FRESHWATER HABITAT REARING PREFERENCES FOR STREAM TYPE JUVENILE CHINOOK SALMON (*Oncorhynchus tshawytscha*) AND STEELHEAD (*O. mykiss*) IN THE SKAGIT RIVER BASIN: PHASE 1 STUDY REPORT

Eric Beamer, Skagit River System Cooperative (SRSC)
Jon-Paul Shannahan, Upper Skagit Indian Tribe (USIT)
Karen Wolf, SRSC
Erin Lowery, University of Washington
David Pflug, Seattle City Light (SCL)

December 2010

Acknowledgements

We acknowledge the follow people and organizations for their contributions to this study:

- Jerry Marsicek (USIT), Tim Shelton (USIT) and Jef Parr (SRSC) for their field data collection efforts
- Correigh Greene (NOAA Fisheries) for statistical power analysis
- Tyson Waldo (Northwest Indian Fisheries Commission) for GIS help with watershed boundaries used in our rare habitat analysis
- Oversight Committee members:
    - George Pess and Correigh Greene (NOAA Fisheries)
    - Ed Conner (SCL)
    - Reed Glesne (National Park Service)
    - Roger Peters (US Fish and Wildlife Service)
    - Dave Beauchamp; University of Washington Cooperative Fish & Wildlife Research Unit, School of Aquatic and Fisheries Sciences
- Funding: the Signatories of the Seattle City Light Fisheries Settlement Agreement and members of the Non-flow and flow Coordinating Commitees, which include representatives from the following agencies and tribes: US Forest Service, US Fish and Wildlife Service, NOAA Fisheries, National Park Service, Sauk Suiattle Indian Tribe, Swinomish Tribe, Upper Skagit Indian Tribe, and the Washington Department of Fish and Game.

Table of Contents

Study objectives and uses

This study is needed to better understand the causes of decline for two ESA listed salmonid species that have at least a portion of their juvenile population exhibiting a stream type life history: Chinook (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*).

The study's purpose is to identify seasonal and habitat type preferences in freshwater habitat in the Skagit River basin by answering the following questions:

1. What habitat types are used by fish seasonally?
2. Where are fish located within the basin seasonally?
3. Where are habitats (by type) within the basin?

Habitat occupation by fish varies by season, due to environmental and ecological factors. Carrying capacity and survival of fish can vary by habitat type and season so it is important to know fish-habitat type associations (preferences) by season. By linking our understanding of the fish (the answers to questions 1 and 2) to the location of habitat types (the answer to question 3), we gain a spatial and temporal understanding of the freshwater rearing period for stream type Chinook salmon and steelhead in the Skagit River basin.

Our study is phased into two parts. Phase 1 of this study is designed to assess the feasibility and statistical capabilities of our sampling design prior to implementing a larger effort anticipated in Phase 2 of the study. The Phase 1 objectives include:

- Assemble a habitat database of the Skagit River basin in GIS;
- Use GIS data to select representative sampling reaches based on stratifying factors of space, time of year, and habitat type;
- Collect pilot level fish observation data, including fish abundance and individual size classes by species, to be used in statistical power analysis;
- Conduct statistical power analysis using pilot data; and
- Refine field methods for fish observation based on pilot fish data collection experiences and relevant scientific literature on juvenile salmonid habitat preferences and sampling methodologies.

The objectives for Phase 1 are geared to develop a scientifically defensible approach for identifying habitat preferences for stream type salmonids during the second phase of this research project. Results for Phase 1 will be used to create a specific proposal for funding Phase 2 of the study.

Results from this study are intended to help direct the use of salmon recovery funds toward purchase of high priority habitats so they can be protected. High priority habitats are places within the basin where a large amount or high percentage of preferred fish habitat is at risk of loss or degradation. Results are also intended to be used as a screening tool for the Skagit Watershed Council's review of salmon recovery project applications. Through the GIS integration of collected fish data and habitat preferences, we may determine that some areas of the watershed are lacking habitat connectivity, or are important because multiple fish populations or species use the area for rearing.

This study does not measure factors causing fluctuations in stream type salmonid population size as it is not a population dynamics study. However, results from this study can be used with annual sub-basin flow data and annual smolt trap data to evaluate production estimates for the different Skagit Chinook salmon stocks (or potentially other species, if population estimates are made using WDFW smolt trap data). Such analyses would help hypothesize environmental and population size mechanisms that influence the percentages of the stream type life history in any Chinook salmon stock.

It was anticipated that data results for bull trout (*Salvelinus confluentus*) would also be generated from this study; however bull trout results were not consistently measured by our field methods and should not be considered a major part of this study.

Study area and conceptual study design

We applied concepts of space, time, and habitat type to our study area to assess habitat in GIS and select sites for fish sampling.

Study area

The study area is defined by the limits of anadromous Chinook salmon habitat within the Skagit River basin (Figure 1). We compared the Chinook salmon range to the ranges of other ESA-listed species (steelhead and bull trout), but rejected the ranges of steelhead or bull trout as the basis of our study area due to difficulty in accessing all areas year-round. The steelhead and bull trout ranges have 19 to 25% more habitat (by length of channel) respectively, than the Chinook salmon range. The steelhead and bull trout ranges also have more channels located in the upper watershed, with poor year-round access compared to the Chinook salmon range.

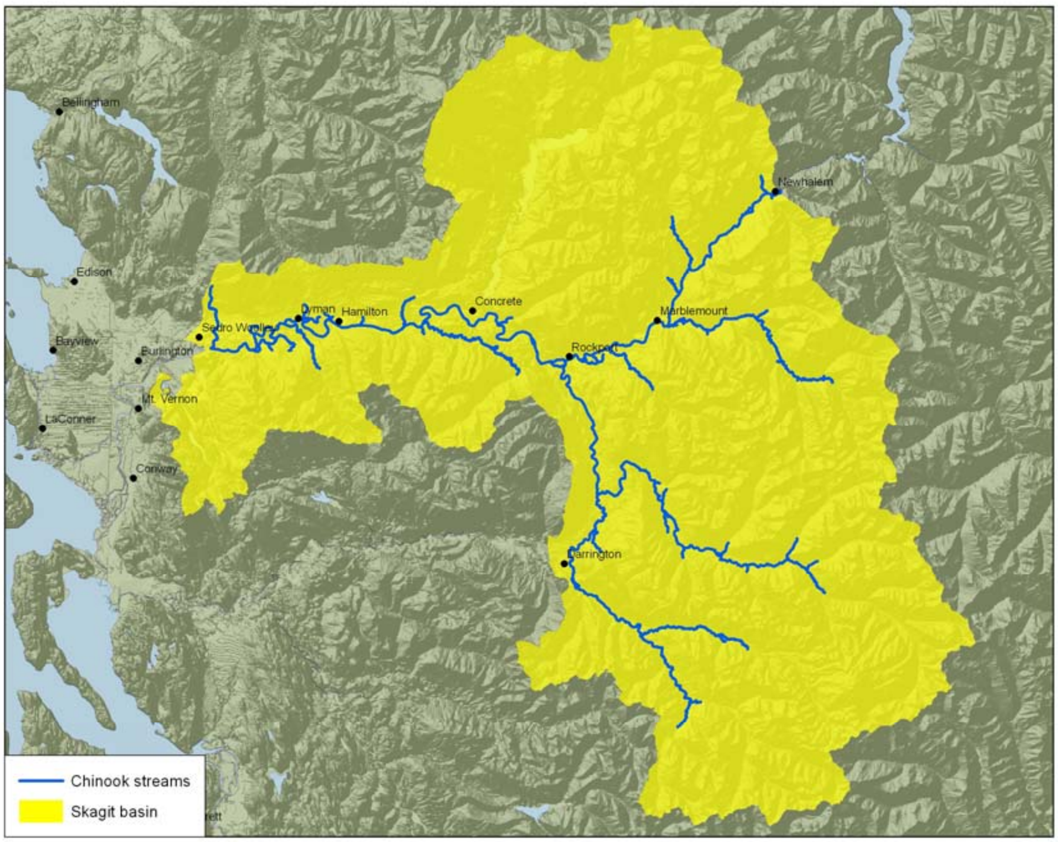

Figure 1. Limits of Chinook salmon in the Skagit River basin according to Northwest Indian Fisheries Commission Limiting Factors Fish Distribution data.

Space

We used multiple spatial strata to account for potential differences in Chinook salmon abundance and distribution caused by variation in population size or juvenile life history types between the six stocks present within the Skagit River basin (Figure 2). Spatial strata are based on Chinook stock rearing ranges and are similar to spatial strata delineated by hydro-region (after Beechie 1992; Beechie et al. 2006), which was suggested as an alternative approach by one member of the Oversight Committee.

For Phase 1, the sites were selected across the study area in order to sample a range of habitat types and spatial diversity. The rationale for limiting sites by spatial strata for Phase I relates to the focus of collecting pilot level fish data to represent a wide range of conditions and fish abundance for statistical power analysis.

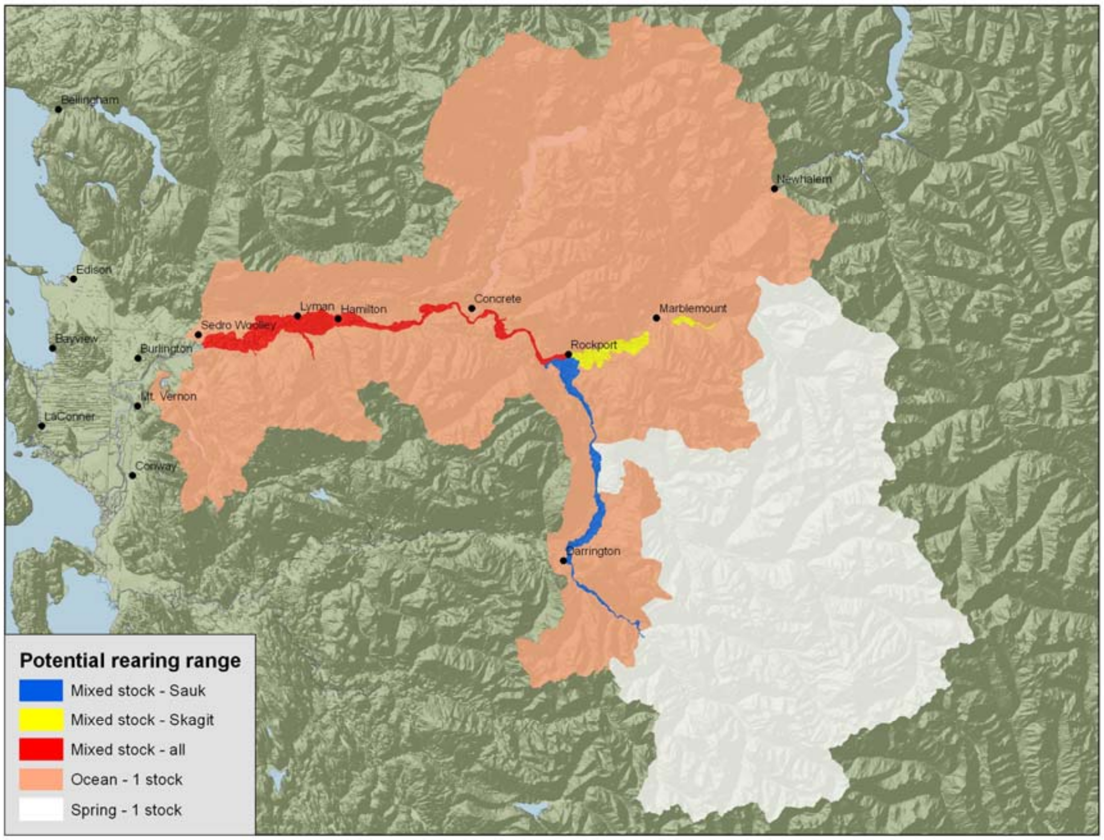

Figure 2. Proposed simplified spatial strata based on the juvenile rearing ranges of six wild Chinook stocks in the Skagit River basin. These spatial strata have some commonalities with watersheds that have regulated and unregulated hydrographs, as well as basin hydrology characteristics that control flow and temperature regimes (e.g., snow to rain-on-snow or rain-dominated hydrographs).

Time

We defined six potential time strata based on ecologically significant life stages, or transitions between life stages, of juvenile salmonids in freshwater habitat (Table 1).

Table 1. Potential temporal strata based on differences in environmental and ecological factors.

Time strata	Period in year	Description
Spring	May/early June	Most ocean type salmonids have migrated (Chinook fry life history types, most Chinook parr life history types, all chum and pink fry); most yearling (or older) have migrated (yearling Chinook, yearling coho, age 2+ steelhead and bull trout). For the juvenile Chinook salmon remaining most will exhibit a stream type life history pattern and they will be observed as age 0 fish.
End of summer	Aug/early Sep	This is a period of low flow and higher water temperature. This period represents a time near the end of a fast growth period in salmonids and potentially a time when carrying capacity is maximized for summer habitat. All ocean-type Chinook juveniles have outmigrated. All observations of Chinook salmon are of stream type fish.
Fall	Oct	This period follows immediately after the water year's first freshet flow and after water temperature has dropped. It generally has higher average flows than summer. The fish in this time period have moved from summer to winter habitat which has been trigger by freshets, temperature, and possibly daylight reduction.
Winter with spawners	Nov/Dec	This is a period in winter with abundant adult salmon spawners present in system. Spawning adult salmon may influence the distribution of juvenile salmonids because of an abundant food supply (carcasses and eggs). Live adult salmon may influence the distribution of younger salmonids through pressures of territory. In pink salmon years (odd), abundant salmon carcasses will be available in October.
Late winter	Feb/early Mar	This is a period during winter with few adult salmon present and few carcasses remaining. It is considered a time of scarce food, low and stable flows, and cold water temperatures. Stream type salmonids will be in preferred winter habitat types. They will also be competing with fry which are now emerging from egg pockets.
Migration	April	This is the period of peak stream type smolt migration

In Phase 1 of this study we collected fish data from two time periods (end of summer and late winter). Data from these two periods should give us results representing the possible extremes in mean fish density, or variance, for conducting statistical power analysis. It is anticipated that Phase 2 of this study will collect fish data from some of these additional time strata. The level of sampling effort for phase 2 will be based on balancing fiscal availability with the sampling recommendations from the Phase I statistical power analysis. Additional considerations for developing a study design for full implementation will be influenced from additional recommendations from the Phase I report. For instance time estimates for conducting the sampling during different seasons, definitive temperature parameters for day vs. night snorkeling not necessarily representative by the season approach used in Phase 1, and other logistical constraints of implementing such a large scale study.

Nested scale habitat classification

mainstems, smaller mainstems and tributaries, and floodplain channels based on channel reach classification systems after Beechie et al. (2005) and Montgomery et al. (1999). We used the methods of Beechie et al. (2005) to classify channel units within large mainstems and Bisson et al. (1981) for smaller mainstems and tributaries. Together, our approach presents a nested scale habitat classification for channels in freshwater that can be mapped in GIS and/or defined in the field, and sampled (Table 2).

Table 2. Habitat types used in this study. Finer-scale habitat types were refined with Oversight Committee input.

<table>
<tr><th>Largest Scale

(random selection basis)</th><th>Intermediate Scale

(classify in field, map in GIS)</th><th>Unit Scale

(basis of fish count records)</th><th>Finest Scale

(attached to each record)</th></tr>
<tr><td rowspan="2">Large mainstems (> 50 m bfw)</td><td>Mid-channel</td><td>Pool
Riffle
Glide</td><td rowspan="9">Temperature

Substrate embeddedness

Turbidity

LWD count

Depth classes

Cover type (e.g, complex wood, simple wood, cobble, boulder, deepwater, riprap, etc)

Substrate type (e.g., sand, gravel, cobble, boulder, rubble, riprap, etc)</td></tr>
<tr><td>Edge</td><td>Bar (edge)
Backwater
Bank – natural
Bank – modified</td></tr>
<tr><td rowspan="3">Small mainstems or tributaries (< 50 m bfw)</td><td>Pool riffle channel</td><td rowspan="3">Pool
Riffle
Glide
Pond</td></tr>
<tr><td>Forced pool riffle / plane bed channel</td></tr>
<tr><td>Step pool or steeper channel</td></tr>
<tr><td rowspan="4">Floodplain channels (non-mainstems in large mainstem floodplains)</td><td>Blind – channel starts in the floodplain and is not connected to the river at its inlet</td><td rowspan="4">Pool
Riffle
Glide
Pond</td></tr>
<tr><td>Primary river – channel is connected to river at its inlet</td></tr>
<tr><td>Secondary river – channel is connected to another floodplain channel at its inlet</td></tr>
<tr><td>Tributary – channel in the floodplain with its primary source water as hillslope tributary</td></tr>
</table>

Inclusion of rare habitat types

Several members of the Oversight Committee suggested we consider the potential importance of rare habitat features that might be under-sampled by a typical randomization procedure using only the habitat types listed in Table 2. Rare habitat types were those considered to be conceptually important to stream ecology and salmonids. Two rare habitats were considered: tributary junctions (after Kiffney et al. 2006) and large log jams (after Abbe and Montgomery 1996). In Phase 1 of this study we created GIS habitat data layers of each rare habitat type in order to include them as a potential stratifying factor in Phase 2 of this study.

GIS-based habitat assessment

We applied two stratifying classes (space and habitat types) identified in the study's conceptual design to assemble a freshwater habitat inventory of the study area in the Skagit River basin. We used existing GIS data to define the limits of Chinook salmon habitat (Figure 1) and modified existing or created new GIS data within the Skagit's Chinook salmon range to represent habitat types or space strata necessary for the study's design. These data included: 1) a polygon data layer to represent large mainstem and floodplain channels based on year 2006 orthophotos (the most current photos at the time of this initiating this study in 2007), 2) an arc data layer to represent smaller mainstem and tributary channels, and 3) a polygon layer of watersheds and floodplains attributed by stock specific Skagit Chinook salmon spawning and juvenile rearing ranges. We also made two GIS data layers of rare habitat types (logjams and tributary junctions) after Oversight Committee members suggested that they were needed for our study design.

GIS-based habitat results were constructed to answer the following questions:

1. Where are freshwater rearing habitats for juvenile yearling Chinook salmon within the Skagit River basin?
2. What is the quantity of habitat (by type) for each of the Skagit Chinook salmon stocks?

The GIS-based habitat results were used to randomly select sampling sites for Phase 2 of this study. The habitat results can be used to expand fish use results for space, time, and habitat strata. The extent of the five individual GIS data layers created is shown in Figure 3.

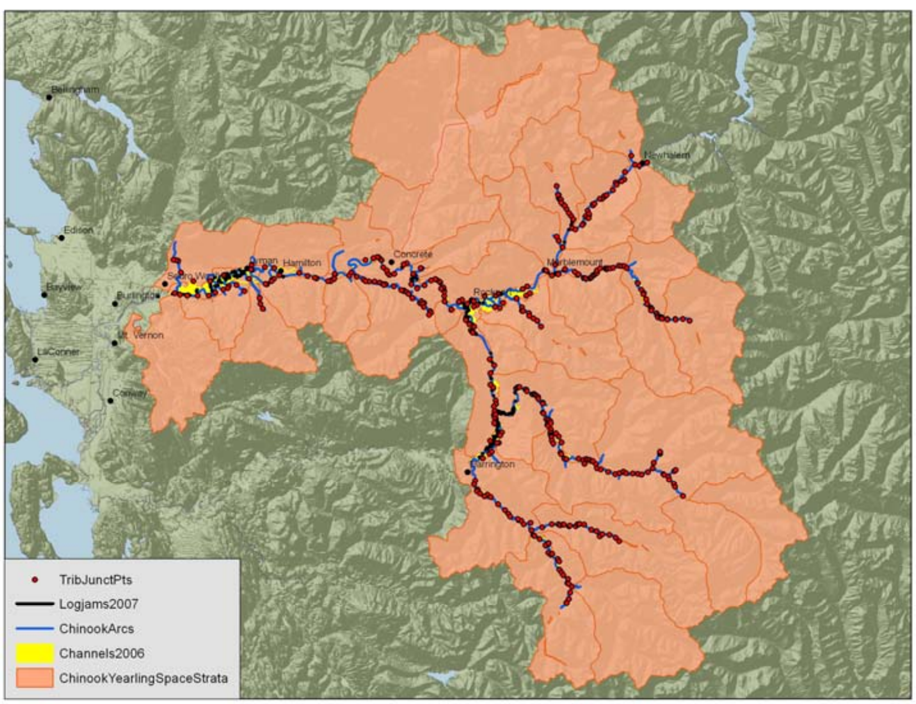

Figure 3. Extent of five GIS data layers created or modified for this study.

