Evaluation of Large Wood Treatment on Habitats and Fish Populations of Green River and Crab Creek, Tributaries of Five Rivers in the Alsea Basin

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Introduction

During October 2002, 465 tree-length Douglas Fir trees were placed in the lower portions of Green River, EF Green River and Crab Creek of the Alsea River Basin as part of an aquatic habitat restoration project. This report describes the effects of this treatment on channel structure and Coho populations of the treated sections of these streams. The project encompassed seven years of pre- and post-treatment effectiveness monitoring that extended from 2001 to 2007.

Coho were selected as the study's principle species of observation because it has recently been the center of listing and delisting evaluations and because the work of multiple agencies has produced an efficient and reliable method for censusing juvenile Coho populations in small streams.

The treatment goal was to introduce sufficient large wood to insure the development of quantifiable changes in both aquatic habitats and the abundance, distribution, and over-winter retention rates of juvenile Coho salmon. The placement of tree length Douglas Firs by heavy lift helicopter into approximately 10 miles of stream corridor makes this the largest single treatment of its kind to date in the region. The trees averaged about 120 feet long and ranged in diameter at the large end from 24" - 36" inches. Crab Creek received 172 trees, Green River 248 trees, and EF Green River 45 trees. Previously, 46 trees had been placed during 1997 in the lower one mile of Green River.

Placement of large wood produces many positive changes to channel and floodplain morphologies that can help restore floodplain interaction and improve channel function. Examples of these benefits are the retention of mobile substrates that include nutrient-loaded fines and spawning gravels; the development of floodplain connectivity that provides low velocity off channel winter habitats; and the provision of both summer cover from predation and winter cover from high water velocity (in the form of low velocity micro-habitats).

In most small Coho-bearing streams, it is the lack of large wood complexity during winter flow regimes that appears to limit survival to the smolt stage. Thus, a primary target for this study was to quantify changes in over-winter survival rates for juvenile Coho associated with the introduction of large amounts of full spanning trees.

Changes in stream morphology are typically evaluated by conducting aquatic habitat surveys. Personnel from Ecosystems Northwest conducted physical habitat inventories for Green River, the Lincoln County Soil and Water Conservation District conducted physical habitat inventories for Crab Creek.

Changes in fish populations can be measured in several ways. For this study, calibrated snorkel surveys performed by Bio-Surveys LLC provided estimates of population size for year to year comparisons.

As suggested by the distribution of effort, the project was cooperatively managed and funded. Participating agencies included OWEB, USFS, NFF, and USFWS.

This was a monitoring and evaluation project. The principle goal was to determine how habitat conditions and fish populations changed over time on the 6th field sub basin scale, not to compare events occurring within stream reaches. The evaluation therefore focuses on overall changes that can be seen at reach and higher levels of data compilation, as opposed to examining fish behaviors such as how they associate with pools of differing complexity. The questions pursued here are of the nature, "Did pool area or depth increase?", "Did the aquatic surface area increase?", "Did side channels increase?", and "Did the population center shift?"

It is important to recognize that the addition of large wood to small channels does not always immediately and observably alter channel morphology. Until a major high water event occurs, full-spanning wood may exist in a relatively passive state, although trapping litter and offering some cover. Fortunately for the purposes of this evaluation, the 2005-2006 winter was a high water year. An above bankfull flow event interacted with treatment wood to initiate long-term channel evolution by diverting, trapping and scouring. The effects of these events within the pre- and post-project data comparisons were of considerable interest.

The main body of the report reflects this emphasis, and relies heavily on three primary types of data reduction, the results of which are presented in the Figures and Tables sections. These present tabular summaries of aquatic habitat data (Microsoft Excel pivot tables), charts representing Coho pool counts based on snorkel inventories, and a bi-yearly tabulation of population size (summer / post winter) that allows calculation of overwinter survival rates. Some of these results are further reduced to simpler in-text tables and charts.

Report organization

In the beginning, the Green / Crab Final Report focused on the task of evaluating a large instream log placement by reviewing pre and post-project physical and biological data. However, the report has evolved into a discussion of methodologies and attempts to take a hard look at some of the problems encountered when trying to quantify physical habitat attributes during different seasons of the year. The authors were compelled to look beyond the current confines of the habitat inventory process because many of the obvious questions could not be answered utilizing the available data.

If we assume that winter habitat is the primary limitation to salmonid production and we design wood placement projects to provide winter habitat (Green and Crab), then we should structure our evaluation to quantify the changes in "winter habitat" before and after the treatment. To highlight the issues that face this type of analysis, we developed a questionnaire approach. The questionnaire is an attempt to design appropriate questions and then see if the data can provide suitable answers.

Because this approach doesn't follow an established analysis pathway, we have included explanations under the heading of "Questions that investigate wood treatment". This section walks the user through a rational for utilizing a set of specific questions and then specifies how the authors believe each question may be evaluated.

After the questionnaire methodology is presented , we apply the questions to each of the three stream segments monitored during this project (Green, EF Green and Crab Cr). This is presented in the Results section of the report. The resources utilized to evaluate the questions are presented in the Tables and Figures sections of the report. Some in-text tables specific to a particular stream segment are included within the Results and Discussion sections.

Additional supporting information is provided in the appendices, where it may be reviewed without interfering with the central function of the report. We encourage the reader to follow through to the appendices where much of the current analysis is presented, along with suggestions on how future work of this type might be more effectively conducted

Results of a snorkel survey calibration study conducted in Lobster Creek are also presented as an appendix. This work provided coefficients to expand snorkel counts based on the relation between snorkel counts and electro shock mark / recapture estimates.

Methods

Aquatic habitat surveys

Data collection

The aquatic habitat surveys were conducted according to the following schedule:

Stream	Year	Date	Pre/Post Treatment	# Rchs	Start	Length (m)	Protocol	Performed by
Green River	2000	July 27-Sept 6	Pre-treatment	3	Mouth	13,810	US Forest Service 2000 Level II	Ecosystems Northwest
Green River	2006	Aug 26-Oct 7	Post-treatment	3	Mouth	13,675	US Forest Service 2006 Level II	Ecosystems Northwest
EF Green River	2000	July 27-Sept 6	Pre-treatment	2	Mouth	3,756	US Forest Service 2000 Level II	Ecosystems Northwest
EF Green River	2006	Oct 17-24	Post-treatment	2	Mouth	3,872	US Forest Service 2006 Level II	Ecosystems Northwest
Crab Creek	2002	Oct 22-29	Pre-treatment*	6	1.2 km above mouth	5,885	Oregon Dept Fish and Wildlife, Aquatic Inventories	Lincoln County Soil and Water Conservation District
Crab Creek	2003	July 7-21	Post-treatment	4	1.2 km above mouth	5,890	Oregon Dept Fish and Wildlife, Aquatic Inventories	Lincoln County Soil and Water Conservation District
Crab Creek	2006	June 5-14	Post-treatment	9	1.2 km above mouth	5,890	Oregon Dept Fish and Wildlife, Aquatic Inventories	Lincoln County Soil and Water Conservation District

*Pre-treatment because survey preceded winter flows

Data analysis

Some US Forest Service Aquatic Inventory definitions differ from those used by ODFW AQI. In addition, the Forest Service definitions changed between the between 2000 and 2006. Specific problems of habitat definition encountered were:

- In 2000, the Forest Service protocol did not identify some specific pool types, whereas these pool types were identified in 2006. A principle omission of the 2000 survey was that it did not distinguish between lateral scour pools and straight scour pools.
- The Forest Service protocol of both years did not distinguish between gravel / small cobble riffles and riffles with pockets.
- The Forest Service protocols of both years did not specifically identify cascades, including them as rapid habitat.
- The Forest Service protocols of both years did not document the specific habitat composition of side channels. It also did not identify channel branch level, preventing assessment of side channel braiding.
- Alcoves and backwaters were not included in the Forest Service protocols.
- Alcoves and backwaters were defined by the AQI protocol as a separate channel, distinct from primary and side channels. The location of these habitats in the channel system therefore cannot be specified.
- Micro-habitat pools were not inventoried in any survey.

Various adjustments prior to analysis were required to accommodate these characteristics of the protocols. The adjustments are summarized in Appendices 2 and 3, which show how field data were converted for data summary purposes.

After this data preparation was complete, Excel pivot tables created summary statistics that allow year to year comparisons of channel, reach, and habitat features.

Habitat surface areas were used to estimate the total rearing capacity of the system for juvenile Coho salmon. In this method, the surface area of each habitat type is multiplied by a density value that represents the full seeding level for that habitat. Refer to Appendix 4 for a description of this method.

Juvenile Coho salmon abundance and distribution

Field snorkel surveys

Data defining the distribution and abundance of juvenile Coho salmon were collected by surveys conducted by snorkel divers in both the winter and summer.

Summer surveys occurred during the daytime using a methodology referred to as Rapid Bio-Assessment (RBA). A random number between 1 and 5 specified the first sample pool. Thereafter, every 5th pool was surveyed.

All pools met specific standards for inclusion in the sample. The pool had to be at least as long as the average stream width, and it had to have a definitive hydrological control in the tail.

Additional data collected in the summer surveys included pool properties (type, complexity, length, and width), water visibility and distance between pools. Distance was measured by pacing, and pacing was calibrated with measurements for each stream sampled and each surveyor.

Winter surveys were conducted at night when flows had dropped sufficiently to provide adequate visibility. A hand-held high intensity halogen lantern illuminated the field of vision. The effective range was approximately 15 ft. All winter night surveys (2002-2007)were successfully completed during the week surrounding February 20. This temporal window was critical to represent maximum winter exposure to critical flows and an accurate estimate of pre-smolts just prior to smoltification.

In narrow stream channels where a single diver could see both banks simultaneously, a single diver was utilized. In wide stream channels such as lower Green River, two snorkelers worked side by side, each surveying one side of the pool.

Survey schedule

Snorkel surveys were conducted in Green River, EF Green River and Crab Creek according to the following schedule:

Stream	Year	Summer day surveys	Winter night surveys
Green River	2001	X	
	2002	X	X
	2003	X	X
	2004	X	X
	2005	X	X
	2006	X	X
EF Green River	2001	X	
	2002	X	X
	2003	X	X
	2004	X	X
	2005	X	X
	2006	X	X
Crab Creek	2001	X	
	2002	X	
	2003	X	
	2004	X	
	2005		
	2006		

Data analysis

Pool estimates

Typically, some fish are missed in each pool during a snorkel survey. The counts were therefore multiplied by a calibration factor that expanded the counts. Calibration factors for summer daylight counts are well established by previous studies which compared snorkel counts to multi-pass electroshock capture estimates (Appendix 1).

Winter night counts were calibrated as part of this project in cooperation with ODFW Research. The winter night snorkel calibration study was conducted in Lobster Creek in the Alsea basin. Appendix 1 describes this study and the development of calibration factors which were applied to the project winter snorkel counts.

Calibration factors based on the Lobster Creek work and previous studies were used to expand snorkel count data of the current project.

	Pool Complexity		
	Low	Medium	High
Summer day snorkel count	1.20	1.20	1.20
Winter night snorkel count	1.23	1.23	1.89

Note that the factor varies with pool complexity for night surveys. This effect was clearly established in the Lobster Creek calibration study.

Pool density

The calibrated snorkel count was divided by the pool’s surface area to calculate fish density for that pool.

Population size

The total number of juvenile Coho salmon present in the system at the time of the snorkel survey was estimated as five times the sum of calibrated pool counts. This is based on the survey method which sampled every 5^{th} pool.

Questions that investigate wood treatment effects

The goal of the treatment assessment is to evaluate the dynamic and evolutionary changes to aquatic habitat quality and quantity that have been created by the addition of large wood, and then to determine if the juvenile Coho population has responded in measurable ways to these changes.

Changes created by wood are often described in terms of channel complexity, the broad array of inter-woven relationships existing between channel form, gradient, flow, constriction, wood and substrate that govern habitat quality. More specifically, the term "complex habitat" is commonly used to describe channels that possess wood, rock, floodplain interaction, adjoined terracing, overhanging banks, deep pools, meander and braiding. Basically, anything that deviates from straight and smooth is an aspect of habitat complexity.

A richly complex stream channel provides a variety of slow and fast water habitats that support a diverse biota, from simple algae to juvenile salmonids. Abundant opportunities exist in complex channels for the growth of food organisms, as well as for fish to gather these foods and find shelter from high flows and predation.

In undisturbed systems, this complexity is maintained by the regular recruitment of timber, canopy litter and substrates from both riparian and upslope locations. Large wood and substrate are especially important because they initiate the deflection and erosion that create diverse channel forms and maintain a trajectory of increasing complexity. The more diverse the channel form, the more opportunity there is for the development of habitat complexity.

Human altered systems lack some or all of these resources, and progressively lose the conditions of complexity described above. Channel simplification is characterized by progressive reductions in wood density, substrate diversity, channel sinuosity, and interactive off-channel habitat. The channel becomes straighter and smoother.

The process of channel simplification is usually associated with a reduction in the recruitment potential for riparian coniferous species. In the Oregon Coastal Range, most aquatic habitats currently exhibit the attributes of habitat simplification caused by the removal of riparian and upslope wood resources that erosion, wind throw, and landslide would normally deliver to the channel.

In simplified channels that lack low velocity refuge, juvenile Coho are forced to expend valuable energy maintaining position during winter flow regimes. In addition, food chains are less productive because canopy litter and nutrient-rich sediments are no longer trapped and stored, but flushed downstream. Thus conditions providing winter safety and summer growth are both affected. For these reasons, the primary goal of the large wood treatment conducted in Green River, EF Green River and Crab Creek was to develop habitat complexity which provides refuge from winter flows and which traps mobile, nutrient-rich substrates and woody debris.

The whole notion of winter habitat is elusive and often difficult to define and or quantify in a replicable fashion. The reason for this is that winter habitat is many things in many configurations. The concept of winter habitat must be viewed as the intersection of two unrelated processes.

The first process is the transition in adaptive behavior that occurs for Coho in the seasonal transition from summer to winter. Summer conditions are associated with elevated stream temperatures that trend toward optimization of food web production and the accumulation of those resources into higher trophic levels (macroinvertebrates are converted to salmonid flesh). During summer conditions Coho are utilizing the majority of pool surface areas for feeding.

During winter conditions that result in lower stream temperatures and higher flows, Coho adjust their behavior from active feeding to the conservation of energy. No longer are all pool surface areas suitable habitat because velocities increase that require caloric utilization greater than caloric acquisition. At this point a shift in habitat utilization occurs that selects for low velocity habitats that require less energy for maintaining position. This behavioral response quickly limits the productive capacity of a given pool surface area. This is why dramatic reductions in summer fish abundance (26%)are observed after the first fall freshets (Midcoast Winter Distribution of Juvenile Salmonids Utilizing Rapid Bio-Assessment and Nocturnal Snorkeling Protocols, 2003).

The second process is the transition of stable summer pool environments to dynamic winter pool habitats that are altered many times over during the course of a single winter. Flows increase and subside repeatedly to expose the residents of any pool habitat to highly variable and complex shifts in low velocity surface areas within a single habitat unit.

It is the juxtaposition of these low velocity refugia that distinguish high quality winter habitat that persists through the full range of winter flows from the low quality winter habitat that may only function during a limited range of flows. As an example, highly complex pool habitats with good wood retention may perform very well during low to moderate winter flows, but become uninhabitable during higher events because of the lack of adjacent interactive floodplain surface area. Conversely, a pool with low wood complexity may not provide low velocity habitat during mean low winter flows even though it is adjacent to a highly interactive floodplain with excellent high flow habitat potential. It is the complex association between these two habitats (main channel and floodplain) that defines "functional high quality" winter habitat for salmonid juveniles that have altered their behavior and become winter dependant on low velocity refugia.

The purpose of this section of the report is to pose a series of questions designed to evaluate changes in habitat complexity created by wood treatment. The questions are concerned with: 1) Conditions in the active channel, 2) Conditions on the floodplain adjacent to the active channel, 3) How the treatment wood is functioning, and 4) How the Coho have responded to changes created by treatment.

Some of the questions about habitat complexity and winter refuge can be answered with the standardized counting and measuring approach of a summer inventory, and some cannot. Often, the answers are only vaguely represented in summer inventory data, even though these data form the basis of the assessment. Thus many questions that deserve a thorough answer can be only partially answered or not at all using current information. The reason for this deficiency is simple to define*: A substantial component of the habitat complexity created by large wood treatment exists above the active summer channel and current summer methodologies are blind to conditions outside the active summer channel..*

In the Results section, these questions are answered as well as current data allow for Green River, EF Green River, and Crab Creek. Appendices 6 and 7 describe in more detail the problems of winter habitat and wood treatment evaluation, and offer suggestions on how to strengthen future assessment projects.

1) What limitations exist in the data that may prevent an effective comparison of pre-and post-treatment conditions?

Explanation:
Year to year differences in water level as well as changes in survey protocol, extent and timing can interfere with pre- and post-treatment comparisons.

Evaluation:
Assess the following year to year differences: 1) Habitat definitions and other protocol characteristics; 2) Survey timing; 3) Water level as indicated by pool tail crest values; 4) Study site and reach lengths.

2) Has the mainstem primary channel become more finely divided into smaller habitat units?

Explanation:
Wood effectively placed into long scour pools and riffles can be expected to divide these units into smaller, more numerous units. Additional habitat units provide the heterogeneity that creates complexity.

Evaluation:
Assess the number and average lengths of specific habitat types.

3) Has mainstem primary channel pool frequency and/or surface area increased?

Explanation:
Wood generates diversion and scour that can create pools. Simplified channels dominated by shallow riffles benefit from this effect. Increase in pool frequency by count suggests increased complexity. Increases in pool surface area indicate a higher summer rearing capacity.

Evaluation:
Assess the frequency and surface areas of various pool types in relation to other habitat types.

4) Has residual pool depth increased in the mainstem primary channel?

Explanation:
Residual pool depth is measured as the maximum pool depth minus pool tail crest (PTC) height. This provides a measure of depth that can be equitably compared across years because it factors out differences in water level.

Evaluation: Calculate residual pool depth as Maximum Depth – PTC. Summarize and compare these depths pre- and post- treatment for different pool types. Do the same for pools having residual depths > 1 m to assess increases in deep, sheltering pools.

5) Have lateral scour and channel sinuosity increased in the mainstem primary channel?

Explanation:
Wood-generated diversion and scour can produce lateral erosion, overhang, and eddies. Erosion recruits substrate and native wood. Overhang provides cover. Eddies provide winter low velocity refugia.

Evaluation:
Calculate the proportion of lateral scour pools in the study section, as length and area.

Assess the prevalence of overhang. Directly measure sinuosity

6) Has scour depth increased in the mainstem primary channel?

Explanation:
Wood-generated diversion and scour can produce increased depth, which provides cover. In general, this type of cover is more beneficial to Cutthroat and Steelhead than to juvenile Coho. In fact, deep scour pools may actually create conditions favorable to more effective predation on juvenile Coho by large Cutthroat trout and Mergansers. However, this effect must be seen in a broader context, which is the goal of restoring the system to a state of dynamic, functional health. Improvements in scour depth indicate progress toward this goal.

Evaluation:
Use residual pool depth to assess changes in scour pool depth.

7) Have dam pools increased in the mainstem primary channel in association with treatment wood?

Explanation:
Placed large wood and trapped native wood create dam pools that can function as both summer and winter habitat. Because dam pools have fixed hydraulic controls, as opposed to erodible substrate controls, their prevalence in summer inventories can be used as a surrogate for direct estimates of winter habitats.

Evaluation:
Assess the frequency and surface area of dam pools, and their relation to the treatment wood.

8) Have winter-stable beaver dams become more abundant?

Explanation:

Beaver pools are also maintained by fixed hydraulic controls that can persist year round. Summer inventories are therefore able to inform us of changes occurring in a highly important type of winter habitat. The introduction of large treatment wood can substantially improve opportunities for beaver dam construction by providing the foundation of a dam, and by trapping litter that can be used in dam construction.

Evaluation:
Assess the frequency and surface area of beaver dams, and their relation to treatment wood.

9) Have deposition plains developed behind the treatment wood?

Explanation:
Mobile substrate trapping is a highly important wood treatment effect. It can elevate the channel grade leading to floodplain connectivity, create depositions of spawning gravel, support vegetation growth, and provide erodible surfaces that evolve into braided channels. Often, these new channels begin as pocket riffles (see also Question 12).

Evaluation:
Determine if aggradation has occurred at specific wood treatment sites. Measure the height difference below and above the structure under the assumption that the structure was placed on a level plane. These measurements should be performed pre-and post-treatment

10) Are more gravels being sorted to grades suitable for Coho spawning?

Explanation:
Flow through channels newly created on deposition plains and scour around treatment wood within existing channels can sort gravels to grades suitable for Coho spawning.

Evaluation:
Assess the abundance of spawning gravel and qualify the gravel's condition by assessing % fines.

11) Are braided channel systems increasing?

Explanation:
Braiding is an indicator of sediment storage resulting in channel complexity, floodplain interaction and dynamic channel meander, all of which contribute to winter slow-water refuge.

Evaluation:
Assess the frequency of branching order complexity, and habitat structure of side channels.

12) Is pocket water increasing?

Explanation:
Pocket water occurs in riffle water when large cobble or boulders create small areas of scour depth and reduced velocity. These "micro-pools" provide cover with feeding lanes in a food-rich habitat for small fish such as juvenile Coho salmon. Large fish (Cutthroat) and piscivorous diving birds (Mergansers) are less effective hunters in these small pool habitats than in large, deep pools. The presence of these habitat types indicates a trend away from channel simplicity.

Evaluation:
Assess the quantity of riffles with pockets, especially upstream of placed wood, and their association with newly formed braided channels.

13) How much large wood was documented pre- and post-treatment?

Explanation:
An accounting of the amount and sources of large wood establishes the baseline against which future evaluations are measured. The current use is to estimate how much large native wood has been recruited as treatment wood creates deflection and impoundment effects.

Evaluation:
Develop the following wood budget:

- Treatment Large Wood: As reported by tree placement crew.
- Pre-project Large Wood: As reported in the inventory.
- Post-project Large Wood: As reported in the inventory.
- Confirm that the sum of Pre-project Large Wood and Treatment Large Wood equals or exceeds Post-project Large Wood.
- Calculate Native Wood Recruitment: Subtract (Pre-project wood +Treatment Wood) from Post-project Wood.

14) Is the treatment wood trapping native wood including canopy litter?

Explanation:
A key goal in placing large wood is to trap and hold naturally recruited wood that might otherwise encounter little resistance to transport. Accumulation of small wood vastly improves the function of treatment wood by reducing percolation and thus slowing, elevating, and impounding water behind the structure. These events tend to create deposition plains and beneficial floodplain interactions. The process of catching and holding small wood can initially be erratic as wood is captured and then released at different water levels, becoming more effective with time.

Evaluation:
Assess the functionality of the placed wood with regard to the described effects. Note that habitat inventories generally do not provide the site-specific information needed to answer questions of this type. See Appendix 7and 8 for examples of how this might be accomplished.

15) Is treatment wood creating impoundment effects that increase off-channel winter habitat (alcoves and backwaters)?

Explanation:
This is a more specific consideration of the topic introduced above. Large key log structures create constrictions and slow water flow, causing an increase in upstream water elevation. This impoundment effect can flood vegetated edge habitat, creating complex compositions of alcoves and backwaters that increase in surface area as flows increase.

We noted above that dam pools and beaver dams have stable hydraulic controls that persist through multiple water levels. Conversely, backwaters and alcoves lack this type of stable control, and because the great majority of them only water up significantly during winter flows, they are generally invisible to summer inventories.

A few backwaters and alcoves which connect to active channels are sometimes, but not always, inventoried in summer surveys. Alterations in the abundance of these habitat types is currently utilized as a surrogate for quantifying floodplain interaction, but this approach fails to accurately portray the true potential because only wetted surface areas are measured at low summer flow profiles.

Off-channel alcoves and backwaters comprise the winter low-velocity habitat that most affects the winter survival of juvenile Coho salmon. Low terraces upstream of log placements are particularly important in this respect. In simplified channels that lack low velocity habitat, fish find little off-channel refuge until the water level begins to interact with the floodplain. Large wood changes this scenario through the process of constriction, deposition, water elevation and access to terraces. These terraces would not otherwise have been flooded during moderately elevated water levels, the most frequent and dangerous winter events for juvenile salmonids.

