Lewis River Implementation Study:
Merwin Tailrace Fish Behavior

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1. INTRODUCTION

The Merwin upstream fish passage facility was originally completed with construction of the Merwin Dam. This trapping facility historically operated with three entrances but was reconfigured to improve operation related to fish removal. The current facility is operated with one trap entrance located on the South side of the dam to the right of the discharge from turbine Unit 1. Questions have been raised as to how effective the trap is at various turbine operations and flow conditions, and in particular how effective the adult trap is when turbine Unit 1 is operational.

Section 4.3 of the Final Settlement Agreement for the Lewis River Hydroelectric Projects called for the construction and future operation of an adult trap and transport facility at the Merwin Project. Section 4.1.1 of the Agreement called for studies to inform design decisions regarding upstream and downstream fish passage facilities and stated that the studies should include an evaluation of the movement of fish in the corresponding tailrace or forebay. An additional requirement of the Settlement Agreement was development of an Adult Trap Efficiency performance standard. In developing such a standard the Agreement called for evaluation of entry rate, fallback, crowding at the entrance, delay and abandonment of the trap area.

To effectively meet the requirements identified in the Settlement Agreement, the tailrace study will consider the following objectives: 1) to document operation of the current trap as defined by adult trap efficiency (ATE); 2) to determine if fish are able to locate, approach, and enter the current trap under varying flow conditions and turbine operation, and 3) to confirm and test selected fish monitoring technology in considering future trap monitoring needs.

After the Phase I study is completed study results will be used in Phase II, helping PacifiCorp Energy select the best technology available for long term monitoring of the new trap facility based on daily ATE.

2. GENERAL STUDY METHODS

2.1 DEVIATIONS FROM THE STUDY PLAN

During the course of this study unanticipated events occurred that resulted in changes to the proposed study plan. Items eliminated from the study are described below.

2.1.1 Objective 1 – Estimate the abundance of adult salmonids entering the tailrace daily.

We attempted to quantify the number of fish entering and leaving the tailrace based on fish detections using a fixed split-beam hydroacoustic array. The array was located at the downstream entrance to the tailrace and was designed to provide as complete coverage as possible across the river, downstream of the tailrace and just above the boat access buoy line. A review of data collected during the summer steelhead run indicated that the array was not able to provide reliable fish counts. Fish milling in the area of the array resulted in negative daily fish counts in the tailrace, yet increasing numbers of fish were being captured in the Merwin trap.

In addition, a Quality Assurance test on hydroacoustic fish counts was conducted by comparing counts from a defined section of the split-beam array with the same coverage by a DIDSON. A subset of the split beam five minute interval detections were compared to DIDSON counts over the same time period. The split beam counts were lower than DIDSON counts on average, except when testing with a dummy target (Table 2-1). When there were targets in the common field, the split beam counts were greater than the DIDSON. It appeared that the far-shore split beam counts were indicative of the presence of fish; however, the split beam likely underestimated the number of fish that were passing on the far shore.

Based on the split-beam and DIDSON comparison, we hypothesized that the split-beam transducers detected fewer fish entering the tailrace because these fish were moving upstream in low velocity areas behind small boulders and they were undersampled by the hydroacoustic array. In contrast, fish moving downstream appeared to take advantage of the faster tailrace velocities higher in the water column and were more detectable to the split-beam. As a result, the split beam was better at detecting fish moving downstream than upstream resulting in a negative number of fish entering the tailrace daily.

Given the complications of the hydroacoustic array to quantify fish moving into and out of the tailrace and the fact that no replacement method for obtaining daily counts in the tailrace was found, this first objective was eliminated from the study.

Table 2-1.   A comparison of DIDSON and split-beam hydroacoustic counts over specified time periods when the far-shore split beam was operational.

Start	Finish	DIDSON Count	Up	Down	DIDSON Comparison Count	Split Beam Count	Notes
7:50	7:55	**3+1 target**	3	0	**2 + 1 target**	2	1 of SB "fish" was likely target
8:00	8:05	**8**	7	1	**6**	0	
8:10	8:15	**4+2 targets**	4	0	**3 + 2 targets**	11	4 of SB "fish" were likely targets
8:20	8:25	**4+1 target**	3	1	**2+1 target**	5	
8:30	8:35	**10**	9	1	**5**	0	some recycling of fish thru DIDSON field
8:40	8:45	**9**	6	3	**6**	1	1 downstream was milling and uncertain direction
8:50	8:55	**5**	3	2	**3**	0	
9:30	9:35	**0**			**0**	0	
10:00	10:05	**0**			**0**	0	
11:20	11:25	**1+1 target**	1		**1+1 target**	0	
12:00	12:05	**1**	1		**1**	0	
12:30	12:35	**1(2)**		1(2)	**1(2)**	0	A second fish depending the time difference
13:00	13:05	**3(4)**	3	(1)	**3(4)**	0	A fourth fish depending on time difference
13:30	13:35	**2**	1		**1**	1	Don't know direction on second fish
14:00	14:05	**3(4)**			**2(3)**	0	1 fish too close to DIDSON to be seen in SB, one more fish depending on time difference
14:30	14:35	**0**			**0**	0	
14:40	14:45	**1**	1		**1**	1	
21:20	21:25	**7**	5	1	**6**	2	1 fish stayed in DIDSON the entire time, so direction uncertain

In addition, an attempt was made to quantify tagged fish entering and exiting the Project area using the fixed aerial detection antenna, the most downstream of the seven fixed detection zones used in this study. Examination of detection records of tagged fish that entered the fixed array indicated the aerial antenna could not be reliably used to exclusively determine whether a tagged fish entered or exited the project area. For example, aerial antenna detections were not recorded in 28%, 14%, and 62% of the tagged fish that entered the array for summer steelhead, coho salmon, and hatchery winter steelhead respectively. Tag anomalies (tag collisions and radio frequency interference), fish moving at depth under high water conditions, equipment failure, download failure, and direct movement into the trap all likely attribute to the variability of the aerial antenna in detecting fish upon entering the tailrace. As a result, we did not feel confident in assessing the movement of fish across the zone created by the aerial antenna below the tailrace, or as proposed, fish movement into and out of the tailrace. In addition, the calculation of total time fish spent in the tailrace was not calculated based on the time a fish first moved into this detection zone as proposed, but rather, was calculated by the time between last and first detection and then subtracting from that any 24-hour period where the fish was not detected in any of the tailrace detection zones.

2.2. COMPLETED STUDY OBJECTIVES

2.2.1 Objective 2 – Estimate the number of trap entry attempts made by adult salmonids in the tailrace.

A video camera located above the trap entrance was used to observe and quantify behavior of fish approaching and entering the trap. Video analysis was conducted to determine the total number of entries, attempts, and fallbacks at the trap. Video images of trap activity were recorded daily from 13 May 2005 through 14 July 2006 (Table 2-2). It was infeasible to review all of the thousands of hours of video tape recorded. Therefore we reviewed 5 to 10, 24-hour tapes at the beginning of the run for each species/stock. Results from reviewing video tapes were used to generate a model that predicted total daily counts of fish attempting to enter and entering the trap based on two, two-hour blocks of video. An independent model was developed for summer steelhead and coho salmon. Model equations can be found in stock-specific methods below and a detailed description of the model development for all species can be found in Appendix A. The number of attempts and fallbacks at the trap reviewed in the video tape were expanded with the model to generate an estimated total number of daily trap attempts.

Table 2-2.   Video record used to document trap counts and fish behavior by species/stocks.

Species/Stock	Date of Video Record
Summer steelhead	6/13/2005 – 9/7/2005
	6/13/2006 – 7/29/2006
Coho salmon	9/7/2005 – 12/13/2005
Winter steelhead	12/27/2005 – 01/26/06
Spring Chinook salmon	5/21/06 – 5/25/06

2.2.2   Objective 3 – Estimate the number of adult fish that enter the trap and become captive.

Video of fish at the trap was used to generate counts of trap attempts and fallback. Subtracting the number of the observed fallbacks from the number of observed trap entries provided an estimate of successful trap entries. A video-based trap efficiency estimate for migrating fish, ATE_{mig}, was then determined by dividing the total number of successful entries (C_d) by total attempts (A_d).

A trap efficiency rate will account for different numbers of fish that are capable of entering the trap under different scenarios. For example, trap efficiency rate should be similar if there are 100 or 1000 fish below the trap, whereas the number of successful entries might vary by an order of magnitude. Because we do not know the number of fish waiting to enter into the trap, we defined the trap efficiency rate denominator with the number of observed attempts. It should be noted that this approach cannot differentiate between a single fish attempting to enter the trap 10 times and 10 fish attempting to enter the trap 1 time each. While there are different physiological consequences to these two scenarios (e.g., a single fish may become exhausted after 10 attempts and forego passage), the rate as defined here still provides a measure of how treatment conditions affect trap entry.

The efficiency rate is a proportion that must lie between 0 and 1; therefore a generalized linear model for binomial data was used to analyze the proportions (McCullagh and Nelder 1989). The single predictor variable was the operational condition, Unit 1 On versus Unit 1 Off.

Radiotelemetry data and trap captures also were combined to generate trap efficiency rates. An overall trap efficiency was estimated for each salmonid run, $ATE_{pop\text{-}OFF}$ was specific for the operational treatment of Unit 1 OFF and $ATE_{pop\text{-}ON}$ was specific for the Unit 1 ON. For the calculation of ATE_{pop} the numerator was the total number of fish caught in the trap while the

denominator was the number of fish known to have entered the tailrace (defined as having at least one detection in the 7 zones or captured in trap without detection).

2.2.3 Objective 4 – Determine what (if any) tailrace conditions impede fish movement into the trap.

A minimum of seven distinct operating scenarios can occur at Merwin Dam based on whether or not turbines are operational and knowing that at least one of three turbines is continuously operating. The number of potential scenarios increases exponentially if variable flow rates are added. In addition, other tailrace conditions (tailrace elevation, spill, trap entrance head, trap gate opening dimension) may possibly influence fish behavior and trap efficiency. Given time constraints and migration windows for fish species, controlled testing to evaluate fish behavioral responses to all possible perturbations of tailrace conditions was not logistically feasible.

Given the proximity of Unit 1 to the trap entrance, we conducted controlled tests to determine and compare ATE when Unit 1 was operating (Unit 1 ON) and when it was not operating (Unit 1 OFF). Treatments were applied systematically, to the maximum extent possible, but in several instances high flow conditions or project operation needs took precedent. Consequently, this resulted in modification of the block schedule (Table 2-3).

Table 2-3. Dates of operational treatments for analyses.

Unit 1 Off	Unit 1 On
13 June - 6 September 2005	22 Sept – 24 October 2005
25 October – 1 November 2005	2 November – 21 November 2005
22 November - 13 December 2005	14 December 2005 – 28 February 2006
01 March – 17 May 2006	18 May – 19 May 2006
20 May – 21 May 2006	22 May – 24 May 2006
25 May – 13 June 2006	14 June – 14 July 2006

2.2.3.1 Fish Behavior Comparisons

Fish behavior was documented on video with the optical camera and reviewed to evaluate the effects of operating conditions. A suite of fish behaviors were observed at the trap entrance. These behaviors were categorized into the following four behavioral categories: attempt, failed attempt, entry, or fallback. A description of the behaviors and behavioral categories can be found in the Stock Specific Methods, Section 3.0. When possible these behaviors were enumerated and compared between the Unit 1 OFF and Unit 1 ON treatment. Paired counts of

fish in each behavioral category were used to evaluate behavioral changes in relation to operational treatment.

2.2.3.2 Radiotelemetry Study

A radio-telemetry study was conducted to monitor the behavior of adult fish in the tailrace. Specifically, the main objective of the radiotelemetry study was to compare the distribution and movement of tagged fish in the tailrace under different operating scenarios of Unit 1 ON and OFF. This study involved tagging returning summer steelhead, coho salmon, winter steelhead, and Chinook salmon and monitoring their behavior with fixed radio array in the Project Area. The study began with the radiotagging of steelhead on 16 August 2005 and continued through the tracking of spring Chinook salmon through 14 July 2006 (Table 2-4). Radiotelemetry data collected in the study was assumed to be representative of the corresponding fish populations and used to improve understanding of fish behavior in the tailrace both prior to, and after, fish first located the trap entrance.

Table 2-4.   Radiotelemetry study variables.

Species/Run	Study Window	Number of Fish Tagged	Number of Fish in Analysis
Summer Steelhead	17 Aug 2005 – 17 Oct 2005	97	56
Coho Salmon	31 Oct 2005 – 27 Dec 2005	100	60
Hatchery Winter Steelhead	3 Jan 2006 – 18 Mar 2006	100	61
Wild Winter Steelhead	06 Apr 2006 – 10 June 2006	17	5
Spring Chinook Salmon	12 May 2006-14 July 2006	100	46

We attempted to collect and tag 100 adult fish from each of four species/runs (Table 2-4). Initial attempts to collect naïve summer steelhead by gill netting and hook and line sampling proved ineffective. Thus, experienced fish that had previously negotiated trap location and entry were collected from the Merwin trap. Tagged fish were transported from the Merwin trap and released into the sorting pond at Lewis River hatchery. Approximately 50 fish were sorted into the upper pond. Anaesthetized fish were netted, measured, tagged and immediately returned to water using a fish transport truck. All tags were gastrically implanted. High levels of tag loss were seen after tagging. To help minimize tag loss due to regurgitation, tags for spring Chinook salmon were encased in roughened casing before insertion (Shibihara 2002).

Approximately 100 fish from each stock were tagged with Lotek MCFT-3A coded fish transmitters. These tags were 16 mm in diameter, 41 mm in length and weigh 16 g in air. Tags had burst rates of 1.5 to 2 seconds tag life was estimate at 685 days.

After all fish from a release group were tagged the fish were loaded into a hatchery transport tank and were transported to the Lewis River for release. Tagged fish were released in the pool just below the tailrace. Tagging personnel monitored each release and both regurgitated tags and tag mortalities were collected.

The only exception to this protocol occurred with the first group of summer steelhead. These fish were transported directly from the Merwin trap to the Merwin Boat Ramp. Unanesthetized fish were tagged while held in water in a large cooler fitted with cloth fish cradles. These fish were individually carried in the wet cradle for release immediately after tagging.

Operational treatments were scheduled to begin immediately prior to, or at the time of, release of tagged fish. The duration of the first treatment was determined by the capture of a majority of tagged fish in the trap when possible. Operational constraints overrode the treatment schedule but still every attempt was made to ensure similar duration of operational treatments for each stock.

2.2.3.3 Fixed Array

A total of 7 fixed detections zones were established for this study (Figures 2-1 and 2-2). This included 6 underwater antennae with 5 receivers in the tailrace proper (Zones 1 through 6) and one aerial antenna with a single receiver located downstream of the tailrace (Zone 7). A mobile antenna was used to verify the presence of tagged fish, tags in the trap, and to search for lost or missing tagged fish downstream of the release site.

An aerial antenna was used to create detection Zone 7, the most downstream detection zone (Figure 2-2). Detections in this zone were used to indicate that a tagged fish had entered or exited the Project Area. Five underwater dipole antennas (Grant Engineering Systems) were used to cover the tailrace and to create five distinct detection zones (1 through 5 along the powerhouse and control room walls (Figure 2-2). A sixth underwater antenna, comprised of striped coaxial cable, was used to cover the gallery underneath and behind the powerhouse. The receiver's power and blank levels were adjusted at the time of installation to prevent overlap between detection zones. Dummy tags were then dragged through the zones to verify their boundaries. It was not feasible to complete this exercise between Zone 1 and Zone 3. Instead, radio-telemetry data was reviewed for overlap. If overlap was detected between these two zones, a blank was used to eliminate weak detections in Zone 7 that had stronger simultaneous records in Zone 3.

Zone 6

Powerhouse   **Overhead
Camera
Coverage**

Trap

Zone 5

Zone 4

Zone 1

Zone 2

Zone 3

Access Road Bridge
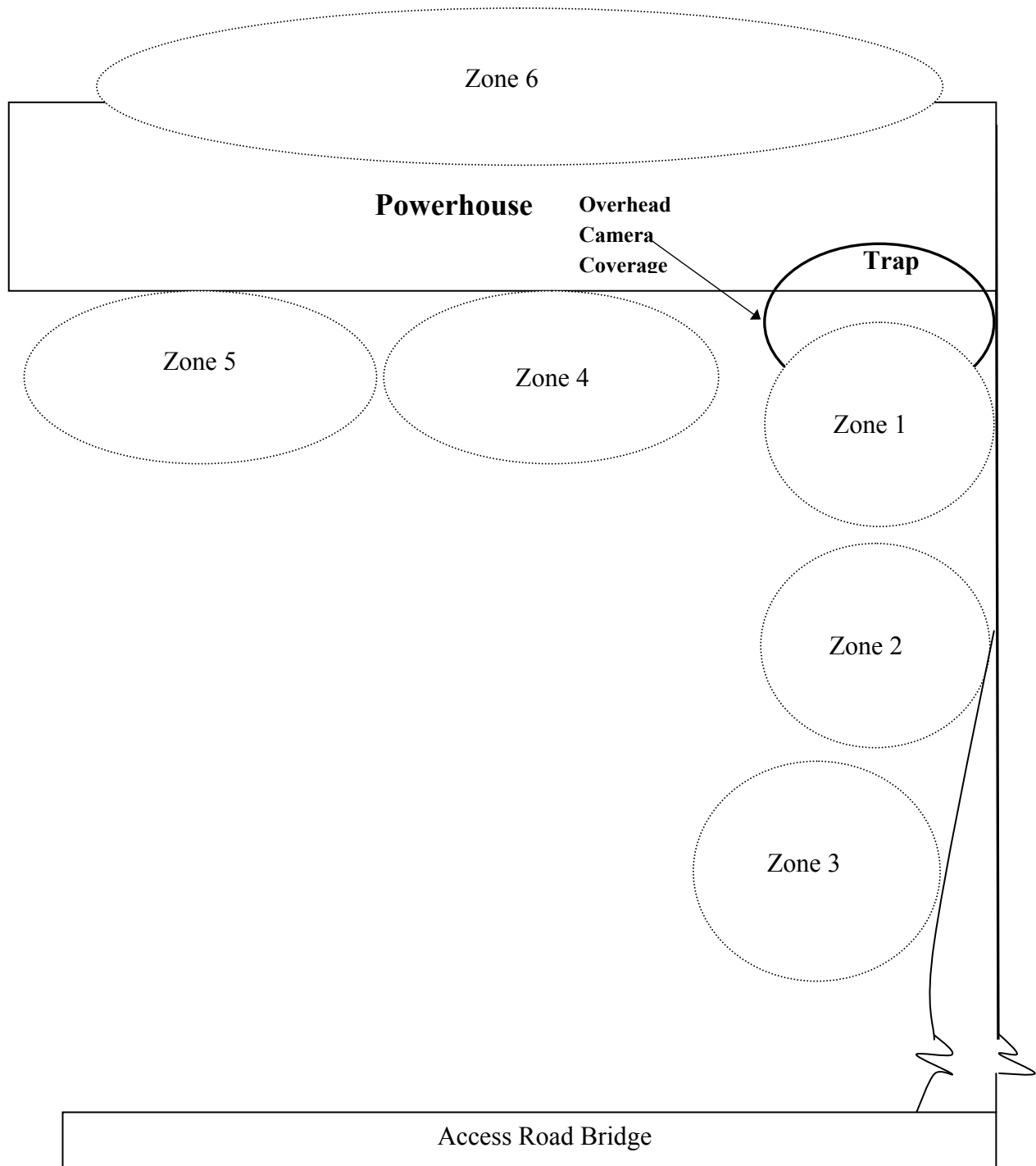
Figure 2-1.   The fixed radio telemetry array proposed to monitor fish
distributions and movements in the tailrace. (Drawing not to scale.)
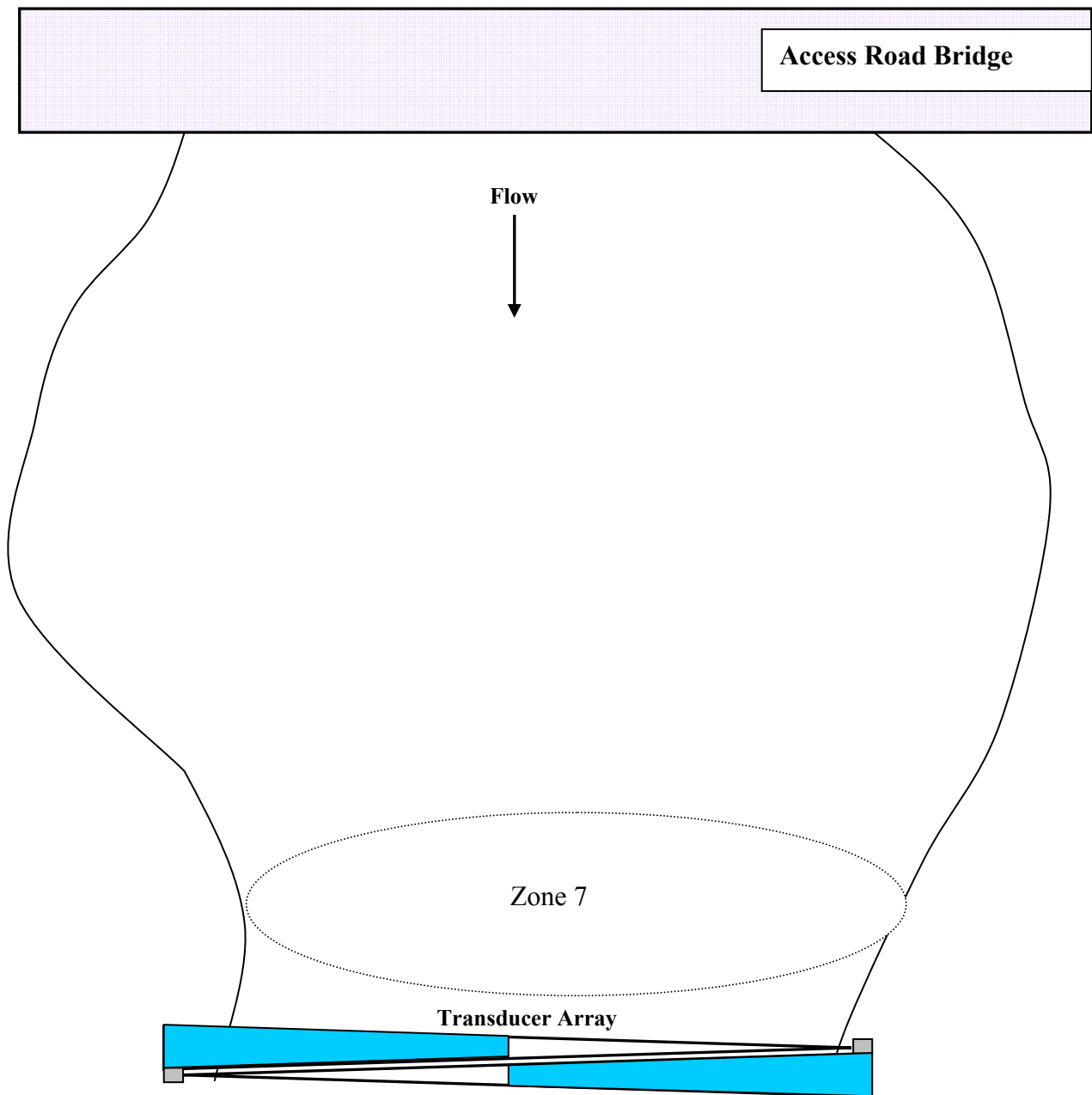
Figure 2-2.　Conceptual plan view of proposed fixed hydroacoustic and radiotelemetry arrays to detect adult salmonids entering the Project Area. (Drawing not to scale.)

2.2.3.4 Treatment Groups

For analysis, fish were classified into treatment groups based on the operating condition that occurred at the time of the initial detection. There were distinct behavioral and operational conditions that occurred during the migration of each stock. Thus the description of treatment groups and how fish were assigned to these groups is described under stock-specific methods.

2.2.3.5 Statistical Analyses

The behavior of each tagged fish was analyzed as it moved through the 7 detection zones in the tailrace. Tagged fish were selected as the unit of replication for the following reasons: 1) individuals with substantially greater numbers of detections would have dominated the analysis if number of detections aggregated across all fish were analyzed; 2) there were individual behavioral differences among fish, and we wanted to incorporate this variability; 3) analysis was completed on the data as it was measured, rather than on an averaged or summed quantity that may have obscured individual fish behavior; and 4) because we analyzed each fish individually, we had additional flexibility about the treatment conditions. Operational changes that resulted in treatments that spanned the duration of initial tagging through capture in the trap were still usable for the analysis.

The analysis of zone transitions focused on the movement in and out of Zone 1, which was adjacent to the trap entrance. Because the 7 zones were set up to be mutually exclusive, a generalized linear model for proportions was used to determine if the proportional use of the zones differed between treatments. The number of contacts in each zone was analyzed using a generalized linear model assuming negative binomial errors. Contacts were used for the temporal unit of measure since each contact represents a unique detection event recorded every 5 to 6 seconds that the fish is located within the detection zone.

We assumed a negative binomial distribution for analysis of the number of contacts. The negative binomial is an extension of the Poisson distribution that accounts for increased variability. For an analysis assuming Poisson or negative binomial distributions, a generalized linear model is used (McCullagh and Nelder 1989). The resulting test, called an analysis of deviance was used to determine if the number of contacts was different between treatment groups. All fish with one transition were removed from the analysis, because these fish were either not present in the array for very long, were unable to be detected, or moved through the array very quickly.

The total number of transitions for each fish was included as a covariate because the total number of transitions varied among fish. Some fish were more inclined to move and be detected within the zones. Therefore, fish with higher total transitions would have been expected to have higher transitions between the zones of interest. The on-off treatment was fit after the total number of transitions (i.e., to the residuals of a regression between number of zone transitions and total transitions) to ensure that the variability attributable to the on-off treatment was unique.

The zone transition analysis should be considered as a method to try to understand patterns in movement. Because the arrays do not exhaustively sample the study area, fish can move between zones without being detected. Furthermore, it is possible for fish to be near or in a zone without being detected, thus the rate of movement may be higher than the transitions that were documented.

2.2.4 Objective 5 – If tailrace conditions preclude trap entry or cause migration delay what locations would be preferred for a new trap entrance?

The radio telemetry data provided information on the total time that tagged fish spent in the Project Area and the total time fish spent in each of the detection zones within the tailrace. The data collected for the different treatment groups also was used to compare time spent in the Project Area under different operating conditions. The hypothesis tested was that total time spent in the radio telemetry array was not significantly different for fish in OFF and ON treatment groups. The total time in the tailrace (in hours) was calculated for each fish by calculating the time between last and first detection and then subtracting from that any 24-hour period where the fish was not detected in any of the tailrace detection zones. Total time was then compared under OFF and ON treatments using analysis of variance (ANOVA).

The time individual fish spent in each tailrace detection zone was tallied for the different treatment groups and used to compare distributions of tailrace habitats used by tagged fish. Similar to the time in distinct detection zones, the number of contacts between radio-receivers and tagged fish (unique signal detections recorded every 5 to 6 seconds) was used as a measure of time in these analyses. The hypotheses tested were that distributions of time spent in detection zones were not significantly different for treatment groups Unit 1 ON and Unit 1 OFF. The time individual steelhead spent in each zone was calculated for fish in different treatment groups and used to generate distributions of habitat use within the tailrace for each fish. The number of contacts was modeled as a negative binomial random variable. The total number of contacts was also included as a covariate, because the total number of contacts varied among fish.

In addition, we summed the number of zone transitions, movements from one detection zone to the next, to assess individual fish movement and compared these counts under the different operating scenarios. The distribution of zone transitions was compared between treatment groups. The hypothesis tested was that transition count distributions were not significantly different for treatment groups Unit 1 ON and Unit 1 OFF. These data were summarized for OFF and ON treatments to account for behavioral changes associated with project operations that might suggest alternative locations that increase the probability of fish encountering the trap.

3. STOCK SPECIFIC METHODS

3.1 SUMMER STEELHEAD

3.1.1 Deviation from the Study Plan

The application of the operational treatment, OFF/ON SPLIT, was scheduled to accommodate the movements of radio-tagged steelhead. For summer steelhead, the radio tag study occurred in the later part of the run and the Unit 1 ON treatment was the second treatment, so the start date for that treatment was determined by the returns from the first steelhead release. Dates for the video analysis were determined by dates when the target species represented the largest proportion of the trap catch based on trap records. By the time Unit 1 ON was applied for the summer steelhead tag study, relatively few steelhead were being collected in the trap as compared to coho salmon. Thus, we delayed the video comparative analysis for summer steelhead until spring 2006. The available data on the behavior of summer steelhead entering and/or attempting trap entry in 2006 were summarized to describe fish behavior when Unit 1 was not operating.

3.1.2 Summer Steelhead Daily Catch

Due to time required to review video tapes and project schedule, it was infeasible to review all 3528 hours of summer steelhead video. Instead, we reviewed 10 days of video tape and used the results of that review to select the best daily two two-hour blocks of video from each 24 hour period to estimate the total number of fish that entered the trap. Counts of fish in the trap were only available on certain days because the trap was not checked on the weekends or holidays. After evaluating the days on which video tapes were viewed and days in which a daily trap count was observed, there were 5, 24-hour videos that could be used to compare the video catch to the trap catch. Some hours were not observed in all 5 days due to trap operations or fogging of the camera lens. These hours were not used in the analysis because counts could not reliably be derived from these video periods. A total of 104 hours of video tape observations between 13 June 2005 and 13 July 2005 were used to generate the steelhead model. The steelhead model was then refined by viewing pre-determined time blocks of video tape that equaled an additional 40 hours of tape recorded over five days. A generalized linear model assuming Poisson errors (typical for count data) was fit to the trap count data. The predictor variables in the model were two of the 16 possible observations blocks. The model was:

Trap Count = f(Observation$_i$, Observation$_j$), where i = 1….16 and j = 1….16, i $\neq$ j.

We fit the model for all possible two-way combinations of the 16 observation blocks and used information criterion (Akaike's Information Criteria) to determine which two observations fit the trap count data the best.

The model to predict the number of trap counts was:

Predicted = exp {4.50+ 0.153*(# counted from 4:00-6:00) + 0.016*(# counted from 14:00-16:00)}.

The mean estimate and standard errors of the coefficients are:

Parameter	Value	SE
(Intercept)	4.50	0.074
Hours 4:00 & 5:00	-0.003	0.0128
Hours 14:00 & 15:00	0.0159	0.0027

3.1.3 Summer Steelhead Video Observations

From 13 June through 7 September 2005, we video recorded approximately 2,000 hours of summer steelhead behavior at the trap. The time frames were selected for the summer steelhead analysis because trap catch data indicated that summer steelhead dominated the trap catch during these periods. Behavioral categories used to describe steelhead behavior are defined in Table 3-1.

Table 3-1.   Descriptions of steelhead behaviors observed at the trap entrance.

Behavioral Category	Behavior	Description
Exploratory Approaches	Roll	A fish observed in front of the trap with a portion of its body out of water but not jumping into the trap.
	Early Jump	When a fish jumps from the tailrace into the wave below the trap entrance and upon contact immediately falls back into the tailrace.
Trap Attempts	Hit	When a fish jumps from the tailrace and strikes the cement wall surrounding the trap entrance.
	Corner	When a fish displays directional movement toward a corner area on either side of the trap entrance.
	Surf/Velocity	When a fish swims into the wave face and either briefly holds a stationary position on the wave or swims horizontally along the wave face but is unable to swim into the trap entrance.
	Entry	When a fish swims into the entrance of the trap and is captured by the weir.
	Fall back	When a fish swims into the entrance of the trap but is not captured by the weir and instead drops back into the tailrace.

For summer steelhead, these behavior data were used to evaluate the overall success of tagged fish at entering the trap. The trap efficiency rate was defined as the number of successful entries divided by the number of attempts at trap entry. The total number of attempts was calculated as the sum of behaviors in the attempt category. The number of successful attempts was calculated as the number of Entries minus Fallback. It is important to note that during summer steelhead and coho salmon testing, fish from both Unit 1 ON and OFF/ON Split treatment groups were captured in the trap during Unit 1 operation and thus were combined with Unit 1 ON trap catch for this analysis.

In order to compare behaviors between treatments, additional summer steelhead video was reviewed in late spring/early summer 2006. The number of hours available for review was limited by the dates when summer steelhead comprised more than 75 percent of the trap catch and dates when high quality video was not compromised (high flow events in the spring 2006 resulted in moisture entering the camera and compromising video quality during the spring migration). Approximately 43 hours of summer steelhead was reviewed. Behavioral categories used to describe summer steelhead behavior were the same as for coho salmon and were defined in Table 3-5.

For summer steelhead, 2006 behavioral data were used to evaluate the overall success of tagged fish at entering the trap and for comparing trap entry success and behavior between treatments. The trap efficiency rate was defined as the number of successful entries divided by the number of attempts at trap entry. The total number of attempts was calculated as the sum of behaviors in the attempt category. The number of successful attempts was calculated as the number of Entries minus Fallback.

3.1.4 Summer Steelhead Radio Telemetry

A total of 97 summer steelhead were collected and tagged (Table 3-2). Fifty were tagged on the 16 and 17 August 2006 and 47 were tagged on 22 September 2006. There were three different fish scenarios that occurred during summer steelhead tracking that affected the determination of treatment groups. In the first scenario, fish initially entered the Project Area under the same operational condition (Unit 1 OFF, Unit 1 On) as released and never left the tailrace, or left but returned under the same operational condition. These fish were placed into the same treatment group as their release. In the second scenario, fish from the first release group entered the project area under the alternative treatment condition (as compared to the time of their release) and thus, were placed into the alternative treatment group (Unit 1 ON). A third scenario occurred where three fish from the first release group entered the tailrace and remained in the

Table 3-2. A summary of radio-tagged summer steelhead released downstream of the Merwin Dam tailrace.

Tag Number	Release Group	Date Tagged
10	1	16 Aug 2005
11	1	16 Aug 2005
12	1	16 Aug 2005
13	1	16 Aug 2005
14	1	16 Aug 2005
15	1	16 Aug 2005
16	1	16 Aug 2005
17	1	17 Aug 2005
18	1	17 Aug 2005
19	1	17 Aug 2005
20	1	17 Aug 2005
21	1	17 Aug 2005
22	1	16 Aug 2005
23	2	22 Sep 2005
24	2	22 Sep 2005
25	2	22 Sep 2005
26	2	22 Sep 2005
27	2	22 Sep 2005
29	2	22 Sep 2005
30	2	22 Sep 2005
32	2	22 Sep 2005
33	2	22 Sep 2005
34	2	22 Sep 2005
35A	1	16 Aug 2005
35B	2	22 Sep 2005
36	1	16 Aug 2005
37	1	16 Aug 2005
38	1	16 Aug 2005
39	1	16 Aug 2005
40	1	16 Aug 2005
41	1	17 Aug 2005
42	1	17 Aug 2005
43	1	17 Aug 2005
44	1	17 Aug 2005
45	1	17 Aug 2005
46	1	17 Aug 2005
47	1	17 Aug 2005

Table 3-2. A summary of radio-tagged summer steelhead released downstream of the Merwin Dam
tailrace.

Tag Number	Release Group	Date Tagged
48	2	22-Sep-05
49	2	22-Sep-05
50	2	22-Sep-05
51	2	22 Sep 2005
52	2	22 Sep 2005
53	2	22 Sep 2005
54	2	22 Sep 2005
55	2	22 Sep 2005
56	2	22 Sep 2005
57	2	22 Sep 2005
58	2	22 Sep 2005
59	2	22 Sep 2005
60	1	16 Aug 2005
61	1	16 Aug 2005
62	1	16 Aug 2005
63	1	16 Aug 2005
64	1	16 Aug 2005
65	1	16 Aug 2005
66	1	17 Aug 2005
67	1	17 Aug 2005
68	1	17 Aug 2005
69	1	17 Aug 2005
70	1	17 Aug 2005
71	1	17 Aug 2005
72	2	22 Sep 2005
73	2	22 Sep 2005
74	2	22 Sep 2005
75	2	22 Sep 2005
76	2	22 Sep 2005
77	2	22 Sep 2005
78	2	22 Sep 2005
79	2	22 Sep 2005
80	2	22 Sep 2005
82	2	22 Sep 2005
83	2	22 Sep 2005
84	2	22 Sep 2005
85	1	16 Aug 2005
86	1	16 Aug 2005

Table 3-2. A summary of radio-tagged summer steelhead released downstream of the Merwin Dam
tailrace.

Tag Number	Release Group	Date Tagged
87	1	16 Aug 2005
88	1	16 Aug 2005
89	1	16 Aug 2005
90	1	16 Aug 2005
91	1	17 Aug 2005
92	1	17 Aug 2005
93	1	17 Aug 2005
94	1	17 Aug 2005
95	1	17 Aug 2005
96	1	17 Aug 2005
97	2	22 Sep 2005
98	2	22 Sep 2005
100	2	22 Sep 2005
101	2	22 Sep 2005
102	2	22 Sep 2005
103	2	22 Sep 2005
104	2	22 Sep 2005
105	2	22 Sep 2005
106	2	22 Sep 2005
107	2	22 Sep 2005
108	2	22 Sep 2005
109	2	22 Sep 2005

tailrace when operational conditions changed to Unit 1 ON. As a result, these fish were
categorized into a distinct treatment group OFF/ON Split. A total of 56 tagged summer
steelhead were used in the analysis and were classified into three distinct treatment groups, Unit
1 OFF, Unit 1ON, and OFF/ON Split for analysis. Twenty-six fish were categorized in the OFF
treatment and 27 fish were categorized into the ON treatment. Three fish split their time in the
array between the OFF and ON treatments. Given that this treatment group contained only three
fish no statistical analyses were completed. Instead we used descriptive and graphical analyses
to compare the behavior of these fish under different operational scenarios.

For summer steelhead the radiotelemetry records from the aerial array were filtered to eliminate
signals with power less than 80. This provided a clear separation for detections in between
Zones 3 and 7. The blanked aerial data was applied to analyses of fish distributions within the
tailrace.

