SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX A

BIOLOGICAL SAMPLING IN THE SKOKOMISH RIVER BASIN

Integrated Feasibility Report and Environmental Impact Statement

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U.S. Fish and Wildlife Service

Biological Sampling in the Skokomish River Basin, Washington: Army Corps of Engineers General Investigation

July 2011

By Roger Peters, Zhuozhuo Li, Scott Sanders, Roger Tabor, Carrie Cook-Tabor, and Paul Bakke

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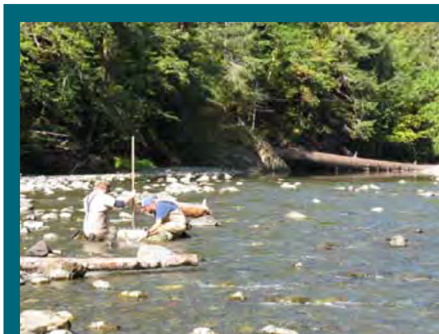
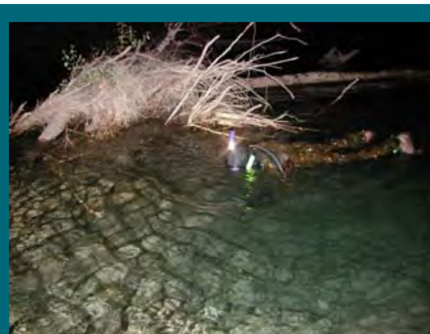
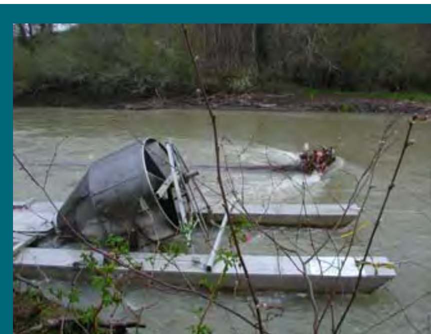

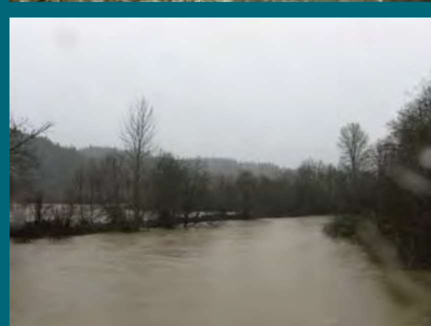


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Acronyms

AI	Admiralty Inlet
ANOSIM	Analysis of Similarities
AW	Average Water Depth
BC	Braided Channel
BFW	Bankfull Width
B-IBI or BIBI	Benthic Index-of-Biotic-Integrity
BOR	Bureau of Reclamation
BP	Before Present
BVSTEP	A routine in Primer that compares the rank correlation between two triangular similarity matrices.
BW	Backwater
C	Confined channel
CPUE	Catch Per Unit Effort
CSYU	Cooperative Sustained Yield Unit
DO	Dissolved Oxygen
DW	Deep water
ELJ	Engineered Logjam
EMAP	Environmental Monitoring and Assessment Program
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FERC	Federal Energy Regulatory Commission
FWS	U.S. Fish and Wildlife Service
GI	General Investigation Study
GIS	Geographic Information System
GLO	General Land Office
HCB	Hood Canal Bridge
HCCC	Hood Canal Coordinating Council
HSRG	Hatchery Scientific Review Group
HWY	Highway
IBI	Index of Biotic Integrity
JDF	Strait of Juan de Fuca

LDP	Large Debris Pile
LWD	Large Wood
MC	Main Channel
MDS	Multi-dimensional scaling
NF	North Fork (Skokomish River)
NMFS	National Marine Fisheries Service
NNFSF	New North Fork South Fork Skokomish study reach
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelemetric Units
NWIFC	Northwest Indian Fisheries Commission
OC	Overflow Channel
ONFSF	Old North Fork South Fork Skokomish study reach
PCA	Principal Component Analysis
PIT	Passive Integrated Transponder
PMP	Project Management Plan
PNPTT	Point No Point Treaty Tribes
PR	Point of Release
RKM	River Kilometer
RVM	River mile
RM	River Mouth
SASSI	Salmon and Steelhead Stock Inventory
SC	Side Channel
SD	Standard Deviation
SE	Standard Error
SF	South Fork (Skokomish River)
SFV	South Fork (Skokomish) Vance study reach
SSHIAP	Salmon and Steelhead Habitat Inventory
SR	State Route
SW	Shallow Water
TAG	Technical Advisory Group
TMDL	Total Maximum Daily Load
TFW	Timber-Fish-and-Wildlife

U	Unconfined Channel
USACE	U. S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator coordinate system
WDF	Washington Department of Fisheries (currently Washington Department of Fish and Wildlife
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOE	Washington Department of Ecology
WFPB	Washington Forest Practices Board

Summary

Background

The U.S. Army Corps of Engineers (USACE) and its partners, the Skokomish Indian Tribe and Mason County (local sponsors), funded the U.S. Fish and Wildlife Service (FWS) to collect biological data throughout the Skokomish Basin as part of the feasibility phase of their Skokomish River Basin Ecosystem Restoration and Flood Risk Management General Investigation Study (Skokomish GI or GI). The purpose of the GI is to restore proper natural function to the Skokomish Basin while reducing flood damages to valley residents. Specific objectives are to 1) maintain a sustainable river alignment; 2) maintain agricultural use in the river valley; 3) provide flood protection in the valley; 4) maintain a sustainable groundwater table; 5) restore spawning, rearing, and migration habitats for salmonids; 6) restore, where possible, the natural complexity of the aquatic and riparian ecosystem; 7) assess, and if needed, improve water quality critical to fish survival and migration, 8) reduce sedimentation and altered sediment transport processes; and 9) monitor the projects and use adaptive management where necessary. Some potential actions resulting from this project include levee and dike removals and/or setbacks, sediment control structures, reconnecting side channels or oxbows, riparian planting, and dredging sections of the river channel. The goal of these projects will be to increase fish habitat availability, complexity, connectivity, and stability, and to decrease or lessen floods damages.

Work described in this report address the first two tasks of the Skokomish GI Project Management Plan (PMP), collection of existing research and data (Task 1) and physical data collection (Task 2). The purpose of Task 1 is to determine what information exists, consolidate that information into a usable and informative form, and determine data gaps. The purpose of Task 2 is to collect information that is lacking.

Based on initial efforts to complete Task 1, it became evident that descriptive information is lacking for juvenile salmonids and overall ecosystem health in this system. For example, information on simple life history traits such as distribution, outmigration timing, and community structure of primary and secondary producers (i.e., periphyton and benthic invertebrates) are lacking. The data collections and assessments described in this report are focused on goals developed in conjunction with the USACE, Skokomish Indian Tribe, and Mason County. These goals include obtaining information on juvenile fish life history traits and ecosystem health within the Skokomish Basin. In addition, the data collected during this investigation will provide information regarding general habitat availability, the seasonal distribution and abundance of fish in the river and its estuary, outmigration timing of salmonids in this system, and the species composition of primary and secondary producers. These data are useful in determining the overall health of the Skokomish Basin and in planning ecosystem restoration and flood risk management projects.

Data collection for this study was completed from June 2008 through September 2009, which means the data cannot describe year-to-year variability. Data collection was completed for eight major themes including habitat condition; fish distribution and abundance; winter survival; winter diet composition in different habitats; overall Skokomish Basin production and outmigration timing; estuarine use, timing, and residency; early estuarine and marine migration and survival; and primary and secondary species composition.

This report is organized as a watershed assessment; however, nearshore areas adjacent to the Skokomish estuary were not included since they are outside the scope of this project. The introduction provides the necessary background to understand the need and scope of the project. A study description describes the Skokomish Basin and its geology, climate, and biological community. Next, are two sections describing the physical and biological characteristics of the Skokomish Basin. Each of these sections firsts presents existing information, followed by results from the new data collection. Within the biological characteristics section, individual species of salmonids are discussed. This discussion is organized around their general habitat requirements, historic adult salmonid distribution and population trends, specific juvenile habitat requirements, a summary of existing information, and results from the new data collections. A short summary of limiting factors is provided for each species. The final section of the report is a discussion of overall limiting factors and recommended habitat restoration measures. A companion set of appendices describe the methods used to collect and analyze new data for the Skokomish GI.

Skokomish Basin Condition: Physical Characteristics

The Skokomish River originates in the southeastern Olympic Peninsula of Washington State and flows southeast, emptying into Annas Bay at the southern end of Hood Canal. The river drains a watershed area of approximately 622 km^2 (240 mi^2). The Skokomish Basin consists of the estuary, the mainstem and the following three primary sub-basins: the North Fork Skokomish- 305 km^2 (117 mi^2), South Fork Skokomish - 331 km^2 (128 mi^2), and Vance Creek - 61 km^2 (24 mi^2). The Skokomish watershed has variable terrain ranging from alluvial and glacial valley bottoms and relatively gentle slopes to rugged and steep terrain with near vertical side slopes. Soil depths in the Skokomish Basin are shallow except in the river valleys, where sediment may be hundreds of feet deep. The climate is a temperate marine climate with wet winters and dry summers. Annual rainfall in the Skokomish Basin varies from 152 cm in the lower valley to 304 cm in the headwaters.

Natural and anthropogenic disturbances influence the watershed. Significant natural disturbances include flooding, mass wasting, fire, and wind-throw, although mass wasting is also influenced by anthropogenic causes such as logging and associated road building. Other anthropogenic influences include river and estuarine diking, road building, riverine dredging, hydroelectric dams, and general development.

The interaction of the physical characteristics of the Skokomish Basin and watershed processes combined to form the main factors limiting adult and juvenile salmon habitat in the watershed – channel aggradation, or an increase in overall sediment in the river. The six primary factors that have influenced channel aggradation are mass wasting events, flow reduction, channel destabilization due to large wood removal and riparian clearing, channel confinement through levee construction, channelization through straightening, bank armoring and dredging, and constriction by bridge embankments. The combination of these six factors results in increased sediment supply to the channel, reduced sediment transport capabilities, and reduced stable floodplain storage for sediment.

Mass wasting appears to have increased in the Skokomish Basin as a result of logging and associated road building, based on landslide inventories. However, it is still unclear how much this has contributed to the current level of aggradation in the lower South Fork Skokomish and the Skokomish mainstem. It is possible that much of the sediment that has entered the river in the upper watershed has not yet reached the lower watershed. These sediments could thus become available in the future to induce future aggradation in the lower mainstem, unless they can somehow be stabilized in the upper and middle reaches.

The second cause of aggradation is reduced flows resulting from the Cushman hydroelectric project, which has reduced the rivers ability to transport its sediment load. This project, on the North Fork Skokomish River, has historically diverted significant proportions of the North Fork Skokomish discharge (i.e., up to 96%) directly to Hood Canal. These reductions have also been significant (80%) during important high sediment transport discharges such as bankfull discharge. Thus, the rivers ability to transport sediment downstream of the confluence of the North Fork Skokomish with the South Fork Skokomish has been seriously reduced since the 1920s. However, this impact has likely been mitigated as a result of a new flow regime resulting from the new Federal Energy Regulatory Commission (FERC) license agreement implemented in July 2010. This agreement calls for greater minimum base flows and more importantly a „normative flow regime‟ that will increase discharges below the projects during freshets to facilitate sediment transport. This should increase the sediment transport capabilities of the system.

Levee construction along the lower mainstem has impacted sediment transport and storage. The levees isolate the river from its floodplain, resulting in suspended sediment that would have been stored in the floodplain to be stored in the channel in the rivers lowermost reaches, and eliminating the rivers ability to store coarse sediment in secondary channels through channel avulsion and migration processes. Levees also cause flood flows to backwater upstream of the constriction, resulting in increased coarse sediment deposition and subsequent channel aggradation upstream from the levees. This aggradation usually results in bank erosion, which further increases sediment supply to the channel.

Large wood removal early in the twentieth century coupled with clearing of riparian old growth conifer forests for farming and wood production likely resulted in destabilization of an island braided channel morphology, converting it to the wider single-thread or braided morphology seen today. This channel evolution would have released large amounts of coarse and fine sediments stored as stable floodplain deposits, and would have reduced the sediment transport efficiency of the river, resulting in aggradation.

Channelization, including the straightening and widening of the channel for flood conveyance, though poorly documented, is known to have been done, particularly in the mid twentieth century. Channel straightening increases the slope and channel widening increases the flow cross section, achieving a temporary increase in hydraulic capacity. However, a wide, planar channel bed cannot transport sediment as effectively as a natural channel with a deeper thalweg and a lower width to depth ratio. Thus, channelization likely set the stage for increased aggradation in these reaches as well.

Constriction of the channel and floodplain by bridge embankments causes backwatering during peak flow events, resulting in aggradation upstream of the bridge. Floodplain constriction reduces the ability of the river to deposit suspended sediment on the floodplain, making these sediments more available to be deposited in-channel further downstream where the slope is decreased, particularly in the zone influenced by tidal action. Bridge embankments also cut off secondary channels which formerly served as deposition sites for coarse sediment during floods.

Channel aggradation has two potential impacts to salmonid populations; channel instability which can scour redds and reduced habitat quality in terms of pool frequency and depth, and large wood cover. Data within the Skokomish Basin are lacking to make a definitive conclusion regarding the impact of scour on salmonid populations in the system. However, increased scour-related mortality has been observed in other systems with impaired sediment supply and sediment transport equilibrium. This issue was not evaluated in this study, but should be a high priority data gap in future assessments.

Past habitat data collections have concluded that pool and large wood cover are somewhat impaired in the system. In general pool frequency and large wood (LWD) abundance is low. In general, habitat quality improves as you move up the Skokomish Basin and as you move from the mainstem to the tributaries. Pool frequencies have been rated poor in the South Fork Skokomish, but fair or good in tributaries, except Church Creek. Large wood cover levels were not adequate to provide good quality cover in nearly one-third of the sites sampled historically.

Increased sediment supplies, reduced flows, and levees have also had a significant effect on estuarine habitat. The delta has become steeper, resulting in the loss of important intertidal and eelgrass habitat. This has also reduced the mesohaline mixing zone, which is an important transition area for juvenile and adult salmonids as they transition between freshwater and seawater. Diking and filling has also resulted in the loss of tidal channels and vegetated wetlands.

We collected new data throughout the Skokomish Basin, but our efforts were limited to habitats below barriers to anadromous fish migration (i.e., anadromous zone) and included tributaries, lateral habitats, off-channel habitats, and the estuary. Data was collected using a stratified approach, moving from large spatial scales to successively finer scales. Existing Geographic Information System (GIS) data, barrier information, and consultation with professional biologists was used to estimate the extent of the anadromous fish zone. Based on this analysis, there is approximately 132 km of anadromous fish habitat in the Skokomish Basin. Just over half of this habitat (55.4%) was classified as mainstem habitat and the rest (44.6%) as tributary habitat. A majority of the habitat was also classified as low gradient (<1%) and unconfined, with very little classified as having gradients greater than 4%. In addition, 4.1 km of the lower mainstem was estimated to lie within the stream estuary ecotone, the transition zone between the river and its estuary.

Instream habitat data was collected from 21 study reaches (22 km) during the summer of 2008 and 24 study reaches (22 km) during the winter of 2009. As expected, the majority of the available habitat existed in the main channels. However, braided channel habitat (channels separated by unvegetated islands) was the next most common and side channel (channels separated by islands with mature vegetation) and backwater habitats were found in low proportions. Overall, deep water habitats commonly associated with pools made up between 25% and 44% of the habitat. However, deep water habitats were absent or in low abundance in several study reaches. In addition, deep water habitats, which are very important habitats during the winter, were in lowest abundance during that period. Fine wood and vegetative cover was the most common cover element available in the reaches we evaluated. Large wood and large wood debris piles were present at intermediate levels to other cover elements. Overhead cover and undercut banks were relatively uncommon.

We identified 28 different off-channel pond complexes through evaluation of aerial photographs. These ponds had a total surface area of 20.3 hectares and a perimeter of 29,499 m. The ponds ranged in size from 0.08 to 4.96 hectares and averaged 0.7 hectares. We sampled 14 different pond sites located in six different ponds during the summer and 20 sites located in 7 different ponds during the winter. Two of the ponds, within the anadromous zone were determined to not be accessible to juvenile salmonids, one due to the level of vegetation in the pond, and the other was in the middle of an agricultural field and lacked access channels to the river or its tributaries. One pond was determined to lie outside the anadromous zone due to its location on a terrace and the lack of obvious egress channels to the river or its tributaries.

Based on the habitat assessment, the tributary junctions, especially the Vance Creek and South Fork Skokomish confluence are the most degraded portions of the watershed. These areas are the most effected by land use practices throughout the Skokomish Basin and several of these areas, including lower Vance Creek, go subsurface during late summer and early fall due to sediment aggradation. This has the potential to block the upstream migration of adult salmon, thereby significantly reducing habitat availability for their progeny. These areas are also likely to be susceptible to scour which can severely impact salmon redds and juvenile salmon overwintering in the substrate.

Skokomish Basin Conditions: Biological Characteristics

We collected data for periphyton and macroinvertebrate community structure in the Skokomish to assess ecosystem health. Samples were collected from 29 locations throughout the Skokomish Basin including the North Fork Skokomish, South Fork Skokomish and 5 different tributaries. Taxa richness, the total number of unique diatom taxa found at a given site, averaged 32 species and was slightly greater in mainstem sites than tributary sites. The Shannon diversity ($base_2$) averaged 3.31. Scores for the three biocriteria metrics generally indicated good to excellent ecosystem health, with only one site, Pine Creek, receiving a score of poor.

Macroinvertebrate abundance and community structure generally indicated good habitat quality. Macroinvertebrate abundance (mean of 6,835 individuals per sample) generally indicated values of waters in good conditions with high primary and secondary productivity. Taxa richness, the total number of unique taxa at each site, was generally moderate to high across all sites (mean 48). Shannon‟s index averaged 2.86.

Scores for the Benthic Index-of-Biotic-Integrity (B-IBI or BIBI) developed for Puget Sound lowland streams and larger western Washington Rivers indicated moderate to high overall biological integrity throughout the Skokomish Basin. B-IBI scores for tributaries were more commonly rated as having higher biological integrity than mainstem sites. Although B-IBI scores generally indicated healthy community structure, long-lived macroinvertebrate taxa and shredder macroinvertebrates were somewhat low. This could be due to a lack of channel roughness caused by high embeddedness, the quality of interstitial spaces in the steam bed, lack of habitat complexity, scour effects of highly mobile river bottom, lack of wood boles or other habitat features that long-lived species use as special refugia during high flows. In addition, there was a lack of snails, pea clams, and crustaceans in the system, which are generally common in mid- to low-elevation stream in western Washington.

Twenty-three species of fish have been identified in the Skokomish Basin. A majority of these species are salmonids. We observed 15 species of fish in freshwater environments during our sampling, including 3 introduced species, common carp, largemouth bass, and brook trout. Salmonid species observed included Chinook, coho, chum, rainbow/steelhead, cutthroat, and bull trout. Coho salmon were numerically the dominant species of salmonid in the system.

Juvenile salmonid distribution and abundance, which was identified as a data gap by the Skokomish GI sponsors, is obviously influenced by adult salmon distribution and abundance. Four fish species, Puget Sound Chinook salmon, Puget Sound steelhead, Hood Canal Summer chum, and bull trout have been listed under the Federal Endangered Species Act. Thus, abundance for these species is expected to be low. The distribution of Chinook salmon is often limited in the South Fork Skokomish and Vance Creek due to the channel going subsurface. Adult chum salmon also appear to be restricted to the lower sections of the South Fork Skokomish due to the first canyon in this system. They spawn in most of the tributaries to the Skokomish River, with the heaviest concentrations in the lower 7.6 km of the North Fork Skokomish. Coho salmon spawn in most of the tributaries, with the highest concentrations in the lower North Fork Skokomish and Vance Creek. They appear to have been restricted historically to the lower portions of the South Fork Skokomish due to the first canyon. However, we observed juvenile coho salmon in the upper South Fork during our study, suggesting that adults were able to migrate through the Canyon the fall prior to our surveys (2007). Steelhead and bull trout adults are the most widely distributed salmonids in the Skokomish Basin. They appear to use most tributaries as well as the upper reaches of the South Fork Skokomish and Vance Creek.

Juvenile salmon have a diverse array of freshwater and estuarine habitat requirements which vary by species and life history strategies within species. However, the basic requirements can be summarized as 1) stable gravel with ample flow of water with high dissolved oxygen levels and appropriate temperatures for egg incubation and early rearing, 2) high quality freshwater habitat for early and potentially extended rearing, 3) connected freshwater migratory habitats, and an estuarine environment to allow transition from freshwater to sea water. These requirements have been described for the species of juvenile salmon expected to be present in the Skokomish Basin.

Data for the status and distribution of juvenile Chinook salmon in the Skokomish River is limited to outmigration data in Skabob Creek and estuarine sampling. We observed Chinook salmon in mainstem, tributary, freshwater, the stream-estuary ecotone, and the estuary during our sampling efforts. Juvenile Chinook were more common in the mainstem then tributary and pond habitats. Their distribution was limited to the lower Skokomish Basin, generally below the first canyon in the South Fork Skokomish and Vance Creek, and their distribution was greater in the winter than during the summer. However, this difference may have been an artifact of our sample sites.

We estimated that 239,511 Chinook salmon migrated past the screw trap between mid-March and late July. A majority (93%) of these fish were hatchery parr and smolts. Naturally produced Chinook salmon smolts migrate from the Skokomish River primarily in January and February. However, small numbers were observed outmigrating from March through July. Hatchery smolts emigrated from mid-May when they were released from the hatchery through

July. Both naturally produced and hatchery produced Chinook salmon were caught in low numbers, although we caught seven times as many hatchery Chinook than wild Chinook.

The timing of estuary use is consistent with that observed during outmigration, extending from January through August. Juvenile Chinook salmon catch per unit effort (CPUE) in the estuary was generally low and was dominated by hatchery Chinook. We could only calculate one population estimate for juvenile Chinook salmon in the Nalley Island section of the estuary. The estimate for this sampling event, which occurred May 27, 2009, was 55,104 individuals (95% Confidence Interval: 20,099 to 133,080). In general, hatchery Chinook arrived at the estuary later in the year, apparently due to hatchery release strategies, and left the estuary sooner than their unmarked, presumed wild counterparts.

Juvenile Chinook salmon distribution and abundance appear to be limited most by the stability of their incubation environment. We saw relatively few juvenile Chinook salmon in the freshwater rearing habitat, in outmigration sampling, and in the estuary. Adult Chinook salmon were distributed throughout the Skokomish Basin as a result of higher than normal late summer discharges, and an adult supplementation program initiated by the Skokomish Indian Tribe and Washington Department of Fish and Wildlife (WDFW), which resulted in adults being trucked into the upper South Fork Skokomish. The fact that we saw so few individuals suggests that reproductive success or incubation survival was relatively low. This could be due to poor reproductive fitness of hatchery Chinook salmon spawning with naturally produced adults or scour occurring during high flows.

Juvenile chum salmon generally migrate to sea shortly after emergence. Thus, their freshwater rearing requirements are largely incubation and early rearing. We found no information on the freshwater distribution and abundance of juvenile chum salmon in the Skokomish River. We observed chum salmon in mainstem, tributary, and pond freshwater habitats in the lower Skokomish Basin below the South Fork Skokomish canyon. However, we observed chum above the first canyon in Vance Creek, which contrasted observations for juvenile Chinook salmon. Unlike Chinook salmon, they did not use the entire North Fork Skokomish up to the lower Cushman dam.

We estimated 52,179 chum salmon migrated downstream during screw trap sampling between mid-March through July. However, it appears that our estimates were significantly biased and underestimated production since 10 million chum were released from hatcheries in the Skokomish River during this period. Peak daily chum salmon migration occurred from late-January through mid-July, peaking in mid-February. There was a second large peak in mid-April following the hatchery release. Out-migrating chum salmon averaged 42 mm in fork length and grew throughout the season. Chum salmon caught immediately after the hatchery release, and presumably hatchery chum (chum are not marked prior to release from the hatchery) were much larger than the chum caught immediately prior to the hatchery release.

Juvenile chum salmon were the most numerous salmonid caught in the estuary. They were present from February through June, peaking in mid-May. The difference in peak outmigration and estuary residence suggests that juvenile chum salmon held in the stream-estuary ecotone or adjacent estuary prior to entering the Nalley Island section of the estuary, highlighting the potential importance of this habitat.

Coho salmon generally rear in freshwater for a year before migrating to sea. Thus, they have greater freshwater requirements than either Chinook or chum salmon. In contrast, they generally move through the estuary quicker than Chinook or chum salmon. Juvenile coho salmon were observed in tributary, mainstem, and pond habitats. They had a much greater distribution than either Chinook or chum salmon. They were observed in the upper South Fork Skokomish above the series of canyons. Juvenile coho salmon were also numerically the dominant salmonid present in the Skokomish Basin. However, their abundance decreased dramatically from summer to winter.

We estimated that 352,603 coho fry and smolts migrated downstream during our outmigration sampling, with unmarked fish comprising 80% of the total. Coho fry were more numerous than coho smolts, accounting for 51% of the total. Wild coho smolt outmigration was estimated at 87,639. Both coho fry and smolts were caught during our entire outmigration sampling (January through July). Fry outmigration peaked in late-April and early-May, while smolt migration peaked from mid-May through mid-June. Hatchery coho smolt outmigration peaked in mid-April, immediately after release. The size distribution of coho salmon caught during the outmigration sampling was bimodal due to the presence of fry and smolts in the outmigration sampling. Fry were generally less than 60 mm, while smolts were generally between 80 and 100 mm fork length.

Coho salmon were captured in the estuary from April through September, with peak abundance occurring from mid-May through late-June. Unmarked coho salmon were present in the estuary before and after (i.e., longer) their marked counterparts. Coho fry as small as 50 mm were frequently observed in the Nalley Island section of the Skokomish estuary. Thus, coho fry use both the stream-estuary ecotone and the estuary during the summer. However, their absence during the fall and early winter suggests that they potentially migrate back upstream into the lower mainstem or off-channel habitats present in the lower river during the winter. Thus, the stream-estuary ecotone and the estuary appear to be extremely important for juvenile coho salmon in this system.

Juvenile coho salmon appear to be limited by freshwater winter rearing habitat. They were present in large numbers during the summer 2008 surveys, suggesting better incubation success than Chinook salmon. However, their numbers decreased dramatically during the winter and we estimated less than 100,000 smolts were produced. The lack of winter pool habitat would contribute significantly to the observed reduction from summer to winter

Juvenile steelhead are the most dependent salmonid species on freshwater habitat of all anadromous species in the Skokomish River. They spend up to three years in freshwater before migrating to sea. Juvenile steelhead are found throughout the Skokomish Basin in relatively low densities. They also had the greatest distribution of any juvenile salmonid species, being present in the upper reaches of the South Fork Skokomish, North Fork Skokomish, McTaggert Creek, and Vance Creek.

We caught very few steelhead in outmigration sampling. However, they were caught from early February through July, when sampling was terminated. A majority of the steelhead caught were unmarked. Based on body size, we caught fish that appeared to be from three different age classes (0+, 1+, and 2+).

We did not capture any steelhead in our estuary sampling. Results from acoustic tagging suggest that steelhead migrate through the lower river relatively quickly (generally less than 5 days). Steelhead smolts use the nearshore habitat of Hood Canal as more than just a migratory corridor, and generally spend approximately 2 weeks travelling from the mouth of the

Skokomish River to the Hood Canal Bridge. Survival through the lower river is generally high (>80%) for wild fish, but much lower (<50%) for their hatchery counterparts.

Steelhead appear to be limited by overwinter habitat conditions. Steelhead typically spawn in the spring after most of the large freshets which would scour their redds. In addition, outmigration, estuarine, and early marine survival (through Hood Canal) appear to be relatively high. The lack of winter pool habitat and unstable channels likely limit production, since steelhead use pool habitats during the winter, and often hide in the substrate during daylight hours during the winter.

The biological community has also potentially been influenced by hatchery activities in the Skokomish Basin. Two of the three hatcheries in the watershed produce Chinook, coho, and chum salmon that are released into the Skokomish Basin on-station fry or smolt releases. Significant out of basin stocks have been reared and released into the Skokomish Basin historically. The impact of these out of basin stocks on the fitness of natural spawned salmon in the Skokomish Basin is unknown. Hatchery fish released into the system compete with naturally produced fish, may increase predation on naturally produced fish which can impact their subsequent survival. Finally, hatchery adults that return successfully may spawn with wild fish; potentially reducing the fitness of the natural offspring. This is a particular concern with Chinook salmon which stray in large numbers to the lower South Fork Skokomish and Vance Creek and can contribute significantly to the number of naturally spawning fish.

Based on the information compiled in this report, it appears that the primary factor limiting juvenile salmonid distribution and abundance in the Skokomish Basin is excessive sedimentation and aggradation. Although not measured specifically in this report, scour and/or burial of redds of fall spawning salmonids and low overwinter survival of freshwater dependent species such as coho and steelhead appear to limit production. Scour could be the result of the disequilibrium between sediment input and sediment transport in the system. The excessive sediment would also result in poor pool frequency and/or quality, which we observed in our habitat surveys.

We recommend a process based approach of restoration that reduces sediment inputs, reduces artificial channel constrictions, provides floodplain storage for sediments, stabilize active channel sediment, and ample discharges to transport existing sediment. Sediment inputs would be reduced by controlling anthropogenic sources of sediment in the system, improving and decommissioning roads in the Skokomish Basin, reducing logging associated mass wasting events, and stabilizing existing mass wasting areas. Reductions in artificial channel constrictions and increased floodplain storage of sediment can be obtained by levee removal and/or significant setbacks. Active channel stability can be increased through the introduction of large wood, especially engineered logjams. Active monitoring of the new FERC license agreement for the operation of the Cushman hydroelectric facility will help determine if the prescribed flows are adequate for sediment transport requirements in the system.

Introduction

The U.S. Army Corps of Engineers (USACE) is currently in the feasibility phase of the Skokomish River Basin General Investigation (Skokomish GI or GI). The purpose of the GI is to investigate and formulate a solution to address ecosystem restoration and flood risk management in the Skokomish Basin. The goal of the GI is to restore proper natural function to the Skokomish Basin while reducing flood damages to valley residents. Specific objectives are to 1) maintain a sustainable river alignment, 2) maintain agricultural use in the river valley, 3) provide flood protection in the valley, 4) maintain a sustainable groundwater table, 5) restore spawning, rearing, and migration habitats for salmonids, 6) restore, where possible, the natural complexity of the aquatic and riparian ecosystem, 7) assess, and if needed, improve water quality critical to fish survival and migration, 8) reduce sedimentation and altered sediment transport processes, and 9) monitor the projects and use adaptive management where necessary. A current conditions report will be prepared as part of the feasibility phase of the GI. The current conditions report will outline the current conditions of the Skokomish Basin as it relates to the goals of the project and is completed by examining existing information, identifying information gaps, and collecting additional information to address identified information gaps.

The Skokomish GI requires the evaluation of both physical and biological information, including channel geomorphology, hydrology, sediment transport, aquatic community structure, and physical habitat before a plan is evaluated and eventually recommended. From an aquatic community structure and habitat perspective, adequate information exists for the spawning distribution and abundance of adult salmonids throughout the Skokomish Basin. However, information related to the community structure of aquatic primary (periphyton) and secondary (invertebrates) producers, juvenile salmonid life history traits, and general habitat availability is lacking. This information is critical to develop strategies to meet the sponsors‟ objective of ecosystem restoration and to plan flood risk management in a manner consistent with the restoration objective. This study, developed in conjunction with agency and tribal staff, reviewed existing information and collected additional biological and habitat data. The purpose of this data collection was to provide information for aquatic community structure, general habitat availability, and juvenile salmon life history traits, including distribution, abundance, outmigration patterns, and estuarine use.

Watershed and/or river management and ecosystem restoration planning requires a thorough understanding of watershed processes, community structure, ecology, habitat conditions, and habitat requirements of biota. Watershed assessments generally evaluate landscapes, physical processes, and land-use factors influencing riverine ecosystems (Beechie et al 2003). Beechie et al. (2003) suggest that watershed assessments be used to estimate historic and current smolt production based on habitat conditions, and identify causes of habitat loss and restoration actions necessary to recover those habitats. Several assessments of watershed condition, fish habitat conditions and limiting factors focusing, in part or completely, on the Skokomish Basin have been completed (e.g.; Watershed Management Team 1995; KCM 1997; ME2 Environmental Services 1997; Correa 2003). However, many of these assessments were limited in scope (i.e. habitat focus) or were restricted to summarizing available information. Thus, information for current conditions in the Skokomish Basin is limited.

Flooding has always occurred in the Skokomish Basin, but several studies (Jay and Simenstad 1996, Stover and Montgomery 2001, Bountry 2009, USACE 2010) have concluded that it has been exacerbated during the last century. Increased flooding is probably a result of channel aggradation, which has been exacerbated by increased sediment delivery, levee construction, and instream flow manipulations resulting from human activities in the Skokomish Basin (USACE 2010). These issues are discussed briefly here and in more detail later in this report. Extensive logging and associated road building in the upper South Fork Skokomish and Vance Creek sub-basins has resulted in increased landslides, thereby increasing sedimentation in the river. This situation has been exacerbated in the lower river, by the construction of levees in the floodplain, which constrict flows and limit sediment transport (Bountry et al. 2009). In addition, the ability of the Skokomish River to transport sediment has been decreased historically as a result of water diversions that occur at two City of Tacoma Hydroelectric Project Dams, Federal Energy Regulatory Commission (FERC) #460. However, a new settlement agreement between the Skokomish Tribal Nation and Tacoma Public Utilities will reduce future diversions (Cushman Project 2009). The alteration of these three processes (flow regime, sediment delivery and sediment transport/storage) has resulted in approximately 1.6 meters of aggradation during the last 40 years. This aggradation has reduced channel conveyance to the point that overbank flow near the Highway (HWY) 101 bridge that historically occurred at 13,000 cfs now occurs at 4,100 cfs (Bountry et al. 2009). However, overbank flows occur at only 2,500 cfs downstream of the HWY 101 Bridge (Karl Erickson, USACE, Personal Communication).This reduced conveyance means there is a 90% chance of overbank flow during a given year (USACE 2010). Channel aggradation and increased frequency in overbank flows has negatively influenced aquatic communities, including salmonids and their habitats.

The status and distribution of adult salmonids, which will obviously influences subsequent juvenile distribution, is relatively well known. This information is summarized in Salmon and Steelhead Stock Inventories (SASSI) completed from the early 1990‟s through 2006 (SASSI 1992, 2002, 2006). Salmon production in the Skokomish Basin has been reduced from historic levels (Watershed Management Team 1995). Twelve salmonid stocks have been identified in the Skokomish Basin (SASSI 1992, 2002, 2006). Of these, 3 are listed as healthy, 2 as depressed, 2 as extinct (Nehlsen et al. 1991), and 5 are listed as unknown. Four salmonid species in the Skokomish Basin are part of population segments that have been listed as threatened under the Endangered Species Act (ESA). These include Puget Sound Chinook (*Oncorhynchus tschawytscha*) (1999, Federal Register Volume 64, 14308); Hood Canal Summer Chum (*O. keta*) (1999, Federal Register Volume 64, 14508); Coastal-Puget Sound, Washington bull trout (*Salvelinus confluentus*) (1999, Federal Register Volume 64, 58910); and Puget Sound steelhead (2007, Federal Register Volume 72, 26722). Stock status is based on yearly spawning ground surveys completed by WDFW and the Skokomish Indian Tribe.

Relative to adult salmonids, little is known about juvenile salmonids and their habitats in the Skokomish Basin. The distribution of juvenile salmonids can be inferred from the spawning distribution of adults, although juvenile salmonids can move upstream upon emergence (e.g. Kaya 1989). In addition, relatively little information exists regarding the habitat requirements of juvenile salmonids in relatively large river channels. This is an important factor in the Skokomish Basin since a majority of the available habitat is mainstem habitat. This is because limited tributary habitat is available due to natural anadromous barriers which occur short distances upstream of the tributary mouths in this Skokomish Basin (Watershed Management Team 1995). This lack of information resulted in this topic being identified as an important information gap during the initial phases of the GI.

Information regarding the community structure of lower trophic levels is also lacking. The U.S. Fish and Wildlife Service (FWS) collected invertebrate data from two reaches in the Skokomish Basin in the mid 1990"s, one in the North Fork Skokomish (NF) above Lake Cushman and one in the lower Skokomish River (Celedonia 2004). Based on this survey, aquatic health was rated as excellent in the North Fork Skokomish, above Cushman Dam and fair in the lower Skokomish mainstem. However, this data is relatively old and may not accurately represent current conditions.

This study will provide important information to help fill the information gaps described above. The information is critical for planning ecosystem restoration and flood risk management measures consistent with ecosystem restoration. In addition, this data will establish baseline conditions in the Skokomish Basin which can be used to assess the influence of future projects resulting from proposed alternatives in this GI. This is a critical need for evaluating the effectiveness of riverine restoration projects, which is often lacking in most restoration assessments (Pess et al. 2005).

The objectives of this study were to: 1) identify potential limiting factors to juvenile salmon production within the Skokomish Basin; 2) identify seasonal distribution, abundance and survival; 3) estimate Skokomish Basin production; 4) determine smolt out-migration timing; 5) evaluate estuarine use and residence time of juvenile salmon; and 6) evaluate the community structure of periphyton and aquatic invertebrates. A literature review was completed to gather existing information for the Skokomish Basin to address the objectives described above. Potential limiting factors will be identified by assessing seasonal distribution, abundance, and survival throughout the Skokomish Basin. This information will help identify potential bottlenecks in production and/or survival. Distribution, abundance, and survival data was collected using a combination of seasonal snorkel and habitat surveys, along with Passive Integrated Transponder (PIT) tagging and subsequent recapture surveys. Skokomish Basin production estimates were completed using the information collected during the habitat and snorkel surveys, as well as limited fyke netting and screw trap data collected in the lower river. This trapping also provided information regarding out-migration timing in this system. Estuarine use and residence timing was assessed using beach and purse seining. The community structure of primary and secondary producers was evaluated by collecting samples throughout the Skokomish Basin.

This report is organized into several sections which generally summarize existing information for the Skokomish watershed and new field data collected as part of the GI. This information will be used to identify factors limiting juvenile salmonids in the Skokomish watershed; identify additional information needs; and guide potential restoration activities. The report sections are organized into six parts: 1) a description of the study area, including a general description of the stream network, geology, climate, and fish assemblage; 2) a general overview of the disturbance regime and their relationship to physical processes in the Skokomish Basin; 3) a description of historic and current habitat data, 4) historic and current stock status of each species in the watershed; 5) a comparison of the general habitat requirements of juvenile salmonids; 5) a description of juvenile salmon seasonal distribution and abundance throughout the watershed, outmigration timing and abundance, and timing and relative abundance in the estuary; and 6) a summary of current conditions, factors limiting juvenile salmonids in the Skokomish Basin based on these current conditions, and recommended restoration activities.

Detailed descriptions of the methods used for new data collection and general results are provided in companion set of appendices.

Skokomish Basin Condition: Physical Characteristics

The physical characteristics of the Skokomish Basin are characterized in this section of the report, including the physical setting (i.e., drainage, geology, and climate), disturbance regime (natural and management), and resulting fish habitat conditions. The descriptions of the physical setting and disturbance regime are relatively brief in an effort to generally familiarize the reader with the general attributes of the watershed and the physical processes influencing the watershed. It is not our intent to provide an in depth fluvial geomorphology investigation in this section of the report since this information has been examined in detail in several reports (i.e., USFS 1995, ME2 1997, Correa 2003, Bountry et al. 2009, Skokomish Tribe and WDFW 2010, USACE 2010). The primary purpose of this section is to provide a brief summary of these conditions and summarize how these factors have influenced habitats for fish and other aquatic organisms. This is completed by providing a brief summary of the physical setting, natural physical processes and management activities that influence the watershed, the interaction of these two factors, summarizing past habitat data collection and summary efforts, and summarizing the new data collected as part of the GI.

Drainage Area

The Skokomish River originates in the southeastern Olympic Peninsula of Washington State and flows southeast, emptying into Annas Bay at the southern end of Hood Canal (Figure 1). The river drains a watershed area of approximately 622 km^2 (240 mi^2). The Skokomish Basin consists of the mainstem, three primary sub-basins: the North Fork Skokomish 305 km^2 (117 mi^2), South Fork Skokomish 331 km^2 (128 mi^2), and Vance Creek 61 km^2 (24 mi^2), but also includes several smaller tributaries with an additional 416 km (260 mi) of stream habitat. New habitat data collected as part of the GI was collected throughout the Skokomish Basin, but was limited to habitats below barriers to anadromous fish migration (i.e., anadromous zone) and included tributaries, lateral habitats, and off-channel habitats. No new habitat data was collected in the estuary for the GI. As a result of these criteria, approximately 123 km (76 mi) of the 514 km (319 mi) of stream habitat in the Skokomish Basin, was included in the area where new data collection was completed for the GI (Williams et al. 1975).

The Skokomish estuary consists of the mouth of the Skokomish River and its delta that is tidally influenced. It is the largest and most complex river estuary in Hood Canal. The Skokomish estuary has undergone significant change since the mid-1800, when land clearing was initiated to convert the land to agricultural and residential uses. Much of the estuary was completely diked by the 1930‟s significantly reducing the total estuary area. However, estuarine restoration in the form of extensive dike removal and burrow ditch filling has occurred since 2007, partially restoring some of this lost habitat.

In addition to direct alterations resulting from diking, the Skokomish estuary has also been influenced by indirect alterations resulting from water diversions and increased sediment delivery in the upper basin (Jay and Simenstad 1996). These alterations have resulted in tidal influence in the mainstem that reaches approximately 5.6 to 6.4 km upstream of the mouth (Skokomish Indian Tribe and WDFW 2010, citing Marty Ereth, former Skokomish tribal biologist, personal communication), significantly less than historic values. Data presented in this report suggests that tidal influence may actually have shifted even further downstream (see Biological Characteristics section for details). They have also resulted in finer substrate in the inner delta (Jay and Simenstad 1996).

Collins and Sheikh (2005) used a regional process-based classification scheme to classify tidal wetlands in Puget Sound. They classified the Skokomish estuary along with estuaries of major rivers with river deltas and tidal freshwater floodplains in major glacial troughs. These systems were characterized by broad low gradient valleys created by sub-glacial fluvial erosion (Collins and Sheikh 2005). Bortleson et al. (1980) classified habitat conditions in the Skokomish estuary broadly as intertidal and subaerial. Collins and Sheikh (2005) also classified intertidal wetland habitats within Puget Sound and determined that approximately 70 percent of the Skokomish estuary composed of emergent estuarine wetlands (~70%) with the remaining wetlands classified as scrub-Shrub wetlands.

The mainstem Skokomish River flows from the confluence of the North and South Fork Skokomish River through the broad, alluvial Skokomish Valley before entering Hood Canal via the relatively large estuary described above (Todd et al. 2006). This section of river has been relatively dynamic in recent years. As stated above, tidal influence in the mainstem appears to be shifting downstream (Skokomish Tribe and WDFW 2010). In addition, the confluence of the North Fork Skokomish and South Fork Skokomish was altered in 2004 when the North Fork Skokomish became blocked with sediment and large wood, resulting in a channel avulsion. The channel of the North Fork Skokomish overtopped a levee and connected to an historic channel, now entering the mainstem Skokomish River at river kilometer (RKM) 12.9 (river mile (RVM) 8) (at the mouth of the old Richert Springs inlet), downstream of its previous confluence.

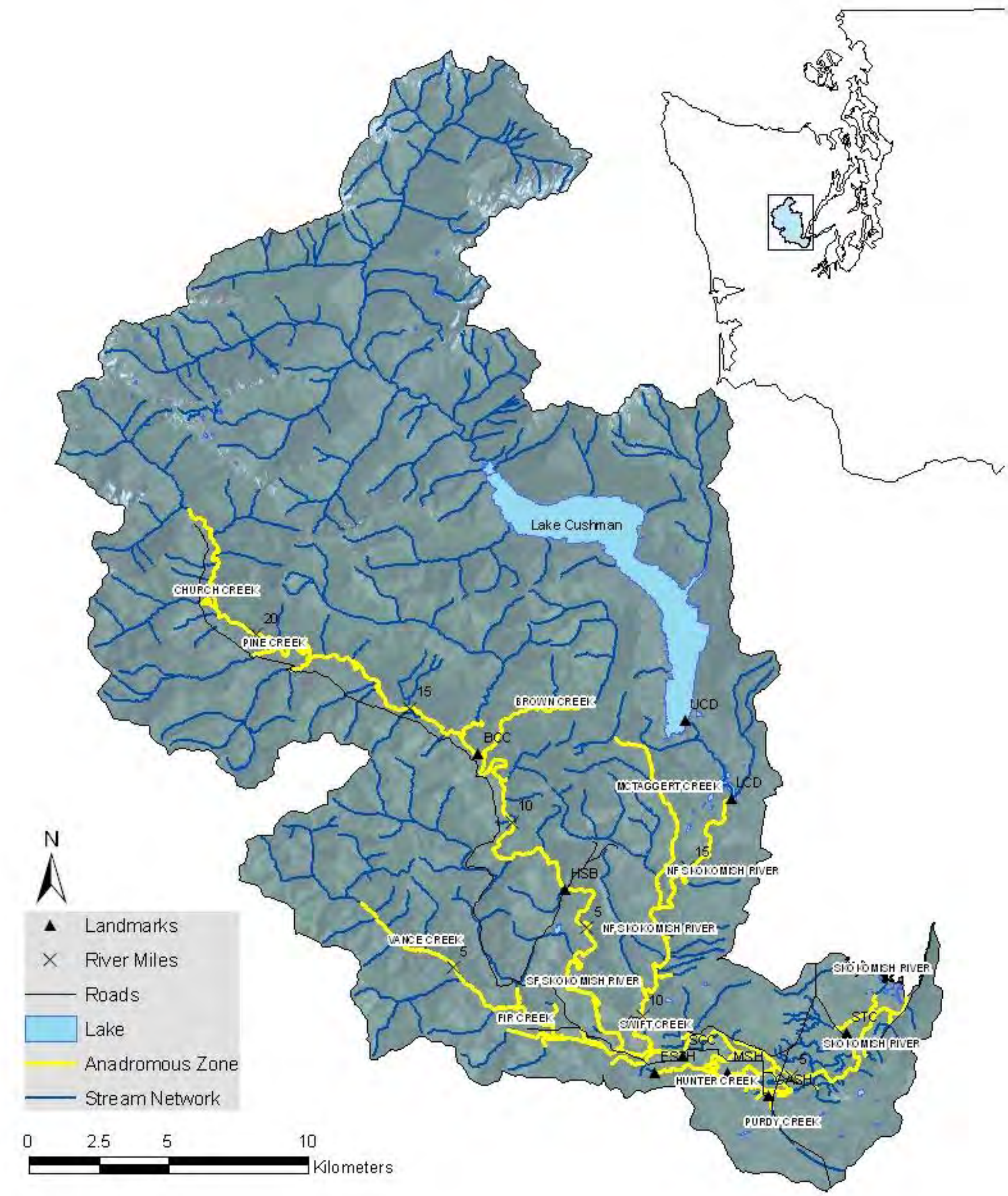

Figure 1. Stream network of the Skokomish Basin along with that portion of the watershed accessible to anadromous salmon (i.e., anadromous zone). Data collection for this project was collected in the anadromous zone and the estuary only, with the exception of one macroinvertebrate and periphyton sample collected above Lake Cushman on the North Fork Skokomish (see Chapter 9). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

The mainstem below the confluence is low gradient (slope less than 0.0024 ft/ft; Bountry et al. 2009), when compared to all other sections of the river network, and has an extensive floodplain. However, the river has been hydraulically disconnected from this floodplain in many areas, by levees, bank armoring, and channelization (BOR 2007). Land-use in this section of river is primarily agriculture and private residence, including the Skokomish Indian Reservation. Significant tributaries of this section of river include Hunter Creek, Weaver Creek, and Purdy Creek. These are mainly spring fed systems that all enter the mainstem between RKM 5.8 (RVM 3.6) and RKM 12.7 (RVM 7.9) (WDFW and PNPTT 2000).

The North Fork Skokomish drains approximately 305 km^2 (118 mi^2), but is impounded at RKM 27.7 (RVM 17.3) by the first of two City of Tacoma Dams, which creates the 40 ha (100 acre) Kokanee Reservoir. The much larger Cushman Dam is located 2.7 km (1.7 mi) further upstream, creating the 1,619 ha (4,000 acre) Cushman Reservoir, which expanded a pre-existing natural lake. An additional 17.7 km (11 mi) of river lies upstream of Cushman Reservoir. This section of river is contained mainly within Olympic National Park and is characterized by steeply wooded hillsides and a deeply incised canyon. The impoundment at Kokanee Reservoir blocks anadromous fish passage, while the Cushman Dam has historically diverted approximately 80% of the North Fork Skokomish flow directly to Hood Canal. However, a recent legal agreement will initiate trap-and-haul passage for salmon and significantly reduce water diversions to Hood Canal (Cushman Project 2009). One main tributary, McTaggert Creek, joins the North Fork Skokomish below Kokanee Reservoir. Land-use in the North Fork Skokomish consists of Olympic National Park, commercial timber production, and limited private residence and agricultural use below Kokanee Reservoir.

The South Fork Skokomish drains an area of approximately 331 km^2 (128 mi^2) and can be broadly characterized into four sections: the lower portion from the confluence up to the canyon at RKM 8.0 (RVM 5), the canyon portion which extends from RKM 8 (RVM 5) upstream to RKM 16.1 (RVM 10), a wide alluvial valley section from RKM 16.1 (RVM 10) to RKM 37.8 (RVM 23.5) and a final canyon which stretches from RKM 37.8 (RVM 23.) another 8 KM to the headwaters. The lower portion is characterized by a wide, alluvial valley with significant human influence related to residential and agriculture properties. The canyon section is a steep, bedrock dominated gorge that reaches 120 meters deep in places and is only 18 meters wide at its narrowest point (TAG 2003). There are steep cascades within this section (RKM 8.9-10.5; RVM 5.5-6.5) that have been identified as a barrier to upstream migration for some species of salmon (WDF 1957). The upper valley section is generally unconfined and has a moderate gradient (typically, 0.013; M2, 1997). Land use in this section is dominated by commercial timber harvest and associated road building. The upper canyon is also a steep gradient bedrock gorge that lies within Olympic National Park. The South Fork Skokomish originates in Olympic National Park, flows through U.S. Forest Service (USFS) and Green Diamond Resources (formerly Simpson Timber) property, and then through agriculture and private residential areas (WDFW and PNPTT 2000). Land-use in this sub-basin is commercial timber harvest, agriculture and residential. Several tributaries enter the South Fork Skokomish including Vance, LeBar, Cedar, Pine, and Church Creeks. The largest tributary to the South Fork Skokomish is Vance Creek, entering at RKM 1.3 (RVM 0.8), while the remaining tributaries enter the upper portions of the South Fork Skokomish. These upper Skokomish Basin tributaries are all relatively short streams with anadromous gradient blockages generally within the first mile. The exception is Browns Creek which has more than 4.8 km (3 mi) of anadromous habitat.

Vance Creek, which enters the South Fork Skokomish at RKM 1.3 (RVM 0.8), has a drainage area of 61 km^2 (23.8 mi^2). Vance Creek flows through a broad valley with moderate gradient for the first 6.4 km (4 mi) and then abruptly steepens until an anadromous barrier (10 m falls) at RKM 11.4 (RVM 7.1) (TAG 2003). Vance Creek originates on USFS land and then flows through Green Diamond Resources timber land before entering agricultural and residential land. Land-use in this sub-basin is dominated by commercial timber production.

Geology

Bedrock in much of the Skokomish watershed consists of submarine basalt flows dating from the Eocene Epoch, approximately 37 to 50 million years ago, which have been uplifted due to tectonic plate movement. The uppermost headwaters, however, are underlain by marine sedimentary slates, mudstones, and sandstones of similar age, which originally formed part of the accretionary wedge associated with the subduction zone. Superimposed on this bedrock, are hundreds of feet of sediments deposited by Pleistocene continental glaciation, which overran the Southeast corner of the Skokomish Basin, from the area around Lake Cushman, reaching inland from the Hood Canal about 8 miles in the vicinity of Vance Creek. Alpine glaciation, originating in the Olympic Mountains, likewise filled portions of the middle and upper watershed with glacial sediments. Fluvial erosion during the centuries since the Pleistocene has cut into these sediments, creating the broad alluvial valleys of the lower South Fork Skokomish and mainstem, and the much narrower alluvial valley comprising the middle portions of the South Fork Skokomish. Each of these alluvial segments remain bounded by high terraces of glacial sediment, which can be eroded by the river channel where it impinges on the valley sides. Soil depths for the watershed as a whole are generally less than one meter, except in the valleys of the lower river, where glaciation and fluvial deposition has accumulated over 30 meters of sediment in some places, particularly in the southern portion of the watershed (WDFW and PNPTT 2000).

Although these glacial processes and the sediments they deposited occurred more than 14,000 years ago, they are important to understanding how management activities and climate change can influence the current river channel. An excellent description of this relationship is described in detail by the Skokomish Tribe and WDFW (2010). Recently deglaciated landscapes go through a paraglacial period which is characterized by unstable conditions that persist until glacial sediments are essentially removed from the basin or become stable (Ballantyne 2002). The morphology of rivers within this geomorphic setting was historically an interaction between valley floor forests composed of large conifer trees and large in-channel logjams, which typically created a stable, island-braided river channel (Collins et al. 2003). Channel avulsions are the main mechanism of channel migration in these systems; however, these typically result in the main channel re-activating relic channels. Thus, these systems can attain a relatively stable state that will transport the sediment load or even accommodate long-term storage of alluvial sediment in the channel migration zone without disruption of its morphological pattern, and can sustain complex aquatic habitat in the process. It is known from studies in similar river systems, however, that these systems are sensitive to external perturbations which can re-activate paraglacial sediment transport (Ballantyne 2002), resulting in unstable channel conditions and re-mobilization of floodplain sediment sources. Perturbations capable of destabilizing the system include altered sediment load or hydraulic energy (such as triggered by climate change, forest harvest, increased road density, tectonic movements, etc.) or loss of the logjams and large conifer trees that stabilized the floodplain islands and comprised the source for large wood recruitment (Skokomish Tribe and WDFW, 2010).

Climate

The climate in the Skokomish Basin can be described as a temperate, marine climate with wet winters and dry summers. This climate supports a diverse flora and favors the growth of trees (WDFW and PNPTT 2000). Due to its location on the east side of the Olympic Mountain Range, there is a precipitation gradient from the headwaters down to Hood Canal. The extreme upper portions of the watershed receive nearly 304 cm (120 inches) of rain annually, while areas near Hood Canal receive approximately 152 cm (60 inches) of rain annually.

Long-term climate change is underway in the Pacific Northwest, including the Skokomish drainage (Mote 2003). These changes are especially important in watersheds which contain headwaters at intermediate elevations commonly known as the transient snow zone. The transient snow zone can shrink appreciably in response to relatively small increases in winter temperatures, which alters the pattern of runoff and the severity of peak flows (Cuo et al. 2008). This area is relatively large in the Skokomish Basin, which suggests that a relatively large change in precipitation from snow to rain has occurred and will likely continue to spread in the Skokomish Basin (Knowles et al. 2006), meaning that runoff shifts from spring and summer to mid-winter, and that peak flow magnitudes increase. This change in precipitation type will thus subsequently influence sediment transport and channel stability (see below for more details).

Hydrology

Historically, sub-basins in the Skokomish River had three different flow regime patterns that were directly related to the influence of snowmelt, including strong, weak, and no snowmelt influence (Skokomish Tribe and WDFW 2010). These varied flow regimes combine to provide the flow regime of the Skokomish Basin as a whole. Historically, peak runoff in the watershed occurred during the winter when precipitation is at its highest and a second, smaller peak occurred during the spring as mountain snow melted. The South Fork Skokomish and Mainstem, however, do not display this bimodal pattern of runoff, showing significant peaks only in only the winter season (England, 2007). Flows declined after the spring snowmelt reaching base flows in August or September. A peak flow of 36,600 cfs was observed on November 23, 1990 (USGS 2008) and base flows in the mainstem are approximately 205 cfs, based on 90% exceedence values from 1943-2008. However, lower sections of both the South Fork Skokomish and Vance Creek, where sediment aggradation has occurred, often go dry during summer base flow.

The current flow regime varies considerably from this historic regime (Skokomish Tribe and WDFW 2010). The primary peak runoff still occurs during the winter and flows still decline to base flows in August or September. However, the magnitude of the second spring runoff appears to be decreasing both in the South Fork Skokomish and North Fork Skokomish (above Cushman), and is completely absent below the two dams in the North Fork Skokomish (England 2007). This could be the result of changes in forest cover resulting from historic intensive logging in the watershed (South Fork Skokomish) or long-term climate change (Cuo et al., 2009;

Skokomish Tribe and WDFW 2010). Climate change appears to be the primary factor influencing hydrology (Skokomish Tribe and WDFW 2010), since the regime has shifted in both sub-basins, and little logging has occurred in the North Fork Skokomish above Lake Cushman (the gauge used for this assessment by Cuo et al.). The influence of climate change on hydrologic patterns may include higher annual maximum, fall, winter and early spring streamflow, but lower summer flow (Cuo et al. 2009, Mantua et al. 2010). Reductions in base flows from historic levels have been observed in the Skokomish Basin (Skokomish Tribe and WDFW 2010).

Peak discharges in the Skokomish Basin appear to be changing from historic values, although the available reports must be interpreted carefully. As mentioned above, climate change models predict increases in peak discharges in the Skokomish Basin. However, peak discharges are reduced from historic values in the mainstem Skokomish River due to water diversions at the Cushman dam (The Skokomish Tribe and WDFW 2010). England (2007) reports that there is an increasing trend in maximum flows in the North Fork Skokomish (1925-2006, 1967-2006) above the dams and in the mainstem Skokomish River (1944-2006, 1976-2006), which has recorded flows during the diversion period due to dam operation. Peak flow trends in the gage on the South Fork Skokomish are more difficult to discern due to its much shorter period of record (England 2007). These increasing trends in peak flow magnitude are evident in many stream gage records throughout Washington, including the Skykomish, Duckabush, Dungeness (England, 2007) and Stehekin Rivers (Bakke, 2009).

Regardless of how peak flows have changed from historic levels, it is quite clear that the channel‟s ability to convey those discharges has been reduced relative to historic values. Historic channel capacity at the HWY 101 Bridge was 13,000 cfs, but is currently approximately 4,100 cfs (Bountry et al. 2009). This is equivalent to a 1.1 year event and has a 90% chance of being exceeded during a given year (USACE 2010). Overbank flows occur at even lower discharges of only 2,500 cfs downstream of the HWY 101 Bridge (Karl Erickson, USACE, personal communication). Thus, channel capacity appears to be less than one-third of historic values, thereby increasing the frequency of overbank flow in the valley.

Disturbance Regime

Disturbance in the watershed can be categorized as either natural or anthropogenic (human influenced). The influence of these disturbances on the watershed will be determined in large part by the geology and hydrology of the system. The primary natural disturbances in the Skokomish watershed include flooding, mass wasting, fire, windthrow, insects and disease, non-native invasive plant species, and climate change. Each of these natural disturbances can result in increases in the other natural disturbances to some degree. However, climate change has the potential to influence the frequency and intensity of all of these natural disturbances (i.e., by influencing temperature and hydrology).

Mass wasting events and flooding are caused by a combination of physical attributes of the watershed, such as its topography and soil composition. The steep slopes of the upper Skokomish Basin, level of precipitation, relatively large size of the transient snow zone, and shallow soils, result in slopes that are prone to mass wasting events and flooding. These natural disturbances have also been exacerbated by anthropogenic influences, which are discussed in more detail later.

Fires have always influenced the Skokomish watershed (USFS 1995, ME2 Environmental Services 1997). The last large fire occurred in 1834, which burned approximately 4% of the watershed (1,102 ha; 2,500 acres). An extremely large fire hasn"t occurred in the Skokomish Basin since approximately 1701, when about half (13,759 ha, 34,000 acres) the watershed was burned. It appears that large fires occurred approximately once every 200 years prior to the 1701fire (USFS 1995, ME2 Environmental Services 1997). It"s likely that stable watershed processes and associated channel conditions occurred between these fires and that this stability was not impacted greatly by the fire in 1834. Current fire management in the watershed varies depending on land ownership. Naturally occurring fires within Olympic National Park are monitored but not actively extinguished by fire crews. All fires occurring on the Olympic National Forest, on the other hand, are extinguished as soon as possible (USFS 1995).

There have been a number of different human impacts in the watershed, which vary with regard to the location where they occur. Logging and associated road building has occurred throughout the watershed, except within the boundaries of Olympic National Park. Other human impacts, which have been more common in the lower mainstem, include land conversion from forest to agriculture, removal of large wood from the channel, estuarine diking, riverine levee construction, dredging and channelization, and general development, which all combine to reduce floodplain connectivity. Two dams constructed on the North Fork Skokomish have altered the rivers hydrology and block anadromous fish passage. In addition, there are three fish hatcheries in the lower watershed, George Adams, McKernan, and Eels Springs.

Interaction of Physical Characteristics and Processes

The interaction of various physical characteristics and processes in the watershed has resulted in the main factor that limits habitat for both adult and juvenile salmon (and people) in the watershed: channel aggradation, or an increase in the overall sediment in the river channel, with its associated syndrome of morphological characteristics and changes to channel processes. Channel aggradation causes a host of problems affecting salmonid habitat. In this section, we will provide a brief overview of the factors which have contributed to aggradation, as a prelude to discussing its effects on salmonid habitat. To provide perspective, we will summarize the historic narrative of anthropogenic modifications to the watershed, and include a brief discussion of the sensitivity of a river channel in this geomorphic setting to alterations of the physical processes that determine channel structure, function, and stability.

Hypotheses for triggering aggradation and increased flooding in the Skokomish River commonly fall into the following six categories (Bountry et al., 2009; Skokomish Indian Tribe and WDFW, 2010):

1. Rapid deforestation in the form of clearcut logging, resulting in an increased sediment load;
2. Removal of large wood pieces and logjams, and clearing of riparian zone old-growth forest, resulting in conversion of an island-braided system to a less-stable braided system, triggering release of stored floodplain sediments;

3. Reduction in flow from the North Fork Skokomish due to the operation of Cushman dam, resulting in reduced sediment transport capacity in the lower mainstem;
4. Channelization of the river channel using riprap, crib structures, cabled logs, and removal of large wood, resulting in temporary improved hydraulic capacity, but reduced sediment transport efficiency;
5. Confinement of the channel by levees, resulting in backwatering of some areas, translation of depositional zones in a downstream direction, in-channel deposition of suspended sediments in low gradient areas, and loss of storage of coarse sediments in secondary channels;
6. Hydraulic constrictions of flow at bridge crossings, causing back watering and loss of sediment transport capacity.

Unfortunately, although each of these mechanisms is physically plausible and contributes to varying degrees, there is no professional consensus among the various people who have studied physical processes in the Skokomish River as to which of these hypothesized mechanisms are more important than others (Bountry et al., 2009). This is unfortunate because without clear understanding of the mechanisms for aggradation, we are less likely to be able to come to a consensus on which management solutions will be the most effective. What is indisputable, however, is that the river is aggrading (Stover and Montgomery, 2001), and at rates higher than those which could have existed for any extended period of time in the past. For example, at the U.S. Geological Survey (USGS) gaging station at the HWY 101 Bridge, Stover and Montgomery documented an aggradation rate of 1.3 meters over the 32 year period from 1965 to 1997, a rate of 0.4 meters per decade. The six mechanisms discussed above that may potentially be influencing this aggradation are discussed below.

Rapid deforestation in the form of clearcut logging is perhaps the most often cited mechanism for causing the observed changes in the lower Skokomish River. Logging activities in the upper South Fork Skokomish Basin and in Vance Creek have been documented to increase the rate of mass wasting events in the portion of the watershed that has been harvested by a factor of 3.1 (ME2 Environmental Services, 1997), from 1.1 to 3.4 events per km^2, during the 50 year period from 1946 to 1995. Mass wasting volumes contributed to the river during this time period by landslides associated with forest practices were estimated to be about 229,000 m^3, not including the large amounts of sediment input associated with the edges of fluvio-glacial terraces in middle portions of the watershed which were not mapped, but which could have been destabilized as a result of increased sediment input from harvest-related mass wasting, from logging of riparian trees, or removal of logjams.

This documented increase in the rate of mass wasting in the watershed, considered together with the rapid pace of forest harvest that occurred when much of the watershed was managed under the Shelton Cooperative Sustained Yield Unit, and the accelerated harvest that occurred in the early 1950s when the area was proposed to become inundated by a third hydropower dam reservoir, has led several previous researchers to conclude that extensive logging and its associated road building, mainly in upper portions of the South Fork Skokomish (SF) and Vance Creek sub-basins, is the main cause of increased sediment loads to the river channel (Canning et al. 1998; KCM 1993, 1997; Stover and Montgomery 2001). Indeed, approximately 60 to 80% of the South Fork Skokomish drainage basin has been harvested and thousands of miles of roads and railroad lines have been built (Canning et al. 1988; KCM 1993). As a whole, the Skokomish watershed has experienced over 600 mass wasting events over the last 50 years. Sixty-five percent (65%) of these events were associated with the road network, and presumably would not have occurred in the absence of forest management (ME2 Environmental Services 1997). Generally speaking, road densities are higher in the lower watershed, but these are found on lower gradient slopes and at least a portion of them are paved, reducing the potential for them to release sediment into the river channel. Upper watershed tributaries have an average of about 2.8 km of road per km^2 (km/km^2) of watershed (4.5 mi/mi^2) while the middle and upper South Fork Skokomish have about 1.55 km of road km^2 of watershed (2.5 mi/mi^2) (Correa 2003). These are much higher values than observed in the nearby Duckabush and Hamma Hamma watersheds with road densities of 0.37 and 0.87 km/km^2, respectively (WDFW and PNPTT 2000).

Although significant amounts of additional sediment has entered stream channels as a result of the exacerbated mass wasting and logging activities in this system, it is unclear how much this has contributed to aggradation in the lower river. ME2 Environmental Services (1997) used aerial photos to estimate changes to the surface area of active channel and unvegetated terraces in five alluvial reaches over the period from 1929 to 1997, and detected and increasing trend in the three reaches located in the middle and upper South Fork Skokomish. They then went on to assume that these changes in unvegetated surface represent increases in active channel sediment storage, from which they could compute the storage volume change and compare it to the sediment input rate from mass wasting processes as well as an estimate of sediment transport derived from extrapolation of the bedload model (Simons and Associates, 1994). With these assumptions, they concluded that the sediment volume inputs from mass wasting represented only a small proportion (about 10 percent) of the change in active channel storage, the rest presumably coming from unmapped erosion and mass wasting associated with the glacio-fluvial terraces bounding the river. They further concluded that the estimated residence time for sediment stored in these depositional reaches was relatively long, on the order of 40 to 160 years for the two upper South Fork Skokomish reaches, which was too long for it to have influenced the current aggradation processes in the lower mainstem.

However, their methodology provides no means to check their assumptions. In particular, the assumed relationship between unvegetated area and sediment storage, and the relationship between presumed changes in storage and volume of sediment transported are highly uncertain, since no systematic measurements of streambed elevation were taken for comparison. Nor are there sediment transport measurements for the reaches in question to calibrate or confirm the transport model, which is in dispute (Watson, 1996). These considerations lead to an alternative interpretation of this analysis, which is that the increase in unvegetated area may better represent erosion than sediment in storage (deposition), in which case, two conclusions follow (Skokomish Indian Tribe and WDFW, 2010):

- that the increased mass wasting sediment input during the mid to late twentieth century, which is directly attributable to forest harvest and associated road building, was sufficient to massively destabilize the channel in these alluvial reaches along the South Fork Skokomish, releasing volumes of sediment from floodplain storage in quantities much larger than the volume which originally triggered the destabilization (a "knock-on" or cascading effect, in geomorphic terms); and,
- that significant portions of this *eroded* sediment volume may have been transmitted downstream.

In other words, the mass wasting triggered a threshold response, causing channel destabilization, which produced positive feedback in the form of additional sediment input, and was transmitted on downstream as a "knock-on" effect or cascading response. Whether this is the major cause of aggradation in the lower South Fork Skokomish and mainstem, however, remains undetermined.

This leads naturally to consideration of the next possible mechanism for aggradation, which is that removal of large wood pieces and logjams, and clearing of riparian zone old-growth forest, resulted in conversion of an island-braided system to a less-stable braided system, triggering release of stored floodplain sediments.

Large wood input and retention as logjams can influence channel form as significantly as both sediment and hydraulic inputs (Montgomery et al. 2003). The island-braided channel type, in which main and secondary channels are separated by stable, vegetated islands observed in some river systems is thought to evolve in sediment-rich systems in the presence of logjams (i.e., Collins and Montgomery 2002; Abbe and Montgomery 2003). In addition, logjams can be important in the development of floodplains (Abbe and Montgomery 2003) and in limiting bank erosion (Abbe and Montgomery 2003; O‟Connor et al. 2003). Changes in the amount and the size of wood in a river can have similar impacts to changing sediment inputs or discharge patterns (Montgomery et al. 2003). Removal of large logjams has resulted in significant channel widening in other systems (Triska 1984; Brooks and Brierley 2000). Although removal of logjams initially increases the sediment transport capacity (Harvey et al. 1988; Brooks and Brierley 2000), if the ensuing bank erosion leads to a wider channel, and the concurrent drop in surface water elevation leads to reduced side channel activation, the end result is a system with lower sediment transport capacity (Huang and Nanson, 2007), setting the stage for aggradation.

There is evidence from early descriptions and early aerial photos that the South Fork Skokomish River flowed through a dense old-growth coniferous forest, that its channel was relatively narrow compared to current conditions, and that large logjams were a significant feature (Skokomish Indian Tribe and WDFW, 2010). The Skokomish Indian Tribe and WDFW (2010) hypothesize that the watershed and its associated channels were in a relatively stable condition prior to Euro-American settlement. The upper South Fork Skokomish alluvial valley above the South Fork Skokomish canyon, Vance Creek floodplain below the Vance Creek canyon, lower South Fork Skokomish below the South Fork Skokomish canyon and the lower mainstem are hypothesized to have consisted of stable river channels, side channels, and relic channels. These channels were thought to be separated by islands vegetated with mature forests and to contain numerous logjams, some of which were very large. This hypothesis is supported by early land surveys (Figure 2). The Skokomish River system, like most Olympic Peninsula rivers, is sediment rich, and had adjusted itself into an equilibrium morphology that accommodated the presence of large wood while efficiently transporting its sediment load. This morphology was likely an island-braided or anabranching system (Huang and Nanson, 2007), perhaps functionally similar to that described by Collins et al. (2003) for other Puget Sound rivers such as the lower Nisqually.

