Skagit System Cooperative
Research Department
P.O. Box 368
11426 Moorage Way
La Conner, WA 98257-0368

JUVENILE SALMONID USE OF NATURAL AND HYDROMODIFIED STREAM BANK HABITAT IN THE MAINSTEM SKAGIT RIVER, NORTHWEST WASHINGTON.

Report Prepared by:

Eric M. Beamer and Richard A. Henderson

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United States Army Corps of Engineer, Seattle District
Environmental Resources Section
4735 East Marginal Way South
Seattle, Washington 98134-2385

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ABSTRACT

This study examined juvenile salmonid use and habitat changes associated with stream bank protection at the site level in the mainstem Skagit River. Natural and hydromodified banks were paired by location over an eighty mile river length. Bank habitat was defined as either "natural" or "hydromodified" based on the presence of riprap or other human induced bank modification and distinguished from mid-channel units (e.g., riffle, glide, and pool) by differences in water current velocity.

Natural banks had a higher percentage of their area in wood, cobble, boulder, aquatic plants, undercut bank, and no cover types when compared to hydromodified banks. While no riprap or rubble was found in natural banks, wood cover was common in some hydromodified banks. Wood cover in hydromodified banks increases with increasing time after hydromodification. We found no significant difference in water surface velocity between natural and hydromodified banks. Riprap/rubble and wood cover were not correlated with water surface velocity. However, the gradient of the bank unit and the streamflow discharge were correlated with water surface velocity.

The findings of this study reveal some consistent trends in fish use across sampled reaches. For juvenile chinook and coho in bank habitat, fish abundance has a significant positive correlation with the amount of wood cover. Wood cover in hydromodified banks explained 82% of the variation in chinook abundance. For juvenile coho at the end of summer rearing, wood cover in both bank types explained 62% of the variation in fish abundance. There is evidence of preference for riprap (but not rubble) and some specific types of wood cover by rainbow suggesting that rainbow may not be adversely impacted at the site level by bank hydromodification if rock particles are large. While wood cover is the most common natural bank cover, fish abundance within wood cover types is not uniform. Fish abundance is greater in rootwad cover than single logs for all species and life stages examined, except sub-yearling chum. Sub-yearling chum prefer aquatic plants and cobble, two other cover types more common in natural banks. The findings also suggest that the use of natural cover types along with bank protection may mitigate some site (but not reach) level impacts of hydromodification. Results presented can form the basis for estimating restoration project benefits, planning mitigation, or assessing the impacts of habitat loss.

INTRODUCTION

There is a history of human induced stream channel and floodplain modification for over 100 years in the Skagit River basin (Bortleson *et al.* 1980, Collins 1998, and Beechie *et al.* 1994). The cumulative effects of dams, dikes, dredging, bank protection, snag removal, and development have changed the balance between natural river and floodplain processes resulting in changed habitat conditions, often with an adverse biological consequence. Because of past and continuing impacts to river systems, efforts to understand the causes of habitat change and their biological consequences in rivers and floodplain systems are underway. These efforts seek ways to avoid, protect, restore, or mitigate for human disturbance to natural processes and habitat conditions.

This study examines some of the fish use changes associated with stream bank protection in the mainstem Skagit River. Stream bank protection projects impact river and floodplain habitat at the *site level* (10^2 meters in linear scale) and the *reach level* ($\geq 10^4$ meters). At the reach level, bank protection usually reduces channel migration and avulsion rates, changing the habitat characteristics in an entire river reach. At the site level, bank protection projects convert natural habitat to hydromodified habitat. This study focuses on fish use and habitat changes associated with the *site level* impact of stream bank protection in the Skagit River mainstem.

The need for this study stems from a general lack of information regarding the impacts of bank modification on juvenile salmon use in large mainstem channels, and specific lack of information in the Skagit River or north Puget Sound region. Fish utilization of large mainstem habitat is thought to be different than that of small channels in the Skagit Watershed or large channels outside of north Puget Sound region due to differences in fish life history patterns, watershed hydrology, and fish population levels. Therefore, the Army Corps of Engineers has requested this study as part of their investigations regarding a potential future Skagit River flood protection project.

METHODS

The geographic scope of this study is shown in Figure 1. It extends from river mile 8.5 (near Mount Vernon) to river mile 85.2 (near Marblemount). Natural and hydromodified banks were paired by location over the eighty mile river length. This was done to find fish use and habitat trends by bank type, independent of differences in fish use caused by variation in mainstem channel types, fish life history patterns, or fish population levels within the Skagit River.

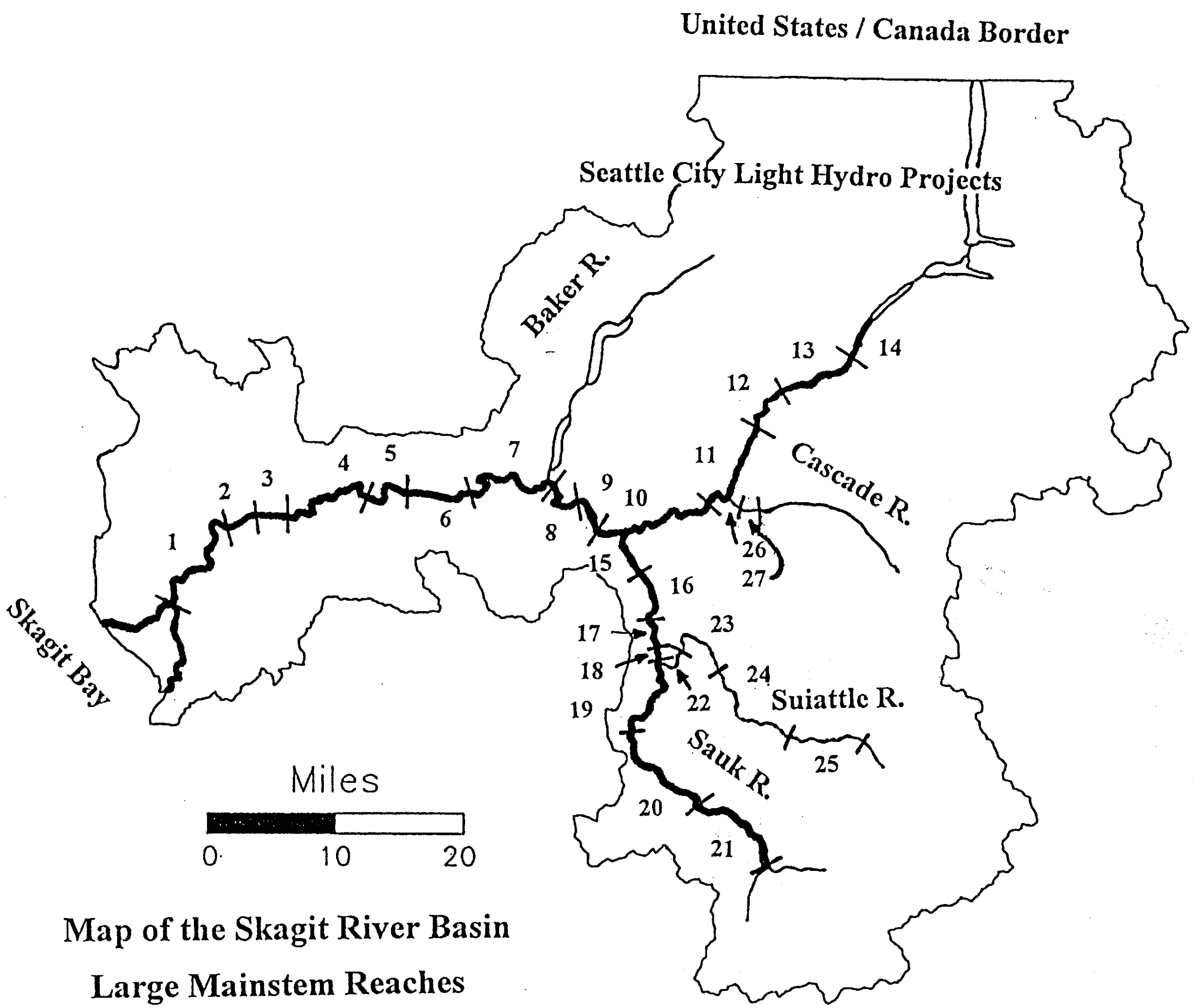
BANK HABITAT DEFINITION

Hayman *et al.* (1996) classified the wetted habitat area along the river shoreline into three groups of edge habitat types. *Banks* had a vertical, or nearly vertical shore; *bars* had a shallow, low-gradient interface with the shore; and *backwaters* were enclosed, low-velocity areas separated from the main river channel (Figure 2). Bank habitat was further defined as either "natural" or "hydromodified" based on the presence of riprap or other human induced bank modification. Edge habitat units were distinguished from mid-channel units (e.g., riffle, glide, and pool) by differences in water current velocity. The demarcation line between edge and mid-channel units was generally a visible current shear line between the two units, with edge units having lower velocity (Figure 2). The scope of this study was with natural and hydromodified bank units only.

FISH SAMPLING

Each natural or hydromodified bank unit was electrofished from a boat, using a grid point shocking system adapted from Weigand (1991). Grid point spacing ranged from 15 to 30 meters over the entire unit, and 12 to 38 grid points were established in each bank habitat unit, depending on the size of the unit (Figure 2).

At each grid point, the electroshocker was turned on for 10 seconds, off for 5, and back on for 10 seconds. The stunned fish were retrieved by dipnets. A total of five people were necessary to conduct this sampling: one boat operator, one anode pole operator, one notekeeper, and two people who dip-netted the stunned fish. For each grid point, we recorded the catch of all fish by species and age classes, as well as the habitat data in the following section.



Large Mainstem Reaches

1	SK030
2	SK040
3	SK050
4	SK060A
5	SK060B
6	SK070
7	SK080A
8	SK080B
9	SK090
10	SK100
11	SK110
12	SK120
13	SK130
14	SK140
15	Sa010
16	Sa020
17	Sa030
18	Sa040
19	Sa050
20	Sa060
21	Sa070
22	Su010
23	Su020
24	Su030
25	Su040
26	Ca010
27	Ca020

Figure 1. Skagit River Basin, Washington, showing large mainstem reaches. Reaches where bank units were sampled are Sk030-070 and Sk100-120.

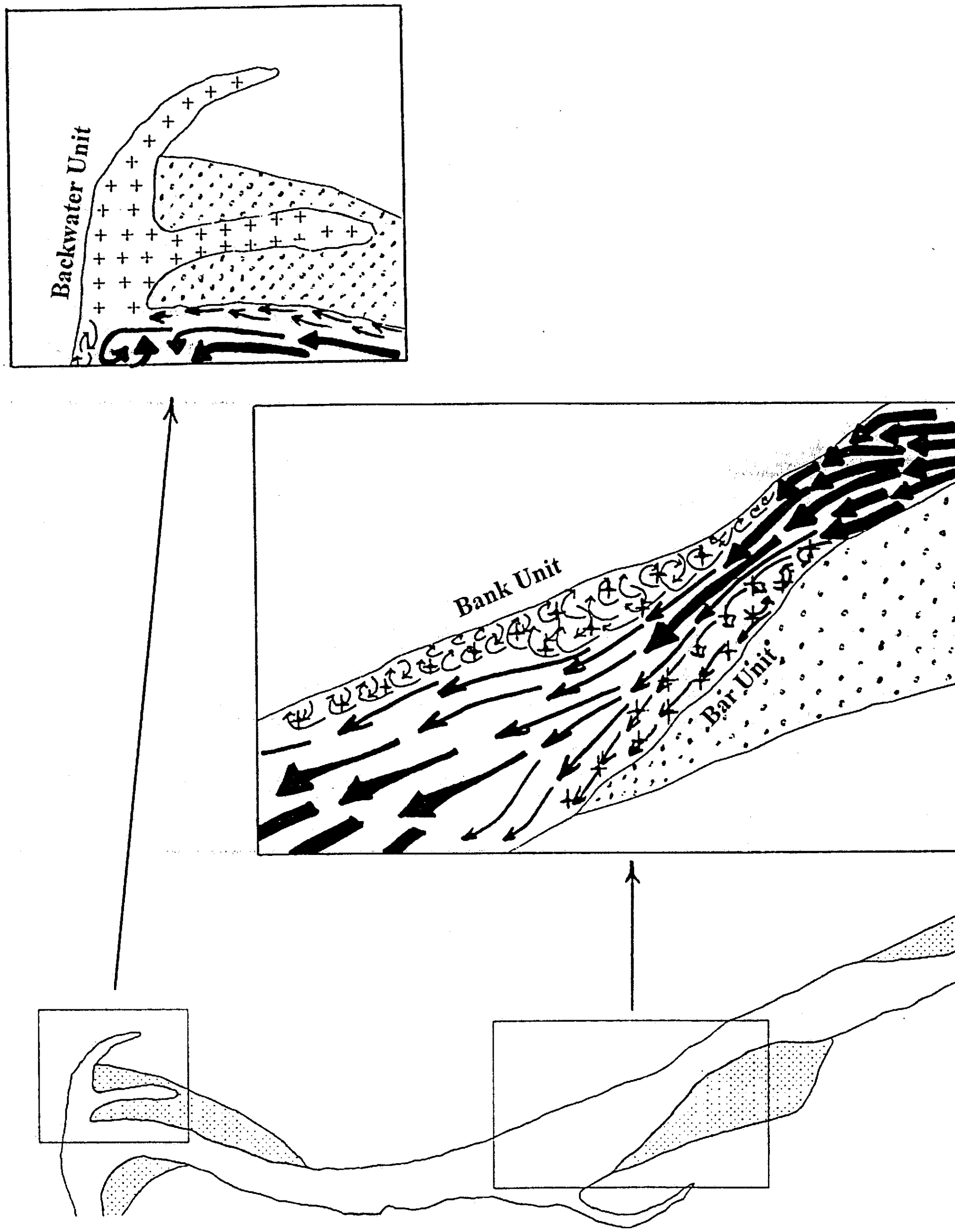


Figure 2. Schematic Top View of Edge Habitat Units for Large Mainstem Habitat.

Arrows represent the direction of current. Larger bold lined arrows represent higher water velocity areas. Smaller light lined arrows represent lower velocity areas.

Grid points [+]

Open Gravel or Sand Bar [:.]

HABITAT SAMPLING

Each sampled bank habitat unit was classified according to surface water velocity and cover type during the process of electrofishing. These data were collected at each grid point that was shocked. The habitat conditions recorded at each grid point represented the dominant condition within a two-meter diameter circle at the site. Surface water velocity was estimated by dropping a chip of wood into the river and clocking the amount of time that it took to float the length of the boat when held stationary. We classified velocity as high, medium, or low according to Weigand (1991): high surface water velocity was greater than 45 cm/sec; medium was 15 - 45 cm/sec; and low was less than 15 cm/sec. The definitions used for cover types are shown in Table 1.

Table 1. Definitions of cover types within bank habitat units.

Cover Type	Definition
Boulder	Rounded rocks ≥ 256 mm diameter (basketball size)
Bedrock	Exposed solid rock
Cobble	Rounded rocks 64 mm to 256 mm diameter
Deep Water	Water depth ≥ 1.0 meter (other cover types take precedence)
Plants	Live, non woody aquatic vegetation
Piling	Vertically driven logs
Riprap	Angular boulder sized rock placed for bank protection
Rubble	Angular cobble sized rock placed for bank protection
Undercut Bank	Submerged area underneath an overhanging bank
Wood	Woody debris of various types (see below)
Anchored brush	Branches of non-tree woody plants hanging in the water
Branch	Woody debris < 20 cm in diameter, not accumulated in debris piles
Bank roots	Roots of live trees and shrubs in the water
Debris piles	Numerous or single types of wood cover accumulated in a pile or jam
Single log	Woody debris ≥ 20 cm diameter, not accumulated in debris piles
Rootwad	Roots and lower trunk of non-growing trees (any size)
No Cover	Substrate is < cobble sized, depth is < 1.0 meter, and no other previously defined cover type is present

ANALYSIS METHODS

Data collected in natural bank and hydromodified bank units throughout the Skagit River were paired by location (i.e., within the reach or adjacent reach) and time period. Mean values of fish abundance (fish per grid point shocked) and habitat conditions were compared using T-tests (2 groups) or Newman-Keuls Multiple Comparisons tests (> 2 groups). The null hypothesis: mean fish abundance is the same between cover types was tested with the α level at 0.05. Statistical power was calculated for tests that did not reject the null hypothesis. Power ($1-\beta$) is the probability of not rejecting the null hypothesis when it is in fact false and should be rejected. If power was low (< 0.75), then the results of the test could not be used to *support* the null hypothesis because the probability of committing a type II error was high. Tests were conducted when the sample size in each group was ten or larger. The three time periods were: (1) the peak of spring outmigration for sub-yearling chinook and chum, (2) end of summer rearing, and (3) end of winter rearing for juvenile coho, rainbow sub-yearlings, and rainbow yearlings or older[1]. Even though stream type chinook are present within the Skagit, we could not analyze chinook data for the end of summer or winter time periods because none were captured during these periods.