As we study year to year changes in channel structure with summer inventories to evaluate wood treatment effects, we dramatically underestimate one of the most common and influential effects of large wood.

Evaluation:
Assess the quantity of alcoves and backwaters documented in the summer habitat inventories, with the understanding that this approach measures only a small fraction of the off-channel winter habitat potentially available.

16) Has the summer carrying capacity increased?

Explanation:
Each type of summer habitat tends to support a maximum fish density. When density exceeds this level, increased mortality, migration and other density dependent mechanisms reduce population size. The summer carrying capacity of a stream segment is thus defined by the types and amounts of the habitats available to the fish.

Evaluation:
Using summer habitat inventory data, sum up the surface area of each habitat type. Multiply each sum by the maximum fish density supported by this habitat type. ODFW research has provided estimates of these habitat specific densities (refer to Appendix 4).

17) Has the winter carrying capacity increased?

Explanation:
The same general principle as described for summer carrying capacity applies: Carrying capacity is determined by the types and amounts of functional habitat types. However, the dynamics are entirely different. Summer water levels tend to be stable, while winter water levels fluctuate regularly and sometimes dramatically. Whereas the summer needs are primarily food and protection from predators, the winter requirement is primarily protection from high velocity flow.

To define a useful winter habitat assessment, we therefore return to previous discussions concerning the availability of beaver dams and dam pools, and then alcoves and backwaters located on the floodplain rather than focusing only on active channel habitats. As stated, these critical winter habitats are not adequately assessed by summer inventories. We either have to modify summer inventory methods, or conduct winter inventories. We also have to think with the individual system, and not get trapped into a rigid assessment mode.

Evaluation:
One possible approach, similar to the calculation of summer carrying capacity, is to 1) Assess the surface area of off-channel winter habitats (alcoves, backwaters, braided side channel systems) and mainstem active channel habitats (natural dam pools, beaver dam pools and eddies; 2) Multiply the area of each habitat type by the maximum Coho density it supports, and 3) Sum up the products as the total number of fish that can be supported during winter flows.

Current resources do not provide this information because off-channel winter habitat surface areas are not documented in summer inventories. Estimation of surface areas for critical winter habitats would require supplemental data based on newly developed methods that account for fluctuating winter flows.

18) Has the summer or winter population size increased?

Explanation:
A reasonable expectation of habitat improvement is increased population size for rearing juveniles. However, year to year population changes are also strongly influenced by many other factors, especially the number of adult spawners seeding the system each year.

In some situations, fish move in ways that do observe study site boundaries. For example, fish may move from a tributary study site downstream into a mainstem study site. Under circumstances like this, fish censused within the communal study sites should be seen as part of a single interactive population.

Evaluation:
For each year, calculate the juvenile population size as five times the sum of snorkel pool counts, for both winter and summer surveys. Combine data from adjacent study sites to make this calculation if fish move freely among the sites. Evaluate year to year changes in juvenile population size in relation to the number of adult spawners.

19) Has over-winter survival (retention) increased?

Explanation:

A broadly accepted assumption in the management of Coastal Coho populations is that the amount of winter habitat currently limits smolt production in most streams which are adequately seeded. Over-winter survival rate is therefore a critical evaluation of habitat improvement created by restoration work.

Evaluation:
Calculate over-winter survival rate as the winter population size divided by the previous summer population size. Apply the same consideration of fish movement across study site boundaries that are described in the Question 18.

Note that this approach assumes all losses from the study stream are mortalities, and that juveniles leaving the system before the summer survey do not successfully rear in downstream habitats. The assumption that retention is essentially the same as survival is likely not accurate. However, the conservative method for estimating over-winter survival rate is to assume they are lost to the population. Part of the evaluation process should be to assess the likelihood that this assumption is correct.

20) Has the distribution of juvenile Coho salmon changed?

Explanation:
We expect that wood introduction provides immediate protection from high water flow and predation for young Coho, and that progressive change to channel and flood plain conditions provide further benefits. We might therefore see changes in either the concentration or extent of fish distribution as these physical changes develop.

Evaluation:
Investigate the shape of curves representing the along-stream distribution of juvenile Coho. This is done for both winter and summer seasons. For this purpose, pool counts are used because they are more informative about production potential and carrying capacity than densities.

We use the following method: 1) Simplify the jagged or saw tooth effect typical of distribution data by using Excel's Trend function that draws a smooth line capturing the basic form of the display. 2) Combine these "sense of the system" trend lines for different years into a common display. 3) Look for patterns of change across years.

We also look for progressive movements of the population center in the following manner: 1) For each year, find the population center as the River Mile which divides the population in half. 2) Compare across years.

Results

Treatment effects created in each stream by the introduction of large wood are assessed by answering the questions presented above. The appendices, figures and tables used to answer each question are listed as "Resources".

Crab Creek

1) What limitations exist in the data that may prevent an effective comparison of pre-and post-treatment conditions?

Resources: Appendix 2; Table 1

Survey protocol – The same protocol was used in the three surveys. Micro-pool structure was not assessed.
Surveyors – The same crew conducted the surveys in all three years.
Survey extent – The study site beginning and end points were well defined and observed. Survey lengths were essentially the same.
Survey timing – Survey timing varied considerably: 2002 was late October, 2003 was mid July, and 2006 was early June.
Water level – Average PTC levels were within 2cm of each other. Water levels were similar despite differences among survey dates, allowing useful comparisons among years.

Conclusions: No important restrictions in use of data to assess changes in summer habitats.

2) Has the mainstem primary channel become more finely divided into smaller habitat units?

Resources: Table 5.

The total number of mainstem primary channel habitat units remained essentially constant: 277 units in 2002, 279 in 2003, and 276 in 2006.

The average unit length remained the same: 21m in all years.

Conclusions: No change is evident as of the 2006 survey.

3) Has mainstem primary channel pool frequency and/or surface area increased?

Resources: Table 5.

In the three survey years, the total pool counts were 143, 143 and 121. The large majority of the pools were scour pools, and both straight and lateral scour pools decreased in number.

Total surface area of all pools decreased each year (23,551m2, 19,764m2, 13,965m2). Scour pool areas generally decreased. Similar patterns occurred in the relative contribution (% of total area): 70 %, 63 % and 44 %. These losses were balanced by increases in pocket riffles.

Conclusions: The recent dynamic of the mainstem primary channel has been strongly affected by depositional events, leading to the conversion of some sour pools to pocket riffles in new channels on deposition plains. Refer to Question 11.

4) Has residual pool depth increased in the mainstem primary channel?

Resources: Table 4.

Overall residual pool depth within the mainstem primary channel changed very little: 0.52m (2002), 0.52m (2003), and 0.59m (2006). The largest increase was in straight scour pools (0.46m, 0.52m, 0.60m).

The number of pools having a residual depth > 1m increased slightly (3, 2, 5 in the three surveys) as did their surface area (512m2, 406m2, 747m2).

Conclusions: Modest to undetectable changes have occurred in residual pool depth, indicating that no important changes have developed in overall pool depth, or in the amount of deep, sheltering pools.

5) Have lateral scour and channel sinuosity increased in the mainstem primary channel?

Resources: Table 5.

The numeric proportion of the mainstem primary channel occupied by lateral scour pools was 0.30 in 2002, 0.25 in 2003 and 0.25 in 2006.

Similar types of proportions calculated for habitat lengths were 0.40, 0.27, and 0.24.

No data are available for overhang or sinuosity.

Conclusions: Based on habitat counts and lengths, lateral scour in the mainstem primary channel decreased from pre- to post-treatment. Confirming evidence based on overhang and sinuosity are lacking.

6) Has scour depth increased in the mainstem primary channel?

Resources: Table 4.

Average residual depth of lateral scour pools remained similar in the three survey years: 0.55m, 0.52m and 0.59m (unit counts of 53, 54, and 44). For straight scour pools, the averages are 0.46m, 0.52m and 0.60m (unit counts of 4, 3, and 4).

Conclusions: A clear pattern of change cannot be defined. The lateral scour averages are ambiguous, while the straight scour averages are based on very few pools. Although a slight increase in scour depth is suggested, the differences could easily have come from variabilities inherent in the identification of the precise point of maximum depth for measurement.

7) Have dam pools increased in the mainstem primary channel in association with treatment wood?

Resources: Table 5.

A single dam pool occupying 305m2 was recorded in 2003. Dam pools were absent in 2002 and 2006.

The data notes the location of key wood pieces (structure log pieces) at each habitat unit site. There were no key pieces identified for habitat unit #216.

Conclusions: Dam pools have not increased and the single dam pool documented was not the result of treatment wood.

8) Have winter-stable beaver dams become more abundant?

Resources: Table 5.

Four beaver ponds occupying 2,647m2 were recorded in 2000. None were recorded in 2003. A single pond of 213m2 was recorded in 2006.

Conclusions: Beaver pond abundance decreased. (Note, current methodologies are not able to identify causes for change in beaver dam abundance, or their relationship to treatment wood.)

9) Have deposition plains developed behind the treatment wood?

Resources: None.

Summer inventory data do not address this question.

Conclusions: No conclusions can be drawn with current data.

10) Are more gravels being sorted to grades suitable for Coho spawning?

Resources: Survey data comment fields contain accurate estimates of spawning gravel in the Crab Creek study site. These are recorded as the # of GC units (an area of 1 sq meter)

.The surveys found the following amounts of Coho spawning gravel:
2000 – 119 m2
2003 – 73 m2
2006 – 230 m2

Conclusions: Because pool surface area was converted to pocket riffle habitat in the case of Crab Cr, it was expected that we should observe an increase in the abundance of spawning gravel. This was observed with a 93% increase from the pre-project year to the most recent post-project year. The evolution of these habitats has also created a broad array of channel roughness features which function to sort and clean spawning gravels. Even though we have no metric within the existing data to evaluate gravel quality, surveyor comments indicate that the majority of gravels documented are of high quality.

11) Are braided channel systems increasing?

Resources: Tables 2 and 6.

The number of side channels increased from 4 to 7 to 9 in the three inventoried years. These changes were represented as length increases from 46m to 92m to 164m and area increases from 132m2 to 227m2 to 506m2. These channels are predominantly “secondary”, which represent the first level of separation from the primary channel.

Conclusions: Side channel habitat has increased post-treatment, providing almost four times the area that previously existed. Complex braiding of the side channel system has not yet appeared.

12) Is pocket water increasing?

Resources: Tables 5 and 6, personal communication with surveyors.

The number of pocket riffles in the mainstem primary channel increased from 28 in 2000 to 34 in 2003 and then to 71 in 2006. Corresponding increases occurred in the total length of this habitat (684m, 824m, 1,779m) and total area (2,871m2, 3,155m2, 8,281m2).

The number of pocket riffles in mainstem side channels increased from 0 in 2000 to 1 in 2003 and then to 3 in 2006. Corresponding values for total length were 0m, 22m, and 80m, and total area were 0m2, 12m2, and 212m2).

Personal communication with the surveyors: Pocket riffles are common in deposition plains that have developed upstream of some treatment sites.

Conclusions: Substantial increases in pocket riffle habitat have occurred during the study. The large majority of this occurred in the main channel, and a minor amount in side channels. Because side channels are predominantly “secondary” (first level of separation from the primary channel), we may conclude that little to none of the pocket riffle habitat is currently associated with braided channels systems. The surveyor field observations allow the following interpretation: Treatment wood is trapping mobile substrates forming deposition plains, and pocket riffles (as well as other habitat types) are forming on these new erodible surfaces.

13) How much large wood was documented pre- and post-treatment?

Resources: Table 8; Personal communication with project managers.

Large wood accounting, represented as the total of small, medium and large wood for the 2002 and 2006 surveys:
Pre-project = 570
Treatment = 172
Post-project (2003) = 848
Post-project (2006) = 915

Pre-project + Treatment = 742

Conclusions: The post-project wood counts of both years exceed the sum of pre-project and treatment wood, indicating that the survey counts fairly represent the large wood content of the study site. The counts therefore provide a baseline for monitoring the recruitment of native wood to the active channel.

14) Is the treatment wood trapping native wood including canopy litter?

Resources: See Question 13.

Based on the large wood counts reported in Question 13, large native wood recruitment estimates are:
2003 survey = 848 – 742 = 106
2006 survey = 915 – 742 = 173

Summer inventory data do not address the question of canopy litter trapping.

Conclusions: As of the 2006 study, large native wood recruitment is estimated at 173 pieces, equaling the number of treatment pieces added (assuming that all new native wood is due to trapping). No conclusions about canopy litter trapping can be made with current data.

15) Is treatment wood creating impoundment effects that increase off-channel winter habitat (alcoves and backwaters)?

Resources: Table 7.

The number of summer inventoried alcoves and backwaters increased from 14 in 2002 to 33 in 2003 and then to 41 in 2006. Total lengths of these habitats increased (160m, 281m, 223m) as did the total area (417m2, 769m2, 785m2). The great majority of this habitat was backwater pools.

The summer inventories do not provide data on impoundment effects or the amount of alcove and backwater habitat that exists above the active summer channel prism on the floodplain.

Conclusions: The abundance of channel-connected alcoves and backwaters has increased, but these habitats still contribute only a very small portion of the summer habitat. No conclusions can be drawn about the impoundment effects of wood treatment, the amount of alcove and backwater habitats existing on adjacent floodplains, or changes in access to these habitats during winter flows.

16) Has the summer carrying capacity increased?

Resources: ODFW estimates of habitat-specific summer rearing densities; Tables 5-7.

Based on all summer habitat areas, including those of the mainstem primary channel, side channels, and subunit pools (alcoves, backwaters), the following calculations can be made:

Maximum density		Habitat surface area (m2)			Summer Carrying capacity (# fish)		
Habitat type	Fish/m2	2000	2003	2006	2000	2003	2006
Alcoves	0.92		38	21	0	35	20
Backwaters	1.18	417	731	763	493	863	901
Beaver Ponds	1.84	2,647		213	4,871	0	392
Cascades	0.24	0	3	45	0	1	11
Dam Pools	1.84		305		0	562	0
Glides	0.77	4,683	3,856	5,480	3,606	2,969	4,220
Lateral Scour Pools	1.74	14,689	9,616	8,192	25,559	16,732	14,254
Mid Ch Scour Pools	1.74	6,000	7,322	4,905	10,440	12,740	8,534
Plunge Pools	1.51	237	206	186	358	311	280
Rapids	0.14	0	448	824	0	63	115
Riffles	0.12	5,727	7,432	11,766	687	892	1,412
Trench Pools	1.79		2,483	367	0	4,445	657
				Total	**46,014**	**39,611**	**30,796**

Conclusions: The rearing capacity of the summer channel has progressively decreased from approximately 46,000 in 2000 to 40,000 in 2003 and then to 31,000 in 2006. These changes reflect the conversion of pool habitat to riffle habitat. The probable cause of these habitat conversions is substrate trapping behind treatment wood that has filled some pools and created erodible surfaces where new riffle-dominated channels have developed. These channel conditions are presumably transitory, and will eventually give way to more mature channel systems having a mix of pools and riffles, as well as greater floodplain connectivity.

17) Has the winter carrying capacity increased?

Resources: None.

Summer inventory data provide insufficient information to address this question.

Conclusions: No conclusions can be drawn with current data.

18) Has the summer or winter population size increased?

Resources: Bio-Surveys estimates of summer coho parr abundance from snorkel inventories; Figure 5.

The summer Coho population of Crab Creek was surveyed between 1998 and 2004, except for 1999. The following table reports estimates of summer parr numbers in Crab Cr and its tributaries:

Crab Survey year	Summer parr estimate
1998	2,778
2000	6,018
2001	16,170
2002	15,498
Post 2003	28,284
Post 2004	26,592

The Crab Cr parr estimates can be compared to those of Alsea Basin Spawner returns:

Year	Basin spawner estimate
1997	680
1998	213
1999	2,050
2000	2,465
2001	3,339
2002	6,060
2003	8,957
2004	6,005
2005	9,500

The parr abundance table indicates that a large increase (83%) in summer abundance occurred during the first post project year. A review of the spawner estimate table and Figure 5 shows that the increase was likely due to the large increase (81%) in adult escapement during the 2002 brood year that preceded the highest summer estimate of 28,284 parr.

The two post projects estimates of abundance compared to the 2006 post project estimate of summer carrying capacity (see question #16) indicate that limited additional potential exists for increasing summer coho capacity (current capacity =30,796). To support this observation, higher basin scale adult escapement in 2003 actually resulted in lower summer coho abundance in 2004. This reduction could be directly linked to the decline in summer pool surface area reported for question #3.

Conclusions: The summer population size has increased dramatically from pre project levels of abundance. This increase appears to be directly related to large increases in adult escapement for the related brood years and not directly related to wood treatment. In addition, it appears that Crab Cr can approach summer capacity with Alsea Basin adult escapement estimates greater than 6,000. Post treatment summer capacity is 33% less than pre treatment potential (see question #16).

19) Has over-winter survival (retention) increased?

Resources: None.

The Coho population of Crab Creek was not surveyed during the winter to address this question. However, Crab and Green share a common ridge, similar aspects, similar basin size, identical geologies and gradients and were treated similarly with large wood. We therefore believe that the level of over-winter survival found for Green applies well to Crab.

Conclusions: The significant conclusion for Crab is that even though summer capacity may have been reduced, it is likely that smolt production has increased as was observed for Green (see Green Question #19).

20) Has the distribution of juvenile Coho salmon changed?

Resources: None.

The Coho distribution for Crab Creek was not analyzed because only summer distribution data was available and our primary concern was that shifts between summer and winter distribution may have been related to the presence or absence of treatment wood.

Conclusions: No conclusions can be drawn with current data.

Green River

1) What limitations exist in the data that may prevent an effective comparison of pre-and post-treatment conditions?

Resources: Appendix 1; Table 9.

Survey protocol – The pre-treatment survey did not distinguish between straight scour and lateral scour pools. Neither survey distinguished between gravel riffles and pocket riffles. Micro-pool structure was not assessed. The habitat composition of side channels was not documented. Alcoves and backwaters were not documented.
Surveyors – The crew changed between years. In 2006, the crew changed mid-survey due to injuries.
Survey extent – The study site beginning and end points were well defined and observed. Survey lengths were closely similar.
Survey timing – The pre-treatment survey lasted over a month, from late July to early September. The post-treatment survey also occurred over an extended period, from late August to early October.
Water level – Average PTC levels were within 2cm of each other, indicating that water levels were similar despite differences among survey dates, allowing meaningful comparisons to be made between years.

Conclusions: Changes in staff between surveys and within the 2006 survey are a potential source of between-survey differences found in the data analyses that follow. Therefore, data collection methods restrict assessment of pre-and post-treatment habitat changes. Water level differences do not restrict assessment.

2) Has the mainstem primary channel become more finely divided into smaller habitat units?

Resources: Table 13.

The total number of Reach 1 mainstem primary channel habitat units increased from 158 pre-treatment to 202 post-treatment. The most significant increases occurred in the number of scour pools (83 to 119) and riffle habitats (63 to 79).

The average unit length decreased overall from 45m to 35m. Scour pools average lengths decreased from 56m to 45m, and riffles from 28m to 18m.

Conclusions: The mainstem primary channel of the treatment zone (Reach 1) appears to have become more finely divided post-treatment. However, this conclusion is compromised by the uncertain influence of protocol and surveyor changes which occurred between surveys.

3) Has mainstem primary channel pool frequency and/or surface area increased?

Resources: Table 13.

The Reach 1 pool count increased from 94 to 123. The dominant pool type and cause of this change was scour pools (83 to 119). However, the total riffle count also increased (64 to 79).

The total pool area decreased (36,397m2 to 34,740m2), but the relative contribution of pools increased (77% to 85%). Riffle habitats decreased in both area (10,771m2 to 6,436m2) and relative contribution (23% to 15%).

Conclusions: The pattern suggests conversion of riffle habitat to pool habitat. The post-treatment increase in riffle count may reflect the creation of more and smaller riffle units that together occupy less area than the less numerous pre-treatment riffles. However, this effect is not clearly defined because changes in protocol and surveyors between surveys may have created much of the differences.

4) Has residual pool depth increased in the mainstem primary channel?

Resources: Table 12.

Overall residual pool depth within Reach 1 of the mainstem primary channel decreased from 0.79m in 2000 to 0.68m in 2006. The dominant pool type was scour pools, where residual pool depth decreased from 0.80m to 0.67m.

The number of pools having a residual depth > 1m decreased from 23 to 16, and the surface area of this type of habitat decreased from 11,296m2 to 6,982m2.

Conclusions: Pool depth and specifically deep, sheltering pools of the Reach 1mainstem primary channel appear to have decreased post-treatment.

5) Have lateral scour and channel sinuosity increased in the mainstem primary channel?

Resources: None

Lateral scour pools were not distinguished from straight scour pools in the pre-treatment survey. Overhang and sinuosity were not evaluated in either survey.

Conclusions: No conclusions can be drawn with current data.

6) Has scour depth increased in the mainstem primary channel?

Resources: Table 12.

Average residual depth of scour pools decreased from 0.80m to 0.67m (unit counts of 83 and 119).

Conclusions: Scour depth may have decreased slightly overall. However, this effect is stated with limited confidence because identifying maximum pool depth has an associated range of variability that probably encompasses the degree of change quantified.

7) Have dam pools increased in the mainstem primary channel in association with treatment wood?

Resources: Table 15.

Seven dam pools occupying 1,972m2 were recorded in 2000. None were recorded in 2006.

Conclusions: Dam pool abundance appears to have decreased. Differences in surveyor habitat identification could be the source of this change. Association with treatment wood cannot be assessed using current inventory methods.

8) Have winter-stable beaver dams become more abundant?

Resources: Table 11.

Four beaver ponds occupying 2,697m2 were recorded in 2000. Four ponds of 2,369m2 were recorded in 2006.

Conclusions: Beaver pond abundance did not change. (Note: current methodologies are not able to identify causes for change in beaver dam abundance, or their relationship to treatment wood.)

9) Have deposition plains developed behind the treatment wood?

Resources: None.

Summer inventory data do not address this question.

Conclusions: No conclusions can be drawn with current data.

10) Are more gravels being sorted to grades suitable for Coho spawning?

Resources: None.

The USFS summer inventory protocol does not address this question.

Conclusions: No conclusions can be drawn with current data.

11) Are braided channel systems increasing?

Resources: Tables 14.

One side channel was recorded in 2000 and none in 2006. Side channel total length decreased from 61m to none, and total area decreased from 332m2 to none.

Conclusions: There is no indication of side channel development. The survey protocol ignores branching order (secondary, tertiary, etc), precluding conclusions about the complexity (braiding) nature of side channels.

12) Is pocket water increasing?

Resources: None.

The survey protocol did not distinguish between homogeneous riffles and pocket riffles.

Conclusions: No conclusions can be drawn with current data.

13) How much large wood was documented pre- and post-treatment?

Resources: Table 14; Personal communication with project managers.

Large wood accounting, represented as the total of small, medium and large wood for Reach 1of the 2000 and 2006 surveys:
Pre-project = 261
Treatment = 248
Post-Project = 205
Pre-project + Treatment = 509

Conclusions: The sum of pre-project + treatment wood far exceeds the post-project wood count. The post-project count and perhaps the pre-project do not appear to accurately represent the large wood content of R1. The counts therefore cannot be used for calculating native wood recruitment as of the 2006 survey. Further investigation may identify the cause of the discrepancy. One possibility is that the 2006 wood counts were not implemented according to the protocol used in the 2000 survey, and that future wood counts may overcome this problem.

14) Is the treatment wood trapping native wood including canopy litter?

Resources: See Question 13.

The large wood counts reported in Question 13 do not allow calculation of native wood recruitment.

Summer inventory data do not address the question of canopy litter trapping.

Conclusions: No conclusions can be drawn with current data.

15) Is treatment wood creating impoundment effects that increase off-channel winter habitat (alcoves and backwaters)?

Resources: None.

The summer inventories did not document alcoves and backwaters connected to the summer channel.

The summer inventories do not provide data on impoundment effects or the amount of alcove and backwater habitat that exists in the channel prism above the active summer channel or outside the channel prism on the floodplain.

