

**Research Report**  
Research Project T1803 Task 23  
Fish Culvert Passage

**JUVENILE COHO MOVEMENT  
STUDY**

by

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16. ABSTRACT <p style="text-indent: 40px;">This pilot study was initiated to investigate movement patterns, habitat utilization, and velocity preferences for young of the year coho salmon (<i>Oncorhynchus kisutch</i>) during the spring in Western Washington and to examine potential factors controlling redistribution timing in the fall.</p> <p style="text-indent: 40px;">Water velocity appeared to be an important factor in predicting juvenile coho (&lt; 55 mm) distribution. Mark-recapture studies indicated that upstream movement by juvenile coho through culverts is low. Timing for fall redistribution of juvenile coho from main channels into off-channel habitat was investigated in relation to water temperature, stream flow, date, and moon phase. The majority of movement by juvenile coho in the Skagit, Suiattle, and Stillaguamish River basins occurred during new and half moon phases. Movement into off-channel habitat by juvenile coho in the Hoh River basin corresponded with floods where flow increased by 2000 cubic feet per second (cfs) and coincided with a new moon. Studies at Remote Site Incubators indicate that recently emerged coho fry move up and downstream. Upstream movement ranged between 100 and 200 meters from April through June. After June, coho fry were found over 500 m upstream.</p>			
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## Introduction

Salmon are an important part of Pacific Northwest culture and economy, but have disappeared from 40 percent of their historical breeding grounds in Washington, Oregon, Idaho, and California (National Research Council (NRC) 1996). Despite great investments in fish ladders, hatcheries, and regulations protecting riparian zones, salmon abundance continues to decline (NRC 1996). Historical watershed reconstruction has shown that key habitat features for coho (*Oncorhynchus kisutch*) have been lost (SSHEAR 1996), and numerous efforts are currently under way to restore off-channel habitat throughout the state with the hope of restoring stocks.

Alevins emerge from the egg pockets as free-swimming fry and disperse from nest sites in the spring and early summer. Dispersal distances from nest sites to initial juvenile feeding grounds vary according to species and population (Northcote 1978; Nielsen 1993), and a mass redistribution of juveniles to more favorable habitats may occur at various times during the year. Movement from large main stem rivers into streams and off channel habitats during the fall, and movement within streams during summer have been documented (Foy 1986, SSHEAR 1996). Juvenile salmonid movement can be stimulated by a number of factors that generally characterize declining environmental conditions (Kahler 1999). Movement may be due to increased competition for foraging territory (Chapman 1962), a reduction in food abundance (Wilzbach 1985) related to natural variations in population abundance, lack of adequate habitat, or low discharge conditions. Movement may have ecological significance even if the absolute distance moved is not great (Swingland and Greenwood 1984, Dingle 1996), making it difficult to associate an incremental distance moved with behavior. For example, moving from a pool to a riffle increases the amount of energy a fish must expend to hold position, and changes the amount and type of available prey. Bisson et al. (1988) found that coho salmon preferred pools with average velocities of less than 20 cm/s.

The Restricted Movement Paradigm (RPM) is another explanation as to why juvenile coho display certain types of movement and foraging behavior (Smithson and Johnston 1999). The RPM states that fish movement is restricted to a pool or reach. However, Smithson and Johnston (1998) found that stream fishes may spend the majority of their time in a pool or reach, but they may also make regular exploratory trips away from their home pool. In their study, fish were marked with passive integrated transponder (PIT) tags and recaptured days later. Results showed that the majority of marked fish were found in pools, and a significant portion of recaptured fish were found in pools other than those of the initial collection (Smithson and Johnston, 1999).

Juvenile salmon have the capacity to move both with and against stream currents to search for suitable habitat and food. Field studies with marked native fish in streams have revealed the importance of upstream mobility for juvenile salmon (Kahler 1999). Foraging tactics of drift feeding salmonids favor maximizing energy intake and minimizing energy expenditure (Wilzbach 1985). A fish can maximize its fitness by occupying a low current velocity site with ready access to drifting food, and juvenile coho are most likely displaying these characteristics when feeding (Bisson et al. 1988).

Kahler (1999) investigated the movement patterns and growth of juvenile coho in Western Washington streams with snorkeling and recapture techniques. He found that summer movements were prevalent in the population, with estimates of substantial

movement of tagged fish ranging from 28 to 60 percent. Upstream movement exceeded downstream movement in three out of four instances. Distances moved downstream exceeded upstream movement in higher gradient systems, and upstream movement was less common in small streams than in large (Kahler 1999). Kahler (1999) also noted that fish movement peaked as discharge declined toward base flow.

Culverts may act as barriers to upstream habitat for juvenile fish. In the State of Washington, culverts are designed to meet average barrel velocity requirements that can range from 3 to 6 feet per second, depending on culvert length and the species of fish in the basin. Passage regulations are currently designed for returning adult salmon; however, the importance of upstream passage for juveniles has been documented (e.g., Cederholm 1988, King County 1995). The swimming capabilities of salmon fry have been described (Powers et al. 1997), but little is presently known about the environmental conditions that stimulate movement. Smaller fish have slower swimming speeds, which causes them to expend more energy relative to their size during burst and prolonged speeds. When passing through culverts, fish often use a prolonged speed with an occasional burst at the inlet or outlet, or a series of bursts between resting areas (Powers et al. 1997). Taylor and McPhail (1985) measured burst-swimming capabilities of 40- to 70-mm coho fry and calculated the average bursts to range from 2.1 to 2.4 fps with a maximum of 3.4 fps (Powers et al., 1997).

Powers et al. (1997) performed a study to determine whether certain culvert characteristics influenced passage of juvenile coho (60-90 mm). Passage was found to be greatest in corrugated pipe and lowest in smooth pipe. When moving through roughened pipe, juvenile coho used the boundary layer, a low velocity area along the side of roughened pipe, to facilitate passage.

Warren and Pardew (1998) used mark-recapture techniques to examine the effects of four types of road crossings during spring base flows and summer low flows in the Ouachita Mountains, West-central Arkansas. They found water velocities at road crossings to be inversely proportional to fish movement, with the highest velocities at culvert crossings and the lowest in open-box crossings.

Major redistributions of juvenile coho to more favorable habitats regularly occur at certain times of the year. Movement may be attributed to habitat needs, escape from freshets, thermal requirements, prey availability, predator avoidance, lunar cycle, or photoperiod. Describing the window during which juvenile salmon move within streams and rivers and characterizing environmental conditions during movement periods will provide insight into what motivates movement. Identification of habitat types and flow characteristics of areas occupied by young of the year salmon can potentially provide clues about the most favorable conditions from an energetic prospective. Examining movement patterns of newly emergent fry will be useful in determining whether there is a need to accommodate juvenile fish at road crossing structures.

A secondary objective is to provide pilot information to assist in the development of a protocol for field assessment of juvenile salmonid passage through culverts (Williams et al., in prep).

## **Objectives**

1. Identify range of conditions (especially hydrology and temperature) under which young of the year fish (especially West side coho salmon) move during the spring dispersal period.
2. Monitor juvenile salmonid movement in streams during the spring.
3. Analyze existing tributary trap data for fall movement out of rivers and into tributaries by examining trends in movement timing and environmental conditions.
4. Provide recommendations for future studies investigating these questions.

## **Study Sites and Methods**

### ***Habitat Work***

Juvenile coho habitat preference was investigated along a 50-meter reach in Griffin Creek on April 8, 2000. Polarized sunglasses were used to locate fish and block nets and dip nets used to collect fish. Upon collection, coho fry were sedated with MS-222, counted, measured (fork length), revived, and released in the same area that they were taken. Water velocity measurements were taken where fish were collected with a Swoffer-type velocity meter. The type of habitat occupied by juveniles was classified as backwater pool, bank, undercut bank, pool, or large woody debris (LWD).

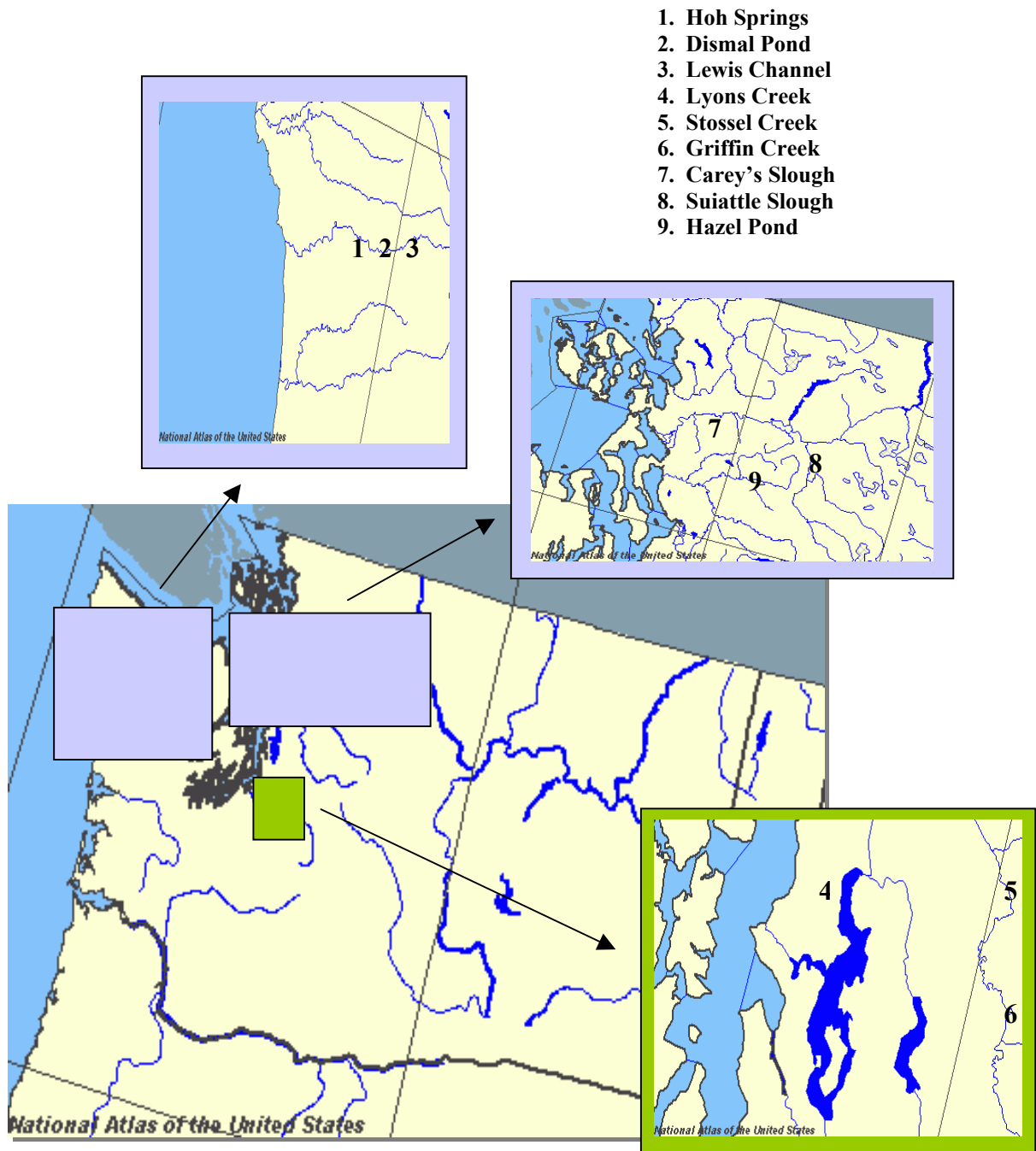
### ***Culvert Work***

Stossel Creek, Lyons Creek, and Griffin Creek were selected as pilot study sites to determine the utility of monitoring juvenile salmonid movement in streams with road crossings with a mark-recapture study (Figure 1). Study sites were selected according to three criteria: uniform channel habitat across all study reaches, low gradient (0-1%), and presence of a natal coho population.

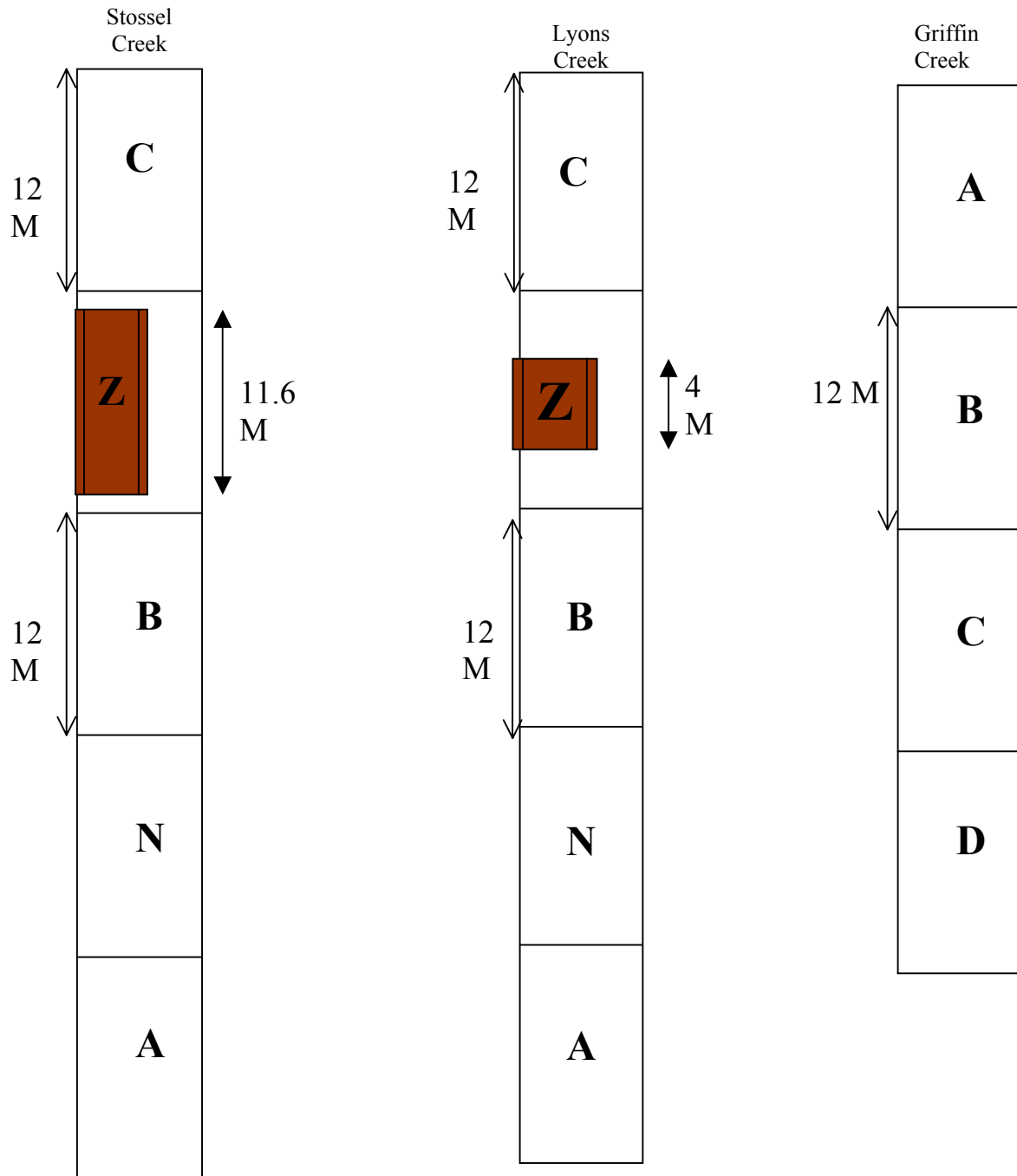
Fish movement was determined by methods similar to those described in Cupp et al. (1999). The two streams with culverts, Stossel Creek and Lyons Creek, were divided into five sampling reaches, A, B, C, N, and Z, each 12 m long (Figure 2). Sample reach C was located directly upstream and adjacent to the reach containing the culvert reach Z. Reach B was located directly downstream from reach Z, followed by reach N (a buffer reach), and reach A. Griffin Creek, which contained no man-made barriers to fish, served as a control stream. Four 12-m sample reaches, A, B, C, and D, were established at Griffin Creek (Figure 2). Fish stained with Bismarck Brown were released in reach B and fin-clipped fish released in reach C.