In order to examine trends in fish use by different bank unit cover types over a range of fish population levels (i.e., reach average densities), we standardized fish use data as *relative fish utilization* after Bisson et al. (1982). Relative fish utilization is calculated:

$$\text{Relative fish utilization} = (\text{mean}_{\text{cover type } i} - \text{mean}_{\text{reach}}) / \text{mean}_{\text{reach}}$$

where $\text{mean}_{\text{cover type } i}$ is the average fish density (i.e., fish per grid point) for a specific cover type, and $\text{mean}_{\text{reach}}$ is the mean fish per grid point for the reach. Cover types with higher fish use than the average of the reach are positive numbers, while cover types with lower fish use than the reach average are negative numbers. The lowest possible number is negative one (-1), which results from a cover type with no fish. Some cover types were not analyzed due to a lack of data.

[1] No distinction was made between resident rainbow trout and juvenile steelhead. We assume that juvenile habitat preference is the same for both the resident and anadromous life history forms of *O. mykiss*.

RESULTS AND DISCUSSION

Habitat and fish use data are arranged in five appendices attached at the end of this report.

- Appendix 1. Location of sampling sites,
- Appendix 2. Summary of habitat conditions,
- Appendix 3. Summary of chinook sub-yearling and chum sub-yearling use during the peak of spring outmigration,
- Appendix 4. Summary of coho and rainbow use at the end of summer rearing, and
- Appendix 5. Summary of coho and rainbow use at the end of winter rearing.

Appendix 1 contains a table giving the river mile description of natural and hydromodified bank units. Appendix 2 contains a table showing the habitat conditions of each bank unit at the time of fish sampling. For Appendices 3 through 5, fish use (mean catch per grid point, standard deviation of the mean, and sample size) is summarized in a table by bank unit (natural or hydromodified) and reach. Tables showing fish use as the reach average, average by different cover types, and relative fish utilization by cover type are also part of Appendices 3, 4, and 5.

HABITAT CONDITIONS

Cover

Natural banks had a higher percentage of their area in wood, cobble, boulder, aquatic plants, and undercut bank cover types when compared to hydromodified banks (Table 2). Conversely, hydromodified banks had a higher percentage of their area in riprap and rubble cover. While no riprap or rubble was found in natural banks, wood cover was common in some hydromodified banks. To help understand why wood cover was so high in some hydromodified banks we divided them into two categories (trees on the banks were "young" or "old") to roughly separate banks that were recently hydromodified from those that were hydromodified some time ago. Banks with young trees had an average of 2.9% their area in wood cover and banks where trees were older had an average of 61.2% of their area in wood cover. The inference is that wood cover in hydromodified banks increases with increasing time after hydromodification.

Natural banks also had a higher percentage of their area in no cover when compared to hydromodified banks (Table 2). This appears to be related to the gradient of the bank unit[2] (Figure 3). At lower gradients, substrate sizes tend toward particles without fish cover value (gravel and sand). At steeper gradients, substrate particles tend toward those with fish cover value (cobbles and boulders). Hydromodified banks showed no relationship with gradient, probably due to the high level of riprap and rubble in these units.

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[2] The gradient of a bank unit is the change in water surface elevation over the length of the bank unit. Each bank unit was measured one time with an auto level when stream flow was representative of other sampling efforts.

Table 2. Summary of cover type results by bank unit type. Means significantly different (higher) are shown in bold print (α level at 0.05).

	Hydromodified Banks			**Natural Banks**		
	mean	S.D.	n	mean	S.D.	n
Edge Cover Type:						
%No Cover	1.3%	2.9%	25	**6.9%**	8.2%	36
%Boulder	1.0%	2.3%	25	**6.4%**	11.9%	36
%bedrock	0.3%	1.3%	25	0.0%	0.0%	36
%Cobble	2.3%	5.0%	25	**19.4%**	17.4%	36
%Deepwater	0.7%	1.8%	25	2.2%	5.8%	36
%Riprap	**50.8%**	39.2%	25	0.0%	0.0%	36
%Rubble	**13.8%**	17.3%	25	0.0%	0.0%	36
%Plants	0.4%	1.1%	25	**2.6%**	6.1%	36
%Undercut	1.0%	2.7%	25	**2.8%**	5.3%	36
%Wood	28.6%	33.5%	25	**59.5%**	18.9%	36

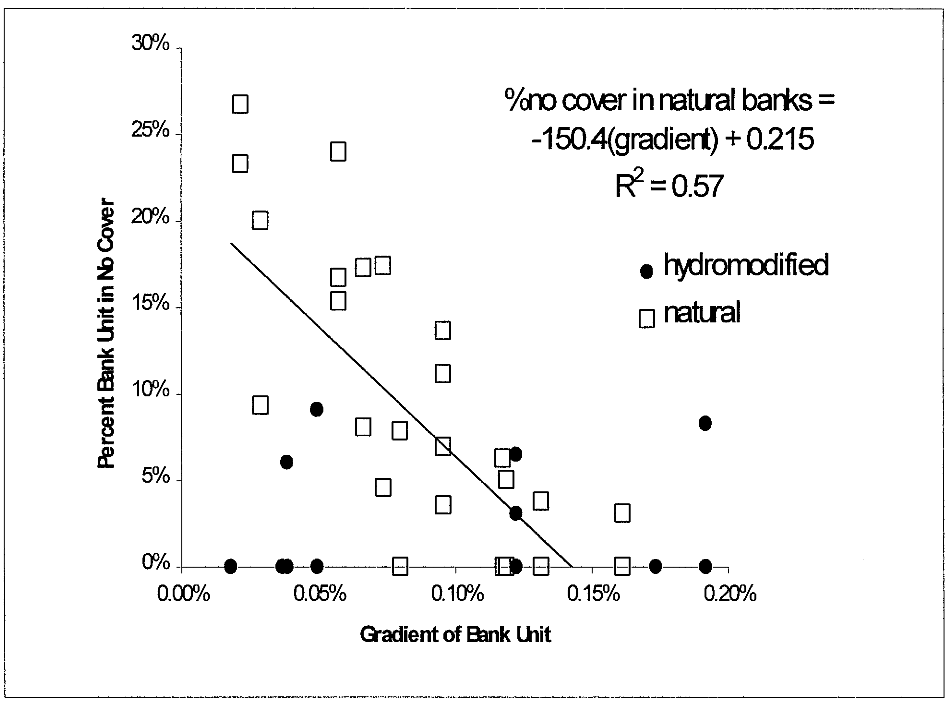

Figure 3. The relationship between bank unit gradient and the area (% no cover) a bank unit is designated as having no cover.

Surface Water Velocity

We compared water surface velocity results between hydromodified and natural banks and found no significant difference in the mean percentage a bank unit was defined as low, medium, or high velocity (Table 3). We investigated whether the primary cover types differentiating hydromodified banks (riprap/rubble) from natural banks (wood) influenced surface water velocity. Riprap/rubble and wood cover were not correlated with water surface velocity. However, the gradient of the unit and the streamflow discharge were correlated with water surface velocity ($R^2 = 0.29$, $P < 0.001$).

Table 3. Summary of water surface velocity results by bank unit type.

	Hydromodified Banks			Natural Banks		
	mean	S.D.	n	mean	S.D.	n
Water Surface Velocity:						
%Low velocity	64.2%	26.7%	25	61.8%	23.0%	36
%Medium velocity	29.0%	19.9%	25	30.0%	19.3%	36
%High velocity	6.8%	10.1%	25	8.2%	8.7%	36

FISH USE DIFFERENCES BETWEEN NATURAL AND HYDROMODIFIED BANKS

The findings of this study reveal some consistent trends in fish use across sampled reaches. For juvenile chinook and coho in bank habitat, fish abundance has a significant positive correlation with the amount of wood cover. Wood cover in hydromodified banks explained 82% of the variation in chinook abundance (Figure 4). While some hydromodified banks have similar amounts of wood cover as natural banks, chinook abundance tended to be lower than average when compared to natural banks with the same amount of wood cover. This may be explained by differences in wood cover types between natural and hydromodified banks. Natural banks may have more of the complex wood cover types (e.g., rootwads, debris piles) preferred by chinook, while hydromodified banks may have more of the simpler types of wood cover (e.g., single logs, branches).

For juvenile coho at the end of summer rearing, wood cover in both bank types explained 62% of the variation in fish abundance (Figure 5). During the low flows of summer rearing, the amount of wood cover in hydromodified banks is less than the amount of wood in natural banks resulting in generally less coho rearing in hydromodified banks when compared to natural banks in the same area of the river.

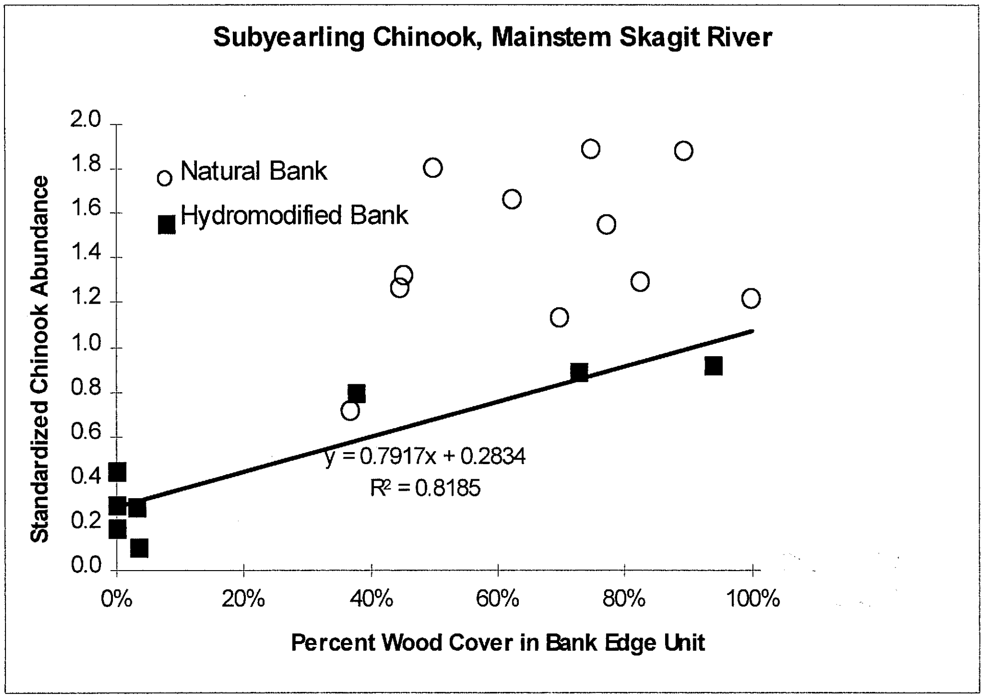

Figure 4. Plot of sub-yearling chinook abundance during spring outmigration as a function of wood cover in bank habitat of the mainstem Skagit River. Chinook abundance is standardized as a proportion of the average of the reach; the average of each reach equals 1.0.

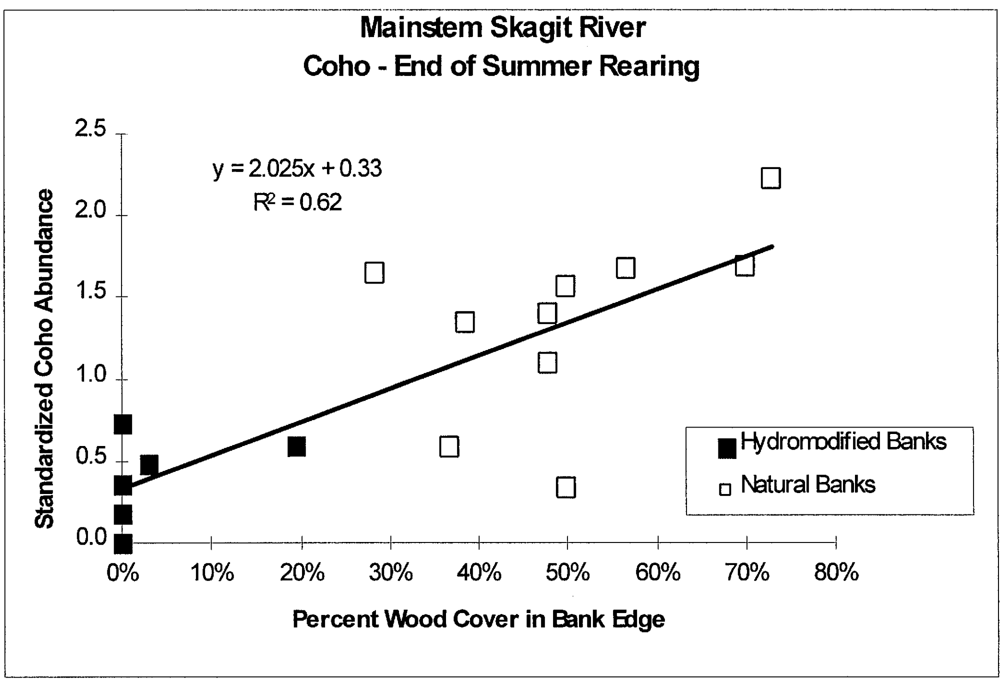

Figure 5. Plot of coho summer rearing abundance as a function of wood cover in bank habitat of the mainstem Skagit River. Coho abundance is standardized as a proportion of the average of the reach; the average of each reach equals 1.0.

For sub-yearling chum outmigrants, results suggest that aquatic plants and cobble are preferred (Figure 6.). Chum abundance in plant and cobble cover was always higher than the reach average (i.e., a positive number) while chum abundance in wood and rubble cover was always less than the reach average (i.e., a negative number). Chum abundance in riprap cover was usually less than the reach average. Both aquatic plant and cobble cover are more common in natural banks than in hydromodified banks.

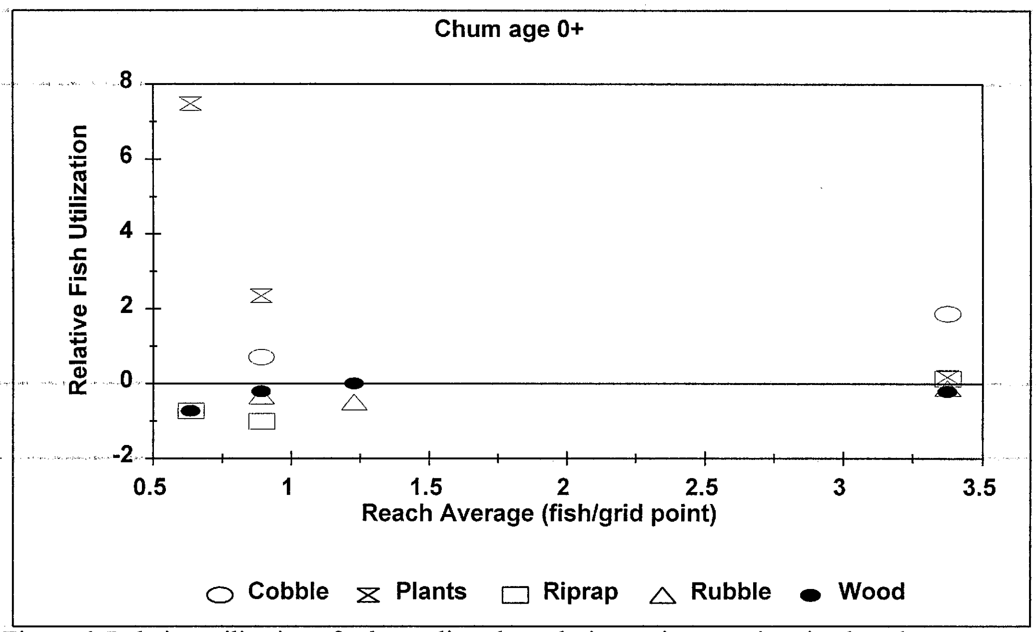

Figure 6. Relative utilization of sub-yearling chum during spring outmigration by edge cover type in the Skagit River. Negative numbers correspond to fish abundance < than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance > than the reach average.

Unlike juvenile chinook, chum, and coho, rainbow generally do not show strong preferences among natural bank cover types. However, there is evidence of preference for riprap (but not rubble) and some specific types of wood cover by rainbow. Sub-yearling rainbow abundance was generally higher than the reach average in riprap cover during the winter and always lower than the reach average in rubble and no cover types (Figure 7). The same trend is true for older rainbow during winter. Figure 8 shows the abundance of older rainbow during winter was generally higher than the reach average in riprap cover and always less than the reach average in the rubble, cobble, and no cover categories. These results suggests that rainbow may not be adversely impacted at the site level by bank hydromodification if rock particles are large.