Conclusions: No conclusions can be drawn about the amount of alcoves and backwaters connected to the summer channel. Similarly, no conclusions can be drawn the about the impoundment effects of wood treatment, the amount of alcove and backwater habitats existing on adjacent floodplains, or changes in access to these habitats during winter flows.

16) Has the summer carrying capacity increased?

Resources: ODFW estimates of habitat-specific summer rearing densities; Tables 13 and 14.

The following calculations are based on habitat areas of the mainstem primary channel in Reach 1. Undefined habitats of side channels totaling 332m2 are not included.

Maximum density		Habitat surface area (m2)		Carrying capacity (# fish)	
Habitat type	Fish/m2	2000	2006	2000	2006
Alcoves	0.92			0	0
Backwaters	1.18			0	0
Beaver Ponds	1.84	2,697	2,369	4,962	4,359
Cascades	0.24			0	0
Dam Pools	1.84	1,972		3,628	0
Glides	0.77			0	0
Scour Pools	1.74	31,758	32,371	55,259	56,326
Plunge Pools	1.51			0	0
Rapids	0.14	65		9	0
Riffles	0.12	10,771	6,346	1,293	762
Trench Pools	1.79			0	0
			Total	65,152	61,446

Conclusions: Summer carrying capacity appears to have decreased slightly post-treatment. However, the reduction is small and could easily have been created by differences in surveyor approach to habitat definition.

17) Has the winter carrying capacity increased?

Resources: None.

Summer inventory data provide insufficient information to address this question.

Conclusions: No conclusions can be drawn with current data.

18) Has the summer or winter population size increased?

Resources: Figures 5,6and 7; Table 23; ODFW publications "Oregon Coast Coho ESU Abundance Summary from 1950-2005" and "Preliminary Estimates of 2005 Spawner abundance in the Oregon Coast ESU", which provide estimates of adults returns to the Alsea Basin.

EF Green River feeds directly into the Green River study site, allowing fish to move freely between the two study sites. The population estimates for the two sites are therefore combined in the table below.

	Combined Green River and EF Green Population Size	
Year	Summer	Winter
2001	32,244	
2002	20,261	8,824
2003	26,550	12,386
2004	33,453	15,511
2005	16,590	16,816
2006	39,468	10,734
2007		20,422

These estimates should be evaluated in relation to the following estimates of adult return rates to the Alsea basin.

Year	Spawner estimate
1997	680
1998	213
1999	2,050
2000	2,465
2001	3,339
2002	6,060
2003	8,957
2004	6,005
2005	9,500

The summer population size has increased with the largest summer parr abundance observed in 2006. Only 2 of 5 summers inventoried post treatment however have exceeded pre project summer levels. Winter population size has steadily increased every year post treatment with the highest observed over winter survival documented in February 2007. The only exception to this trajectory was a decline in winter abundance in 2006 that tracked a decline in the basin wide abundance of adults in 2005.

It may be seen that adult returns to the Alsea basin have steadily increased through recent years. The Green/EF Green summer population size has also indicated a relatively consistent pattern of increasing abundance (the only exception being the pre project year) . This suggests that basin scale indicators of adult abundance have a direct relationship to the number of adults entering Green River. Subbasin specific adult escapement data are not available for Green River.

An adult / juvenile relationship is visible in Figure 5. A decline in 2004 adults was followed by a sharp decline in summer 2005 Coho parr and then by a decline in 2006 smolts. Conversely, a 2005 adult increase was followed by a 2006 parr increase and then a 2007 smolt increase. The apparent ability of these measurement tools to track Coho production lends support for its use in evaluating the general relationship between basin scale adult abundance and local juvenile abundance.

The abundance of summer parr has not radically increased (+22%) between the pre-treatment year (32,244) and the highest post treatment year (39,468). The abundance of post winter pre-smolts has however increased significantly (+131%) between the pre treatment year (8,824) and the best post treatment year (20,422).

Conclusions
The summer abundance has not changed dramatically since the treatment with large wood. The winter abundance has exhibited a steady increase with no indication of a ceiling in capacity. The Green River 6th field seems to currently be limited by adult escapement.

19) Has over-winter survival (retention) increased?

Resources: Table 23 and Figure 6.

Over-winter survival rates in the Green/EF Green River population were measured as the winter population size divided by the previous year's summer population size:
2002 - 27% (pre-project)
2003 - 61%
2004 - 58%
2005 - 50%
2006 - 65%
2007 – 52%

This review has access to extensive smolt production data (RBA post winter snorkel data) collected over an extended temporal range utilizing a consistent method and the same samplers to reduce the potential for variability linked to the methodology. Because seeding levels greatly influence smolt production, it is important to note that the metric utilized in this comparison is over-winter survival rate to the smolt stage. The currently available data (6 years winter / summer comparisons) suggests that a ceiling has not been reached in smolt production potential. In addition there is inadequate winter habitat inventory data (as previously discussed) to model the pre or post project smolt production potential.

Additional collaborating data collected from the mainstem of Five Rivers (below the confluence of Green River) suggests that very few coho (4,220 for winter 2002) are winter rearing in this large 5th order corridor. This is an important observation because it suggests that if juveniles are not retained in upper basin 6th fields (Green River) then they find limited winter refugia in 5th field stream corridors downstream. This study was not able to evaluate potential winter habitat that may exist for juveniles in the mainstem of the Alsea and its associated inter tidal habitats.

Conclusions:
Interestingly, as observed in Figure 6, the relationship between summer parr abundance and post winter smolt abundance is very well defined (R2=0.98) throughout the range of observed summer abundance. This suggests that a carrying capacity has not been reached in either the summer or winter abundance of juvenile coho. We assume that a saturation point exists along the slope of this curve where increased summer parr abundance results in diminishing over winter survival rates and consequently smolt production. However, this point is not apparent in the current data.

These observations suggest that to date the Green River subbasin post wood treatment has been limited only by adult escapement. Additional smolt production potential currently exists that has not been realized. This conclusion is also supported by a review of the 2006 summer rearing densities which resulted in an average value for the mainstem

Green River of only 0.6 coho/sq. meter of pool surface area, which is far below levels of full seeding level of 1.7 Coho/sp meter documented by ODFW for coastal basins. However, EF Green with 2006 average summer densities of 1.4 Coho/sq meter maybe approaching capacity.

The pre-project relationship observed in Figure 6 between summer and winter Coho abundance also suggests that Green River was winter limited prior to the placement of log structure. Note for example that one of the highest summer abundances of Coho resulted in the lowest smolt production for the 2001pre-treatment brood year.

20) Has the distribution of juvenile Coho salmon changed?

Resources: Figures 1 and 3; Table 24.

We have two measures of distribution change: Coho pool counts from the river mouth to the end of distribution, and calculated population distributional midpoints.

The pool count figures are presented as smoothed trend lines for each year. Although the trend lines vary among years, no strong pattern of year to year progressive change is apparent in either the winter chart (Figure 1) or the summer chart (Figure 3). The population midpoints (Table 24) also show no progressive pattern of change in either season.
Both representations of distribution show the winter population to be shifted downstream of the summer population. This is apparent in the average midpoint values of RM 3.9 for summer and RM 2.6 for winter.

Conclusions: The distribution pattern of juvenile Coho has not been strongly affected by the addition of treatment wood. It is probable that the distribution of Coho in Green River continues to be more strongly affected by the location of spawning sites and temperature levels for summer populations, and by channel morphology for winter populations than by wood placement.

EF Green River

1) What limitations exist in the data that may prevent an effective comparison of pre-and post-treatment conditions?

Resources: Appendix 3; Table 16.

Survey protocol – The pre-treatment survey did not distinguish between straight scour and lateral scour pools. Neither survey distinguished between gravel riffles and pocket riffles. Micro-pool structure was not assessed. The habitat composition of side channels was not documented. Alcoves and backwaters were not documented.
Surveyors – The crew changed between years. In 2006, the crew changed mid-survey due to injuries.
Survey extent – The study site beginning and end points were well defined and observed. Survey lengths were closely similar.
Survey timing – The pre-treatment survey lasted over a month, from late July to early September. The post-treatment survey was conducted over a shorter period in mid-late October.
Water level – Average PTC depths were the same (.08m). Water levels were the same despite differences among survey dates, allowing meaningful comparisons among years.

Conclusions: Changes in staff between surveys and within the 2006 survey are a potential source of between-survey differences found in the data analyses that follow. Therefore, data collection methods restrict assessment of pre-and post-treatment habitat changes. Water level differences do not restrict assessment.

2) Has the mainstem primary channel become more finely divided into smaller habitat units?

Resources: Table 20.

The total number of mainstem primary channel habitat units increased from 104 pre-treatment to 238 post-treatment. The increases occurred in scour pools, rapid, riffles, and side channels.

The average unit length decreased overall (36m to 16m) and for all habitat types which appeared in both surveys (specifically, 26m to 15m for scour pools, 36m to 20m for rapids, and 43m to 13m for riffles).

Conclusions: The channel appears to have become more finely divided post-treatment. However, this conclusion is compromised by the uncertain influence of protocol and surveyor changes which occurred between surveys.

3) Has mainstem primary channel pool frequency and/or surface area increased?

Resources: Table 20.

The pattern is similar to that of Green River: the pool count increased (54 to 138), as did the riffle count (50 to 100).

Total pool area increased (5,629m2 to 6,735m2), as did the relative contribution of pools (52% to 68%), while riffle area and relative areal contribution of riffles both decreased correspondingly.

Conclusions: The pattern suggests conversion of riffle to pool habitat. The post-treatment increase in riffle count may reflect the creation of more and smaller riffle units that together occupy less area than the less numerous pre-treatment riffles. There was a substantial reduction in beaver ponds from pre- to post- treatment, causing some of the increases seen in both scour pools and riffles. Changes in protocol and surveyor may have created much of these differences as well.

4) Has residual pool depth increased in the mainstem primary channel?

Resources: Table 19.

Overall residual pool depth within the mainstem primary channel changed little from 2000 to 2006 (0.46m to 0.40m). The dominant pool type by far was scour pools, which showed the same pattern (0.43m to 0.39m).

The number of pools having a residual depth > 1m decreased from 4 to 1, and the surface area of this type of habitat decreased from 1,272m2 to 309m2.

Conclusions: Pool depth and specifically deep, sheltering pools of the mainstem primary channel appear to have decreased post-treatment.

5) Have lateral scour and channel sinuosity increased in the mainstem primary channel?

Resources: None

Lateral scour pools were not distinguished from straight scour pools in the pre-treatment survey. Overhang and sinuosity were not evaluated in either survey.

Conclusions: No conclusions can be drawn with current data.

6) Has scour depth increased in the mainstem primary channel?

Resources: Table 16.

Average residual depth of scour pools decreased from 0.43m to 0.39m (unit counts of 51 and 130).

Conclusions: Scour depth may have decreased slightly overall. However, this effect is stated with limited confidence because identifying maximum pool depth has an associated range of variability that probably encompasses the degree of change quantified.

7) Have dam pools increased in the mainstem primary channel in association with treatment wood?

Resources: Table 20.

No dam pools were recorded in 2002. Five were recorded in 2006, occupying 134m2.

Conclusions: Dam pool abundance appears to have increased. Differences in surveyor habitat identification could be the source of this change. Association with treatment wood cannot be assessed using current inventory methods.

8) Have winter-stable beaver dams become more abundant?

Resources: Table 20.

Three beaver ponds occupying 1,199m2 were recorded in 2000. Three ponds of 724m2 were recorded in 2006.

Conclusions: The number of beaver ponds remained the same, but surface area appears to have decreased. The dynamic nature of beaver constructions and possible differences in surveyor estimation approach could account for this decrease.
(Note: current methodologies are not able to identify causes for change in beaver dam abundance, or their relationship to treatment wood.)

9) Have deposition plains developed behind the treatment wood?

Resources: None.

Summer inventory data do not address this question.

Conclusions: No conclusions can be drawn with current data.

10) Are more gravels being sorted to grades suitable for Coho spawning?

Resources: None.

Summer inventory data do not address this question.

Conclusions: No conclusions can be drawn with current data.

11) Are braided channel systems increasing?

Resources: Table 21.

No side channels were recorded in 2000. In 2006, 3 side channels totaling 47m in length and 38m2 in area were recorded.

Conclusions: There is indication of very minor side channel development. The survey protocol ignores side channel braiding order (secondary, tertiary, etc), precluding conclusions about side channel complexity.

12) Is pocket water increasing?

Resources: None.

The survey protocol did not distinguish between gravel riffles and pocket pool riffles.

Conclusions: No conclusions can be drawn with current data.

13) How much large wood was documented pre- and post-treatment?

Resources: Table 22; Personal communication with project managers.

Large wood accounting, represented as the total of small, medium and large wood in the 2000 and 2006 surveys:
Pre-project = 75
Treatment = 45
Post-Project = 93
Pre-project + Treatment = 120

Conclusions: The sum of pre-project + treatment wood exceeds the post-project wood count. The post-project count and perhaps the pre-project do not appear to accurately represent the large wood content of the study site. The counts therefore cannot be used for calculating native wood recruitment as of the 2006 survey.

14) Is the treatment wood trapping native wood including canopy litter?

Resources: See Question 13.

The large wood counts reported in Question 13 do not allow calculation of native wood recruitment.

Summer inventory data do not address the question of canopy litter trapping.

Conclusions: No conclusions can be drawn with current data.

15) Is treatment wood creating impoundment effects that increase off-channel winter habitat (alcoves and backwaters)?

Resources: None.

The summer inventories did not document alcoves and backwaters connected to the summer channel.

The summer inventories do not provide data on impoundment effects or the amount of alcove and backwater habitat that exists outside the channel prism (on the floodplain).

Conclusions: No conclusions can be drawn about the amount of alcoves and backwaters connected to the summer channel. Similarly, no conclusions can be drawn the about the impoundment effects of wood treatment, the amount of alcove and backwater habitats existing on adjacent floodplains, or changes in access to these habitats during winter flows.

16) Has the summer carrying capacity increased?

Resources: ODFW estimates of habitat-specific summer rearing densities; Tables 20 and 21.

The following calculations are based on habitat areas of the mainstem primary channel. Undefined habitats of side channels totaling 38m2 are not included.

Maximum density		Habitat surface area (m2)		Carrying capacity (# fish)	
Habitat type	Fish/m2	2000	2006	2000	2006
Alcoves	0.92			0	0
Backwaters	1.18			0	0
Beaver Ponds	1.84	1,199	724	2,206	1,332
Cascades	0.24			0	0
Dam Pools	1.84		134	0	247
Glides	0.77			0	0
Scour Pools	1.74	4,430	5,877	7,708	10,226
Plunge Pools	1.51			0	0
Rapids	0.14	58	2,293	8	321
Riffles	0.12	5,171	873	621	105
Trench Pools	1.79			0	0
			Total	10,543	12,230

The 2006 summer snorkel estimate for Coho in EF Green and its tributaries was 10,734. This number is very similar to the modeled summer carrying capacity of 12,230. The average summer rearing density for pool habitats in EF Green was 1.4 fish / sq. m. These two metrics agree well to indicate that summer carrying capacity has been nearly reached in EF Green and that this portion of the Green River basin may become summer limited when Alsea basin adult escapement exceeds 9,500.

Conclusions: Summer carrying capacity appears to have increased slightly post-treatment. However, the increase is small and could easily have been created by differences in surveyor approach to habitat definition. Summer carrying capacity has nearly been reached with Alsea basin adult Coho escapement estimates of 9,500. EF Green is approaching a condition where the abundance of summer habitat begins to limit coho production potential.

17) Has the winter carrying capacity increased?

Resources: None.

Summer inventory data provide insufficient information to address this question.

Conclusions: No conclusions can be drawn with current data.

18) Has the summer or winter population size increased?

See Green River Question 18.

19) Has over-winter survival (retention) increased?

See Green River Question 19.

20) Has the distribution of juvenile Coho salmon changed?

Resources: Figures 2 and 4; Table 24.

We have two measures of distribution change: Pool counts from the river mouth to the apparent end of distribution and calculated population distributional midpoints.

The pool count figures are presented as smoothed trend lines for each year. Although the trend lines vary among years, no strong pattern of year to year progressive change is apparent in either the winter chart or the summer chart. The population midpoints also show no progressive pattern of change in either season.

Both representations of distribution show the winter population to be shifted downstream of the summer population. This is apparent in the average midpoint values of RM 0.79 for summer and RM 0.58 for winter.

Conclusions: The distribution pattern of juvenile Coho has not been strongly affected by the addition of treatment wood. It is probable that the distribution of Coho in EF Green River continues to be more affected by location of spawning sites, temperature levels, and channel morphology than by wood placement.

Discussion

General evaluation of treatment effects

The following table is a synthesis of the responses of the three stream study segments to the questions posed in the analysis. The intent is to compare responses across systems in an attempt to detect patterns of change that may be consistent in response to wood treatment.

Question	Topic	Crab Creek	Green River	EF Green River
1	Data limits on analysis	No significant limitations	Limited by surveyor and protocol changes, incomplete documentation.	Limited by surveyor and protocol changes, incomplete documentation.
2	Sub-division of mainstem primary channel	No change	Substantial increase	Substantial increase
3	Pools / surface area and number	Substantial reduction.	Increase	Increase
4	Residual pool depth	No significant change	Decrease	Decrease
5	Lateral scour and sinuosity	Lateral scour = reduced. Sinuosity = no data.	No data	No data
6	Scour depth	No significant change	Slight decrease	Slight decrease
7	Dam pool abundance and association with treatment wood	No significant change	Decrease	Increase
8	Winter-stable beaver ponds	Reduced abundance	No change	Decrease in area but not number
9	Deposition plains behind treatment wood	No data	No data	No data
10	Spawning gravels	Initial decrease, then substantial increase	No data	No data
11	Braided channels	Side channels = increase. Braiding = no change.	Side channels = no significant change. Braiding = no data	Side channels = Slight increase. Braiding = no data.
12	Pocket water	Substantial increase	No data	No data
13	Large wood accounting	Properly reported.	Accounting failure (pre-project + treatment exceeds post-project)	Accounting failure (pre-project + treatment exceeds post-project)
14	Native wood recruitment and litter trapping	Native wood = 173 pieces; Litter trapping = no data.	Native wood = cannot be calculated. Litter = no data.	Native wood = cannot be calculated. Litter = no data.
15	Impoundments and off-channel habitat	Impoundments = no data. Off-channel habitat = increase, but remain small fraction of total habitat.	No data	No data
16	Summer carrying capacity	Substantial decrease	Small decrease	Small increase
17	Winter carrying capacity	No data	No data	No data
18	Summer and winter population sizes	83% increase in summer coho parr abundance 1st post project year (directly related to 81% increase in adult escapement)	No time trend. Positive trends with basin adult escapement level (combined Green River and EF Green River data)	
19	Over-winter survival	No data	Pre-project = 27%. Post-project = 50 to 65% (combined Green River and EF Green River data)	
20	Coho distribution	No data	Time trends = no change. Average summer midpoint higher than average winter midpoint (combined Green River and EF Green River data)	

It may be observed that there was only a single measure of performance, scour depth, that produced a consistent response across the three study sites There are multiple reasons for this discussed previously:. Some data was not collected on all 3 reaches (fish abundance data only exist for Green and EF Green); protocols differed between the USFS and ODFW that often did not quantify similar attributes (spawning gravel); and issues with adherence to protocol existed in some data sets.

These problems have restricted our ability to interpret wood treatment effects. However, the restoration story begins to come to life with site-specific observations like the following provided by the Crab Creek surveyors.

- Some log placements occurred in pool habitats.
- During major winter high water events, some large spanning wood was lifted above the stream bed so far that previously trapped transient wood was released downstream.
- Some of the log placements functioned primarily not to hold canopy litter as anticipated, but to deflect flow, cause bank erosion, and recruit standing riparian wood.
- Some log placements trapped migratory canopy litter, which resulted in capturing small mobile substrates and elevating the stream bed. These new plains of soft substrates were then eroded in complex patterns, creating braided channel systems. A dominant habitat type in these braided channels was inventoried as “riffle with pockets”.

We believe that the intricacy of log placement was not sufficient at many sites to prevent whole structure complexes from floating up during high winter flows and releasing accumulated transient wood. This has delayed the evolution toward floodplain interaction and the development of channel complexity by not allowing these structures to seat and capture transient bed load that aggrades the active channel above the log structure.

Many single and double log structures provide limited effect on channel complexity. This observation is significant for large tree length placements where older age conifers have smooth boles and limited axial branching that is effective at capturing transient canopy litter. Wood treatment structures would be far more effective if composed of open grown trees having complex branching.

In reviewing the data and surveyor notes, we have found a recurring pattern. This is that log structures produce varied and sometimes opposing effects involving trapping and deflection that are poorly represented in reach level summaries A structure can increase the number of units by dividing an existing unit. The structure might deflect and re-direct the channel, creating new lateral scour and downstream sinuosity. Impoundments created behind structures may cover upstream units , reducing the number or units. New units may appear on aggraded surfaces behind structures. These might be riffles or scour pools, or combinations of these in varied and changing compositions. Ultimately changes occurring on these new deposition plains with erodible surfaces are likely to mature into braided channels.

When response metrics are combined for a project reach, then these dynamic events, the most informative events to follow wood treatment, are often lost in by summarizing data over long stretches of the stream. We therefore believe that reach level summaries are not the appropriate approach for much of our wood treatment assessment work.

A stratified selection of individual sites monitored over time is likely to provide a much better assessment of the stream dynamics that follow wood treatment. In addition, this type of approach is probably the only way that functional winter habitat can be accurately identified and described. The reason is that fish concentrations and distribution   are most effectively quantified and understood in relation to specific sites and their structures. When this is done, some sites will most likely exhibit disproportionately high rearing densities during winter flow conditions. *It is our conclusion that it is highly important to identify and understand these few special sites because their characteristics define functional winter habitat.*

It has been common within the scope of this project to identify pool habitats during winter flows that have similar levels of apparent wood complexity and extremely different abundances of over wintering coho juveniles. We should ask, “What are the morphological metrics that distinguish one from the other?” The answer to this question was not attainable utilizing the standard set of summer measurements averaged over the reach scale. In addition, the wood metrics required to parse out these relationships was not available for the Green river effort where all of the fish abundance data was collected.

Appendices 6 and 7 have been developed as a supplement to this analysis in an attempt to address some of the potential issues that confront aquatic habitat monitoring.

Habitat Alterations

We have found it necessary to apply differential levels of confidence to the varied data sets and their conclusions. A strong response observed in Crab Cr and supported by several different metrics was the change in the abundance of both pool number and pool surface area. Total surface area of all pools decreased each year (23,551m2, 19,764m2, 13,965m2). Scour pool areas generally decreased. Similar patterns occurred in the relative contribution (% of total area): 70 %, 63 % and 44 %. These losses were balanced by increases in pocket riffles. To support the conclusion that pool surface area has been converted to fast water habitat, the abundance of spawning gravel increased 93% within the project reach from 119 to 230 sq. meters. This condition has been caused by aggradation within the active channel caused by full spanning wood complexes trapping canopy litter and migratory substrates. The aggradation has occurred within pool habitats resulting in a large reduction of pool surface area as well as a reduction in summer capacity for Coho.

An extension of this response to aggradation would be the expectation that improvements in floodplain connectivity would be observed. These changes were not observed in the abundance of off channel and backwater habitats. This lack of response however, is more likely due to the inability of the methodology to capture off channel interactions during summer inventories than an actual lack of effect.

Even though a similar response was not observed in Green and EF Green we believe that the reduction in pool frequency and surface area documented in Crab Cr represents the actual effect of full spanning wood jams positioned in the active channel of these low gradient sandstone systems. Related to this observed affect of aggradation is the consistent lack of increased vertical scour within all 3 stream reaches. There was no significant net change in the abundance of deep pool habitat or the average residual pool depth before and after treatment.

Another valuable metric of change that we have associated high confidence with is the high frequency of native wood that has accumulated in the Crab Cr system post treatment. In 2006, 19% of the total instream wood volume was contributed by natural process from the adjacent riparian. This effect is a significant indicator of an interactive floodplain, the presence of lateral scour hydraulics and functional instream wood complexity capable of retention. The percentage of natural wood contribution was 12% in the first post project year. The relative contribution of natural wood to total wood abundance appears to be increasing and suggests that habitat conditions and overall habitat complexity continues to develop and mature. The largest benefits to fish production may yet to be encountered in the future as the foundation laid down with large second growth structure logs provides the trigger for a series of chain reactions that continue to evolve as long as the foundation wood remains active in the system. Theoretically this could be decades.