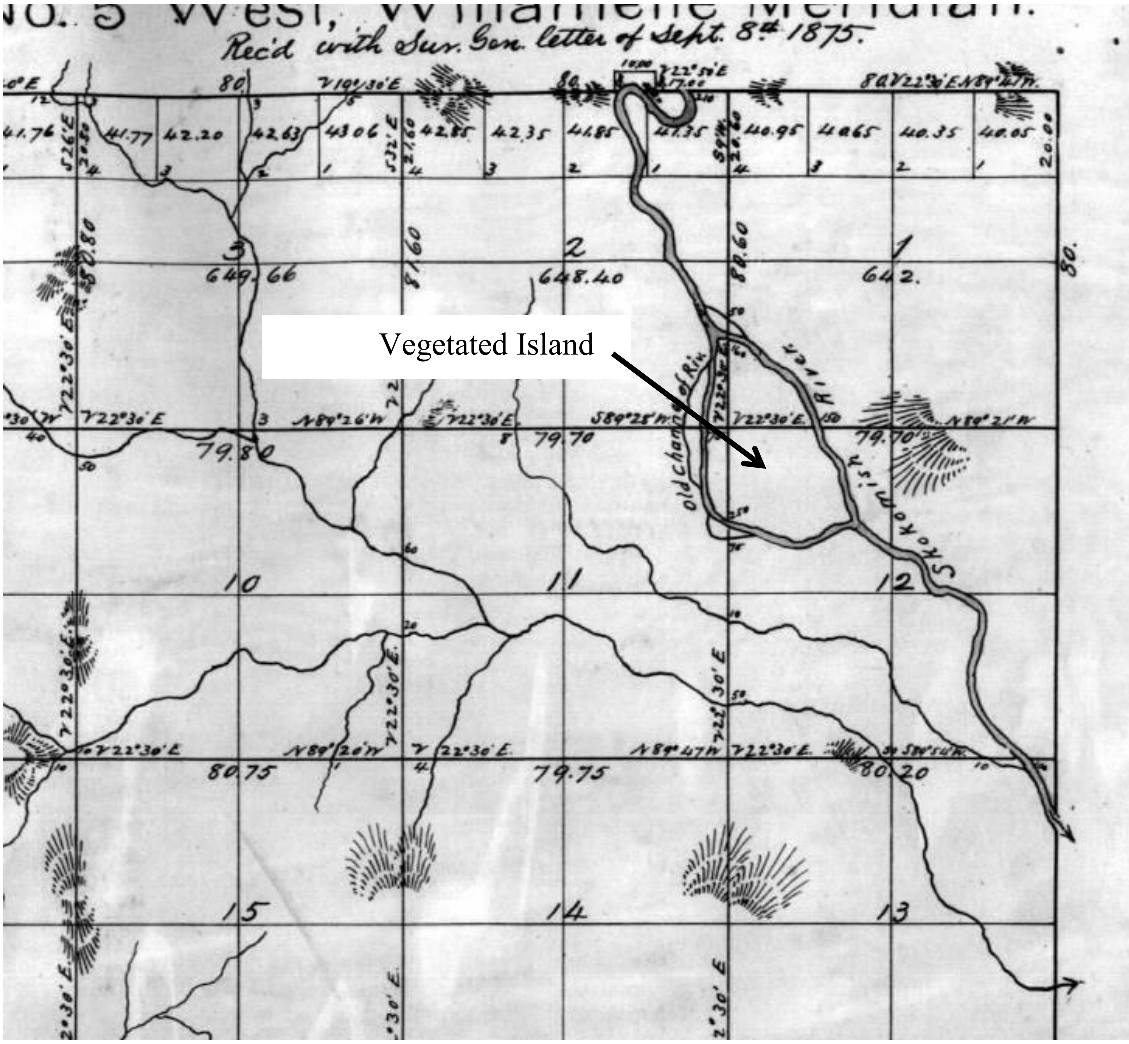

Figure 2. Example of the stable vegetated islands hypothesized to exist in the upper South Fork Skokomish, lower South Fork Skokomish below the Canyon, lower Vance Creek below the Canyon, and lower mainstem just below the North Fork Skokomish confluence. This map shows a vegetated island approximately one mile downstream of the canyon on South Fork Skokomish River (General Land Office) GLO Surveyor map from July 1875). The canyon is located at the top of the map with Vance Creek shown at the bottom of the map (Modified from Skokomish Indian Tribe and WDFW 2010).

These island-braided river systems are capable of storing large volumes of sediment in their islands and floodplains, and depend on an intact riparian forest and large, somewhat stable log jams for their overall channel stability. Removal of the logjams alters the partitioning of hydraulic energy in such a way as to cause increased bank erosion and channel instability, which can lead to export of stored sediment from the reach. Removal of riparian trees hastens the process of destabilization, such that the net effect of land clearing and channel cleaning can be a massive release of stored sediment, as described by Ballantyne (2002). As the channel widens through bank erosion, its capacity to transport sediment becomes reduced over what it was with multiple channels with lower width to depth ratios (Huang and Nanson, 2007), and it begins to aggrade. Several investigators have concluded that this phenomenon may be responsible for the current condition of the lower South Fork Skokomish and mainstem Skokomish Rivers.

This island braided morphology may have been common in sediment-rich areas such as the Skokomish Valley where stream gradient is decreasing in a downstream direction, with resulting decrease in stream power and sediment transport capacity. The steady decrease in gradient as you move from the mountains toward the marine environment is common to most western Washington Rivers. However, these systems apparently transported sediments efficiently with stable morphology prior to human manipulation. Downstream decreasing gradient is associated with transitions in morphology, which include changes in channel type (i.e., from a plane-bed or forced pool-riffle to island-braided morphology, Collins et al. 003), cross-sectional shape or area, substrate type, and bedload composition. The island braided morphology seems to be a transitional type that occurs where the sediment load is dominated by coarse bedload, and sediment storage as relatively stable islands and bars is occurring over long time scales (decades to centuries). Downstream from island braided reaches, it would be expected to encounter a meandering pool-riffle channel type with finer-textured bedload and with suspended load dominating the sediment yield (Beechie et al., 2006). However, in the Skokomish, as in some other Western Washington rivers, that latter transition never occurs, but rather the coarse-bedded morphology extends all the way to where the river transitions into a deltaic setting (Bountry et al., 2009).

Reduction in flow from the North Fork Skokomish due to the operation of Cushman dam, resulting in reduced sediment transport capacity in the lower mainstem is another factor often cited as cause for aggradation (Orsborn 1991a; Jay and Simenstad 1996; Stover and Montgomery 2000). For periods of time following the construction of the dams in 1930, the entire flow of the North Fork Skokomish was diverted directly into Hood Canal (Wampler 1980) through the penstocks of the Potlatch Power plant. More recently, Orsborn (1991a) reported that average monthly flows in October to March were reduced by 78 to 83%, while monthly average flows in the April to September period were reduced by 90 to 96%. More importantly, from a sediment transport standpoint, 2 and 50 year flood peak discharges have been reduced by 80% and 74%, respectively.

Channelization (straightening) of the river channel using riprap, crib structures, cabled logs, and removal of large wood, resulting in temporary improved hydraulic capacity, but reduced sediment transport efficiency is the next mechanism of interest. When a channel is straightened to increase flood conveyance, it is usually widened as well. This tends to improve hydraulic capacity, but actually reduces the sediment transport capacity over that of a more sinuous channel with a deep thalweg, a lower width to depth ratio, and the presence of secondary currents along the bed and banks that keep sediment mobilized. Channelization of the

Skokomish Basin began in the 1930s. At least four locations are thought to have been straightened, including the lower South Fork Skokomish just downstream of the canyon, just downstream of the Vance Creek confluence, the mainstem just below the old North Fork Skokomish confluence and the Church levee, and between HWY 101 and State Route (SR) 106. Due to the lack of information about the level of channelization it is impossible to quantify the impacts of this activity. However, sediment transport would likely have been reduced and edge habitat for juvenile salmon was certainly reduced.

Confinement of the channel by levees, resulting in backwatering of some areas, translation of depositional zones in a downstream direction, in-channel deposition of suspended sediments in low gradient areas, and loss of storage for coarse sediments in secondary channels is the next most commonly referenced cause of aggradation in the mainstem Skokomish River (Bountry et al. 2009). Levees that cause river channel or flood plain constrictions can cause a backwater pool to form upstream of the constriction (Bureau of Reclamation (BOR) 2002), which would result in slower velocities and subsequent sediment deposition in the backwater zone (i.e., local aggradation). This local aggradation would reduce channel gradients upstream, further impacting sediment transport. By contrast, the initial constriction caused by the levee may actually increase local sediment transport capacity. However, this increased capacity will also be relatively local in nature and may result in the relocation of sediment deposits. For example, if the levee acts as a constricting "conduit" between an area of relatively higher gradient and a reach downstream where the gradient is less, the levee can cause translation of a depositional area in a downstream direction, where coarse sediment that would have been deposited upstream may then be transferred and deposited further downstream than it otherwise would have been. Levees isolate the river from its floodplain, which removes some potential deposition zones for coarse sediment, such as side channels, from the system. As the river approaches its estuary, suspended sediment may begin to deposit on the channel bed instead of spreading out over the floodplain as would happen without levee confinement. Levee construction can increase stage height during floods due to the complex interaction between channel roughness, deposition, and reduction in floodplain connectivity (Pinter et al. 2000; BOR 2002; Remo and Pinter 2007).

In the Skokomish Basin, levees have been constructed from the confluence of the South Fork Skokomish with Vance Creek all the way down to Hood Canal (Figure 3). The construction of these levees on the mainstem Skokomish River coincides with the beginning of main channel aggradation documented by Stover and Montgomery (2001). Reviewing this information suggests that the greatest impacts of levee constricting the channel and/or floodplain occur at four locations including, Nalley Island, near the old North Fork Skokomish confluence, just downstream of the Church dike, and the HWY 101 roadway across the Skokomish floodplain. Figure 3 shows the location of current levees and levees/dikes that have been removed;

Hydraulic constrictions of flow at bridge crossings, causing back watering and loss of sediment transport capacity, is the final mechanism of interest. Narrow bridges or those with fill used for the bridge approaches, can have impacts similar to those described above for levees. These bridge features can constrict the channel, isolating the river from its floodplain and side channels, and resulting in backwatering upstream of the bridge and the subsequent deposition of sediments (BOR 2002). There are currently four channels in the lower Skokomish River valley with bridge crossings, including from north to south, the Skokomish River overflow channel, mainstem Skokomish River, Weaver Creek and Purdy Creek (West Consultants, Inc. 2006). Two other bridges occur, one on Vance Creek, upstream of the HWY 101 bridges and one downstream on the Skokomish River serving SR 106. These bridges appear to have been first built in the 1930s (Table 1). Several of these bridges were rebuilt in the 1970s and 1980s. LiDAR clearly show that floodplain fill has been used to provide approaches for these four bridge (Figure 4). Many of these bridges are narrow openings relative to the channel width of the channels they cross and have resulted in at least some backwatering in the Skokomish Valley during flooding. For example, water has backed up behind the Highway 101 Bridge and SR 106 Bridge during floods (Bountry et al. 2009). In 2009, the 110 ft. span over Purdy Creek was replaced in 2009 with a 350 ft. span. Increasing the size of this single span is expected to generally decrease backwatering upstream of all four HWY 101 bridges (West Consultants, Inc. 2006).

Each of the factors discussed above could potentially be impacted by climate change. Climate change has been a continuous occurrence throughout the history of the world. However, current climate change appears to have been accelerated by human activities (Climate Impacts Group 2009). Climate change can influence the intensity and timing of precipitation, alter contribution ratio of rain and snow, alter vegetation cover, increase sea level (Goudie 2006) and alter disturbance regimes (Climate Impacts Group 2009). These factors can in turn alter sediment transport capabilities of the river and material input (i.e., sediment, LWD). These changes could be significant enough to further destabilize the channel. Sea level rise would impact the Skokomish delta by increasing base level elevation, resulting in potentially greater reductions in sediment transport capabilities in the lower river. In contrast to other natural disturbances (i.e., fires, extreme floods), which occur over short periods (usually less than weeks), climate change occurs over long time periods and is more similar to long-duration anthropogenic disturbances (i.e., logging) (Bakke 2009). Although change occurs over a longer timeframe, sudden changes in the associated physical processes may occur as some threshold is reached (i.e. hydrologic inputs sufficient to cause mass wasting), thereby having an immediate impact to aquatic habitat. In addition, these long-term changes can result in long term instability relative to more sudden impacts. Although climate change has influenced peak flows in other basins, it"s unclear if these same changes have occurred in the Skokomish River (England 2007). As discussed above under the „hydrology" sub-section, there are some indications that peak discharges and trends in peak discharges have increased in some parts of the watershed but not others. Although summer low flows are reduced relative to historic values, these could be the result of sediment aggradation in the lower South Fork Skokomish, lower Vance Creek, and mainstem as well as flow reductions resulting from diversion of flows from the North Fork Skokomish. Based on this information, it appears that climate change has had a minimal impact on sediment inputs and hydrology of the Skokomish Basin.

In conclusion, the combination of the physical nature of the Skokomish Basin as a sediment rich system; increased sediment inputs resulting from land clearing and logjam removal; and reduced hydraulic capabilities resulting from water diversion, river and floodplain constrictions (i.e., levees and bridges) has resulted in too much sediment entering the river channel and has reduced the rivers hydraulic energy to remove the sediment, thereby resulting in channel aggradation. Whether the resulting aggradation is primarily the result of increased sediment input or reduced inability of the river to transport this sediment is unclear. Changes in either sediment inputs or sediment transport capabilities would result in aggradation and thereby influence the other factor through positive feedback. Regardless of the cause, this increased sediment deposition in the river channel increases the frequency of flooding, which negatively influences humans and fish habitat. In addition, increases in flooding frequency results in a host of natural and anthropogenic responses which generally adversely affect juvenile salmon rearing habitat. It is also quite clear that both increased sediment inputs and decreased hydraulic capabilities of the system need to be addressed to reduce flooding in the Skokomish Basin and improve fish habitat.

Table 1provides a summary of the timeline of natural and human induced events that may have influenced the processes leading the hypotheses regarding channel aggradation and habitat in the Skokomish Basin. This table was modified from Skokomish Indian Tribe and WDFW (2010). These events can generally be classified as climate change, land clearing, logjam removal, floodplain constriction, channelization, water withdrawal, and restoration. Each of the disturbances listed have the potential to re-activate paraglacial processes (Ballantyne 2002), which would result in channel instability.

Table 1. Timeline of natural and human induced events that have influenced factors affecting channel stability and fish habitat in the Skokomish Basin. The decade when the event occurred, a summary of the event, the factor influenced (i.e., sediment input, hydrology), and the likely impact of the alteration are listed. Modified from a similar table (Table 4.38) in Skokomish Indian Tribe and WDFW (2010).

Decade	Event	Factor Influenced	Likely Impact
~14,000 BP	Glacial recession in the Skokomish Basin		
<1850	Only minor alterations of watershed by humans exist; homeland of Twana people	None	None
1850	Euro-Americans begin settling lower Skokomish floodplain	Sediment and Large Wood (LWD) input	Minimal reduction in bank stability and LWD input
1860	Land clearing and agriculture development of lower Skokomish floodplain	Sediment and LWD input	Minimal reduction in bank stability and LWD input
1870	Land clearing and agriculture development of lower Skokomish floodplain	Sediment and LWD input	Minimal reduction in bank stability and LWD input
1880	Continued agricultural development of lower Skokomish floodplain	Sediment and LWD input	Increased sediment input due to erosion in the lower river, reduced LWD inputs in the lower river
1880	Beginning of industrial logging in lower valley	Sediment and LWD input	Increased sediment input due to erosion in the lower river, reduced LWD inputs in the lower river
1890	Logging of lower valleys, logjam clearing, log driving; farm development continued	Sediment and LWD input	Impacts sediment and LWD inputs. These events likely resulted in substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion, but logs not allowed to accumulate
1900	Logging of lower valleys	Sediment and LWD input	Likely substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion, but logs being actively removed

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1900	Logjam clearing	Sediment input, sediment transport, channel stability	Likely substantial increases in sediment input due to erosion in the lower river, LWD retention and bank stability reduced, channel evolution from island braided to braided underway
1900	Log driving	Sediment input, sediment transport, channel stability	Likely substantial increases in sediment input due to erosion in the lower river, LWD retention and bank stability reduced, channel evolution from island braided to braided underway
1900	Farm development continued	Sediment input and LWD input	Likely substantial increases in sediment inputs due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion but logs actively removed
1910	Extensive logging of lower North Fork Skokomish (NF) on Pope and Talbot lands	Sediment input and LWD input	Likely substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion but logs actively removed
1910	SR 106 (old State Road 21 and 14)	Hydrology	Reduced floodplain conveyance of flood flows due to hypothesized fill for bridge abutments. This likely reduced sediment transport above the bridge resulting in increased sediment deposition.
1920	Construction of Cushman dams; diversion of NF flow out of the Skokomish Basin at Cushman Dam No. 2 in 1930	Hydrology	Sediment transport capabilities of the North Fork Skokomish and mainstem river are reduced resulting in aggradation in the mainstem Skokomish which further limits sediment transport capabilities
1930	Clearcut logging begins on USFS lands in the SF	Sediment input and LWD input	Likely substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion in the upper South Fork Skokomish

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1930	Extensive diking within river delta for farm development	Hydrology	Reduced floodplain conveyance for floodwaters, resulting in backwatering upstream of dikes likely causing sediment deposition upstream. Reduced sediment storage on delta islands, increased sediment storage on the delta prism
1930	Channel channelization/straightening	Hydrology	Reduced sediment transport capabilities
1930	River channel gravel mining	Sediment inputs	Reduced channel sediments. Likely resulted in local head cutting along with potential bed and bank scour, channel destabilization
1930	HWY 101 bridges built at Purdy Cr., Weaver Cr., north Skokomish overflow channel	Hydrology	Reduced conveyance for floodwaters, backwatering and sediment deposition upstream of the bridge
1930	Evidence of aggradation	Sediment input	Likely increase in bank erosion
1940	Creation of Shelton Cooperative Sustained Yield Unit (CSYU) Agreement on Simpson Timber and USFS lands in the South Fork (SF) Skokomish (1946); logging accelerates	Sediment and LWD input, hydrology	Increased mass wasting in upper reaches, triggering channel instability and sediment inputs in alluvial reaches along South Fork Skokomish and Vance Creek, as well as increased frequency of moderate flood peaks in the South Fork Skokomish
1940	Lower mainstem aggrades 1.5 ft (0.46 m)	Hydrology	Likely increase in bank erosion and decreased channel habitat diversity
1950	Clearcutting in SF anticipating hydroelectric project	Sediment and LWD input, hydrology	Reduced slope and bank stability results in increased mass wasting and sediment inputs, reduced wood recruitment, increased flood peaks in the South Fork Skokomish
1950	Logjam removal in SF and other streams in anticipation of an additional hydroelectric project	Sediment input	Reduced bank stability, release of sediments from protected islands and from upstream accumulations

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1950	Diking in Vance Creek and lower river	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwatering, reduced floodplain and side channel storage of sediment and increased retention of sediments in the channel
1950	Variable aggradation in lower river	Hydrology	Likely increase in bank erosion and decreased channel habitat diversity due to ongoing aggradation
1960	Extensive development of dikes	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwater effects, reduced floodplain and secondary storage of sediment and increased retention of sediments in the channel
1960	Accelerating road building and logging in the CSYU	Sediment and LWD input, hydrology	Increased mass wasting and sediment inputs, triggering channel instability and mobilization of floodplain sediments; reduced wood recruitment due to riparian zone logging, , increased frequency of flood peaks in the South Fork Skokomish
1960	Evidence for increased aggradation in lower river.	Hydrology	Likely increase in bank erosion and reduced channel habitat diversity
1970	Dike and revetment system lengthened and repaired	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwater effect , reduced floodplain and secondary channel storage of sediment and increased retention of sediments in the channel
1970	Road building and logging in CSYU occurring at high rates	Sediment and LWD input, hydrology	Increased mass wasting and sediment inputs, triggering channel instability and mobilization of floodplain sediments; reduced wood recruitment due to riparian zone logging; increased frequency of flood peaks in the South Fork Skokomish

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1970	HWY 101 bridge at Weaver Creek re-built	Hydrology	Unknown. It's unclear if this resulted in increased or decreased conveyance (i.e., additional, wider bridge, or new additional smaller bridge?)
1980	Rapid logging of CSYU continues to early 1980s, then declines later in the decade	Sediment and LWD input, hydrology	Increased mass wasting and sediment inputs, triggering channel instability and mobilization of floodplain sediments; reduced wood recruitment due to riparian zone logging; increased frequency of flood peaks in the South Fork Skokomish
1980	Dike structural repairs and additions to various structures made	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwater effects; reduced floodplain and secondary channel storage of sediment and increased retention of sediments in the channel
1980	Timber-Fish-and-Wildlife (TFW) agreement signed	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
1980	3.2 ft (0.98 m) of aggradation since 1969 measured at HWY 101	Hydrology	Likely increase in bank erosion and reduced channel habitat diversity
1980	HWY 101 bridges over the Skokomish and SR 106 bridge rebuilt	Hydrology	Unknown. It's unclear if the bridge is wider and if additional floodplain filling occurred.
1990	Logging on USFS lands in SF reduced significantly then essentially stopped (mid 1990's)	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
1990	Watershed restoration activities begin on USFS lands.	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
1990	Extensive logging of second growth on Simpson lands	Sediment input and Hydrology	Impacts to sediment inputs and hydrology likely reduced compared to historic impacts

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1990	Forest and Fish Law enacted (1999)	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
2000	Logging of second growth timber on Simpson lands	Sediment input and Hydrology	Impacts to sediment inputs and hydrology likely reduced compared to historic impacts
2000	Continued evidence for aggradation	Hydrology	Likely increase in bank erosion and reduced channel habitat diversity
2000	Restoration work in upper SF to close roads	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
2000	GI initiated	No effect	No effect
2000	Cushman Settlement reached (2009)	Hydrology	Minimal impact to this point
2010	Cushman Settlement agreement implemented	Hydrology	Improved sediment transport capabilities in the North Fork Skokomish below the two dams and in the lower mainstem
2010	Floodplain restoration in SF by USFS	Sediment input	Increased bank stability and floodplain sediment storage, and potential for improved sediment transport
2010	Dikes removed and borrow ditches filled on Nalley Island	Hydrology	Increased conveyance of floodwater, reduced backwater effect, increased sediment storage capability on delta islands and reduced sediment storage in the channel
2010	Purdy Creek Bridge improved (2009)	Hydrology	Increased conveyance of floodwater, reduced backwater effect, improved local sediment transport
2010	Air temperatures increased by 0.8^{o}C (1.5^{o}F) since 1920 in the Pacific Northwest	Sediment input and Hydrology	Likely increase in peak flow magnitudes and shift from spring peak flows to winter peak flows, reduced summer baseflows; potential increase in mass wasting due to wetter winters.

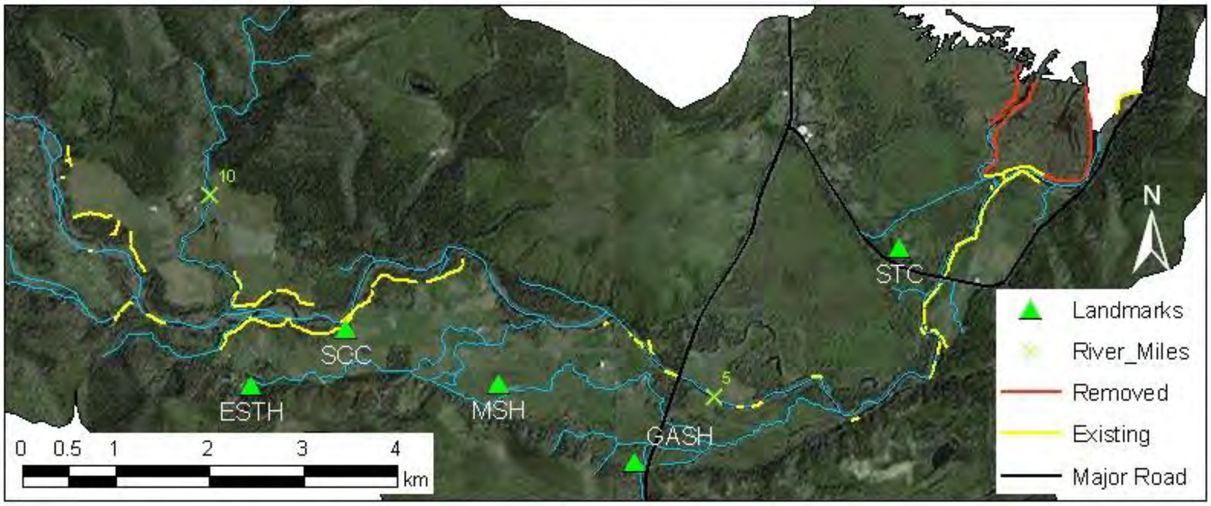

Figure 3. Locations of current levees and levees/dikes that have been removed in the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH).

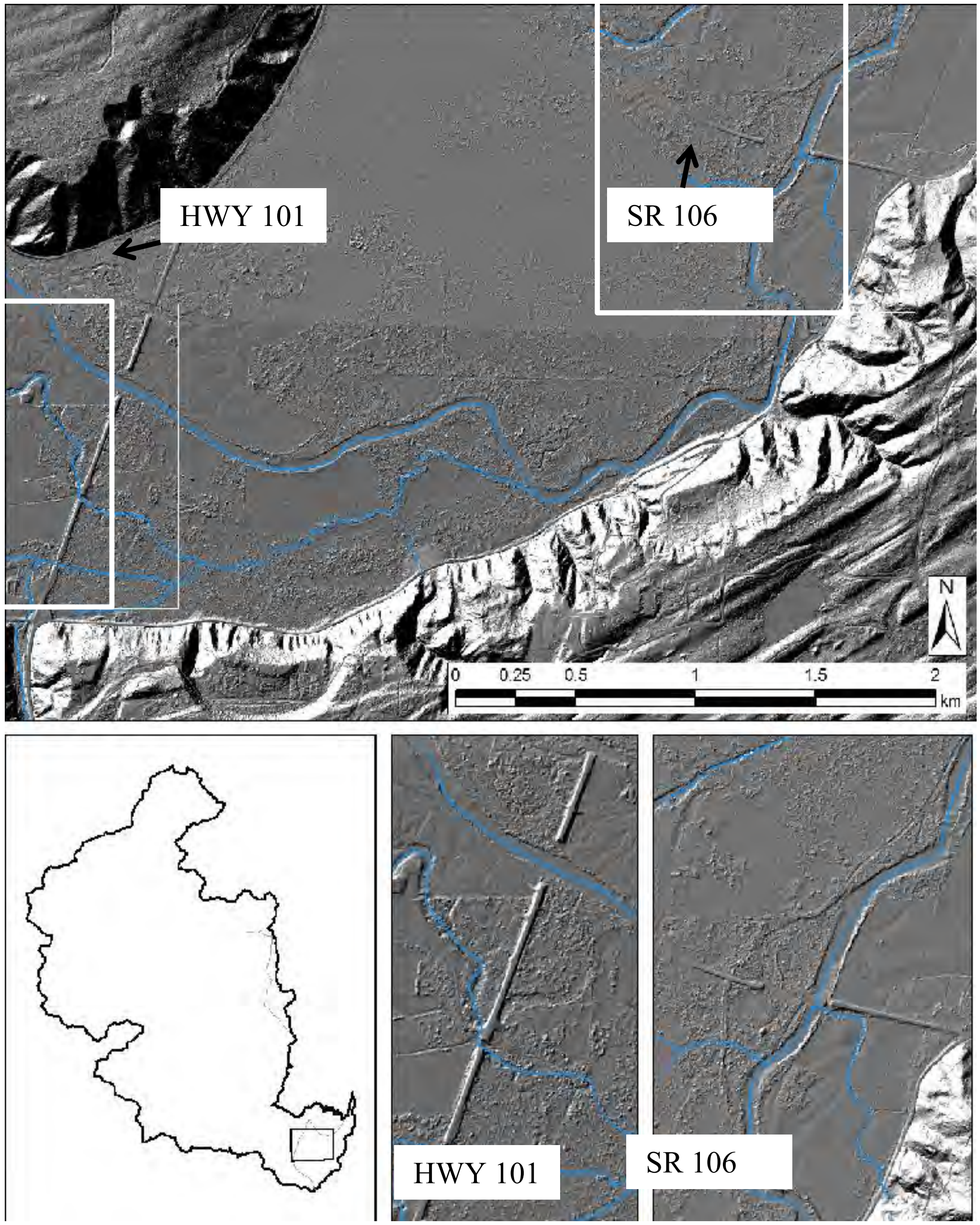

Figure 4. LiDAR images depicting the floodplain fill that has been used to provide approaches for four HWY 101 bridges and one SR 106 bridge in the lower Skokomish Basin.

Current Habitat Conditions for All Species: Stream Habitat

The natural and anthropogenic processes described above combine to form the current fish habitat existing in the Skokomish Basin. The focus of the current study is on habitat for juvenile anadromous salmonids and the following section describes the current state of juvenile salmonid habitat. However, reference will also be made to impacts on adult salmonids as well, since the distribution and abundance of adults can influence the distribution and abundance of juveniles. Information from data collected as part of the Skokomish GI, as well as past habitat data collections, are summarized in this section.

Sample Sites

New data collected for the Skokomish GI was conducted in numerous study reaches and off-channel ponds throughout the Skokomish Basin (see Appendix A for details). Study reaches within the Skokomish Basin were stratified by channel confinement and stream gradient, for a total of 8 strata (Table 2). We then sampled a total of 21 study reaches during the summer of 2008 and 24 study reaches during the winter of 2009 (Figure 5). Of the reaches sampled during the summer, 16 were randomly selected and 5 were selected by the USACE. Of the winter sample reaches, 19 sites were randomly selected and 5 were selected by the USACE (See Appendix B for details of habitat sampling methods). A total of 22,618 m in stream length was sampled during the summer, 15,100 m from randomly selected reaches and 7,518 m from the USACE reaches. A total of 22,963 m was sampled during the winter, with 17,808 m from randomly selected reaches and 5,154 m from the USACE reaches.

Two of the USACE selected reaches, the Old North Fork Skokomish, South Fork Skokomish confluence reach (ONFSF) and the New North Fork Skokomish, South Fork Skokomish confluence (NNFSF) reaches, intersected one of the randomly selected reaches (2-27) and, therefore were shortened so that the reaches did not overlap. This resulted in these two USACE reaches being shorter than they would have been otherwise based on their bankfull width. In addition, the reaches 2-30 and 2-38, which were only sampled during the summer, also overlapped, and were shortened to prevent the overlap resulting in these reaches being shorter than they would have been otherwise based on their bankfull width. The downstream end of the snorkeled reach for 2-30 was at the same point as the upstream end of the snorkeled reach for 2-38.

General habitat availability for anadromous salmonids was determined by reviewing segment reach length data from the Northwest Indian Fisheries Commission (NWIFC) Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) (NWIFC 2004), barrier information from WDFW (Williams et al. 1975), and discussions with fisheries biologists familiar with the system (L. Ogg, USFS – retired; Marty Ereth, Skokomish Indian Tribe – now with Pierce County; personal communication). Based on this assessment, we determined that there is approximately 132 km (82 mi) of anadromous fish habitat in the Skokomish Basin (Figure 6). There is slightly more mainstem (55.4%) habitat than tributary (44.6%) habitat within the anadromous zone of the Skokomish Basin. A majority of this habitat is low gradient (<2%) unconfined channels (floodplain width ≥ 4 channel widths), which makes up nearly 80% of the anadromous zone within the Skokomish Basin (Table 2; Figure 5). Very little of the anadromous habitat (<8%) has a gradient greater than 4%. In addition, there are about 4.1 km of the mainstem and 1.6 km of side channel classified as being in the stream estuary ecotone (Figure 7). The classification of the stream-estuary ecotone was based on observations of tidal influence during our sampling (observed at site 2.23 but not site 2.28 – see Figure 5) and the present of estuarine dependent species such as flounder.

Table 2. Stream segment strata used to stratify tributary and mainstem river habitat in the Skokomish Basin based on stream gradient and channel confinement.

Strata	Stream Gradient	Channel Confinement	Total Stream Length (km)	Percent of Total Length	Number of Sites Sampled
S1U	<1%	Unconfined	79.40	60.1	20
S1C	<1%	Confined	16.39	12.4	5
S1-2U	1-2%	Unconfined	13.11	9.9	5
S2-4U	2-4%	Unconfined	7.60	5.8	2
S2-4C	2-4%	Confined	7.95	5.4	2
S4-8C	4-8%	Confined	5.71	4.3	2
S8C	>8%	Confined	1.97	1.5	2

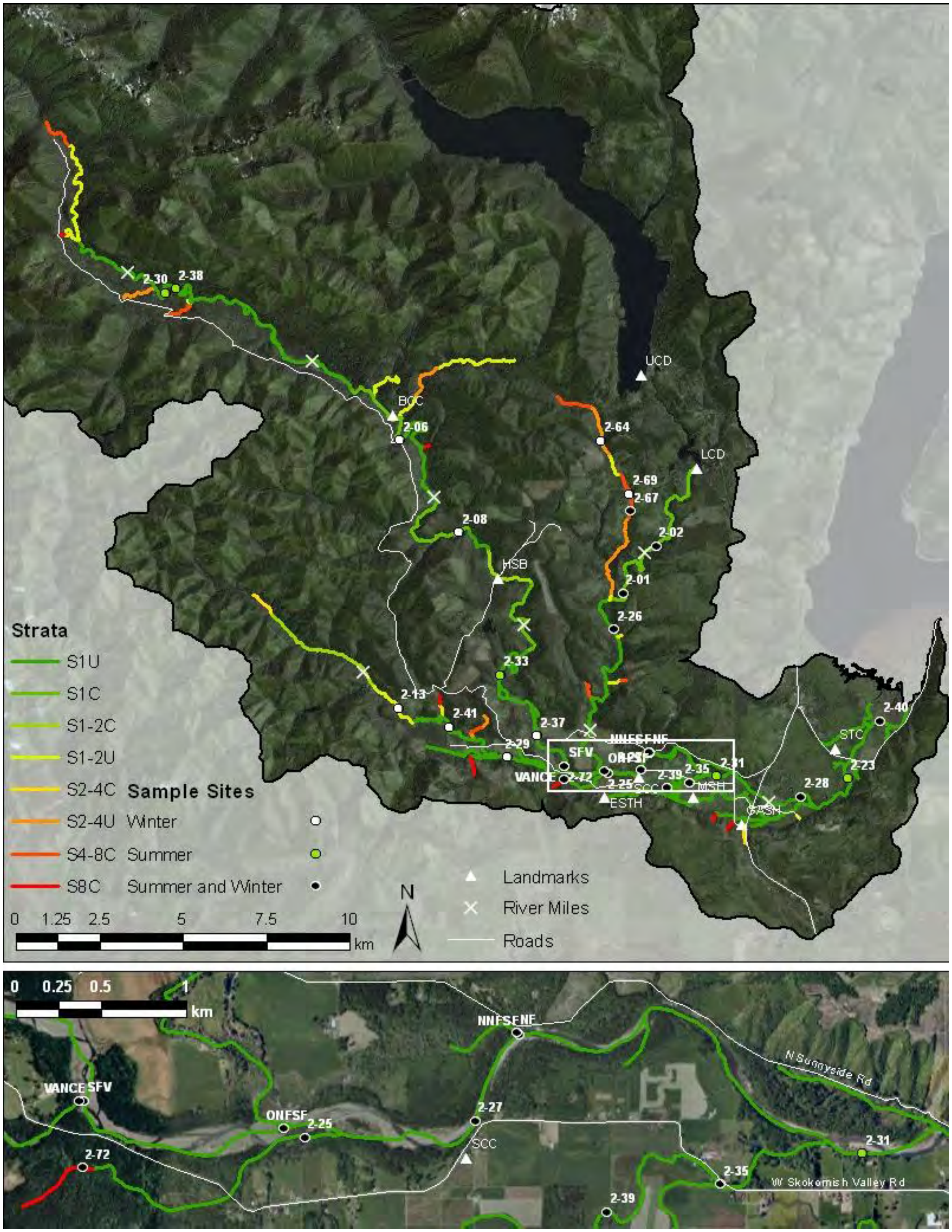

Figure 5. Locations where habitat was measured during the summer and winter of 2008 and 2009, respectively. Strata codes represent gradient at <1% (1), 1-2% (1-2), 2-4% (2-4), 4-8% (4-8) and >8% (8), while confinement codes are confined (C) and unconfined (U). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

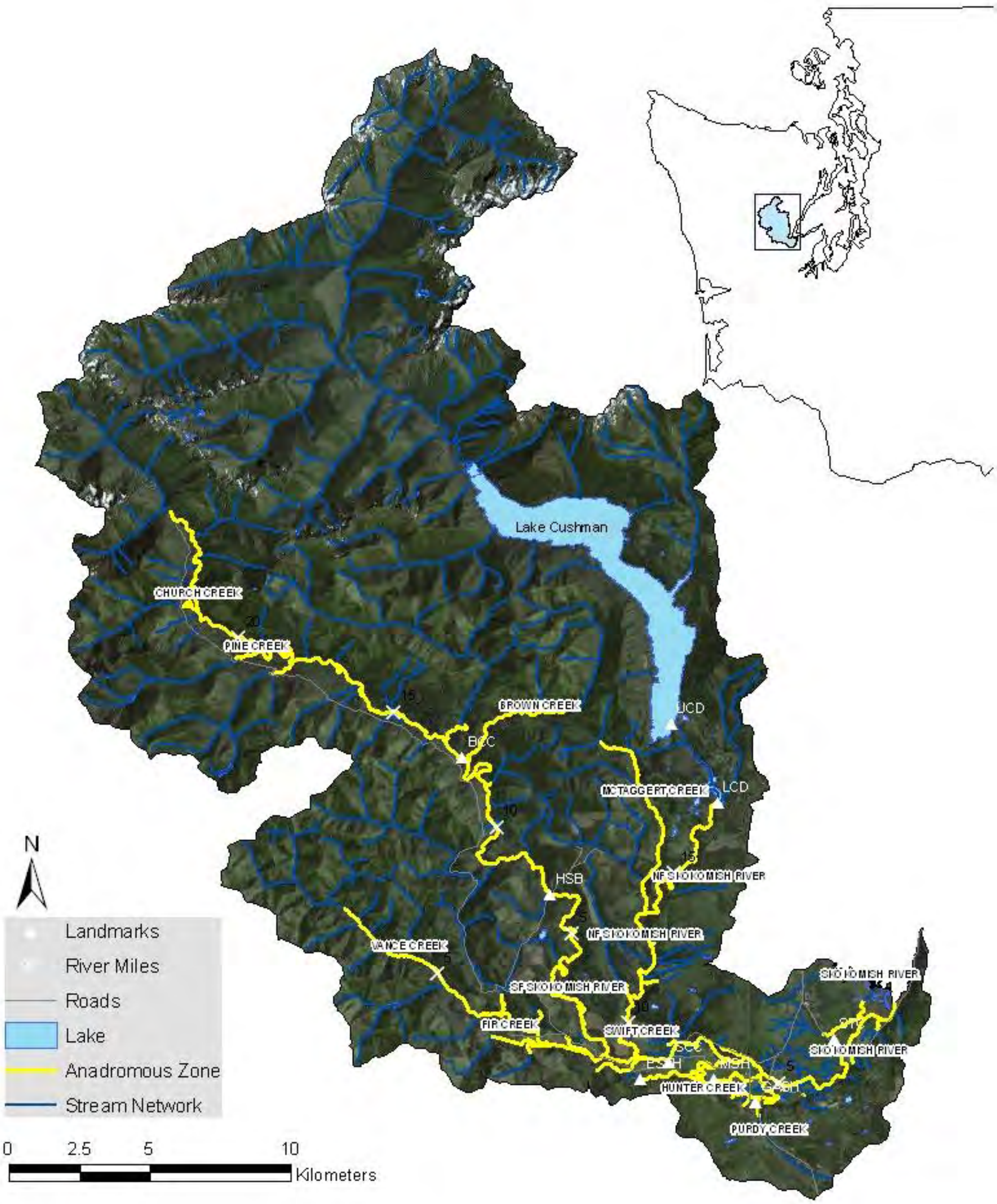

Figure 6. Anadromous fish zone within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

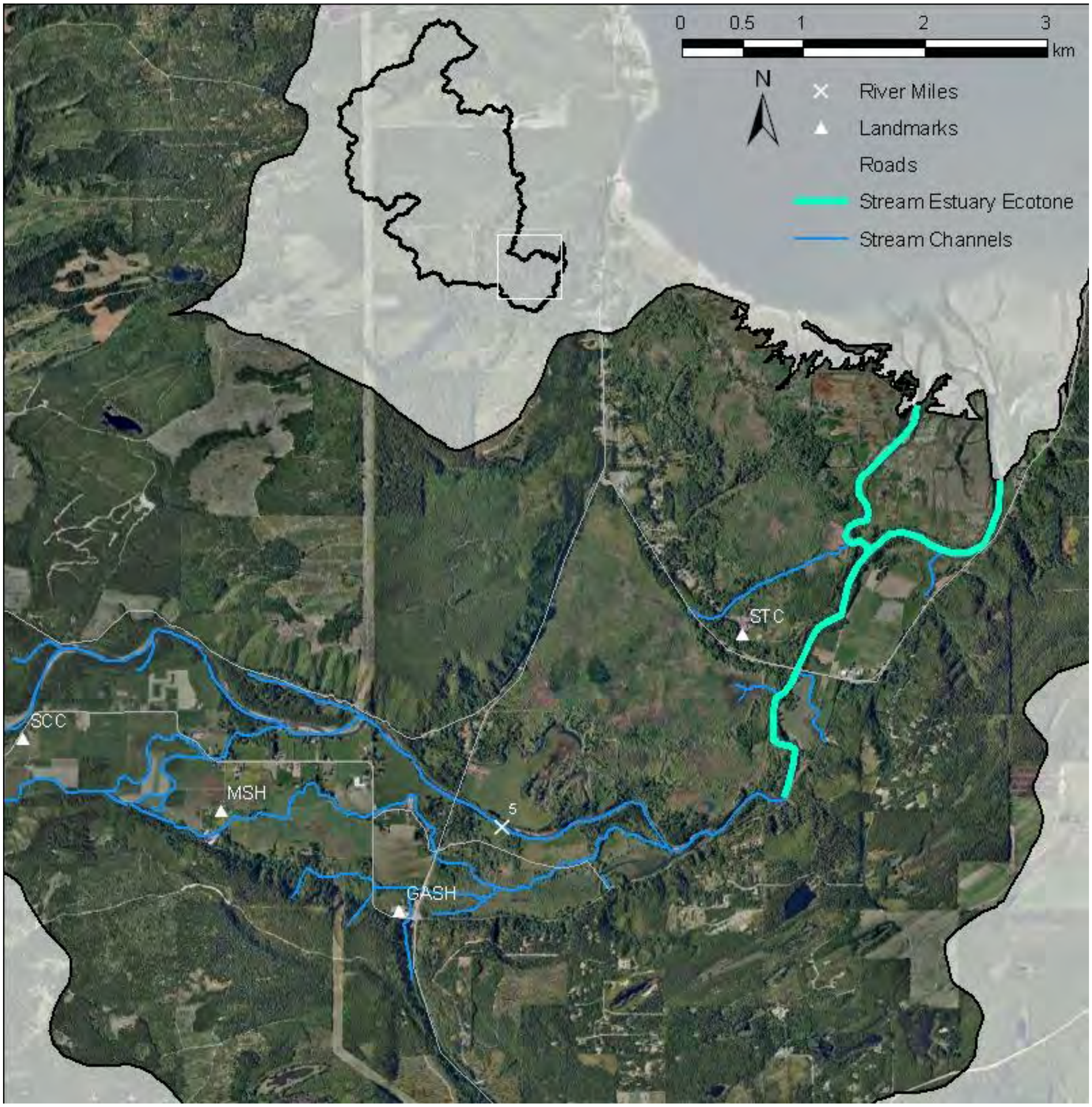

Figure 7. Extent of the stream estuary ecotone in the lower Skokomish River. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC).

The fact that a majority of the available habitat is in the mainstem rather than tributaries is somewhat unique and may somewhat limit salmon productivity in the system. In general, a significant proportion of habitat available to juvenile salmonids in river basins is usually located in tributaries (i.e., ~33% in the Skagit Basin (Beechie et al. 1994), and tributaries are thought to produce significant proportions of juvenile salmonids, particularly coho salmon (i.e., Beechie et al. 1994). However, this limitation may be overcome by the fact that so much of the Skokomish Basin is made up of low gradient unconfined reaches, which are generally the most productive salmon habitats (Burnett et al. 2007). Unfortunately, much of this habitat in the Skokomish Basin is also the most degraded.

Salmonid Habitat Degradation

Threats to juvenile salmon habitat in the Skokomish watershed are the result of the cascading effects of the disturbances to physical process occurring throughout the watershed as described above. The resulting sediment aggradation and general impact to the general processes has four main effects on juvenile fish habitat including reduced 1) habitat availability, 2) habitat connectivity, 3) habitat stability, and 4) habitat quality. Each of these effects and the factors responsible for them are discussed below.

Reduced Habitat Availability

Habitat availability in the Skokomish Basin has been reduced as a result of dams, loss of side channel habitat, and channelization. Construction of the two Cushman dams blocked migration to approximately 26 km (16 mi) of mainstem habitat, based on assessment of stream segment lengths in the Seg-16a Geographic Information System (GIS) layer provide by SSHIAP (NWIFC 2004). This assumes that prior to the construction of the dams; salmon were able to ascend to RKM 53 (RVM 33), as asserted by the Skokomish Indian Tribe and WDFW (2010). We estimated that an additional 13 km (8 mi) of tributary habitat would have been available, based on this same data source. We assumed that migratory barriers were present in tributary reaches with more than a 4% gradient; a relatively conservative measure. A majority of the isolated tributary habitat was from Big Creek and Dow Creek. However, it‟s unclear what the gradient of these streams was, as they currently lie below Lake Cushman, which is not depicted on our GIS layers. Based on this assessment, the Cushman projects block access to approximately 25% of the mainstem habitat and 18% of the tributary habitat available to anadromous salmon in the Skokomish Basin. In addition, the Cushman projects block access to approximately 320 ha (965 acre) of lake habitat that would have been provided by the pre-dam Lake Cushman. This loss of habitat may be even more important than the actual amount of habitat loss implies, since the area inundated and blocked by Cushman Dam has been stated to potentially have been some of the most productive salmon habitat in the Skokomish Basin (Skokomish Indian Tribe and WDFW 2010). The impact of the two Cushman dams will be partially mitigated through the new FERC licensing agreement that requires upstream passage of adults and downstream passage of juveniles through these projects.

The loss of vegetated islands and their associated side channels, as a result of clearing riparian zone old-growth forests and removal of logjams, represents a significant loss of habitat for salmonids. Based on the assessment above, several locations within the Skokomish Basin historically had well established vegetated islands within the valley floodplain, which were surrounded and intersected by numerous river channels (see Figure 2). Although some of these channels were likely relic channels, which may have contained water only during high flows, many likely had flowing water during non-base flow periods (Skokomish Indian Tribe and WDFW 2010). Currently, there are very few vegetated islands in the valleys of the Skokomish Basin. We examined aerial photographs from 2007 at a 1:2,500 scale using GIS to determine the number of side channels in the system. For the purpose of this exercise we defined main channel, side channel, and braided channel habitat as follows:

- Main channel: Primary channel containing a majority of the stream discharge

- Braided channel: Secondary channel separated from the main channel by a grave bar lacking vegetation or having only sparse and young (<2 yrs) vegetation, such as immature trees and/or brush.
- Side channel: Secondary channel separated from the main channel by an island with mature vegetation.

Examination of aerial photos show eight vegetated islands in the lower Skokomish Basin below the canyons, seven in the lower mainstem, and one in lower Vance Creek. Total side channel stream length was estimated at 4.6 km in the lower mainstem and 360 m in lower Vance Creek. However, more than a third of this total was associated with the distributary channel around Nalley Island, located in the Skokomish estuary. Although it‟s possible we missed some side channels during this analysis, it is still quite likely that channel diversity has been reduced throughout the Skokomish Basin, especially in the upper and lower South Fork Skokomish. For example, the Skokomish Indian Tribe and WDFW (2010) state that an island described by the GLO surveyor Ross Shoecraft, which was located just downstream of the South Fork Skokomish canyon was approximately 1 mile (1.6 km) long and a half mile wide. Thus, the side channel around this lost island would have represented a third of current estimated side channel habitat. It‟s likely that this channel was significantly longer than 1.6 km (the length of the island) and that several other side channels may have traversed the island as well.

In addition to assessing aerial photos for channel complexity, we obtained data on all channel types within our study reaches. We observed side channels in only 6 of our study reaches during both summer and winter surveys (Table 3; Table 4; Figure 8). Side channel habitat, when present, also generally made up less than 20% of the total channel length surveyed at the site. This limited availability of side channels occurred despite the fact that we surveyed a nearly continuous stretch of stream from just above the old North Fork Skokomish confluence to just above HWY 101; an area that historically likely had numerous side channels. The apparent reduction in side channel habitat represents a significant loss of habitat for salmon. Adult salmon are known to spawn in side channels (Eiler et al. 1992; Hiss 1995). In addition, loss of channel diversity reduces available habitat for juvenile salmonids. Juvenile salmon use side channel habitat extensively (Murphy et al. 1989; Hirschi and Reed 1998; Jeanes and Hilgert 2000; Peters, FWS, unpublished data). Juvenile Chinook salmon densities in reaches of the Cedar River were positively related to the amount of edge habitat and the proportion of side channel habitat within the reach (R. Peters, FWS, unpublished data). This is likely due to the fact that newly emerged juveniles are dependent on edge habitat associated with the river bank and velocities in the mainstem may be too fast (Rosenfeld et al. 2008). Juvenile Chinook salmon in the Cedar River were rarely more than a couple of meters away from the river edge (R. Peters, FWS, unpublished data). Thus, the loss of side channel habitat represents a significant loss of edge habitat for juvenile salmonids.

Although the number of side channels in the Skokomish Basin has been reduced, the number of braided channels has likely increased (Table 3 and Table 4). Our GIS assessment counted eight braided channels totaling 1.6 km in the lower mainstem, 13 braided channels totaling 2.4 km in the lower South Fork Skokomish, 15 braided channels totaling 1.2 km in lower Vance Creek, and 35 braided channels totaling 4.6 km in the upper South Fork Skokomish. We observed braided channels in all but 3 of the summer study reaches and 6 of the winter study reaches. Braided channels were three times and four times more abundant than side channels during summer and winter, respectively. In addition, braided channels made up a majority of the habitat within one reach in the summer and winter surveys. Thus, it appears that there may have been a transition from side channel dominated lateral habitats to braided channel lateral habitats throughout much of the Skokomish Basin. Although braided channels also provide edge habitat, the quality of this edge habitat for juvenile salmon is likely reduced relative to side channels. Juvenile Chinook salmon densities in the Cedar River, Washington were positively related to overhead cover provided by adjacent riparian vegetation (R. Peters, FWS, unpublished data), likely due to the added protection from predators (Helfman 1981). This may explain why juvenile Chinook salmon in the Cedar River showed a marked preference for side channels relative to the mainstem river and associated braided channel (R. Peters, FWS, unpublished data; Murphy et al. 1989).

Table 3. Percent (based on length) of the habitat in reaches surveyed during this study composed of braided channels (BC), backwaters (BW), main channel (MC), overflow channel (OC), and side channels (SC), along with the ratio of total channel length to main channel length per reach (Tot:MC Ratio) in the different study reaches during the summer of 2008. Site names of reaches correspond to those in Figure 5. The range, mean, and Standard Error (SE) conditions observed over all the sites are also provided.

	Bankfull	Channel Type					Tot:MC
Site Name	Width (m)	BC	BW	MC	OC	SC	Ratio
2-01	15.7	10.2	11.3	78.6	0	0	1.3
2-02	17.8	12.2	9.1	78.6	0	0	1.3
2-23	32.8	1.8	7.5	90.7	0	0	1.1
2-25	11.4	10.0	0	79.5	0	10.5	1.3
2-26	14.6	9.2	4.1	79.5	0	7.2	1.3
2-27	29.7	16.8	4.1	67.8	0	11.4	1.5
2-28	33.6	1.7	2.7	95.6	0	0	1.0
2-30	40.8	7.0	7.9	85.1	0	0	1.2
2-31	43.3	4.4	3.6	72.8	0	19.1	1.4
2-33	56.5	17.5	11.8	70.7	0	0	1.4
2-35	9.9	0	0	100.0	0	0	1.0
2-38	49.0	61.1	3.3	35.2	0.4	0	2.8
2-39	12.3	7.4	0	92.6	0	0	1.1
2-40	41.7	0	0	93.2	0	6.8	1.1
2-67	8.2	16.2	0.5	83.2	0	0	1.2
2-72	5.3	9.2	5.9	84.9	0	0	1.2
NF	17.1	0	0	100.0	0	0	1.0
NNFSF	53.0	13.9	5.5	80.7	0	0	1.2
ONFSF	70.0	17.3	4.0	48.5	0	30.3	2.1
SFV	42.6	32.4	10.9	56.7	0	0	1.8
Vance	24.7	22.7	0	77.3	0	0	1.3
Mean	30.0	12.9	4.4	78.6	0.0	4.1	1.4
SE	4.0	3.0	0.9	3.6	0.0	1.7	0.1
Minimum	5.3	0.0	0.0	35.2	0.0	0.0	1.0
Maximum	70.0	61.1	11.8	100.0	0.4	30.3	2.8

Table 4. Percent (based on length) of the habitat in reaches surveyed during this study composed of braided channels (BC), backwaters (BW), main channel (MC), overflow channel (OC), and side channels (SC), along with the ratio of total channel length to main channel length per reach (Tot:MC Ratio) during the winter of 2009. Site names of reaches correspond to those in Figure 5. The range, mean, and Standard Error (SE) conditions observed over all the sites are also provided.

	Bankfull	Channel Type					Tot:MC
Site Name	width (m)	BC	BW	MC	OC	SC	Ratio
2-01	15.7	3.2	8.5	88.3	0	0	1.1
2-02	18.0	9.3	15.0	75.7	0	0	1.3
2-06	35.0	27.1	0	72.9	0	0	1.4
2-08	30.0	17.3	3.7	79.0	0	0	1.3
2-13	17.0	0	0	100.0	0	0	1.0
2-25	14.3	0	6.3	75.1	0	18.5	1.3
2-26	14.6	2.7	21.3	63.6	0	12.4	1.6
2-27	43.0	9.4	12.2	76.3	0	2.2	1.3
2-28	35.0	0.8	9.2	90.1	0	0	1.1
2-29	31.0	18.5	9.8	68.4	0	3.3	1.5
2-35	12.3	0	0	100.0	0	0	1.0
2-37	40.0	15.0	22.0	63.0	0	0	1.6
2-39	9.9	5.4	0	94.6	0	0	1.1
2-40	42.0	15.6	0	84.4	0	0	1.2
2-41	30.0	55.8	5.0	39.2	0	0	2.6
2-64	3.0	10.2	4.5	85.3	0	0	1.2
2-67	12.3	15.0	0	85.0	0	0	1.2
2-69	5.0	19.7	0	80.3	0	0	1.2
2-72	5.0	24.3	17.9	57.7	0	0	1.7
NF	15.0	0	0	100.0	0	0	1.0
NNFSF	53.0	0	1.7	98.3	0	0	1.0
ONFSF	70.0	29.7	9.0	39.0	0	22.3	2.6
Vance	30.0	0	5.9	84.1	0	10.0	1.2
Mean	25.3	12.1	6.6	78.3	0	3.0	1.4
SE	3.5	2.8	1.5	3.6	0	1.3	0.1
Minimum	3.0	0	0	39.0	0	0	1.0
Maximum	70.0	55.8	22.0	100.0	0	22.3	2.6

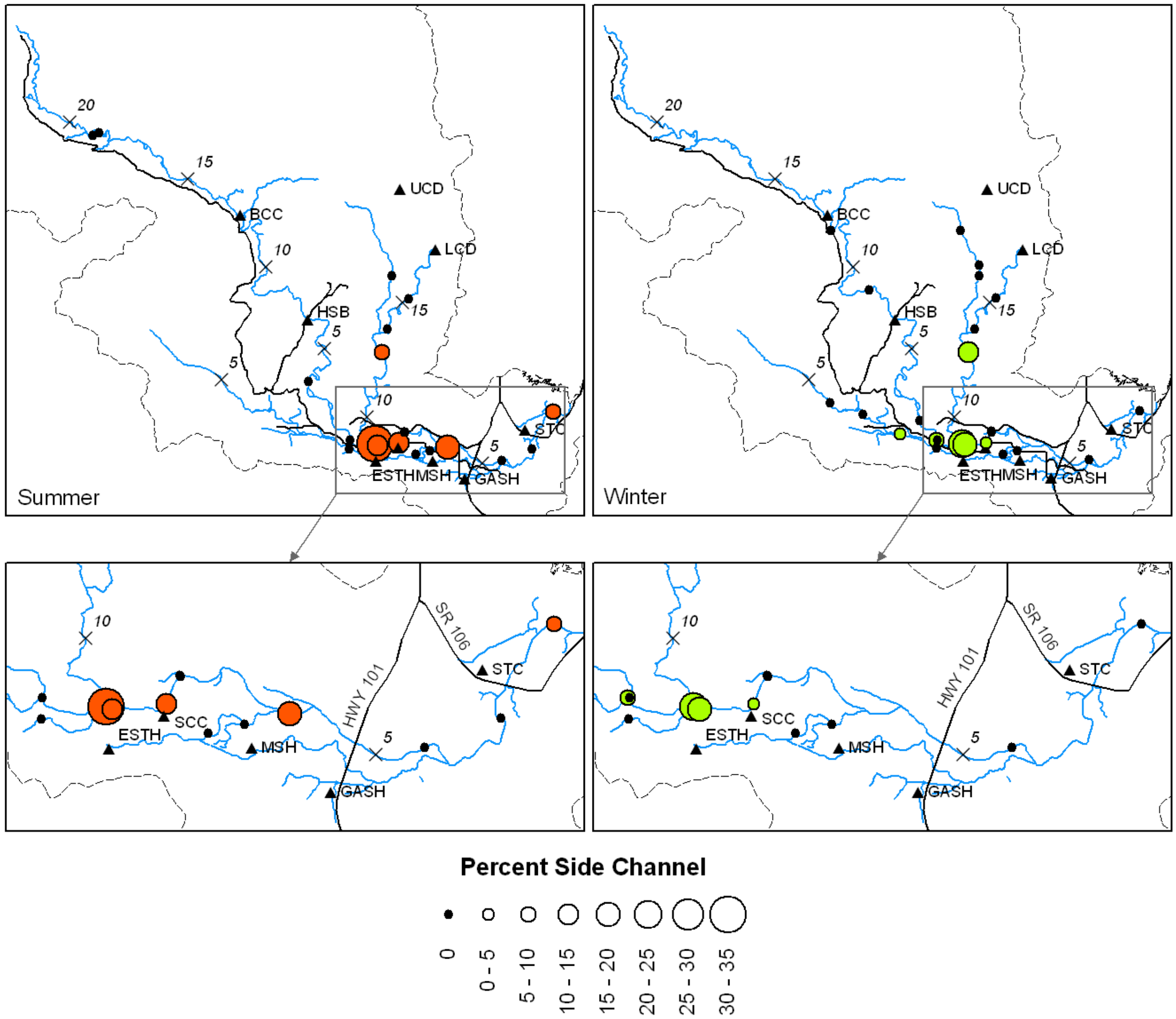

Figure 8. Percent (based on length) of habitats in the study reaches sampled during this study composed of side channels during the summer of 2008 and the winter of 2009 in the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

In addition to the creation of dams and the loss of side channels, channel straightening has caused a loss in stream habitat within Skokomish Basin. Although it is difficult to quantify the impacts of this activity, it is likely that overall loss is substantial. For example, Bountry et al. (2009) noted channel straightening below the HWY 101 Bridge (Figure 9). This single event reduced the channel from approximately 2.4 km (1.49 mi) to 1.4 km (0.86 mi), a 1 km (42%) reduction in total channel length in this area. Bountry et al. (2009) also state that channelization may have occurred in the vicinity of the Church Dike (near the Skokomish Community Church (SCC) on the maps), which is located downstream of the old North Fork Skokomish confluence.

Channelization also likely eliminated the rivers connection to side channel habitat, further reducing overall habitat availability as discussed previously.

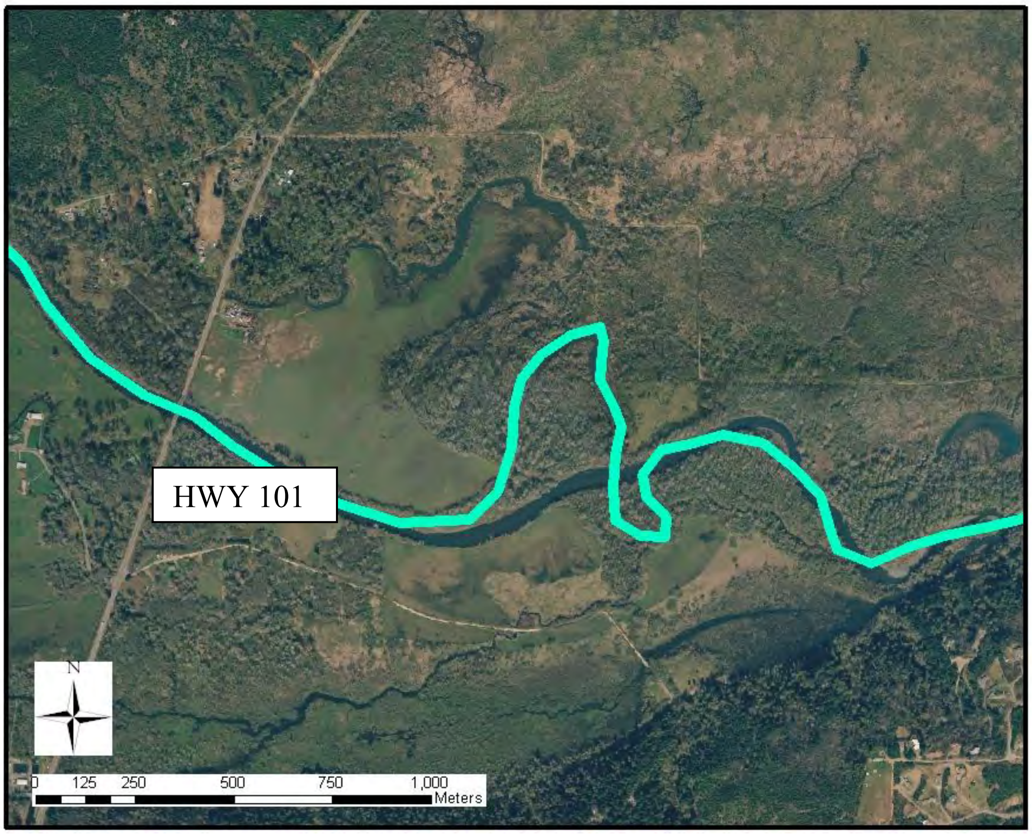

Figure 9. An example of channelization found within the Skokomish Basin. The 1938 channel (aqua line) is plotted over the 2007 channel shown in the base aerial photo of the river directly below Highway 101. This channelization represents a 42% reduction in channel length at this location (2.4 km). Figure is modified from Bountry et al. (2009).

Reduced Habitat Connectivity

Reduced habitat connectivity can result from numerous land management activities including dam construction, flow diversion, levee construction, road fill associated with bridge approaches, channelization, sediment aggradation, reduced base flow discharges, and road construction associated with logging activities. Cushman Dam completely blocks anadromous fish from the upper Skokomish Basin and was therefore discussed with habitat loss above. However, flow diversion from Cushman directly to Hood Canal can also impact habitat connectivity by reducing low flow discharge and isolating habitat. Much of the North Fork Skokomish was isolated from the rest of the river due to low flows resulting from historic water diversions from Lake Cushman (Skokomish Indian Tribe and WDFW 2010). However, the new

FERC agreement will provide additional flow during the low flow period, thereby improving habitat connectivity.

In an effort to control frequent high flow and overbank events, residents of the valley, along with various federal and state agencies, have historically undertaken an aggressive diking, channelization, and bank stabilization campaign (Canning et al. 1988). While this discontinuous network of dikes and associated structures may have mitigated low-level and site-specific flooding, they are of little use during large magnitude flood events (Rigby 2000). Diking has occurred quite extensively in the lower watershed, from approximately Vance Creek downstream. Some diking has also occurred on the north bank of the South Fork Skokomish, directly upstream of Vance creek. Levee construction, road fill associated with bridge approaches, and channelization can impact habitat connectivity by disconnecting the main channel from its floodplain and side channel habitats. In addition, adult and juvenile salmonids pushed into the floodplain during flood events that overtop the levees can become stranded there as flows recede, especially in areas where levees prevent floodwaters from moving from the floodplain back into the main channel.

Off-channel habitat is crucial to overwintering juveniles such as coho and steelhead, which use them to escape high winter flows. Off-channel habitats are also used as predator refugia by juvenile salmonids, and adult salmon utilize off channel habitat for spawning. The patchwork mosaic of diking can make it more difficult or impossible for juveniles that find their way onto the floodplain to return to the river proper when flows recede, particularly when the water is cold, when overbank flows are more likely (Bradford 1997). Sediment aggradation in this system has led to increase in overbank flow, even without an increase in overall discharge (Stover and Montgomery 2001). This has resulted in flooding occurring at successively reduced discharges and progressive increases in this potential impact.

Channel aggradation also impacts summer low flows by causing the complete dewatering of the lower portions of Vance Creek and the South Fork Skokomish (Skokomish Indian Tribe and WDFW 2010). This creates a complete barrier to upstream passage by adults and subsequently impacts the distribution of juveniles. For example, the barrier reduces the ability of juvenile salmon to redistribute within the system prior to winter freshets. In addition, the dewatering significantly reduces the amount of available rearing habitat and results in the stranding and potential mortality of juveniles. The dry channel conditions in the lower South Fork Skokomish result in approximately 12 km (7.5 mi) of the South Fork Skokomish being inaccessible to adult Chinook salmon.

Loss of floodplain connectivity appears to be worse in the lower watershed than the upper watershed. According to Correa (2003), habitat in the mainstem Skokomish, the South Fork Skokomish from RKM 14.5 to RKM 19.3 (RVM 9.0 to RVM 12.0) and Hunter, Weaver, and Vance Creeks are the most degraded, in terms of floodplain connectivity (Figure 10; detailed table in Appendix B). Although there are numerous data gaps in the data set used by Correa (2003), the fact that this is the portion of the watershed that has undergone the most anthropogenic influences suggests these results are likely representative of the Skokomish Basin as a whole.

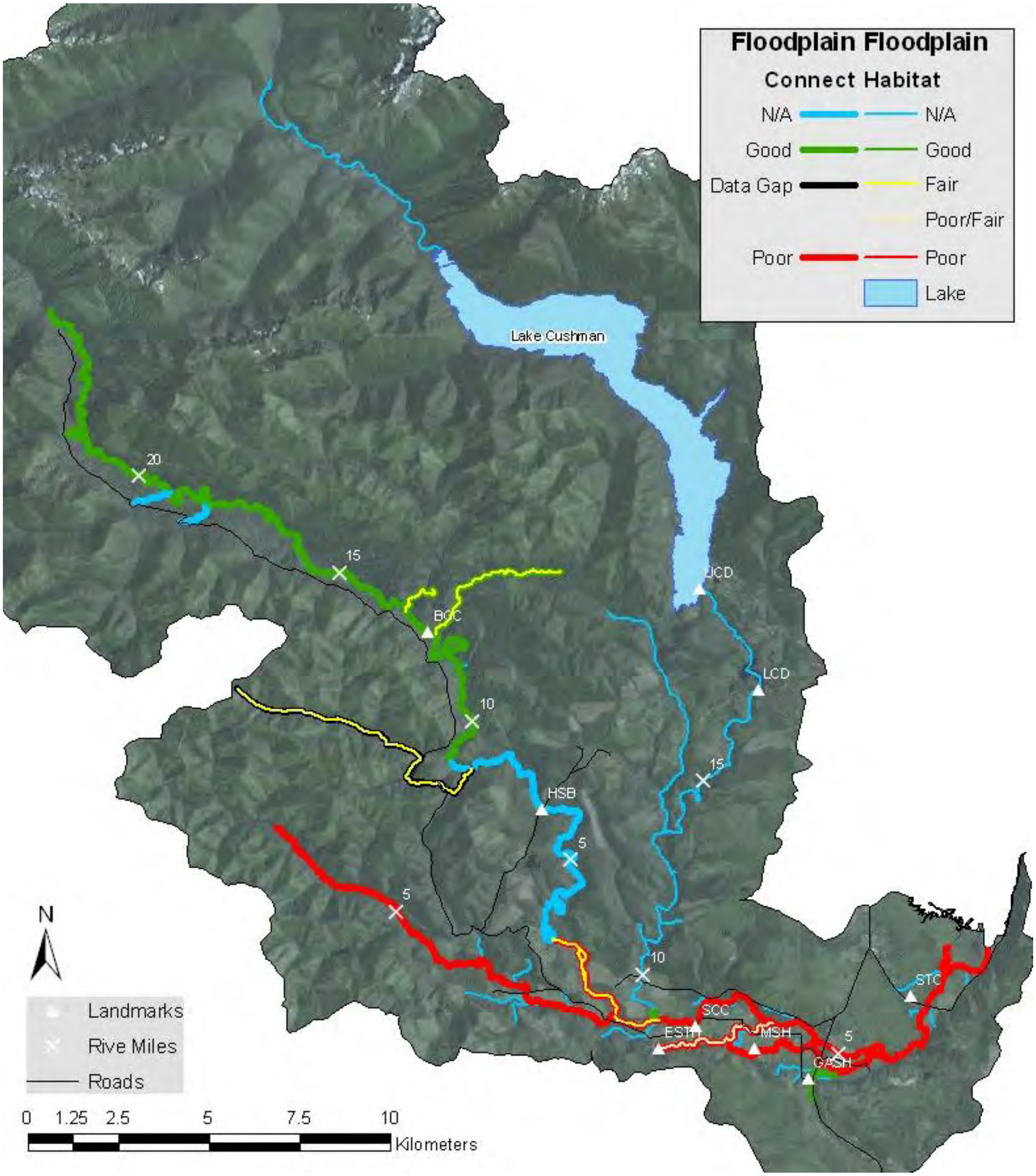

Figure 10. Floodplain connectivity ratings (bold lines) and floodplain habitat ratings (fine lines) for areas within the Skokomish Basin (based on Correa 2003), including areas where data gaps exist. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Reduced Channel Stability

Channel aggradation within the Skokomish Basin has been reported to total approximately 1.8 m in the Skokomish River from 1939 to 1997 (Stover and Montgomery 2001). The combination of Simons and Associates (1993 and 1995) and England (2007) data yields a similar estimate of total aggradation of 1.4 m. This channel aggradation causes several negative effects on juvenile salmon survival. The dramatic increase in sediment results in a largely unstable stream bed, where localized scour and fill can occur at lower discharges than those found in the original non-aggrading stream bed. This localized scour can physically removing redds during the process (Tripp and Poulin 1986; Schuett-Hames et al. 2000). In addition, localized fill can also bury salmon redds that would have otherwise escaped the effects of scour (Gottesfeld et al. 2004). In addition, fine sediment deposited in redds that weren"t scoured can suffocate salmon redds by restricting water flow past developing embryos (Devries 2000).

