THESIS

THE EFFECT OF INFORMAL EXTRACTIONS ON FISH SIMULT VARIABLES

Submitted by
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Master of Natural Resources

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In partial fulfillment of the requirements
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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY CARA A. MCCLEER ENTITLED THE EFFECT OF INFORMAL EXTRACTIONS ON FISH SIMULT VARIABLES BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

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ABSTRACT OF THESIS

THE EFFECT OF INFORMAL EXTRACTIONS ON FISH SIMULT VARIABLES

Despite the fullness of debate over that government and private agencies spend on salmon habitat enhancement projects, with salmon numbers in the Columbia Basin. While plenty of money is spent on projects, there is little information on the effectiveness of habitat and salmon conservation efforts. Without an understanding of whether or not projects meet their objective, time and money will continue to be spent without knowing if it is working or not.

Redfish Creek is a 12 km fish bearing stream, in a 5 km fished section, and is evaluated for effects of an illegal Columbia National Forest (Columbia NF), Oregon Forest Service, Cedar Creek, Clackamas Creek, Dark Creek, Fish Creek, Hot Springs Creek, Mill Creek, Nestucca River, Pacific Ocean, Salmon River, Tillamook Bay, Tillamook Forest, Tillamook County, Tillamook Forest Watershed, Tillamook Watershed, Tillamook Watershed Project, Tillamook Watershed Project Area, Tillamook Watershed Project Area Watershed, Tillamook Watershed Project Area Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed Watershed, Tillamook Watershed Project Area Watershed

Abstract

Objective: to determine whether pool frequency, pool depth, pool area, pool volume, and pool connectivity are correlated with habitat variables in reaches that have undergone habitat improvement in full-turbulent variables such as energy dissipation and shear stress. Pool depth and pool area are the most commonly used variables for habitat improvement. Pool volume and pool connectivity are proposed indicators for the first time. Methods: Data were collected from 30 reaches in Cedar Creek, Lake Creek, Deadman Creek, and Clear Creek, British Columbia, Canada. Results: Pool frequency correlates with pool depth (DEP) (Pearson's correlation coefficient = 0.67), pool area (AREA) (0.64), pool volume (VOL) (0.64), pool connectivity (CONN) (0.64), and the mean energy dissipation factor (EDF) (0.64). Pool depth correlates with pool area (0.84), pool volume (0.84), pool connectivity (0.84), and EDF (0.84). Pool area correlates with pool volume (0.99), pool connectivity (0.99), and EDF (0.99). Pool volume correlates with pool connectivity (0.99) and EDF (0.99). Pool connectivity correlates with EDF (0.99). Because pools have been previously correlated with spawning habitat, and because pool frequency, pool depth, pool area, pool volume, and pool connectivity are correlated with EDF, pool habitat improvements should be based on EDF. Because EDF is a measure of full-turbulent energy dissipation, it is a more robust habitat variable than pool depth, pool area, or pool volume. Because pool connectivity is a measure of fish access to pools, it is a more robust habitat variable than pool depth, pool area, or pool volume. Because EDF and pool connectivity are correlated with pool frequency, they are correlated with spawning habitat. Because EDF is a measure of full-turbulent energy dissipation, it is a more robust habitat variable than pool connectivity.

CHAPTER 10
STUDY AREA

Location of the Cedar Creek, Lake Creek, Deadman Creek, and Clear Creek watersheds in the Thompson River watershed, British Columbia, Canada.

The study is focused on six streams within the Cedar Creek watershed, Lake Creek watershed, Deadman Creek watershed, and Clear Creek watershed in the Thompson River watershed, British Columbia, Canada (Figure 10.1). The Cedar Creek, Lake Creek, Deadman Creek, and Clear Creek watersheds are located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Cedar Creek watershed is located in the Kamloops subzone of the IDF (IDFdk) and IDFdk1, which are within the North Thompson Plateau ecosystem (Lloyd et al. 1990).