Changes in Fish Abundance

The fish abundance data displays a strong linear relationship between seasonal survival rates and even adult abundance indicators provided by the Alsea basin scale estimates of adult Coho. Because of the collaboration of these multiple indexes, the consistency of the field crew and methodology throughout the extent of the 7 year study we believe that the fish data collected in Green and EF Green is not only a viable metric of the change in coho production and over winter survival but is likely very representative of the changes that have also occurred in Crab Cr in relation to large wood treatment.

The relationship between summer parr abundance and post winter presmolt abundance is extremely linear ($R^2=0.98$) throughout the range of the variability in summer abundance (figure 6). This suggests that no carrying capacity has been reached in either the summer or winter abundance of juvenile coho. We assume that a saturation point exists along the slope of this curve where increased summer parr abundance results in diminishing smolt production but that relationship has not occurred to date within the scope of this post project evaluation.

There is the potential that gravel resources could become a seasonal limitation in Green River and that summer parr numbers could never reach the full rearing potential of the available summer habitat. However, spawning gravel was not an attribute collected by the USFS protocol and no modeling of this potential scenario is currently possible.

These observations suggests that the Green River subbasin post wood treatment, has to date, been only limited by adult escapement. Additional smolt production potential currently exists that has not been realized. This conclusion is also supported by a review of the 2006 summer rearing densities which resulted in an average value for the mainstem Green River of only 0.6 coho/sq. meter of pool surface area, which is far below levels of full seeding observed in coastal basins (1.7 coho/sq.meter). EF Green may however be approaching capacity with average summer densities in 2006 at 1.4 coho / sq. meter.

The pre project relationship observed in Figure 6 between summer and winter coho abundance also suggests that Green River was winter limited prior to the placement of log structure. One of the highest summer abundances of coho resulted in the lowest smolt production for the 2001brood year.

Recommendations

Some general guidelines

- Five and 10 year physical monitoring/assessment (develop new protocol).
- Continue bi-annual fish abundance monitoring (summer / winter)
- Focus on site specific inter-relationships, functionality, problems, and needs.
- Consider that standardization is useful. Regimentation is not.
- Evaluate specific sites of wood placement (i.e., don't integrate all of the wood into a single reach or treatment section analysis).
- Take photos of these sites and their up- and down-stream effects over time.
- Use a guided questionnaire to supplement the inventory. Place the inventory data against a backdrop of understanding, questioning, and identified uncertainties.
- Document what did work. But give more attention to what didn't work.
- Ask,"What would I do differently now that I see these effects and changes?"
- Let the questions evolve with the system.
- Develop summer survey protocols for channel complexity, floodplain interaction, and low velocity edge habitat..
- Develop a working definition of "complex pool", understanding that wood abundance is not a complete measure of habitat complexity

We should note that an alternate way to classify the braided channel riffle with pocket pool habitat described above is as small pools interspersed with short riffles, a "micro-habitat" structure. Survey protocols typically ignore such micro-pools by not allowing the definition of pools which are shorter than long, lack hydraulic control, or do not occupy the entire channel width.[1] However, micro-pools contribute importantly to the total pool component of the system even if they don't appear as such in survey data. They do this by providing excellent summer rearing and feeding habitat for juvenile Coho. They also identify the beginning of progressive change in channel structure created by wood placement.

[1] S*ome survey protocols do not distinguish between gravel riffles and riffels with pockets.*

Figures

Figure 1. Winter population trend lines for Green River juvenile Coho salmon.

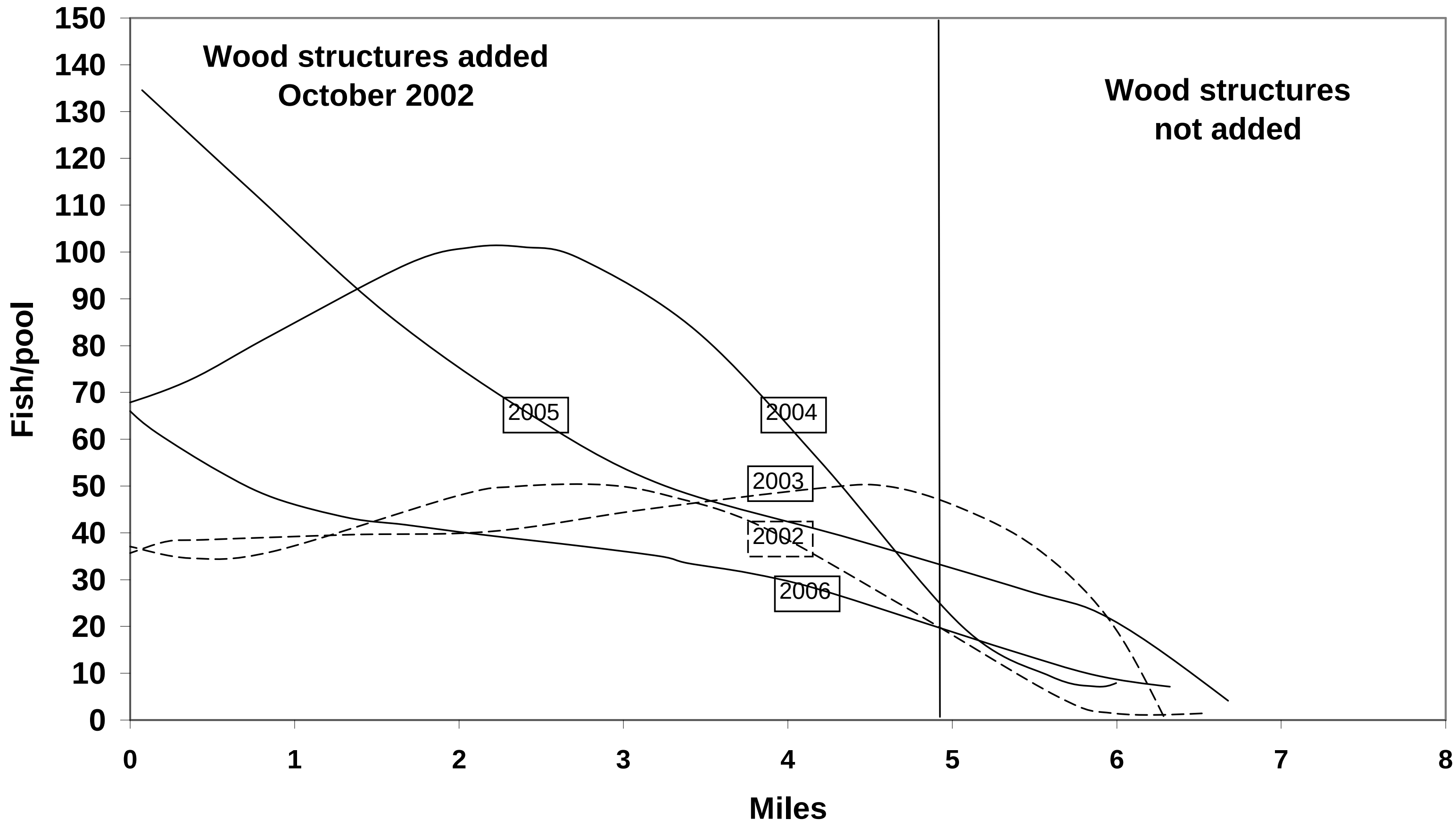


Figure 2. Winter population trend lines for EF Green River juvenile Coho salmon.

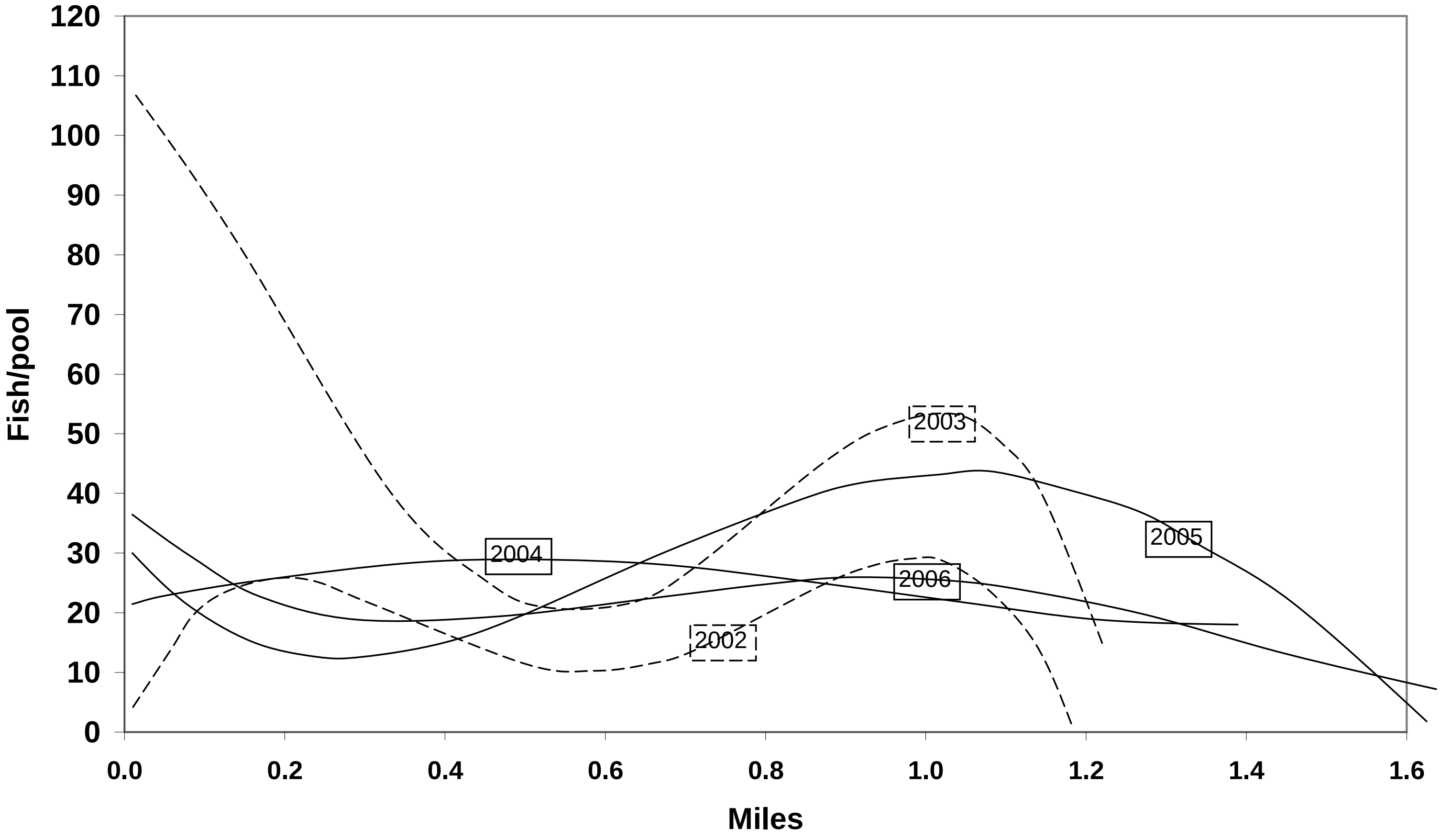


Figure 3. Summer population trend lines for Green River juvenile Coho salmon.

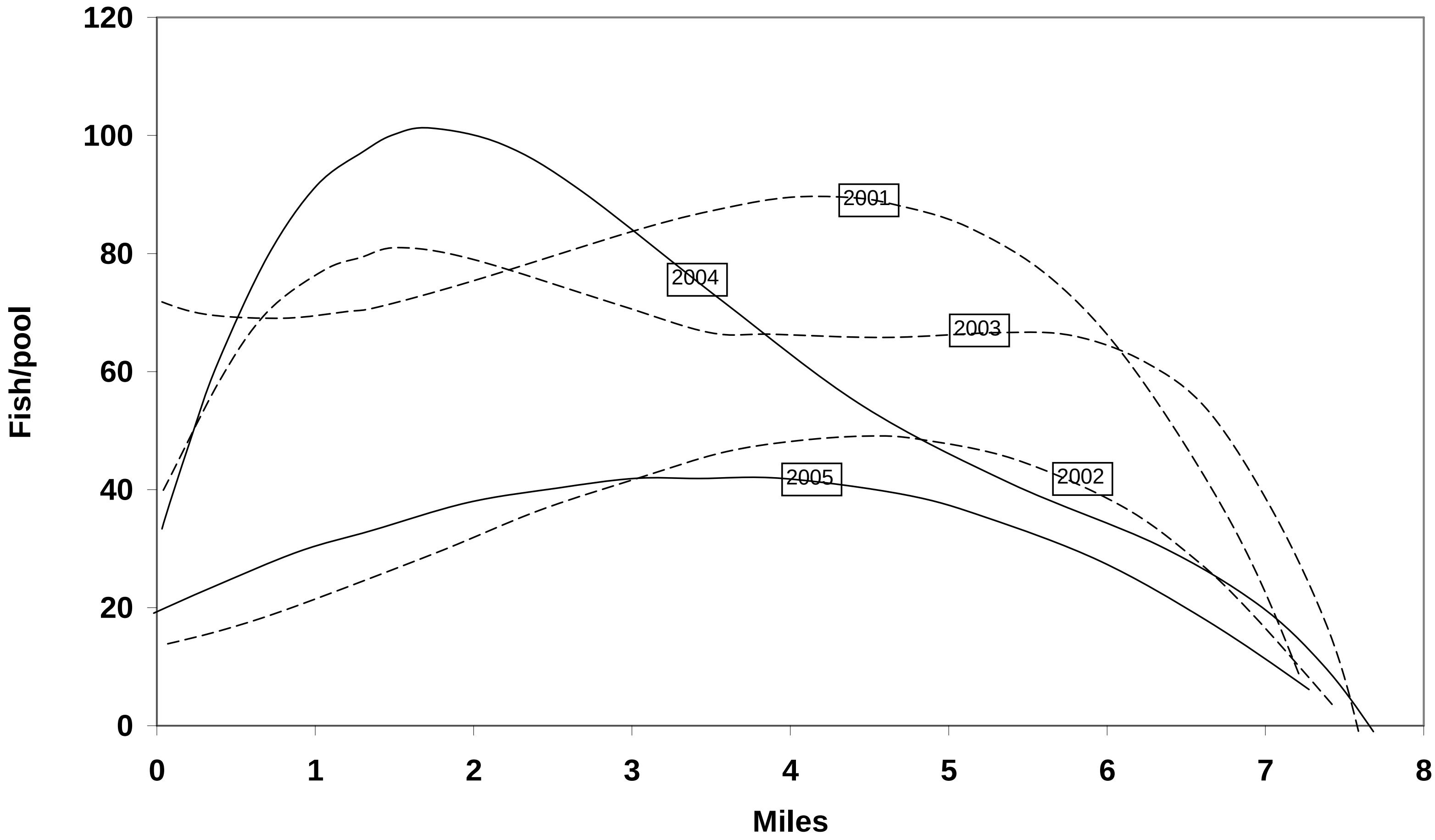


Figure 4. Summer population trend lines for EF Green River juvenile Coho salmon.

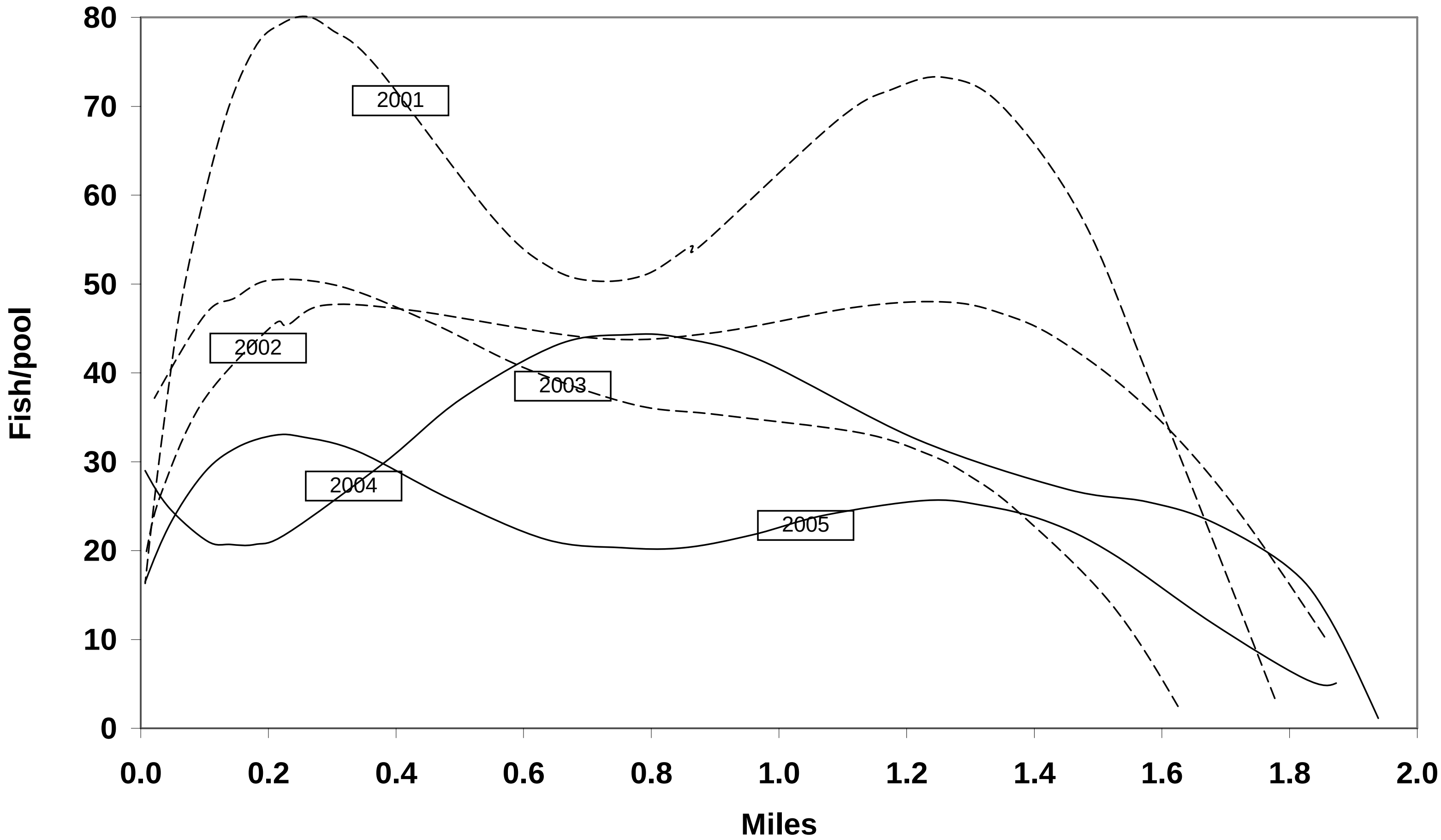


Figure 5. Adult Coho escapement to the Alsea Basin in relation to juvenile populations and survival rate in Green River and EF Green River.

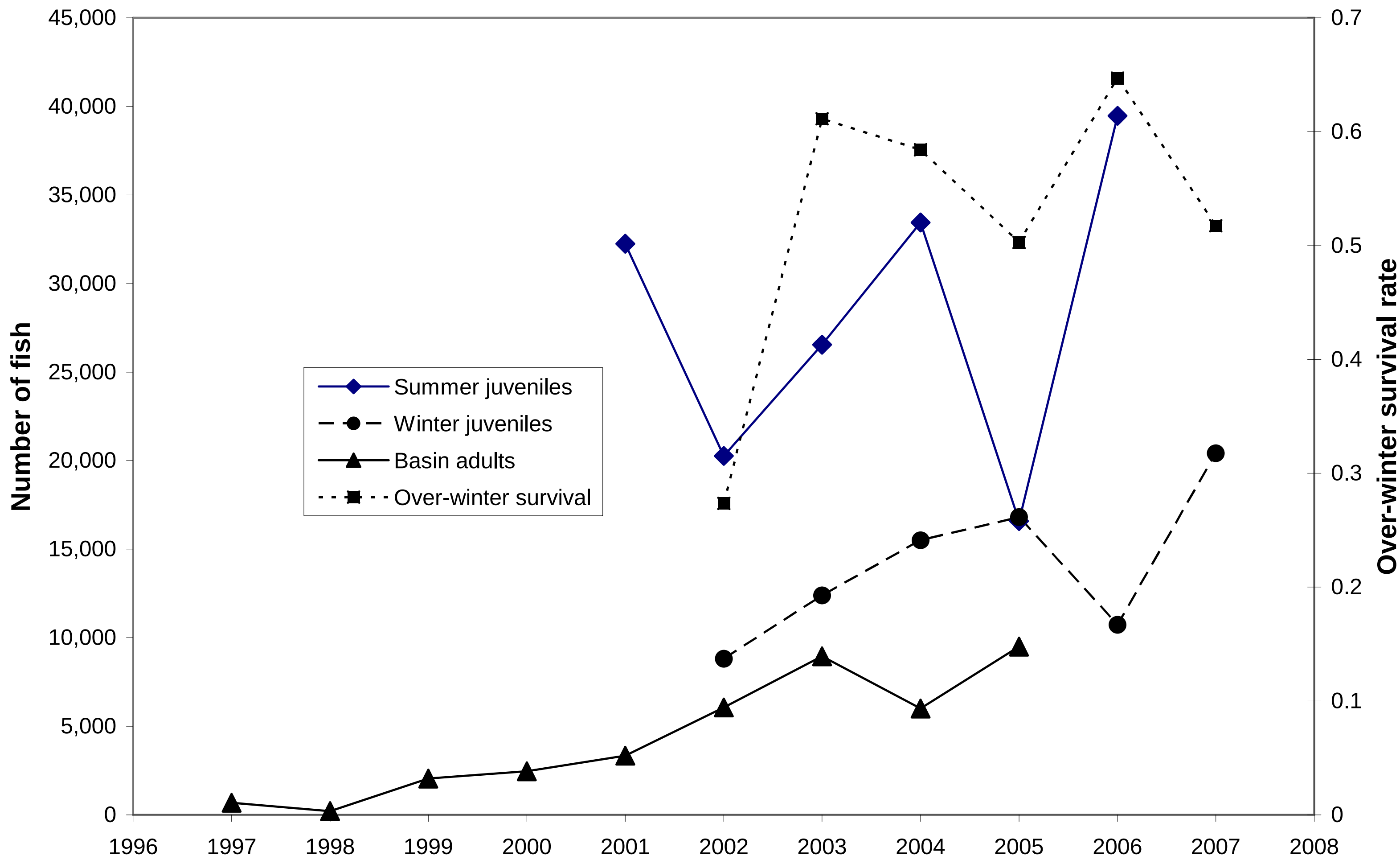


Figure 6. Relation between summer and winter population sizes of juvenile Coho salmon in Green River and EF Green River, 2001-2006