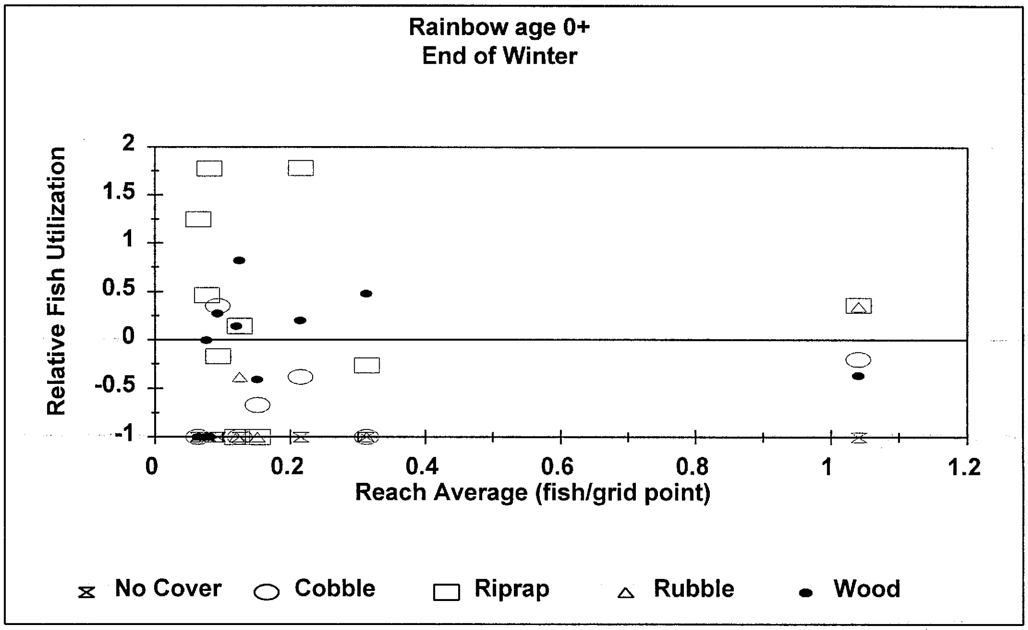

Figure 7. Relative utilization of sub-yearling rainbow at the end of winter by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

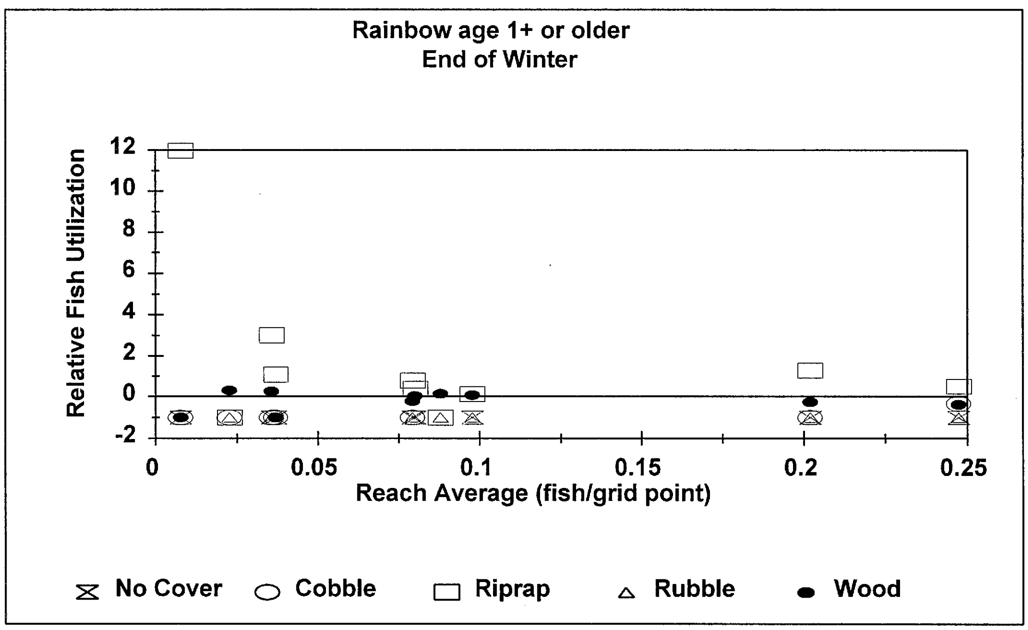

Figure 8. Relative utilization of rainbow (yearling or older) at the end of winter by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

IMPLICATIONS FOR HABITAT LOSS, RESTORATION, AND MITIGATION

Our results show that traditional bank protection projects using riprap would have a dramatic adverse impact on juvenile chinook, coho, and chum habitat. Also, the use of smaller rock material (i.e., rubble) for bank protection would adversely impact all species examined in this study. Table 4 illustrates these points by showing the expected change in fish abundance by cover type normalized to fish abundance in riprap cover (i.e., $mean_{cover\ type}/mean_{riprap}$). For example, sub-yearling chinook and summer coho abundance averaged 5.4 and 3.7 times higher in wood cover than in riprap, respectively. Average fish abundance in rubble cover is less than one half of the average fish abundance in riprap, with the exception of sub-yearling rainbow during summer.

Another interesting finding is that while wood cover is the most common cover type in natural banks, fish abundance within the different wood cover types is not uniform. For example, coho abundance in rootwads averaged 17.9 times higher than riprap at the end of summer and 4.2 times higher at the end of winter. In contrast, coho abundance in single log cover was less than riprap for both time periods (0.5 and 0.2, respectively). The trend that fish abundance is greater in rootwad cover than single logs is consistent for all species and life stages examined, with the exception of sub-yearling chum. Juvenile chum salmon strongly prefer aquatic plants over all other cover types (12 to 54 times greater than each of the other cover types).

Lastly, the findings of this study also suggest that the use of natural cover types along with bank protection may mitigate some *site* level impacts of hydromodification. However, using natural cover types with bank protection will not mitigate *reach* level impacts to fish habitat from hydromodification. The values in Table 4 can form the basis of estimating restoration benefits, planning mitigation or assessing the impacts of habitat loss.

Table 4. Expected change in fish abundance by cover type normalized to fish abundance in riprap. Results are average values for all reaches sampled. Values where the expected change is greater than threefold are shown in bold print.

Cover Type	Sub-yearling Chinook	Sub-yearling Chum	Summer Rainbow Age 0+	Summer Older Rainbow	Summer Coho Parr	Winter Rainbow Age 0+	Winter Older Rainbow	Winter Coho Presmolt
No Cover	0.9	0.3	0.9	0.0	0.0	0.0	0.0	0.0
Boulder	1.3	0.3	1.2	0.3	0.5	0.0	0.0	0.0
Cobble	**3.3**	1.3	**6.9**	0.3	1.5	0.4	0.1	0.0
Plants	2.1	**16.4**	NA	NA	NA	0.0	0.0	0.0
Riprap	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Rubble	0.4	0.4	1.8	0.4	0.2	0.3	0.0	0.1
Wood	**5.4**	0.8	2.1	0.7	**3.7**	0.8	0.4	1.6
bankroots	**4.5**	0.2	1.2	**3.1**	1.9	0.3	0.0	0.0
debris piles	**6.4**	1.2	2.6	0.4	1.9	1.8	0.9	2.2
single logs	1.2	0.5	0.8	0.4	0.5	0.2	0.1	0.2
rootwads	**8.7**	0.6	**3.9**	1.3	**17.9**	1.7	2.0	**4.2**

FISH CAPTURE EFFICIENCY

The conclusions of this study depend on the assumption that fish were captured at the same rate between the various habitat types sampled. The ability to catch fish with electrofishing gear is affected primarily by water temperature and conductivity as well as water velocity, water visibility, and cover complexity.

Water temperature and conductivity should not be significant factors because we stratified the fish abundance comparisons by space and time. That is, fish abundance data were compared only between sites with similar temperature and conductivity. Water visibility should not be a factor because we sampled only when water conditions had high visibility ($\geq$ 2 meters), usually several times greater than the depth of the water that was shocked. Because edge habitat units were defined as the lower velocity flow areas, differences in catchability due to water velocity should also be small. This conclusion is supported by the water surface velocity results that found little difference between hydromodified and natural banks (Table 3).

For evaluating the possible effect of cover complexity on electrofishing catchability we examined data from 100 different grid points. For these grid points we observed how many fish were observed at the grid point during the 10 seconds of electrofishing, but not captured. These fish were categorized as either "missed sub-yearlings" (small salmonids) or "missed yearlings" (larger salmonids). The rate of "missed" fish was then calculated as number of fish missed divided by the sum of fish captured and missed [$missed/(missed + catch)$]. The miss rate is higher in natural bank habitat than hydromodified bank habitat for both sub-yearling and yearling (or older) salmonids. The average miss rate for 55 grid points in hydromodified bank habitat was 1.1% and 27.3% for sub-yearling and yearling salmonids respectively. The miss rate for 45 grid points in natural bank habitat was 42.9% and 55.2% for sub-yearling and yearling salmonids respectively. These data suggest that relative fish abundance for both age classes may be underestimated in natural bank habitat when compared to hydromodified banks.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. From Figure 4 we infer that there are differences in wood cover types between natural and hydromodified banks. Future work should investigate this issue by determining whether there are differences between the types of wood cover in hydromodified banks and natural banks. Also, because there was a difference in the amount of wood cover between "old" and "new" hydromodified banks, the wood recruitment processes and rate of wood cover recruitment for hydromodified banks should be investigated.

2. This study did not account for a potential change in the wetted width of bank habitat if natural banks are hydromodified. Future work should look at whether there is a difference in the wetted width of natural and hydromodified banks when under the same geomorphic and hydrologic conditions. If hydromodified banks are hydraulically smoother, they most likely have a narrower low velocity edge thus reducing the area of the bank unit.

3. The results shown in Table 4 are based on limited data for chum. For all species, the data shown in Table 4 for boulder and aquatic plant cover types are also limited. More data should be collected for these areas to complete our understanding of fish use by bank cover type.

4. This study focused on fish abundance changes associated with different bank cover types over a range of fish densities and locations within the Skagit River. The results apply to estimating restoration benefits, planning mitigation or assessing the impacts of habitat loss. The fish capture efficiency results suggest that relative fish abundance in natural banks is underestimated compared to hydromodified habitat. We recommend more analysis of capture efficiency to possibly correct for this bias.

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APPENDIX 1. LOCATION OF SAMPLING SITES.

Name and Location of bank units sampled.

River Reach	Unit Number	Unit Name	River Mile
SK030	2	SPUDHOUSE BANK	8.5
SK060	4	LB COTTONWOOD	39.2
SK060	5	RB COTTONWOOD	39.2
SK060	8	DAY IS. BANK	35.5
SK060	9	FERNANDO RIPRAP	38.8
SK030	13	TEN DOLLAR RIPRAP	18.1
SK100	18	BANK BELOW SUTTER	70.3
SK100	19	BANK BELOW HOOPER	72
SK100	22	BARNABY RIPRAP	70.1
SK100	23	ILLABOT BANK	71.9
SK110	28	TAYLOR BANK	80.2
SK040	50	LOD HEAVEN	20.9
SK050	52	RIVERFRONT PARK BANK	23.9
SK050	53	PIPELINE BANK	24
SK070	55	MILL CREEK BANK	45
SK070	56	PRESSENTIN RIPRAP	46.8
SK120	60	COPPER BANK	83.6
SK120	61	ALMA RIPRAP	84.3
SK120	62	SHOVELSPUR BANK	85.2

APPENDIX 2. SUMMARY OF HABITAT CONDITIONS

Summary of habitat characteristics by unit.

Reach	Unit Name	Date	Bank Type	%Low vel.	%Med. vel	%High vel.	%No Cover	%Boulder	%bedrk	%Cobble	%DW	%Riprap	%Rubble	%Plants	%Undercut	%Wood
SK030	SPUDHOUSE BANK	02/23/93	natural	87%	13%	0%	23%	0%	0%	3%	23%	0%	0%	0%	0%	50%
SK030	TEN DOLLAR RIPRAP	03/09/93	hydromodified	42%	48%	9%	6%	0%	0%	0%	0%	85%	6%	0%	0%	3%
SK030	SPUDHOUSE BANK	09/22/93	natural	90%	10%	0%	27%	0%	0%	0%	17%	0%	0%	0%	0%	57%
SK030	TEN DOLLAR RIPRAP	09/22/93	hydromodified	29%	71%	0%	0%	0%	0%	0%	6%	91%	0%	0%	0%	3%
SK040	LOD HEAVEN	03/27/95	natural	85%	12%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
SK040	LOD HEAVEN	04/27/95	natural	81%	15%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
SK040	LOD HEAVEN	03/20/96	natural	81%	19%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	94%
SK050	PIPELINE BANK	03/29/95	hydromodified	91%	9%	0%	0%	0%	0%	0%	3%	6%	18%	0%	0%	73%
SK050	RIVERFRONT PARK BAN	03/29/95	hydromodified	78%	22%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	94%
SK050	PIPELINE BANK	04/27/95	hydromodified	97%	3%	0%	0%	0%	0%	0%	3%	6%	18%	0%	0%	73%
SK050	RIVERFRONT PARK BAN	04/27/95	hydromodified	82%	18%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	94%
SK050	PIPELINE BANK	03/27/96	hydromodified	94%	6%	0%	0%	0%	0%	0%	0%	52%	0%	0%	0%	48%
SK050	RIVERFRONT PARK BAN	03/27/96	hydromodified	88%	12%	0%	9%	0%	0%	0%	0%	3%	9%	0%	0%	79%
SK060	LB COTTONWOOD	02/24/93	natural	45%	41%	14%	5%	0%	0%	14%	5%	0%	0%	0%	0%	77%
SK060	RB COTTONWOOD	02/24/93	natural	30%	50%	20%	20%	0%	0%	5%	0%	0%	0%	0%	5%	70%
SK060	DAY IS. BANK	03/08/93	natural	62%	24%	14%	17%	0%	0%	0%	0%	0%	0%	0%	0%	83%
SK060	FERNANDO RIPRAP	03/08/93	hydromodified	25%	46%	29%	0%	0%	0%	0%	0%	93%	7%	0%	0%	0%
SK060	DAY IS. BANK	09/14/93	natural	59%	41%	0%	8%	0%	0%	19%	0%	0%	0%	0%	0%	73%
SK060	FERNANDO RIPRAP	09/15/93	hydromodified	37%	44%	19%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
SK060	LB COTTONWOOD	09/15/93	natural	43%	43%	13%	17%	0%	0%	35%	0%	0%	0%	0%	0%	48%
SK060	RB COTTONWOOD	09/15/93	natural	25%	53%	22%	9%	0%	0%	41%	0%	0%	0%	0%	0%	50%
SK100	BANK BELOW SUTTER	03/10/93	natural	54%	42%	4%	17%	0%	0%	13%	8%	0%	0%	0%	0%	63%
SK100	BANK BELOW HOOPER	03/12/93	hydromodified	34%	58%	8%	0%	0%	0%	0%	0%	92%	8%	0%	0%	0%
SK100	BARNABY RIPRAP	03/17/93	hydromodified	19%	63%	19%	0%	0%	0%	6%	0%	81%	13%	0%	0%	0%
SK100	ILLABOT BANK	03/17/93	natural	58%	32%	11%	0%	0%	0%	11%	0%	0%	0%	0%	0%	89%
SK100	BANK BELOW HOOPER	09/20/93	hydromodified	46%	49%	5%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
SK100	BANK BELOW SUTTER	09/20/93	natural	60%	32%	8%	24%	0%	0%	8%	20%	0%	0%	0%	0%	48%
SK100	BARNABY RIPRAP	09/20/93	hydromodified	19%	44%	38%	0%	0%	0%	6%	0%	94%	0%	0%	0%	0%
SK100	ILLABOT BANK	09/20/93	natural	35%	35%	30%	5%	0%	0%	25%	0%	0%	0%	0%	0%	70%
SK100	BANK BELOW SUTTER	03/25/98	natural	85%	15%	0%	15%	0%	0%	0%	0%	0%	0%	8%	0%	77%
SK100	BANK BELOW HOOPER	03/26/98	hydromodified	67%	33%	0%	8%	0%	0%	0%	0%	75%	0%	0%	0%	17%
SK110	TAYLOR BANK	03/02/95	natural	10%	86%	3%	0%	0%	0%	38%	0%	0%	0%	0%	17%	45%
SK110	TAYLOR BANK	04/12/95	natural	31%	69%	0%	0%	0%	0%	52%	0%	0%	0%	0%	3%	45%
SK110	TAYLOR BANK	05/11/95	natural	43%	54%	4%	0%	0%	0%	29%	0%	0%	0%	21%	18%	32%
SK110	TAYLOR BANK	09/08/95	natural	32%	61%	7%	0%	4%	0%	64%	0%	0%	0%	0%	4%	29%
SK110	TAYLOR BANK	03/19/96	natural	70%	30%	0%	4%	0%	0%	33%	4%	0%	0%	7%	0%	52%
SK120	ALMA RIPRAP	03/03/95	hydromodified	44%	38%	19%	0%	0%	0%	0%	0%	13%	13%	3%	9%	59%
SK120	COPPER BANK	03/03/95	natural	33%	42%	24%	0%	15%	0%	21%	0%	0%	0%	0%	6%	58%
SK120	SHOVELSPUR BANK	03/03/95	natural	39%	42%	18%	0%	37%	0%	5%	0%	0%	0%	0%	16%	42%
SK120	ALMA RIPRAP	04/13/95	hydromodified	75%	25%	0%	0%	0%	0%	0%	0%	13%	50%	0%	0%	38%
SK120	COPPER BANK	04/13/95	natural	64%	36%	0%	0%	12%	0%	39%	0%	0%	0%	3%	0%	45%
SK120	SHOVELSPUR BANK	04/13/95	natural	71%	18%	11%	0%	32%	0%	32%	0%	0%	0%	0%	0%	37%
SK120	ALMA RIPRAP	05/10/95	hydromodified	69%	22%	9%	0%	0%	0%	0%	0%	13%	16%	3%	9%	59%
SK120	COPPER BANK	05/10/95	natural	67%	18%	15%	0%	15%	0%	21%	0%	0%	0%	0%	6%	58%
SK120	SHOVELSPUR BANK	05/10/95	natural	58%	26%	16%	0%	32%	0%	5%	0%	0%	0%	0%	16%	47%
SK120	ALMA RIPRAP	09/07/95	hydromodified	55%	39%	6%	6%	3%	0%	0%	0%	19%	52%	0%	0%	19%
SK120	COPPER BANK	09/07/95	natural	81%	10%	10%	0%	19%	0%	42%	0%	0%	0%	0%	0%	39%
SK120	SHOVELSPUR BANK	09/07/95	natural	55%	21%	24%	0%	37%	0%	26%	0%	0%	0%	0%	0%	37%
SK120	ALMA RIPRAP	03/14/96	hydromodified	78%	19%	3%	3%	6%	6%	16%	6%	31%	0%	0%	0%	38%

Summary of habitat characteristics by unit.