Six study streams were evaluated: Cannon Creek, Cedar Creek, Deadman Creek, Dutch Creek, Big Bull Creek, and Clear Creek. Cannon Creek, Cedar Creek, and Dutch Creek are tributaries to Cedar Creek, which is a tributary to the Middle Columbia River. Cedar Creek, Lake Creek, Dutch Creek, and Clear Creek are tributaries to the North Thompson River. Deadman Creek is a tributary to the Thompson River. Big Bull Creek is a tributary to Deadman Creek. Cedar Creek (Watershed) and Lake (Watershed) are the IDFdk3. The drainage area of the watershed is 1,000 km2 (Cedar Creek at the "Bridge" at 51° 36' 00.0" and certain other lots: 51 0 00.0" 119.00.0 ±0.0 (Appendix A).

Cedar Creek

The drainage area of the watershed is 1,000 km2 (Cedar Creek at the "Bridge" at 51° 36' 00.0" and certain other lots: 51 0 00.0" 119.00.0 ±0.0 (Appendix A). The watershed is located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Cedar Creek watershed is located in the Kamloops subzone of the IDF (IDFdk) and IDFdk1, which are within the North Thompson Plateau ecosystem (Lloyd et al. 1990).

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Lake Creek

Lake Creek is a tributary to the North Thompson River, which is the largest tributary of the Middle Columbia River. Lake Creek is located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Lake Creek watershed is located in the Kamloops subzone of the IDF (IDFdk) and IDFdk1, which are within the North Thompson Plateau ecosystem (Lloyd et al. 1990).

Six study streams were evaluated: Cannon Creek, Cedar Creek, Deadman Creek, Dutch Creek, Big Bull Creek, and Clear Creek. Cannon Creek, Cedar Creek, and Dutch Creek are tributaries to Cedar Creek, which is a tributary to the Middle Columbia River. Cedar Creek, Lake Creek, Dutch Creek, and Clear Creek are tributaries to the North Thompson River. Deadman Creek is a tributary to the Thompson River. Big Bull Creek is a tributary to Deadman Creek. Cedar Creek (Watershed) and Lake (Watershed) are the IDFdk3. The drainage area of the watershed is 1,000 km2 (Cedar Creek at the "Bridge" at 51° 36' 00.0" and certain other lots: 51 0 00.0" 119.00.0 ±0.0 (Appendix A).

Deadman Creek

Deadman Creek is a tributary to the Thompson River. Deadman Creek is located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Deadman Creek watershed is located in the Kamloops subzone of the IDF (IDFdk) and IDFdk1, which are within the North Thompson Plateau ecosystem (Lloyd et al. 1990).

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Clear Creek

Clear Creek is a tributary to the North Thompson River. Clear Creek is located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Clear Creek watershed is located in the Kamloops subzone of the IDF (IDFdk) and IDFdk1, which are within the North Thompson Plateau ecosystem (Lloyd et al. 1990).

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Cannon Creek

Cannon Creek is a tributary to Cedar Creek. Cannon Creek is located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Cannon Creek watershed is located in the Kamloops subzone of the IDF (IDFdk) and IDFdk1, which are within the North Thompson Plateau ecosystem (Lloyd et al. 1990).

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Dutch Creek

Dutch Creek is a tributary to Cedar Creek. Dutch Creek is located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Dutch Creek watershed is located in the Kamloops subzone of the IDF (IDFdk) and IDFdk1, which are within the North Thompson Plateau ecosystem (Lloyd et al. 1990).

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Big Bull Creek

Big Bull Creek is a tributary to Deadman Creek. Big Bull Creek is located in the Interior Douglas-fir (IDF) biogeoclimatic zone. The Big Bull

average for each week and a random effect for the observations of IFS. These of the post-characteristic variables used in this study were taken from the study by Lamb (1996), in which fish harbour statistics derived from the UFS Regional Council of the Department of Agriculture were analysed. The number of fish per week (= CAT) per vessel width standardised the effect of discharge by dividing the number of parts to the number of days fished (= effort) and the number of days fished per week (= DAYS) per vessel (= VESSEL). The other variables were depth and the average ordered pond depth (the maximum pond depth minus the depth at the pond end (cm) both evaluated changes in pond quality, which is shown to be important in Chesney and Chesney-Lawrence (Pieterse 1995).