3.1.5 Performance of the Radio Telemetry Array

During the course of the summer steelhead study there were windows of time when fish movement data was unavailable for several detection zones and certain times (Table 3-3). In addition, due to the high number of tags in the study area at any one time there were numerous records where radio receivers were detecting multiple tags of the same radio signal (frequency and pulse rate) but were unable to determine the tag code (i.e., "tag collision"). There were 2,451 tag collisions that occurred during the study with 81% occurring in Zone 7, the largest detection zone covered by the aerial antenna. After accounting for the anomalies in the data set there remained more than 6,800 records and 192,800 distinct signal detections of tagged steelhead that were recorded by the radio telemetry array during the 8 week window for steelhead. All data comparisons for the treatment groups were completed with these 6,800 data records.

Table 3-3.   Data file summary by detection zone for summer steelhead radio tracking. √ = data, N = no data.

Download Date	Detection Zone						
	1	2	3	4	5	6	YAGI
8/30/2005	√	√	√	√	ND[a]	√	√
9/7/2005	√	√	√	√	√	√	ND[a]
9/20/2005	√	√	√	√	√	√	ND[b]
9/28/2005	√	√	√	√	√	√	√
10/4/2005	√	√	√	√	√	√	√
10/11/2005	√	√	√	√	√	√	√
10/18/2005	√	√	√	√	√	√	√
10/26/2005	√	√	√	√	√	√	√
10/31/2005	√	√	√	√	√	√	√

[a] indicates receiver download error

[b] indicates corrupted data file

3.2 COHO SALMON

3.2.1 Deviation from the Study Plan

The proposed schedule for implementing operational treatments, Unit 1 OFF/ON, was planned to accommodate the movements of radio tagged coho salmon. Due to operational requirements,

however, we were unable to assign continuous temporal treatment blocks for the release groups. Consequently, this resulted in 2 operational intervals for Unit 1 OFF and 2 intervals for Unit 1 ON for each release group (Table 3-4).

Table 3-4.   Summary of treatment dates for the coho salmon radio-tracking study.

Treatment	Start Date	End Date
Unit 1 OFF	10/31/2005	11/01/2005
Unit 1 OFF	11/22/2005	12/13/2005
Unit 1 ON	11/02/2005	11/21/2005
Unit 1 ON	12/14/2005	12/31/2005

3.2.2 Coho Salmon Daily Trap Counts

It was infeasible to review all 1,700 hours of coho salmon video due to time and schedule constraints. Instead, we reviewed 10 days of tapes and generated a model to predict the best two two-hour blocks for viewing. Counts of fish from the trap were used to indicate the best hours to view the tapes. Counts of fish in the trap were only available on certain days because the trap was not checked on the weekends or holidays. After evaluating the days on which video tapes were viewed and days in which a daily trap count was observed, there were 4, 24-hour videos that could be used to compare the video catch to the trap catch. Thus a total of 96 hours of video counts observed between 07 Sep 2005 and 30 Sep 2005 were used to generate the coho salmon model. An additional 55 hours of viewing pre-determined time blocks (02:00:00 – 07:00:00 and 11:00:00 – 16:00:00) of video tape was used to define the coho salmon model. A generalized linear model assuming Poisson errors (typical for count data) was fit to the trap count data. The predictor variables in the model were two of the 16 possible observations blocks. The model was:

Trap Count = f(Observation$_i$, Observation$_j$), where I = 1….16 and j = 1….16, I $\neq$ j.

We fit the model for all possible two-way combinations of the 16 observation blocks and used information criterion (Akaike's Information Criteria) to determine which two observations fit the trap count data the best.

The model to predict the number of trap counts was:

Predicted = exp {4.15 + 0.016*(# counted from 2:00-4:00) + 0.022*(# counted from 11:00-13:00)}.

The mean estimate and standard errors of the coefficients are:

Parameter	Value	SE
(Intercept)	4.15	0.0756
Hours 11:00 & 13:00	-0.0222	0.0014
Hours 02:00 & 04:00	0.0166	0.0024

3.2.3 Coho Salmon Video Observations

From 7 September through 9 December 2005 we recorded approximately 1700 hours of coho salmon behavior at the trap. This time frame was selected for the coho salmon analysis because trap catch data indicated that coho salmon dominated the trap catch during this period. Video footage of the trap entrance was not recorded for approximately three weeks during this period due to equipment failure. Behavioral categories used to describe coho salmon behavior were defined in Table 3-5. Video observations of coho salmon differed from steelhead in that behaviors included in the early jumps category for steelhead were exploratory but for coho salmon jump attempts at entering the trap were categorized as early jumps.

Table 3-5.   Descriptions of coho salmon behaviors observed at the trap entrance.

Behavioral Category	Behavior	Description
Exploratory Approaches	Roll	A fish observed in front of the trap with a portion of its body out of water but not jumping into the trap.
Trap Attempts	Early Jump	When a fish jumps from the tailrace into the wave below the trap entrance and upon contact immediately falls back into the tailrace.
	Hit	When a fish jumps from the tailrace and strikes the cement wall surrounding the trap entrance.
	Corner	When a fish displays directional movement toward a corner area on either side of the trap entrance.
	Surf/Velocity	When a fish swims into the wave face and either briefly holds a stationary position on the wave or swims horizontally along the wave face but is unable to swim into the trap entrance.
	Entry	When a fish swims into the entrance of the trap and is captured by the weir.
Fall back	Fall back	When a fish swims into the entrance of the trap but is not captured by the weir and instead drops back into the tailrace.

For coho salmon, behavioral data were used to evaluate the overall success of tagged fish at entering the trap and for comparing trap entry success and behavior between treatments. The trap efficiency rate was defined as the number of successful entries divided by the number of attempts at trap entry. The total number of attempts was calculated as the sum of behaviors in the attempt category. The number of successful attempts was calculated as the number of Entries minus Fallback.

3.2.4 Coho Salmon Radio Telemetry

A total of 100 coho salmon were collected and tagged (Table 3-6). Fifty fish were tagged on 31 October 2005 and 50 were tagged on 29 November 2005. A total of 60 tagged coho salmon were detected by the array and used in the analysis. Thirty-six fish were categorized in the OFF treatment and 17 fish were categorized in the ON treatment. Seven fish split their time in the array between the OFF and ON treatments. Data on SPLIT fish were included for descriptive purposes but were not used in the analysis.

Similar to summer steelhead, there were three different treatment scenarios that occurred during the coho salmon tracking that influenced treatment group categories. In the first scenario initial entry into the Project Area occurred under the same operational condition (Unit 1 OFF, Unit 1 On) as their release and remained in the tailrace, or exited but returned under the same operational condition. Fish under this scenario were placed into the same treatment group as their release. In the second scenario, fish from the first release group entered the project area under the alternative treatment condition (as compared to the time of their release) and thus placed into the alternative treatment group (Unit 1 ON or OFF). A third scenario occurred when two fish entered the tailrace under Unit 1 OFF and remained in the tailrace through Unit 1 ON and therefore were classified as OFF/ON splits. A fourth scenario involved five fish that entered the tailrace under Unit 1 ON and remained through Unit 1 OFF and were classified as ON/OFF splits. Because the split treatment group contained only seven fish, no statistical analyses were completed. Instead we used descriptive and graphical analyses to compare the behavior of these fish under different operational scenarios.

Table 3-6.   A summary of radio-tagged coho salmon released downstream of the Merwin Dam
tailrace.

Tag Number	Release Group	Date Tagged
60	1	31 Oct 2005
61	1	31 Oct 2005
62	1	31 Oct 2005
63	1	31 Oct 2005
64	1	31 Oct 2005
65	1	31 Oct 2005
66	1	31 Oct 2005
67	1	31 Oct 2005
68	1	31 Oct 2005
69	1	31 Oct 2005
70	1	31 Oct 2005
71	1	31 Oct 2005
72	1	31 Oct 2005
73	1	31 Oct 2005
74	1	31 Oct 2005
75	1	31 Oct 2005
76	1	31 Oct 2005
77	1	31 Oct 2005
78	1	31 Oct 2005
79	1	31 Oct 2005
80	1	31 Oct 2005
81	1	31 Oct 2005
82	1	31 Oct 2005
83	1	31 Oct 2005
84	1	31 Oct 2005
85	2	29 Nov 2005
86	2	29 Nov 2005
87	2	29 Nov 2005
88	2	29 Nov 2005
89	2	29 Nov 2005
90	2	29 Nov 2005
91	2	29 Nov 2005
92	2	29 Nov 2005
93	2	29 Nov 2005
94	2	29 Nov 2005
95	2	29 Nov 2005
96	2	29 Nov 2005
97	2	29 Nov 2005
98	2	29 Nov 2005

Table 3-6.   A summary of radio-tagged coho salmon released downstream of the Merwin Dam
tailrace.

Tag Number	Release Group	Date Tagged
99	2	29 Nov 2005
100	2	29 Nov 2005
101	2	29 Nov 2005
102	2	29 Nov 2005
103	2	29 Nov 2005
104	2	29 Nov 2005
105A	2	29 Nov 2005
105B	2	29 Nov 2005
106A	2	29 Nov 2005
106B	2	29 Nov 2005
107A	2	29 Nov 2005
107B	2	29 Nov 2005
108A	2	29 Nov 2005
108B	2	29 Nov 2005
109A	1	31 Oct 2005
109B	2	29 Nov 2005
109C	2	29 Nov 2005
110A	1	31 Oct 2005
110C	2	29 Nov 2005
111	1	31 Oct 2005
112	1	31 Oct 2005
113	1	31 Oct 2005
114	1	31 Oct 2005
115	1	31 Oct 2005
116	1	31 Oct 2005
117	1	31 Oct 2005
118	1	31 Oct 2005
119	1	31 Oct 2005
120	1	31 Oct 2005
121	1	31 Oct 2005
122	1	31 Oct 2005
123	1	31 Oct 2005
124	1	31 Oct 2005
125	1	31 Oct 2005
126	1	31 Oct 2005
127	1	31 Oct 2005
128	1	31 Oct 2005
129	1	31 Oct 2005
130	1	31 Oct 2005
131	1	31 Oct 2005

Table 3-6.   A summary of radio-tagged coho salmon released downstream of the Merwin Dam
             tailrace.

Tag Number	Release Group	Date Tagged
132	1	31 Oct 2005
133	1	31 Oct 2005
136	2	29 Nov 2005
137	2	29 Nov 2005
138	2	29 Nov 2005
139	2	29 Nov 2005
140	2	29 Nov 2005
141	2	29 Nov 2005
142	2	29 Nov 2005
143	2	29 Nov 2005
144	2	29 Nov 2005
145	2	29 Nov 2005
146	2	29 Nov 2005
147	2	29 Nov 2005
148	2	29 Nov 2005
149	2	29 Nov 2005
150	2	29 Nov 2005
151	2	29 Nov 2005
152	2	29 Nov 2005
153	2	29 Nov 2005
154	2	29 Nov 2005

3.2.5 Performance of the Radio Telemetry Array

During the course of the coho salmon study the signal detection by the radio telemetry array was
compromised or data was lost due to mechanical failure and human error. As a result, there were
periods of time when data was unavailable on fish movement for several detection zones at
certain times (Table 3-7). In addition, due to the high number of tags in the study area at any one
time there were detection events where radio a receiver was detecting multiple tags with the
same radio signal (frequency and pulse rate) but was unable to determine the tag code. This
number of tag collisions was substantially reduced for coho salmon compared to summer
steelhead. There were 278 tag collisions that occurred during the coho salmon radio telemetry
study. Of the 278 tag collisions, 68% occurred in Zone 7, the largest detection zone covered by
the aerial antenna. After accounting for the anomalies in the data set, there remained more than
4,922 records and 25,475 distinct signal detections of tagged coho salmon recorded by the radio
telemetry array during the 8 week coho salmon study. All data comparisons for the treatment
groups were completed with these 4,922 clean data records.

Table 3-7.   Data file summary by detection zone for coho salmon radio tracking. √ = data, N = no data.

Download Date	1	2	3	4	5	6	YAGI
			Detection Zone				
10/31/2005	√	√	√	√	√	√	√
11/3/2005	ND[a]	ND[a]	ND[a]	ND[a]	ND[a]	ND[a]	ND[a]
11/10/05	√	√	√	√	√	√	√
11/17/05	√	√	√	√	√	√	√
11/22/05	ND[b]	√	√	√	√	√	√
11/29/05	√	√	√	√	√	√	√
12/09/05	√	√	√	√	√	√	√
12/14/05	√	√	√	√	√	√	√
12/22/05	√	√	√	√	√	√	√
1/3/06	√	√	√	√	√	√	√

[a] indicates receiver or down load error

[b] indicates no messages displayed in data file, indicating corrupted file?

3.3 WINTER STEELHEAD

3.3.1 Deviation from the Study Plan

The proposed schedule for implementation of the operational treatment, Unit 1 OFF/ON, was scheduled to accommodate the movements of radio tagged hatchery winter steelhead. Due to very high seasonal flows, power demands, and operational requirements, Unit 1 ON treatment was operated continuously through the first and second release groups and by the time the Unit 1 OFF treatment was applied, relatively few steelhead could be assigned to the Unit 1 OFF treatment. To try and gain additional data, a small group of wild steelhead were tagged, released, and assigned to a Unit 1 OFF treatment group (Table 3-8).

Spill that occurred during the winter steelhead run also compromised the image of the video camera installed at the Merwin trap. Large scale spilling (12,000 cfs) was initiated on 06 January 2006 and extended through 19 January 2006. As a result, the quality of the video footage was poor from January 9 through February when the camera could be removed and serviced. Consequently, the majority of the winter steelhead run passed the dam before the Unit

1 Off treatment could be applied. Thus, the video analysis portion of the winter steelhead study could not be completed.

Table 3-8.   Summary of treatment dates for the winter steelhead radio-tracking study.

Release Group	Number Released	Treatment	Start Date	End Date
01/03/06	50	Unit 1 ON	01/03/06	02/28/06
01/26/06	50	Unit 1 ON	01/03/06	02/28/06
04/06/06	4	Unit 1 OFF	03/01/06	05/17/06
04/19/06	4	Unit 1 OFF	03/01/06	05/17/06
04/28/06	9	Unit 1 OFF	03/01/06	05/17/06

3.3.2 Winter Steelhead Daily Catch

This objective could not be completed due to mechanical failure of the video camera installed above Merwin Trap.

3.3.3 Steelhead Video Observations

This objective could not be completed due to mechanical failure of the video camera installed above Merwin Trap.

3.3.4 Winter Steelhead Radio Telemetry

A total of 100 hatchery winter steelhead were collected and tagged (Table 3-9). Fifty fish were tagged on the 03 January 2006 and 50 were tagged on 26 January 2006. A total of 60-tagged winter steelhead were detected by the array and used in the analysis. Three fish were categorized in the OFF treatment and 58 fish were categorized in the ON treatment.

Because the Unit 1 ON treatment was applied through most of the winter steelhead study, an additional 17 wild steelhead (a third group) were released after Unit 1 changed to an OFF treatment. A total of 2 tagged wild winter steelhead were detected by the array. However, limited data was collected on the wild winter steelhead because only one fish was detected on multiple days and zones. Given the small number of tagged wild winter steelhead that entered the tailrace, no comparative analyses were done and we have presented this data graphically and in tabular form along with the hatchery steelhead data.

Table 3-9.   A summary of radio-tagged winter steelhead released downstream of the Merwin Dam
             tailrace. Asterisk indicates wild winter steelhead.

Tag Number	Release Group	Date Tagged
28*	3	06 May 2006
29*	4	19 May 2006
31*	3	19 May 2006
41*	5	28 May 2006
48*	3	06 May 2006
57*	4	19 May 2006
60*	5	28 May 2006
87*	5	28 May 2006
94*	5	28 May 2006
99*	3	06 May 2006
101*	5	28 May 2006
105*	3	06 May 2006
110	1	03 Jan 2006
111	1	03 Jan 2006
112	1	03 Jan 2006
112*	4	19 May 2006
113	1	03 Jan 2006
114	1	03 Jan 2006
115	1	03 Jan 2006
116	1	03 Jan 2006
117	1	03 Jan 2006
118	1	03 Jan 2006
119	1	03 Jan 2006
120	1	03 Jan 2006
121	1	03 Jan 2006
122	1	03 Jan 2006
123	1	03 Jan 2006
123*	5	28 May 2006
124	1	03 Jan 2006
125	1	03 Jan 2006
126	1	03 Jan 2006
127	1	03 Jan 2006
128	1	10 Jan 2006
129	1	03 Jan 2006
130	1	10 Jan 2006
131	1	03 Jan 2006
132	1	03 Jan 2006
133	1	03 Jan 2006
134	1	10 Jan 2006
135	2	26 Jan 2006

Table 3-9. A summary of radio-tagged winter steelhead released downstream of the Merwin Dam tailrace. Asterisk indicates wild winter steelhead.

Tag Number	Release Group	Date Tagged
136	2	26 Jan 2006
137	2	26 Jan 2006
138	2	26 Jan 2006
138*	5	28 May 2006
139	2	26 Jan 2006
140	2	26 Jan 2006
141	2	26 Jan 2006
142	2	26 Jan 2006
143	2	26 Jan 2006
144	2	26 Jan 2006
145	2	26 Jan 2006
146	2	26 Jan 2006
147	2	26 Jan 2006
148	2	26 Jan 2006
149	2	26 Jan 2006
150	1	03 Jan 2006
151	2	26 Jan 2006
152	2	26 Jan 2006
153	2	26 Jan 2006
153*	5	28 May 2006
154	2	26 Jan 2006
155A	1	03 Jan 2006
155B	2	26 Jan 2006
156A	1	03 Jan 2006
156B	2	26 Jan 2006
157A	1	03 Jan 2006
157B	2	26 Jan 2006
157*	5	28 May 2006
158A	1	03 Jan 2006
158B	2	26 Jan 2006
159A	1	03 Jan 2006
159B	2	26 Jan 2006
160	1	03 Jan 2006
161	1	03 Jan 2006
162	1	10 Jan 2006
163	1	10 Jan 2006
164	1	03 Jan 2006
165	1	03 Jan 2006
166	1	03 Jan 2006
167	1	03 Jan 2006

Table 3-9. A summary of radio-tagged winter steelhead released downstream of the Merwin Dam tailrace. Asterisk indicates wild winter steelhead.

Tag Number	Release Group	Date Tagged
168	1	03 Jan 2006
169	1	03 Jan 2006
170	1	03 Jan 2006
171	1	10 Jan 2006
172	1	03 Jan 2006
173	1	10 Jan 2006
174	1	03 Jan 2006
175	1	03 Jan 2006
176	1	03 Jan 2006
177	1	03 Jan 2006
178	1	03 Jan 2006
179	2	26 Jan 2006
180	2	26 Jan 2006
181	2	26 Jan 2006
182	2	26 Jan 2006
183	2	26 Jan 2006
184	2	26 Jan 2006
185	2	26 Jan 2006
186	2	26 Jan 2006
187	2	26 Jan 2006
188	2	26 Jan 2006
189	2	26 Jan 2006
190	2	26 Jan 2006
191	2	26 Jan 2006
192	2	26 Jan 2006
193	2	26 Jan 2006
194	2	26 Jan 2006
195	2	26 Jan 2006
196	2	26 Jan 2006
197	2	26 Jan 2006
198	2	26 Jan 2006
199	2	26 Jan 2006
200	2	26 Jan 2006
201	2	26 Jan 2006
202	2	26 Jan 2006
203	2	26 Jan 2006
204	2	26 Jan 2006

Unlike summer steelhead and coho salmon, there were only two treatment scenarios that occurred during the hatchery winter steelhead radio tracking study. In the first scenario, initial entry into the Project Area occurred under the same operational condition (Unit 1 ON) as their release and remained in the tailrace, or exited but returned under the same operational condition. Fish under this scenario were placed into the same treatment group as their release. In the second scenario, fish from the first and second release groups entered the project area under the alternative treatment condition (as compared to the time of their release) and thus placed into the alternative treatment group (Unit 1 OFF). Because the Unit 1 ON treatment dominated the operational schedule during the study, 57 of the 60 tagged hatchery steelhead that entered the array were assigned to the Unit 1 ON treatment group. Given that the Unit 1 OFF treatment group contained only three fish no statistical analyses were completed. Instead we used descriptive and graphical analyses to compare the behavior of these fish under different operational scenarios.

3.3.5 Performance of the Radio Telemetry Array

During the course of the hatchery winter steelhead study signal detection was compromised or data was lost due to mechanical failure and human error. As a result, there were periods of time when data was unavailable on fish movement for several detection zones at certain times (Table 3-10). In addition, due to the high number of tags in the study area at any one time there were times where a radio receiver was detecting multiple tags with the same radio signal (frequency and pulse rate) but was unable to determine the tag code. The number of tag collisions was low for hatchery winter steelhead as compared to summer steelhead. There were 365 tag collisions that occurred during the hatchery winter steelhead radio telemetry study. Of the 365 tag collisions, 86% occurred in Zones 6 and 7. After accounting for the anomalies in the data set, there remained 2,302 records and 17,907 distinct signal detections of tagged hatchery winter steelhead recorded by the radio telemetry array during the 8-week hatchery winter steelhead study. All data comparisons for the treatment groups were completed with these 2,339 clean data records.

Table 3-10. Data file summary by detection zone for hatchery winter steelhead radio tracking. √ = data available, ND = no data.

Download Date	Detection Zone						
	1	**2**	**3**	**4**	**5**	**6**	**YAGI**
1/3/06	√	√	√	√	√	√	√
1/12/06	√	√	√	√	√	√	√
1/19/06	√	√	√	√	√	√	√
1/26/06	√	√	√	√	√	√	√
02/02/06	ND[a]	ND[a]	ND[a]	√	√	ND[a]	ND[a]
02/09/06	√	√	√	ND[a]	ND[a]	√	√
02/23/06	√	√	√	√	√	√	ND[b]
03/02/06	√	√	√	√	√	√	√
03/09/06	√	√	√	√	√	√	√
03/17/06	√	√	√	√	√	√	√
03/24/06	√	√	√	√	√	√	√

[a] indicates receiver download error

[b] indicates corrupted file

3.4 CHINOOK SALMON

3.4.1 Deviations from the Study Plan

Operational requirements precluded having continuous operational treatments for spring Chinook salmon release groups. Instead, the operation of Unit 1 changed 8 times over the duration of the Chinook salmon radio tag study and resulted in 4 Unit 1 OFF operational treatment intervals and 4 Unit 1 ON operational treatment intervals (Table 3-11). Records from the distinct treatment windows were combined for analysis.

The multiple changes in treatment resulted in complications when assigning treatment groups since a fish that entered the tailrace under one treatment may have experienced changes in treatment conditions prior to leaving the tailrace. To account for this variability in treatment exposure we assigned the Chinook salmon to treatment by considering both the treatment at the time of first detection and the treatment at the time of trap capture or last detection if not captured in the trap. Thus, a fish that entered under UNIT 1 OFF and was last detected under UNIT 1 OFF was an OFF fish even if it experienced UNIT 1 ON conditions during its time in

the tailrace. Similar to other species fish that entered the tailrace under one treatment and left under the other we classified as SPLIT fish.

Based on previous year's catch records at the Merwin trap, we did not anticipate that Chinook salmon would comprise more than 50% of the trap catch for multiple weeks during the Chinook run. Trap counts indicated that coho salmon usually dominate in the first half of the Chinook salmon run and summer steelhead dominate during the latter half. Since Chinook salmon did not account for the majority of the upstream migration into the trap for more than several weeks, the video analysis portion of the Chinook salmon study was completed with a limited data set.

Table 3-11.   Schedule of operational treatments for the Chinook salmon study.

Treatment	Start Date	End Date	Number of Days
Unit 1 OFF	05/12/2006	05/17/2006	6
	05/20/2006	05/21/2006	2
	05/25/2006	06/13/2006	20
	06/27/2006	06/29/2006	3
Total			**31**
Unit 1 ON	05/18/2006	05/19/2006	2
	05/22/2006	05/24/2006	3
	06/14/2006	06/26/2006	13
	06/30/2006	07/14/2006	15
Total			**33**

3.4.2 Chinook Salmon Daily Catch

This objective was based on counts from video images and daily trap checks. There time period when Chinook salmon dominated trap catch was short enough to limit the video observations on trap entry for this stock. As such we could not be complete and analysis of daily catch for Chinook salmon.

3.4.3 Chinook Salmon Video Observations

Limited video data were available when Chinook salmon represented the majority of the trap catch at the Merwin trap. Approximately 120 hours of Chinook salmon behavior was recorded at the trap and used to compare fish behavior under different treatment conditions. Behavioral categories used to describe Chinook salmon behavior were the same as for coho salmon and were defined in Table 3-5.

For Chinook salmon, behavioral data were used to evaluate the overall success of tagged fish at entering the trap and for comparing trap entry success and behavior between treatments. The trap efficiency rate was defined as the number of successful entries divided by the number of attempts at trap entry. The total number of attempts was calculated as the sum of behaviors in the attempt category. The number of successful attempts was calculated as the number of Entries minus Fallback.

3.4.4 Chinook Salmon Radio Telemetry

A total of 100 Chinook salmon were collected and tagged (Table 3-12). Fifty fish were tagged on the 12 May 2006 and 50 were tagged on 14 June 2006. Forty six tagged Chinook salmon were detected by the array and used in the analysis. Fifteen fish were categorized in the OFF treatment and 21 fish were categorized in the ON treatment. Ten fish split their time between the ON and OFF treatment. Because the SPLIT groups contained only ten fish, no statistical analyses were completed. Instead we used descriptive and graphical analyses to compare the behavior of these fish under different operational scenarios.

Table 3-12. A summary of radio-tagged Chinook salmon released downstream of the Merwin Dam tailrace.

Tag Number	Release Group	Date Tagged
1	2	14 June 2006
2	1	12 May 2006
3	1	12 May 2006
4	1	12 May 2006
5	1	12 May 2006
6	1	12 May 2006
7	1	12 May 2006
8	1	12 May 2006
9	1	12 May 2006
10	1	12 May 2006
11	1	12 May 2006
12	2	14 June 2006
13	2	14 June 2006
14	2	14 June 2006
15	2	14 June 2006

Table 3-12.   A summary of radio-tagged Chinook salmon released downstream of the Merwin Dam tailrace.

Tag Number	Release Group	Date Tagged
16	2	14 June 2006
17	2	14 June 2006
18	2	14 June 2006
19	2	14 June 2006
20	2	14 June 2006
21	2	14 June 2006
22	2	14 June 2006
23	1	12 May 2006
24	1	12 May 2006
25	1	12 May 2006
26	1	12 May 2006
27	1	12 May 2006
28	1	12 May 2006
29	1	12 May 2006
30	1	12 May 2006
31	1	12 May 2006
32	1	12 May 2006
33	1	12 May 2006
34	1	12 May 2006
35	1	12 May 2006
36	1	12 May 2006
37	2	14 June 2006
38	2	14 June 2006
39	2	14 June 2006
40	2	14 June 2006
41	2	14 June 2006
42	2	14 June 2006
43	2	14 June 2006
44	2	14 June 2006
45	2	14 June 2006
46	2	14 June 2006
47	2	14 June 2006
48	2	14 June 2006

Table 3-12.   A summary of radio-tagged Chinook salmon released downstream of the Merwin Dam
             tailrace.

Tag Number	Release Group	Date Tagged
49	2	14 June 2006
50	2	14 June 2006
160	1	12 May 2006
161	1	12 May 2006
162	1	12 May 2006
163	1	12 May 2006
164	1	12 May 2006
165	1	12 May 2006
166	1	12 May 2006
167	1	12 May 2006
168	1	12 May 2006
169	1	12 May 2006
170	1	12 May 2006
171	1	12 May 2006
172	1	12 May 2006
173	1	12 May 2006
174	1	12 May 2006
175	1	12 May 2006
176	1	12 May 2006
177	1	12 May 2006
178	1	12 May 2006
179	1	12 May 2006
180	1	12 May 2006
181	1	12 May 2006
182	1	12 May 2006
183	1	12 May 2006
184	1	12 May 2006
185	1	12 May 2006
186	2	14 June 2006
187	2	14 June 2006
188	2	14 June 2006
189	2	14 June 2006
190	2	14 June 2006

Table 3-12.   A summary of radio-tagged Chinook salmon released downstream of the Merwin Dam
              tailrace.

Tag Number	Release Group	Date Tagged
191	2	14 June 2006
192	2	14 June 2006
193	2	14 June 2006
194	2	14 June 2006
195	2	14 June 2006
196	2	14 June 2006
197	2	14 June 2006
198	2	14 June 2006
199	2	14 June 2006
200	2	14 June 2006
201	2	14 June 2006
202	2	14 June 2006
203	2	14 June 2006
204	2	14 June 2006
205	2	14 June 2006
206	2	14 June 2006
207	2	14 June 2006
208	2	14 June 2006
209	2	14 June 2006

3.4.5 Performance of the Radio Telemetry Array

There was limited data lost or compromised due to mechanical failure or human error during the
Chinook salmon study compared to summer steelhead, coho salmon, and winter steelhead (Table
3-13). Although there were instances of tag collision, the occurrence was comparatively low.
For example, the 107 tag collisions that occurred during the Chinook salmon study were less
than half the number that occurred during the coho study, which recorded the second lowest
number of tag collisions. Of the 107 tag collisions, approximately 68% occurred at the three
detection zones (1, 2, 3) located along the control room, with the majority (35%) occurring in
Zone 1. After accounting for the tag collisions in the data set, there remained 4,140 records and
9,946 distinct signal detections recorded by the radio telemetry array during the 9-week Chinook
salmon study window. All data comparisons for the treatment groups were completed with these
4,140 clean data records.

Table 3-13.   Data file summary by detection zone for Chinook salmon radio tracking. √ = data,
N = no data.

Download Date	Detection Zone						
	1	**2**	**3**	**4**	**5**	**6**	**YAGI**
05/19/2006	√	√	√	√	√	√	√
05/26/2006	√	√	√	√	√	√	√
06/02/2006	√	√	√	√	√	√	√
06/08/2006	√	√	√	√	√	ND[a]	√
06/16/2006	√	√	√	√	√	√	√
06/23/2006	√	√	√	√	√	√	√
06/30/2006	√	√	√	√	√	√	√
07/07/2006	√	√	√	√	√	√	√
07/14/2006	√	√	√	√	√	√	√

[a] indicates receiver or download error

4.   RESULTS

We tagged and tracked 414 adult salmonids during upstream migrations starting in the August 2005 with summer steelhead and proceeding through mid-July 2006 with spring Chinook salmon (Table 4-1). The results of these tracking studies are presented by species.

4.1 SUMMER STEELHEAD

A total of 56 tagged steelhead were detected in the radio telemetry array during the radio-telemetry study. Thirty-eight of the tagged steelhead never entered the study area and may have moved downstream, lost tags, or died (Table 4-2). Three tagged steelhead were captured in the trap but were never detected by the array (Table 4-3). A number of possibilities may explain how fish entered the trap undetected by the array including 1) fish could have entered the tailrace during the weeks of September 9 and September 20 when download error caused detection records to be lost, 2) the fish could have moved at greater depths than the array was able to cover, 3) tags may have malfunctioned, and 4) undetected fish may have entered array with limited transitions and their detection may have been missed due to tag collision.

The total time each fish was in the array varied widely and ranged from 1 minute to more than days with more than 50% of summer steelhead remaining in the tailrace for 19.4 hours (Table 4-4). The mean number of transitions for tagged fish also appeared slightly greater under the Unit 1 OFF treatment compared to the Unit 1 ON treatment (Table 4-5). However, the median number of transitions was slightly greater under the Unit 1 ON treatment compared to the Unit 1 OFF treatment.

Thirty eight tagged steelhead were not used in the analysis because they never entered or spent an insufficient time in tailrace array (Table 4-2). The disposition of these fish is presented in Appendix A Table A-1. Many of these fish moved downstream after release and were located through mobile tracking. Fish that did not enter or left the array exhibited spatially variable movement patterns downstream of the tailrace. Some fish showed limited movement while other moved distances greater than a mile.

Table 4-1. Disposition of radio-tagged salmon.

Species	Total Released	Total Lost at Release	Total Mortality	Total Harvested	Total Recaptured	Total Detected by array	Total Captured in Trap	Total Detected by Mobile Tracking	Total at Lewis River Hatchery	Total of Unknown Disposition
Summer Steelhead	97	1	1	1	83	56	41	23	6	14
Coho Salmon	100	2	0	3	90	60	22	44	21	10
Hatchery Winter Steelhead	100	4	0	1	84	60	45	16	10	14
Wild winter Steelhead	17	0	0	0	2	2	1	0	0	15
Chinook Salmon	100	0	0	4	57	52	27	4	0	43

Table 4-2.   Summary of summer steelhead radio-telemetry tags not included in the analysis.

Tag Number	Tag Group	Date Tagged	Comments
16	1	16-Aug-05	Record insufficient for analysis*
21	1	17-Aug-05	No recapture, disposition unknown
26	2	22-Sep-05	No recapture, disposition unknown
27	2	22-Sep-05	Record insufficient for analysis*
29	2	22-Sep-05	Record insufficient for analysis*
33	2	22-Sep-05	No recapture, disposition unknown
35A	1	16-Aug-05	Tag mortality
35B	2	22-Sep-05	Record insufficient for analysis*
40	1	16-Aug-05	Record insufficient for analysis*
43	1	17-Aug-05	No recapture, disposition unknown
45	1	17-Aug-05	No recapture, disposition unknown
47	1	17-Aug-05	Harvested
48	2	22-Sep-05	Record insufficient for analysis*
50	2	22-Sep-05	Record insufficient for analysis*
52	2	22-Sep-05	No recapture, disposition unknown
55	2	22-Sep-05	Record insufficient for analysis*
56	2	22-Sep-05	No recapture, disposition unknown
57	2	22-Sep-05	Record insufficient for analysis*
58	2	22-Sep-05	Record insufficient for analysis*
59	2	22-Sep-05	Record insufficient for analysis*
62	1	16-Aug-05	Record insufficient for analysis*
63	1	16-Aug-05	No recapture, disposition unknown
69	1	17-Aug-05	Detected downstream during mobile tracking
73	2	22-Sep-05	Detected downstream during mobile tracking
76	2	22-Sep-05	No recapture, disposition unknown
77	2	22-Sep-05	No recapture, disposition unknown
78	2	22-Sep-05	Detected downstream during mobile tracking
79	2	22-Sep-05	Detected downstream during mobile tracking
82	2	22-Sep-05	No recapture, disposition unknown
84	2	22-Sep-05	No recapture, disposition unknown
89	1	16-Aug-05	Record insufficient for analysis*
91	1	17-Aug-05	No recapture, disposition unknown
93	1	17-Aug-05	Detected downstream during mobile tracking
94	1	17-Aug-05	No recapture, disposition unknown
102	2	22-Sep-05	Detected downstream during mobile tracking
105	2	22-Sep-05	Record insufficient for analysis*
106	2	22-Sep-05	Record insufficient for analysis*
109	2	22-Sep-05	Record insufficient for analysis*

* Indicates that one radio tag event was recorded by the array but was too little time (seconds) or too little power (less than 80 for aerial antennae to be used in the analysis.

Table 4-3. Summary of radio-tagged summer steelhead that moved through the array undetected.

Tag Number	Tag Group	Date Tagged	Date in Trap	Operation Treatment	Tag Disposition
49	2	22-Sep-05	26-Sep-05	Unit 1ON	Fish collected with tag
72	2	22-Sep-05	11-Oct-05	Unit 1 ON	Fish collected with tag
88	1	16-Aug-05	NA	Unit 1 OFF	NA

Table 4-4. Summary of tag records for radio-tracked summer steelhead in the Merwin Dam tailrace.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time in Tailrace (hours)	Trap Capture?
Unit 1 – OFF	10	16 Aug 2005	9/7/2005	9/7/2005	0.06	N
	11	16 Aug 2005	8/23/2005	9/16/2005	187.48	N
	12	16 Aug 2005	8/19/2005	9/7/2005	26.18	Y
	14	16 Aug 2005	8/29/2005	8/30/2005	42.19	Y
	15	16 Aug 2005	8/22/2005	8/22/2005	0.26	N
	17	17 Aug 2005	8/18/2005	8/24/2005	154.28	Y
	18	17 Aug 2005	8/22/2005	8/24/2005	39.56	Y
	20	17 Aug 2005	8/24/2005	8/24/2005	10.82	Y
	37	16 Aug 2005	9/5/2005	9/6/2005	18.23	Y
	39	16 Aug 2005	8/20/2005	8/21/2005	6.74	N
	42	17 Aug 2005	8/21/2005	9/1/2005	261.70	Y
	44	17 Aug 2005	9/8/2005	9/8/2005	12.31	Y
	46	17 Aug 2005	8/22/2005	8/23/2005	19.40	Y
	60	16 Aug 2005	9/7/2005	9/10/2005	67.70	Y
	61	16 Aug 2005	8/26/2005	8/29/2005	70.60	Y
	64	16 Aug 2005	9/7/2005	9/7/2005	0.01	N
	65	16 Aug 2005	8/21/2005	8/24/2005	73.41	Y
	66	17 Aug 2005	9/19/2005	9/20/2005	13.22	N
	67	17 Aug 2005	9/9/2005	9/9/2005	6.80	N
	68	17 Aug 2005	8/19/2005	8/22/2005	6.10	Y
	70	17 Aug 2005	8/31/2005	9/1/2005	19.99	Y
	71	17 Aug 2005	9/6/2005	9/7/2005	21.20	Y
	85	16 Aug 2005	9/17/2005	9/18/2005	32.95	Y
	86	16 Aug 2005	8/23/2005	8/29/2005	6.64	N
	90	16 Aug 2005	8/20/2005	8/20/2005	6.48	Y
	96	17 Aug 2005	8/17/2006	8/22/2006	18.29	Y

Table 4-4.   Summary of tag records for radio-tracked summer steelhead in the Merwin Dam tailrace.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time in Tailrace (hours)	Trap Capture?
Unit 1 – ON	19	17 Aug 2005	9/7/2005	10/1/2005	19.31	N
	23	22 Sep 2005	9/30/2005	10/3/2005	25.05	Y
	24	22 Sep 2005	9/22/2005	9/22/2005	0.01	N
	25	22 Sep 2005	9/22/2005	9/27/2005	30.72	Y
	30	22 Sep 2005	9/22/2005	9/26/2005	32.62	Y
	32	22 Sep 2005	9/22/2005	9/22/2005	0.02	N
	34	22 Sep 2005	9/22/2005	9/23/2005	27.67	Y
	38	16 Aug 2005	9/22/2005	9/22/2005	0.06	Y
	41	17 Aug 2005	10/2/2005	10/5/2005	33.65	Y
	51	22 Sep 2005	9/22/2005	9/22/2005	0.01	N
	53	22 Sep 2005	9/22/2005	9/22/2005	0.07	N
	54	22 Sep 2005	9/22/2005	10/14/2005	125.85	Y
	74	22 Sep 2005	9/25/2005	9/26/2005	18.29	Y
	75	22 Sep 2005	9/27/2005	10/9/2005	149.72	Y
	80	22 Sep 2005	10/11/2005	10/12/2005	25.37	Y
	83	22 Sep 2005	9/27/2005	9/28/2005	25.23	Y
	87	16 Aug 2005	10/1/2005	10/3/2005	13.16	Y
	92	17 Aug 2005	9/22/2005	9/22/2005	0.02	Y
	95	17 Aug 2005	10/16/2005	10/17/2005	16.79	Y
	97	22 Sep 2005	9/22/2005	9/29/2005	5.96	Y
	98	22 Sep 2005	9/29/2005	9/29/2005	9.21	Y
	100	22 Sep 2005	9/28/2005	9/28/2005	8.39	Y
	101	22 Sep 2005	10/9/2005	10/9/2005	14.02	Y
	103	22 Sep 2005	10/3/2005	10/4/2005	22.81	N
	104	22 Sep 2005	9/22/2005	9/25/2005	7.44	N
	107	22 Sep 2005	9/22/2005	10/6/2005	34.74	Y
	108	22 Sep 2005	10/13/2005	10/17/2005	23.01	Y
OFF/ON – Split	13	16 Aug 2005	8/20/2005	9/29/2005	722.52	Y
	22	17 Aug 2005	9/7/2005	9/26/2005	21.05	N
	36	16 Aug 2005	8/29/2005	9/24/2005	25.99	N

Table 4-5. Descriptive statistical summary of tag records in the array by treatment group for radio-tracked summer steelhead in the Merwin Dam tailrace.