Reach	Unit Name	Date	Bank Type	%Low vel.	%Med. vel	%High vel.	%No Cover	%Boulder	%bedrk	%Cobble	%DW	%Riprap	%Rubble	%Plants	%Undercut	%Wood
SK120	COPPER BANK	03/14/96	natural	58%	27%	15%	3%	3%	0%	36%	0%	0%	0%	0%	0%	58%
SK120	SHOVELSPUR BANK	03/14/96	natural	79%	16%	5%	8%	26%	0%	11%	3%	0%	0%	0%	3%	45%
Sk070	MILL CREEK BANK	03/29/95	natural	82%	18%	0%	4%	0%	0%	0%	0%	0%	0%	18%	4%	75%
Sk070	PRESSENTIN RIPRAP	03/29/95	hydromodified	79%	18%	4%	0%	7%	0%	14%	0%	25%	46%	0%	4%	4%
Sk070	MILL CREEK BANK	05/08/95	natural	93%	7%	0%	4%	0%	0%	0%	0%	0%	0%	21%	4%	71%
Sk070	PRESSENTIN RIPRAP	05/08/95	hydromodified	89%	11%	4%	0%	7%	0%	14%	0%	25%	46%	0%	4%	4%
Sk070	MILL CREEK BANK	09/22/95	natural	100%	0%	0%	14%	0%	0%	36%	0%	0%	0%	0%	0%	50%
Sk070	PRESSENTIN RIPRAP	09/22/95	hydromodified	95%	5%	0%	0%	0%	0%	0%	0%	68%	32%	0%	0%	0%
Sk070	MILL CREEK BANK	03/26/96	natural	96%	4%	0%	11%	0%	0%	30%	0%	0%	0%	0%	0%	59%
Sk070	PRESSENTIN RIPRAP	03/26/96	hydromodified	100%	0%	0%	0%	0%	0%	0%	0%	96%	0%	0%	0%	4%
Sk070	MILL CREEK BANK	05/01/96	natural	83%	17%	0%	7%	0%	0%	7%	0%	0%	0%	14%	0%	72%
Sk070	PRESSENTIN RIPRAP	05/01/96	hydromodified	77%	23%	0%	0%	0%	0%	0%	0%	88%	0%	4%	0%	8%

APPENDIX 3. SUMMARY OF JUVENILE CHINOOK AND CHUM USE DURING SPRING OUTMIGRATION.

Summary of habitat characteristics and chinook 0+ use (fish per grid point shocked) by edge unit type.

Reach	Unit Name	Date	Bank Type	ave. Chin0+	s.d.	n
SK030	SPUDHOUSE BANK	02/23/93	natural	1.13	2.87	30
SK030	TEN DOLLAR RIPRAP	03/09/93	hydromodified	0.18	0.39	33
SK040	LOD HEAVEN	03/27/95	natural	1.15	1.41	26
SK050	RIVERFRONT PARK BA	03/29/95	hydromodified	0.88	2.06	32
SK050	PIPELINE BANK	03/29/95	hydromodified	0.85	2.65	33
SK060	LB COTTONWOOD	02/24/93	natural	3.55	9.83	22
SK060	RB COTTONWOOD	02/24/93	natural	2.60	6.09	20
SK060	FERNANDO RIPRAP	03/08/93	hydromodified	0.43	0.74	28
SK060	DAY IS. BANK	03/08/93	natural	2.97	3.26	29
SK100	BANK BELOW SUTTER	03/10/93	natural	9.08	13.34	24
SK100	BANK BELOW HOOPER	03/12/93	hydromodified	2.45	2.86	38
SK100	BARNABY RIPRAP	03/17/93	hydromodified	1.63	3.01	16
SK100	ILLABOT BANK	03/17/93	natural	10.26	15.67	19
SK110	TAYLOR BANK	04/12/95	natural	1.83	3.15	29
SK120	ALMA RIPRAP	04/13/95	hydromodified	1.16	1.89	32
SK120	COPPER BANK	04/13/95	natural	1.91	3.71	33
SK120	SHOVELSPUR BANK	04/13/95	natural	1.03	1.53	38
Sk070	PRESSENTIN RIPRAP	03/29/95	hydromodified	0.04	0.19	28
Sk070	MILL CREEK BANK	03/29/95	natural	0.64	0.95	28

Summary of habitat characteristics and chum age 0+ use (fish per grid point shocked) by edge unit type.

Reach	Unit Name	Date	Bank Type	ave. Chum0+	s.d.	n
SK040	LOD HEAVEN	04/27/95	natural	1.35	2.15	26
SK050	PIPELINE BANK	04/27/95	hydromodified	0.82	1.38	33
SK050	RIVERFRONT PARK BA	04/27/95	hydromodified	1.55	2.28	33
SK110	TAYLOR BANK	05/11/95	natural	2.00	2.09	28
SK120	COPPER BANK	05/10/95	natural	0.39	1.09	33
SK120	SHOVELSPUR BANK	05/10/95	natural	0.84	1.64	38
SK120	ALMA RIPRAP	05/10/95	hydromodified	0.50	1.08	32
Sk070	MILL CREEK BANK	05/08/95	natural	2.93	4.72	28
Sk070	PRESSENTIN RIPRAP	05/08/95	hydromodified	3.82	7.37	28
Sk070	MILL CREEK BANK	05/01/96	natural	1.00	2.46	29
Sk070	PRESSENTIN RIPRAP	05/01/96	hydromodified	0.23	0.65	26

Average number of chinook age 0+ (fish/grid pt.) in bank habitat, peak abundance during spring.

Reach	Sk070, 95 Chin 0+	Sk030, 93 Chin 0+	Sk050, 95 Chin 0+	Sk120, 95 Chin 0+	Sk060, 93 Chin 0+	Sk100, 93 Chin 0+
reach ave.	0.34	0.63	0.95	1.45	2.30	5.48
ratio:wood/riprap	3.82	8.46	2.10	4.85	7.42	5.60
Cover Type:						
No Cover		0.44			0.30	1.50
Cobble	0.00			0.63	5.40	7.67
RipRap	0.14	0.21	0.50	0.50	0.46	2.08
Rubble	0.00	0.00	0.13	0.88	0.00	1.40
Wood	0.55	1.81	1.05	2.43	3.43	11.66
Wood types:						
Debris piles	0.57		1.08	3.61	5.55	14.00
Single log			0.43	2.00	0.33	1.00
Rootwad	1.00		3.11		3.70	27.71

Relative utilization by cover type in bank habitat.

Reach Cover Type:	Sk070, 95 Chin 0+	Sk030, 93 Chin 0+	Sk050, 95 Chin 0+	Sk120, 95 Chin 0+	Sk060, 93 Chin 0+	Sk100, 93 Chin 0+
No Cover		-0.30			-0.87	-0.73
Cobble	-1.00			-0.57	1.34	0.40
RipRap	-0.58	-0.66	-0.47	-0.66	-0.80	-0.62
Rubble	-1.00	-1.00	-0.87	-0.40	-1.00	-0.74
Wood	0.61	1.85	0.11	0.67	0.49	1.13
Wood types:						
Debris piles	0.68		0.14	1.48	1.41	1.55
Single log			-0.54	0.37	-0.86	-0.82
Rootwad	1.95		2.29		0.61	4.05

Average number of chum age 0+ (fish/grid pt.) in bank habitat during spring.

Reach	Sk070, 96 Chum 0+	Sk120, 95 Chum 0+	Sk050, 95 Chum 0+	Sk070, 95 Chum 0+
reach ave.	0.64	0.89	1.23	3.38
Cover Type:				
Cobble		1.53		9.75
Plants	5.40	3.00		4.00
RipRap	0.17	0.00		3.86
Rubble		0.60	0.63	3.00
Wood	0.17	0.71	1.23	2.67
Wood types:				
Anchored brush		0.22	0.00	1.50
Bankroots	0.00		0.00	2.25
Debris piles		0.94	1.81	4.33
Single log	0.20	0.80	0.38	

Relative utilization by cover type in bank habitat.

Reach Cover Type:	Sk070, 96 Chum 0+	Sk120, 95 Chum 0+	Sk050, 95 Chum 0+	Sk070, 95 Chum 0+
Cobble		0.71		1.89
Plants	7.49	2.36		0.19
RipRap	-0.73	-1.00		0.14
Rubble		-0.33	-0.49	-0.11
Wood	-0.73	-0.21	0.01	-0.21
Wood types:				
Anchored brush		-0.75	-1.00	-0.56
Bankroots	-1.00		-1.00	-0.33
Debris piles		0.05	0.48	0.28
Single log	-0.69	-0.10	-0.69	

Chinook, sub-yearling at the peak of spring outmigration

We evaluated chinook use of natural and hydromodified banks for six different reaches in the Skagit River over two springs, 1993 and 1995. Relative abundance of sub-yearling chinook in bank habitat varies by a factor of sixteen (0.34 to 5.48 chinook per grid point). The statistical tests compared mean chinook per grid point by bank unit types and cover types.

Mean chinook per grid point was significantly higher in natural banks than hydromodified banks in two of six reaches. Chinook abundance was 16 times higher in natural banks for the reach with the lowest relative abundance (Sk070, 0.34 fish/grid pt.) and 3.7 to 6.3 times higher in the reach with the highest relative abundance (Sk100, 5.48 fish/grid pt.).

The remaining four tests were unable to detect a significant difference between the means of chinook per grid point by bank unit type. However, the statistical power of these tests was very poor (0.07 to 0.44) so these results do not support the hypothesis that chinook abundance in natural and hydromodified banks is the same.

Of the tests comparing cover types, we found mean chinook per grid point was significantly higher (2.8 to 8.1 times) in wood cover than rubble cover. Chinook abundance was also 5.6 to 7.5 times higher in wood cover than riprap cover. In only one test were we unable to detect a significant difference between cover types; this was for reach Sk030 between wood and riprap cover. However, the statistical power of this test was poor (0.46) so it does not refute the results of other tests. When comparing chinook use in wood cover by other natural cover types, we only had one test. This resulted in the ordering of mean chinook abundance by cover type as: wood > boulder > cobble.

Within wood cover, three separate tests were conducted. Mean chinook per grid point in debris piles or bankroot cover was greater than branches. Another test found chinook abundance greater in rootwads than debris piles or single logs. The last test found chinook abundance greater in debris piles than single logs. Together, these results suggest that chinook abundance in wood cover types are ordered: rootwads > debris piles or bankroots > single logs or branches.

Relative fish utilization for sub-yearling chinook by cover types is shown in Figures 3-1 & 3-2. Chinook abundance in wood cover is always higher than the reach average (i.e., a positive number). Chinook use in riprap, rubble and no cover are always less than the reach average (i.e., a negative number). Riprap is usually closer to the reach average than rubble, suggesting that large rock particles are better cover for sub-yearling chinook than smaller particles. For the wood cover types, rootwads and debris piles are always higher than the reach average, whereas single logs are generally less than the reach average.

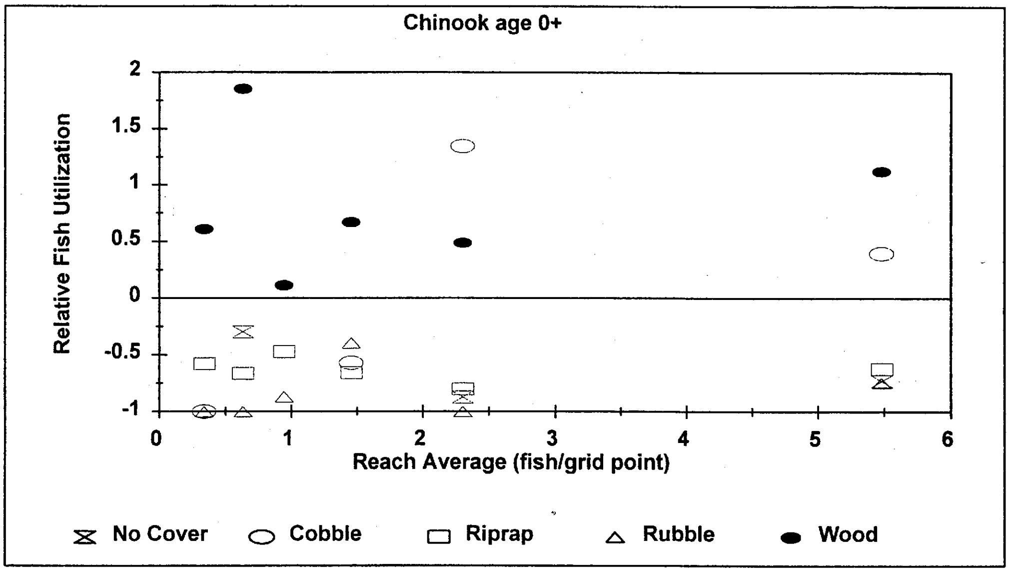

Figure 3-1. Relative utilization of sub-yearling chinook during spring outmigration by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

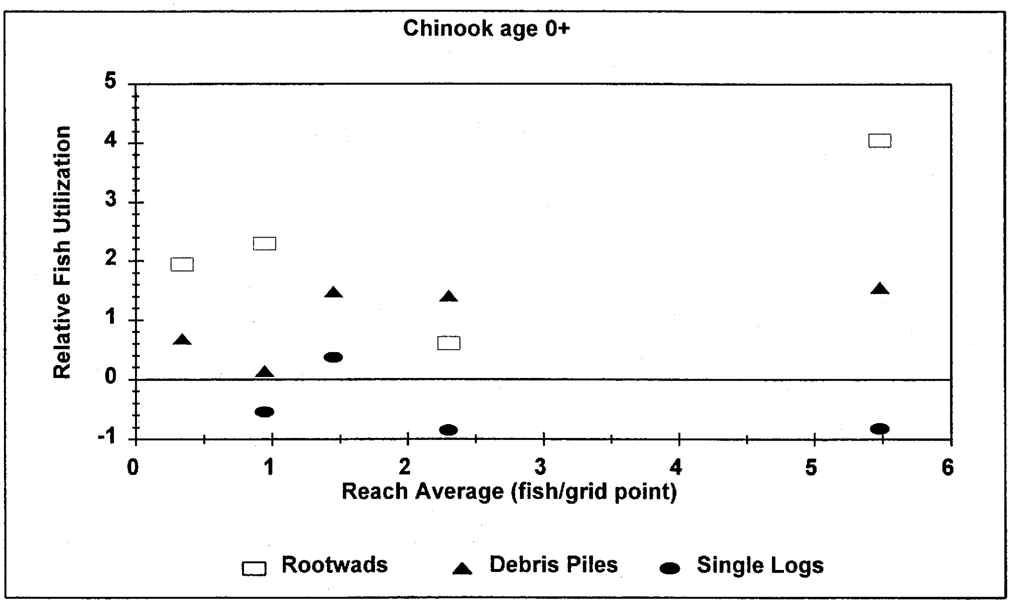

Figure 3-2. Relative utilization of sub-yearling chinook during spring outmigration by wood cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

Chum, sub-yearling at the peak of spring outmigration

Juvenile chum use in natural and hydromodified banks was compared for three different reaches of the Skagit River over two springs, 1995 and 1996. Relative abundance of sub-yearling chum in bank habitat varies by a factor of five (0.64 to 3.38 chum per grid point). The statistical tests compared mean chum per grid point by bank unit types and cover types.