Aggradation can also result in unstable channel conditions at larger spatial scales. This results from the channels inability to transport the excess sediment, resulting in frequent avulsions through unstable gravel bars or islands. This also result in the stranding of juvenile salmon as portions of the active channel become isolated from the mainstem as water levels recede (Sommer et al. 2005).

A dramatic example of the effects of aggradation on channel stability and migration were illustrated by the changes that occurred at the confluence of the North and South Fork Skokomish during the 2004 water year. The North Fork Skokomish became blocked by sediment and LWD from the South Fork Skokomish. The North Fork Skokomish eventually breached a levee, entered an abandoned stream channel, and now enters the mainstem approximately 2 km downstream from its original confluence (Geo Engineers 2006). This event resulted in the dewatering of redds and isolation of juveniles in the reach downstream of the avulsion. Ironically, this event increased the available habitat for salmonids by lengthening the North Fork Skokomish stream reach.

Reduced Habitat Quality

In addition to habitat loss, reduced connectivity, and reduced habitat stability, aggradation and the factors that have influenced aggradation have negatively influenced the quality of the habitat that remains. Aggradation can cause five main disturbances that affect juvenile salmon habitat, including 1) reduced riparian cover, 2) decreased summer instream flows, 3) increased summer temperatures, 4) decreased LWD, and 5) decreased pool habitat. Many of these factors are interrelated, with impacts to one factor subsequently impacting another. Channel aggradation has also precipitated a host of anthropogenic responses in the lower watershed, such as clearing woody debris jams, riverine gravel removal, diking, and bank stabilization (USACE 2010) that exacerbate the problems stated above or that are themselves detrimental to juvenile salmon habitat. Dunham and Chandler (2001), Correa (2003), and Merlin Biological (2005) report specific habitat details for the South Fork Skokomish mainstem and Church Creek, the entire Skokomish watershed, and the South Fork Skokomish sub-basin, respectively. In addition, ME2 Environmental Services (1997) (on behalf of The Simpson Timber Co.) and the USFS and the Skokomish Tribe (1995) both completed watershed analysis on the South Fork Skokomish and its tributaries. These past and current data collections and summaries suggest that some level of habitat degradation has occurred in the Skokomish Basin, with less degraded habitat in the upper watershed and tributaries relative to the lower watershed and mainstem.

The Skokomish Indian Tribe and WDFW (2010) document increases in active channel widths throughout this region. This increase in active channel width will impact juvenile salmon habitat in several different ways. First, it reduces the availability of overhead cover, which protects juvenile salmon from predators (Helfman 1981). Second, the reduction in riparian vegetation adjacent to the wetted channel reduces shading, which can result in increased water temperatures (see below for more a further discussion of this topic). Third, it reduces the input of large wood to the river channel, thereby reducing instream cover, an important component of juvenile salmonid habitat (i.e., Shirvell 1994; Peters 1996a ; Roni and Quinn 2001; Beechie et al. 2005). Finally, channel widening is likely associated with reduced channel depths and loss of pool habitat. However, increased channel width and reduced riparian cover may actually increase primary productivity due to increased solar radiation reaching the stream channel (reviewed by Chamberlain et al. 1991).

Reduced Riparian Vegetation

Based on past studies and data collected during this study, riparian vegetation appears to be degraded within the Skokomish Basin, with the greatest degradation occurring in the lower Skokomish watershed and in mainstem channels relative to tributaries. Correa (2003) classified riparian conditions throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (Figure 11). The Skokomish mainstem, Weaver Creek, Hunter creek, and the lower South Fork Skokomish (RKM 0 – 4.8) were classified as having poor riparian conditions. Purdy Creek was classified as poor to good, while Richert Springs was classified as fair to good. The South Fork Skokomish was classified as fair from RKM 16.1 to 37.8, but good in the remaining sections. Tributaries to the upper South Fork Skokomish were classified as good (Rock Creek, Brown Creek, LeBar Creek, Cedar Creek, and Pine Creek), with the exception of Church Creek, which was classified as fair. No assessment was completed for the North Fork Skokomish or Vance Creek.

Based upon our data collection, riparian vegetation conditions appear to be severely degraded in some areas, but relatively healthy in others (Figure 12, Figure 13, Figure 14). Based on mature riparian vegetation cover, riparian conditions were most degraded in the upper South Fork Skokomish, the mainstem Skokomish from the Vance Creek confluence to HWY 101 and in Hunter Creek (Figure 12). Mature riparian cover varied from poor to relatively good (>70%) in the North Fork, Vance Creek, McTaggert Creek, and was generally good in Swift Creek and the lower mainstem below HWY 101. Riparian conditions based on riparian cover along the stream bank were similar, except that riparian cover was generally greater than 50% along the banks of the North Fork Skokomish and McTaggert Creek (Figure 13). Riparian condition ratings based on percent riparian cover in the middle of the channel varied from those stated above for the lower mainstem Skokomish (Figure 14). Riparian cover in the middle of the channel at these locations was generally less than 30%. The riparian conditions at the remaining sites were similar to those observed for mature riparian canopy and riparian cover along the bank. The varied riparian conditions observed are likely the result of the interacting influences of historic land clearing and logging practices that allowed for harvest to occur adjacent to the channel, recovery at these locations, and changes in overall channel width.

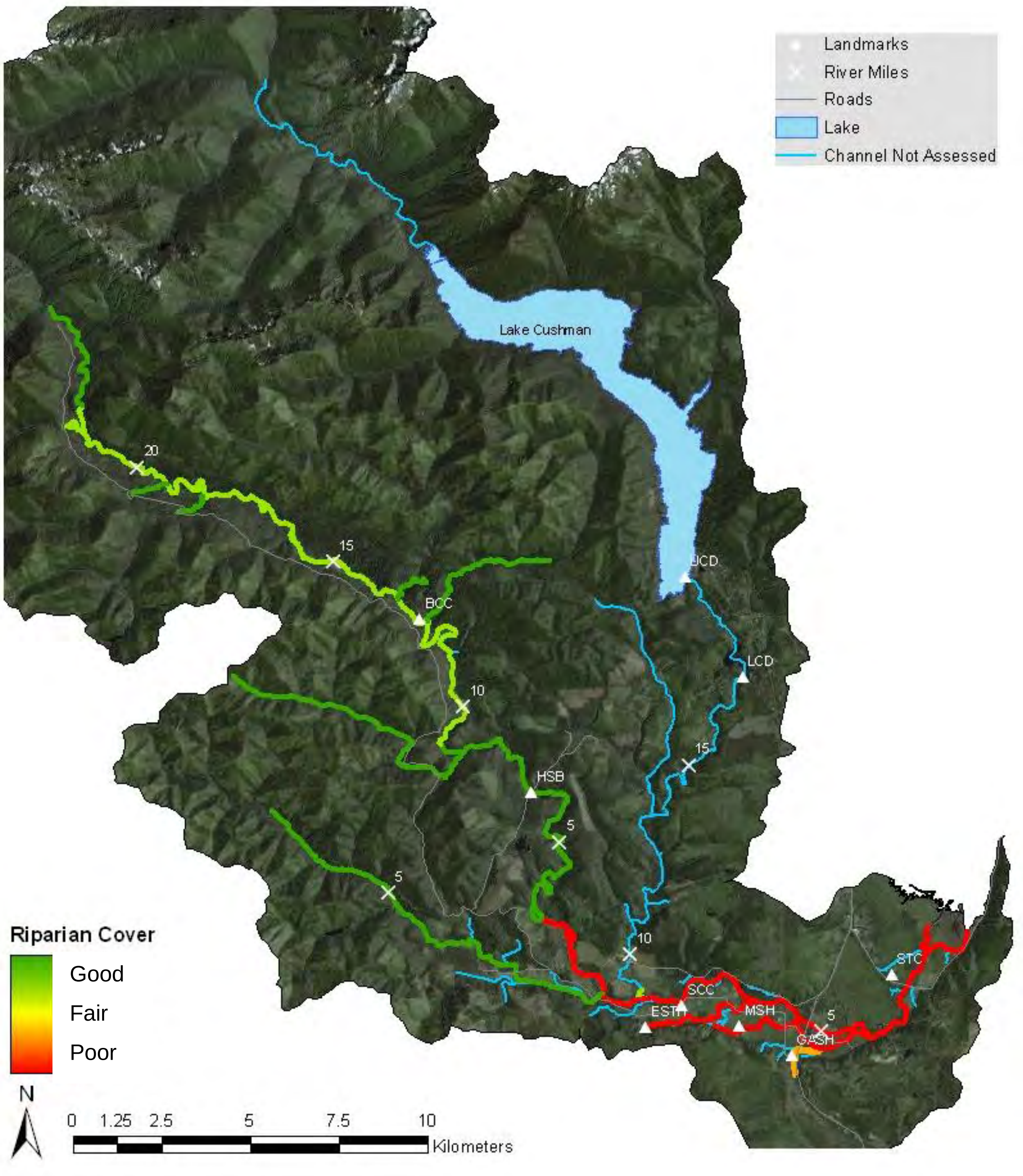

Figure 11. Riparian conditions throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

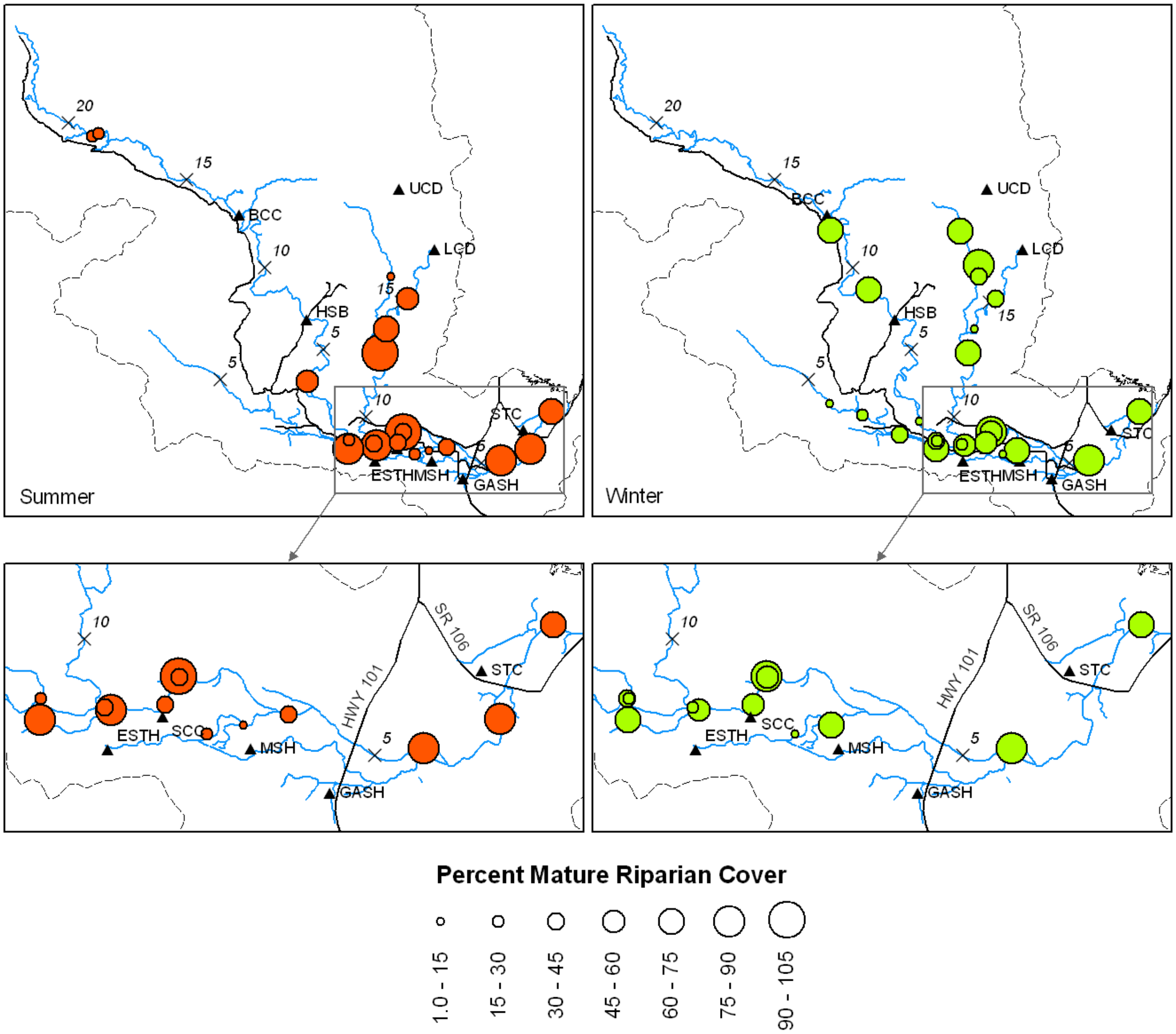

Figure 12. Percent mature riparian cover of the total bank at each site sampled in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

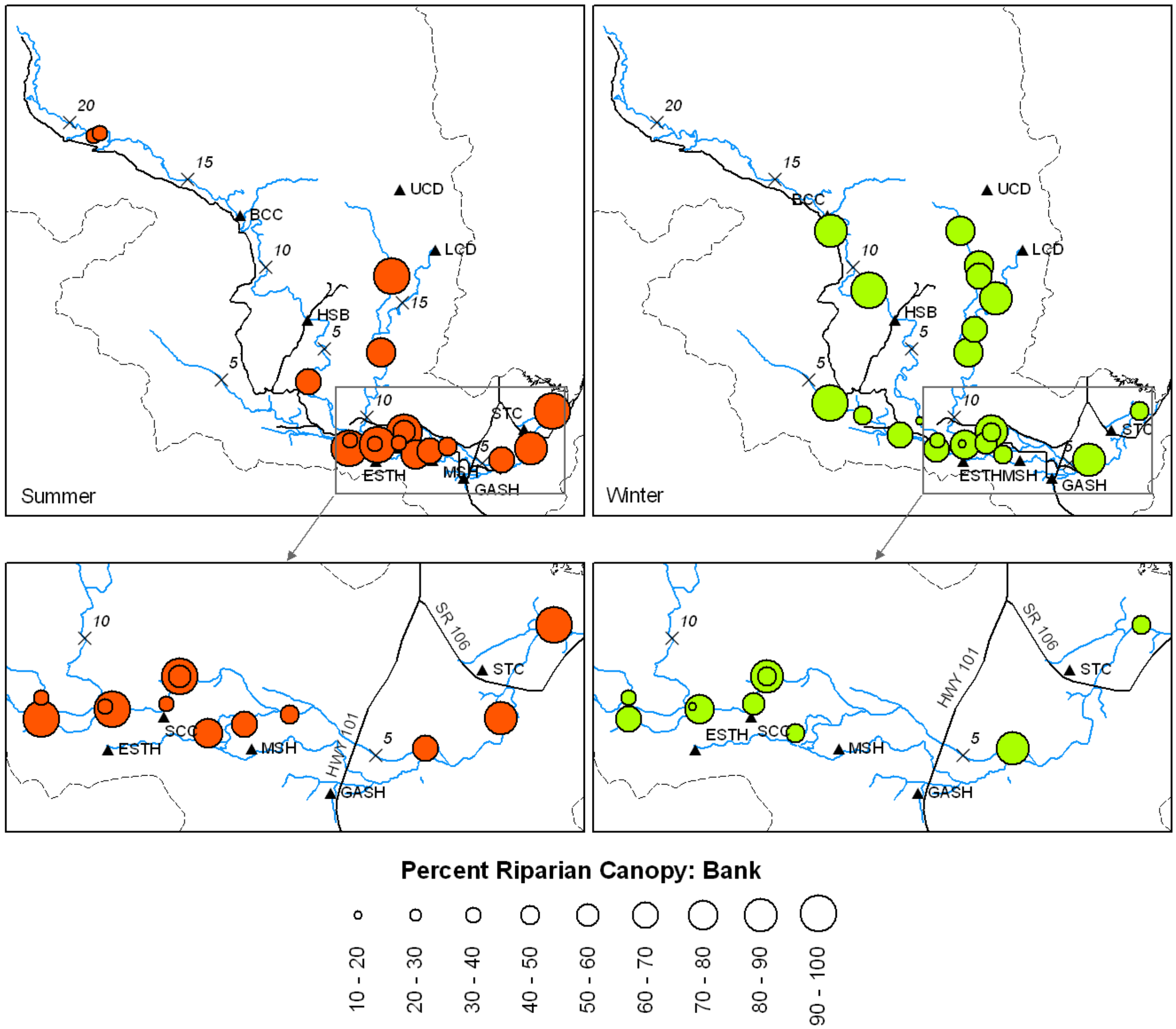

Figure 13. Percent of bank with riparian canopy at each site sampled during the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

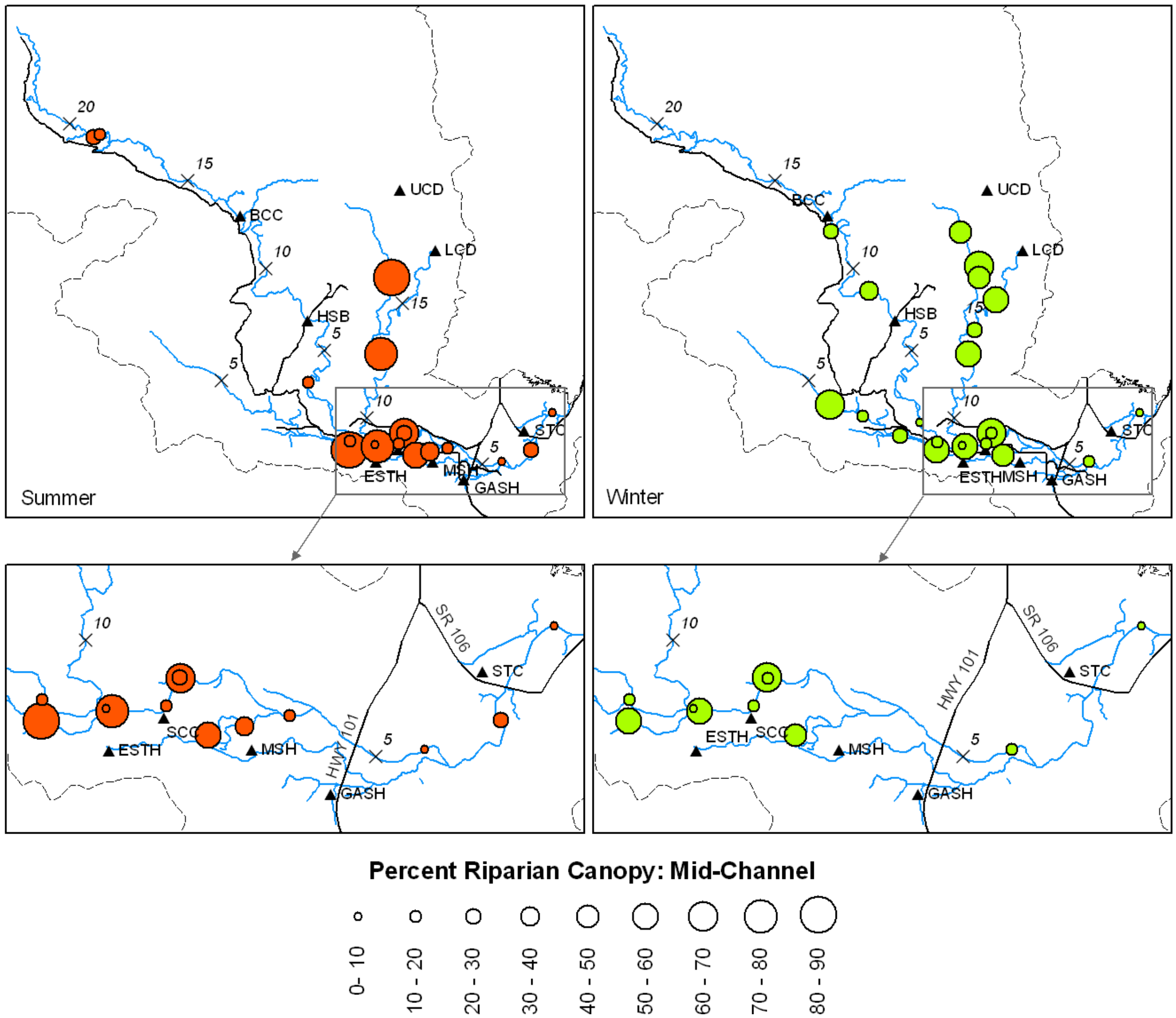

Figure 14. Percent riparian canopy cover in the mid-channel at each site sampled in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Decreased Instream Flows

Summer low flows in the Skokomish Basin are reduced relative to historic values (Skokomish Tribe and WDFW 2010). This could be the result of the river going sub-surface as a result of aggradation in the lower South Fork Skokomish, lower Vance Creek, and mainstem, as well as flow reductions resulting from diversion of flows from the North Fork Skokomish. As described above, channel aggradation can impact summer low flows by causing flows to go subsurface. Complete dewatering of the lower portions of Vance Creek and the South Fork Skokomish has been observed recently (Skokomish Indian Tribe and WDFW 2010). This creates a complete barrier to upstream passage by adults and subsequently impacts the distribution of juveniles. The South Fork Skokomish was dry for several hundred meters above the confluence of the North Fork Skokomish during the summer of 2009, but not the summer of 2008.

Increased Summer Temperatures

Increased water temperatures appear to be a sporadic problem in the Skokomish Basin, with some past studies identifying water quality issues, while others have not. Water temperature problems appear to be a greater concern in the lower Skokomish Bain than the upper Skokomish Basin. Skokomish Indian Tribe (2006) noted severe water quality impairment for warm water temperature and low dissolved oxygen (DO) during summer low flows at the HWY 101 Bridge. Interestingly enough, they found that these two metrics were not violated further downstream at the SR 106 Bridge. However, State standards for fecal coliform levels were violated at the SR 106 Bridge site. Mid Skobob Creek and the mouth of Purdy Creek were listed as severely impaired for fecal coliforms, temperature, and DO. The upper section of Purdy Creek, the Weaver Creek sampling sites, and Hunter Creek were not impaired for temperature but were impaired for DO and fecal coliform. In addition, data collected by the Washington Department of Ecology (WDOE) indicates that concentrations of fecal coliform bacteria in the lower river valley exceeded State water quality standards in Ten Acre Creek, in addition to Weaver, and Purdy Creeks, and at the SR 106 Bridge.

Correa (2003) classified water temperature conditions throughout portions of the Skokomish Basin based on qualitative criteria of good, fair, and poor (Figure 15). Data for main channels existed only for the upper South Fork Skokomish (above RVM 23.5), which was classified as having good water temperatures. Hunter, Weaver, and Purdy Creeks, which are tributaries to the mainstem, were classified as having good water temperatures. Water temperatures at all but one of the South Fork Skokomish tributaries assessed had water temperatures classified as good, including Church, Pine, Cedar and Brown Creeks. Lebar Creek was classified as having fair water temperatures.

Dunham and Chandler (2001) assessed several sites within the South Fork Skokomish Basin (Figure 16). With the exception of one site, which had temperatures that exceeded 18^{o}C for 36 days, temperature was not identified to be a major issue in the South Fork Skokomish. Although this one site had temperatures much greater than the other sites evaluated, the observed temperatures were still less than those expected be a barrier to adult Chinook salmon (i.e., 21^{o}C, Richter and Kolmes 2005; Strange 2010). In addition, temperatures at this site were less than lethal limits for juvenile salmon (i.e., Becker and Genoway 1979; Geist et al. 2010) and less than temperatures expected to impact growth (i.e., Brett et al. 1982; Marine and Cech 2004; Geist et al. 2010).

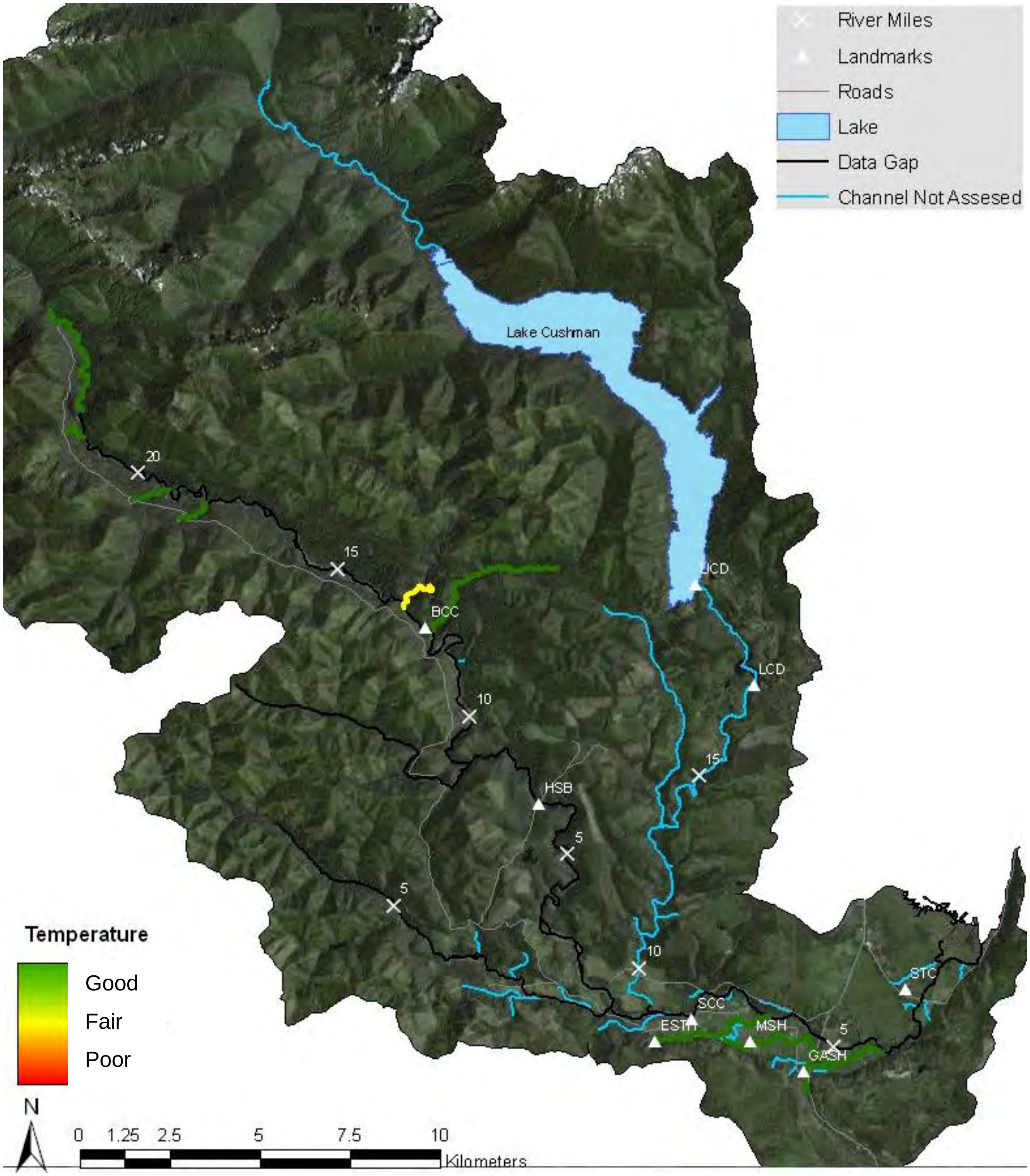

Figure 15. Water temperature conditions throughout sections of the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 5. Summer mean and maximum temperature data collected during a 48 day period in 2000 and the number of days temperatures exceeded temperature thresholds of 12-20^{o}C (from Dunham and Chandler 2001, sites are displayed in Figure 16).

		Summer		Number of days temperatures exceeded:				
Stream	Site	Mean	Max	12C	14C	16C	18C	20C
Church Cr.	1	10.67	13.58	23	0	0	0	0
S.F. Skokomish	1	15.22	19.27	48	48	44	13	0
S.F. Skokomish	10	13.71	18.36	48	45	28	5	0
S.F. Skokomish	11	13.29	17.54	48	44	20	0	0
S.F. Skokomish	12	13.38	17.52	48	45	20	0	0
S.F. Skokomish	13	12.81	16.72	47	41	11	0	0
S.F. Skokomish	14	12.44	16.02	47	37	1	0	0
S.F. Skokomish	15	11.84	15.50	46	23	0	0	0
S.F. Skokomish	16	11.14	14.97	43	19	0	0	0
S.F. Skokomish	17	10.26	14.51	36	8	0	0	0
S.F. Skokomish	18	10.35	14.32	37	8	0	0	0
S.F. Skokomish	19	9.68	13.46	26	0	0	0	0
S.F. Skokomish	2	15.39	19.39	48	48	42	13	0
S.F. Skokomish	20	8.82	10.82	0	0	0	0	0
S.F. Skokomish	21	8.00	9.43	0	0	0	0	0
S.F. Skokomish	22	8.47	10.23	0	0	0	0	0
S.F. Skokomish	23	10.92	13.18	12	0	0	0	0

Figure 16. Study sites where habitat and fish data were collected by Dunham and Chandler (2001). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Reduced LWD

As discussed above, reductions in large wood input to the river channel occurs as the active channel width increases. LWD has several beneficial effects for juvenile salmon, including increasing habitat complexity and number of pools, providing instream cover and predation refugia, and increasing primary productivity (Quinn 2005). A number of past studies have assessed large wood levels within the Skokomish Basin and have identified reaches where wood levels are below a desired standard. According to Correa (2003), habitat in the mainstem Skokomish, the South Fork Skokomish from RVM 0 to RVM 10 and Hunter, Weaver, Vance, LeBar, and Pine creeks are the most degraded, in terms of LWD presence (Figure 17).

Data from Merlin Biological (2005) indicates that LWD and pool frequency generally increase as you move upstream on the South Fork Skokomish, with habitat greatly improving upstream of RKM 25.1 (RVM 15.6) (Table 6). In addition, their report found that most of the major tributaries had significant old growth buffers and that LWD loading was in good condition overall. Although LWD and pool frequency increases as you move upstream in the South Fork, data from Dunham and Chandler (2001) indicate relatively poor LWD quality in the South Fork Skokomish and Church Creek (Table 7). Only about one-third of the sites they sampled were classified as having wood present that provided good quality cover (i.e. wood class ratings of 3 or 4). The observation of increased wood in the upper watershed likely is the result of increased wood delivery as a result of landslides (Benda et al. 2003) in the area.

Fox et al. (2003) developed recommended large wood quantities and volumes for western Washington river‟s (Table 8). Although we collected different wood metrics, we attempted to compare observed quantities and volumes of large wood from the current study with their recommendations. We determined that large wood was limited in many sites of lower Vance Creek, the South Fork Skokomish, and the mainstem (Figure 18). The number of Large Debris Piles (LDP) per bankfull width was very low for all sites sampled. In particular, the USACE Vance Creek site did not have any LDP during either summer or winter surveys. The number of single LWD in the South Fork Skokomish was also very low and translated to 0 to 0.07 LWD per m with an average of 0.02. This indicates poor LWD quality within the reach.

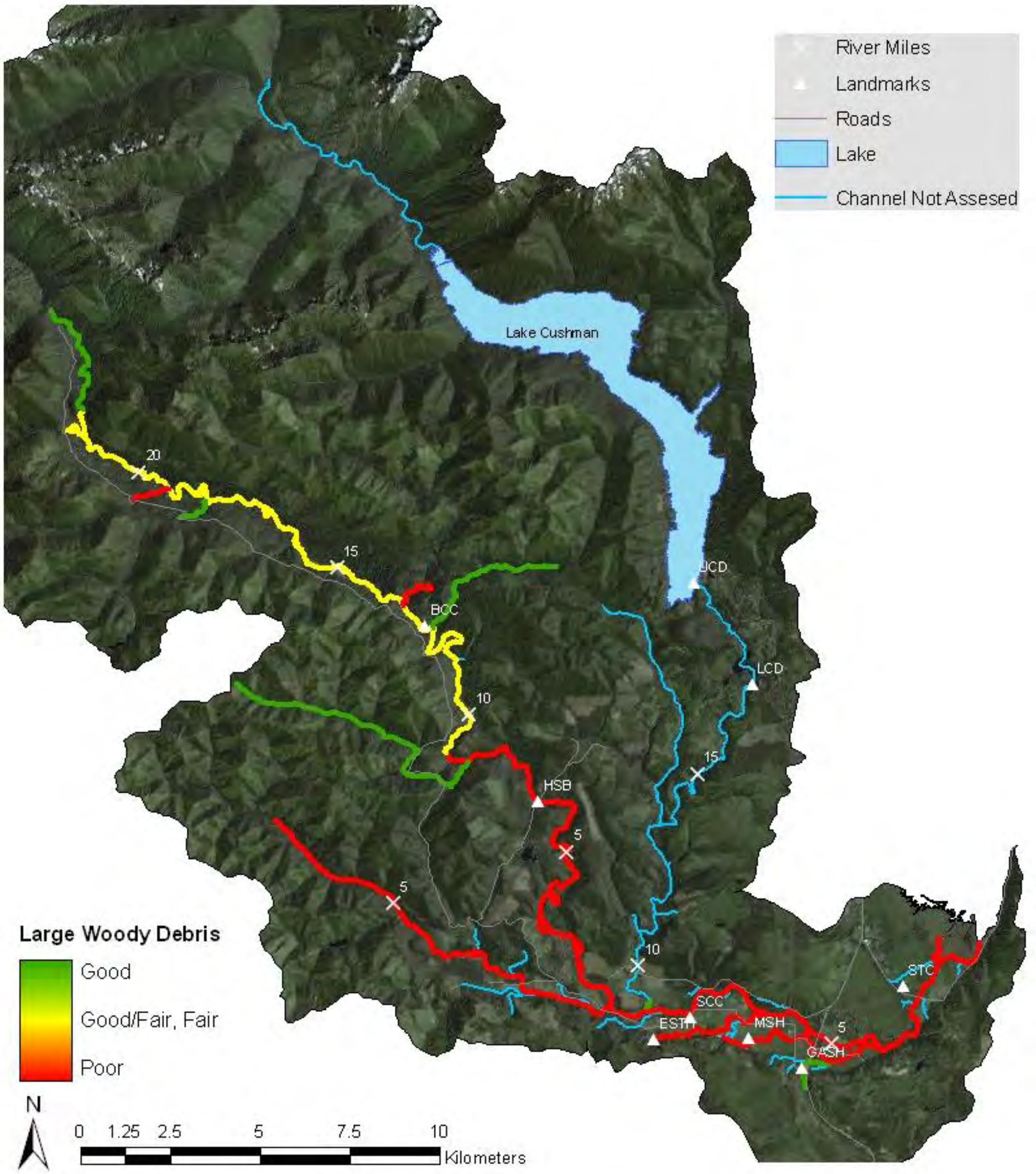

Figure 17. Classification of levels of large woody debris (LWD) throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003 Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 6. Juvenile salmon relevant habitat in the South Fork Skokomish of the Skokomish River watershed. Modified from Merlin Biological (2005).

Reach	Pools/km (mi)	Pools > 0.91 m deep/km (mi)	No. of LWD/km (mi)	Dominant/Subdominant Substrate
RKM 17.7-22.9 (RVM 11-14.2)	14.5 (9)	12.4 (7.7)	138.1 (85.8)	Gravel/cobble
RKM 22.9-25.1 (RVM 14.2-15.6)	13.8 (8.6)	13.8 (8.6)	42.5 (26.4)	Gravel/cobble
RKM 25.1-34.4 (RVM 15.6-21.4)	16.9 (10.5)	15.8 (9.8)	273.1 (169.7)	Gravel/cobble
RKM 34.4-37.8 (RVM 21.4-23.5)	20.9 (11.3)	17.4 (10.8)	203.3 (126.3)	Gravel/cobble
RKM 37.8-41.8 (RVM 23.5-26.0)	23.2 (14.4)	19.6 (12.2)	221.5 (137.6)	Cobble/gravel

Table 7. Summary of habitat data metrics for Church Creek and the South Fork Skokomish River (from Dunham and Chandler 2001, sites are shown on Figure 16).

Stream	Site	Length (m)	Mean Width (m)	Max Depth (m)	Gradient	Conductivity	No. of Large Woody Debris (per meter) Single	Rootwads	Aggregates	Total	Wood class	% fines
Church Creek	1	100	6.96	1.01	2.16	34.7	0.12	0.06	0.01	0.19	2	12.0
S.F. Skokomish	1	100	15.71	1.40	0.31	62.9	0.07	0.03	0.01	0.11	3	31.5
S.F. Skokomish	10	108	14.89	1.35	0.18	56.5	0.08	0.02	0.00	0.10	2	25.9
S.F. Skokomish	11	100	37.65	0.65	0.99	60.6	0.15	0.04	0.03	0.22	2	9.0
S.F. Skokomish	12	97	10.07	1.65	0.00	37.3	0.09	0.02	0.01	0.12	2	32.0
S.F. Skokomish	13	102	13.16	1.35	0.95	35.1	1.47	0.49	0.17	2.13	4	25.0
S.F. Skokomish	14	100	14.24	0.73	0.19	33.7	0.10	0.01	0.01	0.12	3	4.6
S.F. Skokomish	15	100	19.59	0.83	0.24	31.6	0.02	0.00	0.00	0.02	1	15.5
S.F. Skokomish	16	115.5	10.87	1.43	0.24	63.1	0.02	0.00	0.00	0.02	1	18.8
S.F. Skokomish	17	80	10.59	1.80	1.54	59.3	0.01	0.00	0.01	0.03	1	3.8
S.F. Skokomish	18	110	10.80	0.73	0.79	54.8	0.08	0.01	0.00	0.09	1	10.0
S.F. Skokomish	19	100	11.80	1.12	1.74	59.8	0.03	0.01	0.01	0.05	1	2.5
S.F. Skokomish	2	100	19.91	1.10	0.45	64.0	0.05	0.00	0.01	0.06	4	7.0
S.F. Skokomish	20	103.2	13.98	3.00	0.52	35.4	0.04	0.01	0.01	0.06	2	24.7
S.F. Skokomish	21	80	7.16	1.36	1.75	55.4	0.15	0.00	0.01	0.16	2	10.7
S.F. Skokomish	22	155	7.28	0.55	1.46	31.2	0.14	0.01	0.07	0.21	2	4.5
S.F. Skokomish	23	100	5.85	0.73	8.11	42.7	0.06	0.01	0.03	0.10	4	2.8

Table 8. Recommended ranges of instream wood quantity and volumes for western Washington streams by bankfull width class (BFW Class) (From Fox et al. 2003).

LWD Piece Quantity: Number of Pieces Per 100 m of Channel Length

Region	BFW Class	Good	Fair	Poor
Western WA	0-6 m	>38	26-38	<26
	>6-30 m	>63	29-63	<29
	>30-100 m	>208	57-208	<57

LWD Volume: Cubic Meters Per 100 m of Channel Length

Region	BFW Class	Good	Fair	Poor
Western WA	0-30 m	>99	28-99	<28
	>30-100 m	>317	44-317	<44

Key Piece Quantity: Number of Pieces Per 100 m of Channel Length

Region	BFW Class	Good	Fair	Poor
	0-10 m	>11	4-11	<4
	>10-100 m	>4	1-4	<1

Minimum Piece Volume to Define Key Pieces

Bankfull width Class	Minimum Piece Volume (m^3)
0-5 m	1*
>5-10	2.5*
>10-15	6*
>15-20	9*
>20-30 m	9.75
>30-50 m	10.5**
>50-100 m	10.75**

* Existing Washington Forest Practices Board (WFPB) (1997 definitions)

** Rootwads must be attached

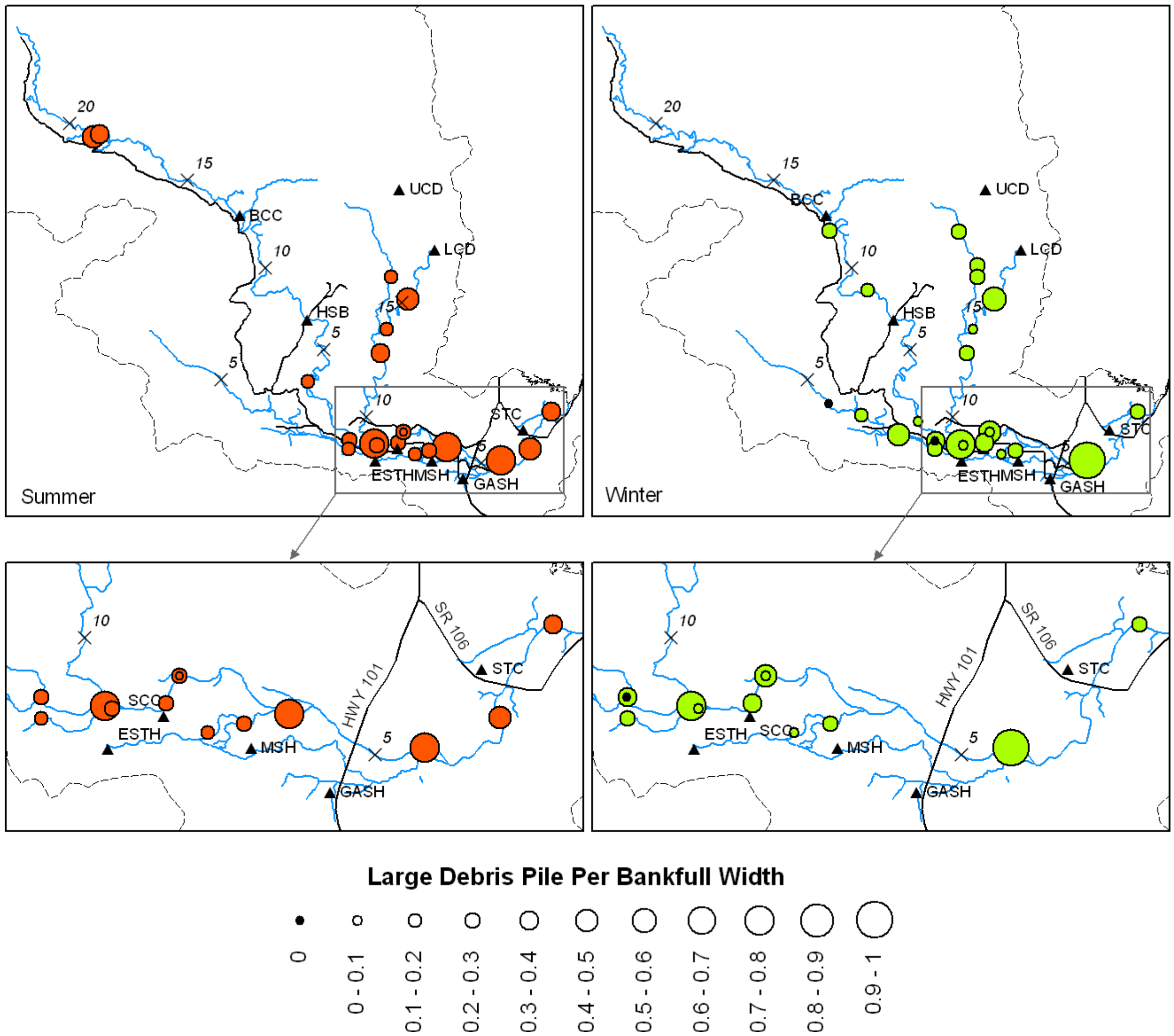

Figure 18. Number of large debris piles per bankfull width at each site sampled in the summer of 2008 and winter 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Reduced Pool Habitat

Data from Merlin Biological (2005) indicates that pool frequency and depth increases as you move upstream on the South Fork Skokomish, with habitat greatly improving upstream of RKM 25.1 (RVM 15.6) (Table 6). The USFS and Skokomish Tribe (1995) rated the entire South Fork Skokomish as having poor pool frequency. In contrast, all the tributaries, except Church Creek, were rated as good or fair for pool frequency. Correa (2003) classified reaches of the South Fork Skokomish and several tributaries and found that percent pool habitat was poor in the from RKM 0 (RVM 0) to RKM 4.8 (RVM 3) and RKM 16.1 (RVM 10) to RKM 37.8 (RVM 23.5), but good from RKM 4.8 (RVM 3) to RKM 16.1 (RVM 10) and above RKM 37.8 (RVM 23.5). The percent of pool habitat was also poor in Weaver, Hunter, Vance, LeBar and Pine Creeks. The percent pool habitat was rated as good in Richert Springs and Cedar Creek (Figure 19). Classification of pool quality in these reaches varied from that of percent pool habitat, indicating that the quality of the few pools that were present was generally good in the South Fork Skokomish, but poor in the tributaries (Figure 20). Pool quality throughout the entire South Fork Skokomish was rated as good, while pool quality in tributaries was rated as good in only Brown Creek.

ME2 Environmental Services (1997) provides similar information to Correa (2003) and Merlin Biological (2005) in their watershed analysis of the South Fork Skokomish, but separated the data into summer and winter rearing habitats, and also highlighted four "areas of special concern". In general, ME2 Environmental Services (1997), reports that the pool depth was good across all fish bearing reaches, although they used their own subjective determination of what depth was required for juvenile salmon rearing. For summer rearing habitats, they state that percent pool habitat was good in the alluvial terrace tributaries of the South Fork Skokomish (tributaries to Vance Creek), fair in the upland tributaries (Fir Creek), and poor in tributaries above the South Fork Skokomish canyon (Brown, Pine, and LeBar Creeks). Data for Vance Creek was difficult to obtain because of its dry channel. In terms of winter rearing habitat, their most significant finding is the virtual non-existence of off channel habitat in the South Fork Skokomish watershed, although similar habitat can be found in the lower reaches of the alluvial terrace tributaries and in side channels of the upper watershed.

Data collected during the current study generally support the previous findings with regard to pool availability. The mean percent of summer sample sites that consisted of deep water (DW) was 44.8% in the summer and 25.8% in the winter (Table 9). Shallow water (SW) habitats comprised 29% in the summer and 40.6 % in the winter. The percentage of deep water habitats decreased in 12 of 15 between the summer to winter surveys from an average of 47% to 30% in the sites we sampled both summer and winter (n = 15). Based on Washington Department of Natural Resources (WDNR) watershed analysis indices (WDNR 1997), the habitat quality rating for percent pool (using percent deepwater as percent pools) would be poor for 9 of 21 summer sites, fair for 6 sites, and good for the other six sites. For winter sites, 20 of 23 sites would be rated as poor, two sites would be rated as fair, and one site would be good. Overall, the percent of the habitat that consists of pools to provide summer and winter rearing habitat for juvenile salmonids is rated as poor in most areas of the Skokomish River (Table 9). Percent DW habitats tended to be greater in the stream estuary ecotone, tributaries and the North Fork Skokomish than the South Fork Skokomish during the summer, and greatest in tributaries and the North Fork during the winter (Figure 21).

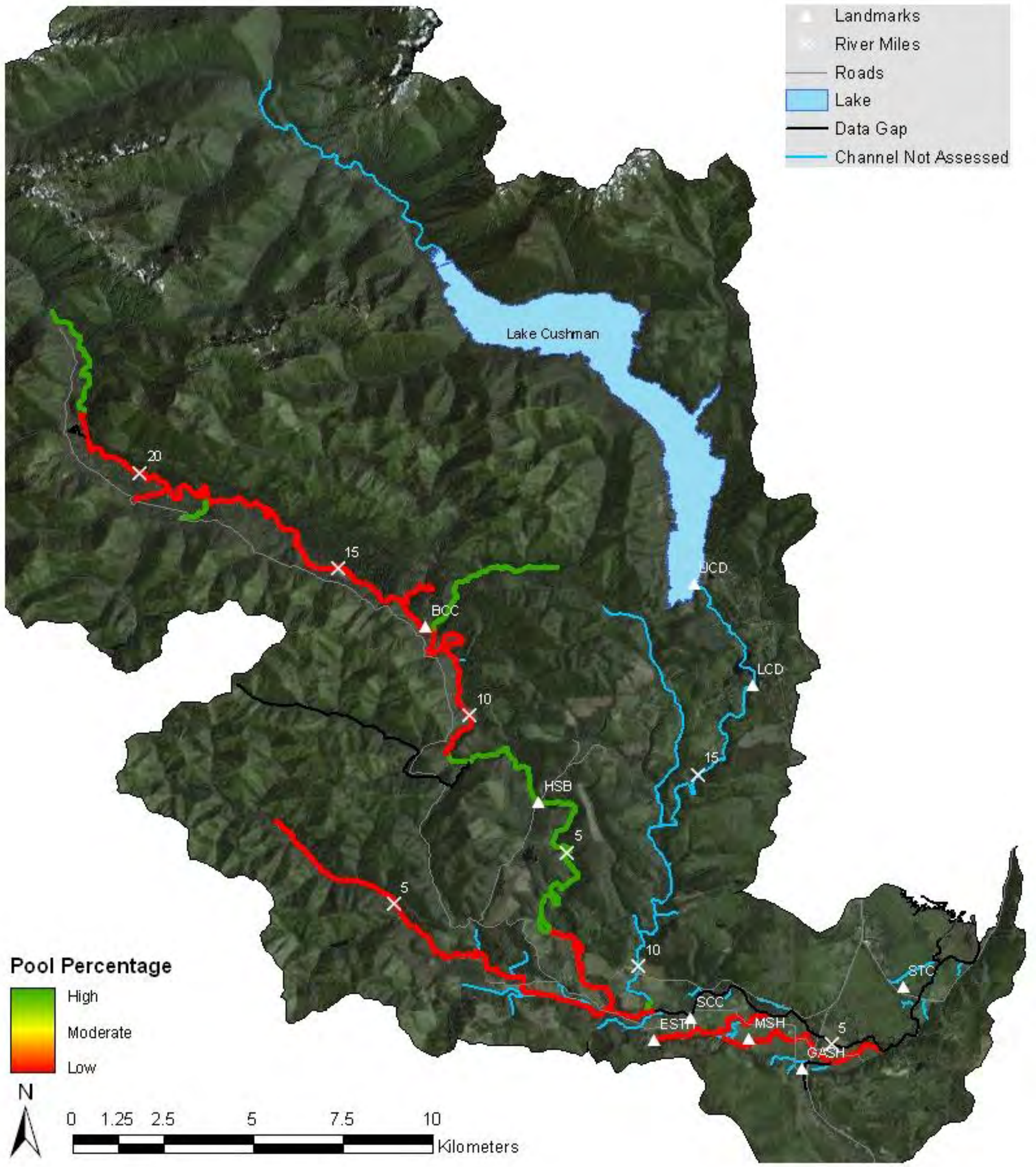

Figure 19. Classification of percent pool habitat throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

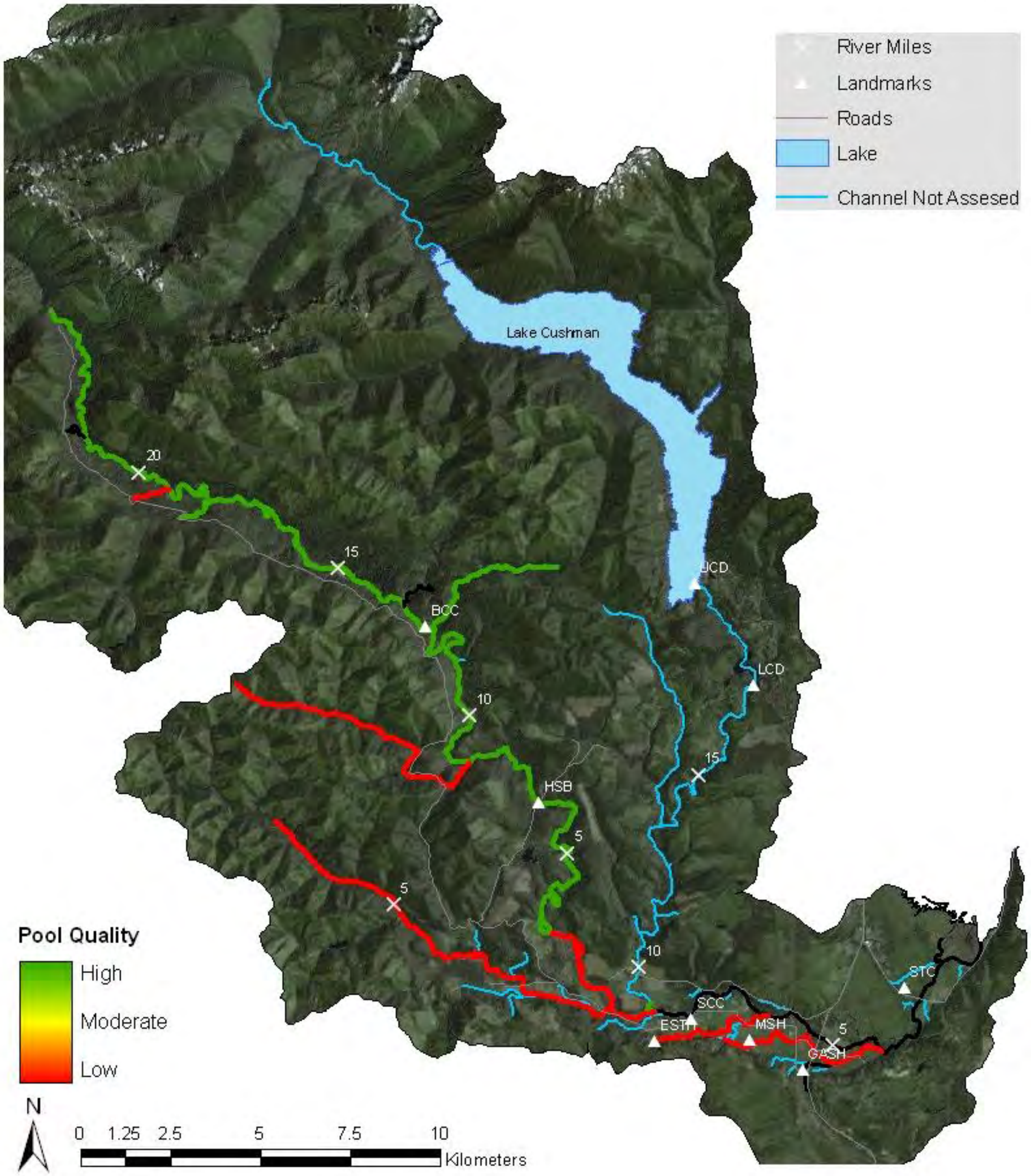

Figure 20. Classification of pool habitat quality throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 9. Percent of average depth water (AW), deep water (DW), and shallow water (SW) present in study reaches sampled during summer 2008 and winter 2009, along with the mean, standard error (SE), minimum, and maximum values observed for all of the reaches. AW habitats are typically glides, runs, and rapids. DW habitats are generally pools, while SW habitats are generally shallow glides and riffles.

Summer				Winter			
Site Name	AW	DW	SW	Site Name	AW	DW	SW
2-01	0.4	76.1	23.5	2-01	41.4	49.3	9.3
2-02	18.5	59.5	22.0	2-02	51.9	25.7	22.4
				2-06	47.6	6.8	45.6
				2-08	53.1	18.8	28.1
				2-13	87.6	12.4	0
2-23	20.2	47.6	32.2				
2-25	0	45.3	54.7	2-25	0	34.0	66.0
2-26	50.1	35.7	14.2	2-26	34.6	31.5	33.9
2-27	28.3	34.7	37.0	2-27	50.8	27.9	21.3
2-28	16.1	25.5	58.4	2-28	9.5	14.6	76.0
				2-29	38.1	15.2	46.7
2-30	4.4	23.9	71.7				
2-31	30.1	44.0	26.0				
2-33	0	44.6	55.4				
2-35	100	0	0	2-35	0	0	100
				2-37	26.9	22.7	50.4
2-38	0	46.4	53.6				
2-39	28.2	68.4	3.4	2-39	40.9	53.7	5.4
2-40	42.0	58.0	0	2-40	0	28.8	71.2
				2-41	43.3	26.6	30.1
				2-64	9.3	29.5	61.2
2-67	52.6	41.4	6.0	2-67	56.8	16.5	26.7
				2-69	7.3	9.2	83.4
2-72	0	99.8	0.2	2-72	5.7	87.4	6.9
NF	0	100	0	NF	39.6	0	60.4
NNFSF	51.7	30.6	17.7	NNFSF	57.2	34.7	8.1
ONFSF	64.4	14.3	21.3	ONFSF	54.3	28.1	17.6
SFV	25.2	22.1	52.7				
VANCE	19.0	22.2	58.8	VANCE	17.1	20.1	62.8
Mean	26.2	44.8	29.0	Mean	33.6	25.8	40.6
SE	5.8	5.6	5.2	SE	4.9	4.0	5.9
Minimum	0	0	0	Minimum	0	0	0
Maximum	100	100	71.7	Maximum	87.6	87.4	100

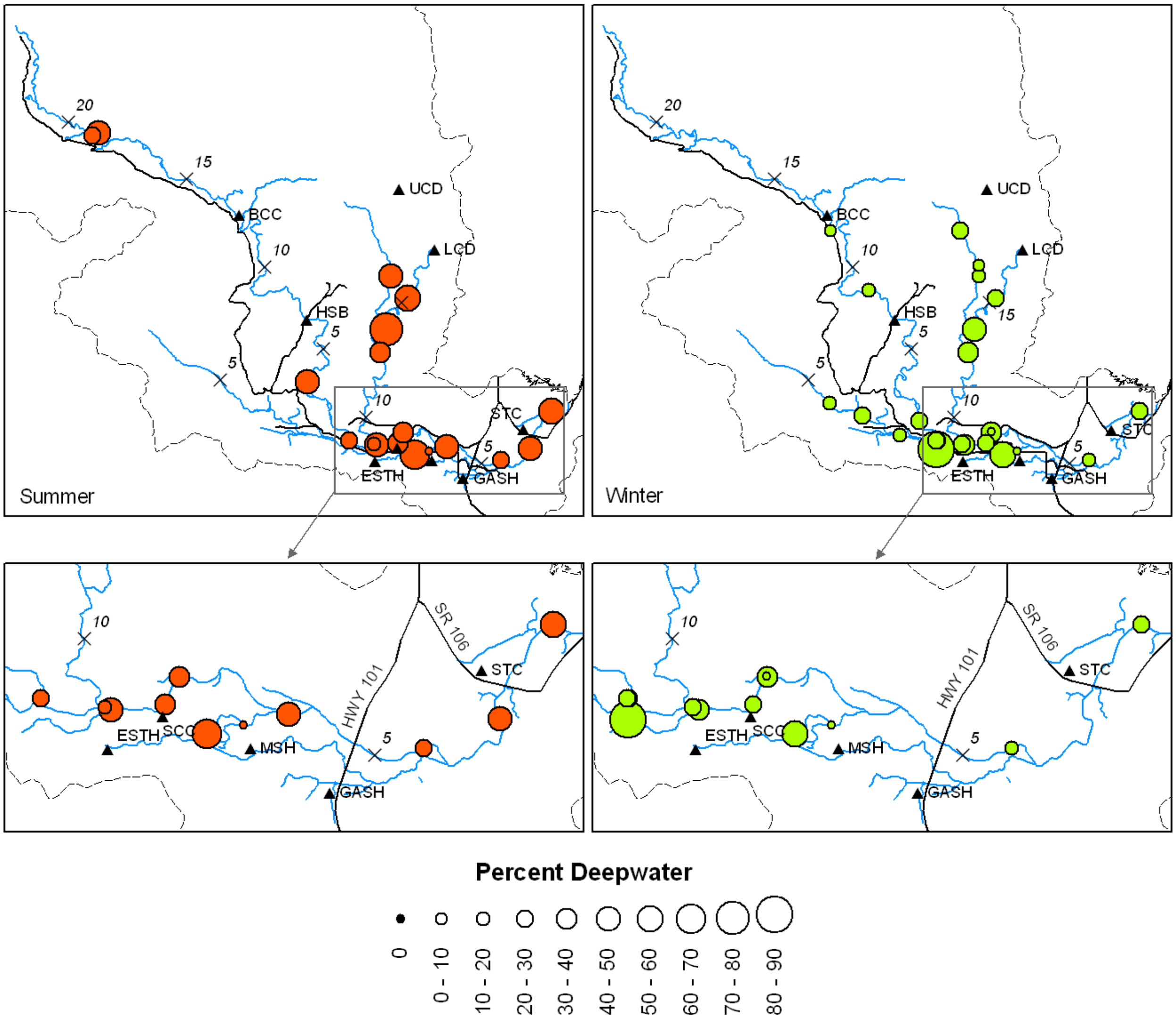

Figure 21. Percent of the habitat surveyed classified as deep water at sites assessed in the summer of 2008 and winter of 2009 within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

We measured four metrics to evaluate pool quality, including average thalweg depth, maximum thalweg depth, average residual pool depth, and maximum residual pool depth. These four metrics allow for comparisons of pool depths to be compared to overall reach depths. Residual pool depths, defined as the maximum pool depth minus the pool tail (crest) depth (Lisle 1987), are sensitive to management activities (Kershner et al. 2004) and have been correlated to fish densities (Mossop and Bradford 2006).

Pool quality, based on depth, in the reaches we sampled was variable based on the data we collected during this study and varied somewhat from that reported by others (Merlin

Biological 2005, Correa 2003). However, since neither Merlin Biological (2005), nor Correa 2003 clearly defined their criteria for classifying pool quality, comparisons are very difficult.

Average thalweg depths varied from approximately 0.25 m to nearly 2.25 m (Figure 22), while maximum thalweg depths varied from 0.25 m to nearly 5 m (Figure 23). Average and maximum thalweg depths were generally greatest in the mainstem, Hunter Creek and the South Fork Skokomish and shallowest in Vance Creek, Swift Creek, the North Fork Skokomish and McTaggert Creek. Average residual pool depths ranged from approximately 0.2 m to 1.6 m (Figure 24), while maximum residual pool depth ranged from 0.4 m to nearly 4 m (Figure 25). As expected, average and maximum residual pool depths were shallowest in tributaries relative to the mainstem, with the exception of Hunter Creek, which had relatively deep water and the upper South Fork Skokomish which had very shallow residual pools compared to other mainstem habitats. Both average and maximum residual pool depths appeared to be shallower during the winter than during the summer within the South Fork Skokomish and upper mainstem Skokomish (above HWY 101), but not in tributaries or the North Fork Skokomish. This suggests that pools may have filled during fall freshets after we completed the summer surveys and before we completed the winter surveys. The observation of shallow residual pool depths in the upper South Fork Skokomish contrasts observations by Correa (2003). The cause for this discrepancy is unclear, but may be due to sediment deliveries from historic or active landslides.

Judging pool quality is across different stream sizes is difficult. Residual pool depth observations from our surveys and those from Merlin Biological (2005) were similar. Pleus et al. (1999) provided the criteria to determine what habitats are considered pools (Table 10). Our mean residual pool depths greatly exceeded these values throughout the Skokomish Basin, suggesting that pool depths within the somewhat limited pools available is in relatively good condition. Mossop and Bradford (2006) found that mean maximum residual pool depths ranging from 0.1 to 0.5 m was correlated with juvenile Chinook salmon densities in small tributaries of the Yukon River with bankfull widths of approximately 5 m. These streams would be similar in size to Swift Creek and McTaggert Creek, where mean residual pool depths were 0.2-0.4 m and 0.1-0.2 m, respectively. This suggests that pool quality in Mctaggert Creek may be in somewhat poor condition (Figure 24). Mean residual pool depths in the upper South Fork Skokomish, which has a bankfull width substantially wider than 5 m, were generally less than 0.6 m. Thus, pool quality in the upper South Fork appears to be degraded (Figure 24).

Table 10. Minimum residual depth criteria for habitat units within streams of different bankfull width to be classified as pools (from Pleus et al. 1999).