The number of pods per vessel width is another measure of pond frequency that is recommended by the PALTEMP model (see Chesney for a review concerning valuable assessments from Indian (McGlamery and Williams 1997, Gilbert and Gill 1998). Percent pond, average pond area and average pond depth are other measures of pond quality and are used in the Chesney-Lawrence (Chesney-Lawrence and Cassell 1996, Bruce and Barnett 1985, Bruce et al. 1985, Hume 1996, Nicholson et al. 1996) and Chesney-Lawrence (Chesney-Lawrence and Cassell 1996) models. Percent of surface area is used to indicate congestion in nucleus with different mean diffie widths. The coefficients of variation for width (= variance/mean) or pond area (= ...

Figure 7. First chart of Step 1 data analysis for determining improvements in submerged fish harbour statistics

Transport/Stream = (stream-stream intercept, V = stream/stream, NS = not significant, S = significant)

Step 2 analysed only the streams in the model; therefore, stream effect and treatment effect were fixed (Figure 8). All the interaction between treatment effect and stream effect were significant (at 5%) and the treatment effect across all streams in the model were all stream. Given that the treatment was significant, then it is valuable to examine the treatment effect with a significant interaction between stream and treatment effect. The stream effect and the treatment effect were significant, then the treatment effect on a stream by stream basis was tested (step 3) (Figure 9). Both these steps only compared treatment reaches to control reaches in the same stream.

Figure 8. First chart of Step 2 and 3 data analysis for determining improvements in submerged fish harbour statistics

Transport/Stream = (stream-stream intercept, V = stream/stream, NS = not significant, S = significant)

Objective 2: Determine whether stream reaches treated with log and boulder weirs meet macroinvertebrate and aquatic habitat criteria for healthy stream reaches (based on habitat characteristics and stream complexity)

Post-treatment variable means for treatment reaches and control stream were compared statistically and agreed defined guidelines scientifically determined and used by agreed target values (Table 4) (Lamb 1996, Lamb 1997, Lamb 1998, Pieterse et al. 1997).

Table 4. Scientifically and agreed Target values for fish habitat variables

Variable	Target	Source
Pools per wetted width	0.0875	Lamb 1997
Pools per wetted width by wetted width		FSC/FDOF
Pool: riffle ratio	0.462	(NZMS 1000 and NZG 1995)
Area	0.048	
Volume	0.048	
Average maximum pool depth (m)	0.0875	Lamb 1997
Average residual pool depth (m)	0.1538	Lamb 1997
Habitat units per wetted width	0.1538	Lamb 1997
Habitat units per wetted width	0.1	Pierce et al. 1997
Pool: riffle ratio	1	Pierce et al. 1997
pool width : depth ratio	< 10	FSC/FDOF
		(NZMS 1000 and NZG 1995)

Five of the target variables, the number of pools per wetted width, the average maximum pool depth, the average residual pool depth, the habitat units per wetted width and the pool: riffle ratio were evaluated and decision of riffle width, were derived from the study by Lamb (1996). He calculated fish habitat variables in stream ranges (stream in stream-stream pairs) for sequence length (pool-pool or riffle-riffle average area between 0 to 10 m and 20 to 100 m) of 10 and 7 m and 0 and 20 m of 5 m. The Mann-Whitney U test, a non-parametric test (Siegel and Castellan 1988) was used to compare treatment reaches to the control reaches. The Mann-Whitney U test was used to compare treatment reaches to the control reaches. The Mann-Whitney U test was used to compare treatment reaches to the control reaches. The Mann-Whitney U test

Table 6. Treatment and control reach means from ANOVA test for treatment versus control for study streams in the Umatilla NF, 1989 to 2000.