Mean chum per grid point was significantly different between bank units in one reach. A natural bank (Taylor Bank) was 2.3 to 5.1 times greater than two other natural banks and one hydromodified bank in reach Sk110/120. The remaining three tests were unable to detect a significant difference between the means of chum per grid point by bank unit type. However, the statistical power of these tests was very poor (ranging between 0.12 to 0.34) so these results do not support the hypothesis that chum abundance in natural and hydromodified banks is the same.

Of the tests comparing cover types, we found mean chum per grid point was significantly higher (32 times) in aquatic plant cover than wood or riprap cover. Four other tests were unable to detect a significant difference between the means of chum per grid point by cover types that included: wood, riprap, rubble, boulder, cobble, and undercut banks. However, the statistical power of these four tests was very poor (ranging between 0.03 to 0.27) so these results do not support the hypothesis that chum abundance in these cover types is the same. Within wood cover, two separate tests were conducted. Mean chum per grid point in debris piles was 4.8 times higher than at single logs. The other test found no significant difference in chum abundance between rootwads and single logs

Relative fish utilization for sub-yearling chum by cover types is shown in Figures 3-3 & 3-4. Chum abundance in plant and cobble cover was always higher than the reach average (i.e., a positive number) while chum abundance in wood and rubble cover was always less than the reach average (i.e., a negative number). Chum abundance in riprap cover was usually less than the reach average. For the wood cover types, debris piles were always higher than the reach average while other wood cover types were always negative (anchored brush, bankroots, and single logs).

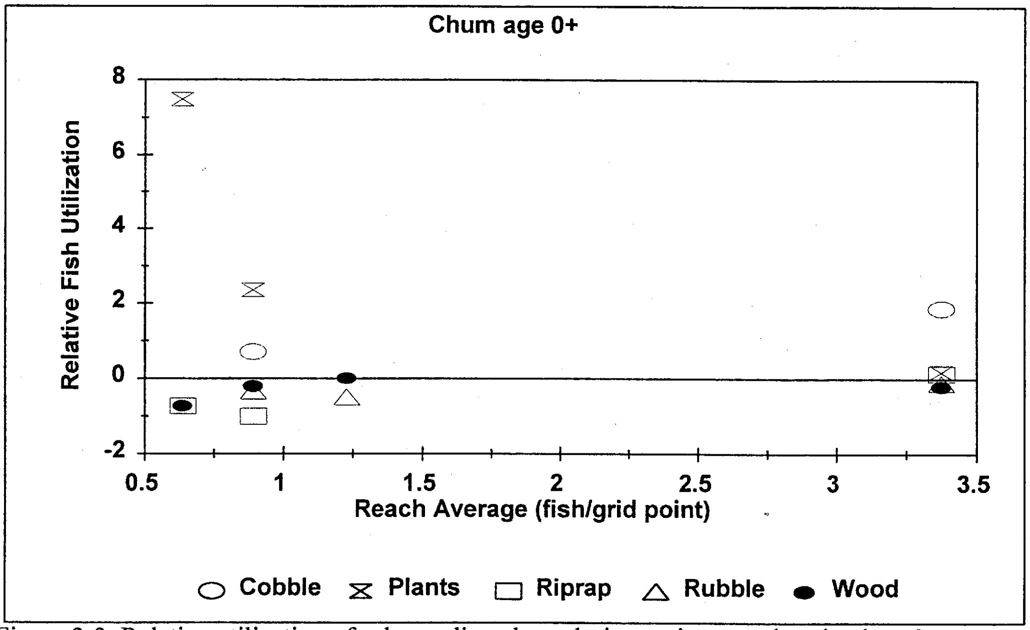

Figure 3-3. Relative utilization of sub-yearling chum during spring outmigration by edge cover type in the Skagit River. Negative numbers correspond to fish abundance < than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance > than the reach average.

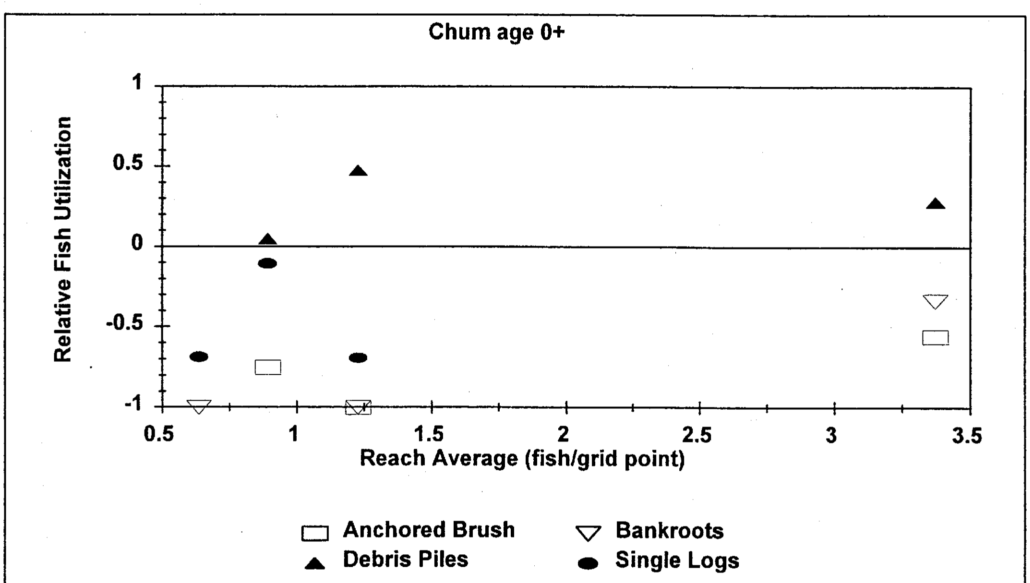

Figure 3-4. Relative utilization of sub-yearling chum during spring outmigration by wood cover type in the Skagit River. Negative numbers correspond to fish abundance < than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

APPENDIX 4. SUMMARY OF COHO AND RAINBOW USE AT THE END OF SUMMER REARING.

Summary of fish use (fish per grid point shocked) by edge unit type, end of summer rearing.

Reach	Unit Name	Date	Bank Type	ave.RB0+	s.d.	n	ave.RB1+or>	s.d.	n	Coho parr	s.d.	n
SK030	SPUDHOUSE BANK	09/22/93	natural	0.03	0.18	30	0.00	0.00	30	0.10	0.40	30
SK030	TEN DOLLAR RIPRAP	09/22/93	hydromodified	0.09	0.29	34	0.00	0.00	34	0.03	0.17	34
SK060	DAY IS. BANK	09/14/93	natural	0.43	0.73	37	0.03	0.16	37	0.62	1.14	37
SK060	FERNANDO RIPRAP	09/15/93	hydromodified	0.11	0.32	27	0.04	0.19	27	0.00	0.00	27
SK060	LB COTTONWOOD	09/15/93	natural	0.48	1.08	23	0.00	0.00	23	0.30	1.11	23
SK060	RB COTTONWOOD	09/15/93	natural	0.31	0.74	32	0.00	0.00	32	0.09	0.30	32
SK100	BANK BELOW HOOPER	09/20/93	hydromodified	0.92	0.93	39	0.54	0.88	39	1.28	1.92	39
SK100	BANK BELOW SUTTER	09/20/93	natural	1.04	1.57	25	0.04	0.20	25	2.44	5.76	25
SK100	BARNABY RIPRAP	09/20/93	hydromodified	0.25	0.45	16	0.63	0.89	16	0.31	0.79	16
SK100	ILLABOT BANK	09/20/93	natural	0.55	0.76	20	0.25	0.44	20	2.95	2.54	20
SK110	TAYLOR BANK	09/08/95	natural	1.79	1.77	28	0.11	0.31	28	2.25	3.46	28
SK120	ALMA RIPRAP	09/07/95	hydromodified	0.68	1.11	31	0.13	0.34	31	0.81	1.17	31
SK120	COPPER BANK	09/07/95	natural	0.58	1.03	31	0.35	0.88	31	1.84	3.08	31
SK120	SHOVELSPUR BANK	09/07/95	natural	0.66	0.99	38	0.03	0.16	38	0.79	1.45	38
Sk070	MILL CREEK BANK	09/22/95	natural	0.77	1.51	22	0.00	0.00	22	1.14	2.88	22
Sk070	PRESSENTIN RIPRAP	09/22/95	hydromodified	0.21	0.54	19	0.00	0.00	19	0.26	0.73	19

Average number of coho parr (fish/grid pt.) in bank habitat, end of summer.

Reach	Sk100 Coho parr	Sk110/120 Coho parr	Sk070 Coho parr	Sk060 Coho parr	Sk030 Coho parr
reach ave.	1.75	1.37	0.73	0.28	0.06
ratio:wood/riprap	3.64	2.03	4.73		4.50
Cover Type					
No Cover	0.00	0.00	0.00	0.00	0.00
Cobble	0.75	0.49	1.13	0.00	0.00
RipRap	1.20	1.50	0.31	0.00	0.04
Rubble	0.20	0.38	0.17	0.00	0.00
Wood	4.38	3.05	1.45	0.61	0.17
Wood types:					
Bankroots	3.57	4.25	0	0.00	
Debris piles	5.30	3.29	0.33	0.69	0.00
Single log	0.71	2.40	0.00	0.24	0.00
Rootwad	25.00		4.33	1.75	0.75

Relative utilization by cover types in bank habitat.

Reach Cover Type	Sk100 Coho parr	Sk110/120 Coho parr	Sk070 Coho parr	Sk060 Coho parr	Sk030 Coho parr
No Cover	-1.00	-1.00	-1.00	-1.00	-1.00
Cobble	-0.57	-0.64	0.54	-1.00	-1.00
RipRap	-0.31	0.10	-0.58	-1.00	-0.41
Rubble	-0.89	-0.73	-0.77	-1.00	-1.00
Wood	1.51	1.23	0.99	1.20	1.67
Wood types:					
Bankroots	1.04	2.11	-1.00	-1.00	
Debris piles	2.03	1.41	-0.54	1.50	-1.00
Single log	-0.59	0.76	-1.00	-0.13	-1.00
Rootwad	13.29		4.92	5.31	11.00

Average number of rainbow yearling or older (fish/grid pt.) in bank habitat, end of summer

Reach	Sk100 RB1+or>	Sk110/120 RB1+or>	Sk060 RB1+or>
reach ave.	0.37	0.15	0.02
ratio: riprap/wood	3.55	0.67	2.45
Cover Type			
No Cover	0.00	0.00	0.00
Cobble	0.13	0.10	0.00
RipRap	0.68	0.17	0.05
Rubble	0.10	0.19	0.00
Wood	0.19	0.25	0.02
Wood types:			
Bankroots	0.29	1.50	0.00
Debris piles	0.30	0.13	0.00
Single log	0.00	0.20	0.00
Rootwad	0.00		0.13

Relative utilization by cover types in bank habitat.

Reach Cover Type	Sk100 RB0+	Sk110/120 RB0+	Sk060 RB0+
No Cover	-1.00	-1.00	-1.00
Cobble	-0.66	-0.34	-1.00
RipRap	0.84	0.12	1.70
Rubble	-0.73	0.26	-1.00
Wood	-0.48	0.68	0.10
Wood types:			
Bankroots	-0.23	9.11	-1.00
Debris piles	-0.19	-0.16	-1.00
Single log	-1.00	0.35	-1.00
Rootwad	-1.00		6.44

Average number of rainbow 0+ (fish/grid pt.) in bank habitat, end of summer rearing.

Reach	Sk110/120 RB0+	Sk100 RB0+	Sk070 RB0+	Sk060 RB0+	Sk030 RB0+
reach ave.	0.89	0.77	0.51	0.34	0.06
ratio:wood/riprap	1.95	1.47	3.55	3.26	0.50
Cover types:					
No Cover	0.00	0.71	0.00	0.50	0.00
Cobble	1.20	0.75	1.75	0.29	0.00
RipRap	0.50	0.68	0.08	0.14	0.11
Rubble	0.63	1.00	0.50	0.00	0.00
Wood	0.98	1.00	0.27	0.44	0.06
Wood types:					
Bankroots	0.50	1.43	0	0.25	
Debris piles	1.38	0.70	0.33	0.69	0.00
Single log	0.60	1.00	0.00	0.20	0.00
Rootwad		2.00	0.33	0.88	0.25

Relative utilization by cover types in bank habitat

Reach Cover Types:	Sk110/120 RB0+	Sk100 RB0+	Sk070 RB0+	Sk060 RB0+	Sk030 RB0+
No Cover	-1.00	-0.07	-1.00	0.49	-1.00
Cobble	0.34	-0.03	2.42	-0.15	-1.00
RipRap	-0.44	-0.11	-0.85	-0.59	0.78
Rubble	-0.30	0.30	-0.02	-1.00	-1.00
Wood	0.09	0.30	-0.47	0.32	-0.11
Wood types:					
Bankroots	-0.44	0.86	-1.00	-0.26	
Debris piles	0.54	-0.09	-0.35	1.06	-1.00
Single log	-0.33	0.30	-1.00	-0.41	-1.00
Rootwad		1.60	-0.35	1.60	3.00

Coho parr at the end of summer rearing

Coho parr abundance in natural and hydromodified banks was compared in five reaches of the Skagit River. Relative abundance of coho parr in bank habitat varies by a factor of twenty-nine (0.06 to 1.75 fish per grid point). The statistical tests compared mean coho per grid point by bank unit type and cover type.

Three tests found mean coho per grid point significantly higher (2.3 to 9.5 times) in natural banks than hydromodified banks. Four tests were unable to detect a significant difference between mean coho abundance between bank types. However, the statistical power of these tests was poor (0.14 to 0.40) so these results do not support the hypothesis that coho abundance in natural and hydromodified banks is the same.

Of the tests comparing cover types, two tests found mean coho per grid point was significantly higher in wood cover than riprap or rubble cover (3.7 to 22 times higher). Another test found coho abundance significantly higher in wood cover than rubble, boulder, or cobble cover. Two tests were unable to detect a significant difference in coho abundance between wood and riprap cover. However, the statistical power of these tests was very poor (< 0.20) so the results do not support the hypothesis that coho abundance in wood and riprap cover is the same.

Relative fish utilization for coho parr by cover type is shown in Figures 4-1 and 4-2. Coho abundance in wood cover is always higher than the reach average (i.e., a positive number) while rubble and no cover are always less than the reach average (i.e., a negative number). Coho abundance in riprap and cobble cover are usually less than average. For the wood cover types, rootwads are always much higher than the reach average while single logs are usually lower than average. The results for bankroot and debris pile cover types is mixed.