Bankfull Width (m)	Residual Pool Depth (m)
0 – 2.49	0.1
2.5-4.9	0.2
5-9.9	0.25
10-14.9	0.3
15-19.9	0.35
>20	0.4

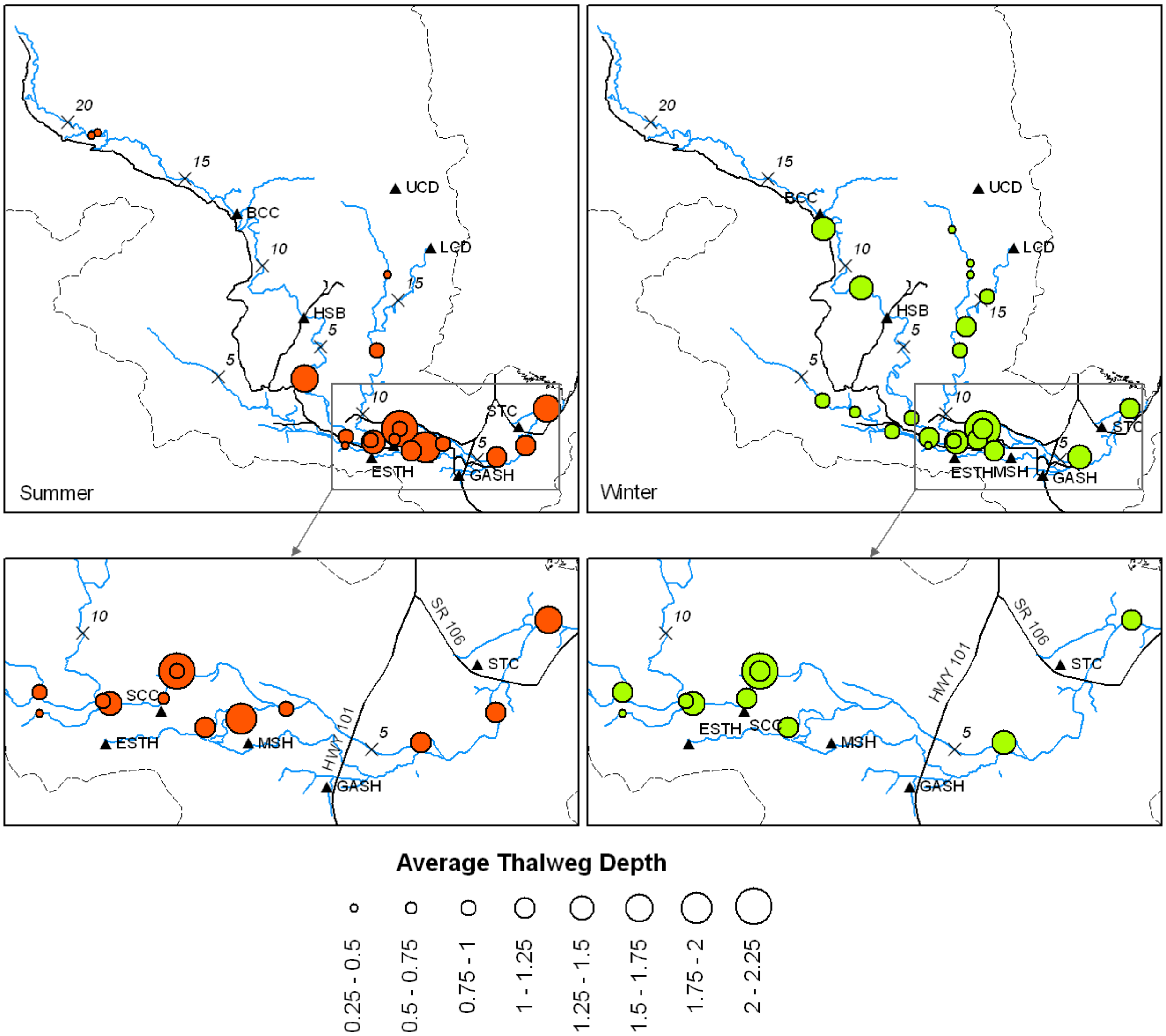

Figure 22. Average thalweg depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

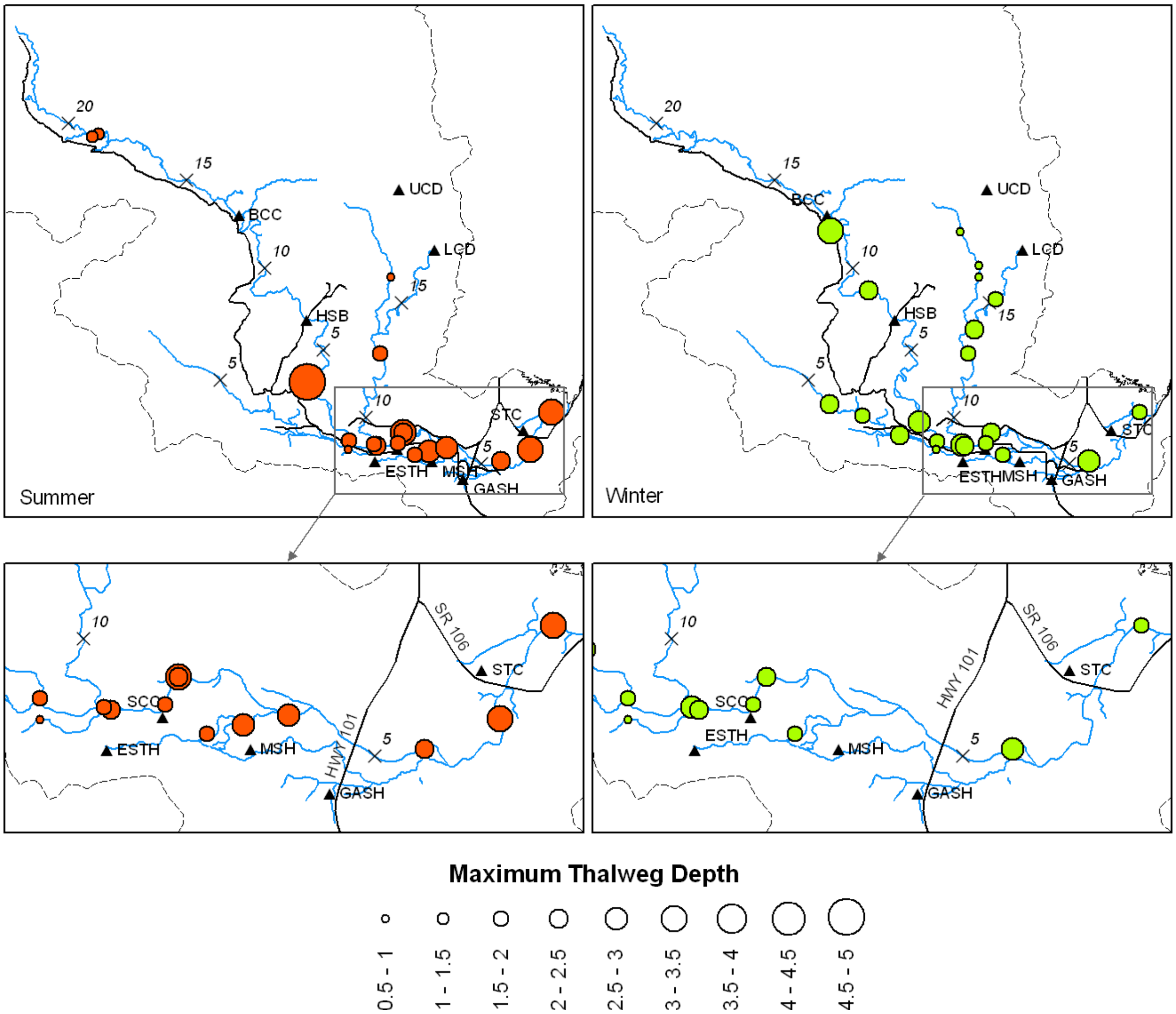

Figure 23. Average maximum thalweg depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

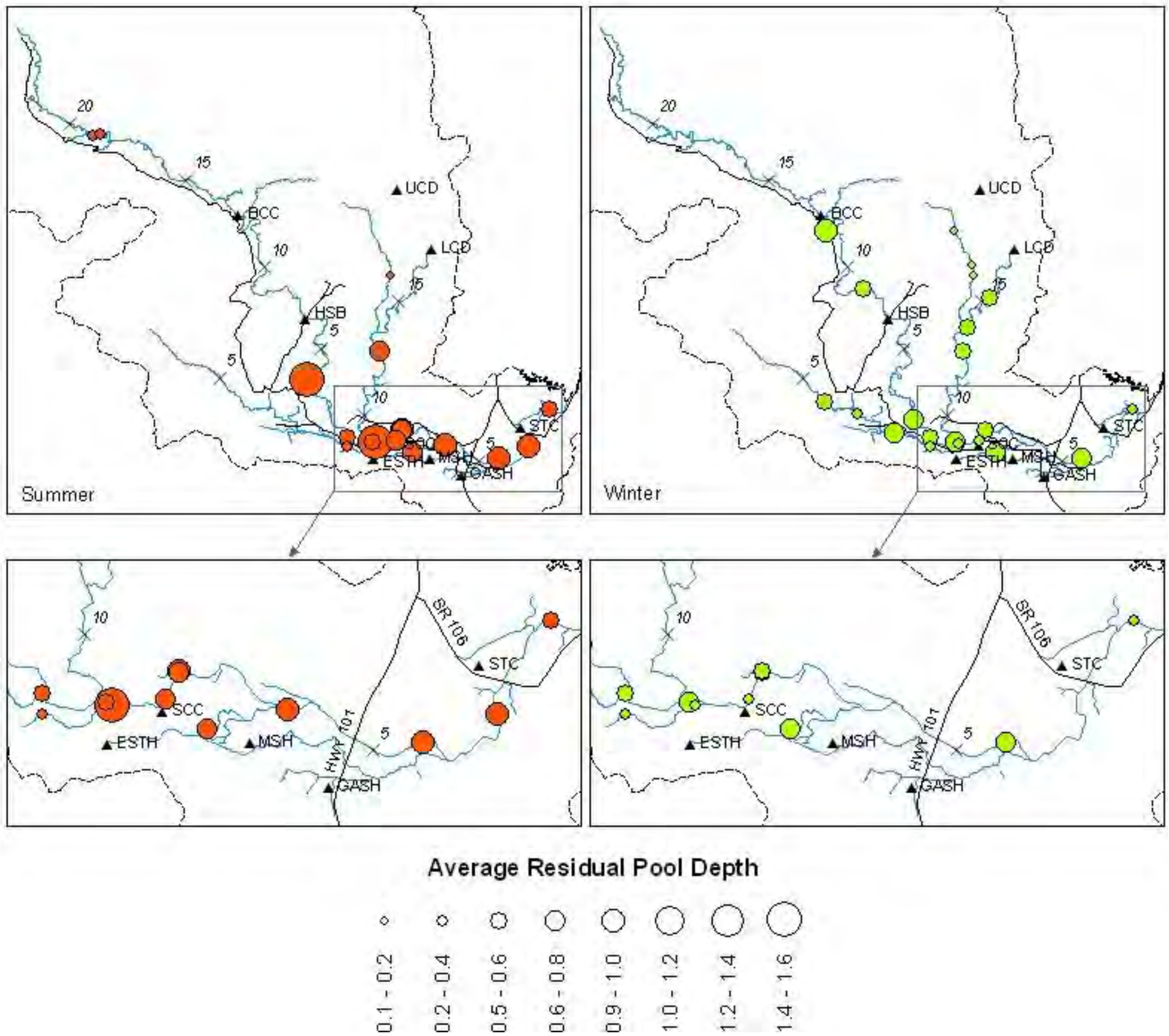

Figure 24. Average residual pool depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009.within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

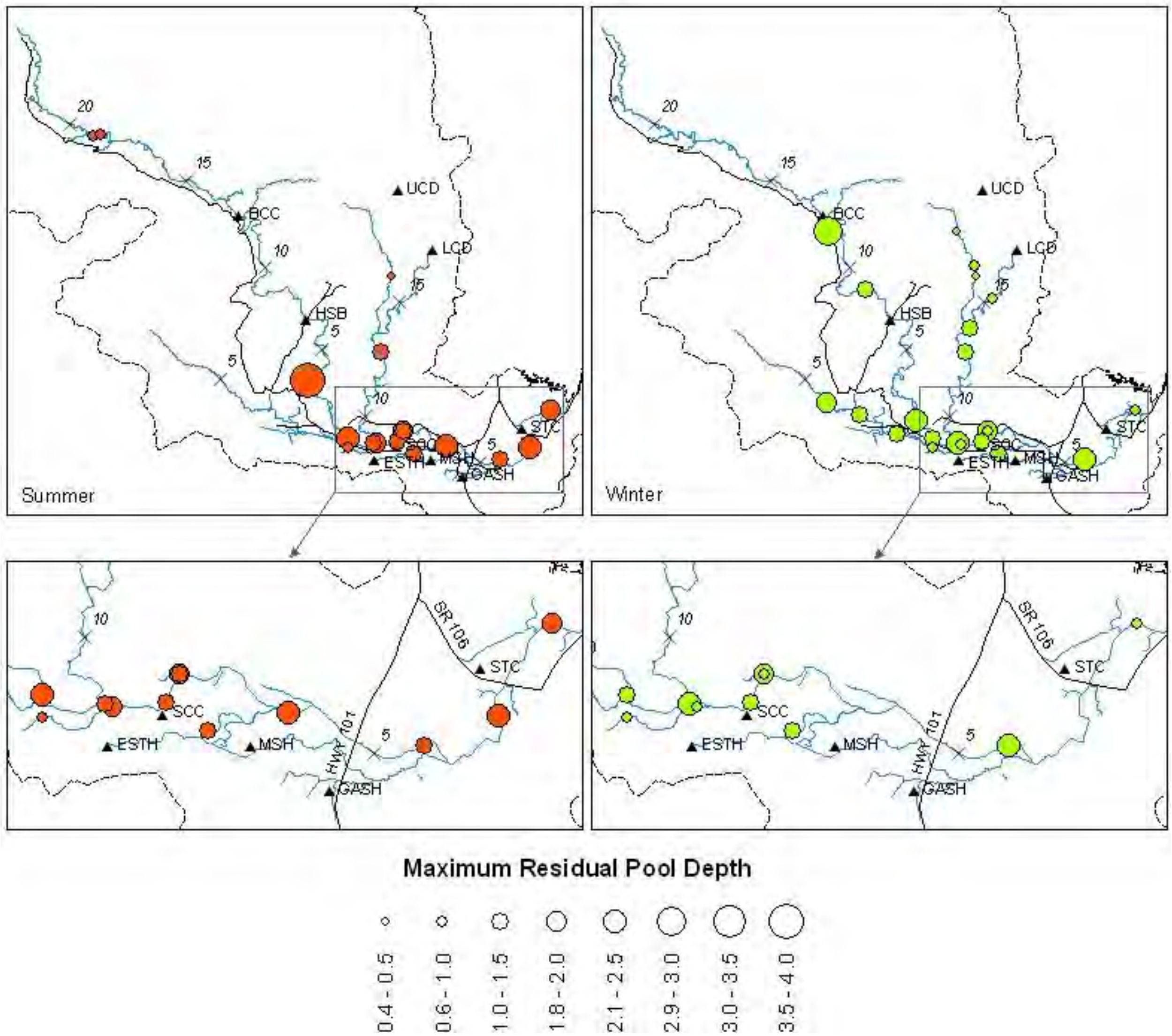

Figure 25. Maximum residual pool depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009 within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Based on the discussion in this section, it is apparent that impact to large scale habitat conditions have been impacted in the Skokomish Basin to a greater degree than finer spatial scale habitat conditions. The Skokomish Basin is somewhat unique for western Washington Basins, in that a majority of the habitat available to anadromous salmonids is mainstem habitat rather than tributaries (i.e. 55.4% mainstem). The relative scarcity of tributary habitat may be compensated for by the high proportion of mainstem and tributary habitat that are productive low gradient, unconfined systems. However, these systems also appear to be the most highly degraded.

Of the four main habitat issues discussed above, habitat loss appears to be the most significant. The Cushman Dams block anadromous salmonids access to approximately 25% and 18% of the available mainstem and tributary habitat in the basin, respectively. Significant habitat has also been lost by the apparent loss of vegetated islands and their associated side channel habitats, which are productive to both adult (Eiler et al. 1992; Hiss 1995) and juvenile salmonids (Murphy et al. 1989; Hirschi and Reed 1998; Jeanes and Hilgert 2000; Peters, FWS, unpublished data). Much of this side channel habitat has apparently been transformed into less productive braided channel habitat. Channel straightening also appears to have resulted in significant losses of channel length available for salmonids. This along with channel aggradation that has reduced tidal influence in the lower mainstem also appears to have substantially reduced the stream-estuary ecotone, an important rearing and transition area for salmonids.

Reductions in habitat connectivity also appear to be significant. The extensive network of levees that run from approximately Vance Creek downstream to the estuary reduces access to lateral and off-channel habitats. In addition, these levees may also result if fish that have been washed into the floodplain during overbank flows being trapped and isolated from mainstem habitats. Finally, dry channels during summer low flow block adult migration to significant proportions of the watershed.

Although there is no quantitative data available to evaluate channel and bed stability in the Skokomish River, the literature suggests that the aggrading conditions of this system would result in unstable habitat that would be detrimental to salmon. Local scour and fill, sufficient to scour salmon redds, would be expected to occur at relatively low discharges relative to a system where sediment inputs and transport capabilities are in equilibrium (Tripp and Poulin 1986). In addition, frequent (i.e., yearly) avulsions and abandonment would be expected in the braided system, which would isolate salmon redds and juvenile salmonids rearing in those channels. The potential significant impacts of channel and bed instability and the lack of information in the Skokomish Basin would make this an important data gap to address in the future.

Although finer scale habitat issues such as reduced riparian cover, decreased summer flows, increased summer temperatures, decreased LWD, and decreased pool habitat exist, they likely don‟t impact salmon in the Skokomish Basin to the same degree as the larger scale habitat issues discussed above. Riparian conditions in the basin are somewhat degraded, but conditions also vary considerably. Decreased summer flows are a significant issue in the basin; however, the new Cushman FERC agreement will address one of the primary concerns. However, subsurface flows in Vance Creek and the South Fork Skokomish need to be addressed. Summer temperatures appear to be only a sporadic issue in the basin, occurring primarily in the lower basin. LWD and pool habitat abundance is degraded in the system and is perhaps the greatest concern of these fine scale issues. Although pool habitat appears to be reduced in the system, the quality of the existing pools, based on depth, seems to be adequate for juvenile salmonids.

Current Habitat Conditions for All Species: Off-Channel Pond Habitat

Off-channel ponds provide critical habitat to juvenile salmonids, especially during winter storm events (i.e., Peterson 1982a, Peterson and Reid 1984; Cederholm and Scarlett 1991). However, the physical characteristics of these ponds can influence fish growth and survival (Peterson 1982b). For example, fish growth generally decreases, while survival generally increases in deeper ponds relative to shallow ponds (Peterson 1982b). In addition, the availability of cover and open spaces lacking cover can influence fish use in ponds and lakes (Tabor et al. 2006). For this reason, we evaluated the availability and conditions of off-channel ponds in the Skokomish Basin. Habitat availability was completed using a GIS assessment to determine the spatial distribution and extent of off-channel ponds in the system, while site specific physical conditions within the ponds was assessed by visiting randomly selected site within off-channel pond habitat (see Appendices B and C for details).

Our GIS habitat assessment identified 28 different off-channel ponds that could potentially be accessible to anadromous salmonids (Table 11, Figure 26). The total surface area and perimeter of these ponds was 20.3 ha and 29,499 m, respectively. The ponds ranged in size from 0.08 to 4.96 ha, and averaged 0.7 ha. Since the ponds were smaller than 8 ha, they were all classified as palustrine systems. Two ponds were classified as being outside the anadromous zone. Pond #21 was located on a terrace and lacked an obvious egress channel to the N.F. Skokomish or McTaggart Creek and pond #20 was dry during the summer and had no outlet to the mainstem Skokomish River during the winter. All the remaining ponds were determined to be within the trout, coho, or bull trout zone. Ponds #26, #27, and #28 were outside the Chinook and chum zone. In addition, pond #25 was outside the chum zone.

We selected 14 sites within these ponds for summer sampling. These sites were located within six of the 26 different off-channel ponds. Four of these sites (two each in two ponds) were dry during the summer and therefore were not sampled. We selected 20 pond sampling sites for winter sampling. These sites were located in seven different ponds. Two sites were located in a pond (# 14) that was completely chocked with aquatic vegetation (i.e., no open water) and therefore were not sampled. Two additional sites in another pond (#20) were not sampled because the pond lacked a connection to the river channel (located in the middle of an agricultural pasture).

Cover was relatively abundant in the ponds we sampled during both summer and winter (Table 12). Terrestrial and aquatic vegetation provided the most cover area in both the nearshore and offshore transect at most sites during both summer and winter. Many of the transects were completely covered by these cover types. For example, many of the transects had bottoms that were covered entirely by aquatic vegetation. Small and large woody debris piles were the next most common cover types. Some large woody debris was occasionally present, while rock and undercut bank cover was rare. These results are reflected in the proportion of the transect area covered by the different cover elements (Table 11, Table 12). The lack of open space with no cover, observed during the summer, could reduce the quality of pond habitats for juvenile salmon, since juvenile salmon appear to move away from complex habitats at night to rest near the bottom in open areas lacking cover (Tabor et al. 2002).

Pond depths were relatively consistent among the sites we sampled (Table 14). In general, nearshore depths were around 1 m, ranging from 0.46 to 1.9 m. Offshore depths averaged just less than 2 m, ranging from 0.96 to 2.61. Depths were consistent between summer and winter sampling events. These depths suggest that only the shoreline would have provided rearing habitat for newly emerged juvenile salmonids, but the rest of the pond habitat would be used after about 4 months of rearing. Tabor et al. (2006) found that most juvenile Chinook salmon in Lake Washington were found in water less than 0.5 m deep through April and that it wasn"t until May that a majority of the fish used depths up to 2 m. However, the dense aquatic vegetation covering the pond bottoms we sampled may influence fish distribution within the ponds, since it may serve as a „false bottom" resulting if fish perceiving the depth as shallower than that we measured (Tabor et al. 2006). The depths of the ponds we surveyed would suggest that they would be relatively productive habitats, but may have reduced overwinter survival relative to deeper ponds (Peterson 1982b).

The bank slope at the sites we surveyed was relatively gradual and became flatter the further you moved from shore (Table 15). There were no major differences at the sites between summer and winter surveys. The bank angles of the first 1.5 m of the pond averaged between 25 and 30^{o} during the summer and winter; ranging from approximately 19 to 37^{o} during the summer and 15 to 51^{o} during the winter. The bank angle from 1.5 to 3 m offshore averaged approximately 12^{o} during summer and winter and ranged from approximately 3 to 33^{o} during the summer and 1.5 to 25^{o} during the winter. These slopes are within the range found to be preferred by juvenile Chinook salmon in riverine habitat (Cedar River, R. Peters, FWS, unpublished data) and thus would likely provide quality habitat for early rearing juvenile salmonids.

The substrate at the pond sites sampled was not very diverse, with only fine substrate (<2mm), substrate from 2-16 mm in size, or aquatic vegetation observed at our transects (Table 16). Aquatic vegetation and fine substrate were the primary dominant substrates during the summer, with aquatic vegetation the most common dominant substrate type (both nearshore and offshore). In contrast to summer observations, fine substrate was the dominant substrate at most sites during the winter. Aquatic vegetation was the subdominant substrate at all but one of the remaining sites (nearshore transect at S-09), where substrate 2-16 mm in size was the subdominant substrate. As discussed above, the presence of dense aquatic vegetation covering the bottom may limit juvenile salmonid use of the ponds at during the summer. This is due to juvenile salmonids preference for open areas away from cover at night (Tabor et al. 2002, R. Peters, FWS, unpublished data).

Table 11. Surface area (ha), perimeter length (m), potential fish use, and the number of sites sampled within off-channel pond habitat identified during the current assessment of the Skokomish Basin (GIS based assessment 1:1,000). Fish zones (i.e., trout zone, chum zone) represent areas that are assumed to be accessible to these fish species. Trout zone includes areas where either cutthroat trout or steelhead were present. See Figure 26 for their location in the Skokomish Basin.

Pond #	Area (ha)	Perimeter (m)	Trout Zone	Coho Zone	Chum Zone	Chinook Zone	Bull Trout Zone	Number of sample sites	
								Summer	Winter
1	0.3	924.6	Yes	Yes	Yes	Yes	Yes	1	1
2	0.4	529.6	Yes	Yes	Yes	Yes	Yes	0	0
3	0.2	753.7	Yes	Yes	Yes	Yes	Yes	0	0
4	0.5	540.0	Yes	Yes	Yes	Yes	Yes	0	0
5	0.2	266.4	Yes	Yes	Yes	Yes	Yes	0	0
6	1.6	2143.8	Yes	Yes	Yes	Yes	Yes	0	2
7	0.2	519.2	Yes	Yes	Yes	Yes	Yes	0	0
8	0.1	236.1	Yes	Yes	Yes	Yes	Yes	0	0
9	0.1	187.0	Yes	Yes	Yes	Yes	Yes	0	0
10	0.1	216.5	Yes	Yes	Yes	Yes	Yes	0	0
11	0.2	522.2	Yes	Yes	Yes	Yes	Yes	0	0
12	3.0	3316.1	Yes	Yes	Yes	Yes	Yes	4	4
13	0.1	397.1	Yes	Yes	Yes	Yes	Yes	0	0
14	1.5	1599.8	Yes	Yes	Yes	Yes	Yes	0	0
15	5.0	6324.4	Yes	Yes	Yes	Yes	Yes	4	8
16	0.4	1429.8	Yes	Yes	Yes	Yes	Yes	0	0
17	0.3	1215.5	Yes	Yes	Yes	Yes	Yes	0	0
18	0.5	702.8	Yes	Yes	Yes	Yes	Yes	0	0
19	0.6	845.4	Yes	Yes	Yes	Yes	Yes	0	0
20	1.4	1756.2	No	No	No	No	No	0	0
21	1.1	624.8	No	No	No	No	No	0	0
22	0.2	422.7	Yes	Yes	Yes	Yes	Yes	0	0
23	0.3	617.0	Yes	Yes	Yes	Yes	Yes	0	0
24	0.4	720.3	Yes	Yes	Yes	Yes	Yes	0	0
25	0.4	265.6	Yes	Yes	No	Yes	Yes	0	0
26	0.5	922.8	Yes	Yes	No	No	Yes	1	1
27	0.4	988.3	Yes	Yes	No	No	Yes	0	0
28	0.2	511.8	Yes	Yes	No	No	Yes	0	0

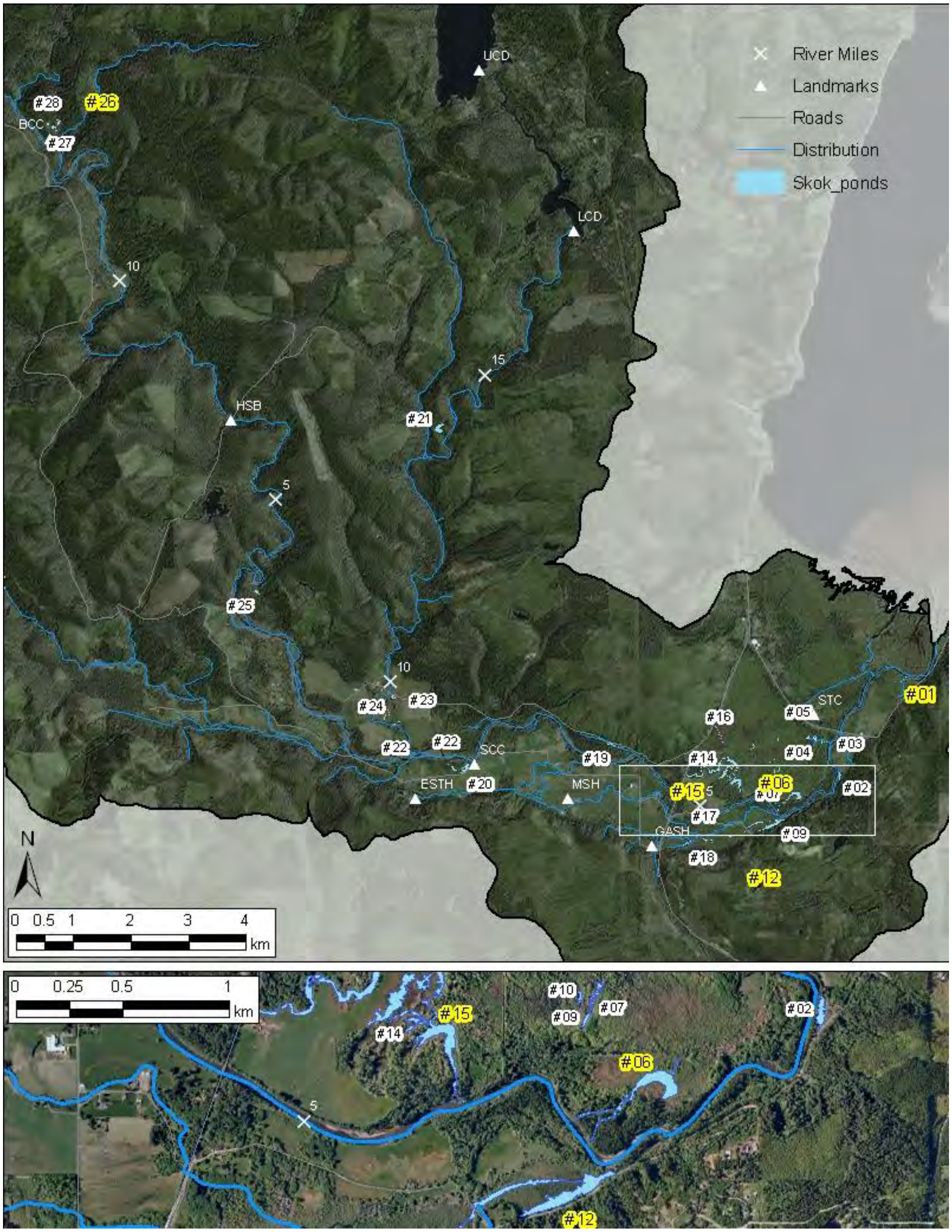

Figure 26. Location of ponds in the Skokomish Basin. Labels in yellow indicate ponds that were sampled for fish abundance and habitat conditions. Ponds labeled with yellow backgrounds contained sites sampled during this study, those with a white background were not. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 12. Proportion of each nearshore transect surface area (450 m^2) comprised of various coarse cover types in the Skokomish Basin ponds during the summer of 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

Season	Pond #	Site	Aquatic vegetation	Terrestrial vegetation	Small woody debris and brush	Small debris piles	Large debris piles	Large woody debris
Summer	1	S-05	0.33	0.03	0.08	0	0	0
	12	S-09	0.67	1.00	0.14	0.39	0.23	0.01
		S-21	0.17	0.50	0.02	0.77	0.27	0
		S-25	0	1.00	0.21	1.00	0	0.22
		S-29	0.20	1.00	0.21	1.00	0	0.02
	15	S-10	0.67	0.11	0.16	0.01	0	0
		S-14	1.00	0	0.01	0.03	0	0.01
		S-19	1.00	0.67	0.02	0.02	0	0
		S-22	1.00	0.67	0	0.09	0	0.01
	26	S-16	0	0	0	0.12	0	0.05
Winter	1	S-05	0	0.33	0.05	0	0	0.02
	6	S-15	0	0.33	0.04	0.07	0.18	0
		S-31	1.00	0	0	0.05	0.17	0.02
	12	S-09	0	0.26	0.17	0.33	0.09	0.03
		S-21	0.16	0.33	1.00	0	1.00	0
		S-25	0.33	1.00	1.00	0.67	0.07	0.01
		S-29	1.00	1.00	0.49	0.40	0	0
	15	S-03	1.00	0	0.07	0.02	0.11	0.00
		S-10	0.33	1.00	0.12	0.05	0.10	0.01
		S-14	0.20	1.00	0	0.01	0	0.01
		S-19	0.33	1.00	0	1.00	0	0
		S-22	0.33	1.00	0	1.00	0.07	0.01
		S-23	1.00	0	0.04	0	0.18	0.03
		S-34	0.50	1.00	0.03	0.07	0.30	1.00
		S-35	0.67	1.00	0.01	0.20	0.00	0.03
	26	S-16	0	1.00	0	0	1.00	0

Table 13. Proportion of offshore transect surface area (450 m^2) comprised of various coarse cover types in Skokomish Basin ponds during the summer 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

Season	Pond #	Site	Aquatic vegetation	Terrestrial vegetation	Small debris piles	Large debris piles	Large woody debris
Summer	1	S-05	0	0	0	0	0
	12	S-09	0.13	1.00	0.63	0	0
		S-21	0	1.00	0.55	0.10	0.02
		S-25	0	1.00	0	0	0
		S-29	0	1.00	0	0	0
	15	S-10	0.67	0	0	0	0
		S-14	1.00	0	0	0	0
		S-19	1.00	0	0	0	0
		S-22	1.00	0	0	0	0
	26	S-16	0	0	0.05	0	0.04
Winter	1	S-05	0	0.50	0	0	0
	6	S-15	0	0	0	0	0.01
		S-31	0	0	0.01	0.03	0.03
	12	S-09	0	0	1.00	0	0
		S-21	1.00	0.04	0.02	0.02	0.01
		S-25	1.00	0	1.00	0.02	0
		S-29	1.00	0	1.00	0	0
	15	S-3	0	0	0	0	0
		S-10	0	1.00	0	0.03	0
		S-14	0	1.00	0	0.03	0
		S-19	0	1.00	1.00	0	0
		S-22	0	1.00	1.00	0	0.01
		S-23	0	0	0	0	0
		S-34	0	1.00	0.01	0.07	0.01
		S-35	0	1.00	0.01	0.04	0.01
	26	S-16	0	1.00	0	1.00	0

Table 14. Mean and standard error (SE) for the depth at nearshore and offshore transects of each sampled Skokomish River pond during summer of 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

		Nearshore		Offshore	
Pond #	Site	Mean (m)	SE	Mean (m)	SE
			Summer		
1	S-05	1.39	0.23	2.33	0.25
12	S-09	0.63	0.06	2.11	0.27
	S-21	0.62	0.05	1.22	0.19
	S-25	1.19	0.11	1.88	0.14
	S-29	1.19	0.16	1.98	0.19
15	S-10	1.02	0.12	1.3	0.15
	S-14	1.12	0.21	1.42	0.17
	S-19	1.06	0.13	1.94	0.14
	S-22	1.42	0.10	2.08	0.15
26	S-16	1.01	0.13	1.26	0.17
Mean	all	1.07	0.086	1.75	0.130
			Winter		
1	S-05	1.90	0.05	1.55	0.15
6	S-15	1.15	0.17	1.65	0.58
	S-31	0.82	0.21	1.97	0.52
12	S-09	0.76	0.10	2.55	0.12
	S-21	0.77	0.07	1.56	0.23
	S-25	1.22	0.19	2.28	0.16
	S-29	1.16	0.19	2.56	0.18
15	S-03	0.76	0.12	0.96	0.28
	S-10	0.81	0.06	2.14	0.23
	S-14	0.64	0.12	1.38	0.42
	S-19	0.71	0.08	2.34	0.27
	S-22	0.99	0.07	2.2	0.09
	S-23	1.06	0.18	1.6	0.30
	S-34	1.23	0.11	2.61	0.20
	S-35	0.98	0.12	2.07	0.12
26	S-16	0.46	0.06	1.02	0.18
Mean	all	0.96	0.084	1.90	0.132

Table 15. Mean slope angle (degree) at 1.5 m and 3 m from shore of nearshore transects in Skokomish Basin ponds during summer of 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

		1.5 m		3 m	
Pond #	Site	Mean	SE	Mean	SE
		Summer			
1	S-05	28.63	5.23	33.32	7.55
12	S-09	19.59	2.90	6.79	2.16
	S-21	19.67	2.14	5.60	3.69
	S-25	34.14	4.69	9.55	4.30
	S-29	32.44	6.45	12.48	4.15
15	S-10	31.15	3.22	6.97	3.34
	S-14	29.55	5.72	15.75	6.51
	S-19	28.58	4.05	15.77	3.53
	S-22	37.72	2.94	17.14	3.44
26	S-16	31.58	5.19	3.53	8.56
Mean	all	29.31	5.78	12.69	8.67
		Winter			
1	S-05	51.36	1.16	1.52	2.75
6	S-15	31.35	2.37	13.37	9.16
	S-31	18.99	4.82	18.32	7.80
12	S-09	21.49	3.05	11.88	3.57
	S-21	22.97	2.24	9.81	1.47
	S-25	28.04	6.31	25.47	2.31
	S-29	29.82	5.97	16.93	6.34
15	S-03	24.59	5.35	3.57	1.81
	S-10	24.79	2.59	7.93	1.89
	S-14	17.50	3.63	11.79	3.77
	S-19	23.33	4.09	3.81	1.20
	S-22	29.29	2.54	10.12	2.56
	S-23	25.47	6.82	20.95	2.67
	S-34	35.17	4.17	10.49	2.51
	S-35	27.04	3.30	14.39	3.10
26	S-16	15.51	3.31	2.78	3.66
Mean	all	26.69	8.38	11.45	6.78

Table 16. Dominant and subdominant substrate types along nearshore and offshore transects of Skokomish Basin ponds. 1=less than 2mm particle size; 2=2-16mm particle size; 7=plants.

			Nearshore		Offshore	
Season	Pond #	Site	Dominant	Subdominant	Dominant	Subdominant
Summer	1	S-05	1	-	1	-
	12	S-09	7	1	1	7
		S-21	1	7	1	7
		S-25	7	1	7	1
		S-29	7	1	7	1
	15	S-10	7	-	7	-
		S-14	7	-	7	-
		S-19	7	-	7	-
		S-22	7	-	7	-
	26	S-16	7	-	7	-
Winter	1	S-05	1	-	1	-
	6	S-15	1	-	1	-
		S-31	1	-	1	-
	12	S-09	1	2	1	7
		S-21	1	7	7	1
		S-25	1	7	7	1
		S-29	1	7	7	1
	15	S-03	1	1	1	1
		S-10	1	7	1	7
		S-14	1	7	1	7
		S-19	1	7	1	7
		S-22	1	7	1	7
		S-23	1	1	1	1
		S-34	1	7	1	7
		S-35	1	7	1	7
	26	S-16	1	-	1	-

Water temperatures at the pond sites we sampled were within appropriate ranges (Bjornn and Reiser 1991; Richter and Kolmes 2005) for juvenile salmonids (Table 17). Summer temperatures averaged approximately 15°C, which is well below lethal limits. These temperatures exceeded the optimum temperature (8-11°C) for growth efficiency listed by Brett et al. (1969), but not those reported (14-17°C) by Richter and Kolmes (2005). The differences observed in the temperature ranges providing for the most efficient growth between Brett et al. (1969) and Richter and Kolmes (2005) are likely due to differences in procedures and/or acclimation temperatures used prior to the experiments. Thus, based on these different results, it"s likely that the temperatures we observed are at the upper end of the temperatures providing for optimum growth of juvenile salmonids. Four sites had temperatures greater than 19°C, which is still below lethal levels (Bjornn and Reiser 1991, Marine and Cech 2004). As expected, temperatures were much cooler in the winter than during the summer. The observed temperatures were within the optimum range for growth efficiency listed by Brett et al. (1969), but below those listed by Richter and Kolmes (2005). Thus, winter temperatures appear to be on lower end of the temperature range providing for optimal growth efficiency.

DO was relatively consistent between nearshore and offshore transects during both summer and winter (Table 17). Dissolved oxygen (DO) was slightly greater at the nearshore transect than the offshore transect, possibly due to wave and/or photosynthesis activity. However, four summer nearshore sites had DO values less than 5 mg/l, which is generally considered detrimental to salmonids. At two nearshore sites and four offshore sites, summer DO levels were less than 3 mg/l. Additionally, DO levels often fluctuate diurnally and even lower levels may have occurred early in the morning before aquatic macrophytes began actively photosynthesizing. As expected, DO values were also much greater during the winter surveys than they were during the summer surveys, and were also a bit greater in nearshore areas than offshore areas. DO levels during the summer were less than 8 mg/l, where food conversion efficiency in salmonids is inhibited (Davis 1975; Alabaster et al. 1979). The DO levels measured in the Skokomish River pond habitats was less than that observed in off-channel ponds in other systems. For example, Peterson (1982a) measured DO levels in off-channel ponds of the Clearwater River during the winter and found DO levels were greater than 7 mg/l in all cases and generally greater than 10 mg/l. Given this, further and more detailed evaluations of DO in these off channel ponds are warranted.

Water turbidity was relatively low among nearshore and offshore transects during summer and winter (Table 17). Water turbidity levels of less than 3 Nephelemetric Units (NTUs), as generally observed in this study, are generally not considered to impact juvenile salmonids foraging (i.e., Bash et al. 2001) or growth (Sigler et al. 1984). In fact, juvenile coho salmon don‟t avoid turbid waters until turbidity levels reach about 70 NTU (Bisson and Bilby 1982). Although, the turbidity levels we observed during our sampling were low, this could be somewhat biased by the fact that we didn‟t sample during high flow events, since we wouldn‟t have been able to complete our snorkel surveys to assess fish abundance. Thus, our results may be biased towards lower turbidity levels since turbidity may have increased in the ponds during high flow events, especially if the ponds were inundated. Although, this may have occurred, our sampling suggests that potential turbidity issues would likely be short in duration, thereby limiting their impacts.

Water pH was lower in offshore transects relative to nearshore transects during both summer and winter, and was also reduced during the winter relative to summer (Table 17). The differences in pH values we observed between summer and winter are possibly due to differences in density and photosynthesis activity of aquatic vegetation. Water pH measurements were taken shortly after dusk and pH levels may have been somewhat lower at dawn during the winter due to reduced photosynthesis activity. Regardless, all pH levels appear to be within a normal range for juvenile salmonids. The acidic conditions observed at the offshore transects during the winter is concerning, since the levels observed (i.e. pH ~ 5.1) would potentially impact survival and impair smolt development (McCormick et al. 2009).

Salinity was extremely low (< 0.05 ppt) at the pond sites we sampled (Table 17), suggesting that saltwater intrusion rarely occurs. In fact, nearly all values were zero and those that weren"t, were close to zero.

Based on the water quality data we collected, there does not appear to be any major water quality issue during the winter in pond habitats of the Skokomish watershed. However, summer water quality measurements indicated DO levels could be low enough to impact salmonids. Two sites, S-9 and S-21, had DO levels less than 3 mg/l, yet abundance of coho salmon fry was relatively high. DO levels were only taken at one spot in the water column and coho salmon fry may be using other areas in the water column with greater DO levels. To get a more complete picture of DO levels, measurements need to be taken diurnally throughout the summer and throughout the water column. Additionally, summer DO levels may fluctuate from year to year based on weather conditions and thus, DO levels need to be measured over several years.

Off-channel habitat in the Skokomish Basin appears to be abundant and in relatively good condition relative to providing habitat for juvenile salmonids. Twenty-six ponds were determined to lie within the anadromous zone, with 23 of these likely accessible to Chinook salmon. Water depths and bank angles associated with the pond margins were within the preferred range for juvenile salmonids. The water depths (<3 m) would be expected to provide productive habitats that would provide ample food for juvenile salmonids; however, overwinter survival may be somewhat reduced at these depths (Peterson 1982b). The dense mats of aquatic vegetation covering the bottom could reduce habitat quality for fish since open spaces preferred at night (Tabor et al. 2006) would be lacking. However, this would need to be evaluated further before any management recommendations could be proposed. With the exception of DO, water quality within the ponds is within the appropriate range for juvenile salmonids. Thus, off-channel pond habitat appears to be abundant and of sufficient quality to provide substantial rearing for juvenile salmonids.

Table 17. Mean and SE values for Dissolved Oxygen (DO) (mg/l), temperature, turbidity (NTU), pH, and salinity (parts per thousand (ppt) across all sampled Skokomish River pond sites in both nearshore and offshore transects during summer and winter.

	Nearshore				Offshore			
	Summer		Winter		Summer		Winter	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
DO (mg/l)	6.27*	0.82	8.09	0.30	5.41*	0.79	7.10	0.73
Temperature (°C)	15.62	1.46	8.69	0.29	15.41	1.46	7.58	0.77
Turbidity (NTU)	2.78	0.67	2.17	0.20	2.81	0.76	1.08	0.32
pH	8.97	0.05	6.79	0.88	8.50	0.51	5.09	0.76
Salinity (ppt)	0.03	0.02	0.01	0.01	0.02	0.01	0.04	0.04

* Four data points each were less than 5mg/l

Combined, 9,000 fish were observed along 52 transects (nearshore/offshore and summer/winter combined (Table 18). The total area surveyed of nearshore transects was only 50% larger than offshore transects; however, 7.4 times as many fish were observed along the nearshore transects as the offshore transects. The number of fish per transect was generally higher during the summer than the winter (summer, 376 fish/transect; winter 261 fish/transect). This was due in large part to the large number of small juvenile coho salmon observed during the summer along some transects. There also appeared to be large differences in fish species composition and abundance between ponds. For example, only a few brook trout (n = 35; 8.8 fish/transect) were observed in Pond #26; whereas, in Pond #15 5,598 fish were observed (233 fish/transect) representing 10 fish species. Sixty-four percent of all fish were threespine stickleback, which were commonly observed in both summer and winter. Juvenile salmonids consisted primarily of coho salmon (90.7% of all juvenile salmonids). Other juvenile salmonids included Chinook salmon, cutthroat trout, and chum salmon. Large trout were frequently encountered in ponds. Based on other sampling, the vast majority of trout in ponds appear to be cutthroat trout. Sculpin, which are a common inhabitant of lowland systems of the Puget Sound, were occasionally observed; however, their abundance was lower than expected. Dense vegetation and woody debris as well as their coloration patterns (well-camouflaged) may have limited our ability to observe them. The number of non-native fishes included 35 brook trout in Pond #26 and 20 largemouth bass, one unidentified ictalurid, and one common carp in Pond #15.combined;

Table 18. Number of fish observed along 150-m transects in Skokomish River ponds, summer 2008 (8/20-9/24) and winter of 2009 (2/23-4/8). Trout includes cutthroat trout and steelhead. Other fish includes lamprey, chum salmon, brook trout, common carp, catfish, largemouth bass, and flounder.

Location	Season	Pond #	Number of transects	Chinook	Coho	Trout	Stickleback	Sculpin	Other
Nearshore	Summer	1	1	0	787	1	77	13	2
		12	4	22	728	26	565	14	0
		15	4	0	27	0	1,470	1	14
		26	1	0	0	0	0	0	14
		total	10	22	1,542	27	2,112	28	30
	Winter	1	1	0	8	0	1	1	1
		6	2	10	134	1	34	2	1
		12	4	17	156	74	258	69	2
		15	8	138	318	61	2,805	12	10
		26	1	0	0	0	0	0	3
		total	16	165	616	136	3,158	84	17
Offshore	Summer	1	1	0	130	2	0	3	0
		12	4	21	5	1	7	0	0
		15	4	0	90	1	384	0	3
		26	1	0	0	3	0	0	15
		total	10	21	225	7	391	3	18
	Winter	1	1	0	9	5	5	60	4
		6	2	3	40	3	48	11	1
		12	4	0	0	6	0	3	0
		15	8	23	89	3	71	4	7
		26	1	0	0	0	0	0	3
		total	16	26	138	20	127	78	12

A series of univariate regression analyses were conducted to examine the relationship between pond habitat variables and fish abundance. Habitat variables examined included percent cover (aquatic and terrestrial vegetation, woody debris piles, and large woody debris), complexity score (combined score of cover types), depth, slope, and predator abundance (density of large predatory fishes). Densities of each major fish category (threespine stickleback, sculpins, trout, juvenile coho salmon, and juvenile Chinook salmon) were analyzed separately. Because few fish were observed in the offshore transects, analyses were limited to the nearshore transects. In general, few habitat variables were closely related to nearshore fish abundance. The strongest relationship was between winter trout density and total coarse cover area as well as complexity score (Figure 27). This relationship was substantially reduced if each of the cover types was examined separately with trout density.

Regression analyses were also conducted just for Pond #15 transects (number of transects: summer, n = 4; winter, n = 8) to determine if using one pond would reduce the variability between transects. Other ponds could not be used due to a small sample sizes. In general, there was little improvement in the regression analyses by just using Pond #15. However, the density of juvenile Chinook salmon was slightly negatively related to mean depth and slope (Figure 28). These results are consistent with research of juvenile Chinook salmon in lentic waters (Sergeant and Beauchamp 2006; Tabor et al. 2006). Additionally, trout density was slightly positively related to slope ($r^2 = 0.33$).

We also compared substrate type with fish densities. Because there were only two categories (with and without plants), we used the Mann-Whitney *U* test to make comparisons. For winter samples, the only significant comparison was with trout density (Figure 29). Transects where the dominant substrate was plants had a significantly higher density of trout than transects with sand/silt as the dominant substrate. Summer sample sizes were too small to make any comparisons. However, the two sites with the highest number of juvenile coho salmon in the summer were also the only two sites where plants (aquatic macrophytes) were not the dominant substrate type. This result may be an artifact of our surveys being only conducted at night. Juvenile coho salmon appear to move away from complex habitats at night to rest near the bottom in more open areas (Tabor et al. 2002).

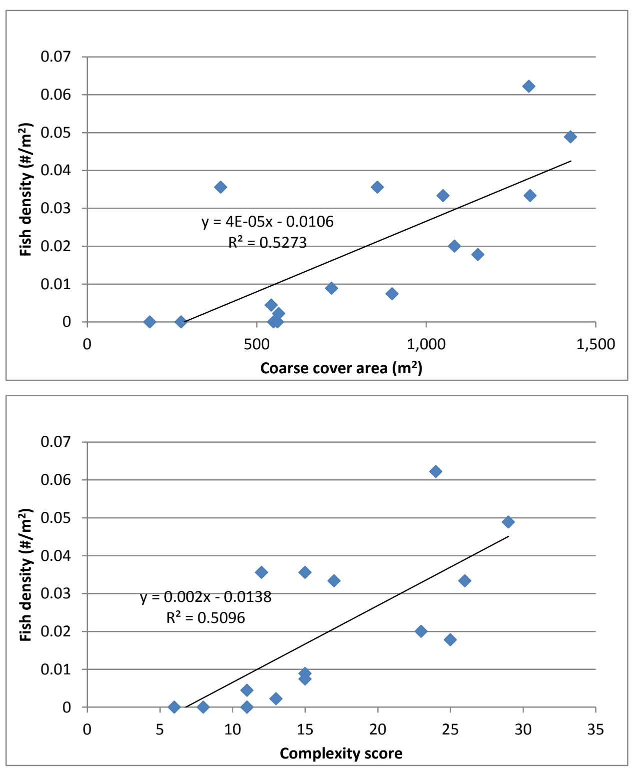

Figure 27. Relation between cover (total cover area and a complexity score) and winter trout density (#/m^2) in Skokomish Basin ponds. Cover area and the complexity score incorporate aquatic and terrestrial vegetation, small and large woody debris piles, and large woody debris. Based on other sampling, the vast majority of trout in ponds appear to be cutthroat trout.

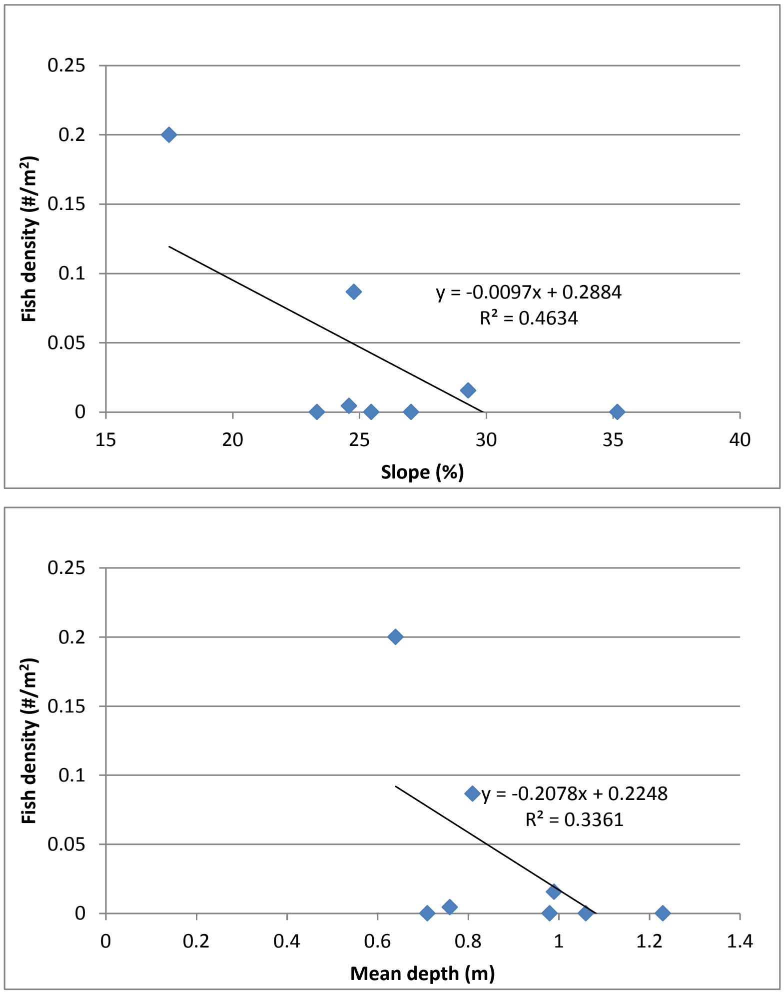

Figure 28. Relation between slope (%) and mean depth (m) with juvenile Chinook salmon density (#/m^2) in Pond #15, winter 2009 (2/24-3/26).

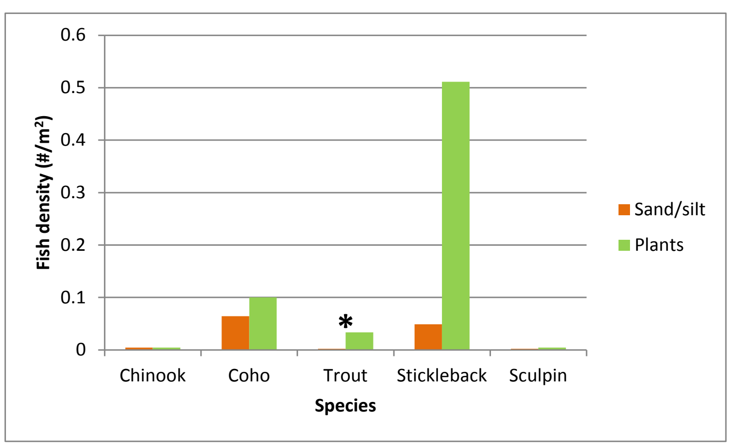

Figure 29. Winter median fish density (#/m^2) of transects with two different dominant substrate types. Asterisk indicates a significant difference between the two substrate types (Mann-Whitney *U* test; $P < 0.05$).

Results of our pond surveys indicated off-channel ponds are routinely used by salmonids and other fishes. Ponds can provide valuable habitat during both winter and summer. However, ponds are generally considered more important for winter habitat by providing refuge from high discharge events (Peterson 1982a) and providing ideal foraging conditions (Peterson 1982b). In some systems, winter habitat limits salmonid smolt production and off-channel ponds can be an integral element of winter habitat. For example, enhanced off-channel ponds on Fish Creek in Oregon represented less than 1% of the Fish Creek Basin habitat but contributed 50% of the coho salmon smolt production (Reeves et al. 1991). In the Skokomish Basin, off-channel ponds appear to provide valuable winter habitat for coho salmon, Chinook salmon, and cutthroat trout. The only salmonid species to use the ponds extensively in the summer was coho salmon. The importance of off-channel ponds as summer habitat is unclear. Ponds likely provide good foraging conditions; however, low DO levels, possible increased predation risk (e.g., from largemouth bass), and reduced connectivity to the mainstem may limit their value as summer habitat.

Construction and rehabilitation of off-channel ponds is considered a valuable tool in habitat restoration efforts (Frissell and Ralph 1998). We identified 28 different off-channel ponds with a total area over 20 ha. Therefore, a fair amount of pond habitat already exists but habitat conditions and connectivity to the mainstem are not well known. A closer examination of each pond is needed to ensure that they are adequately connected to the mainstem. If they are not well connected, rehabilitation efforts are needed. Managers should also look for new opportunities where a pond could be constructed. Shallow ponds (maximum depth < 2 m) are more productive than deeper lakes (maximum depth > 3 m) but juvenile salmonids may have lower survival rates in shallow ponds (Peterson 1982b). An ideal pond may be a shallow pond that has numerous cover aspects (e.g., woody debris) to reduce predation risk. Shallow ponds may be less expensive to construct but may require more maintenance once sediments and vegetation limit the amount of open water.

Rehabilitation efforts could also consider the removal of non-native predatory fishes. Of the five ponds we examined, two had non-native predatory species that could impact survival of juvenile salmonids and other fishes. An inventory of all ponds is needed to determine the overall distribution of non-native fishes. Largemouth bass were present in Pond#15. Largemouth bass are native to eastern North America and have been widely introduced in North America including the Pacific Northwest. They typically inhabit ponds, lakes, and slow-moving rivers. Their greatest impact on salmonid populations appears to be in rearing lakes of juvenile coho salmon (Reimers 1989; Bonar et al. 2005). Adult brook trout were present in Pond#26. Brook trout are also native to eastern North America and have been widely introduced. In lakes where they occur, they appear to an important predator of juvenile salmonids inhabiting the littoral zone (Biro et al. 2008).

Current Habitat Conditions for All Species: Estuarine and Nearshore Habitat

The Skokomish estuary is the largest and most complex river estuary in Hood Canal, historically covering 799 ha (1,974 acres) at the Skokomish River mouth and Hood Canal interface (Todd et al. 2006). However, direct (diking) and indirect (sediment inputs, water withdrawal) effects have altered the estuary significantly. Habitats have been altered leading to the Skokomish stream-delta complex being rated as severely impaired (Todd et al. 2006).

The Skokomish estuary likely to consist of diverse array of habitats including, old-growth riparian forests, emergent freshwater marshes, salt marshes, tidal channels, and mud flats historically (Skokomish Tribe and WDFW 2010). However, the current estuary has been significantly changed from historic conditions due to human alterations. Human induced changes to the Skokomish estuary began prior to 1885, when the Bureau of Indian Affairs facilitated land clearing for agricultural and residential uses (Todd et al. 2006). In addition, the land management activities in the upper watershed would have influenced the physical characteristics near this time by increasing bank erosion and sediment delivery to the system. Extensive diking in the estuary began in the late 1930s, which would have isolated habitats and influenced hydraulic (both riverine and tidal) and sediment transport characteristics in the estuary.

Direct changes to the estuary have eliminated the old-growth riparian forests and isolated tidal channels. Bortleson et al. (1980) classified historic and current riverine nearshore wetlands in the Skokomish Basin as intertidal (5 km^2 vs. 4.5 km^2) and subaerial (2.1 km^2 vs. 1.4 km^2) and determined that they have been reduced by 10 and 33 percent, respectively. Collins and Sheikh (2005) classified these same historic habitats as estuarine (2.6 km^2), riverine tidal (0.3 km^2) and palustrine (4.0 km^2). Of this habitat a majority was composed of emergent estuarine wetlands (~70%) with the remaining wetlands divided nearly equally among scrub-shrub estuarine and riverine-tidal wetlands (Collins and Sheikh 2005). In contrast, the current Skokomish estuary lacks riverine-tidal wetlands, while emergent estuarine wetlands are similar to their historic values and scrub-shrub estuarine wetlands have nearly doubled in their availability (Collins and Sheikh 2005).

Recent restoration of the Skokomish estuary has been reversing the loss of estuarine habitat. Restoration began naturally in the mid-1990s when the outer dike of Nalley Island was breached during a storm. Additional estuarine restoration occurred recently with extensive dike removal and borrow ditch filling at Nalley Slough (2007) and Nalley Island (2010). These restoration projects reclaimed approximately 324 acres of estuarine habitat in the Skokomish estuary (ESRP 2010).

Indirect changes to the estuary have also occurred and have substantially influenced current habitat conditions. Increased sediment inputs and the diversion of water out of the basin in the upper basin have resulted in physical changes in the estuary. Deposition has occurred on the inner delta, while erosion has occurred on the outer delta, resulting in the steepening of the delta surface (Jay and Simenstad 1996). The total area of unvegetated tidal flats has decreased by about 2%, while highly productive low intertidal surface area (15-19%) and eelgrass (*Zostera marina*) habitat (17%) have decreased substantially more. Aggradation in the estuary has also resulted in the development of salt marsh islands and general extension of salt marshes within the estuary. In addition, sediments have become finer within the inner delta (Jay and Simenstad 1996).

We found little information regarding eelgrass habitat specific to the Skokomish estuary. Jay and Simenstad(1996) state that eelgrass habitat in the estuary has been reduced by 17% due to increased sediment deposition and delta steepening resulting from increased sediment inputs upstream and out of basin water diversion. Thom and Hallum (1990) report that between 32.5 and 35.2 percent of Hood Canal shoreline is occupied by eelgrass based on surveys completed by WDF between 1975 and 1989 and the coastal zone atlas (1977). Thus, it appears that the loss of eelgrass habitat throughout the greater Hood Canal area has not been as great as that in the Skokomish estuary.

Riverine and estuarine aggradation has also impacted tidal influence in the stream-estuary ecotone, which appears to be shifting downstream (Skokomish Tribe and WDFW 2010). It was reported to extend to approximately 14.5 km (9 mi) upstream of the river mouth to the an area near the confluence of the North Fork and South Fork Skokomish Rivers (Jay and Simenstad 1996). Skokomish Indian Tribe and WDFW (2010, citing Marty Ereth, former Skokomish tribal biologist, personal communication) place the extent at approximately 5.6 to 6.4 km upstream of the mouth (3.5-4 mi). Our fish collection data, suggests that tidal influence may actually have shifted even further downstream to approximately 4 km (2.5 mi) upstream of the mouth.

Although the authors realize that the nearshore habitat adjacent to the Skokomish estuary provide important habitat for juvenile salmonids and other fish species found in Hood Canal, these nearshore areas are outside the scope of this GI. Thus, they are not covered in this report. In addition, Puget Sound nearshore habitats have been described in detail in the Puget Sound Nearshore Ecosystem Restoration Project, which is a cost-shared GI by the USACE and WDFW.

Skokomish Basin Conditions: Biological Characteristics

Dating back to the early 1900s, biologists have used various metrics describing aquatic biological communities to elucidate the status and trends of water bodies, especially lakes and rivers (Cairns and Pratt 1993). In particular, benthic macroinvertebrates and algae have been commonly used as indicators of fresh water quality. Benthic macroinvertebrates are a group of organisms (insects, worms, and crustaceans) that reside in the benthos (bottom substrates) of freshwaters (e.g., rivers and lakes) for at least part of their life cycle. Those organisms that are retained in sampling nets of mesh sizes > 200-500 µm are termed "macro", which distinguishes them from other more microscopic animals and multicellular organisms. Periphyton is a term that describes a community of autotrophs and detritivors growing on surfaces of the benthos. The largest component of periphyton is algae, particularly diatoms that use sunlight to fix carbon dioxide (CO_2) in the biochemical process of photosynthesis. Periphyton forms the base of the aquatic food web and is grazed upon by many different macroinvertebrate taxa (as well as some vertebrates, such as larval frogs), which in turn provide food for stream dwelling fish, birds, and herepetofauna.

Biological monitoring, or biomonitoring, is the practice of using biological responses to evaluate changes in the environment. Although changes can be natural, most biomonitoring programs have been established to detect changes due to anthropogenic impacts. Aside from changing in predictable ways to the impacts of pollution and habitat degradation, macroinvertebrates and periphyton have qualities that make them good candidates as bioindicators. They are ubiquitous, have a large number of species and a diverse array of life history requirements, spend long periods of time (or their entire life) in the effected habitat, and are relatively sedentary compared with the spatial grain and extent used in most biomonitoring studies. Benthic macroinvertebrate communities, in particular, integrate the effects of multiple stressors across multiple spatial and temporal scales and, in effect, continuously monitor the conditions of the water they inhabit (Rosenberg and Resh 1993).

We collected periphyton and macroinvertebrates samples from the same 29 locations in the Skokomish River watershed from 25 August - 14 October, 2009 in riffle habitats. Details of the methods used to collect the samples can be found in Appendix C.

Primary and Secondary Producers

Primary Producers: Periphyton

We collected periphyton from the same 29 locations in the Skokomish River watershed, including sites in the mainstem, South Fork Skokomish, North Fork Skokomish, and 5 different tributaries. Periphyton are a group of organisms typically used in bioassessments worldwide (e.g., Lange-Bertalot 1979, Van Dam et al. 1994, Patrick 1973). We analyzed the standing crop, or amount of biomass present at the time of sampling as well as the diatom community structure based on taxa richness and relative abundance. Taxa richness, the total number of unique diatom taxa found at a given site, averaged 32 species (range 13 – 56; Table 19) Although taxa richness was higher in mainstem sites (35) than in tributary sites (27), this difference was not statistically significant (Kruskall-Wallis test = 3.0, $P = 0.08$). Shannon diversity ($base_2$) averaged 3.31, ranged from 0.60 to 4.56. The amount of chlorophyll-a, an estimate of the algal component of periphyton standing crop, averaged 26.5 mg/cm^2 (range 2.3 – 207.9, Table 19).

We used periphyton as bioindicators by calculating numeric biocriteria for each site based on the taxa present and their abundances. These biocriteria are based on the concept that certain taxa will increase or decrease in abundance in the presence of a particular disturbance (see appendix C for more details). Scores for the three biocriteria metrics generally scored well across all mainstem and tributary sites (Table 19). Taxa derived scores for the siltation index, pollution index, and metals index showed 90%, 100%, and 59% of the streams scoring at the "excellent" level, respectively. The majority of the sites not scoring in the excellent category for metals scored in the "good" category, suggesting that overall metal impairment is not widespread in the Skokomish River watershed. The only site scoring a "poor" ranking for any metric was Pine Creek, which showed possible impairment from metals (Table 19). This site had the lowest diatom richness (13) and Shannon diversity (0.60) of all the sites sampled. The scores for the Montana bioindex, a multimetric index similar to Index of Biotic Integrity (IBI) and based on Montana streams, revealed that the 89% and 64% of the mainstem and tributary sites were in good or excellent condition, respectively.

Figure 30. Locations where periphyton and invertebrate samples were collected during the summer of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 19. Summaries of diatom assemblage metrics and bioindicator scores for 29 study sites where periphyton was sampled in the Skokomish River watershed. Bioindicator scores for siltation, pollution, and metals impacts, as well as a B-IBI based on diatom assemblages, were derived from work in Montana (Bahls 1993, Teply and Bahls 2005) which represents one of the most comprehensive regional studies available. Full summary statistics are provided in Appendix JJD_2.

Site	Site Code	Taxa Richness	Shannon Diversity*	Chl-a (mg/cm^2)	Siltation Biocriteria	Pollution Biocriteria	Metals Biocriteria	Montana Bioindex
MS Skok	2-23	45	4.31	33.42	Excellent	Excellent	Excellent	Good
MS Skok	2-31	41	3.92	18.48	Excellent	Excellent	Good	Good
MS Skok	2-28	50	4.56	33.31	Excellent	Excellent	Excellent	Excellent
MS-ONP Index	ONP Index	26	2.62	15.44	Excellent	Excellent	Excellent	Good
NF Skok	2-01	30	2.61	207.92	Excellent	Excellent	Good	Good
NF Skok	2-26	56	3.87	7.46	Excellent	Excellent	Excellent	Good
SF Skok	2-06	42	3.99	17.77	Excellent	Excellent	Excellent	Excellent
SF Skok	2-12	20	2.24	6.74	Excellent	Excellent	Fair	Fair
SF Skok	2-30	26	2.94	10.75	Excellent	Excellent	Good	Good
SF Skok below Canyon	2-33	47	4.21	25.92	Excellent	Excellent	Excellent	Excellent
SF Skok	2-37	38	3.82	7.40	Excellent	Excellent	Excellent	Good
SF Skok	2-38	22	3.22	4.34	Excellent	Excellent	Good	Good
SF Skok	2-42	19	2.77	42.52	Excellent	Excellent	Good	Fair
SF @ Vance	SF Vance	28	2.87	8.87	Excellent	Excellent	Excellent	Good
SF Skok Old NF/SF CF	SFONF	24	3.05	53.66	Excellent	Excellent	Excellent	Good
MS Skok below new CF	SFNNF	41	3.57	2.33	Excellent	Excellent	Good	Good
SF Skok	2-08	42	4.24	70.10	Good	Excellent	Excellent	Good
SF Skok	2-10	35	3.71	17.72	Excellent	Excellent	Excellent	Good
Browns Cr.	2-14	29	3.50	13.14	Excellent	Excellent	Excellent	Good
Browns Cr.	2-17	28	3.37	14.08	Good	Excellent	Excellent	Good
Church Cr.	2-15	18	2.15	24.80	Excellent	Excellent	Good	Fair
McTaggert Cr.	2-18	25	2.81	3.12	Excellent	Excellent	Excellent	Fair
McTaggert Cr.	2-64	28	3.16	26.42	Excellent	Excellent	Good	Good
McTaggert Cr.	2-67	30	3.47	7.85	Excellent	Excellent	Excellent	Good
McTaggert Cr.	2-69	26	2.82	16.46	Excellent	Excellent	Good	Good
Vance Cr.	2-13	34	3.74	10.07	Fair	Excellent	Good	Fair
Vance Cr.	2-29	31	3.93	20.16	Excellent	Excellent	Excellent	Good
Vance Cr CF	Vance	31	3.95	16.07	Excellent	Excellent	Excellent	Excellent
Pine Cr.	2-63	13	0.60	31.61	Excellent	Excellent	Poor	Poor

* Shannon diversity based on Log(base2)

Secondary Producers: Macroinvertebrates

We also collected benthic macroinvertebrate samples using a slack sampler, a net with 500 µm mesh used for sampling benthic organisms that captures dislodged individuals from a 1.25 m^2 portion of the river bottom. We conducted this sampling concurrent with the 29 locations where we collected periphyton (Table 20; Figure 30; see appendix C for additional details on sampling and processing methods). Across all sites, invertebrate abundance averaged 6835 individuals per sample (range 1578 – 18,648), high values that are generally indicative of waters in good condition with high primary and secondary productivity. Differences between mainstem Skokomish River sites (mean 7232, Standard Deviation (SD) = 3380) and tributary sites (mean 6187, SD – 5238) were not statistically different (t = 0.66, P = 0.52). Taxa richness, or the total number of unique taxa at each site, averaged 48 (range 37-66) and was moderate to high across sites. There were no sites with relatively few taxa, a common effect on macroinvertebrate communities inhabiting degraded waters. Differences between mainstem (mean 46.4, SD = 6.5) and tributary (mean 51.4, SD = 6.1) were statistically different (t = -2.1, P = 0.05). The relatively high taxa richness and abundance was reflected in Shannon diversity values that averaged 2.86 and ranged from 1.92 – 3.40. Differences in Shannon diversity were not different between mainstem and tributary sites (t = -0.88, P = 0.39).

Similar to the approach taken with periphyton, we calculated two multimetric indices for each location and estimated the biological condition based on comparisons with other data that spanned conditions from severely degraded to relatively pristine reference conditions. The B-IBI scores based on Karr"s (1998) index showed that none of the sites sampled were degraded to a level for B-IBI classification of low biological integrity (Table 20). Of the 18 Skokomish River sites, 15 were scored as having moderate biological integrity and 3 were scored as having high biological integrity. This was in contrast to the tributary sites, which had a much higher proportion of sites scoring in the highest integrity category. Of the 11 tributary sites, nine were rated as having high biological integrity. The four sites in McTaggert Creek were scored as 48, 48, 50, and 50, sites in Brown"s and Church Creeks scored > 46, and Pine Creek scored 48 (Table 20), with the highest possible index score being 50. The only two tributary sites that scored moderate condition were in Vance Creek. Specific details of the 10 metric scores used to calculate Karr"s B-IBI, as well as other biocriteria for each site are provided in an appendix (Appendix C).

When Celedonia"s (2004) large river B-IBI was used, the Skokomish River sites had higher scores than the scores based on Karr"s B-IBI, which was developed for smaller, wadeable streams. The large river B-IBI had 14 sites scored as being in excellent condition and 4 sites in good condition. Although there were qualitative differences between the two multimetric approaches, this should be expected because the criteria that they use to make comparisons are based on different metrics and a different suite of reference streams and rivers. Also, Celedonia"s B-IBI site ranking has 4 categories (excellent, good, fair, poor) whereas Karr"s index has three categories, which may also lead to differences in the results between the two indices. Nevertheless, the two B-IBI indexes were in general agreement that none of the 18 Skokomish River sites were of low/poor biological integrity.

Both of the B-IBIs used for assessment of Skokomish watershed condition, one for streams and smaller rivers and the other for larger rivers, strive to balance structural and functional community attributes (Karr and Chu 1999, Celedonia 2004). These multimetric indices are expected to discriminate among differentially impacted sites based on independently derived criteria that likewise discriminates, but is often more expensive to conduct, among gradients of disturbance. As pointed out by Caledonia (2004), the metrics selected are but a small subset of available attributes and should balance structural and functional categories, respond to gradients of human disturbance in a predictable fashion, and can effectively separate minimally disturbed from severely impacted sites.

We also created a graphical representation of a suite of metrics for each site, inclusive of the 10 metrics used for Karr"s index as well as a suite of other informative metrics (Figure 31). This approach shows a matrix of columns (sites) and rows (biocriteria metrics) with each cell in the matrix being colored according to the Karr"s B-IBI score for that metric at a particular site. The color scheme used is that of a heat map, where red indicates low biological condition, yellow indicates moderate biological condition, and green indicates high biological condition. The columns are arranged into groups of mainstem, north Fork Skokomish, south Fork Skokomish, and tributary sites. Reading the heat map allows for visual interpretation of how each metric score varies across different study sites (reading across a row), as well as indicating the biological condition of a particular site is across a suite of different macroinvertebrate metrics that are generally indicative of impairment (reading down a column).

The heat map (Figure 31) reveals some interesting trends in metric scores useful for interpreting differences in biological condition, especially between mainstem and tributary sites. Particularly notable is that long-lived taxa in the mainstem Skokomish River watershed are depauperate, with 75% of mainstem, 50% of North Fork Skokomish, 75% of the South Fork Skokomish, and 45% of tributary sites having low numbers of long-lived macroinvertebrate taxa. This could be due to a lack of channel roughness caused by high embeddedness (see habitat results below) decreasing the quantity of interstitial spaces in the stream bed, the lack of habitat complexity, scour effects of a highly mobile river bottom, or the lack of wood boles or other habitat features that long-lived species use as spatial refugia during high flows. A shift in the proportion of long-lived to shorter-lived taxa following disturbance has been shown for multiple trophic levels and taxonomic groups, including stream macroinvertebrates (e.g., Davies and Jackson 2006). Another functional taxonomic attribute, the percent of shredder macroinvertebrates, was also low. This invertebrate group contains a wide range of taxa that feed upon allochthonous organic material provided by surrounding riparian forests and represents an important nutrient source for stream communities (reviewed by Cummins et al. 1989). The course particulate organic matter processed by shredders into fine particulate matter is utilized by other invertebrate species along the river continuum (Vannote et al. 1980). The paucity of shredders present could be due to the fact that most of the sites occurred in stream and river reaches with low vegetation and riparian canopy cover. Also, lack of channel and habitat complexity, especially log jams and other features that would help retain allochthonous material, could be playing a role in the paucity of shredders present.

Table 20. Summaries of macroinvertebrate assemblage metrics and B-IBI scores for 29 study sites where invertebrates were collected from riffle habitats in the Skokomish River watershed. The B-IBI was based on Karr (1998) and calculated using 10 metrics whereas the Large River B-IBI of Celedonia (2004) was based on 9 metrics (see text). A more comprehensive set of macroinvertebrate assemblage statistics are available in Appendix JD_1.

Site	Site Code	Total Abundance	Taxa Richness	Shannon Diversity	Karr‟s B-IBI*	Lg. River B-IBI**
MS Skok	2-23	2388	42	2.30	30-M	8.3-E
MS Skok	2-31	5078	53	3.11	40-H	9.4-E
MS Skok	2-28	3992	49	2.96	36-M	8.3-E
MS Skok ONP Index	ONPindex	5986	47	3.19	40-H	9.4-E
NF Skok	2-01	9543	46	3.10	38-M	10.0-E
NF Skok	2-26	9792	41	2.39	38-M	8.3-E
SF Skok	2-06	1832	46	2.82	44-H	7.2-G
SF Skok	2-12	12,864	40	2.77	36-M	8.9-E
SF Skok	2-30	12,288	48	3.09	40-M	8.9-E
SF Skok below Canyon	2-33	3681	66	3.34	38-M	9.4-E
SF Skok	2-37	5356	46	3.01	38-M	9.4-E
SF Skok	2-38	11,232	40	2.70	36-M	7.8-G
SF Skok	2-42	6276	52	2.95	42-M	9.4-E
SF @ Vance	SF Vance	7349	49	3.14	38-M	8.9-E
SF Old NF/SF CF	SFONF	8144	47	2.58	32-M	8.3-E
MS Skok below new CF	SFNNF	5032	44	2.68	36-M	8.3-E
SF Skok	2-08	11,271	42	2.65	36-M	6.1-G
SF Skok	2-10	8064	37	1.92	30-M	6.7-G
Brown‟s Cr.	2-14	3294	46	2.44	40-H	n/a
Brown‟s Cr.	2-17	4592	50	3.02	42-H	n/a
Church Cr	2-15	2796	46	3.00	40-H	n/a
McTaggert Cr.	2-18	5324	60	3.40	50-H	n/a
McTaggert Cr.	2-69	5078	60	3.24	48-H	n/a
McTaggert Cr.	2-67	5151	60	2.89	48-H	n/a
McTaggert Cr.	2-64	2957	47	2.79	50-H	n/a
Vance Cr.	2-13	4723	46	2.96	46-H	n/a
Vance Cr.	2-29	13,920	47	2.73	36-M	n/a
Vance Cr. CF	Vance	18,648	49	2.59	34-M	n/a
Pine Cr.	2-63	1578	55	3.16	48-H	n/a

*10 metric B-IBI modified from Karr (1998) Top B-IBI score = 50; H = High biological integrity (BIBI Scores > 40), M = Moderate biological integrity (BIBI Scores between 25-39), L = Low biological integrity (BIBI Scores between 0-24) based on comparisons with a Pacific Northwest montane stream with high biological integrity (Bob Wissman, ABA, personal communication).
**Lg River IBI – 9 metric B-IBI based on M.T. Celedonia (2004) and intended for larger river systems in western Washington. See text for details.