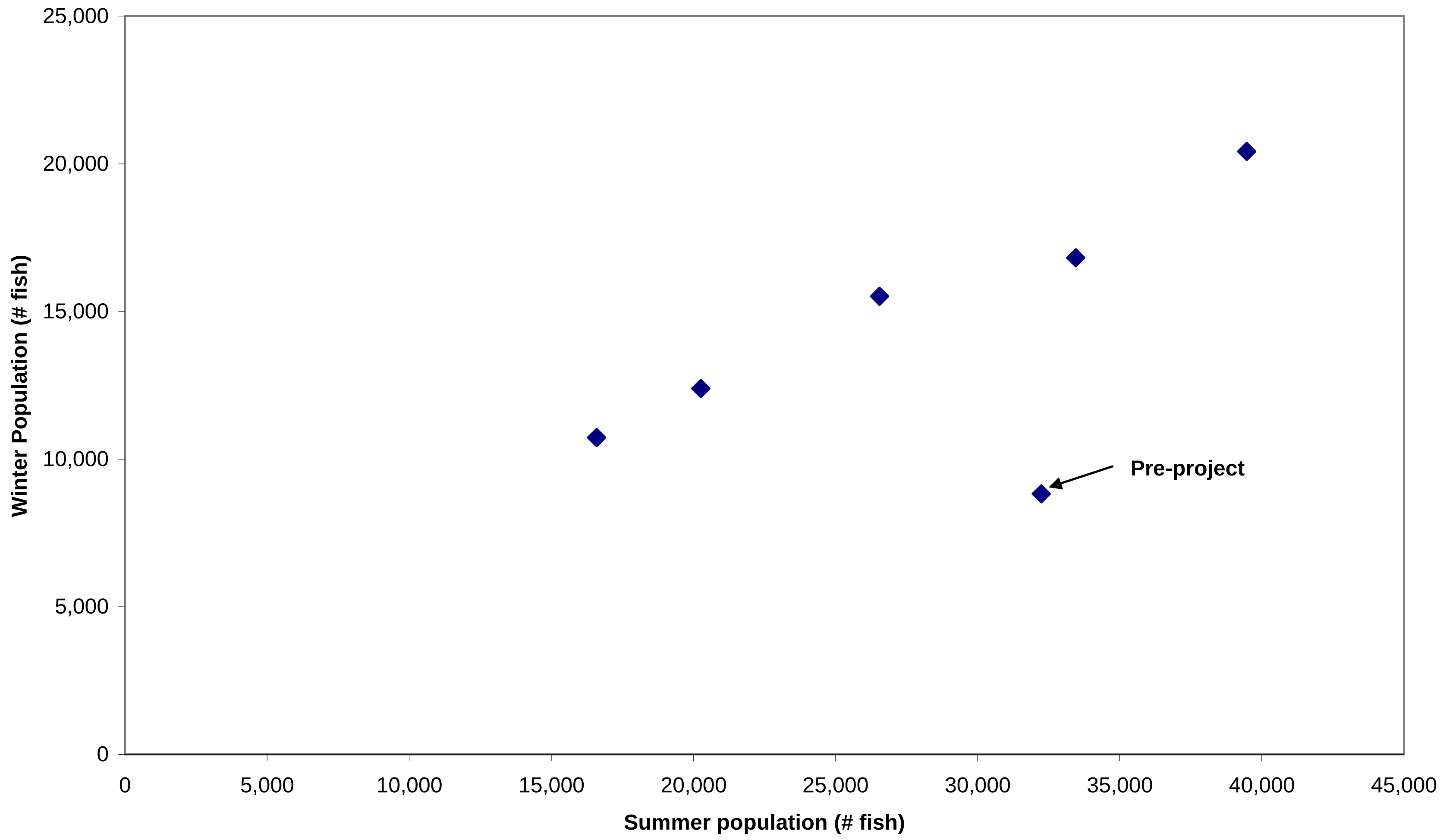
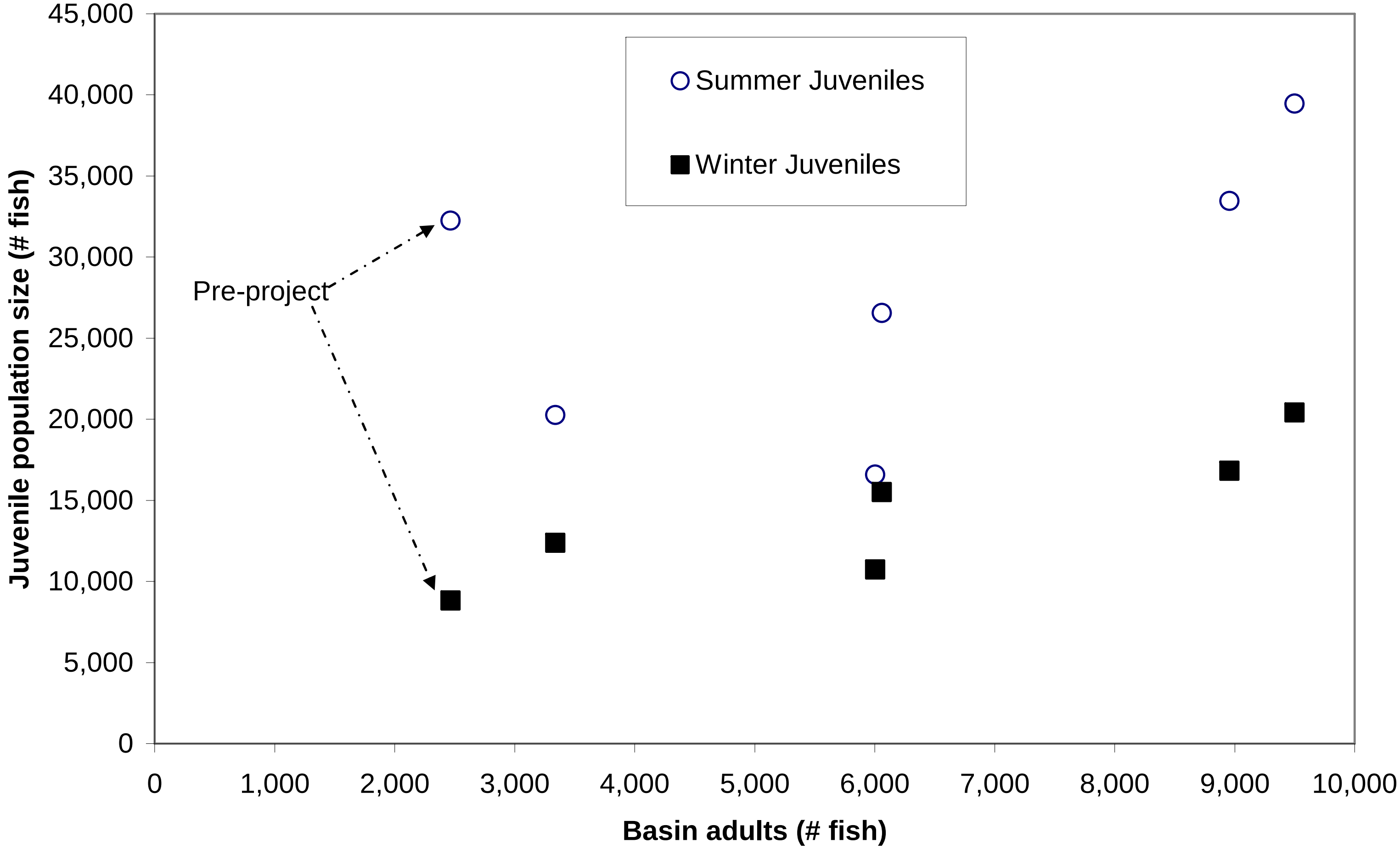


Figure 7. Adult escapment to the Alsea Basin and size of subsequent summer and winter Green River juvenile populations.



Tables

Table 1. Crab Creek reach dimensions

Crab Creek reach length

Sum of COR_LENGTH	Year		
REACH_NEW	2002	2003	2006
1	1,124	997	998
2	1,358	1,659	568
3	226	1,040	523
4	2,611	2,194	616
5	195		120
6	372		1,114
7			959
8			562
9			430
Grand Total	5,885	5,890	5,890

Crab Creek reach area

Sum of COR_AREA	Year		
REACH_NEW	2002	2003	2006
1	4,837	5,939	5,633
2	13,664	10,248	3,605
3	1,115	6,031	3,000
4	11,970	10,736	3,705
5	1,001		796
6	2,299		5,755
7			5,316
8			2,839
9			2,607
Grand Total	34,885	32,954	33,257

Table 2. Crab Creek wetted channel dimensions

Crab Creek channel length

Sum of COR_LENGTH	Year		
Channel Type	2002	2003	2006
Mainstem primary	5,885	5,890	5,890
Mainstem side	46	92	167
Tributary primary	72	82	141
Subunit pools	175	299	260
Grand Total	6,178	6,363	6,459

Crab Creek channel area

Sum of COR_AREA	Year		
Channel Type	2002	2003	2006
Mainstem primary	34,256	31,856	31,728
Mainstem side	132	227	513
Tributary primary	39	60	114
Subunit pools	458	811	902
Grand Total	34,885	32,954	33,257

Crab Creek channel area details

Sum of COR_AREA		Year		
Channel Code	Description		Year	
		2002	2003	2006
0	Single channel	33,040	30,220	23,922
1	Primary channel, adjacent side channel	1,216	1,637	7,806
2	Side channel (secondary)	132	227	505
3	Side channel (tertiary)			7
4	Side channel (quaternary)			1
10	Subunit pools	458	811	902
11	Primary channel of tributary	39	60	114
	Grand Total	34,885	32,954	33,257

Table 3. Crab Creek pool tail crest (PTC) dimensions

Crab Creek PTC count and average depth

		Year		
Channel Type	Data	2002	2003	2006
Mainstem primary	Count of DEPTH_PTC	139	136	121
	Average of DEPTH_PTC	0.126	0.147	0.145
Mainstem side	Count of DEPTH_PTC	1	3	2
	Average of DEPTH_PTC	0.050	0.033	0.100
Subunit pools	Count of DEPTH_PTC	1		
	Average of DEPTH_PTC	0.000		
Tributary primary	Count of DEPTH_PTC			
	Average of DEPTH_PTC			
Total Count of DEPTH_PTC		141	139	123
Total Average of DEPTH_PTC		0.124	0.145	0.144

Table 4. Crab Creek residual pool dimensions.

Crab Creek residual pools - number and average depth

General Habitat Type	Pool
Exclude Al,Bw,IP	Yes

			Year		
Channel Type	Specific Habitat Type	Data	2002	2003	2006
Mainstem primary	Beaver Pond	Count of Residual Pool Depth	4		1
		Average of Residual Pool Depth	0.63		0.80
	Dammed pool	Count of Residual Pool Depth		1	
		Average of Residual Pool Depth		1.15	
	Lateral scour pool	Count of Residual Pool Depth	82	71	69
		Average of Residual Pool Depth	0.55	0.52	0.59
	Plunge pool	Count of Residual Pool Depth	4	3	4
		Average of Residual Pool Depth	0.51	0.75	0.48
	Straight scour pool	Count of Residual Pool Depth	53	54	44
		Average of Residual Pool Depth	0.46	0.52	0.60
	Trench pool	Count of Residual Pool Depth		14	3
		Average of Residual Pool Depth		0.46	0.55
Mainstem primary Count of Residual Pool Depth			143	143	121
Mainstem primary Average of Residual Pool Depth			0.52	0.52	0.59
Mainstem side	Lateral scour pool	Count of Residual Pool Depth	1	2	
		Average of Residual Pool Depth	0.35	0.50	
	Straight scour pool	Count of Residual Pool Depth		1	2
		Average of Residual Pool Depth		0.25	0.50
Mainstem side Count of Residual Pool Depth			1	3	2
Mainstem side Average of Residual Pool Depth			0.35	0.38	0.50
Total Count of Residual Pool Depth			144	146	123
Total Average of Residual Pool Depth			0.52	0.52	0.59

Crab Creek residual pools > 1 m – number and area

			Year		
Channel Type	Specific Habitat Type	Data	2002	2003	2006
Mainstem primary	Dammed pool	Count of Resid Pool Depth>=1m		1	
		Sum of COR_AREA		305	
	Lateral scour pool	Count of Resid Pool Depth>=1m	3		3
		Sum of COR_AREA	512		616
	Plunge pool	Count of Resid Pool Depth>=1m		1	
		Sum of COR_AREA		100	
	Straight scour pool	Count of Resid Pool Depth>=1m			2
		Sum of COR_AREA			131
Mainstem primary Count of Resid Pool Depth>=1m			3	2	5
Mainstem primary Sum of COR_AREA			512	406	747
Total Count of Resid Pool Depth>=1m			3	2	5
Total Sum of COR_AREA			512	406	747

Table 5. Crab Creek habitat dimensions of the mainstem primary channel.

Crab Creek mainstem habitat counts

Channel Type	Mainstem primary			
Sel Hab Anal	Yes			
Count of UNIT_NUMB		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Beaver Pond	4		1
	Dammed pool		1	
	Lateral scour pool	82	71	69
	Plunge pool	4	3	4
	Straight scour pool	53	54	44
	Trench pool		14	3
Pool Total		143	143	121
Riffle	Cascade over bedrock			1
	Cascade over boulders		1	
	Rapid over bedrock		5	4
	Rapid with boulders		1	2
	Riffle	71	64	35
	Riffle with pockets	28	34	71
Riffle Total		99	105	113
Glide	Glide	35	31	42
Glide Total		35	31	42
Grand Total		277	279	276

Crab Creek mainstem habitat lengths

Channel Type	Mainstem primary			
Sel Hab Anal	Yes			
Sum of COR_LENGTH		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Beaver Pond	243		31
	Dammed pool		44	
	Lateral scour pool	2,306	1,588	1,423
	Plunge pool	33	38	26
	Straight scour pool	986	1,195	763
	Trench pool		375	74
Pool Total		3,568	3,239	2,316
Riffle	Cascade over bedrock			8
	Cascade over boulders		5	
	Rapid over bedrock		82	103
	Rapid with boulders		8	43
	Riffle	751	979	619
	Riffle with pockets	684	824	1,779
Riffle Total		1,435	1,898	2,552
Glide	Glide	800	671	951
Glide Total		800	671	951
Grand Total		5,804	5,809	5,819

Crab Creek mainstem average habitat lengths

Channel Type	Mainstem primary			
Sel Hab Anal	Yes			
Average of COR_LENGTH		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Beaver Pond	61		31
	Dammed pool		44	
	Lateral scour pool	28	22	21
	Plunge pool	8	13	6
	Straight scour pool	19	22	17
	Trench pool		27	25
Pool Total		25	23	19
Riffle	Cascade over bedrock			8
	Cascade over boulders		5	
	Rapid over bedrock		16	26
	Rapid with boulders		8	21
	Riffle	11	15	18
	Riffle with pockets	24	24	25
Riffle Total		14	18	23
Glide	Glide	23	22	23
Glide Total		23	22	23
Grand Total		21	21	21

Crab Creek mainstem habitat areas

Channel Type	Mainstem primary			
Sel Hab Anal	Yes			
Sum of COR_AREA		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Beaver Pond	2,647		213
	Dammed pool		305	
	Lateral scour pool	14,667	9,517	8,192
	Plunge pool	237	206	186
	Straight scour pool	6,000	7,253	4,737
	Trench pool		2,483	367
Pool Total		23,551	19,764	13,695
Riffle	Cascade over bedrock			45
	Cascade over boulders		3	
	Rapid over bedrock		419	611
	Rapid with boulders		28	213
	Riffle	2,772	4,173	3,113
	Riffle with pockets	2,871	3,155	8,281
Riffle Total		5,643	7,778	12,263
Glide	Glide	4,618	3,856	5,417
Glide Total		4,618	3,856	5,417
Grand Total		33,812	31,398	31,376

Crab Creek mainstem habitat areas (%)

Channel Type	Mainstem primary			
Sel Hab Anal	Yes			
Sum of COR_AREA		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Beaver Pond	7.8%	0.0%	0.7%
	Dammed pool	0.0%	1.0%	0.0%
	Lateral scour pool	43.4%	30.3%	26.1%
	Plunge pool	0.7%	0.7%	0.6%
	Straight scour pool	17.7%	23.1%	15.1%
	Trench pool	0.0%	7.9%	1.2%
Pool Total		69.7%	62.9%	43.7%
Riffle	Cascade over bedrock	0.0%	0.0%	0.1%
	Cascade over boulders	0.0%	0.0%	0.0%
	Rapid over bedrock	0.0%	1.3%	1.9%
	Rapid with boulders	0.0%	0.1%	0.7%
	Riffle	8.2%	13.3%	9.9%
	Riffle with pockets	8.5%	10.0%	26.4%
Riffle Total		16.7%	24.8%	39.1%
Glide	Glide	13.7%	12.3%	17.3%
Glide Total		13.7%	12.3%	17.3%
Grand Total		100.0%	100.0%	100.0%

Table 6. Crab Creek habitat dimensions of mainstem side channels.

Crab Creek side channel habitat counts

Channel Type	Mainstem side			
Sel Hab Anal	Yes			
Count of UNIT_NUMB		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Lateral scour pool	1	2	
	Straight scour pool		1	2
Pool Total		1	3	2
Riffle	Riffle	2	3	3
	Riffle with pockets		1	3
Riffle Total		2	4	6
Glide	Glide	1		1
Glide Total		1		1
Grand Total		4	7	9

Crab Creek side channel habitat lengths

Channel Type	Mainstem side			
Sel Hab Anal	Yes			
Sum of COR_LENGTH		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Lateral scour pool	8	26	
	Straight scour pool		21	47
Pool Total		8	48	47
Riffle	Riffle	16	22	14
	Riffle with pockets		22	80
Riffle Total		16	45	95
Glide	Glide	22		23
Glide Total		22		23
Grand Total		46	92	164

Crab Creek side channel habitat areas

Channel Type	Mainstem side			
Sel Hab Anal	Yes			
Sum of COR_AREA		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Lateral scour pool	23	99	
	Straight scour pool		69	167
Pool Total		23	168	167
Riffle	Riffle	45	47	63
	Riffle with pockets		12	212
Riffle Total		45	59	275
Glide	Glide	65		63
Glide Total		65		63
Grand Total		132	227	506

Table 7. Crab Creek habitat dimensions of subunit pools (alcoves and backwaters)

Crab Creek subunit habitat counts

Channel Type	Subunit pools			
Sel Hab Anal	Yes			
Count of UNIT_NUMB		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Alcove		2	1
	Backwater	14	31	40
Pool Total		14	33	41
Grand Total		14	33	41

Crab Creek subunit habitat lengths

Channel Type	Subunit pools			
Sel Hab Anal	Yes			
Sum of COR_LENGTH		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Alcove		54	6
	Backwater	160	227	216
Pool Total		160	281	223
Grand Total		160	281	223

Crab Creek subunit habitat lengths

Channel Type	Subunit pools			
Sel Hab Anal	Yes			
Sum of COR_AREA		Year		
General Habitat Type	Specific Habitat Type	2002	2003	2006
Pool	Alcove		38	21
	Backwater	417	731	763
Pool Total		417	769	785
Grand Total		417	769	785

Table 8. Crab Creek large wood abundance.

Crab Creek large wood volume and pieces by channel type

		Year		
Channel Type	Data	2002	2003	2006
Mainstem primary	Sum of WVOLUME	482	2,461	3,017
	Sum of NPIECES	553	815	864
	Sum of KEYPIECES	9	159	165
Mainstem side	Sum of WVOLUME			108
	Sum of NPIECES			22
	Sum of KEYPIECES			6
Tributary primary	Sum of WVOLUME			10
	Sum of NPIECES			6
	Sum of KEYPIECES			0
Subunit pools	Sum of WVOLUME	17	150	145
	Sum of NPIECES	17	33	23
	Sum of KEYPIECES	0	6	6
Total Sum of WVOLUME		499	2,611	3,281
Total Sum of NPIECES		570	848	915
Total Sum of KEYPIECES		9	165	177

Table 9. Green River reach dimensions

Green River reach lengths

Channel type	Mainstem primary	
Stream	Green River	
Sum of Len (m)	Year	
REACH	2000	2006
1	7,149	7,076
2	4,545	4,557
3	2,117	2,042
Grand Total	13,810	13,675

Green River reach areas

Stream	Green River		
Sum of Area (m2)		Year	
REACH	Channel type	2000	2006
1	Mainstem primary	47,232	41,086
	Mainstem side	332	
	Special Case	379	
	Tributary primary	63	
1 Total		48,006	41,086
2	Mainstem primary	17,599	16,853
	Mainstem side	84	538
	Tributary primary	60	
2 Total		17,743	17,391
3	Mainstem primary	4,650	5,258
	Mainstem side	73	122
	Tributary primary	31	
3 Total		4,753	5,380
Grand Total		70,502	63,857

Table 10. Green River wetted channel dimensions

Green River channel length

REACH	1	
Stream	Green River	
Sum of Len (m)	Year	
Channel type	2000	2006
Mainstem primary	7,149	7,076
Mainstem side	61	
Special Case	41	
Tributary primary	45	
Grand Total	7,296	7,076

Green River channel area

REACH	1	
Stream	Green River	
Sum of Area (m2)	Year	
Channel type	2000	2006
Mainstem primary	47,232	41,086
Mainstem side	332	
Special Case	379	
Tributary primary	63	
Grand Total	48,006	41,086

Table 11. Green River Pool Tail Crest (PTC) dimensions

Green River PTC count and average depth

REACH	1		
Stream	Green River		
General Habitat Type	Pool		
		Year	
Channel type	Data	2000	2006
Mainstem primary	Count of PTC (m)	94	123
	Average of PTC (m)2	0.15	0.12
Total Count of PTC (m)		94	123
Total Average of PTC (m)2		0.15	0.12

Table 12. Green River residual pool dimensions

Green River residual pools - number and average depth

REACH	1			
Stream	Green River			
General Habitat Type	Pool			
			Year	
Channel type	Specific Habitat Type	Data	2000	2006
Mainstem primary	Beaver pond	Count of Resid Pool Depth (m)	4	4
		Average of Resid Pool Depth (m)2	1.1811	1.0668
	Dam pool	Count of Resid Pool Depth (m)	7	
		Average of Resid Pool Depth (m)2	0.40	
	Scour pool	Count of Resid Pool Depth (m)	83	119
		Average of Resid Pool Depth (m)2	0.80	0.67
Mainstem primary Count of Resid Pool Depth (m)			94	123
Mainstem primary Average of Resid Pool Depth (m)2			0.79	0.68
Total Count of Resid Pool Depth (m)			94	123
Total Average of Resid Pool Depth (m)2			0.79	0.68

Green River residual pools > 1 m - number and area

REACH	1			
Stream	Green River			
General Habitat Type	Pool			
Resid Pool Depth>=1m	yes			
			Year	
Channel type	Specific Habitat Type	Data	2000	2006
Mainstem primary	Beaver pond	Count of Resid Pool Depth (m)	3	1
		Sum of Area (m2)	1,617	811
	Scour pool	Count of Resid Pool Depth (m)	20	15
		Sum of Area (m2)	9,679	6,171
Mainstem primary Count of Resid Pool Depth (m)			23	16
Mainstem primary Sum of Area (m2)			11,296	6,982
Total Count of Resid Pool Depth (m)			23	16
Total Sum of Area (m2)			11,296	6,982

Table 13. Green River habitat dimensions of the mainstem primary channel.

Green River mainstem habitat counts

REACH	1		
Channel type	Mainstem primary		
Stream	Green River		
Sel Hab Anal	Yes		
Count of Unit #		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	4	4
	Dam pool	7	
	Scour pool	83	119
Pool Total		94	123
Riffle	Rapid	1	
	Riffle	63	79
Riffle Total		64	79
Grand Total		158	202

Green River mainstem habitat lengths

REACH	1		
Channel type	Mainstem primary		
Stream	Green River		
Sel Hab Anal	Yes		
Sum of Len (m)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	388	312
	Dam pool	292	
	Scour pool	4,684	5,375
Pool Total		5,364	5,687
Riffle	Rapid	8	
	Riffle	1,776	1,389
Riffle Total		1,784	1,389
Grand Total		7,149	7,076

Green River mainstem average habitat lengths

REACH	1		
Channel type	Mainstem primary		
Stream	Green River		
Sel Hab Anal	Yes		
Average of Len (m)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	97	78
	Dam pool	42	
	Scour pool	56	45
Pool Total		57	46
Riffle	Rapid	8	
	Riffle	28	18
Riffle Total		28	18
Grand Total		45	35

Green River mainstem habitat areas

REACH	1		
Channel type	Mainstem primary		
Stream	Green River		
Sel Hab Anal	Yes		
Sum of Area (m2)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	2,697	2,369
	Dam pool	1,972	
	Scour pool	31,728	32,371
Pool Total		36,397	34,740
Riffle	Rapid	65	
	Riffle	10,771	6,346
Riffle Total		10,835	6,346
Grand Total		47,232	41,086

Green River mainstem habitat areas (%)

REACH	1		
Channel type	Mainstem primary		
Stream	Green River		
Sel Hab Anal	Yes		
Sum of Area (m2)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	5.71%	5.77%
	Dam pool	4.17%	0.00%
	Scour pool	67.17%	78.79%
Pool Total		77.06%	84.55%
Riffle	Rapid	0.14%	0.00%
	Riffle	22.80%	15.45%
Riffle Total		22.94%	15.45%
Grand Total		100.00%	100.00%

Table 14. Green River habitat dimensions of mainstem side channels.