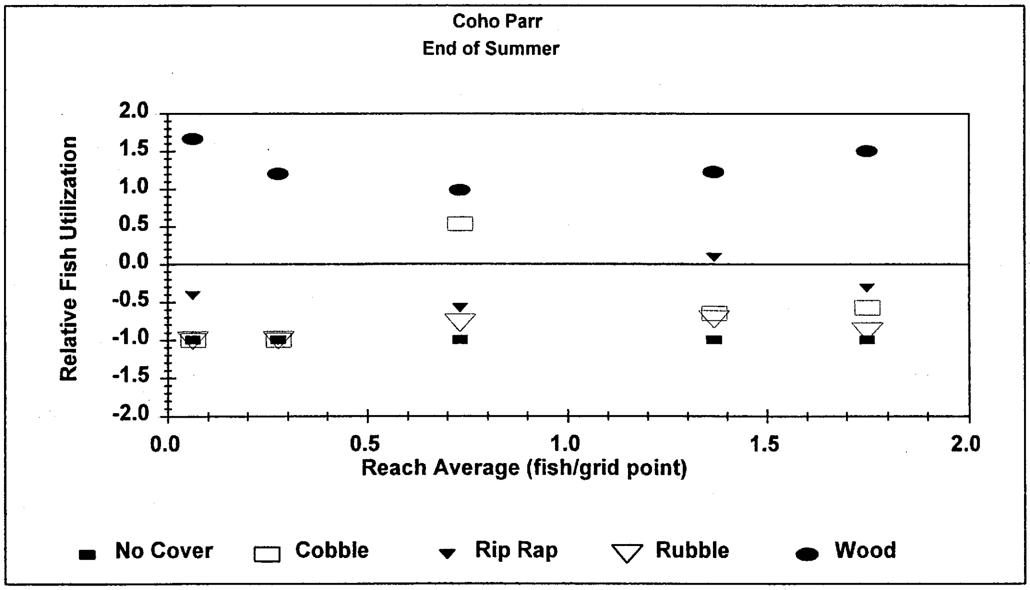

Figure 4-1. Relative utilization of coho parr at the end of summer by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

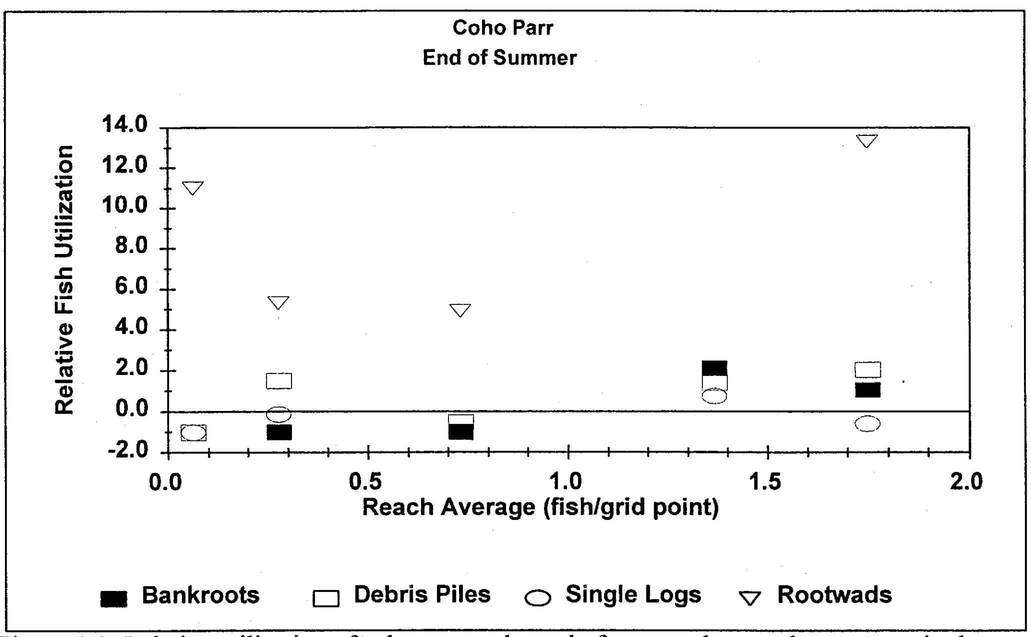

Figure 4-2. Relative utilization of coho parr at the end of summer by wood cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

Sub-yearling Rainbow at the end of summer rearing

Sub-yearling rainbow abundance in natural and hydromodified banks was compared in five reaches of the Skagit River. Relative abundance of sub-yearling rainbow in bank habitat varies by a factor of fifteen (0.06 to 0.89 fish per grid point). The statistical tests compared mean rainbow per grid point by bank unit type and cover type.

Two tests found mean rainbow (age 0+) per grid point significantly higher (2.6 to 4.2 times) in natural banks than hydromodified banks. Four other tests were unable to detect a significant difference between mean sub-yearling rainbow abundance between bank types. However, the statistical power of these tests was poor (ranging from 0.16 to 0.36) so these results do not support the hypothesis that sub-yearling rainbow abundance in natural and hydromodified banks is the same.

While mean rainbow abundance was greater in wood cover than riprap cover in four of the five reaches, all tests were unable to detect a significant difference in sub-yearling rainbow abundance between wood and riprap cover. However, the statistical power of these tests was poor (from 0.08 to 0.40) so the results do not support the hypothesis that sub-yearling rainbow abundance in wood and riprap cover is the same. Between wood and cobble cover, two tests were unable to detect a significant difference in rainbow abundance. These tests also had inadequate power to support the idea that rainbow abundance in wood and cobble cover is the same.

Relative fish utilization for sub-yearling rainbow by cover type is shown in Figures 4-3 and 4-4. Unlike chinook, chum, and coho, there are not strong trends in sub-yearling rainbow abundance by cover type, with the exception that abundance is usually less than the reach average for no cover. For the wood cover types, sub-yearling rainbow abundance in rootwads is usually higher than the reach average while the results for single log, bankroot, and debris pile cover is mixed.

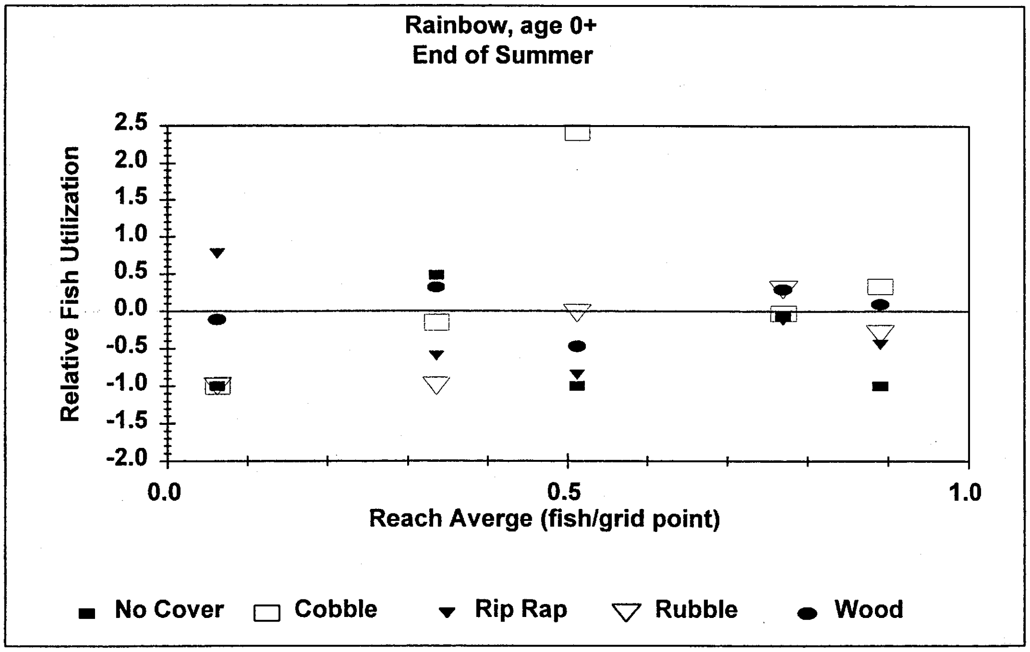

Figure 4-3. Relative utilization of sub-yearling rainbow at the end of summer by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

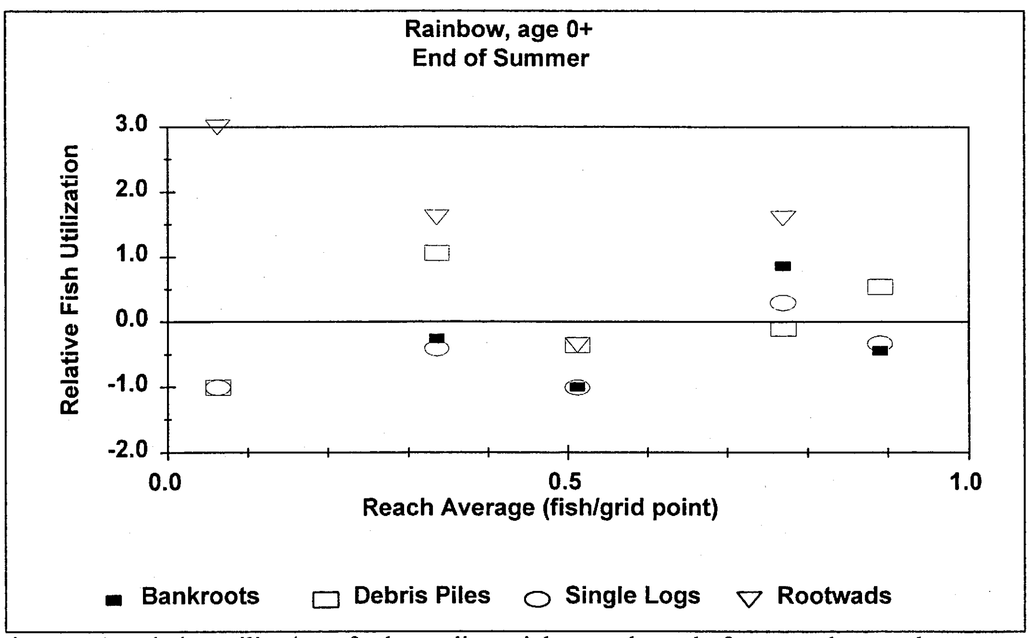

Figure 4-4. Relative utilization of sub-yearling rainbow at the end of summer by wood cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

Rainbow (yearling or older) at the end of summer rearing

Yearling or older rainbow abundance in natural and hydromodified banks was compared in three reaches of the Skagit River. Two other reaches were sampled, but no fish were captured. Relative abundance of older rainbow in bank habitat varies by a factor of eighteen (0.02 to 0.37 fish per grid point). The statistical tests compared mean rainbow per grid point by bank unit type and cover type.

Two tests found mean rainbow (age 1+ or older) per grid point significantly different in natural banks than hydromodified banks. One test found a natural bank to be higher while another test found a hydromodified bank to be higher. Four other tests were unable to detect a significant difference in mean older rainbow abundance between bank types. However, the statistical power of these tests was poor (≤ 0.20) so these results do not support the hypothesis that older rainbow abundance in natural and hydromodified banks is the same.

While mean rainbow abundance was greater in riprap cover than wood cover in two of the three reaches, all tests were unable to detect a significant difference in older rainbow abundance between wood and riprap cover. However, the statistical power of these tests was poor (0.08 to 0.40) so the results do not support the hypothesis that older rainbow abundance in wood and riprap cover is the same. Between wood and rubble cover, mean abundance of older rainbow was higher in wood cover for all three reaches. However, the tests were unable to detect a significant difference in rainbow abundance. These tests also had inadequate power to support the idea that rainbow abundance in wood and rubble cover is the same.

Relative fish utilization for older rainbow by cover type is shown in Figures 4-5 and 4-6. Older rainbow abundance in riprap cover was usually higher than the reach average (i.e., a positive number) while rainbow abundance in cobble and no cover was always less than the reach average (i.e., a negative number). Results for wood and rubble are mixed, but rainbow abundance in wood cover is always higher than rubble. For the wood cover types, no clear trend is evident. However, rainbow abundance in rootwad and bankroot cover was much higher than average in one of the three reaches sampled.

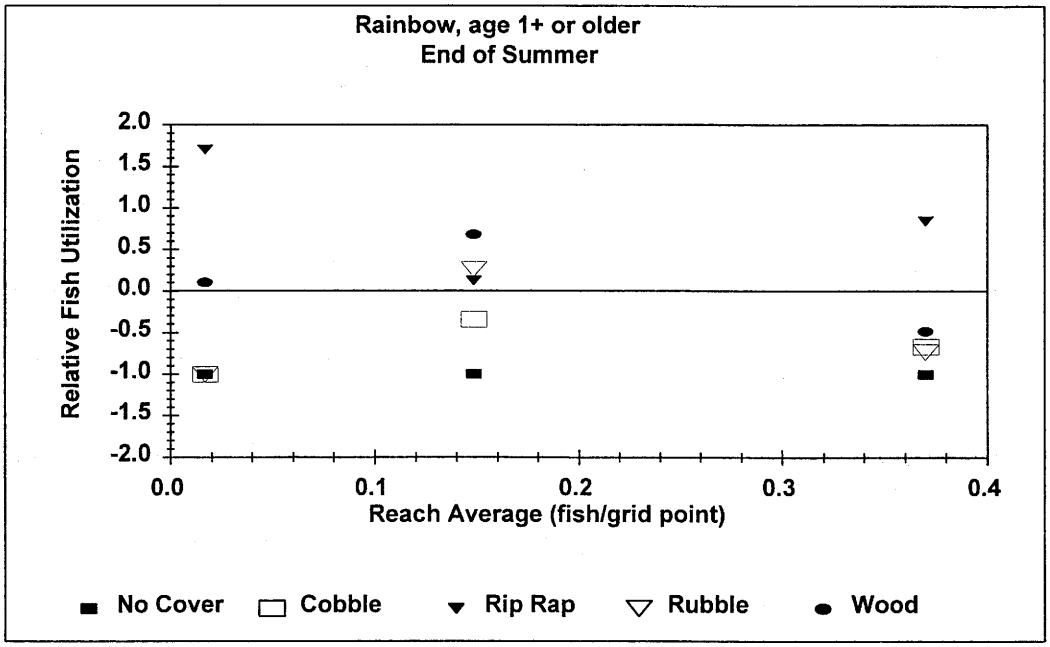

Figure 4-5. Relative utilization of rainbow (yearling or older) at the end of summer by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

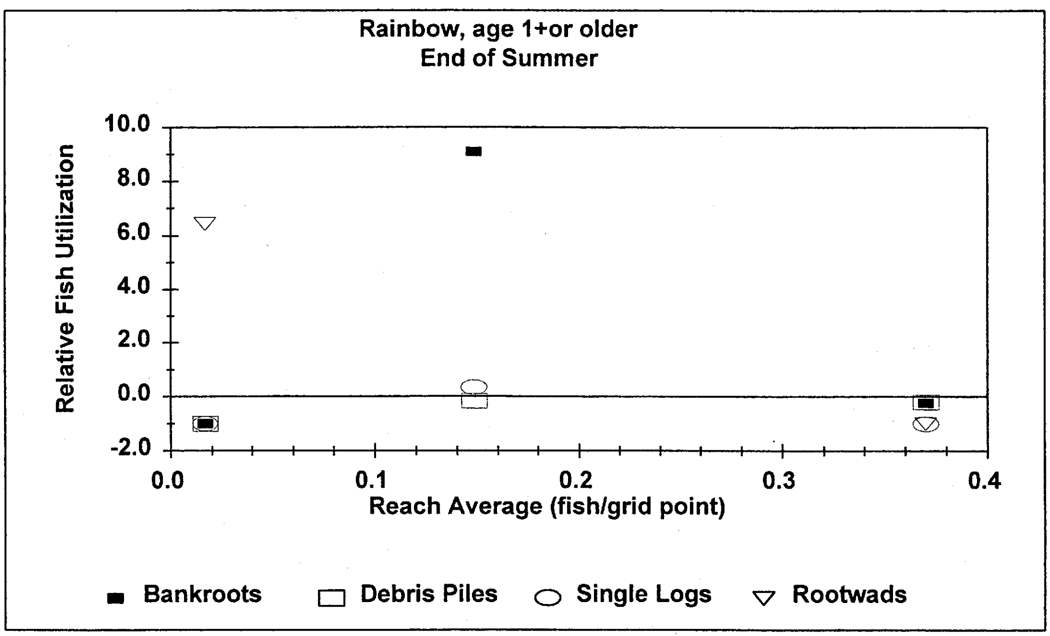

Figure 4-6. Relative utilization of rainbow (yearling or older) at the end of summer by wood cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

APPENDIX 5. SUMMARY OF COHO AND RAINBOW USE AT THE END OF WINTER REARING.

Summary of fish use (fish per grid point shocked) by edge unit type, end of winter rearing.