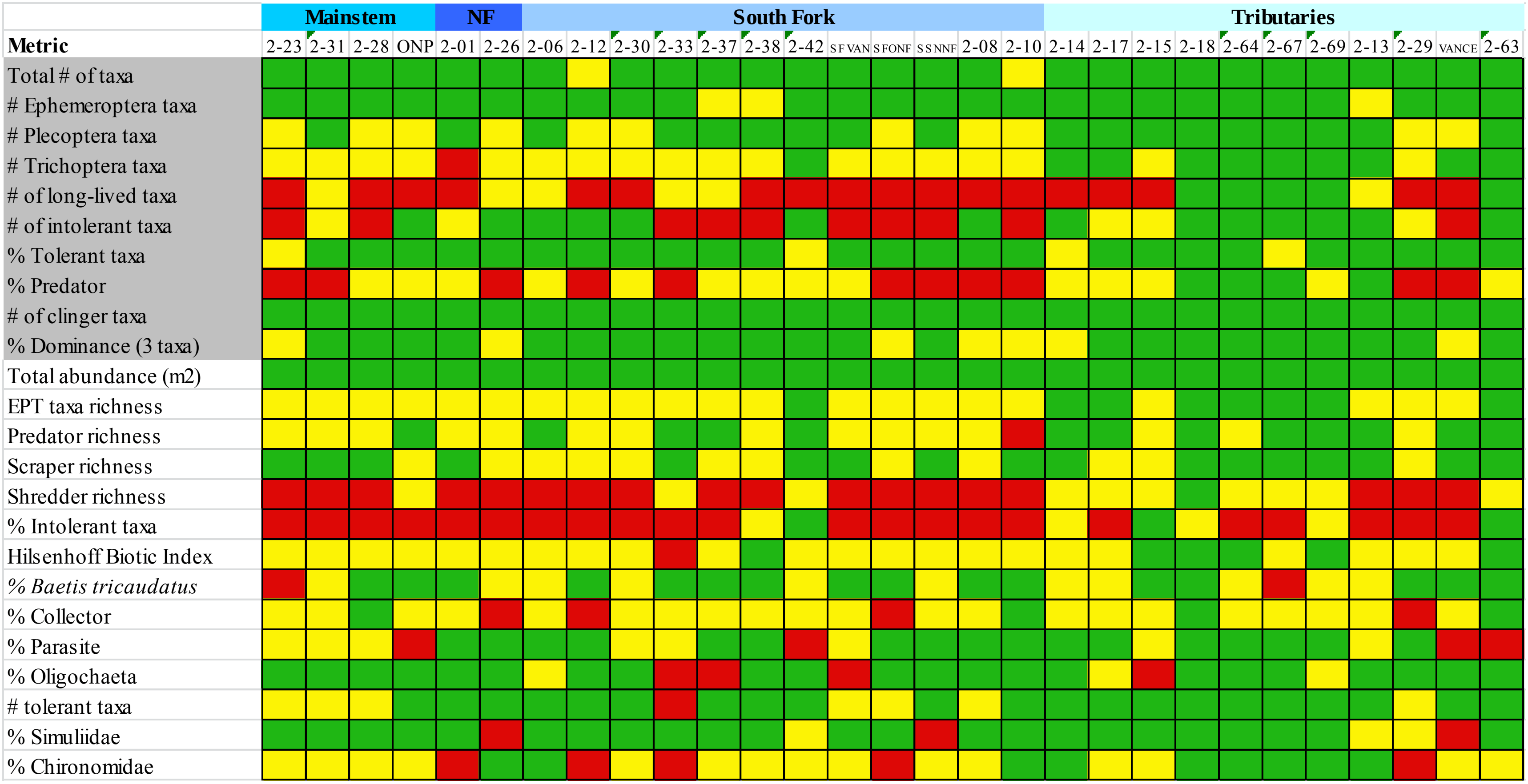

Figure 31. Heat map showing scores for several macroinvertebrate bioindicator metrics for study sites sampled in the Skokomish River watershed. The first 10 metrics (shaded gray) were used to create B-IBI scores (Karr 1998) based on comparisons with a Pacific Northwest montane stream with high biological integrity, whereas the others were scored by Bob Wissman (personal communication), a regional expert in macroinvertebrate taxonomy Cells were coded green (high biological integrity), yellow (moderate biological integrity) and red (low biological integrity) and columns were ordered by channel type and ecology.

Linking Primary and Secondary Species Assemblages to Environmental Data

In addition to the multimetric and reference condition methods discussed above, we also examined the macroinvertebrate and periphyton data using a suite of multivariate statistics (See appendix C for detailed methods). We discuss the results for each test separately for macroinvertebrate and diatom data.

The multi-dimensional scaling (MDS) plot for macroinvertebates (Figure 32) revealed that community structure differed among tributary, mainstem, and South Fork Skokomish sites, with clear separation occurring in the plot among these three site groups. On average, tributary sites were grouped together in the MDS plot (i.e., thus, by definition, more similar to each other in assemblage structure) than they were to South Fork Skokomish or mainstem sites. The South Fork Skokomish and mainstem sites also shared more within group similarity than among different groups, but the differences were not as strong as found in the tributary sites. The stress value of the macroinvertebrate ordination was 0.20, at the upper limit for interpretable results in MDS (Clarke and Ainsworth 1993).

The two-way Analysis of Similarities (ANOSIM) procedure in Primer, which was used to examine the variability in species composition among groups of sites, confirmed the visual interpretation of the MDS plots for macroinvertebrates that there were differences in assemblage structure among groups. We looked at two different ways to group the data. R values were significant for both type of channel (Mainstem, South Fork Skokomish, and Tributary; $R = 0.46$) and confinement ($R = 0.65$) (Table 21). Pair-wise comparisons for channel type suggested that tributary sites were significantly more different from South Fork Skokomish ($R = 0.51$) sites than they were from mainstem sites (not significantly different). Mainstem sites were also significantly different from South Fork Skokomish sites, based on pair-wise comparisons.

The MDS plot for diatoms also revealed separation among stream channel types, although there appeared to be much more overlap among groups than seen in the macroinvertebates. The stress value of the ordination was 0.17, within the level of interpretable structure recommended by Clarke and Ainsworth (1993). This assessment was confirmed by the lower ANOSIM scores (Table 21) seen among sites ($R = 0.3$). Unlike the macroinvertebrate results comparing confined versus unconfined reaches, there was not a significant difference due to confinement in the diatom assemblage structure (Figure 32, Table 21). The trend in pair-wise comparisons between different sites mirrored the results seen for macroinvertebrates; significant differences in assemblage structure occurred between mainstem/tributary sites and South Fork Skokomish sites, with mainstem and tributary sites not being significantly different.

To further explore the possible causes for differences in assemblage structure, we looked at univariate and multivariate approaches that linked environmental variables to the MDS plots of assemblage structure. We began with an ordination of the 14 environmental variables, which produced a Principal Component Analysis (PCA) that showed some separation among the different channel types (Figure 33). The first axis separated tributary from mainstem and South Fork Skokomish sites and was largely correlated with bank full width, water temperature, wetted width, and velocity. The second axis separated mainstem sites from tributary sites, and was correlated with increased cobble and embeddedness and decreasing levels of gravel. While the results were statistically significant, the two PCA axes explained only 35% of the variability in the data.

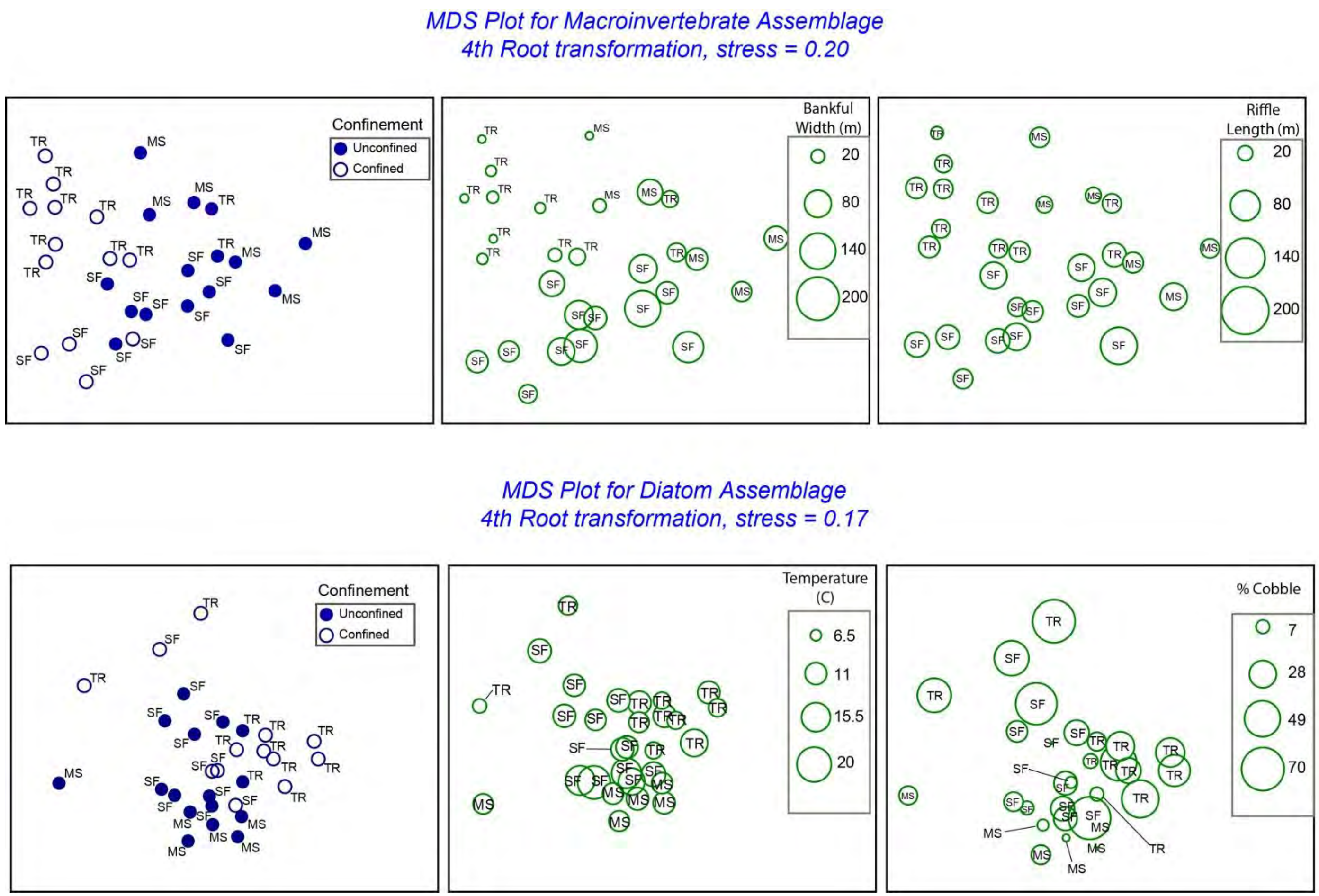

Figure 32. Non-metric multidimensional scaling plots of macroinvertebrate and diatom community composition data (both 4th-root transformed) collected from mainstem, tributary, and South Fork Skokomish study sites. The upper row of panels represent 3 views of the same ordination of macroinverebrate data, whereas the lower row shows the diatom ordination. Far left panels have points labeled according to whether a site was confined (open circle) or unconfined (shaded circle). Center panels are labeled with bubble plots that are proportional to the site scores for bankfull width (macroinvertebates) or embeddedness (diatoms). Far right panels are labeled with bubble plots that are proportional to the site score for riffle length (macroinvertebates) or % cobble (diatoms).

Table 21. Results of two-way crossed ANOSIM (Analysis of Similarities) with river type (mainstem (MS), South Fork Skokomish (SF), tributary (TR)) and confinement (confined, unconfined) as factors. The significance of global R values and pair-wise comparison R values were computed with 999 permutations and exact statistics are given in parentheses. Pair-wise comparisons were computed only when the global test was significant.

			Pair-wise Comparisons		
Dataset	**Factor**	**Global R**	MS-SF	MS-TR	TR-SF
Macroinvertebrate	Type	**0.46** (0.001)	**0.32**(0.02)	0.21(0.18)	**0.51**(0.001)
	Confinement	**0.65** (0.001)			
Diatoms	Type	**0.3** (0.005)	**0.46** (0.003)	0.25(0.25)	**0.24** (0.04)
	Confinement	0.1 (0.27)			

Next, as explained in the methods section in detail, we used the Bio-Env routine in Primer to match triangular similarity matrices of biological (macroinvertebrate or diatom) and environmental data. The idea is to search multiple subsets of environmental data for those that maximize the correlation between biological and environmental ordinations. We performed a step-wise searching routine using Primer's BVSTEP and found a moderate level of rank correlation between the biological and environmental resemblance matrices. For the macroinvertebrate assemblage data, the top 10 combinations of environmental data produced rank correlation coefficients ranging between 0.369 and 0.343 (Table 22). The variables appearing in the most sub-sets included bank full width (6 of 10 models), wetted width (10 of 10), and water depth (6 of 10).

The Bio-Env results for diatoms also showed a moderate level of rank-correlation among the 10 top subsets of data (Table 23). The top models had a rank correlation of 0.450 and were composed of either 5 (bank full width, water temperature, conductivity, % boulder, and % cobble) or 4 (water temperature, conductivity, % boulder, and % cobble) variables. Water temperature (7 of 10), % cobbles (10 of 10) and conductivity (10 of 10) appeared in the top 10 subsets of environmental data. Interestingly, a different suite of variables were significant for the two different Bio-Env procedures run for diatoms and macroinvertebrates. This suggests that different environmental factors may be responsible for the distribution, abundance, and assemblage structure in these two communities. However, much more study would be required, as we examined only a small number of possible explanatory variables.

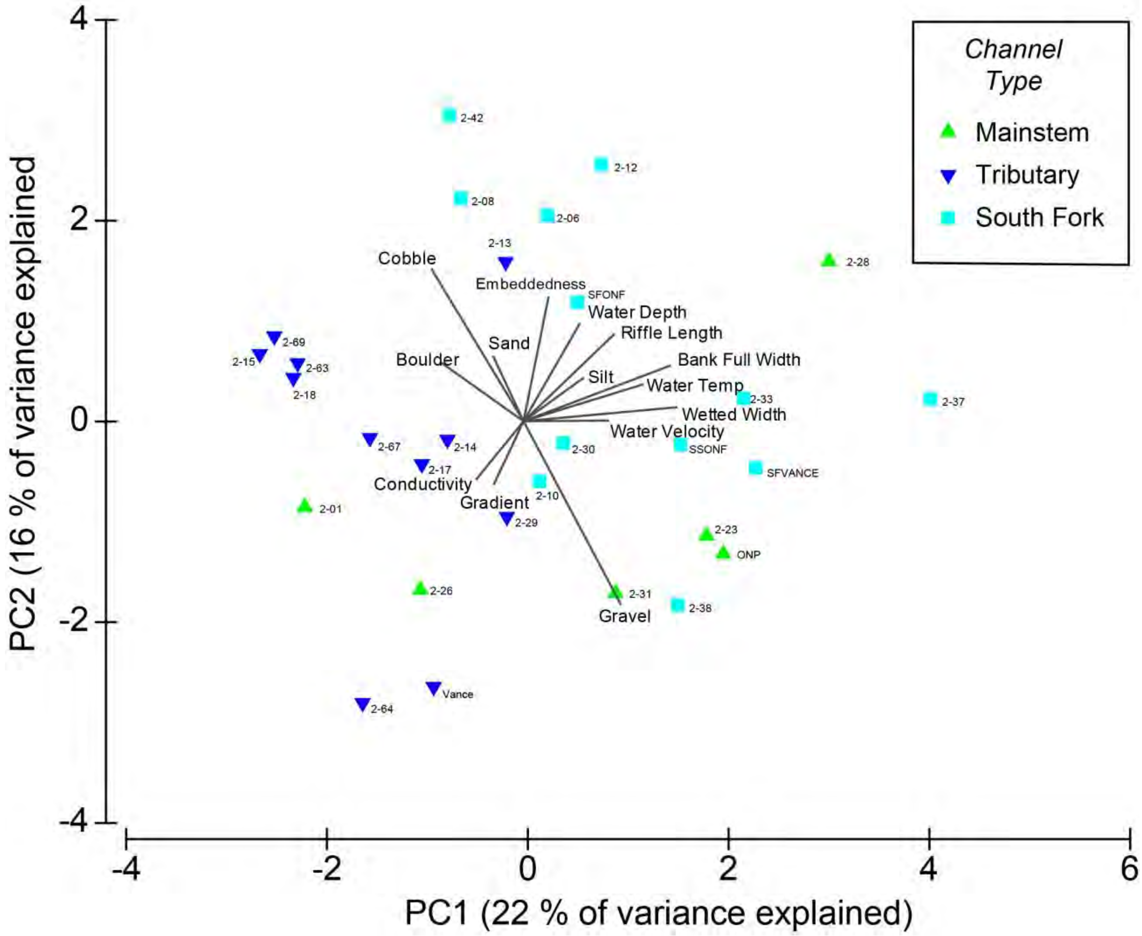

Figure 33. Results from correlation-based principal components analysis (PCA) of 14 environmental variables collected at macroinvertebrate and diatom collection sites. The PCA explained 38% of the variance within the first two principal components. Sites are denoted by channel type (mainstem, tributary, and South Fork Skokomish) and labeled with study codes. Eigen vectors reflect variable loadings (direction and magnitude) on each axis.

Finally, we plotted the a few of the variables that showed up in the majority of subset models from the Bio-Env routine as bubble plots in the original MDS ordinations. This univariate approach is another way to visualize gradients that may play a meaningful role in separating groups of sites from one another in the species assemblage space visualized in the MDS plots. The size of the bubbles is proportional to the variable score at each site. When superimposing bank full width as bubbles on the MDS plot, the smaller size of tributary sites compared with South Fork Skokomish sites becomes apparent (Figure 32). The mainstem sites have, on average, smaller bank full widths than the South Fork Skokomish sites. A gradient among South Fork Skokomish bank full widths also exists and it appears that the within this group the macroinvertebrate assemblages of wider South Fork Skokomish sites are more similar to each other than to other South Fork Skokomish sites with smaller bank full widths. Riffle length also was smaller in riffles than mainstem or South Fork Skokomish sites, although the gradients are not as large as those seen for bank full widths. The bubble plots for diatoms exposed a large gradient in % cobble, but not as large of a difference in embeddedness (Figure 32). For % cobble, the distribution of bubble sizes was not related to channel type, as sites from mainstem, South Fork Skokomish, and tributary sites had some sites with large and small % cobble values. Nevertheless, there was a tendency for sites with larger % cobble to group together in the diatom MDS plot, suggesting that the diatom communities were being influenced by substrate size, in addition to channel type.

A final observation about the macroinvertebrate communities observed in the Skokomish River watershed was the lack of snails, pea clams, and crustaceans in the samples. These taxa are fairly common in mid- to low-elevation streams in western Washington (Bob Wissman, Aquatic Biology Associates, personal communication). The skeletons of mollusks and crustaceans are composed of calcium carbonate and thus sufficient levels of calcium must be in the environment for these animals to occur or survive (Greenway 1985). Lack of these invertebrates may be indicative of low calcium levels, which may be a natural occurrence due to the underlying geology. Additional studies are required to explain this preliminary finding of limited mollusk and crustacean populations throughout the Skokomish Basin.

Table 22. Best subsets of environmental variables whose triangular similarity matrix had the highest Spearman's correlation coefficient with the macroinvertebrate similarity matrix using the BVSTEP routine of Primer. Subsets of possible variables were Bankfull width (BFW), gradient, Riffle Length, Wetted width, Water Depth, Water Velocity, Water Temperature, Conductivity, % boulder, %cobble, %gravel, %sand, %silt, and embeddedness.

No. Variables	Correlation Coefficient	Selected Variables
5	0.369	BFW, Wetted Width, Depth, %Cobble, % Sand
5	0.358	BFW, Wetted Width, Depth, % Gravel, % Sand
4	0.356	BFW, Wetted Width, %Cobble, % Sand
4	0.351	BFW, Wetted Width, Depth, % Gravel, % Sand
5	0.349	Length, Wetted Width, Depth, %Cobble, % Sand
5	0.349	BFW, Wetted Width, % Gravel, % Sand, %Silt
5	0.348	Wetted Width, Depth, %Cobble, % Sand, embeddedness
5	0.347	BFW, Wetted Width, %Cobble, % gravel, % Sand
1	0.346	Wetted Width
5	0.343	Wetted Width, Depth, %Cobble, % Sand

Table 23. Best subsets of environmental variables whose triangular similarity matrix had the highest Spearman's correlation coefficient with the diatom similarity matrix using the BVSTEP routine of Primer. Subsets of possible variables were Bankfull width (BFW), gradient, Riffle Length, Wetted width, Water Depth, Water Velocity, Water Temperature, Conductivity, % boulder, %cobble, %gravel, %sand, %silt, and embeddedness.

No. Variables	Correlation Coefficient	Selected Variables
5	0.450	BFW, Temperature, Conductivity, %boulder, %Cobble
4	0.450	Temperature, Conductivity, %boulder, %Cobble
4	0.441	BFW, Temperature, Conductivity, %Cobble
3	0.438	Conductivity, %boulder, %Cobble
5	0.432	Temperature, Conductivity, %boulder, %Cobble, % gravel
2	0.432	Conductivity, %Cobble
3	0.431	BFW, Conductivity, %Cobble
5	0.427	BFW, Temperature, Conductivity, %Cobble, % gravel
4	0.424	BFW, Temperature, Conductivity, %Cobble
5	0.418	BFW, Temperature, Conductivity, %Cobble, % gravel

Habitat Conditions at Primary and Secondary Sampling Locations

There was a great deal of similarity between mainstem and tributary sites in both macroinvertebrate and periphyton biocriteria scores, yet these two river types usually differ in habitat features important to biological communities. Thus, we collected a suite of habitat measurements relevant to macroinvertebrate and periphyton communities at two spatial scales and then tested for differences between mainstem and tributary sites. The first scale characterized microhabitat within the 1.25 m^2 slack sample location where macroinvertebrates and periphyton were collected. At this scale, differences in habitat features such as particle size (e.g., boulder vs. sand), water velocity (slow vs. fast) and depth can drive differences in community structure in two otherwise similar river reaches. The second spatial scale measured the riffle from where slack samples were collected. Again, differences in important features such as particle size, water depth, vegetative cover (shading), and velocity at this scale can drive differences in biological communities living in riffles.

Aside from the size of the riffles and the wetted width of the channel (which are generally larger in mainstem rivers compared to tributaries), mainstem and tributary sites were similar in many of the measured habitat characteristics (Table 24). The average length of sampled riffles was longer in mainstem sites (50 m, range 22 m – 121 m) than in tributary sites (34 m, range 14 m – 50 m) (Kruskall-Wallis test = 4.6, $P = 0.03$). Mainstem sites also had higher wetted widths (24 m, range 6 m – 49 m) than tributary sites (6 m, range 2 m – 11 m) (Kruskall-Wallis test = 17.1, $P < 0.001$). Gradient for both mainstem and tributary sites was similar (0.56 % vs. 0.55%, $t = -0.093$, $P = 0.93$), as was average embeddedness (2.1 for both, $t = 0.26$, $P = 0.80$), depth of slack sample (which was constrained by the study design to be less than 30 cm), and water velocity (0.37 vs. 0.32 m s^{-1} $t = 0.80$, $P = 0.43$).

We also estimated the particle size of substrate at the microhabitat and riffle scale (Table 25). Both methods revealed that most of the riffles sampled were dominated by gravel. We averaged the 5 visual substrate scores (percentage of the river bed composed of fines, sand, pebble, gravel, cobble, boulder) collected at each riffle and found that gravel was the dominant substrate at 73% of the sites, with cobbles being the highest percentage at the remaining sites.

Average embeddedness scores, which rated the proportion and extent of substrate covered in sand or silt on a scale of 1 to 5 (1 = < 5%, 2 = 6-25%, 3 = 25-50%, 4 = 51-75% and 5 = >76%), was generally less than 3 for most sites, suggesting that less than 50% of the substrate within the slack frame was embedded by fines and sand. At the riffle level, the median D_{50} particle size across all sites was 49 mm (6.5 mm – 109.5 mm), with mainstem sites having significantly larger D_{50} than tributary sites (60 mm vs. 31 mm, respectively, Kruskall-Wallis test = 5.8, P = 0.02). The unit less ratio of D85:D15, measure of substrate variability was also significantly different between mainstem (13.2) and tributary (24.1) counts (Kruskall-Wallis test = 5.8, P = 0.02).

Table 24. Location and habitat characteristics of 29 mainstem and tributary sites where macroinvertebrate and periphyton samples were collected from 25 August – 14 October, 2009 in the Skokomish Basin, Washington (see **Figure 30** for locations within the Skokomish Basin). (UTM = Universal Transverse Mercator coordinate system)

Site	Site Code	UTM Northing	UTM Easting	Wetted Width (m)	Gradient (%)	Riffle Length (m)	Depth (m)	Velocity (ms^{-1})	Conductivity (µS)
MS Skok	2-23	4-89-395	52-40-052	37	0.23	32	0.24	0.38	67.9
MS Skok	2-31	4-85-256	52-40-217	34	0.18	38	0.18	0.48	80.2
MS Skok	2-28	4-87-855	52-39-506	34	0.80	66	0.24	0.38	26.9
MS-ONP Index	ONP Index	4-75-209	52-62-294	29	0.56	52	0.21	0.24	92.0
NF Skok	2-01	4-82-593	52-45-677	14	0.41	24	0.23	0.12	159.6
NF Skok	2-26	4-82-340	52-44-533	6	0.58	36	0.19	0.25	68.5
SF Skok	2-06	4-75-876	52-50-263	15	1.0	55	0.21	0.54	67.6
SF Skok	2-12	4-66-135	52-56-684	18	0.78	65	0.15	0.22	27.9
SF Skok	2-30	4-68-814	52-54-613	11	0.50	31	0.17	0.37	64.9
SF Skok below Canyon	2-33	4-79-242	52-42-482	33	0.42	121	0.10	0.07	61.3
SF Skok	2-37	4-80-000	52-41-501	49	0.87	43	0.16	0.64	68.1
SF Skok	2-38	4-69-147	52-54-773	18	0.75	40	0.15	0.65	58.3
SF Skok	2-42	4-66-530	52-55-897	12	0.24	64	0.22	0.45	65.5
SF @ Vance	SF Vance	4-80-965	52-40-471	20	0.27	69	0.21	0.38	66.7
SF Skok Old NF/SF CF	SFONF	4-81-689	52-40-272	11	0.18	64	0.18	0.37	58.7
MS Skok below new CF	SFNNF	4-83-02	52-40-650	44	0.72	22	0.14	0.57	49.6
SF Skok	2-08	4-78-067	52-47-320	26	0.59	34	0.18	0.34	72.4
SF Skok	2-10	4-75-399	52-51-194	22	0.88	51	0.10	0.20	66.2
Browns Cr.	2-14	4-77-025	52-52-393	6	0.98	39	0.19	0.43	66.2
Browns Cr.	2-17	4-76-360	52-51-418	9	0.48	30	0.12	0.30	68.8
Church Cr.	2-15	4-66-043	52-56-442	3	0.67	30	0.12	0.21	42.0
McTaggert Cr.	2-18	4-82-429	52-49-220	4	0.48	40	0.15	0.17	60.5
McTaggert Cr.	2-64	4-81-961	52-50-200	2	0.18	14	0.06	0.26	67.9
McTaggert Cr.	2-67	4-82-830	52-48-083	6	0.62	27	0.16	0.40	64.5
McTaggert Cr.	2-69	4-82-798	52-48-610	5	0.53	33	0.14	0.39	65.6
Vance Cr.	2-13	4-76-028	52-41-941	11	0.96	39	0.21	0.53	74.4
Vance Cr.	2-29	4-79-116	52-40-702	8	0.61	50	0.12	0.31	56.7
Vance Cr CF	Vance	4-80-570	52-40-186	7	0.53	32	0.08	0.33	85.3
Pine Cr.	2-63	4-68-257	52-54-648	9	0.15	40	0.12	0.24	46.6

Table 25. Summary statistics from Wolman (1954) pebble count data of study riffles and average values of dominant substrate size and embeddedness from five 1.25 m^2 samples of the stream bed where macroinvertebrates were sampled. D_{50} is the median particle size and D_{85}:D_{15} is a unit less ratio that provides an estimate of particle size variability based on 100 randomly selected substrate particles (see **Figure 30** for locations within the Skokomish Basin).

Site	Site Code	D_{50} (mm)	D_{85}:D_{15}	Slack Dominant-%	Embedded
MS Skok	2-23	6.5	32.3	GR-95	2.2
MS Skok	2-31	77.5	1.6	GR-81	1.6
MS Skok	2-28	24.5	51.7	GR-67	3.0
MS-ONP Index	ONP Index	109.5	4.5	GR-56	2.8
NF Skok	2-01	109.5	17.4	GR-55	1.6
NF Skok	2-26	48.5	3.2	GR-75	1.0
SF Skok	2-06	48.5	23.8	GR-41	2.4
SF Skok	2-12	77.5	3.2	CO-46	2.6
SF Skok	2-30	77.5	6.3	GR-68	2.2
SF Skok below Canyon	2-33	48.5	8.8	GR-69	1.6
SF Skok	2-37	77.5	2.2	GR-78	2.2
SF Skok	2-38	77.5	4.5	GR-100	2.0
SF Skok	2-42	77.5	8.9	CO-66	2.6
SF @ Vance	SF Vance	24.5	25.8	GR-86	2.0
SF Skok Old NF/SF CF	SFONF	48.5	6.2	GR-75	2.0
MS Skok below new CF	SFNNF	24.5	11.9	GR-86	1.8
SF Skok	2-08	77.5	17.4	CO-68	2.8
SF Skok	2-10	48.5	8.8	GR-72	2.0
Browns Cr.	2-14	77.5	33.5	GR-67	2.2
Browns Cr.	2-17	12.5	25.8	GR-71	3.3
Church Cr.	2-15	77.5	3.2	CO-44	2.2
McTaggert Cr.	2-18	77.5	33.5	GR-47	2.4
McTaggert Cr.	2-64	24.5	16.2	GR-86	2.0
McTaggert Cr.	2-67	11	59.1	CO-50	1.2
McTaggert Cr.	2-69	12	30.7	GR-35	2.0
Vance Cr.	2-13	11	12.4	CO-53	2.2
Vance Cr.	2-29	11	8.8	GR-73	1.6
Vance Cr CF		11	8.8	GR-90	1.8
Pine Cr.	2-63	12	33.5	CO-70	2.0

Conclusion: Primary and Secondary Producers

Our assessment of both macroinvertebrate and periphyton communities, based on indices proven to respond in a predictable way to aquatic ecosystem impairment, showed that most sites sampled in the Skokomish Basin were of moderate to high biological integrity. We did document differences among mainstem and tributary sites for some metrics, but as of yet unanalyzed differences in the size of the streams, their hydrological regime, and the surrounding land-use undoubtedly interact to explain some of these patterns. Our assessment of the Skokomish River watershed did not find any sites that indicated severe impairment to biological condition. Additional analyses coupling environmental factors with biological assemblage structure for both periphyton and macroinvertebrates are warranted and should be pursued.

We also note that our sampling occurred during a single season with a single sampling event occurring at each site. Although this level of effort is typical of watershed and regional scale studies, additional effort could find more detailed explanations for the patterns that we briefly described above and would be useful and necessary to make comparisons following any restoration actions that follow in the watershed. Morley et al. (2008), for example, studied macroinvertebrate and periphyton assemblage structure in the Elwha River for three years prior to dam removal. Although the patterns they describe for the current pre-dam removal conditions in the river above, between, and below the dams were generally consistent among years, there was some inter-annual variability which is expected for such dynamic ecological systems and should be accounted for when trying to determine the effects of restoration actions.

Fish Assemblage

Twenty-three species of fish have been identified in the Skokomish and South Fork Skokomish rivers (Watershed Management Team 1995); however, verification that Dolly Varden (*S. malma*) is present in the system has not been accomplished (Jeff Chan, FWS, personal communication). Most of the identified fish are salmonids, including: Chinook salmon, coho salmon, chum salmon, rainbow trout/steelhead, cutthroat trout (*O. clarki*), bull trout, and mountain whitefish (*Prosopium williamsoni*), all of which are common in the Skokomish Basin. Sockeye salmon (*O. nerka*) and pink salmon (*O. gorburscha*) were historically found in the Skokomish River. Five species of sculpin (*Cottus sp*.) are found in the Skokomish River, including prickly sculpin (*C. asper*), coast range sculpin (*C. alecticus*), riffle sculpin (*C gulosus*), Reticulate sculpin (*C. perplexus*), and shorthead sculpin (*C. confusus*). River lamprey (*Lampetra ayrsi*), western Brook lamprey (*L. richardsoni*),), and Pacific lamprey (*L. tridentate*) have also been observed in the Skokomish Basin.

Two WDFW hatcheries, George Adams and McKernan, currently release hatchery Chinook, coho, and chum salmon, and steelhead into the Skokomish Basin as on-station smolt releases, released at the hatchery. However, these facilities have historically out-planted fry into other locations in the Skokomish Basin in addition to the on-station releases. These two facilities release approximately 3.8 million Chinook; 300,000 coho; 8.5 million chum; and 34,000 steelhead. A third hatchery, Eels Springs raises cutthroat trout, rainbow trout, and kokanee for put-and-take fisheries in local lakes.

Juvenile Salmon Habitat Requirements and Status

General Requirements for all Juvenile Salmonid Species

All juvenile salmon spend at least a portion of their life in fresh water and have certain physical and biological requirements during these life history stages. While the length of time an individual spends in fresh water varies significantly among species, all Pacific salmon, at a minimum, must incubate in the gravel as eggs and alevins, emerge as fry, and then migrate to sea after some length of time residing in the stream or other freshwater habitats (i.e., ponds). Some species such as chum migrate to sea quickly and rely little on the resources and characteristics of the fresh water environment into which they hatch. Others, such as steelhead, spend months or even years in fresh water and therefore require different and/or additional physical characteristics. It is important to note that species which rely heavily on freshwater habitats to rear and grow generally do not spend much time in the estuary on their way to sea (e.g. coho and steelhead), while species that quickly migrate to sea (e.g. fall Chinook and chum) use the estuary for up to several weeks in preparation for their entry into salt water. Therefore, while an individual species may not require all habitats that they encounter as juveniles to be intact, as an aggregate, salmon stocks in the Skokomish Basin require a continuum of intact habitats from incubation through their eventual migration to salt water.

Incubation

All juvenile salmon begin their lives as eggs deposited in the gravel by an adult salmon. At a basic level, the more water there is in a stream, the more spawning habitat is available, up to a point when high velocity flows begin to reduce available habitat and stream characteristics can be used to estimate this relationship (Stalnker and Arnette 1976; Bovee 1978, 1982, 1986, Bovee and Milhous 1978). Once deposited into the substrate, DO, temperature, and channel stability are the three main factors that determine embryo survival and eventual emergence. In general, embryos may survive if DO levels are less then saturation, but their development may deviate from normal (Doudoroff and Warren 1965). Phillips and Campbell (1962) conclude that an average DO of 8.0 mg/L is sufficient for proper survival. In a review, Bjornn and Reiser (1991) advise that levels should remain near saturation with no more than temporary drops below 5.0 mg/L. Temperature directly affects the saturation level of DO, but is also the main determinant of the hatch time of embryos. There is some measure of species specificity which is discussed below, but generally salmon eggs need between 87 and 120 days to hatch at 5^{o}C and 139 to 173 days to emerge at the same temperature. Although salmon eggs have the ability to hatch in a wide range of temperatures, the optimal temperature is between 5 and 11 ^{o}C (Murray and McPhail 1988). Salmon eggs and alevins require a stable environment for incubation and early rearing. Several studies have shown a negative relationship between egg-to-fry or smolt production with increased peak flow during incubation (e.g., Thorne and Ames 1987; Scrivener and Brownlee 1989; Seiler 1999). This mortality may be related to physical scour of redds (Schuett-Hames et al. 2000), scour-related fine sediment intrusion into the redd (Devries 2000), or through burial as a result of gravel deposition and channel migration.

The physical characteristics of the substrate which allow it to transmit water and the actual volume of water transferred per unit of time, are two commonly used variables to assess the suitability of a redd for incubation (Wickett 1954; Vaux 1968). These two factors combine to determine the DO concentrations delivered to incubating eggs. Sheridan (1962) showed that surface water was responsible for delivering DO, as opposed to groundwater, and that DO levels decreased with redd depth. Embryo survival for several species of salmon have been directly linked to the apparent velocity of water through the redd (Cooper 1965; Coble 1961).

The main effect on embryo survival and their eventual ability to emerge up through the gravel is the size and amount of fine sediment in the gravel. The size of "fine sediment" particles varies from 0.84 mm up to 6.4 mm, with most studies agreeing on a category of less than 1 mm in diameter (McCuddin 1977; Stowell et al. 1983). Several studies have documented a negative trend between the percentage of fine sediment and embryo survival and emergence. Chapman (1988) reported that survival is not inhibited if less than 10% of the substrate is fine sediment, although at 15-20% fine sediment, dramatic reductions in survival have been documented (Holtby 1988). While the exact size and percentage of fine sediment that inhibits embryo survival varies by study, the conclusions remain the same, fine sediment in the redd is the single biggest threat to embryo survival and emergence as it directly affects the temperature and DO regime that the eggs experience.

Salmonid embryos are capable of surviving dewatering events for up to 5 weeks if temperatures remain in a suitable range, fine sediment does not impede air flow, and humidity stays at 100% (Reiser and White 1983). Possibly in an effort to combat the possibility of dewatering, chum and sockeye salmon have been observed spawning in areas of groundwater upwelling (Lister et al. 1980).

Salmon also require a stable incubation environment from the time of spawning through emergence. Excessive bed scour or channel migration can significantly impact incubation survival. Several studies have shown a negative relationship between egg-to-fry or smolt production with increased peak flow during incubation (e.g., Thorne and Ames 1987; Scrivener and Brownlee 1989; Seiler 1999). These authors inferred that direct scour of eggs or embryos was the mechanism resulting in mortality. However, no direct measurements of mortality were recorded. Recent studies have examined scour in and/or adjacent to salmonid redds and have identified potential factors resulting in increased scour. Salmonids have adapted to local scour conditions and bury eggs just below average scour depths (Montgomery et al. 1996). Therefore, very little change in scour depth would be required to result in significant mortality. Tripp and Poulin (1986) observed scour depths sufficient to destroy salmonid redds and this scouring was related to the frequency of landslides. Schuett-Hames et al. (2000) concluded that scour can be a significant source of mortality and is positively related to channel complexity.

Although scour related mortality has been inferred from several field studies, the actual mechanism of mortality remains unclear. DeVries (2000) determined that scour sufficient to result in direct displacement or crushing of embryos in low gradient streams with sediment transport equilibrium was unlikely regardless of flood magnitude and duration. He suggested that scour-related mortality was more likely in streams or stream reaches experiencing sediment transport imbalances. This would occur in streams or stream reaches experiencing increased sediment inputs as a result of landslides or increased bank erosion (e.g., the landslides observed by Tripp and Poulin 1986). He also suggested that scour-related fine sediment intrusion may be a more important mortality mechanism than direct redd scour. Thus, it seems that sediment transport regimes of rivers may be as important, or perhaps more important than increased peak flows with respect to scour- or peak flow-related mortality of salmonid embryos.

Rearing

After successfully hatching and emerging from the gravel, juvenile salmon enter the stream environment, where several factors affect their growth and survival: the physical environment, availability of food and competition for it, and predation. Similar to their requirements for incubation, temperature and the associated level of dissolved oxygen provide the physical basis for juvenile salmon development. In addition, suitable physical habitat characteristics such as water depth, current velocity, presence of wood, etc. are necessary for optimal growth to be attained. The amount of food available for consumption is determined by a combination of factors including general stream productivity and competition with other animals. Finally, some measure of protection from predators is required to ensure survival to seaward migration.

Physical Characteristics

For most free swimming juvenile salmonids, the upper limit of life threatening temperatures occurs between 23 and 25^{o}C (reviewed by Bjornn and Reiser, 1991), with the lower limit being near freezing (Brett and Alderice 1958). Growth efficiency is determined by a combination of ration size and temperature, with higher temperatures being optimal if there is enough food available, with the peak lying at about 8-11^{o}C for a fish fed at satiation (Brett et al. 1969). Most salmon rear in streams with DO levels near saturation, but DO levels could become a factor if temperatures are high, flows are low, and there a large amounts organic material (Hall and Lantz 1969). Minimal requirements for survival appear to lie near 5 mg/L, but food conversion efficiency is inhibited at levels below 8 mg/L (Davis 1975; Alabaster et al. 1979). Turbidity may also effect the growth and survival of juvenile salmon. The degree of disruption in growth seems to depend on fish size, with smaller fish experiencing more difficulty (Sigler et al. 1984). Bisson and Bilby (1982) reported that juvenile coho avoided areas with turbidities higher than 70 NTUs.

The habitat present in the stream is an important determinant of its ability to produce and grow juvenile salmonids. Although habitat requirements vary by species, general guidelines exist. The depth and velocity preferred by juvenile salmon varies by age and species, with larger fish generally preferring, or at least being capable of inhabiting, higher velocity flows. Lister and Genoe (1970) reported that coho and Chinook fry were found in the margins of a stream after emergence and moved to progressively faster and deeper areas as they grew. Results vary widely, but preferred depths of juvenile salmon less than 100 mm fork length range from <15 cm to approximately 60 cm and current velocities from 5 to 30 cm/s (see Bjornn and Reiser 1991 for a complete review, with a summary in the species specific section below). Juvenile salmon show a preference for additional habitat characteristics other than simply depth and current velocity, the most notable, being presence of LWD. LWD can have dramatic effects on channel hydrology, fundamentally changing other physical characteristics of a stream as well as effect primary productivity. Roni and Quinn (2001) found increased densities of coho salmon in stream reaches with artificially placed wood.

Productivity and Competition

The ability of a stream to produce and grow juvenile salmon is also determined by the streams inherent productivity and the level of competition present. Stream productivity is based on a complex combination of climate, water chemistry, and allocthonous and autochtonous inputs (reviewed by Murphy and Meehan 1991). It is important to note that, generally speaking, Northwestern coastal streams and rivers are food limited for juvenile salmonids (Mason 1976; Slaney et al. 1986). On the other hand, Northwestern streams vary widely in the level of competition present, with some producing a few large fish and others producing many small ones. On a basic level, the number of successful adult spawners the previous fall will determine the raw number of competitors, while space and stream productivity will determine the amount of resources available to divide between them. Bjornn and Reiser (1991) provide a detailed review of factors affecting the carrying capacity of a stream for rearing juvenile salmonids.

Predation

Juvenile salmonids in streams experience predation primarily from fishes but also from birds and mammals (Quinn 2005). Larger salmonids and sculpin have been shown to be particularly vigorous predators (Patten 1975, Pearsons and Fritts 1999). Mergansers, kingfishers and herons can also be significant sources of mortality to juvenile salmon populations (Wood 1987). Cover, including LWD, riparian vegetation, undercut banks, aquatic vegetation, and large substrate can all provide refugia from predation for juvenile salmon. Several studies using various indices of cover have all concluded that increased cover results in higher densities of juvenile salmonids (Wesche 1974; Bisson et al. 1987; Holtby 1988; Peters 1996a).

Seaward migration

Juvenile salmon habitat requirements during their migration to sea are largely the same as those during their residence in fresh water residence, with the addition of one major habitat requirement, the coastal estuary. Before entering salt water, juvenile salmonids must at least pass through the estuary, while some spend several months rearing there. The estuary is a complex mosaic of habitats governed by the interaction of river outflow and tidal inflow, providing a broad range of micro habitats for the juvenile salmon. Estuaries are widely regarded as important habitat for juvenile salmon, not only for their ability to provide a transition zone for the physiological changes smolting salmon experience, but also as an additional rearing ground and migration corridor for seaward migration, they provide a refugia from predation (Simenstad et al. 1981). Different species of salmon depend on estuaries to varying degrees, which will be discussed below.

Chinook Salmon

Adult

Puget Sound Chinook: Fall/Summer Skokomish Chinook were classified as threatened as a component of Puget Sound Chinook ESA listing in 1999, and this status was reaffirmed in 2005. They were designated as their own stock in the 2002 SASSI based on geographic location, and have been rated as depressed. Allozyme analysis indicates that they are distinct from South Puget Sound Chinook stocks (Marshall 2000). However, this stock is likely a non-native stock arising from imported Green River lineage Chinook salmon in the 1960‘s (Skokomish Tribe and WDFW 2010). Spawning takes place between September and October with the historical peak being in mid-October, although currently spawning is generally finished by this time. It is generally accepted that Kokanee Dam is the first blockage to anadromous fish passage on the North Fork Skokomish (Skokomish Tribal Nation and WDFW 2007). Low flow events in August and September can result in all of the stream flow being sub-surface in the South Fork Skokomish in the vicinity of Vance Creek, thereby completely restricting upstream access on the South Fork Skokomish. Smolts are produced at the George Adams Hatchery at RKM 1.6 (RVM 1.0) on Purdy Creek which enters the main stem Skokomish at RKM 5.8 (RVM 3.6) (WDFW and PNPTT 2000).

Hatchery escapement data is based on the number of adults that return to this facility. Natural spawning occurs in the main stem Skokomish, the South Fork Skokomish (to RKM 8.0(RVM 5.0)) and North Fork Skokomish (to RKM 25.7 (RVM 16)), and Purdy, Hunter, and Vance Creeks. Data on natural spawners is based on counts from RKM 3.5 (RVM 2.2) to RKM 20.4 (RVM 12.7) on the main stem, Purdy Creek from RKM 0.0 (RVM 0.0) to the hatchery rack at George Adams, and RKM 0.0 (RVM 0.0) to RKM 8.9 (RVM 5.5) on the South Fork Skokomish (Figure 34). The escapement goal for this stock is approximately 3,650 fish, 1,650 natural spawners (i.e., river spawners) and 2,000 hatchery fish to George Adams Hatchery (Skokomish Indian Tribe and WDFW 2007). The overall goal has generally been met, largely due to large numbers of hatchery Chinook returning to the system. In contrast, the natural spawner escapement goal has only been met three times since 1990. Natural escapement, or the number of fish spawning in the river regardless of origin, was 531 in 2007 and 1,149 in 2008. In contrast, hatchery returns were 13,270 and 13,695 respectively. It is important to note that hatchery Chinook from George Adams stray in large numbers to the main stem and its tributaries and account for 20 to 80% (average approximately 60%) of the natural spawning fish in this system (WDFW 2007).

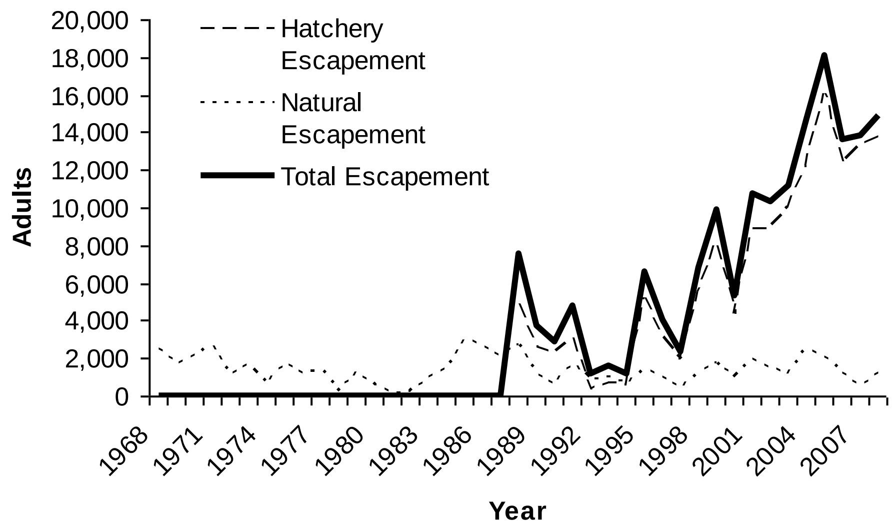

Figure 34. Hatchery escapement, natural escapement, and total escapement of adult fall Chinook in the Skokomish River from 1968 to 2007. Data for hatchery escapement is from the George Adams facility on Purdy Creek. Data on natural spawners is based on counts from RKM 3.5 (RVM 2.2) to RKM 20.4 (RVM 12.7) on the main stem, Purdy creek from RKM 0.0 (RVM 0.0) to the hatchery rack at George Adams, and RKM 0.0 (RVM 0.0) to RKM 8.9 (RVM 5.5) on the South Fork Skokomish. All data is from the WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm.

Puget Sound Chinook: Spring

The Skokomish River once supported a run of spring Chinook salmon. They were reported to have spawned in similar river locations as Fall Chinook (WDFW 1957). The stock was reported as in decline as early as 1950, but still used the lower 5 miles of the South Fork Skokomish and 13 miles of the North Fork Skokomish. However, in 1991, Nehlsen et al. (1991) reported the stock extinct. This extinction is likely due to overfishing (James 1980) and the construction of the Cushman Dams James (1980) which blocked access to a major component of their habitat and altered hydraulic patters in the system (Skokomish Tribe and WDFW 2010).

Puget Sound Chinook: Lake Cushman

Chinook salmon are also found in Lake Cushman, above Cushman Dam No. 1. The small self-sustaining population spawns upstream of the reservoir in RKM 45.4 (RVM 28.2) to RKM 48.1 (RVM 29.9) during the month of November (Skokomish Tribal Nation and WDFW 2007). Genetic analysis failed to reveal stock origin, but there is little individual differentiation, indicating that spawner numbers are low or the stock experienced a bottleneck in the past (Marshall 1995). A stock status has not been determined for Cushman Chinook, but the Northwest Fisheries Science Center considers them part of the Puget Sound Chinook salmon Evolutionary Significant Unit (ESU) (Meyers et al. 1998; NMFS 1999) which thereby confers protection under the ESA.

Juvenile

Of all the salmonid species in the Skokomish watershed, fall Chinook probably have the most extensive juvenile habitat requirements. They require both freshwater and estuarine habitats for growth and rearing. Because they rear in the lower watershed, they are affected by basically every habitat altering action that has occurred in the watershed. Summer low flows resulting from aggradation and flow reductions have the potential to limit habitat available to juveniles by blocking adult migration, dewater eggs or delivering lethal temperature and DO levels to incubating eggs. Scour from winter high flow events has the biggest impact on fall Chinook because their spawn timing occurs almost entirely before the initial high flows of fall, which can potentially scour their redds. Diking, channelization, and bank armoring result in the indirect effects of altering the habitat that is available to juvenile Chinook for rearing, namely, reducing pool depth and frequency and limiting off channel habitat. As mentioned previously, fall Chinook juveniles are the most reliant on estuarine habitat of all species in the Skokomish River, therefore the decreases in habitat that have been recorded in the Skokomish estuary, particularly the loss of eel grass, will impact them greatly. It is also important to note that limitations in any of the aforementioned habitats may not only limit overall stock production, but also impact life history diversity, i.e., the balance of age 0+ and 1+ smolts (Greene et al. 2010).

Natural spawned fall Chinook juveniles generally migrate out of the Skokomish River in the spring or early summer of their first year, so they spend at least a couple months feeding in freshwater before their seaward migration (Lestelle and Weller 1994). Spring or stream type Chinook typically spend a full year in the stream migrating out to sea in the spring of their second year (Taylor 1990). Fresh water habitat is important to the growth and survival to both types before their seaward migration. Chinook fry have been recorded in a wide range of depths and velocities, with average depths of approximately 40 cm and velocities of 15 cm/s (reviewed in Bjornn and Reiser 1991; Peters et al., unpublished data). They are generally found rearing in the lower reaches of a river system as compared to coho and steelhead. Both types make extensive use of the estuary as a rearing environment, transitional zone, and migratory corridor. Because of the diverse life history patterns exhibited by Chinook, they can be found in the estuarine environment in Hood Canal during all months of the year (Iwamoto and Salo 1977). Peak migration in Hood Canal begins in early March and peaks from late April through June, with fry from fall spawning adults generally preceding yearlings from the spring migrating adults (Seiler et al. 1981). Average estuarine residency times for individual juvenile Chinook could be as much as 189 days in larger systems but is more likely 20-40 days in a system such as the Skokomish, with smaller fish staying longer than larger ones (reviewed in Simenstad et al. 1981).

Available data on the population status of juvenile Chinook salmon in the Skokomish River is limited. We found no information on freshwater distribution and abundance of juvenile Chinook salmon in the Skokomish River. However, outmigration data was collected at several locations throughout the Skokomish Basin (WDFW 1957) and from a panel trap operated by the Skokomish Tribe in Skobob Creek between 18 April and 30 May 2003. Estuarine use and timing data for juvenile Chinook salmon was collected by the Skokomish Tribe between December 27, 2004 and July 5, 2005.

Juvenile Chinook salmon distribution was restricted to the lower Skokomish Basin generally below the first canyon on both the South Fork Skokomish (RKM 5) and Vance Creek

(RKM 6). However, they were estimated to be present all the way up to the lower dam on the North Fork Skokomish. Juvenile Chinook had a much greater distribution in the winter than in the summer, when they were present only below the confluence of the South Fork Skokomish and Vance Creek, and were absent from the North Fork Skokomish (Figure 35). However, this is likely an artifact of the timing of our summer sampling effort, which wasn‟t initiated until most juvenile Chinook salmon would have emigrated from the system.

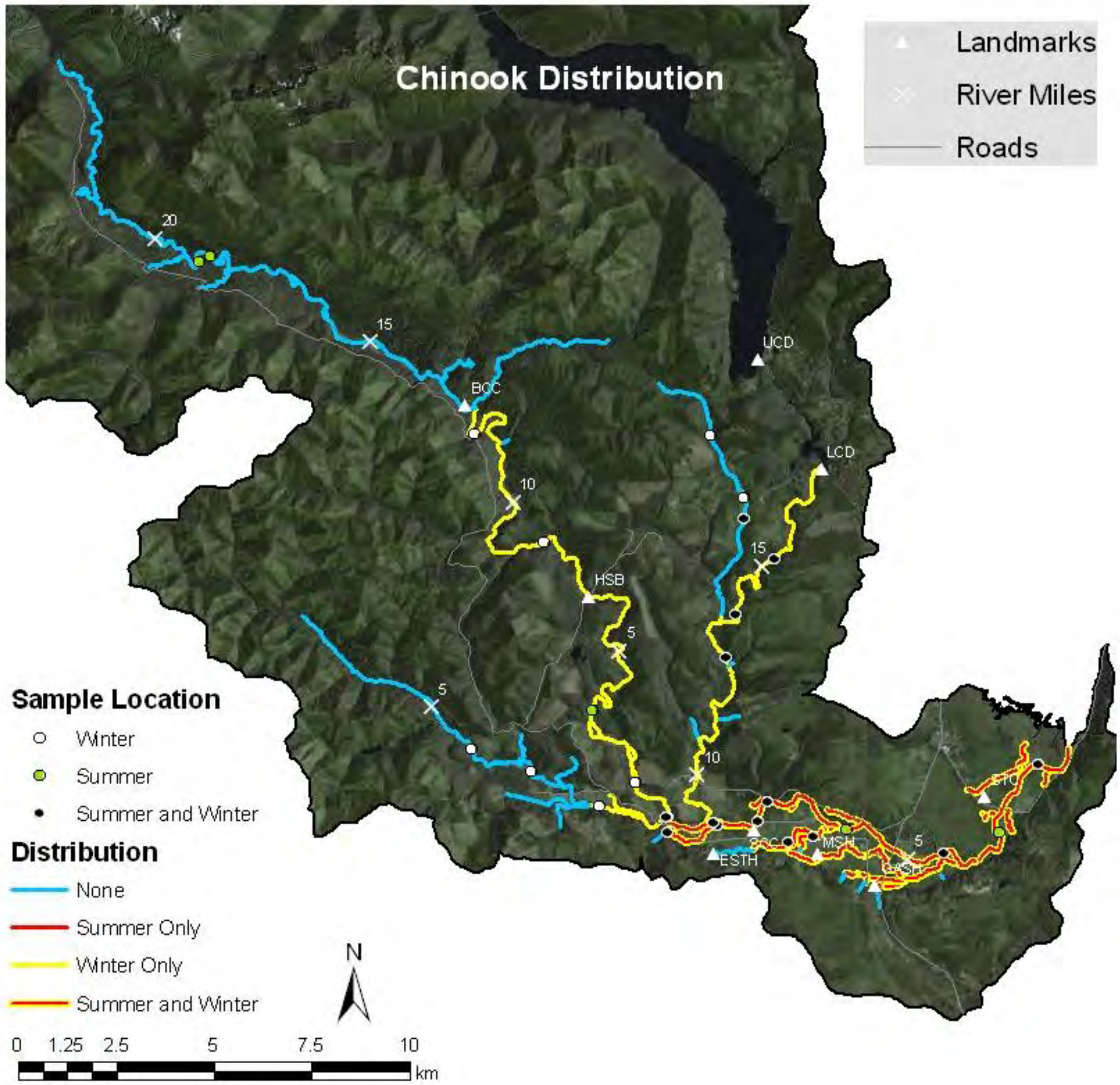

Figure 35. Expected juvenile Chinook salmon distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Our fish surveys results indicated juvenile Chinook salmon abundance varied by season and fish size class. We estimated that 3,157 and 17,963 juvenile Chinook salmon were present in the Skokomish Basin during the summer of 2008 and winter 2009, respectively. A majority of these fish were classified as greater than 50 mm fork length (large) in the summer (61%), while a majority were classified as being less than 50 mm fork length (small) in the winter (82.5%). The variation in abundance and size between the two seasons is likely due to the timing of our surveys. Our summer surveys didn‟t begin until June after most juvenile Chinook salmon would have been expected to have left the system. Those that remained had likely been rearing for some time in freshwater and therefore would have been relatively large. In contrast, our winter surveys were completed from January through March, when many juvenile Chinook were emerging from the gravel.

We observed juvenile Chinook salmon in main stem, tributary and freshwater pond habitats. The importance of mainstem, tributary, and pond habitat for juvenile Chinook salmon differed by size class and season (Table 26). Small juvenile Chinook salmon were nearly equally distributed between mainstem and tributary habitat during the summer, while no small juvenile Chinook were observed in ponds. However, during the winter, over half of the small juvenile Chinook salmon were estimated to be rearing in mainstem habitats, with the remaining fish nearly equally distributed between tributaries and ponds. In contrast, a majority of large juvenile Chinook salmon were estimated to be rearing in ponds during the summer, with nearly equally small percentages rearing in mainstem and tributary habitats. During the winter, a majority of larger juvenile Chinook salmon were rearing in the mainstem, with about half as many rearing in tributaries and very few rearing in ponds.

In general, juvenile Chinook salmon are relatively uncommon in pond habitats. For example, Murphy et al. (1989) reported that juvenile Chinook salmon were relatively uncommon in beaver ponds or off-channel sloughs (similar to our backwaters). In addition, Morley et al. (2005) reported that juvenile Chinook salmon densities were low in about half the constructed groundwater-fed side channels they sampled. These sites were relatively deep and homogenous, in contrast to reference side-channels. Thus, they were likely similar to the pond habitats that we sampled in the Skokomish watershed. Thus, the large percentage of large juvenile Chinook salmon rearing in ponds during the summer is somewhat surprising. Although, juvenile Chinook salmon do rear in larger lakes when present in their watersheds (Tabor 2004, 2006).

Table 26. Proportion of the different sized juvenile Chinook salmon population estimated to be rearing in mainstem, tributary, and pond habitats during the summer (2008) and winter (2009).

fish	Season	Proportion Mainstem	Proportion Tributary	Proportion Pond
Chinook >50 mm	Summer	0.05	0.06	0.88
Chinook >50 mm	Winter	0.68	0.31	0.01
Chinook <50 mm	Summer	0.45	0.55	0.00
Chinook <50 mm	Winter	0.52	0.23	0.24

Reach densities of small juvenile Chinook were positively related to the percentage of the reach that was composed of backwater habitat during the winter; however, the relationship explained very little of the overall variability ($r^2 = 0.18$). Reach densities of small juvenile Chinook salmon were negatively related to sediment score, although the relationship explained little of the variability ($r^2 = 0.26$). Thus, small juvenile Chinook salmon appear to prefer smaller substrate, which is consistent with observations from other systems (Hillman et al. 1989a; Hillman et al. 1989b; Garland et al. 2002; Peters, unpublished data), although large substrate preferences have also been reported (Lister et al. 1995).

Within pond habitats, the importance of nearshore and off-shore areas changed between seasons and size class for juvenile Chinook salmon. Densities of Chinook >50 mm were greater in the offshore (84 fish/ha) than the nearshore (44 fish/ha) during the summer; however, the 90% confidence intervals overlapped suggesting that this difference was not statistically different. In contrast, no Chinook salmon >50 mm were observed in the off-shore transect during the winter, while nearly 3 Chinook >50 mm were observed in the nearshore transect. Densities of small Chinook (<50 mm) were much greater in the nearshore (241 fish/ha) than the off-shore (80 fish/ha) during the winter. However, the 90% confidence intervals overlapped, suggesting the results were not statistically significant.

Although differences in densities were observed in some cases, these differences translated to differences in production for only small Chinook during the winter. The nearshore area of the ponds represented approximately 40% of the total pond surface area. Estimated abundance of large juvenile Chinook in the nearshore during the summer was approximately 26% of the total production from ponds in the summer. Although all of the large Chinook were observed in nearshore areas during the winter, the estimated production from all the ponds was only 19 fish. In contrast, small Chinook production in nearshore areas during the winter represented approximately 67% of the total production even though the nearshore represented only 40% of the total pond habitat. Thus, any restoration of existing pond habitat, or the development of new pond habitat should consider improving the ratio of nearshore to off-shore habitats.

As stated above, juvenile Chinook salmon densities were slightly negatively related to mean depth and slope in the near-shore area of the ponds (Figure 28). Thus, few juvenile Chinook salmon were observed in sampled areas as bank slope and mean depth increased, which is consistent with other reports in lentic habitats (Sergeant and Beauchamp 2006; Tabor et al. 2006).

Our estimates of distribution may be influenced by the timing of our summer sampling and the distribution of our winter sampling sites. Summer sampling was completed between May and early October. Thus, most ocean type Chinook salmon had likely left the system before our sampling occurred. In addition, the winter distribution of juvenile Chinook salmon may have been greater than reported; however, we were unable to access the upper watershed due to snow during the winter of 2009. Adult Chinook salmon transported to the upper watershed as part of an adult supplementation program implemented by the WDFW and the Skokomish Tribal Nation spawned in the upper watershed (Matt Kowalski, Skokomish Tribe, personal communication).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. WDF (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 miles above mouth), and the Skokomish mainstem (old

U.S. HWY 101 bridge). Juvenile Chinook salmon were caught in all five outmigration sampling locations. Outmigration occurred from February through September. Peak catches varied among the sampling locations. Outmigration peaked in late July in the upper South Fork Skokomish, with less prominent peaks observed in April, May, and June. The peak catches occurred in late April to mid-May in the lower South Fork Skokomish. Large catches were observed in mid-February and peaked in March in Vance Creek. A small peak occurred in catches in the North Fork Skokomish in late March, although catches were relatively low at this site. A bimodal pattern was observed at the lower mainstem site, with peaks in mid-March and mid-May. Based on relative abundance estimates, WDF (1957) determined that the lower South Fork Skokomish was the most important producer of fall Chinook, followed by Vance Creek and the North Fork Skokomish respectively.

The Skokomish tribe sampled outmigrating fish in Skobob Creek during 2003 using a panel trap. During this period, a total of 170 Chinook smolts were captured, with a relatively uniform distribution throughout the operating time of the trap. (Skokomish Indian Tribe, unpublished data). A screw trap has also been operated by NMFS on the South Fork Skokomish near the confluence with Vance Creek since 2007 to assess production and outmigration timing steelhead from April 1 to June 15.

New Chinook salmon outmigration data was collected during this project (see Appendix Outmigration for details on methods and general results). A total of 275 wild and 1,742 hatchery Chinook were captured from January 21 to July 19, 2009 (Figure 36). Chinook fry were caught primarily in January and February (77% of season fry total), but were also caught in low numbers (<10) from March through early July. Wild Chinook smolts were captured sporadically and generally in low numbers from late January through mid-July. One exception was the 51 fish captured on May 19, 2009; it is possible that a majority of these fish were unmarked hatchery fish released on either May 15 or May 18. Hatchery Chinook were caught from mid-May through mid-July. The peak catch occurred in mid-May, immediately after the hatchery releases.

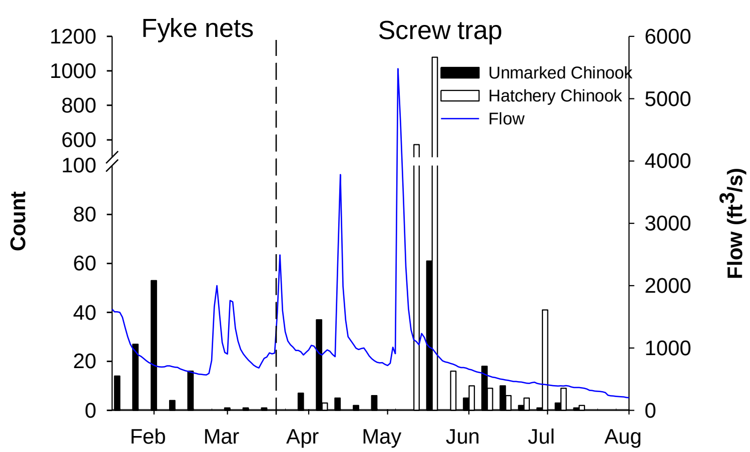

Figure 36. Weekly counts (first axis) of juvenile unmarked and hatchery Chinook captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

An estimated 239,511 Chinook migrated pass the screw trap between mid-March and late July (Table 27). About 93% (222,745) of the total Chinook estimate was hatchery parr and smolts, with unmarked (wild) Chinook comprising the remaining 7% (16,766). We feel that we likely underestimated outmigration numbers for naturally produced Chinook salmon. First, substantial numbers of Chinook salmon fry were caught in our fyke nets prior to operating the screw trap. However, we could not assess the efficiency of these traps because we never recaptured any marked individuals. Thus, our efficiency was likely very low. These early catches were not included in our outmigration estimate. In addition, our efficiency estimates for the screw trap appear to be flawed. The hatchery Chinook figure corresponded to about 6% of the 3,899,993 Chinook released by the Washington Department of Fish and Wildlife (WDFW) into the Purdy Creek between mid-May and mid-July 2009. The large difference in our estimate relative to the actual hatchery release may be due to poor survival of hatchery fish released at this location or due to underestimation at our trap. It‟s extremely unlikely that 94% of the hatchery Chinook release perish before reaching our trap. In addition, outmigration estimates for coho and chum salmon were also relatively low relative to the hatchery release. Thus, it is assumed that we underestimated production from the system.

Our underestimation was likely due to the release location being too close to the outmigration trap. Volkhardt et al. (2007) state that fish should be released at least two pool/riffle sequences upstream to allow fish to allow for a similar distribution pattern throughout the river to what is expected naturally. Our release site was located approximately 500 m upstream and was separated from our trap by one short riffle, a relatively large pool, and along run habitat. In addition, this site was located one complete meander bend upstream, providing at least two turns to distribute fish across the channel. This site was the last easily accessed site for approximately an additional 1,200 meters. We selected the closer site since we felt releasing the fish at the next access upstream might be too far upstream and could result in potentially significant predation losses.

Outmigration patters in the Skokomish River are similar to those from other Puget Sound systems. Chinook outmigration timing data from the Elwha River screw trap indicates that 0-age smolts begin to migrate downstream in late February and that the migration can continue all the way to the end of June in some years, but generally tapers off significantly by the beginning of June. The peak is generally the second half of March (National Oceanic and Atmospheric Administration (NOAA), unpublished data). On the Elwha, age 1+ smolts exhibit a very similar outmigration pattern to age 0+ smolts. Seiler (2003) reports a bimodal peak for juvenile Chinook salmon in the Cedar River. Large numbers of Chinook fry migrate to Lake Washington during January and March, with a second smaller peak migrating in mid-May to early-July. Kinsel et al. (2008) report that on average 50% of juvenile Chinook salmon migration occurs by the end of March in the Skagit system. In contrast, Griffith and Van Arman (2010) observed few juvenile Chinook outmigrants in February in the Stillaguamish River, where bi-modal peak outmigration occurred in April and early May to early June.

Table 27. Estimated migration of salmonid species during screw trap sampling on Skokomish River, March-July, 2009.

Species	Life Stage	Origin	Catch	Expanded Catch	Marked	Recaptured	Efficiency	Population Estimate	C. I. (95%)	
									Lower	Upper
Chinook	Fry	Unmarked	33	39	2	0[1]	0.4%[2]	101	0	209
	Parr	Unmarked	27	28	16	0	0%	3472	-	-
		Hatchery	243	278	231	1	0.4%	34472	-	-
	Total		270	306	247	1	0.4%	37944	0	80848
	Smolt	Unmarked	98	108	70	0	0%	12936	-	-
		Hatchery	1499	1574	1007	8	0.8%	188530	-	-
	Total		1597	1682	1077	8	0.7%	201466	76786	326146
Chum	Fry		5347	5734	90	9	10.0%	52179	23062	81297
Coho	Fry	Unmarked	1630	1969	639	6	0.9%	180023	55737	304309
	Parr	Unmarked	187	261	65	0	0%	26274	-	-
		Hatchery	3	3	3	0	0%	302	-	-
	Total		190	264	68	1[3]	1.0%[4]	18872	0	23781
	Smolt	Unmarked	762	1014	396	6	1.5%	87639	-	-
		Hatchery	765	857	208	0	0%	74069	-	-
	Total		1527	1871	604	6	1.0%	161708	50092	273324

[1] Calculated from season trap efficiency rate of Chinook parr.
[2] Season trap efficiency rate of Chinook parr.
[3] Calculated from season trap efficiency rate of coho smolts.
[4] Season trap efficiency rate of coho smolts.