Green River side channel habitat counts

REACH	1	
Channel type	Mainstem side	
Stream	Green River	
Sel Hab Anal	Yes	
Count of Unit #		Year
General Habitat Type	Specific Habitat Type	2000
Side channel	Side channel	1
Side channel Total		1
Grand Total		1

Green River side channel habitat lengths

REACH	1	
Channel type	Mainstem side	
Stream	Green River	
Sel Hab Anal	Yes	
Sum of Len (m)		Year
General Habitat Type	Specific Habitat Type	2000
Side channel	Side channel	61
Side channel Total		61
Grand Total		61

Green River side channel habitat areas

REACH	1	
Channel type	Mainstem side	
Stream	Green River	
Sel Hab Anal	Yes	
Sum of Area (m2)		Year
General Habitat Type	Specific Habitat Type	2000
Side channel	Side channel	332
Side channel Total		332
Grand Total		332

Table 15. Green River large wood abundance

Green River large wood by channel type

REACH	1		
Stream	Green River		
		Year	
Channel type	Data	2000	2006
Mainstem primary	Sum of LWD_SMALL	206	189
	Sum of LWD_MEDIUM	42	16
	Sum of LWD_LARGE	13	0
Mainstem side	Sum of LWD_SMALL		
	Sum of LWD_MEDIUM		
	Sum of LWD_LARGE		
Special Case	Sum of LWD_SMALL		
	Sum of LWD_MEDIUM		
	Sum of LWD_LARGE		
Tributary primary	Sum of LWD_SMALL		
	Sum of LWD_MEDIUM		
	Sum of LWD_LARGE		
Total Sum of LWD_SMALL		206	189
Total Sum of LWD_MEDIUM		42	16
Total Sum of LWD_LARGE		13	0
	Grand Total	261	205

Table 16. EF Green River reach dimensions

EF Green River reach length

Channel type	Mainstem primary	
Stream	EF Green River	
Sum of Len (m)	Year	
REACH	2000	2006
1	2,168	2,287
2	1,588	1,585
Grand Total	3,756	3,872

EF Green River reach area

Stream	EF Green River		
Sum of Area (m2)		Year	
REACH	Channel type	2000	2006
1	Mainstem primary	7,468	7,315
	Mainstem side		0
	Tributary primary	7	
1 Total		7,475	7,315
2	Culvert	20	
	Mainstem primary	3,390	2,585
	Off channel		0
	Tributary primary	20	
2 Total		3,430	2,585
Grand Total		10,905	9,900

Table 17. EF Green River wetted channel dimensions

EF Green River channel length

Stream	EF Green River	
Sum of Len (m)	Year	
Channel type	2000	2006
Mainstem primary	3,756	3,872
Mainstem side		47
Tributary primary	34	
Culvert	16	
Off channel		79
Grand Total	3,806	3,998

EF Green River channel area

Stream	EF Green River	
Sum of Area (m2)	Year	
Channel type	2000	2006
Mainstem primary	10,858	9,740
Mainstem side		38
Tributary primary	27	
Culvert	20	
Off channel		0
Grand Total	10,905	9,778

Table 18 EF Green River Pool Tail Crest (PTC) dimensions

EF Green River PTC count and average depth

Stream	EF Green River		
General Habitat Type	Pool		
		Year	
Channel type	Data	2000	2006
Mainstem primary	Count of PTC (m)	54	138
	Average of PTC (m)	0.08	0.08
Total Count of PTC (m)		54	138
Total Average of PTC (m)		0.08	0.08

Table 19 EF Green River residual pool dimensions

EF Green River residual pools - number and average depth

Stream	EF Green River			
General Habitat Type	Pool			
			Year	
Channel type	Specific Habitat Type	Data	2000	2006
Mainstem primary	Beaver pond	Count of Resid Pool Depth (m)	3	3
		Average of Resid Pool Depth (m)	1.04	0.74
	Dam pool	Count of Resid Pool Depth (m)		5
		Average of Resid Pool Depth (m)		0.50
	Scour pool	Count of Resid Pool Depth (m)	51	130
		Average of Resid Pool Depth (m)	0.43	0.39
Mainstem primary Count of Resid Pool Depth (m)			54	138
Mainstem primary Average of Resid Pool Depth (m)			0.46	0.40
Total Count of Resid Pool Depth (m)			54	138
Total Average of Resid Pool Depth (m)			0.46	0.40

EF Green River residual pools > 1 m - number and area

Stream	EF Green River			
General Habitat Type	Pool			
Resid Pool Depth>=1m	yes			
			Year	
Channel type	Specific Habitat Type	Data	2000	2006
Mainstem primary	Beaver pond	Count of Resid Pool Depth (m)	2	
		Sum of Area (m2)	1,102	
	Scour pool	Count of Resid Pool Depth (m)	2	1
		Sum of Area (m2)	170	309
Mainstem primary Count of Resid Pool Depth (m)			4	1
Mainstem primary Sum of Area (m2)			1,272	309
Total Count of Resid Pool Depth (m)			4	1
Total Sum of Area (m2)			1,272	309

Table 20. Green River habitat dimensions of the mainstem primary channel.

EF Green River mainstem habitat counts

Channel type	Mainstem primary		
Stream	EF Green River		
Sel Hab Anal	Yes		
Count of Unit #		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	3	3
	Dam pool		5
	Scour pool	51	130
Pool Total		54	138
Riffle	Rapid	1	64
	Riffle	49	36
Riffle Total		50	100
Grand Total		104	238

EF Green River mainstem habitat lengths

Channel type	Mainstem primary
Stream	EF Green River
Sel Hab Anal	Yes

Sum of Len (m)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	294	134
	Dam pool		66
	Scour pool	1,309	1,939
Pool Total		1,604	2,139
Riffle	Rapid	36	1,273
	Riffle	2,117	460
Riffle Total		2,152	1,733
Grand Total		3,756	3,872

EF Green River mainstem average habitat lengths

Channel type	Mainstem primary		
Stream	EF Green River		
Sel Hab Anal	Yes		
Average of Len (m)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	98	45
	Dam pool		13
	Scour pool	26	15
Pool Total		30	16
Riffle	Rapid	36	20
	Riffle	43	13
Riffle Total		43	17
Grand Total		36	16

EF Green River mainstem habitat areas

Channel type	Mainstem primary		
Stream	EF Green River		
Sel Hab Anal	Yes		
Sum of Area (m2)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	1,199	724
	Dam pool		134
	Scour pool	4,430	5,877
Pool Total		5,629	6,735
Riffle	Rapid	58	2,293
	Riffle	5,171	873
Riffle Total		5,229	3,165
Grand Total		10,858	9,900

EF Green River mainstem habitat areas (%)

Channel type	Mainstem primary		
Stream	EF Green River		
Sel Hab Anal	Yes		
Sum of Area (m2)		Year	
General Habitat Type	Specific Habitat Type	2000	2006
Pool	Beaver pond	11.04%	7.31%
	Dam pool	0.00%	1.36%
	Scour pool	40.80%	59.36%
Pool Total		51.84%	68.03%
Riffle	Rapid	0.54%	23.16%
	Riffle	47.63%	8.81%
Riffle Total		48.16%	31.97%
Grand Total		100.00%	100.00%

Table 21. Green River habitat dimensions of mainstem side channels.

EF Green River side channel habitat counts

Channel type	Mainstem side	
Stream	EF Green River	
Sel Hab Anal	Yes	
Count of Unit #		Year
General Habitat Type	Specific Habitat Type	2006
Side channel	Side channel	3
Side channel Total		3
Grand Total		3

EF Green River side channel habitat length

Channel type	Mainstem side	
Stream	EF Green River	
Sel Hab Anal	Yes	
Sum of Len (m)		Year
General Habitat Type	Specific Habitat Type	2006
Side channel	Side channel	47
Side channel Total		47
Grand Total		47

EF Green River side channel habitat area

Channel type	Mainstem side	
Stream	EF Green River	
Sel Hab Anal	Yes	
Sum of Area (m2)		Year
General Habitat Type	Specific Habitat Type	2006
Side channel	Side channel	38
Side channel Total		38
Grand Total		38

Table 22. EF Green River large wood abundance

EF Green River wood pieces by channel type

Stream	EF Green River		
		Year	
Channel type	Data	2000	2006
Mainstem primary	Sum of LWD_SMALL	67	56
	Sum of LWD_MEDIUM	4	28
	Sum of LWD_LARGE	4	7
Mainstem side	Sum of LWD_SMALL		0
	Sum of LWD_MEDIUM		2
	Sum of LWD_LARGE		0
Tributary primary	Sum of LWD_SMALL		
	Sum of LWD_MEDIUM		
	Sum of LWD_LARGE		
Culvert	Sum of LWD_SMALL		
	Sum of LWD_MEDIUM		
	Sum of LWD_LARGE		
Off channel	Sum of LWD_SMALL		0
	Sum of LWD_MEDIUM		0
	Sum of LWD_LARGE		0
Total Sum of LWD_SMALL		67	56
Total Sum of LWD_MEDIUM		4	30
Total Sum of LWD_LARGE		4	7
	Grand Total	75	93

Table 23. Green River juvenile Coho contributions by year, season, and stream segment.

STREAM	SUMMER 2001	WINTER 2002	SUMMER 2002 (Log Placement)	WINTER 2003	SUMMER 2003	WINTER 2004	SUMMER 2004	WINTER 2005	SUMMER 05	WINTER 06
Green R	25,170	7,569	11,910	9,083	21,570	13,419	25,215	14,288	12,246	8,844
Ryan	0		0		114		120		36	
Trib A	0		156		204		342		18	
Trib B	0		102		102		54		84	
Trib C	42		126		336		240		108	
Trib D	42		366		156		486		30	
Trib E	0		264		0		120		0	
EF Green R	5,622	1,255	5,405	3,303	3,594	2,092	4,668	2,528	3,078	1,890
Trib A	636		1,224		102		1,080		294	
Trib B	732		708		372		1,128		696	
TOTAL POPULATION ESTIMATE	32,244	8,824	20,261	12,386	26,550	15,511	33,453	16,816	16,590	10,734
OVERWINTER SURVIVAL RATE		27.37%		61.13%		58.42%		50.27%		64.70%
		Pre-Project		1st Post Project		2nd Post Project		3rd Post Project		4th Post Project

Note:
The calculated overwinter survival rate does not include the winter contribution of the small tributaries in the Green River 6th field. Annual spot checks in some of these tributaries during the winter inventory indicated that additional Coho production was present. Therefore the stated overwinter survival rates represent a minimum estimate.

Each winter inventory was an exact replicate of effort which included surveying to the end of Coho distribution on mainstem Green River and to the top of the last interactive floodplain on EF Green (above the culvert crossing that was removed in 2002). These tributary contributions would be small in comparison to the mainstem during most winters because of the downstream migration to the mainstem that was noted in each winter inventory.

Each of the stream contributions has been corrected for the visual bias that was calculated from electrofish calibrations for both winter night time effort and summer day time effort. These calibration factors are designed to portray a more accurate estimate of true rearing densities throughout a range of variable habitat complexities. The calibration factors are as follows:

n x 1.20 for summer estimates of all habitat complexities
n x 1.23 for winter nocturnal estimates in low and medium complexity habitats
n x 1.89 for winter nocturnal estimates in high complexity habitats

Table 24. Population midpoints measured as River Mile where cumulative count begins to exceed 50% of total count.

	Green River		EF Green River	
Year	Summer	Winter	Summer	Winter
2001	3.86	nd	0.89	nd
2002	4.36	2.77	0.87	0.50
2003	3.86	3.20	0.51	0.32
2004	3.05	2.34	0.80	0.54
2005	4.09	2.21	0.79	0.81
2006	4.13	2.50	0.90	0.74

Appendix 1. An evaluation and calibration of winter juvenile Coho snorkel counts

Introduction

Rapid Bio-Assessment ("RBA") is a method for quantifying stream fish populations that has been successfully used by Oregon coastal Watershed Councils for eight years to evaluate the summer distribution and abundance of juvenile salmonids on the 6th field scale. In this method, snorkeling is utilized to visually identify and count juvenile salmonids without removing them from the stream. The standard protocol samples every 5th pool utilizing a random start.

Considerable effort has been expended during these inventories to evaluate the accuracy of the method. The gist of these findings is that summer snorkel inventories for Coho during the summer are replicable, with visual estimates typically underestimating the actual number by less than 20 percent. The "calibration coefficient" for summer snorkel surveys is thus generally set at 1.20. The actual rate for any given pool can vary under several influences, principally diver expertise, pool cover complexity, stream width, water clarity, and species specific behavior.

The RBA method was also utilized during this effort for winter night inventories of juvenile salmonids. Winter population data provides a basis for detecting seasonal shifts in population size and distribution, and for evaluating the success of in-stream structure projects intended to improve winter habitat. There is precedence for this approach. Roni and Fayram (2002) found that nocturnal snorkel counts do not significantly differ from estimates produced by daytime multi-pass reduction electrofishing.

This encouraged us to conduct winter nocturnal snorkel inventories and to compare estimates produced by this method with those produced by daytime electrofishing. Ratios of estimates produced by the two methods can then be used to calibrate future diver counts.

A winter-time study of this type was cooperatively conducted by Bio-Surveys and ODFW research staff during 2002. The study included day and night snorkel diver surveys as well as electroshock mark and recapture estimates. This approach provides comparisons among three types of survey techniques, the principle interest being how well winter night diver counts compare with estimates produced by electrofishing, a sampling method of known reliability.

The study site was a short 300 meter segment of the mainstem of Lobster Creek, a tributary of Five Rivers in the Alsea basin. Lobster Creek is a 4th order subbasin with an average winter active channel width of 13.2 meters. This stream was selected for the study because high summer rearing densities of Coho have been observed in it and because it offers good visibility during storm events that otherwise shorten the sampling window. In addition, this segment of Lobster Cr is representative of high quality Coho habitat for the mid coast of the Oregon coast range.

The following data were collected for each of the six Lobster Creek sample pools:

1) Replicate day snorkel counts by two experienced snorkel divers. Diver expertise strongly affects both identification and count accuracy.
2) Night snorkel diver counts by the same two snorkelers.
3) Electroshock mark and recapture estimates of pool population size. Although electrofishing does not provide a true census of a pool population, it is generally reliable and is commonly used to evaluate snorkel count effectiveness.
4) Night-time water temperature. Fish activity level, feeding, detachment from cover and other behaviors are influenced by temperature, and these behaviors affect snorkel count efficiency. Note that day temperature varied little from night temperature in this study.
5) Pool complexity (rated 1-5 on an ascending scale based on the amount of cover provided by wood, large substrate, overhanging vegetation, and undercut banks). The more complex the cover, the more difficult fish observation.

6) Pool dimensions. The wider the stream, the greater the chance that a fish can swim by the snorkeler unnoticed.

Additional day/night snorkel counts are available for pools surveyed in Green River and EF Green River during the winter of 2002 as part of an on-going RBA monitoring program. While electrofish estimates are not available for these pools, the snorkel data allowed further investigation of the relation between day and night snorkel counts, as well as their relation to cover complexity.

Methodology

Lobster Creek

Six pools of different levels of cover complexity in Lobster Creek were snorkeled twice during the day by different divers and then twice again at night. On the following day, these same pools were blocked with fine mesh nets at pool head and tail and electrofished to produce mark-and-recapture estimates of number of fish in each pool. Each pool was rested at least 30 minutes between snorkel events to allow fish to return to pre-disturbance behavior.

Electrofishing used three 1,000 volt Smith Root backpack shockers, which were operated simultaneously to broaden the field of effective galvanotaxis. Captured fish were measured and caudal fin clipped without anesthetization, allowed to recover at least two hours, and then released back into the blocked pool. Recapture was initiated after an additional two hours to allow the fish to re-orient to pool structure. The same capture method described above was used in the recapture process.

All of the work occurred February 10 to 26, 2002 during receding flow conditions, with night stream temperatures between 3 and 6 deg C. Water clarity was excellent throughout the study.

Complexity ratings were re-classified from the original scale of 1-5 to “High” (4 and 5) or “Medium” (2 and 3) to group data for analysis. Note that Low complexity pools were not included in the sampling program because such pools typically have too few fish to justify inclusion in this limited study.

Water temperature at the time of sampling varied between 2.50 and 5.56 degrees C. As a matter of preliminary investigation, we divided the pools into the four pools having temperatures greater than 5 degrees C, and the 2 pools less than 5 degrees C. With two snorkeler counts per pool, this provided 10 counts for the higher temperature pools and 4 counts for the lower temperature pools.

Green River and EF Green River

Day and night winter snorkel counts are available for 62 pools in Green River and 15 pools in EF Green River. Pool complexity and size data, but not temperature, are included in these studies. A single snorkel count was made in each pool during the day and then again during the night.

The RBA snorkel protocol differs in one respect from that of the Lobster Creek study. During RBA sampling, water clarity and pool width are assessed for each pool to determine if complete side-to-side visibility is possible. If not, then two divers simultaneously survey the pool instead of one. In the Lobster Creek study, only one diver was needed despite the wide aspect of the stream, because water clarity was high.

Data analysis

The primary goal of the study was to create expansion factors that can be used to elevate snorkel count data to estimates of pool population size. This is accomplished by calculating the average ratio of electrofishing estimate to snorkel count. It was also helpful to view the relationship as “what fraction is the snorkel count of the electrofish estimate”, which is the average ratio of snorkel count to electrofish estimate.

The two ratios are related, but each must be calculated independently: Mathematically, the reciprocal of one average is not the other average.

The ratio can be seen graphically as the slope of the line when snorkel count is charted against electrofish estimate. Log and square root transforms did not improve linearity of this relationship for the Lobster Creek data, which is limited to six pools having moderate to large Coho populations. However, the Green River/EF Green River displays better with a sqrt+0.5 transformation, and is presented in this mode.

Zero counts created problems of division when calculating ratios that were not satisfactorily resolved by adding constants to the counts. For this analysis, data pairs involving zeros were omitted.

Results

Lobster Creek

Data description

Table 1 lists the physical characteristics of the sample pools. Table 2 shows the electrofish mark and recapture data and resulting estimates of population size and variance. Table 3 lists the day and night snorkel counts.

Diver expertise and count replication

Replicate night counts of the same pool are extremely close, and replicate day counts are also very close (Figures 1 and 2; Table 4). Our assessment is that differences between divers had little influence on the relation between snorkel counts and electrofish estimates in this study. This may be explained by the fact that the two divers have considerable experience and have worked together for many years.

Pool width effects

Pool size varied insufficiently in the six sample pools to warrant analysis.

Water temperature effects

We found that the average daytime snorkel to electrofish estimate ratio was distinctly lower for the lower temperature group than for the higher temperature group (Table 5). This distinction did not hold true for night snorkel observations.

Pool complexity effects

The average ratio of snorkel count to electrofish estimate was lower for high complexity pools than for low complexity pools (Table 4). This difference is substantial for both day surveys (0.46 vs. 0.25) and night surveys (0.84 vs. 0.54). The 0.84 night ratio for medium complexity pools is similar to that found in previous studies aimed at calibrating daytime summer snorkel surveys.

Night snorkel counts vs. electrofish estimates

The relationship between night snorkel count and electrofish estimate appears to be clearly defined with little scatter (Figure 1). It is probable that the relationship is curvilinear with a decreasing slope. That is, proportionally fewer fish are probably seen by the snorkeler as the pool population increases. However, we lack sufficient data in the 0 to 100 fish range to properly define the curve.

Day snorkel counts vs. electrofish estimates

In contrast to the night count vs. electrofish relationship, the day count vs. electrofish relationship exhibits no pattern at all (Figure 1). Replicate snorkeler counts agree well, as in the night vs. electrofish presentation.

Day vs. night snorkel counts

The average ratio of day to night count is slightly higher for medium complexity pools than for high complexity pools (Table 7). There is no discernable pattern when the data are charted (Figure 3).

Green River and EF Green River

Diver expertise and count replication

The RBA protocol does not include diver count replication.

Pool width effects

The effect of pool width on the relative performance of day and night snorkel counts could not be assessed with these data because the RBA protocol employs two divers working together when conditions of pool width and/or water clarity appear likely to reduce count accuracy.

Water temperature effects

Temperature data are not available.

Pool complexity effects

The average ratio of day to night snorkel count appears to increase with pool complexity (Table 8). At high pool complexity, the ratio exceeds 1.0 (day counts tend to exceed night counts).

Day vs. night snorkel counts

Figure 4 charts night vs. day snorkel counts. Note that the counts have been transformed by adding a constant 0.5 and then by the square root function. Despite considerable scatter, a positive slope is suggested.

It is apparent in Figure 4 that day counts produce more zero counts than night counts. The general superiority of night counts over day counts is seen in the following summary:

- Total fish observed in the 77 pools: Day = 765, Night = 1330.
- Average of Night Count minus Day Count: 9.3 fish.
- Number of pools where the day count was zero, and the night count exceeded zero: 11
- Reverse of above: 1.
- Number of pools where the day count exceeded the night count: 16.
- Reverse of above: 45.

Discussion

Day vs. night surveys

The Lobster Creek data, although quite limited, show a very strong relationship between night snorkel counts and electrofishing estimates. On the other hand, the day snorkel counts are highly variable and exhibit no definable relationship to either electrofish estimates or night counts.

The more extensive Green/EF Green data suggest that a reliable relationship may exist between day and night snorkel counts, and by extension perhaps between day counts and electrofish estimates. However, the day vs. night relationship becomes highly tenuous at low counts. Specifically, there appears to be a much greater likelihood that a zero day count will occur when the night survey finds fish than the other way around. That is, night surveys are more likely than day surveys to find fish in sparsely populated pools.

It would be desirable to identify what factors contribute to zero or greatly reduced day counts in pools where night surveys or electrofish capture finds several to many fish. Based on very limited data, we speculate that changes in fish behavior relating to temperature change may be one of these factors, acting in the following manner: After a freshet, clearing weather and receding stream levels commonly produce a drop in stream temperature. Under these conditions, Coho tend to be less active and more cover oriented during the day. Under the same conditions, Coho appear to be less cover-oriented at night. This behavioral pattern may produce much of the variability and reduced observation rates found in daytime snorkel counts when compared to nighttime counts.

In this context, we believe that daytime winter counts at specific sites such as a particular pool or structure may provide reliable data when winter stream temperatures are elevated (>6 deg C) sufficiently to stimulate fish movement. This approach could then be useful when assessing conditions at or near restoration sites. However, the best method for assessing reach-level population changes appears to be night snorkeling.

Overall, we conclude that night counts are more reliable than day counts, especially in low count pools. This was the expected result, as well as a primary impetus for the Lobster Creek study.

Defining the snorkel:electrofish relationship

We need to better define the snorkel count vs. electrofish estimate relationship for sparsely populated pools (which typically are low complexity pools). Does the ratio found at higher counts hold true? Or, is the relationship curvilinear? If the latter, what transformation best represents the pattern (linearizes the relationship and randomizes the residuals)? How are the various influences (pool complexity and width, temperature, etc) factored in?

Sufficient low count data needed to define this part of the relationship are difficult to obtain. In a pool with one to a few fish, missing a single fish by either sampling method can have a large effect on the ratio estimator. In addition, data points that involve one or two fish often generate extremely large or small ratios and thus excessive scatter. A few such points can distort an otherwise much more consistent relationship found for higher count pools.

The Lobster Creek sampling approach was to avoid these problems by focusing on medium and high complexity pools known to support a substantial Coho population. We therefore currently lack winter snorkel vs. electrofish data that define the relationship in the low count range.

Calibration

Conversion of snorkel counts to electrofish estimates could use two basic approaches: The equation of a fitted curve, or a table of conversion ratios (expansion factors). Current data are insufficient to support development of an equation. Thus, we default to a tabular approach. As described, day counts proved to be too variable to generate reliable conversion ratios.

The table of conversion ratios to calculate probable electrofish estimates from night snorkel counts might be based on one to several predictor variables, including diver expertise, pool complexity, pool dimension (principally width), water temperature, and as yet undefined stream-specific conditions. At this point, we really only have useful data concerning pool diver expertise and complexity, with diver expertise a minor effect in the current data. This leaves us with pool complexity, which we believe is a highly important influence on both Coho selection of pools and on snorkel count effectiveness.