Stream	Variable	Treatment	Control	Change	p-value
Camas Creek	pool width : depth ratio	9.5	12	- 2.5	0.0149
Desolation Creek	deep pools / wetted width	0.11	0.033	0.077	0.0001
Desolation Creek	pools / wetted width	0.102	0.052	0.050	0.0134
Desolation Creek	habitat units / wetted width	0.23	0.10	0.13	<0.0001
Desolation Creek	coefficient of variation for riffle width	17%	26%	- 9%	0.0032

ANCOVA and ANOVA tests were also used to determine whether a treatment effect for any of the 11 variables could be detected for streams in general (Step 1), or for the streams in the statistical model (Step 2). No significant results for treatment reaches versus control reaches were found for any of the variables for streams in the Umatilla NF (Step 1) or for streams in the statistical model (Step 2). In addition, only 5 of the 11 variables had a significant covariate: deep pools per wetted width, pools per wetted width, average maximum pool depth, the coefficient of variation for riffle width, and the pool : riffle ratio (Table 7). Using pre-treatment data for each variable as the covariate did not significantly improve the strength of the test. Therefore, ANOVA tests were also used because a model with more streams and no covariate was just as effective as the ANCOVA test.

Table 7. List of variables and p-values associated with the strength of the covariate from the ANCOVA tests (Step 2). Values in bold indicate significance at α = 0.05.

Variable	p-value for covariate
number of deep pools (> 2 ft) / wetted width (ft)	**< 0.0001**
number of pools / wetted width	**0.0012**
average maximum pool depth (ft)	**0.0025**
average residual pool depth (ft)	0.3074
% pools	0.0161
average pool area (ft^2)	0.5568
average pool volume (ft^3)	0.0110
number of habitat units / wetted width (ft)	0.2530
coefficient of variation for riffle widths (%)	**0.0507**
pool : riffle ratio	**0.0077**
pool width : depth ratio	0.8925

Objective 2

Determine whether stream reaches treated with log and boulder weirs meet scientifically and agency-defined target values for fish habitat variables that describe pool characteristics and stream complexity.

Fish habitat variables in treated reaches were compared with the following target values to determine whether reaches treated with ISS resemble healthy streams: the number of deep pools per wetted width, the number of pools per wetted width, the average maximum pool depth, the average residual pool depth, the number of habitat units per wetted width, the standard deviation of riffle width, the pool : riffle ratio, and the pool width : depth ratio (Table 8). All study streams met a least one target value and all streams except Lane Creek met the Lamb target value for the number of deep pools (>2 ft) per wetted width. No stream met the pool : riffle ratio target or the PACFISH target for the number of pools per wetted width.

Table 8.Percent divergence from scientifically and agency-defined target values for fish habitat variables for treated stream reaches in the Umatilla NF, Oregon.

Numbers italicized and in bold are the agency or scientifically defined target values. Underlined numbers in bold indicate that the treatment reaches met or exceeded the target value. A Û indicates that the same reaches prior to treatment had met the target value and that ISS decreased fish habitat. Desolation Creek and Wilson Creek could not be evaluated in this way because no pre-treatment data existed. A positive value shows the percent by which the target was exceeded and a negative value shows how far, in percent, the individual stream is from the target.

	dp/ww	p/ww	pdep	resid.	HU/ww	Srw	p/r	w/d
Target	***0.0075***		***0.68***	***0.51***	***0.13***	***1.4***	***1.0***	***< 10***
		0.501						
Camas	**140**	-1100	Û -31	-15	-71	-16	-200	-5.0
		0.462						
Lane	-55	-1500	-52	-40.3	-120	-110	-1700	**3.9**
		0.608						
Deso	**2700**	-530	**42**	**40.0**	**160**	**4.02**	-420	**0.98**
		0.462						
Ditch	**38**	-730	-67	-51	-58	-110	-340	Û -16
		0.462						
B. Wall	**180**	-900	-25	-9.00	-59	-120	-150	**26**
		0.540						
Wilson	**1300**	-430	**33**	**38**	**67**	**28**	-130	**15**

dp/ww = deep pools (> 2 ft) / wetted width, p/ww = pools / wetted width, pdep = average pool depth (m), resid. = residual pool depth (m), HU/ww = habitat units / wetted width, Srw = standard deviation of riffle width (m), p/r = pool : riffle ratio, w/d = pool width : depth ratio.