Coho fry were captured in the study site by electroshocking and netting. Fish were separated into two equal groups, measured (fork length), and tagged. One group was tagged with Bismarck Brown, which gave fish a distinctive orange hue, and the other by adipose fin clipping. In Lyons Creek and Stossel Creek, fish marked with Bismarck Brown were released in sample reach B, and fish marked by caudal peduncle clipping in sample reach A. Tagged fish were released in reaches B and C in Griffin Creek.

Fish were recaptured on the following day in Stossel and Lyons creeks, and three days later in Griffin Creek. After Lyons Creek was resampled for fish, velocity measurements were taken with a Swoffer propeller-type flow meter and an Acoustic Doppler Velocimeter (ADV) at 60 percent of the water depth. Twelve velocity measurements were taken, three at 0.5 meters outside and three at 0.5 meters inside of the culvert at either end.



**Figure 1.** Location of habitat, culvert and fall movement study sites



**Figure 2.** Schematic representing the experimental design for the culvert passage study

The Acoustic Doppler Velocity meter (ADV) is an instrument that measures water velocity in three dimensions in a sampling volume 5 to 10 cm from the probe. A desktop computer powered by an automotive battery was operated from inside our vehicle. One technician recorded ADV output while the other positioned the probe in the stream. Only the immediate area around and inside of the crossing structure could be sampled because of the probe cord. Stream temperature was recorded on release and recapture days.

Fish movement through the culvert (from reaches B, N, and A to C) and below the culvert (within reaches A, B, and N) was assessed by the proportional daily movement estimator (PDM).  $PDM = M_i * R^{-1} * D^{-1}$ , where  $M_i$  is the number of marked fish that move,  $R$  is the total number of recaptured (both marked and unmarked) in the two reaches, and  $D$  is the number of days since marking.

Fish movement from one study reach to another (e.g., A to B) was reported as a proportion of daily movement (PDM). PDM estimates are sensitive to the time interval between fish recovery and release, and are relative and descriptive in nature. A positive PDM signifies upstream movement, and a negative PDM signifies downstream movement. Larger juvenile cutthroat trout (*Oncorhynchus clarki*) were used rather than coho in Lyons Creek, where the rate of recapture was 46 percent.

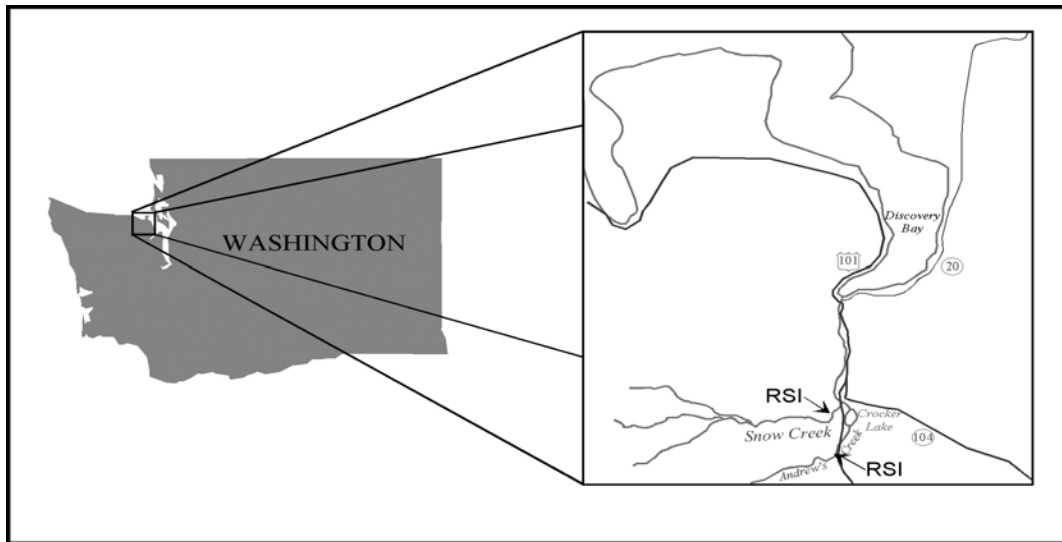
### ***Fall Trap Data Work***

Juvenile coho movement data from main stem channels into off channel habitat during the fall at three sites in the North Coast region and three sites in the North Sound region were provided by Washington Department of Fish and Wildlife. Study sites in the North Sound region were located in the Skagit, Suiattle, and Stillaguamish basins, and study sites for the North Coast region were located in the Hoh basin (Figure 1). In the North Coast, juvenile coho were caught in upstream traps at the entrances to Dismal Creek Pond, Calawah Springs, and Lewis Channel in the fall of 1996-1998. In the North Sound, juvenile coho were caught in upstream traps at the entrances to Carey's Slough, Suiattle Slough, and Hazel Pond in the fall of 1987-1989. Environmental variables that potentially influenced redistribution into off channel areas were examined by comparing trap data, moon phase, temperature, flow, and date.

### ***Remote Site Incubator Work***

Two methods were used for detecting upstream movement of recently emerged coho fry. The primary method of detection was to deploy minnow traps in the two selected creeks, Andrews and Snow creeks (Figure 3). The secondary method was a snorkeling effort that was observational and qualitative in nature. The snorkeling effort was implemented to enhance and compare the predicted and observed upstream boundaries of the coho fry with the results of the minnow traps. Snow Creek and Andrews Creek are located on the Northeastern section of the Olympic Peninsula in Washington State (Figure 3). Snow Creek is in Jefferson County and flows into the southern end of Discovery Bay. Andrews Creek is a tributary stream that feeds into Snow Creek approximately one-half mile north of Crocker Lake, and both creeks are in Water Resource Inventory Area (WIRA) #17. Coho fry emergence locations are well known, and a significant length of upstream habitat exists for potential fry distribution

following emergence. Stream habitat was characterized by methods outlined in Cupp et al. (1999) and WDFW (1998).



**Figure 3.** Location of Snow and Andrews creeks on the Olympic Peninsula, Washington State

Supplemental snorkeling information and stream temperatures were collected in the study area to assist in the distribution assessment.

### Minnow Traps

Sixteen baited minnow traps were placed in the study area in 2000 at several locations (Appendix Table A1) upstream and downstream from the RSI (Photo 1, Appendix C). Because the emphasis of the study was on upstream migration, five traps were placed above each of the RSIs in both Snow Creek and Andrews Creek. Upstream traps were spaced at increasing distances from the RSIs (e.g., 25 m, 50 m, 100 m, 200 m, 400 m) or until there was an estimated current barrier greater than 4 feet per second (fps), which would most likely impede any movement upstream by coho fry. Such a barrier was found on Snow Creek approximately 250 meters upstream from the upper RSI (Photo 2, Appendix C). One trap, S5, was placed 40 meters above this barrier. To provide some measure of downstream movement, two traps were placed below the RSI in Snow Creek, one trap was placed below the RSI in Andrews Creek, and three traps were placed below the confluence of the two creeks.

In 2001, twelve baited minnow traps were placed in the study area at several locations upstream and downstream from the RSI or release point (Table A2). Five traps were placed above the upper RSI at Snow Creek, one below, and six traps were set above the release point at Andrews Creek. Upstream traps were spaced at increasing distances from the RSIs (e.g., 25 m, 50 m, 100 m, 200 m, 400 m) or until there was an estimated current barrier greater than 4 feet per second (fps), which would most likely impede any



movement upstream by coho fry. Such a barrier was found on Snow Creek approximately 250 meters upstream of the upper RSI. We used an adaptive approach to estimate maximum upstream movement of juvenile coho fry during the the 2001 study. As coho fry progressively moved upstream, traps were removed from the lowest point upstream of the RSI or release point, given a new site designation, and placed above the highest upstream trap. At a minimum, two traps were placed above the maximum distance that coho fry moved the week before. Although the focus of this study was upstream movement, one trap was placed 97 meters below the RSI on Snow Creek in order to document movement downstream.

Baited minnow traps were the primary method used for detecting upstream movement of recently emerged coho fry, and followed methods used in 2000 (Southard 2000). Minnow traps were used, as opposed to electro-shocking, seining or dip-netting, because it was simple, cost effective, less obtrusive, and captured variations in feeding and movement over a 24-hour period.

Minnow traps were oriented parallel to the current and anchored so that the traps were completely submerged. The traps were baited and deployed for approximately 24 consecutive hours each week between April 20, 2000, and June 8, 2000, and again from April 25, 2001, to June 14, 2001, for a total of eight sampling periods per year.

In 2000, traps were baited with whole slices of bread, which is readily available and used routinely by Jefferson County Conservation District. The use of disease-free salmon eggs was not used because of the suspected potential to provide false motivation that would cause fry to move upstream beyond their “normal” tendency. In 2001, salmon eggs were used to bait the traps. Pilot studies were conducted in Snow Creek April 6 and April 10, 2001, to compare the catch rates of bread, salmon eggs, and no bait over four 3-hour sampling periods. No significant differences ( $p < 0.05$ ) were detected in catch rates between bait types, frequency of trap check (0.5 and 3.0 hours), and time of day (time period A: 1010-1240, B: 1457-1720, C: 1900-2030, D: 2230-0100 hours) (Williams et al., in prep).

Trap openings were set at 1.5 cm initially in 2000 but later reduced to 1.0 cm because of the capture of larger salmon, trout, and two different species of mice: a deer mouse (*Peromyscus maniculatus*) and a Pacific jumping mouse (*Zapus trinotatus*), preliminarily identified by Randy Cooper of WDFW (personal communication).

No anesthetics were used to handle fish caught in the minnow traps and no mortalities were observed during field operations. Captured fish were identified using the Field Identification Guide of Coastal Juvenile Salmonids (Pollard et al., 1997). Fork-length (FL) measurements were taken for all salmonids and total length (TL) for sculpins. Once species identification and measurements had been completed, fish were immediately released.

### Snorkeling

The purpose of the snorkel surveys was to compare the upper distribution observations with the minnow trap data. A two-person team, one observer and one recorder, was used to conduct the snorkel surveys on May 25, 2000. One person would snorkel the stream and verbally relay the observational data to the recorder. In Snow Creek, the team surveyed upstream until coho fry were no longer observed. In Andrews Creek, the team worked downstream until the first observations of coho were observed.

These two different snorkeling methods were used to determine the most effective detection of coho fry between the up- and downstream snorkeling methods. No snorkeling was done in 2001.

#### Stream Temperatures

Stream temperatures were recorded in both Snow Creek (Trap S1) and Andrews Creek (Trap A1) every hour during the project using Optic Stow Away Temperature sensors in 2000 and HOBO sensors in 2001. The sensors were deployed in shaded areas and anchored to the streambed on April 20, 2000, and were retrieved one week after the last trap was checked on July 16, 2000, and again from April 26, 2001, through June 19, 2001.

## Results and Discussion

### *Habitat Work*

Very little information exists for fry 25 to 40 mm, whereas many studies have reported on older fish. Our findings show that the distribution of coho fry between 30 and 50 mm long appears to be influenced more by water velocity than habitat type. In early April, 70 percent of fish captured in Griffin Creek inhabited regions with water velocities of between 0 and 0.1 feet/second, and 90 percent of juveniles inhabited areas with velocities of less than 0.4 ft./sec. (Figure 4). Juvenile coho were most commonly found in pools and along the bank, but were also associated with large woody debris (LWD) (Figure 5). Fry were often found milling about in large aggregations (20 or more fish), suggesting that feeding territories had not yet been established. In early April 117 juvenile coho were captured, and the average fork length was 37 mm (Table 1).

### *Culvert Passage and Fry Movement*

In juvenile coho culvert passage and spring movement studies recapture rates were too low to make inferences about juvenile coho movement. Only 2 of the 36 fish released in Stossel Creek and 2 of the 60 fish released in Griffin Creek were recaptured. Movement by marked cutthroat trout through the culvert was not observed in Lyons. However, three fish measuring 103, 95, and 40 mm long moved from the lower most reach (A) into the culvert. This finding suggests that the Lyons Creek culvert is not a barrier to salmonids greater than 40 mm. Fish tagged with Bismarck Brown were recovered in two study reaches other than reach B and yielded PDM values of 1.5 and -0.25. Fin-clipped fish released from reach A were recovered in reaches B and N with a PDM value of 0.33 (Table 2).

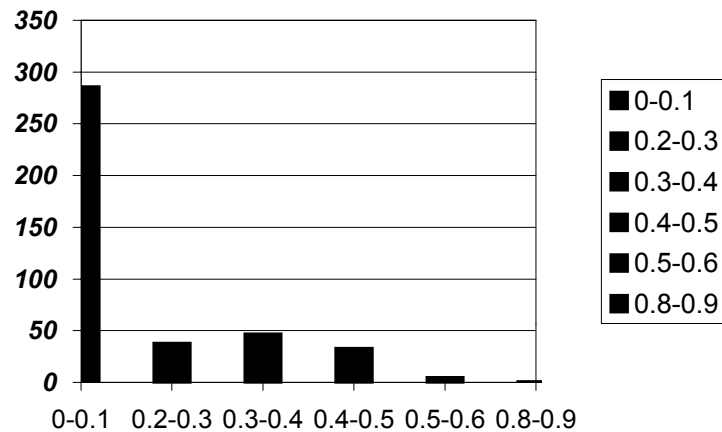
Two tagged juvenile coho were recovered in Stossel. Both were fin clipped fish that moved from the lower most reach A into the natural reach N and had a PDM of 0.5. The objective of having a natural reach was to determine the number of fish motivated to move upstream under natural stream conditions; however, it is difficult to form conclusions about juvenile coho movement in Stossel Creek because of a low rate of recapture. Even though upstream movement was observed in the spring, the extent to which this movement is biologically significant has not yet been determined. Fish movement may be driven by food availability, territory limitations, or other variables. Without further studies examining the reasons for movement, it will be difficult to speculate on the implications of road crossings for juvenile salmonids.

Two fin-clipped fish were recovered three days later at Griffin Creek. One moved 12 m from reach C to B, and one 24 m from reach C to A. Fish movement into each of these reaches reflected PDM values of 0.16. A low recapture rate at Griffin Creek prevented us from reaching conclusions about fish movement in streams without road crossing structures.