Reach	Unit Name	Date	Bank Type	ave.RB0+	s.d.	n	ave.RB1+or>	s.d.	n	ave.Coho presmolt	s.d.	n
SK030	SPUDHOUSE BANK	02/23/93	natural	0.00	0.00	30	0.03	0.18	30	0.00	0.00	30
SK030	TEN DOLLAR RIPRAP	03/09/93	hydromodified	0.12	0.33	33	0.12	0.33	33	0.06	0.35	33
SK060	LB COTTONWOOD	02/24/93	natural	0.14	0.47	22	0.14	0.35	22	0.00	0.00	22
SK060	RB COTTONWOOD	02/24/93	natural	0.20	0.52	20	0.15	0.49	20	0.10	0.45	20
SK060	DAY IS. BANK	03/08/93	natural	0.62	1.08	29	0.07	0.26	29	0.52	1.09	29
SK060	FERNANDO RIPRAP	03/08/93	hydromodified	0.21	0.50	28	0.43	1.23	28	0.04	0.19	28
SK100	BANK BELOW SUTTER	03/10/93	natural	0.46	1.06	24	0.21	1.02	24	0.42	1.64	24
SK100	ILLABOT BANK	03/17/93	natural	0.58	0.77	19	0.00	0.00	19	0.26	0.56	19
SK100	BANK BELOW HOOPER	03/12/93	hydromodified	1.61	1.53	38	0.24	0.63	38	0.89	1.27	38
SK100	BARNABY RIPRAP	03/17/93	hydromodified	1.13	1.96	16	0.63	1.36	16	0.00	0.00	16
SK040	LOD HEAVEN	03/27/95	natural	0.15	0.37	26	0.04	0.20	26	0.08	0.39	26
SK050	RIVERFRONT PARK BA	03/29/95	hydromodified	0.06	0.35	32	0.19	0.64	32	0.13	0.55	32
SK050	PIPELINE BANK	03/29/95	hydromodified	0.15	0.62	33	0.03	0.17	33	0.18	0.46	33
Sk070	MILL CREEK BANK	03/29/95	natural	0.18	0.55	28	0.04	0.19	28	0.00	0.00	28
Sk070	PRESSENTIN RIPRAP	03/29/95	hydromodified	0.07	0.26	28	0.04	0.19	28	0.11	0.42	28
SK110	TAYLOR BANK	03/02/95	natural	0.07	0.26	29	0.00	0.00	29	0.03	0.19	29
SK120	COPPER BANK	03/03/95	natural	0.42	0.94	33	0.00	0.00	33	0.27	0.98	33
SK120	SHOVELSPUR BANK	03/03/95	natural	0.11	0.39	38	0.05	0.23	38	0.11	0.39	38
SK120	ALMA RIPRAP	03/03/95	hydromodified	0.00	0.00	32	0.03	0.18	32	0.16	0.72	32
SK040	LOD HEAVEN	03/20/96	natural	0.04	0.20	26	0.15	0.46	26	0.12	0.59	26
SK050	RIVERFRONT PARK BA	03/27/96	hydromodified	0.06	0.35	33	0.03	0.17	33	0.12	0.42	33
SK050	PIPELINE BANK	03/27/96	hydromodified	0.12	0.33	33	0.12	0.42	33	0.09	0.29	33
Sk070	MILL CREEK BANK	03/26/96	natural	0.11	0.32	27	0.00	0.00	27	0.04	0.19	27
Sk070	PRESSENTIN RIPRAP	03/26/96	hydromodified	0.07	0.27	27	0.07	0.27	27	0.07	0.38	27
SK110	TAYLOR BANK	03/19/96	natural	0.15	0.36	27	0.00	0.00	27	0.00	0.00	27
SK120	COPPER BANK	03/14/96	natural	0.27	0.91	33	0.00	0.00	33	0.09	0.52	33
SK120	SHOVELSPUR BANK	03/14/96	natural	0.03	0.16	38	0.00	0.00	38	0.00	0.00	38
SK120	ALMA RIPRAP	03/14/96	hydromodified	0.44	0.76	32	0.03	0.18	32	0.03	0.18	32
SK100	BANK BELOW SUTTER	03/25/98	natural	0.00	0.00	13	0.08	0.28	13	0.69	1.55	13
SK100	BANK BELOW HOOPER	03/26/98	hydromodified	0.17	0.58	12	0.08	0.29	12	0.67	1.23	12

Average number of coho parr (fish/grid pt.) in bank habitat, end of winter rearing.

	Sk030,93 Coho parr	Sk110,96 Coho parr	Sk070,95 Coho parr	Sk070,96 Coho parr	Sk050,96 Coho parr	Sk050,95 Coho parr	Sk110,95 Coho parr	Sk060,93 Coho parr	Sk100,93 Coho parr	Sk100,98 Coho parr
reach ave.	0.03	0.03	0.05	0.06	0.11	0.13	0.14	0.18	0.51	0.68
Cover Type										
No Cover	0.00	0.00	0	0.00	0.00			0.00	0.00	0.00
Cobble	0	0.00	0.00	0.00			0.00	0.00	0.00	
RipRap	0.07	0.10	0.43	0.08	0.06	0.00	0.00	0.04	0.69	0.89
Rubble	0.00		0.00		0.00	0.00	0.00	0.00	0.20	
Wood	0.00	0.05	0.00	0.06	0.14	0.15	0.15	0.31	0.47	0.75
Wood types:										
Bankroots		0.00	0.00	0.00	0.00	1.00		0	0.00	
Single log		0.00	0.00	0.00	0.07	0.07		0.00	0.00	
Rootwad		0.00	0.00	0.25	0.00	0.22		0.90	1.71	

Relative utilization by cover type in bank habitat.

Cover Type:	Sk030,93 Coho parr	Sk110,96 Coho parr	Sk070,95 Coho parr	Sk070,96 Coho parr	Sk050,96 Coho parr	Sk050,95 Coho parr	Sk110,95 Coho parr	Sk060,93 Coho parr	Sk100,93 Coho parr	Sk100,98 Coho parr
No Cover	-1.00	-1.00	-1.00	-1.00	-1.00			-1.00	-1.00	-1.00
Cobble	-1.00	-1.00	-1.00	-1.00			-1.00	-1.00	-1.00	
RipRap	1.25	2.25	7.00	0.38	-0.49	-1.00	-1.00	-0.79	0.36	0.31
Rubble	-1.00		-1.00		-1.00	-1.00	-1.00	-1.00	-0.60	
Wood	-1.00	0.57	-1.00	0.06	0.25	0.14	0.04	0.73	-0.07	0.10
Wood types:										
Bankroots			-1.00	-1.00	-1.00	6.58		-1.00	-1.00	
Single log			-1.00	-1.00	-0.39	-0.49		-1.00	-1.00	
Rootwad			-1.00	3.50	-1.00	0.69		3.95	2.39	

Average number of rainbow age 0+ (fish/grid pt.) in bank habitat, end of winter rearing.

Reach	Sk030,93 RB0+	Sk100,98 RB0+	Sk050,96 RB0+	Sk070,96 RB0+	Sk050,95 RB0+	Sk070,95 RB0+	Sk110,95 RB0+	Sk110,96 RB0+	Sk060,93 RB0+	Sk100,93 RB0+
reach ave.	0.06	0.08	0.08	0.09	0.12	0.13	0.15	0.22	0.31	1.04
Cover Type:										
No Cover	0.00	0.00	0.00	0.00		0		0.00	0.00	0.00
Cobble	0			0.13		0.00	0.05	0.13	0.00	0.83
RipRap	0.14	0.22	0.11	0.08	0.00	0.14	0.00	0.60	0.23	1.42
Rubble	0.00		0.00		0.00	0.08	0.00		0.00	1.40
Wood	0.00	0.00	0.08	0.12	0.14	0.23	0.09	0.26	0.46	0.66
Wood types:										
Bankroots			0.00	0.00	0.00	0.25		0.17	0	0.50
Single log			0.00	0.00	0.17	0.00		0.33	0.22	0.14
Rootwad			0.00	0.25	0.33	0.00		0.50	1.10	1.86

Relative utilization by cover types in bank habitat.

Reach Cover Type	Sk030,93 RB0+	Sk100,98 RB0+	Sk050,96 RB0+	Sk070,96 RB0+	Sk050,95 RB0+	Sk070,95 RB0+	Sk110,95 RB0+	Sk110,96 RB0+	Sk060,93 RB0+	Sk100,93 RB0+
No Cover	-1.00	-1.00	-1.00	-1.00		-1.00		-1.00	-1.00	-1.00
Cobble	-1.00			0.35		-1.00	-0.67	-0.38	-1.00	-0.20
RipRap	1.25	1.78	0.46	-0.17	-1.00	0.14	-1.00	1.79	-0.26	0.36
Rubble	-1.00		-1.00		-1.00	-0.38	-1.00		-1.00	0.34
Wood	-1.00	-1.00	-0.00	0.27	0.14	0.82	-0.41	0.20	0.48	-0.37
Wood types:										
Bankroots				-1.00	-1.00	1.00		-0.19	-1.00	-0.52
Single log				-1.00	0.38	-1.00		0.55	-0.29	-0.86
Rootwad				1.70	1.76	-1.00		1.32	2.51	0.78

Average number of rainbow yearling or older (fish/grid pt.) in bank habitat, end of winter rearing.

Reach	Sk110,96 RB1+or>	Sk110,95 RB1+or>	Sk070,95 RB1+or>	Sk070,96 RB1+or>	Sk030,93 RB1+or>	Sk100,98 RB1+or>	Sk050,95 RB1+or>	Sk050,96 RB1+or>	Sk060,93 RB1+or>	Sk100,93 RB1+or>
reach ave.	0.01	0.02	0.04	0.04	0.08	0.08	0.09	0.10	0.20	0.25
Cover Type:										
No Cover	0.00		0	0.00	0.00	0.00		0.00	0.00	0.00
Cobble	0.00	0.00	0.00	0.00	0				0.00	0.17
RipRap	0.10	0.00	0.14	0.08	0.14	0.11	0.00	0.11	0.46	0.38
Rubble		0.00	0.00		0.00		0.00	0.00	0.00	0.00
Wood	0.00	0.03	0.05	0.00	0.06	0.08	0.10	0.11	0.15	0.16
Wood types:										
Bankroots	0.00		0.00	0.00			1.00	0.00	0	0.00
Single log	0.00		0.00	0.00			0.07	0.00	0.22	0.00
Rootwad	0.00		0.00	0.00			0.11	1.00	0.30	0.71

Relative utilization by cover type in bank habitat.

Cover Type:	Sk110,96 RB1+or>	Sk110,95 RB1+or>	Sk070,95 RB1+or>	Sk070,96 RB1+or>	Sk030,93 RB1+or>	Sk100,98 RB1+or>	Sk050,95 RB1+or>	Sk050,96 RB1+or>	Sk060,93 RB1+or>	Sk100,93 RB1+or>
No Cover	-1.00		-1.00	-1.00	-1.00	-1.00		-1.00	-1.00	-1.00
Cobble	-1.00	-1.00	-1.00	-1.00	-1.00				-1.00	-0.33
RipRap	12.00	-1.00	3.00	1.08	0.80	0.39	-1.00	0.14	1.28	0.52
Rubble		-1.00	-1.00		-1.00		-1.00	-1.00	-1.00	-1.00
Wood	-1.00	0.31	0.27	-1.00	-0.21	0.04	0.14	0.08	-0.27	-0.37
Wood types:										
Bankroots	-1.00			-1.00			10.38	-1.00	-1.00	-1.00
Single log	-1.00			-1.00			-0.24	-1.00	0.10	-1.00
Rootwad	-1.00			-1.00			0.26	9.22	0.49	1.89

Coho presmolts at the end of winter rearing

Juvenile coho use in natural and hydromodified banks was compared for six different reaches in the Skagit River over four winters, 1993, 1995, 1996 and 1998. Relative abundance of presmolt coho in bank habitat varies by a factor of seventeen (0.06 to 1.04 coho per grid point). The statistical tests compared mean coho per grid point by bank unit types and cover types.

Only two reaches found mean coho per grid point significantly different between bank units. In reach Sk060A, coho abundance was significantly higher in a natural bank (Day Island Bank) than two other natural banks and one hydromodified bank. In contrast, coho abundance in a hydromodified bank was significantly higher than another hydromodified bank, but not two natural banks in reach Sk100. The remaining eight tests were unable to detect a significant difference between the means of coho per grid point by bank unit type. However, the statistical power of these tests was very poor (0.03 to 0.26) so these results do not support the hypothesis that coho abundance in natural and hydromodified banks is the same.

Of the tests comparing cover types, one test found mean coho per grid point was significantly higher (7.8 times) in wood cover than riprap cover. Five other tests were unable to detect a significant difference in coho abundance between wood and riprap cover. Two test found no significant different in coho abundance between cover types that included: wood, rubble, boulder, and cobble. However, the statistical power of these tests was very poor (0.04 to 0.14) so these results do not support the hypothesis that coho abundance in these cover types are the same. Within wood cover types, the one test conducted found no significant difference in coho abundance between debris piles and single logs.

Relative fish utilization for presmolt coho by cover types is shown in Figures 5-1 and 5-2. Coho abundance in wood and riprap cover was usually higher than the reach average (i.e., a positive number) while coho abundance in rubble, cobble and no cover was always less than the reach average (i.e., a negative number). For the wood cover types, rootwads were usually much higher than the reach average while single logs were always negative.

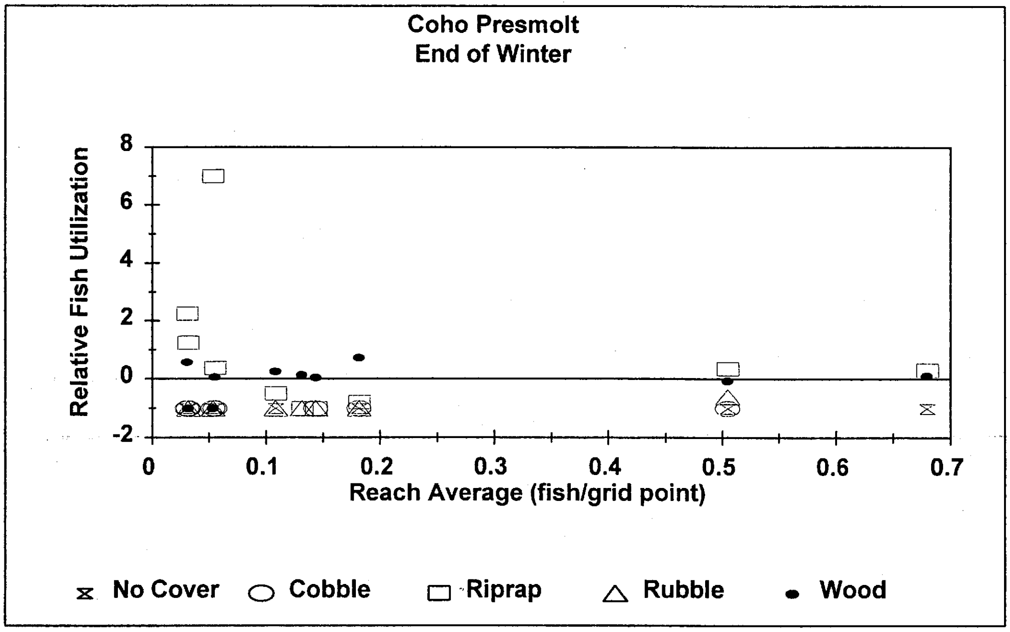

Figure 5-1. Relative utilization of coho presmolts at the end of winter by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

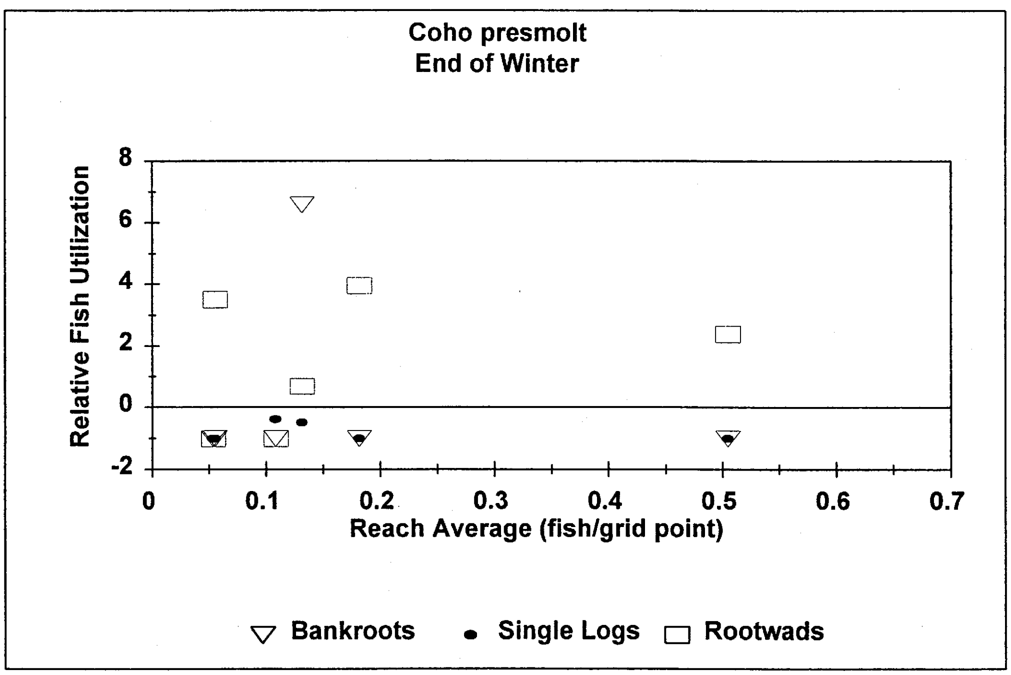

Figure 5-2. Relative utilization of coho presmolts at the end of winter by wood cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

Sub-yearling rainbow at the end of winter rearing

Sub-yearling rainbow use in natural and hydromodified banks was compared in six reaches of the Skagit River over four different winters (1993, 1995, 1996, and 1998). Relative abundance in bank habitat varies by a factor of seventeen (0.06 to 1.04 fish per grid point). The statistical tests compared mean rainbow per grid point by bank unit type and cover type.