Most streams that did not meet or exceed the target value were at least 15% lower than the target value. The exception to this was the average residual pool depth for Big Wall Creek which was only 9% less than the target value of 0.51 m (1.7 ft) and the pool width : depth ratio for Camas Creek which was only 5 % less than the target value of 10.

None of the variables on any of the streams attained the target value as a result of ISS. One of three scenarios occurred 1.) the target value was met prior to treatment, 2.) the target was not met prior to treatment in the treated reaches but showed the same trend (did not meet target prior to treatment but did after treatment) in the control reaches, thus suggesting that the variable increased due to natural conditions, or 3.) the stream could not be evaluated in this way because it did not have pre-treatment data (i.e., Desolation Creek and Wilson Creek).

Many variables on various streams showed a decrease in fish habitat over time because of natural conditions. Again the cause of the reduction in fish habitat is determined by evaluating the trend in the pre- and post-treatment data in both the treated and the control reaches. Therefore, the only variables and streams that no longer resembled reaches that support healthy salmonid populations as a result of ISS (indicated by Û in Table 8) were the average maximum pool depth in Camas Creek and the pool width : depth ratio in Ditch Creek. The treatment reaches in these streams met the targets prior to treatment but not after treatment and the control reaches in these streams did not met the target prior or after treatment. This suggests that there was no substantial change in channel morphology as a result of natural conditions and that the treatment actually degraded stream habitat.

ISS Integrity and Function

Streams in this study all have ISS that are approximately 10 years old, have experienced floods in 1996 greater that the 25-year return interval, have a frequency of at least 10 ISS per treated mile, and have at least two treatment and control reaches (Appendix D). The ISS assessment revealed that less than 12% of the ISS in the study streams were destroyed or buried by floods (Appendix D). The original number of ISS in each stream and the original ISS frequency in the treated reaches is shown in Table 9. The percent functioning and partially functioning ISS for each stream are presented in the last column of Table 9.

Table 9. Results of ISS survival and performance in the Umatilla NF from approximately 1989 to 2000.

Streams	Number of ISS (original)	ISS/mile	Percent Functioning and Partially Functioning ISS	Functioning and Partially Functioning ISS/mi
Camas Ck.	38	10	82	7.6
Lane Ck.	34	21	38	8
Desolation Ck.	241	28	78	21
Ditch Ck.	30	18	80	14
Big Wall Ck.	54	11	91	9.5
Wilson Ck.	176	32	78	25

ISS structures were considered to be functioning if they met the project objective of creating a downstream scour pool that extended the width of the stream. ISS were considered to be functioning if they provided some form of pool habitat such as an upstream pool (dammed pool) or a substantial pocket pool. Greater than 75% of ISS were considered to be functioning or partially functioning in all of the study streams except Lane Creek, where only 38% were functioning. The number of functioning and partially functioning ISS per mile was correlated to the number of target values attained in each stream (Figure 13). The streams with the

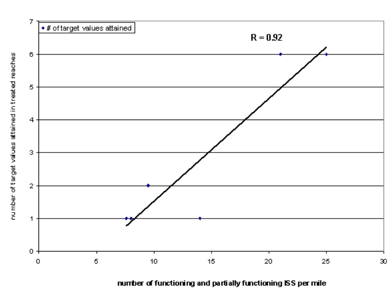

Figure 13. Graph showing the correlation between the number of functioning and partially functioning ISS per mile and the number of target values attained in streams in the Umatilla NF, Oregon between 1997 and 2000.

highest number of functioning and partially functioning ISS per mile (i.e., Desolation Creek and Wilson Creek) met the most target values. Conversely, streams with the lowest frequency of functioning and partially functioning ISS (i.e., Camas Creek, Lane Creek, Ditch Creek and Big Wall Creek) met the fewest target values.