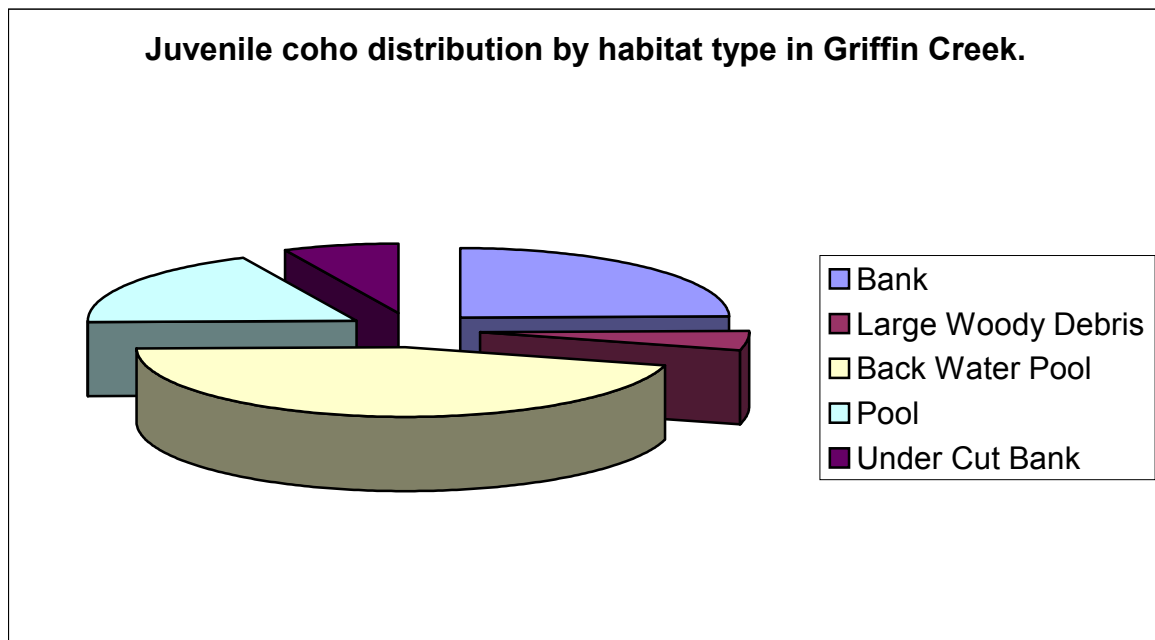
Lyons Creek cutthroat trout exhibited the most positive PDM values and Griffin the most negative PDM values (Table 2); however, PDM may not be related to movement because water velocity was not recorded in Griffin. A major limitation of this study was the inability to detect the frequency of movement over a temporal range. Fish may have moved out of and back into a study reach before the stream could be resampled. A low recapture rate further reduced the power of detecting a true

representation of instream movement. Water temperature across study sites and sampling dates was relatively constant (12-13 °C) during sampling periods and is believed to have had little influence on movement (Table 2).

Velocity (ft./sec) vs. number of fish inhabiting area.



**Figure 4.** Distribution of juvenile coho relative to water velocity in Griffin Creek. Measurements were taken in early April 2000.



**Figure 5.** Relative distribution of juvenile coho according to habitat type. Coho were found to inhabit one of five different habitats in early April 2000 in Griffin Creek.

**Table 1.** Statistical summary of juvenile coho fork lengths sampled in Griffin Creek during early April 2000.

<b>Fork Length</b>	<b>Values</b>
<b>Mean</b>	37 (mm)
<b>Median</b>	37 (mm)
<b>Standard Deviation</b>	2.3 (mm)
<b>Minimum</b>	32 (mm)
<b>Maximum</b>	44 (mm)
<b>Count</b>	117

**Table 2.** Data summary for Proportion of Daily Movement (PDM) experiments in Stossel, Lyons, and Griffin creeks. Velocity measurements were acquired with an ADV and Swoffer-type velocity meter.

	<i>Coho fry</i> Stossel Cr.	<i>Cutthroat trout</i> Lyon Cr.	<i>Coho fry</i> Griffin Cr.
PDM Bismarck Brown	0	.33	0
PDM Fin Clipped	0.5	1.25	-0.16
# Fish Released	36	24	60
# Fish Recaptured	2	11	2
Recapture Rate (%)	5.5	46	3.3
Average Fork Length (mm)	57	96	39
Range Fork Length (mm)	35 - 86	38 - 183	30 - 58
Average Velocity Left Bank (ft/sec)	2.4	0.37	NA
Average Velocity Thalweg (ft/sec)	2.1	0.21	NA
Average Velocity Right Bank (ft/sec)	2.3	0.09	NA
Water Temperature (°C)	12	13	13
Culvert Diameter (m)	1	3.3	NA

### ***Velocity Results***

Downstream velocity (X-vector) measurements taken with the ADV meter were similar to those taken with the Swoffer-type velocity meter (Table 3). With the exception of station one, horizontal (Y-vector) and lateral (Z-vector) velocity values were much lower than those in the downstream vector at all stations (Table 3). A general trend of the ADV meter was to overestimate velocity in comparison to the Swoffer-type meter (Figure 6). The potential for an ADV to describe complex flow characteristics in relation to fish movement was not as apparent as we had anticipated. In our study, velocity measurements taken with a propeller type meter were adequate enough to characterize velocity, and the ADV provided velocity measurements at too fine a scale to relate to movement.

If ADV technology is utilized in future field efforts, we strongly recommend using the ADV Field version rather than the lab version. The ADV Field version uses the

same program and technology as the Lab version, but operates from a laptop rather than desktop computer.

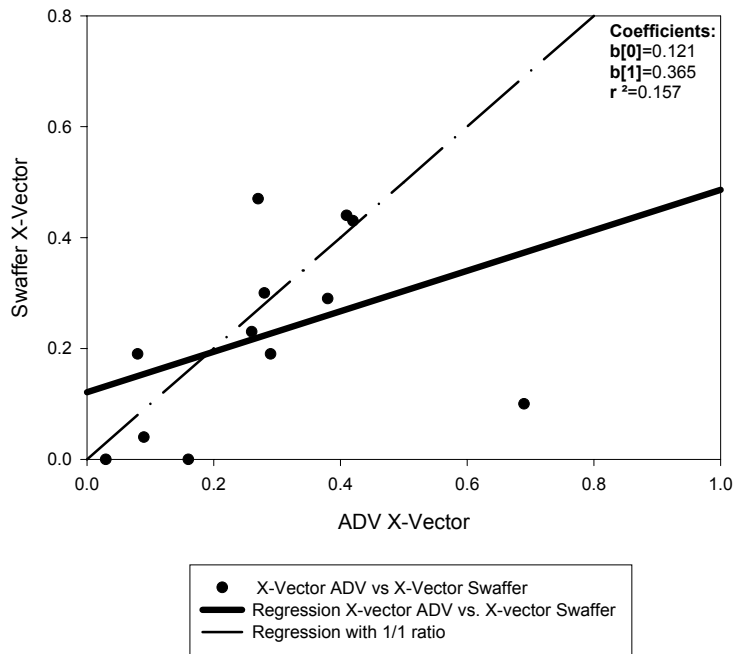
**Table 3.** Velocity measurements (ft./sec.) taken with an ADV and Swoffer-type meter in Lyons Creek during late June. Stations correspond to instream sampling locations diagramed in Figure 3.

Station	ADV X-vector	ADV Y-vector	ADV Z-vector	Swoffer X-vector
1	0.29	0.27	-0.02	0.19
2	0.38	0.17	-0.05	0.29
3	0.26	-0.06	-0.05	0.23
4	0.08	0.02	-0.03	0.19
5	0.28	-0.01	0.00	0.30
6	0.09	-0.01	-0.02	0.04
7	0.03	-0.01	-0.02	0.00
8	0.42	-0.05	0.01	0.43
9	0.16	-0.08	-0.03	0.00
10	0.27	0.02	-0.04	0.47
11	0.41	0.17	-0.10	0.44
12	0.69	0.03	-0.06	0.10

### ***Fall Movement***

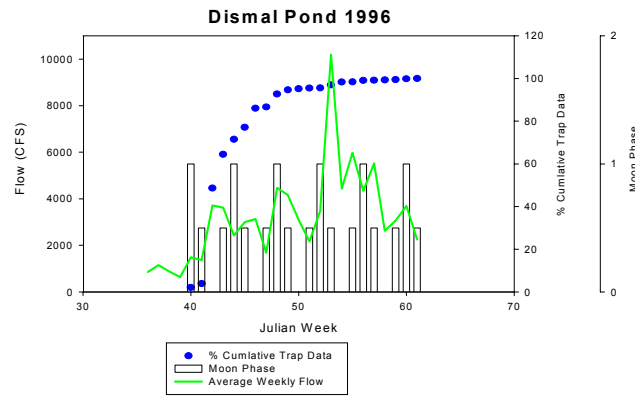
The largest amount of juvenile coho movement from the Hoh River into Dismal Pond in the fall of 1996-1998 occurred between Julian weeks 40 and 50, with the largest proportion of individuals moving during new moon and half moon periods (Figure 7a-c). The majority of movement occurred within a two-week period, causing date to be an important indicator of redistribution timing. In 1996 and 1997 the majority of movement occurred over weeks 42-43 and 41-42, respectively (Figure 7a and 7b). In fall 1998 the largest amount of movement occurred over weeks 49-50 (Figure 7c). Significant numbers of fish were trapped during weeks when a new moon occurred. Forty-five percent of the fish trapped in Dismal Creek were caught during a week with a new moon in 1996, 64 percent in 1997, and 33 percent in 1998 (Figure 7a-c).

The middle 80 percent of the run in Dismal occurred between Julian weeks 42-46 in 1996, 40-41 in 1997, and 47-50 in 1998 (Figure 7a-c). Redistribution timing estimates for 1997 may not be as reliable as those from 1996 and 1998 because 63 percent of the fish were caught during the first fish-trapping week, and presumably the first portion redistributers were not detected (Figure 7b). A total of 2,317 juvenile coho were caught in 1996, 1,565 in 1997, and 1,935 in 1998.

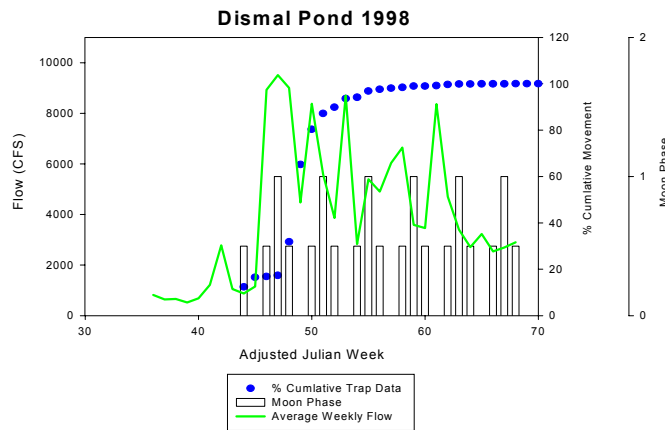
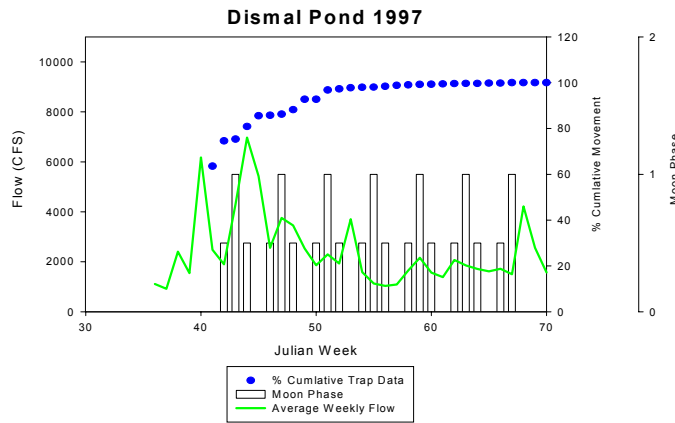


**Figure 6.** A graphical comparison of downstream velocity estimates from ADV and Swaffer-type meters (represented as a dark solid line). The associated regression statistics ADV vs. Swaffer-type meter is reported in the upper right corner of the graph. The theoretical relationship if both velocity meters produced identical estimates is represented as a dash/dotted line.