The size of juvenile Chinook salmon caught during our outmigration sampling was quite variable. The fork length of unmarked (wild) Chinook salmon ranged from 32 mm to 143 mm, averaging 56 mm. Weekly average fork lengths increased from around 40 mm in late January and February to above 75 mm in late May and early June (Figure 37), indicating that juvenile Chinook salmon were rearing in freshwater habitat. Weekly average fork lengths for hatchery Chinook ranged between 70 mm and 85 mm from May through early July. Comparison of length frequency distributions between unmarked and hatchery Chinook showed unmarked Chinook salmon were much smaller than their hatchery counterparts (Figure 38). The dominant size range for wild and hatchery Chinook were 31-40 mm and 81-90 mm, respectively. WDF (1957) stated that newly emerged Chinook averaged about 40 mm and the earliest yearlings averaged about 88 mm. Yearlings, which were more abundant in the lower South Fork Skokomish than the upper South Fork Skokomish averaged between 82 and 127 mm. Zero-aged Chinook ranged from about 40-42 mm at all the stations sampled. These size classes are similar to what we observed during our sampling efforts. Our data also suggests that a yearling life history strategy is still exhibited in the Skokomish River. Whether these yearlings are from naturally produced Chinook or residual or unmarked hatchery fish is unclear.

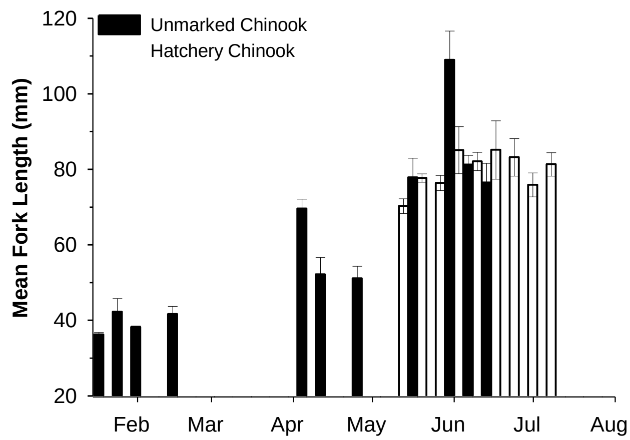

Figure 37. Weekly mean fork lengths and standard errors of juvenile unmarked and hatchery Chinook captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

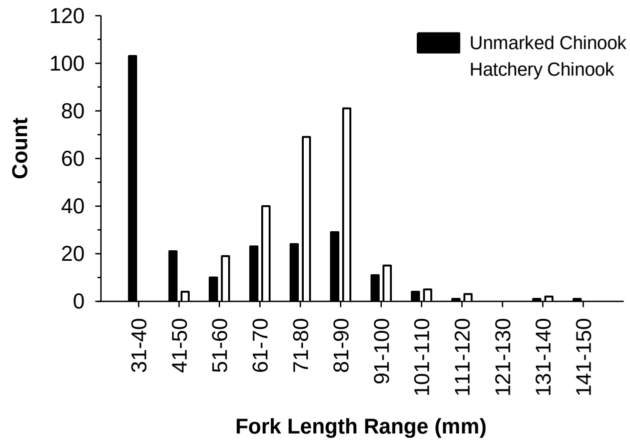

Figure 38. Length frequency of juvenile Chinook captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

Existing data for Chinook salmon estuary use and timing was collected by the Skokomish Tribal Nation between December 27, 2004 and July 5, 2005. The estuary sampling occurred in the vicinity of Nalley Island and West Slough. A total of 17 and 25 Chinook were captured at Nalley Island and West Slough, respectively. They were captured beginning from January through the end of April, with the peak occurring in late January through early February (Skokomish Indian Tribal, unpublished data). It"s unclear why so few Chinook salmon were captured during their surveys or why the residence time was so short. This information contrasts sharply with the new data collected as part of the Skokomish GI.

New estuarine use data was collected from July 2008 through September 2009 during this project (See Appendix Estuary for details of methods). Sampling occurred exclusively on Nalley Island both at high and low tide (Figure 39). Juvenile Chinook were captured in the estuary from January through August, with peak abundance occurring in late May (Figure 40). A majority (75%) of the Chinook salmon observed in the estuary were of hatchery origin and the residence time of hatchery and unmarked Chinook salmon varied (Figure 41). In general, hatchery fish were observed later in the year and last observed earlier in the year than unmarked fish. Unmarked juvenile Chinook were first observed several months before their hatchery counterparts, but a single hatchery Chinook was captured four weeks after the last unmarked Chinook were captured.

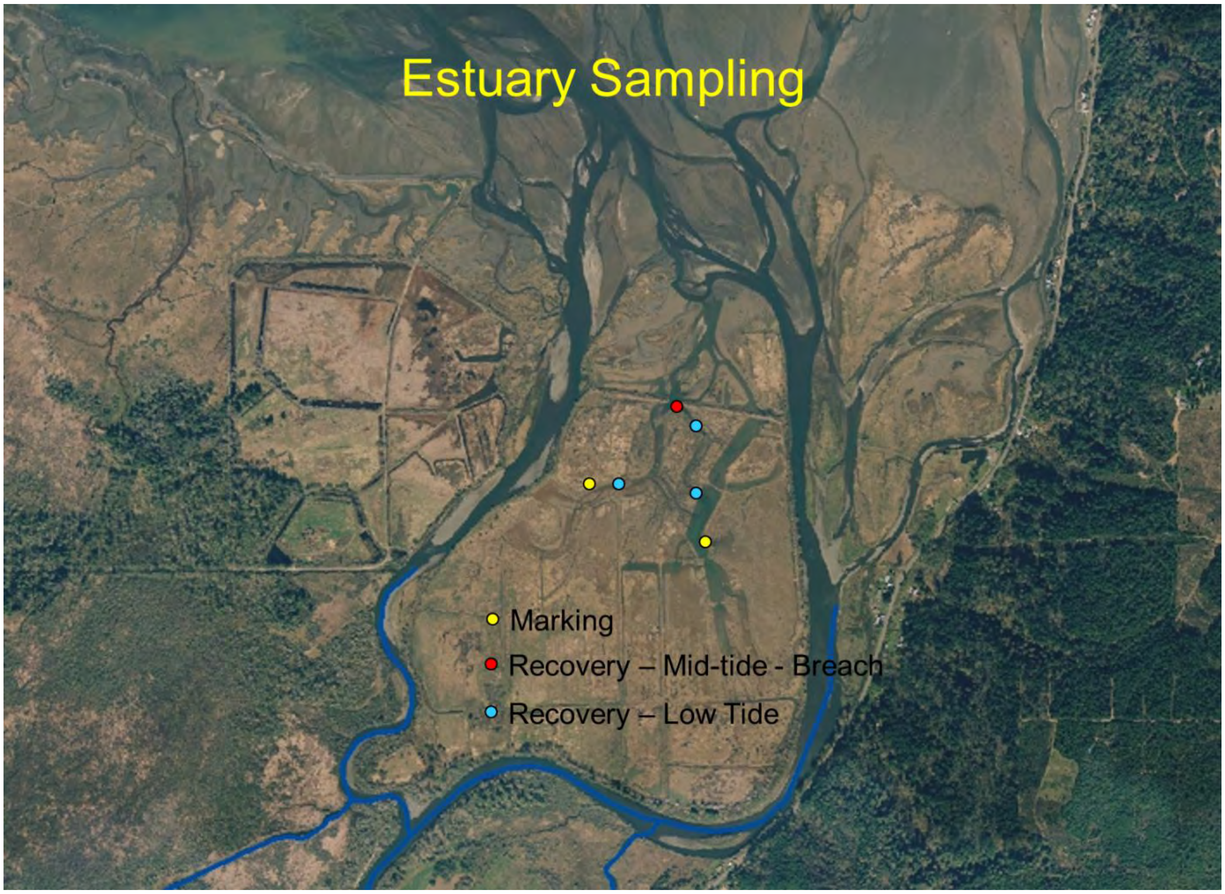

Figure 39. Primary sampling locations within the Skokomish River estuary. All the sampling was completed on Nalley Island. Fish were sampled at marking sites during high tide, marked and released back to those locations. Fish were sampled for marks at the Breach (red dot) from mid-tide to low tide and at the low tide sites during low tide.

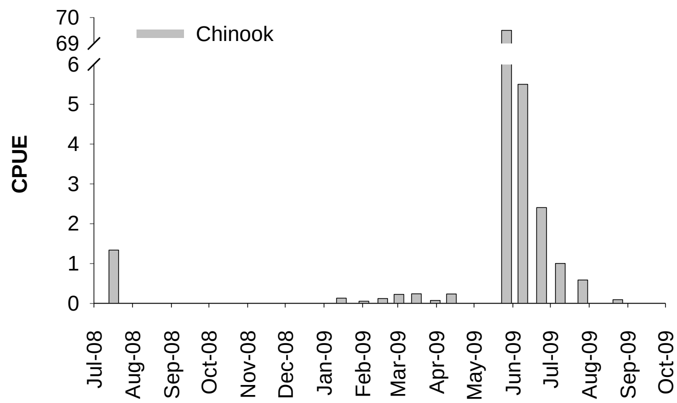

Figure 40. Catch-Per-Unit-Effort (CPUE) of Chinook salmon captured in the Nalley Island portion of the Skokomish River estuary between July 2008 and September 2009.

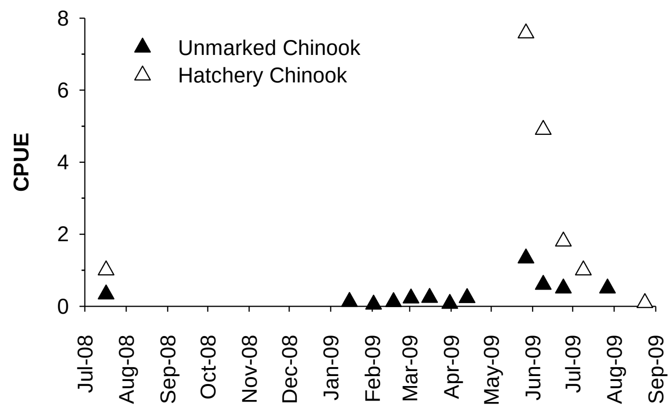

Figure 41. Comparison of residence timing of hatchery and unmarked juvenile Chinook salmon captured in the Nalley Island section of the Skokomish River estuary between July 2008 and September 2009.

Juvenile Chinook salmon in the estuary were differentially marked during each estuary survey to evaluate individual residence time and to calculate population estimates in the Nalley Island section of the estuary (see Appendix Estuary for details). Individual residence time for juvenile Chinook salmon could not be calculated since no juvenile Chinook salmon marked in the estuary was recaptured at a later date. However, juvenile Chinook marked at the screw trap between June 10 and June 18, 2009 for the outmigration study were captured in the estuary (Upper East 2 site) on June 24, 2009. Population estimates for juvenile Chinook could only be calculated on one day, May 27, 2009. The population estimate was 55,104 with 95% confidence intervals of 20,099 to 133,080. The 95% confidence intervals were quite large due to the low number of recaptures (2) in the relatively large number of marked fish released (335) and handled looking for recapture (491).

We summarized CPUE by location to examine the spatial distribution patterns within the estuary (Figure 42). CPUE for Chinook salmon was highest at the UW2 (low tide) location.

The size of juvenile Chinook salmon varied with survey (Figure 43). Juvenile Chinook salmon ranged from 71 to 90 mm in fork length. Mean fork lengths generally increased during the spring and summer months (Figure 43). Size differences among hatchery and unmarked fish varied among sample date (Figure 44), but in general mean lengths of hatchery juvenile Chinook salmon were 10 and 9 mm longer than their unmarked counterparts.

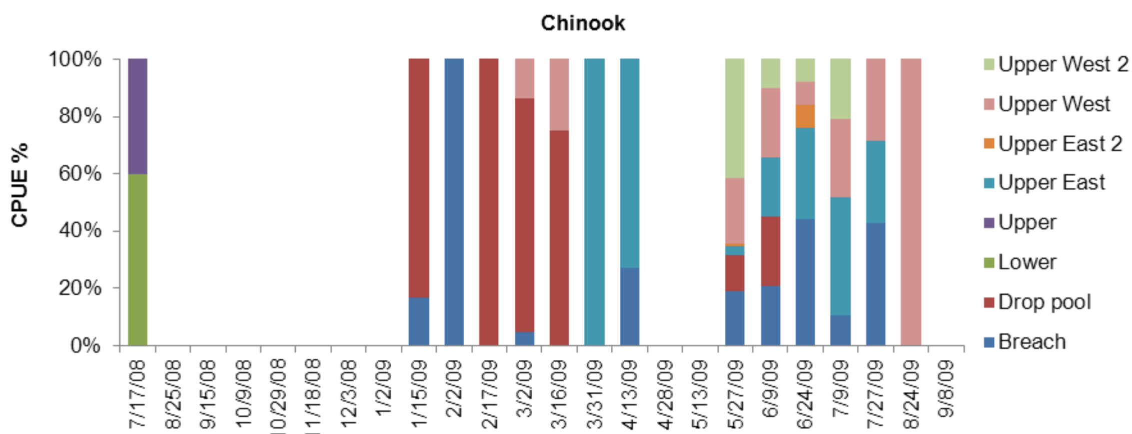

Figure 42. CPUE percentages of Chinook by sampling location, July 2008-September 2009.

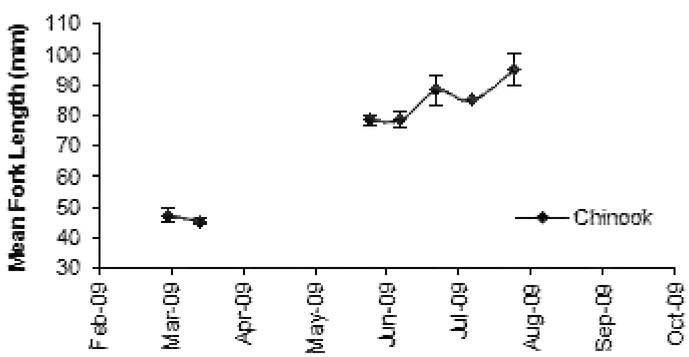

Figure 43. Mean fork lengths (+/- SE) of juvenile Chinook salmon caught in the Nalley Island section of the Skokomish River estuary between February and September 2009.

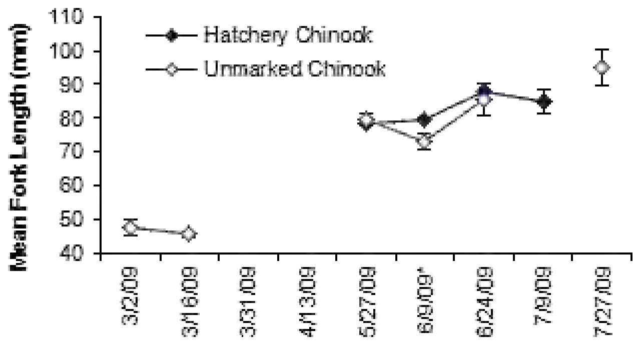

Figure 44. Mean fork length (+/- SE) of hatchery and unmarked juvenile Chinook salmon captured in Nalley Island section of the Skokomish River estuary between February and September 2009. The mean lengths are based on samples sizes of four or more. Asterisks next to the sampling dates, indicate the dates on which hatchery and unmarked fish are significantly different in length.

Limiting Factors: Chinook Salmon

The Skokomish Tribe and WDFW (2010) completed an extensive review of factors influencing Chinook salmon in the Skokomish Basin. Thus, it"s unnecessary to completely restate their findings here. However, it is useful to discuss how the new data we collected may influence their conclusions. In addition, we do not entirely agree with all of the assertions made by those authors. We discuss these differences in the section below.

It is important to note that the current Skokomish Chinook salmon population likely has little resemblance to the historic population. This is due to the fact that the historic populations have either become extinct (Spring Chinook) or largely replaced by non-native stocks. The native population was driven to extinction and very low numbers as a result of hydro development, habitat degradation, and overharvest (Skokomish Tribe and WDFW 2010). Hydro development blocked access to very productive habitat for spring Chinook salmon and diverted substantial portions of the Skokomish Basin discharge out of the Skokomish Basin. This, along with land clearing activities, LWD removal, and floodplain isolation through levee and bridge construction, resulted in severe habitat loss and degradation. Overharvest, documented early in the 20th century, clearly impacted the population returning to this less productive habitat. This resulted in hatchery intervention that brought in the non-native Green River Chinook salmon stock. The large releases of these non-native hatchery fish into the system completely changed the population structure of Chinook salmon in the Skokomish River (Myers et al. 1998; Ruckelshaus et al. 2006). Thus, the habitat use and timing observed during the new data collection may not resemble that of the historic stock.

The life history patterns of juvenile Chinook salmon in the Skokomish Basin is similar to what might be expected for river-type Chinook salmon throughout Puget Sound. Their distribution was limited to the lower Skokomish Basin. This was apparently due to barriers to adult migration. WDFW (1957) noted that the cascades in the South Fork Skokomish canyon were barriers to adult fall/winter Chinook salmon. This still appears to be true, despite the aggradation that has occurred just below the canyon and that has likely extended upstream into the canyon an unknown distance.

Abundance and production estimates in the Skokomish Basin suggest the population is severely depressed. Natural escapement, which includes both naturally, produced fish, as well as hatchery fish spawning in the river have been at relatively consistent and low numbers since the late 1960"s. In addition, a majority of the spawners have been of hatchery origin (average of approximately 60% - WDFW 2007). These returns also appear to result in few juveniles. We estimated that just less than 18,000 juvenile Chinook salmon were present in the Skokomish Basin (not including the estuary) during the winter of 2009. This is relatively consistent with our outmigration estimate (i.e., 16,000 unmarked). Both estimates likely underestimate total production due to the fact that juvenile Chinook would be emigrating from the system during our snorkel surveys and thus would not have been counted. The smolt trapping estimates were likely low due to the release point being too close to the trap, which elevated our estimated trap efficiency. However, these values would still be low relative to those from other Washington State River Basins. For example, Seiler et al. (2003) estimated that 81,000 and 65,000 Chinook smolts were produced in the Cedar River in 1999 and 2000, respectively. In fact, their estimates of Chinook production from Issaquah Creek (30,000) exceeded our estimates for the Skokomish, despite the fact that Chinook migration had begun prior to their trap installation (Sieler et al. 2003).

As expected, juvenile Chinook salmon were observed throughout the system, including mainstem, tributary and off-channel pond habitats. Mainstem habitats appear to be more important during the winter, since a majority of the fish were observed in mainstem habitats relative to tributary and off-channel habitats at that time. However, pond habitats appear to become more important during the summer. Juvenile Chinook salmon were also common in the estuary and were relatively abundant compared (i.e., 55,000) to their observed abundance in freshwater habitats, despite the fact that we sampled a very small portion of the estuary. This suggests that a majority of juvenile Chinook salmon in the system may be migrating directly to the estuary without rearing in the freshwater environment for extended periods.

Based on our assessment, we feel Chinook salmon are limited in part by reduced availability, connectivity, stability, and quality of habitat, as well as impacts related to hatchery propagation in the system. However, habitat loss, channel stability, and hatchery influences are probably the most important factors impacting Chinook salmon in the Skokomish Basin. Significant spawning and rearing habitat has been lost as a result of dam construction in the North Fork Skokomish. Chinook salmon are isolated from additional spawning habitat for much of the early fall as a result of channel dewatering in the South Fork Skokomish and Vance Creek. Although habitat stability has not been sufficiently evaluated in this system, the level of aggradation suggest that scour of redds is likely a major issue. This would be exacerbated by the low flows associated with the timing of Chinook spawning in the system. These habitat factors would be exacerbated by the level of straying of non-local hatchery Chinook to the system (60% hatchery spawners – Green River lineage), since these fish would be expected to have reduced survival and reproductive capabilities relative to a natural locally adapted stock (i.e., HSRG 2004, Jonsson and Jonsson 2006; Araki et al. 2008).

Chum Salmon

Adult

Chum – Upper Skokomish Late Fall

Fall chum salmon in the upper Skokomish River are a wild, naturally reproducing stock. They were deemed an individual stock in the original 1992 SASSI based on their spatial and temporal spawning distribution and genetic analysis. They were originally listed as healthy in the 1992 SASSI and that status remains today. They spawn in most tributaries of the Skokomish system from December through January, with the heaviest concentration being the lower 7.6 km (4.7 mi) of the North Fork Skokomish. Natural spawner counts (Figure 45) are based on index reaches in the lower North Fork Skokomish, Reichert Springs, Swift Creek, and Vance Creek. They do not appear to be able to pass through the canyon on the South Fork Skokomish (ME2 Environmental Services, 1997). Allozyme analysis indicates that this stock contributes to the genetic heterogeneity of Hood Canal Chum but not all pairwise comparisons show significant differentiation (Phelps 1995).

Chum - Lower Skokomish Fall Chum

Lower Skokomish River Fall chum were identified as an individual stock in the 1992 SASSI based on their temporal and geographic differentiation with upper Late Fall chum. Spawning is concentrated between November and December and occurs in Purdy and Weaver Creeks along with the lower main stem Skokomish River. No quantitative data on adult escapement exists for the stock but many (probably strays) spawn in the river proper and its tributaries. Based on these qualitative observations, the stock has been listed as healthy. No genetic analysis has been done on this stock.

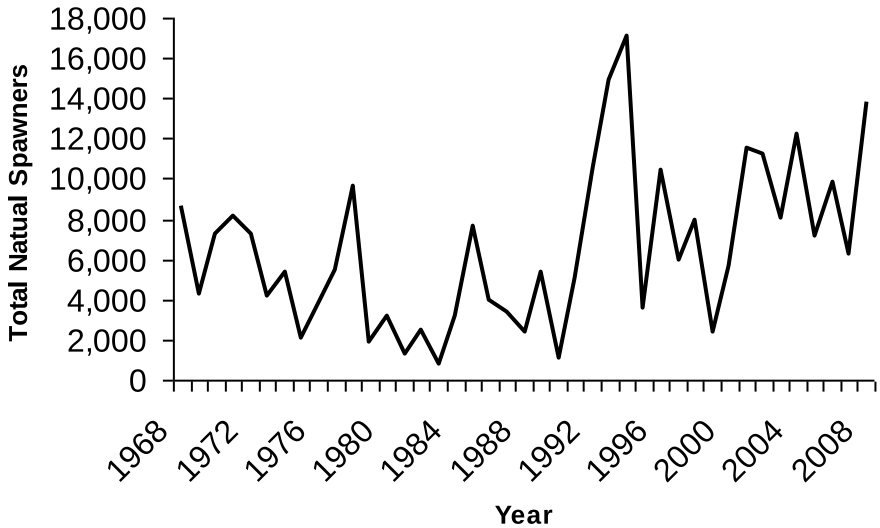

Figure 45. Total natural spawners of late fall upper chum in the Skokomish River from 1968 to 2008. Data are based on index reaches in the lower North Fork Skokomish, Reichert Springs, Swift Creek, and Vance Creek. All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm

Chum - Summer Chum

Skokomish River summer chum were identified as an individual stock in the Summer Chum Conservation Initiative (WDFW and PNPTT 2000) based on their early spawn timing, but have been labeled extinct in the Skokomish River as of the 2002 SASSI. A few summer chum are recorded in the main stem every year but not enough to characterize them as a self-sustaining population. Historically, they spawned from mid-September to mid-October in the lower portions of the watershed (WDFW and PNPTT 2000).

Juvenile

Fall chum in Hood Canal emerge from mid-April through May (Koski 1975). All juvenile chum salmon migrate directly to sea after emergence, and therefore rely little on freshwater habitat. However, some freshwater rearing has been inferred in other systems based on increasing size of individuals in freshwater (Peters 1996b). Regardless of how long they spend in freshwater, they do require the basic physical requirements of suitable temperature, flow, cover, etc. presented above for incubation and seaward migration. Migratory conditions are likely very important to juvenile chum salmon since they migrate at a small size, which increases their vulnerability to predation. In addition, factors such as discharge, turbidity, and light levels are important to fish during seaward migration (Tabor et al. 2004). Next to Chinook salmon, chum have been described as the most reliant on the estuary habitat, based on residence time (~25 days) (Simenstad et al. 1981). They use the estuary as a rearing location, refugia from predation, transition zone, and migration corridor. As with other species, eel grass beds provide important habitat for juvenile chum during their residency in the estuary (Wissmar and Simenstad 1988).

Chum salmon migrate directly to the estuary after emergence so their reliance on fresh water habitat is limited, although the effects of summer low flows and winter high flows and the associated sedimentation of redds can all affect spawning distribution and incubation success. The lack of surface water in lower Vance creek and the South Fork Skokomish during the summer months can limit the distribution of early chum salmon (i.e., summers) or dry up incubating eggs that were spawned prior to the channel going dry. In addition, because they spawn before (summer) or during the high winter flows (falls), main stem redds may be scoured or dewatered as a result of channel migration prior to emergence. Chum are the second most reliant salmonid species on the Skokomish estuary. In Puget Sound, during the first few weeks of estuarine residency, they occupy the top few centimeters of the water column and remain extremely close to shore (Ron Egan, WDFW, Olympia, WA, pers. comm., cited in WDFW and PNPTT 2000). Declines in estuary habitat, particularly the loss of near-shore areas and eelgrass beds, is the main limiting factor for juvenile chum salmon in the Skokomish watershed.

We found no published information on the freshwater distribution and abundance of juvenile chum salmon in the Skokomish River (Figure 46). During the field work conducted for this study, juvenile chum salmon were observed in main stem, tributary and freshwater pond habitats. Their distribution was restricted to the lower South Fork Skokomish, apparently by the first canyon in the South Fork Skokomish (RKM 5). In contrast to Chinook salmon, chum salmon were observed upstream of the first canyon in Vance Creek, suggesting that flows may limit adult Chinook salmon upstream migration in Vance Creek early in the fall. However, chum salmon distribution was reduced in the North Fork Skokomish relative to Chinook salmon, extending only to RKM 9. This is likely due to the presence of small cascades in this region of the North Fork Skokomish.

Juvenile chum salmon had a greater distribution during the winter of 2009 than they did during the summer of 2008. Similar to Chinook salmon, this was likely due to the timing of our summer surveys, which were completed from late May through October. Thus, most juvenile chum salmon would have likely left the system by the time we initiated our surveys. The lack of sampling locations upstream of the canyons during the winter due to lack of access (deep snow) also may make our estimates of chum salmon distribution conservative. This possibility is supported by the observation of chum salmon above the first canyon in Vance Creek RKM 5, but is refuted by the more limited distribution of juvenile chum salmon in the North Fork Skokomish.

Juvenile chum were observed in mainstem, tributary, and pond habitats, although they were only present in pond habitats during the summer. In contrast, they were most common in mainstem habitat during the winter, with about half as many in tributaries and very few in pond habitats. We estimated a total chum fry population of 86 fish in the summer. In contrast, we estimated 25,577 fish during the winter (95% Confidence Interval: 8,810-50,599). All the juvenile chum salmon were rearing in ponds during the summer, while only 101 juvenile chum (of 25,577) were in the ponds during the winter.

Juvenile chum salmon densities in pond habitats were very low during both summer and winter. No juvenile chum salmon were observed in nearshore areas during the summer, while densities were approximately 6 fish/ha in the offshore transects. In contrast, juvenile chum salmon were observed in both the nearshore (8.9 fish/ha) and offshore (4.4 fish/ha) transects during the winter. Although these differences in density translated to large differences in the proportion of juvenile chum salmon produced from nearshore (0% summer, 58% winter) and offshore areas (100% during summer, 42% during winter), the limited production of chum salmon from the ponds does not warrant specific habitat restoration recommendations in ponds for chum salmon.

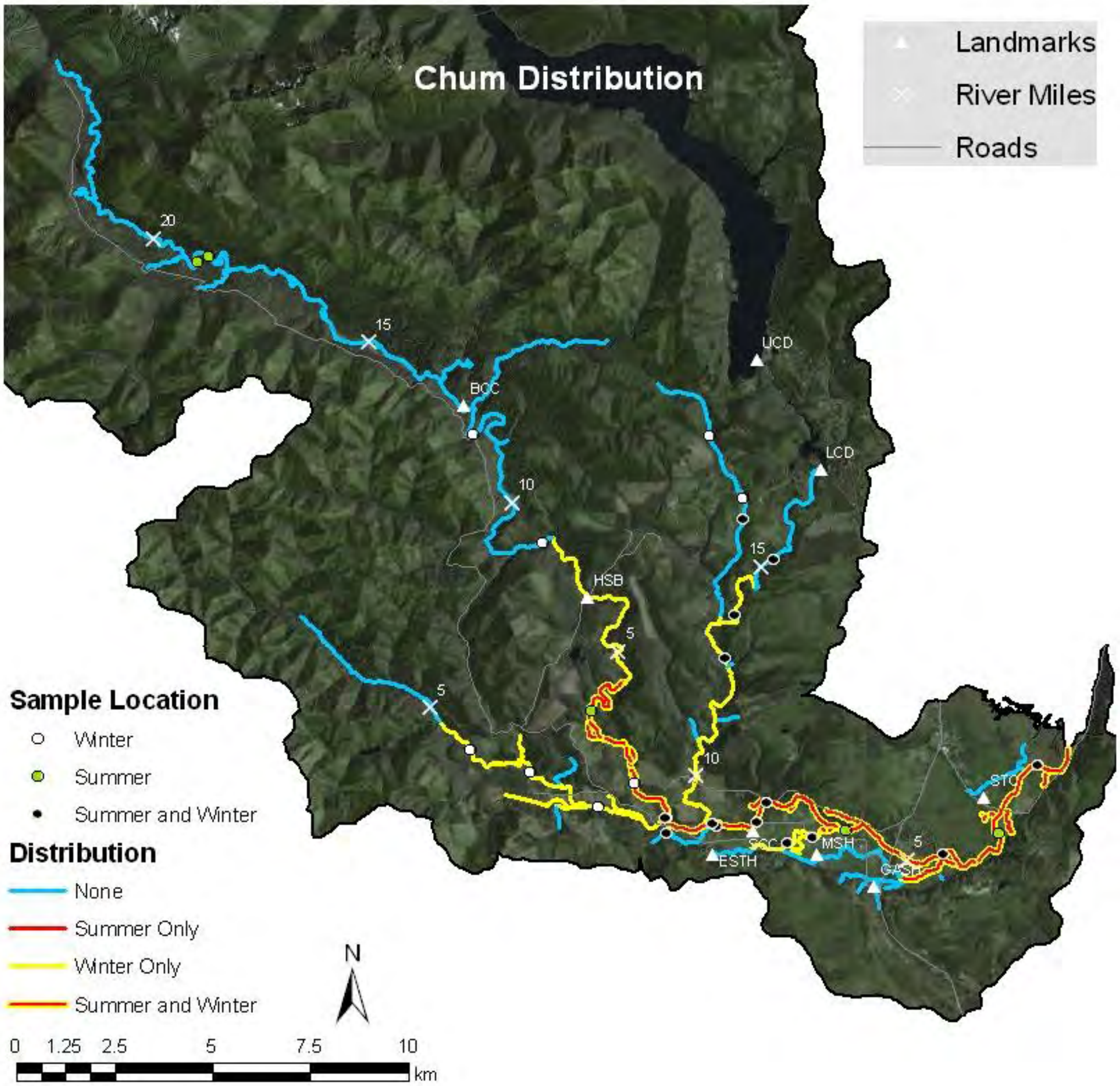

Figure 46. Expected juvenile chum salmon distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. WDF (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 mi above mouth), and the Skokomish mainstem (old U.S. HWY 101 bridge). Chum salmon were caught at all but the upper South Fork Skokomish sampling site. Outmigration started earlier at the mainstem site and was progressively later at upstream traps. Outmigrants were caught from mid-January through the June. Peak catches varied by location. Peak catches occurred in mid-May at the lower South Fork Skokomish site, April and early May in Vance Creek, and the end of March in the mainstem. A tri-model pattern occurred in the North Fork Skokomish with peaks occurring in March, April, and mid-May (the largest). Based on relative abundance estimates derived from this sampling effort, WDF (1957) concluded that the North Fork Skokomish was the largest chum producer followed by Vance Creek and then the lower South Fork Skokomish. However, they go on to state that the lower mainstem site could not be included in this assessment and that this area "is conclusively known" to be one of the largest production areas for chum salmon, especially early chum (i.e., summer chum).

Additional sampling was completed by the Skokomish Tribe using a panel trap to sample Skobob Creek between 18 April and 30 May, 2003. Because of the limited availability of information it is impossible to compare trends in abundance, but a discussion of relative abundance to other species and outmigration timing is possible. In 2003, a total of 26 chum fry were captured in the panel trap and they had a relatively uniform size distribution throughout the operating time of the trap. It is important to note, that while all species must eventually pass through the estuary, Skobob creek is not a major chum spawning tributary.

We caught a total of 8,054 chum salmon during our outmigration trapping efforts from January 21 to July 13, 2009 (Figure 47). Peak daily migration occurred on February 18, when 1,887 fish were counted. Prior to April in which two hatchery releases occurred (1^{st} and 16^{th}), 2,789 chum were captured. During the month of April, 5,105 chum were captured. From early May through mid-July, 160 chum were captured and daily catches were all fewer than 10 fish.

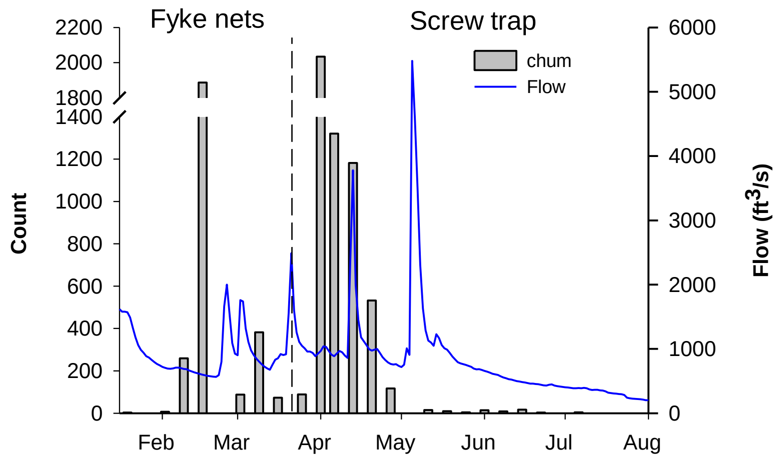

Figure 47. Weekly counts (first axis) of juvenile chum captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

We estimated that 52,179 chum migrated downstream during screw trap sampling (Table 27). The number was extremely low considering that 10 million chum released by WDFW in Weaver Creek, a tributary of Skokomish River, in 2009. This apparent large discrepancy between our estimate and the total hatchery release could be due to low survival of hatchery chum salmon released at this location or underestimation at the trap. Recapture rates of chum salmon (10% overall, 9 of 90), especially hatchery chum salmon (20%, 4 of 20) were much greater than those of other species which were generally between 0.5 and 1%. In addition, our estimates of hatchery coho salmon production represented only 25% of the hatchery coho smolt release from the same location. Thus, our production estimates are likely low. This is potentially due to the release location of marked individuals used to assess trap efficiency being located too close to the outmigration trap. If the release location was too close, the fish would not distribute equally across the river, resulting in an overestimate of trap efficiency. Although we followed the guidelines of Volkhardt et al. (2007), locating our release point two pool/riffle sequence (500 m) upstream of our trap, it was apparently too close in this system.

The fork lengths of chum fork caught during the outmigration sampling ranged from 30 mm to 84 mm and averaged 42 mm. Juvenile chum salmon are relatively small at outmigration, but freshwater rearing and growth also appear to occur. WDF (1957) noted that juvenile chum salmon outmigrants averaged 38 to 40 mm but showed definite growth in both Vance Creek and the mainstem in June. Juvenile chum salmon outmigrants in the current study had fork lengths that ranged from 30 to 84 mm and averaged 42 mm. Over the season, weekly mean fork lengths increased from below 40 mm in late January and early February to over 60 mm in early July (Figure 48). During the first three weeks of April when hatchery chum were released and presumably had a large presence, average lengths increased considerably into the 45-50mm range. Length frequency distribution indicated that the dominant size range was 36 to 40 mm (Figure 49).

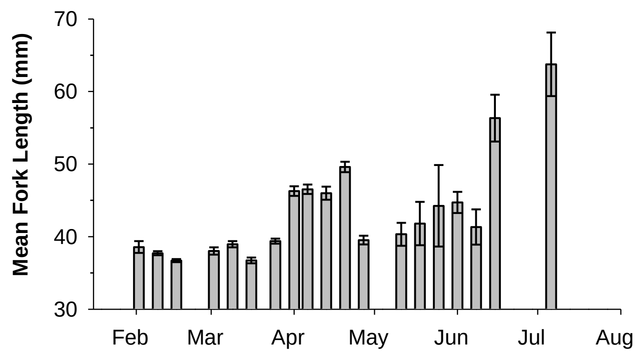

Figure 48. Weekly mean fork lengths and standard errors of juvenile chum captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

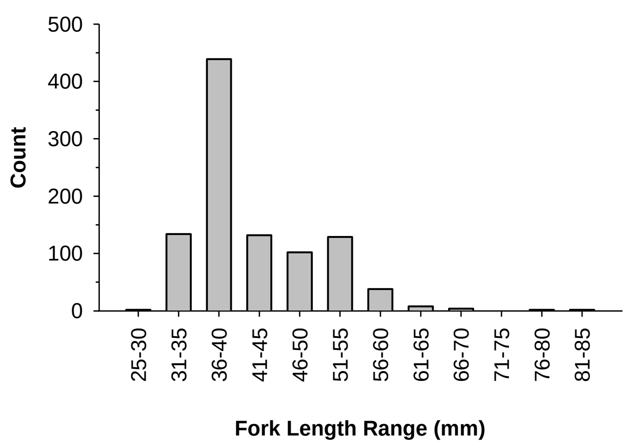

Figure 49. Length frequency distribution of juvenile chum captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

Estuary data was collected by the Skokomish Tribe between 27 December 2004 and 5 July, 2005. The estuary sampling occurred in the vicinity of Nalley Island and West Slough. A total of 1,232 and 120 chum fry were captured at Nalley Island and West Slough, respectively. They were captured throughout the sampling period, with the peak occurring from early February through April (Skokomish Tribe, unpublished data).

Juvenile chum salmon were the most numerous salmonid caught in the estuary during our sampling efforts, with a total of 2,261 being caught. Juvenile chum were captured from February through June, with abundance gradually increasing from March until the peak in mid-May (Figure 50). No juvenile salmon were observed during surveys from October through December. We could not calculate population estimates for juvenile chum salmon in the Nalley Island section of the Skokomish estuary since no marked fish were recaptured during our mark-recapture surveys. In addition, individual residence times could not be estimated for chum salmon since no marked fish were re-captured during subsequent surveys. However, juvenile chum salmon was one of five species to dominate the catch in the Nalley Island section of the Skokomish River estuary during different part of the year, along with shiner perch, Pacific Staghorn sculpin, surf smelt, and starry flounder. Juvenile chum salmon made up the largest percentage of the catch from March through mid-May.

CPUE increased steadily from mid-February through mid-May and hen declined sharply, with low CPUE observed until early July (Figure 50). Juvenile chum salmon CPUE was greatest lower in the Nalley Island portion of the estuary near the breach. Juvenile chum salmon fork length varied from 30 to 70 mm; however, 45% of the fish were less than 40 mm. Average fork lengths increased during the spring and summer months (Figure 51).

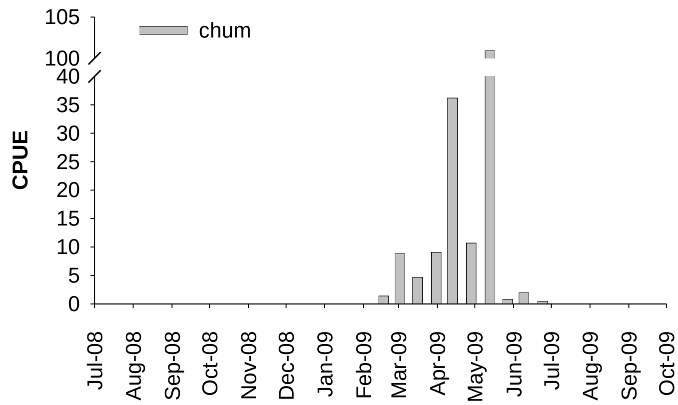

Figure 50. Catch-Per-Unit-Effort (CPUE) of juvenile chum salmon in the Nalley Island portion of the Skokomish River estuary between July 2008 and September 2009.

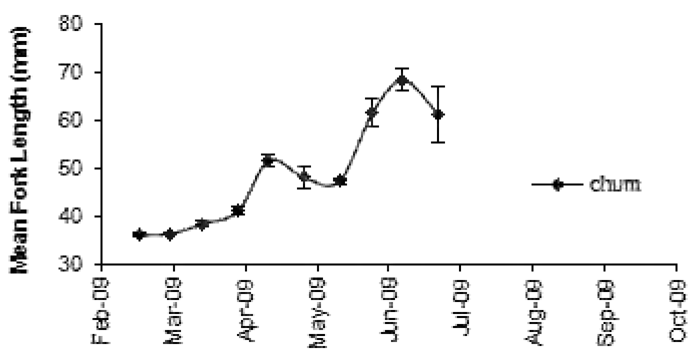

Figure 51. Mean fork lengths (+/- SE) of juvenile chum salmon caught in the Nalley Island section of the Skokomish River estuary between February and September 2009.

Limiting Factors: Chum Salmon

The general lack of information for chum salmon in the Skokomish Basin makes it difficult to assess limiting factors for this species. However, information can be inferred based on the status of the three stocks historically present in the Skokomish Basin, summer chum, lower fall chum, and upper late fall chum. Summer chum are apparently extinct in the system, while late upper fall chum are apparently healthy. Lower fall chum are listed as healthy; however, there is limited information regarding their actual abundance. The difference in stock status between summer chum and upper late fall chum suggest that habitat factors related to the difference is the timing of their major life history events. These major factors are river entry and spawning timing, and potentially outmigration timing and estuarine use.

Skokomish summer chum salmon spawn between mid-September and mid-October (WDFW and PNPTT 2000), which is much earlier than upper late fall chum in the Skokomish basin, which spawn from December through January. The primary habitat differences related to these spawning times is river discharge during spawning migration and egg incubation. Summer chum enter the river during summer low flow, when migratory barriers often exist in Vance Creek and the South Fork Skokomish. This would limit habitat available for summer chum salmon spawning. However, it‟s unclear if summer chum salmon spawned in these locations historically, since summer chum generally spawn within the lowest one to two miles of tributaries (WDFW and PNPTT 2000). In contrast, upper late fall chum salmon migration occurs during the time of year that discharge is adequate for upstream migration. The entry of summer chum salmon during low flow periods would also result in redds being closer to the middle of the channel potentially making them more susceptible to scour. In addition, they would spawn before the major fall freshets, meaning their redds would have to survive the high discharges associated with this time period. In contrast, upper late fall chum generally spawn after these major high flow periods, which would make them less susceptible to scour. Thus, the scour of redds is a potential factor influencing summer chum salmon stocks in the Skokomish Basin.

Differences in estuarine timing could also result in the differences observed in population status between summer chum and upper late fall chum. Summer chum fry generally emerge in late March to early April approximately one month earlier than Hood Canal fall chum (WDFW and PNPTT 2000). This early emergence could influence food availability for summer chum; however, this has not been documented for the Skokomish Basin. Thus, it‟s unclear how food availability may influence summer and upper late fall chum in the Skokomish Basin. This should be evaluated further in the future.

The loss of estuarine habitat likely limits chum salmon in the Skokomish Basin. The documented loss of the stream-estuarine ecotone and estuarine habitat as a result of diking described above would significantly reduce habitat available for chum salmon. As stated above, chum salmon are reliant upon estuarine and nearshore habitat for rearing. This limiting factor has recently been addressed by the removal of dikes at Nalley Slough and Nalley Island. Thus, it appears the most likely factor limiting chum salmon in the Skokomish Basin currently, is the stability of their spawning habitat. Given the lack of information regarding spawning habitat stability, this issue should be evaluated in the future.

Coho Salmon

Adult

Skokomish River coho were identified as an individual stock based on their distinct spawning distribution. They were labeled as healthy in the 1992 SASSI, which was upheld in 2002. It is a mixed stock with natural spawning occurring in most accessible tributaries to the Skokomish River with the most significant area being the lower North Fork Skokomish and Vance creek. The cascades within the South Fork canyon have been listed as a natural migratory barrier to coho salmon (WDF 1957); however, we observed juveniles well upstream of this location (see below for details). George Adams Hatchery has made substantial releases of fry from several out of basin locations. Nevertheless, allozyme analysis has identified the stock as distinct from all other Washington coho (David Teel, National Marine Fisheries Service (NMFS), cited on WDFW SASSI webpage). Spawner escapement estimates are based on: 1) cumulative fish day counts at a number of index reaches on small Skokomish River tributaries: Swift Creek (RKM 0.0 (RVM 0.0) to RKM 0.5 (RVM0.3)), Kirkland Creek (RKM 0.0 (RVM 0.0)) to (RKM 1.0 (RVM0.6)), Kirkland Cr. unnamed tributary (16.0015, RKM 0.0 (RVM 0.0) to RKM 1.4 (RVM0.9)), and Fir Creek (RKM 0.0 (RVM 0.0) to RKM 0.5 (RVM 0.3)); and 2) cumulative fish-days values for the North Fork Skokomish River index areas (RKM 19.3 (RVM 12.0) to RKM 25.1 (RVM 15.6)) which began in 1993 (Figure 52). A cumulative fish day count of 20,000 to 100,000 is roughly equal to a total escapement of 2,000 to 5,000 adult fish (All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm).

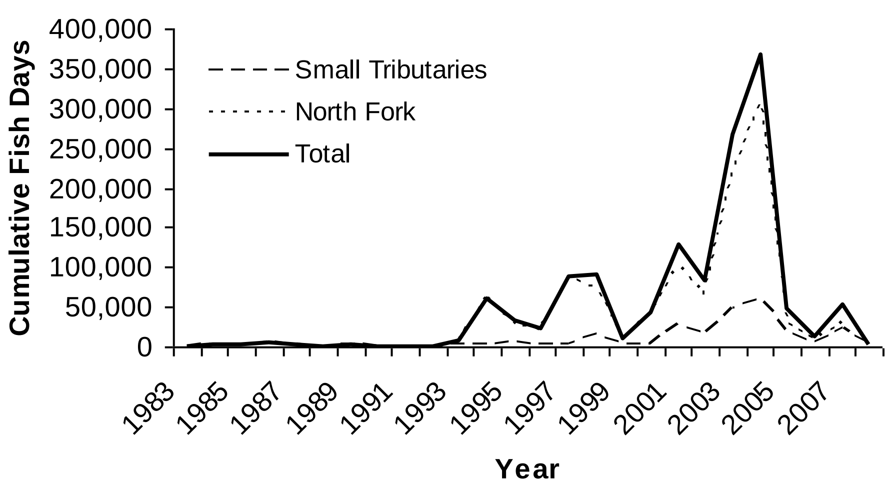

Figure 52. Cumulative fish days for coho spawners in small tributaries of the South Fork Skokomish and the North Fork Skokomish River

Juvenile

Coho salmon generally do not migrate to sea until the spring of their second year of life and therefore rely heavily on freshwater habitat as juveniles. Although they are typically spawned in higher gradient streams, they generally rear in the middle reaches of a watershed and prefer slower velocities than most other juvenile salmonids (Quinn 2005). In a review, Bjornn and Reiser (1991), report coho juveniles being found in depths of 30 to 122 cm and velocities of approximately 5 to 20 cm/s. Coho juveniles generally prefer pools over riffles, and their densities are positively correlated with LWD presence (Roni and Quinn 2001). In addition, the importance of wood cover may increase with stream size (Peters 1996a). During high flow periods throughout the winter months, coho make extensive use of off channel habitat and migrate several kilometers down tributaries and main stem reaches to reach these habitats (Peterson 1982). Until recently, it was assumed that juvenile coho salmon do not make extensive use of estuaries, relying on them primarily as a transition zone and migration corridor during smolt outmigration. However, Miller and Sadro (2003) reported that coho fry may also use the stream-estuary ecotone to rear during the summer, migrating upstream to overwinter in side channel or off-channel habitat located in the lower watershed.

Coho salmon juveniles rear for at least one year in freshwater and then pass quickly through the estuary on their seaward migration. Therefore, deficiencies in their freshwater rearing requirements will be their main limiting factor. In the Skokomish River watershed, the disruption of LWD delivery, along with the reduction of off channel habitat are potentially two main habitats limiting factors effecting coho salmon. Juvenile coho growth in the middle reaches of the watershed are potentially effected by decreased quantities of LWD and the resultant lack of pool and slow water habitat that it creates. This potential is exacerbated by low flows which can isolate pools which result in increased densities, reduced food delivery and high temperatures. In the middle and lower reaches of the watershed, juvenile overwinter survival may be lowered due to the reduction in off channel habitat caused by channelization and diking as it reduces the amount of habitat available for predator and high flow refugia. Reduced pool frequency in the lower watershed due to aggradation, particularly in lower Vance creek, will also affect coho growth and survival as they prefer pool habitats. Lower flows and higher water temperatures in the lower watershed due to aggradation will also affect summer survival of juvenile coho. Coho smolts generally migrate through the estuary rapidly, so moderate declines in estuarine habitat should not greatly impact them; however, reductions in the mesohaline mixing zone could interfere with their physiological transition to salt water. However, as stated above coho fry may also use the stream-estuary ecotone to rear during the summer (Miller and Sadro 2003)

Next to trout, coho salmon had the widest distribution in the Skokomish Basin. They were observed in tributary, main stem, and pond freshwater habitats (Figure 53). Juvenile coho salmon were observed up to RKM 30 in the South Fork Skokomish, RKM 6 in Vance Creek, RKM 7 in McTaggart Creek, and up to the lower dam in the North Fork Skokomish River. As with the other species, distribution of coho salmon was somewhat greater in the winter. Historic accounts suggest that coho salmon cannot pass the cascades in the South Fork Skokomish canyon (WDF 1957). However, we observed juvenile coho salmon well upstream of this location. In reviewing our records, four different snorkelers observed coho salmon in two different sites (2-30 and 2-38) upstream of the cascades, including one snorkeler with over ten years of snorkeling experience. Thus, it is our opinion that coho can now access the upper reach in limited numbers (based on the few fish we observed). This may be due to aggradation occurring in the lower river, which may have made these cascades passable to coho salmon, or due to later return timing for coho salmon in the system. WDF (1957) stated that coho salmon have been reported above the canyon, but they had not been recorded there by Washington Department of Fisheries personnel. They go on to conclude that these reports are likely spring Chinook and discount coho spawning upstream of the canyon. They report that coho spawn from October through February. However, Skokomish Tribal fisheries personnel have observed coho salmon spawning in mid- to late March during recent years (Matt Kowalski, Skokomish Tribe, Personal Communication). This somewhat later timing may result in hydraulic conditions in the cascades that allow some coho salmon to pass the cascades. The final option is that the cascades are passable intermittently and we just happened to sample during a year when they were able to pass this intermittent barrier.

The total number of juvenile coho salmon rearing in the Skokomish basin varied substantially between summer and winter. We estimated that just over 1 million and just over 108,000 juvenile coho salmon were rearing in riverine and pond habitats during the summer and winter, respectively. A majority of these fish were coho fry during the summer (98.2%), while the majority were classified coho parr (58.3%) during the winter. The remaining winter fish were nearly equally classified as coho smolts and coho fry. Survival estimate of coho fry from summer to winter, assuming all coho fry were classified as either coho parr or smolts during the winter was 8.6%. In contrast, Quinn and Peterson (1996) estimated coho salmon survival from October through smolt migration to be between 25.4% and 46.2% in Big Beef Creek, Hood Canal, Washington. Ebersole et al. (2006) observe overwinter survival rates of 10% in a coastal Oregon watershed, and our observations on the Skokomish were within the range they observed.

Although, a majority of juvenile coho salmon we observed were found in riverine habitat there was some seasonal and size class variation. During the summer, all coho parr and coho smolts were found in riverine habitat and 95% of coho fry were found in riverine habitat. However, during the winter, 16.5% of coho parr and 18.1% of coho smolts were found in pond habitats. Thus, off-channel pond habitat appears to be more important to these larger size classes during the winter than during the summer.

The relatively small proportion of fish using off-channel ponds is somewhat surprising. For example, we estimated that approximately 10,000 coho salmon used all off-channel ponds in the Skokomish basin during the winter of 2009. In contrast, Peterson (1982a) estimated that approximately 9,500 coho immigrated into two ponds with a total surface area just over 2 ha in the Clearwater River Basin. Cederholm et al. (1988) observed between 1,700 and 5,500 juvenile coho salmon immigrants into a 0.5 ha pond (after restoration). Thus, our estimate of approximately 10,000 coho in nearly 20 ha of off-channel pond habitat is surprising. It"s possible that our estimates are biased since large portions of the ponds were covered in dense vegetation which we could not sample. However, our winter surveys were completed at night, when one would expect juvenile coho salmon to be laying in open water away from cover (i.e. Tabor et al. 2006, Peters, personal observation). The apparent low numbers of fish using off-channel ponds in this system is surprising especially since survival in these types of habitats is generally quite good. For example, Peterson (1982a) observed 28% percent and 78% survival, while Cederholm and Scarlett 1991 observed 43 and 70% survival in off-channel ponds in the Clearwater River. Thus, further examination of the numbers of coho using these systems is warranted to determine if physical habitat or water quality issues are preventing greater use of these habitats or if our estimates are accurate. Other than some low DO levels and the dense mats of aquatic vegetation covering the bottom, thereby reducing open areas for nighttime rearing, the habitat conditions in the ponds we surveyed seemed to be appropriate. However, we did not assess the access to off-channel ponds.

The distribution of coho salmon within the ponds varied between summer and winter. Coho fry preferred nearshore (3,414 fish/ha) areas to offshore (1,155 fish/ha) areas during the summer. However, no coho fry were observed in nearshore areas during the winter, while densities of nearly 21 fish/ha were observed in the offshore areas. In contrast, yearling coho densities were greater in nearshore (639 fish/ha) areas than offshore areas (221 fish/ha) during the winter. No coho parr were observed during the summer. Coho smolt densities were also greater in nearshore areas (217 fish/ha) than offshore areas (121 fish/ha) during the winter. Although differences in point estimates were substantially different in some cases, the 90 percent confidence intervals overlapped, suggesting the differences are not statistically significant. This is likely due to the relatively small sample size and large variability in the data

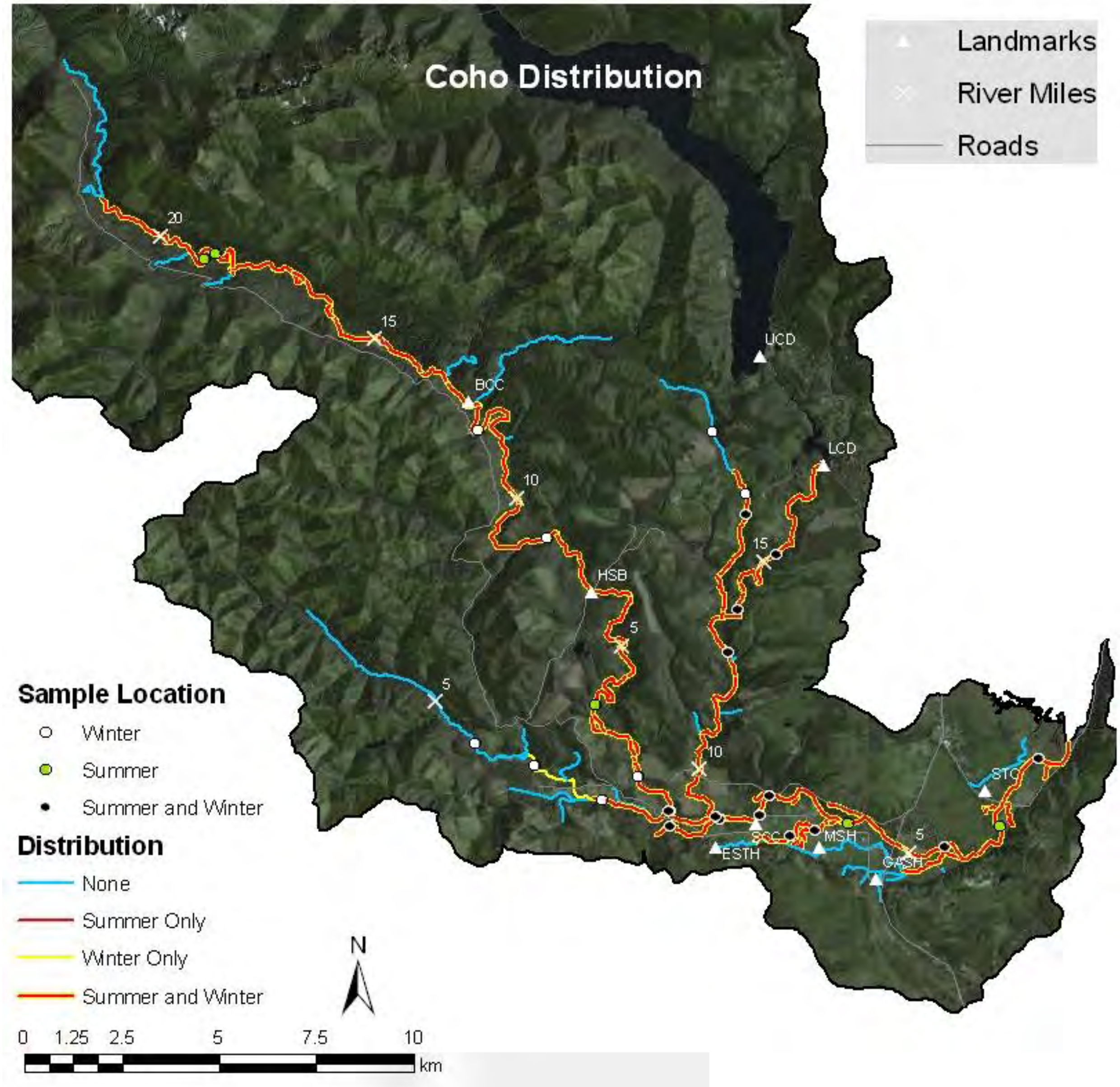

Figure 53. Expected juvenile coho salmon distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. WDF (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 mi above mouth), and the Skokomish mainstem (old U.S. HWY 101 bridge). They observed outmigration from January through September, with a peak in April through May. Catches were significantly reduced by late June with few fish caught through the rest of the sampling period. Additional data was collected by the Skokomish Indian Tribe in Skobob Creek where they operated a panel trap between 18 April and 30 May, 2003. In 2003, a total of 11,058 coho fry were captured in the panel trap, with a fairly uniform catch distribution throughout the trapping. However, two noticeable peaks occurred on 11 May and 26 May, where approximately 1,400 fish were captured.

A total of 2,633 unmarked and 771 hatchery coho were captured during our 2009 trapping season (Figure 54). Both fry and smolts were captured during the entire sampling period of January 21 to July 29, 2009. Coho fry outmigration peaked in late April through late May. Unmarked coho smolt outmigration peaked from mid-May through mid-June, while hatchery coho smolt outmigration peaked in mid-April, immediately after release (4/14-4/18/09).

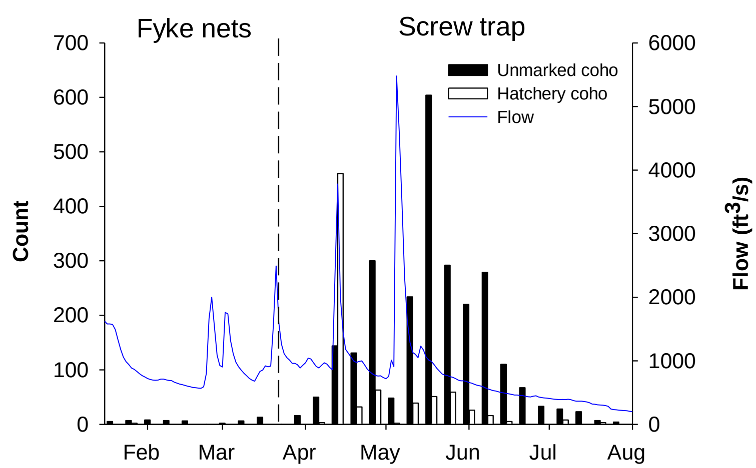

Figure 54. Weekly counts (first axis) of juvenile wild and hatchery coho captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

A total of 352,603 coho were estimated to have migrated downstream during screw trap sampling, with 80% unmarked and 20% of hatchery origin (Table 27). Coho fry was the most numerous size class, accounting for 51% of the coho population, while smolts were slightly less abundant and accounted for 46% of the population. Unmarked coho smolts were estimated at 87,639 and more abundant than their hatchery counterparts. The estimated number of hatchery smolts to migrate past the trap was approximately 25% of the 298,541 coho smolts released by WDFW into Purdy Creek in mid-April 2009. Thus, either survival of hatchery fish released into the system is very low, or our estimates are especially conservative. Based on apparent underestimation of chum salmon from hatchery releases (discussed above), we assume that our estimates of coho salmon outmigration was also biased low.

WDF (1957) provide relative abundance estimates for coho salmon from their five sampling locations. No coho salmon were caught in the upper South Fork Skokomish trap. Vance Creek was listed as the most productive area followed by the North Fork Skokomish and then the lower South Fork Skokomish. However, they noted that the variation in production from the four areas was less than that observed for juvenile Chinook salmon. They estimated that 56,000, 35,000, and 21,000 coho salmon migrated past their Vance Creek, North Fork Skokomish, and lower South Fork Skokomish outmigration sampling locations, respectively. They could not make an overall estimate at the mainstem due to the size and non-uniform flow patterns at their lower mainstem sampling location. Summing the above estimates, which would seem reasonable since they cover different parts of the watershed, would provide an estimate of approximately 120,000 coho, substantially less than our estimate. However, their sampling locations miss several locations that likely produce significant numbers of coho salmon including Swift Creek, Hunter Creek, Purdy Creek, Weaver Creek, and lower mainstem lateral habitats and ponds.

The size of fish sampled during our outmigration sampling was quite variable. Unmarked coho sizes ranged from 25 to 159 mm and averaged 62 mm. Weekly mean fork lengths of wild coho showed considerable variation from late January to early April, ranging from 37 to 81 mm (Figure 55). During the following months, unmarked coho sizes were mostly between 50 and 75 mm. Weekly mean fork lengths of hatchery coho smolt were between 100 and 120 mm during most weeks the fish were present. Length frequency distributions also varied considerably between unmarked and marked coho (Figure 56). The most common size range was 31 to 40 mm for unmarked coho and 121 to130 mm for marked coho. The size distribution observed during our study was similar to that observed by WDF (1957). They observed 0-age coho throughout their outmigration sampling at all but the upper South Fork Skokomish outmigration station. These fish ranged in size from about 38 to just over 50 mm through about July, after which no 0-age size data is provided. Yearling fish averaged about 100 mm in the North Fork Skokomish during May, while the size of yearling fish increased from about 70 mm in February to about 100 mm in May.

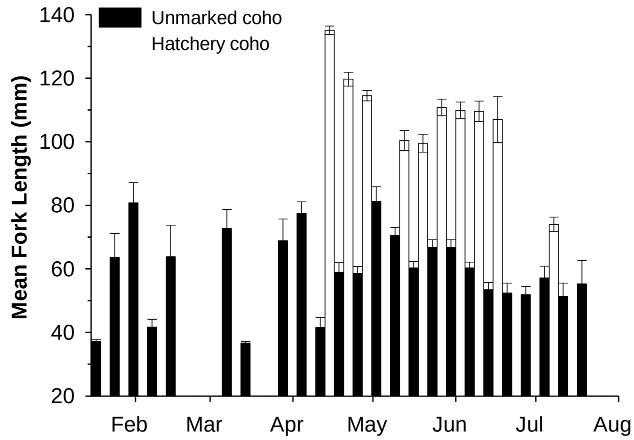

Figure 55. Weekly mean lengths and standard errors of juvenile wild and hatchery coho captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on the Skokomish River in 2009.

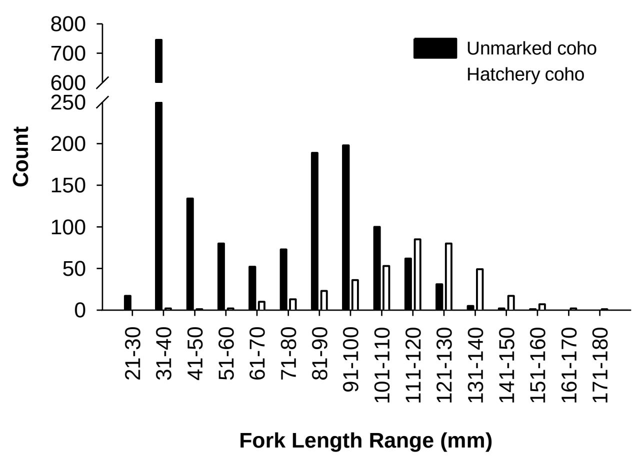

Figure 56. Length frequency distribution of juvenile coho captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on the Skokomish River in 2009.

Estuary data was collected by the Skokomish Indian Tribe between 27 December, 2004, and 5 July, 2005. The estuary sampling occurred in the vicinity of Nalley Island and West Slough. A total of 1,981 and 1,304 coho salmon were captured at Nalley Island and West Slough, respectively. However, these fish were not noted as fry or smolts, so we could not determine the relative numbers of fry and smolts in the samples. Very few fish were captured before mid-April and the peak occurred between mid-April and mid-May, although they were recorded until the last sampling event on 5 July (Skokomish Indian Tribe, unpublished data).

We caught 367 juvenile coho salmon during the estuary sampling. Juvenile coho salmon were captured from April through September, and were most abundant from mid-May through late June (Figure 56). Hatchery coho salmon represented 27% of all juvenile coho salmon captured in the estuary. Unmarked coho salmon were captured at least 15 days before their hatchery counterparts were captured and nearly three months after hatchery coho salmon were last captured (Figure 57). Of the coho salmon captured, about 60% were smolts, 25% were parr, and 15% were fry.

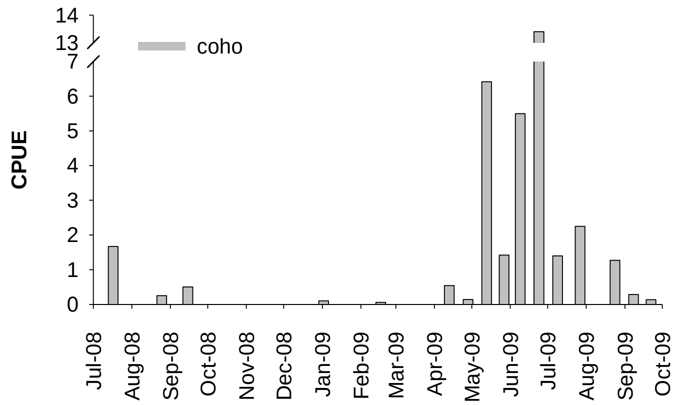

Figure 57. Catch-Per-Unit-Effort (CPUE) for juvenile coho salmon in the Nalley Island portion of the Skokomish River estuary between July 2008 and September 2009.

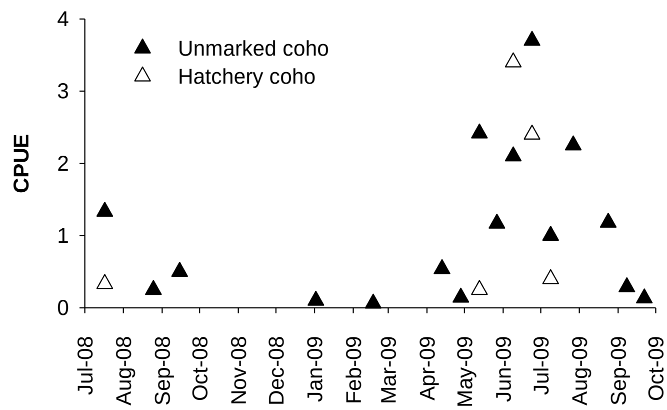

Figure 58. Comparison of residence timing of hatchery and unmarked juvenile coho salmon captured in the Nalley Island section of the Skokomish River estuary between July 2008 and September 2009.

Individual residence times and population estimates for juvenile coho salmon could not be estimated, since no marked fish were ever recaptured. Juvenile coho salmon in the estuary ranged from 71 to 90 mm in fork length and generally increased during the spring and summer months (Figure 59). Hatchery coho salmon were 9 mm longer than their unmarked counterparts (Figure 59).

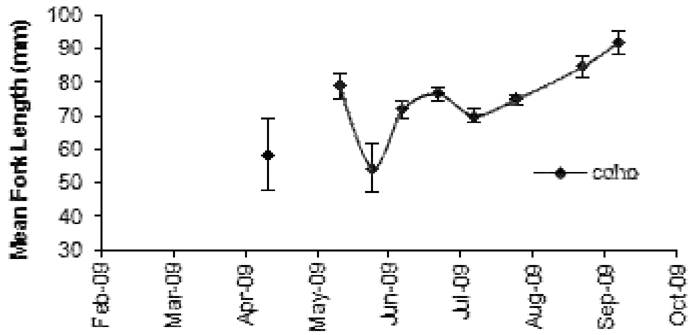

Figure 59. Mean fork lengths (+/- SE) of juvenile coho salmon caught in the Nalley Island section of the Skokomish River estuary between February and September 2009.

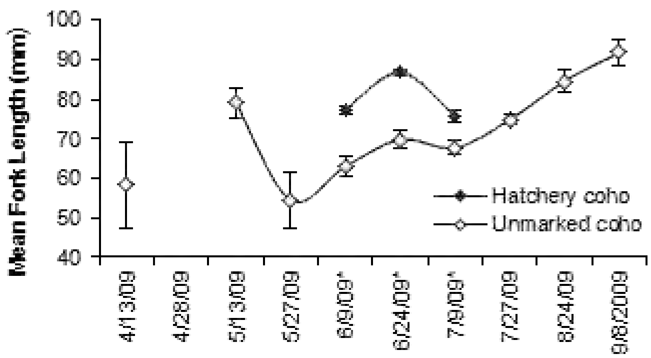

Figure 60. Mean for length (+/- SE) of hatchery and unmarked juvenile coho salmon captured in Nalley Island section of the Skokomish River estuary between February and September 2009. The mean lengths are based on samples sizes of four or more. Asterisks (*) next to the sampling dates, indicate the dates on which hatchery and unmarked fish are significantly different in length.

Limiting Factors: Coho Salmon

Although Skokomish River coho salmon have been listed as healthy by SASSI (2002), potentially significant habitat issues exist for this species. Juvenile coho salmon generally prefer pool habitats with slower velocities and densities have been found to be positively related to LWD presence (Roni and Quinn 2001). Pool habitat and LWD levels are somewhat reduced in the Skokomish Basin. In addition, pool habitats were reduced even more during the winter and the depths of existing pools were shallower than during the summer. Pool habitat is critical to juvenile coho salmon during the winter. This lack of pool habitat and LWD cover may be why the survival estimates we developed for the Skokomish Basin were substantially lower than those observed for coho salmon in Big Beef Creek (Quinn and Peterson 1996). Although our survival estimates were lower than those observe by (Quinn and Peterson 1996), they were within the range observed in an Oregon Coastal system (Ebersol et al. 2006).

