*
CHF0	RM 9	6/3-6/5	537	1	1	3	6		2	13	2.42
	RM 27	6/3-6/5	482		1	1	2	1	1	6	1.24
	RM 48	6/3-6/5	477				3	2		5	1.05
	RM 80	6/3-6/5	498		1	2	4	2	1	10	2.01
	RM 0[c]	6/3-6/5	428		1			1		2	0.47
									Total	*36*	*1.49*
STS (larges)	RM 9	4/12-4/15	229	1		10	3	1		15	6.55
	RM 27	4/12-4/15	219		1	4	2			7	3.20
	RM 48	4/12-4/15	220		1	3	2	1		7	3.18
	RM 64.5	4/12-4/15	224			5				5	2.23
	RM 79[d]	4/12-4/15	187			5				5	2.67
									Total	*39*	*3.61*
STS (smalls)	RM 9	5/4-5/7	243			8	1			9	3.70
	RM 27	5/4-5/7	245			4				4	1.63
	RM 48	5/4-5/7	242			4				4	1.65
	RM 79[d]	5/4-5/7	238		1	1	2			4	1.68
									Total	*21*	*2.17*

[a] *CHS = spring chinook salmon, CHF0 = subyearling fall chinook salmon, and STS = summer steelhead.*

[b] *COLR = Columbia River (RM 0), ESANIS = East Sand Island(RM 5), RICEIS = Rice Island (RM 21), 3MILIS = Three Mile Island (RM 256), CRESIS = Crescent Island (RM 317), and RICHIS = Richland Island (RM 339).*

[c] *RM 0 release was from juvenile salmon transported from Westland Canal (RM 27.3) to the mouth of the Umatilla River.*

Appendix Table A-4. PIT-tag detections for hatchery spring chinook and subyearling fall chinook salmon and summer steelhead released for reach-specific survival tests and detected at West Extension Canal (RM 3.7), Umatilla River, and within the mainstem Columbia River, spring 1999.

Release site	Release date	Number released	Number of detections at interrogation site[a]					Total[b] detected	Percent detected		Mean travel speed (mi/d)[c]		Mean travel time (days)	
			WEID	JDA	BON	TWX	CRI		WEID	Total	WEID	JDA	JDA	BON
							Spring Chinook Salmon							
Cottonwoodd	3/9	80	3	8	2	0	0	13	4	16	0.08		40.79	52.90
(RM 11)	3/10	79	4	10	3	0	1	18	5	23	0.95		38.10	32.72
	3/11	87	5	11	9	0	0	25	6	29	5.11		34.47	42.08
Total		**246**	**12**	**29**	**14**	**0**	**1**	**56**	**5**	**23**	**1.34**	**2.04**	**37.37**	**42.35**
Echo	3/9	79	2	10	4	0	1	17	3	22	11.51		38.90	39.46
(RM 27)	3/10	81	7	6	2	0	0	15	9	19	2.06		44.02	46.30
	3/11	97	3	4	3	0	0	10	3	10	20.34		36.88	43.84
Total		**257**	**12**	**20**	**9**	**0**	**1**	**42**	**5**	**16**	**3.23**	**1.90**	**40.22**	**42.99**
Rieth	3/9	80	5	4	1	0	1	11	6	14	6.23		43.61	46.06
(RM 48)	3/10	80	6	5	2	1	0	14	8	18	15.63		43.41	41.43
	3/11	90	2	4	1	0	1	8	2	9	2.83		43.96	43.41
Total		**250**	**13**	**13**	**4**	**1**	**2**	**33**	**5**	**13**	**6.87**	**1.75**	**43.66**	**43.08**
Imeques	3/9	81	1	6	1	0	1	9	1	11	23.69		43.17	21.60
(RM 80)	3/10	81	5	5	0	0	0	10	6	12	6.48		41.39	42.06
	3/11	90	10	5	0	0	0	15	11	17	9.14		37.54	-
Total		**252**	**16**	**16**	**1**	**0**	**1**	**34**	**6**	**13**	**8.39**	**1.88**	**40.70**	**31.83**

[a] *WEID = West Extension Canal (RM 3.7 on Umatilla River), JDA = John Day Dam (RM 216), BON = Bonneville Dam (RM 145),*
[b] *Total detected = the total number of PIT-tagged fish detected minus duplicate tag detections.*
[c] *WEID mean travel speed is from time of release to detection at WEID and JDA mean travel speed is from time of detection at WEID*

Appendix Table A-4. Continued.

Release site	Release date	Number release	Number of detections at interrogation site[a] WEID	JDA	BON	TWX	CRI	Total[b] detected	Percent detected WEID	Total	Mean travel speed (mi/d)[c] WEID	JDA	Mean travel time (days) JDA	BON
							Subyearling Fall Chinook Salmon							
Steelhea	6/3	166	10	16	3	0	3	32	6	19	0.89		16.49	19.41
Park	6/4	200	40	13	6	0	4	63	20	32	0.89		15.88	20.11
(RM 9)	6/5	171	37	9	7	0	2	55	22	32	0.98		20.06	18.33
Total		**537**	**87**	**38**	**16**	**0**	**9**	**150**	**16**	**28**	**0.93**	**4.39**	**17.39**	**19.16**
Echo	6/3	166	38	15	4	0	3	60	23	36	2.39		18.57	22.15
(RM 27)	6/4	151	33	15	2	0	1	51	22	34	3.13		18.49	23.55
	6/5	165	51	9	3	0	0	63	31	38	2.38		18.12	18.94
Total		**482**	**122**	**39**	**9**	**0**	**4**	**174**	**25**	**36**	**2.55**	**4.15**	**18.42**	**21.10**
Rieth	6/3	166	39	10	4	0	1	54	23	33	4.51		20.26	17.09
(RM 48)	6/4	146	38	10	3	0	2	53	26	36	5.32		18.29	18.37
	6/5	165	40	8	3	0	2	53	24	32	3.83		17.48	23.26
Total		**477**	**117**	**28**	**10**	**0**	**5**	**160**	**25**	**34**	**4.46**	**4.09**	**18.70**	**18.95**
Imeques	6/3	166	37	12	8	0	3	60	22	36	6.05		21.36	25.15
(RM 80)	6/4	166	36	6	4	0	2	48	22	29	5.44		18.86	34.10
	6/5	166	26	2	3	0	3	34	16	20	4.75		19.54	35.47
Total		**498**	**99**	**20**	**15**	**0**	**8**	**142**	**20**	**29**	**5.43**	**3.77**	**20.26**	**29.13**
Echo	7/20	150	0	9	0	0	0	9	0	6	-		7.44	-
(RM 27)	7/23	138	0	11	3	0	0	14	0	10	-		8.46	10.78
	7/26	140	0	14	2	0	2	18	0	13	-		9.35	7.53
Total		**428**	**0**	**34**	**5**	**0**	**2**	**41**	**0**	**10**	**-**	**8.93**	**8.55**	**9.48**

Appendix Table A-4. Continued.

Release site	Release date	Number release	Number of detections at interrogation site[a]					Total[b] detected	Percent detected		Mean travel speed (mi/d)[c]		Mean travel time (days)	
			WEID	JDA	BON	TWX	CRI		WEID	Total	WEID	JDA	JDA	BON
							Summer Steelhead (large grade)							
Steelhead	4/12	68	21	9	0	0	0	30	31	44	0.50		26.21	16.28
Park	4/13	63	19	6	1	0	0	26	30	41	0.28		26.42	21.93
(RM 9)	4/14	63	17	5	4	0	2	28	27	44	0.37		21.23	22.19
	4/15	35	8	6	0	0	2	16	23	46	0.33		20.36	-
Total		**229**	**65**	**26**	**5**	**0**	**4**	**100**	**28**	**44**	**0.36**	**3.15**	**24.23**	**21.42**
Echo	4/12	57	10	7	1	0	0	18	18	32	0.88		29.46	29.21
(RM 27)	4/13	63	14	5	2	0	1	22	22	35	2.18		21.09	20.88
	4/14	64	16	1	4	0	3	24	25	38	1.62		25.02	32.75
	4/15	35	8	7	1	0	0	16	23	46	1.05		15.48	26.06
Total		**219**	**48**	**20**	**8**	**0**	**4**	**80**	**22**	**37**	**1.36**	**3.25**	**23.53**	**26.57**
Rieth	4/12	59	9	1	1	0	1	12	15	20	1.55		38.80	21.28
(RM 48)	4/13	63	10	6	2	0	2	20	16	32	1.84		21.40	29.57
	4/14	63	14	7	0	0	0	21	22	33	2.15		30.74	12.97
	4/15	35	5	4	1	0	0	10	14	29	4.58		18.86	25.77
Total		**220**	**38**	**18**	**4**	**0**	**3**	**63**	**17**	**29**	**2.02**	**2.86**	**26.69**	**24.79**
Minthorn	4/12	56	5	5	0	0	0	10	9	18	2.79		33.69	39.62
(RM 64.5)	4/13	63	8	7	2	0	1	18	13	29	1.80		34.76	32.12
	4/14	63	5	5	1	0	0	11	8	17	1.70		32.84	49.39
	4/15	42	7	4	2	0	0	13	17	31	2.78		20.56	20.80
Total		**224**	**25**	**21**	**5**	**0**	**1**	**52**	**11**	**23**	**2.14**	**2.44**	**31.27**	**32.42**

Appendix Table A-4. Continued.

Release site	Release date	Number release	Number of detections at interrogation site[a]					Total[b] detected	Percent detected		Mean travel speed (mi/d)[c]		Mean travel time (days)	
			WEID	JDA	BON	TWX	CRI		WEID	Total	WEID	JDA	JDA	BON
							Summer Steelhead (large grade)							
Bonifer	4/12	61	4	1	2	0	0	7	7	11	2.28		33.21	39.35
(RM 79[d])	4/13	63	6	7	1	0	0	14	10	22	3.07		31.95	32.54
	4/14	63	9	2	0	0	0	11	14	17	2.22		46.00	-
Total		**187**	**19**	**10**	**3**	**0**	**0**	**32**	**10**	**17**	**2.49**	**2.11**	**36.26**	**35.95**
							Summer Steelhead (small grade)							
Steelhea	5/4	65	21	2	0	0	1	24	32	37	0.61		21.08	-
Park	5/5	53	12	9	0	0	0	21	23	40	0.49		17.60	-
RM 9	5/6	60	17	2	1	0	1	21	28	35	0.53		23.19	23.80
	5/7	65	14	3	0	0	1	18	22	28	0.59		16.35	-
Total		**243**	**64**	**16**	**1**	**0**	**3**	**84**	**26**	**35**	**0.56**	**4.05**	**18.86**	**23.80**
Echo	5/4	68	15	3	0	0	0	18	22	26	1.48		24.19	-
(RM 27)	5/5	51	6	2	0	0	0	8	12	16	1.25		24.07	-
	5/6	62	9	4	1	0	0	14	15	23	1.73		20.95	20.93
	5/7	64	11	5	0	0	0	16	17	25	1.44		23.47	-
Total		**245**	**41**	**14**	**1**	**0**	**0**	**56**	**17**	**23**	**1.48**	**3.30**	**23.16**	**20.93**
Rieth	5/4	65	10	4	0	0	1	15	15	23	1.73		27.39	57.46
(RM 48)	5/5	52	8	0	2	0	0	10	15	19	2.13		24.82	29.90
	5/6	60	3	2	1	0	0	6	5	10	1.91		27.95	35.54
	5/7	65	12	2	2	0	0	16	18	25	2.25		24.73	27.10
Total		**242**	**33**	**8**	**5**	**0**	**1**	**47**	**14**	**19**	**2.01**	**2.87**	**26.66**	**34.50**

[d] *River mile 2 of Meacham Creek, flows into the Umatilla River at mile 79.*

Appendix Table A-4. Continued.