Variable	Treatment Group			
	Unit 1 OFF	Unit 1 ON	OFF/ON Split	
			OFF	ON
Detection Dates	17 Aug 05 – 9 Sep 05	22 Sep 05 – 17 Oct 05	20 Aug 05 – 21 Sep 05	22 Sep 05 – 29 Sep 05
Number of Tagged Fish	26	27	3	3
Total Hours in Array	1122.6	669.2	693.9	57.6
Range of Total Hours in Array	0.01 – 261.7	0 – 149.7	0.07 – 668.0	0.14 – 36.5
Mean Hours in Array[a]	43.2 (12.5)	24.8 (6.7)	231.3 (218.5)	19.2 (10.5)
Median Hours in Array	18.8	18.3	25.9	21.0
Total Zone Transitions	1177	1070	782	38
Range of Zone Transitions	0 – 231.0	0 – 168.0	0 – 778	3.0 – 20.0
Mean Zone Transitions[a]	45.3 (10.9)	39.6 (8.1)	260.7 (258.7)	12.7 (5.0)
Median Zone Transitions	26.5	30.0	4.0	15.0

[a] Parentheses indicate ± 1 standard error of the mean.

4.1.1 Objective 2 – Estimate the number of trap entry attempts made by adult salmonids in the tailrace.

During the 2005 video analysis there were 14,649 observations were documented of summer steelhead approaching the trap (Table 4-6). There were 5,035 observations of exploratory behaviors and 8,313 observations of attempts at trap entry, including 4,005 successful entries and 1,301 observations of fallback (Table 4-6).

During the 2006 video analysis there were 2,539 observations documented of summer steelhead approaching the trap (Table 4-7). During Unit 1 OFF conditions we observed 1,361 exploratory behaviors and 1,361 attempts at trap entry, including 332 successful entries and 235 observations of fallback (Table 4-7). During Unit 1 ON conditions there were 1,361 observations of exploratory behaviors and 1,178 observations of attempts at trap entry, including 372 successful entries and 300 observations of fallback (Table 4-7).

Table 4-6. 2005 video analysis summary of summer steelhead behavior at the Merwin tailrace trap.

		Unit 1 OFF Observations	
Behavior Category	**Behavior**	**Count**	**Percent (%)**
Exploratory Behavior	Roll	2614	52
	Early Jump	2421	48
	Total Exploratory Behavior	**5035**	
Attempts	Surf/Velocity	1615	19
	Corner	1269	15
	Hit	123	1
	Entries	5306	64
	Total Attempts	**8313**	
Fall Backs	Fall Back	1301	25
	Successful Entries	**4005**	**48**

Table 4-7.   2006 video analysis summary of summer salmon behavior at the Merwin tailrace trap.

		Unit 1 OFF Observations		Unit 1 ON Observations	
Behavior Category	**Behavior**	**Count**	**Percent (%)**	**Count**	**Percent (%)**
Exploratory Behavior	Roll	930	100	502	100
	Total Exploratory Behavior	**930**		**502**	
Attempts	Early Jump	71	5	38	3
	Surf/Velocity	681	50	424	36
	Corner	17	1	28	2
	Hit	35	3	16	1
	Entries	557	41	672	57
	Total Attempts	**1361**		**1178**	
Fall Backs	Fall Back	235	42	300	45
	Successful Entries	322	24	373	32

4.1.2 Objective 3 – Estimate the number of adult fish that enter the trap and become captive

Due to limitations with hydroacoustic counts at this location, radio telemetry data was used to calculate trap efficiency for the total summer steelhead population, ATE_{pop}. Overall, the ATE_{pop} was 71%. When broken down by operational treatment groups the $ATE_{pop-off}$ was 69% and the ATE_{pop-on} was 72%. Although 42 fish entered the trap, we were unable to assign one fish (tag #88) to either population because the date of trap entry was not noted. Specific calculations follow.

ATE_{pop} = 42/59 (42 fish captured in the trap/(56 fish that entered the tailrace radiotelemetry array + 2 fish entered the trap undetected+ 1 OFF/ON Split fish that entered the trap during "ON" condition)) = 71%.

$ATE_{pop-off}$ = 18/ 26 (18 fish captured in the trap/(24 fish that entered the tailrace + 2 fish entering the trap undetected)) = 69%.

ATE_{pop-on} = 23/32 (22 fish captured in the trap/(29 fish that entered the tailrace array + 2 fish entering the trap undetected + 1 OFF/ON Split fish that entered the trap during "ON" condition)) = 72%.

The trap efficiency of summer steelhead migrating upstream into the Merwin trap (ATE_{mig}) was determined by fish behavior counts recorded during the 2005 and 2006 video analysis. In 2005, ATE_{mig} was calculated as follows: ATE_{mig} = 4,005 successful trap entries/ 8,313 total attempts= 48%. Adult trap efficiency could not be broken down by operational treatment because Unit 1 was off through the duration of the summer steelhead run. In 2006, ATE_{mig} was calculated as follows: ATE_{mig} = 695 successful trap entries/ 2,539 total attempts= 27%. When analyzed by operational treatment group the $ATE_{mig-off}$ was 24% and the ATE_{mig-on} was 32%. Specific calculations follow.

ATE_{mig} = 695 successful trap entries (total minus fallback)/ 2,539 trap attempts = 27%.
$ATE_{mig-off}$ = 322 successful trap entries/ 1,361 trap attempts = 24%.
ATE_{mig-on} = 373 trap entries/ 1178 trap attempts = 32%.

4.1.3 Objective 4 – Determine what (if any) tailrace conditions impede fish movement into the trap.

4.1.3.1 Radiotelemetry Study

4.1.3.1.1 Analysis of Temporal Distribution in Detection Zones

The total time summer steelhead spent is each detection zone ranged from a few minutes to almost 4 hours. Descriptive analysis of mean time spent in the tailrace zones indicates that summer steelhead spend more time in more zones under the Unit 1 OFF treatment compared to Unit 1 ON (Figure 4-1). In addition, the five fish that spent more than 100 hours in the tailrace array varied where they spent their time. Plots depicting time for fish with the longest total times under Unit 1 ON and Unit 1 OFF are represented in Figures 4-2 and 4-3. In general, these fish showed decreased use of Zones 3, 5, 6, and 7, and increased use of Zone 4 under Unit 1 ON conditions. These patterns of zonal use were also evident for fish from the OFF/ON SPLIT treatment group (Figures 4-4 and 4-5).
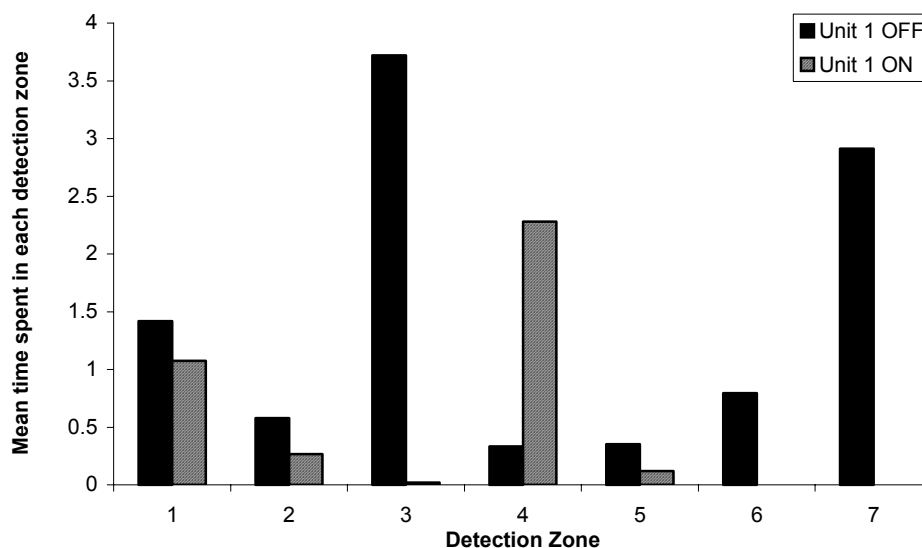
Figure 4-1.   Mean time radio-tagged summer steelhead spent in each detection zone.
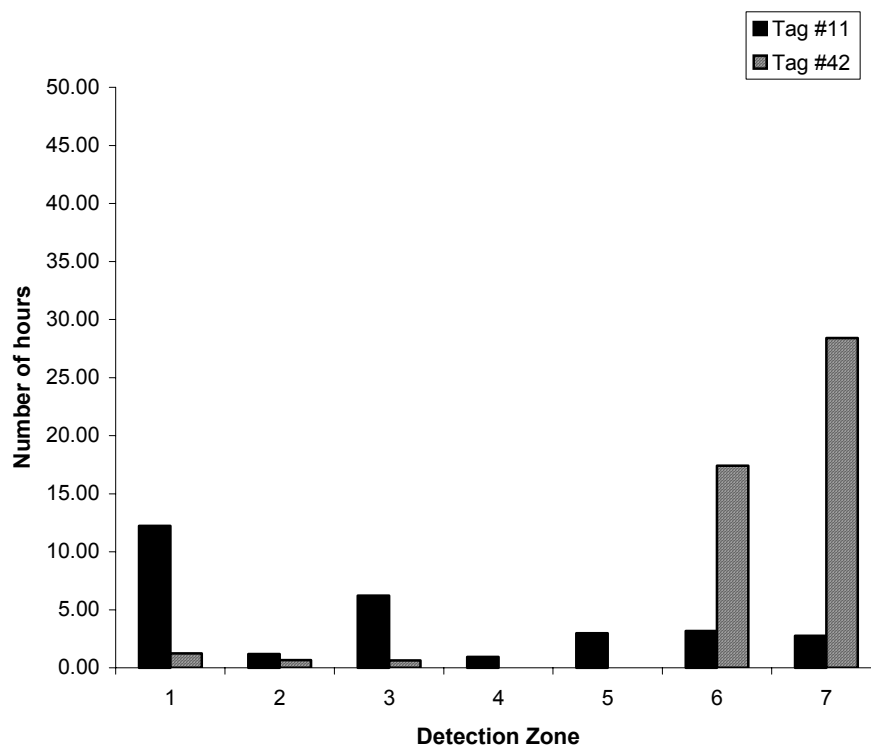
Figure 4-2.   Time two radio-tagged summer steelhead spent in each tailrace
detection zone for Unit 1 OFF.
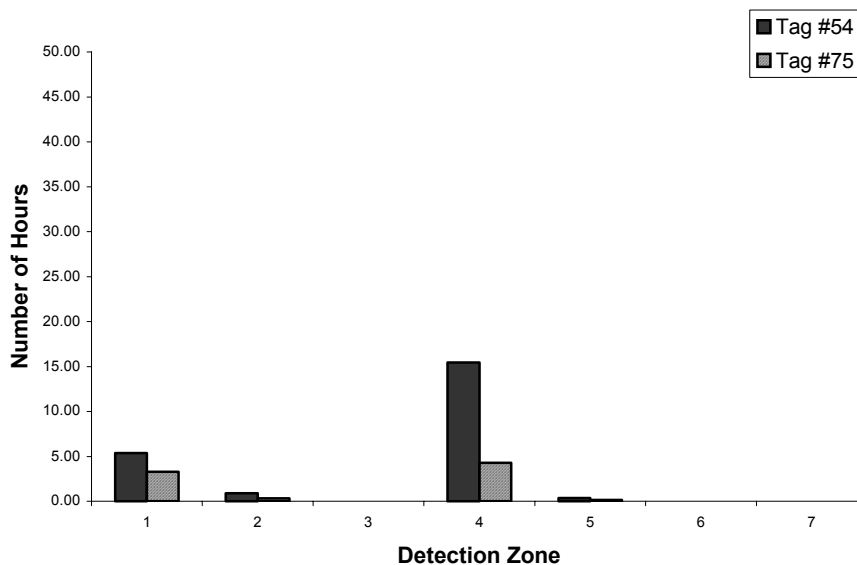
Figure 4-3.   Time two radio-tagged summer steelhead spent in each tailrace
detection zone for Unit 1 ON.
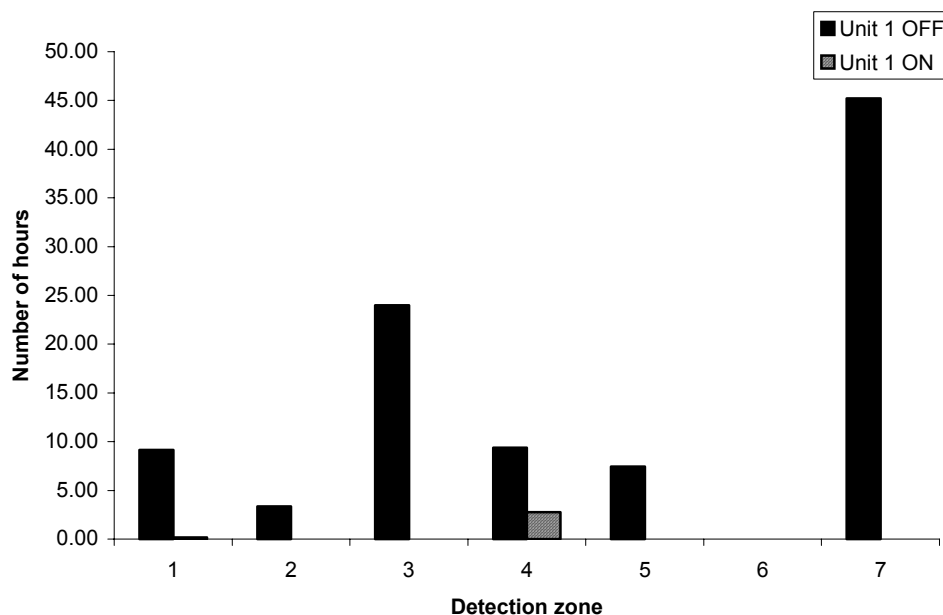
Figure 4-4. Time radio-tagged steelhead #13 from the OFF/ON Split treatment
pent in each radio detection zone.
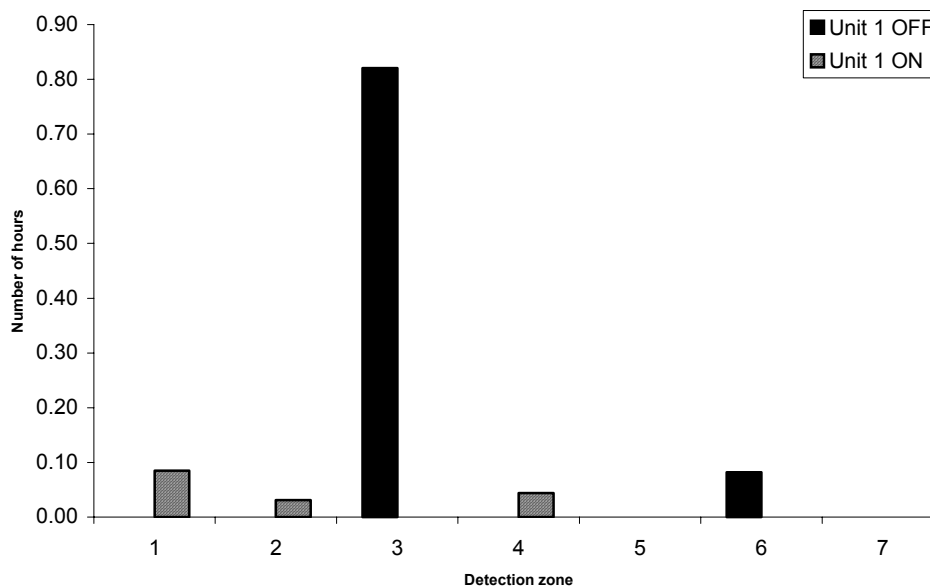
Figure 4-5. Time radio-tagged summer steelhead #36 from the OFF/ON Split
treatment spent in each detection zone.

Statistical analysis of the time fish spent in each detection zone, as determined by the number of radio contacts, was used to explore treatment effects. The hypothesis tested was that the numbers of contacts in each zone were similar under Unit 1 ON and Unit 1 OFF. The numbers of contacts are depicted in box plots for each zone (Figures 4-6 and 4-7). As can be seen by the box plots, there were too few contacts in Zone 3, Zone 6 and Zone 7 when Unit 1 was ON to complete the statistical comparisons for these zones. Nevertheless, the actual number of contacts observed showed that there was considerably less time spent in Zone 3 under Unit 1 ON (median value = 6) as compared to Unit1 OFF (median value = 665). There were also substantially fewer contacts in Zone 7 under Unit 1 ON (median value = 0) as compared to Unit 1 OFF (median value = 9). Clear differences in Zone 6 were not evident (median value = 0 under both treatments). The results of the statistical analyses showed no difference in the amount of time spent in Zones 1, 2, and 5 (Table 4-8). However, summer steelhead did spend significantly more time in Zone 4 when Unit 1 was on. The total time summer steelhead spent in the array was highly variable both within and between treatments. Graphical depictions of fish that spent the most time in the tailrace illustrate the variability encountered by the array in detecting fish (Figures 4-3 through 4-7).

Table 4-8. Summary of results of generalized linear models for summer steelhead radio contacts by detection zone.

Zone	$\chi^2_{1,47}$ value	P value
Zone 1	0.014	0.91
Zone 2	0.29	0.59
Zone 3	*	*
Zone 4	15.79	P<0.001
Zone 5	0.01	0.92
Zone 6	*	*
Zone 7	*	*

* model did not converge due to very few contacts in one group

4.1.3.1.2 Analysis of Zone Transitions

We enumerated the number of zone transitions, movements from one zone to the next, that summer steelhead made, and compared the distribution of transition counts between treatment groups. The hypothesis tested was that transition count distributions are not significantly different for treatment groups Unit1 OFF and Unit1ON. During the study period summer steelhead exhibited substantial movement within the tailrace resulting in 6,134 zonal transitions that were distributed among the 42 potential directional movements. The greatest number of fish movements were within the three zones along the control room wall, within the two zones along the face of the powerhouse, between the control room zones (1, 2, and 3) and within the powerhouse zones (4, 5) (Figures 4-8 and 4-9).
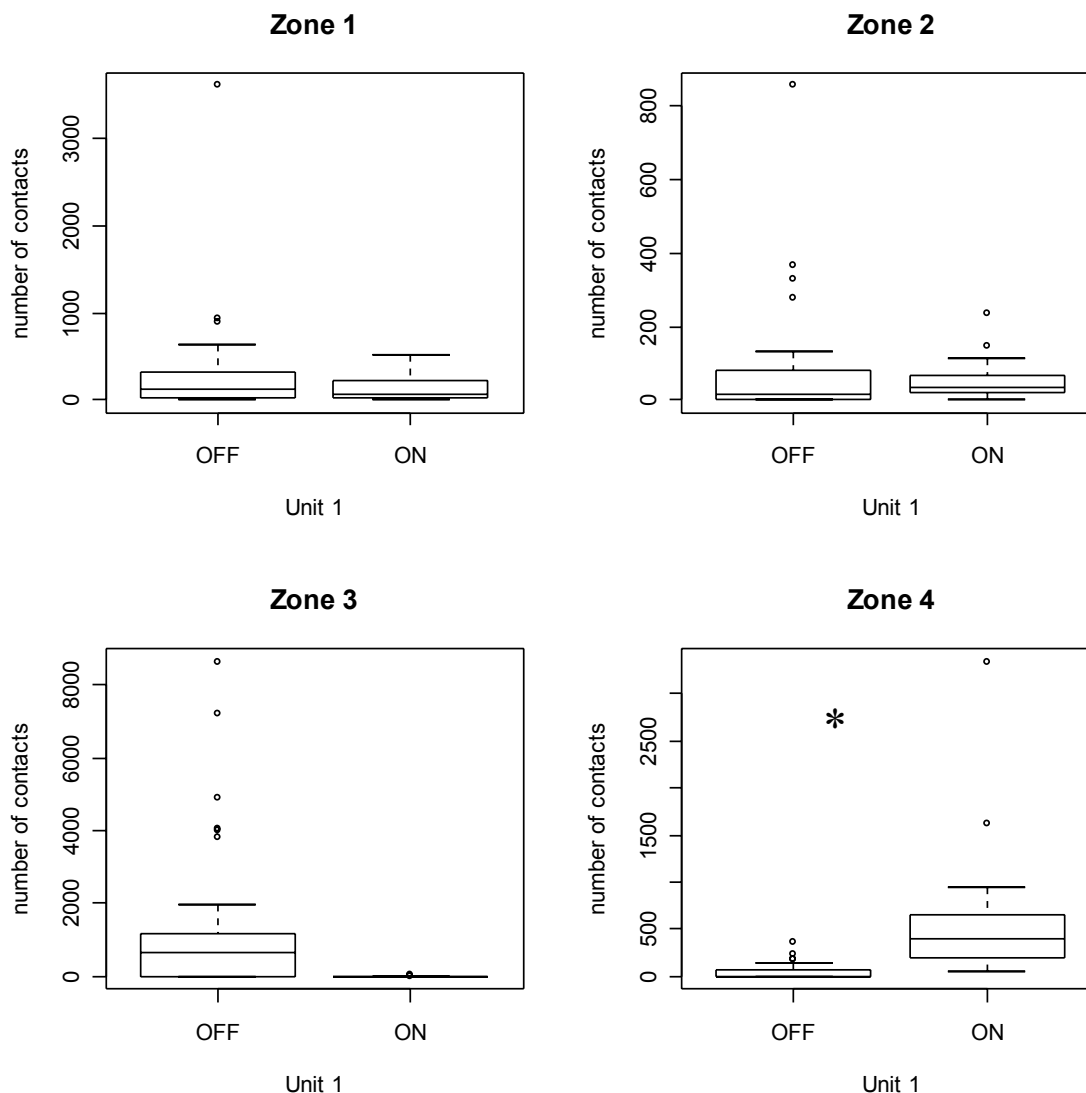
Figure 4-6.   Boxplots of number of summer steelhead radio contacts in detection
Zones 1 through 4 with Unit 1 off (n=29) and Unit 1 on (n=31).
Boxes indicate the 25-75th percentiles, whiskers indicate 95th
percentiles, and extreme observations are displayed as points.
Contacts were substantially higher in Zone 3 under Unit 1 OFF but
statistical tests could not be conducted due to the low number of
contacts under Unit 1 ON; whereas contacts were significantly
higher ($p < 0.001$, $\chi^2_{1,47} = 28.5$) in Zone 4 under Unit 1 ON.
*Indicates significant difference between treatments.

Zone 5

Zone 6

Zone 7
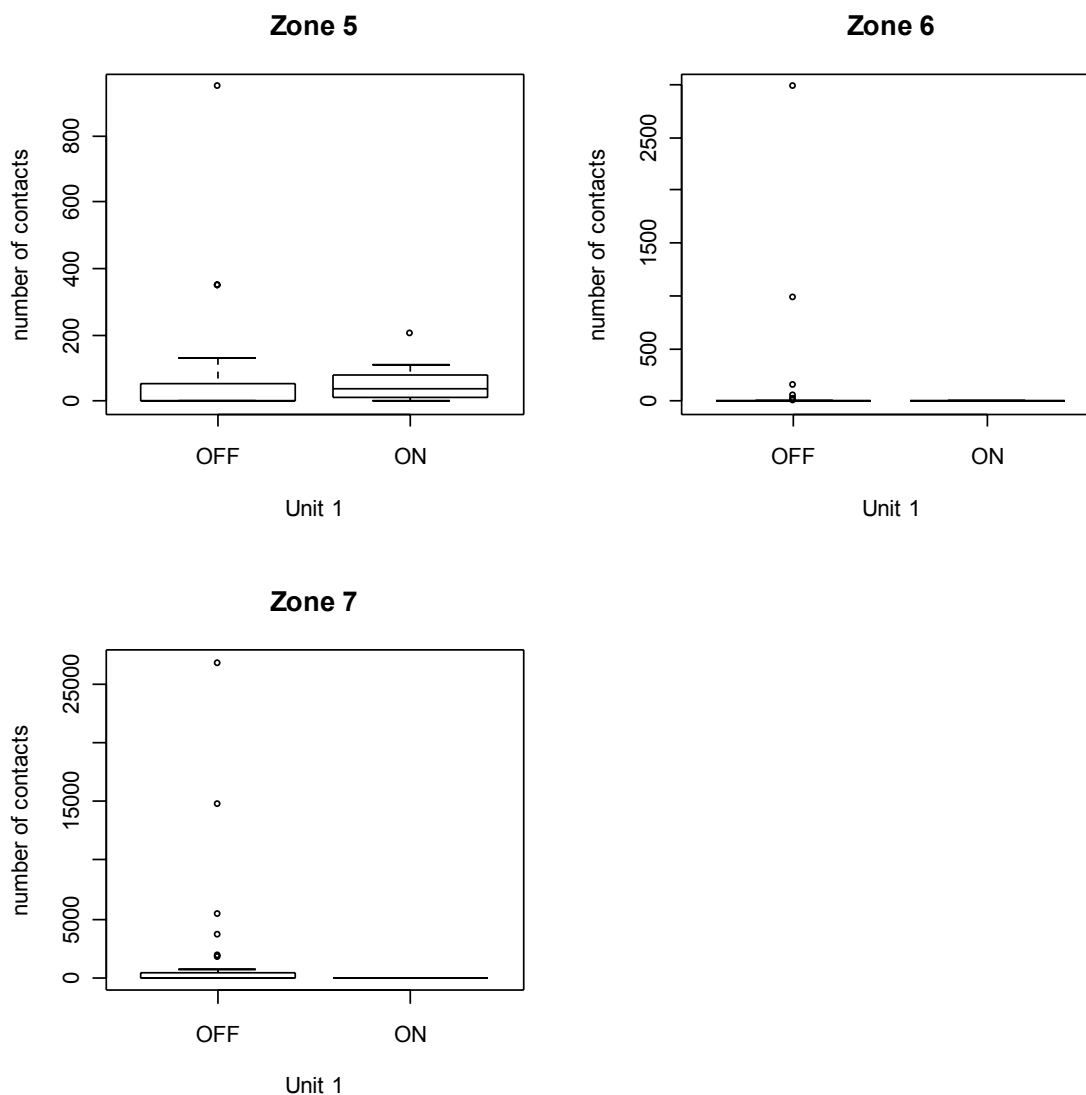
Figure 4-7.   Boxplots of number of summer steelhead contacts in detection Zones 5 through 7 with Unit 1 off (n=29) and Unit 1 on (n=31). Boxes indicate the 25-75th percentiles, whiskers indicate 95th percentiles, and extreme observations are displayed as points. Contacts were substantially higher in Zones 6 and 7 when Unit 1 OFF, but statistical tests could not be conducted due to the low number of contacts under Unit 1 ON.
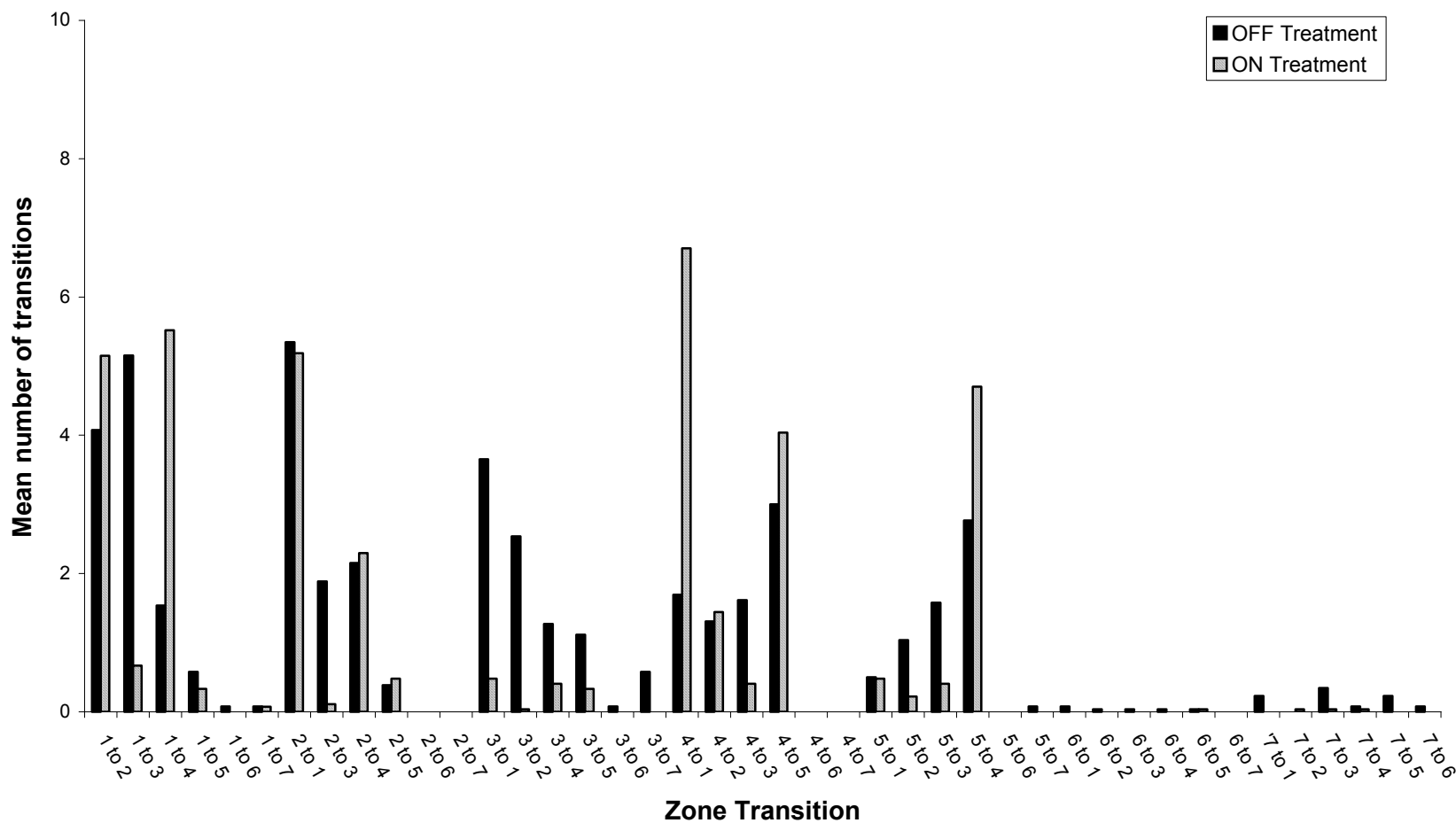
Figure 4-8.   Mean number of transitions by radio-tagged summer steelhead among tailrace detection zones.
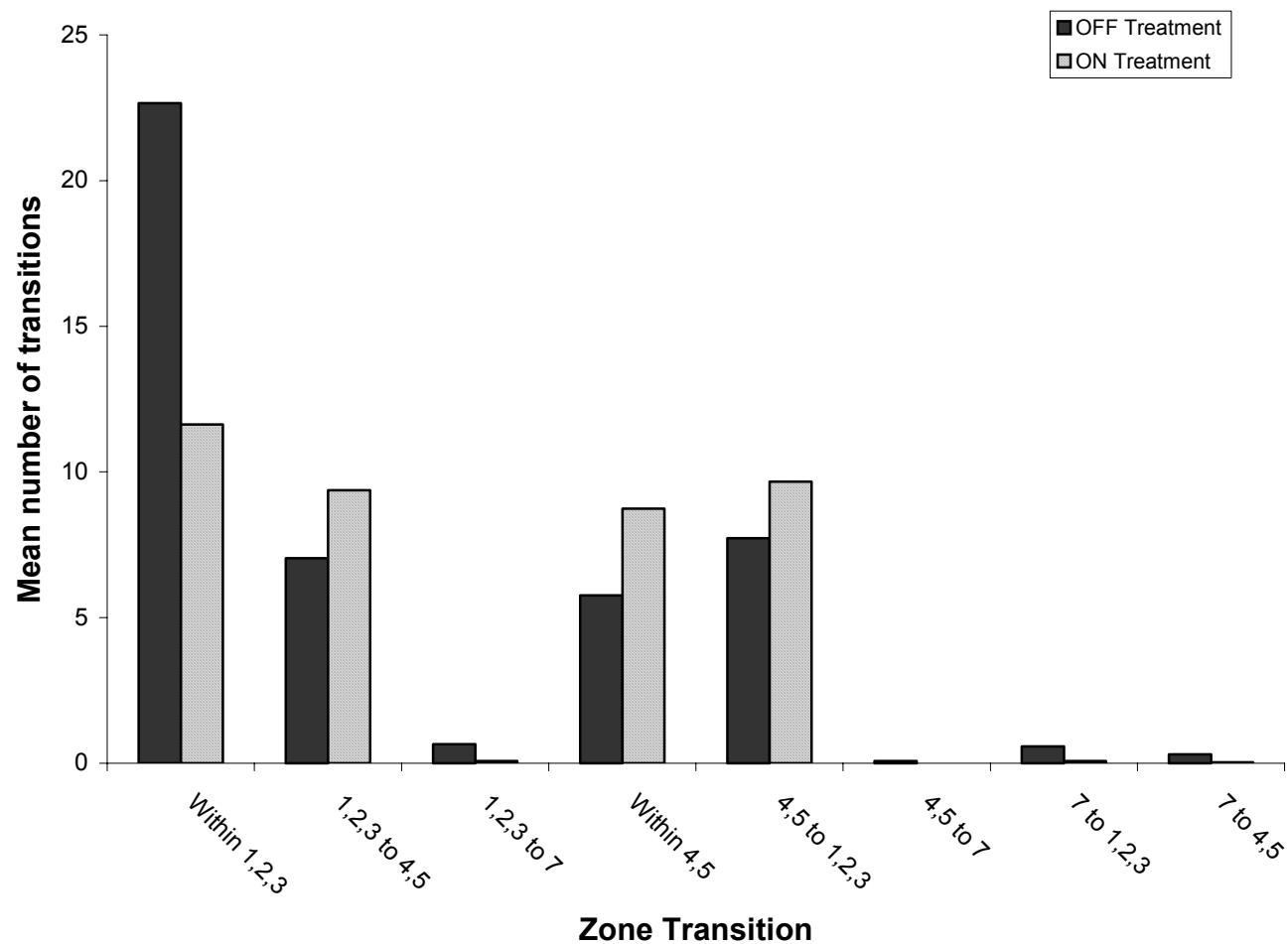
Figure 4-9.   Mean number of summer steelhead transitions among grouped tailrace detection zones.

As is evident in these graphs, the pattern of zone transitions changed with the treatment. There was an increase in the number of transitions between the detection zones along the powerhouse wall (Zones 1, 4, and 5) and a decrease in those in front of the trap along the wall of the control room and bedrock outcropping (Zones 1, 2, and 3) under Unit 1 ON as compared to Unit 1 OFF. This pattern was confirmed by statistical analysis of the number of transitions.

Statistically significant changes on movement patterns along the control room and powerhouse walls were detected between treatments. Under Unit 1 ON conditions, the number of transitions from Zone 1 to Zones 2 and 4 significantly increased as did the number of transitions from Zones 4 and 5 to Zone 1 and Zone 5 to Zone 4. Significant decreases were evident in the number of transitions from Zones 1 and 2 to Zone 3, Zone 3 to Zones 1 and 2, and from Zone 5 to Zones 2 and 3 (Table 4-9). To summarize the pattern of transitions, movement between Zones 1 and 3 decreased while movement between Zones 1, 2, 4, and 5 increased when Unit 1 was on (Figures 4-8 and 4-9).

Table 4-9.   The effect of Unit 1-ON zone transitions. Effects in bold are significant at the 0.05 level.

Transition from	To	Effect of Unit 1	$\chi^2_{1,41}$ value	P value
Zone 1	Zone 2	**increase**	4.26	0.039
	Zone 3	**decrease**	25.6	< 0.001
	Zone 4	**increase**	44.6	< 0.001
	Zone 5	increase	*	*
Zone 2	Zone 1	increase	0.73	0.392
	Zone 3	**decrease**	22.9	< 0.001
	Zone 4	increase	0.33	0.564
	Zone 5	increase	1.81	0.297
Zone 3	Zone 1	**decrease**	15.4	< 0.001
	Zone 2	**decrease**	28.5	< 0.001
	Zone 4	decrease	1.61	0.205
	Zone 5	decrease	1.82	0.177
Zone 4	Zone 1	**increase**	42.6	< 0.001
	Zone 2	increase	0.357	0.50
	Zone 3	**decrease**	5.08	0.025
	Zone 5	**increase**	7.27	0.007
Zone 5	Zone 1	increase	0.315	0.575
	Zone 2	**decrease**	10.2	0.012
	Zone 3	**decrease**	6.37	0.012
	Zone 4	**increase**	12.09	0.001

* Model could not converge due to low number of transitions

Movement of summer steelhead in the array was variable both within and between treatments. Movement of individual fish that spent the most time in the tailrace depicts some of this variability (Figures 4-10 and 4-11) while maintaining the overall patterns described above. In addition plots for representative fish from the ON/OFF Split treatment are presented in Figures 4-12 and 4-13. These plots all show similar movement to the overall pattern described for other treatment groups with a decrease the number of transitions, more time moving among Zones 1, 4, and 5, and less time moving among Zones 1, 2, and 3 with UNIT 1 ON as compared to Unit 1 OFF.