Large mainstems and floodplain channels

The GIS layer *Channels2006* was created by digitizing polygons on-screen over Skagit and Snohomish County orthophotos (2006 National Agriculture Imagery Program [NAIP] photos), at a scale of no greater than 1:3000. Large mainstem river channels, secondary channels, gravel bars, and vegetated areas (surrounded by water or gravel bars) were delineated (Figure 4). The polygon layer extends from the Skagit River at Sedro-Woolley to Newhalem; the Cascade River from its confluence with the Skagit River to its confluence with the North Fork Cascade River; the Sauk River from its confluence with the Skagit River to the junction between the North and South Fork Sauk Rivers; and the Suiattle River from its confluence with the Sauk River to near Downey Creek.

Polygon definitions are:

- Main Channel, Wet – This is the wetted channel in mainstem Skagit, Sauk, Cascade, and Suiattle Rivers. In some places this was one wide channel; in other places it was a main channel with two or more smaller channels. In these cases, the widest channel was chosen as the main channel and the others were mapped as secondary channels. In a few cases where the channel split around a small gravel bar and looked equally wide, there was no distinction between the two.
- Secondary Channel, Wet – These are secondary channels of two types: a) channels adjacent to a mainstem channel and separated from mainstem only by a gravel bar, and narrower than the single mainstem channel mapped; and b) channels that were separated from the main channel by forested islands or large swaths of vegetated bars, also typically narrower than the mainstem channel.
- Secondary Channel, Wet? – In some cases it was difficult to distinguish the actual wetted portion of the secondary channels because of photo quality, vegetation or shadows obscuring the channel – in those cases where absolutely no water was visible but a channel appeared to be present, a question mark was noted behind the word 'wet'.
- Gravel Bars – Unvegetated, exposed gravel bars. Located adjacent to wetted main and secondary channels, and in some cases could be used to map the location of secondary channels that would be wetted under higher flow conditions.
- Vegetated Bars – Areas adjacent to wetted main or secondary channel or their bars. These areas contain vegetation growth that does not appear to be mature. Vegetation growth ranges from sparse vegetation, where the ground is visible between plants, to small but dense trees (mostly hardwoods, lighter color green). Vegetated bars do not appear to have mature hardwood or coniferous species growing (darker color green).
- Forested Island – Area with what appears to be mature vegetation, often coniferous (dark green signature), with little ground showing between plants. Forested islands were only mapped if their perimeter was completely enclosed by one or more of the above polygon types, usually a wetted channel or bar.
- Cleared Field – An area cleared for agricultural/pastoral purposes; mapped similarly to Forested Island.

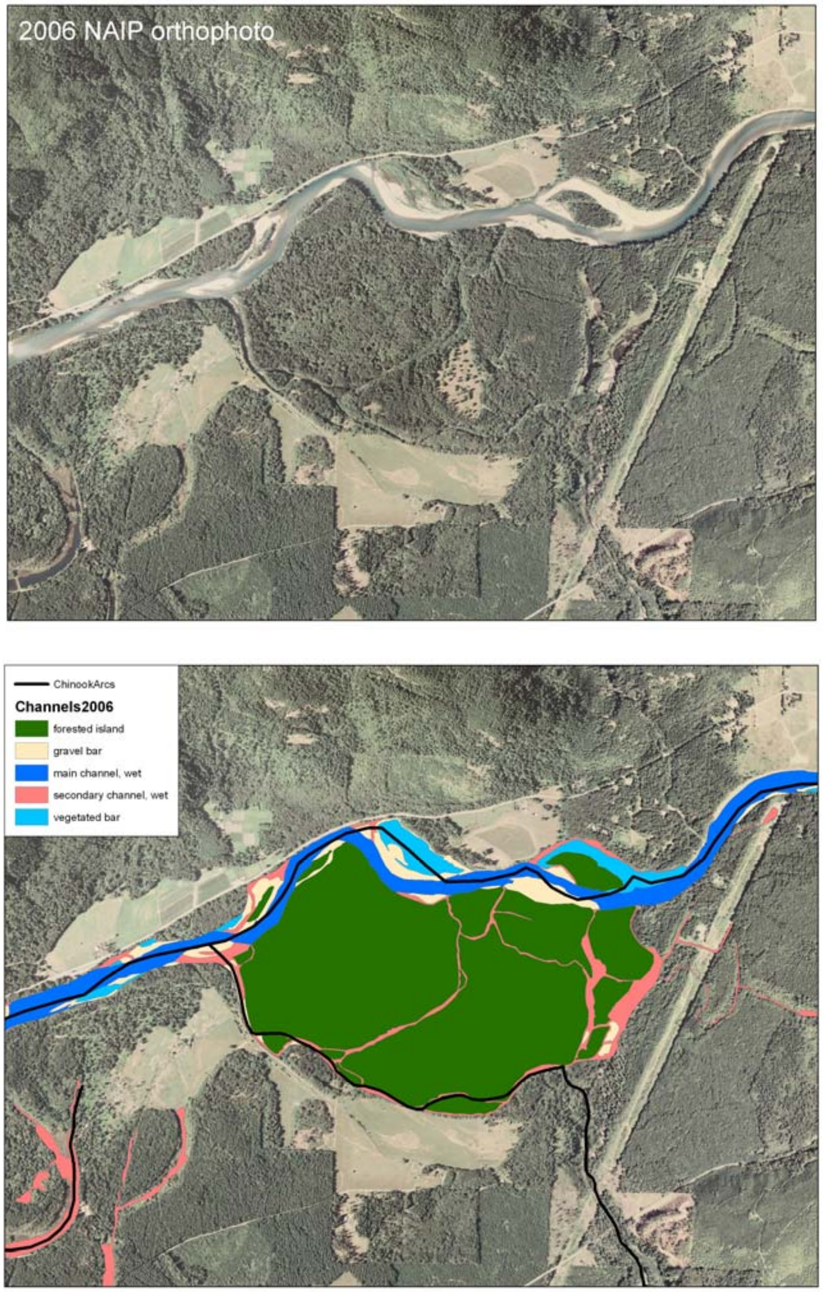

Figure 4. Example of the detail in *Channels2006* data layer. The top panel is the Illabot Creek/Slough area without the overlay of GIS data layers. The bottom panel has been overlaid with both the polygon (*Channels2006*) and arc (*ChinookArcs*) layers. In our final edit of *ChinookArcs*, we deleted arcs that are representing channels in the polygon layer so there is no duplication of habitat in the GIS layers. Note the differing alignment of some channel polygons with some of the Chinook arcs. Mis-aligned arcs with the year 2006 channel alignment is due to channel movement since the period when the arc layer was originally digitized (we do not know what photo year-set was used to create the arc layer). This example figure does not show all habitat types found in the polygon data layer(i.e. it does not show any digitized polygons attributed as 'cleared fields' or 'secondary channel, wet?'). The layer is not a comprehensive classification of the entire floodplain; we created and attributed only channel polygons and polygons between channels. That is why some cleared fields are visible in the photo, but are not digitized polygons.

Smaller mainstems and tributaries

The GIS layer *ChinookArcs* was created to represent the smaller mainstems and tributaries within the range of Chinook salmon in the Skagit River basin not already represented by the *Channels2006* GIS layer. These smaller mainstems and tributaries are shown as arcs and fall outside SRSC's 2006 channels polygon data layer. The original GIS arcs were from NWIFC's Limiting Factors Fish Distribution data. We included arcs attributed for known or presumed distribution of Chinook salmon. The definitions are:

- Known Distribution - includes habitat where the presence of salmonids has been documented by published sources, survey notes, biologist observations, or Technical Advisory Group knowledge. This includes habitat used by any life stage for any length of time, including intermittent streams that may only contain water during peak flows when they provide off-channel refuge habitat.
- Presumed Distribution - includes habitat for which there are no documented records or sightings of known salmonid use, but which is downstream of any known fish passage barrier and otherwise conforms to species-specific habitat.

We did not include arcs with a potential, historic, or artificial distribution of Chinook salmon. The arcs were edited by SRSC to include attributes of Chinook salmon rearing stocks based on SRSC's *ChinookYearlingSpaceStrata* data layer.

Stock specific Chinook salmon spawning and rearing ranges

The GIS layer *ChinookYearlingSpaceStrata* was created by combining polygons from Washington StateDNR's Watershed Administrative Units (WAU) data and SRSC's floodplain theme. It includes juvenile Chinook rearing ranges and adult Chinook spawning ranges (Figures 5 & 6).

We attributed each polygon by the following categories related to spawning and juvenile rearing range:

- The attribute '*Spawnrng*' classifies the Skagit Chinook salmon stock that spawns in habitat within the area represented a polygon.
- The attribute '*Yrl_stratu*' classifies the juvenile Chinook stock that could rear in habitat within the area represented the polygon. In many cases, multiple stocks can rear in the habitat represented by a polygon.
- The attribute '*Strat_simp'* is a simplified form of juvenile Chinook salmon rearing by stock. In this case, the juvenile Chinook salmon rearing stocks are combined into classes: 1) mixed stock – all, 2) mixed stock – Sauk, 3) mixed stock – Skagit; 4) Ocean – 1 stock, or 5) Stream – 1 stock.

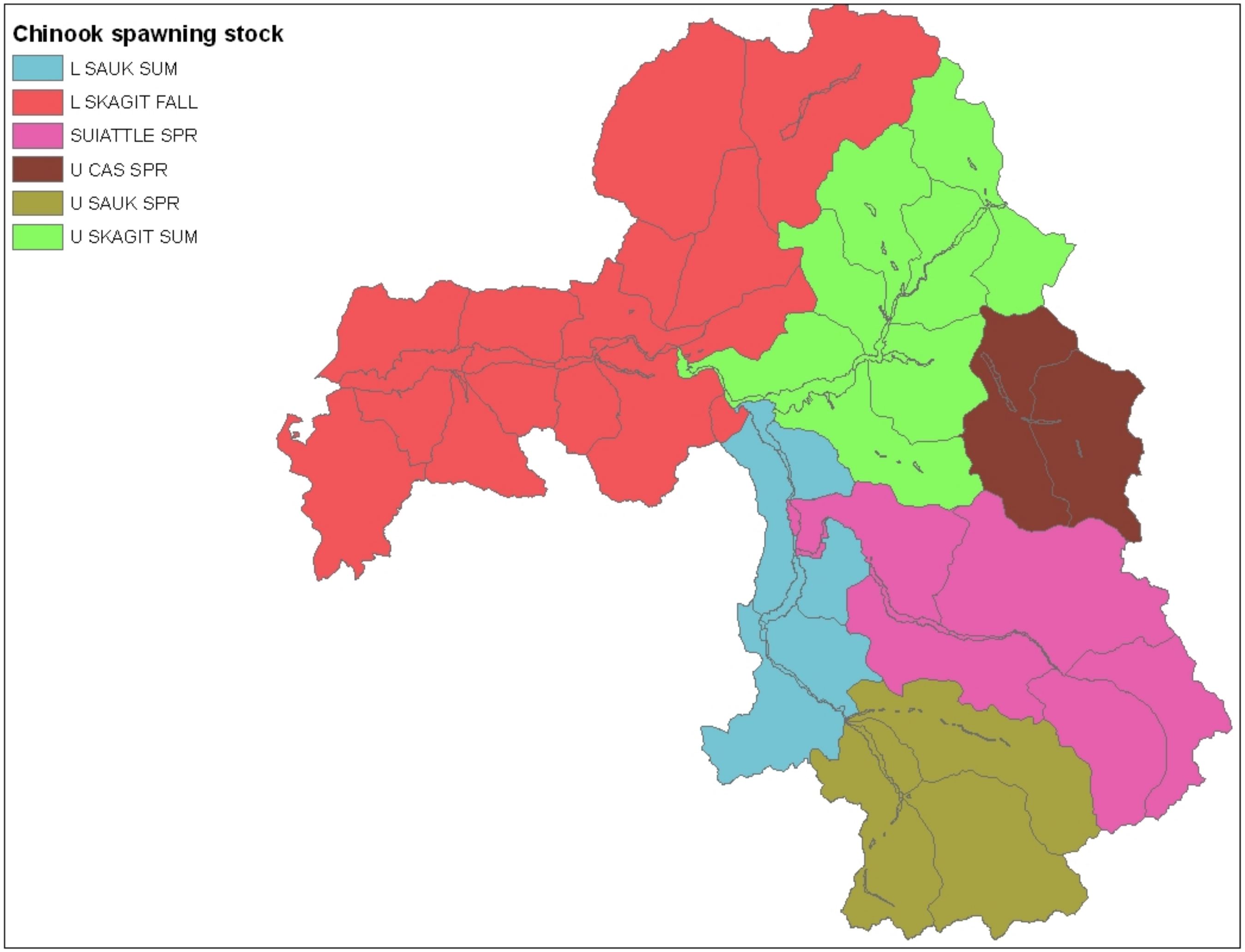

Figure 5. Map of *ChinookYearlingSpaceStrata* layer showing the spawning range, in polygon form, of the six Skagit Chinook salmon stocks.

Figure 6. Map of *ChinookYearlingSpaceStrata* layer showing the juvenile salmon freshwater rearing ranges, in polygon form, of the six Skagit Chinook salmon stocks. In many cases, floodplain polygon areas are a mixture of Chinook salmon stocks.

Tributary junctions

Reviewers of the study design suggested that stream type salmonids might be more abundant at or near tributary junctions due to localized increases in productivity and habitat complexity (Kiffney et al 2006). Tributary junctions were thought to be rare and therefore might not be represented in our fish sampling design. The GIS layer *TribJunctPts* was constructed in order to characterize tributary junctions, evaluate their degree of rareness, and incorporate sampling of tributary junctions as part of our study design.

The GIS theme *TribJunctPts* was created by digitizing points at tributary junctions on-screen over Skagit County and Snohomish County hydrography (stream) data layers. Chinook salmon-bearing streams were identified using the *ChinookArcs* GIS data layer and represent the range in which we documented a tributary junction. The tributary junction points were snapped to "drainlines" created with ESRI's ArcHydro. We used these points and drainlines to create watershed polygons, and the total area of each watershed was recorded with the associated point in the *TribJunctPts* layer. Watershed areas were added together to determine each point's total upstream watershed area; each watershed's percentage of total upstream area was then computed and recorded (Figure 7).

The above process identified 381 tributary junctions within the Chinook salmon rearing range of the Skagit River basin – hardly a rare habitat. Thus, we considered tributary junctions 'rare' under criteria related to watershed size and ecological importance of the junction as a biological hotspot. We first applied criterion based on Kiffney et al. (2006), where: a tributary junction is considered rare when the tributary watershed area is greater than 5% of the watershed area it flows into. Of the 381 tributary junctions, 42 fit this criterion.

Because the Skagit and Sauk Rivers have such large watershed areas, many very large Chinook salmon-bearing tributaries (e.g., Bacon Creek, Finney Creek) that flow directly into the Skagit or Sauk Rivers do not fit the category based on Kiffney et al. (2006), and would not be considered rare. Not considering tributary junctions such as Bacon and Finney Creeks with the Skagit River did not seem correct so we developed a second criteria. Our second criterion is: a tributary junction is also considered rare if the tributary watershed area is greater than 15 km^2 and the tributary watershed area is greater than 1% of the watershed area it flows into. Of the 381 tributary junctions, 13 fit this criterion. Using both criteria, 55 tributary junctions fit these criteria (Figure 8).

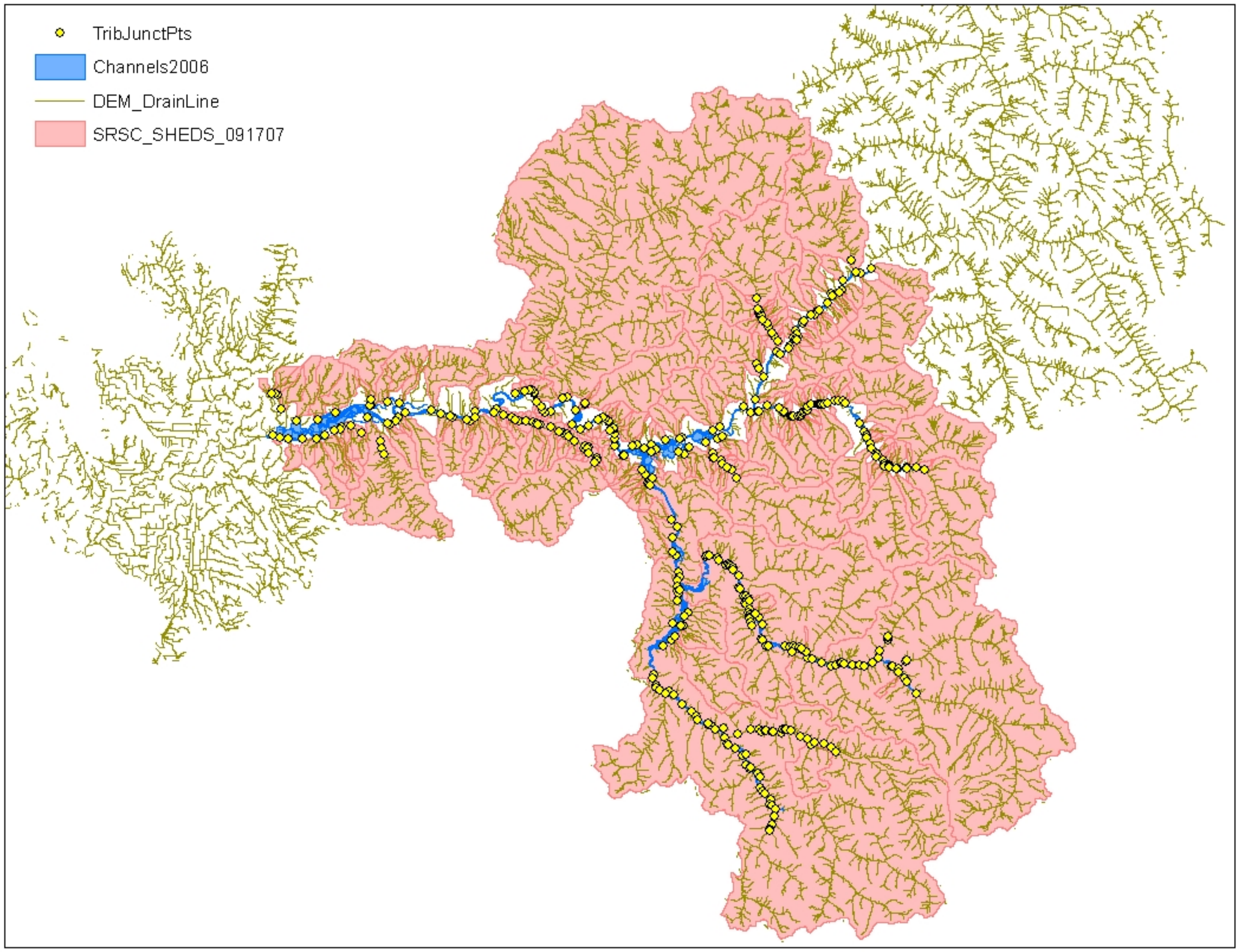

Figure 7. NWIFC's drainlines and watersheds created with ArcHydro overlaid by the Chinook salmon rearing range results in 381 tributaries junctions.