Current data are limited to pools of medium and high complexity, and because Coho favor pools of higher complexity, sample pool populations were also generally high. Lacking data for low complexity pools with few to no fish, we assigned the medium complexity ratio to low complexity pools, to produce the following working calibration table:

	Pool Complexity		
	Low	Medium	High
Day snorkel count	Not defined	Not defined	Not defined
Night snorkel count	1.23	1.23	1.89

These expansion factors represent average ratios of electrofish estimate to snorkel count data from the Lobster Creek study. The values are likely to change as more information becomes available.

Figures

Figure 1. Relation between night snorkeler counts and electrofish mark and capture estimates of juvenile Coho in Lobster Creek sample pools.

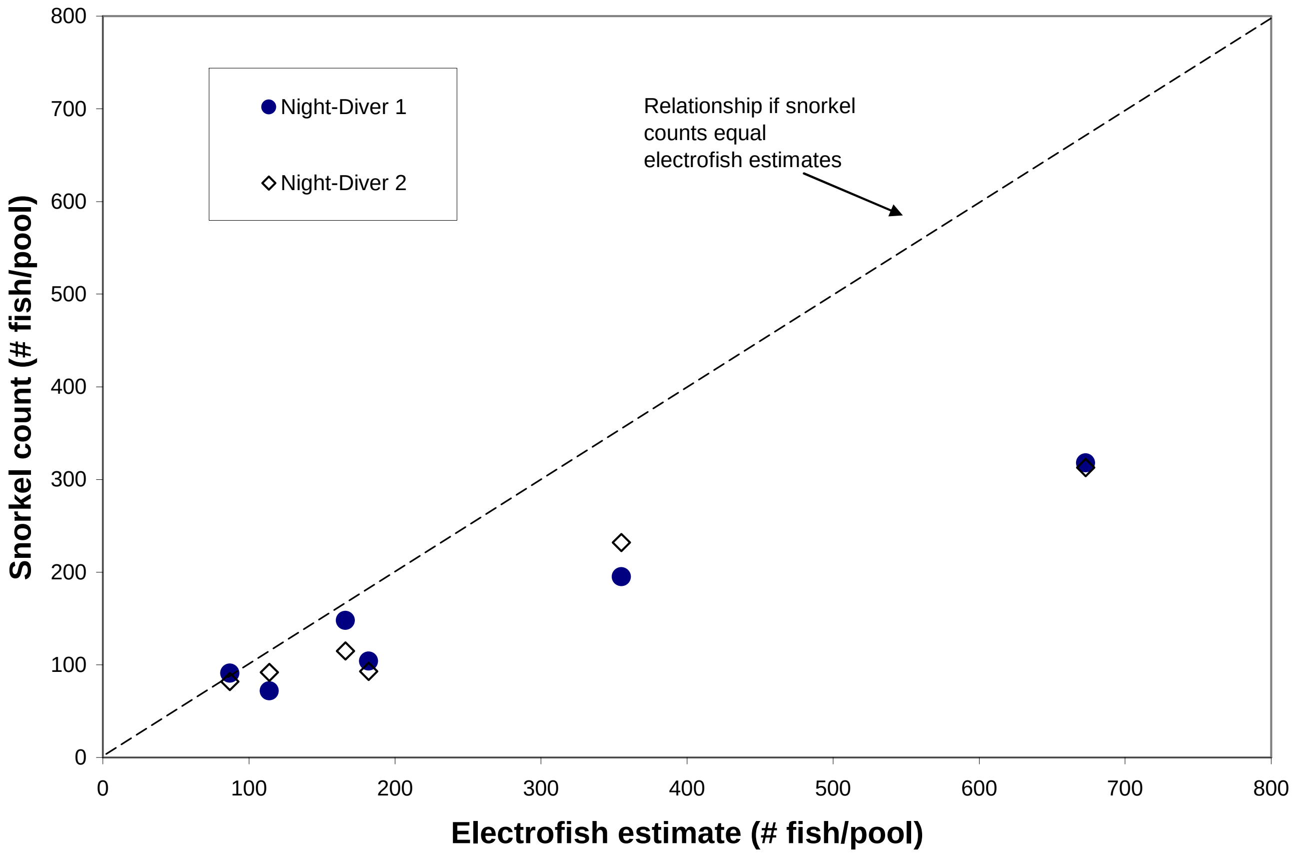


Figure 2. Relation between day snorkeler counts and electrofish mark and capture estimates of juvenile Coho in Lobster Creek sample pools.

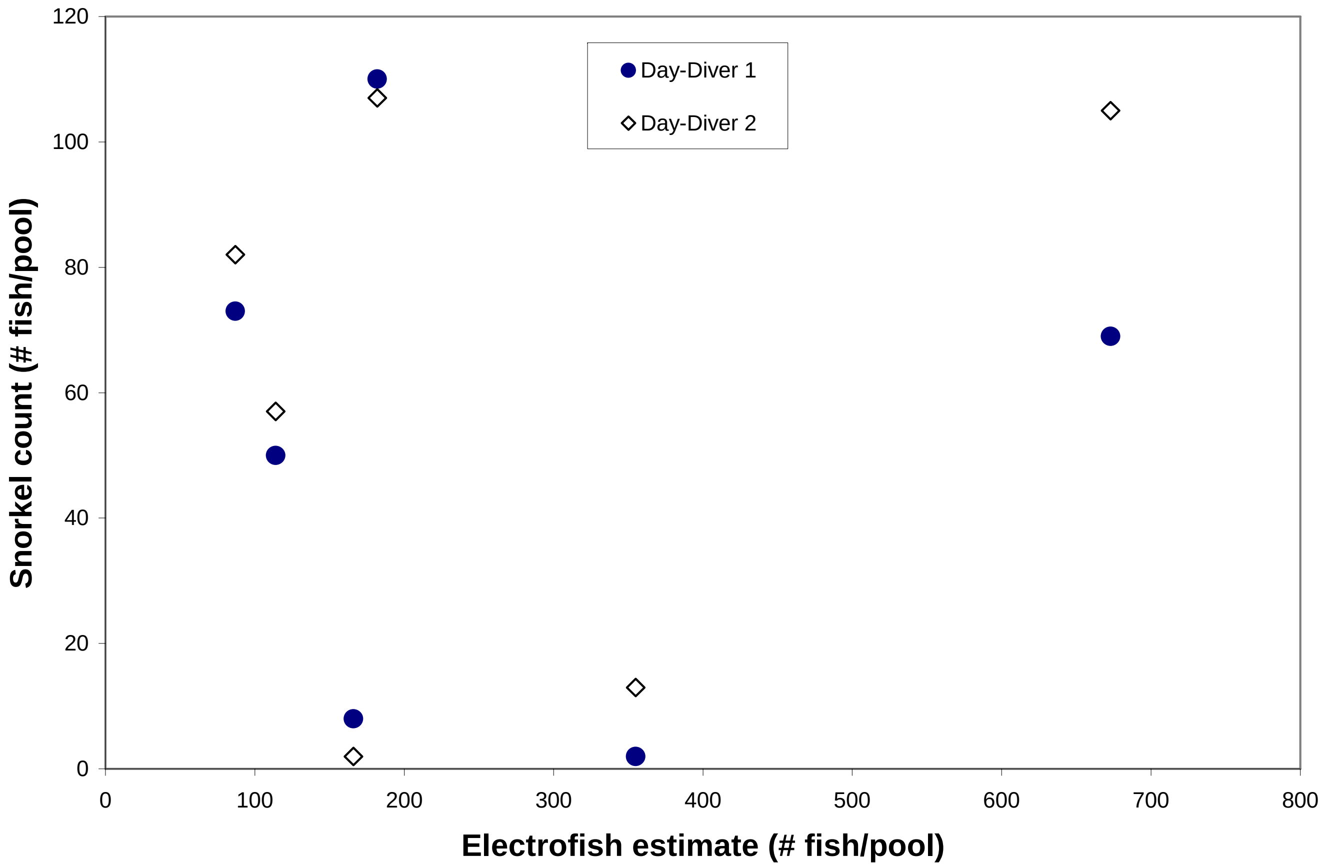


Figure 3. Relation between day and night snorkeler counts of juvenile Coho in Lobster Creek sample pools.

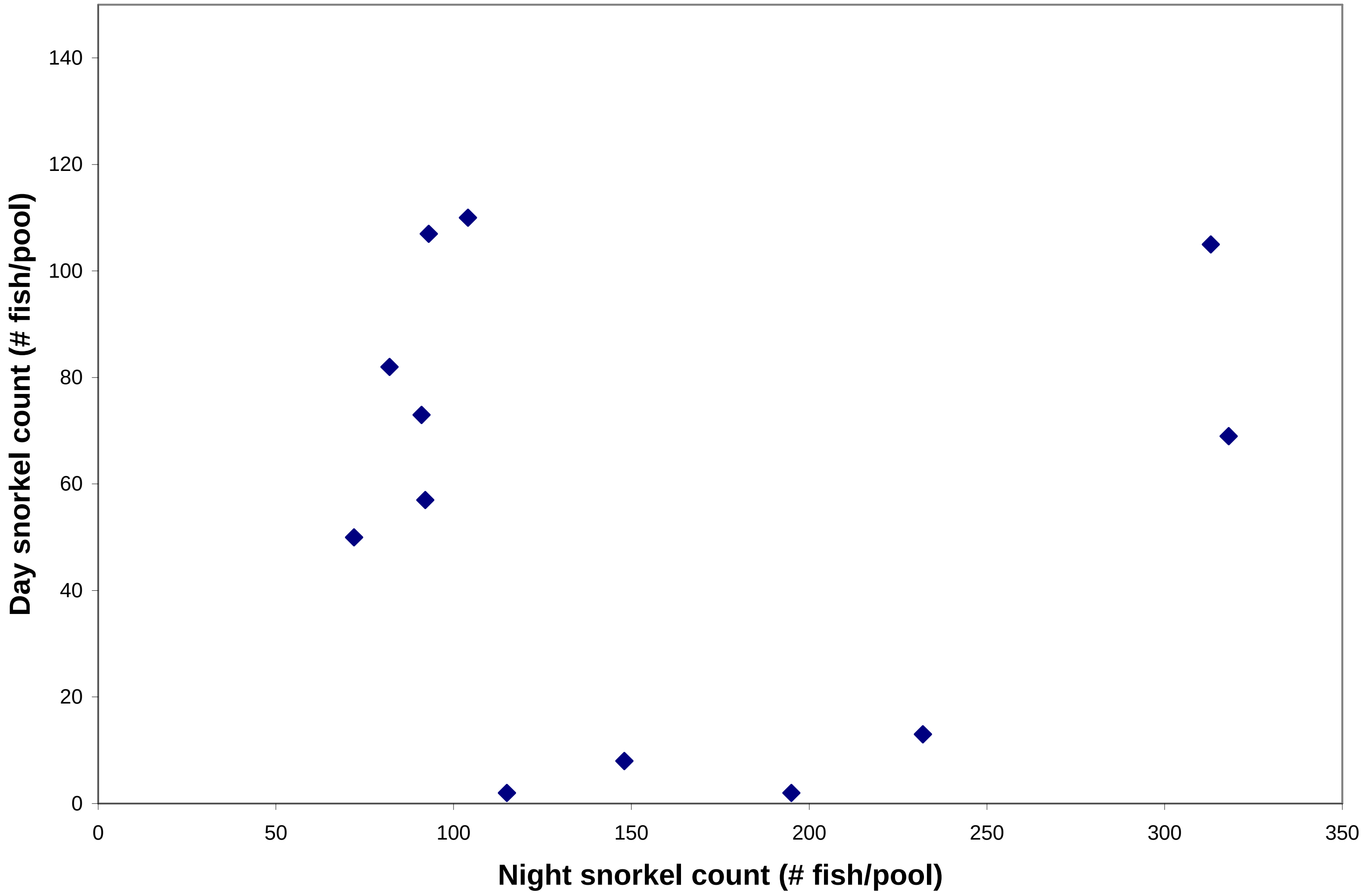
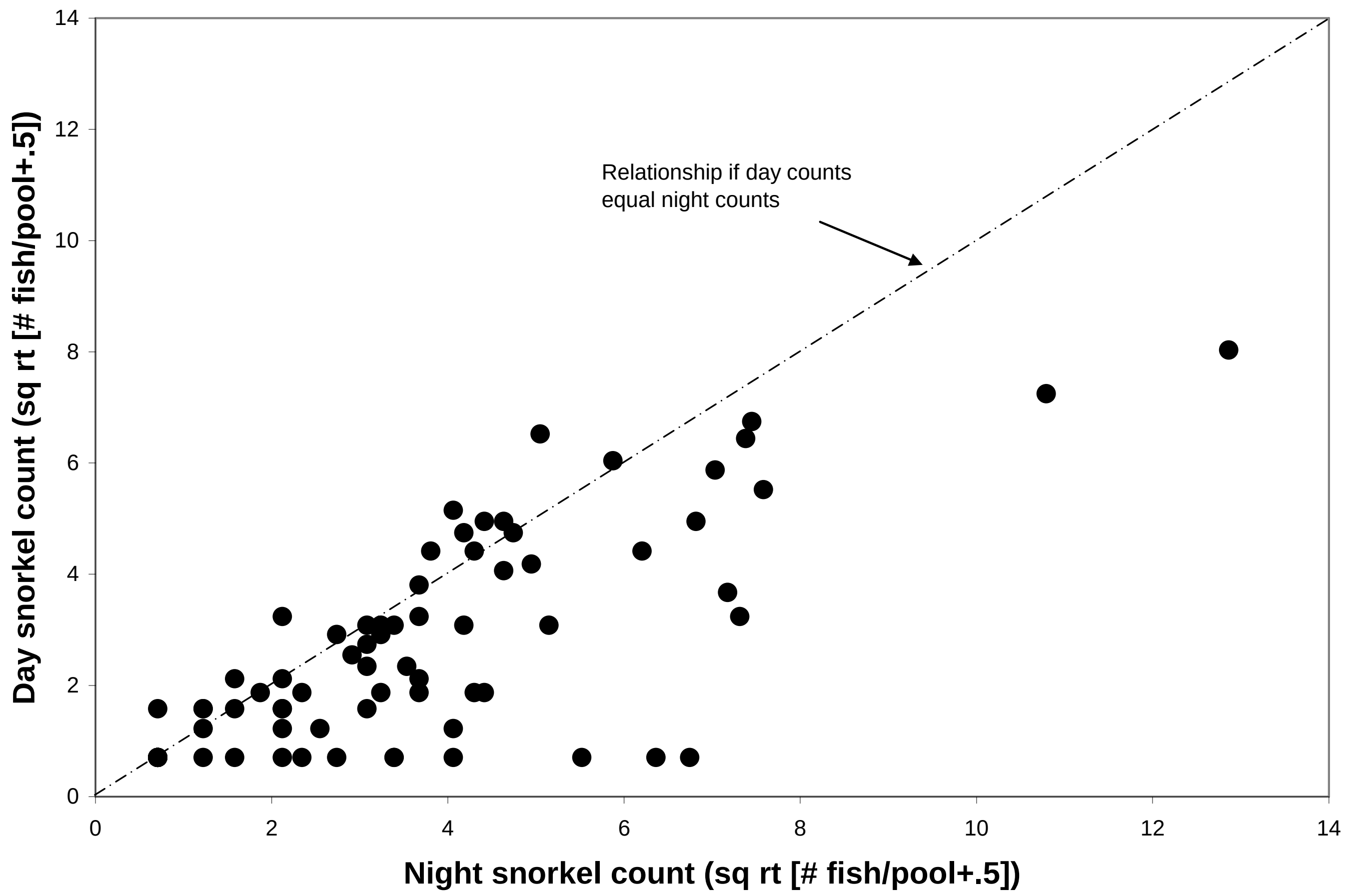


Figure 4. Relationship between night and day snorkel count, Green River and EF Green River, 2002



Tables

Table 1. Description of Lobster Creek sample pools.

Pool #	Pool Type	Length (m)	Width (m)	Complexity Rating	Date	Night Temperature (C)
1	Lateral scour	50.3	14.3	Medium	2/10/2002	3.33
2	Lateral scour with backwater	31.1	14.6	High	2/11/2002	2.5
3	Lateral scour	39.3	13.4	High	2/12/2002	3.33
4	Lateral scour	31.7	14.6	Medium	2/10/2002	3.33
5	Alcove	13.4	2.4	High	2/26/2002	5.56
6	Lateral scour	32.3	10.4	Medium	2/26/2002	5.56

Table 2.Lobster Creek electroshock captures and pool population estimates (Jeff Rogers, ODFW Research).

Pool #	Initial Catch	Marks Released	Total Fish Recaptured	Marks Recaptured	Mortalities at Recapture	Population Estimate	Variance	95 % CI	CI % of Estimate	Density (Fish/m2)
1	82	80	88	43	2	166	137.78	23.06	13.89	0.23
2	234	230	309	106	4	673	1,457.81	75.03	11.15	1.48
3	188	185	171	90	2	355	323.13	35.32	9.95	0.67
4	39	39	56	19	0	114	200.86	27.85	24.43	0.25
5	69	65	80	29	4	182	351.80	36.86	20.25	5.57
6	61	59	53	37	2	87	20.25	8.84	10.16	0.26

Table 3. Lobster Creek snorkel counts.

Pool #	Day		Night	
	Diver 1	Diver 2	Diver 1	Diver 2
1	8	2	148	115
2	69	105	318	313
3	2	13	195	232
4	50	57	72	92
5	110	107	104	93
6	73	82	91	82

Table 4. Effect of snorkeler on average ratio of snorkel count to electrofish estimate, Lobster Creek.

	Snorkeler	
	1	2
Average day count/electrofish estimate	0.34	0.37
Average night count/electrofish estimate	0.69	0.68

Table 5. Relation between temperature and ratio of snorkel count to electrofish estimate, Lobster Creek.

	Temperature Level	
	Greater than 5 degrees C	Less than 5 degrees C
Average of Day/MR	0.74	0.16
Average of Night/MR	0.77	0.65

Table 6. Effect of pool complexity on average ratio of snorkel count to electrofish estimate, Lobster Creek.

	Pool Complexity	
	Medium	High
Average day count/electrofish estimate	0.46	0.25
Average night count/electrofish estimate	0.84	0.54

Table 7. Effect of pool complexity on average ratio of day to night snorkel counts, Lobster Creek.

	Pool Complexity	
	Medium	High
Average day/night snorkel count ratio	0.53	0.47

Table 8. Relation between pool complexity and average ratio of day to night snorkel count, Green River and EF Green River (excludes 23 pools having either day or night counts of zero; sample size in parentheses).

	Complexity Group			
	Low	Medium	High	All
EF Green	2.00 (1)	0.88 (12)	(none)	0.96 (13)
Green	0.17 (4)	0.76 (22)	1.10 (15)	0.77 (41)
All	0.63 (5)	0.79 (33)	1.09 (15)	0.81 (52)

Appendix 2. Data coding and interpretation used in the analysis of the Crab Creek physical habitat survey data (ODFW AQI survey protocol).

Habitat type interpretation

Code	General habitat type	Specific habitat type	Select for habitat analysis
AL	Pool	Alcove	Yes
BP	Pool	Beaver Pond	Yes
BW	Pool	Backwater	Yes
CB	Riffle	Cascade over boulders	Yes
CC	Other	Culvert crossing	Excluded habitat
CR	Riffle	Cascade over bedrock	Yes
DC	Other	Dry channel	Excluded habitat
DP	Pool	Dammed pool	Yes
DU	Other	Dry unit	Excluded habitat
GL	Glide	Glide	Yes
IP	Other	Isolated pool	Excluded habitat
LP	Pool	Lateral scour pool	Yes
PD	Other	Puddled	Excluded habitat
PP	Pool	Plunge pool	Yes
RB	Riffle	Rapid with boulders	Yes
RI	Riffle	Riffle	Yes
RP	Riffle	Riffle with pockets	Yes
RR	Riffle	Rapid over bedrock	Yes
SB	Step	Step over boulders	Excluded habitat
SC	Step	Step over cobble	Excluded habitat
SD	Step	Step over beaver dam	Excluded habitat
SL	Step	Step over logs	Excluded habitat
SP	Pool	Straight scour pool	Yes
SR	Step	Step over bedrock	Excluded habitat
SS	Step	Step over structure	Excluded habitat
TP	Pool	Trench pool	Yes

Channel type interpretation

Code	Channel type
0	Mainstem primary
1	Mainstem primary
2	Mainstem side
3	Mainstem side
4	Mainstem side
5	Mainstem side
6	Mainstem side
10	Subunit pools
11	Tributary primary
12	Tributary side

Appendix 3. Data coding and interpretation used in the analysis of the Green River and EF Green River physical habitat survey data (USFS survey protocols).

Survey year	Code	Channel type	General habitat Type	Specific habitat type	Select for habitat analysis
2000	PD	Mainstem primary	Pool	Dam pool	Yes
2000	PB	Mainstem primary	Pool	Beaver pond	Yes
2000	RR	Mainstem primary	Riffle	Rapid	Yes
2000	RI	Mainstem primary	Riffle	Riffle	Yes
2000	R	Mainstem primary	Riffle	Riffle	Yes
2000	S	Mainstem side	Side channel	Side channel	Yes
2000	T	Tributary primary	Tributary	Tributary (first unit)	Excluded habitat
2000	D	Mainstem dry	Dry mainstem channel	Dry mainstem channel	Excluded habitat
2000	C	Culvert	Culvert	Culvert	Excluded habitat
2000	RC	Mainstem primary	Riffle	Cascade	Yes
2000	P	Mainstem primary	Pool	Scour pool	Yes
2000	F	Special Case	Special Case	Special Case	Excluded habitat
2006	LATERAL	Mainstem primary	Pool	Scour pool	Yes
2006	MIDCHNL	Mainstem primary	Pool	Scour pool	Yes
2006	PLUNGE	Mainstem primary	Pool	Scour pool	Yes
2006	RAPID	Mainstem primary	Riffle	Rapid	Yes
2006	RIFFLE	Mainstem primary	Riffle	Riffle	Yes
2006	SLOW	Mainstem side	Side channel	Side channel	Yes
2006	FAST	Mainstem side	Side channel	Side channel	Yes
2006	Debris	Mainstem primary	Pool	Dam pool	Yes
2006	CONVERGE	Mainstem primary	Pool	Scour pool	Yes
2006	BVRDAM	Mainstem primary	Pool	Beaver pond	Yes
2006	CHUNIT	Off channel	Channel unit	Off channel	Excluded habitat

Appendix 4. Methods used to estimate Coho seasonal rearing capacity and potential smolt production

A principle tool used to quantify the number of Coho that can be reared in a given section of a stream is the Nickelson Model. The analysis is based on the premise that each type of pool, riffle, glide, and rapid is able to support a certain density of Coho during each season. These rearing densities vary by the season, and we have suitable information for the summer season. The summer rearing densities used in the current analysis are listed below.

Habitat type	Fish/sq m
Cascades	0.24
Rapids	0.14
Riffles	0.12
Glides	0.77
Trench Pools	1.79
Plunge Pools	1.51
Lateral Scour Pools	1.74
Mid Chan Scour Pools	1.74
Dam Pools	1.84
Alcoves	0.92
Beaver Ponds	1.84
Backwaters	1.18

Data of Tom Nickelson based on ODFW research.

Physical habitat surveys provide estimates of the amount of each habitat type, and these estimates are multiplied by the appropriate density values in the table to generate estimates of summer rearing capacity.

Smolt potential is calculated as the number of fish expected to survive from summer rearing to smolt age, based on estimates of season-to-smolt survival rates (e.g., summer to smolt, . We have two sets of survival rates, one provided by ODFW and the other by Jim Hall (Alsea Watershed Study). They are quite different and often generate quite different estimates of smolt production. We use the products of these calculations in a “what if” frame of thinking to bracket the widest probable range of values, with the intent of identifying worst and best case outcomes. The two sets of survival rates are listed below.