Off-channel ponds, although abundant in the Skokomish Basin, may also limit coho salmon in this system due to their distribution. This statement is based on the relatively low numbers of coho salmon that we estimated to be using this habitat. It"s unclear if the low number were due to migration barriers between the main channel and the off-channel ponds, the physical characteristics of the ponds, the locations of the ponds within the system, or just due to general low use of this habitat type in this system relative to other systems in western Washington. An assessment of migratory barriers to off-channel ponds would be relatively easy to complete and should be pursued in the future. With the exception of low DO at a couple of the sites we surveyed and the dense mat of aquatic vegetation, the physical characteristics of the ponds seemed adequate for juvenile coho salmon rearing. The fact that most of the off-channel ponds were low in the basin adjacent to the stream-estuary ecotone could result in less use than expected if juvenile coho salmon avoided this area due to tidal influence or saline water conditions. However, we observed juvenile coho salmon migrating through this area throughout our outmigration sampling and they were frequently observed in the estuary. In addition, salinities were very low in this area during our sampling. Thus, this does not appear to be an issue. Finally, juvenile coho salmon in the Skokomish Basin simply may not use off-channel ponds to the degree that they do in other western Washington Rivers. This seems unlikely given the wet maritime climate present in the basin, but is certainly a possibility.

Reduced habitat quality and connectivity in the estuary may also limit coho salmon in the system. As stated above, large numbers of juvenile coho salmon migrated through the stream-estuary ecotone during our sampling and coho fry were frequently observed in the Nalley Island portion of the estuary, despite the nearly complete enclosure of the island by dikes. In order to access Nalley Island, juvenile coho would have to migrate to the seaward side of the island and migrate through the dike breach. Once there, they would be required to make this same migration to move back upstream during the winter as observed in Oregon Coastal systems (Sadro and Miller 2003). Much of this potential limiting factor has been eliminated by the dike removal projects at Nalley Slough and Nalley Island. Given the small proportion of the watershed available for coho salmon, the extensive wetlands in the lower river, and the extensive estuary, this life history strategy could be very important for coho salmon production in this system. The level of expression of this life history pattern should be further evaluated in the future.

Steelhead

Adult

Summer

There is limited information on the status of summer steelhead in the Skokomish Basin. They were identified as an individual stock in the 1992 SASSI, but their status remains unknown. Historically, their spawning distribution was thought to be in the South Fork Skokomish canyon section (ME2 Environmental Services, 1997). Along with all other Puget Sound steelhead stocks, they were listed as threatened under the ESA on May 11, 2007. They are thought to spawn from February through April, but specific data on escapement is not collected.

Winter

Skokomish River winter steelhead were identified as an individual stock in the 2002 SASSI based on their distinct spawning distribution. Their depressed classification was retained in the 2006 SASSI based on chronically low escapement numbers and a continued negative trend. In addition, the stock was listed as threatened under the ESA on May 11, 2007. Most spawning takes place in main stem and South Fork Skokomish River from mid-February to mid-June. They are capable of accessing the entire watershed that is below anadromous barriers and initiate spawning in mid-April and continue through mid-June (ME2 Environmental Services 1997). Escapement data is based on redd counts from index reaches in the main stem Skokomish (RKM 0.0 (RVM 0.0) to RKM 14.5 (RVM 9.0)), in the North Fork Skokomish River (RKM 14.5 (RVM 9.0) to RKM 20.9 (RVM 13.0)) and in the South Fork Skokomish River (RKM 0.0 (RVM 0.0) to RKM 34.4 (21.4)) (Figure 61). Allozyme analysis seems to indicate that Skokomish winter steelhead are distinct from other Hood Canal stocks (Phelps 1997). In 2007, a winter steelhead supplementation program was started in the South Fork Skokomish to address the decline of the stock. Approximately 30,000 eggs are removed from redds in the river each year, and 20,000 to 30,000 two year old smolts are subsequently released into the system (Barry Berejikian, NOAA, personal communication).

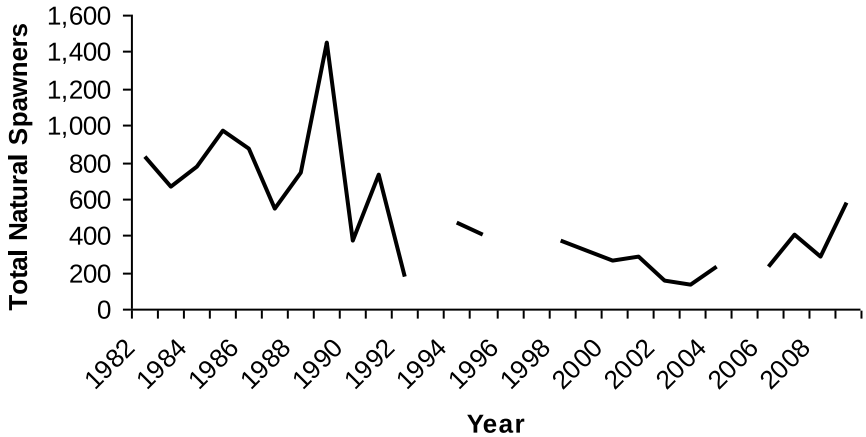

Figure 61. Total natural adult winter steelhead in the Skokomish River from 1982 to 2008. Escapement data is based on redd counts from index reaches in the main stem Skokomish (RKM 0.0 (RVM 0.0) to RKM 14.5 (RVM9.0)), in the North Fork Skokomish (RKM 14.5 (RVM 9.0) to RKM 20.9 (RVM 13.0)) and in the South Fork Skokomish (RKM 0.0 (RVM 0.0) to RKM 34.4 (RVM 21.4)). All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm

Juvenile

Steelhead rely heavily on freshwater habitats and exhibit a broad array of life history patterns that result in anywhere from 1 to 3 years of residency in freshwater before seaward migration. In general, they rear higher up in a watershed than either Chinook or coho, and therefore are found in higher gradient areas than other species. As reviewed by Bjornn and Resier (1991) juvenile steelhead have been recorded in a wide range of depths and velocities with approximate means being a depth of 40 cm and a velocity of 20 cm/s although velocities up to 40 cm/s have been recorded. This represents a range which is generally shallower and swifter than most other pacific salmon juveniles. Juvenile steelhead use riffles and fast flowing pool habitats during the summer (Bisson et al. 1988), but prefer pool habitats in the winter (Roni 2002). Similar to coho, juvenile steelhead make extensive use of off channel habitat during winter months and in some instances were found in higher densities then the main channel (Mundie and Traber 1983). Due to their lengthy residency in freshwater, steelhead generally do not reside in the estuary for extended periods on their way to sea (Quinn 2005).

Steelhead are the most dependent salmonid species on freshwater habitat of all anadromous species in the Skokomish River, spending up to three years in freshwater before migrating to sea. Therefore, they will be even more heavily dependent on intact freshwater habitats than juvenile coho salmon. Because they generally rear in the middle and upper reaches of the watershed, impacts from logging may impact them the most. This is especially true, since much of the sediment inputs from logging are presumed to still be in the upper watershed (Pentec 1997). Thus, spawning habitat may be unstable or redds may be susceptible to fine sediment intrusion. In addition, since steelhead are spring spawners, they will be most affected by reduced flows, and higher water temperatures during spring and summer. Loss of LWD inputs and associated channel simplification is an issue in Brown, LeBar, and Church creeks (ME2 Environmental Services 1997). Increased sediment supply and higher stream temperatures could affect growth rates, which may ultimately influence life history patterns and age of smoltification. As they move through the lower reaches of the Skokomish Basin, the lack of off channel habitat due to reduced floodplain connectivity may reduce survival by limiting access to predator and high flow refugia.

There is little data for rearing densities of juvenile steelhead in the Skokomish Basin. Dunham and Chandler (2001) present data for combined rainbow and cutthroat trout densities at several sites in the South Fork Skokomish and one site in Church Creek (Table 28). Based on their data, trout appear to be distributed throughout the Skokomish Basin in relatively low densities. Data collected during this GI confirm these results of wide distribution (Figure 62). Juvenile trout were estimated to use the South Fork Skokomish up to RKM 30, the North Fork Skokomish upstream to the first dam, and up to RKM 8 on Vance Creek. Our predicted distribution suggests that trout did not use many of the tributaries in the upper Skokomish Basin. However, this is likely due to the lack of sampling locations in those tributaries. As with the other species, trout were estimated to have a greater distribution during the winter than the summer. However, this was may have been influenced by the distribution of our summer and winter sample sites.

Trout were observed in mainstem, tributary, and pond habitats. Although we did not separate trout into *O. mykiss* and cutthroat during our snorkel surveys, sampling for winter diet analysis suggest that *O. mykiss* were more common in mainstem and tributary habitats (188 in mainstem, 80 tributary, 1 pond). Others have also found that cutthroat trout tend to use pond habitats more than *O. mykiss,* especially if the bottom is composed of fine sediments. Thus, *O. mykiss* appear to prefer tributary and mainstem habitats to the pond habitats.

Table 28. Combined rainbow and cutthroat trout densities observed in Church Creek and several sites in the South Fork Skokomish River (from Dunham and Chandler (2001), sites are shown in Figure 62.

		Density (per m^2)	
Stream	Site	Juvenile	Adult
Church Cr	1	0.06	0
S.F. Skokomish	1	0.06	0
S.F. Skokomish	10	0.09	0
S.F. Skokomish	11	0	0
S.F. Skokomish	12	0.03	0
S.F. Skokomish	13	0.12	0
S.F. Skokomish	14	0.03	0
S.F. Skokomish	15	0.03	0
S.F. Skokomish	16	0.08	0
S.F. Skokomish	17	0.07	0
S.F. Skokomish	18	0.03	0
S.F. Skokomish	19	0.02	0
S.F. Skokomish	2	0.06	0
S.F. Skokomish	20	0.02	0
S.F. Skokomish	21	0	0
S.F. Skokomish	22	0.03	0
S.F. Skokomish	23	0	0

Figure 62. Expected juvenile trout (*O. mykiss* and *O. clarkii*) distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. Washington Department of Fisheries (WDF) (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 mi above mouth), and the Skokomish mainstem (old U.S. HWY 101 bridge). Steelhead were caught at all five locations. Migration timing varied somewhat by location but generally occurred from February to September (the end of sampling). Peak outmigration occurred later in the South Fork Skokomish (late July) than it did in the other three stations, where the peak occurred in May. It‟s unclear if this timing is due to different aged fish, since no size class information is provided for the outmigration timing data. Although comparisons of relative abundance could not be made for all five locations, WDF (1957) determined that steelhead production in the upper South Fork Skokomish was greater than that of the canyon and lower South Fork Skokomish. The Skokomish tribe also sampled outmigration fish on Skobob Creek during 2003. No juvenile steelhead were captured during this effort (Skokomish Indian Tribe, unpublished data). Finally, a screw trap has been operated by NOAA fisheries on the South Fork Skokomish near the confluence with Vance Creek since 2007 to assess production and outmigration timing steelhead from April 1 to June 15. It appears that downstream migration may have occurred prior to the initiation of their sampling on April 1. Production estimates of 7,600 and 4,000 smolts were obtained for 2007 and 2008, respectively (Chris Tatara, NOAA Fisheries, personal communication). These estimates represent smolts greater than 125 cm and do not account for missed trap days or production from downstream habitat.

We collected additional outmigration data for the current study. We used fyke nets and a screw trap to monitor *O. mykiss* outmigration in the Skokomish River from June 2008 through July 2009 (See Appendix Outmigration for details). We caught a total of 51 *O. mykiss* during the January through July 2009 sampling period, with 50 unmarked and one marked hatchery fish. Our catches were likely low due to the fact that steelhead migrate near the bottom of the water column and the only appropriate location for our 5 foot screw trap to fish was in a relatively deep run. Although the fyke nets fished in a deeper location, they covered a very small portion of the overall surface area of the lower river, as did the screw trap.

O. mykiss were first caught in early February and last caught on the last day of trapping (July 2, 2009). Peak catches of unmarked *O. mykiss* occurred in early to mid-May (Figure 63). The lone hatchery *O. mykiss* caught during our sampling was caught on May 22, 2009. Unmarked *O. mykiss* caught in the outmigrant trap averaged 128 mm. These fish appeared to represent several year classes (Figure 64). Newly emerged fry were caught in early July. Apparent 1+ parr and 2+ parr were observed throughout the sampling. Washington Department of Fisheries (WDF 1957) reported that zero age *O. mykiss* averaged about 32 mm in fork length. They reference yearling *O. mykiss*; however, the figure they reference as showing lengths of yearling (their figure 18) is missing from the report. Thus, we could not determine the average length of these yearling fish.

No juvenile steelhead were captured in the sampling completed by the Skokomish Indian Tribe estuary sampling in 2005 (Skokomish Indian Tribe, unpublished data). We also did not capture any steelhead in our estuary sampling in 2008-2009. This is in agreement with the idea that juvenile steelhead move through the estuary quickly and is supported by the steelhead telemetry data collected for this study (See Appendix Steelhead Outmigration, Estuary, Early Marine Survival for details).

Although juvenile steelhead generally migrate through the estuary rapidly, it is important to note that more extensive estuarine use has been documented in other systems. Bond et al. (2008) noted extensive use of the estuary by smaller (<150 mm) juveniles when compared with larger (>150 mm) individuals who moved almost directly to sea. More importantly, the smaller individuals that utilized the estuary exhibited relatively high growth rates during that period and had higher subsequent survival to adults.

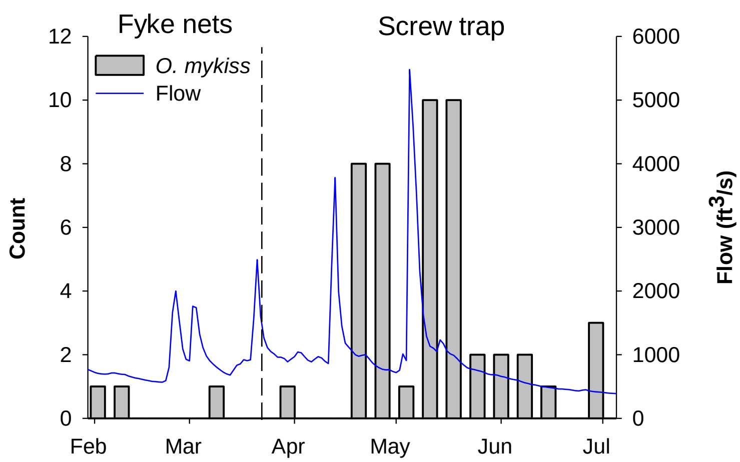

Figure 63. Weekly counts (first axis) of juvenile *O. mykiss* captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on the Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

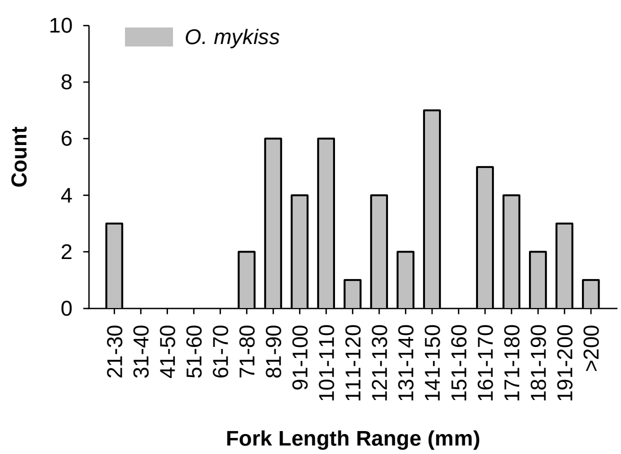

Figure 64. Length frequency distribution of *O. mykiss* captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on the Skokomish River in 2009.

Smolt Size

Wild smolts tagged in 2006, as part of the early marine survival assessment, were significantly larger on average than wild and hatchery smolts tagged in 2007 and 2008, and wild smolts tagged in 2009 ($ANOVA_{length}$: $F_{5,212} = 23.57$, $p < 0.001$; $ANOVA_{weight}$: $F_{5,212} = 20.68$, $p<0.001$; Tukey‟s Multiple Comparison; Table 29). This difference is likely due to different capture methods employed in 2006 (some smolts were caught by hook-and-line). Age-1 hatchery smolt sizes in 2008 were comparable to those of wild smolts, though age-2 hatchery smolts in 2009 were both longer and heavier than all other groups (Table 29).

Table 29. Average length and weight of wild and hatchery reared steelhead tagged during this study. Only fish >155 mm were tagged, so smaller fish were excluded from these data.

Year	Number tagged	Rearing History	Mean Length (mm)	Mean Weight (g)
2006	27	Wild	195 ± 4	69.8 ± 6.0
2007	51	Wild	182 ± 3	56.0 ± 3.1
2008	41	Wild	180 ± 3	53.7 ± 2.5
	42	Hatchery	171 ± 1	49.0 ± 1.1
2009	23	Wild	175 ± 4	50.9 ± 3.3
	29	Hatchery	211 ± 3	93.5 ± 5.3

Smolt Survival

Wild steelhead smolt survival from the Point of Release (PR) to the River Mouth (RM) ranged from 82% to 99% (Figure 66). Survival estimates for hatchery smolt groups in freshwater were much lower (2008: 48%; 2009: 21%). All groups traveled from the PR to RM in less than 7 days and there were no significant differences in freshwater travel time between groups (Table 30).

Table 30 Travel and Residence Times between the point of release (PR) and the river mouth (RM), the RM to Hood Canal Bridge (HCB), HCB to the Strait of Juan de Fuca (JDF), and the RM to HCB). Numbers in parentheses indicate the sample size used to calculate the mean and SE.

Group	Travel Times (d ± SE)			Residence Time (d)
	PR-RM	RM-HCB	HCB-JDF	RM-HCB
2006 (Wild)	2.4 ± .07 (20)	15.6 ± 4.1 (15)	6.1 ± 0.9 (6)	17.4 ± 4.8 (15)
2007 (Wild)	4.7 ± 0.8 (31)	14.4 ± 2.9 (18)	7.3 ± 2.3 (4)	15.1 ± 2.8 (18)
2008 (Wild)	3.9 ± 1.4 (13)	11.1 ± 1.9 (11)	5.4 ± 0.3 (3)	19.9 ± 6.4 (11)
2008 (Hatchery)	6.42 ± 1.4 (10)	14.0 ± 3.8 (4)	3.29 (1)	14.1 ± 2.7 (4)
2009 (Hatchery)	2.4 ± 0.4 (17)	11.1 ± 1.8 (7)	5.3 ± 0.26 (2)	12.5 ± 1.6 (7)
2009 (Hatchery)	1.3 ± 0.2 (6)	10.3 ± 1.8 (4)	4.86 (1)	10.4 ± 1.7 (4)

River mouth to Hood Canal Bridge (HCB)

A very wide range of survival rates was observed for the smolts migrating from RM to HCB. The RM-HCB survival estimate was only 40% for hatchery smolts migrating in 2008, compared to a very high estimate of 100% survival for hatchery smolts in 2009 (Figure 66). Survival of wild smolts ranged from 62% in 2007 to 85% in 2008 and 2009 (Figure 66).

Mean RM-HCB travel times ranged from 10.3 days (2009 Hatchery) to 15.6 days (2006 Wild; Table 29). Wild and hatchery smolts from all years took similar amounts of time to travel from RM to HCB.

Mean Hood Canal residence time tended to be only slightly longer than RM-HCB travel times (Table 29), indicating that hatchery and wild smolts did not generally stay within Hood Canal once they reached the Hood Canal Bridge. Average residence times of each smolt group in Hood Canal were not different from each other.

Hood Canal Bridge to Admiralty Inlet (AI)

Survival estimates from the HCB to AI were generally lower than rates estimated through Hood Canal (Figure 2C), despite the HCB-AI distances being only 30% the distance of the RM-HCB segment (~25 km compared to 75 km). Overall, the lowest survival rate was experienced by wild smolts in 2008 (29%), while hatchery smolts had the highest survival rate in 2009 (65%) (Figure 66).

Hood Canal Bridge to the Strait of Juan de Fuca (JDF)

The 2006 HCB-JDF survival estimate was lower than the 2006 RM-HCB estimate (40% compared to 72.5%), though the distance from the RM to the HCB is over twice as long (~135 km compared to 75 km).

All smolt groups took less time on average to travel from the HCB to the JDF (135 km) than they took to travel the length of Hood Canal (75 km) (Table 29). Only one hatchery smolt was detected at JDF in 2008 and travelled from HCB to JDF in 3.3 days. The 2007 wild smolts (n=4) averaged 7.3 d to travel from the HCB to the JDF (Table 29).

Point of release to Strait of Juan de Fuca

In 2006, the minimum survival rate for Skokomish River wild smolts was estimated to be 28.6%. This estimate is a composite of the PR-RM, RM-HCB and HCB-JDF modeled survival rates. This was lower than survival estimates for two other Hood Canal steelhead populations tagged in the same year (Big Beef Creek: 41.7%; Dewatto River: 33.3%), but higher than the survival estimates for the Hamma Hamma River hatchery population (16.0%) (see Moore et al. 2010 for more details).

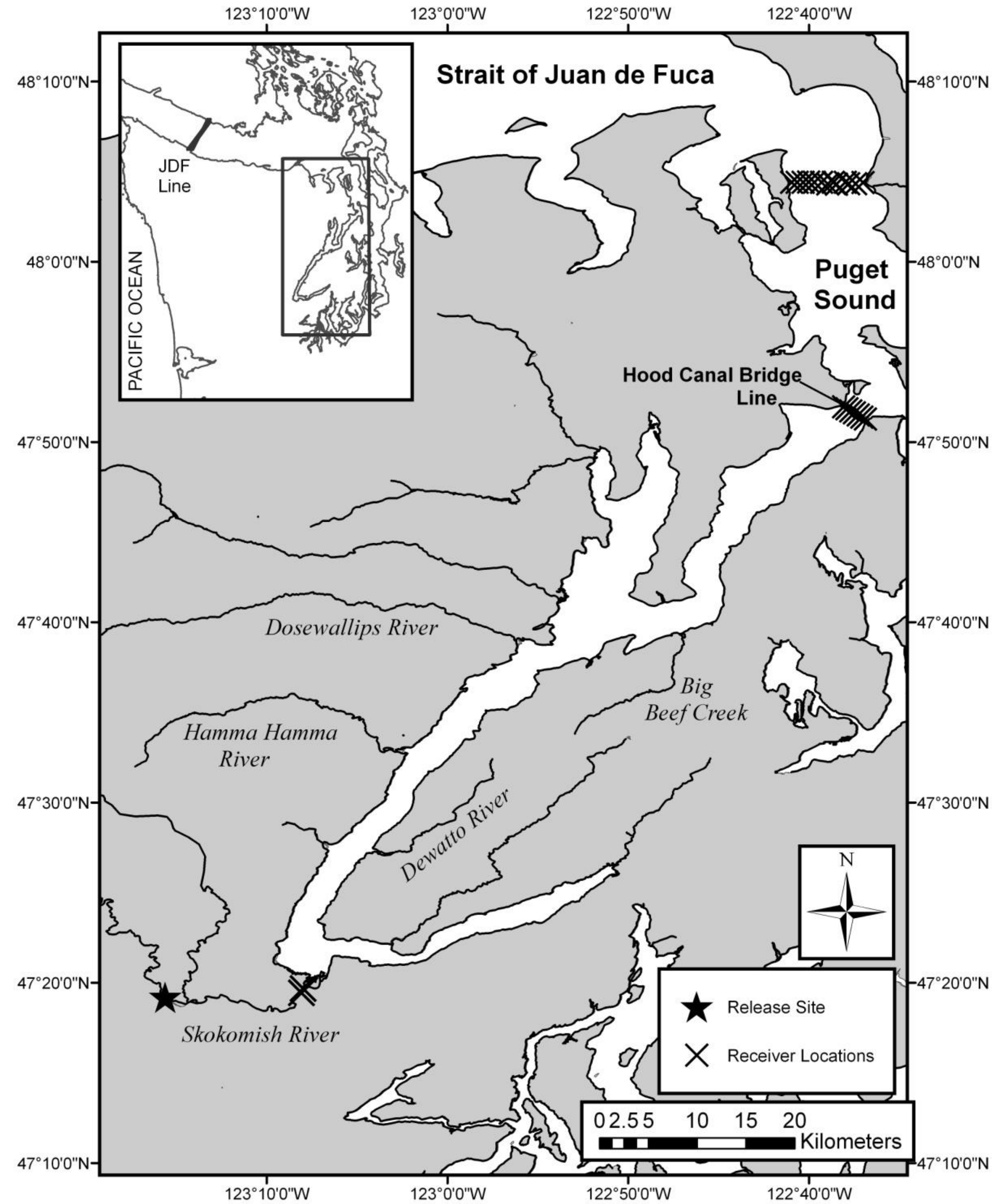

Figure 65. Locations of acoustic telemetry receivers in Hood Canal and Strait of Juan de Fuca. Two receivers were placed at each river mouth (RM) to detect outmigrating smolts. The Hood Canal Bridge Line was comprised of four receivers in 2006 and seven receivers in 2007, 2008, and 2009. The Admiral Inlet line (spanning the north entrance to Puget Sound) consisted of 13 receivers, and 30 receivers (31 in 2006) made up the Strait of Juan de Fuca line (JDF).

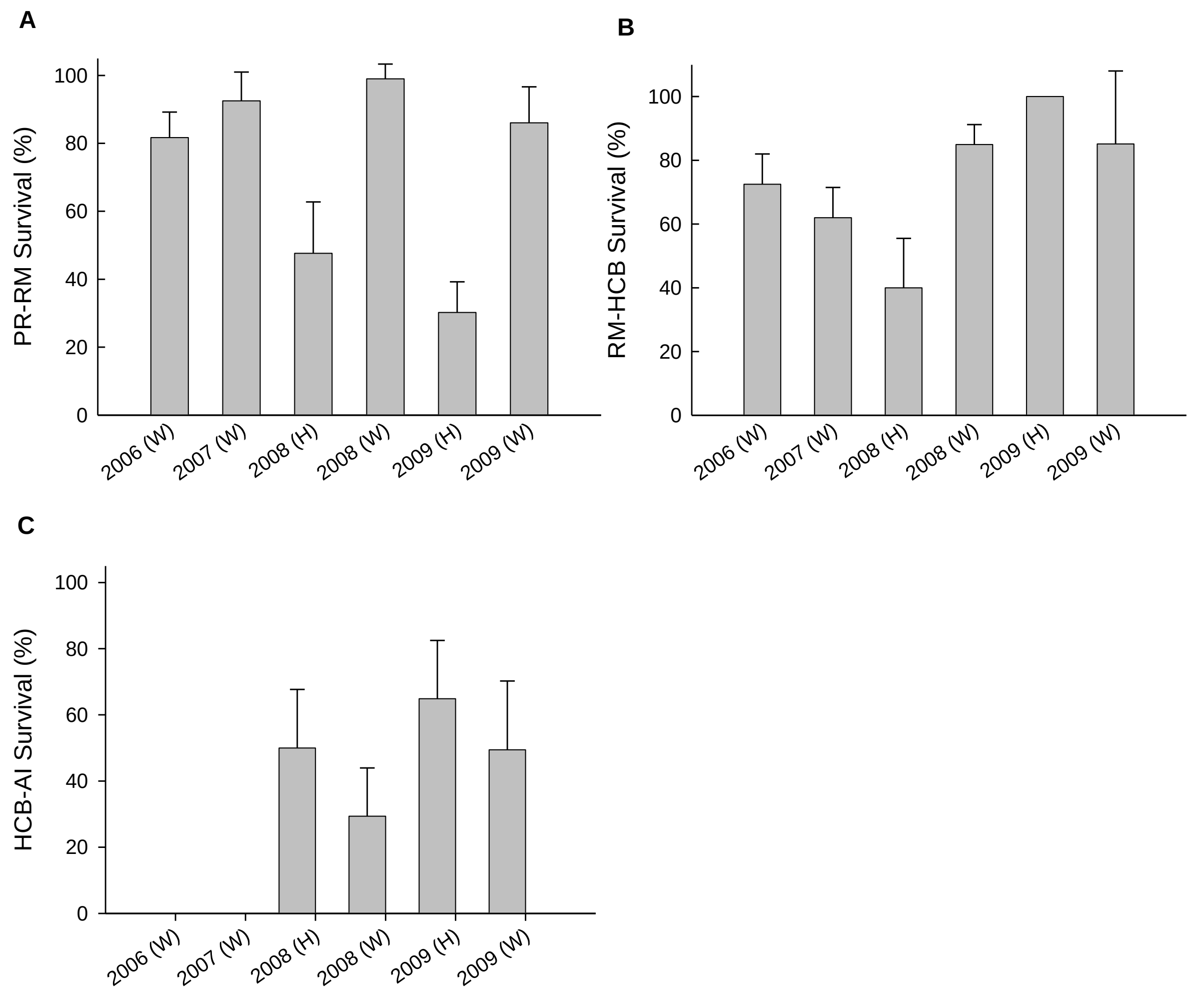

Figure 66. Bar chart showing survival rate estimates ± standard errors for three migration segments: (A) Point of release to river mouth (PR-RM), (B) River mouth to the Hood Canal Bridge (RM-HCB), and (C) Hood Canal Bridge to the Admiralty Inlet (AI) line (HCB-AI). The AI line was deployed in 2008, so no survival estimates to this point were made in 2006 or 2007.

Limiting Factors: Steelhead

Steelhead use freshwater habitats more extensively than any of the other anadromous salmonids found in the Skokomish Basin. In contrast, they appear to use estuarine habitat the least of the anadromous salmonids found in the Skokomish Basin. Based on their limited use of the estuary and the high survival through this habitat, freshwater habitats appear to be limiting steelhead in this basin.

The two habitat conditions that seem the most likely to limit steelhead production in the Skokomish Basin appear to be reduced lateral habitats such as side channels and the lack of pool habitat. Steelhead make extensive use of side channel habitat during the winter (Swales et al. 1986), which is lacking in the Skokomish system. In contrast to coho salmon, steelhead use off-channel ponds with fine substrate infrequently. Thus, although this type of habitat is abundant in the Skokomish Basin, it provides limited habitat for steelhead. The lack of side channel habitat would likely have the greatest impact on juvenile steelhead during fall and winter freshets.

The lack of pool habitat in the system would also impact juvenile steelhead during the winter. Juvenile steelhead prefer pool habitat during the winter, which provide refugia from high currents during the winter. However, pool habitat is lacking throughout the Skokomish Basin, especially in the critical fall and winter freshet season. Thus, one would expect winter survival to be impacted by this lack of preferred habitat.

Bull Trout

General Habitat Requirements

Although some stocks of bull trout are anadromous, they all make extensive if not exclusive use of fresh water habitats. In the Skokomish, they can be found in all reaches of the watershed below anadromous barriers (USFS, unpublished date, cited in Simpson 2000). On a micro habitat level, they generally prefer deeper water (33 cm) and slower velocities (9 cm/s) (Pratt 1984). Perhaps most important, compared to other salmonids, is their reliance on cold, well-oxygenated water (Goetz 1989). Bull trout generally occur in streams with temperatures less than 15°C (59°F), with spawning generally occurring in streams with temperatures below 9°C (48°F) (USFWS 2004). Dramatic increases in spawning migrations have been demonstrated above Lake Cushman on the North Fork Skokomish after fall water temperatures decline below 10°C (Brenkman et al. 2001.)

Bull trout in the Skokomish River watershed do not appear to be anadromous, based on otolith microchemistry (Larry Ogg, USFS, cited in Correa 2003) and therefore depend entirely on freshwater habitats throughout their life histories. However, it should be noted that some juveniles have been found in a screw trap in the lower river near the estuary, possibly indicating the existence of anadromy. Although apparently not a typical life history variation in the Skokomish at this point in time, it is important to note the extensive use of estuary, near shore, and open ocean habitats have been documented by Brenkman and Corbett (2005) and Brenkman et al. (2007) by bull trout of all sizes in other Olympic peninsula rivers. A healthy bull trout population would likely exhibit a broad continuum of migratory behaviors and thereby, habitat needs. In addition, bull trout are an apex predator, relying on healthy prey resources to support viable populations. Furthermore, juvenile salmon are generally their main prey source when populations are sympatric (Beauchamp et al. 2001; Clarke et al. 2005). Therefore, recovering healthy salmon stocks could be an important step towards maintaining robust bull trout populations.

Bull trout generally require colder water than their salmon counterparts, and are found higher in the watershed. Populations above Lake Cushman have pristine habitat refugia available to them in Olympic National Park, and are not likely to experience any major factors limiting habitat in the foreseeable future, although the dams potentially act as barriers to migration of what could historically be anadromous or adfluvial populations. In addition, the population that spawns directly upstream of Lake Cushman may have fewer habitats available than they did historically due to the increased size of the lake as a result of the dam.

The South Fork Skokomish population is generally found upstream of a majority of the watershed‟s major disturbances. This area still has a high sediment load as a result of logging that may impact this population. Perhaps most importantly, logging may reduce the riparian cover near the stream channel thereby reducing LWD and pool frequency, and increasing stream temperatures. Also, bull trout redds are highly susceptible to scour as the smaller bodied individuals cannot bury their eggs as deep as salmon. Increased fine sediment supply from logging activities in the upper watershed can also effect egg-fry survival. Although the bulk of their population in the South Fork Skokomish lies upstream of the canyon section, they have been documented throughout the watershed and in a screw trap run by the Skokomish Tribe, and are therefore susceptible to previously mentioned factors affecting the lower watershed as well, such as low flows, high temperatures, and lack of pool habitat.

Adult

Three distinct stocks of bull trout exist in the Skokomish River watershed, a fluvial population in the South Fork Skokomish, a lacustrine-adfluvial population in Lake Cushman, and a fluvial population in the upper North Fork Skokomish. The two populations in the North Fork Skokomish are geographically isolated from the South Fork Skokomish stock by Cushman Dams #1 and 2 built by Tacoma Power (formerly City of Tacoma) in the 1920‟s and 1930‟s. All bull trout were listed as threatened under the ESA November 1, 1999. The SASSI report lists the status of both the South Fork Skokomish and upper North Fork Skokomish stocks as unknown, while the Lake Cushman stock is deemed to be healthy.

The Lake Cushman stock migrates into the North Fork Skokomish, below Staircase rapids (RKM 45.2 (RVM 28.1)), to spawn from late September through the end of December (Figure 67). Snorkel surveys conducted by WDFW (1971-1994) and the Park Service (1995-present) have occurred in different areas below and slightly above Staircase Rapids making different years difficult to compare, but both indicate stable populations (Figure 68). Snorkel surveys of the upper North Fork Skokomish (~RKM 49.09 (RVM 31)) in 1988 and 1995 both detected bull trout, but spawn timing or location remains unknown.

The USFS has monitored bull trout in the South Fork Skokomish and its tributaries since 1994 and indicates that they are present in the South Fork Skokomish proper and in Church, Pine, Cedar, LeBar, Brown, Rock, Flat and Vance Creeks. The highest concentrations of fish have been observed in the South Fork Skokomish from RKM 34.6 (RVM 21.5) to the falls at RKM 40.2 (RVM 25). Spawn timing is assumed to be mid-September through December but spawning locations are unknown. Bull trout have only been observed downstream of anadromous barriers and therefore have access to this habitat throughout their life history. However, otolith microchemistry indicates that they are not anadromous (Larry Ogg, USFS, cited in Correa 2003), although more recently, emigrating smolts have been observed (SASSI 2006). Redd counts from RKM 29.8 (RVM 18.5) to RKM 38.2 (RVM 23.75) in South Fork Skokomish River and from RKM 0 (RVM 0) to RKM 1.6 (RVM 1.0) in Church Creek indicate a depressed, but stable population (Figure 69).

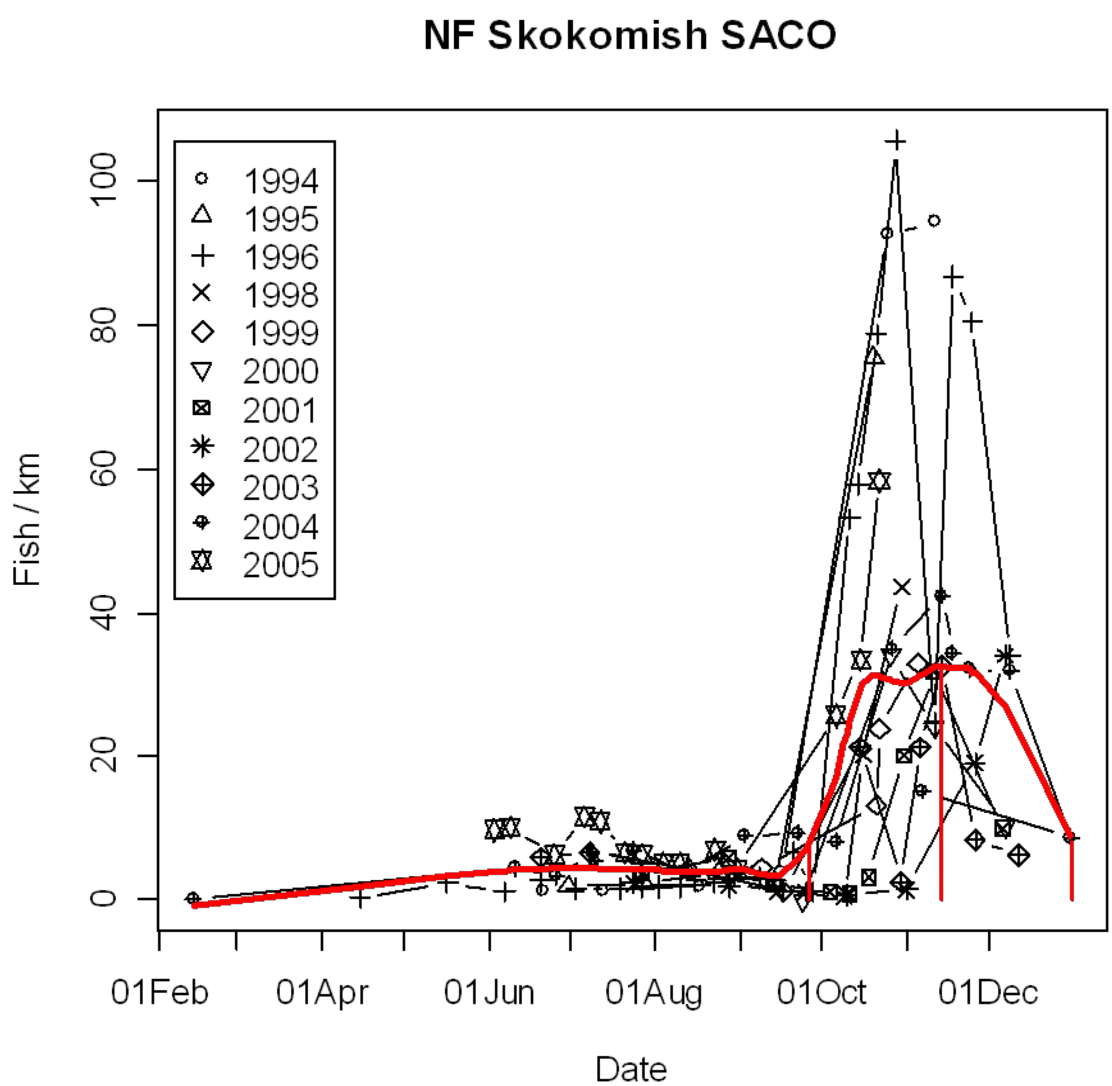

Figure 67. Onset, peak, and end of bull trout migration in the North Fork Skokomish River between Staircase and Lake Cushman (Sam Brenkman, Olympic National Park, unpublished data). The red line shows the mean onset (September 26), peak (November 14), and end (December 31) of bull trout migration.

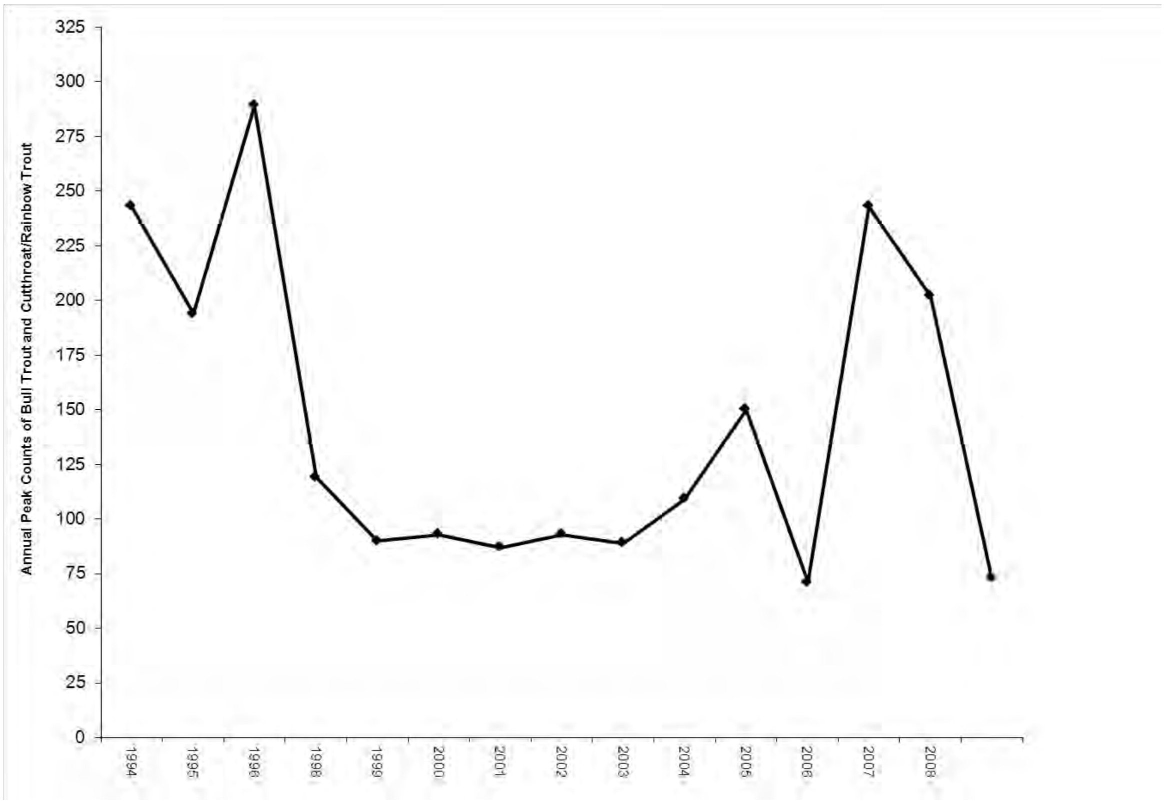

Figure 68. Annual peak snorkel counts in the North Fork Skokomish River, 1994-2009 (Sam Brenkman, Olympic National Park, unpublished data).

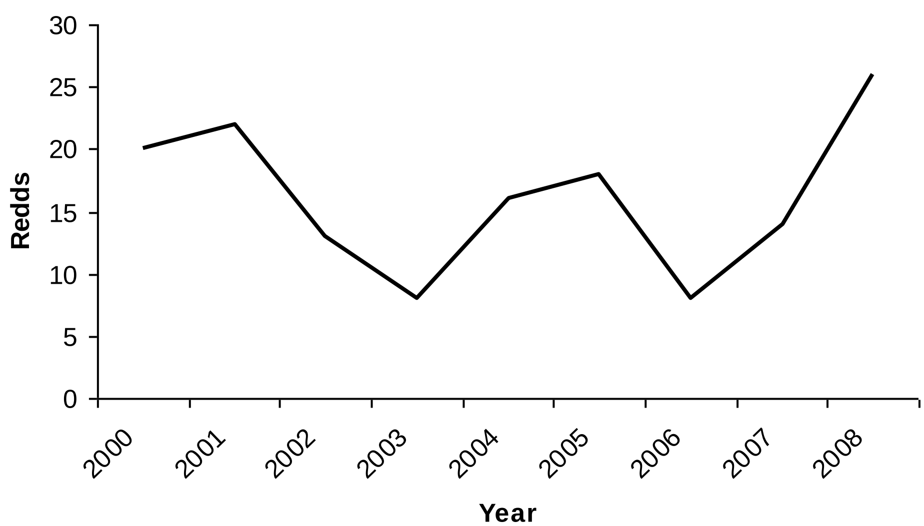

Figure 69. Adult bull trout redd counts from RKM 29.8 (RVM 18.5) to RKM 38.2 (RVM 23.75) in South Fork Skokomish and from RKM 0 (RVM 0) to RKM 1.6 (RVM1.0) in Church Creek. All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm

There is limited data describing bull trout rearing densities in the Skokomish Basin. Brenkman (1998) assessed the distribution of bull trout in the North Fork Skokomish River using a combination of snorkeling and single pass electrofishing. Based on this information, bull trout appear to display only a lacustrine-adfluvial life history pattern in this area. They found no evidence of non-migratory bull trout in the Skokomish Basin. Bull trout are primarily observed from Staircase Rapids downstream to Lake Cushman and in the lower sections of Elk and Slate Creek. Based on these surveys, Brenkman (1998) suggest that bull trout are not present in the river or its tributaries above RKM 52. Dunham and Chandler (2001) present data for bull trout for 16 sites in the South Fork Skokomish and one site in Church Creek (Table 31). Bull trout were present in only 5 of 16 South Fork Skokomish sites and were not observed at the Church Creek site. Densities were less than 0.01 fish/m^2 at all sites where bull trout were observed.

We observed a total of 12 bull trout in 5 of the 21 riverine study reaches we sampled during the summer of 2008 and 2 bull trout in one of 23 riverine study reaches sampled during the winter. We did not observe bull trout in pond habitat during either survey. Based on the locations we observed bull trout, the channel type they were observed in, and the channel type of adjacent segments we estimated seasonal bull trout distribution (Figure 70). They were expected to be distributed throughout the Skokomish Basin during both the summer and winter based on our summer observations. We caught one bull trout during our winter survival survey at the USACE Vance Creek reach. This bull trout had a fork length of 132 mm.

Based on the numbers and distribution of bull trout observed during the summer, we estimated that a total of 115 bull trout (95% confidence interval: 42-207) bull trout were present in the anadromous portion of the Skokomish Basin. This represents a rearing density of 1.6 fish/km. No estimate was produced for the winter data due to the small number of fish and since we observed bull trout in only one reach. The summer estimate, when combined with the 2008 peak annual count for the North Fork Skokomish obtained by Olympic National Park personnel (202 fish, Sam Brenkman, Olympic National Park, unpublished data) provide a Skokomish Basin estimate for these two populations of 317 fish. This value is less than half the recovery goal for the Skokomish River (700 fish with an increasing trend) (USFWS 2004). Although snorkel estimates are known to underestimate population size, we took that into account and expanded our estimates by a factor of 1.5 based on bounded count expansion equations (See Appendix F for details of methods). Olympic National Park did not expand their estimates; suggesting that these estimates are low. Assuming a similar expansion factor would increase their estimates to 304 fish, resulting in a Skokomish Basin estimate of 419 fish, which is still substantially lower than the recovery goal.

We did not catch any bull trout during our outmigration or estuary sampling. Otolith microchemistry assessment of bull trout from the Skokomish Basin suggests that bull trout in this system do not display an anadromous life history pattern (Larry Ogg, USFS, Personal Communication, cited in Correa 2003). Although, the current evidence suggests that bull trout in the Skokomish River don"t use the estuary. The apparent low abundance in the Skokomish Basin makes it unlikely that we would catch a bull trout during our sampling efforts even if they were present. In addition, extensive use of estuary, near shore, and open ocean habitats have been documented by Brenkman and Corbett (2005) and Brenkman et al. (2007) by bull trout in other Olympic peninsula rivers. Further assessment of bull trout in the system is warranted to fully address this issue.

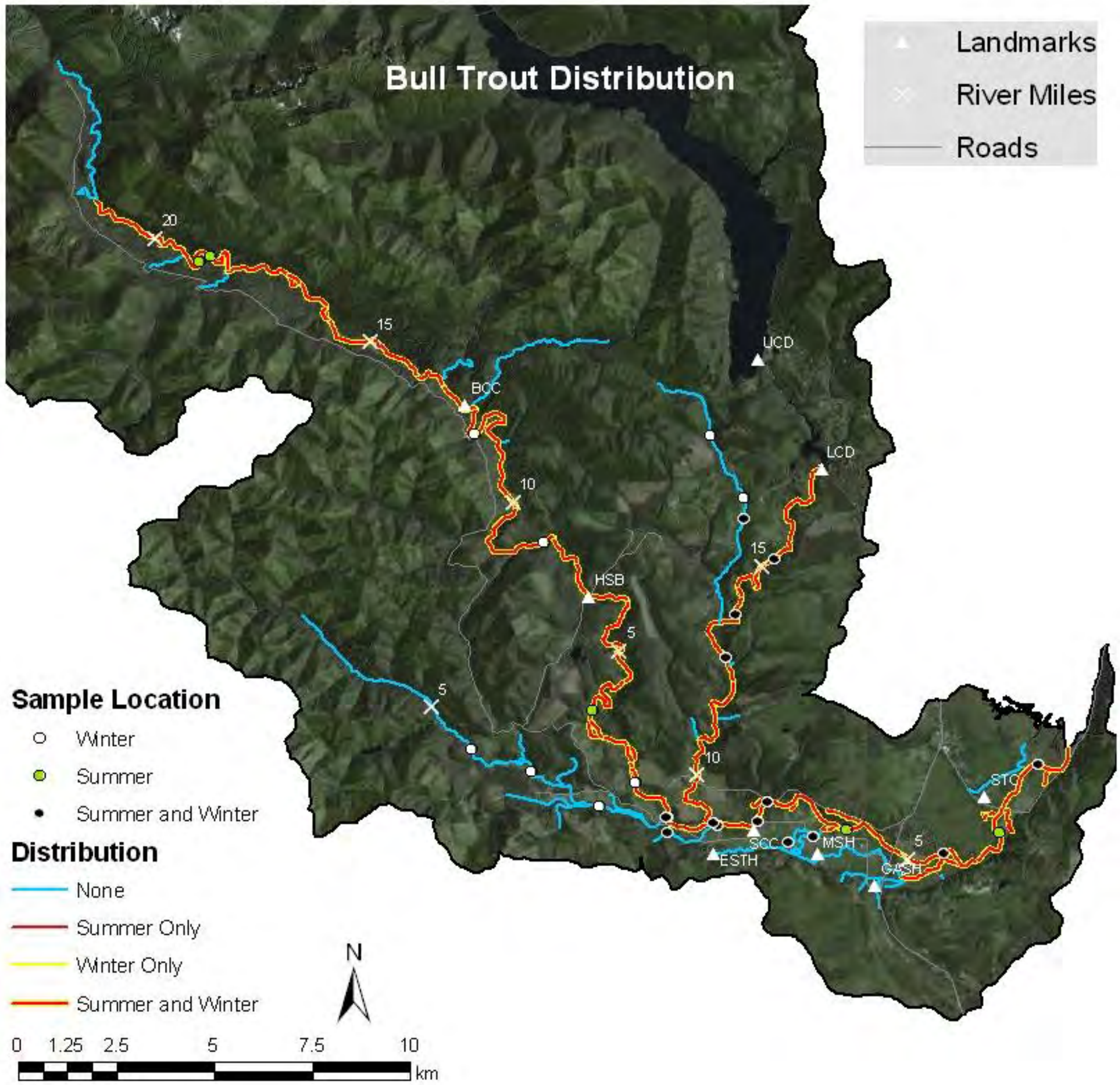

Figure 70. Expected bull trout distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 31. Presence of all bull trout and densities of juvenile and adult bull trout observed in Church Creek and several sites in the South Fork Skokomish River (From Dunham and Chandler 2001), sites are shown in **Figure 62**.

			Density (per m^2)	
Stream	Site	Present	Juvenile	Adult
Church Cr	1	No	0	0
S.F. Skokomish	1	No	0	0
S.F. Skokomish	10	No	0	0
S.F. Skokomish	11	No	0	0
S.F. Skokomish	12	No	0	0
S.F. Skokomish	13	**Yes**	0	0
S.F. Skokomish	14	**Yes**	0	0
S.F. Skokomish	15	No	0	0
S.F. Skokomish	16	**Yes**	0	0
S.F. Skokomish	17	No	0	0
S.F. Skokomish	18	No	0	0
S.F. Skokomish	19	**Yes**	0	0
S.F. Skokomish	2	No	0	0
S.F. Skokomish	20	**Yes**	0	0
S.F. Skokomish	21	No	0	0
S.F. Skokomish	22	No	0	0
S.F. Skokomish	23	No	0	0

Cutthroat Trout

General habitat requirements

Coastal cutthroat trout exhibit a wide variety of migratory life history strategies including anadromous, potamodromous stream-dwelling and lake-dwelling (i.e., potamodromous fishes migrate entirely within freshwater, Myers 1949), and headwater stream-resident life history forms, all of which have age specific habitat requirements (Trotter 1989). Anadromous fish spawn in small tributaries from late winter through spring, with the peak in Washington being February (Hartman and Gill 1968; Trotter 1989). Spawning sites are generally not far from pools (Hunter 1973; Jones 1978). Juveniles remain in habitats along stream edges for the first few months after emergence and their densities may be affected by the availability of these lateral habitats (Moore and Gregory 1988). When they increase in size, they move to pools unless coho salmon are present, in which case they are driven to riffles (Glova and Mason 1976, 1977). They have also been shown to utilize floodplain pools and side channel habitat as winter refugia (Bustard and Narver 1975; Sedell et al. 1984; Hartman and Brown 1987). Several studies have reported mean depths and current velocities that cutthroat have been shown to occupy, with smaller fish utilizing depths of 32-54 cm and velocities of 10 – 14 cm/s, while larger fish prefer deeper (54-62 cm) and faster (14-22 cm/s) areas, although all size classes have been shown to inhabit a wide range of depths and velocities (Thompson 1972, Hanson 1977, Pratt 1984). While feeding in-stream, cutthroat are drift feeders generally residing at the heads of pools (Wilzbach and Hall 1985). Age of seawater entry varies for anadromous cutthroat depending on the type of marine environment they enter. Juvenile cutthroat trout generally smolt after 2 years if they migrate to sheltered saltwater areas, but generally smolt after 3 or 4 if they migrate to the open ocean. However, juvenile cutthroat can smolt at any point from age 1 to 6 (Giger 1972; Lowery 1975; Trotter 1989; ; Johnson et al. 1999). Seaward migration peaks in May and the fish remain in shallow nearshore areas while in salt water. They generally spend only the summer at sea before returning to rivers in the next fall or winter after going to sea (Johnson et al. 1999). Headwater stream-resident cutthroat trout become sexually mature as early as age 2, but seldom live beyond age 4 or 5, rarely migrating more than 200 m from their birthplace (Trotter 1989).

Adults

We didn‟t find any information regarding adult cutthroat trout in the Skokomish system. We observed very few adult bull trout during our sampling and only in the off-channel ponds associated with the confluence of Purdy Creek with the mainstem Skokomish River.

Juveniles

Trout were observed in mainstem, tributary, and pond habitats. Although we did not separate trout into *O. mykiss* and cutthroat during our snorkel surveys, sampling for winter diet analysis suggest that cutthroat trout were more common in tributary and pond habitats (0 mainstem, 107 tributary, 17 pond). Others have also found that cutthroat trout tend to use pond habitats more than *O. mykiss*, especially if the bottom is composed of fine sediments. Based on this information, we assume that most of the trout observed in the ponds were cutthroat.

Cutthroat trout appear to prefer nearshore areas of off-channel pond habitats. Densities in the nearshore were greater than those in the offshore for zero-age trout during the winter, 1+ trout during summer and winter, 2+ trout during the winter, but not summer, and >3+ trout during summer and winter. Although the mean densities were differed, the confidence intervals generally overlapped, suggesting that the differences were not statistically different. This is likely due to the relatively small sample size and large variance estimates.

Other Historic Stocks (Pink and Sockeye)

While pink salmon and sockeye salmon are no longer found in the Skokomish Basin there potential for recolonization should be noted. Pink salmon are increasing exponentially in the North Pacific in general and Puget Sound specifically, providing a nearby source population for recolonization (Ruggerone 2010). In addition, a resident sockeye population persists behind Cushman dam as landlocked kokanee (Correa 2003). Although no plans to reintroduce them to the anadromous zone exist, they are likely genetic remnants of the original sockeye population in the Skokomish and thus could be a viable source stock if reintroductions were desired in the future.

Other Species

We observed 27 non-salmonid species in the Skokomish Basin and the Nalley Island portion of the estuary. The most abundant species included shiner perch, surf smelt, Pacific staghorn sculpin, three-spine stickleback, starry flounder, and Pacific sand lance (larvae). The most common species observed during our surveys are described below. For more detailed information on species and their abundance, please see Appendices G and H.

Lamprey

Western brook and Pacific lampreys were observed in our fish surveys. As Pacific, river, and western brook lamprey ammocoetes (larvae) are nearly indistinguishable from each other, we were unable to identify some juvenile lamprey captured in our surveys. Because river lamprey have been captured in other Puget Sound systems (Wydoski and Whitney 2003) and may exist in the Skokomish Basin, they are included in the summaries below.

Lampreys are a primitive group of fishes that are eel-like in form but lack jaws and paired fins (Moyle 2002). These species have a round sucker-like mouth (oral disc), no scales, and breathing holes instead of gills. Pacific lamprey is the largest of the three species, reaching lengths of 70 cm (McPhail 2007). Adult river lampreys vary in length from 16 to 30 cm, while Western brook are usually less than 16 cm long (McPhail 2007). Pacific and river lampreys are anadromous and parasitic, while the nonparasitic western brook lamprey normally spends it entire life in freshwater (Wydoski and Whitney 2003). Available information on the abundance, distribution, and stock status of lamprey species in western Washington is extremely limited and largely anecdotal. Data collected on juvenile lamprey is also often listed as “lamprey sp.”

Western Brook Lamprey Life History

Information for western Brook Lamprey was pulled from Wydoski and Whitney (2003). Adult Western brook lampreys spawn in gravel bottomed streams in a riffle or at the tailout of a pool (McPhail 2007). Both sexes construct the nests, often moving stones with their mouths (Pletcher 1963). Spawning occurs from March to July and Western brook lampreys lay 1,100 to 5,500 eggs per adult female. After the eggs are deposited and fertilized, the adults typically die within 3 to 36 days. The newly hatched ammocoetes emerge about 10 days after spawning and drift into silty backwater areas (Pletcher 1963). They remain burrowed in the stream bottom, living as filter feeders on algae and detritus for 2 to 7 years. Metamorphosis to adult stage occurs from February through July, and at this time their gonads are not fully developed. They burrow into the stream substrate where they remain dormant through the winter months. In the spring, western brook lampreys emerge from their burrows sexually mature and remain in freshwater where they may migrate short distances to spawn (McPhail 2007). Western brook lampreys are nonparasitic and do not feed as adults.

River Lamprey Life History

The parasitic and anadromous river lamprey is genetically and morphologically similar to western brook lamprey, which overlaps in range. Except for the last 6 months to 1 year of life, the western brook lamprey and the river lamprey are indistinguishable from each other. Little information is available on river lamprey life history. According to Moyle (2002), their life span is 6 to 7 years. Adult lampreys spawn in gravel bottomed streams, at the upstream end of riffle habitat. Both sexes construct the nests, often moving stones with their mouths. River lampreys lay 11,400 to 37,300 eggs per adult female. After the eggs are deposited and fertilized, the adults typically die within 3 to 36 days. After the eggs hatch, young ammocoetes drift downstream to areas of low velocity and silt or sand substrate. They remain burrowed in the stream bottom, living as filter feeders on algae and detritus for 2 to 7 years. Metamorphosis from the ammocoete to macropthalmia life stage occurs between July and April. At this time, macropthalmia are thought to live deep in the river channel, which may explain why they are rarely observed. As adults, their oral disc develops just before they enter the ocean between May and July. During the approximately 10 weeks they are at sea in the parasitic phase, they remain close to shore, feeding primarily on smelt, herring, and salmon near the surface (Beamish 1980). After the adult feeding phase, river lamprey return to freshwater, migrate to spawning areas, and cease feeding. Their degree of fidelity to their natal streams is unknown.

Pacific Lamprey Life History

Pacific lamprey is the most widely distributed lamprey species on the west coast of the United States. Historically, they are thought to be distributed wherever salmon and steelhead have occurred. Adult Pacific lampreys are parasitic and feed on a variety of fish. In the ocean, they have been caught in depths ranging from 300 to 2,600 feet, and as far off the west coast as 62 miles in the ocean. After spending 1 to 3 years in the marine environment, Pacific lampreys cease feeding and migrate to freshwater between February and June. Adults migrate upstream nocturnally (Potter 1980; Beamish and Levings 1991; Chase 2001) from late spring to fall (Luzier et al. 2006). They are thought to overwinter and remain in freshwater habitat for approximately one year before spawning, during which time they may shrink in size up to 20 percent (Fox and Graham 2008).

Pacific lampreys spawn in similar habitats to salmon; in gravel bottomed streams, at the upstream end of riffle habitat and at the tailouts of pools, typically above suitable young larvae (ammocoete) habitat (Mattson 1949; Pletcher 1963; Kan 1975). Spawning occurs between March and July depending upon location within their range (Wydoski and Whitney 2003). The degree of homing is unknown, but adult lampreys cue in on ammocoete areas. Ammocoetes release pheromones that are thought to aid adult migration and location of suitable spawning habitat. Both sexes construct the nests, often moving stones with their mouth (Pletcher 1963). Pacific lampreys lay 30,000 to 238,400 eggs per adult female (Kan 1975; Wydoski and Whitney 2003; Close et al. 2002). After depositing and fertilizing the eggs, the adults typically die within 3 to 36 days (Pletcher 1963; Kan 1975; Beamish 1980). Embryos hatch in approximately 20 days. Ammocoetes drift downstream to areas of low velocity and fine substrates (Stone and Barndt 2005) where they burrow, grow, and live as filter feeders for 2 to 7 years and feed primarily on microscopic plant and animal material (Wydoski and Whitney 2003; Beamish 1987). Several generations and age classes of ammocoetes congregate in high densities that form colonies. Downstream movement happens year round. Due to poor swimming ability, movement is probably driven by flow conditions and velocities (Moursund 2002). Movement is mostly nocturnal (Beamish and Levings 1991, White and Harvey 2003, Moursund et al. 2000) and correlated with discharge but not temperature (Hammond 1979; Potter 1980; Beamish and Levings 1991; Close et al. 1995). Metamorphosis to macropthalmia (juvenile phase) occurs gradually over several months as they develop eyes, teeth, and become free swimming.

Transformation from ammocoetes to macropthalmia typically begins in July to October (McGree et al. 2008). Juveniles emigrate to the ocean between late fall and spring where they mature into adults (Close et al. 1995; Kostow 2002).

Lamprey Habitats

Riffle and side channel habitats are important for lamprey spawning. Lamprey larvae are most abundant where the stream channel is relatively deep (0.4−0.5 m), gradient is low (<0.5%) and the riparian canopy is open (Torgerson and Close 2004). Ammocoetes rear in areas located near reaches where spawning occurred (Pletcher 1963). At finer scales, larval occurrence corresponds positively with low water velocity, pool habitats and the availability of suitable burrowing habitat (Roni 2002; Pirtle et al. 2003; Torgerson and Close 2004; Graham and Brun 2005). Ammocoetes are known to use slow depositional areas along streambanks and burrow into fine sediments during rearing periods (Pletcher 1963; Lee et al. 1980; Richards 1980; Potter 1980; Torgerson and Close 2004; Graham and Brun 2005; Cochnauer et al. 2006). Because lamprey ammocoetes colonize areas and are relatively immobile in the stream substrates, good water quality is essential for rearing. Potential threats to lampreys across their range include artificial barriers to migration, poor water quality, harvest, predation by nonnative species, stream and floodplain degradation, loss of estuarine habitat, decline in prey, ocean conditions, dredging, and dewatering (Jackson et al. 1996; Close et al. 1999; BioAnalysts, Inc. 2000; Close 2000; Nawa et al. 2003).

Summary of Lampreys Sampled

Most lampreys we captured or surveyed in the Skokomish Basin were identified as Western brook lamprey (Table 32). The majority of these lampreys were captured in outmigration surveys in 2008 and 2009 (Table 32 and Figure 71). Lamprey were also observed or captured during snorkel surveys and PIT tag surveys, while few numbers were captured at a lamprey weir operated on the main channel, in off-channel ponds, and while seining at a few snorkel sites (Table 32).

During the outmigration trapping period, a total of 204 Western brook lampreys were captured (Figure 71), ranging from 27 to 215 mm in total length. In 2009 when the entire outmigration period was sampled, catch peaked in late January and early February. The average fish size generally decreased during this trapping period, from around 130 mm in total length in late January, to around 85 mm during mid-July (Figure 72). Length frequency distribution of all fish captured in 2009 showed a wide of range of sizes; however, about half of all Western brook lampreys captured were between 110 and 150 mm in length (Figure 73).

We also observed Western brook lampreys during both summer and winter snorkel surveys. Between June and September 2008, an estimated 63 brook lampreys were observed in the mainstem, tributaries (Hunter and Vance Creeks), and the North Fork Skokomish (see Appendix F for details of sampling methods). Two unidentified lampreys were observed at the USACE SFV site, which were estimated to be 15 cm (6 in) and 45 cm (18 in) in length. Between February and April 2009, six brook lampreys were observed in the mainstem and the South Fork Skokomish.

During PIT tag surveys, a total of 25 lampreys were captured and measured. These fish were not identified to species. They ranged in size from 47 to 171 mm, and averaged 94 mm in length. Additionally, we captured a total of 15 lampreys at a specially designed lamprey weir located near the screw trap from July 9 to July 29, 2009 (Table 32). Western brook lampreys caught at this site ranged in length from 80 to 153 mm, and averaged 135 mm. The Pacific lampreys ranged from 165 to 200 mm in length, and averaged 180 mm.

During summer pond surveys we observed four Western brook lampreys at site #14, three in the nearshore area and one in the offshore area, and one was also observed in the nearshore area at site #10. Two unidentified lampreys were observed at site #05 during winter surveys, one each in the nearshore and offshore areas. In addition, one brook lamprey (TL=130mm) was captured during seining at the North Fork Skokomish and South Fork Skokomish confluence in July 2008.

Based on our snorkel estimates, the efficiency of these estimates, and the percentage of habitat surveyed, we estimated Skokomish Basin population size for lamprey (see Appendix F for detailed methods). We estimated that 1,165 lampreys existed in the Skokomish Basin during the summer of 2008 and 30 lampreys were in the Skokomish Basin during the winter of 2009. The difference in estimates is likely due the life history patterns of brook lamprey. The summer estimates were completed from May through the summer and would have occurred when adult brook lamprey were spawning. We saw several pairs building nests during these surveys. However, brook lampreys burrow in the substrate during the winter (McPhail 2007) and thus would not have been visible during our surveys.

Table 32. Number of lampreys caught or observed during our sampling throughout the Skokomish River in 2008 and 2009.

Surveys	Capture Date(s)	Number	Length (mm) Mean	Min.	Max.	Std. Dev.
Western brook lamprey						
Outmigration	6/11/2008 - 7/19/2009	204	123	27	215	32.9
Lamprey weir	7/17/2009 - 7/29/2009	9	135	80	153	23.1
Off-channel Ponds	8/21/2008	5	NA	NA	NA	NA
Seining	7/15/2008	1	130	NA	NA	NA
Pacific lamprey						
Outmigration	7/2/2008	4	157	136	175	20.4
Lamprey weir	7/9/2009 - 7/29/2009	5	180	165	200	14.6
Unidentified lamprey						
Outmigration	5/2/2009-7/17/2009	7	101	55	134	26.8
Lamprey weir	7/9/2009	1	120	NA	NA	NA
PIT Tag surveys	12/16/2008 - 3/3/2009	25	94	47	171	34.8
Off-channel Ponds	4/8/2009	2	NA	NA	NA	NA
Winter snorkel		30				
Summer snorkel	6/24/2008 - 9/18/2008	1,165 [a]				

[a] Estimated number based on expansion of snorkel estimates using bounded counts of observations. Most lampreys observed were identified as Western brook lamprey.

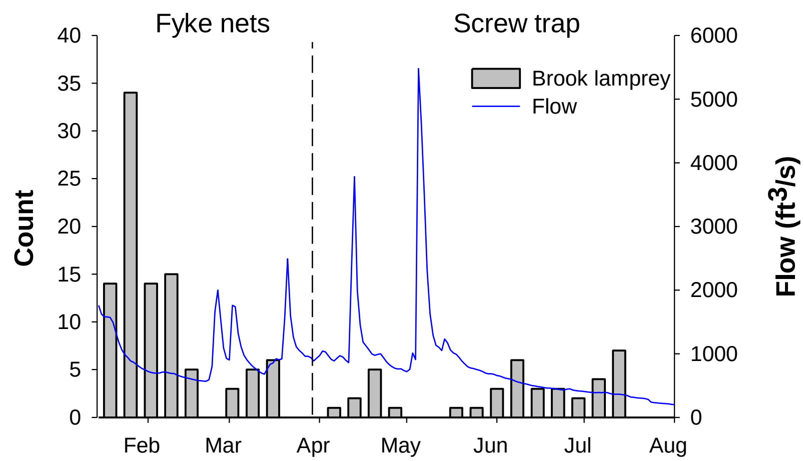

Figure 71. Weekly counts (first axis) of Western brook lampreys captured in fyke nets (6/11/08 - 3/17/09) and a screw trap (4/9-7/19/09), and daily average flow (second axis) of the Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

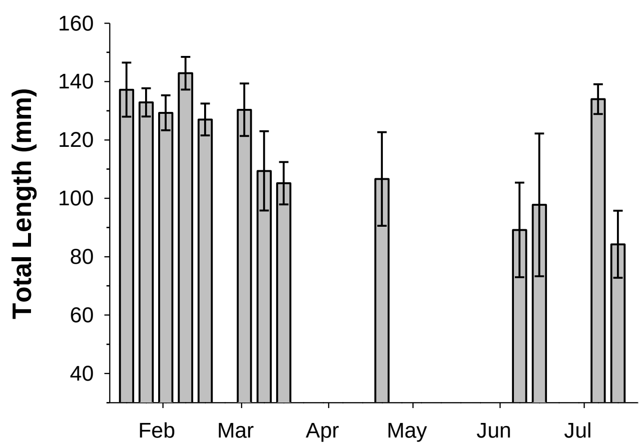

Figure 72. Weekly mean total lengths and standard errors of Western brook lampreys captured in fyke nets (1/21-3/17/09) and a screw trap (4/9-7/19/09) on the Skokomish River in 2009.

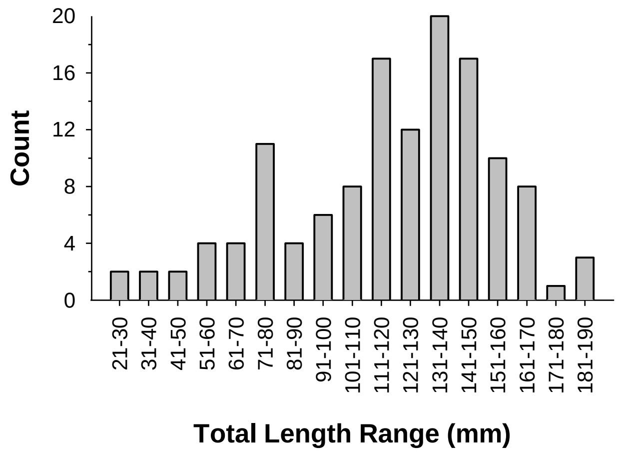

Figure 73. Length frequency distribution of Western brook lampreys captured in fyke nets (1/21-3/17/09) and a screw trap (4/9-7/19/09) on the Skokomish River in 2009.