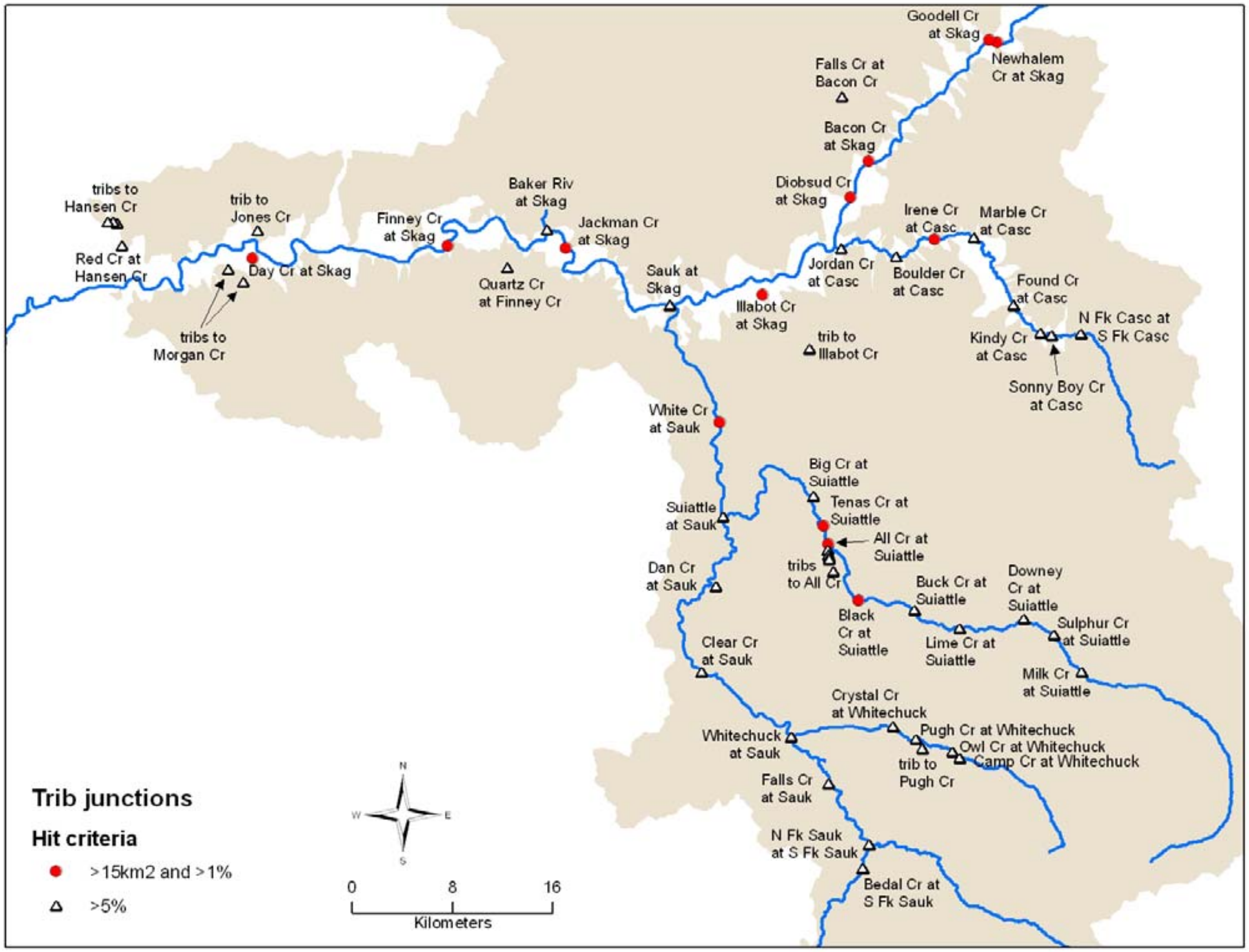

Figure 8. Location of 55 tributary junctions defined as rare habitat within the Skagit River Basin, based on 2 new criteria.

Large wood jams

Reviewers of the study design suggested that large wood jams are a rare habitat that might not be represented in our GIS-based habitat inventory or fish sampling design. The GIS layer *Logjams2007* was made in order to characterize log jams.

The log jam layer was created by digitizing arcs over oblique (Pictometry) aerial photographs flown in 2007 (Figures 9 & 10). Arcs were digitized where the photo showed three dimensional accumulations of woody debris touching the water's edge at a minimum length of five meters. The arcs were adjusted over orthophotos in GIS to eliminate the positional error inherent in digitizing arcs over oblique photos. These log jams were remotely identified and not ground-truthed; some log jams could have been missed due to the angle the photos were shot, and the available photo coverage did not extend to the furthest reaches of our study area, including the Upper Cascade River, most of the Suiattle River, and the Upper Sauk River (Figure 11). We used GIS to calculate the length of each arc in meters.

The above process identified 347 log jams within the photo area – hardly a rare habitat (Figure 11). Thus, we considered rare habitat for log jams to include those large enough to have a geomorphic influence on the channel rather than those that merely add complexity to the water's edge. We considered log jams that touched at least 100 meters of water's edge as a good surrogate for geomorphic influence because most of the larger jams created islands or slowed lateral channel migration. Only 11%, or 53, of all log jams fit our definition of rare log jams (Figures 12). Log jams greater than 100m in length were classified per Abbe & Montgomery (1996) as bar apex, meander, or "other" (Figure 13).

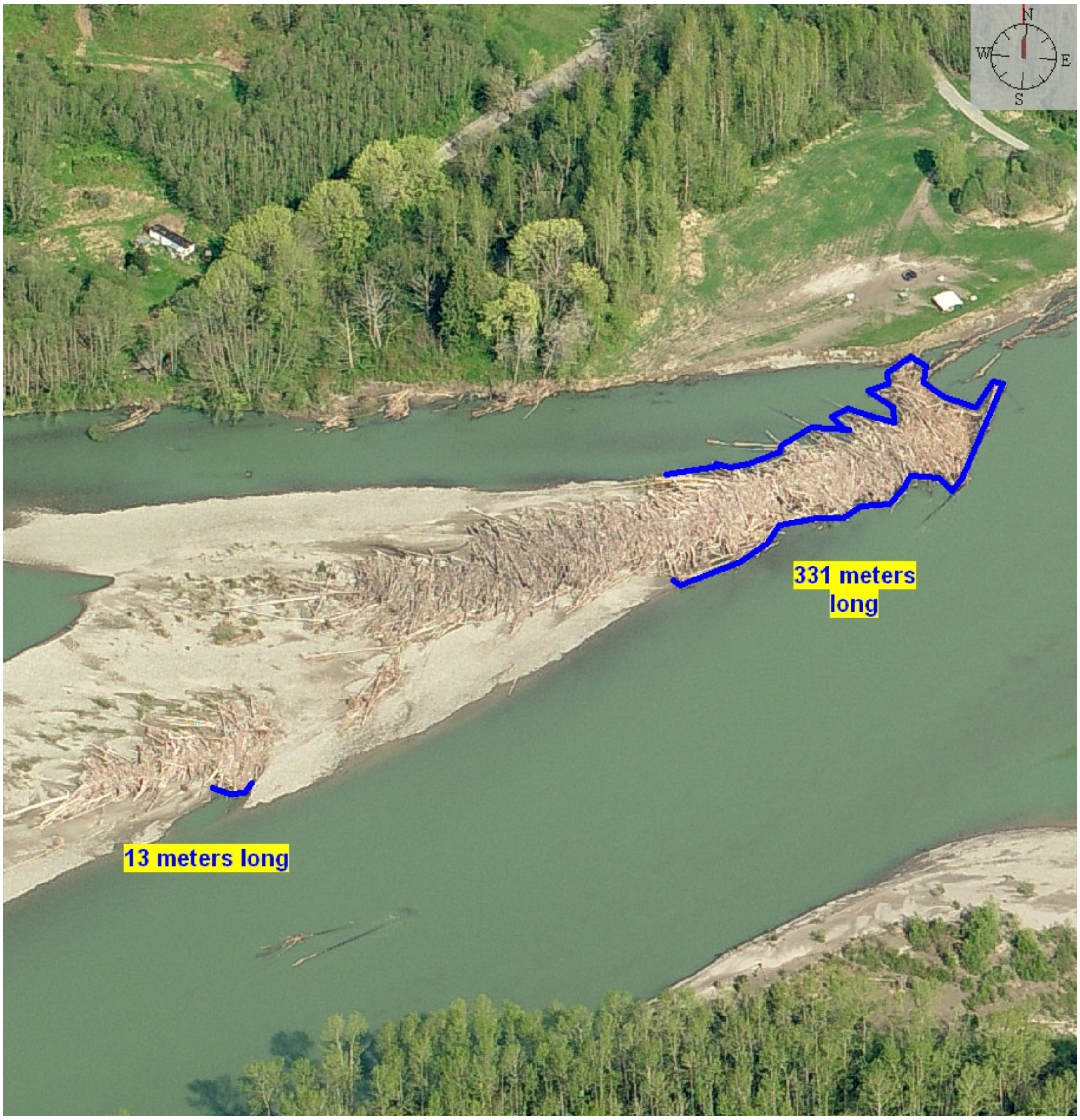

Figure 9. Example of a bar apex jam (331 meters long) that is having a geomorphic influence on channel form, and another smaller log jam. Shown as digitized over oblique Pictometry photo.

Figure 10. Example of three meander jams of varying lengths. Shown as digitized over oblique Pictometry photo.

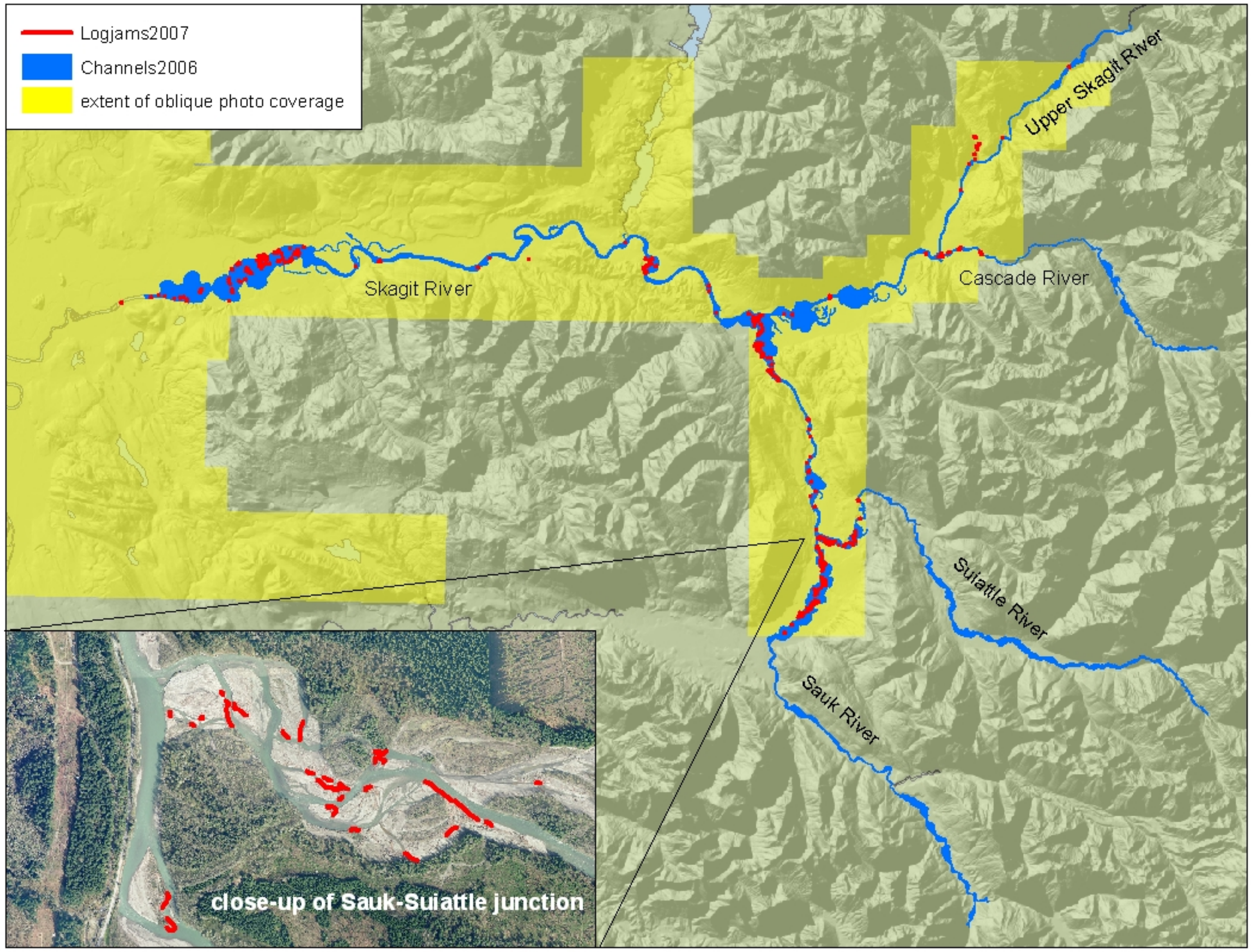

Figure 11. All jams mapped (347 arcs). Figure shows extent of Pictometry oblique photo coverage used to identify jams. Close-up view is on 2007 orthophoto.

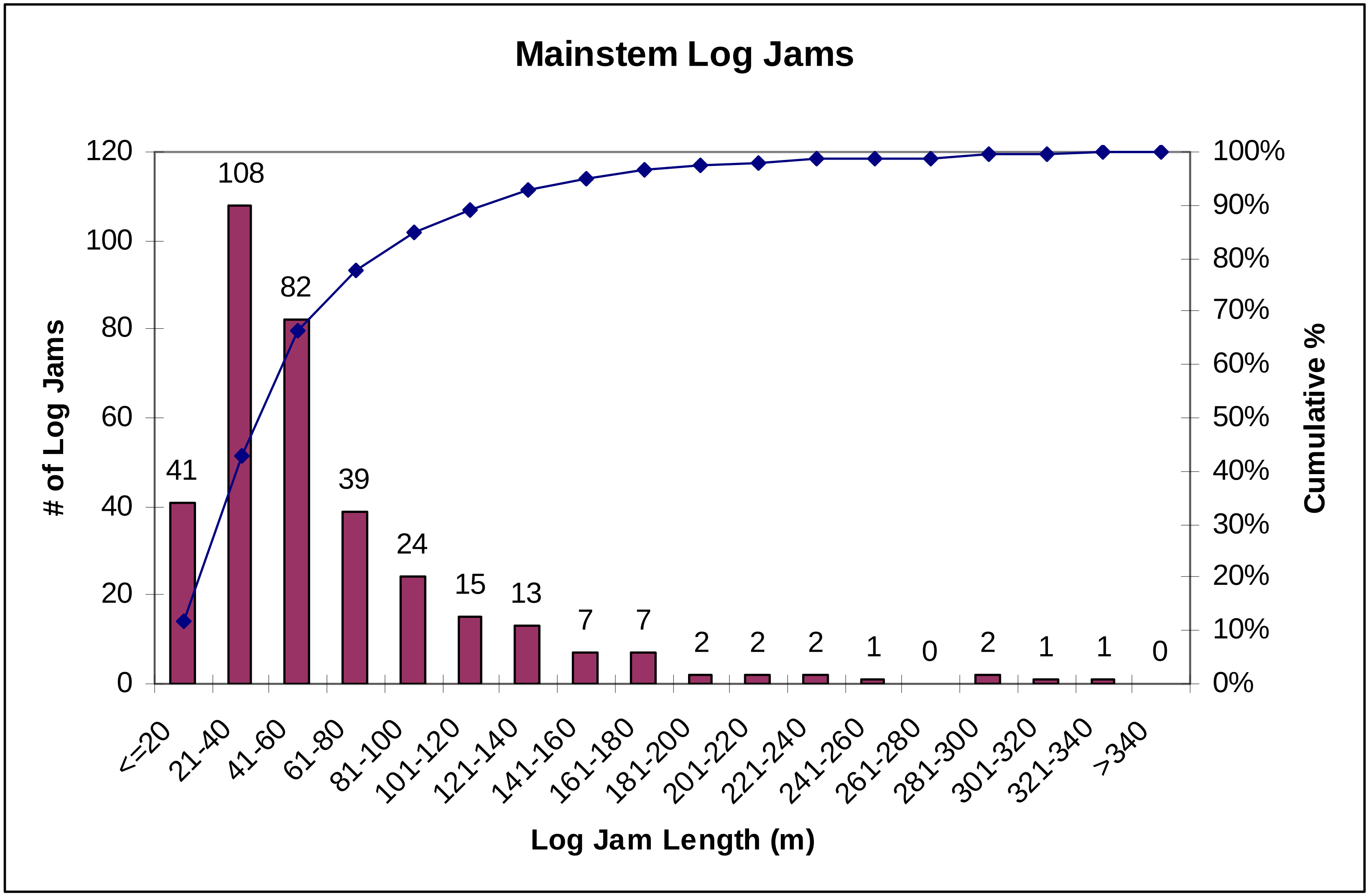

Figure 12. Frequency distribution of log jams by length of jam touching the water's edge in year 2007 oblique Pictometry photos. Eighty-nine percent (89%) of the jams are shorter than 100 meters in length.

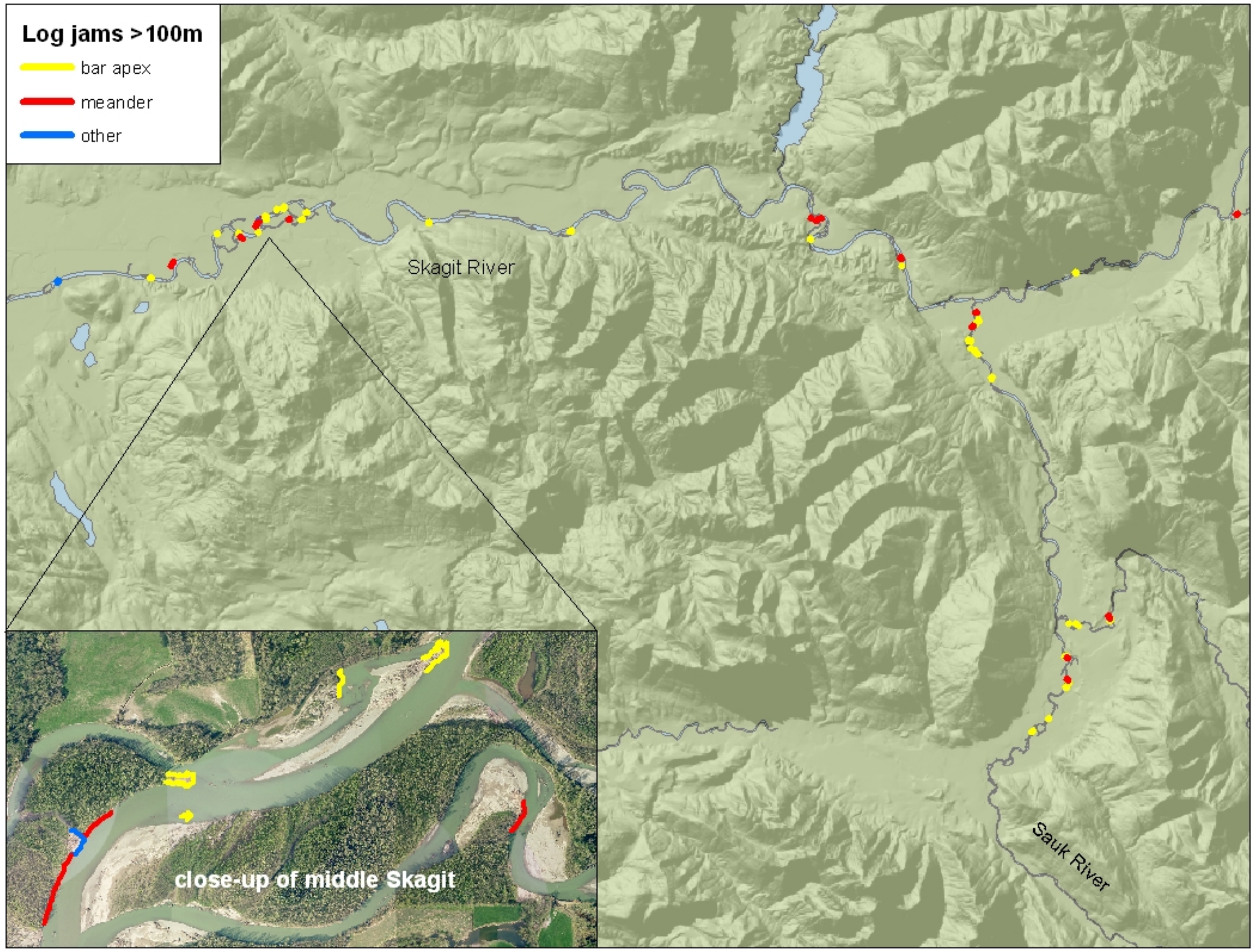

Figure 13. Log jams greater than 100m in length (53 log jams). Jams identified as bar apex, meander, or other, based on Abbe & Montgomery (1996). Close-up view is on 2007 orthophoto.