4.1.4 Objective 5 – If tailrace conditions preclude trap entry or cause migration delay what locations would be preferred for a new trap entrance?

4.1.4.1 Radio Telemetry Study

The null hypothesis tested was that the time fish spend in the tailrace is the same when Unit 1 was off versus when Unit 1 was on. An Analysis of variance (ANOVA) was conducted using a (log(minutes) +1) transformation on the data. The ANOVA test fails to reject the null hypothesis ($p = 0.149$, $F_{1,52} = 2.15$) indicating that the total time fish spend in the tailrace did not differ when Unit 1 was on versus when it was off (Figure 4-14).
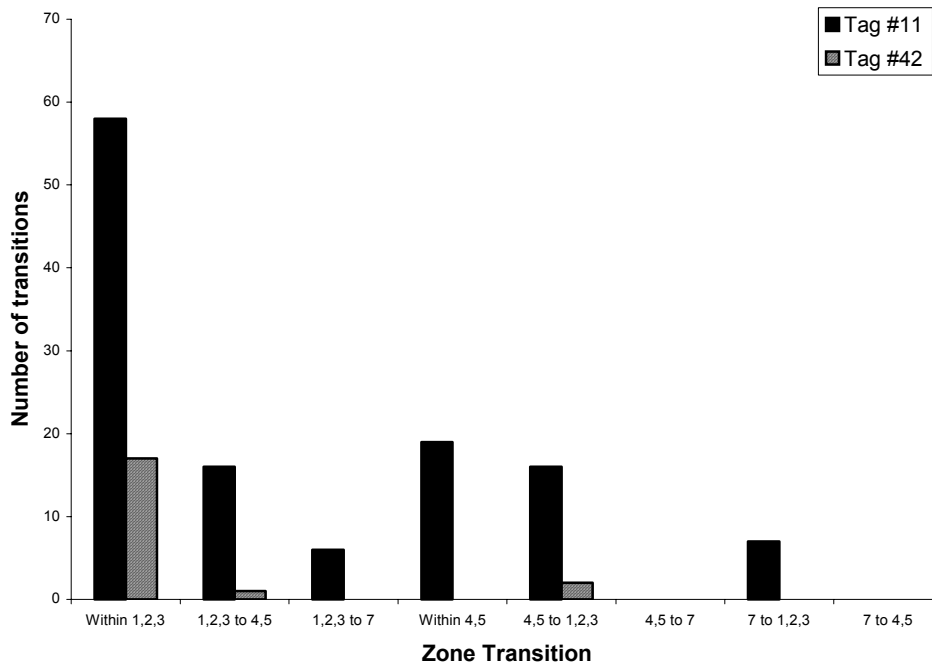
Figure 4-10. Zone transitions among grouped tailrace detection zones for two radio-tagged summer steelhead under Unit 1 OFF.
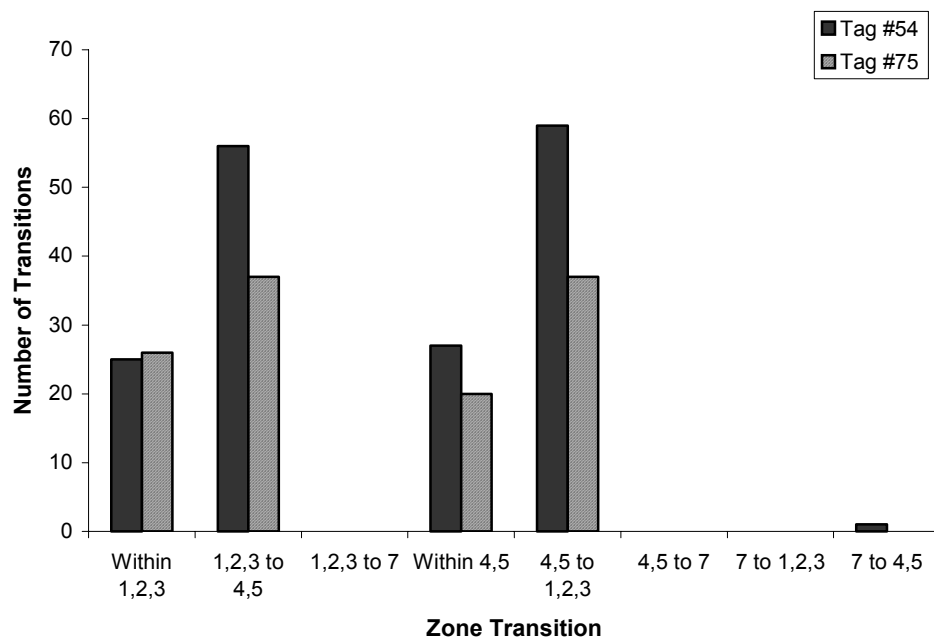
Figure 4-11.   Zone transitions among grouped tailrace detection zones for two
                 radio tagged summer steelhead under Unit 1 ON.
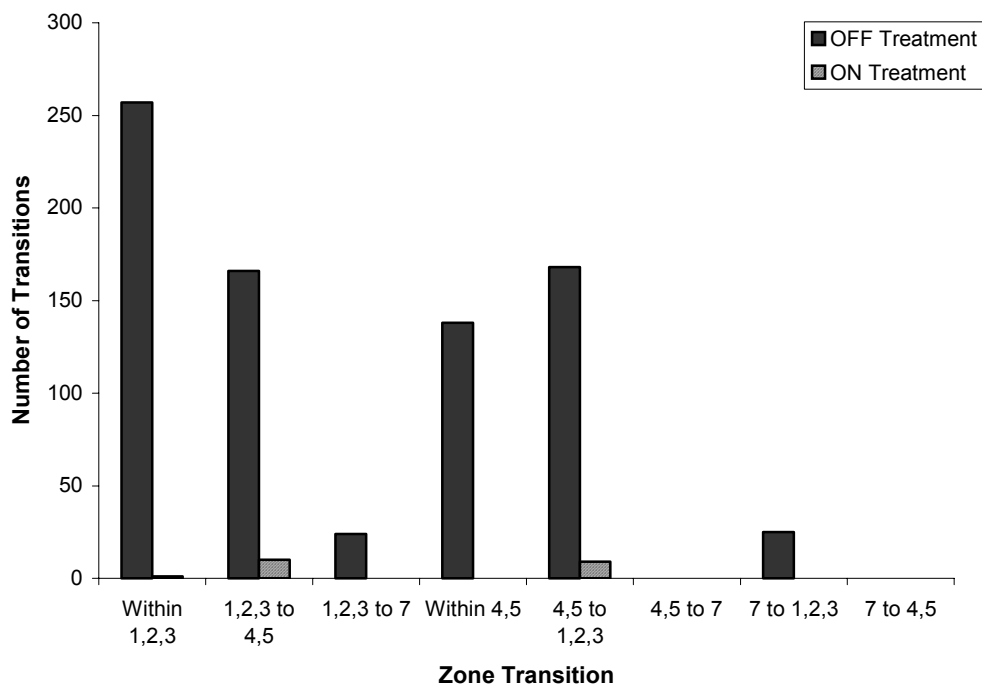
Figure 4-12.   Zone transitions among grouped tailrace detection zones for summer
                 steelhead #13 from the ON/OFF SPLIT.
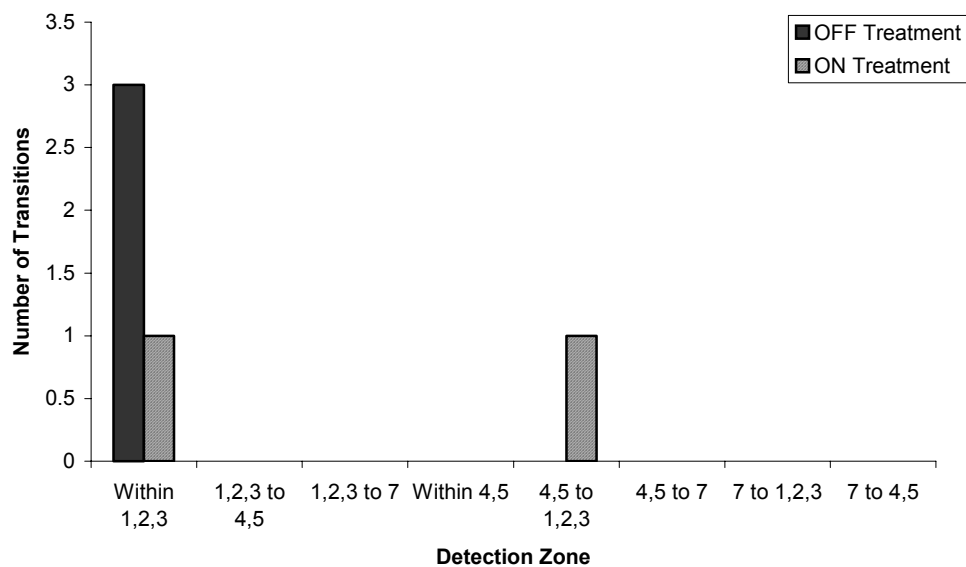
Figure 4-13.   Zone transitions among group tailrace detection zones for radio-
               tagged summer steelhead #36 from ON/OFF SPLIT treatment.
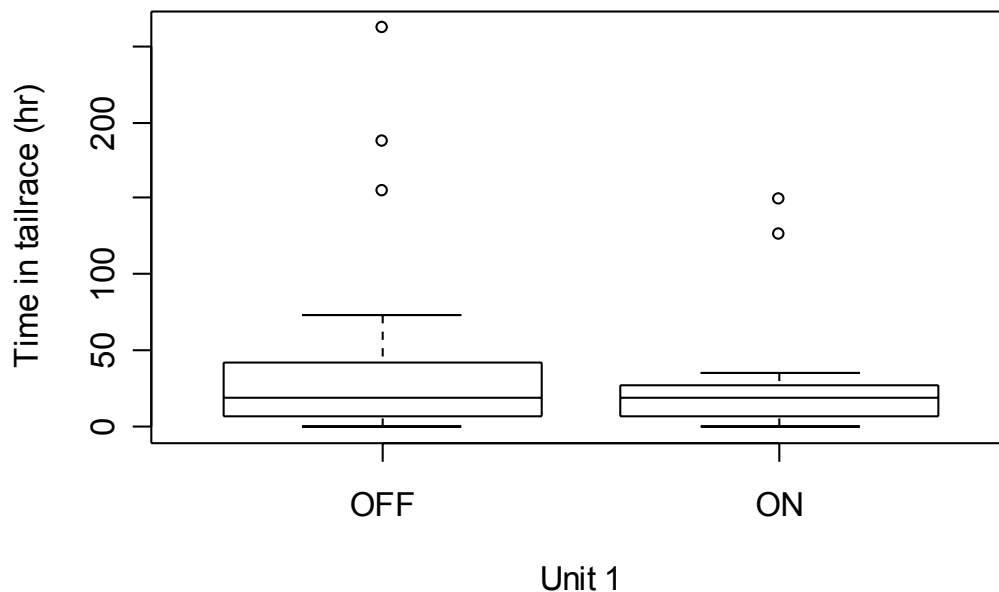
Figure 4-14. Box plot of the total time spent in the Merwin tailrace by summer
steelhead when Unit 1 was off (n=26) and when Unit 1 was on
(n=27). Boxes indicate the 25-75th percentiles, whiskers indicate
95th percentiles, and extreme observations are displayed as points.
A number of possibilities may explain how fish entered the trap
undetected by the array including 1) fish could have entered the
tailrace during the week of November 2 when download error caused
detection records to be lost, 2) the fish could have moved at greater
depths than the array was able to cover, 3) tags may have
malfunctioned, and 4) undetected fish may have entered array with
limited transitions and their detection may have been missed due to
tag collision.

4.2 COHO SALMON

A total of 60 tagged coho salmon were detected in the radio telemetry array during the study. Thirty-six tagged coho salmon lost tags, left or never entered the study area, or died (Table 4-10). A total of 4 tagged coho salmon entered the trap undetected by the array (Table 4-11).

The total time each fish spent in the array varied widely from a 2 minutes to 25 days (Table 4-12). Mean hours spent in the tailrace was nearly 3-fold greater for fish under the Unit 1 ON treatment scenario compared to the Unit 1 OFF treatment group with more than 50% of the coho salmon remaining in the tailrace for 23.1 hours (Table 4-13). Accordingly, mean number of transitions for tagged fish was three times greater for fish in the Unit 1 ON treatment compared to the Unit 1 OFF treatment and 4 times greater in terms of median number of transitions (Table 4-12).

Forty tagged coho salmon were not used in the analysis because they never entered or spent an insufficient amount of time in the tailrace array (Table 4-10). The disposition of these fish is also presented in Appendix A, Table A-1). Many of these fish moved downstream after release and were located through mobile tracking. Fish that did not enter or left the array exhibited spatially variable movement patterns downstream of the tailrace. Some fish showed limited movement while other moved distances greater than a mile.

Table 4-10. Summary of coho salmon radio-telemetry tags not used in the analyses.

Tag Number	Release Group	Date Tagged	Comments
61	1	31-Oct-05	No recapture, disposition unknown
62	1	31-Oct-05	No recapture, disposition unknown
64	1	31-Oct-05	Tag recovered in water at release
65	1	31-Oct-05	Detected downstream
66	1	31-Oct-05	No recapture, disposition unknown
67	1	31-Oct-05	Detected downstream
68	1	31-Oct-05	No recapture, disposition unknown
69	1	31-Oct-05	Detected downstream
70	1	31-Oct-05	Detected downstream
71	1	31-Oct-05	Detected downstream
78	1	31-Oct-05	Detected downstream
79	1	31-Oct-05	Detected downstream
81	1	31-Oct-05	Detected downstream

Table 4-10. Summary of coho salmon radio-telemetry tags not used in the analyses.

Tag Number	Release Group	Date Tagged	Comments
96	2	28-Nov-05	Detected downstream
98	2	28-Nov-05	Detected downstream
102	2	28-Nov-05	Detected downstream
107B	2	28-Nov-05	Detected downstream
109C	2	28-Nov-05	No recapture, disposition unknown
110C	2	28-Nov-05	Detected downstream
112	1	31-Oct-05	Detected downstream
115	1	31-Oct-05	Detected downstream
117	1	31-Oct-05	Detected downstream
120	1	31-Oct-05	Detected downstream
122	1	31-Oct-05	Detected downstream
124	1	31-Oct-05	No recapture, disposition unknown
126	1	31-Oct-05	Detected downstream
127	1	31-Oct-05	Detected downstream
129	1	31-Oct-05	Detected downstream
131	1	31-Oct-05	Tag recovered in water at release
136	2	28-Nov-05	Detected downstream
139	2	28-Nov-05	No recapture, disposition unknown
141	2	28-Nov-05	No recapture, disposition unknown
143	2	28-Nov-05	Detected downstream
144	2	28-Nov-05	Detected after completion of study
151	2	28-Nov-05	Detected downstream
152	2	28-Nov-05	Detected after completion of study

Table 4-11.   Summary of radio tagged coho salmon that moved through the array undetected.

Tag Number	Tag Group	Date Tagged	Date in Trap	Operational Treatment	Tag Disposition
60	1	31-Oct-05	15-Nov-05	Unit 1ON	Fish collected with tag
130	1	31-Oct-05	15-Nov-05	Unit 1 ON	Fish collected with tag
108A	2	29 Nov 05	06 Dec 05	Unit 1 OFF	Fish collected with tag
109B	2	29 Nov 05	06 Dec 05	Unit 1 OFF	Fish collected with tag

Table 4-12.   Summary of tag records by fish for radio tracked coho salmon in the Merwin Dam tailrace.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time In Tailrace (Hours)	Trap Capture?
Unit 1 OFF	83	31 Oct 2005	11/23/2005	11/24/2005	17.05	N
	85	29 Nov 2005	12/03/2005	12/04/2005	18.11	N
	86	29 Nov 2005	12/01/2005	12/08/2005	8.52	Y
	87	29 Nov 2005	11/30/2005	12/05/2005	20.11	Y
	88	29 Nov 2005	12/06/2005	12/12/2005	7.45	Y
	89	29 Nov 2005	12/01/2005	12/10/2005	5.72	Y
	91	29 Nov 2005	11/29/2005	11/29/2005	9.61	N
	92	29 Nov 2005	11/29/2005	12/10/2005	9.62	N
	93	29 Nov 2005	11/29/2005	12/05/2005	8.01	Y
	94	29 Nov 2005	11/29/2005	12/02/2005	64.91	Y
	95	29 Nov 2005	11/29/2005	12/02/2005	26.17	N
	97	29 Nov 2005	11/29/2005	12/01/2005	41.21	Y
	99	29 Nov 2005	11/30/2005	11/30/2005	0.30	N
	100	29 Nov 2005	11/29/2005	11/29/2005	0.03	N
	101	29 Nov 2005	11/29/2005	12/01/2005	49.31	Y
	103	29 Nov 2005	12/01/2005	12/09/2005	10.25	Y
	104	29 Nov 2005	11/29/2005	12/11/2005	44.67	N
	105A	29 Nov 2005	11/29/2005	12/03/2005	85.39	Y
	106A	29 Nov 2005	11/30/2005	11/30/2005	1.94	N
	106B	29 Nov 2005	11/30/2005	12/01/2005	8.72	N
	107A	29 Nov 2005	12/01/2005	12/04/2005	7.38	N
	108B	29 Nov 2005	12/02/2005	12/11/2005	9.94	N
	119	31 Oct 2005	11/28/2005	11/29/2005	9.84	N
	123	31 Oct 2005	11/28/2005	12/03/2005	96.44	Y
	137	29 Nov 2005	12/10/2005	12/10/2005	6.49	N
	138	29 Nov 2005	12/7/2005	12/09/2005	6.70	N
	140	29 Nov 2005	12/01/2005	12/01/2005	0.87	N
	142	29 Nov 2005	11/29/2005	12/08/2005	90.08	N
	145	29 Nov 2005	11/29/2005	11/29/2005	0.39	Y
	146	29 Nov 2005	11/29/2005	12/01/2005	6.02	N
	147	29 Nov 2005	12/04/2005	12/04/2005	1.23	N

Table 4-12. Summary of tag records by fish for radio tracked coho salmon in the Merwin Dam
tailrace.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time In Tailrace (Hours)	Trap Capture?
	148	29 Nov 2005	11/29/2005	11/29/2005	8.26	Y
Unit 1 OFF	149	29 Nov 2005	11/29/2005	12/07/2005	26.44	N
	150	29 Nov 2005	11/29/2005	11/29/2005	0.18	N
	153	29 Nov 2005	12/01/2005	12/03/2005	27.28	Y
	154	29 Nov 2005	12/04/2005	12/07/2005	78.67	Y
Unit 1 ON	63	31 Oct 2005	11/05/2005	11/16/2005	87.21	N
	72	31 Oct 2005	11/04/2005	11/17/2005	142.99	N
	73	31 Oct 2005	11/04/2005	11/06/2005	48.97	N
	74	31 Oct 2005	12/14/2005	12/14/2005	10.09	N
	76	31 Oct 2005	11/04/2005	11/04/2005	3.41	N
	77	31 Oct 2005	12/16/2005	12/17/2005	29.67	N
	80	31 Oct 2005	11/04/2005	11/05/2005	32.85	N
	84	31 Oct 2005	11/04/2005	11/11/2005	134.23	N
	109A	31 Oct 2005	11/04/2005	11/18/2005	118.09	N
	110A	31 Oct 2005	11/05/2005	11/06/2005	14.11	N
	113	31 Oct 2005	11/04/2005	11/12/2005	192.95	N
	116	31 Oct 2005	11/05/2005	11/05/2005	15.34	N
	118	31 Oct 2005	11/04/2005	11/05/2005	29.40	Y
	121	31 Oct 2005	11/04/2005	11/16/2005	63.22	N
	128	31 Oct 2005	11/04/2005	11/21/2005	76.40	N
	132	31 Oct 2005	11/04/2005	11/15/2005	73.05	N
	133	31 Oct 2005	11/04/2005	11/08/2005	64.66	N
OFF/ON Split	90	29 Nov 2005	11/29/2005	12/14/2005	32.00	N
	105B	29 Nov 2005	11/29/2005	12/21/2005	17.37	N
ON/OFF Split	75	31 Oct 2005	11/04/2005	12/02/2005	600.13	Y
	82	31 Oct 2005	11/13/2005	11/25/2005	98.95	N
	111	31 Oct 2005	11/05/2005	12/05/2005	51.42	Y
	114	31 Oct 2005	11/16/2005	11/24/2005	133.94	N
	125	31 Oct 2005	11/06/2005	11/22/2005	13.65	N

Table 4-13. Descriptive statistical summary of tag records in the array by treatment group for radio-tracked coho salmon in the Merwin Dam tailrace.

			Treatment Group			
	Unit 1 OFF	**Unit 1 ON**	**OFF/ON Split**		**ON/OFF Split**	
Variable			**OFF**	**ON**	**ON**	**OFF**
Detection Dates	23 Nov 05–12 Dec 05	04 Nov 05–17 Dec 05	29 Nov 05–09 Dec 05	14 Dec 05–21 Dec 05	22 Nov 05–05 Dec 05	04 Nov 05–21 Nov 05
Number of Tagged Fish	36.0	17.0	2.0	2.0	5	5
Total Hours in Array	942.0	1136.6	28.1	21.3	235.1	633.9
Range for Hours in Array	0.03– 138.7	3.4 – 193.0	1.9 – 26.2	5.8 – 15.5	1.1 – 151.3	12.6 – 419.7
Mean Hours in Array[a]	26.2 (5.6)	66.9 (13.1)	14.0 (12.2)	10.7	47.0 (26.7)	126.8 (74.7)
Median Number of Hours in Array	9.6	63.2	14.0	10.7	27.09	71.9
Total Number of Zone Transitions	463.0	656.0	39	0	180	472
Range for Zone Transitions	0 – 92.0	0 – 113.0	0 – 39.0	0	0 – 128.0	16 – 374
Mean Number of Zone Transition [a]	12.9 (3.1)	38.6 (9.6)	19.5 (19.5)	0	36 (23.7)	94.4 (69.9)
Median Number of Zone Transitions	8.0	33.0	19.5	0	24.0	28.0

[a] Parentheses indicate ± 1 standard error of the mean.

4.2.1 Objective 2 – Estimate the number of trap entry attempts made by adult salmonids in the tailrace

During video analysis, we enumerated 14,241 observations of coho salmon approaching the trap (Table 4-14). There were a total 4,234 observations of exploratory behaviors and 8,564 observations of attempts at trap entry, including 1,443 observations of fallback. To compare behavior between treatment conditions we were able to review 171 hours under Unit 1 OFF and 196 hours under Unit 1 ON likely indicative of peaking coho salmon during this treatment. The total number of successful trap entries (entries – fall backs) was 1,171 and 3,519 for Unit 1 OFF and Unit 1 ON respectively. Coho salmon appeared to spend more time locating the trap under the Unit 1 ON treatment compared to the Unit 1 OFF treatment based on exploratory behavior. However, fish under the Unit 1 ON treatment made fewer attempts at the trap and a higher percentage of the fish were able to successfully enter the trap compared to fish under the Unit 1 OFF treatment.

Table 4-14.   Video analysis summary of coho salmon behavior at the Merwin tailrace trap.

Behavior Category	Behavior	Unit 1 OFF Observations		Unit 1 ON Observations	
		Count	Percent (%)	Count	Percent (%)
Exploratory Behavior	Roll	695	100	4235	100
	Total Exploratory Behavior	**695**		**4235**	
Attempts	Early Jump	385	13	536	536
	Surf/Velocity	769	25	1173	17
	Corner	320	10	405	6
	Hit	18	1	86	1
	Entries	1568	51	4901	69
	Total Attempts	**3060**		**7101**	
Fall Backs	Fall Back	397	25	1382	28
	Successful Entries	1171	38	3519	50

4.2.2 Objective 3 – Estimate the number of adult fish that enter the trap and become captive

Due to limitations with hydroacoustic counts at this location, the only possible means to calculate trap efficiency for the total coho salmon population, ATE_{pop}, was by using the coho salmon radio telemetry data. Overall, the ATE_{pop} for coho salmon was 34.4%. When broken down by operational treatments group the $ATE_{pop-off}$ was 44.2% and the ATE_{pop-on} was 14.3%. Specific calculations follow.

ATE_{pop} = 22 fish captured in the trap/ 64 fish that entered the tailrace radiotelemetry array = 34.4%.

$ATE_{pop-off}$ = 19 fish captured in the trap/43 fish that entered the tailrace = 44.2%

ATE_{pop-on} = 3 fish captured in the trap/21 fish that entered or were present in the tailrace = 14.3%.

The success rate for fish migrating upstream into the Merwin trap (ATE_{mig}) was determined by fish behavior counts recorded during the video analysis. Overall, ATE_{mig} was 46%. When analyzed by operational treatment group the $ATE_{mig-off}$ was 38% and the ATE_{mig-on} was 50%. Specific calculations follow.

ATE_{mig} = 4,690 successful trap entries (total minus fallback)/ 10,161 trap attempts = 46%.

$ATE_{mig-off}$ = 1,171 successful trap entries/3,060 trap attempts = 38%

ATE_{mig-on} = 3,519 trap entries/7,101 trap attempts = 50%.

Statistical analysis was conducted to compare the video-based trap efficiency rate between treatment groups (Figure 4-15). The trap entry success rate was significantly higher with UNIT 1 On than UNIT 1 Off ($\chi^2_{1,318}$ = 9.85, p = 0.0017). Note that the number of replicates (141 and 179 hours for Unit 1 On and Unit 1 OFF respectively) and the number of observations (see Table 4-3) for which there were non-zero attempts into the trap; therefore, the number of observations are less than the number of hours of video that were observed.
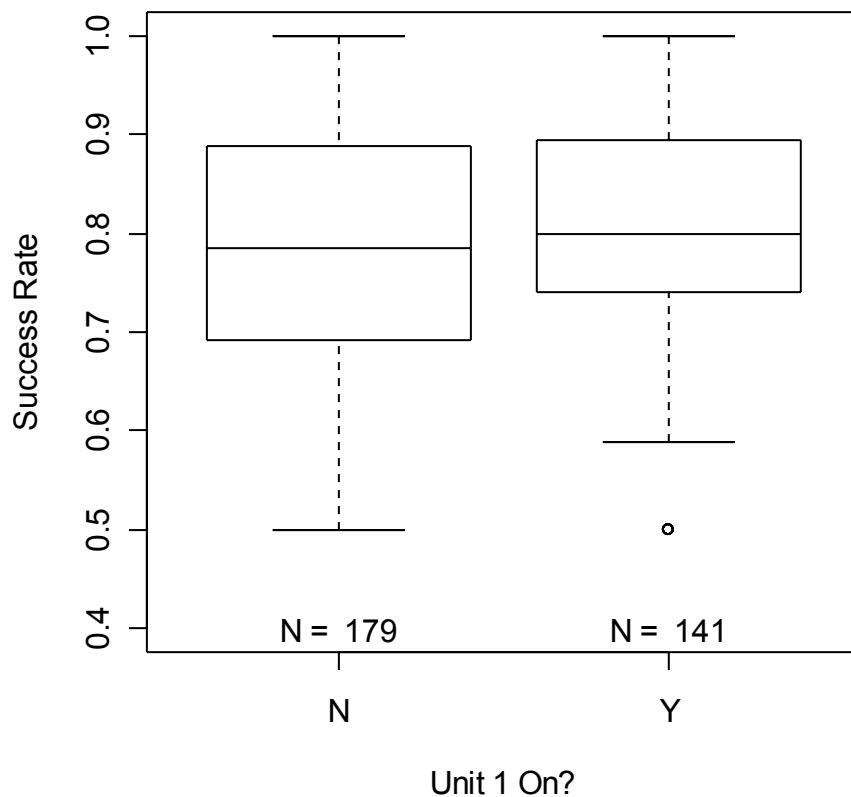
Figure 4-15.   Coho salmon video based trap efficiency rate for the Merwin trap
               when Unit 1 is On versus Off. Boxes indicate 25th - 75th
               percentiles, whiskers represent 95th percentiles, and lines through
               the center of box indicate the median.

4.2.3 Objective 4 – Determine what (if any) tailrace conditions impede fish movement into the trap.

4.2.3.1 Coho Salmon Radiotelemetry Study

4.2.3.1.1 Coho Salmon Analysis of Temporal Distribution in Detection Zones

The total time coho salmon spent is each detection zone ranged from several minutes to approximately 3 hours. Descriptive analysis of mean time in the tailrace indicate that coho salmon spent little time in Zones 3 and 6 and the most time in Zone 7 (Figure 4-16). Plots for fish that spent the most time in the array show this same pattern even under different treatment conditions (Figures 4-17 and 4-18). This pattern was not evident for fish in the split treatment groups (Figures 4-19 and 4-20). Split treatment fish showed a strong preference for Zones 4 and 5.
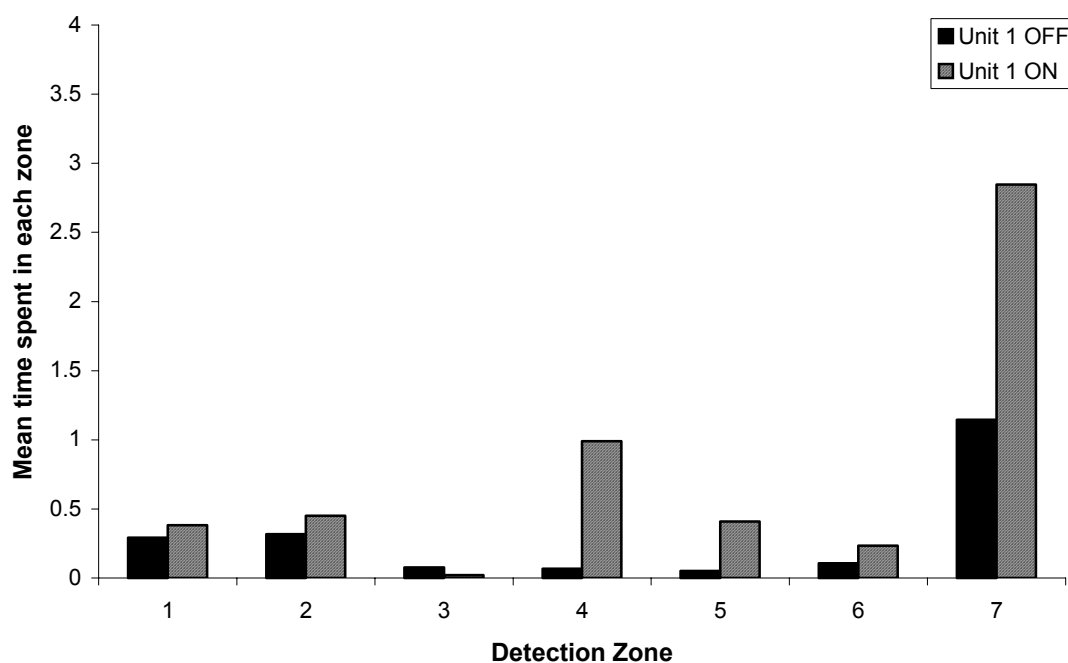
Figure 4-16.   Mean time radio-tagged coho salmon spent in each tailrace detection zone.
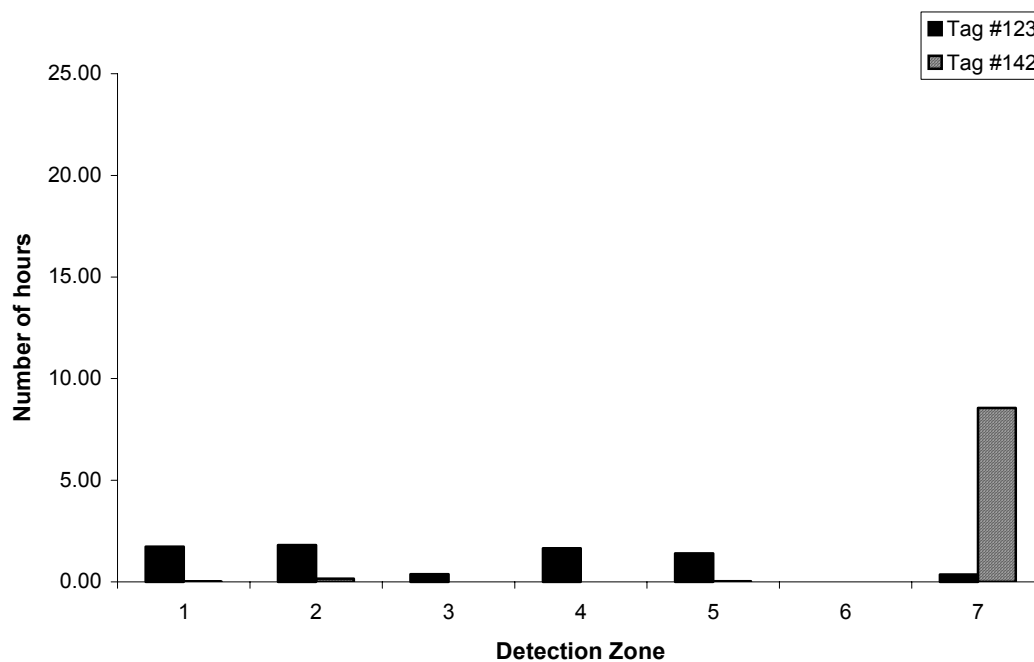
Figure 4-17.   Mean time two radio-tagged coho salmon spent in tailrace detection zones under Unit 1 OFF.
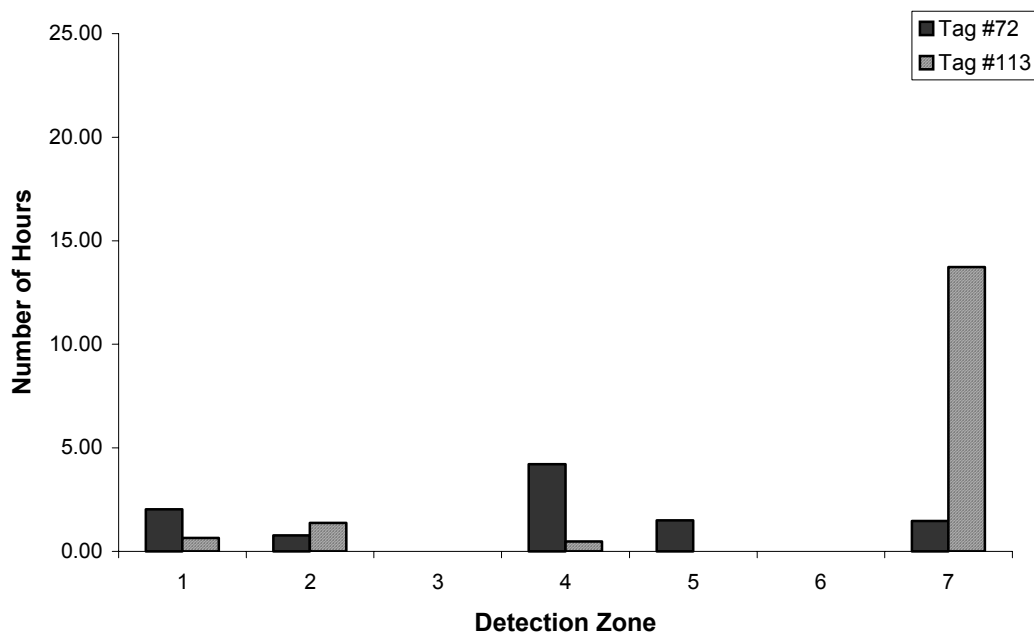
Figure 4-18.   Mean time two radio-tagged coho salmon spent in each detection zone under Unit 1 ON.
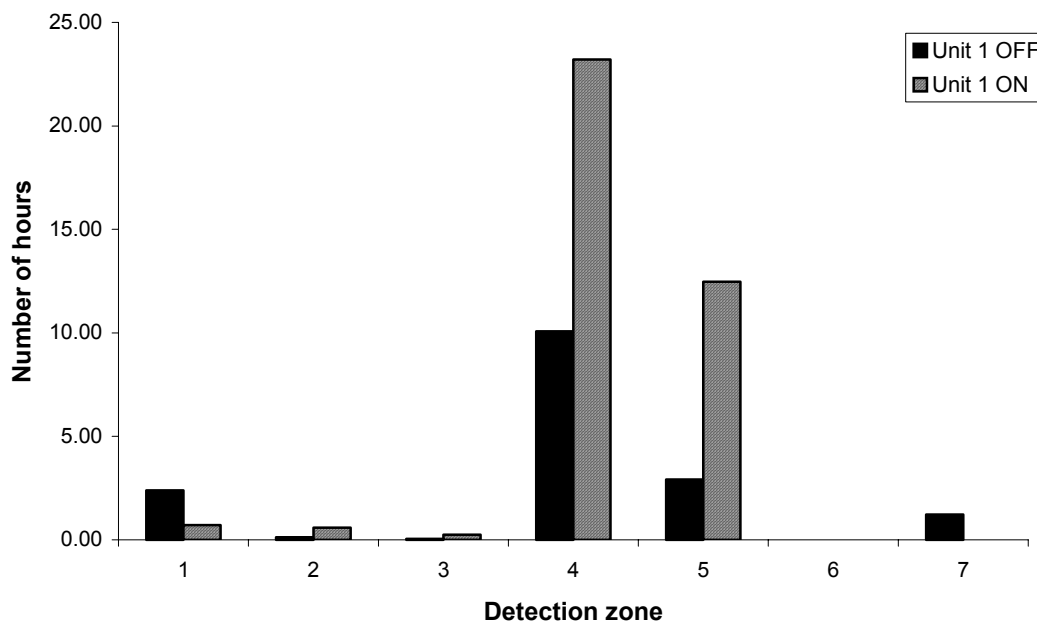
Figure 4-19.   Number of hours radio-tagged coho salmon # 75 from the ON/OFF
                Split group spent in tailrace detection zones.
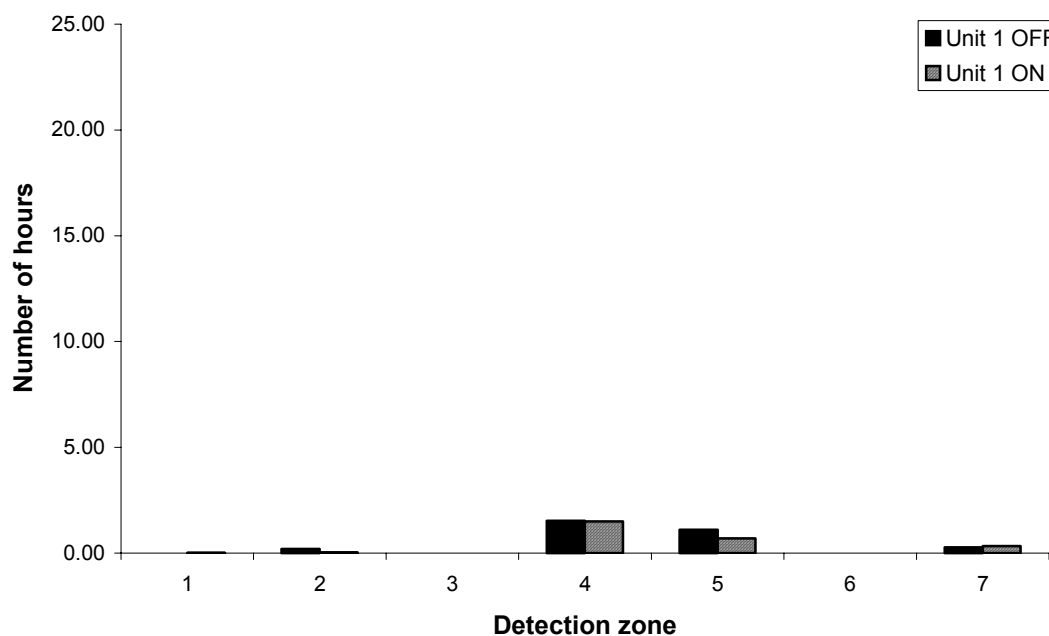
Figure 4-20.   Number of hours radio-tagged coho salmon #114 from the ON/OFF
                Split spent in tailrace detection zones.