ODFW Research		Jim Hall	
Life stage	Survival rate	Life stage	Survival rate
Egg to smolt	0.3200	Egg to smolt	0.0270
Spring to smolt	0.4600	June to Smolt	0.0644
Summer to smolt	0.7200	Fall to smolt	0.1110
Winter to smolt	0.9000	Winter to smolt	0.2870

Several factors can limit the usefulness of this type of analysis:

- Typically, only summer data are available. Winter and spring inventories are almost never conducted.
- Habitat inventories may be lacking altogether within a sub-watershed, or may miss important Coho-bearing reaches.
- Inventory protocols often vary among agencies (e.g., trench pools may be identified in one survey, but not in another).

- Variable surveyor experience and point of view can generate variable data sets (e.g., one surveyor may see a glide where another sees a pool tail out).
- Habitat conditions can change year to year, sometimes dramatically. High water years can change habitat structures. Beaver can move into or out of a drainage, or be removed for management purposes. Slope failures, natural timber recruitment, logging and similar events can introduce large amounts of soil and wood into a channel.
- The model relies on a highly simplified view of the Coho life cycle and the forces that control season to season survival.
- Model results depend heavily on assumptions made about season to season survival rates, and these rates are both evasive and debatable.

We attempt to address these problems in the following ways:

- To estimate winter rearing capacity, we use an empirical polynomial regression equation provided by ODFW that predicts smolt rearing density based on summer inventory data describing channel gradient, % pools, number of beaver ponds, active channel width, and reach length.
- The spring season is ignored in the analysis.
- Where possible, we approximate missing reach habitat data with information collected in nearby reaches, or with habitat sub samples collected during RBA surveys.
- We run the model using two sets of survival rates. One set is provided in ODFW Information Report 98-4, and the other set is based on the unpublished data of James Hall at Oregon State University. The two sets of rates vary in their assumptions about survival, and thus provide outputs that express alternative views of seasonal rearing potentials. More specifically, the ODFW survival rates are higher than those of the OSU study because they assume that only density independent mortalities occur, while the OSU rates are based on population studies where all forms of mortality occurred.

Clearly, the model's output should be seen as just one guideline in a decision making process that necessarily relies heavily on the professional judgment of the biologists conducting the assessment as other information is reviewed.

Some very important habitat conditions which are not adequately evaluated during physical habitat surveys must also be considered. These include sediment loading and elevated summer temperature. Information on these topics is commonly sparse.

Appendix 5. Comments on observed seeding levels

ODFW research suggests that the full seeding level for juvenile Coho in Oregon coastal streams is about 1.65 fish/m2. In the current project, winter densities occasionally, but not regularly, exceeded this level. However, summer densities commonly exceeded this value in all three streams, sometimes approaching 6 fish/m2.

We interpret this as the effects of peak spawning where high quality gravels were abundant. In addition, late emergence could help explain some of these higher densities where late spring freshets were not occurring to spread emergent fry downstream from the sites of incubation.

The occurrence of high density throughout the summer is generally thought to result in reduced juvenile growth rates, poor condition, and reduced survival rate to smolt.

Appendix 6. Winter habitat assessment

The problem of summer vs. winter habitat assessment

The habitat needs of juvenile Coho salmon vary by temperature, season, and conditions of water level and flow rates. During the warm, low flow conditions of summer, the primary habitat requirements revolve around the acquisition of food and protection from predators. These needs are met primarily in pools and riffle pockets, which can be competently observed and enumerated by summer habitat inventories.

During the cold, high flow conditions of winter, the primary habitat requirements revolve almost exclusively around the need for protection from high water velocities. The conditions that provide this protection are dynamic in nature, less easily defined than those of summer habitat, and are typically not well documented in summer habitat inventories. There is need for both a better understanding of how slow water habitat is formed and how to evaluate it.

Because instream structure placement radically alters winter habitat conditions and winter habitat conditions are often cited as the primary limitation to survival, it follows that the appropriate metrics of change in channel structure and habitat abundance should be gathered that focus on the development of low velocity habitats both within the channel prism and on associated floodplain terraces.

As discussed in the Methods section, the approach taken here was to create a structured questionnaire form to capture the significant morphological relationships potentially altered by the introduction of instream structure wood. The questions posed often can not be answered using summer habitat inventory data. We believe the methods used in habitat inventories need revision to address these important questions.

Wood complexity

Explanation

Wood complexity is an entirely different metric than the wood counts utilized in most Aquatic Habitat Inventory protocols that are typically compared to a standard. Complexity reaches beyond quantification and evaluates the actual function of wood and wood complexes. Each wood structure is variable. It can be a single piece or a conglomeration of multiple pieces and sizes. It can be in the thalweg or off-channel outside the channel prism.

In general, higher complexity is associated with wood jams that contain 3 or more well anchored wood components that are effectively capturing and retaining transient woody material and canopy litter. Single or double wood structures are also generally low complexity without the capability of retaining these same transient components.

Importance

Any complex woody structure of 3 or more well anchored pieces that incorporates low velocity off channel surface area is a winter habitat magnet for juvenile salmonids. These sites can be responsible for highly disproportionate winter rearing potential. It is highly likely that these sites and their frequency may be the single greatest driver for improving the over winter survival of salmonid juveniles to the smolt stage. Take into consideration that the majority of interactive floodplain surface areas are typically only accessible during higher winter flow events whereas a well anchored and seasoned wood structure can function full time at any flow regime for the provision of low velocity refugia.

Channel complexity and floodplain interaction

Any discussion of Coho life history and habitat requirements must include the topics of channel complexity and floodplain interaction: Coho behaviors are adapted to and function best in complex channels; channel complexity generates floodplain interaction; floodplain interaction creates and maintains essential winter habitat for Coho.

Channel complexity refers to the structural features of wood, rock, overhanging banks, and deep pools occurring within meandering and braided channels. The floodplain is the terrestrial zone adjacent to the active channel but outside the channel prism that is inundated during high runoff. This inundation essentially expands the channel edge, which in simplified channels is the primary location of slow water that offers safety from the high velocities within the main flow. Floodplain interaction refers to how frequently and how effectively flows exit the channel to cover and modify the floodplain. Complex channels create floodplain interaction by resisting flow and by providing channel grades which are near floodplain elevations.

The main flow, where the central force and volume of flow occurs, is called the thalweg. In a straight scour pool or a riffle, the thalweg is positioned center channel. However, in a lateral scour pool, the thalweg runs along the outside of the channel curve, where it creates scour and depth. On the inside of the curve, the water slows, forms eddies, and releases suspended fines to form soft substrates and create zones of low velocity refugia.

Floodplains and terraces

Floodplains typically contain terraces created when water escapes the dominant channel prism. Channel constriction, flow volume, gradient and valley form are the primary factors that interact to form functional floodplains. Constrictions occur wherever water encounters objects that resist flow. For example, the channel may become more narrow or sinuous; it may contain obstacles such as large wood; an encroaching hillslope may confine the channel and restrict flow or the influence of an incoming tide can cause flow restriction.

All of these conditions slow and elevate flood waters upstream of the constriction. The elevation of flow forces water outside the channel prism. At these locations the scouring force of water that was confined to the channel prism dissipates creating low velocities and allowing fine sediments to drop out. Depositions of this type can create terraces.

Multiple terraces are created by different flow regimes above and beyond the elevation of the active summer channel. In addition, when a channel changes course, it may cut through old terraces. The floodplains of most streams therefore contain terraces at variable heights above the active summer channel. Each of these terraces reflect a unique level of inundation frequency.

It is common to refer to exceptional high water events and the terraces they have created in terms of how frequently such events occur. Thus there are 100, 50, 25, and 10 year floods events and their associated terraces. There is also a “mean annual floodplain” or “mean annual bankfull” which will be referred to later. However, these are all arbitrary reference points in a continuum of flood and terrace elevations.

High terraces are rarely flooded, of course, while the lowest terraces are flooded on a regular basis – perhaps many times during a winter. In addition, the higher a terrace, the less frequently it is subject to the deposition of fine sediments and thus the more consistent its elevation relative to the active stream channel.

Moving down a stream valley, terraces created by a 100 year flood are easily identified and can be observed as originating from a common event by their elevation and vegetation type. The 25 and 50 year terraces begin to exhibit less stability in vegetation class and are more variable in elevation. This variability exists because they have been created by more interaction with active channel features such as debris flow jams and the recruitment of riparian vegetation. In addition, variable water levels are interacting to create erosion and deposition. The lowest terraces (higher frequency inundation, 3-5 year) form a dynamic, variable, and complex system of off channel habitats that are most significant for juvenile salmonids and their winter habitat requirements.

A complex channel system with a high level of floodplain interaction creates the most diverse and favorable conditions for juvenile Coho salmon seeking slow water refuge during peak flows. At the other end of the scale, a simplified channel that interacts poorly with its floodplain offers very few opportunities for escape from high velocity winter flows.

The conditions on low terraces interest us greatly when investigating the character of Coho winter low velocity refugia. This is because these are areas of slow water close to the active channel which are frequently flooded and available to Coho during times of critical high flow.

In describing low terraces, we are therefore defining a highly important winter habitat for juvenile Coho and other small salmonids. The low terrace system, as well as how it and channel edges function as winter habitat, must be well understood if we are to properly interpret changes brought by wood treatment to Coho bearing streams. It is also necessary to understand how juvenile Coho respond to changing water levels.

It would be the concern of an effectively defined inventory protocol to measure and evaluate the amount, condition, and potential for increase of slow water habitat that allows juvenile Coho salmon to persist through winter high flows. However, the diverse and changing character of winter flows and the terrain they cover make winter habitat evaluations highly difficult to conceive, much less implement.
We believe that the observations on winter Coho behavior described below help characterize Coho winter habitat toward achieving this goal.

Snorkel diver observations of winter conditions and fish behavior

Over the past six years, Bio-Surveys has conducted winter snorkel surveys in five Oregon coastal streams. In that period, approximately 100 pools have been surveyed by day and 600 by night, providing a very large, if informal set of behavioral observations collected during winter flow and temperature regimes. These are summarized below:

- The low velocity edges of large 5th order lateral scour pools mirror the low velocity edge habitats observed in impounded habitats and thus provide a micro habitat that functions like a high quality dam pool.
- In rock-dominated systems, juvenile Coho commonly seek low-velocity refugia in micro-habitats dominated by silt and fine deposits (e.g., eddies). The abundance (area) of this substrate type might be used to indicate the amount of low velocity micro-habitat present within the channel prism during winter flows.
- During winter temperature regimes and at night, juvenile salmonids of all species commonly rear side by side with no predator / prey interaction.
- In lower 5th order mainstem corridors, low velocity edge habitat provides all of the winter rearing potential. Virtually no juvenile salmonid rearing occurs within the thalweg.
- Inner riparian vegetation such as Reed Canary Grass, sedges, willow, exposed inner riparian root mats provide highly important complex cover within low velocity edge habitats.
- The reliance of habitat inventory protocols on strict hydraulic unit definitions often bypasses highly productive micro habitats that exist on the periphery of the active channel and do not conform to unit definitions because of size or position.
- Alcove and backwater off-channel habitats sometimes hold substantial numbers of juvenile Coho. Under current methodology, only backwaters associated with pools are snorkeled, missing all alcoves and those backwaters associated with riffle and rapid habitats.
- Although the location of juvenile Coho within any pool is predictably associated with low velocity zones having fine sediments, this feature in itself does not predict pool preference (i.e., fish density).

In addition, temperature-dependent behaviors have been observed. When stream temperature drops below 5 deg. C:

- Juvenile salmonids rest in contact with the substrate at night.
- Juvenile Coho and 0+ age trout are capable of seeking shelter in course, well sorted (i.e., have low levels of sediment) gravels during daylight hours.
- Older age class Steelhead and Cutthroat associate almost entirely with complex cover and are only sporadically seen during daylight hours.

Defining winter habitat

The observations above suggest that juvenile Coho salmon adapt to changing seasonal conditions with behaviors like the following:

- During the summer period devoted to feeding and growth, they utilize the full range of opportunities provided by the entire pool area.
- As winter approaches, they move to shallow stream margins outside the main flow. They appear to do this in association with changes in channel velocity and stream temperature.

- As the water rises and the edge creeps up and out, the fish move with it, accessing backwaters that now contain water.
- When rising water escapes the channel prism, they follow it out onto the floodplain where low terraces and vegetation provide large areas of slow water with structure and cover.
- If the water continues to rise, it will cover higher and higher terraces up into permanent vegetation and woody shrubs. Under these conditions, flow over the low terraces may have altered the low velocity nature of these intermediate refuges. Under the behavioral model presented, fish continue to follow the edge above the turbulence.
- As the flow recedes, they return to the low terraces which again function as slow water refugia.

It is important to emphasize the role of lateral scour pools during low to moderate winter flows. Both the outside and the inside of a lateral scour curve have edges. However, these edges have altogether different properties and effects on Coho behavior and survival. Even at the low flows of winter snorkel studies, juvenile Coho have not been found associated with depth or other features typical of summer cover and feeding, i.e., along the outside of the curve. Rather, they have been found almost entirely in eddies of the inner edge and other low velocity subdivisions of a habitat unit.

Inside eddies are a primary source of winter habitat because they are protected through a range of flows by the development of a point bar and the potential for the accumulation of debris and organics. Other sources of winter habitat include low velocity areas within the channel created by woody structure, and backwaters on the floodplain.

Although winter habitat exists in these varied forms, locations and elevations, it is uncommon for any individual site to provide a continuum of low velocity habitat throughout the complete range of flow levels. Based on snorkel observations of fish abundance, *sites which provide the highest quality winter habitat occur where continuous low velocity habitat exists through all winter flow levels.* This occurs when site specific channel and floodplain interactions complement each other to provide low velocity shelter at different flow levels. This is the primary feature that distinguishes highly functional winter habitat units from most other potential winter habitats. There might be a water level that is most critical at one site, but this level won't necessarily be the critical level at all sites. Our inability to define a single "critical flow" that applies to all sites greatly complicates any attempt to design a winter inventory strategy for quantifying winter habitat.

Addressing the problem of utilizing the currently collected summer habitat attributes as a surrogate for a winter habitat evaluation

We evaluate the rearing capacity of a reach or stream as a whole, knowing that dynamic forces such as high winter flows, density dependent mortalities, thermal excursions that can either impel or restrict migration, and intermittent use of tributaries generate this capacity, but that we generally have little information concerning these forces.

Ironically perhaps, our summer surveys suggest to us that high-water winter survival is often the key to smolt production. There is generally safety on the flood plain if the water level attains this height. On the other hand, elevated flows that stay within the active channel force fish to seek refuge within the channel, and this is a dangerous time for fish living in simplified, entrenched channels.

We rarely, if ever, survey interactive flood plains to quantify high water refugia. And we can't effectively survey main channel habitats at elevated water levels using standard survey methods for the simple reason that these stream corridors become unwadeable. Our goals would be more effectively served by attempting to interpret what winter mean bankfull conditions are during summer low water surveys. Summer habitat surveys that focus only on the wetted active channel provide only muted, incomplete images of the events, structures and relationships that determine Coho success and failure. If we rely only on summer active channel metrics, we get a highly simplified view of a dynamic system and we miss most of the physics and biology that we are trying to understand and to influence with restoration efforts.

There is a related issue, which is the scale of data collection and summary. Inventories focus on quantifying the number of objects in a stream segment, such as a reach. Various additions (e.g., sum of areas) and divisions (e.g., proportion of the channel composed of pool habitat) give us an overall picture of the segment. However, this approach tends to mask the simultaneous creative and destructive events that restoration work creates at specific sites. For example, one treatment site may create a scour pool through diversion, while another buries a scour pool through impoundment and sediment trapping. A reach summary then tells us that there is little change in habitat structure relating to scour, while the truth is that both treatment sites are undergoing important changes. We would learn more by investigating the dynamics occurring at specific sites, even if time constraints prevent us from evaluating all of the sites.

The point is that we can learn a great deal about system function and development, and much better assess the effects of restoration efforts, if more appropriate sources of information are utilized for evaluation. In the case of monitoring instream restoration projects that are designed to address a problem of limited winter habitat, we need to assess the conditions of winter habitat, not those of summer habitat. Inventories would have to evaluate the state of floodplain interaction. They would also have to quantify micro-habitats within the channel prism that do not possess normal hydraulic controls (eddies) which offer protection at varied water levels.

If we were to follow these recommendations, we might conduct investigations that ask:

- How much low-velocity habitat exists? (and not exclude micro-habitats).
- How much winter-stable beaver pond habitat exists?
- At mean bankfull flows how much floodplain refugia exists, is it associated with a complex pool that is capable of providing refuge for juvenile salmonids during low winter flow regimes (linkage through the range of winter flows).
- What channel morphology and wood resources are currently working within the channel to generate floodplain connectivity?
- Are these resources creating hydraulic confinement (damming effect) or just channel roughness?
- What is the timeframe for this development (is there evidence of maturation)?
- What is the best approach to accelerate the process?
- How much, where located, and how long to recruitment are native wood resources that will naturally stimulate and maintain channel complexity?

The answers to these and similar questions constitute an assessment of function, as opposed to an inventory of objects and form. An assessment can create a legacy of insights and expectation that will stimulate future effort and guide restoration design. What are those logs a site x doing now? Did the new braided channel mature or wash out? Is the channel more elevated and connected? Standardization has its place, but not to the degree that it denies the natural and productive processes of intuitive investigation.

An initial response to these concerns is presented in “Questions that investigate wood treatment effects” of the Methods section. The purpose of these questions, and others of a similar nature, is to provide a functional but non-limiting structure of investigation.

Our purpose in placing the wood is to encourage normal channel function. However, in the world of channel development “normal” equates to “dynamic and unpredictable”. It is therefore difficult to anticipate the long term location and function of placed wood. However, it is reasonable to ask how quickly and in what manner the placed wood is affecting deposition, erosion, and channel development in the short term at specific sites of placement.

Thoughts on winter habitat evaluation

If winter habitat is limiting for juvenile salmonids as is suggested by many research documents, then a clear definition of what winter habitat is would be a prerequisite for providing more of it and measuring the change. Winter habitat is then the low velocity refuge with cover typically associated with off-channel habitats on floodplains including low gradient tributaries, secondary channels, ponds, alcoves and tidal marshes. Locations that provide interaction with the floodplain guarantee that as flows fluctuate, a shift to adjacent low velocity habitats will require limited use of of a fish’s caloric resources. In addition, winter habitats also exist within the channel prism through the provision of micro habitats created by wood complexity and pool type (dam pools and lateral scours). Preferred habitats are a combination of complex cover, no velocity, and immediate linkage to adjacent low velocity habitats on the floodplain during increasing flow regimes. Maintenance of the body condition attained during the summer is critical for juvenile salmonids during winter flow regimes. Juveniles in poor condition and those of smaller than average length are the first to depart from 3rd and 4th order stream corridors with the approach of winter flows.

Therefore, an evaluation of winter habitat would have to involve an assessment of potential interactive floodplain surface area. At what flow should this surface area be quantified? There is a definitive need here to establish a replicable metric for evaluation. Therefore it makes some sense to suggest that the mean bankfull indicator be utilized as a metric of at least potential floodplain interaction. Mean bankfull may not be the critical flow stage but it is at least a visible indicator that can be identified and replicated by introductory level technicians. As the bankfull indicator makes excursions onto the adjacent floodplain, surface areas of off channel habitat could be estimated. These evaluations could also be conducted during summer flow regimes when streams are stable and wadeable.

The second level of evaluation involves the low velocity micro habitats that exist within the channel prism. These are areas associated with cover or inside meander bends that are habitats within a normal habitat unit (pool). They do not exhibit the firm borders and hydraulic controls we typically associate with a habitat unit but definitely function differently from the remainder of the habitat unit surface area because of the low or absent velocity. Both of these fundamental types of winter habitat exist within a range of variable quality and therefore can be ranked for several other important attributes-- cover, complexity, and linkage (active channel / floodplain)

Because winter habitat quantification poses so many problems, we believe it may be more prudent to devise an approach for collecting the attributes that are visible and measurable during summer low flows than to attempt to collect adequate and coherent data using winter habitat inventories. This is the topic of Appendix 7.

Appendix 7. Suggested method for profiling channel complexity and floodplain interaction

There is a significant data gap in our understanding of the dynamic function of complex woody structure and its benefit for especially the provision of winter refugia for juvenile salmonids. Part of this lack of institutional knowledge is our continuous insistence on counting sticks and stones (the only way to gather data with introductory level biological technicians). If we could alter the current paradigm to view the functionality of wood and resist the desire to count, we could begin to understand what makes a certain wood configuration productive for salmonid juveniles and begin to replicate it. For this approach to function, we need to interface the variable functionalities of woody structure (habitat) and its winter rearing potential by collecting and comparing the associated fish abundances. This approach trusts the fish to guide us in identifying functional habitat.

The actual quantification of winter habitat is clearly problematic. Attempt to describe a set of metrics that can be utilized in the winter, in a replicable fashion, from year to year by different surveyors with varying degrees of experience and you begin to realize that valid comparisons between years may be a fool’s errand. The very nature of winter habitats is dynamic because of almost daily alterations in flow and subsequent active channel elevation. Each of these shifts results in comparable shifts in surface area, floodplain interaction and micro-habitat surface area. The whole drama of complex change goes far beyond existing concepts and measurement tools.

Assuming that we are not likely to acquire a replicable methodology for the direct measure of winter habitat we should set our sights on improving summer methodologies. This would require the development of supplemental indexes that profile channel complexity, floodplain interaction and site specific evaluations of winter habitat continuity through a range of flow regimes.

Field measurements

We have concluded that attempts to directly quantify winter habitat meet large and possibly insurmountable problems. An alternate approach is to evaluate the level of channel function and floodplain connectivity that create and sustain this habitat. . The questions are, What specifically can we use to evaluate channel function and connectivity? What can we measure?

Suggestions include:

- Sinuosity (scaling and other errors should be evaluated; bias is probably consistent)
- Overhang
- Pool surface area or %??
- Wood complexity rating
- Large substrate content
- Lateral scour pool frequency (# LP/# units)
- Lateral scour pool Depth/Width ratio and its variance (standard error of mean, transformed)
- Braiding level (frequency by length of 2nd, 3rd, etc). Compose a ranking and weighting system such as [branch order] x [length] (i.e., a third order branch of 30 m has a ranked weight of 30 x 3 = 90). Sum the ranked weights of all side channels and divide by primary channel length.
- Mean bankfull minus channel gradient (periodic or random measurements to represent stream segment)
- Count and measure area of active/recent deposition plains, standardized by average channel width or bankfull width (larger systems would have larger plains)
- Point bar widths (water edge to mean bankfull) divided (standardized) by average channel width.
- Bedrock abundance in the mainstem primary channel
- Entrenchment

Note that sinuosity and bedrock are very informative indicators of channel function.

Using these and similar tools, we improve the summer inventory methodology to characterize the level of channel complexity and floodplain interactivity. This tells us much about how well the system is providing the low velocity habitat required by over-wintering Coho juveniles. Beyond this, it provides far better insights into the state of the system and its needs for restoration work than can be provided by basic habitat inventories.

Profiling the system

These indicators can be scaled and presented together as a visual profile of the system:

- Scale each indicator from 0 to 5
- Present the scaled indicators as a bar chart. This is a visual profile of that stream segment's channel complexity and floodplain interactivity level.

We assume that a very favorable profile indicates abundant high quality winter habitat. In practical application, we profile channel complexity and floodplain interactivity pre- and post-treatment.

This approach does not replace the summer inventory, but substantially improves its ability to assess system function, winter habitat availability, and wood treatment effects.

Appendix 8. An approach to wood treatment assessment

Below is a suggested format for assessing individual wood placement sites. Items in topics 1, 4 and 5 require a narrative response. Items in topics 2-3 are rated from 0-5, with 0 indicating no development of the feature and 5 indicating extensive and mature development of the feature. Photo documentation is essential.
1) Placement

- Habitat type/description
- How placed
- Number of pieces, sizes and types

- Associatation with an interactive floodplain

2) Overall assessment of habitat development
- Summer habitat
- Winter habitat
- Spawning habitat development
- Complexity

3) Positive Effects
- Wood trapping
- Deflection
- Multiple (braided) channel development
- Bed elevation (deposition plain)
- Spawning gravel accumulation
- Plunge pool development
- Dam pool development
- Scour pool development
- Pocket riffle development

4) Negative or non-constructive effects
- Passage problems
- Wash out
- Not interacting

5) Biologist's description of wood placement, and the features and processes that have developed in response to placement.