Habitat quantities

The 1,854.3 hectares of habitat associated with large mainstems based on the year 2006 orthophotos is nearly identical to the same area calculated for mainstem habitat (mid-channel and edge units) for the year 2000 period (1,850.1 hectares). The year 2000 was created for the Skagit Chinook Recovery Plan (SRSC and WDFW 2005). With the year 2006 data, we have spatially specific results of mainstem habitat for two time periods.

Table 3. Habitat quantities by space and habitat type strata.

Simplified space strata (n=5)	**Space strata based on unique juvenile Chinook salmon rearing ranges (n=10)**	**Small mainstems & tributaries (length in km)**	**Large mainstem**		**Floodplain (secondary) channel area (ha)**
			Perimeter (edge) in km	**Area (ha)**	
Mixed stock - all	All Stocks	7.71	145.78	960.62	227.86
	Mixed stock - all Total	**7.71**	**145.78**	**960.62**	**227.86**
Mixed stock - Sauk	All Sauk & Suiattle Stocks		46.08	155.92	52.40
	L. Sauk Summers & U. Sauk Springs	0.60	65.30	119.67	66.43
	Mixed stock - Sauk Total	**0.60**	**111.38**	**275.59**	**118.84**
Mixed stock – Skagit	U. Skagit Summers & U. Cascade Springs		38.34	152.91	89.04
	Mixed stock – Skagit Total		**38.34**	**152.91**	**89.04**
Ocean - 1 stock	L. Sauk Summers	3.69			
	L. Skagit Falls	48.90			0.70
	U. Skagit Summers	22.66	55.66	172.15	24.83
	Ocean - 1 stock Total	**75.24**	**55.66**	**172.15**	**25.53**
Spring - 1 stock	Suiattle Springs	15.10	102.51	180.40	50.76
	U. Cascade Springs	3.28	36.43	39.20	24.10
	U. Sauk Springs	21.23	35.71	44.72	18.55
	U. Skagit Summers & U. Cascade Springs	1.30	25.34	28.73	4.89
	Spring - 1 stock Total	**40.91**	**199.99**	**293.04**	**98.30**
	Grand Total	**124.46**	**551.15**	**1,854.3**	**559.57**

Phase 1 Fish Data Collection Field Methods and Suggested Modifications

Background

Phase I goals include an evaluation of the proposed field methods to determine if a snorkel based approach could be used in the Skagit River to evaluate the seasonal and spatial rearing preferences of stream type Chinook salmon and *O. mykiss* in freshwater habitat by coupling empirically derived preferences (obtained by snorkeling) with a GIS data layer of Skagit River basin habitats. Specifically, habitat preferences by species will be determined based on fish counts during snorkel surveys stratified by time and space throughout the basin. This section describes the field methods used to collect fish count information from two temporal periods and a variety of habitat types.

Phase 1 will also provide important information that can also be used to determine how pre-project assumptions either support or hamper actual field data collection, as well as test the budgetary assumptions used to generate cost estimates. Given the size of the basin, volume of flow, hydrology dominated by glacier melt, and the potential for turbid flows a phased approach was utilized to validate a snorkel based approach in the Skagit River Basin. Past research in the Skagit River under much lower Chinook population sizes, and different gear types (boat-based electrofishing) were unable to observe yearling Chinook during their freshwater residency (Hayman et al 1996).

Phase 1 was scaled to determine if current population sizes provide the juvenile densities needed over a watershed or landscape scale to statistically assess rearing preferences using snorkel observations. Part of the analysis includes reviewing relevant scientific literature to support and direct the study approach and findings. Fish observations during phase one will provide the data for conducting a power analysis to determine the frequency of sampling in a fully implemented study.

Seasonal or Temporal Sampling

It is well documented that fish habitat preferences will change ontogenetically. Thus, we needed to evaluate the seasonal changes of habitat preferences. Six temporal sampling periods have been identified based primarily on Chinook salmon life history stages (Table 1, see conceptual design section).

It was decided that two seasons would offer the maximum environmental and biological variability for phase one goals, while keeping the level of effort manageable (and cost low) as a pilot level study. The summer period (August – Mid September) would include observations during summer low stream flows, and higher water temperatures. During this time period there could be limited space and food availability due to generally higher fish abundance following a productive summer rearing season and most sub-yearling Chinook salmon would have migrated out of freshwater habitat areas, leaving only stream type Chinook salmon present. The winter period (Late January- Mid March) would include lower winter flows, colder water temperatures, and the emergence of young of the year Chinook fry along with stream type Chinook salmon that survived the winter. We hypothesized that the winter rearing period would have the lowest abundance of juvenile stream type Chinook salmon than other time periods within the year.

Site Selection

Seven sites were selected for the phase one pilot study. Site selection was not random selection but based on several factors including the level of effort needed to complete phase one objectives, assumed Chinook rearing distribution, regulated and unregulated watersheds, hydraulic characteristics that control flow and temperature regimes (snow vs. rain), diversity of channel and habitat types, proximity to rare habitat types (large log jams and tributary junctions), and accessibility during both summer and winter sampling periods.

Field reconnaissance was conducted at potential sites prior to snorkel sampling to determine the feasibility of each of the sites. This effort was focused on ground truthing habitat types, assessing safety factors, and to identify the most efficient means for directing survey crews into the sites. Two potential sites were removed from the list, one due to loss of road closure (Upper Sauk near Bedal Campground) and the other (Cascade River near Found Creek) due to time and safety constraints while accessing the site in winter flows. Location of the final sampling sites for Phase 1 are shown in Figure 14. The seven sites were; Skagit River near Newhalem, Skagit River near Day Creek, Cascade River (near Kindy Creek for the summer sampling and below Boulder Creek for the winter sampling), Suiattle River near Big Creek, Upper Sauk near Peek a boo Creek, Bacon Creek near Falls Creek, and Finney Creek near Quartz Creek. Differences in sampling locations from the winter and summer sites is the result of the irregularly heavy snow pack in lower elevations during the winter of 2008. Budgetary and time restraints restricted renting equipment for accessing the same locations in both seasons.

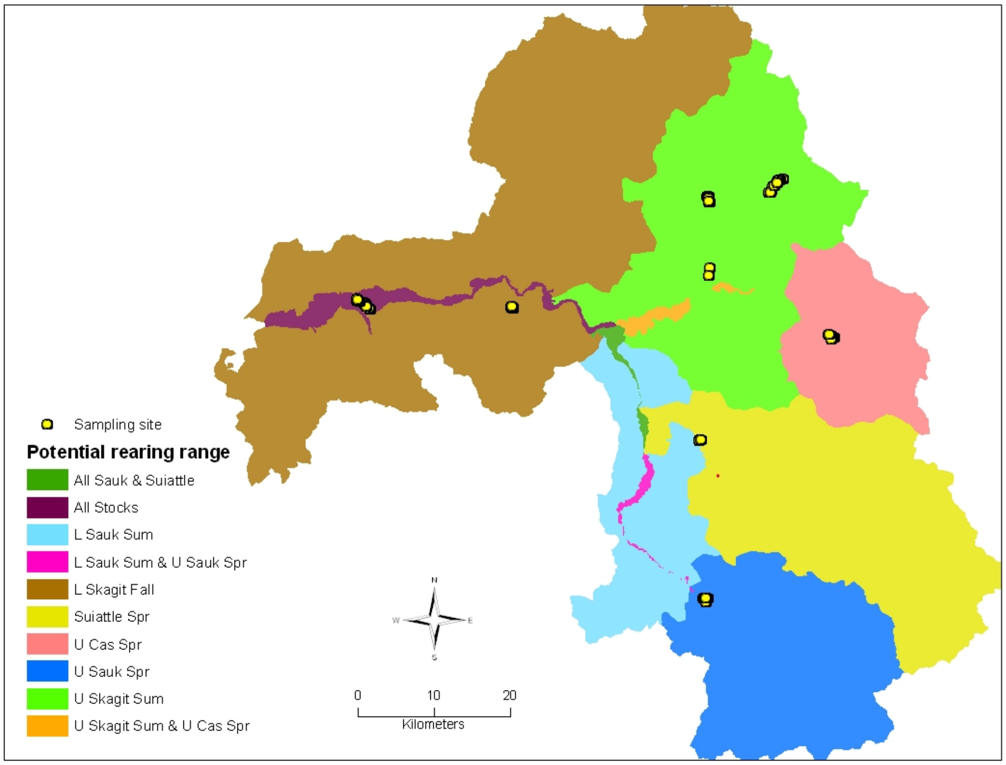

Figure 14. Locations of Phase 1 snorkel sampling sites within the Skagit River basin. The multiple sampling sites per station are representative of the channel types sample at each sampling location. The two sampling stations in the Cascade reflect the lack of access to the upper watershed during an irregular snow year; sampling was conducted near Kindy Creek for the summer strata and below Boulder Creek for the winter strata.

Habitat Types

For each of the seven sites, specific channel types were identified and delineated for habitat measurements and snorkeling based on the channel types shown in Table 2 (shown in conceptual design section of this report). For each tributary or floodplain reach, 10 channel units (e.g., pool, riffle, glide, etc.) were selected to snorkel in an upstream direction. Two hundred (200) meter sections of large mainstem reaches were snorkeled in the upstream direction along both mainstem edges classified by edge unit types (e.g., bank, bar, backwater). We snorkeled in the downstream direction within the mid-channel area of large mainstems based on channel units (pool, riffle, glide). The area covered on these drifts did not include the entire habitat type, but using visibility estimates and divers spacing we were able to quantify area surveyed. Thus, we collected multiple snorkel-based counts of fish by the habitat unit types present within mainstems (edge, mid-channel), tributary, and floodplain channels for all sites. A total of 243 channel units were sampled in Phase 1 with tributary and floodplain channels being the most common types sampled (Table 4).

Table 4. Snorkeling sample size by season, channel type, and space. NP = habitat type was not present. NS = habitat type is present, but was not sampled.

Season	Large scale habitat type	Bacon	Finney	Skagit Near Day	Suiattle Near Big	Upper Cascade	Upper Sauk	Skagit R Near Newhalem	Grand Total
Summer	Floodplain channel	9	9	NP	NP	8	10	14	50
	Large mainstem edge	NP	NP	8	NS	NP	NP	3	11
	Large mainstem Mid-channel	NP	NP	3	NS	NP	NP	10	13
	Tributary channel	17	10	NP	10	18	10	NP	65
Total		26	19	11	10	26	20	27	139
Winter	Floodplain channel	6	9	NP	NP	15	9	9	48
	Large mainstem edge	NP	NP	NS	4	NP	NS	3	7
	Large mainstem Mid-channel	NP	NP	NS	0	NP	NS	NS	0
	Tributary channel	10	20	NP	10	9	NS	NP	49
Total		16	29	0	14	24	9	12	104
Grand Total		42	48	11	24	50	29	39	243

The Yellow cells (shown in Table 4) depict areas where channel type calls differentiated from conceptual study design. The conceptual design denotes large mainstem channels on two separate measurements; >50 m bankful width, and a distinct visual shear line between mid-channel and edge habitats. Although bankful width is a useful tool for delineating channel types, using this metric solely for channel type delineation was difficult for field crews. For instance bankful width could only be measured at sampling station or it could be averaged over the reach. During low summer flows many of larger tributaries (Bacon, Finney, Cascade, and Sauk) could measure larger than the bankful criteria but flows and habitat types lacked the distinction between edge and mid-channel habitat types. Therefore, the stations were sampled like tributaries, where the entire channel was sampled and divided into habitat types of pool, riffle, and glide. Summer sampling in Bacon included 10 habitat types in Falls Creek a tributary, and 7 in Bacon Creek. Finney Creek in the summer is a small tributary, and quartz Creek was dry therefore not sampled. The Suiattle River sampling in summer only included Big Creek, the mainstem Suiattle was too turbid for sampling. The Cascade River summer sampling included Kindy Creek a tributary and mainstem Cascade also sampled like a tributary or full channel sampling. The Upper Sauk River was sampled like a tributary in summer, and the winter observations were cancelled due to an unexpected rain on snow event that prevented sampling. Also, the Skagit near Day Creek samples are missing for end of winter, due to pre-project assumptions on timed needed for winter sampling. and generally winter samples for all channel types other than floodplains are low for the winter period.

When investigating the number of snorkel samples by habitat type for Phase 1, we find sampling was skewed toward pools and riffles with few other unit types sampled however at many sites not all habitat types were present (Table 5). Overall, our sampling in Phase 1 may be unbalanced with the distribution of habitat types that occur within the basin. Goals of Phase 1 were not to replicate sampling consistent with the distribution present within the basin. Goals of Phase 1 were to collect snorkel counts of fish within the habitat present at 7 selected sites distributed around the basin for two time periods: summer and winter. We assumed that collected data in Phase 1 would represent the range and variability of fish abundance possible within the basin for use in power analysis. Phase 2 of the study, if implemented, would use a random design for site selection to better represent the distribution of habitat types present within the basin.

After completion of Phase I two recommendations can be made for implementing a phase 2 study design. The first recommendation is to account for extra time or equipment to access sites that may be difficult to access during the winter due to snowpack. The second more important recommendation is to evaluate the method for defining channel types, distinguishing tributaries from mainstems and mainstems from tributaries.

Table 5. Snorkeling sample size by season, habitat type, and channel unit type.

Season	Channel Type	Large mainstem edge type: backwater	bank	bar	Habitat unit type: glide	pool	riffle	step pool	Grand Total
Summer	FP channel	never exist	never exist	never exist	9	25	16		50
	mainstem edge	2	5	4	never exist	never exist	never exist	never exist	11
	mainstem mid-channel	never exist	never exist	never exist	5		8	rare	13
	tributary	never exist	never exist	never exist	8	32	22	2	65
Summer Total		3	5	4	22	57	46	2	139
Winter	FP channel	never exist	never exist	never exist	3	25	20		48
	mainstem edge		2	1	never exist	never exist	never exist	never exist	3
	mainstem mid-channel	never exist	never exist	never exist		2	2	rare	4
	tributary	never exist	never exist	never exist	2	23	24		49
Winter Total			2	1	5	50	46		104
Grand Total		3	7	5	27	107	92	2	243

Specific Habitat Measurements per Habitat Unit Types

The study design based physical and biological data collection on the distinction between channel types. One method was used for large mainstem (>50 m bankful width) channels, and the other method for both tributary and floodplain channels. The large mainstem channel units were divided into edge habitats and mid-channel habitat units. Edge units included banks, bars, and backwater pools, and mid-channel units included glides, pools, and riffles. The second method was used in both tributary and floodplain channels. These channel types were divided into habitats including pool, riffle, and glide. Procedures for measuring habitat did not change based on season and were always completed in the day prior to snorkeling for both winter summer surveys. Working upstream in floodplains and tributaries each unit was measured with a laser range finder to measure length and width of wetted channel. The wetted width and BFW measurements were taken at representative locations within the unit that most closely represented the entire unit. Depth measures were taken at three representative sites for riffles and glides, and for pools the max depth and tail depth were recorded. All depth measurements were made using a stadia rod and measured to the nearest 0.01 m. For large mainstem edge units the width of edge habitat was measured by a visual shear line between slower edge flows and faster mid-channel flows. Length measurements were either taken from GPS points, or field measurements and depth measurements were based on average depths. Then in each habitat unit regardless of channel types, percent substrate and are of cover types (wood, live vegetation, substrate, pool depth and undercut bank) were visually estimated. Using Timber Fish and Wildlife guidelines LWD was also tallied for individual habitat units.

Surface velocity measurements were also taken at three representative locations within each unit type, except in pools were tail velocity was measured and recorded. A copy of the physical attribute datasheets is shown in Figure 15.

___________________	Date:_______	Time:_____________	Crew:___________________________	Error checked by:________
_____ Visibility Ave:_______(M)		Turbidity:___________	pH:_______ DO:______	Date checked:____________

: Surve (Circle): Mainstem Edge Mainstem Mid-channel Floodplain Channel Trib Junction Log Jam Tributary

								pool measurements				Substrate = 100%					Cover =100%				
Length (M)	Wetted Width (M)	BFW Width AVE	Ave Depth M	Ave.Velocity (__/S)	VelocityBin (H,M,L)	% BLDR	Embed edness	MaxPool depth (M)	PoolTail Depth (M)	Pool Type	PFC	B	C	Gr	S	fill ins	W	V	S	P	other

Type	Comments

ate: B= boulder, C= cobble, GR= gravel, S= sand,Bed=bedrock, O= other

W= wood, V= live vegetation, S= boulder, cobble, P=pool/deep wate **Embeddeness** (Riffle only) O=optimal, S=suboptimal, M=mar

wood, jam, bedrock, bank **pool type:** PLs=lateral scour, PTr= trenchpool, PBw=pool back velocity bin H=>45cm/s,M 15-45cm/S

1 M for 2 M, 0.1 M into BFchannel **NSO:**river/channel type/unit type/#

Figure 15. Scan of datasheet.

Fish Observations

Underwater observation using snorkeling gear is a well documented approach to study stream dwelling fish. Methods using underwater observations have been used to estimate fish abundance (Pollard and Bjornn 1973, Hankin and Reeves 1988), habitat preference (Fusch and White 1981, Quinones and Mulligan 2005, Everest and Chapman 1972) fish behavior (Branford and Higgins 2001, Shirvell 1990, Peters in review), basin distribution (Hankin and Reeves 1988), and modeling relationships between landscape attributes and salmonid abundances (Thompson and Lee 2000). Snorkeling does not require excessive equipment limiting the personal needed to deploy and transport equipment. Given the limited equipment required for snorkeling this method is considered the easiest for working in remote locations. The equipment is also relatively inexpensive compared to other types of sampling equipment. Snorkeling is nonlethal and non-intrusive which is conducive to working with species protected under the Endangered Species Act. The disadvantages to snorkeling include the difficulty of making observations in turbid conditions, impossible to collect tissues samples, difficulty of making accurate fish identification calls, and estimating abundance of schooling fish in complex habitats.

Electrofishing is another method often used for fish distribution, enumeration, and habitat studies. However, low conductivity is normal for many streams in the Cascade Range making the use of electrofishing difficult. Many of the streams in our study area also contain deep pools with high water velocities making electrofishing difficult in much of the Skagit Basin (McMillan et.al 2010). Several researches have also indicated that electrofishing biases fish habitat descriptions because of displacement of fish during capture or in avoidance of capture. The advantages of electrofishing include sampling in shallow water too shallow for other methods, removal of fish from concealment in gravel, ability to secure specimens for direct measurement and sampling, and improved accuracy of counts when block netting or multiple passes are used. In addition to the difficult environmental characteristics found throughout the Skagit Basin electrofishing also can be lethal to salmon and developing embryos, since the focus of the study is three endangered species encountering unnecessary take of listed species must be a factor in the study design. Therefore it was decided to limit the use of electrofishing in this study.

Studies that used snorkeling for fish observations have all strongly recommended proper training prior to conducting field observations. Two members of the field crew completed swift water rescue training, and all members of the field crews completed a first aid CPR course prior to the field studies. The three divers in this study have extensive knowledge and experience identifying and handling juvenile fish in the Pacific Northwest.

Size Classes

In addition to personal experience field crews went through training and calibration on underwater fish identification and size class estimates prior to and during the implementation of the study. Small fish decoys or fish secchies were built to represent the size range of juvenile fish expected to be found in this study. Divers practiced and trained on their ability to accurately identify the fish decoys in the different size bins being used in the study. Roni and Fayram (2000) found when comparing night snorkeling to electrofishing length distributions they saw no significant difference when examining fish <160 mm. Thurow and Schill (1996) found no difference in length frequency distributions of bull trout from electrofishing and snorkel counts. Griffin (1981) found no difference in snorkel or electrofishing age frequency distributions of cutthroat and brook trout. The Phase I approach for collecting size (age equivalent) data for all juvenile species used an assumed bin size grouping system for all species. Size equivalent to age was based on recommendations from the oversight committee, which they recommended four size bins for this study; < 80 mm (fry), >80mm < 150 (parr), >150-<160 (yearling), and >160 mm (sub-adults or adults). Prior to conducting the field surveys a brief electroshock effort was conducted near each sampling location on the day of sampling. This effort provided a small sample of fish to identify species composition and size classes present within the stream reach being surveyed.