**Figure 7a**



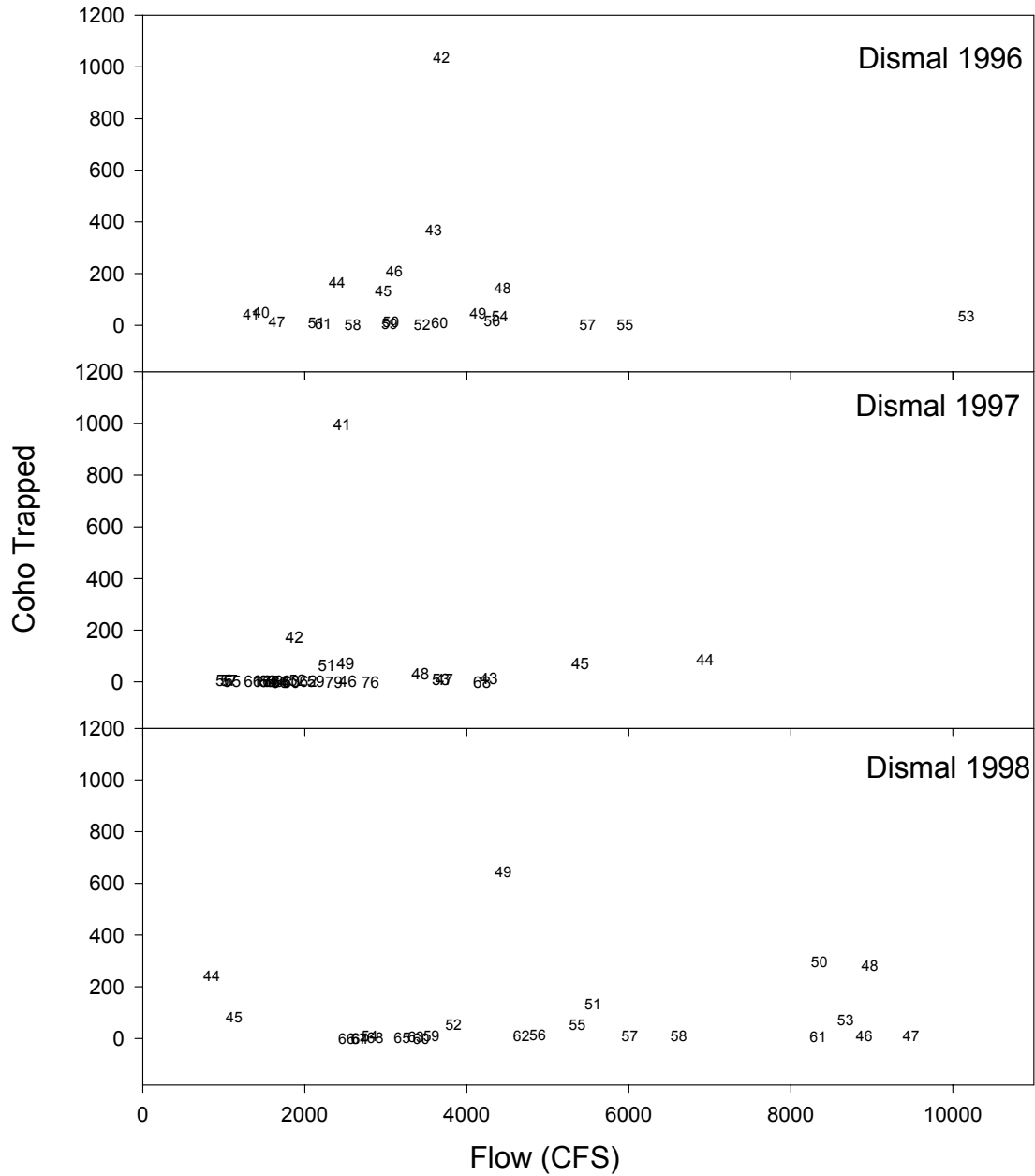
**Figure 7b.**



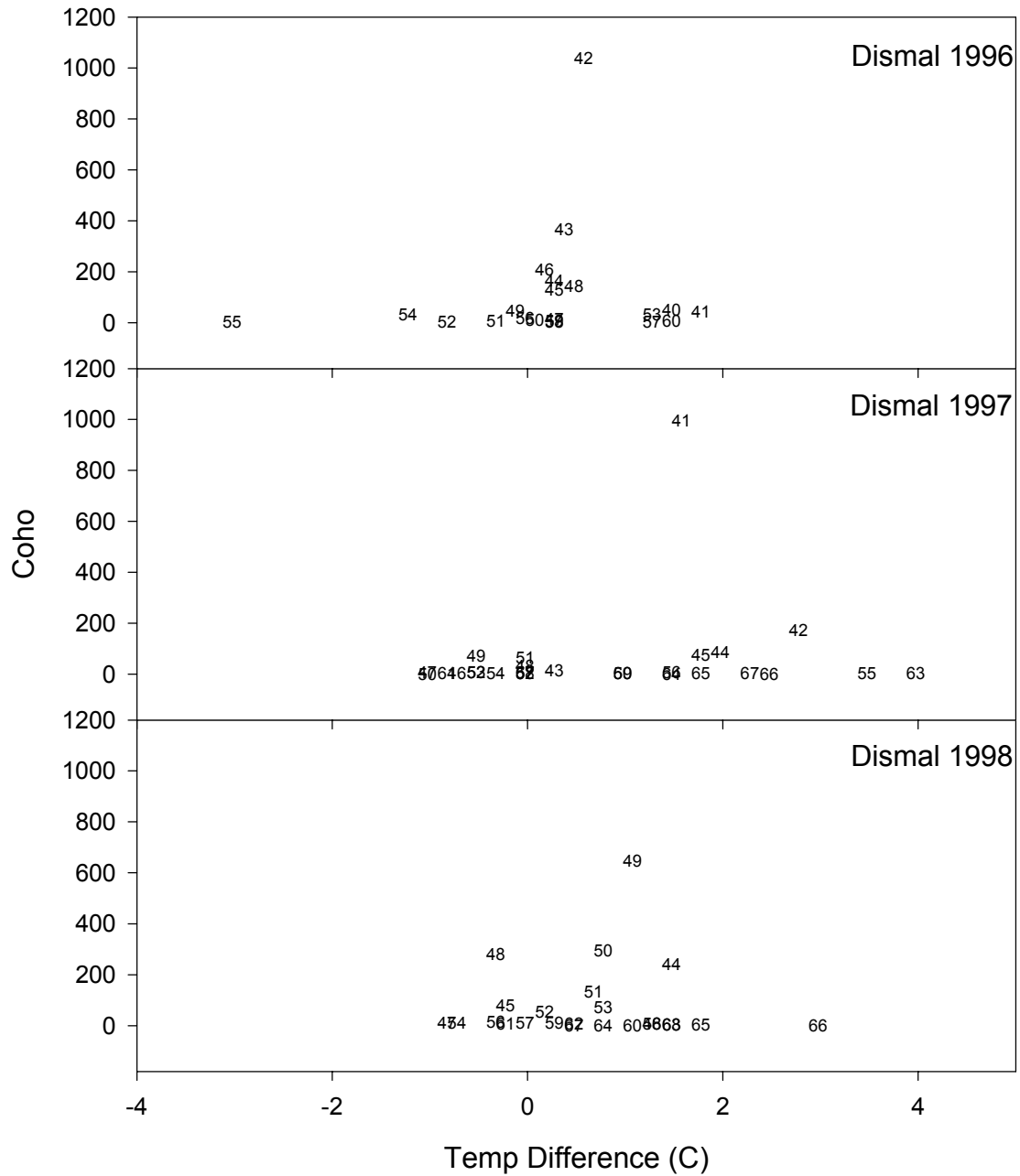
**Figure 7c.**

**Figure 7a-c.** A comparison of river flow (CFS), fish movement described by the % of cumulative trap data, and moon phase (1=full, .5=half, and 0=new). Data reported was collected during the coho fry redistribution periods in Dismal Pond from 1996-98. A key relating Julian dates to calendar dates is located in Appendix A.

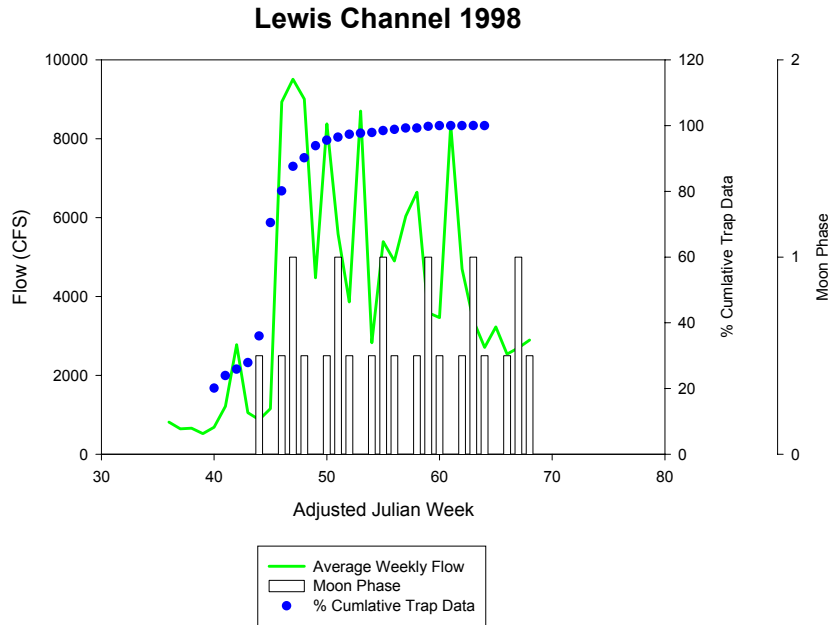




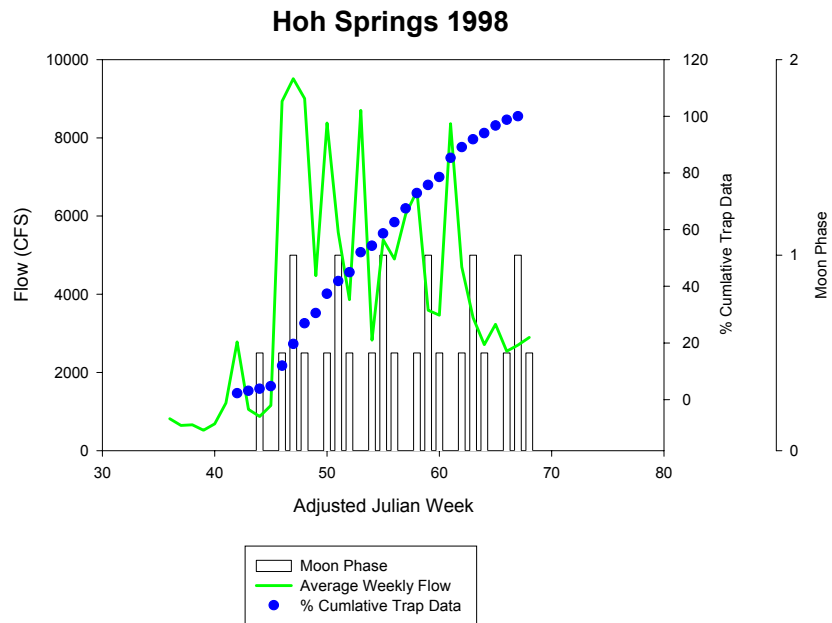
**Figure 8.** Flow vs. fish movement during the coho fry redistribution period in Dismal Pond 1996-98. Numbers correspond to adjusted Julian week. A key relating Julian dates to calendar dates is located in Appendix A.



**Figure 9.** Difference between Hoh River and Dismal Pond temperature (Tributary – River) vs. fish movement during the coho fry redistribution period from 1996-98. Numbers correspond to adjusted Julian week. A key relating Julian dates to calendar dates is located in Appendix A.

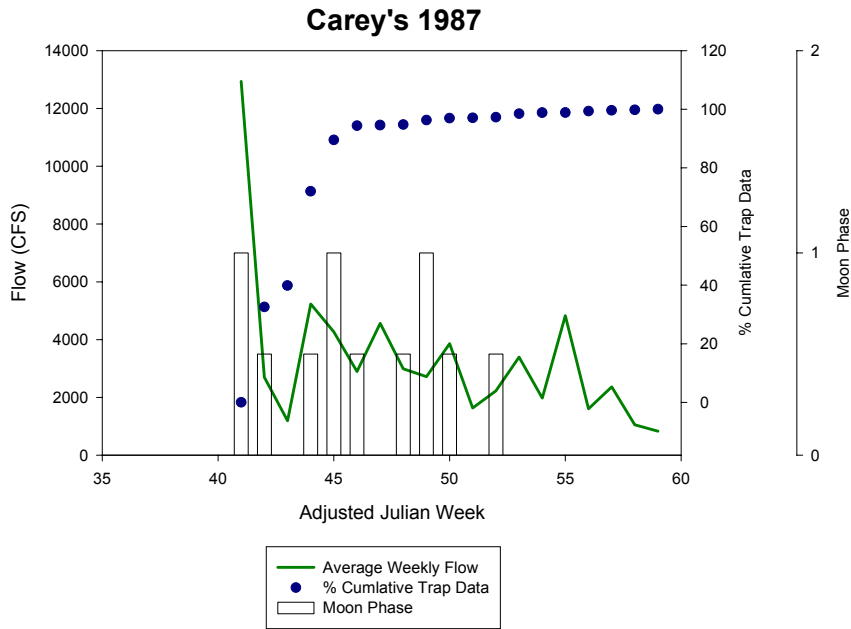


**Figure 10.** A comparison of river flow (CFS), fish movement described by the % of cumulative trap data, and moon phase (1=full, .5=half, and 0=new). Data reported is taken during the coho fry redistribution period in Lewis Channel 1998-99. A key relating Julian dates to calendar dates is located in Appendix A.

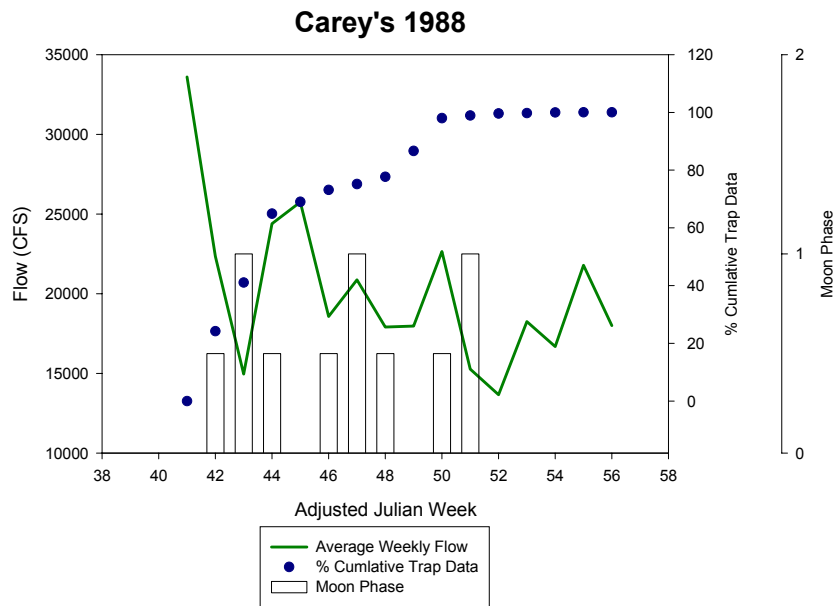


**Figure 11.** A comparison of river flow (CFS), fish movement described by the % of cumulative trap data, and moon phase (1=full, .5=half, and 0=new). Data reported is taken during the coho fry redistribution period in Hoh Springs 1998-99. A key relating Julian dates to calendar dates is located in Appendix A.

**Figure 12a.**



**Figure 12b.**



**Figure 12a-b.** A comparison of river flow (CFS), fish movement described by the % of cumulative trap data, and moon phase (1=full, .5=half, and 0=new). Data reported is taken during the coho fry redistribution period at Carey's Slough 1987-88. A key relating Julian dates to calendar dates is located in Appendix A.

Fish movement into off channel habitat increased with flow. In 1996 and 1998 the largest proportion of fish moved when Hoh River flow was 4,000 cubic feet per second, while in 1997 the largest proportion of fish moved when flow was 2,500 cubic feet per second (Figure 8). Large percentages of the total immigration to Dismal pond correspond with floods, where flow increased by 2,000 CFS and coincided with the week of a new moon.

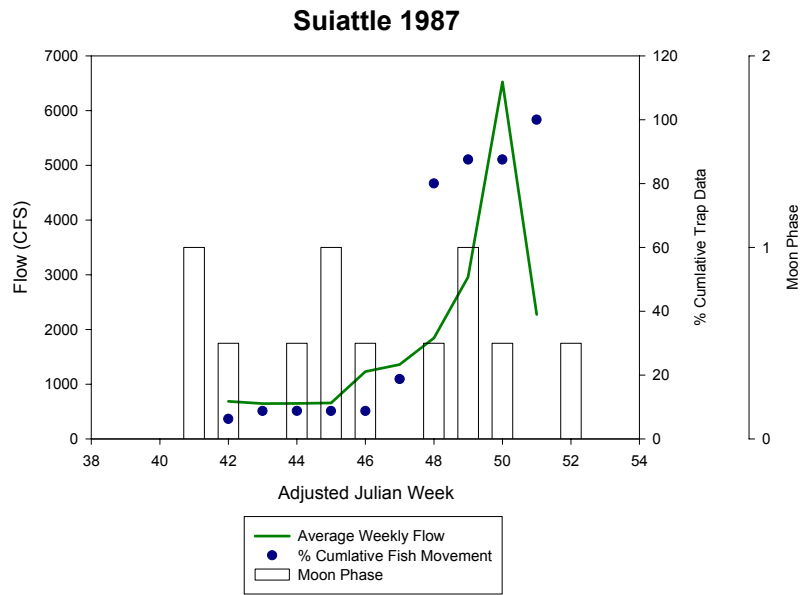
The majority of juvenile coho moved into Dismal Creek pond when tributary temperatures were 1-2°C higher than the Hoh River (Figure 9). A decrease in river temperature may be due to rain or snow events and may trigger fish to move from the Hoh River into off channel habitat. However, these data suggest that combinations of environmental variables influence fall redistribution timing.

The majority of movement into Lewis Channel in 1998 occurred between Julian weeks 45-47 and during new moon and half moon phases (Figure 10). Much like Dismal, movement into Lewis Channel increased with flow. Movement into Hoh Springs differed from movement into other study sites because fish gradually moved into Hoh Springs over a 20-week period. Moon phase, flow, and date did not influence fish redistribution at Hoh Springs (Figure 11).

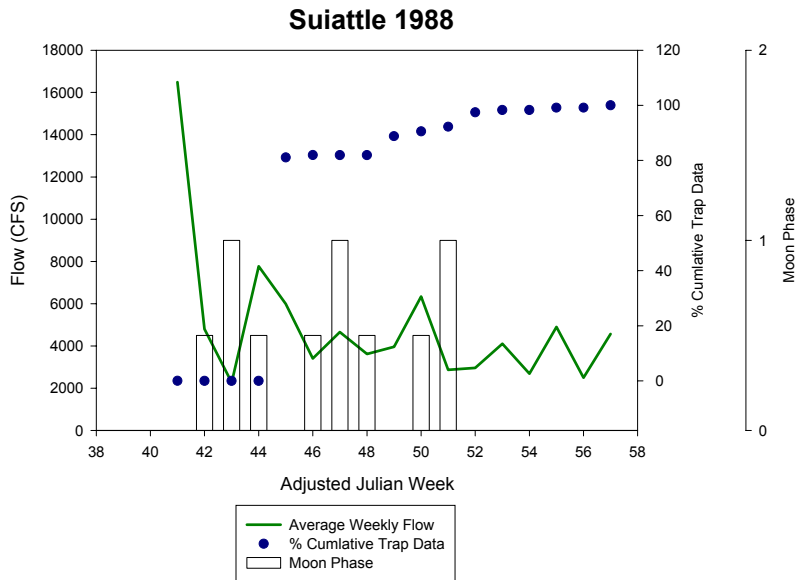
The three off-channel sites analyzed in the North Sound were Carey's Slough, Suiattle Slough, and Hazel Pond. The largest amount of juvenile coho movement into Carey's Slough occurred between Julian weeks 42 and 44 (Figures 12a and 12b). The largest proportion of fish moved during a new moon or half moon period in 1987, and during a half moon or full moon period in 1988 (Figures 12a and 12b). Redistribution occurred over a shorter time period in Suiattle Slough. Seventy percent of juvenile coho were trapped during Julian week 48 in 1987, and 80 percent of juvenile coho were trapped during Julian week 45 in 1988 (Figures 13a and 13b). Redistribution into Suiattle Slough during 1987 and 1988 corresponded with new moon periods (Figure 13a and 13b).