Release site	Release date	Number release	Number of detections at interrogation site[a]					Total[b] detected	Percent detected		Mean travel speed (mi/d)[c]		Mean travel time (days)	
			WEID	JDA	BON	TWX	CRI		WEID	Total	WEID	JDA	JDA	BON
							Summer Steelhead (small grade)							
Bonifer	5/4	62	1	2	0	0	1	4	2	6	2.26		26.01	-
(RM 79[d])	5/5	52	2	2	0	0	0	4	4	8	4.55		31.08	-
	5/6	61	4	0	0	0	1	5	7	8	2.46		25.54	-
	5/7	63	3	1	1	0	0	5	5	8	3.15		24.49	18.13
Total		**238**	**10**	**5**	**1**	**0**	**2**	**18**	**4**	**8**	**2.89**	**2.87**	**26.65**	**18.13**

Appendix Table A - 5. Estimates of survival and/or abundance for hatchery and natural juvenile salmonids migrating from the Umatilla River basin, 1995 - 1999.

	Year				
Species[a]	1995	1996	1997	1998	1999[b]
			Survival (95% C.I.)		
HCH 1^+	426%	--	71% (±31.1%)	--	--
HCHS 0^+	3%	--	--	--	--
HCHS 1^+	67%	34% (± 76.1%)	--	73% (±6.7%)	37% (±6.7%)
HCHF 1^+	--	40% (±5.3%)	--	70% (±15.3%)	78% (±12.7%)
HCHF 0^+	18%	141% (±4.0%)	35% (±4.9%)	152% (±7.2%)	54% (±3.1%)
HCOH	2,243%	38% (±5.5%)	34% (±18.9%)	129% (±10.9%)	--
HSTS	154%	94% (±10.4%)	--	50% (±7.1%)	64% (±13.2%)
NCH					35%[c]
NSTS					31%[c]
			Abundance		
HCH 1^+	2,341,223	--	530,321	--	
HCHS 0^+	9,657	--	--	--	
HCHS 1^+	294,052	129,593	--	413,303	888
HCHF 1^+	--	226,767	--	258,296	379
HCHF 0^+	420,608	3,637,933	2,902	4,227,783	1,879
HCOH	33,967,417	554,501	476,378	2,020,387	--
HSTS	225,139	137,478	--	68,670	443
NCHS	74,342	1,856	1,151	18,724	19,414
NCHF	--	--	1,318	124,504	1,155
NCOH	--	346	1,200	3,384	2,708
NSTS	58,876	73,134	--	53,854	45,513

[a] *HCH 1^+ = hatchery yearling chinook salmon, HCHS 0^+ = hatchery subyearling spring chinook salmon, HCHS 1^+ = hatchery yearling spring chinook salmon, HCHF 1^+ = hatchery yearling fall chinook salmon, HCHF 0^+ = hatchery subyearling fall chinook salmon, HCOH = hatchery coho salmon, HSTS = hatchery summer steelhead, NCH = natural chinook salmon, NCHS = natural spring chinook salmon, NCHF = natural fall chinook salmon, NCOH = natural coho salmon, and NSTS = natural summer steelhead.*

[b] *Abundance estimates for hatchery fish are for tagged fish. Abundance estimates for natural fish include tagged and untagged fish.*

[c] *Survival estimates based on tagged fish.*

Appendix Table A - 6. Daily observations at the rotary-screw trap (RM 1.2), lower Umatilla River, 30 September 1998 - 8 March 1999.

			Water	Cone RPM[c]		River	Water temp.		Air temp. (°F)	
Date	Time	Debris[a]	color[b]	Start	End	gauge	Min.	Max.	Min.	Max.
09/30/98	1520	M	CLR		1.3	2.6				
10/02/98	1400	M	CLR	0.0	2.0	2.8				
10/04/98	1530	H	CLR	0.5	3.0	2.8	58	72		
10/06/98	1355	H	CLR	2.3	3.0	2.8	54	58		
10/08/98	1400	H	CLR		2.3	2.7	58	78	46	74
10/10/98	1530	H	LGRN	2.3	2.3	2.7	56	62	41	72
10/12/98	1430	H		1.5	2.5	2.7	54	58	38	66
10/15/98	1600	H	CLR	0.0		2.7	53	56	38	58
10/18/98	1630	H	CLR	0.0	2.5	2.7	52	56	32	68
10/20/98	1325		CLR	0.0	3.3	2.8	50	54	30	63
10/22/98	1650	H	LGRN	0.0	2.8	2.8	48	52	28	63
10/25/98	1615	H	LGRN	0.0	2.3	2.8	50	54	34	74
10/27/98	1600	H	LGRN	2.0	2.6	2.8	52	56	37	74
10/29/98	1643	H	LGRN	2.3	2.8	2.8	50	56	30	62
10/31/98	1030	H	LGRN	3.0	3.0	2.8	48	52	27	50
11/02/98	1150	H	LGRN	2.5	2.9	2.7	50	52	34	52
11/04/98	1435	H	LGRN	3.3	3.3	2.7	49	52	39	56
11/06/98	1400		LGRN	2.7	3.0	2.7	48	52	30	56
11/08/98	1500	H	CLR	2.3	3.3	2.8	47	50	31	56
11/10/98	1530	H	LGRN		3.0	2.8	52	54	32	54
11/12/98	1100	M	CLR	2.8	3.0	2.7	46	50	34	56
11/14/98	1230	M	CLR		2.0	2.7	46	51	34	66
11/16/98	1400	H	CLR	2.8	2.9	2.6	49	53	40	70
11/18/98	1340	H	LGRN	2.3		2.7	47	52	38	58
11/19/98	1336	M	LGRN	1.3	2.6	2.8	46	50	31	58
11/22/98	1040	H	LBRN	2.5	5.8	3.5	50	52	40	62
11/23/98	919	H	BRN	0.0	5.8	3.6	46	49	38	56
11/24/98	1428	H	BRN	3.2	3.0	3.2	46	48	40	56
11/25/98	1420	M	OLVD	2.6	3.5	3.1	46	50	45	70
11/26/98	930	H	LBRN	0.0	8.5	3.9	50	52	51	68
11/27/98	1130	H	LBRN	0.0	6.5	3.6	46	50	40	58
11/28/98	1040	M	OLVD	4.8	5.0	3.3	46	48	42	48
11/30/98	1000		LOLV	3.7		3.1	44	49	33	52

[a] *L = low, ML = moderately low, M = moderate, MH = moderately high, H = high.*

[b] *CLR = clear, LGRN = light green, GRN = green, DGRN = dark green, LBRN = light brown, BRN = brown, DBRN = dark brown, LOLV = light olive, OLV = olive, DOLV = dark olive.*

[c] *Cone RPM's (rotations per minute) are before and after trap check and debris removal.*

Appendix Table A - 6. Continued.

Date	Time	Debris[a]	Water color[b]	Cone RPM[c] Start	End	River gauge	Water temp. Min.	Max.	Air temp. (°F) Min.	Max.
12/02/98	1429		LBRN	5.6	5.7	3.4	44	48	38	57
12/03/98	1030	H	BRND	0.0	8.8	4.4	44	46	34	52
12/03/98	1030	H	BRND	0.0	8.4	4.4	44	46	34	52
12/04/98	1445	M/H	BRND	7.7	7.8	4.0	42	46	27	49
12/05/98	1053		LBRN	6.5	6.8	3.6	41	44	25	44
12/06/98	1133	M	LBRN	4.8	4.5	3.3	40	42	30	44
12/07/98	1345	L/M	LOLV	3.8	3.8	3.2	41	41	28	48
12/08/98	1340	L/M	LOLV	3.3	3.0	3.2	40	43	35	51
12/10/98	1340	L	LGRN	1.8	1.7	2.9	39	44	24	49
12/11/98	1405	L	LGRN	1.9	2.3	2.9	40	42	33	42
12/13/98	1526	M	LBRN	5.5	5.3	3.3			40	60
12/14/98	1440	M	OLVD	6.2	6.3	3.5			33	60
12/15/98	1450		OLVD	6.0	5.8	3.4	42	44	30	52
12/16/98	1515	L	OLVD	4.4	4.0	3.2	40	44	28	50
12/17/98	1400	L	LOLV	3.2	3.8	3.1	40	43	26	56
12/18/98	1430	L	LOLV	3.2	2.0	3.0	41	45	29	56
12/20/98	2015		GRN	FROZEN		3.3	31	42	6	40
12/26/98	1421	L	CLR		2.8	3.0			16	50
12/27/98	1400	L	CLR	3.0	3.0	3.0	32	34	33	48
12/28/98	1415	L	LBRN	4.5	4.8	3.2	34	39	37	58
12/29/98	1005	M	BRND	0.0	9.0	3.9	38	42	46	56
12/29/98	1435		BRND		8.5	4.0				
12/30/98	900	M	BRND	0.0	8.5	4.8	44	44	40	56
12/30/98	1400	H	BRND	PULLED		4.9				
01/03/99	1440	H	BRN	7.8	8.0	4.3	37	41	22	41
01/04/99	1335	M	LBRN	7.2	8.0	4.0	36	39	28	34
01/05/99	1130	LM	LBRN	7.0	7.3	3.6	37	39	30	38
01/06/99	1340	L	LBRN	5.3	5.0	3.3	37	43	33	52
01/07/99	1245	L	LOLV	4.8	4.8	3.3	41	44	33	54
01/08/99	1400	L	LOLV	4.8	4.5	3.5	41	45	28	54
01/09/99	1230	L	LGRN	2.0	2.8	3.1	42	43	40	50
01/11/99	1300	L	LOLV	3.0	3.0	3.2	41	46	33	52
01/12/99	1415	L	GRN	3.0	2.5	3.1	42	47	32	54
01/14/99	1410		LGRN	0.0	3.0	3.1	41	43	37	56
01/16/99	1430	H	BRN	7.0	10.2	4.5	42	48	34	58
01/17/99	1300	H	BRND	5.5	10.0	4.3	40	44	30	52
01/18/99	1335	L	LBRN	0.0	8.8	4.0	40	44	30	59
01/20/99	1000	H	OLV	8.3	7.5	3.7	42	44	33	60
01/21/99	1400	M/H	LBRN	7.5	6.8	3.8	41	45	34	56
01/22/99	1430	M/H	BRN	5.5	7.8	3.8	42	46	38	54

Appendix Table A - 6. Continued.