During the implementation of phase I study samplers noted that several of the Chinook observed during late summer did not meet the size bins for yearlings, but knowledge of migration and residency timing suggested any Chinook would be yearlings. To accurately collect fish size and age data, any grouping of age classes should be single species, not across all species. For the phase 2 study implementation we recommend reviewing the WDFW smolt data, and SRSC's delta and estuary data to compile size, age, and migration timing information to establish Skagit specific size/age classes to apply for our underwater observations.

Species Identification

One of the most difficult tasks for underwater research is the proper identification of juvenile fish species. Divers are often approaching specimens from the rear or from above limiting the use of phenotypic characteristics for species identification. Most field methods for studying fish capture or retain specimens for later identification in a more controlled environment. Underwater observations require divers to quickly assess identification as fish tend to flee once encountered by an observer. In addition to the possibility of quick fleeing response divers are subject to environmental obstacles like water turbidity, contrasting light and shadows, water turbulence as a visual barrier, multiple species in large schools actively swimming, and ability of fish to hide in complex habitat. In the pilot phase of this report divers found it most difficult to identify trout to the species level. Kennedy et al. (2009) examined field misclassification of steelhead and cutthroat trout and hybrids. Identifying trout fry can be difficult even while handling live specimens; underwater identification is even more difficult. To respond to this challenge we considered all trout fry as a generic trout, and avoided any association between cutthroat, steelhead and bull trout. Trout parr are also difficult to identify to species underwater, if a diver was able to accurately identify species then it was recorded, if not the trout was enumerated to the generic parr trout size class. It appears that handling of trout is the best method for species identification, and for fry lethal examination might be required. The small scale electrofishing effort prior to underwater observations proved to be an effective method for obtaining samples for identification. After consultation with the oversight committee, it was determined that lacking species specific data for trout observations would limit future analysis of the data. Several recommendations were discussed; however Appendix A explains the approach used to develop a recommendation for full study implementation. The modeling of physical and biological factors for determining steelhead and coastal cutthroat presence/absence predictors were not able to effectively predict stream assemblages. Therefore we recommend electrofishing a sub-sample of juvenile trout during the same seasonal strata as snorkel surveys, in the same channel and habitat types, to classify unidentified trout using post hoc identifications.

Day or Night Sampling

Our literature review revealed that the accuracy of visual counts of age 0 Chinook salmon and steelhead declined with water temperatures during daylight snorkeling (Hillman et al 1992). Below 9°C daylight snorkelers observed less than 20% of fish present, above 14°C snorkelers counted about 70% of the juvenile salmonids present. Thus, our summer snorkel surveys were conducted during the day while winter snorkel surveys were conducted at night based on long term temperature measurements showing water temperatures were lower than 9°C during winter months. This assumption proved true for winter (Table 6), but water temperatures were also below the 9°C threshold on several of our summer surveys (Skagit Newhalem, Cascade River, Suiattle/Big Creek), yet our snorkel surveys were conducted during the day. It is important to realize that fish observations for these sampling dates and locations may underestimate fish abundance since fish in cold water tend to hide in the substrate during daylight hours and are not free swimming within the water column.

Table 6. Summary of water temperatures at the time of sampling by season and location during Phase 1.

Location								
Season	Habitat Type	Skagit Newhalem	Skagit Day Creek	Bacon Creek	Finney Creek	Cascade River	Suiattle River	Upper Sauk River
summer	floodplain	4.7	NA	17.47	15.8	7.6	NA	9.3
	tributary	NA	NA	10.43	NA	10.2	8.3	NA
	mainstem	7.8	12	12.28	14.1	7.4	NA	14.1
winter	floodplain	4.6	NA	6	3.9	5.4	**	3.8
	tributary	NA	NA	NA	4.1	NA	**	NA
	mainstem	3.9	NA	5.6	3.9	5.5	**	NA

** Suiattle River sites were sampled during winter, however loss of equipment prevented measuring water temperatures during the surveys.

Phase 2 sampling design must incorporate flexibility or set water temperature standards for either day or night sampling based on actual water temperatures at specific sampling location, not predefined sampling seasons.

Biases in underwater observations can also be driven by environmental factors primarily temperature, water clarity, and habitat complexity. Water clarity will bias sampling results when turbidity or glacial flour reduces diver's ability to see underwater. A minimum visibility standard should be set so sampling efforts to not underestimate fish abundance due to lack of visibility. Gardiner (1984) recommended that underwater counts require at least 3 m of visibility, while Whitworth and Schmidt (1980) recommended at least 2 m of visibility. Hillman et al. (1992) was able to accurately count salmonids at 1.5 m if water temperatures are above 14 °C. In this study we measured underwater visibility using a small fish lure (around 120mm). The lure was held underwater at a fixed location. One diver moved downstream from the lure to the point where the diver could not clearly see the lure. That distance was measured and recorded. The diver moved farther downstream beyond the visual distance to see the lure. The diver then moved toward the lure stopping when the diver could clearly see the lure. This distance was measured and recorded, and then the average of the two measurements was recorded as the water visibility for that site, if the visibility was greater than channel width that was also recorded. If the measurement was smaller than 2 m the survey for that channel type was cancelled. Except when surveys were conducted on small floodplain channels, where the channel width and depth were less than 2 m. Knowing the visibility of each channel type at individual sampling stations enabled field crews to monitor spacing between divers to ensure complete coverage.

This minimum underwater visibility standard cancelled three surveys during the phase one sampling. In the summer 2007, the Suiattle River was too turbid (visibility < .5m) to conduct a survey on the mainstem. In the winter 2008 a late afternoon rain on snow event cancelled the first attempt to survey three reaches in Finney Creek. All three Finney reaches were surveyed at a later date. Another late afternoon rain event cancelled the Upper Sauk mainstem survey because of increased turbidity and decreased underwater visibility.

Phase I was designed to refine field methods for such obstacles. The method of crawling upstream to collect fish data is impossible given both depth and surface velocity in large mainstem channels. Some researchers find that passive downstream drift is the best method for sampling mid-channel units. The difficulty with mid-channel downstream drifts include; fish response to diver (fish facing upstream), speed at which a diver passes over a fish limits divers ability to identify fish, difficulty controlling drift location within channel, sampler safety, large area to cover given low fish abundance in high velocity waters. We designed a new sampling system to test the assumptions about working in large mid-channel habitats. With the aid of a gas powered winch, and simple climbing gear hardware we were able to pull divers upstream at varying speeds. With the same system we were also able to belay divers downstream. The divers wore breakaway harnesses so they could instantly detach from the pulley system, and swim to safety. We conducted multiple paired scenarios comparing fish observations with the different methods over the same habitats, passive drift vs. belayed drift, passive drift vs. upstream tow, and belayed drift vs. upstream tow. In all comparisons no juvenile fish were observed in any of the methods. Given the difficulty of setting this system up, risks to human safety, and low fish observation we recommend not using this system in the future. The recommendation for full study implementation is to only conduct passive daytime drifts in mid channel units when water temperatures are above 14°C, and to focus efforts on edge habitats for large mainstem waters.

Phase 1 Pilot Fish Results

After refining our field methods we collected pilot level fish observation data, including fish abundance and individual size classes by species from seven sites spread throughout the Skagit River Basin (Figure 14). We used the snorkeling methods described above to collect fish data for two time periods described in Table 1: end of summer and late winter. We also stratified fish data by habitat types shown in Table 2.

A main purpose in collecting fish data was to use it for statistical power analysis to determine options for sampling effort for phase 2 of this study. Phase 2 would use a random sampling design to answer fish questions that are space, time, and habitat type based.

In Phase I we snorkeled 243 sampling units and observed 383 juvenile Chinook salmon, 4509 juvenile steelhead, and 1124 juvenile coho salmon.

Effort by Site and habitat type

Snorkeling effort was unbalanced between sites (Figure 16). The Middle Skagit is the only place where backwater habitat was sampled whereas the Suiattle and Bacon sites are the only places where step pool habitat was sampled. The Skagit sites (Middle and Upper) include mainstem edge and mid-channel habitat in their samples and are different in their habitat distribution than all other sites which are more similar in their distribution of samples. Finney and Upper Sauk are nearly identical in their distribution of unit types sampled. Bacon, Suiattle, and Upper Cascade are nearly identical in their distribution of unit types sampled.

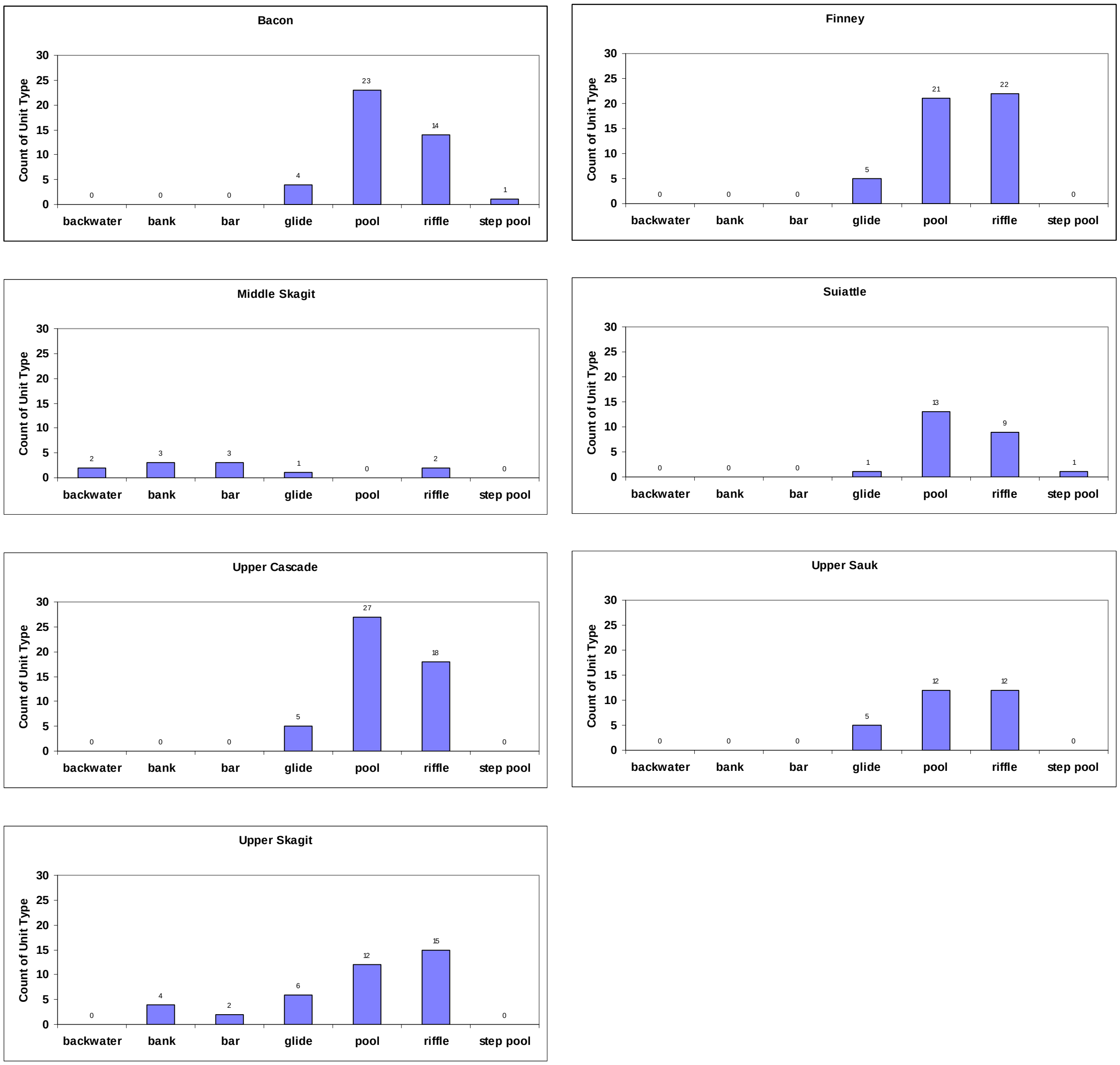

Figure 16. Distribution of habitat units snorkeled by site.

Fish Presence/absence by Site and Season

Chinook

Overall, juvenile Chinook salmon were observed in 39 of 243 snorkel sampling units. Juvenile Chinook salmon were found at three of the seven sites in both summer and winter seasons (Figure 17, upper left panel). Chinook salmon were found at only four of seven sites during summer but five of six sites during winter. Overall, six of the seven sites found juvenile Chinook salmon present. Only the Middle Skagit site did not detect Chinook present; it was only sampled for one time period: end of summer.

Juvenile Chinook salmon were the least frequently observed salmonid compared to presence/absence results for juvenile coho and steelhead.

Steelhead

Overall, younger juvenile steelhead were observed in 161 of 243 snorkel sampling units while older juvenile steelhead were observed in 143 sampling units. Younger and older juvenile steelhead were found at all sites and seasons sampled (Figure 17, right panels). Only the Middle Skagit site did not detect Chinook present; it was only sampled for one time period: end of summer.

Younger and older juvenile steelhead were the most frequently observed salmonid compared to presence/absence results for juvenile Chinook and coho.

Coho

Overall, juvenile coho salmon were observed in 72 of 243 snorkel sampling units. Juvenile coho salmon were found at all sites sampled in both summer and winter seasons (Figure 17, lower left panel). Only the Middle Skagit site did not detect Coho present; it was only sampled for one time period: end of summer.

Juvenile coho salmon were intermediate in their rate of presence compared to presence/absence results for juvenile Chinook and steelhead.

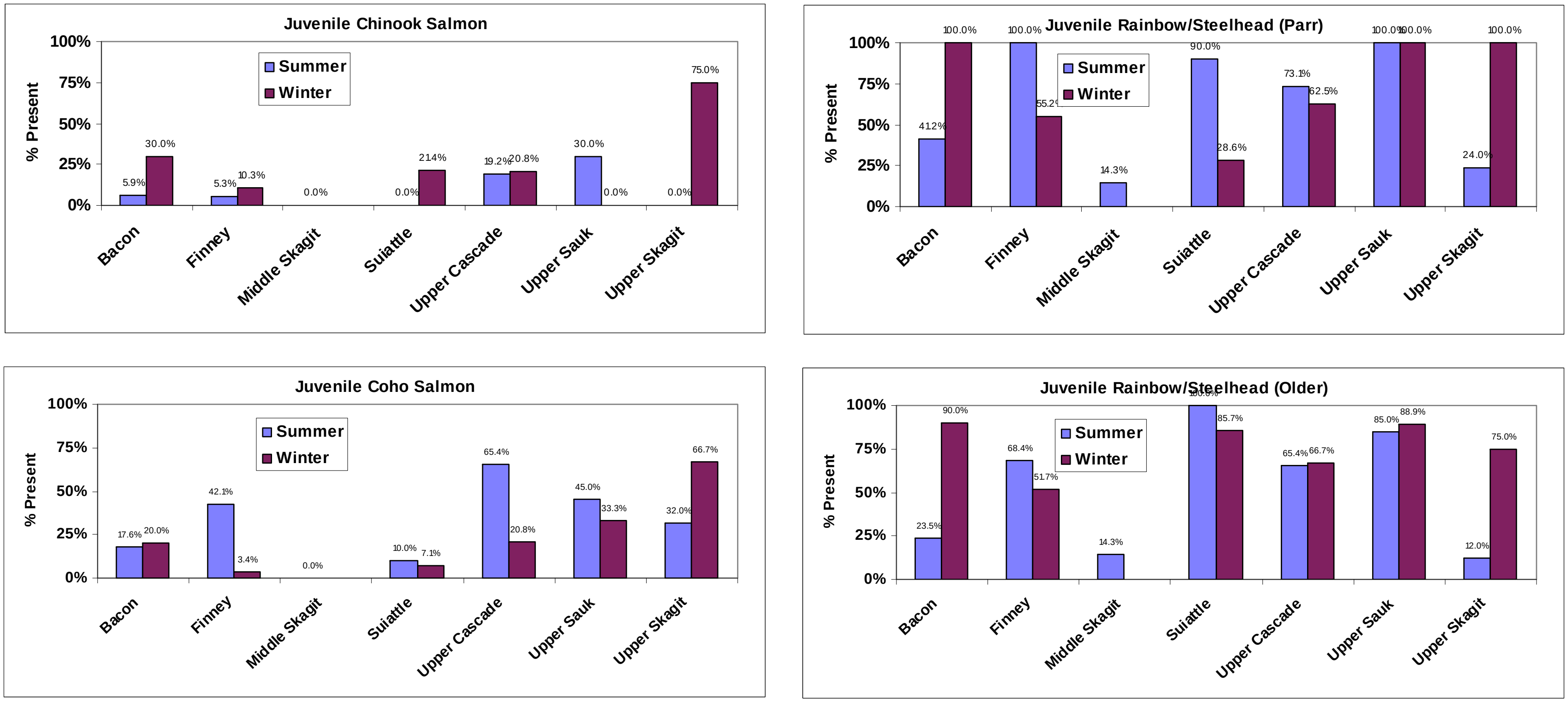

Figure 17. Percent of samples by site and season where juvenile Chinook, coho, and steelhead were present.

Fish Abundance: site/season and unit type/season

We used simple mean values of untransformed fish observed per minute of snorkeling per snorker (including all zero values) to graphically observe patterns of fish abundance by site and season (Figure 18) as well as habitat type and season (Figure 19).

Overall, graphically results suggest that juvenile Chinook salmon are least abundant while juvenile steelhead are most abundant, and coho are intermediate.

There is the potential for site similarities such as Finney and Upper Sauk having very high juvenile steelhead abundance during summer compared to all other sites (Figure 18). There also appears to be seasonal differences with generally lower abundance of steelhead and coho during winter compared to summer reflected in results stratified by either by site or habitat type.

There is also the potential for habitat type differences in fish abundance. Chinook abundance appears higher in banks, pools and glides compared to the other unit types in winter while juvenile coho strongly preferring pools in summer and younger steelhead prefer bars and glides in summer.

These graphical results do not control for unbalanced sample size which is influencing the results (Figure 16). For example, literature suggests that backwaters are an important habitat for both coho and Chinook salmon yet our results, at face value, are not supportive of that conclusion. Backwater habitat was sampled at only one site, the Middle Skagit, and therefore may not represent true fish patterns.

Also, higher abundance of Chinook salmon was observed in winter compared to summer for the Upper Skagit site. This is unexpected as there would likely be less fish near the end of winter than during summer because of ongoing mortality of fish occurring between both periods. As mentioned above in the snorkeling methods section, it is possible that our result for summer sampling in the Upper Skagit reflects not snorkeling at the right time of day. We snorkeled during daylight hours for the summer sampling but the water temperature was low enough to merit night time sampling methods. Thus, our summer results for Upper Skagit are likely bias low. It is our recommendation for future study to sample during daylight or night hours based on measured water temperature, not based solely on season.

These simple graphical results are useful to generate hypotheses which can be tested with appropriate statistics.