Threespine stickleback (Gasterosteus aculeatus)

Threespine stickleback are small, relatively slow-moving fish that rely on spines and armoring to reduce predation risk. Across their native distribution, threespine stickleback inhabit a vast array of habitat types, from small streams to large lakes to the marine environment including the open ocean (McPhail 2007). Both resident and anadromous forms occur. Typically, they are found in slow waters in lower reaches of coastal streams and occur upstream to major fish barriers such as waterfalls. Often they are closely associated with aquatic vegetation. In the Skokomish Basin, they also inhabit a variety of habitat types from estuarine, riverine, and pond habitats. In both the estuarine and river samples, threespine stickleback were a minor component of the total number of fish observed (Table 33). However, 64% of all fish observed during pond snorkel surveys (winter and summer) were threespine stickleback. Five ponds were surveyed and they were observed in four ponds in the lower part of the Skokomish Basin but were absent from Pond #26 in the upper part of the Skokomish Basin. The upper extent of threespine stickleback in the Skokomish Basin is not well known.

Threespine stickleback commonly live for one year, spawn in May through August, and die shortly after spawning (Moyle 2002; Wydoski and Whitney 2003). However, a lifespan of 2-5 years is not uncommon (Baker 1994). Basic life-history information of threespine stickleback in the Skokomish Basin is not well known. We assume they successfully reproduce in the ponds and can complete their entire life-cycle in this habitat. Whether they spawn in riverine or estuarine habitats of the Skokomish Basin is unknown. Threespine stickleback in these habitats may just be fish that have been displaced downstream from the ponds. Length frequency data was only obtained from estuary seining and the screw trap. Screw trap caught fish were generally smaller than those caught in the estuary (Figure 74). Similar to other systems, threespine stickleback were usually less than 80 mm TL.

Table 33. Number of threespine stickleback and all other fishes surveyed during several types of sampling efforts, Skokomish Basin.

Location type	Sampling type	Number of stickleback	Number of other fishes
Estuary	Beach seining	281	58,396
River	Lamprey weir	2	237
River	Beach seine	0	189
River	Snorkeling	709	94,619
River	Fyke net	5	2,987
River	Screw trap	238	10,746
Pond	Snorkeling	5,788	3,212

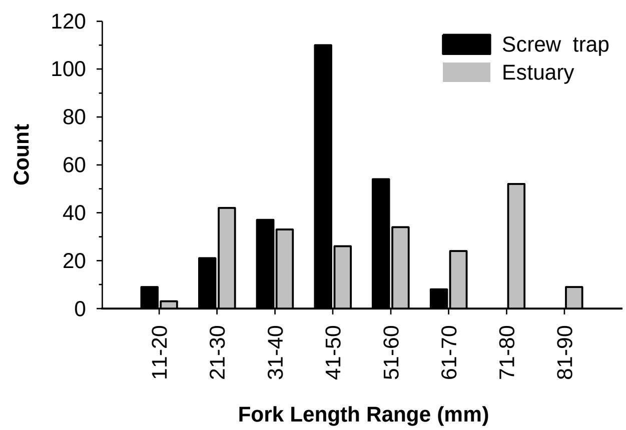

Figure 74. Length frequency of threespine stickleback collected in the estuary (n = 281) with beach seines and in the river (n = 238) with a screw trap, Skokomish Basin.

Freshwater sculpins Cottus spp.

Freshwater sculpins *Cottus* spp. are small benthic fishes that are an important component of freshwater ecosystems of the Pacific Northwest. In many habitats they are often the most abundant type of fish. A few different species often occur in the same watershed and are often spatially segregated (Tabor et al. 2007a). Within the Skokomish River, five species of freshwater sculpin have been documented which includes coastrange sculpin, prickly sculpin, riffle sculpin, reticulate sculpin, and shorthead sculpin (Mongillo and Hallock 1998). Prickly sculpin and coastrange sculpin typically inhabit the lower reaches with prickly sculpin inhabiting pools and other slow-water habitats while coastrange sculpin inhabit riffles and other fast-water habitats. Shorthead sculpin typically occur at higher elevations than the other four species. Riffle sculpin and reticulate sculpin usually occur in middle reaches in a variety of habitat types.

Riffle sculpin and reticulate sculpin are closely related and have not been clearly separated by existing morphometric characteristics (Wydoski and Whitney 2003). Therefore, whether they both occur in the Skokomish Basin is unclear. During our field collections, we referred to them collectively as one species, riffle sculpin. Kinziger et al. (2005) conducted genetic analyses of several sculpin species and found riffle sculpin and reticulate sculpin were unique species. However, the range and distribution of both species is in need of careful examination. For example, Wydoski and Whitney (2003) indicated the northern extent of reticulate sculpin is the Green River in Washington, while Moyle (2002) indicated that reticulate sculpin only extend north to the lower Columbia River. Reticulate sculpin appear to be widespread in many areas of western Oregon (Bond 1963) but their distribution in Washington is not well known. In contrast, riffle sculpin are known to be widespread in western Washington.

Freshwater sculpins were commonly encountered during fish surveys in the Skokomish Basin; however, most sampling efforts did not lend themselves for sampling and identifying freshwater sculpins. River and pond habitats were sampled primarily through snorkel surveys. Freshwater sculpins are small, cryptic, and often hidden in some type of cover and thus can be easily overlooked by snorkelers. Additionally, freshwater sculpins are difficult to identify while snorkeling and field crews just recorded them as unidentified sculpin. The only sampling technique that collected a relatively high percentage of sculpins was the lamprey weir, which collected several coastrange sculpin (Table 34). Freshwater sculpin are often abundant in complex habitats (e.g., riffles, woody debris, rip rap, undercut banks) that are best sampled with electrofishing equipment.

Table 34. Number of freshwater sculpins and all other fishes surveyed during several types of sampling efforts, Skokomish Basin.

		Number of fish				
Location type	Sampling type	Unidentified sculpin	Coastrange	Prickly	Riffle	Other fishes
Estuary	Beach seining	69	0	6	0	58,602
River	Lamprey weir	36	91	4	12	96
River	Beach seine	2	2	1	21	163
River	Snorkeling	3,672	0	0	0	91,206
River	Fyke net	2	1	10	1	2,978
River	Screw trap	10	5	34	3	10,932
Pond	Snorkeling	193	0	0	0	8,807

Coastrange sculpin (Cottus alecticus)

Coastrange sculpin occur in west coast streams of North America from California to Alaska (Wydoski and Whitney 2003). On the Olympic Peninsula, prickly sculpin are known to occur in most major drainages along the entire peninsula at an average elevation of 42 m (Mongillo and Hallock 1997). They are generally found in medium or large streams with a moderate to rapid current. Usually they inhabit areas with a cobble or gravel substrate. Coastrange sculpin also inhabit the shoreline and deeper benthic areas of lakes and occasionally are found in estuaries. In general, coastrange sculpin inhabit riffles, whereas, prickly sculpin inhabit pools and other slow-water habitat. However, in upstream reaches where no other sculpin exist, coastrange sculpin are found in both pools and riffles (Mason and Machodori 1976).

In most locations, the maximum size of coastrange sculpin is 115 mm TL (McPhail and Lindsay 1970) and few fish live past 5 years. In Oregon, coastrange sculpin spawn when they are three years old. However, in the Cedar River, Washington, coastrange sculpin < 60 mm TL have been observed with eggs, suggesting some fish may be sexually mature before age 3. Spawning takes place in the spring, sometime between February and June. Eggs are deposited under rocks and are adhesive, orange, and less than 1.5 mm in diameter. A male sculpin protects the nest and may spawn with several females. Fecundity ranges from 260 to 834, depending on the size of the fish. Larval coastrange sculpin are pelagic and do not become bottom-dwelling for 32-35 days after hatching (Scott and Crossman 1973).

Like other freshwater sculpins, coastrange sculpin appear to be opportunistic feeders. In streams and rivers, coastrange sculpin feed mostly on benthic invertebrates, particularly aquatic insects. During certain times of the year at some locations, fish eggs and small fish can make up a substantial portion of their diet (Roger 1971, Foote and Brown 1998).

Prickly sculpin (Cottus asper)

Prickly sculpin occur along the Pacific slope of North America from Seward, Alaska to Ventura River, California (Scott and Crossman 1979). Prickly sculpin typically only inhabit the lower reaches of most watersheds. On the Olympic Peninsula, prickly sculpin were collected at an average elevation of 23 m, the lowest average elevation of all cottid species (Mongillo and Hallock 1997). Prickly sculpin are commonly found in lakes, ponds, and quiet waters of rivers. In Lake Washington, prickly sculpin inhabit all depths, from the shoreline to depths > 60 m (Tabor et al. 2007a). Prickly sculpin can also be abundant in estuaries, they have been found in salinities as high as 24 ppt.

Prickly sculpin are the largest freshwater cottid in North America, attaining lengths above 220 mm TL (Tabor et al. 2007b). Some prickly sculpin become sexually mature at age 1 (12% in males, 50% in females) and by age 2 over 90% are sexually mature (Rickard 1980). Spawning takes place in the spring. In Washington, spawning usually occurs in April and May. Nests are usually under rocks or logs in areas with slow water velocities. A male sculpin protects the nest and may spawn with several females. Eggs are adhesive and slightly more than

1 mm in diameter. Fecundity ranges from 700 to 9,600, depending on the size of the fish (Rickard 1980). After hatching, the larvae remain pelagic for 30 to 35 days.

Prickly sculpin would best be described as opportunistic feeders. In most locations, they feed mostly on large benthic invertebrates. As prickly sculpin increase in size, they tend to select larger prey items. During certain times of the year at some locations, fish eggs and prey fish can make up a major portion of their diet (Tabor et al 2007b). Because there their size they can consume a variety of fish species. Because of their large size, they can consume a variety of fish species.

Riffle sculpin (Cottus gulosus)

Riffle sculpin occur in west coast streams of North America from California to Washington (Wydoski and Whitney 2003). On the Olympic Peninsula, riffle sculpin are known to occur in most major drainages along the south and west sides including the Sol Duc, Hoh, Queets, Quinault, Humptulips, Wynoochee, Satsop, and Skokomish at an average elevation of 108 m (range, 11-494 m; Mongillo and Hallock 1997). The riffle sculpin is commonly found in quiet waters and slow riffles of small streams and backwaters of large rivers (Tabor et al. 2007a). Riffle sculpin also inhabit ponds and small lakes. Riffle sculpin typically occupy the cool, upper reaches of streams, while prickly sculpin occupy the warm, lower reaches (Moyle 2002). It is found in areas having a variety of substrates, but generally in those with sand or gravel bottoms (Wydoski and Whitney 2003). The spectrum of stream habitats that riffle sculpin occupy is broadest when other sculpin species are absent (Moyle 2002).

Generally, the maximum size of riffle sculpin is 120 mm TL and few fish live past 5 years. Riffle sculpin in Conner Creek, Washington reached an age of 4 years, but most were less than 2 years old, with the average lengths about 35 mm TL for age 1 fish, and 66 cm TL for age 2 (Wydoski and Whitney 2003). It matures at two years of age and spawns in late February, March and April, with nests made in rotting logs and under rocks in swift riffles (Millikan 1968; Moyle 2002). A male sculpin usually protects the nest. Eggs are 2.5 mm in diameter, adhesive and pale yellow to deep orange. Fecundity ranges from 104 to 449, depending on the size of the fish (Bond 1963; Millikan 1976). Because their larvae are demersal and adults often have a restricted home range, riffle sculpin tend to disperse slowly. For example, Moyle (2002) noted that riffle sculpin in a small stream California took over 18 months to recolonize a riffle that went dry that was 500 m downstream of a large population.

Like other freshwater sculpin, riffle sculpin are opportunistic feeders. They feed on a variety of aquatic insects, isopods, amphipods and snails (Millikan 1968). Small fish and fish eggs are occasionally eaten.

Shorthead sculpin (Cottus confuses)

During our surveys, shorthead sculpin were never documented. However, this is largely because shorthead sculpin typically inhabit cool (< 16^{o}C) headwater streams and we only conducted snorkel surveys in the upper Skokomish Basin and sculpins were not identified to species. We assume that many of the sculpins we observed in the upper part of the Skokomish

Basin were shorthead sculpin. In an earlier study, Mongillo and Hallock (1997) documented shorthead sculpin in the upper Skokomish Basin. They found shorthead sculpin inhabited higher elevations than any other non-game species on the Olympic Peninsula. When sympatric with other sculpins, shorthead sculpin appear to primarily inhabit riffles; however, they occupy a wide range of habitats (e.g., pools, ponds, lakes) when allopatric (Tabor et al. 2007a).

Shorthead sculpin occur in the Pacific drainage area of North America and are found in Puget Sound and Columbia River drainages in Washington. The northern range of shorthead sculpin in Puget Sound stops abruptly at the Snohomish River, which is probably due to historic glaciation patterns (McPhail 1967).

The maximize size of shorthead sculpin is about 130 mm TL. In general, shorthead sculpin will spawn during spring after maturing at age 2-3. Fecundity in shorthead sculpin (50-250 eggs) is considered low compared to other sculpin (Bond 1963). A few weeks after hatching, shorthead sculpin adapt a generally benthic lifestyle, which is maintained through the remainder of the fishes‟ life history. In most areas, the diet of shorthead sculpin consists almost entirely of aquatic insects.

Mountain whitefish (Prosopium williamsoni)

Mountain whitefish were never observed in any of our surveys of the Skokomish Basin anadromous zone. This result is surprising given that a population occurs in the North Fork Skokomish above Lake Cushman. Part of their distribution probably also includes Lake Cushman. Mountain whitefish are an abundant fish that are widely distributed along both slopes of the Rocky Mountains (McPhail 2007). Although primarily an inland species, they also occur in coastal rivers in western Washington along the west side of the Olympic Peninsula and east side of Puget Sound. The only location on the east side of the Olympic Peninsula that mountain whitefish occur is the upper North Fork Skokomish River. Why mountain whitefish do not occur in the anadromous zone of the Skokomish River is unclear. Possible explanations might fall into four categories: 1) poor forage conditions, 2) poor habitat conditions and frequent flood events, 3) a catastrophic event after which they were unable to recolonize, and 4) Skokomish River is not part of their historical distribution (i.e., they were introduced to the upper North Fork Skokomish).

1. Forage conditions – Mountain whitefish prey primarily on aquatic insects in rivers, while those in lakes prey on snails, zooplankton, and aquatic insects. Results of our benthic invertebrate surveys indicated that aquatic insects are abundant in the Skokomish River and there should not be any severe food limitation for mountain whitefish. Certainly, there should enough prey to support a small population of mountain whitefish.
2. Habitat conditions – Mountain whitefish display three basic life-history patterns: riverine, lacustrine, and adfluvial (McPhail 2007). Riverine populations typically occupy riffles during the summer and deep pools during the winter (Wydoski and Whitney 2003). The North Fork Skokomish population appears to be an adfluvial population that is in the river during the summer and overwinters in Lake Cushman (Figure 75). Having adequate overwintering habitat may a key element in the persistence of mountain whitefish

populations. Frequent flood events may severely reduce the quality of their overwintering habitat. Additionally, mountain whitefish spawn in the fall or early winter and frequent flood events could reduce spawning habitat. Mountain whitefish eggs are demersal and become lodged in between spaces of gravel and rubble (McPhail 2007). Therefore, mountain whitefish eggs may be more susceptible to scour events than other salmonids that dig deep redds.

3. Catastrophic event – Historically, a large spill of a toxic substance could have eliminated fish populations from a large portion of the Skokomish Basin. Other species could have easily recolonized because they are also found in other environments (i.e., small tributaries, upper reaches, marine environment). Mountain whitefish are found primarily in the mainstem and may have difficulty recolonizing. A catastrophic event would be most likely in a small, urbanized system. This would seem to be extremely unlikely in the Skokomish Basin because of its size and there are several major tributaries that would act a refuge for mountain whitefish. We are unaware of any major catastrophic event that could have eliminated the entire mountain whitefish population.
4. Historical distribution – On the Olympic Peninsula, mountain whitefish do not occur in the north and east watersheds, except for the North Fork Skokomish population. Perhaps this population is an introduced population. We are not aware of attempts to introduce mountain whitefish in Washington. Perhaps it was done accidentally as part of some other introduction in Lake Cushman.

Of the factors listed above, scour of eggs would seem the most likely mechanism that mountain whitefish could be eliminated from the anadromous zone of the Skokomish River. Also, it seems feasible that mountain whitefish are not native to the Skokomish River because they are not native to other areas of the east and north parts of the Olympic Peninsula.

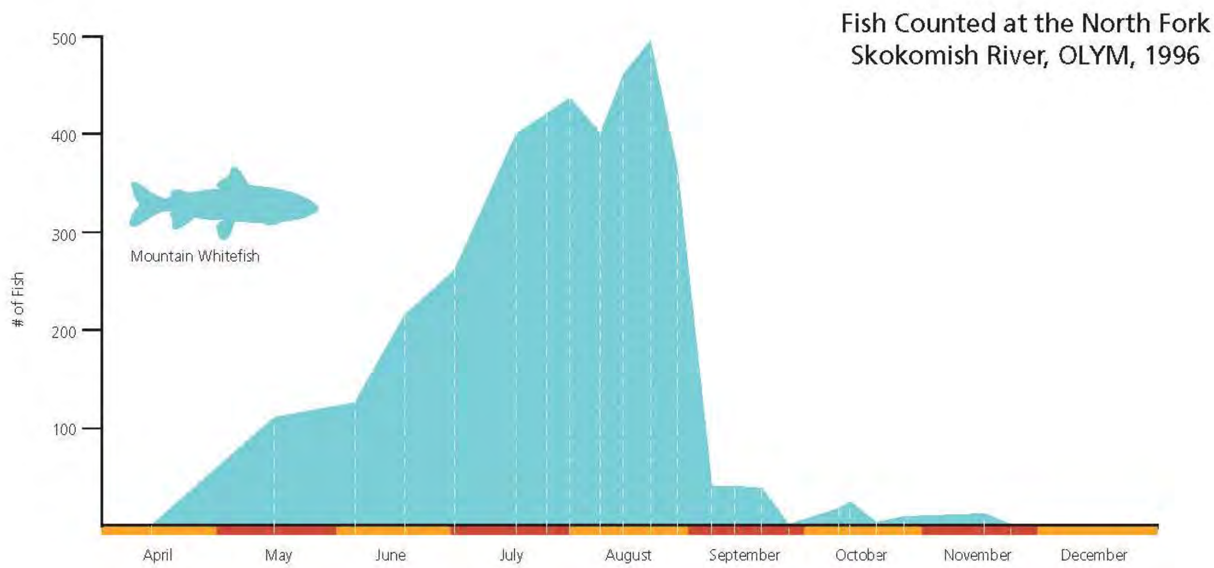

Figure 75. Number of mountain whitefish observed during snorkel surveys of the North Fork Skokomish River above Lake Cushman, 1996. Data and figure are from Sam Brenkman, National Park Service, unpublished data.

Shiner perch (Cymatogaster aggregate)

The shiner perch is a common species found in estuaries and bays of Puget Sound. It occurs primarily in nearshore shallow marine, bay, and estuarine habitats, both intertidally and subtidally (Emmett et al 1991). It also occurs in various coastal streams throughout Puget Sound (Wydoski and Whitney 2003). In our surveys, it was the most abundant species observed overall. Most fish were observed at the Nalley Island estuary, although two individuals were also observed during summer snorkel surveys at site 2-40, just upstream from the estuary and within the stream estuary ecotone. A total of 40,707 shiner perch (69% of total catch at the estuary) were captured by seine (Figure 76). From May through September 2009, it was the most dominant species at the estuary. Peak abundance occurred between late June and early July in 2009. The breach was the most productive location, where about 76% of the total was captured (Figure 77).

Shiner perch are live bearers. The young average 34 to 44 mm in total length at birth (Wilson and Millemann 1969) and adults can reach 200 mm in length (Wydoski and Whitney 2003). Among the subset of shiner perch we collected data from, fork lengths ranged from 27 to 134 mm (Figure 78), and mean fork lengths varied between 52 and 95 mm (Figure 79). Shiner perch less than 50 mm were observed only in June and July of both 2008 and 2009. Moreover, 75% of shiner perch captured during the occurrence of peak abundance in 2009 were in this size range. These figures suggest that June and July constitute the birthing season for shiner perch in the Nalley Island estuary.

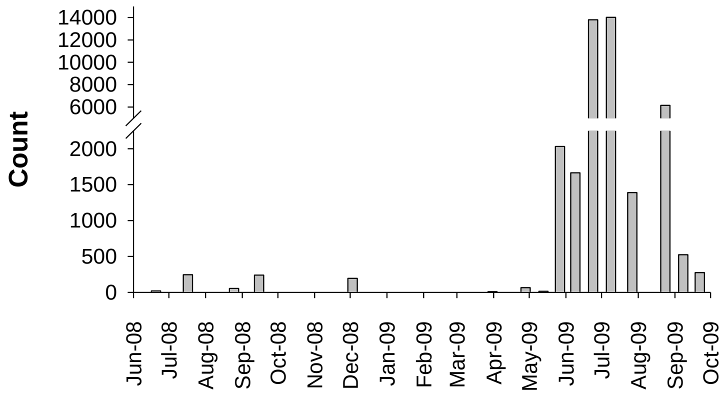

Figure 76. Timing of shiner perch captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

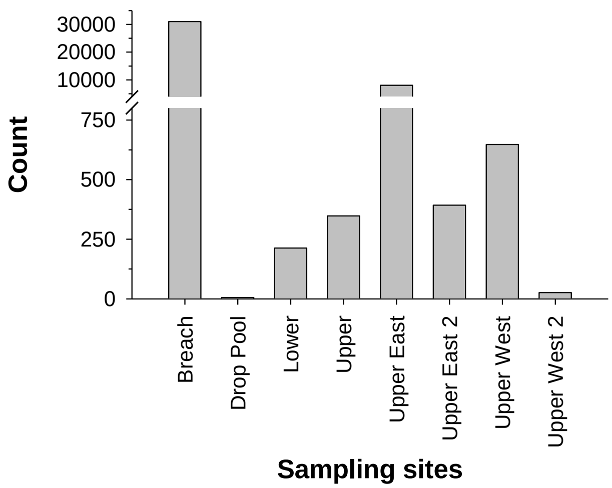

Figure 77. Shiner perch catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

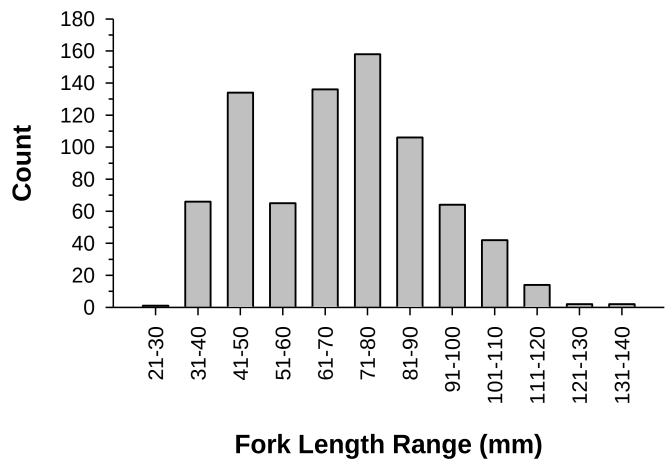

Figure 78. Length frequency distribution of shiner perch captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

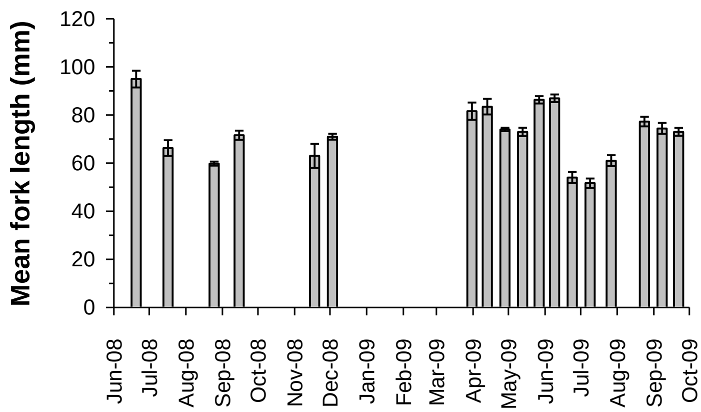

Figure 79. Mean fork length and SE of shiner perch captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

Surf smelt (Hypomesus pretiosus)

The surf smelt is one of the most common forage fish species in the Puget Sound Basin. Larvae, juveniles, and adults can be found over a variety of substrates (Emmett et al. 1991), and adults use mixed sand and gravel beaches in many of the intertidal and shallow subtidal areas as spawning habitat (Penttila 2007). During our surveys, surf smelt were observed in the Nalley Island estuary and just upstream of the estuary. It was the second most abundant species observed at the Nalley Island estuary. A total of 9,552 surf smelt were captured by seine (Figure 80), mostly between October 2008 and March 2009, during which the species is also the most dominant species among all catches. Peak abundance occurred on January 2, 2009 when 6,854 (72%) surf smelt were caught. Population estimate based on mark-capture results indicated that over 200,000 surf smelt were present on that day. The Upper West 2 was the most productive site, where 61% of total was captured Figure 81). At site 2-40, we observed 287 surf smelt in July 2008 during summer snorkel surveys. Over the sampling period, fork lengths varied between 40 and 169 mm (Figure 82), and mean fork lengths varied between 109 and 120 mm during the months from October 2008 through March 2009 (Figure 83).

In Puget Sound, surf smelt spawn throughout the year with heaviest spawning between June and September, and young-of-the-year surf smelt are virtually ubiquitous along shorelines (Penttila 2007). However, during our surveys, few fish (<20) were observed between June and September at the estuary, and over 94% of all surf smelt captured were adults (see size range in Emmett et al. 1991). It is unclear whether the Nalley Island estuary is used as spawning ground.

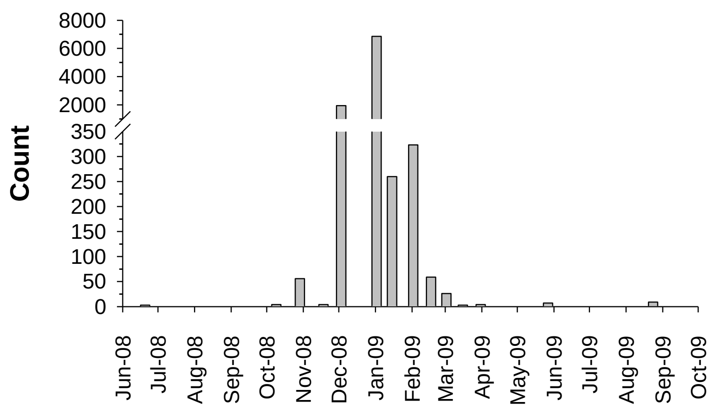

Figure 80. Timing of surf smelt captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

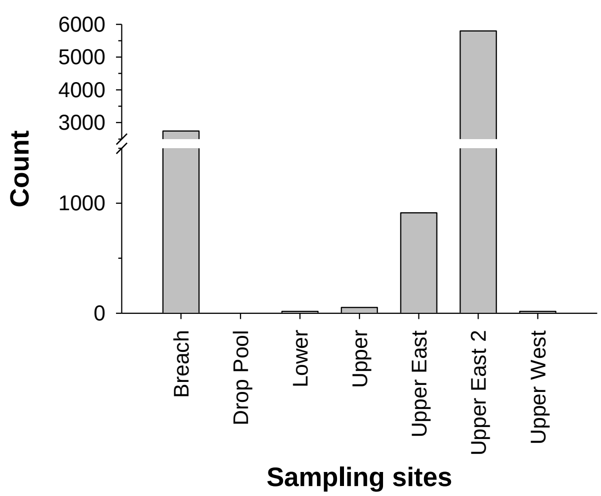

Figure 81. Surf smelt catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

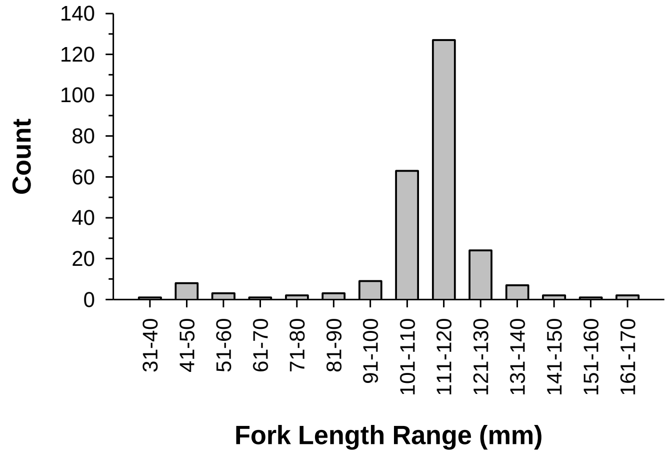

Figure 82. Length frequency distribution of surf smelt captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

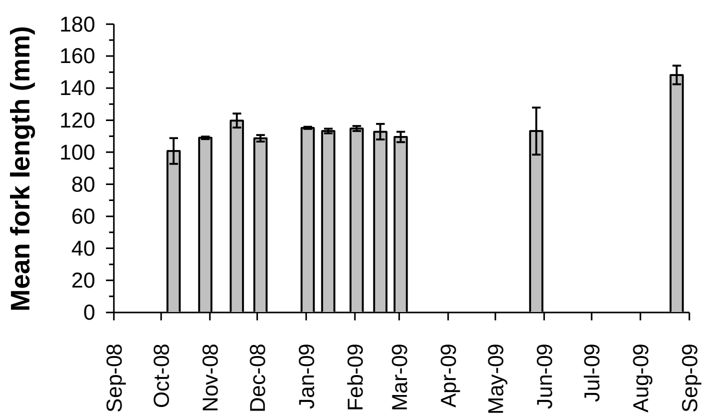

Figure 83. Mean fork length and SE of surf smelt captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

Pacific staghorn sculpin Leptocottus armatus

The Pacific staghorn sculpin is a demersal species widely distributed in Pacific coast estuaries. Adults are usually found in the lower parts of estuaries, while juveniles are found in shallow water, riverine, estuarine, and marine habitats (Wydoski and Whitney 2003, Emmett et al. 1991). During our estuary surveys, it was the most frequently encountered species, present on all but one sampling date. Most staghorn sculpin (2,872) were observed in the estuary between June 2008 and September 2009 (Figure 84), while one fish was also captured in the screw trap on the mainstem in May 2009. Catches were low between August 2008 and March 2009, and substantially higher between April and July 2009. Peak abundance occurred in May and June 2009. The staghorn sculpin were captured at all eight seining sites, and about 40% were captured at the breach (Figure 85). Total lengths varied over a wide range, from 12 to 212 mm

(Figure 86). Mean total lengths increased gradually in 2009, from 24 mm in March to 134 mm in September (Figure 87). The lone staghorn sculpin captured in the screw trap measured 130 mm.

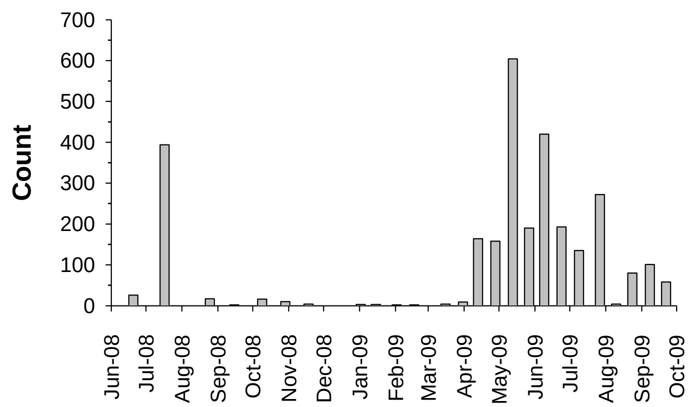

Figure 84. Timing of Pacific staghorn sculpin captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

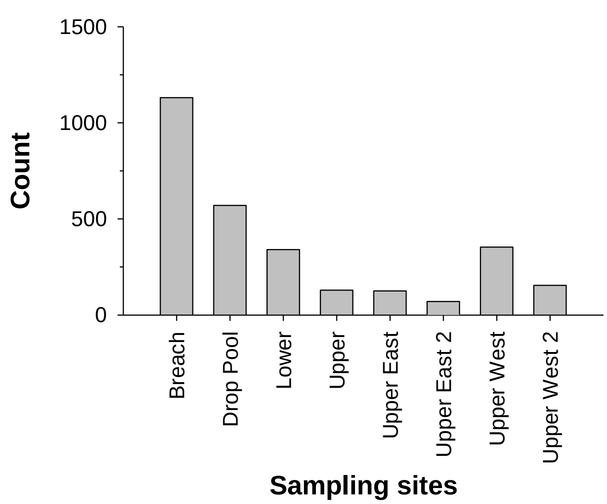

Figure 85. Pacific staghorn sculpin catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

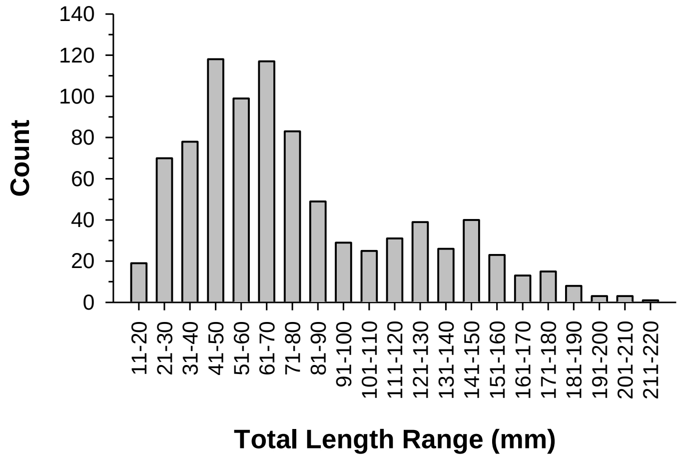

Figure 86. Length frequency distribution of Pacific staghorn sculpin captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

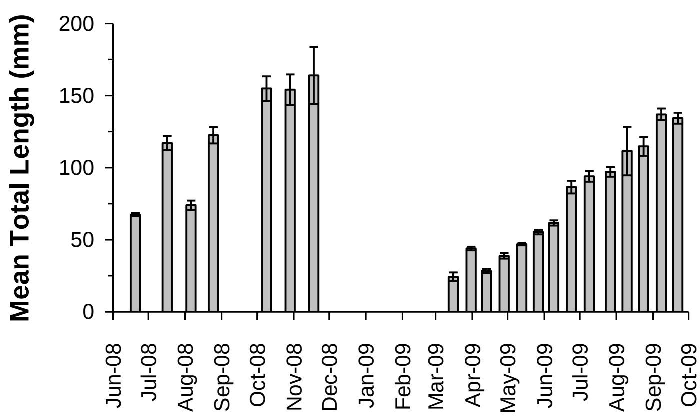

Figure 87. Mean total length and SE of Pacific staghorn sculpin captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

Starry flounder (Platichthys stellatus)

The starry flounder is the most abundant flatfishes in many Pacific coast estuaries north of San Francisco, California (Emmett et al. 1991). The species can tolerate a wide range of salinities, and is found in a variety of habitat types (Wydoski and Whitney 2003). During our surveys, we observed starry flounder in the Nalley Island estuary, the mainstem Skokomish River, and one downstream pond (Table 35). At the estuary, a total of 270 starry flounder were captured between June 2008 and September 2009 (Figure 88). The fish were present on most sampling dates, and were captured at all eight sampling sites (Figure 89). Overall, total lengths ranged from 19 to 226 mm, and the dominant size range appeared to be between 61 and 80 mm (Figure 90). Mean total length gradually increased from 48 in June 2008 to 130 mm in October

2008, and then decreased to 48 mm in June 2009 (Figure 91). The catch was dominated by juveniles and small adults (see size range in Emmett et al. 1991).

On the mainstem Skokomish River, 77 starry flounder were observed at two sites, 2-23 and 2-40, both just upstream of the Nalley Island estuary. Two starry flounder were also captured in the screw trap during outmigration trapping in 2009: one (FL=56 mm) in late June, and one (FL=60 mm) in mid-July. The location of the screw trap represented the upriver extent of the starry flounder observed in our surveys.

During pond surveys, two starry flounder were observed at site #05 in the nearshore transect in September 2008, while three more were observed at the same site in the offshore transect in April 2009.

Table 35. Abundance of starry flounder observed during surveys at Skokomish River in 2008 and 2009.

Location type	Sampling type	Starry flounder total
Estuary	Beach seine	270
Pond	Snorkel	5
River	Snorkel	77
River	Screw trap	2
		354

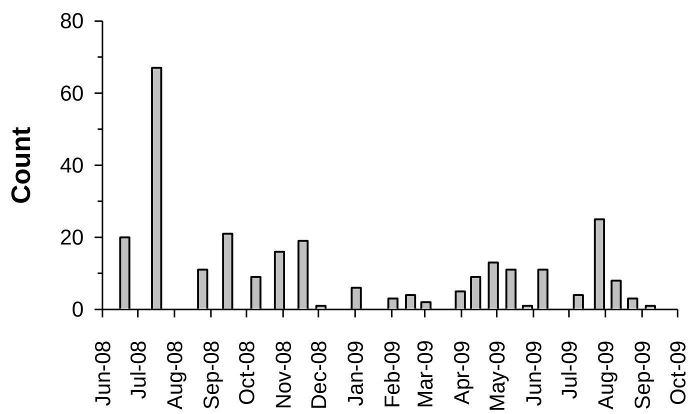

Figure 88. Timing of starry flounder captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

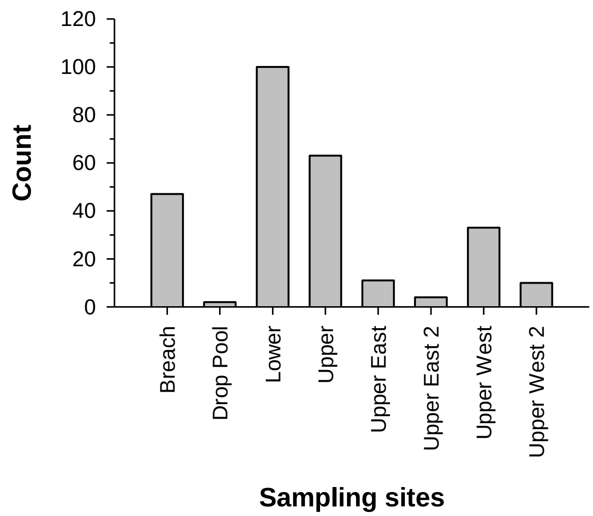

Figure 89. Starry flounder catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

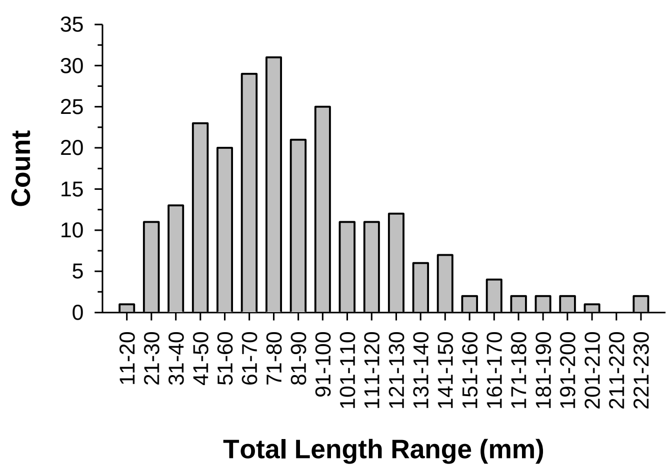

Figure 90. Length frequency distribution of starry flounder captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

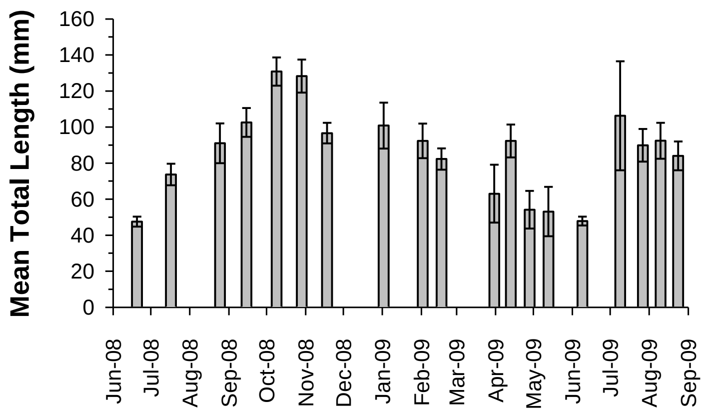

Figure 91. Mean total length and SE of starry flounder captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

Hatcheries

In addition to the habitat limiting factors described above, it is important to acknowledge an anthropomorphically controlled biological factor which impacts native salmon in the Skokomish watershed, hatcheries. There are three hatcheries in the watershed, although only two produce anadromous salmon, George Adams (on Purdy Creek) and McKernan (on Weaver Creek). These facilities currently release hatchery Chinook, coho, and chum salmon into the Skokomish Basin as on-station fry and smolt releases. However, they historically out-planted fry into the Skokomish Basin in addition to the on-station releases. Significant out of basin stocks have been reared and released into the Skokomish watershed. The George Adams facility began production in 1961 and has used three out of basin Chinook stocks and eight out of basin coho stocks. In recent years, it releases approximately 3.8 million Fall Chinook each May, and 300,000 coho each April. The McKernan hatchery began producing chum fry in 1979 and currently releases 8.5 million chum fry each April and 35,000 steelhead. These large releases of juvenile salmon enter the system at the same time as naturally produced individuals and are a significant source of competition, especially the Chinook, coho, and steelhead as they will reside in the stream for at least several months and potentially a full year or more (reviewed by Einum and Fleming 2001; Weber and Fausch 2003; Jonsson and Jonsson 2006; Kostow 2009). In addition, large numbers of hatchery juveniles may increase predation on wild fish by artificially elevating predator populations (Steward and Bjornn 1990; Collis et al. 1995; Nickelson 2003). Large releases of hatchery fish from an overcrowded environment could potentially increase the rate of disease in wild populations (Hedrick 1998; Scramm and Piper 1995). Finally, hatchery fish that return as adults may not return to the hatchery and successfully spawn with wild fish, potentially reducing the fitness of wild offspring (reviewed by Hard et al. 1992; Naish et al. 2007). Hatchery fall Chinook, in particular, stray in large numbers to the lower South Fork Skokomish and Vance Creek (SASSI 2006).

Limiting Factors and Restoration Recommendations

As discussed above, salmon habitat issues in the Skokomish Basin can generally be categorized into four different types: habitat loss, and the reduced connectivity, stability, and quality of remaining habitat. The main factor resulting in habitat loss is the migratory barrier created by the Cushman hydro project. Additional habitat loss, and reduced habitat connectivity, stability, and quality of the remaining habitat are impacted by several factors. This includes the combination of the physical nature of the Skokomish Basin, increased sediment inputs resulting from land clearing and logjam removal, reduced hydraulic capabilities of the river resulting from water diversion, and river and floodplain constrictions (i.e., levees and bridges). These factors have resulted in too much sediment entering the river channel and reduced the rivers ability to transport that sediment, which has resulted in channel aggradation, altered channel morphology and degraded habitat conditions for both humans and fish in the Skokomish Basin.

The relative importance of these different habitat issues can be inferred based on the biological communities in the Skokomish Basin. Biological community structure has long been used to assess the health of ecological systems (Cairns and Pratt 1993). Periphyton and macroinvertebrate communities structure specifically were used to assess the health of the Skokomish Basin. However, there is additional information to be gleaned from the fish community structure as well. This section consolidates the information from the periphyton and macroinvertebrate assessment with an assessment of the fish communities in the Skokomish Basin to further assess the system and potential restoration measures.

Based on primary and secondary producers, the ecosystem health of the Skokomish Basin is relatively good. However, some metrics from these assessments could indicate habitat issues that would impact the fish community in the Skokomish Basin more than they would primary and secondary producers. Long-lived macroinvertebrate taxa were depauperate in a significant number of areas, especially in the South Fork Skokomish and lower mainstem. This may be due to lack of interstitial spaces caused by high embeddedness, lack of habitat complexity, bed scour, or lack of wood boles used as refugia by these taxa. Embeddedness was quite low at the sites we surveyed, suggesting that this factor likely was not responsible for the poor condition of long-lived taxa.

The percentage of the macroinvertebrate community composed of shredders was also relatively low. Shredders feed on allochthonous organic inputs derived from the riparian forest. There low abundance suggests that riparian cover is lacking or that habitat complexity and or logjams that would retain this material is lacking, which is supported by our habitat data collection. The loss of the vegetated islands and widening of the active channel described by the Skokomish Tribe and WDFW (2010) would result in reduced availability of allochthonous inputs. In addition, this would result in greater solar radiation reaching the channel which would generally benefit primary and secondary production (reviewed by Chamberlain et al. 1991). This could in part explain why the periphyton and macroinvertebrate metrics examined generally suggest the system is relatively healthy despite aggradation which would suggest otherwise.

The status and trends in the salmonid community offer some additional insight into the health of the system. Spring Chinook salmon are extinct in the Skokomish Basin due to the combination of numerous habitat factors (i.e., dams, altered hydrology, etc.). Fall Chinook salmon escapement has been stable but low, a trend that may be partially due to hatchery fish spawning in the system. The production resulting from these spawners appears to be relatively low based on our assessment. This suggests that egg to fry survival may be low. This would result from eggs being smothered by fine sediment or scouring during winter storms (i.e., unstable channel). Scour is known to be a problem in rivers with excess sediment in the channel (Tripp and Poulin 1986, Devries 2000). Scour would be exacerbated by low flows during the fall Chinook spawning season that would result in fish spawning closer to the thalweg; increasing their susceptibility to scour.

Two of the three chum salmon stocks in the system are listed as healthy, while the other is extinct. Summer chum salmon are listed as extinct, while lower river fall and upper river late chum salmon are listed as healthy. The primary differences among these three stocks are adult run and spawn timing, emergence timing, and timing of estuarine residence. Summer chum enter the river during the late summer and early fall, compared to late fall and early winter for the fall chum salmon. This timing is similar to adult Chinook salmon, which could result in incidental harvest targeted at Chinook. In addition, they would be impacted by low flows and dewatered channels (i.e., South Fork Skokomish and Vance) during spawning in a manner similar to fall Chinook. This could isolate them from important spawning habitat and/or require them to spawn closer to the thalweg, thereby increasing their susceptibility to redd scour. Fall chum salmon would avoid this potential limiting factor, especially upper late fall chum, which has the highest spawning concentrations in the North Fork Skokomish. The North Fork Skokomish would be expected to have more stable spawning habitat as a result of reduced high flows which are metered by Cushman dam.

Since chum salmon rarely rear for extended periods in freshwater habitats, emergence timing is roughly synonymous with estuary entry. Summer chum would emerge earlier than fall chum and would therefore enter the estuary much earlier. Thus, differences in estuarine conditions could result in the observed differences in stock status. Since both stocks would be exposed to the same physical estuarine habitat conditions, some other factor such as food availability would have to be the cause of the differences observed in stock status. Since summer chum salmon historically thrived in this environment, one would expect that food availability was not an issue historically. It‟s unclear if the habitat alterations in the estuary would result in seasonal changes in food availability. Based on this, it appears that isolation from spawning habitat and channel stability resulting in increased scour of redds is the likely factor causing the differences in stock status of chum salmon in this system.

Coho salmon are listed as healthy in the Skokomish Basin. It‟s unclear if this is partially the result of hatchery strays as has been noted for Chinook salmon. Coho salmon spawn relatively late in the system which would help reduce the potential for their redds to scour. However, they rear for at least a year in the freshwater environment and thus would require high quality rearing habitat. We observed apparent significant reductions in the number of juvenile coho salmon in the system between the summer of 2008 and winter of 2009. This suggests that winter rearing habitat may limit coho salmon production in the system. This is surprising given the extensive wetlands in the lower river. We were surprised by the apparent low densities of juvenile coho salmon rearing in these off-channel ponds relative to densities observed in other systems. This may be due to the level and frequency of overbank flows in the system and the level to which they impact pond habitats. Although coho smolts use the estuary less than either

Chinook or chum salmon, coho fry may use the stream-estuary ecotone extensively (Miller and Sadro 2003). We observed significant numbers of coho salmon in the stream-estuary ecotone and the estuary of the Skokomish River. Estuary conditions do not appear to be limiting this species based on their overall status.

Skokomish River steelhead have been listed as depressed and are part of the greater Puget Sound steelhead that were listed as threatened under ESA. Steelhead generally spawn later in the spring and therefore would be less susceptible to scour than Chinook salmon or summer chum. However, their extended freshwater rearing requirements would make them very susceptible to reduced rearing habitat quality including low summer flows, reduced channel complexity, and disconnection from the floodplain and riparian zone. Steelhead could also be susceptible to scour while rearing. Juvenile steelhead hide in the substrate during the day in the winter when stream temperatures are cold and emerge at night. This behavior, if displayed during flooding, could lead to scouring impacts to juveniles hiding in interstitial spaces in the substrate. We observed relatively high reductions in successive age classes of trout during our surveys; however, these reductions were not as severe as those observe in juvenile coho salmon. Steelhead smolts are generally not as dependent on the estuary as Chinook and chum salmon. Steelhead smolts in the Skokomish passed through the lower river and through lower Hood Canal relatively quickly, suggesting they are not very dependent upon the estuary in this system. In addition, steelhead survival through the estuary was high, suggesting that estuarine conditions are not limiting this species.

Bull trout are listed as threatened under ESA throughout its range in Washington State, and their populations are depressed in the Skokomish Basin. Bull trout spawn in the fall and thus would be susceptible to redd scour. They also are the salmonid most dependent upon freshwater rearing habitat and thus would be susceptible to degraded habitat conditions. Bull trout, as an apex predator, would also be susceptible to factors impacting their food source, namely other fish in the Skokomish Basin. It‟s unclear how dependent bull trout are on estuarine habitat in the Skokomish Basin. No bull trout have been determined to display an anadromous life history pattern in the Skokomish River. However, the prevalence of this life history pattern in other bull trout populations on the Olympic Peninsula and Puget Sound suggest that bull trout in the Skokomish River likely display this life history pattern and we have simply failed to detect that strategy with our limited sampling.

Based on this evaluation it appears that channel stability, and habitat connectivity and quality are the main factors limiting salmon production in this system. The two stocks extirpated from the system, summer chum and spring Chinook were most susceptible to habitat loss (i.e., dams), reduced habitat connectivity, channel stability, and reduced habitat quality. In terms of stocks still present in the watershed, winter steelhead and fall Chinook are classified as depressed in SASSI, and along with bull trout are listed as threatened under ESA. Of these stocks, steelhead and bull trout would be most impacted by habitat loss associated with Cushman dam. Bull trout and Chinook salmon would be susceptible to reduced connectivity during the early fall and scouring of their redds. All three species rely on in-stream habitats, especially steelhead and bull trout and would therefore rely on habitat connectivity, especially during the winter. Fall Chinook would be the only species that was heavily reliant on the estuary.

Coho and fall chum are the only two stocks in the watershed listed as healthy. The main portion of the stock contributing to coho‟s status are the North Fork Skokomish populations, which spawn in an area with relatively high channel stability as a result of flow management at Cushman dam. Fall chum basically forgo rearing in fresh water and spend extended periods of time in the estuary on their way to sea. Based on the status of various stocks, certain conclusions regarding habitat quality in the system can be drawn. First, species that rely heavily on both in-stream or estuary habitats (i.e., chum, Chinook), with the exception of fall chum, are depressed and/or extinct, indicating severe degradation of both habitats. Second, the spawning location and timing of the only fresh water reliant species listed as healthy, coho, is largely in the North Fork Skokomish. This indicates that this portion of the watershed probably has the most stable habitat, or conversely, the South Fork Skokomish is the most degraded of the two major forks of the Skokomish.

Finally, the healthiest stock in the Skokomish Basin, fall chum, does not use in-stream habitat extensively for rearing. Although the other estuary dependent species, fall Chinook, is classified as depressed, it also relies on in-stream habitat and spawns during a period that makes redd scour a significant threat. Therefore, it appears as though the estuary environment of the Skokomish is not as degraded, in terms of limiting salmon production, as the watershed"s freshwater habitat

The healthiest stocks in the Skokomish Basin, coho and late fall chum, generally spawn after a significant risk of scour from fall floods has past. The depressed and extinct stocks in the Skokomish Basin; summer chum, spring and fall Chinook; all place their eggs in the gravel before the potentially catastrophic fall floods scour their redds. The scarcity of long-lived macroinvertebrate taxa also suggests that bed scouring is an issue. In addition, early fall migrating salmon, are exposed to high water temperatures, low dissolved oxygen, and potentially dewatered sections of river. Based on this phenomenon it can be inferred that aggradation in the lower river, which causes both an unstable channel and high winter flows is a major factor limiting salmonid production in the Skokomish river.

Based on our literature review, the biggest data gap related to characterizing salmonid populations remaining to be addressed in the Skokomish River and the factors that influence them is the lack of information on incubation and juvenile salmonids. Data is basically limited to information from a year of sampling outmigration by both a panel trap and netting in the estuary by the Skokomish tribe and two years of smolt trapping by NOAA, although that was focused only on juvenile steelhead. In addition, the extent to which hatchery origin fish are spawning in the wild is incompletely known and could be significant. The remainder of this report will focus on closing the data gap concerning juvenile production and outmigration timing in the Skokomish. Wild and hatchery fish interactions are beyond the scope of this study.

Information compiled in this report point to four major issues related to habitat productivity in the Skokomish Basin including habitat availability, channel stability, habitat quality/complexity, and connectivity. Habitat availability is significantly reduced relative to historic levels as a result of dam construction, loss of side channel habitat, and channel straightening. Channel stability (i.e., bed scour) was listed as a significant threat to several organisms that have low population levels in the system, including long-lived macroinvertebrate taxa, summer chum, fall Chinook, steelhead, and bull trout. Habitat quality/complexity was listed as a likely factor influencing every species evaluated in this report except Spring Chinook and summer chum. However, this was due simply to the weight given to other factors (i.e., dams, scour) impacting these two species. Habitat quality appears to be degraded in both freshwater and estuarine environments; however, it appears to be worse in freshwater environments. Finally, habitat connectivity appears to increase the impacts of the habitat quality and scour, and impacts overall habitat availability.

Habitat and stock restoration recommendations for the Skokomish Basin need to consider the effects of future climate change. Relatively small changes in winter temperatures can shrink the transient snow zone appreciably; altering runoff patterns and the severity of peak flows (Cuo et al. 2008). Since the transient snow zone in the Skokomish Basin is relatively large, one would expect a relatively large change in precipitation from snow to rain to occur in the future (Knowles et al. 2006), resulting in a concurrent shift in runoff from spring and summer to mid-winter and associated increases in peak flow magnitude. This hydrologic change will subsequently influence sediment transport and channel stability which will influence what restoration activities are conducted and how they are designed. For example, restoration of spring Chinook in the South Fork as proposed by the Skokomish Tribe and WDFW (2010) may not be possible given the hydrologic changes which may not be appropriate for spring migrating salmon.

We recognize that several other authors and groups have made habitat restoration recommendations for the Skokomish Basin (i.e., Correa 2003, Skokomish Indian Tribe and WDFW 2010, HCCC 2010). The recommendations made in this report will be combined with those recommendations by the USACE and its partners to develop a final proposed list of habitat restoration projects. We also recognize that several restoration projects have already been completed in the Skokomish Basin. We point these out below as we describe and prioritize our recommendations.

Based on our assessment, we have concluded that factors influencing channel aggradation have the greatest impact on the fisheries resources of the Skokomish Basin. Channel aggradation has resulted in habitat loss, reduced channel stability and complexity have been identified as impacting biological communities in the system. Although habitat loss as a result of Cushman dam is significant, it influences only spring Chinook and steelhead. Flow alterations resulting from the Cushman Project have had a greater overall impact on the fisheries resource compared to loss of habitat as a result of the dam. In addition, the newly signed Cushman agreement provides for upstream and downstream passage of adult and juvenile salmon using trap-and-haul techniques. Thus, the highest priorities for restoration activities is given to projects that would reduce sediment input to stream channels, stabilize sediment already in the active channel, and providing sufficient hydraulic energy to route this sediment effectively.

This does not mean that other restoration projects are not valuable; they just weren‟t prioritized as highly as the projects described above. For example, the development of floodplain channel network in the vicinity of Hunter and/or Weaver Creeks could provide valuable fish habitat, provide for escape routes for fish pushed into the floodplain during overbank flow events, and potentially lower the water table during the summer. This channel network would require substantial riparian planting to ensure that water temperature issues didn‟t arise due to the smaller channels and potentially increased exposure to solar radiation. Although there is value it these types of projects, they simply don‟t address impaired physical processes in the watershed and thus were not prioritized as highly as the projects described above.

Table 36 lists our prioritized restoration projects for the Skokomish Basin. We rank the watershed processes as follows: 1) improved hydraulic energy for sediment transport, 2) reducing sediment inputs, 3) stabilizing active channel sediment, and 4) increasing habitat complexity. However, prioritization of the individual projects did not follow this process order due to the assumed benefits of those projects relative to projects addressing other processes. The individual projects are discussed below based on process ranking.

Improving the river‟s hydraulic energy to transport sediment can be accomplished by either increasing the water available to transport sediment, by eliminating channel and floodplain constrictions that result in backwatering during flooding, or by hastening the conversion of the braided channel morphology back to an island-braided morphology with lower width to depth ratio. Water availability has historically been controlled by the Cushman project. However, the recent settlement has provided for minimum summer flows and „normative‟ flows during winter. Thus, improvements have been made to the amount of flow available to transport sediments. This leaves removal of hydraulic constraints in the lower Skokomish Basin and reduced width to depth ratios as the only remaining factors that need to be addressed with regard to increasing the rivers hydraulic energy for sediment transport.

Several levees and dikes severely constrain the river and its floodplain. The greatest constrictions occur around Nalley Island, HWY 101, downstream of the Church Dike (constrained against the valley wall), and downstream of the old North Fork Skokomish Confluence (Figure 92). A substantial portion of the constrictions at Nalley Island have been removed. The west side levees were removed in 2007, while all levees except those at the upstream end of Nalley Island were removed in 2010. This remaining levee still results in a significant constriction to the eastern channel at the upstream end of Nalley Island. Ideally, this constriction would be eliminated. This would require the mainland levee to be removed or setback as the remaining section of the Nalley Island levee protects sites of historical significance on the island. This would be our highest priority levee removal/setback project, since a channel constriction at this location will set the gradient and subsequent sediment transport regime for the river upstream.

The second (# 2 on Figure 92) priority for removing channel and floodplain constrictions would be the section at the old North Fork Skokomish confluence. Although we recognize that other channel constrictions lower in the system will set the gradient and associated sediment transport capabilities upstream, this constriction is by far the worst. It also occurs at a very poor location geographically in the river, the confluence of three main drainages (i.e., South Fork Skokomish, Vance Creek, old North Fork Skokomish). The area upstream of this location also shows the worst level of channel instability.

The third priority would be the area just downstream of the Church levee (# 3 on Figure 92). The levee constrains the river against the valley wall at this location and there is evidence of channel instability above this location. Finally, the floodplain fill associated with HWY 101 (#4 on Figure 92) would be the final floodplain constriction to be addressed. There is evidence that this fill and the constrictions resulting from the bridges result in backwatering; however, it does not appear to be as critical as the constrictions discussed previously. In addition, there is limited evidence of channel instability upstream of this location.

Although the primary purpose of eliminating these hydraulic constrictions is to improve sediment transport processes, there will be additional benefits to fisheries resources in the system. These projects will improve habitat connectivity as well. Removal of the Nalley Island levees will dramatically increase the effective estuary size of the Skokomish and Hood Canal

Basins. Although fish have been able to access Nalley Island recently as a result of a levee breach, they were required to navigate to the seaward side of the island and then migrate upstream through the breach. Leaving the island also required them to migrate through this breach. We observe coho fry during our summer sampling at Nalley Island. These fish would be expected to migrate upstream during the winter and rear in the main river channel or off-channel ponds (Miller and Sadro 2003). However, this migration route would have been made difficult as a result of these levees. Similar effects would be expected for estuarine dependent Chinook and chum salmon. Removal or setback of the remaining levees will also increase connectivity with lateral habitats and/or promote their development.

Table 36. Prioritized habitat restoration recommendations from this project describing the project type, process addressed, location, and expected effect.

Priority	Project Type	Process Addressed	Location	Expected Effect
1	Hydrologic Restoration	Hydraulic energy	Cushman Dam	Increased sediment transport capabilities, reduced aggradation, and increased channel stability
2	Remove channel, floodplain constriction	Hydraulic energy	1 on Figure 92	Increased sediment transport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
3	Remove channel, floodplain constriction	Hydraulic energy	2 on Figure 92	Increased sediment transport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
4	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	Vance Creek	Reduced sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
5	Remove channel, floodplain constriction	Hydraulic energy	3 on Figure 92	Increased sediment transport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
6	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	South Fork Skokomish and Vance Creek	Reduced sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
7	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	Old North Fork Skokomish Confluence	Reduce sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
8	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	South Fork Skokomish	Reduce sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
9	Remove channel, floodplain constriction	Hydraulic energy	4 on Figure 92	Increased sediment transport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
10	Decommission high risk roads	Sediment Input	South Fork Skokomish and Vance Cr.	Reduced sediment inputs to the river channel, reduced aggradation, increased channel stability and complexity
11	Stabilize eroding slopes	Sediment Input	South Fork Skokomish and Vance Cr.	Reduced sediment inputs to the river channel, reduced aggradation, increased channel stability and complexity

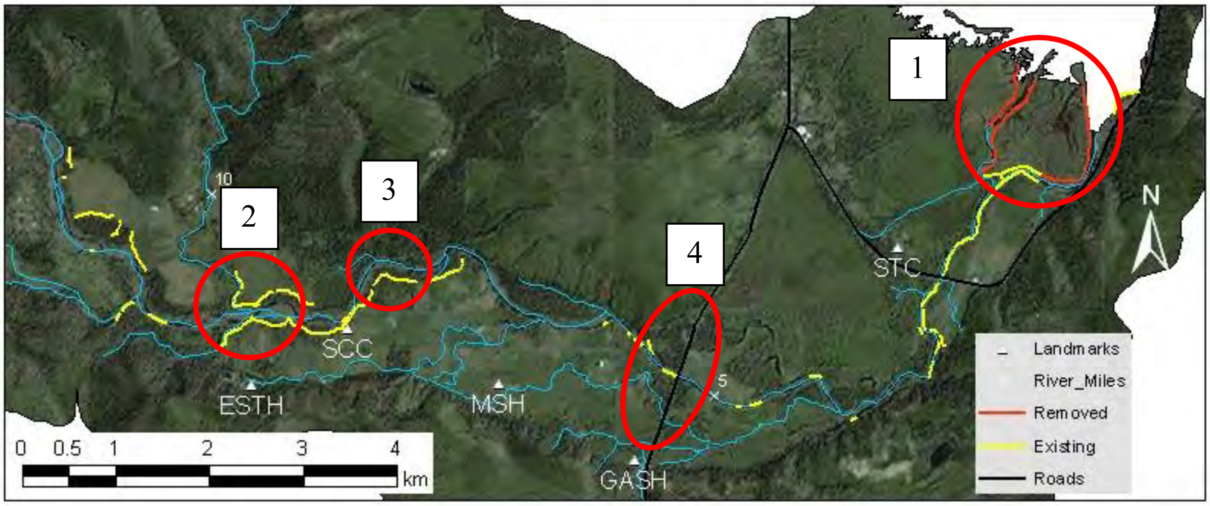

Figure 92. Locations (red circles) where channel and floodplain constrictions likely result in backwatering and reduced hydraulic energy for sediment transport. The red lines reflect levees that have been removed, yellow shows existing levees, and black shows highways with associated fill across the floodplain. The numbers represent our prioritization for restoration work. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCM).

Reducing sediment inputs to the channel was the second priority process to restore. The focus of this effort would be to stabilize sediment inputs arising from mass wasting in the upper South Fork Skokomish and Vance Creek. The individual projects were ranked lower here, due to the fact that significant work has already been accomplished in the upper Skokomish Basin (Anderson et al. 2007). However, it‟s unclear exactly how much work remains to be accomplished relative to what has been done. Further analysis of this information will be required during the alternatives selection and evaluation portion of the Skokomish GI.

In our opinion, the final two project types, stabilization of active channel sediment and increase habitat complexity could be addressed using the same tool. We propose the use of Engineered Logjams (ELJs) to stabilize sediments in the active channel with the ultimate goal of developing mid-channel vegetated islands separated and intersected by side channels. We propose three locations for this activity including Vance Creek below the canyon, the old North Fork Skokomish confluence, and the South Fork Skokomish below the canyon (Figure 93). Additional sites would be beneficial and potentially better than the proposed projects; however, their proximity to houses and infrastructure would require either property acquisition and/or owner cooperation. For this reason, we have not included those locations in the proposed project list. In addition, the proposed sites often go dry during the summer, which would permit construction in the „dry‟ which would greatly reduce construction impacts to fisheries resources.

The prioritization of the ELJs was based on the fact that although these projects may achieve greater long-term benefits, they present greater potential risks to resources and adjacent property. Thus, we propose to complete the Vance Creek site first, due to its smaller channel size and distance from houses and infrastructure. The North Fork Skokomish confluence was selected second based on this same criteria. If these projects prove successful, then the final South Fork Skokomish site could be constructed with more confidence. Additional sites could be developed in the South Fork Skokomish and lower mainstem based on the combined success of these three projects. Given the experimental nature of these projects, we suggest that extensive geomorphic, hydraulic, physical habitat and biological monitoring be completed to assure the desired results are obtained and information is gained to improve subsequent projects.

Several design factors must be considered for ELJ installations with the objectives we‟ve proposed. We describe some of these considerations below; however, the design and construction of these projects should be completed following careful geomorphic and hydrologic assessment. Our proposed design (Figure 94) would be to build large bar apex jams (Abbe and Montgomery 1996) at the upstream end of the proposed island locations. The purpose of these jams would be to stabilize the existing sediment and allow for sediment deposition and vegetation growth downstream of the jam (Abbe and Montgomery 1996). Meander jams would then be built along the proposed channel route to help create meandering channels and protect banks from eroding. Relatively large meander jams would be built at the upstream and downstream end of the developed side channel. The purpose of the upstream jam would be to meter flow through the side channel during flooding and maintain flow during low flow periods. The downstream jam would serve to maintain a pool at this location to ensure the channel doesn‟t fill in and become isolated from the main channel.

Figure 93. Proposed locations (red circles) for engineered logjam (ELJ) installations designed to stabilize active channel sediments, and develop vegetated islands and side channels (i.e., habitat complexity). Landmarks, marked by triangles include the Skokomish Community Church (SCC).

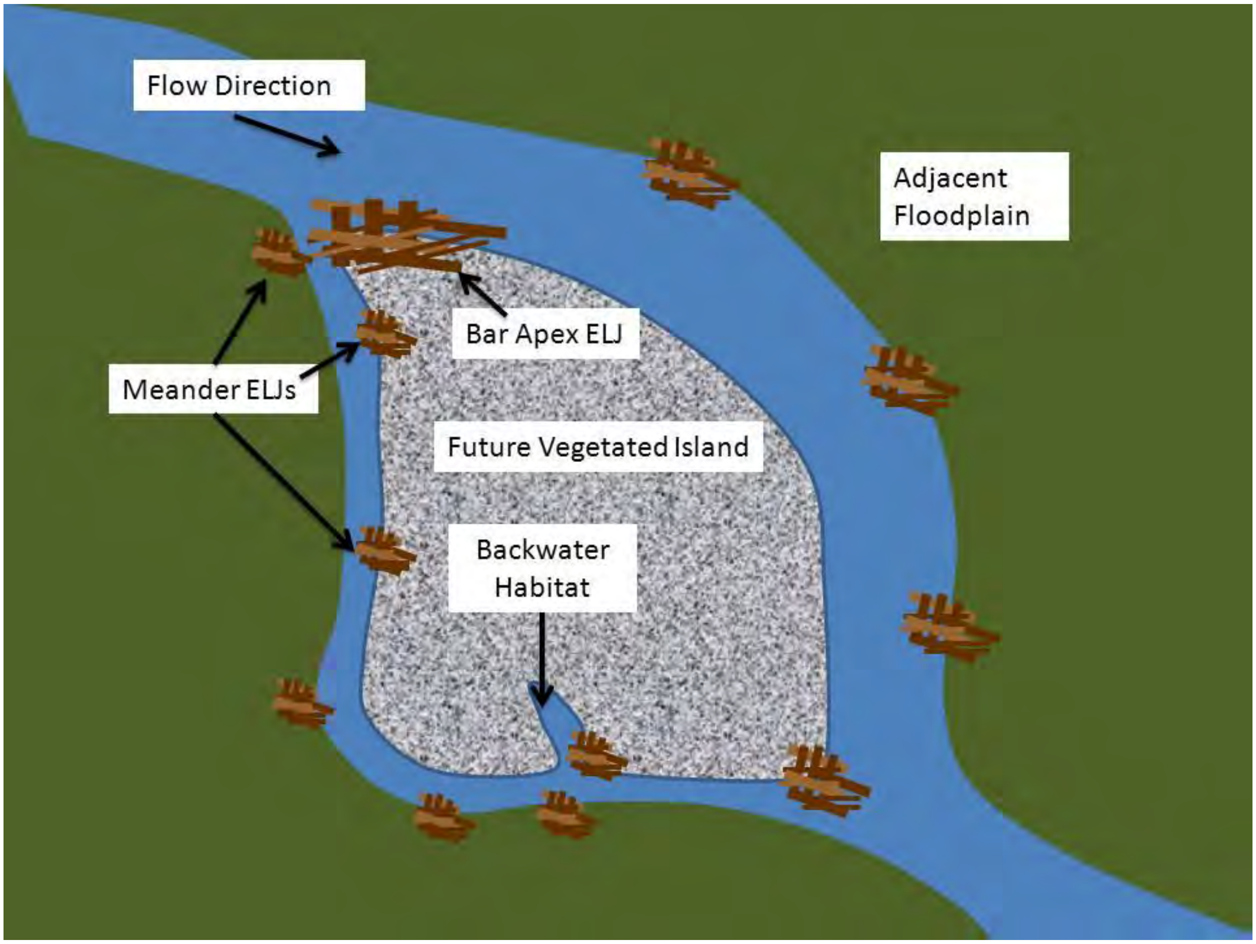

Figure 94. Conceptual design for engineered logjam use to stabilize active channel sediments, promote vegetated island development, and create side channels (i.e., create habitat diversity). The design is conceptual only and would require specific geomorphic and hydrologic evaluation by trained professionals in those fields and is beyond the expertise of the authors and scope of this project.

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