Seventy percent of fry moving into Hazel Pond in the fall of 1989 occurred during Julian weeks 41-43 (Figure 14). Movement into Hazel Pond in 1989 was similar to Carey's Slough in 1988, as the majority of movement occurred during full and half moon periods.

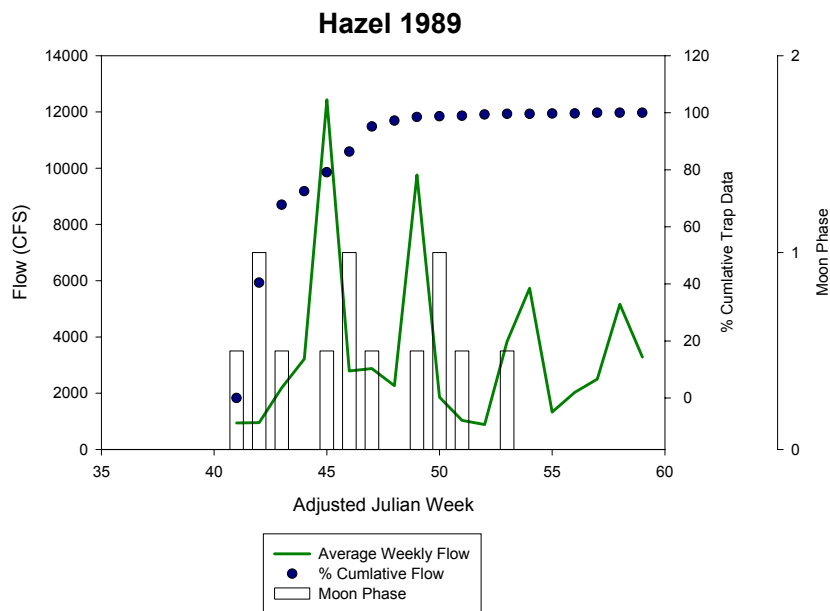
**Figure 13a.**



**Figure 13b.**



**Figure 13a-b.** A comparison of river flow (CFS), fish movement described by the % of cumulative trap data, and moon phase (1=full, .5=half, and 0=new). Data reported is taken during the coho fry redistribution period at Suiattle Slough 1987-88. A key relating Julian dates to calendar dates is located in Appendix A.



**Figure 14.** A comparison of river flow (CFS), fish movement described by the % of cumulative trap data, and moon phase (1=full, .5=half, and 0=new). Data reported is taken over the coho fry redistribution period at Hazel Pond 1989. A key relating Julian dates to calendar dates is located in Appendix A.

***Results from Remote Site Incubators, Year 2000***

Minnow Traps

Minnow traps were effective in capturing coho fry in both creeks. From April 20 through June 8, 2000, a total of 49 coho fry were caught in minnow traps placed above and below the RSI in each creek (Table 4). Of those 49 fry, 28 were caught upstream of the RSIs and 21 were caught below the RSIs.

A total of 17 coho fry were captured in Andrews Creek and 11 were captured in Snow Creek above each of their respective RSIs. No coho were captured below the RSI in Andrews Creek, whereas 21 coho fry were captured below the RSI located in Snow Creek. There was only one sampling day, April 28, 2000, on which no coho fry were captured in either creek.

Except for the first five coho fry captured on April 21, the upstream distances increased as time progressed during the study period until a maximum distance traveled was reached. The maximum upstream distance traveled by newly emerged coho fry caught in a minnow trap in Andrews Creek was 174 meters, and the maximum distance for Snow Creek was 210 meters.

**Table 4.** Summary table of number of coho fry caught above and below RSI in 2000

Date	Andrews Creek				Snow Creek				Total
	No. Above	Maximum Distance	No. Below	Maximum Distance	No. Above	Maximum Distance	No. Below	Maximum Distance	
21-Apr	5	174 m	0	0	0	0	0	0	5
28-Apr	0	0	0	0	0	0	0	0	0
5-May	0	0	0	0	0	0	1	-95 m	1
12-May	2	95 m	0	0	1	25 m	1	-95 m	4
19-May	2	174 m	0	0	0	0	2	-450 m	4
26-May	3	174 m	0	0	5	25 m	3	-560 m	11
2-Jun	3	174 m	0	0	2	130 m	11	-450 m	16
9-Jun	2	174 m	0	0	3	210 m	3	-450 m	8
Total	17 fry		0 fry		11 fry		21 fry		49 fry

A similar result was found in the downstream migration of coho fry in Snow Creek. The first two sampling periods revealed no detectable downstream migration. This increased to a consistent -95 meters after two sampling periods, and then extended to more than -400 meters thereafter. A complete listing of coho fry caught in minnow traps, including date, stream, trap number, fork length, and distance from each of the RSIs, can be found in Table A4a.

A total of 133 specimens, consisting of eight different taxa, were caught in minnow traps during the eight sampling periods. Minus the 49 coho fry, a total of 84 specimens were recorded as by-catch (Table A5a). Of these 84, a total of 9 coho (*Oncorhynchus kisutch*) over 70 mm, 14 trout (*O. mykiss* and *O. clarki*), 45 sculpins (*Cottidae* sp.), 13 crayfish, 2 mice, and one centipede were recorded as by-catch caught in all minnow traps. Of the 133 specimens captured in minnow traps, coho fry were the most abundant (n=49), followed by sculpins (n=45).

### Snorkel Survey

In Snow Creek, snorkel observations were conducted upstream in eight locations until coho fry were no longer observed (Table 5). The last observation of coho fry by snorkeling occurred approximately 25 m upstream from Minnow Trap S2, which was 65 m upstream from the RSI. An estimated total of 104 coho fry were observed in these eight locations. The number of observations generally decreased as the distance from the RSI increased.

In Andrews Creek snorkel observations were conducted in a downstream direction, and two locations were snorkeled. The downstream survey was started approximately 100 m above Minnow Trap A4. The first observations of coho fry occurred just below A4. A total of six coho fry were observed.

In comparing the detection function of up- and downstream snorkeling methods, the downstream method produced results similar to those found with the minnow traps. The downstream methods used in Andrews Creek identified the upper distribution of coho fry at 235 m, and the minnow trap identified the upper distribution at 174 m. In



Snow Creek, however, observations of coho fry appeared to decrease with increasing distance upstream from the RSI. The upstream snorkeling method identified the upper distribution at 65 m, whereas the minnow trap data identified the upper distribution at 210 m.

**Table 5.** Snorkel observations

Creek	Snorkel Location	Distance from RSI (m)	Observations
Snow	Downstream of RSI near S6	-95	approximately 60 coho fry
	At RSI inlet	0	4 coho fry counted
	First pool above RSI by trap S1	25	approximately 25 coho fry
	By trap S2 near undercut bank	40	approximately 5-6 coho fry
	Upstream from S2 in pool	65	approximately 10 coho fry
	Downstream of S3 at logjam	120	no coho fry observed
	Upstream of S3 at logjam	140	no coho fry observed
	Just above S4 by old log cabin	220	no coho fry observed
Andrews	Long scour pool ~ 100m above A4	335	no coho fry observed
	Just below A4	235	6 coho fry counted

### Stream Temperatures

Stream temperatures were recorded at sites every hour on both Andrews and Snow Creek during the study period (Figure 15). The minimum temperature for Andrew's Creek was 5.33°C, and the Snow Creek minimum was 4.61°C recorded on April 24, 2000. The maximum temperatures for Andrews and Snow Creek were recorded on June 4, 2000 and were 13.66°C and 12.98°C, respectively. Although temperatures fluctuated during each day throughout the study period, the overall temperature regime increased with the onset of summer. On average, Snow Creek was 0.65°C colder than Andrews Creek throughout the duration of the study period (Figure 16), based on a daily average of the two streams.

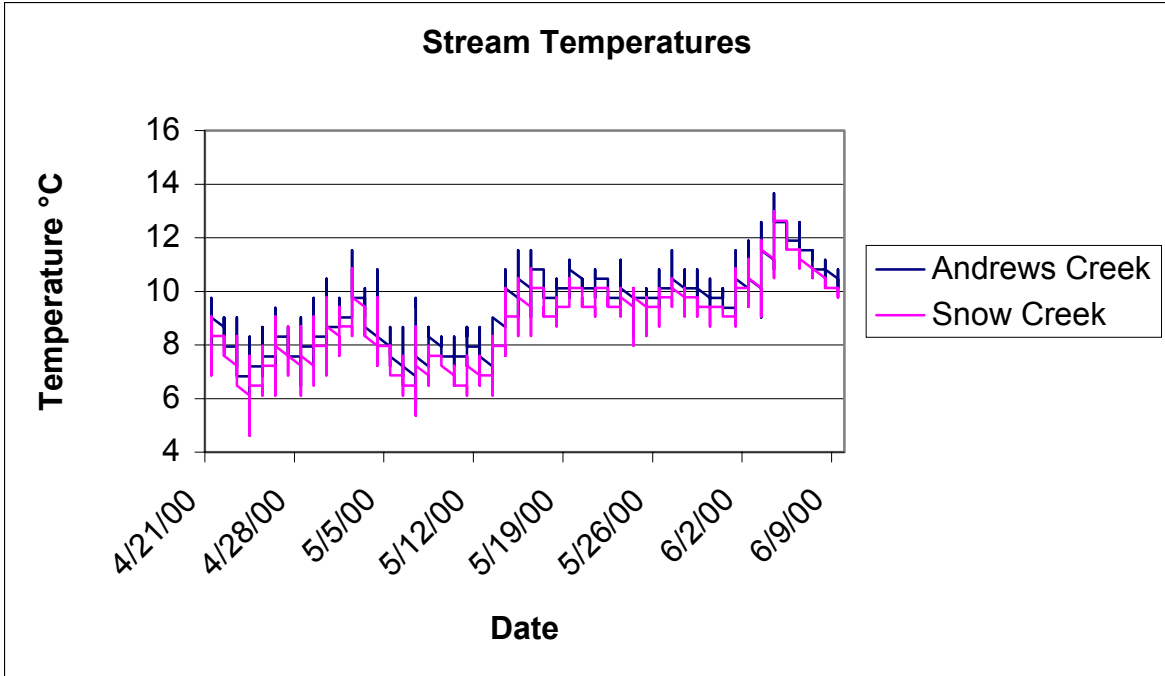


Figure 15. Stream temperatures (recorded every hour)

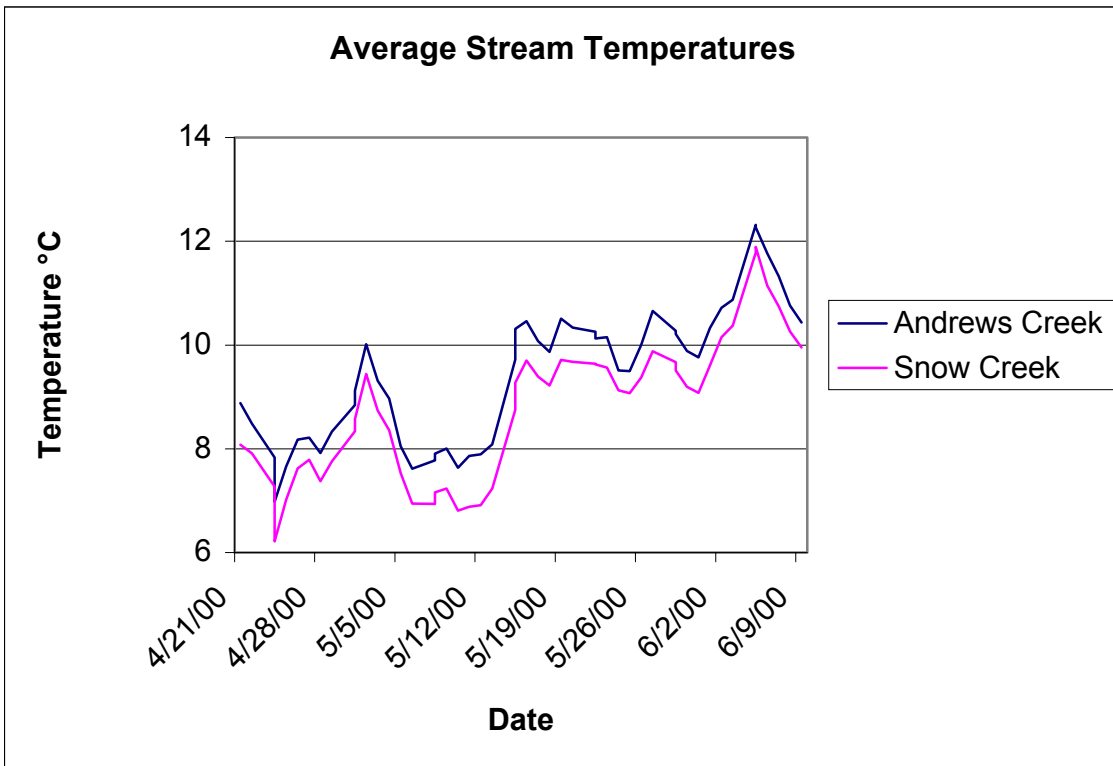


Figure 16. Average daily stream temperatures.

***Results from Remote Site Incubators, Year 2001***

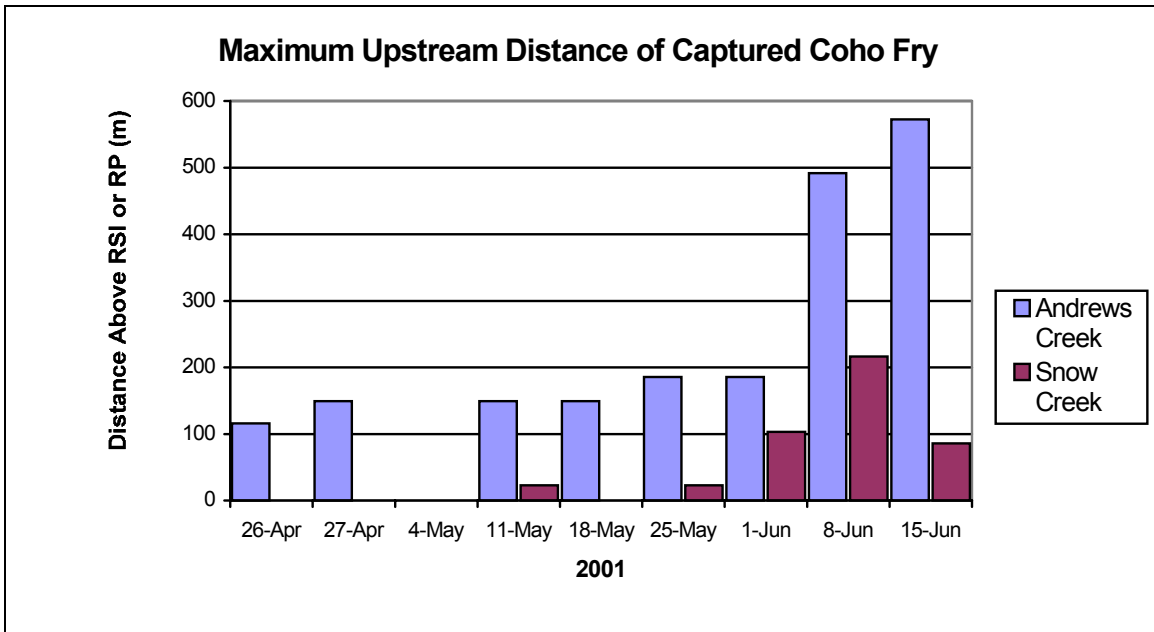
**Minnow Traps**

Minnow traps were effective in capturing coho fry in both creeks. From April 26 through June 15, 2001, a total of 97 coho fry were caught in minnow traps placed above and below the RSI in Snow Creek and the RP in Andrews Creek. Of those 97 fry, 78 were caught upstream of the RSI and RP (Table 6). A total of 47 coho fry were captured in Andrews Creek and 31 were captured in Snow Creek above each of their respective RSI and RP. There was only one sampling period, May 4, 2001, on which no coho fry were captured above the RSI or RP in either creek.