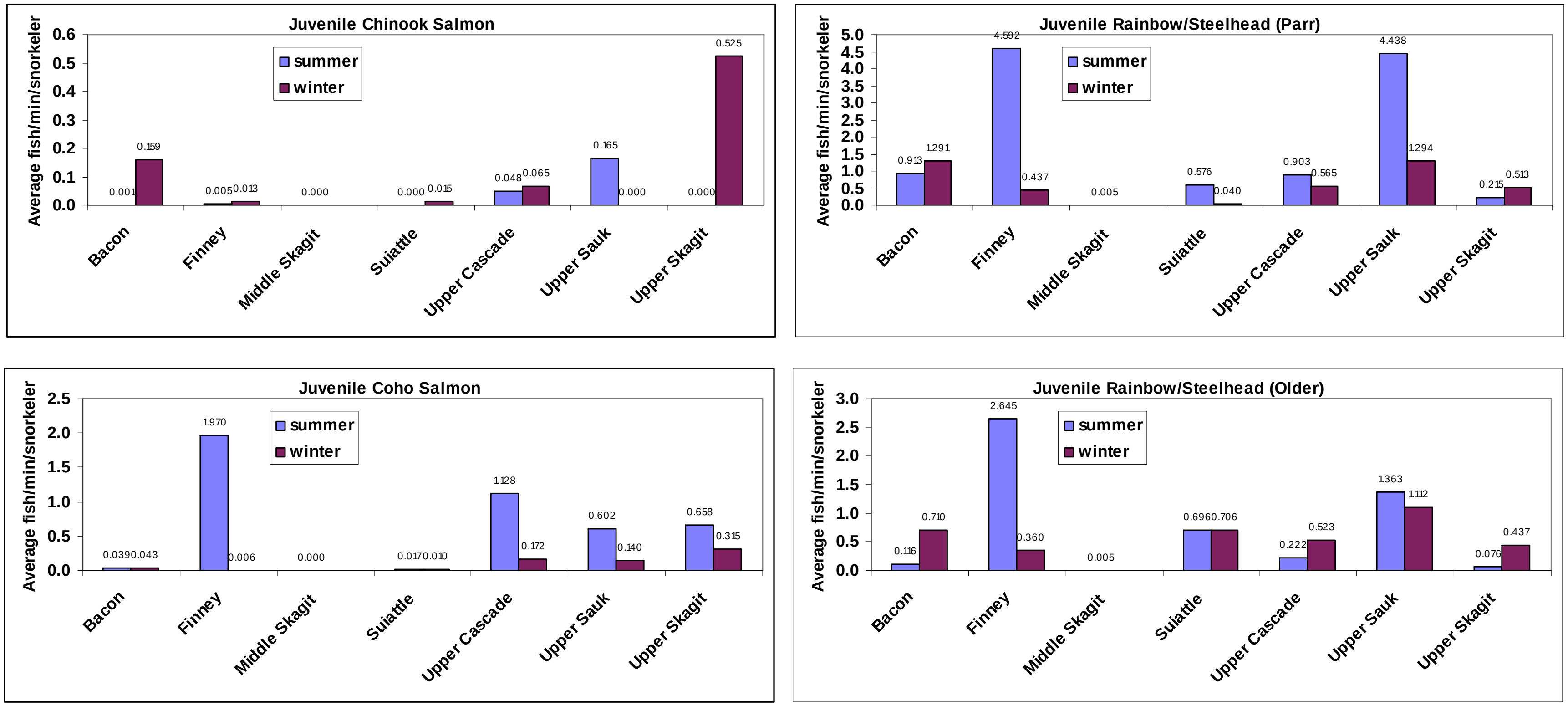

Figure 18. Average abundance of juvenile Chinook, coho, and steelhead by site and season. Note differing Y axis scales.

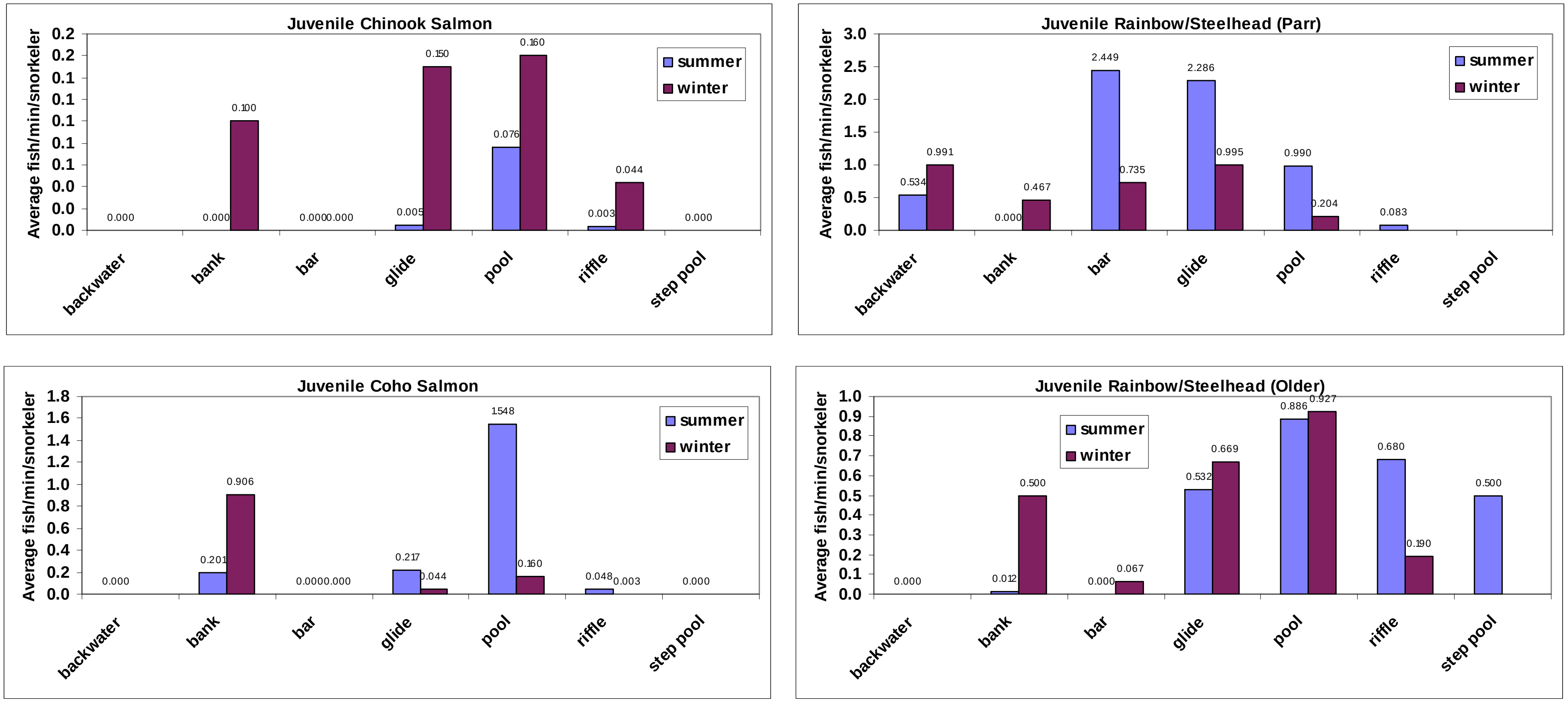

Figure 19. Average abundance of juvenile Chinook, coho, and steelhead by habitat unit type and season. Note differing Y axis scales.

PRIMER Analysis

Typical parametric statistics are limited in their ability to these hypotheses because our data contains many zero observation for individual species. For example, our Phase I data contains 204 zero values for juvenile Chinook salmon, 171 for coho, 82 for younger juvenile steelhead, and 100 for older juvenile steelhead out of 243 snorkel sampling units. When taken together, our Phase I data has 54 (of the 243) sampling units where no Chinook, coho, or steelhead were observed.

To overcome the problems of zeros in our data, we averaged the 243 samples by site, season, channel type, and unit type which resulted in 55 samples where none have completely zero values for either Chinook, coho, or steelhead.

We then used non-parametric (PRIMER) analysis methods using the entire salmonid assemblage (Chinook, coho, steelhead) to test hypotheses related to site, season, and habitat type. Fish abundance data were square root transformed and resembled using Bray-Curtis Similarity to create Multidimensional scaling (MDS) plots. Analysis of Similarity (ANOSIM) statistics were calculated to test whether there were statistically valid influences of site, season, or habitat type on the fish assemblage.

Site

ANOSIM result testing for differences between sites (while controlling for season influence) finds overall very strong site are differences in fish assemblage composition (Global R = 0.28; P = 0.001) (Figure 20). Pairwise analysis shows that Upper Sauk and Finney are very similar in fish assemblage. Upper Skagit and Bacon are also very similar in fish assemblage while others sites are different in their fish assemblage.

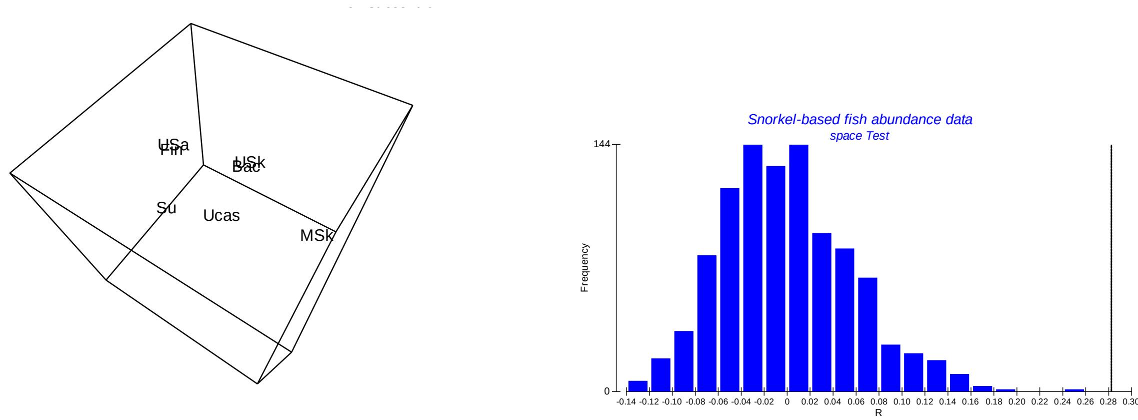

Figure 20. MDS plot controlled for season (left side) and ANOSIM results (right side) of fish abundance data and season. Sites in the MDS plot are: Upper Sauk (USa), Finney (Fin), Upper Skagit (USk), Bacon (Bac), Suiattle (Su), Upper Cascade (Ucas), and Middle Skagit (MSk).

Season

ANOSIM result testing for differences between season (while controlling for site influence) finds winter and summer are different in their fish assemblage composition (Global R = 0.219; P = 0.011) (Figure 21).

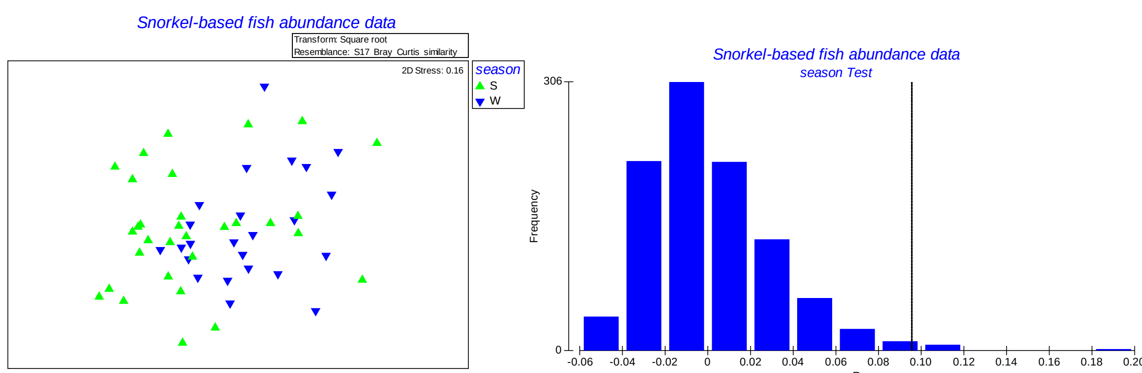

Figure 21. MDS plot controlled for space (left side) and ANOSIM results (right side) of fish abundance data and season. Seasons in the MDS plot are: summer (s) and winter (w).

Habitat Type (Channel Type)

ANOSIM result testing for differences between channel type (while controlling for season and site influence) finds overall channel type differences in fish assemblage composition (Global R = 0.09; P = 0.031) (Figure 22). Pairwise analysis shows that floodplain channels are different than mainstem mid-channel in fish assemblage. Other pairwise comparisons were similar in fish assemblage or lacked data for valid comparisons.

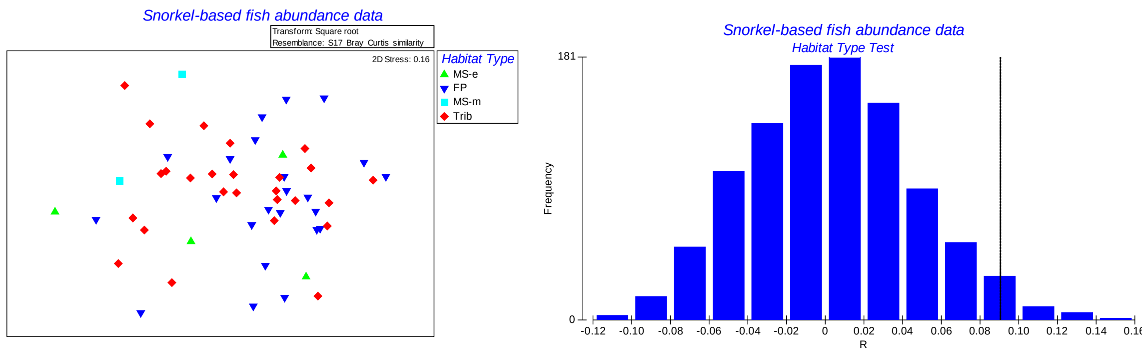

Figure 22. MDS plot controlled for space and season (left side) and ANOSIM results (right side) of fish abundance data and channel type. Channel types in the MDS plot are: mainstem edge (MS-e), floodplain channel (FP), mainstem mid-channel (MS-m), and tributary (Trib).

Habitat Type (Unit Type)

ANOSIM result testing for differences between unit type (while controlling for season and site influence) finds overall strong unit type differences in fish assemblage composition (Global R = 0.182; P = 0.002) (Figure 23). Pairwise analysis shows that pools and riffles, pools and step pools, glides and step pools, glides and riffles all are different in fish assemblage. Other pairwise comparisons were similar in fish assemblage or lacked data for valid comparisons.

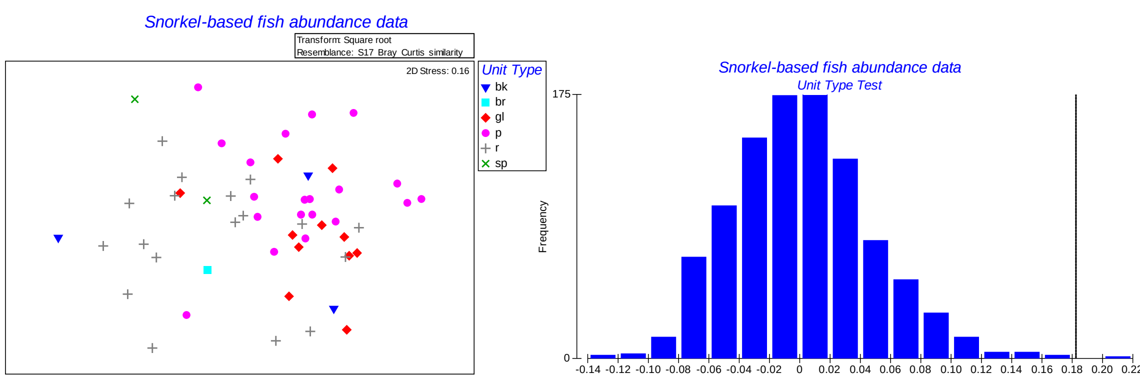

Figure 23. MDS plot controlled for space and season (left side) and ANOSIM results (right side) of fish abundance data and unit type. Unit types in the MDS plot are: bank edge (bk), bar edge (br), glide (gl), pool (p), riffle (r), and step pool (sp).

Hypothesis Testing Conclusions

Space – Space differences in fish assemblage abundance were detectable even with our low level of Phase I data collection (Figure 20). The sites most similar included two pairs: Finney/Upper Sauk and Bacon/Upper Skagit. Finney and Upper Sauk had similar very high average abundance of younger juvenile steelhead in summer compared to other sites. Bacon and Upper Skagit had similar very high average abundance of juvenile Chinook in winter compared to other sites. Thus, differences in space within the Skagit study area need to be considered in any future study of fish assemblage. Differences in fish assemblage results within the study area may be driven by fish population differences or fish preferences to specific habitat types that may be arranged in different proportions within the study area.

Season – Winter and summer differences in fish assemblage abundance were detected even with our low level of Phase I data collection (Figure 21). Thus, differences in season within the Skagit study area need to be considered in any future study of fish assemblage. Seasonal differences in fish assemblage results within the study area may be driven by fish response to different habitat types and transitions to different life stage such as those hypothesized in Table 1.

Habitat Type – Habitat type differences in fish assemblage abundance were detected even with our low level of Phase I data collection, especially at the finer scale level – Figure 23). Habitat type distributions varied by sites (Figure 16), our representation of space, for Phase I of the study area and is likely strongly influencing differences in fish abundance patterns by space (Figure 20). While our results in Phase I may be influenced by unbalanced sampling of habitat types, true unbalance of habitat types within the study area are likely due to differences geomorphology throughout the study area. Thus, application of fish results must be made in the context of an unbiased estimate (or census) of the habitat type distribution for the entire study area. We have provided GIS of habitat types for the entire study area for this purpose.

Statistical Power Analysis

We used two methods for power analysis to determine appropriate sample sizes for future study (Phase II).

Presence/absence analysis

We conducted fish presence/absence analysis on juvenile Chinook salmon and steelhead data using Likelihood Ratio Analysis methods (similar to Chi-squared). The presence/absence results tell us whether our observations of fish presence are randomly spread among different strata (e.g., space, season, habitat type) or whether there are non-normal patterns. Non-normal patterns of fish presence might reflect fish differences by strata (e.g., differences in seeding within the basin, preference to certain habitat types, etc), but they also might reflect sampling biases (differing ability to detect fish) or spurious results due to a lack of sampling size.

Likelihood ratio results are presented in contingency tables along their test statistic (L) and associated P-value. P-values less than 0.05 indicate that observed fish presence is ***different than expected*** under random circumstances. Thus, this analysis method can help determine whether strata (e.g., space, season, habitat type) are influencing the distribution of fish in terms of presence or absence.

For robust likelihood ratio results, contingency tables normally require at least 5 expected observations in >80% of all cells. Thus, we can use results from Tables 7 and 8 to determine whether our sampling effort was adequate for detecting true fish presence/absence patterns (a crude statistical power analysis).

Chinook salmon

A higher incidence of Chinook salmon presence than expected was observed in the Upper Cascade and Upper Sauk during summer, but lower incident than expected of Chinook salmon presence was observed in the Upper Skagit in summer (Table 7). For winter, a lower incidence of Chinook salmon presence than expected was observed in Finney Creek, but higher incident than expected of Chinook salmon presence was observed in the Upper Skagit. Generally, inadequate data (< 5 observation per cell) are present in 8 of the 14 cells, demonstrating that we under sampled to reasonably detect the true presence/absence patterns by site and season using this method.

Steelhead

Both higher and lower incidences of juvenile steelhead presence than expected for sites was observed during summer, but for winter only a lower incident than expected of steelhead presence was observed in Finney (Table 8). Only one incident of inadequate data (< 5 observation per cell) is present in the 14 cells, demonstrating that our sampling was generally adequate for detection of true presence/absence patterns by site and season using this method.

Table 7. Presence/absence analysis of juvenile Chinook salmon by site and season. Observed values are shown in **blue** and expected values are shown in **red**. For comparisons where observed is significantly different that expected fish presence, the direct of that difference is noted.

Site	End of Summer			End of winter		
	Chinook Absent	**Chinook Present**	**Actual v. expected**	**Chinook Absent**	**Chinook Present**	**Actual v. expected**
Bacon	**25**	**1**		**10**	**6**	
	24	**2**		**12**	**4**	
Finney	**18**	**1**		**26**	**3**	Less than expected
	17	**2**		**22**	**7**	
Middle Skagit	**11**	**0**		--	--	
	10	**1**				
Suiattle	**10**	**0**		**11**	**3**	
	9	**1**		**11**	**4**	
Upper Cascade	**21**	**5**	Greater than expected	**19**	**5**	
	24	**2**		**18**	**6**	
Upper Sauk	**14**	**6**	Greater than expected	**9**	**0**	
	18	**2**		**7**	**2**	
Upper Skagit	**27**	**0**	Less than expected	**3**	**9**	Greater than expected
	24	**3**		**9**	**3**	

Contingency table results - For end of summer: L=20.14; p=0.003: For end of winter: L=23.9; p<0.001

Table 8. Presence/absence analysis of juvenile steelhead by site and season. Observed values are shown in **blue** and expected values are shown in **red**. For comparisons where observed is significantly different that expected fish presence, the direct of that difference is noted.