Date	Time	Debris[a]	Water color[b]	Cone RPM[c] Start	Cone RPM[c] End	River gauge	Water temp. Min.	Water temp. Max.	Air temp. (°F) Min.	Air temp. (°F) Max.
01/24/99	1000		LOLV	6.8	6.5	3.6	42	42	42	46
01/26/99	1330	M	LOLV	4.8	4.5	3.3	38	43	29	46
01/28/99	1355	L	GRN	3.2	3.3	3.1	39	43	28	58
01/30/99	1400	L	GRN	2.4	0.8	2.9	42	44	32	59
02/01/99	1430	L	GRN	0.0	1.9	2.9	38	44	27	53
02/03/99	1350	L	LOLV	0.0	1.7	2.9	40	43	38	60
02/05/99	1350	M	LOLV	0.0	3.0	3.1	40	45	24	58
02/07/99	1415		LGRN	0.0	1.5	2.9	40	45	36	63
02/09/99	1005	L	LGRN	0.0	1.0	2.8	40	46	25	50
02/11/99	1445	L	LGRN	1.5		2.7	37	40	22	50
02/14/99	1200	L	CLR	2.5		2.8	38	44	30	50
02/16/99	1435		LGRN	0.0	0.7	2.8	42	47	32	56
02/18/99	1305	H	LOLV	0.0	4.5	3.2	45	48	32	56
02/19/99	1320	H	OLV	2.8	3.4	3.2	42	46	40	56
02/20/99	1420	H	OLVD	0.0	3.3	3.1	42	45	24	57
02/22/99	1055	H	LGRN	3.3	2.9	3.0	42	45	36	55
02/24/99	1420	M	LOLV	3.3	2.7	3.1	42	48	42	66
02/25/99	1027	H	BRN	5.0	8.0	3.9	46	48	43	65
02/26/99	905	H	BRND	0.0	8.5	4.1	42	48	34	60
02/27/99	1100	H	LBRN	7.8	8.0	4.0	42	45	33	54
02/28/99	1730	M	LBRN	0.0	8.8	4.2	42	46	42	60
03/01/99	840	H	BRND	PULLED		5.0	44	47	36	55
03/05/99	822	L	LBRN	7.5	7.8	3.9			26	58
03/07/99	915	H	LOLV	4.9	4.9	3.5	40	44	40	41
03/08/99	1015	L	OLVD	4.3	4.6	3.4	38	44	28	54

Appendix Table A - 7. Daily observations at the West Extension Canal sampling facility (RM 3.7), 9 March - 19 July 1999.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
03/09/99	700	L	OLV	404.7	0.0	44	47									
03/10/99	800	L	OLV	404.7	0.0	44	44	26	58	OFF	OFF	OFF			12	12.5
03/11/99	800	L	OLV	404.7	0.0	44	46	34	60							
03/12/99	830	L	LGRN	404.6	404.1	44	48	32	54	OFF	OFF	OFF	7		12	12.5
03/13/99	730	L	LGRN	404.6	404.2			38	52	OFF	OFF	OFF	7		14	14
03/14/99	800	L	LGRN	404.6	404.3			42	59	OFF	OFF	OFF			14	14
03/15/99	1350	L	LGRN	404.6	404.3			33	62	OFF	OFF	OFF	7		22	22
03/16/99	740	L	LOLV	404.7	404.4			36	58	OFF	OFF	OFF	7	22	22	22
03/17/99	800	L	LOLV	404.8	404.5			36	56	OFF	OFF	OFF	7	19	20	20
03/17/99	1800	L	BRN	404.8	404.1	48	48	49	50					13.5	13.5	13.5
03/17/99	2330	L	BLK	404.8	404.1	46	46	42	49							
03/18/99	800	L	LOLV	404.8	404.1		46									
03/18/99	1250	L	LOLV	404.8	404.1	47	47	44	58	OFF	OFF	OFF	7	13.5	13.5	13.5
03/18/99	2045	L		404.7	404.1											
03/18/99	2400	L	LOLV	404.7	404.1											
03/19/99	630	L	LOLV	404.8	404.1											
03/19/99	1300	L	LOLV	404.8	404.1	50	50	36	60	OFF	OFF	OFF	7	13.5	13.5	13.5
03/19/99	1845	L	LOLV	404.8	404.1											
03/19/99	0015	L	LOLV	404.8	404.1											
03/20/99	820	L	LOLV	404.8	401.2											
03/20/99	1200	L	GRN	404.8	401.1	50	50	36	66	OFF	OFF	OFF	7	13.5	13.5	13.5
03/20/99	1835	L	LOLV	404.8	404.2											
03/20/99	2345	L	LOLV	404.8	404.1											
03/21/99	600	M	BRN	405.0	404.1											
03/21/99	1200	M	BRN	405.1	404.2	50	50	51	69	OFF	OFF	OFF	7	12.5	12.5	12.5
03/21/99	1800	M	BRN	405.2	404.0											
03/21/99	2330	M	BRN	405.2	404.1											

[a] *L = low, ML = moderately low, M = moderate, MH = moderately high, H = high.*

[b] *CLR = clear, LGRN = light green, GRN = green, DGRN = dark green, LBRN = light brown, BRN = brown, DBRN = dark brown, LOLV = light olive, OLV = olive, DOLV = dark olive.*

[c] *Pumpback operations for three pumps (P1, P2, and P3) and a river-return drain pipe (RR) in the pumpback bay; river-return pipe opening is measured in inches.*

[d] *Headgate openings are: S = south gate, M = middle gate, N = north gate; openings are in inches.*

Appendix Table A - 7. Continued.

			Water	River	Canal	Water temp. (°F)		Air temp. (°F)		Pumpback[c]				Headgates[d]		
Date	Time	Debris[a]	color[b]	gauge (ft.)	height (ft.)	Min.	Max.	Min.	Max.	P1	P2	P3	RR	S	M	N
03/22/99	625	M	BRN	405.2	404.1											
03/22/99	1200	M	BRN	405.3	404.1	49	49	37	64	OFF	OFF	OFF	7	11	11	11
03/22/99	1800	M	BRN	405.2	404.1											
03/22/99	2330	M	BRN	405.2	404.1											
03/23/99	625	M	LBRN	405.2	404.0											
03/23/99	1220	M	BRN	405.2	404.2	46	50	47	70	OFF	OFF	OFF	7	11.3	11.3	11.3
03/23/99	1800	M	OLVD	405.2	404.2											
03/23/99	0015	M	OLVD	405.2	404.2											
03/24/99	630	M	LBRN	405.1	404.1											
03/24/99	1400	M	BRN	405.1	404.1	46	51	42	66	OFF	OFF	OFF	7	14.5	14.5	14.5
03/24/99	1730	M	BRN	405.2	404.1											
03/24/99	35	M	BLK	405.2	404.1											
03/25/99	630	M	LBRN	405.1	404.1											
03/25/99	1130	M	LBRN	405.2	404.1	45	50	47	66	OFF	OFF	OFF	7	14.5	14.5	14.5
03/25/99	1950	M	BRN	405.3	404.1											
03/25/99	100	M	BRN	405.3	404.1											
03/26/99	645	MH	BRND	405.3	404.1											
03/26/99	1345	MH	BRND	405.4	404.2	45	48	38	71	OFF	OFF	OFF	7	13	13	13
03/26/99	1845	M	BRND	405.4	404.0											
03/26/99	2250	M	BRND	405.5	404.1											
03/27/99	710	M	BRN	405.4	404.2											
03/27/99	1200	M	BRN	405.4	404.2	44	47	38	58	OFF	OFF	OFF	7	16	15	15
03/27/99	1840	M	BRN	405.3	404.2											
03/27/99	2245	M	BRN	405.2	404.2											
03/28/99	635	M	BRN	405.2	404.1											
03/28/99	1100	M	BRN	405.2	404.1	42	42	34	55	OFF	OFF	OFF	7	17.5	15.5	15
03/28/99	1800	M	BRN	405.1	404.1											
03/28/99	2330	M	BRN	405.1	404.1											
03/29/99	630	M	LBRN	405.1	404.0											
03/29/99	1115	M	LBRN	405.0	404.1	43	44	41	57	OFF	OFF	OFF	7	18	16.5	16
03/29/99	1730	M	LBRN	405.0	404.1											
03/29/99	2330	M	LBRN	405.0	404.1											
03/30/99	630	M	LBRN	405.0	404.1											
03/30/99	1030	M	LBRN	405.0	404.1	42	45	32	57	OFF	OFF	OFF	7	18.3	17	16.3

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
03/30/99	1730	M	LOLV	404.9	404.1											
03/30/99	2300	M	LOLV	404.8	404.2											
03/31/99	650	M	OLV	404.9	404.1											
03/31/99	1200	M	OLV	404.9	404.1	44	46	40	57	OFF	OFF	OFF	7	19.3	18	18.3
03/31/99	1800	M	LOLV	404.8	404.1											
03/31/99	2300	M		404.7	404.1											
04/01/99	730	L		404.8	404.1											
04/01/99	1200	L	GRND	404.8	404.1	46	50	44	57	OFF	OFF	OFF	7	19	18.3	18
04/01/99	1820	L	GRND	404.8	404.1											
04/01/99	2400	L	GRND	404.8	404.1											
04/02/99	630	M	GRND	404.8	404.1											
04/02/99	1200	L	GRND	404.6	404.1	49	50	30	66	OFF	OFF	OFF	7	19.3	19.3	19.3
04/02/99	1830	L	GRND	404.7	404.1											
04/02/99	2300	L	GRND	404.7	404.1											
04/03/99	645	L	LGRN	404.7	404.1											
04/03/99	1200	L	LGRN	404.7	404.1	44	48	36	64	OFF	OFF	OFF	7	20.5	19.3	19.3
04/03/99	1800	L	LGRN	404.7	404.1											
04/03/99	2330	L	LGRN	404.6	404.1											
04/04/99	630	L	LGRN	404.7	404.1											
04/04/99	1130	L	LGRN	404.7	404.1	45	48	32	56	OFF	OFF	OFF	7	20.5	19.3	19.3
04/04/99	1830	L	LGRN	404.7	404.1											
04/04/99	2330	L	LGRN	404.7	404.1											
04/05/99	630	L	LGRN	404.7	404.1											
04/05/99	1200	L	GRN	404.7	404.1	45	46	38	60	OFF	OFF	OFF	7	20.8	19.5	19.8
04/05/99	1800	L	LGRN	404.7	404.1											
04/05/99	2330	L	LGRN	404.5	404.1											
04/06/99	630	L	GRN	404.6	404.1											
04/06/99	1200	L	GRN	404.6	404.1	45	46	32	60	OFF	OFF	OFF	7	21.5	20.8	20.5
04/06/99	1715	L	GRN	404.6	404.1											
04/06/99	2310	L	GRN	404.6	404.1											
04/07/99	700	L	GRN	404.6	404.1											
04/07/99	1200	L	GRN	404.7	404.1	46	50	37	63	OFF	OFF	OFF	7	22.5	21	21
04/07/99	1700	L	GRN	404.6	404.1											
04/07/99	2230	L	GRN	404.6	404.1											