**Table 6.** 2001 summary table of number of coho fry caught above and below RSI

Date	Andrews Creek		Snow Creek		Total
	No. of fry above RP	Maximum Distance (m)	No. of fry above RSI	Maximum Distance (m)	
26-Apr	1	116	0	0	1
27-Apr	3	150	0	0	3
4-May	0	0	0	0	0
11-May	1	150	1	23	2
18-May	2	150	0	0	2
25-May	8	186	1	23	9
1-Jun	6	186	12	103	18
8-Jun	12	492	14	216	26
15-Jun	14	573	3	86	17
<b>Total</b>	<b>47</b>		<b>31</b>		<b>78</b>

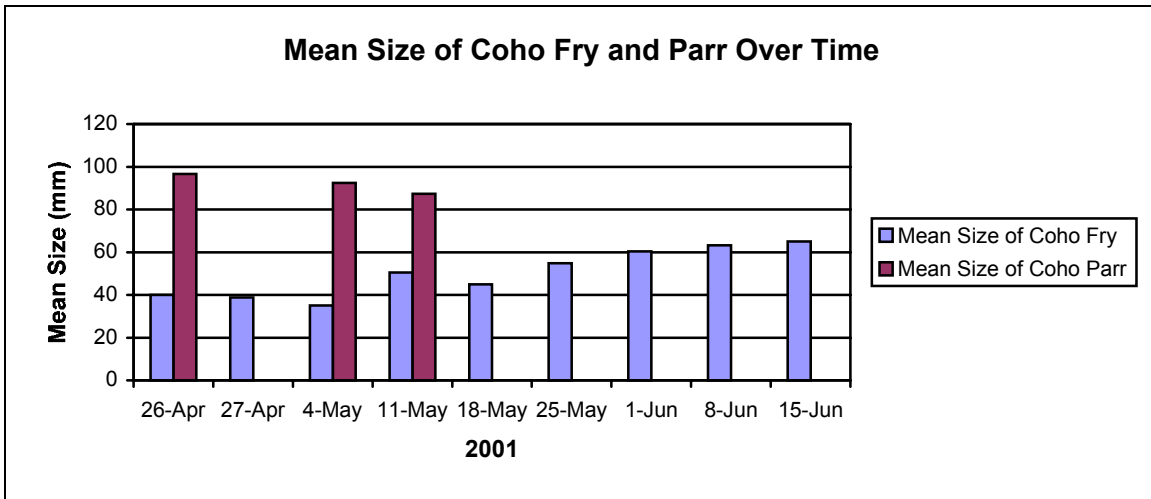
In Andrews Creek, distance of upstream movement increased as time progressed during the study; a maximum upstream distance of approximately 573 meters was documented on June 15, 2001. This included successful passage of several coho fry above a small culvert immediately downstream of trap A-6, which was approximately 490 meters from the release point (appendix table A2). Detectable upstream movement in Snow Creek began on May 11, 2001; a maximum upstream distance of approximately 216 meters was documented on June 8, 2001 (Figure 17). A complete listing of coho fry caught in minnow traps, including date, stream, trap number, fork length, and distance from each of the RSIs, can be found in Table A4b in appendix A.



**Figure 17.** Maximum upstream distance of captured coho fry

A total of 253 specimens, of eight different taxa, were caught in minnow traps during the eight sampling periods. Of the 253 specimens captured in minnow traps, coho fry were the most abundant (n=97). The mean size of coho fry increased throughout the course of the study; on the first sampling date the mean size was approximately 40 mm (FL) and by the last sampling date the mean size had increased to slightly over 60 mm (Figure 18).

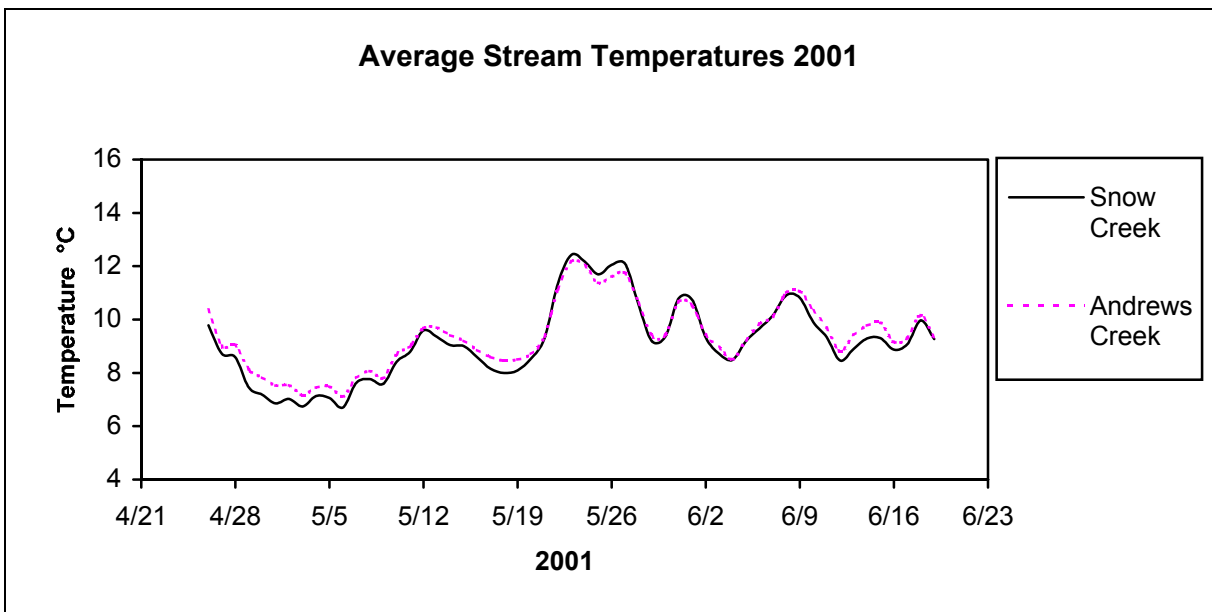
Minus the 97 coho fry, a total of 156 specimens were recorded as by-catch (see appendix Table 4). Of these other species, trout (*O. mykiss* and *O. clarki*) were most abundant (n=88), followed by sculpins (*Cottidae* sp.) (n=46), age 1+ coho (*O. kisutch*) (n=12), crayfish (*Orconectes virilis*) (n=7), and one each northern water shrew (*Sorex palustris*), rough skinned newt (*Taricha granulosa*), and earthworm (*Lumbricus* sp.).



**Figure 18.** Mean size of coho fry and parr over time

Stream Temperatures

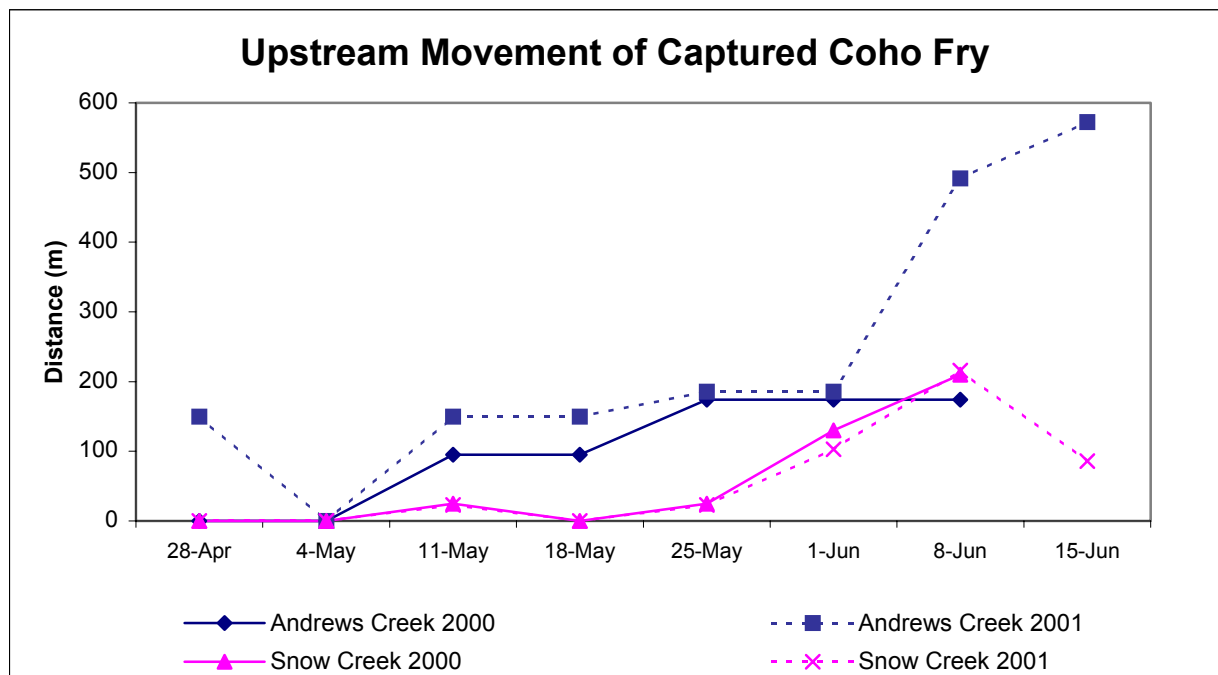
Stream temperatures were recorded every hour on both Andrews and Snow Creek during the study period. On average, Snow and Andrew creeks tracked within one degree of each other (Figure 19). The minimum temperature for Andrew's Creek was 5.40°C and for Snow Creek was 4.99°C, both recorded on May 6, 2001. The maximum temperatures for Andrews and Snow creeks were recorded on May 23, 2001, and were 14.09°C and 14.47°C, respectively.



**Figure 19.** Average daily stream temperatures

### Summary of the Two Years of Remote Site Data

This study clearly establishes that upstream movement of recently emerged juvenile coho fry occurred in 2001 at both Snow and Andrews creeks. This agrees with the previous year's study at this location by Southard (2000) and confirms upstream movement for two consecutive years (Figure 20). Kahler (1999) documented upstream movement of juvenile coho in several other Washington coastal streams using snorkel observations of individually marked fish. Other summaries of the available literature conclude that stream-dwelling salmonid juveniles are highly mobile, and in-stream movement and dispersal is critical to growth and survival (Kahler and Quinn 1998).



**Figure 20.** Upstream movement of captured coho fry 2000/2001

During the last two years, as stream temperatures began increasing in mid-May (Figure 21) the mean size of coho fry captured upstream of the RSI or RP steadily increased (Figures 22). Correspondingly, as the mean size of coho fry started increasing in mid-May, so did the number of coho fry captured upstream of the RSI and RP (Figure 23).

Upstream movement of coho fry could be related to growth, an increase in stream temperature, or a culmination of these and other unknown factors and cues, such as competition for space and food. It is expected that with an increase in size the swimming capability of any given fish would increase, thus allowing larger fish to negotiate and successfully pass higher current velocities. Physiological cues brought about by temperature may initiate upstream movement in order to seek cooler sites. Likewise, increases in fry size may have enabled the coho fry to pass upstream barriers associated with higher current velocities that were previously unattainable at smaller sizes.