Site	End of Summer			End of winter		
	Steelhead Absent	**Steelhead Present**	**Actual v. expected**	**Steelhead Absent**	**Steelhead Present**	**Actual v. expected**
Bacon	19	7	Less than expected	3	13	
	13	13		5	11	
Finney	6	13	Greater than expected	14	15	Less than expected
	9	10		9	20	
Middle Skagit	10	1	Less than expected	--	--	
	5	6				
Suiattle	0	10	Greater than expected	2	12	
	5	5		4	10	
Upper Cascade	9	17	Greater than expected	8	16	
	13	13		7	17	
Upper Sauk	3	17	Greater than expected	1	8	
	10	10		3	6	
Upper Skagit	22	5	Less than expected	3	9	
	13	14		4	8	

Contingency table results - For end of summer: L = 55.67; $p < 0.001$: For end of winter: L = 9.8; $p = 0.098$

Sample size and type II error

We conducted statistical power analysis on fish density data for juvenile Chinook and steelhead to determine sampling effort levels for Phase II

This power analysis is based only on the nonzero transformed data. We thought for about including the zeros, but decided against it for several reasons. First, we may not know what a zero actually means (evidence of absence or absence of evidence?). Second, all the zeros will drag down means and tend to greatly reduce estimates of effect size. Finally, as noted by Figure 24, zeros terribly skew the data, destroying the assumptions going into the power analysis.

Therefore, we did not use data with zero values. This means from a practical standpoint that this analysis is telling us the number of sites needed for at least one detection. This will form a liberal estimate of habitat use patterns, since some of the zeros are meaningful zeros (evidence of the absence of fish). Therefore, this analysis, in combination with the presence/absence data, will bracket our assessment of habitat use for the variables examined.

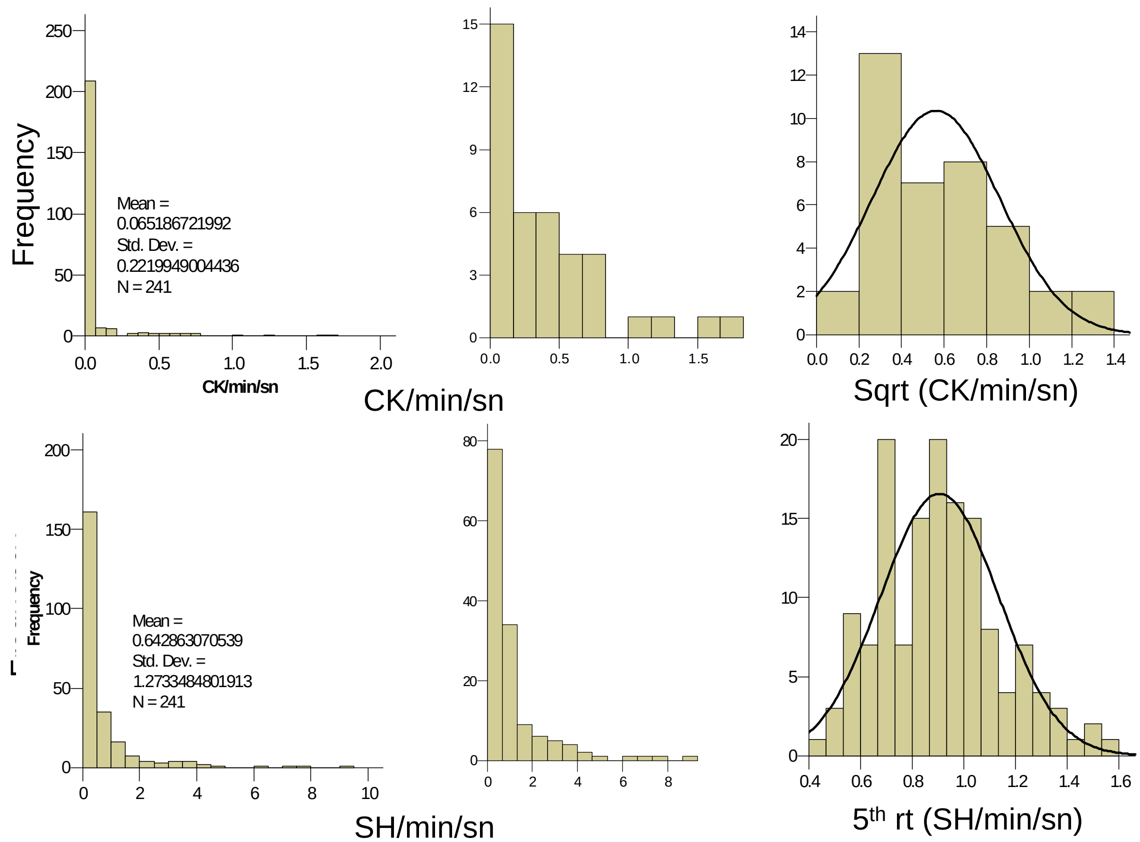

Figure 24. Observed and transformed snorkel based fish abundance results for juvenile steelhead and Chinook salmon. Snorkel observations were standardized by length of time in minutes spent snorkeling (min) and the number of snorkelers (sn) for each habitat unit. Graphs on the left side show the distribution of all data, including the number of zero counts. Graphs in the middle show the distribution without zero counts. Graphs to the right side show the transformed distribution without zero counts. We used square root transformation for Chinook and fifth root transformation for steelhead.

Season

<u>Juvenile Chinook Salmon</u> – In order to achieve statistical power of 0.8, we need to triple our effort for summer and double our effort for winter (Figure 25).

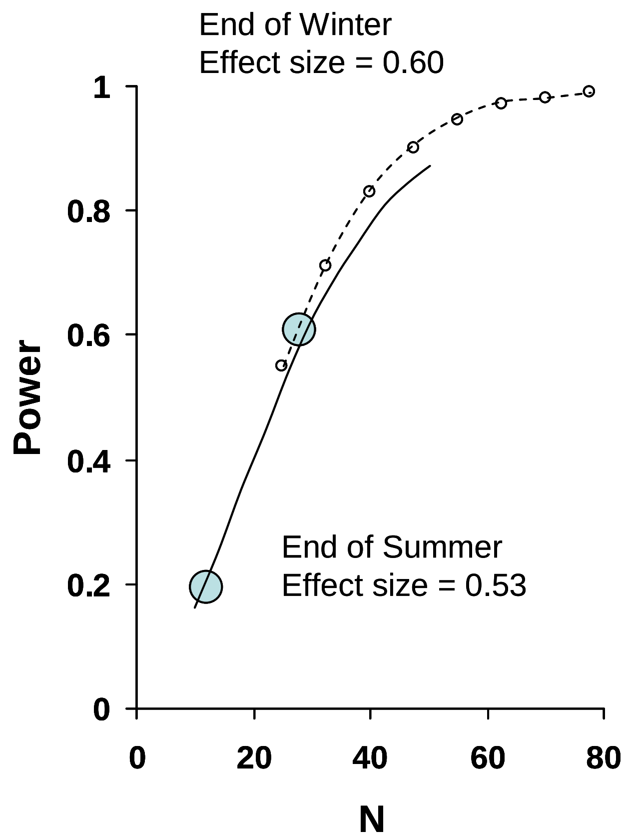

Figure 25. Statistical power curve by sample size for Juvenile Chinook by season. Dashed lines is power curve for winter. Solid line is power curve for summer. The blue dot represents results from Phase I using transformed data shown in Figure 24.

Juvenile steelhead – In order to achieve statistical power of 0.8, we need to double our effort for winter and effort is adequate for summer (Figure 26).

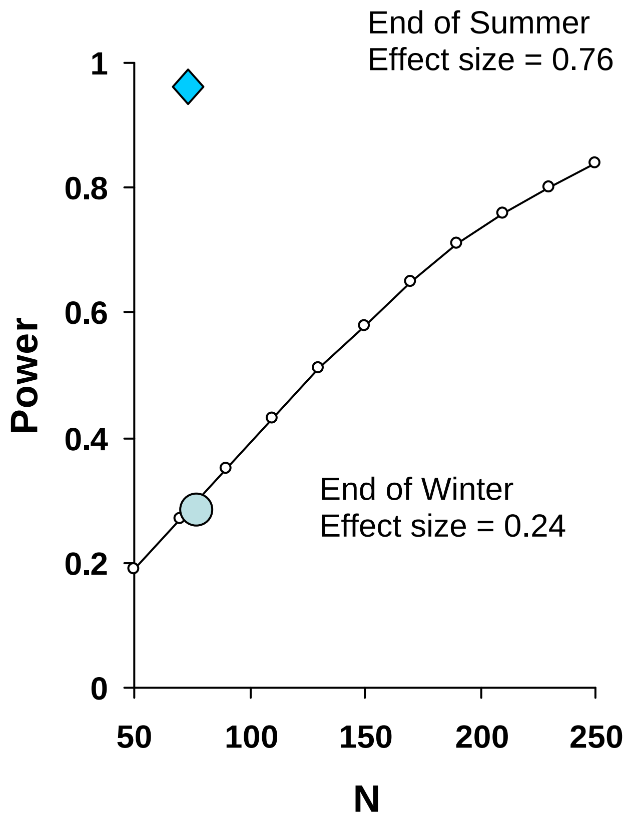

Figure 26. Statistical power curve by sample size for Juvenile steelhead by season. Solid line is power curve for winter. The blue diamond is the observation for summer from Phase I. The blue dot represents results from Phase I using transformed data shown in Figure 24.

Habitat Type (Channel Level)

Juvenile Chinook – In order to achieve statistical power of 0.8, we need to double our effort in winter and summer (Figure 27).

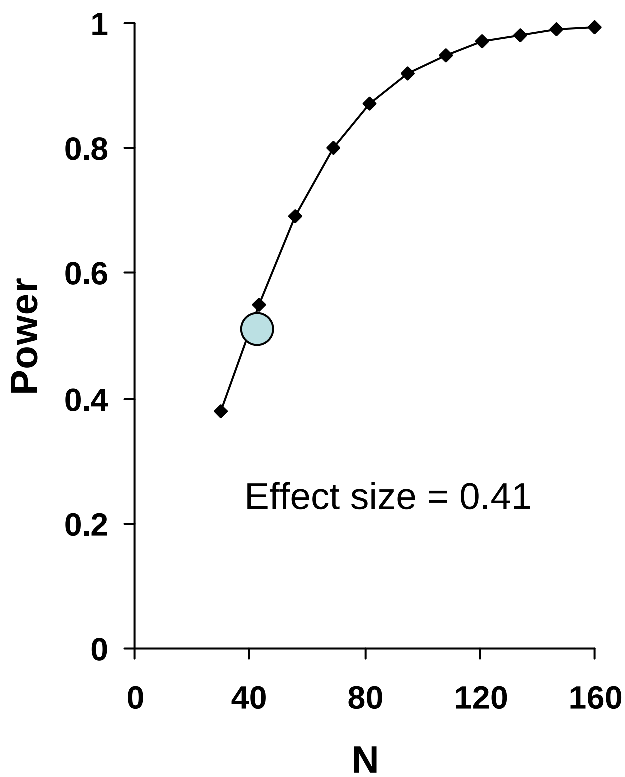

Figure 27. Statistical power curve by sample size for Juvenile Chinook by habitat type with seasons combined. The blue dot represents results from Phase I using transformed data shown in Figure 24.

<u>Juvenile steelhead</u> – In order to achieve statistical power of 0.8, we need to double our effort in winter and summer (Figure 28).

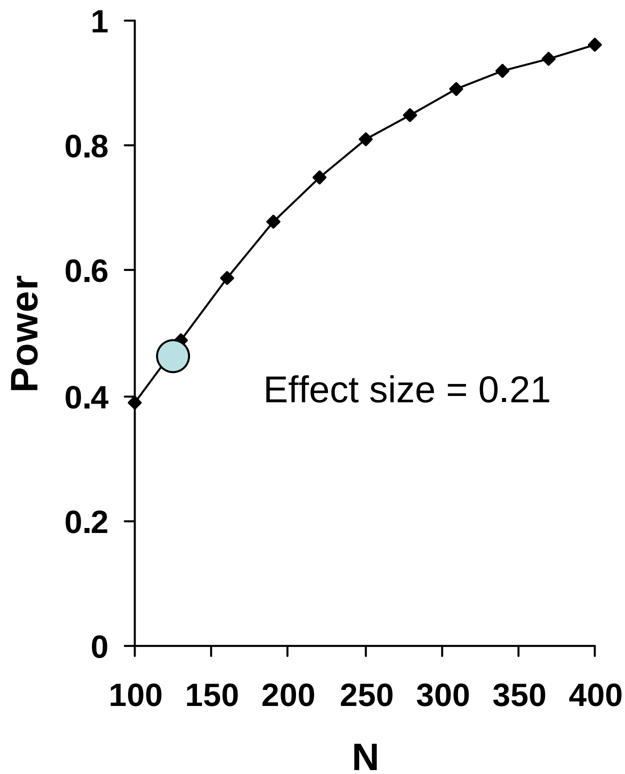

Figure 28. Statistical power curve by sample size for Juvenile steelhead by habitat type with seasons combined. The blue dot represents results from Phase I using transformed data shown in Figure 24.

Rare Habitat (Large Log Jams)

Juvenile Chinook – In order to achieve statistical power of 0.8, we need to trible our effort in winter and summer (Figure 29).

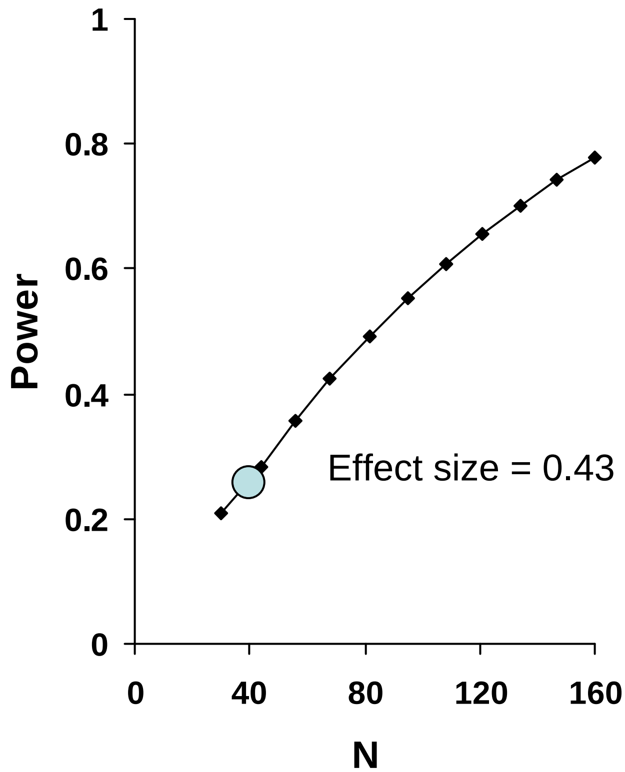

Figure 29. Statistical power curve by sample size for Juvenile Chinook by log jams with seasons combined. The blue dot represents results from Phase I using transformed data shown in Figure 24.

Juvenile steelhead – In order to achieve statistical power of 0.8, we need to double our effort in winter and summer (Figure 30).

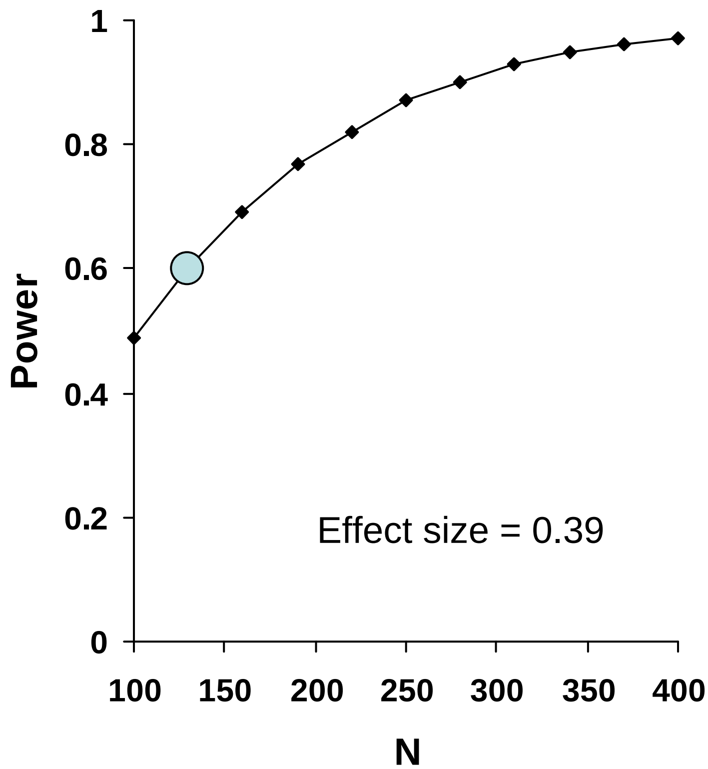

Figure 30. Statistical power curve by sample size for Juvenile steelhead by log jams with seasons combined. The blue dot represents results from Phase I using transformed data shown in Figure 24.

Sample size conclusions

In most cases, juvenile Chinook data are the limiting factor. If we increase our sample sizes by focusing on Chinook salmon, steelhead results will be adequately addressed. Overall, a doubling or tripling (depending on question of space, season, habitat type) of our effort will be sufficient.

We were only able to evaluate log jams as a rare habitat type, so we have no idea how other rare habitats (tributary junctions) might behave and the appropriate sampling scheme. Therefore, we analyzed both log jams and tributary junctions by determining whether we would under-sample these rare habitats in a random design that triples the sampling size.

Rare Habitat Sampling Rate Analysis

Our sampling design for Phase 2 needs to make sure we do not under sample rare habitat. Therefore we analyzed whether tributary junctions that are classified as "rare" habitat would be sampled at an adequate level through a random sample site selection process while not making tributary junctions a stratifying factor.

Results from the statistical power analysis of juvenile Chinook and steelhead results suggest that tripling the effort used in Phase 1 would be adequate to answer space, time, and habitat type questions of fish use at reasonable statistical power ($\beta \geq 0.8$).

The Phase 1 effort attempted to sample eight sites. Therefore, for the Phase 2 study proposal we tripled the effort and randomly selected 24 sites to triple the effort of Phase 1 and also randomly selected an additional six sites to use as back ups in case some of the 24 sites could not be sampled for some reason during implementation of the study. Thus, we have 24 and 30 specific sites randomly selected for sampling in Phase 2 of this study.

There are 55 tributary junctions fitting the rare habitat definition within in our study area. Five of the 55 tributary junctions were selected in the randomly selected 24 sites. Seven of the 55 tributary junctions were selected in the randomly selected 30 sites.

There are 53 large log jams fitting the rare habitat definition within in our study area. Four of the 53 large log jams were selected in the randomly selected 24 sites. Six large log jams were selected in the randomly selected 30 sites.

We compared the number of tributary junctions and large log jams per channel habitat length to estimate whether the randomly selected sites would sample rare habitat at a rate similar to what is present within the study area (Table 9. Since the statistical power analysis suggested we triple our effort, we assumed that tripling the number of sites would also roughly triple the length of channel habitat sampled in Phase 2 compared to what we sampled in Phase 1. In Phase 1 we sampled 3.16 kilometers of channel when there is an estimated 621.78 kilometers of channel for our study area.

Table 9 Length of habitat in kilometers.

Habitat type	Sampled in Phase 1	Entire Study Area
Floodplain channels	1.16	293.16
Large mainstem channels	0.43	204.16
Smaller mainstem and tributary channels	1.57	124.46
Grand Total	3.16	621.78

We estimated the number of tributary junctions and large log jams per kilometer of channel length by dividing the number of each rare habitat by the channel length estimate (Table 10).

There are 0.09 tributary junctions per kilometer of channel in the entire study area. For the 24 sites selected, we would sample tributary junctions at the rate of 0.53 per kilometer of channel assuming a similar per unit length of channel. For the 30 sites selected, we would sample tributary junctions at the rate of 0.74 per kilometer of channel.

There are 0.09 large log jams per kilometer of channel in the entire study area. For the 24 sites selected, we would sample large log jams at the rate of 0.42 per kilometer of channel assuming a similar per unit length of channel. For the 30 sites selected, we would sample large log jams at the rate of 0.63 per kilometer of channel.

Table 10. The rate of rare habitat, tributary junctions and large log jams, per length of channel habitat.

Study Phase Option	Tributary junctions per km	Large log jams per km
Entire Study Area	0.09	0.09
Phase 2 - Proposed 24 sites	0.53	0.42
Phase 2 - Proposed 30 sites	0.74	0.63

The results in Table 10 indicate that tributary junctions and large log jams are proposed to be sampled in Phase 2 more frequently than they occur within the study area. We conclude our Phase 2 sampling design does not <u>under</u> sample rare habitat.