Mean rainbow per grid point in five reaches was significantly different between bank units. However there was no trend between bank types. In three reaches, rainbow abundance in a hydromodified bank was significantly higher than a natural bank. In two reaches, natural banks were higher than hydromodified banks. The remaining five tests were unable to detect a significant difference between the means of sub-yearling rainbow per grid point by bank unit type. However, the statistical power of these tests was very poor (0.07 to 0.28) so these results do not support the hypothesis that the abundance of sub-yearling rainbow in natural and hydromodified banks is the same.

Of the tests comparing cover types, two tests found mean rainbow per grid point was significantly higher in riprap cover than wood cover. However, four other tests were unable to detect a significant difference in rainbow abundance between wood and riprap cover. For other cover types, two other test were unable detect a significant difference in abundance between cover types: wood, rubble, cobble, and boulder. However, the statistical power of these tests was also poor (0.05 to 0.46) so these results do not support the hypothesis that the abundance of sub-yearling rainbow in these cover types is the same. Within wood cover types, two test were conducted. One test found rainbow abundance in bankroots to be higher than branches, while the other test found no significant difference in rainbow abundance between debris piles and single logs.

Relative fish utilization for sub-yearling rainbow by cover types is shown in Figures 5-3 and 5-4. Rainbow abundance was generally higher than the reach average in riprap cover (i.e., a positive number) and always lower than the reach average in rubble and no cover types. Rainbow abundance in cobble was usually less than the reach average. For wood cover, rainbow abundance was mixed, but generally higher than the reach average. For different types of wood cover, abundance in rootwads was usually much higher than the reach average while bankroots were usually less than the reach average, and single log cover was mixed.

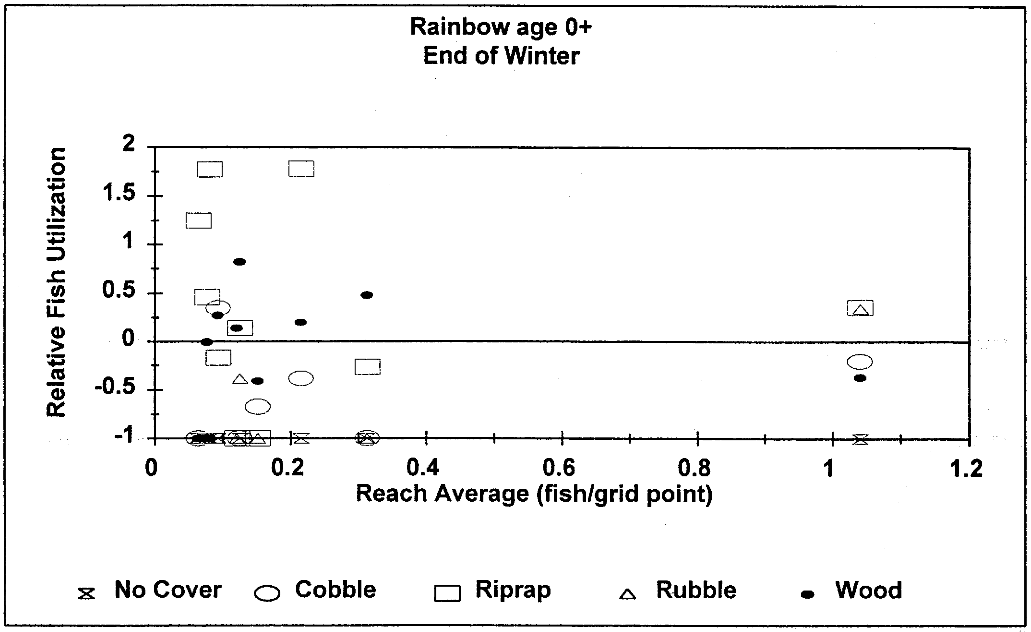

Figure 5-3. Relative utilization of sub-yearling rainbow at the end of winter by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

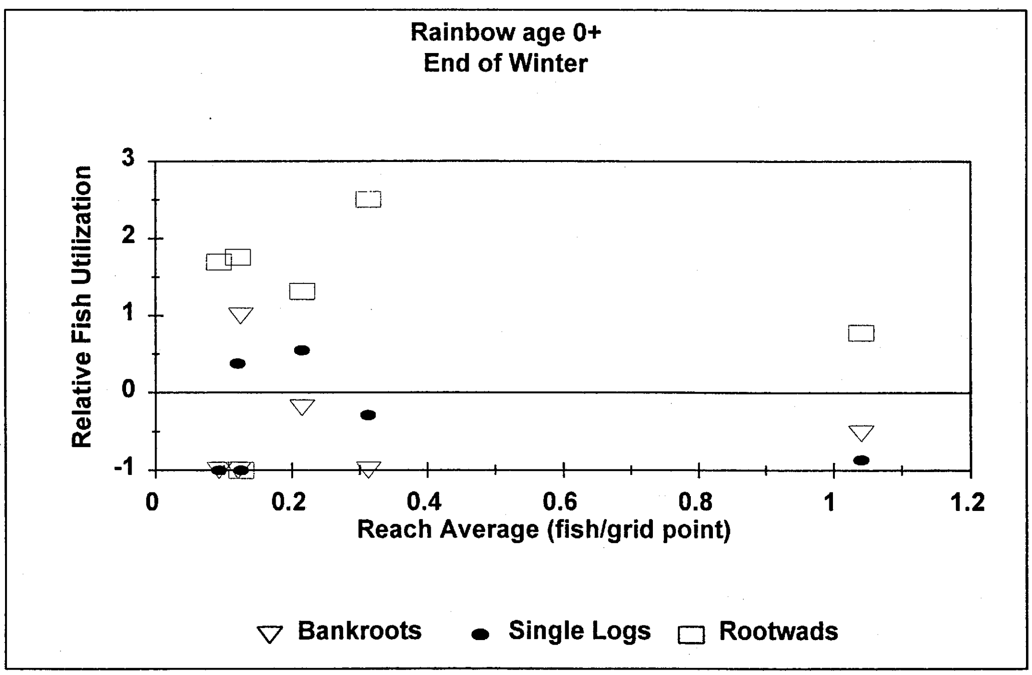

Figure 5-4. Relative utilization of sub-yearling rainbow at the end of winter by wood cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

Rainbow (yearling or older) at the end of winter rearing

Older rainbow (age 1+ or greater) use in natural and hydromodified banks was compared in six reaches of the Skagit River over four different winters (1993, 1995, 1996, and 1998). Relative abundance in bank habitat varies by a factor of twenty-five (0.01 to 0.25 fish per grid point). The statistical tests compared mean rainbow per grid point by bank unit type and cover type.

Only one reach found mean rainbow per grid point significantly different between bank units. In reach Sk100, rainbow abundance was significantly higher in a hydromodified bank (Barnaby Riprap) than a natural bank (Illabot Bank). The remain nine tests were unable to detect a significant difference between the means of rainbow per grid point by bank unit type. However, the statistical power of these tests was poor ($\leq$ 0.32) so these results do not support the hypothesis that the abundance of rainbow (age 1+ or older) in natural and hydromodified banks is the same.

Of the tests comparing cover types, one test found mean rainbow per grid point was significantly higher in riprap cover than boulder, cobble or wood cover. Six other tests were unable to find a significant difference in rainbow abundance between wood and riprap cover while two tests were unable to detect a difference between wood and rubble cover. However, the statistical power of these eight tests was also poor (0.03 to 0.27) so these results do not support the hypothesis that the abundance of rainbow (age 1+ or older) in these cover types is the same. Within wood cover types, the one test conducted found no significant difference in rainbow abundance between debris piles and single logs.

Relative fish utilization for rainbow (age 1+ or older) by cover types is shown in Figures 5-5 and 5-6. Rainbow abundance was generally higher than the reach average in riprap cover (i.e., a positive number) while rainbow abundance was always less than the reach average in the rubble, cobble, and no cover categories. Rainbow abundance in wood cover was mixed, but generally hovered around the reach average. For the wood cover types, rootwads were usually higher than the reach average, while single logs and bankroots were usually less than the reach average.

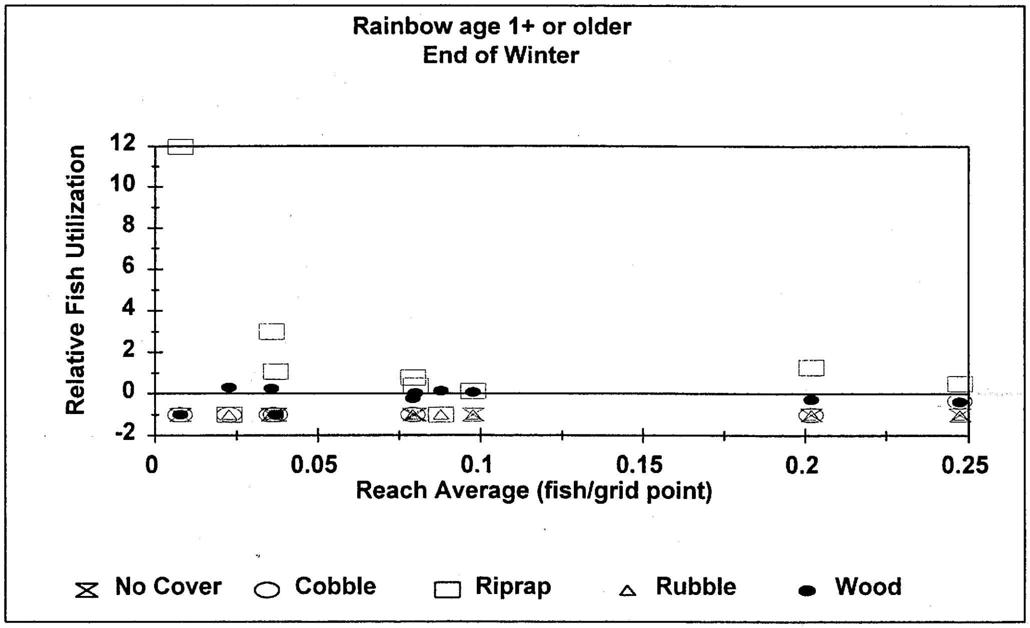

Figure 5-5. Relative utilization of rainbow (yearling or older) at the end of winter by edge cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

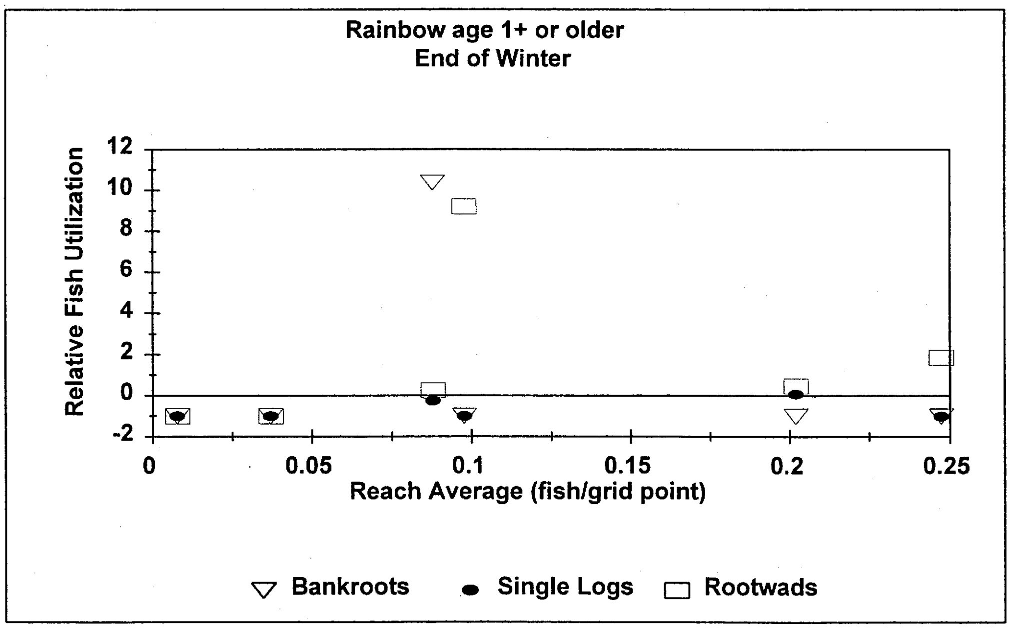

Figure 5-6. Relative utilization of rainbow (yearling or older) at the end of winter by wood cover type in the Skagit River. Negative numbers correspond to fish abundance less than the reach average (-1 is the lowest number possible). Positive numbers correspond to fish abundance greater than the reach average.

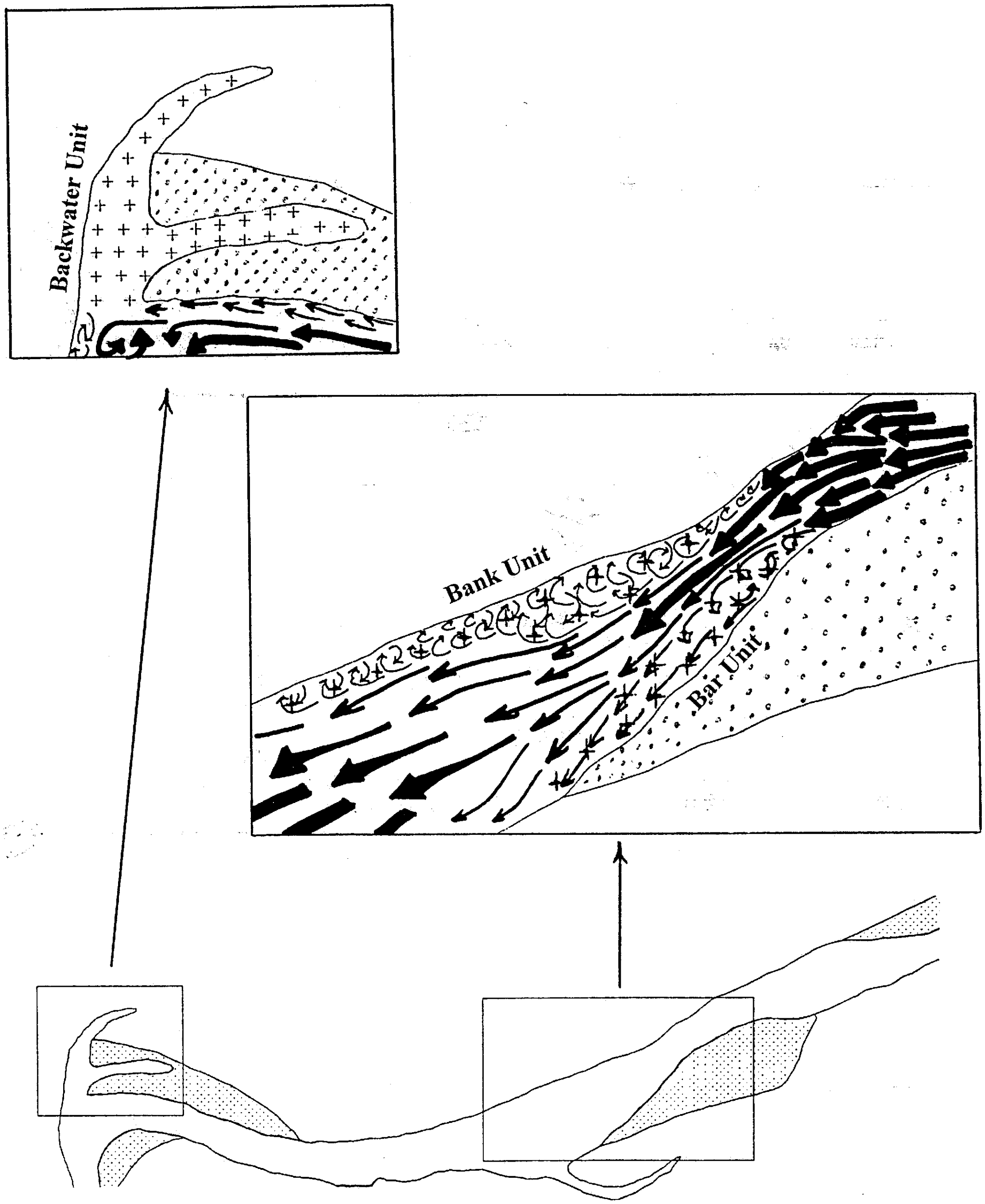

Figure 2. Schematic Top View of Edge Habitat Units for Large Mainstem Habitat.

Arrows represent the direction of current. Larger bold lined arrows represent higher water velocity areas. Smaller light lined arrows represent lower velocity areas.

Grid points [+]

Open Gravel or Sand Bar [⁚]