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
04/08/99	630	L	LGRN	404.6	404.1											
04/08/99	1200	L	LGRN	404.6	404.1	48	53	44	66	OFF	OFF	OFF	7	23	21	21
04/08/99	1700	L	GRN	404.6	404.2											
04/08/99	2310	L	GRN	404.6	404.1											
04/09/99	630	L	LGRN	404.7	404.2											
04/09/99	1200	L	LGRN	404.7	404.2	44	50	35	54	OFF	OFF	OFF	7	23	21	21
04/09/99	1615	L	GRN	404.7	404.1											
04/09/99	2400	L	GRN	404.7	404.1											
04/10/99	645	L	LOLV	404.7	404.1											
04/10/99	1300	L	LOLV	404.7	404.1	44	48	34	66	OFF	OFF	OFF	7	25	22	22
04/10/99	1610	L	GRN	404.7	404.2											
04/10/99	2330	L	GRN	404.7	404.2											
04/11/99	645	L	LOLV	404.7	404.1											
04/11/99	1315	L	LOLV	404.7	404.1	45	48	34	68	OFF	OFF	OFF	7	25	22	22
04/11/99	1800	L	GRN	404.7	404.2											
04/11/99	2300	L	GRN	404.7	404.2											
04/12/99	630	L	GRN	404.7	404.2											
04/12/99	1200	L	GRN	404.7	404.2	48	50	35	66	OFF	OFF	OFF	5	22	22	21.8
04/12/99	1730	L	OLV	404.7	404.1											
04/12/99	2300	L	OLV	404.7	404.1											
04/13/99	630	L	GRN	404.8	404.2											
04/13/99	1200	L	GRN	404.8	404.1	46	51	37	66	OFF	OFF	OFF	7	23	21	22
04/13/99	1605	L	GRN	404.8	404.1											
04/13/99	2300	L	GRN	404.8	404.1											
04/14/99	630	M	GRN	404.8	404.2											
04/14/99	1200	L	GRN	404.8	404.1	50	52	32	64	OFF	OFF	OFF	5	19.5	20	20
04/14/99	1630	L	GRN	404.8	404.2											
04/14/99	2300	L	GRN	404.8	404.2											
04/15/99	700	M	GRN	404.8	404.2											
04/15/99	1145	L	CLR	404.9	404.1	51	52	30	62	OFF	OFF	OFF	7	21	19.5	19.5
04/15/99	1722	L	GRN	404.8	404.1											
04/15/99	2230	L	GRN	404.8	404.1											
04/16/99	630	M	DGRN	404.8	404.1											
04/16/99	1200	M	DGRN	404.8	404.1	47	52	32	70	OFF	OFF	OFF	7	21	19.5	19.5

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
04/16/99	1800	M	GRN	404.9	404.1											
04/16/99	2400	H		404.9	404.1											
04/17/99	630	M	DGRN	404.9	404.1											
04/17/99	1230	M		404.9	404.1	50	54	38	76	OFF	OFF	OFF	7	19	18	18
04/17/99	1800	M	GRN	405.0	404.1											
04/17/99	2400	H		405.0	404.1											
04/18/99	635	L	OLV	405.0	404.1											
04/18/99	1800	M	DOLV	405.2	404.1					OFF	OFF	OFF	7	16	15	15
04/18/99	2330	M	DOLV	405.2	404.1											
04/19/99	645	L	OLV	405.2	403.9									17	16	16
04/19/99	1230	M	DOLV	405.3	404.2	50	53	47	75	OFF	OFF	OFF	7	16.5	15.5	15.5
04/19/99	1900	H	BRN	405.3	404.1									15.5	14.5	14.5
04/19/99	2400	H	BRN	405.3	404.1											
04/20/99	645	M	BRN	405.3	404.0											
04/20/99	1200	M	BRN	405.3	404.1	50	52	48	64	OFF	OFF	OFF	7	16	15.8	16
04/20/99	1800	H	DBRN	405.3	404.1											
04/20/99	2400	H	BRN	405.2	404.1											
04/21/99	630	H	BRN	405.2	404.1											
04/21/99	1200	M	LBRN	405.2	404.1	46	56	36	74	OFF	OFF	OFF	7	16	16	16
04/21/99	1800	M	LBRN	405.1	404.1											
04/21/99	2400	M	LBRN	405.1	404.1											
04/22/99	630	M	BRN	405.0	404.0											
04/22/99	1330			405.0	404.0	50	52	42	65	OFF	OFF	OFF	7	18	17.5	17.5
04/22/99	1800	M	BRN	405.0	404.1											
04/22/99	2400	M	LBRN	405.0	404.1											
04/23/99	700	M	BRN	404.9	404.0											
04/23/99	1125	L	DOLV	404.9	404.1	50	52	39	80	OFF	OFF	OFF	7	19	19	18.5
04/23/99	1800	L	DOLV	404.9	404.1											
04/24/99	100	M	OLV	404.8	404.1											
04/24/99	700	L	DOLV	404.9	404.1											
04/24/99	1145	L	DGRN	404.9	404.1	50	54	40	75	OFF	OFF	OFF	7	20.5	19	18.5
04/24/99	1800	L	DBRN	404.9	404.1											
04/24/99	2300	L		404.9	404.1											
04/25/99	640	L	BRN	404.9	404.1											

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
04/25/99	1400	L	BRN	404.9	404.1	50	53	42	72	OFF	OFF	OFF	7	20.5	19	18.5
04/25/99	1800	M	DOLV	404.9	404.1									20	18	18
04/25/99	2300	M	DOLV	404.9	404.1											
04/26/99	645	L	DOLV	404.9	404.1											
04/26/99	1215	L	BRN	404.9	404.1	52	62	40	72	OFF	OFF	OFF	7	20	18	18
04/26/99	1800	M	DGRN	404.9	404.1											
04/26/99	2300	M	DGRN	404.9	404.2											
04/27/99	630	M	GRN	404.9	404.1											
04/27/99	1200	L	GRN	404.9	404.1	51	53	36	62	OFF	OFF	OFF	7	18.8	17.5	17.5
04/27/99	1800	L	GRN	404.9	404.1											
04/27/99	2330	L	GRN	404.9	404.2											
04/28/99	730	L	GRN	404.8	404.1											
04/28/99	1200	L	GRN	404.8	404.1	49	50	41	60	OFF	OFF	OFF	7	21.8	19.8	19.8
04/28/99	1800	L	LGRN	404.8	404.1											
04/28/99	2300	L	LGRN	404.8	404.1											
04/29/99	720	L	LGRN	404.8	404.1	50	52									
04/29/99	1300	L	LOLV	404.7	404.1			37	68					23	21.5	21
04/29/99	1800	L	LGRN	404.7	404.1											
04/29/99	2300	L	LGRN	404.7	404.1											
04/30/99	730	L	GRN	404.6	404.1											
04/30/99	1200	L	GRN	404.4	404.0	48	53	43	70	OFF	OFF	OFF	7	26.3	23.3	23
04/30/99	1800	L	GRN	404.3	404.1											
04/30/99	2400	L	GRN	404.3	404.1											
05/01/99	715	L	GRN	404.5	404.1											
05/01/99	1200	L	GRN	404.5	404.1	54	56			OFF	OFF	OFF	7	27.3	26.5	26.3
05/01/99	1600	L	GRN	404.5	404.1											
05/01/99	2400	L	GRN	404.5	404.1											
05/02/99	730	L	LGRN	404.6	404.1											
05/02/99	1200	L	LGRN	404.6	404.1	53	57	46	73	OFF	OFF	OFF	7	24.5	24.8	24.8
05/02/99	1600	L	GRN	404.6	404.1											
05/02/99	2100	L	GRN	404.6	404.1											
05/03/99	800	L	LGRN	404.6	404.2											
05/03/99	1730	L	LGRN	404.6	404.2											
05/03/99	2100			404.6	404.1											

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
05/04/99	800	L	LGRN	404.7	404.2											
05/04/99	1430	L	LGRN	404.7	404.2	52	55	42	64	OFF	OFF	OFF	7	22.5	23.5	22.8
05/04/99	1640	L	LGRN	404.7	404.2											
05/04/99	2100	L	LGRN	404.7	404.2											
05/05/99	800	L	LGRN	404.7	404.1											
05/05/99	1300	L	LGRN	404.7	404.2	52	52	38	63	OFF	OFF	OFF	7	23.5	22	22
05/05/99	1800	L	LGRN	404.7	404.1											
05/05/99	2130	L	LGRN	404.7	404.1											
05/06/99	800	L	LGRN	404.7	404.2											
05/06/99	1200	L	LGRN	404.7	404.2	52	64	42	68	OFF	OFF	OFF	7	24.5	24	24
05/06/99	1800	L	LGRN	404.6	404.2											
05/06/99	2400	L	LGRN	404.6	404.2											
05/07/99	745	L	LGRN	404.7	404.1											
05/07/99	1330	L		404.6	404.2	54	64	40	72	OFF	OFF	OFF	7	24.5	24	24
05/07/99	1800	L	LGRN	404.6	404.1											
05/07/99	2400	L	LGRN	404.6	404.2											
05/08/99	740	L	LOLV	404.7	404.2											
05/08/99	1200			404.7	404.2			38	62	OFF	OFF	OFF	7	21	22	22
05/08/99	1800	L	LGRN	404.7	404.1											
05/08/99	2400	L	LGRN	404.6	404.1											
05/09/99	740	M	LOLV	404.7	404.1											
05/09/99	1300	M	LOLV	404.7	404.1	48	57	38	58	OFF	OFF	OFF	7	23	22.5	22.5
05/09/99	1800	L	LGRN	404.7	404.1											
05/09/99	2400	L	LGRN	404.7	404.1											
05/10/99	730	L	LOLV	404.7	404.1											
05/10/99	1200	L	LOLV	404.7	404.1	50	52	32	62	OFF	OFF	OFF	7	23	22.5	22
05/10/99	1800	L	LGRN	404.7	404.1											
05/10/99	2400	L	LGRN	404.7	404.1											
05/11/99	715	L	LGRN	404.6	404.1											
05/11/99	1200	L	LGRN	404.6	404.1		52	42	62	OFF	OFF	OFF	7	23.5	22.5	22
05/11/99	1600	L	LGRN	404.6	404.0											
05/11/99	2200	L	LGRN	404.6	404.1											
05/12/99	730	L	GRN	404.6	404.1											
05/12/99	1200	L	LGRN	404.6	404.1		52	50	66	OFF	OFF	OFF	7	23.5	24	23