Phase II Recommendations

Lessons from implementing field methods during Phase I

Beyond the revised methods identified earlier, several methods modifications are recommended for Phase II. All methods recommendations for Phase II are summarized here:

1. For measurement of mainstem reaches GPS point to point measurements are not accurate for bankfull width and reach unit length. Use a high quality laser range finder instead.
2. Add a cover type of micro-velocity pool
3. Percent substrate should be estimated during snorkeling portion of fieldwork
4. Measure bottom water velocity not surface velocity.
5. Do not conduct mainstem mid-channel sampling at night, only do day light passive drifts if water temperatures above 16°C
6. Plan for all night snorkeling unless water temperatures are above 16°C regardless of season.
7. Add additional time for night snorkeling, and winter work. Include budget for accessing sites in winter with nonautomotive means.
8. Set and establish underwater visibility standards, measured at each channel type for each sampling location.
9. Set field-based standards for distinguishing between mainstem and tributary channel types other than > 50 m bankfull width measurements.
10. Use existing Skagit River juvenile data (Burlington smolt trap and Delta, estuary, and near shore sampling) to determine appropriate size bins for collecting size/age equivalent data.
11. Drop Bull trout focus and analysis. The study design used the Chinook rearing range as the bases of spatial strata and limited juvenile bull trout were observed. This could be a combination of bull trout behavior (diurnal concealment) and resource partitioning with different spatial rearing preferences.
12. Discuss the tradeoffs in cost, knowledge, and do ability between the number of space bins (1-all Skagit; 3-pseudo unique by stream and ocean type mixtures; 5-unique polygons by stocks). Power analysis said to triple the effort for each space/time bin for Chinook.
13. The temporal sampling goal of a Phase II study is to collect habitat use data for as many of the six sampling periods as possible during a 12-month time period, while balancing costs with information and do ability. Our recommended sampling cycle for Phase II is to start – Late Spring/Early Summer with 3.5 seasons.

    A Chinook oriented sampling cycle should begin in lateMay/early June after the majority of ocean-type (fry) Chinook juveniles have migrated leaving mostly Chinook that express a yearling life history to be observed. Zimmerman et al (2010) shows that ocean type fry have outmigrated the lower river by weeks 16-18 (mid to late April) and that parr migration declines after week 22-24 (late May or early June). Fish that remain in-river after this time are presumed to be mostly yearling type juveniles with a few parr migrants that continue to leave the river throughout the much of the summer.

Seasonal sampling would begin mid-May and would be completed March-April of the following year after sampling during the peak of the yearling outmigration period. This approach would identify changes in habitat preferences driven by temporal life history factors. One advantage of this approach is that a single production year would be followed from beginning (fry) to end (yearling outmigration). Zimmerman et al (2010) shows that parr production appears to be limited by habitat availability not fry seeding levels, at least at recent fry population sizes. Since Chinook parr population levels vary little from year-to-year, there is little reason select a sampling year based on adult escapement level and predicted egg-to-migrant survival rates.

Using the same life history stage approach, a steelhead oriented sampling cycle would begin in April/early May before 2-year old smolt steelhead have migrated. Zimmerman (2010) data shows that steelhead have outmigrated past Mount Vernon by weeks 19-21 (early to mid May). Steelhead that remain in-river after this time are presumed to be 1+ juveniles or resident rainbows. Temporal sampling would continue from April through February of the following year so that changes in yearling steelhead habitat preferences can be observed and measured. If the recommended Chinook oriented sampling schedule is followed it would be important for steelhead to include a mid-April-early May sampling period to record pre-smoltification habitat preferences.

14. Identifying age 0+ trout to species - the modeling of physical and biological factors for determining steelhead and coastal cutthroat presence/absence predictors were not able to effectively predict stream assemblages. Therefore we recommend electrofishing a sub-sample of juvenile trout during the same seasonal strata as snorkel surveys, in the same channel and habitat types, to classify unidentified trout using post hoc identifications.
15. Hire personnel that are only tasked with implementing this study.

Power Analysis

In most cases, juvenile Chinook data are the limiting factor in detecting differences in abundance. If we adjust our sample sizes by focusing on Chinook, steelhead results will probably follow.

A doubling or tripling (depending on question of space (site), season, habitat type) of our effort will be sufficient. However, the upper limit of the number of sites we can sample might be constrained by their availability, logistics, and funding.

Future study (Phase II) should triple effort compared to Phase I.

Inclusion of rare habitat in randomized design

Statistical power analysis was unable to adequate test all rare habitat questions. Therefore, we analyzed whether rare habitats (large log jams and tributary junctions) would be under-sampled in a random design that triples the sampling size. We found that 24 and 30 randomly selected sites within the study area did not under represent either log jams or tributary junctions, thus we recommend to not include rare habitat as a stratifying factor in future study (Phase II).

References

Abbe, T, and D Montgomery. 1996. Large Woody Debris Jams, Channel Hydraulics and Habitat Formation in Large Rivers. Regulated Rivers: Research & Management 12:201-221.

Andersen, HV. 2008. Transferability of models to predict selection of cover by coastal cutthroat trout in small streams in western Oregon, USA. Masters Thesis, Fisheries Science, Oregon State University, Corvallis.

Beechie, TJ. 1992. Delineation of hydrologic regions in the Skagit River basin. Skagit System Cooperative, LaConner, WA.

Beechie, T, E Buhle, M Ruckelshaus, A Fullerton, and L Holsinger. 2006. Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation 130:560-572.

Beechie, TJ, M Liermann, EM Beamer, and R Henderson. 2005. A classification of habitat types in a large river and their use by juvenile salmonids. Trans. Amer. Fish. Society 134:717-729.

Beechie, TJ, G Pess, E. Beamer, G Lucchetti, and RE Bilby. 2003. Role of watershed assessments in recovery planning for salmon. Pages 194-225 *in* DR Montgomery, S Bolton, DB Booth, and L Wall, eds. Restoration of Puget Sound Rivers. University of Washington Press, Seattle.

Biggons

Bisson, PA, JL Nielsen, RA Palmason, and LE Grove. 1981. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 in NB Armantrout, ed. Proceeds of Acquisition and Utilization of Aquatic Habitat Inventory Information, Portland, OR.

Bisson, PA, K Sullivan, and JL Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead, and cutthroat trout in streams. Trans. Amer. Fish. Society 117:262-273.

Bonar, SA, M Divens, and B Bolding. 1997. Methods for sampling the distribution and abundance of bull trout and Dolly Varden. Research Report # RAD97-05, WA Dept of Fish & Wildlife, Olympia.

Boss, SM, and JS Richardson. 2002. Effects of food and cover on the growth, survival, and movement of cutthroat trout (Oncorhynchus clarki) in coastal streams. Can. J. Fish. Aquat. Sci. 59:1044-1053.

Burnett, KM, GH Reeves, DJ Miller, S Clarke, K Vance-Borland, and K Christiansen. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. Ecological Applications 17(1):66-80.

Campbell, RF, and JH Neuner. 1985. Seasonal and diurnal shifts in habitat utilized by resident rainbow trout in western Washington Cascade mountain streams. Pages 39-48 in Proceeds of Symposium on Small Hydropower and Fisheries, Denver, Co.

Contour, RC, and JS Griffith. 1995. Nocturnal emergence of juvenile rainbow trout from winter concealment relative to light intensity. Hydrobiologia 299:179-183.

Everest, FH, and DW Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho stream. J. Fish. Res. Bd. Can. 29:91-100.

Fausch, KD, and RJ White. 1981 Competition between brook trout and brown trout for positions in a Michigan stream. Can. J. Fish. Aquat. Sci. 38:1220-1227.

Gardiner, WR. 1984. Estimating population densities of salmonids in deep water in streams. J. Fish Biol. 24:41-49.

Glova, GJ, and JC Mason. 1977. Comparison of coastal cutthroat trout populations in allopatry and those sympatric with coho salmon and sculpins in several small coastal streams on Vancouver Island, B.C. Fisheries and Marine Service Manuscript Report 1434, Pacific Biological Station, Fisheries & Marine Service, Nanaimo, BC.

Griffith, JS, and RW Smith. 1993. Use of winter concealment cover by juvenile cutthroat and brown trout in the South Fork of the Snake River, Idaho. N. Amer. J. Fish. Mgmt. 13:823-830.

Griffith , JS. 1981. Estimation of the Age-frequency Distribution of Stream Dwelling Trout by Underwater Observation.The Progressive Fish Culturist. Vol. 43 No. 1, :51-53.

Hankin, DG, and GH Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45:834-844.

Hartman, GF. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon and steelhead trout. J Fish Res Bd Canada 22(4):1035-1081.

Harvey, BC, RJ Nakamoto, and JL White. 1999. Influence of large woody debris and a bankfull flood on movement of adult resident coastal cutthroat trout (Oncorhynchus clarki) during fall and winter. Can. J. Fish. Aquat. Sci. 56:2161-2166.

Hayman et al. 1996.

Hillman, TW, JW Mullan, and JS Griffith. 1992. Accuracy of underwater counts of juvenile Chinook salmon, coho salmon, and steelhead. N. Amer. J. Fish. Mgmt. 12:598-603.

Kiffney, PM, CM Greene, JE Hall, and JR Davies. 2006. Tributary streams create spatial discontinuities in habitat, biological productivity and diversity in mainstem rivers. Can. J. Fish. Aquat. Sci. 63:2518-2530.

Mesa, MG, and CB Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. Trans. Am. Fish. Soc. 118:644-658.

Meyer, KA, and JS Griffith. 1997. Effects of cobble-boulder substrate configuration on winter residency of juvenile rainbow trout. N. Amer. J. Fish. Mgmt. 17:77-84.

Modde, T, RC Ford, and MG Parsons. 1991. Use of a habitat-based stream classification system for categorizing trout biomass. N. Amer. J. Fish. Mgmt. 11:305-311.

Montgomery, DR, EM Beamer, GR Pess, and TP Quinn. 1999. Channel type and salmonid spawning distribution and abundance. Can. J. Fish. Aquatic. Sci. 56:377-387.

Northcote, TG, and DW Wilkie. 1963. Underwater census of stream fish populations. Trans. Amer. Fish. Society 92(2):146-151.

Peters, RJ, MT Celedonia, DW Lantz, and GR Pess. 2008. Diel distribution of juvenile salmonids near logjams in two western Washington rivers. In review.

Peterson, JT, NP Banish, and RF Thurow. 2003. Analysis of movement patterns of stream-dwelling salmonids in response to three survey methods. Final report CMER 01-104, WA Dept of Natural Resources, Olympia.

Pollard, HA, and TC Bjornn. 1973. The effects of angling and hatchery trout on the abundance of juvenile steelhead trout. Trans. Am. Fish. Soc. 102:745-752.

Quinones, RM, and TJ Mulligan. 2005. Habitat use by juvenile salmonids in the Smith River Estuary, California. Trans. Amer. Fish. Society 134:1147-1158.

Roni, P, and A Fayram. 2000. Estimating winter salmonid abundance in small western Washington streams: A comparison of three techniques. N. Amer. J. Fish. Mgmt. 20:683-692.

Roper, BB, DLScarnecchia, and TJ LaMarr. 1994. Summer distribution of and habitat use by Chinook salmon and steelhead within a major basin of the South Umpqua River, Oregon. Trans. Amer. Fish. Society 123:298-308.

Shirvell, CS. 1990. Role of instream rootwads as juvenile coho salmon and steelhead trout cover habitat under varying streamflows. Can. J. Fish. Aquat. Sci. 47:852-861.

Skagit River System Cooperative & Washington Department of Fish and Wildlife. 2005. Skagit Chinook Recovery Plan. Available at www.sharedsalmonstrategy.org/ or www.skagitcoop.org/.

Thompson, WL, and DC Lee. 2000. Modeling relationships between landscape-level attributes and snorkel counts of Chinook salmon and steelhead parr in Idaho. Can. J. Fish. Aquat. Sci. 57:1834-1842.

Thurow, RF. 1994. Underwater methods for study of salmonids in the intermountain west. Gen. Tech. Rep. INT-GTR-307, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Thurow, RF, and DJ Schill. 1996. Comparison of day snorkeing, night snorkeling, and electrofishing to estimate bull trout abundance and size structure in a second-order Idaho stream. N. Amer. J. Fish. Mgmt. 16:314-323.

Whitworth, WR, and RE Schmidt. 1980. Snorkeling as a means of evaluating fish populations in streams. New York Fish and Game Journal 27:91-94.

Appendix A – Age 0 steelhead and cutthroat trout identification

Objective:

Develop criteria to aid in the identification of steelhead and coastal cutthroat (S&C) trout during snorkel surveys by classifying stream systems within the known Chinook distribution that contain S&C trout using a combination of physical and biological factors. Then, using those criteria, develop predictors to aid in trout identification pre and post-hoc.

Problem:

Positive visual identification of age 0 S&C trout during pilot snorkel surveys conducted by SRSC and USIT was difficult to achieve. In general, the two species of trout within the age 0 year class were indistinguishable by snorkelers resulting in a generic "trout" determination for most individuals. This generalization will reduce the utility of these data for the present and future projects and a solution is need for this problem.

The physical and biological factors used to predict the presence/absence of S&C trout can vary but are assumed to be a function of stream hydrology, gradient, watershed size, climate, and historic introductions. Hartman and Gill (1968) investigated the presence of S&C trout in a variety of streams in British Columbia mainland and Vancouver Island. They report watershed size, gradient, and the presence of a slough at the mouth of the stream as good predictors of the presence of S&C trout. Other research has loosely associated the general hydrology of streams (rain, snow, rain/snow mix), distance from the mouth, and elevation (References ?) with the presence of S&C trout.

This project will attempt to determine predictive factors associated with S&C trout distribution and apply those factors to the Skagit River system to aid in refinement of age 0 S&C trout identification.

Methods:

Physical characteristics (Table 1) and trout assemblages from streams reported in Hartman and Gill (1968) were assessed to determine which factors were associated with trout distribution. Specifically those factors associated with the presence of only steelhead or coastal cutthroat trout and a mix of S&C trout were selected. I then assigned a general hydrology to those streams based on those defined by Beechie (1992). Hydrology was defined as rain dominated (Region 1 in Beecie (1992)), rain and snow mix dominated (Region 2 in Beechie (1992)), and snow dominated (Regions 3, 4, and 5 in Beechie (1992)). I classified the hydrology of streams reported in Hartman and Gill (1968) according to the above criteria using online data from the Water Survey of Canada (http://www.wsc.ec.gc.ca/index_e.cfm?cname=main_e.cfm). These characteristics were compared to the known Chinook distribution within the Skagit River to predict the trout species composition in those streams. Gradient was estimated by taking the mean value of gradient classifications for segments of stream, in the Chinook distribution layer, in the SshaipSegmenGgadient data layer provided by the SRSC (Table 2).

To test the validity of these designations (Table 2) seven reaches in five streams were selected and identified as containing steelhead only (Finney Creek), coastal cutthroat only (Gilligan and Hansen Creeks), or a mix of S&C trout (Day Creek and Grandy Creeks) and were sampled with backpack electroshocker. The trout collected were identified in the field and a subsample of unidentified age 0 trout were identified in the laboratory.

Results:

The trout assemblages within the streams sampled did not completely follow the patterns predicted by the criteria used (Table 3). Of those streams sampled only Finney and Grandy Creek contained the predicted trout assemblages. The Finney creek catch was as predicted with 100% of the trout collected identified as steelhead. Grandy Creek contained coastal cutthroat, 13%, and steelhead, 87% in the upper reach sampled just below the outlet of Grandy Lake but contained 100% steelhead in the lower reach near the Skagit River. Gilligan and Hansen creeks contained both S&C trout rather than only coastal cutthroat. The Gilligan creek trout assemblage was dominated by coastal cutthroat trout, 68% cutthroat, above a 1.3m barrier but steelhead dominated below that barrier, 97% steelhead. The Hansen creek trout assemblage was dominated by steelhead at 87% of the total catch. Day Creek contained only steelhead.

Conclusions:

Since the criteria used were not able to effectively predict the trout assemblages of the streams selected I recommend the following options ordered by difficulty, cost and value:

Option One: An iterative process following the methodology used in the present study. First, refine the sampling criteria through more accurate data layers for the GIS software. For example the size of the drainages used in this study did not appear consistent across all drainages. This is likely due to the fact that some of the larger river drainages represented only the lower flood plain reaches of the drainages with (some but not all) of the smaller tributaries separated out as individual drainages either named or unnamed. This made classification of individual systems difficult and introduced a lot of variability when making trout assembly predictions for some stream systems. Also, other smaller drainages were grouped together because of their size or proximity, which did not give the resolution needed for predicting the trout species assemblages for individual drainages. This will require that all drainages be clearly defined and the tributaries for those drainages grouped and classified by their gradient and confinement separately. This will provide an actual gradient and slope for each stream with confinement separate which may be a better predictor variable than the current gradient/confinement classifications. Second, conduct ground truthing investigations of these classifications to determine their validity. Then refine the trout assemblage predictions by the criteria used in that attempt based on the results of the ground truthing effort. This approach will require a few iterations before its validity can be determined.

Option 2: Collect a sub-sample of unidentified age 0 fish to determine their identity. In streams where age 0 trout are observed during snorkeling surveys, a sample of these trout are collected via electroshocking and identified either in the field or laboratory. Then classify unidentified trout using the post-hoc identifications. This will likely result in a proportional allocation of S&C trout to the age 0 fish observations in those streams.

Option 3: Create a designation of unidentified trout. This option is the “do nothing” or “status quo” option. While it is the least costly option it is also the option of the least value to the yearling study.

References:

Hartman, G.F., and C.A. Gill (1968) Distributions of juvenile steelhead and cutthroat trout (*Salmo gairdneri* and *S. clarki clarki*) within streams in southwestern British Columbia. Journal Fisheries Research Board Canada 25(1): 33-48

Beechie, T.J. (1992) Delineation of hydrologic regions in the Skagit River basin. Skagit System Cooperative

Tables:

Table 1. Physical characteristics of streams from Hartman and Gill (1968) and Beechie (1992) used to predict the trout species assemblage in Skagit River tributaries. Definitions of hydrographic regions are in the text.

	Slope	Average Drainage Area Km^2	Slough Present	Hydrographic Region
Steelhead	0.1	>130	No	All except 1
Cutthroat	0.06	<130	Yes	1
Both	0.04	350	N/A	All

Table 2. Gradient, drainage area, hydrographic zone, and species composition of Skagit River Tributaries used in this study.

Name	Gradient	Drainage Area Km^2	Hydrographic Zone	Predicted Species Composition
Pressentin Creek	2.5	55	1 & 2	Both
Loretta Creek	4	57	1	Sthd
Gilligan Creek	3	61	1	Cutt
Jackman Creek	4	66	2 & 3	Both
Grandy Creek	2	72	1, 2 & 3	Both
Rinker Creek	1	74	3	Both
Newhalem Creek	4	75	2 & 3	Sthd
Dan Creek	3	81	2	Sthd
Diobsud Creek	2	87	2	Both
Day Creek	2	88	1 & 2	Both
Corkindale	2	91	1	Cutt
Goodell	2.5	101	2 & 3	Sthd
Hansen Creek	2.375	104	1	Cutt
Clear Creek	2	124	2 & 3	Sthd
Jordan-Boulder Creeks	3	129	2	Sthd
Bacon Creek	2.125	134	2 & 3	Sthd
Illabot Creek	2.333333	141	2 & 3	Sthd
Lime Creek	3	153	3	Sthd
Finney Creek	1.1	160	1 & 2	Sthd
White Chuck River	2.3	219	3	Sthd
Cascade River	1.59375	496	2 & 3	Sthd

Table 3. Catch composition of electroshocking efforts in Skagit River tributaries used to ground truth predicted species compositions in this study.

Location	n Steelhead	n Cutthroat	Percent Steelhead	Percent Coastal Cutthroat	Total Trout
Day Creek	30	0	100%	0%	30
Gilligan above South Skagit Highway culvert	6	13	32%	68%	19
Gilligan below South Skagit Highway culvert	59	2	97%	3%	61
Grandy Creek Near Skagit River	52	0	100%	0%	52
Grandy Creek Below Grandy Lake	27	4	87%	13%	31
Hansen Creek at Highway 20 Bridge	48	7	87%	13%	55
Finney Creek above South Skagit Highway Bridge	32	0	100%	0%	32