The hypothesis tested was that the numbers of contacts in each zone were similar when Unit 1 was on as when Unit 1 was off. The numbers of are depicted in box plots for each zone (Figures 4-21 and 4-22). As can be seen by the box plots, there were too few contacts in Zone 6 under both treatment conditions to complete the statistical comparisons for these zones. The results of the statistical analyses showed no difference in the amount of time spent in Zones 1, 2, 3, and 7 (Table 4-15). However, coho salmon did spend significantly more time in Zone 4 and Zone 5 with Unit 1 ON compared to Unit 1 OFF.

4.2.3.1.2 Analysis of Zone Transitions

We enumerated the number of zone transitions made by radio-tagged coho salmon and compared the distribution of transition counts between treatment groups. The hypothesis tested was that transition count distributions are not significantly different for treatment groups Unit1 OFF and Unit1ON. During the study period, coho salmon exhibited quite a bit of movement within the tailrace resulting in 3,738 zonal transitions that were distributed among the 42 potential directional movements. The most frequent movement tended to be within the two zones along the face of the powerhouse (4, 5), followed by movement within the zones along the control room (1, 2, 3) and between the control room and the powerhouse zones (Figures 4-23 and 4-24).

The pattern of zone transitions changed with Unit 1 ON treatment as compared to Unit 1 OFF. Overall, there appeared to be an increased number of transitions between the detection zones along the powerhouse wall (Zones 4 and 5) and a decrease in those in front of the trap along the wall of the control room and bedrock outcropping (Zones 1, 2, and 3). Statistically significant changes in movement patterns along the control room and powerhouse walls were detected under the Unit 1 ON treatment compared to Unit 1 OFF treatment. When Unit 1 was operating, the number of transitions significantly increased from Zone 1 to Zone 4, Zone 2 to Zone 4, Zone 4 to Zones 1 and 5, and Zone 5 to Zones 2 and 4 (Table 4-16). Conversely, the number of transitions significantly decreased from Zone 1 to Zone 2, Zone 2 to Zone 1, and Zone 3 to Zone 1. The statistical analyses suggest that the operation of Unit 1 causes an increase in the transitions between Zone 1 and Zones 4 or 5, and a decrease in the transitions between Zone 1 and Zone 2, and Zone 2 and Zone 3.
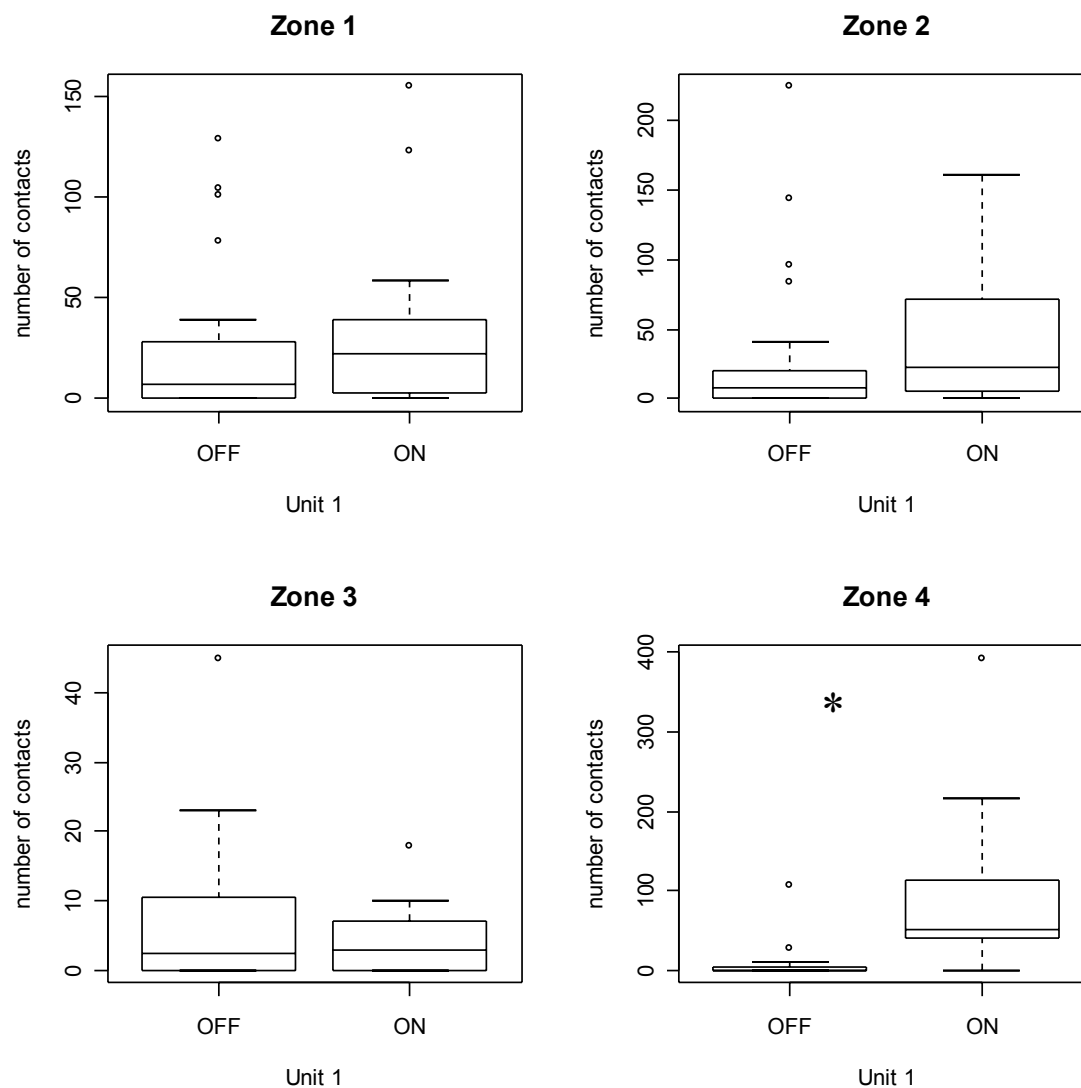
Figure 4-21.   Boxplots of number of coho salmon radio contacts in Zones 1
through 4 with Unit 1 off (n=36) and Unit 1 on (n=17). Boxes
indicate the 25-75th percentiles, whiskers indicate 95th percentiles,
and extreme observations are displayed as points. Statistical tests
indicate contacts were significantly higher ($p < 0.001$, $\chi^2_{1,50} = 25.3$)
in Zone 4 under Unit 1 ON. *Indicates significant difference
between treatments.

Zone 5

Zone 6

Zone 7
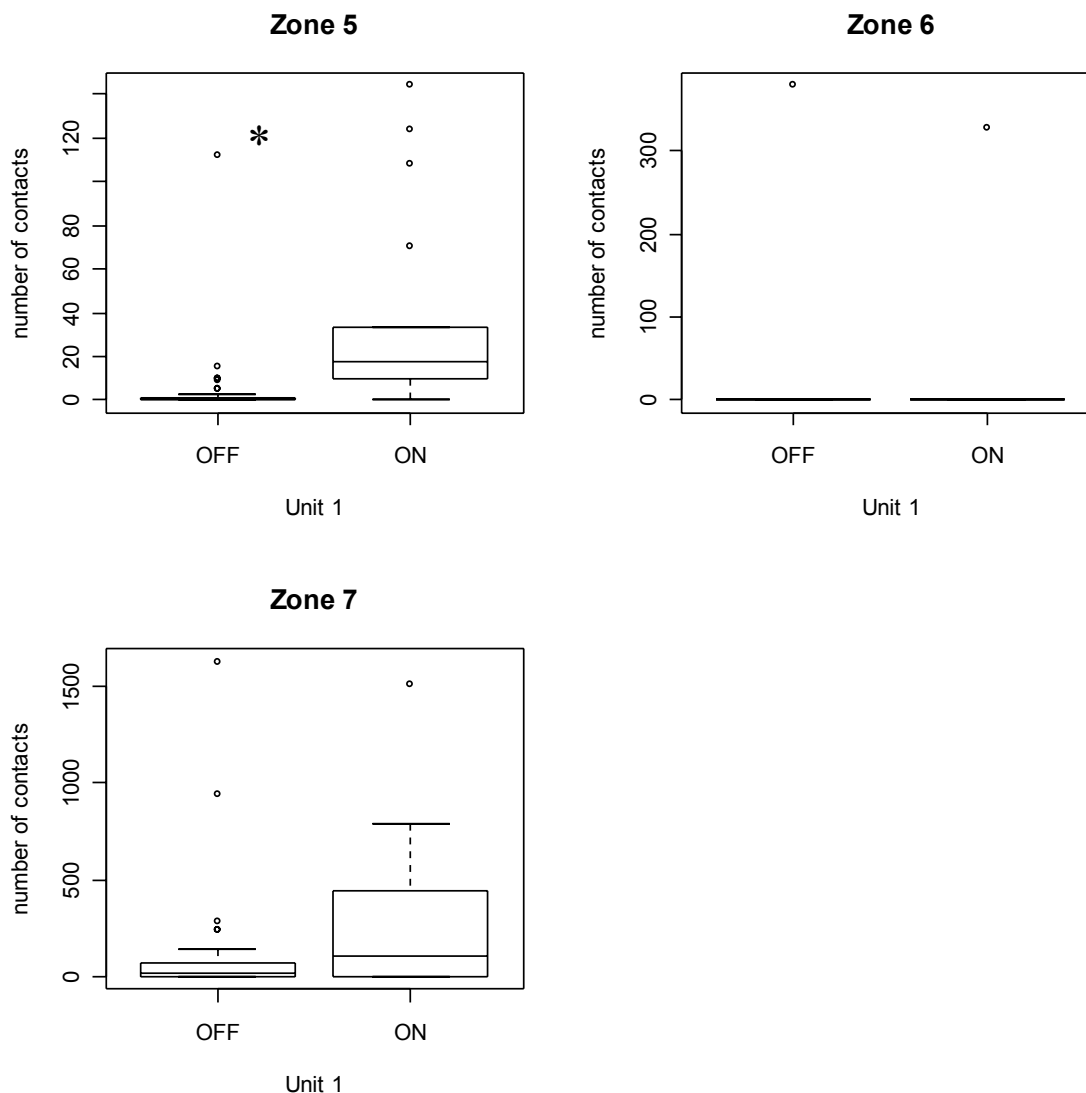
Figure 4-22.   Boxplots of number of coho salmon radio contacts in Zones 5 through 7 under Unit 1 OFF (n=36) and Unit 1 ON (n=17). Boxes indicate the 25-75th percentiles, whiskers indicate 95th percentiles, and extreme observations are displayed as points. Statistical tests could not be conducted in Zone 6 due to the low number of contacts under Unit 1 ON and OFF; whereas contacts were significantly higher ($p < 0.001$, $\chi^2_{1,50} = 14.7$) in Zone 5 under Unit 1 ON. *Indicates significant difference between treatments.
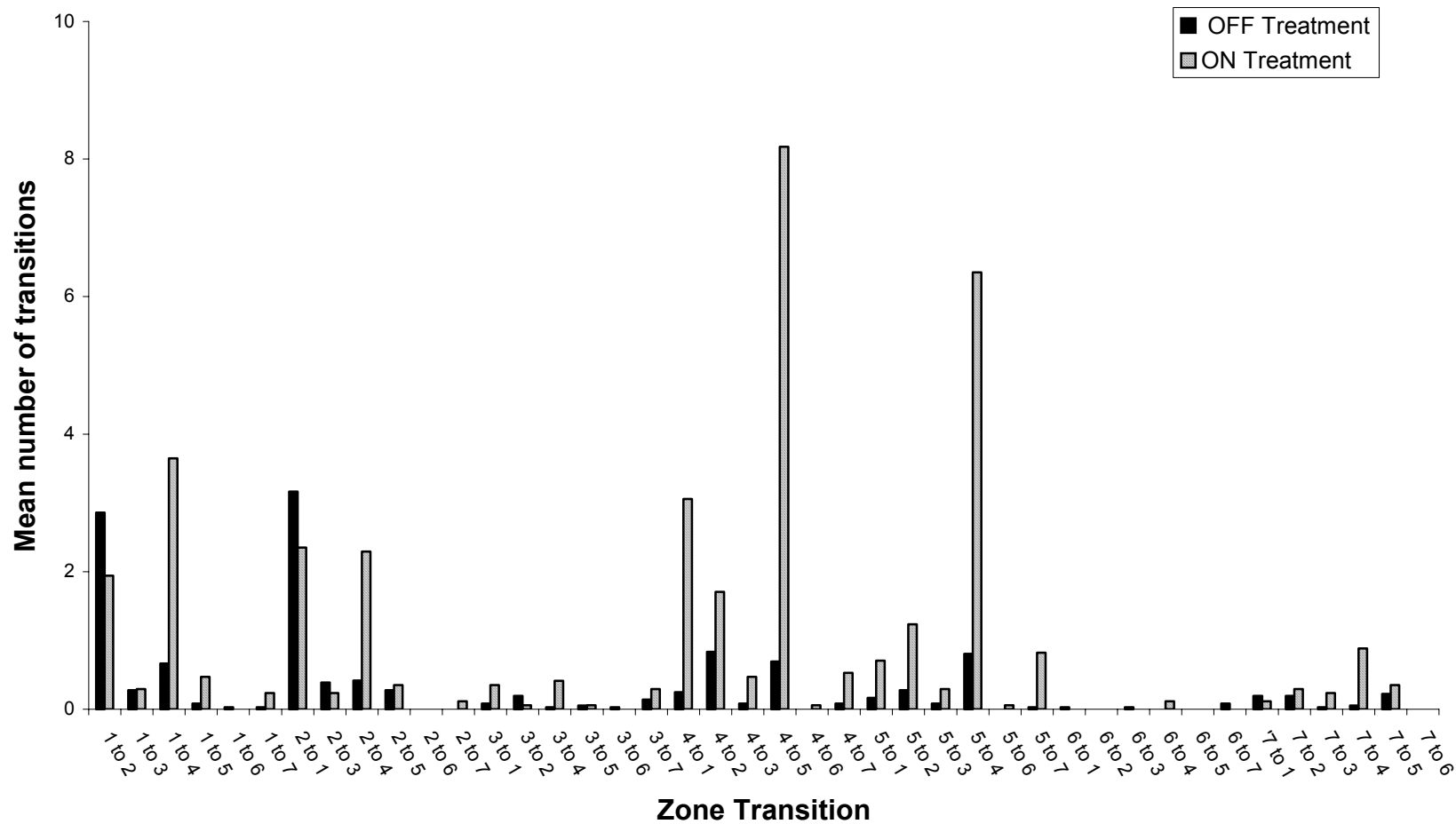
Figure 4-23.   Comparison between treatment groups for mean number of coho salmon transitions between all seven radio telemetry detection zones.

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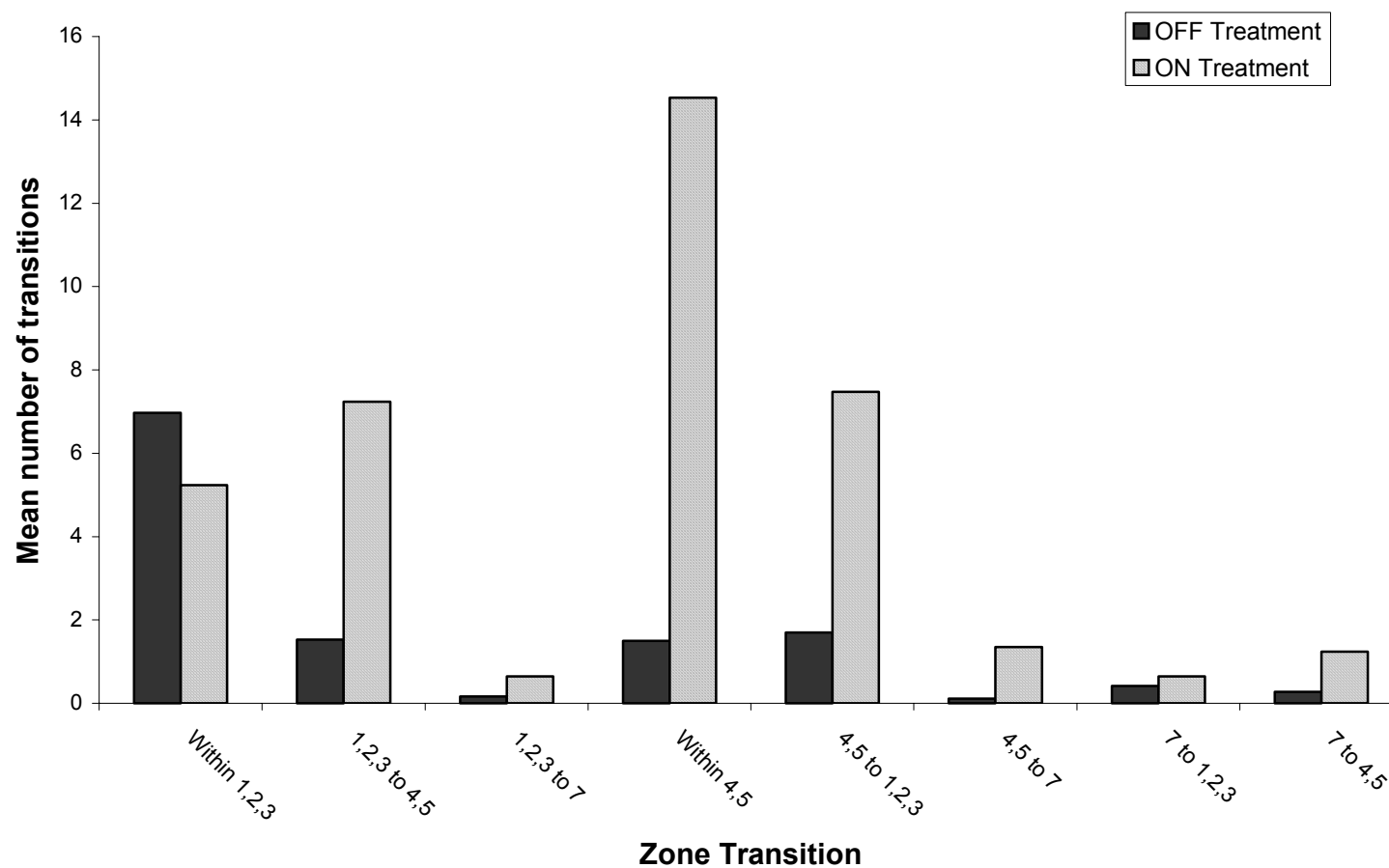
Figure 4-24.   Comparison between treatment groups for mean number of coho salmon transitions with detection zones
grouped by locations within tailrace.

Table 4-15.   Summary of results of generalized linear models for counts of coho salmon radio contacts in each zone. The effect of the total number of contacts is not presented.

Zone	$\chi^2_{1,50}$ value	P value
Zone 1	0.04	0.852
Zone 2	0.36	0.547
Zone 3	0.96	0.326
Zone 4	25.26	< 0.001
Zone 5	14.67	< 0.001
Zone 6	*	*
Zone 7	0.64	0.425

* model did not converge due to very few contacts in one group

Table 4-16.   The effect of Unit 1 on transitions among Zones 1 through 4. Effects in bold are significant at the 0.05 level.

Transition from	To	Effect of Unit 1	$\chi^2_{1,45}$ value	P value
Zone 1	Zone 2	**decrease**	5.75	0.016
	Zone 3	decrease	*	*
	Zone 4	**increase**	16.05	< 0.001
	Zone 5	increase	1.33	0.248
Zone 2	Zone 1	**decrease**	7.44	0.006
	Zone 3	decrease	*	*
	Zone 4	**increase**	8.67	0.003
	Zone 5	decrease	0.12	0.732
Zone 3	Zone 1	increase	1.53	0.216
	Zone 2	**decrease**	5.38	0.020
	Zone 4	increase	0.45	0.502
	Zone 5	decease	1.55	0.212
Zone 4	Zone 1	**increase**	13.37	< 0.001
	Zone 2	increase	0.01	0.943
	Zone 3	increase	0.31	0.578
	Zone 5	**increase**	37.62	< 0.001
Zone 5	Zone 1	increase	*	*
	Zone 2	**increase**	5.28	0.021
	Zone 3	increase	0.72	0.394
	Zone 4	**increase**	24.28	< 0.001

*Model could not converge due to low number of transitions.

The zone transition and use pattern changes indicate that coho salmon tend to align along the right bank when Unit 1 is off and tend to move across the face of the dam when Unit 1 is on. Coho salmon movement in the array was highly variable both within and between treatments. Movement depictions of individual fish that spent the most time in the tailrace illustrate the variability in fish movement between detection zones (Figures 4-25 through 4-28).

Movement of coho salmon in the array was variable both within and between treatments. Movement of individual fish (tag # 123 and 143) that spent the most time in the tailrace depicts some of this variability (Figures 4-25 and 4-26) while being consistent with the overall patterns described above for coho salmon treatment groups. In addition plots for representative fish from the ON/OFF Split treatment are presented in Figures 4-27 and 4-28. These plots all show similar movement to the overall pattern described above with a decrease the number of transitions, more time moving among Zones 1, 4, and 5, and less time moving among Zone 1, 2, and 3 with Unit 1 ON as compared to transitions under Unit 1 OFF.
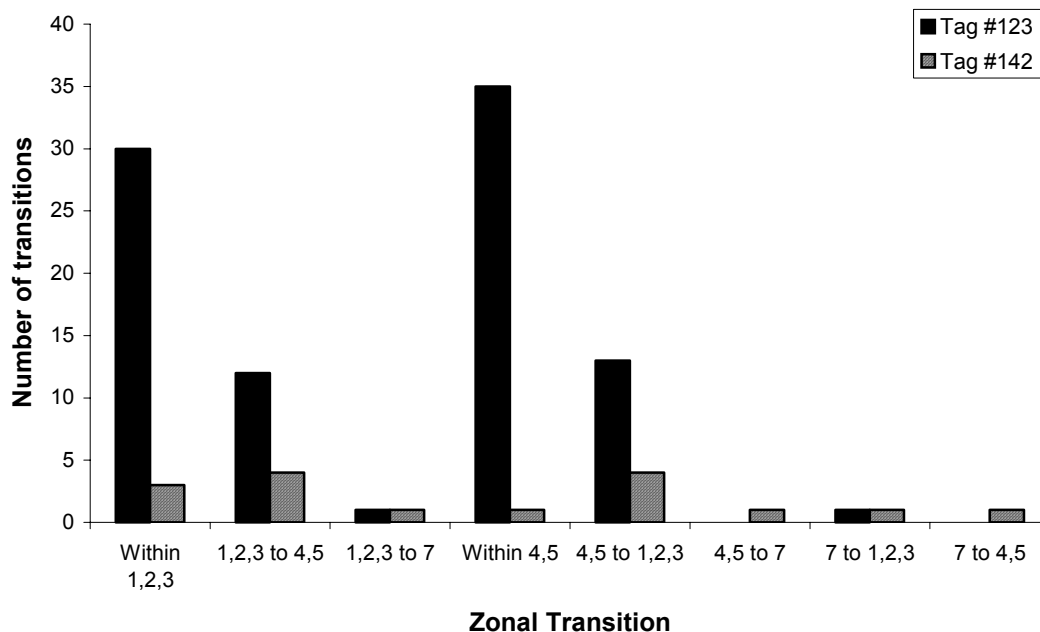
Figure 4-25.   Zone transitions among tailrace detection zones for two radio-tagged coho salmon under Unit 1 OFF.
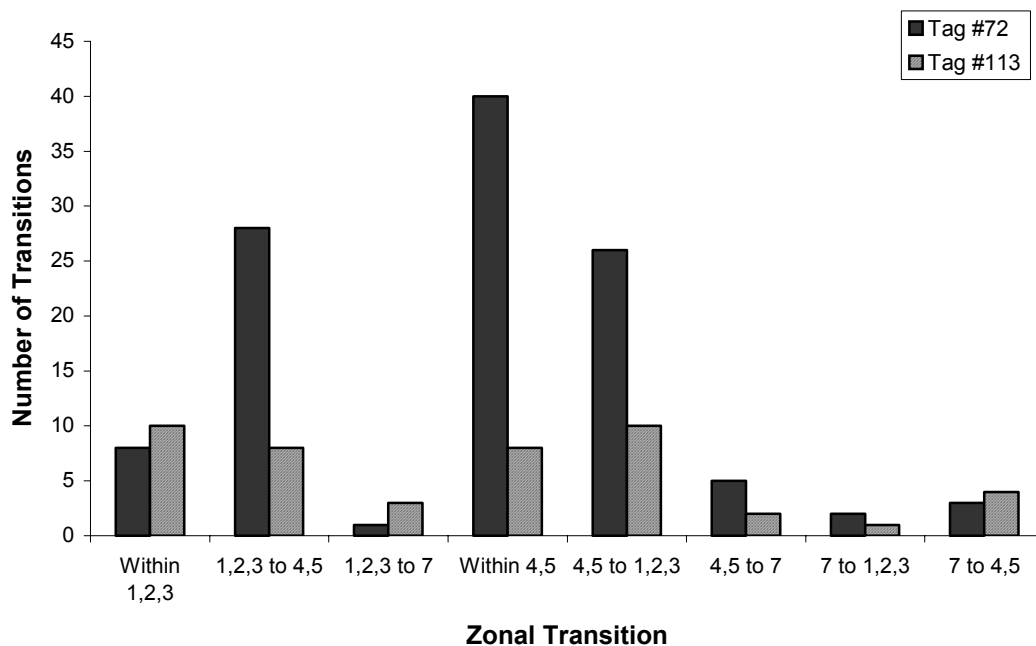
Figure 4-26.   Zone transition among tailrace detections zones for two radio-tagged
               coho salmon under Unit 1 ON.
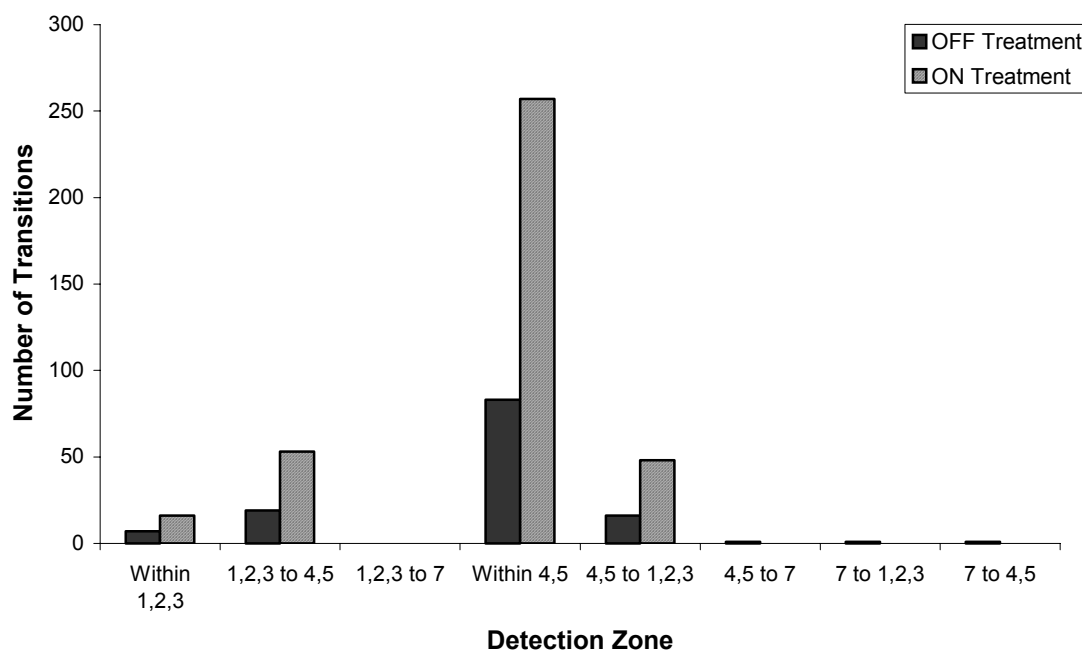
Figure 4-27.   Number of transitions among grouped tailrace detection zones for
               radio-tagged coho salmon # 75 from the Split treatment groups.
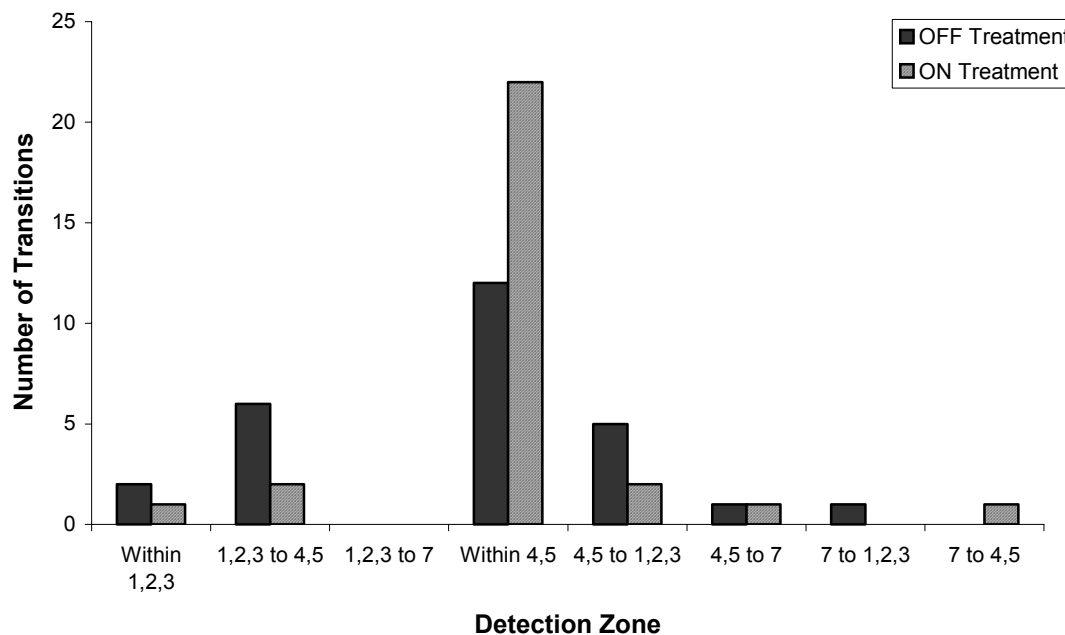
Figure 4-28.   Number of transitions among grouped tailrace detection zones for
radio-tagged coho salmon #114 from the SPLIT treatment groups.

4.2.4 Objective 5 – If tailrace conditions preclude trap entry or cause migration delay what locations would be preferred for a new trap entrance?

4.2.4.1. Radio Telemetry Study

Statistical analysis was used to compare total time spent in the array under Unit 1 OFF and Unit 1 ON. The null hypothesis tested was that the time fish spend in the tailrace is the same when Unit 1 was off versus when Unit 1 was on. An Analysis of variance (ANOVA) was conducted using a (log(minutes) +1) transformation on the data. This model assumes that the residual variability is normally distributed; however, there appears to be strong evidence that it fails to meet the assumption of normality (regression residuals fail Shapiro-Wilk test of normality, W = 0.84, $p < 0.001$). A robust regression (Venables and Ripley 1999) was subsequently fitted to account for the extra variability in the data. Although the average time spent in the tailrace appears to be greater when Unit 1 is on versus when it is off (Figure 4-29), the ANOVA test fails to reject the null hypothesis ($p = 0.103$, $F_{1,46} = 1.19$) indicating that the total time fish spend in the tailrace did not differ between the two operating conditions. This occurs largely because there is substantial variability among fish within the Unit 1 ON treatment group, and substantial variability among fish within the Unit 1 OFF treatment group.
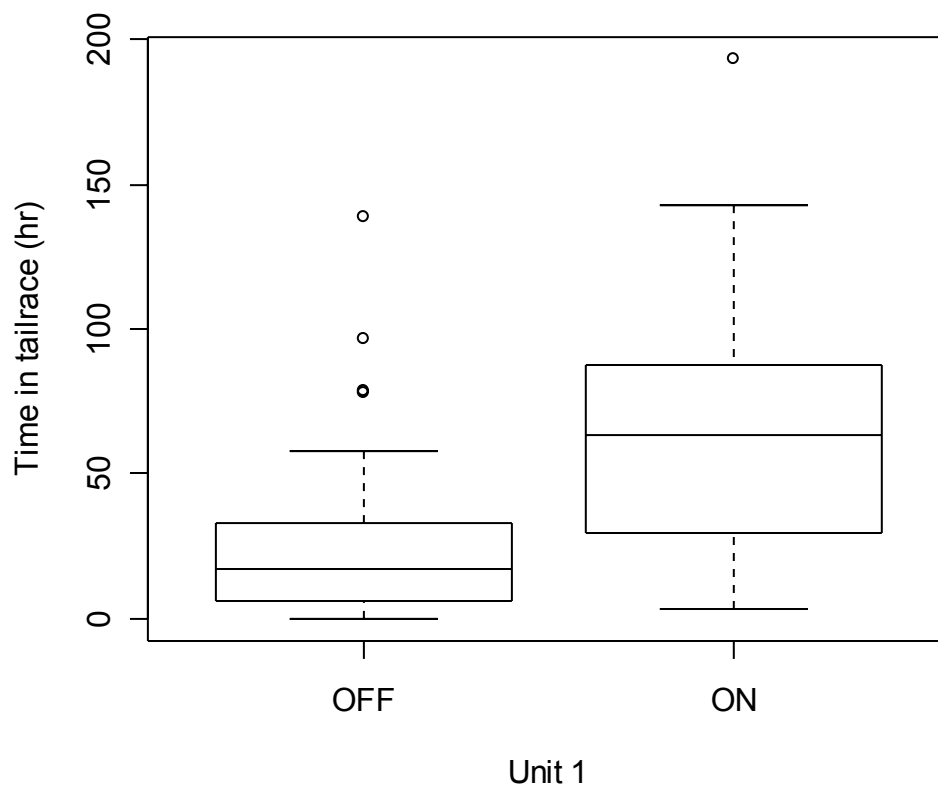
Figure 4-29.   Boxplot of the total time spent in the Merwin tailrace by coho
               salmon when Unit 1 was off (n=31) and when Unit 1 was on (n=17).
               Boxes indicate the 25-75th percentiles, whiskers indicate 95th
               percentiles, and extreme observations are displayed as points. No
               significant difference in total time was detected between Unit 1 OFF
               and ON treatments.

4.3 WINTER STEELHEAD

A total of 60 tagged hatchery winter steelhead were detected in the radio telemetry array during the study. Due to the expanded Unit 1 ON period, 55 of these fish entered the tailrace under Unit 1 ON and only 5 entered under Unit 1 OFF. Thirty-two tagged hatchery winter steelhead were never detected and either moved downstream, lost tags, or died (Table 4-17). A total of 8 tagged hatchery winter steelhead entered the trap undetected by the array (Table 4-18). This is twice the number of tagged fish to bypass the array compared to summer steelhead and coho salmon. This increase in undetected tagged fish can be in part explained due to the high flow spill events that occurred during the winter steelhead study. Five winter steelhead were found to enter the trap during the spill event. Due to large unequal sample sizes Unit 1 OFF and Unit 1 ON treatment comparisons are limited to descriptive data (Table 4-20).

The total time each fish spent in the array varied widely from one minute to 173 hours with more than 50% of the hatchery winter steelhead remaining in the tailrace for 9.8 hours (Table 4-19). Fish undetected by the array exhibited spatially variable movement patterns downstream of the tailrace. Mobile tracking of fish downstream of the tailrace indicated movement was either limited to within a few hundreds meters of the tailrace to distances greater than a mile. For example, five of the tagged fish were detected within several hundred meters of the tailrace near the Merwin boat ramp. Conversely, eight fish were detected at, or downstream of, the Lewis River Hatchery indicating downstream movement in excess of 3 miles.

Table 4-17. Summary of winter steelhead radio-telemetry tags lost to the study. Asterisks indicate wild winter steelhead.

Tag Number	Release Group	Date Tagged	Comments
28*	3	06-May-06	No recapture, disposition unknown
29*	4	19-May-06	No recapture, disposition unknown
41*	5	28-May-06	No recapture, disposition unknown
48*	3	06-May-06	No recapture, disposition unknown
57*	3	19-May-06	No recapture, disposition unknown
60*	5	28-May-06	No recapture, disposition unknown
87*	5	28-May-06	No recapture, disposition unknown
94*	5	28-May-06	No recapture, disposition unknown
99*	3	06-May-06	No recapture, disposition unknown
101*	5	28-May-06	No recapture, disposition unknown
112*	4	19-May-06	No recapture, disposition unknown
112	1	03-Jan-06	Detected downstream

Table 4-17.   Summary of winter steelhead radio-telemetry tags lost to the study. Asterisks
                      indicate wild winter steelhead.