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
05/12/99	2100	L	LGRN	404.6	404.1											
05/13/99	720			404.6	404.1											
05/13/99	1200				404.1					OFF	OFF	OFF	7			
05/13/99	1800	L	LGRN	404.6	404.2	53	56	44	66							
05/13/99	2400	L	LGRN	404.6	404.2											
05/14/99	720	L	LGRN	404.6	404.1											
05/14/99	1200	L	LGRN	404.6	404.1	50	53	40	75	OFF	OFF	OFF	7	26	24.8	24
05/14/99	1630	L	LGRN	404.6	404.1											
05/14/99	2230	L	LGRN	404.6	404.1											
05/15/99	700	L	LGRN	404.6	404.1											
05/15/99	1130	L	LGRN	404.6	404.1	52	54	47	67	OFF	OFF	OFF	7			
05/15/99	1615	L	LGRN	404.6	404.1											
05/15/99	2200	L	GRN	404.6	404.1											
05/16/99	730	L	LGRN	404.6	404.1											
05/16/99	1200	L	LGRN	404.6	404.1	54	55	43	66	OFF	OFF	OFF	7	26	24.8	24
05/16/99	1600	L	GRN	404.6	404.1											
05/16/99	2200	L	GRN	404.6	404.1											
05/17/99	730	L	LGRN	404.5	404.1											
05/17/99	1200	L	LGRN	404.5	404.1	55	56	53	68	OFF	OFF	OFF	7	32	29.8	28.8
05/17/99	1620	L		404.5	404.1											
05/17/99	2400	L			404.1											
05/18/99	730	L	LGRN	404.5	404.2											
05/18/99	1200	L	LGRN	404.6	404.2	52	54	52	68	OFF	OFF	OFF	7	29	28.5	29
05/18/99	1615	L	LGRN	404.6	404.2											
05/18/99		L	LGRN	404.6	404.1											
05/19/99	800	L	LOLV	405.7	404.2									24.5	24.5	24.5
05/19/99	1310	L	LOLV	405.8	404.3	58	60	45	72	OFF	OFF	OFF	7	23	23	23
05/19/99	1800	L	LOLV	404.8	404.5									22	22	22
05/19/99	2230	L	LOLV	404.7	404.1											
05/20/99	730	L	BRN	404.7	404.0											
05/20/99	1200	L		404.7	404.1	56	59	47	70	OFF	OFF	OFF	7	25.3	23.3	23.3
05/20/99	1645	L	OLV	404.7	404.1											
05/20/99	2045	L	OLV	404.7	404.2											
05/21/99	730	M	OLV	404.7	404.2											

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
05/21/99	1200	M	OLV	404.6	404.1	57	59	48	72	OFF	OFF	OFF	7	26.3	26	26
05/21/99	1800	L	LGRN	404.6	404.1											
05/21/99	2400	L	LGRN	404.6	404.1											
05/22/99	745	L	OLV	404.6	404.1											
05/22/99	1200	L	OLV	404.6	404.1	54	60	46	75	OFF	OFF	OFF	7	25.5	25.5	25.3
05/22/99	1800	L	OLV	404.6	404.1											
05/23/99	600	L	OLV	404.6	404.0											
05/23/99	1200	L	OLV	404.5	404.1	60	62	48	78	OFF	OFF	OFF	7	30.5	29	29
05/23/99	1800	L		404.5	404.2											
05/24/99	730	L	OLV	404.6	404.2											
05/24/99	1200	L	OLV	404.6	404.2	62	64	55	86	OFF	OFF	OFF	7	29	28.5	28.5
05/24/99	1800	L	OLV	404.6	404.2											
05/25/99	800	L	LOLV	404.6	404.1											
05/25/99	1200	L	LOLV	404.6	404.2			64	90	OFF	OFF	OFF	7	27.5	27.5	28
05/25/99	1600	L	LOLV	404.7	404.2											
05/25/99	2200	L	LOLV	404.6	404.1											
05/26/99	800	L	LGRN	404.5	404.2											
05/26/99	1200	L	LGRN	404.6	404.2	58	70	56	80	OFF	OFF	OFF	7	31.5	31.5	31
05/26/99	1800	L	LOLV	404.6	404.2											
05/26/99	2320	L	LOLV	404.5	404.1											
05/27/99	720	L	LOLV	404.4	404.1											
05/27/99	1200	L	OLV	404.4	404.1	59	62	45	75	OFF	OFF	OFF	7	38.3	36.3	36.3
05/27/99	1800	L	OLV	404.5	404.3											
05/27/99	2230	L	OLV	404.5	404.2											
05/28/99	730	L	OLV	404.5	404.1											
05/28/99	1030	L	OLV	404.4	404.1	61	63	53	84	OFF	OFF	OFF	7	33	32.3	32
05/28/99	1600	L	OLV	404.5	404.1											
05/28/99	1930	L	OLV	404.5	404.1											
05/29/99	700	L	OLV	404.4	404.0											
05/29/99	1200	L	OLV	404.4	404.1	62	65	56	79	OFF	OFF	OFF	7	36.3	34.3	33.8
05/29/99	1600	L	OLV	404.4	404.1											
05/29/99	1930	L		404.5	404.1											
05/30/99	730	L	OLV	404.4	404.1											
05/30/99	1300	L	OLV	404.3	404.1	64	66	51	79	OFF	OFF	OFF	7	40	37	36.8

Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
05/30/99	1700	L	OLV	404.3	404.1											
05/30/99	1930	L	OLV	404.3	404.1											
05/31/99[e]	730	L	OLV	404.3	404.1											
05/31/99	1200	L	OLV	404.3	404.1	63	66	53	80	OFF	OFF	OFF	7	44.3	39.8	39.8
05/31/99	1640	L	OLV	404.4	404.3											
05/31/99	2400	L	OLV	404.4	404.3											
06/01/99	800	L	GRN	404.4	404.4											
06/01/99	1200	L	GRN	404.4	404.4	62	68	56	80	OFF	OFF	OFF	7	30	30.5	30
06/01/99	1700	L	OLV	404.4	404.4											
06/01/99	2100	L	OLV	404.4	404.4											
06/02/99	800	L	GRN	404.4	404.4											
06/02/99	2000	L	LOLV	404.4	404.3	58	65	49	68	OFF	OFF	OFF	7			
06/02/99	2135	L	LOLV	404.4	404.3											
06/03/99	730	L	OLV	404.5	404.5											
06/03/99	1200	L	OLV	404.5	404.5	57	58	54	74	ON	ON	OFF		31.5	30.8	30
06/03/99	1800	L	OLV	404.5	404.5											
06/03/99	2035	L	OLV	404.5	404.5											
06/04/99	800	L	OLV	404.5	404.5											
06/04/99	1530	L	OLV	404.5	404.4	60	62	56	80	ON	ON	OFF				
06/04/99	2200	L	OLV	404.5	404.4											
06/05/99	630	L	OLV	404.4	404.5											
06/05/99	1045	L	OLV	404.4	404.5	64	64	60	81	ON	ON	OFF				
06/05/99	1445	L	OLV	404.4	404.5											
06/05/99	2100	L	OLV	404.4	404.5											
06/06/99	1020	L	OLV	404.4	404.5											
06/06/99	1440	L	OLV	404.4	404.5	60	64	46	76	ON	ON	OFF				
06/06/99	1625	L	OLV	404.4	404.5									30	30	30
06/07/99	730	L	OLV	404.4	404.5											
06/07/99	1200		OLV	404.4	404.5	62	63	48	69	ON	ON	OFF				
06/07/99	1800	L	OLV	404.4	404.5											
06/08/99	730	L	OLV	404.4	404.5											
06/08/99	1230	L	OLV	404.4	404.5	61	62	48	70	ON	ON	OFF				
06/08/99	1800	L	OLV	404.4	404.5											

[e] *Initiation of Phase I water exchange.*

Appendix Table A-7. Continued.

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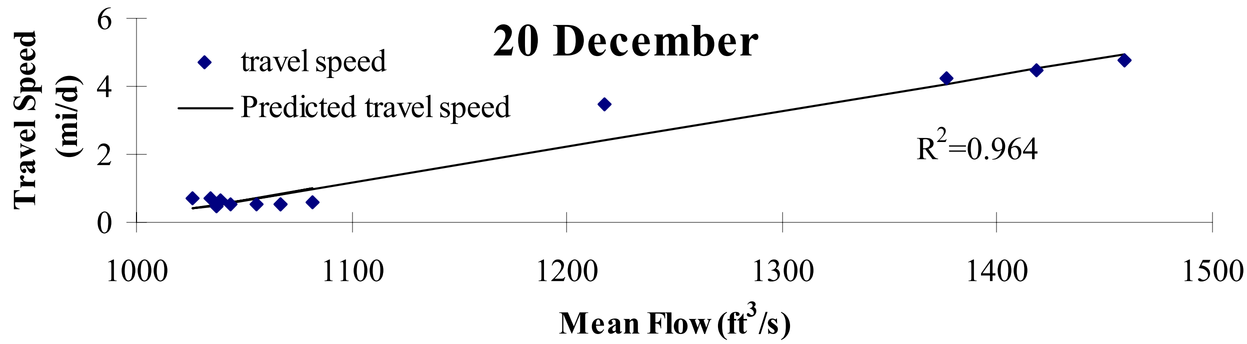
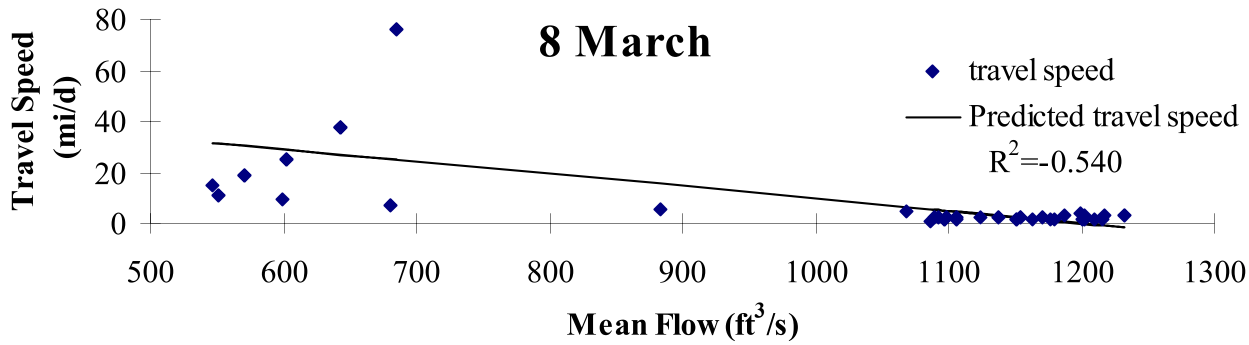
			Water	River	Canal	Water temp. (^oF)		Air temp. (^oF)		Pumpback[c]				Headgates[d]		
Date	Time	Debris[a]	color[b]	gauge (ft.)	height (ft.)	Min.	Max.	Min.	Max.	P1	P2	P3	RR	S	M	N
06/09/99	730	L	LGRN	404.4	404.5											
06/09/99	1200	L	LGRN	404.4	404.5	60	61	54	68	ON	ON	OFF		30	30.5	30
06/09/99	1800	L	LGRN	404.4	404.5											
06/10/99	800	L	LGRN	404.4	404.5											
06/10/99	1130	L	LGRN	404.4	404.5	62	64	52	72	ON	ON	OFF		30	30.5	30
06/10/99	1800	L	LOLV	404.4	404.5											
06/10/99	2240	L	LOLV	404.4	404.5											
06/11/99	845	L	OLV	404.4	404.5											
06/11/99	1200	L	OLV	404.4	404.5	62	66	51	78	ON	ON	OFF				
06/11/99	1530	L	OLV	404.4	404.5											
06/12/99	730	L	OLV	404.4	404.5											
06/12/99	1200	L	OLV	404.4	404.5	66	67	54	83	ON	ON	OFF				
06/12/99	1600	L	OLV	404.4	404.5											
06/13/99	650	L	OLV	404.4	404.5											
06/13/99	1200	L	OLV	404.4	404.4					OFF	OFF	OFF	7			
06/13/99	1800	L	OLV	404.4	404.4											
06/14/99	845	L	OLV	404.4	404.4											
06/14/99	1200	L	OLV	404.4	404.4	66	72	59	90	OFF	OFF	OFF	7			
06/15/99	930	L	CLR	404.4	404.4											
06/15/99	1000					70	72	64	90	OFF	OFF	OFF	7	30	30.5	30
06/16/99	830	L	CLR	404.4	404.4											
06/16/99	1215			404.4	404.4	70	72	74	92	OFF	OFF	OFF	7	30	30.5	30
06/17/99	900	L	CLR	404.4	404.4					OFF	OFF	OFF	7			
06/18/99	830	L	CLR	404.4	404.4											
06/18/99	1130	L	CLR	404.4	404.4	70	72	56	80	OFF	OFF	OFF	7	30	30.5	30
06/19/99	830	L	CLR	404.4	404.4					OFF	OFF	OFF	7			
06/20/99	830	L	CLR	404.4	404.4					OFF	OFF	OFF	7			
06/21/99	1330	L	LGRN	404.4	404.4	68	70	56	82	OFF	OFF	OFF	5	30	30.5	30
06/22/99	930	L	LGRN	404.4	404.4	67	70	58	82							
06/23/99	845	L	CLR	404.4	404.4											
06/23/99	1100	L	CLR	404.4	404.4	64	66	56	82	OFF	OFF	OFF	7	30	30.5	30
06/24/99	830	L	CLR	404.4	404.4											
06/24/99	1100	L	CLR	404.4	404.4	72	72	60	82	OFF	OFF	OFF	7	30	31	30
06/26/99	800	L	CLR	404.4	404.4											
06/26/99	1330	L	CLR	404.4	404.4	62	66	52	80	OFF	OFF	OFF	7	30	30.5	30