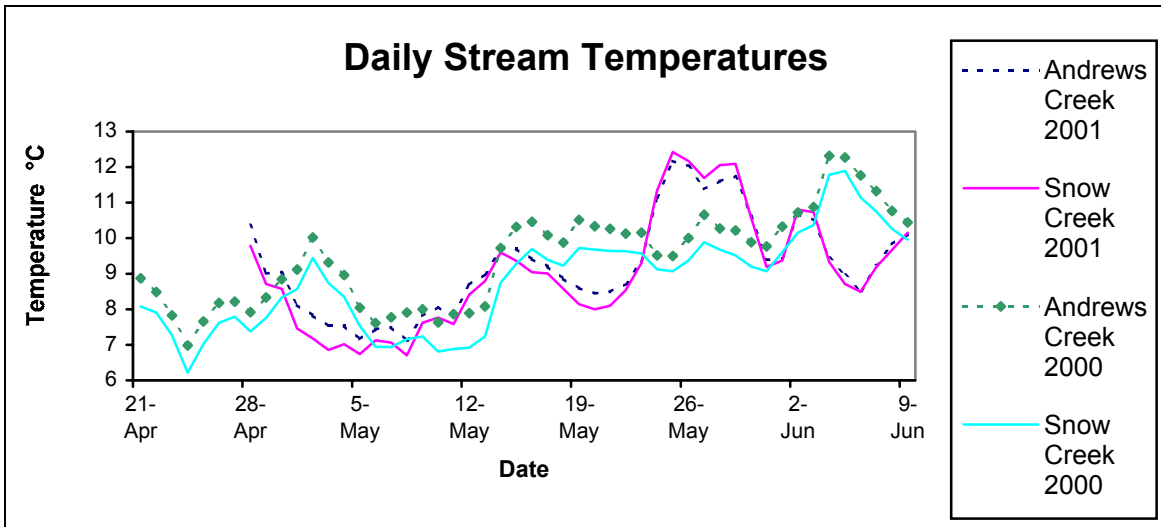


Figure 21. Daily stream temperatures 2000/2001

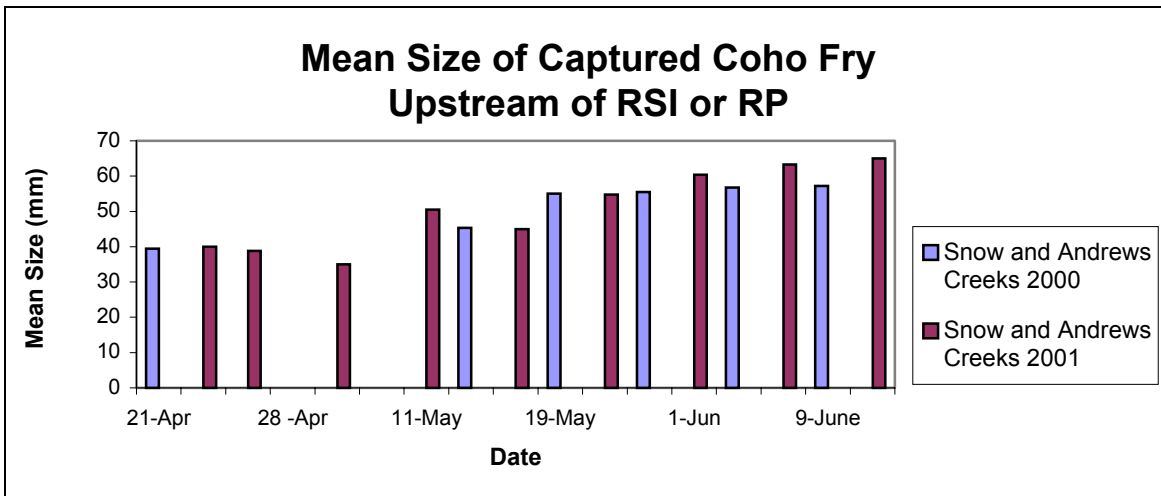
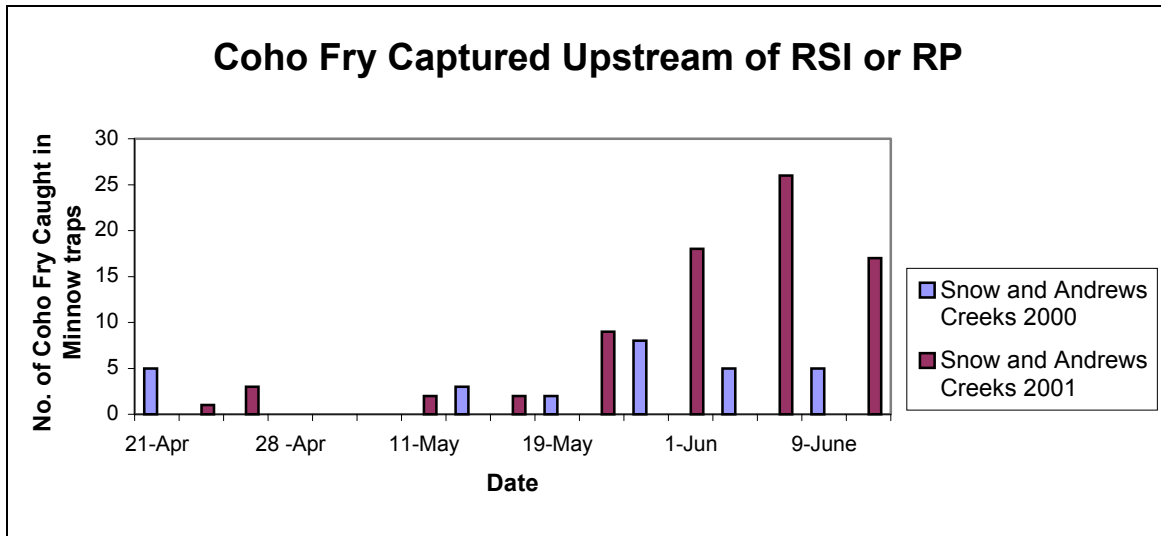


Figure 22. Mean size of coho fry 2000/2001



**Figure 23.** Coho fry captured upstream of RSI or release point

Approximately 25,300 coho fry were released in 2001 from Snow and Andrews creeks and their respective RSI and RP (personal communication, Tom Johnson, WDFW, June 22, 2001), whereas an estimated 34,500 coho fry were released from the combined RSIs last year (WDFW 2000, unpublished data). The 97 coho fry caught in minnow traps from the estimated coho released from the RSI and release point was approximately 0.4 percent of the 2001 total release, whereas the percentage was 0.1 for last year.

The population estimates of coho fry released and the number of coho fry caught in minnow traps during both years of this study suggest insufficient data to conduct strong analysis of population level movements. However, these data do provide a framework for qualitative analysis to make inferences about coho fry movement and relate it to other variables, such as stream temperature and growth rates (mean size). In reviewing each of the minnow trap locations and the habitat associated with traps that caught coho fry, it is clearly evident that pools formed by a physical impediment to normal stream flows with very little current are likely areas in which to find newly emerged coho fry.

This study was important in verifying upstream movement as coho fry emerge and develop. The study, over the course of two years, started with a known point of entry into the stream and followed the movement upstream. Although small in scale, the study created a solid foundation for further and larger-scale investigation of juvenile coho movement and behavior. Moreover, the results of this study have broad implications to other streams and their upstream habitats, demonstrating that some coho fry do in fact move upstream upon emergence.



## **Recommendations**

### ***Habitat and Movement Work***

1. Work in streams with bank full widths of four meters or less.
2. Select study sites where 300-400 fry can be captured, tagged, and released to increase likelihood of recapturing fish.
3. Place fry traps upstream and downstream of study site to determine the amount of fish moving out of the study site.
4. Further investigate population density characteristics for juvenile coho and habitats preferred by them.
5. Future studies should use physiological swimming estimates determined by Powers et al. (1997) with detailed culvert velocity profiles to determine whether culverts are acting as barriers, and focus on variables such as food availability, density, and territory requirements. Efforts should be focused on determining whether these are limiting variables according to which fry distribute themselves.
6. Tagging juvenile coho salmon smaller than 50 mm can successfully be done with Bismarck Brown and adipose fin clipping. Tagging systems that use compressed air were found to damage fin tissue.

### ***Fall Movement***

1. Expect the largest proportion of 0+ coho to move into off channel habitat when flows increase by  $\geq 2000$  CFS during new moon phases. Coho movement may peak during ascending or descending flows associated with a flow peak.

### ***Spring Emergence Movement Studies***

For future studies in upstream coho emergence at a controlled site, the following recommendations are offered:

1. Begin sampling in mid-March to ensure that monitoring data capture the earliest emerging coho.
2. Increase the sampling period and number of minnow traps to attain a more statistically sound study.
3. Reduce the minnow trap openings to 1 cm or less to reduce by-catch.
4. Take regular flow readings above and below the RSIs and at suspected current barriers.

5. Work closely with WDFW Snow Creek station to determine the first coho emergence.
6. Use periodic downstream qualitative snorkel surveys to support the minnow trap catch data.
7. Map the habitat within the study area using a standardized format.

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## **Appendices**

Appendix A: Minnow Trap Location, Minnow Trap Catch and By-Catch

Appendix B: Julian Week Tables

Appendix C: Photographs





**Table A1. Minnow Trap Locations in 2000**

Creek	Trap #	Distance from RSI (m) <sup>1</sup>	Description	Lat / Lon
<b>Snow</b>	Upper RSI	--	--	47° 56.264' N 122° 53.429' W
	S1	25	0.5-m pool formed by two well-bedded logs on right bank.	47° 56.273' N 122° 53.443' W
	S2	40	Undercut left bank with overhanging ferns and vine maple.	47° 56.229' N 122° 53.500' W
	S3	130	Quiet, algae-filled pool on left bank, separated from main channel by single log wedged against stump.	Not taken
	S4	210	0.5-m deep pool on left bank in large log jam	47° 56.245' N 122° 53.440' W
	S5	290	Upstream from fast flowing possible barrier to fry migration. On Left bank in pool.	47° 56.148' N 122° 53.490' W
	S6	-95	Sandy-bottom calm spot behind large boulder on left bank.	Not taken
	S7	-450 <sup>2</sup>	Pool on right bank behind live root mass, just below bridge.	Not taken
<b>Andrews</b>	A1	58	Left side. Shallow pool behind stump. Very little current	47° 55.404' N 122° 53.208' W
	A2	95	Right bank. 0.5-m pool behind post. Little or no current.	47° 55.395' N 122° 53.208' W
	A3	174	Right side. Pool behind root mass. Mild current.	47° 55.344' N 122° 53.255' W
	A4	235	Right side. 0.5-m pool behind log and root mass. Very silty. Little current.	47° 55.313' N 122° 53.211' W
	A5	500 <sup>3</sup>	Left side. Deeply undercut bank beneath live tree roots. Cobbled bottom. Much overhanging vegetation 5 m upstream through culvert	47° 55.010' N 122° 53.376' W
	A6	-2300 <sup>3</sup>	Left side, under live root mass. Broad, deep pool in outfall from Crocker Lake. Silty bottom. Fairly open.	47° 56.617' N 122° 53.068' W
<b>Snow Creek (Below confluence)</b>	C1	-560 <sup>2</sup>	Right side. 20 m downstream from point where Andrew's Creek enters Snow Creek through two 3-ft culvert pipes under US 101. Overgrown with blackberries.	Not taken
	C2	-800 <sup>2</sup>	Right bank. Behind root wad/log pile on one bank only. Silty bottom. Fairly open.	47° 56.796' N 122° 53.287' W
	C3	-3200 <sup>2</sup>	Left bank. Cobble bottom. Farm fields on either side. Some overhanging trees. Partly shaded.	Not taken

<sup>1</sup>Distance from RSI is measured in meters (m), positive numbers are upstream, and negative numbers are downstream

<sup>2</sup>Distance from Snow Creek Upper RSI, measured from map. All others measured on site with hip chain.

<sup>3</sup>Distance from Andrew's Creek RSI, measured from map. All others measured on site with hip chain.

**Table A2. Minnow Trap Locations in 2001**

CREEK	Trap #	Distance from RSI (m) <sup>1</sup>	Description	Latitude/longitude	
Snow	RSI	0	On left bank.	47° 122°	56.311' N 53.447' W
	S-1	23	Back water pool formed downstream of large woody debris on right bank.	47° 122°	56.177' N 53.265' W
	S-2	38	Undercut on left bank.	47° 122°	56.170' N 53.261' W
	S-3	86	LWD pool, downstream of LWD piece, upstream of overall log jam. Right bank.	47° 122°	56.151' N 53.263' W
	S-4	103	Back water pool, under LDW on left bank.	47° 122°	56.147' N 53.270' W
	S-5	216	Pool, downstream of LWD on left bank.	47° 122°	56.113' N 53.264' W
	S-6	-97	Back water pool, downstream of large boulder, on left bank.	47° 122°	56.205' N 53.235' W
	S-7	255	Pool on right side under logs.	47° 122°	56.135' N 53.282' W
	S8	336	Pool on right, under log pile.	47° 122°	56.115' N 53.305' W
Andrews	Release Pt.	0	Pool on right bank under vegetation cover	47° 122°	55.316 N 53.228 W
	A-1	116	Vegetation cover on sloping right bank.	47° 122°	55.152' N 53.141' W
	A-2	149.6	Pool on left bank.	47° 122°	55.142' N 53.149' W
	A-3	174.3	Lateral scour pool, undercut on right bank.	47° 122°	55.134' N 53.153' W
	A-4	185.7	Pool on downstream side of LWD on left bank.	47° 122°	55.133' N 53.159' W
	A-5	234.5	Sloping bank with vegetation cover on right bank.	47° 122°	55.120' N 53.170' W
	A-6	491.5 <sup>2</sup>	Undercut on left side bank.	47° 122°	55.076' N 53.290' W
	A7	531.5	Pool above LWD on left Bank	47° 122°	55.078' N 53.314' W
	A8	572.5	Right Bank lateral pool under over hanging ferns.	47° 122°	55.066' N 53.326' W

<sup>1</sup>Distance from RSI or release point is measured in meters (m), positive numbers are upstream and negative numbers are downstream.

<sup>2</sup>Distance from Andrews Creek release point, measured from map. All others measured on site with tape.

**Table A3a. Individual Coho Fry Caught in Minnow Traps, 2000**

Date	Trap Number	Fork Length (mm)	Distance from RSI (m)	Date	Trap Number	Fork Length (mm)	Distance from RSI <sup>^</sup> (m)
21-Apr	A2	36	95	2-Jun	A2	60	95
21-Apr	A2	39	95	2-Jun	A2	55	95
21-Apr	A2	36	95	2-Jun	A3	57	174
21-Apr	A3	44	174	2-Jun	S3	55	130
21-Apr	A3	42	174	2-Jun	S3	52	130
				2-Jun	S6	48	-95
28-Apr	0	0	0	2-Jun	S6	55	-95
				2-Jun	S6	59	-95
5-May	S6	50	-95	2-Jun	S6	46	-95
				2-Jun	S6	56	-95
12-May	A2	56	95	2-Jun	S7	57	-450
12-May	A2	40	95	2-Jun	S7	57	-450
12-May	S1	40*	25	2-Jun	S7	60	-450
12-May	S6	40	-95	2-Jun	S7	50	-450
				2-Jun	S7	57	-450
19-May	A3	50*	174	2-Jun	S7	54	-450
19-May	A3	60	174				
19-May	S7	45	-450	9-Jun	A3	60	174
19-May	S7	52	-450	9-Jun	A3	51	174
				9-Jun	S1	67	25
26-May	A3	68	174	9-Jun	S3	48	130
26-May	A3	53	174	9-Jun	S4	60	210
26-May	A3	42	174	9-Jun	S6	51	-95
26-May	S1	65	25	9-Jun	S7	57	-450
26-May	S1	57	25	9-Jun	S7	59	-450
26-May	S1	53	25				
26-May	S1	56	25				
26-May	S1	50	25				
26-May	S7	60	-450				
26-May	C1	68	-560				
26-May	C1	63	-560				

A = Andrews Creek  
S = Snow Creek

C = Confluence of Andrews and Snow Creek  
\* = estimated length/escapement without measurement

**Table A4a. By-Catch in Minnow Traps,2000**

Date	Trap #	Species	Length (mm)	Distance from RSI (M)	Date	Trap #	Species	Length (mm)	Distance from RSI (M)
4-21	S5	RBT <sup>1</sup>	76	290	5-19	A3	Sculpin	83	174
	S3	RBT	84	130		A4	Sculpin	70	235
	S2	RBT	74	40		A4	Sculpin	81	235
	S1	RBT	62	25		A4	Sculpin	87	235
	A2	Sculpin	87	95		A4	Sculpin	67	235
	A3	Sculpin	78	174		A4	Sculpin	78	235
	A3	CTT <sup>2</sup>	94	174		A4	Sculpin	83	235
	A4	Sculpin	63	235		A4	Sculpin	70	235
4-28	C3	RBT	84	-3200		A4	Sculpin	79	235
	S2	Crayfish	--	40		A4	Sculpin	71	235
	S2	1 Mouse	--	40		A4	Sculpin	69	235
	A6	Sculpin	82	-2300		A4	Sculpin	70	235
	A6	Sculpin	72	-2300		A4	Sculpin	70	235
	A6	3 Crayfish	--	-2300		A5	Sculpin	76	500
	A1	TRT <sup>3</sup>	100	58		A6	Sculpin	88	-2300
	A1	1 mouse	--	58		A6	2 Crayfish	--	-2300
	A2	Sculpin	80	95	C1	Sculpin	70	-560	
	A2	CTT	115	95	S5	Coho	92	290	
	A5	CTT	90	500	5-26	A1	Sculpin	85	58
	S7	Coho	126	-450		A1	Sculpin	60	58
	S7	Coho	103	-450		A3	CTT	117	174
5-5	A5	Sculpin	65	500		A3	Sculpin	60	174
	S1	Coho	90	25		A3	Sculpin	68	174
	S1	Coho	95	25		A4	Sculpin	90	235
	S1	Coho	95	25		A4	Sculpin	80	235
	S1	Coho	85	25	A6	Crayfish	--	-2300	
	S2	Centipede	--	40	S6	CTT	88	-95	
	S3	CTT	85	130	6-2	A4	Sculpin	68	235
	S6	Coho	102	-95		A5	Sculpin	58	500
	S7	Coho	105	-450		S7	Sculpin	75	-450
5-12	A4	Sculpin	62	235	6-9	A1	Sculpin	70	58
	A4	Sculpin	58	235		A1	Sculpin	62	58
	A5	CTT	105	500		A1	Sculpin	70	58
	S3	RBT	81	130		A2	Sculpin	70	95
	C1	Crayfish	--	-560		A2	Sculpin	86	95
				A2		Sculpin	73	95	
				A3		Sculpin	64	174	
				A4		Sculpin	67	235	
				A5		Sculpin	71	500	
				A6		Crayfish	--	-2300	
				S1		2 Crayfish	--	25	
				S4		Sculpin	79	210	
				C1		Sculpin	102	-560	
				C1		Crayfish	--	-560	
				C2		Crayfish	--	-800	