Tag Number	Release Group	Date Tagged	Comments
116	1	03-Jan-06	Detected downstream
123*	5	28-May-06	No recapture, disposition unknown
125	1	03-Jan-06	Detected downstream
128	1	10-Jan-06	Tag recovered at release
130	1	10-Jan-06	Harvested
134	1	10-Jan-06	Detected downstream
138*	5	28-May-06	No recapture, disposition unknown
140	2	26-Jan-06	Detected downstream
144	2	26-Jan-06	Detected downstream
147	2	26-Jan-06	Tag recovered at release
148	2	26-Jan-06	Detected downstream
153	2	26-Jan-06	Detected downstream
153*	5	28-May-06	No recapture, disposition unknown
154	2	26-Jan-06	No recapture, disposition unknown
156B	2	26-Jan-06	Detected downstream
157*	3	28-May-06	No recapture, disposition unknown
158B	2	26-Jan-06	No recapture, disposition unknown
159B	2	26-Jan-06	No recapture, disposition unknown
162	2	26-Jan-06	Detected downstream
170	1	03-Jan-06	No recapture, disposition unknown
171	1	10-Jan-06	Tag recovered at release
172	1	03-Jan-06	Detected downstream
173	1	10-Jan-06	Tag recovered at release
175	1	03-Jan-06	Record insufficient for analysis
174	1	03-Jan-06	No recapture, disposition unknown
177	1	03-Jan-06	No recapture, disposition unknown
181	2	26-Jan-06	No recapture, disposition unknown
185	2	26-Jan-06	No recapture, disposition unknown
187	2	26-Jan-06	No recapture, disposition unknown
188	2	26-Jan-06	No recapture, disposition unknown
189	2	26-Jan-06	No recapture, disposition unknown
194	2	26-Jan-06	No recapture, disposition unknown
197	2	26-Jan-06	No recapture, disposition unknown
199	2	26-Jan-06	No recapture, disposition unknown
202	2	26-Jan-06	Detected downstream

Table 4-18.   Summary of radio tagged winter steelhead that moved through the array undetected.

Tag Number	Tag Group	Date Tagged	Date in Trap	Operational Treatment	Tag Disposition
110	1	03-Jan-06	06-Jan-06	Unit 1 ON	Fish collected with tag
113	1	03-Jan-06	06-Jan-06	Unit 1 ON	Fish collected with tag
150	1	03-Jan-06	06-Jan-06	Unit 1 ON	Fish collected with tag
167	1	03-Jan-06	06-Jan-06	Unit 1 ON	Fish collected with tag
168	1	10-Jan-06	26-Jan-06	Unit 1 ON	Fish collected with tag
184	2	26-Jan-06	15-Feb-06	Unit 1 ON	Fish collected with tag
190	2	26-Jan-06	02-Mar-06	Unit 1 OFF	Fish collected with tag
204	2	26-Jan-06	26-Jan-06	Unit 1 ON	Fish collected with tag

Table 4-19.   Summary of tag records by fish for radio tracked winter steelhead in the Merwin Dam tailrace. Asterisks indicate wild winter steelhead.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time In Tailrace (Hours)	Trap Capture?
Unit 1 OFF	31*	19-May-06	19-May-06	4-June-06	70.84	Y
	105*	06-May-06	18-May-06	18-May-16	8.72	N
	129	03-Jan-06	03-Jan-06	24-Mar-06	2.35	N
	141	26-Jan-06	01-Mar-06	20-Mar-06	18.81	N
	183	26-Jan-06	08-Mar-06	20-Mar-06	57.52	N
Unit 1 ON	111	03-Jan-06	03-Jan-06	07-Jan-06	95.25	Y
	114	03-Jan-06	07-Jan-06	07-Jan-06	1.04	Y
	115	03-Jan-06	03-Jan-06	06-Jan-06	7.14	Y
	117	03-Jan-06	06-Jan-06	06-Jan-06	35.20	Y
	118	03-Jan-06	03-Jan-06	16-Jan-06	163.67	N
	119	03-Jan-06	03-Jan-06	03-Jan-06	1.19	Y
	120	03-Jan-06	03-Jan-06	06-Jan-06	60.87	Y
	121	03-Jan-06	03-Jan-06	03-Jan-06	0.07	Y
	122	03-Jan-06	03-Jan-06	05-Jan-06	47.89	Y
	123	03-Jan-06	03-Jan-06	06-Jan-06	3.90	Y
	124	03-Jan-06	03-Jan-06	03-Jan-06	0.03	Y
	126	03-Jan-06	04-Jan-06	06-Jan-06	54.92	Y
	127	03-Jan-06	07-Jan-06	08-Jan-06	27.07	N
	131	03-Jan-06	03-Jan-06	07-Jan-06	99.42	Y
	132	03-Jan-06	03-Jan-06	03-Jan-06	0.01	Y
	133	03-Jan-06	04-Jan-06	06-Jan-06	53.63	N

Table 4-19.　Summary of tag records by fish for radio tracked winter steelhead in the Merwin Dam tailrace. Asterisks indicate wild winter steelhead.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time In Tailrace (Hours)	Trap Capture?
	135	26-Jan-06	26-Jan-06	15-Feb-06	0.84	N
	136	26-Jan-06	31-Jan-06	31-Jan-06	13.06	N
	137	26-Jan-06	26-Jan-06	28-Jan-06	45.57	Y
	138	26-Jan-06	26-Jan-06	27-Jan-06	8.65	Y
	139	26-Jan-06	26-Jan-06	07-Feb -06	40.37	N
	142	26-Jan-06	27-Jan-06	30-Jan-06	16.63	N
	143	26-Jan-06	26-Jan-06	27-Feb-06	25.96	Y
	145	26-Jan-06	26-Jan-06	07-Feb-06	3.70	Y
	146	26-Jan-06	26-Jan-06	15-Feb-06	2.10	N
	149	26-Jan-06	27-Jan-06	30-Jan-06	19.80	Y
	151	26-Jan-06	27-Jan-06	27-Jan-06	0.17	N
	152	26-Jan-06	26-Jan-06	27-Jan-06	18.38	Y
	155A	03-Jan-06	03-Jan-06	03-Jan-06	26.13	Y
	155B	26-Jan-06	26-Jan-06	15-Feb-06	2.53	N
	156A	03-Jan-06	03-Jan-06	03-Jan-06	4.48	Y
	157A	03-Jan-06	03-Jan-06	03-Jan-06	1.46	Y
	157B	26-Jan-06	26-Jan-06	08-Feb-06	9.78	N
	158A	03-Jan-06	03-Jan-06	03-Jan-06	2.31	N
	159A	03-Jan-06	03-Jan-06	04-Jan-06	11.80	Y
	160	03-Jan-06	03-Jan-06	03-Jan-06	3.64	Y
	161	03-Jan-06	03-Jan-06	12-Jan-06	172.64	Y
	163	10-Jan-06	10-Jan-06	10-Jan-06	0.06	N
	164	03-Jan-06	03-Jan-06	05-Jan-06	47.31	Y
	165	03-Jan-06	03-Jan-06	03-Jan-06	1.30	Y
	166	03-Jan-06	03-Jan-06	06-Jan-06	3.69	Y
	169	03-Jan-06	10-Jan-06	10-Jan-06	1.71	N
	176	03-Jan-06	03-Jan-06	16-Jan-06	149.07	Y
	178	03-Jan-06	03-Jan-06	04-Jan-06	14.72	Y
	179	26-Jan-06	27-Jan-06	27-Jan-06	5.56	Y
	180	26-Jan-06	26-Jan-06	26-Jan-06	25.81	Y
	182	26-Jan-06	26-Jan-06	26-Jan-06	3.79	Y
	186	26-Jan-06	26-Jan-06	27-Jan-06	26.99	N
	191	26-Jan-06	29-Jan-06	29-Jan-06	0.10	N
	192	26-Jan-06	26-Jan-06	28-Jan-06	44.78	N
	193	26-Jan-06	26-Jan-06	27-Jan-06	25.61	N

Table 4-19. Summary of tag records by fish for radio tracked winter steelhead in the Merwin Dam tailrace. Asterisks indicate wild winter steelhead.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time In Tailrace (Hours)	Trap Capture?
	195	26-Jan-06	05-Feb-06	05-Feb-06	3.43	Y
	196	26-Jan-06	07-Feb-06	07-Feb-06	2.89	Y
	198	26-Jan-06	15-Feb-06	15-Feb-06	1.08	N
	200	26-Jan-06	28-Jan-06	29-Jan-06	27.15	Y
	201	26-Jan-06	27-Jan-06	04-Feb-06	3.84	N
	203	26-Jan-06	27-Jan-06	03-Feb-06	69.29	Y

Table 4-20. Descriptive statistical summary of tag records in the array by treatment group for radio-tracked winter steelhead in the Merwin Dam tailrace.

	Treatment Group	
Variable	**Unit 1 OFF**	**Unit 1 ON**
Detection Dates	**03 Mar 06 – 02 May 06**	**03 Jan 06 – 15 Feb 06**
Number of Tagged Fish	3.0	57.0
Total Hours in Array	78.7	1566.5
Range for Hours In Array	2.4 – 57.5	0.01 – 172.6
Mean Hours in Array[a]	26.2 (16.4)	27.5 (5.4)
Median Number of Hours in Array	18.8	9.8
Total Number of Zone Transitions	3.0	627.0
Range for Zone Transitions	0 –3.0	0 – 128.0
Mean Number of Zone Transition [a]	1.0 (1.0)	11.0 (2.8)
Median Number of Zone Transitions	0.0	3.0

[a] Parentheses indicate ± 1 standard error of the mean.

4.3.1 Objective 2 – Estimate the number of trap entry attempts made by adult salmonids in the tailrace.

This objective could not be completed due to mechanical failure of the video camera installed above Merwin Trap.

4.3.2 Objective 3 – Estimate the number of adult fish that enter the trap and become captive

Due to limitations with hydroacoustic counts at this location and the lack of video images for both treatment groups, the only possible means to calculate trap efficiency for the total hatchery winter steelhead population, ATE_{pop}, was by using the winter steelhead radiotelemetry data. Overall, the ATE_{pop} was 64.7%. When broken down by operational treatments group the $ATE_{pop\text{-}off}$ was 25% and the $ATE_{pop\text{-}on}$ was 67.2%. Specific calculations follow. Please note that wild steelhead were not included in this analysis.

ATE_{pop} = 44 fish captured in the trap/ 68 fish that entered the tailrace radiotelemetry array = 64.7%.

$ATE_{pop\text{-}off}$ = 1 fish captured in the trap/4 fish that entered the tailrace = 25%

$ATE_{pop\text{-}on}$ = 43 fish captured in the trap/64 fish that entered or were present in the tailrace = 67.2%.

4.3.3 Objective 4 – Determine what (if any) tailrace conditions impede fish movement into the trap

4.3.3.1. Hatchery Winter Steelhead Radiotelemetry Study

4.3.3.1.1. Hatchery Winter Steelhead Analysis of Temporal Distribution In Detection Zones

The mean total time winter steelhead spent in each detection zone ranged from a few minutes to approximately 3 hours. Plots of time spent in the tailrace show patterns of more time in Zones 6, 7 and 1 under Unit 1 OFF. Fish from the Unit 1 ON treatment showed a distinct preference for Zone 7. The winter steelhead that spent the most time in the tailrace during the study clearly spent the most time in Zone 7 regardless of treatment. In addition, the winter steelhead with longest time under Unit 1 ON show use of more zones including Zones 1, 4, 5, and 6.

The hypothesis tested was that the numbers of contacts in each zone were similar when Unit 1 was on as when Unit 1 was off. However, we were unable to test for differences in the number of contacts in each zone between the Unit 1 ON and Unit 1 OFF treatment groups because Unit 1 remained operational through most of the winter steelhead study period. Thus, 57 of the 60 fish that entered the array were assigned to the Unit 1 ON treatment. As can be seen by the box plots, there were too few contacts in all seven zones for the Unit 1 OFF treatment group to complete the statistical comparisons for these zones (median value = 0) (Figures 4-30 and 4-31). After accounting for outliers, winter steelhead appeared to spend the most time in Zone 4 and Zone 5. The total time winter steelhead spent in the array was highly variable both within and between

treatments. Graphical depictions of fish that spent the most time in the tailrace illustrate the variability encountered by the array in detecting fish (Figures 4-32 through 4-34).
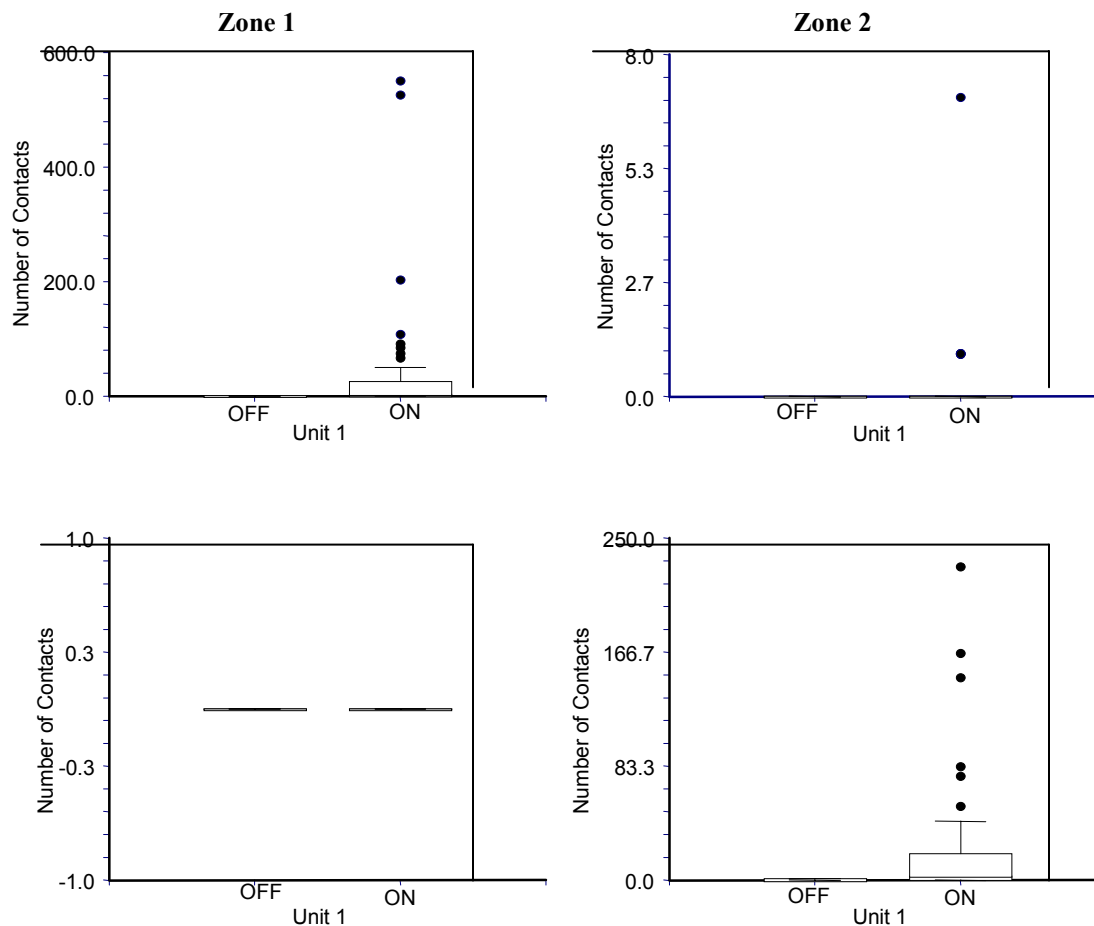
Figure 4-30. Box plots of number of contacts in Zones 1 through 4 with Unit 1 off (n=3) and Unit 1 on (n=58). Boxes indicate the 25-75th percentiles, whiskers indicate 95th percentiles, and extreme observations are displayed as points. Statistical tests could not be performed due to the low sample size of Unit 1 OFF treatment.
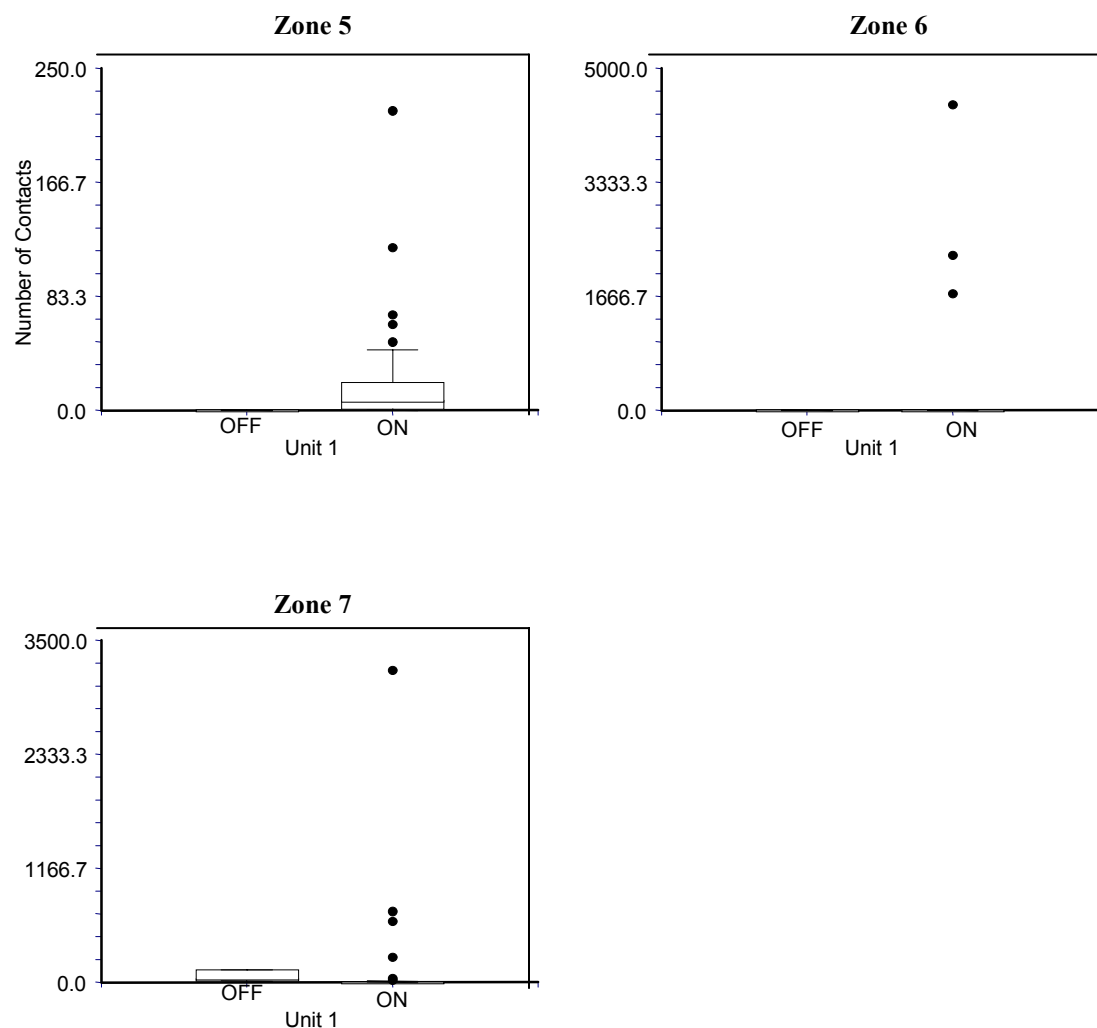
Figure 4-31. Box plots of number of contacts in Zones 5 through 7 with Unit 1 off (n=3) and Unit 1 on (n=58). Boxes indicate the 25-75th percentiles, whiskers indicate 95th percentiles, and extreme observations are displayed as points. Statistical tests could not be conducted due to the low sample size of Unit 1 OFF treatment.
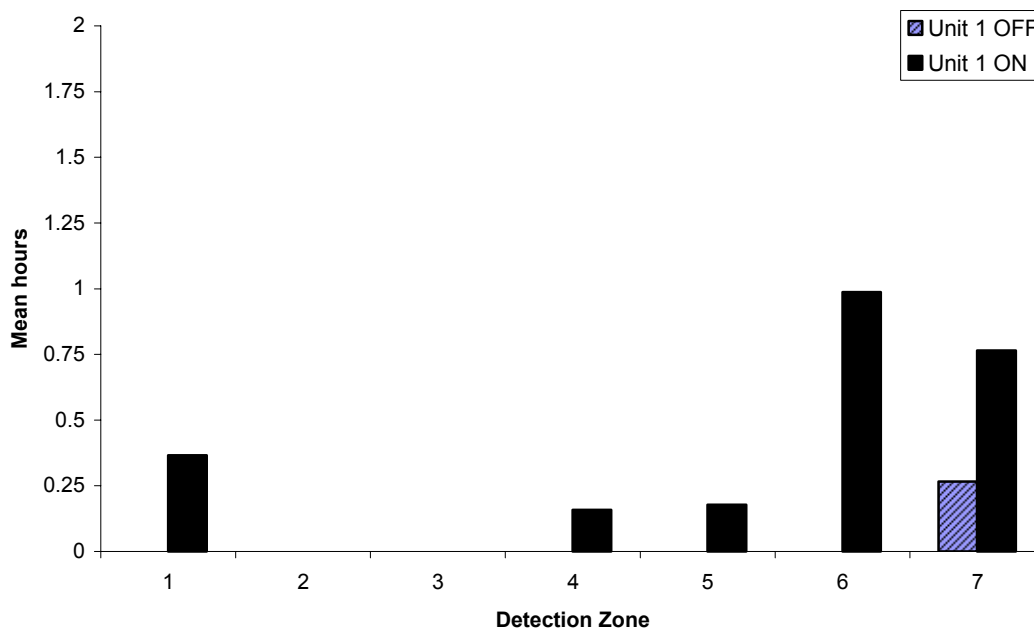
Figure 4-32.   Comparison between treatment groups for mean number of hours spent in each radio telemetry zone by radio tagged hatchery winter steelhead.
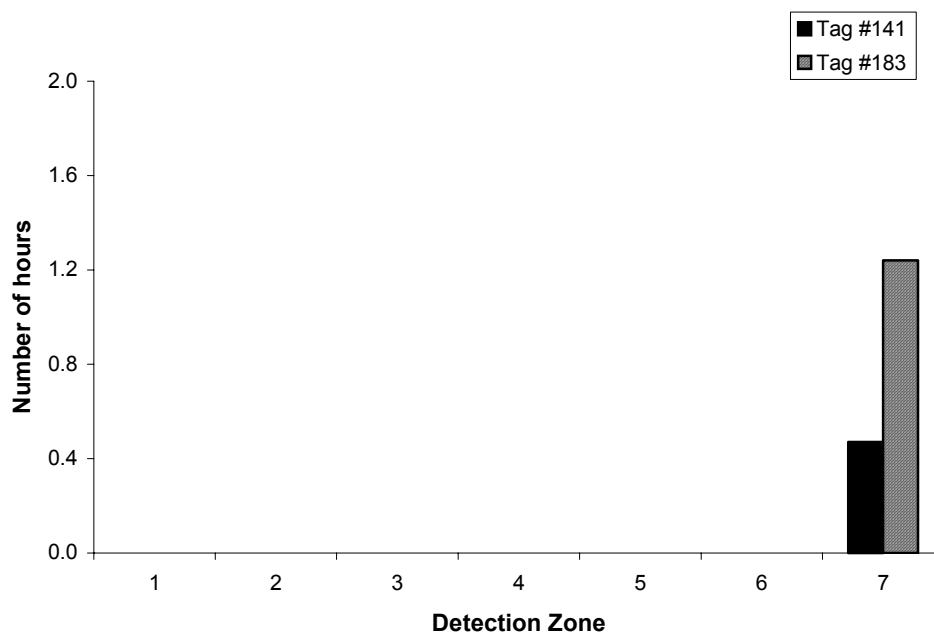
Figure 4-33.   Mean hours spent in each radio telemetry zone for Unit 1 OFF tagged winter steelhead 141 and 183.
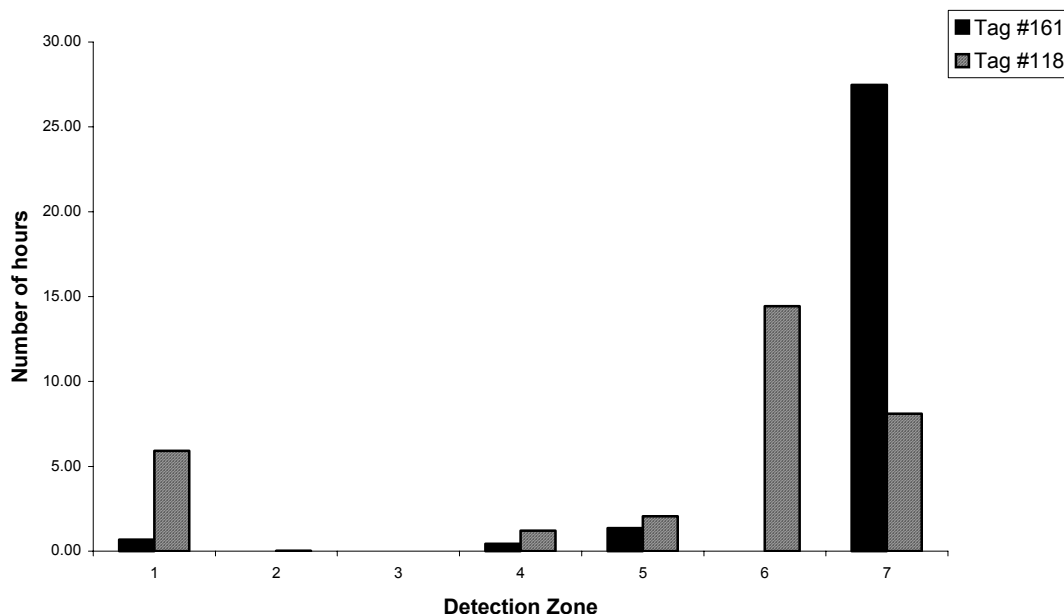
Figure 4-34.   Mean hours spent in each radio telemetry zone for Unit 1 ON tagged
                      winter steelhead 118 and 161.

4.3.3.1.2 Analysis of Zone Transitions

We also enumerated the number of zone transitions, fish movements from one zone to the next, and compared the distribution of transition counts between treatment groups. The hypothesis tested was that the distribution of transition counts were not significantly different for treatment groups Unit1 OFF and Unit1 ON. However, we were unable to test for differences in the number of zone transitions between the Unit 1 ON and OFF treatment groups because Unit 1 remained operational through most of the winter steelhead study period. Overall, we recorded 630 zonal transitions that were distributed among the 42 potential directional movements. The greatest number of movements tended to be clumped within the two zones along the face of the powerhouse (4, 5), followed by movement between the control room zones (1, 2, and 3) and the powerhouse zones (4, 5) (Figures 4-35 and 4-36). Winter steelhead movement appeared greater and used more zones under the Unit 1 ON treatment compared to Unit 1 OFF. Movement depictions of individual fish that spent the most time in the tailrace illustrate patterns observed for the overall group (Figures 4-37 and 4-38).
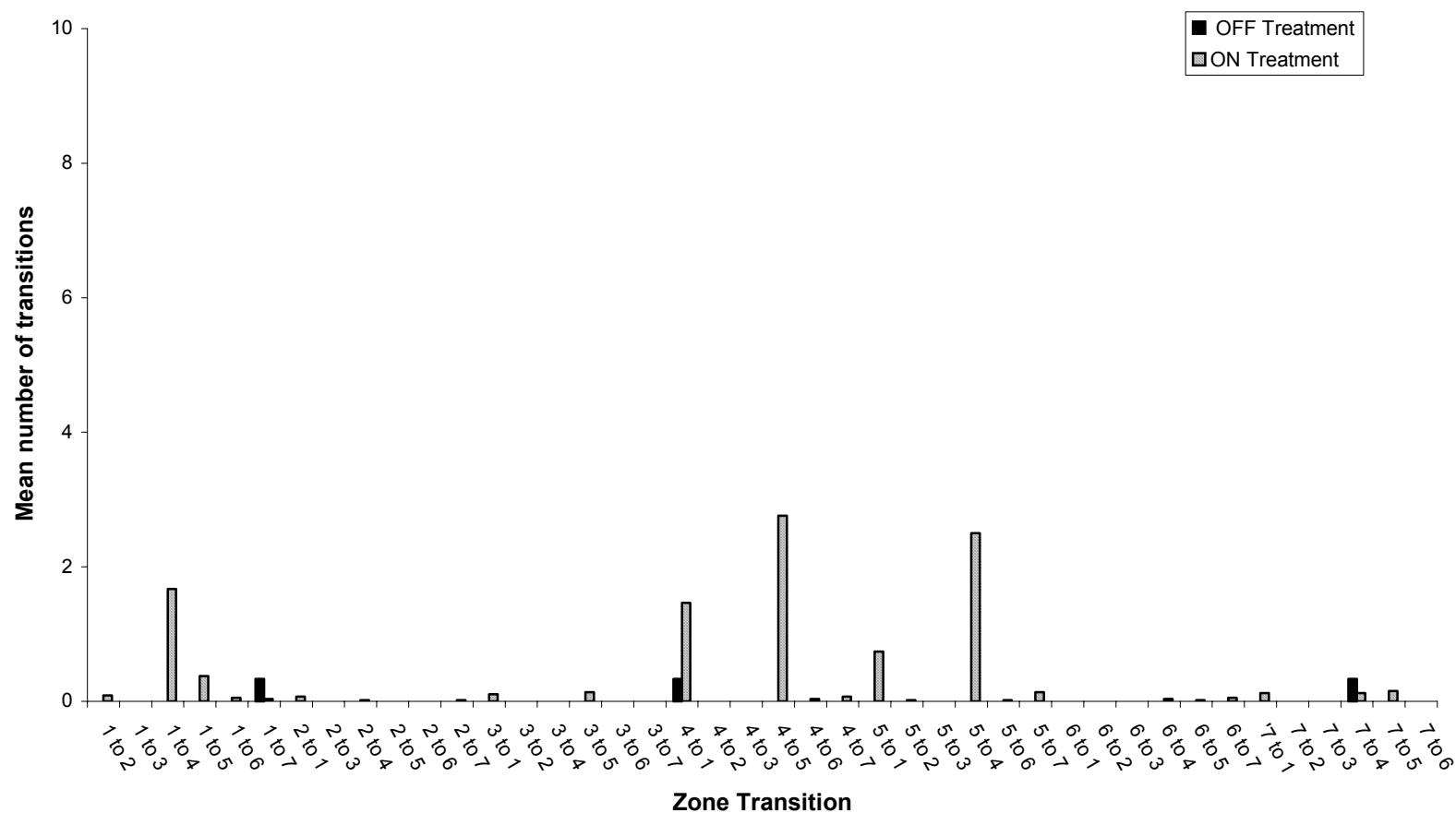
Figure 4-35.   Comparison between treatment groups for mean number of winter steelhead transitions between all seven
               radio telemetry detection zones.
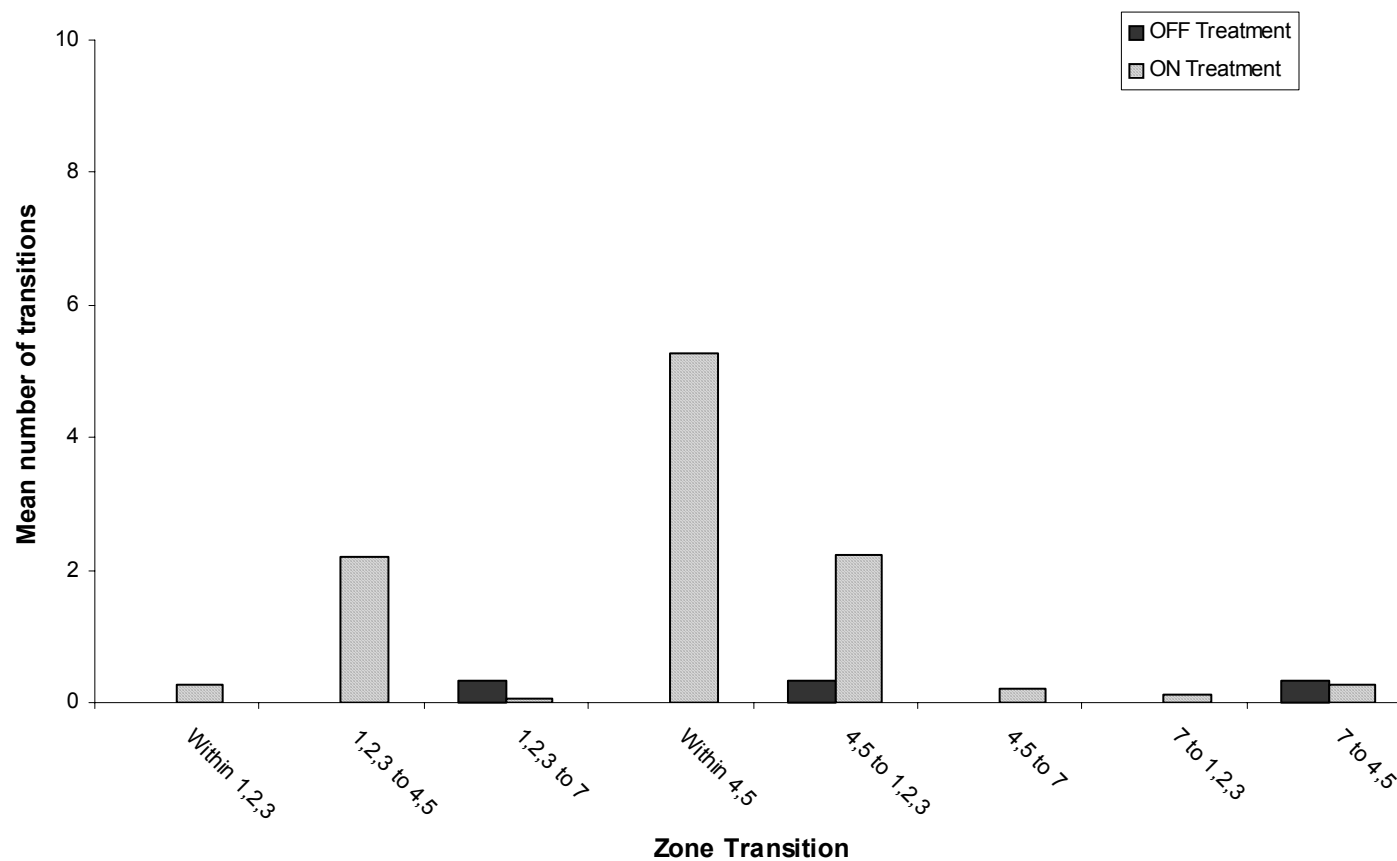
Figure 4-36.   Comparison between treatment groups for mean number of winter steelhead transitions with detection zones grouped by locations within tailrace.
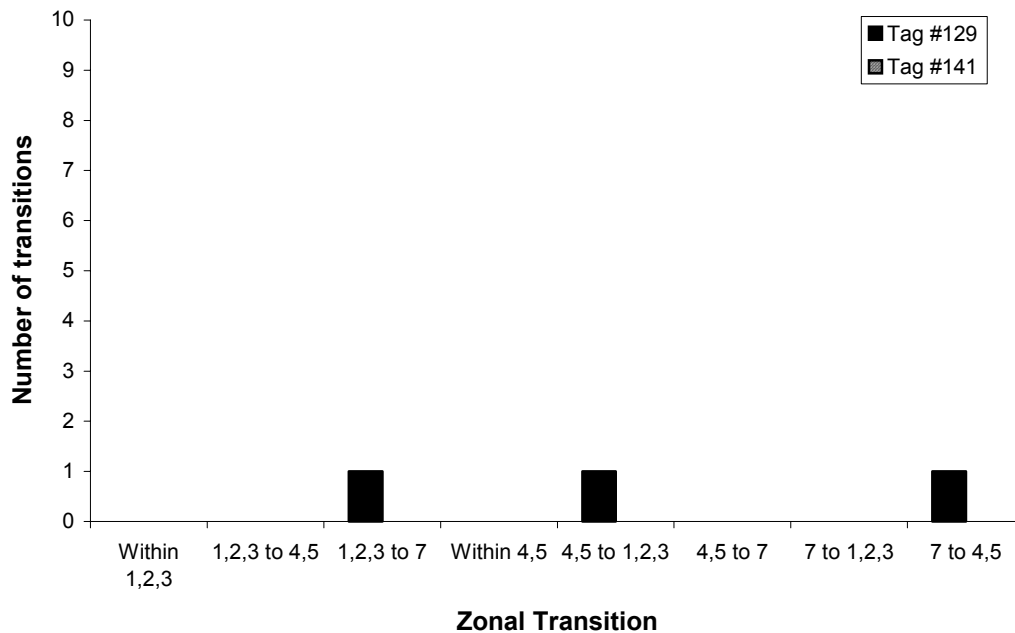
Figure 4-37. Number of zone transitions for Unit 1 OFF treatment winter steelhead 129 and 141 for detection zones grouped by locations within the tailrace.
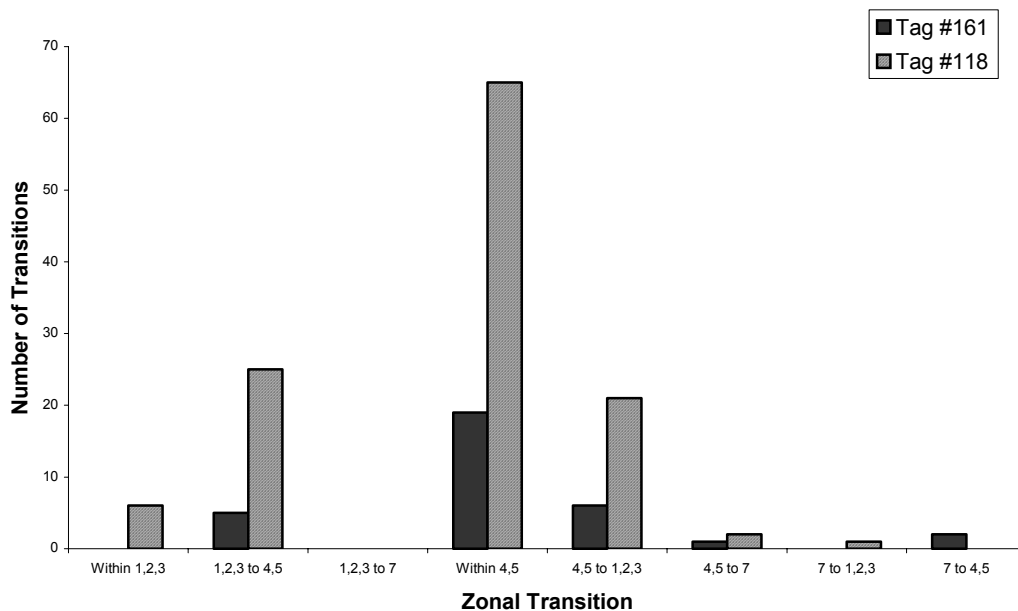
Figure 4-38. Number of zone transitions for Unit 1 ON treatment winter steelhead 118 and 161 for detection zones grouped by locations within the tailrace.