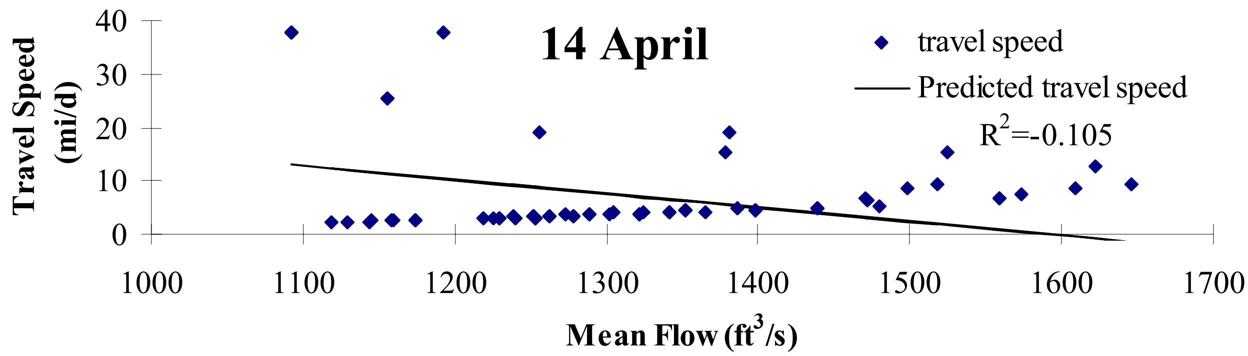
Appendix Table A-7. Continued.

Date	Time	Debris[a]	Water color[b]	River gauge (ft.)	Canal height (ft.)	Water temp. (°F) Min.	Water temp. (°F) Max.	Air temp. (°F) Min.	Air temp. (°F) Max.	Pumpback[c] P1	Pumpback[c] P2	Pumpback[c] P3	RR	Headgates[d] S	Headgates[d] M	Headgates[d] N
06/27/99	845	L	BRND	404.4	404.4											
06/27/99	1100	L	BRND	404.4	404.4	64	66	52	70	OFF	OFF	OFF	7	30	30.5	30
06/30/99	900	L	LGRN	404.4	404.4											
06/30/99	1230	L	LGRN	404.4	404.4	64	66	52	82	OFF	OFF	OFF	7	30	30.5	30
07/01/99	830	L	LGRN	404.4	404.4					OFF	OFF	OFF	7			
07/02/99	1800	L	LGRN	404.4	404.4	64	68	54	84	OFF	OFF	OFF	7	30	30.5	30
07/03/99	930	L	LGRN	404.4	404.4					OFF	OFF	OFF	7			
07/07/99	900	L	LGRN	404.4	404.4					OFF	OFF	OFF	7			
07/08/99	915	L	LGRN	404.4	404.4	64	64	52	90	OFF	OFF	OFF	7	30	30.5	30
07/09/99	900	L		404.4	404.4	66	66	52	80	OFF	OFF	OFF	5	30	30.5	30
07/11/99	1200	L	LGRN	404.4	404.4	70	70	56	94	OFF	OFF	OFF	5	30	30.5	30
07/12/99	700	L	LGRN	404.2	404.2	72	72	62	94	ON	ON	ON		38	39	37.5
07/13/99	735	M	LGRN	404.2	404.2					ON	ON	ON		38	39	37.5
07/14/99	700	L	LGRN	404.2	404.2											
07/14/99	1245	L	LGRN	404.2	404.2	72	72	58	92	OFF	OFF	ON	5	39.5	39	39
07/15/99	800	L	LGRN	404.2	404.1	68	72	54	78	ON	OFF	OFF	5	39.5	39	39
07/16/99[f]	730	L	LGRN	404.2	404.1	68	68	58	78	OFF	OFF	ON	5	39	39	39
07/17/99	820				403.5											
07/17/99	1200	M	LGRN		403.9	68	68	60	80	ON	OFF	ON		39	39	39
07/18/99	830	M	LGRN	404.1	404.1	64	68	52	80	ON	OFF	ON		39.5	39	39
07/19/99	830	M	LGRN	404.0	404.0	65	68	52	82	ON	OFF	ON		39	39	39

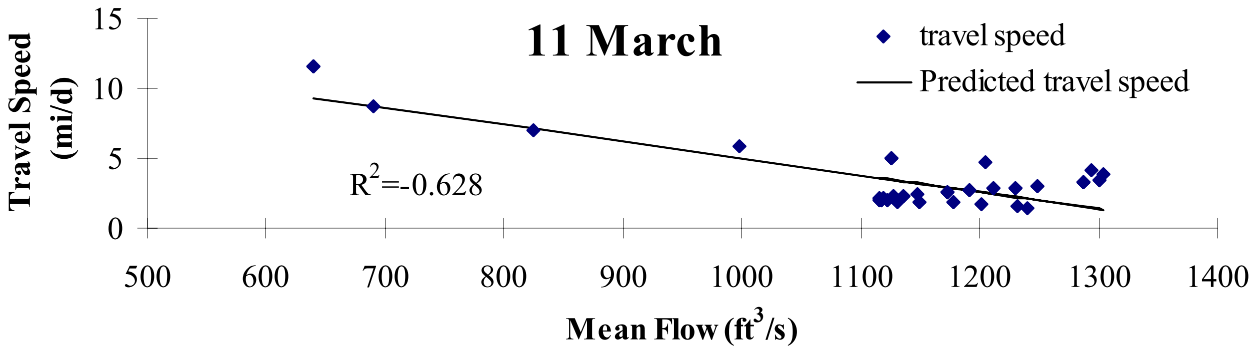
[f] *End of Phase I water exchange.*

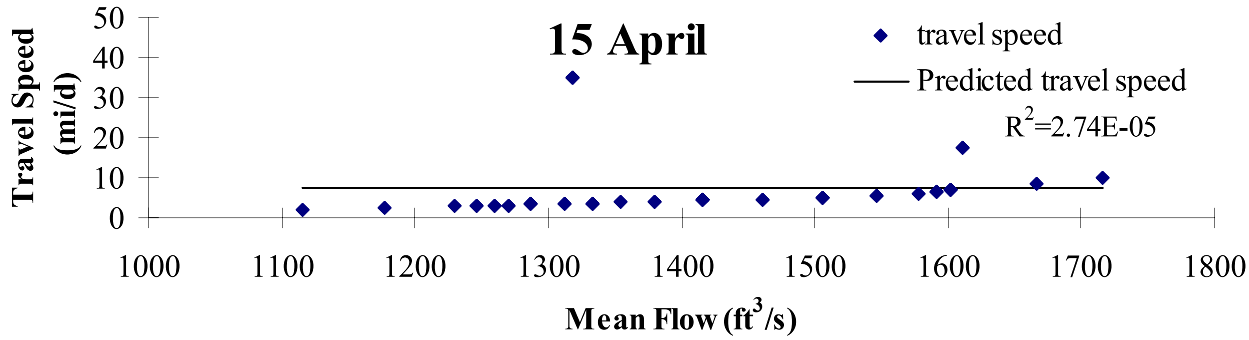




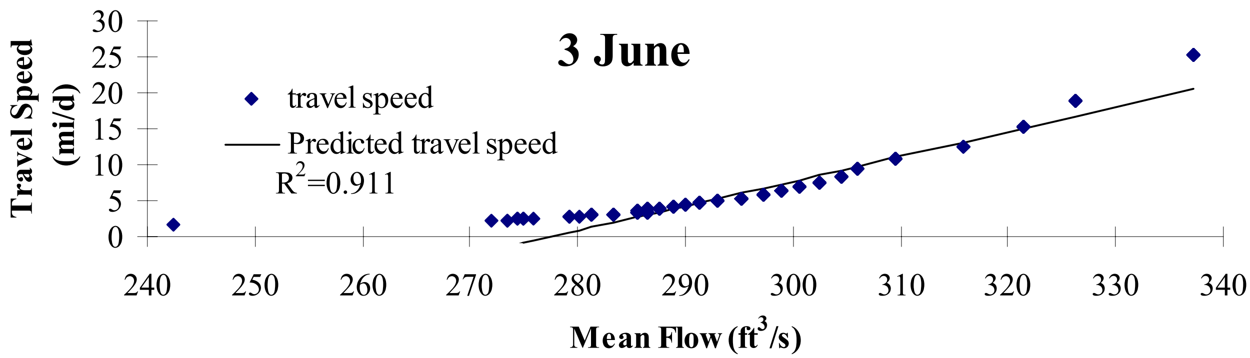


Appendix Figure A-1. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for hatchery spring chinook salmon, Umatilla River, 20 December 1998 - 14 April 1999.