<sup>1</sup>RBT Rainbow trout (*Oncorhynchus mykiss*)

<sup>2</sup>CTT Cutthroat trout (*Oncorhynchus clarki*)

<sup>3</sup>TRT Trout unidentified-either RBT or CTT

**Table A4b. By-Catch in Minnow Traps, 2001(page 1)**

Date	Trap #	Species	Length (mm)	Distance from RSI (M)	Date	Trap #	Species	Length (mm)	Distance from RSI (M)
4/26/01	A2	RBT <sup>1</sup>	90	149.6	5/11/01	A1	RBT	95	116
4/26/01	A3	Shrew	///	174.3	5/11/01	A1	RBT	110	116
4/26/01	S1	RBT	120	23	5/11/01	A1	RBT	115	116
4/26/01	S1	RBT	130	23	5/11/01	A4	RBT	80	185.7
4/26/01	S1	Coho	100	23	5/11/01	A4	RBT	100	185.7
4/26/01	S1	Coho	100	23	5/11/01	A4	RBT	105	185.7
4/27/01	S1	Coho	90	23	5/11/01	A5	RBT	87	234.5
4/26/01	S3	TRT <sup>3</sup>	65	86	5/11/01	S3	RBT	76	86
4/26/01	S4	TRT	65	103	5/11/01	S4	RBT	75	103
					5/11/01	S4	Coho	90	103
4/27/01	A1	Sculpin	55	116	5/11/01	S6	Coho	90	-97
4/27/01	A4	Crayfish	25	185.7	5/11/01	S6	Coho	87	-97
4/27/01	A6	Sculpin	55	491.5	5/11/01	S6	Coho	85	-97
4/27/01	S3	TRT	55	86	5/11/01	S6	Coho	85	-97
4/27/01	S3	Crayfish	///	86					
4/27/01	S5	TRT	70	216	5/18/01	A1	RBT	105	116
4/27/01	S5	RBT	105	216	5/18/01	A1	RBT	90	116
4/27/01	S6	RBT	80	-97	5/18/01	A1	RBT	92	116
					5/18/01	A2	CTT	105	149.6
5/4/01	A1	RBT	95	116	5/18/01	A3	Sculpin	63	174.3
5/4/01	A1	RBT	110	116	5/18/01	A4	Sculpin	65	185.7
5/4/01	A1	RBT	100	116	5/18/01	A6	Sculpin	60	491.5
5/4/01	A1	RBT	105	116	5/18/01	A6	Sculpin	70	491.5
5/4/01	A1	RBT	100	116	5/18/01	S1	CTT	92	23
5/4/01	A1	RBT	95	116	5/18/01	S1	RBT	110	23
5/4/01	A2	RBT	110	149.6	5/18/01	S4	RBT	85	103
5/4/01	A4	CTT <sup>2</sup>	110	185.7	5/18/01	S4	RBT	75	103
5/4/01	A4	CTT	115	185.7	5/18/01	S5	RBT	110	216
5/4/01	A4	Sculpin	70	185.7	5/18/01	S5	RBT	40	216
5/4/01	A4	Sculpin	80	185.7	5/18/01	S6	RBT	85	-97
5/4/01	A4	Earthworm	///	185.7					
5/4/01	S1	Coho	105	23	5/25/01	A1	RBT	105	116
5/4/01	S2	RBT	70	38	5/25/01	A1	RBT	107	116
5/4/01	S4	Coho	95	175	5/25/01	A1	RBT	110	116
5/4/01	S4	Coho	80	175	5/25/01	A2	RBT	115	149.6
5/4/01	S4	Coho	90	175	5/25/01	A3	Sculpin	70	174.3
5/4/01	S4	RBT	110	103	5/25/01	A4	Sculpin	70	185.7
5/4/01	S4	RBT	110	103	5/25/01	A4	Sculpin	85	185.7
5/4/01	S5	TRT	35	216	5/25/01	A4	Sculpin	75	185.7
					5/25/01	A4	Sculpin	90	185.7
5/11/01	A2	RBT	110	149.6	5/25/01	S1	RBT	115	23
5/11/01	A2	RBT	105	149.6	5/25/01	S2	Crayfish	30	38
5/11/01	A2	RBT	110	149.6	5/25/01	S2	Crayfish	35	38
5/11/01	A4	RBT	90	185.7	5/25/01	S4	Newt	175	103
5/11/01	A4	RBT	90	185.7	5/25/01	S5	RBT	80	216

<sup>1</sup>RBT Rainbow trout (*Oncorhynchus mykiss*)

<sup>2</sup>CTT Cutthroat trout (*Oncorhynchus clarki*)

<sup>3</sup>TRT Trout unidentified-either RBT or CTT

**Table A4b. By-Catch in Minnow Traps, 2001(page 2)**

Table A4b.  
By- Catch  
in Minnow  
Traps  
2001 (page

2)Date	Trap #	Species	Length (mm)	Distance from RSI (M)	Date	Trap #	Species	Length (mm)	Distance from RSI (M)
6/1/01	A1	Sculpin	105	116	6/15/01	A1	CCT	115	116
6/1/01	A1	Sculpin	105	116	6/15/01	A1	CCT	110	116
6/1/01	A1	RBT	100	116	6/15/01	A1	CCT	105	116
6/1/01	A1	CTT	110	116	6/15/01	A1	CCT	100	116
6/1/01	A1	CTT	110	116	6/15/01	A1	Sculpin	80	116
6/1/01	A1	CTT	115	116	6/15/01	A1	Sculpin	80	116
6/1/01	A2	CTT	120	149.6	6/15/01	A4	CTT	80	185.7
6/1/01	A2	Sculpin	95	149.6	6/15/01	A4	CTT	80	185.7
6/1/01	A3	CTT	95	174.3	6/15/01	A4	Sculpin	80	185.7
6/1/01	A3	Sculpin	80	174.3	6/15/01	A4	Sculpin	80	185.7
6/1/01	A4	CTT	98	185.7	6/15/01	A4	Sculpin	80	185.7
6/1/01	A4	Sculpin	70	185.7	6/15/01	A4	Sculpin	70	185.7
6/1/01	A4	Sculpin	70	185.7	6/15/01	A4	Sculpin	60	185.7
6/1/01	A4	Sculpin	70	185.7	6/15/01	A5	CTT	80	234.5
6/1/01	S5	RBT	56	216	6/15/01	A6	Sculpin	55	491.5
6/1/01	S5	RBT	80	216	6/15/01	A6	Sculpin	60	491.5
6/1/01	S5	RBT	74	216	6/15/01	A6	Sculpin	70	491.5
6/1/01	S6	RBT	100	-97	6/15/01	A7	Sculpin	70	531.5
6/1/01	S6	RBT	90	-97	6/15/01	A7	Sculpin	70	531.5
6/1/01	S6	RBT	110	-97	6/15/01	A8	CTT	85	572.5
6/1/01	S6	RBT	120	-97	6/15/01	A8	Sculpin	80	572.5
					6/15/01	A8	Sculpin	90	572.5
6/8/01	A1	CTT	110	116	6/15/01	A8	Sculpin	75	572.5
6/8/01	A1	CTT	110	116	6/15/01	A8	Sculpin	85	572.5
6/8/01	A1	CTT	115	116	6/15/01	A8	Sculpin	90	572.5
6/8/01	A1	CTT	112	116	6/15/01	A8	Sculpin	80	572.5
6/8/01	A1	CTT	110	116	6/15/01	A8	Sculpin	85	572.5
6/8/01	A1	CTT	105	116	6/15/01	A8	Sculpin	75	572.5
6/8/01	A1	Sculpin	100	116	6/15/01	S5	Crayfish	20	216
6/8/01	A1	Sculpin	80	116	6/15/01	S6	Crayfish	35	-97
6/8/01	A2	CTT	110	149.6	6/15/01	S7	Crayfish	35	255
6/8/01	A2	CTT	85	149.6					
6/8/01	A2	Sculpin	80	149.6					
6/8/01	A2	Sculpin	85	149.6					
6/8/01	A2	Sculpin	85	149.6					
6/8/01	A4	CTT	95	185.7					
6/8/01	A5	CTT	110	234.5					
6/8/01	A6	Sculpin	65	491.5					
6/8/01	S4	CTT	95	103					
6/8/01	S4	CTT	85	103					
6/8/01	S6	RBT	90	-97					

<sup>1</sup>RBT Rainbow trout (*Oncorhynchus mykiss*)

<sup>2</sup>CTT Cutthroat trout (*Oncorhynchus clarki*)

<sup>3</sup>TRT Trout unidentified-either RBT or CTT

## Appendix B.

**Table B1. Adjusted Julian Week with Corresponding Calendar Dates For 1987-88.**

Julian Week	Date	Adjusted Julian Week
42	10/15/87-10/18/87	42
43	10/19/87-10/25/87	43
44	10/26/87-11/1/87	44
45	11/2/87-11/8/87	45
46	11/9/87-11/15/87	46
47	11/16/87-11/22/87	47
48	11/23/87-11/29/87	48
49	11/30/87-12/6/87	49
50	12/7/87-12/13/87	50
51	12/14/87-12/20/87	51
52	12/21/87-12/27/87	52
1	12/28/87-1/3/88	53
2	1/4/88-1/10/88	54
3	1/11/88-1/17/88	55
4	1/18/88-1/24/88	56
5	1/25/88-1/31/88	57
6	2/1/88-2/7/88	58
7	2/8/88-2/14/88	59
8	2/15/88-2/21/88	60
9	2/22/88-2/28/88	61
10	2/29/88-3/6/88	62
11	3/7/88-3/13/88	63
12	3/14/88-3/20/88	64

**Table B.2. Adjusted Julian Week with Corresponding Calendar Dates For 1988-89.**

Julian Week	Date	Adjusted Julian Week
41	10/15/88-10/16/88	41
42	10/17/88-10/23/88	42
43	10/24/88-10/30/88	43
44	10/31/88-11/6/88	44
45	11/7/88-11/13/88	45
46	11/14/88-11/20/88	46
47	11/21/88-11/27/88	47
48	11/28/88-12/4/88	48
49	12/5/88-12/11/88	49
50	12/12/88-12/18/88	50
51	12/19/88-12/25/88	51
52	12/26/88-1/1/89	52
1	1/2/89-1/8/89	53
2	1/9/89-1/15/89	54
3	1/16/89-1/22/89	55
4	1/23/89-1/29/89	56
5	1/30/89-2/5/89	57
6	2/6/89-2/12/89	58
7	2/13/89-2/15/89	59



**Table B.3. Adjusted Julian Week with Corresponding Calendar Dates For 1989-90.**

Julian Week	Date	Adjusted Julian Week
41	10/15/89	41
42	10/16/89-10/22/89	42
43	10/23/89-10/29/89	43
44	10/30/89-11/5/89	44
45	11/6/89-11/12/89	45
46	11/13/89-11/19/89	46
47	11/20/89-11/26/89	47
48	11/27/89-12/3/89	48
49	12/4/89-12/10/89	49
50	12/11/89-12/17/89	50
51	12/18/89-12/24/89	51
52	12/25/89-12/31/89	52
1	1/1/90-1/7/90	53
2	1/8/90-1/14/90	54
3	1/15/90-1/21/90	55
4	1/22/90-1/28/90	56
5	1/29/90-2/4/90	57
6	2/5/90-2/11/90	58
7	2/12/90-2/15/90	59

**Table B.4. Adjusted Julian Week with Corresponding Calendar Dates For 1996-97.**

Julian Week	Date	Adjusted Julian Week
40	10/6/96	40
41	10/7/96-10/13/96	41
42	10/14/96-10/20/96	42
43	10/21/96-10/27/96	43
44	10/28/96-11/3/96	44
45	11/4/96-11/10/96	45
46	11/11/96-11/17/96	46
47	11/18/96-11/24/96	47
48	11/25/96-12/1/96	48
49	12/2/96-12/8/96	49
50	12/9/96-12/15/96	50
51	12/16/96-12/22/96	51
52	12/23/96-12/29/96	52
1	12/30/96-1/5/97	53
2	1/6/97-1/12/97	54
3	1/13/97-1/19/97	55
4	1/20/97-1/26/97	56
5	1/27/97-2/2/97	57
6	2/3/97-2/9/97	58
7	2/10/97-2/16/97	59
8	2/17/97-2/23/97	60
9	2/24/97-2/26/97	61

**Table B.5**  
**Adjusted Julian Week with Corresponding Calendar Dates For 1997-98.**

Julian Week	Date	Adjusted Julian Week
41	10/7/97-10/12/97	41
42	10/13/97-10/19/97	42
43	10/20/97-10/26/97	43
44	10/27/97-11/2/97	44
45	11/3/97-11/9/97	45
46	11/10/97-11/16/97	46
47	11/17/97-11/23/97	47
48	11/24/97-11/30/97	48
49	12/1/97-12/7/97	49
50	12/8/97-12/14/97	50
51	12/15/97-12/21/97	51
52	12/22/97-12/28/97	52
1	12/29/97-1/4/98	53
2	1/5/98-1/11/98	54
3	1/12/98-1/18/98	55
4	1/19/98-1/25/98	56
5	1/26/98-2/1/98	57
6	2/2/98-2/8/98	58
7	2/9/98-2/15/98	59
8	2/16/98-2/22/98	60
9	2/23/98-3/1/98	61
10	3/2/98-3/8/98	62
11	3/9/98-3/15/98	63
12	3/16/98-3/22/98	64
13	3/23/98-3/29/98	65
14	3/30/98-4/5/98	66
15	4/6/98-4/12/98	67
16	4/13/98-4/19/98	68
17	4/20/98-4/26/98	69
18	4/27/98-5/3/98	70
19	5/4/98-5/10/98	71
20	5/11/98-5/17/98	72
21	5/18/98-5/24/98	73
22	5/25/98-5/31/98	74
23	6/1/98-6/7/98	75
24	6/8/98-6/14/98	76
25	6/15/98-6/21/98	77
26	6/22/98-6/28/98	78
27	6/29/98	79

**Table B.6. Adjusted Julian Week with Corresponding Calendar Dates For 1998-99.**

Julian Week	Date	Adjusted Julian Week
42	10/12/98-10/18/98	42
43	10/19/98-10/25/98	43
44	10/26/98-11/1/98	44
45	11/2/98-11/8/98	45
46	11/9/98-11/15/98	46
47	11/16/98-11/22/98	47
48	11/23/98-11/29/98	48
48	11/30/98-12/6/98	49
50	12/7/98-12/13/98	50
51	12/14/98-12/20/98	51
52	12/21/98-12/27/98	52
1	12/28/98-1/3/99	53
2	1/4/99-1/10/99	54
3	1/11/99-1/17/99	55
4	1/18/99-1/24/99	56
5	1/25/99-1/31/99	57
6	2/1/99-2/7/99	58
7	2/8/99-2/14/99	59
8	2/15/99-2/21/99	60
9	2/22/99-2/28/99	61
10	3/1/99-3/7/99	62
11	3/8/99-3/14/99	63
12	3/15/99-3/21/99	64
13	3/22/99-3/28/99	65
14	3/29/99-4/4/99	66
15	4/5/99-4/11/99	67
16	4/12/99-4/18/99	68
17	4/19/99-4/25/99	69
18	4/26/99-5/2/99	70
19	5/3/99-5/9/99	71
20	5/10/99-5/16/99	72
21	5/17/99-5/23/99	73
22	5/24/99-5/30/99	74
23	5/31/99-6/6/99	75
24	6/7/99-6/13/99	76
25	6/14/99-6/20/99	77
26	6/21/99-6/27/99	78
27	6/28/99-6/30/99	79

**Appendix C.**



Photo 1. Remote Site Incubator



Photo 2. Suspected Current Barrier