4.3.4 Objective 5 – If tailrace conditions preclude trap entry or cause migration delay what locations would be preferred for a new trap entrance?

4.3.4.1 Radio Telemetry Study

We were unable to complete statistical analysis for differences total time between the UNIT 1 ON and OFF winter steelhead treatment groups because Unit 1 remained operational through most of the winter steelhead study period and, consequently, there was a very small sample of UNIT 1 OFF treatment. A descriptive comparison indicates that fish residence time in the tailrace is similar under the Unit 1 ON and Unit 1 OFF treatments. The mean residence time of fish in the tailrace was 26.2 and 27.5 hours for the Unit 1 ON and Unit 1 OFF treatments respectively (Table 4-19).

4.4 SPRING CHINOOK SALMON

A total of 46 tagged Chinook salmon were detected in the radio telemetry array during the study. Of the 46 tagged Chinook salmon detected by the array, 15 entered the tailrace under the operational treatment Unit 1 OFF and 21 under the Unit 1 ON treatment. Due to high number of Unit 1 OFF and ON treatment intervals during the study, 10 fish split their time between the OFF and ON treatments. Fifty Chinook salmon were never detected and either moved downstream, lost tags, died, or were harvested (Table 4-21). Three fish had insufficient records to be included in the analysis (Table 4-21). A fish was categorized as being insufficient for analysis if it had only a single detection recorded by the array with a total detection time of zero. Unlike summer steelhead, coho, and winter steelhead, no Chinook salmon entered the trap undetected by the array.

The total time each fish spent in the array varied widely from one minute to 340 hours with more than 50% of the hatchery Chinook salmon remaining in the tailrace for 40.8 hours (Table 4-22). Mobile tracking surveys and harvest records indicated that at least 4 fish displayed movement in excess of 3 miles. Two fish were harvested outside the Lewis River, one in the Kalama River and a second in the Zone 3 commercial fishery. Two fish were relocated in Cedar Creek; one was harvested and the other detected in a mobile survey. A summary of statistics by treatment group is presented in Table 4-23.

Table 4-21.   Summary of Chinook salmon radio-telemetry tags not used in the analyses.

Tag Number	Release Group	Date Tagged	Comment
3	1	12 May 2006	No recapture, disposition unknown
5	1	12 May 2006	No recapture, disposition unknown
6	1	12 May 2006	No recapture, disposition unknown
11	1	12 May 2006	No recapture, disposition unknown
12	1	12 May 2006	No recapture, disposition unknown
15	2	14 June 2006	No recapture, disposition unknown
16	2	14 June 2006	No recapture, disposition unknown
17	2	14 June 2006	No recapture, disposition unknown
18	2	14 June 2006	Record insufficient for analysis*
19	2	14 June 2006	No recapture, disposition unknown
20	2	14 June 2006	Detected after completion of study
22	2	14 June 2006	No recapture, disposition unknown
26	1	12 May 2006	No recapture, disposition unknown
27	1	12 May 2006	No recapture, disposition unknown
29	1	12 May 2006	No recapture, disposition unknown
31	1	12 May 2006	Record insufficient for analysis*
33	1	12 May 2006	No recapture, disposition unknown
37	2	14 June 2006	No recapture, disposition unknown
38	2	14 June 2006	Detected downstream in Lewis River on 8/25/06
39	2	14 June 2006	No recapture, disposition unknown
40	2	14 June 2006	Collected in the Kalama River on 11/7/06
42	2	14 June 2006	No recapture, disposition unknown
43	2	14 June 2006	No recapture, disposition unknown
44	2	14 June 2006	No recapture, disposition unknown
46	2	14 June 2006	Harvested
48	2	14 June 2006	No recapture, disposition unknown
50	2	14 June 2006	No recapture, disposition unknown
162	1	12 May 2006	No recapture, disposition unknown
165	1	12 May 2006	No recapture, disposition unknown

Table 4-21.   Summary of Chinook salmon radio-telemetry tags not used in the analyses.

Tag Number	Release Group	Date Tagged	Comment
170	1	12 May 2006	No recapture, disposition unknown
171	1	12 May 2006	No recapture, disposition unknown
172	1	12 May 2006	Detected downstream in Lewis River on 8/25/06
174	1	12 May 2006	No recapture, disposition unknown
175	1	12 May 2006	Harvested
176	1	12 May 2006	No recapture, disposition unknown
177	1	12 May 2006	Harvested
178	1	12 May 2006	No recapture, disposition unknown
181	1	12 May 2006	Harvested
183	1	12 May 2006	No recapture, disposition unknown
185	1	12 May 2006	No recapture, disposition unknown
186	2	14 June 2006	Record insufficient for analysis*
189	2	14 June 2006	No recapture, disposition unknown
190	2	14 June 2006	No recapture, disposition unknown
191	2	14 June 2006	No recapture, disposition unknown
194	2	14 June 2006	No recapture, disposition unknown
195	2	14 June 2006	No recapture, disposition unknown
197	2	14 June 2006	Captured in Kalama trap
199	2	14 June 2006	No recapture, disposition unknown
200	2	14 June 2006	No recapture, disposition unknown
201	2	14 June 2006	No recapture, disposition unknown
203	2	14 June 2006	No recapture, disposition unknown
204	2	14 June 2006	No recapture, disposition unknown
205	2	14 June 2006	Detected in tailrace after study
207	2	14 June 2006	No recapture, disposition unknown

*Indicates that one radio tag event was recorded by the array but was too little time (seconds) or too little power (less than 80 for aerial antennae to be used in the analysis).

Table 4-22.   Summary of tag records by fish for radio tracked Chinook salmon in the Merwin Dam
                    tailrace.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time In Tailrace (Hours)	Trap Capture?
Unit 1 OFF	2	12 May 2006	02 June 2006	05 June 2006	12.88	N
	8	12 May 2006	03 June 2006	07 June 2006	106.83	Y
	9	12 May 2006	30 May 2006	31 May 2006	40.83	Y
	23	12 May 2006	15 May 2006	15 May 2006	10.38	Y
	24	12 May 2006	25 May 2006	26 May 2006	27.37	Y
	25	12 May 2006	29 May 2006	31 May 2006	57.37	Y
	35	12 May 2006	12 May 2006	24 May 2006	61.42	Y
	36	12 May 2006	30 May 2006	31 May 2006	10.42	Y
	41	14 June 2006	28 June 2006	29 June 2006	37.05	Y
	160	12 May 2006	03 June 2006	03 June 2006	8.06	Y
	161	12 May 2006	16 May 2006	24 May 2006	114.28	Y
	163	12 May 2006	30 May 2006	02 June 2006	83.82	Y
	173	12 May 2006	27 June 2006	29 June 2006	60.20	Y
	179	12 May 2006	08 June 2006	09 June 2006	27.03	Y
	180	12 May 2006	20 May 2006	21 May 2006	42.75	Y
	182	12 May 2006	06 June 2006	06 June 2006	19.30	Y
	184	12 May 2006	12 June 2006	12 June 2006	16.70	Y
Unit 1 ON	1	14 June 2006	23 June 2006	03 July 2006	18.80	Y
	4	12 May 2006	23 May 2006	23 May 2006	0.00	N
	10	12 May 2006	20 June 2006	20 June 2006	1.29	N
	13	14 June 2006	14 June 2006	16 June 2006	52.05	N
	14	14 June 2006	20 June 2006	25 June 2006	49.30	N
	21	14 June 2006	20 June 2006	22 June 2006	53.80	Y
	30	12 May 2006	23 May 2006	23 May 2006	0.32	N
	32	12 May 2006	19 May 2006	19 May 2006	11.15	N
	45	14 June 2006	13 July 2006	13 July 2006	10.54	N
	47	14 June 2006	20 June 2006	20 June 2006	10.94	Y
	49	14 June 2006	17 June 2006	20 June 2006	74.37	Y
	164	12 May 2006	13 July 2006	13 July 2006	12.12	N
	166	12 May 2006	05 July 2006	05 July 2006	16.60	N

Table 4-22. Summary of tag records by fish for radio tracked Chinook salmon in the Merwin Dam tailrace.

Treatment Group	Tag Number	Date Tagged	Date First Tailrace Detection	Date Last Tailrace Detection	Total Time In Tailrace (Hours)	Trap Capture?
	167	12 May 2006	16 June 2006	20 June 2006	104.30	Y
	187	14 June 2006	04 July 2006	14 July 2006	58.55	N
	193	14 June 2006	14 June 2006	03 July 2006	45.92	N
	196	12 May 2006	01 July 2006	01 July 2006	9.38	N
	198	14 June 2006	22 June 2006	26 June 2006	35.22	Y
	202	14 June 2006	06 July 2006	11 July 2006	40.83	N
	206	14 June 2006	14 June 2006	14 June 2006	0.11	N
	208	14 June 2006	19 June 2006	19 June 2006	8.07	N
OFF/ON Split	7	12 May 2006	21 May 2006	14 June 2006	64.58	Y
	28	12 May 2006	13 May 2006	21 May 2006	103.50	Y
	168	12 May 2006	16 May 2006	05 June 2006	182.28	N
	188	14 June 2006	13 May 2006	21 May 2006	339.68	Y
	209	14 June 2006	27 June 2006	12 July 2006	132.05	N
ON OFF Split	34	12 May 2006	19 May 2006	22 May 2006	73.35	Y
	169	12 May 2006	19 May 2006	25 May 2006	53.88	Y
	192	14 June 2006	16 June 2006	27 June 2006	195.67	N

Table 4-23. Descriptive statistical summary of tag records in the array by treatment group for radio-tagged Chinook salmon in the Merwin
Dam tailrace.

Variable	Unit 1OFF	Unit 1 ON	OFF/ON Split		ON/OFF Split	
			OFF	ON	ON	OFF
Detection Dates	15 May 06 – 29 Jun 06	19 May 06 – 14 Jul 06	12 May 06 – 05 Jun 06	18 May 06 – 24 May 06	21 May 06 – 29 Jun 06	22 May 06 – 12 Jul 06
Number of Tagged Fish	17.0	21.0	5.0	5.0	5.0	5.0
Total Hours in Array	736.7.0	613.7	232.8	181.4	553.1	198.9
Range of Total Hours in Array	8.1– 114.3	0.0 – 104.3	7.2 – 106.2	9.4 – 70.4	17.9 – 256.8	13.8 – 76.0
Mean Hours in Array[a]	43.3 (8.1)	29.2 (4.7)	46.6 (16.2)	36.3 (10.6)	110.6 (45.6)	39.8 (12.3)
Median Hours in Array	37.1	16.6	40.1	40.8	54.3	29.3
Total Zone Transitions	796.0	485.0	446.0	257.0	340.0	246.0
Range of Zone Transitions	12.0 – 227.0	0.0 – 83.0	8.0 – 154.0	13.0 – 130.0	2.0 – 132.0	20.0 – 136.0
Mean Zone Transition [a]	46.8 (12.5)	23.1 (4.7)	89.2 (28.3)	51.4 (21.1)	68.0 (22.6)	49.2 (22.2)
Median Zone Transitions	30.0	16.0	97.0	34.0	73.0	24.0

[a] Parentheses indicate ± 1 standard error of the mean.

4.4.1 Objective 2 – Estimate the number of trap entry attempts made by adult salmonids in the tailrace

During video analysis, 2,752 observations were documented of spring Chinook salmon approaching the trap (Table 4-24). There were 560 observations of exploratory behaviors and 2027 observations of attempts at trap entry, including 498 successful entries and 165 observations of fallback (Table 4-24). To compare behavior between treatment conditions we were able to review 37 hours under Unit 1 OFF and 13 hours under Unit 1 ON. The videos were taken during the peak of the spring Chinook migration. The total number of successful trap entries (entries – fall backs) was 403 and 95 for Unit 1 OFF and Unit 1 ON respectively. Spring Chinook salmon appeared to spend more time locating the trap under the Unit 1 ON treatment (29%) compared to the Unit 1 OFF treatment (17%) based on percentage of exploratory behavior. Fish under the Unit 1 ON treatment made fewer attempts (66% compared to76% with Unit 1 OFF) at the trap and showed a similar percentage of the fish successfully entering (21% compared to 26% with Unit 1 ON) the trap compared to fish under the Unit 1 OFF treatment.

Table 4-24.   Video analysis summary of coho salmon behavior at the Merwin tailrace trap.

Behavior Category	Behavior	Unit 1 OFF Observations		Unit 1 ON Observations	
		Count	Percent (%)	Count	Percent (%)
Exploratory Behavior	Roll	361	100	199	100
	Total Exploratory Behavior	**361**		**199**	
Attempts	Early Jump	223	14	53	536
	Surf/Velocity	611	39	217	17
	Corner	156	10	34	6
	Hit	56	4	14	1
	Entries	530	34	133	69
	Total Attempts	**1576**		**451**	
Fall Backs	Fall Back	127	24	38	28
	Successful Entries	403	26	95	21

4.4.2 Objective 3 - Estimate the number of adult fish that enter the trap and become captive

Due to limitations with hydroacoustic counts at this location, the only possible means to calculate trap efficiency for the total spring Chinook salmon population, ATE_{pop}, was based on radiotelemetry data. The ATE for the total Chinook salmon population, ATE_{pop}, was calculated as indicated below to be 58.7%. When broken down by operational treatments group the $ATE_{pop\text{-}off}$ was 90% and the $ATE_{pop\text{-}on}$ was 34.6%. Specific calculations follow.

ATE_{pop} = 27 fish captured in the trap/ 46 fish that entered the tailrace radiotelemetry array = 58.7.%.
$ATE_{pop\text{-}off}$ = 18 fish captured in the trap/20 fish that entered the tailrace = 90%
$ATE_{pop\text{-}on}$ = 9 fish captured in the trap/26 fish that entered or were present in the tailrace = 34.6%.

Although video data for spring Chinook salmon was limited we were able to calculate the success rate for fish migrating upstream into the Merwin trap (ATE_{mig}) was determined by fish behavior counts recorded during the video analysis. Overall, ATE_{mig} was 25%. When analyzed by operational treatment group the $ATE_{mig\text{-}off}$ was 26% and the $ATE_{mig\text{-}on}$ was 21%. Specific calculations follow.

ATE_{mig} = 498 successful trap entries (total minus fallback)/ 2027 trap attempts = 25%.
$ATE_{mig\text{-}off}$ = 403 successful trap entries/1,576 trap attempts = 26%
$ATE_{mig\text{-}on}$ = 95 successful trap entries/451 trap attempts = 21%.

4.4.3 Objective 4 – Determine what (if any) tailrace conditions impede fish movement into the trap

4.4.3.1 Chinook Salmon Radio telemetry Study

4.4.3.1.1 Chinook salmon analysis of temporal distribution in detection zones

The total time Chinook salmon spent in each detection zone ranged from a few minutes to approximately 114 hours. Plots of time spent in the tailrace show patterns of more time in zone 1, 2, and 4. Fish under the Unit 1 OFF treatment displayed the strongest preference for Zone 2 with a secondary preference for Zones 1 and 4 (Figure 4-39) and some use of Zones 3, 5, and 7. Fish from the Unit 1 ON treatment also show a distinct preference for Zone 4 and some use of Zones 1, 2, and 5 (Figure 4-39). Chinook salmon from the Unit 1 OFF treatment that spent the most time in the tailrace during the study clearly spent the most time in Zones 4 and 7 (Figure 4-40). In addition, Chinook salmon with the longest time under Unit 1 ON treatment show use of
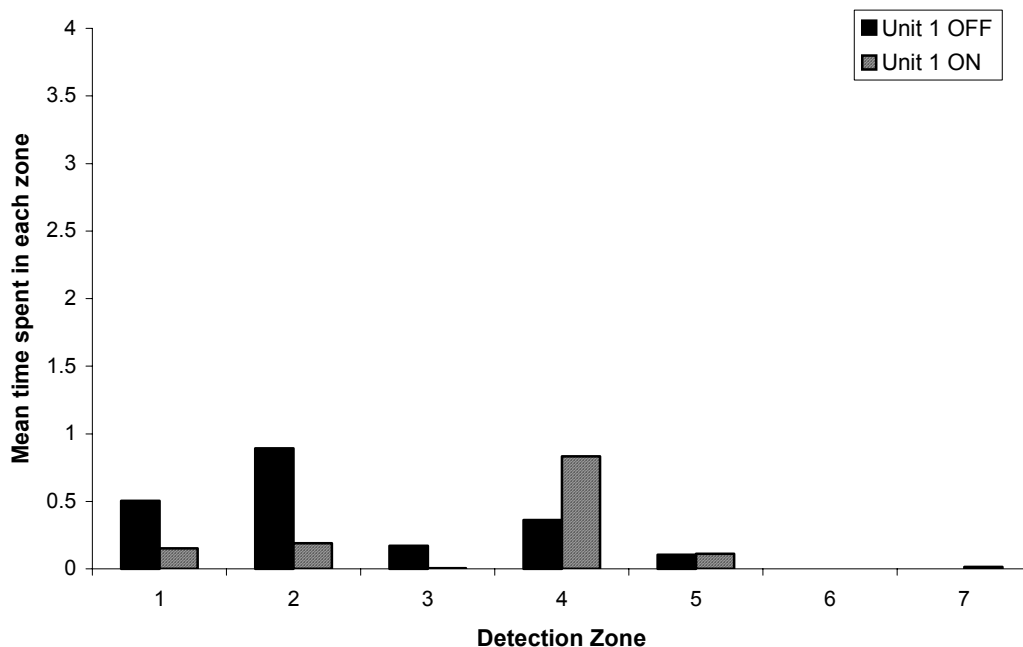
Figure 4-39.   Comparison between treatment groups for mean number of hours spent in each radio telemetry zone by radio tagged Chinook salmon.
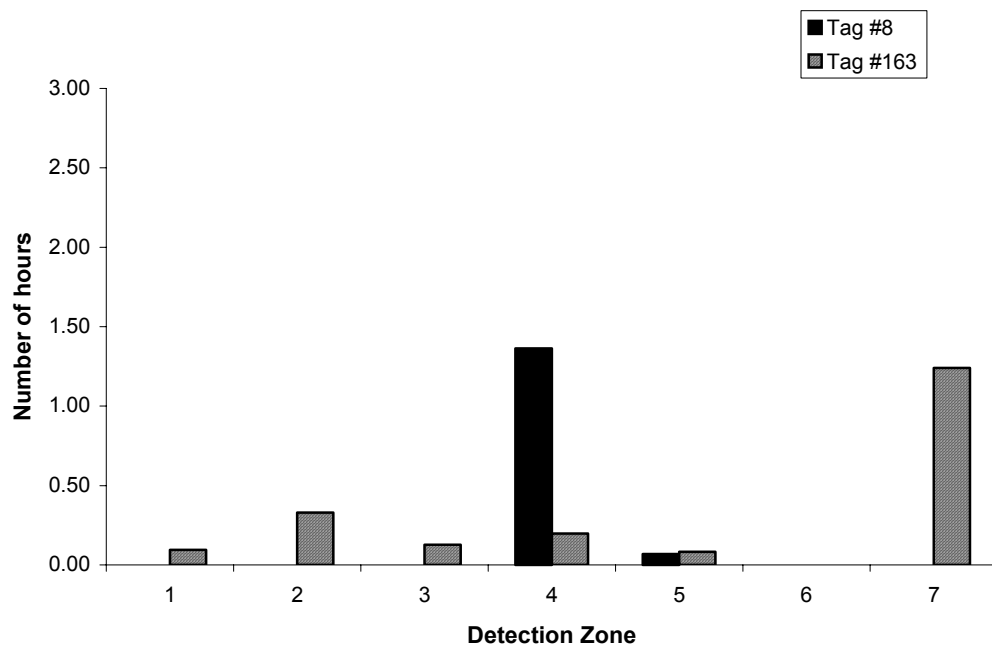

Figure 4-40.   Mean hours spent in each radio telemetry zone for Unit 1 OFF tagged Chinook salmon 8 and 163.

more zones including 1, 2, 4, and 5, with the highest preference for Zones 2 and 4 (Figure 4-41). Fish from the SPLIT treatment indicated the strongest preference for Zones 1, 2, and 4 (Figure 4-42). Chinook salmon that spent the most time in the tailrace under the SPLIT treatment clearly showed a strong preference for Zone 4 under the Unit 1 ON operation (Figures 4-43 and 4-44).

Statistical analysis of time spent in each detection zone based on the number of radio contacts was used to determine treatment effects. The numbers of contacts in each zone were hypothesized to be similar when Unit 1 was on and off. Comparisons of number of contacts between treatments for each zone are depicted in box plots (Figures 4-45 and 4-46). The results of the generalized linear model suggest that operation of Unit 1 caused a significant decrease in the number of radio contacts in Zones 1 through 3 (Table 4-25). Clear differences in the number of contacts between treatments were not evident for Zones 5, 6, and 7 (Table 4-25). Although differences between treatments in Zone 4 were not statistically significant at alpha=0.05, the numbers of radio contacts were substantially higher under UNIT 1 ON.

4.4.3.1.2. Analysis of zone transitions

Overall, we recorded 2,319 zonal transitions that were distributed among the 42 potential directional movements for spring Chinook salmon. The greatest number of movements tended to be between zones 1 and 2 along the face of the control room and also between Zones 4 and 5 along the power house. There were also considerable movement from and to Zones 1 and 2 to and from Zones 4 and 5 (Figures 4-47-4-49). Chinook salmon moved among similar number of zones during both treatment conditions with what appeared to be more movement in Zones 1 and 2 under Unit 1 OFF and more movement in Zones 4 and 5 under Unit 1 ON. Movement depictions of individual fish that spent the most time in the tailrace illustrate patterns observed for Unit 1 OFF and ON treatment fish (Figures 4-50-4-53). Graphical depictions of Split treatment fish that spent the most time in the tailrace clearly show substantial increases in movement between zones when Unit 1 is operational (Figures 4-52 and 4-53). Differences between individual and collective fish movement patterns of Split treatment fish underscore the variability in individual fish movement.

The statistical analyses indicated that UNIT 1 ON resulted in a significant increase in the number of transitions from Zone 1 to Zone 4 (Table 4-24). Significant decreases were evident in the number of transitions from Zone 1 to Zones 2 and 3, Zone 2 to Zone 1, Zone 4 to Zone 3, and Zone 5 to Zone 2 under UNIT 1 ON (Table 4-26). These test indicate increase movement across the powerhouse wall and decrease movement along the control room wall under Unit 1 ON.
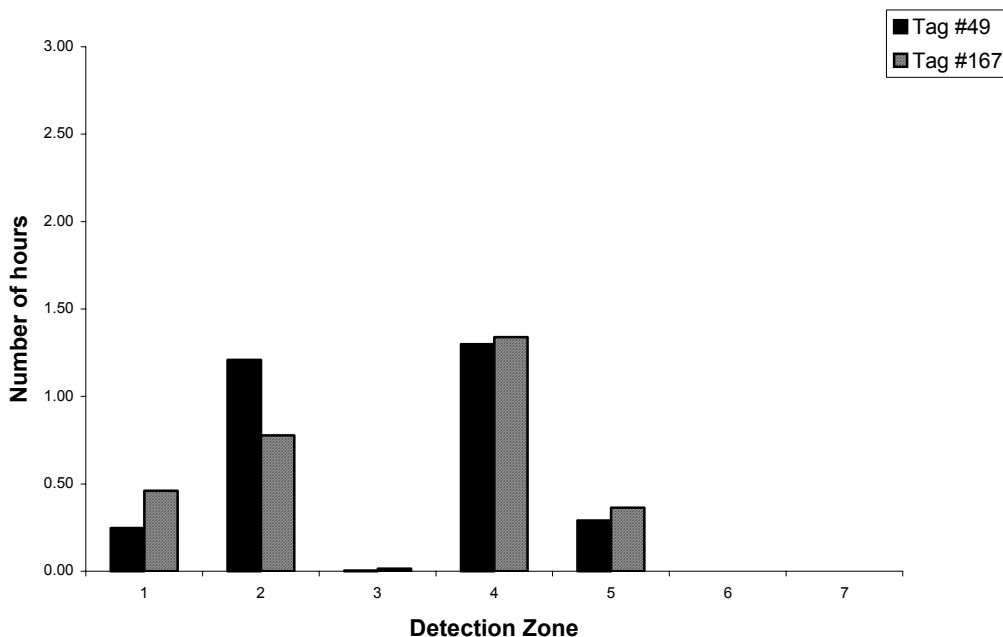
Figure 4-41.   Mean hours spent in each radio telemetry zone for UNIT 1 ON tagged
                Chinook salmon 49 and 167.
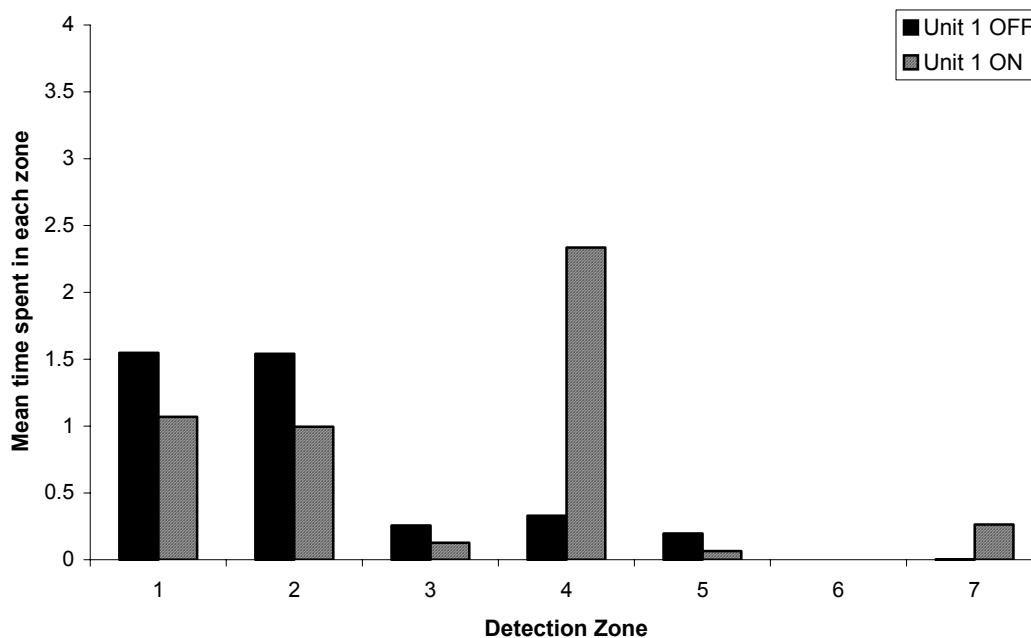

Figure 4-42.   Comparison of mean hours radio-tagged Chinook salmon from the
                SPLIT treatments spent in each tailrace detection zone under UNIT 1
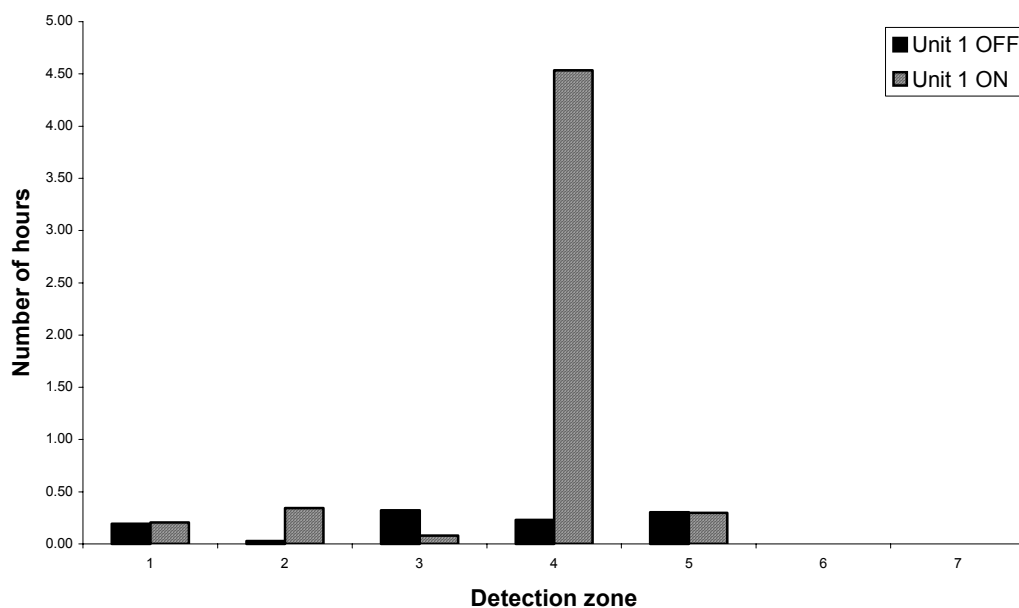   OFF and UNIT 1 ON conditions.

Figure 4-43. Number of hours radio-tagged Chinook salmon # 188 from the ON/OFF Split group spent in tailrace detection zones.
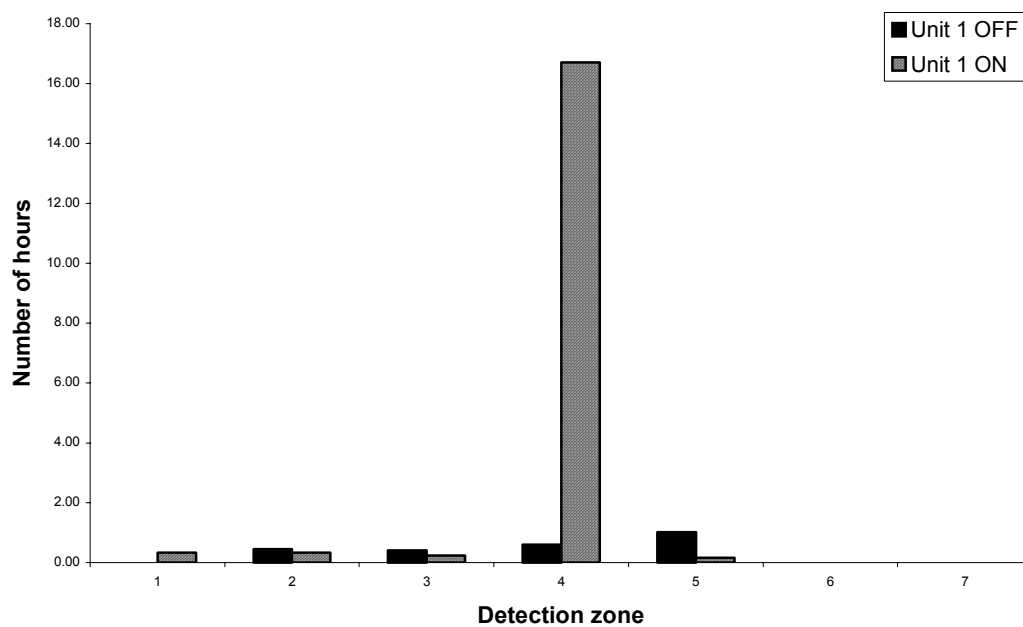

Figure 4-44. number of hours radio-tagged Chinook salmon # 192 from the ON/OFF Split group spent in tailrace detection zones.

Figure 4-45.　Boxplots of number of contacts for Chinook salmon in Zones 1 through 4 under treatments: Unit 1 OFF (N=21) and Unit 1 ON (N=15). Boxes indicate the 25-75th percentiles, whiskers indicate 95th percentiles, and extreme observations are displayed as points. Statistical tests indicate contacts were significantly lower in Zone 1 ($p < 0.005$, $\chi^2_{1,33} = 8.05$), Zone 2 ($p < 0.\ 0.005$, $\chi^2_{1,33} = 7.99$), and Zone 3 ($p < 0.001$, $\chi^2_{1,33} = 37.2$) under Unit 1 ON.
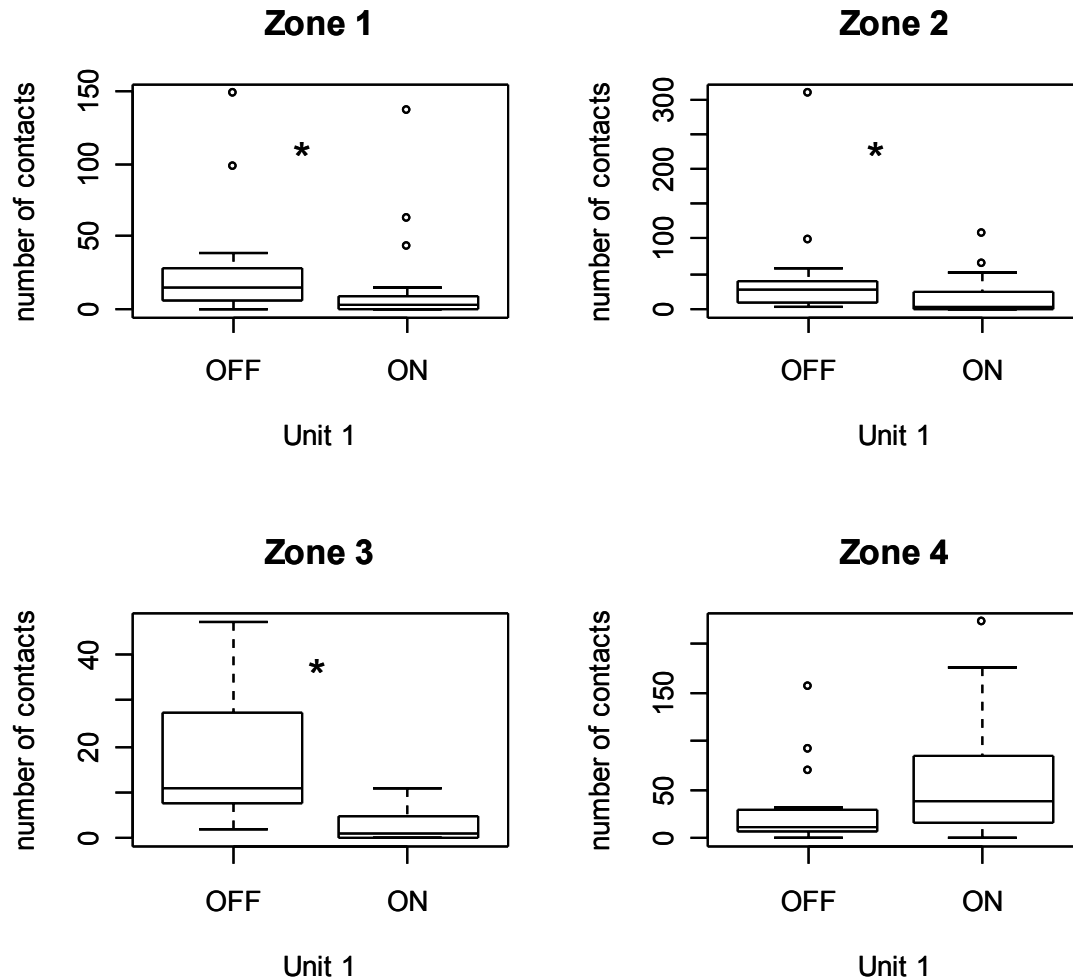
Zone 5