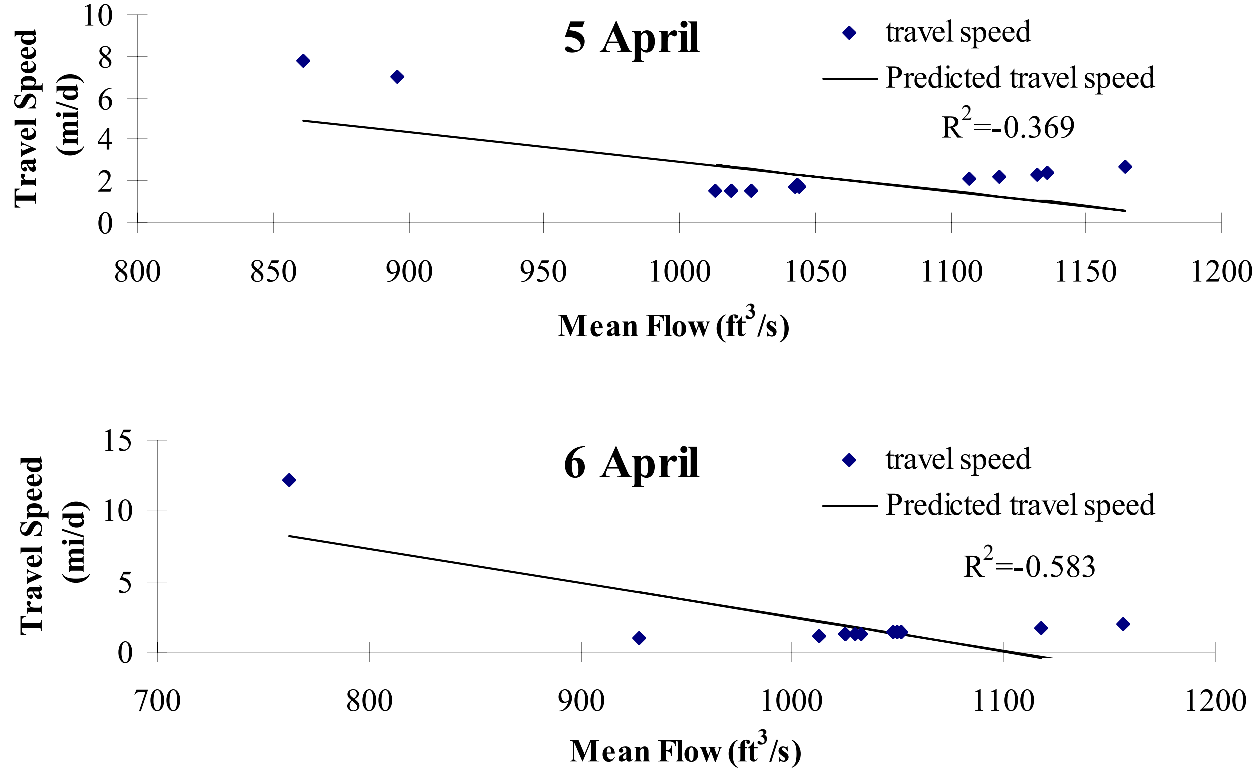




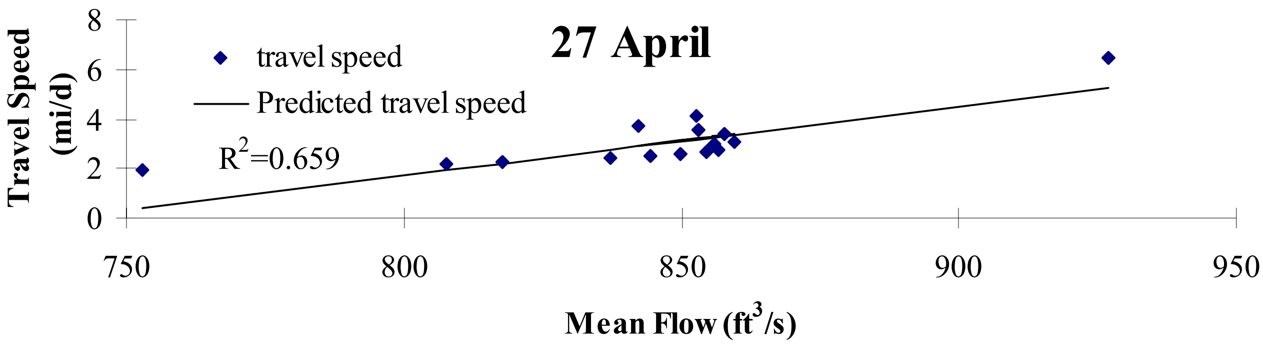
Appendix Figure A-2. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for hatchery fall chinook salmon, Umatilla River, 11 March - 15 April 1999.



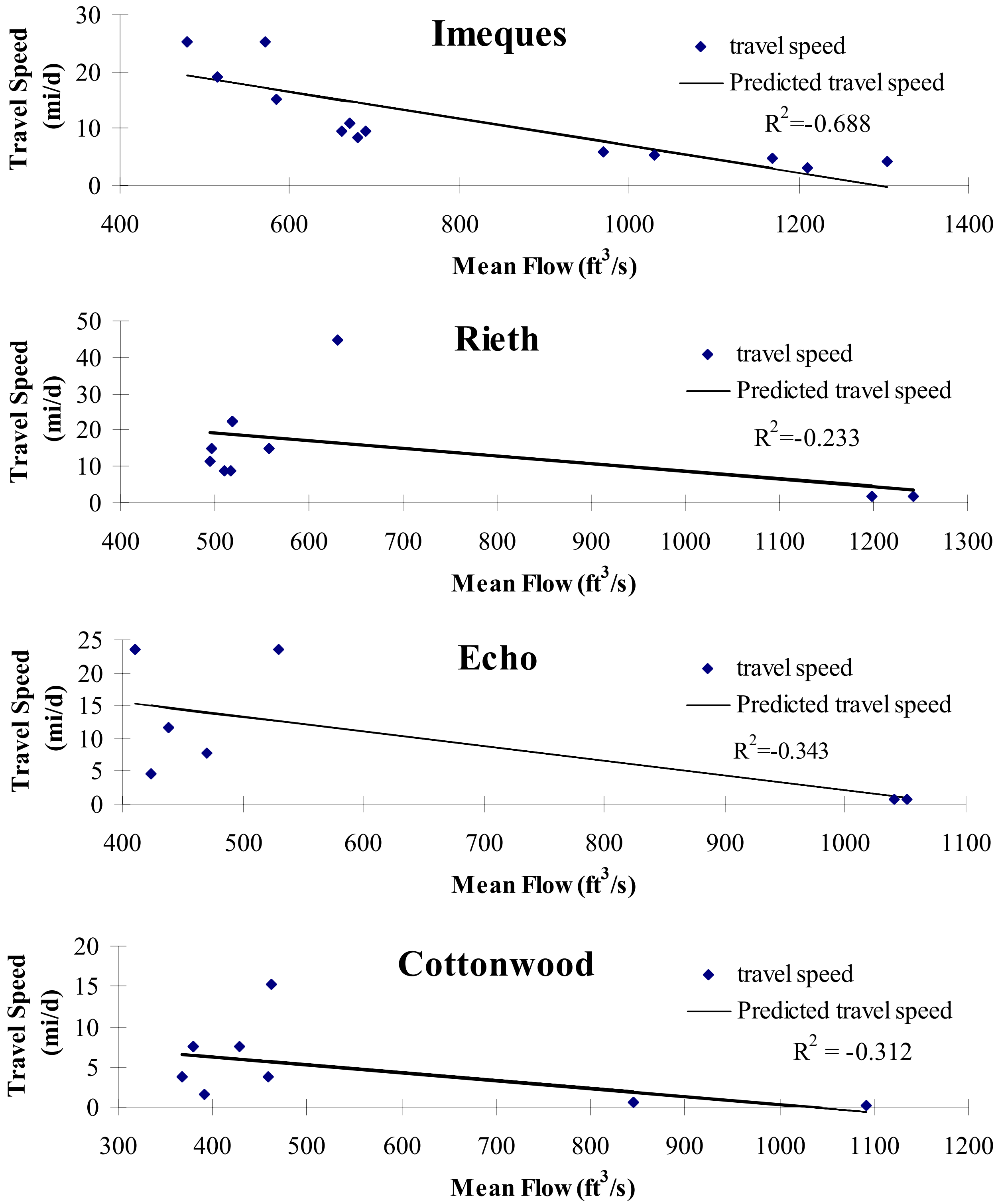
Appendix Figure A-3. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for hatchery subyearling fall chinook salmon, Umatilla River, 3 June 1999.



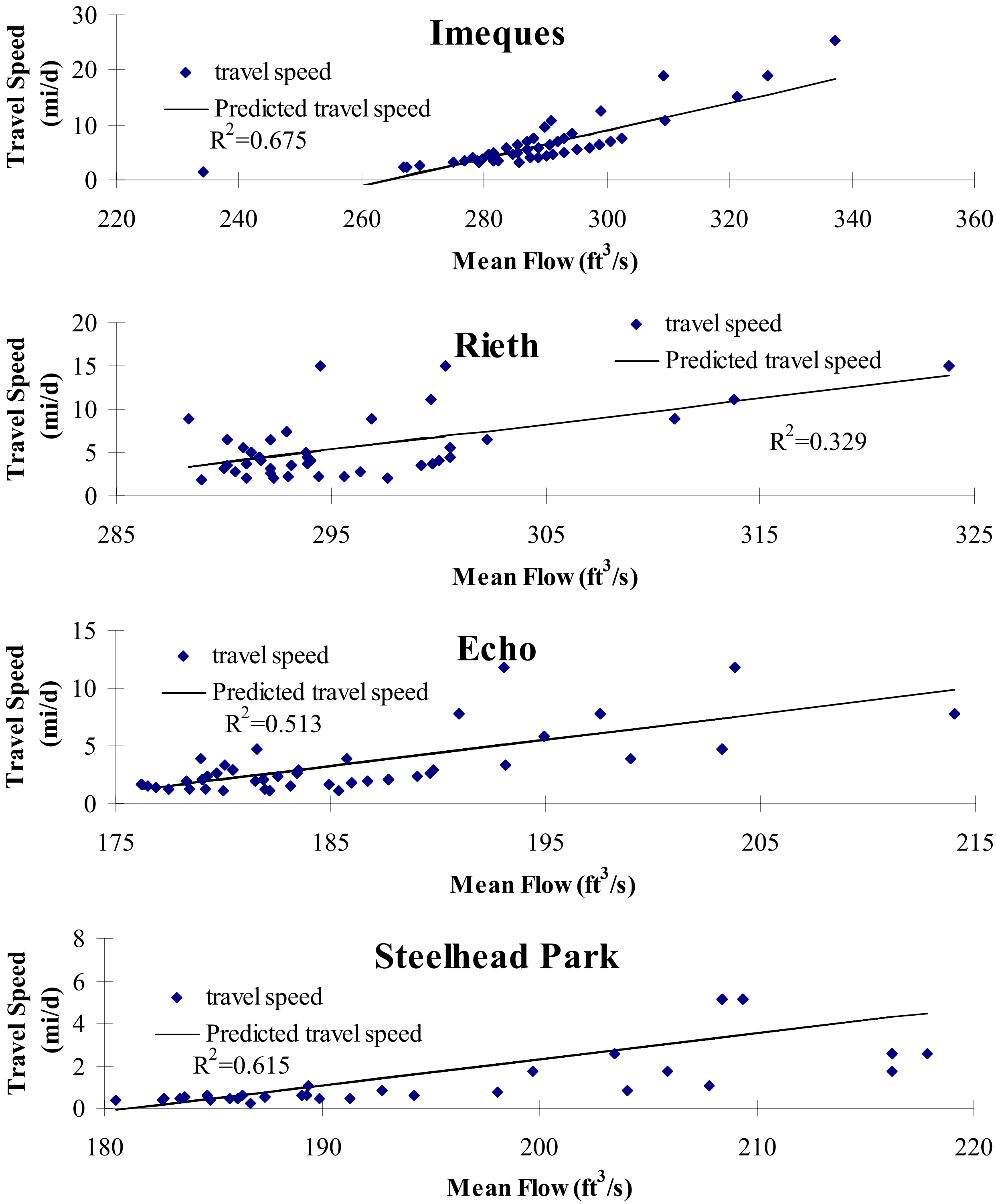
Appendix Figure A-4. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for large-grade hatchery summer steelhead, Umatilla River, 5 - 6 April 1999.