Zone 6

Zone 7
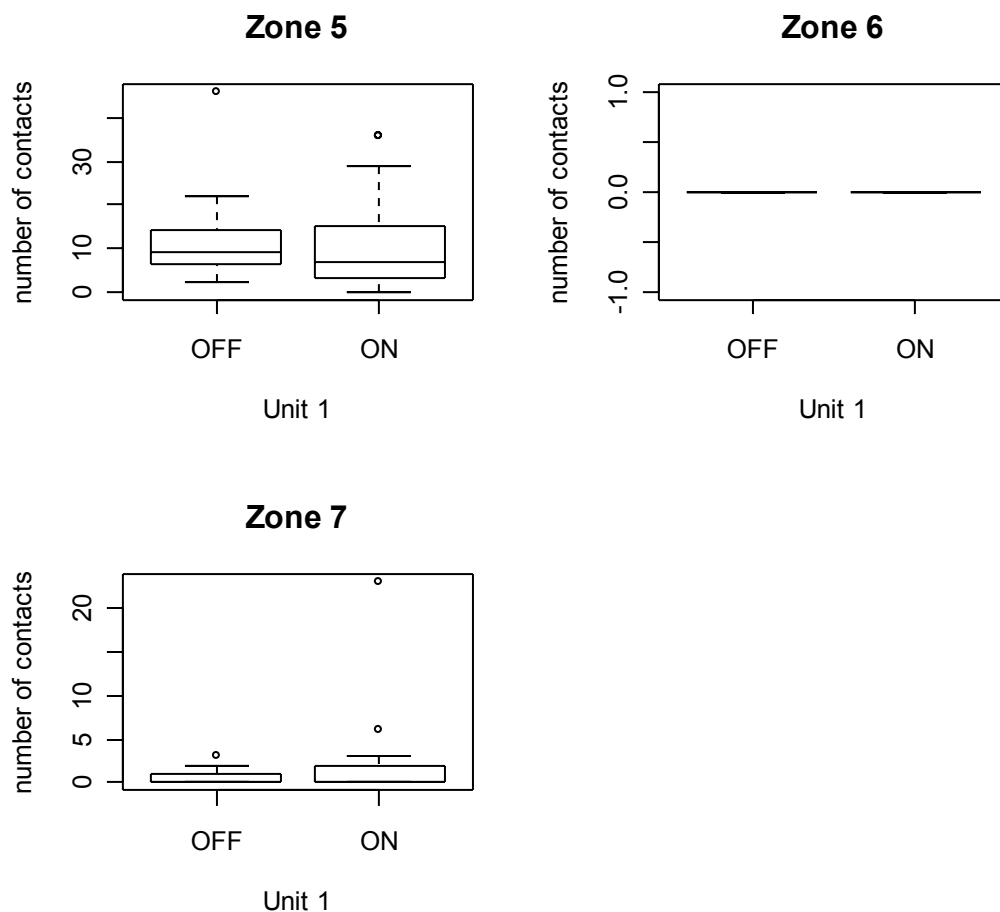
Figure 4-46.   Boxplots of number of contacts for Chinook salmon in Zones 5
through 7 under treatments: Unit 1 OFF (N=21) and Unit 1 ON
(N=15). Boxes indicate the 25-75th percentiles, whiskers indicate
95th percentiles, and extreme observations are displayed as points.
Please note different scale of contacts among zones.
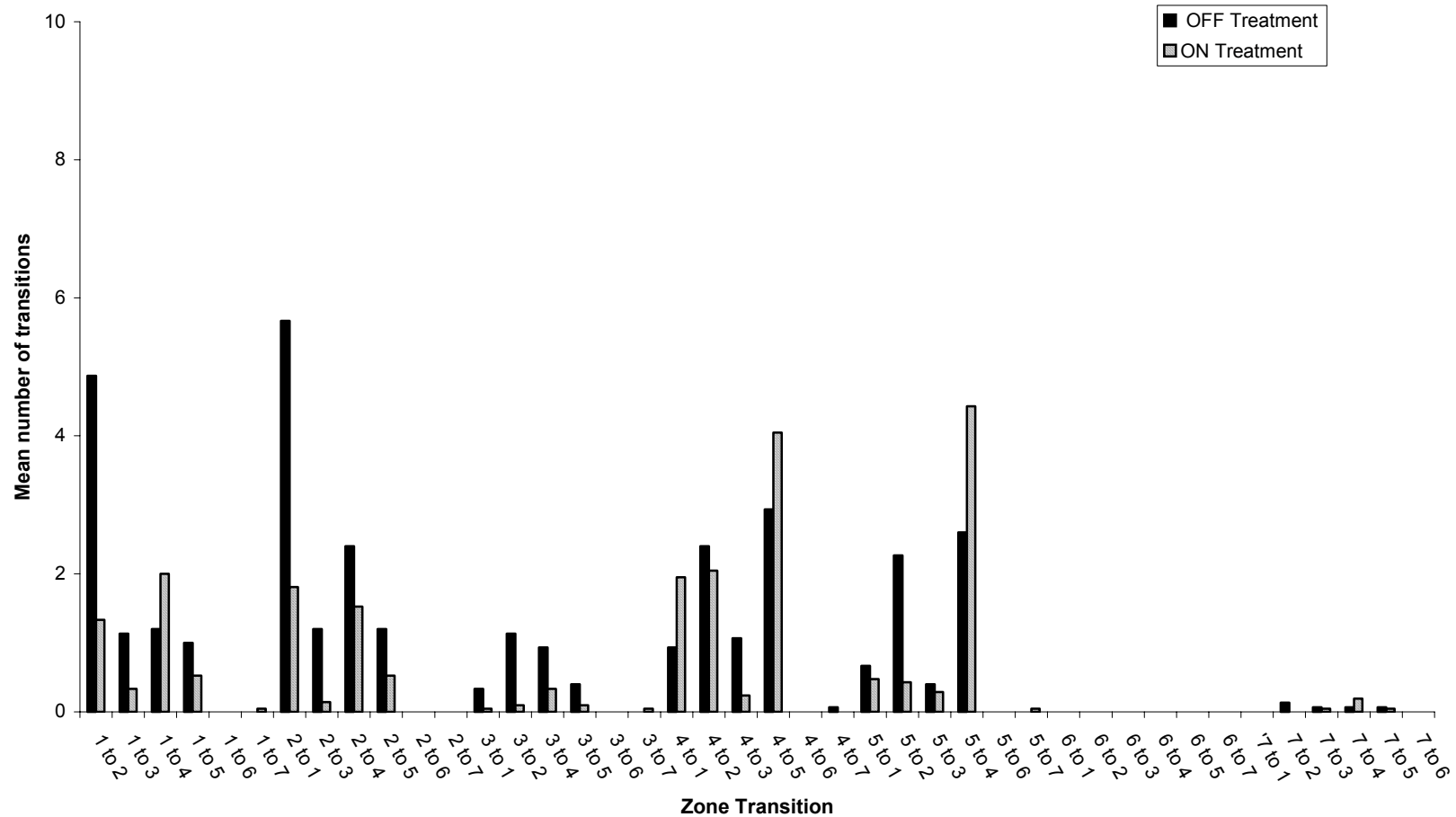
Figure 4-47.   Comparison between treatment groups for mean number of Chinook salmon transitions between all seven radio telemetry detection zones.
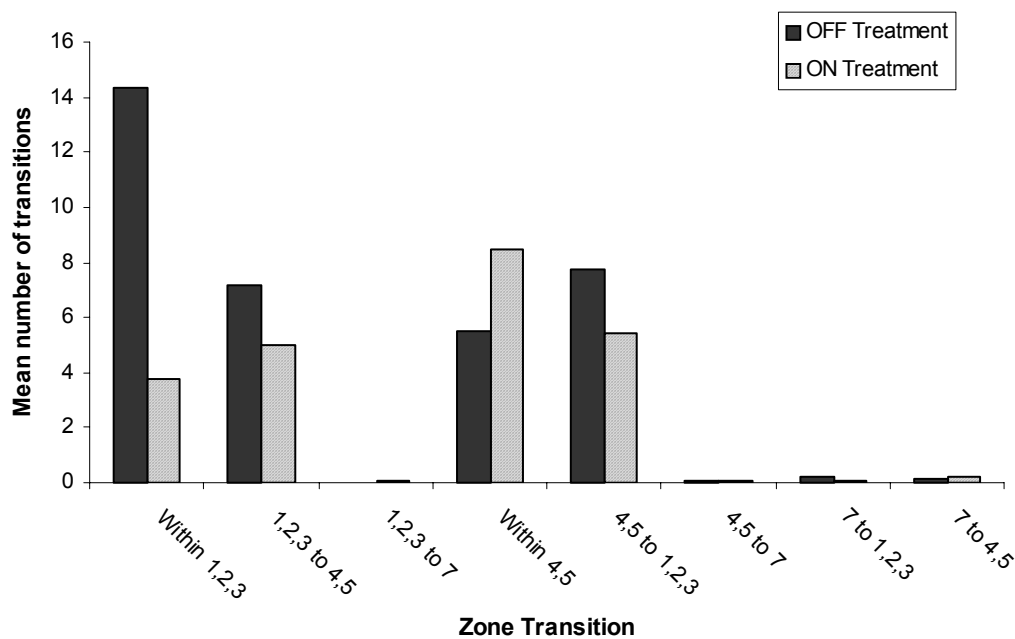
Figure 4-48. Comparison between treatment groups for mean number of Chinook salmon transitions with detection zones grouped by locations within tailrace.
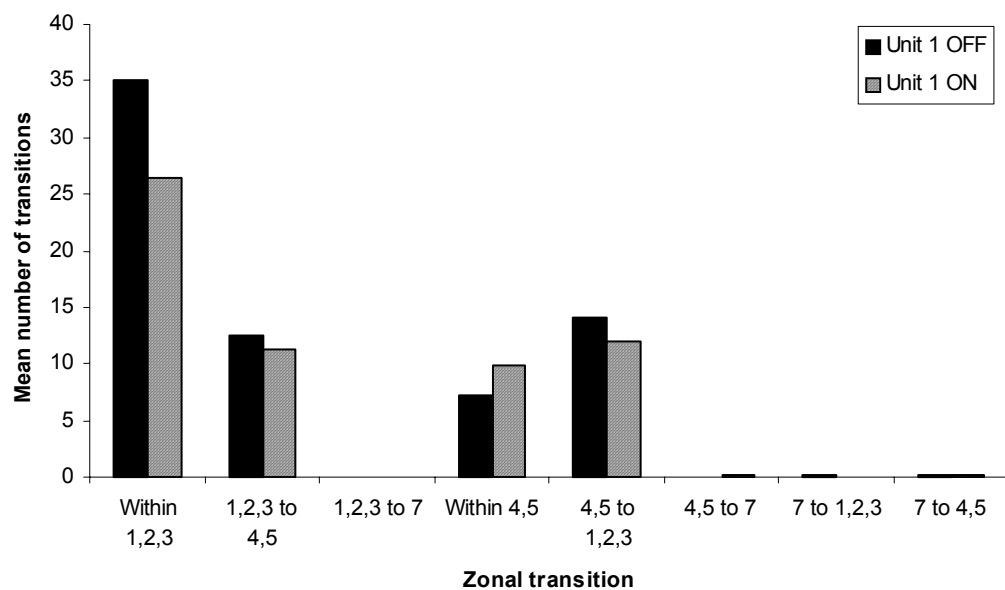
Figure 4-49. Comparison between Split treatment Unit 1 ON and OFF for the mean number of Chinook salmon transitions with detection zones grouped by locations within tailrace.
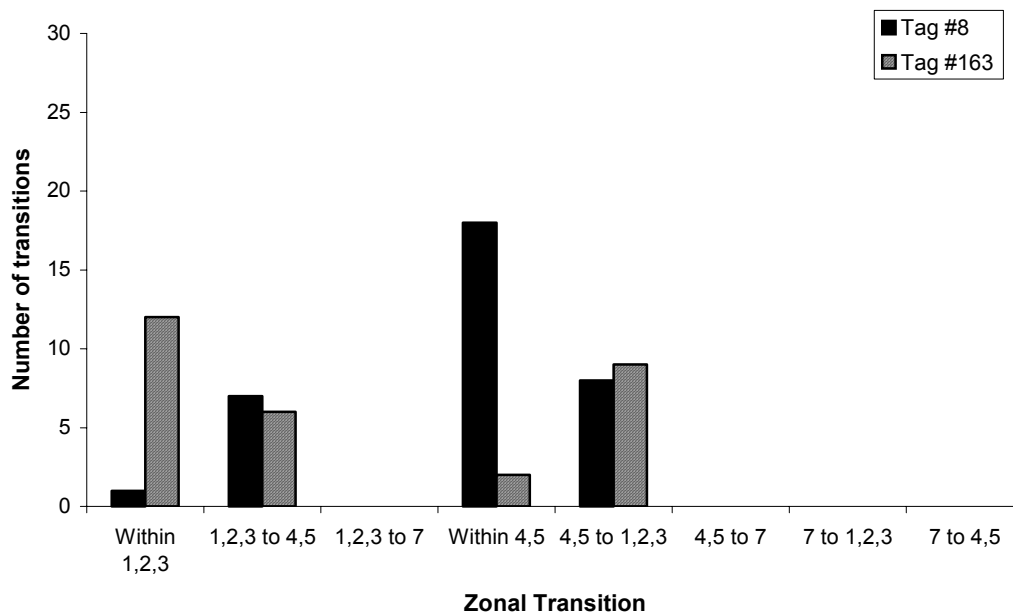
Figure 4-50. Number of zone transitions for UNIT 1 OFF Chinook salmon # 8 and #163 for detection zones grouped by locations within the tailrace.
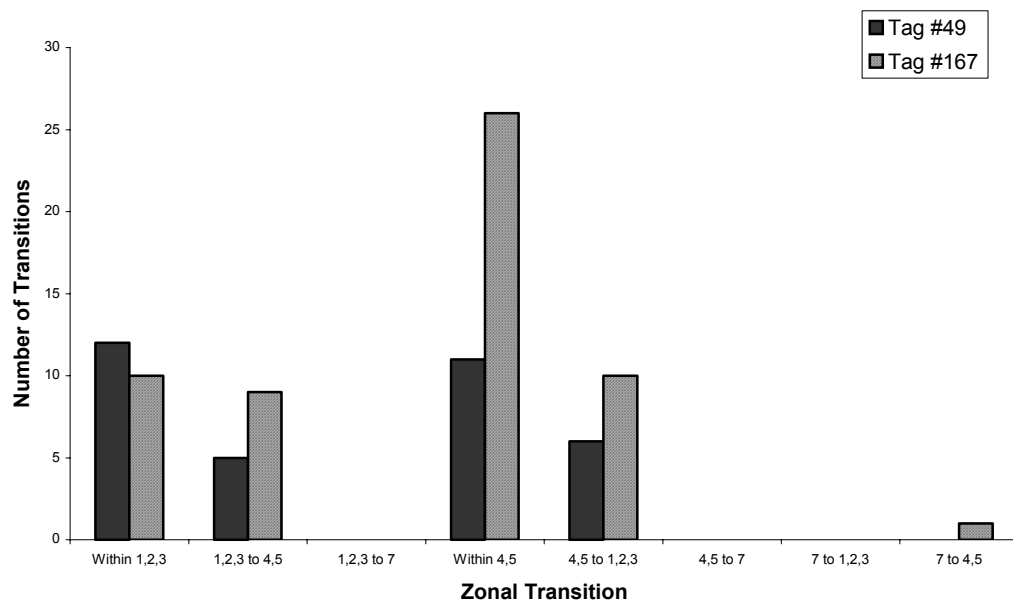
Figure 4-51. Number of zone transitions for Unit 1 ON treatment Chinook salmon 49 and 167 for detection zones grouped by locations within the tailrace.
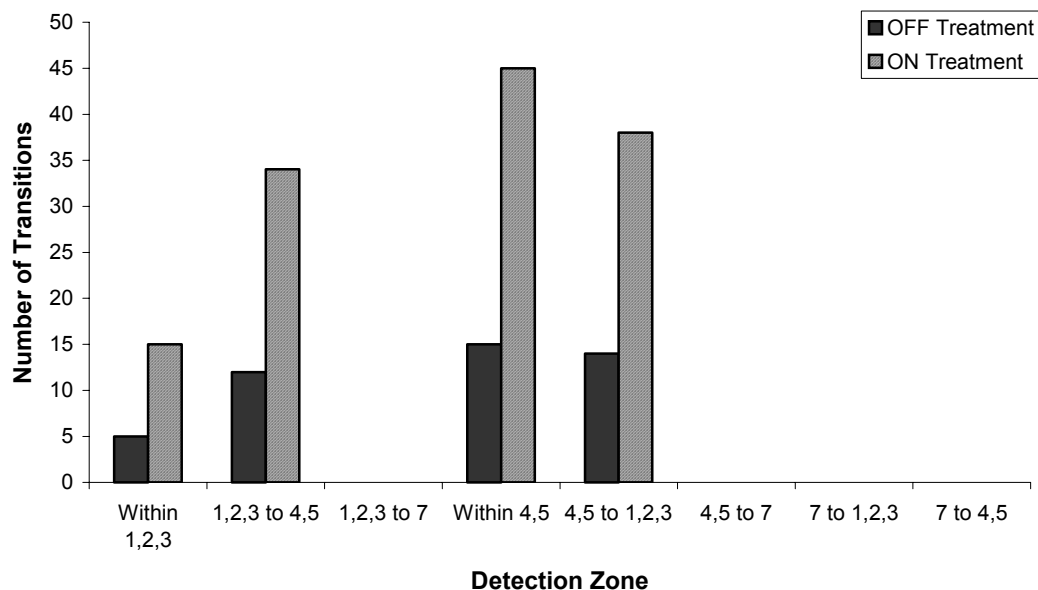
Figure 4-52.   Zone transitions among grouped tailrace detection zones for Chinook
               salmon #188 from the OFF/ON SPLIT.
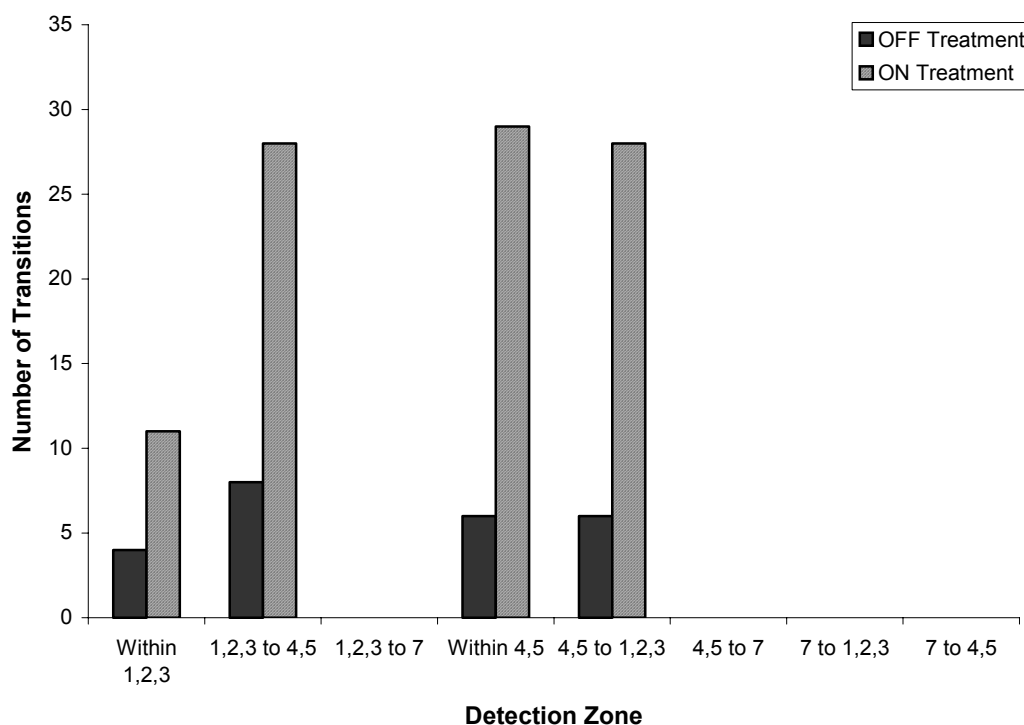
Figure 4-53.   Zone transitions among grouped tailrace detection zones for Chinook
               salmon #192 from the ON/OFF SPLIT.

Table 4-25.   Summary of results of generalized linear models for Chinook salmon radio contacts by detection zone.

Zone	$\chi^2_{1,33}$ **value**	**P value**
Zone 1	6.76	0.010
Zone 2	6.33	0.012
Zone 3	36.6	< 0.001
Zone 4	1.69	0.090
Zone 5	0.038	0.845
Zone 6	*	*
Zone 7	1.44	0.229

*model did not converge due to very few contacts in one group.

Table 4-26.   The effect of Unit 1 on transitions among Zones 1 through 4. Effects in bold are significant at the 0.05 level.

Transition From	To	Effect of Unit 1	$\chi^2_{1,33}$ **value**	**P value**
Zone 1	Zone 2	**decrease**	4.69	0.030
	Zone 3	**decrease**	5.88	0.015
	Zone 4	**increase**	13.0	< 0.001
	Zone 5	increase	0.703	0.402
Zone 2	Zone 1	**decrease**	4.81	0.028
	Zone 3	decrease	*	*
	Zone 4	decrease	1.22	0.270
	Zone 5	increase	1.65e -4	0.990
Zone 3	Zone 1	equal	#	#
	Zone 2	decrease	*	*
	Zone 4	increase	3.06	0.080
	Zone 5	decrease	*	*
Zone 4	Zone 1	increase	3.84	0.050
	Zone 2	increase	0.271	0.603
	Zone 3	**decrease**	6.45	0.011
	Zone 5	increase	1.50	0.220
Zone 5	Zone 1	decrease	0.051	0.821
	Zone 2	**decrease**	10.21	0.001
	Zone 3	increase	0.008	0.926
	Zone 4	increase	2.98	0.084

 *Model could not converge due to low number of transitions in ON treatment

 #Model could not converge due to low number of transition in ON and OFF treatments

4.4.4 Objective 5 – If tailrace conditions preclude trap entry or cause migration delay what locations would be preferred for a new trap entrance?

4.4.4.1 Radio Telemetry Study

Statistical analysis was used to compare total time spent in the array under Unit 1 OFF and Unit 1 ON. The null hypothesis tested was that the time fish spend in the tailrace is the same when Unit 1 was off versus when Unit 1 was on. Although the average time spent in the tailrace appeared to be greater under Unit 1 ON (Figure 4-54), the ANOVA test fails to reject the null hypothesis ($p = 0.103$, $F_{1,34} = 2.74$) indicating that the total time fish spend in the tailrace did not differ between the two operating conditions.
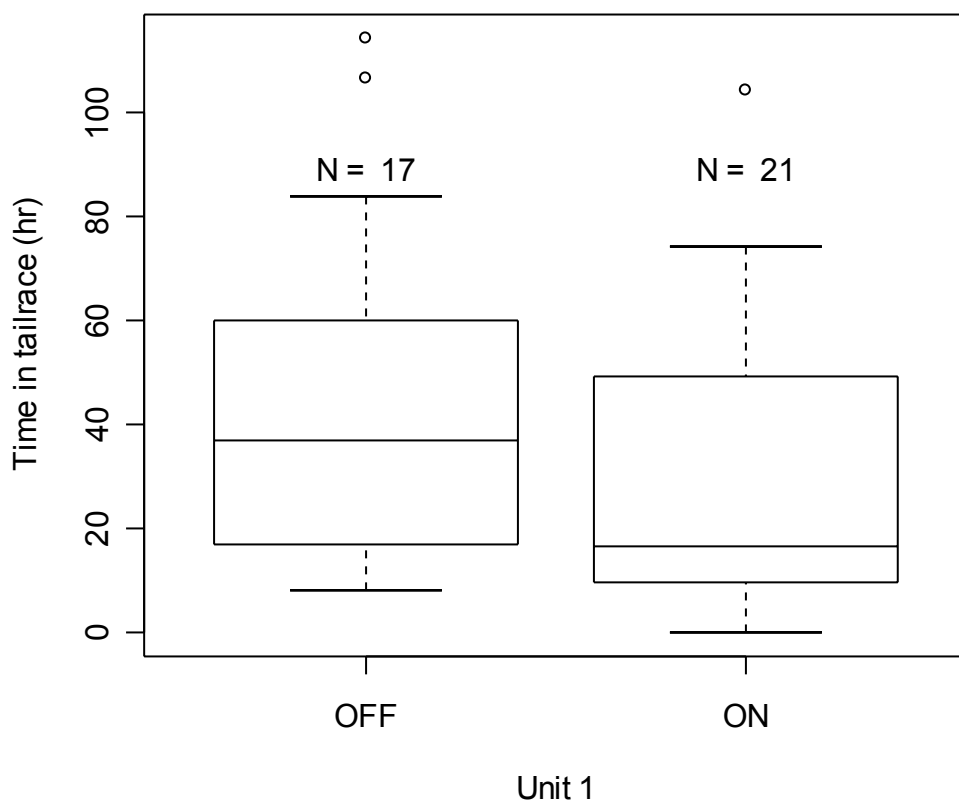

Figure 4-54.   Boxplot of the total time spent in the Merwin tailrace by Chinook salmon when Unit 1 was off and Unit 1 was on. Boxes indicate the 25-75th percentiles, whiskers indicate 95th percentiles, and extreme observations are displayed as points. No significant difference was detected at alpha=0.05..

5. DISCUSSION

Overall, the performance of radio-tagged summer steelhead was good in terms of relocating tagged fish. Although only 61% of tagged summer steelhead entered the radio-telemetry array for a sufficient period to be included in data analyses, more than 86% of the tagged fish were accounted for in the study through fixed array detections, trap or by mobile tracking. This left only 14% of the fish in an unknown disposition category. Performance of radio tagged coho salmon was similar to steelhead in that 60% of the tagged coho salmon spent time in the tailrace array during the study period and the majority of the coho salmon that did not enter the fixed array were relocated during mobile tracking or in trap catch. Only 10% of the coho remained unaccounted for by the end of the study. The overall performance of radio-tagged winter steelhead was less than the other species. Although 60% of the tagged winter steelhead spent time in the tailrace array and had sufficient records for analysis, 28% of the tagged winter steelhead were classified as unknown disposition since they were never seen again after release. It is of interest to note that winter steelhead were the only species with no detections at, or near, the Lewis River Hatchery.

The first objective of this study effort was to estimate the abundance of target anadromous salmonids that entered the tailrace daily. Unfortunately the configuration of the tailrace proper combined with fish use of the large pool downstream of the access bridge in Zone 7 prevented us from being able to obtain reliable daily counts. The tailrace is too deep and large to effectively monitor in its entirety and the salmon milling in the pool downstream of the access bridge in Zone 7 prevents that area from being an accurate entry point for the tailrace. Through the radio-tag study we were able to observe the behavior of adult salmonids in these areas immediately downstream of Merwin dam. There was variability in observed behaviors both among and within species and treatment groups. In general, the radio-telemetry data showed that while some fish come into the tailrace and remain until they enter the trap most fish milled within as well as downstream of the tailrace array over periods that lasted several weeks. As the subsequent discussions will show generalized species-specific behavior patterns were evident. Summer steelhead spent the majority of their time in the tailrace along the control room wall and rock outcrop although they did spend a large amount of time in Zone 7. Coho salmon appeared to exhibit more wandering and spent proportionally more time in the large pool downstream of the access bridge in Zone 7. Winter steelhead moved considerably less within the tailrace than the other species but also showed a lot of time spent in the pool below the bridge. As is suggested by a comparison of Figures 32 and 33, this pattern of pool use for winter steelhead could be driven by several fish that were in the array for days and spent large amounts of time in

Zone 7. Their behavior may also have been influenced by the extended spill period that occurred during winter steelhead testing. During this spill event the trap was submerged. When positioned at its highest elevation (56.3 ft per project datum), the trap becomes submerged with approximately 25,000 cfs discharge. Spring Chinook salmon were unique in that were never detected in Zone 6 behind the dam and spent very little time in Zone 7 as compared to the other three salmonids. Even within the tailrace they clustered near the trap entrance in Zones 1, 2 and 4.

The second objective of this study was to estimate the number of trap entries and determine if trap entry was affected by operation of turbine Unit 1. The video analysis was used to address this objective by enumerating fish exploratory behaviors, attempts at trap entry and fallback. Due to circumstances beyond our control this analysis was only completed for steelhead under UNIT 1 ON and was not completed at all for winter steelhead. Reviewing the trap entrance video showed that about 38% of the observed behaviors for summer steelhead were not attempts at trap entry but behaviors that we called exploratory, including a fish jumping and/or rolling at the surface outside the immediate vicinity of the trap discharge. Comparative data from 2006 showed that summer steelhead exhibited more exploratory behavior when Unit 1 was shut down as compared to when it was operating. The data indicate that summer steelhead were more focused on trap entry when Unit 1 was operating. The most prevalent behavior observed for summer steelhead were focused attempts at trap entry (64% of all attempts in 2005, 41% and 57% in 2006 for Unit 1 OFF and Unit 1 ON respectively). The fallback rate for summer steelhead was variable at 25% in 2005 and as high as 45% in 2006.

Coho salmon were more active than summer steelhead within the array, however, their behavior in and around the trap entrance was remarkably similar, especially when comparing behavior of the two species under the same operating treatment, UNIT 1 ON. Levels of exploratory behavior, total attempts, fall back, and successful entries varied by a few percentage points between species. Differences in behaviors were evident between operational treatment groups of coho salmon. Under UNIT 1 OFF conditions, coho salmon exhibited considerably fewer exploratory behaviors, more poorly directed trap attempts such as corner jumps and hits and fewer directed entries into the trap opening. With fewer directed entries and yet a similar fallback rate, coho exhibited reduced success at trap entry as compared to fish under "ON" conditions.

Spring Chinook salmon showed higher percentages of exploratory behavior in the vicinity of the trap than other species observed. They also exhibited more exploration with UNIT 1 ON as compared to UNIT 1 OFF. We observed fewer attempts at the trap when observing these

Chinook salmon and their percentage of successful entries was approximately half that of coho salmon and steelhead observed. Spring Chinook salmon had similar fallback rates among treatment groups as well as similar rates as steelhead and coho salmon.

A third objective of the study was to estimate population and migrant based adult trap efficiency rates for the Merwin trap. The two types of rates provide different perspectives on the effectiveness of the Merwin trap. The first rate, ATE $_{pop}$, provides an estimate of how successful fish are at locating the trap and negotiating entry. The second rate, ATE $_{mig}$, provides an estimate of how effective the trap is at capturing fish once they have been attracted to it. Consistent with these definitions, ATE $_{pop}$ was based on data from radio-tagged salmon while ATE $_{mig}$ was based on data obtained from video review.

For radio-tagged summer steelhead overall ATE $_{pop}$ was good at 70% and was consistent between "ON" and "OFF" treatments. Summer steelhead ATE $_{mig}$ was substantially lower at 48% in 2005 and 37% in 2006. This difference in efficiencies suggest that for summer steelhead the process of locating the trap and successfully entering it is high, more effort is expended to negotiate a successful entry. In fact for every 3 attempts summer steelhead made at trap entry they were successful only once. A part of this failed entry is attributable to undirected attempts, however even when a summer steelhead has successfully entered the mouth of the trap there is a 25 to 45% chance it will fall back into the tailrace and avoid capture.

When compared to summer steelhead coho salmon performed poorly at locating and entering the trap. The over all ATE$_{pop}$ was almost half that estimated for summer steelhead at 37%. In addition there were large differences among coho salmon treatment group, with ATE $_{pop}$ approximately three times greater under UNIT 1 OFF than under UNIT 1 ON. Although coho salmon did not spend significantly more time in the tailrace when Unit 1 was on, they did exhibit increased wandering behavior and, as mentioned above, spent more time in the Zone 7 pool and away from the trap under "ON" conditions. In contrast to steelhead, finding or being attracted to the trap appears to be a concern for coho salmon under all operating conditions and this effect is amplified when Unit 1 is operating.

Coho salmon that did locate the trap performed very consistently with summer steelhead; overall ATE$_{mig}$ for coho salmon was 46% compared to 48% for summer steelhead. However, there were substantial differences between coho salmon treatment groups. While the UNIT 1 ON group was similar to summer steelhead at 50% efficiency, the efficiency of UNIT 1 OFF group was reduced by 13%. This increase in successful trap entry under UNIT 1 ON conditions is intriguing since tagged coho performed poorly with respect to ATE $_{pop}$ with Unit 1 operating.

This indicates that the poor performance of coho salmon at the trap is more likely a function of trap location or attraction than capture.

It is possible that individual variability is affecting the efficiency of trap entry and some fish must try more than others, perhaps due to changes in the trap elevation, or fish motivation to move upstream. However, the consistency of ATE for both summer steelhead and coho salmon suggests this estimator is representative of trap function over a variety of conditions.

Radio-tagged winter steelhead performed more like summer steelhead than coho salmon with respect to locating and entering the trap with overall ATE $_{pop}$ only 5% lower than summer steelhead. Unlike the other two salmonid runs, winter steelhead showed a dramatic increase in ATE $_{pop}$ from the "OFF" to "ON" condition. This difference must be interpreted with caution given the very small sample size of winter steelhead in the UNIT 1 OFF treatment. The addition of even a small amount of data into this analysis would have a significant effect on ATE $_{pop\text{-}off.}$ For example, the addition of the two tagged wild winter steelhead that entered the array during UNIT 1 OFF would result in an 8% increase in ATE $_{pop\text{-}off.}$

Spring Chinook salmon showed overall ATE $_{pop}$ more similar to summer and winter steelhead than coho salmon but slightly lower at 56%. Spring Chinook salmon were similar to coho salmon in that they showed a reduced ability to locate the trap when Unit 1 was operating compared to when it was off. Radio-tagged spring Chinook salmon in the Unit 1 OFF treatment were the most effective of all groups in locating and entering the trap with an ATE of 90%. Spring Chinook salmon fall back rates were similar between treatments as well as compared to other species observed.

The fourth and fifth objective of this study where to determine what (if any) tailrace conditions impede fish movement into the trap and if conditions precluded trap entry or cause migration delay what locations would be preferred for a new trap entrance. Three analyses provide results relevant to these objectives: 1) time radio-tagged fish spent in tailrace detection zones, 2) number of transitions among tailrace detection zones by radio-tagged fish and 3) the analysis of a treatment effect on total time in the tailrace. Both summer steelhead and coho salmon showed use of multiple detection zones and extensive movement throughout the zones. There were some species-specific differences that were evident. For example, as compared to use patterns under UNIT 1 ON summer steelhead showed more time spread out among tailrace detection zone and increased movement among zones under UNIT 1 OFF. Summer steelhead also spent more time away from the trap in Zones 6 and 7 under the "OFF" treatment. Finally, there was a very clear and significant treatment effect on summer steelhead in and around the trap entrance. Under

"OFF" treatment conditions summer steelhead exhibit a preference for the area just downstream of the trap in front of the control room and rock outcrop. Under the "ON" treatment use of this area is minimized, in particular this is obvious for the zone directly adjacent to the rock outcropping. The preferred area for summer steelhead changes under "ON" conditions to the zones along the powerhouse wall in front of Units 2 and 3 discharges. Consistent with this preference change is the switch from moving upstream toward the trap entrance along the control room wall under "OFF" conditions to moving from left to right across the powerhouse wall to trap entrance. The treatment effects evident for summer steelhead tailrace use patterns did not result in any delay in these fish being able to locate and enter the trap. This was also evident by the failure of the total time analysis to detect a significant difference in time summer steelhead spent in the tailrace under different operating conditions.

Among the three salmonid races tracked by radio-telemetry coho salmon exhibited the most movement. Coho salmon used all the areas covered by fixed antennas in the tailrace but clearly showed a preference for the large pool downstream of the access bridge in Zone 7. The treatment effect evident for coho salmon was similar to summer steelhead in that tagged coho salmon spent significantly more time along the powerhouse wall under Unit 1 ON conditions. Their movement patterns were also similar to summer steelhead in that they showed increased movement to and from the area in front of the powerhouse wall to the trap entrance area and decreased movement upstream along the control room wall to the trap under "ON" as compared to "OFF" conditions. The results of the ATE_{pop} analysis suggest that this change in approach may have had detrimental effects on trap entry since the same group of radio-tagged tagged fish that increased their approaches to the trap along the powerhouse wall also exhibited low ATE_{pop}. Given that these results are based on data from 19 radio-tagged salmon from the UNIT 1 ON treatment, extrapolation to the general coho salmon should be approached with caution. More than 10,000 observations of untagged coho salmon entering the Merwin trap suggest higher trap efficiency and successful capture rate under "ON" as compared to "OFF" conditions. Similar to summer steelhead the analysis of total time in the tailrace showed no significant difference for radio-tagged coho salmon in different treatment groups, suggesting no delay associated with varied behaviors documented.

The small sample size of the UNIT 1 OFF treatment group warrants caution when making conclusions about treatment effects on radio-tagged winter steelhead. However it is interesting that descriptive analyses for winter steelhead showed some patterns similar to summer steelhead and coho. Winter steelhead from both treatments used most of the detection zones but spent very little time in Zone 3, the area adjacent to the rock outcrop along the control room wall. The majority of time in the tailrace array for winter steelhead in both treatment groups was spent in

the large pool in Zone 7. Similar to the other species winter steelhead also showed an increased affinity for the area in front of the powerhouse wall when Unit 1 was operating. Similar to coho, winter steelhead exhibited increased movement among tailrace detection zones when under UNIT 1 ON conditions. Based on the mean residence time, winter steelhead from both treatments spent similar amounts of time in the tailrace suggesting no delay associated with the operational treatment tested.

The results of the spring Chinook salmon radiotelemetry study need to be interpreted cautiously as a controlled study with a block treatment design was not completed. Instead, spring Chinook salmon were exposed to fluctuating treatment conditions and assignment of treatment conditions was conducted after the study was completed. Consequently while all of the fish in the UNIT 1 OFF treatment experienced only the OFF condition, 5 out of 26 of the fish in UNIT 1 ON treatment experienced short durations of UNIT 1 OFF in the middle of their tailrace residence. Due to the randomly fluctuating treatment conditions it is more difficulty to ascertain a true treatment effect on fish behavior in the tailrace.

Spring Chinook salmon moved throughout the tailrace proper (Zones 1-5) but did not appear to move back and forth from the pool below the access bridge nor into the gallery behind the powerhouse. The amount of movements tagged Chinook salmon exhibited was similar between treatments. However, they spent more time moving between Zone 4 and the area just downstream of the trap and less time moving among the 3 zones along the control room wall under UNIT 1 ON. Similar to the other tagged species, spring Chinook salmon did show an increased affinity for the powerhouse wall under UNIT 1 ON, but it was limited to the use to Zone 4 and they did show greater movement into and out of this zone as other species did. When Unit 1 was off spring Chinook tend to hold and move more between Zones 1, 2, 3 apparently using the right shoreline to focus their approach to the trap. These significant differences in use patterns and movement indicate that under Unit 1 ON spring Chinook salmon moved out from the area in front of Unit 1 over to the area in front of Unit 2 and between Units 2 and 3. This suggests that with Unit 1 operating spring Chinook salmon would more likely to encounter flow patterns from additional ladder entrances across the face of the dam.

Within the study period the spring Chinook salmon spent similar amounts of time in the tailrace regardless of treatment condition. Their total time in the tailrace also was comparable to that of other radio-tagged salmonids tracked. Thus, although a treatment effect was evident for radiotagged spring Chinook salmon in locating and entering the trap, it does not appear that this was sufficient to result in delay, as defined by more total time spent in the tailrace.

5.1 SUMMARY

When considering all of the results for the four salmonids reported here, the following four conclusions seem to emerge from the data. First, although various species-specific behavioral patterns emerged, there was no evidence that operation treatment resulted in delay (as defined in Section 2.2.4) or precluded fish from entering the trap. In fact, total time spent in the tailrace was similar between treatment groups for each of the salmonids tested. Second, radio-tagged fish from all species exhibited a change in use pattern, moving away from the control room wall to an area adjacent to the powerhouse wall when Unit 1 is turned on. This change in use pattern associated with operation of Unit 1 suggests that additional trap entrances located near Units 2 and 3 discharge may be attractive to fish under certain operation conditions. Third, the data is equivocal regarding the attractiveness of the trap in its current location. Both summer and winter steelhead were adept at locating and entering the trap and did so at a good and consistent level. Coho salmon performed poorly in locating and entering the trap under both operational conditions. Only Chinook salmon show a strong treatment effect of reduced trap efficiency when Unit 1 was operating. Fourth, summer steelhead, coho, and Chinook that did locate the trap performed similarly with respect to exploratory behaviors, trap attempts, successful entries, and fallback under various tailrace conditions. This suggests a level of performance for negotiating trap entry that may be related to the design and operation of the trap itself and that could be rectified with a new design.