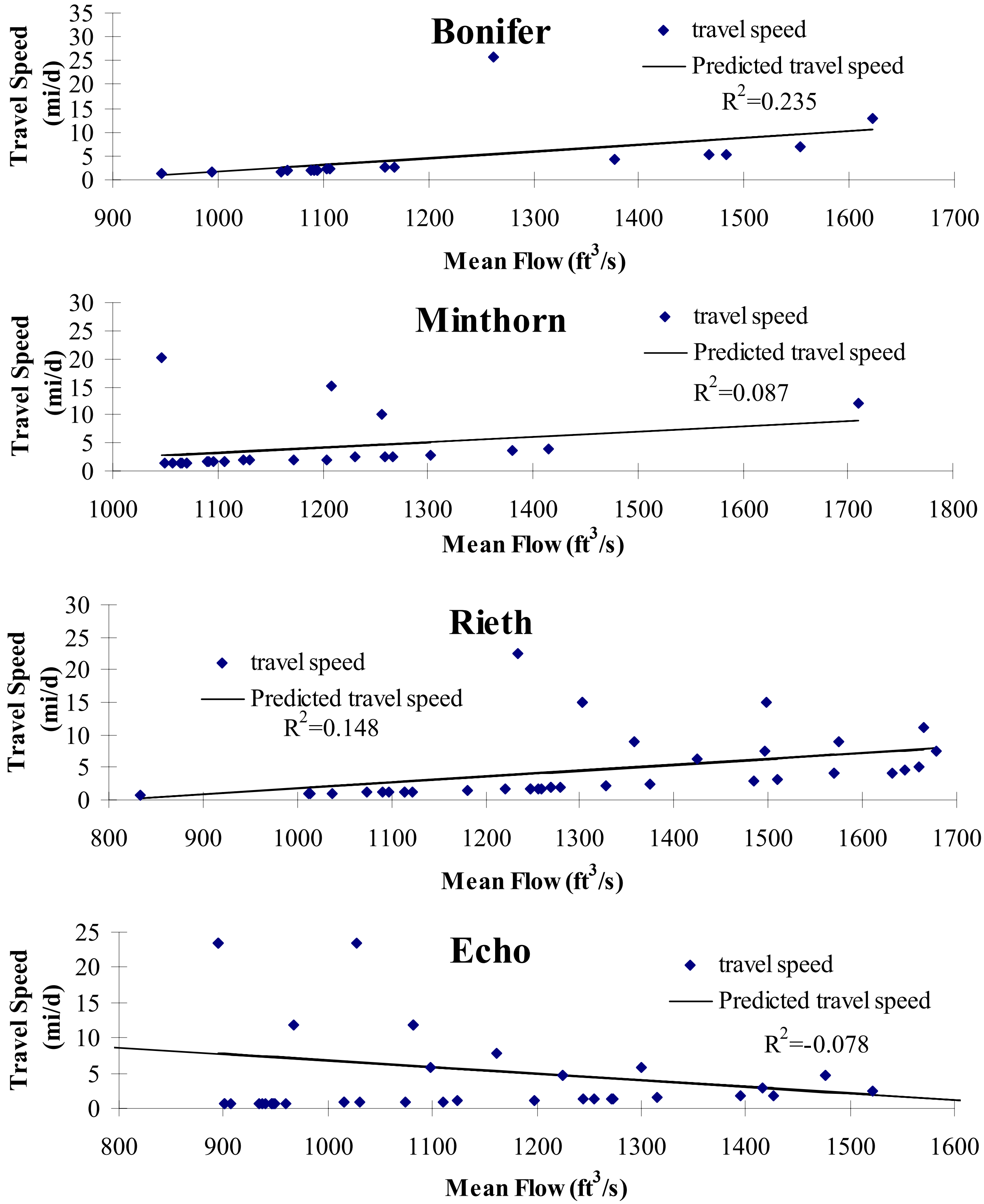
Appendix Figure A - 5. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for small-grade hatchery summer steelhead, Umatilla River, 27 April 1999.



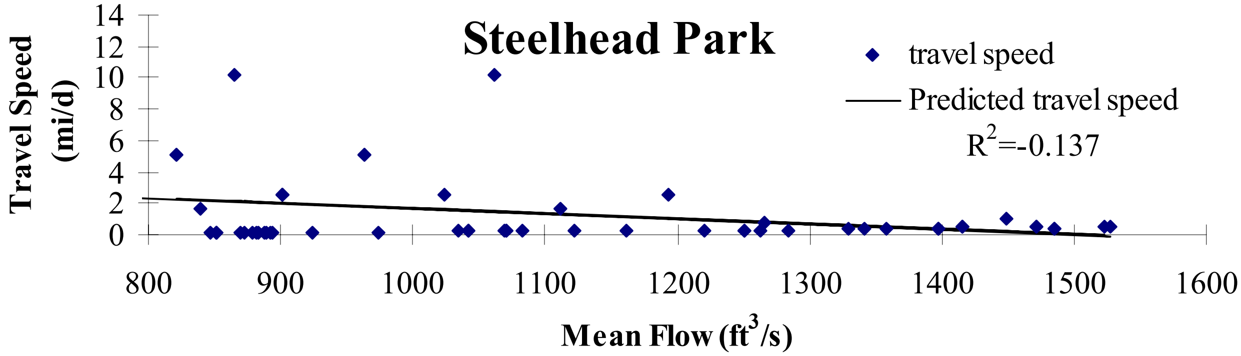
Appendix Figure A - 6. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for spring chinook salmon released for reach-specific survival tests, Umatilla River, 9 - 11 May 1999.



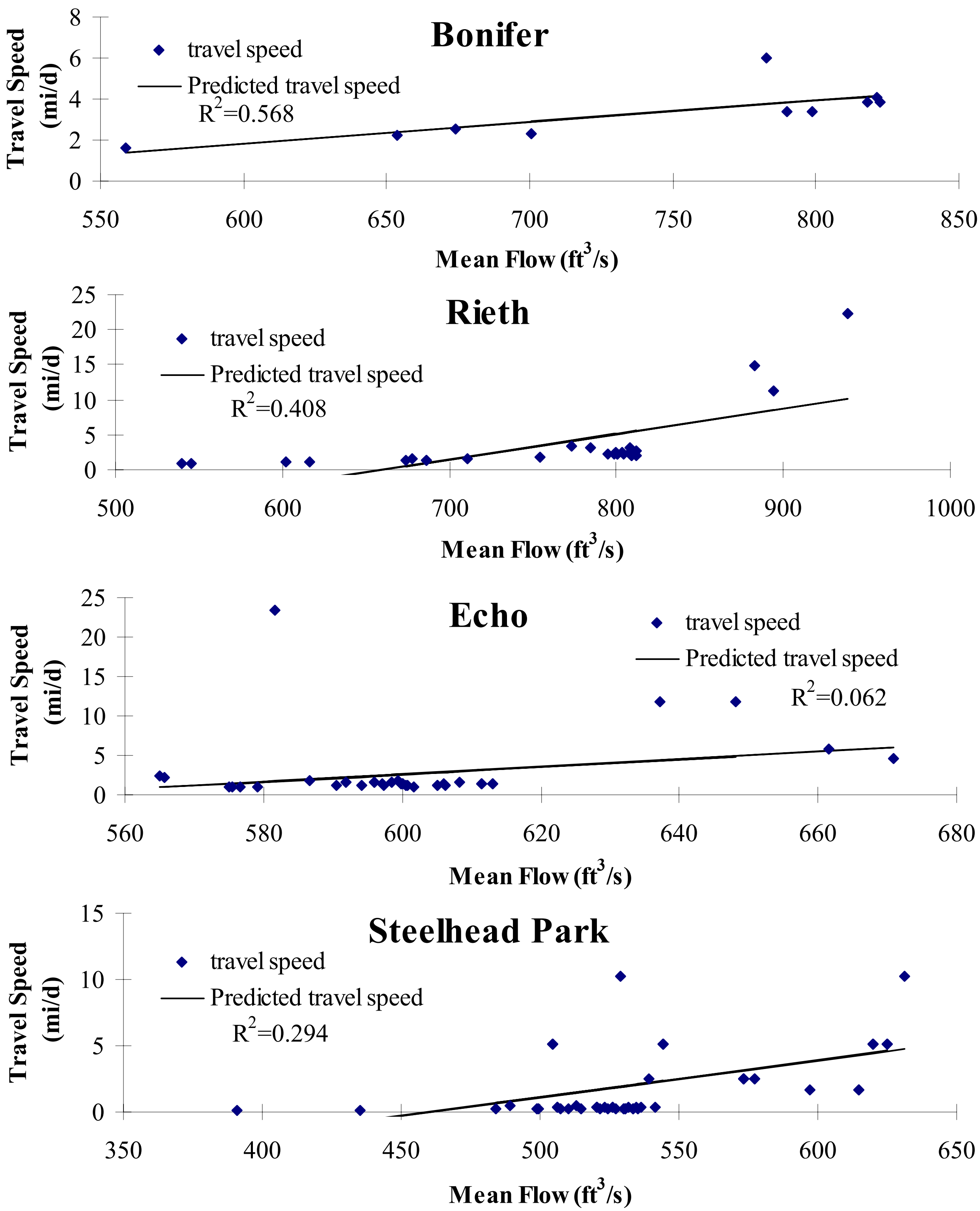
Appendix Figure A - 7. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for subyearling fall chinook salmon released for reach-specific survival tests, Umatilla River, 3 - 5 June 1999.



Appendix Figure A - 8. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for large-grade summer steelhead released for reach-specific survival tests, Umatilla River, 12 - 15 April 1999.



Appendix Figure A - 8. Continued.



Appendix Figure A - 9. A scatter plot of travel speed (mi/d) to Three Mile Falls Dam (RM 3.7) and mean river flow (ft^3/s) for small-grade summer steelhead released for reach-specific survival tests, Umatilla River, 4 - 7 May 1999.