CHAPTER VI

DISCUSSION

This chapter will discuss the results of the data analysis, speculate on potential reasons for the results, and provide suggestions for future restoration. Streams will be individually discussed (Step 3), followed by a discussion of the results from Steps 1 and 2 of the data analysis, which evaluated streams in the Umatilla NF and streams in the statistical model. The streams will then be compared to Taylor's (2000) results. Finally, the main points from all the sections will be combined and the big picture questions will be addressed in the research synthesis section. Conclusions and future research will be discussed in the remaining chapters.

Case Studies

The effectiveness of ISS for improving fish habitat variables was tested by comparing treatment reaches to control reaches in six streams. Although trends in ISS effectiveness could not be detected between streams, ISS were effective in improving some fish habitat variables on a stream-by-stream basis.

Camas Creek

ANCOVA and ANOVA tests did not show significant differences in the number of deep pools (> 2 ft) per wetted width in treated reaches versus control reaches; however, treatment reaches still met the target value. The target value for the number of deep pools per wetted width was attained in the summer of 2000 and not prior to treatment. This suggests that the treatment was successful in meeting management goals. Interestingly, Taylor (2000) found most of the deep pools in Camas Creek below ISS. Her finding supports the results of this study.

ISS improved deep pool habitat on Camas Creek but did not improve average maximum pool depth. In fact, treated reaches had already met the target for the average maximum pool depth prior to treatment, and then failed to meet that target after the ISS treatment. Control reaches met the target before and after the research. According to target value analysis (Objective 2), ISS reduced the average maximum pool depth. In addition, ISS decreased the average pool volume in Camas Creek.

The pool width : depth ratio decreased in reaches treated with ISS. Although the width : depth ratio in the treated reaches in Camas Creek was reduced, these reaches failed to meet the PACFISH target value. Fausch and Northcote (1992) found bankfull width : depth ratios to be negatively correlated to LWD frequencies. Taylor (2000) determined that both small and large LWD frequencies in a treated reach of Camas Creek were below the Lamb (1996) target values (Appendix G). There are many human impacts associated with large width : depth ratios such as logging, farming and grazing (Platts 1991, Ralph et al. 1994). All of these impacts occur or have occurred in the Camas Creek watershed and may contribute to increased width : depth ratios.

Camas Creek met only one target value and is considered to be in poor condition. Restoration efforts should focus on decreasing the width : depth ratio which, may in turn, increase the average maximum pool depth. Installing riparian fencing and revegetating stream banks are suggested as restoration strategies for unnaturally wide channels (Beschta et al. 1991)

Lane Creek

The average maximum pool depth significantly increased in treated reaches in Lane Creek but failed to meet the target defined by Lamb (1996) for streams in the Umatilla NF. Therefore, ISS increased pool depth in Lane Creek but pools in treated reaches remain too shallow to resemble pools in reaches that support healthy salmonid populations. The only target value attained in treated reaches was the pool width : depth and it was met prior to treatment. Because only one target value was attained the quality of fish habitat in Lane Creek is considered poor.

The low frequency of functioning ISS may be contributed to the minimum amount of change in fish habitat. Although Lane Creek had a high frequency of ISS, less than 40% of these were functioning or partially functioning which may not have been adequate to influence channel morphology. Because the frequency of functioning and partially functioning ISS is correlated to the number of target values attained, maintenance of existing ISS may improve fish habtiat.

The Taylor study (2000) determined that large LWD is lacking in the treated section of Lane Creek but small LWD exceeded the Lamb (1996) target value (Appendix G). It appears that a lack of LWD in Lane Creek is not a big problem and that restoration approaches, other than adding material to the stream, should be considered.

Desolation Creek

The largest number of fish habitat variables that statistically increased in treated reaches occurred in Desolation Creek. Also, besides Wilson Creek, treated reaches of Desolation Creek had the most fish habitat variables that met scientifically and agency-defined target. The number of deep pools per wetted width and the number of habitat units per wetted width increased in treated reaches and attained the Lamb (1996) target values. The coefficient of variation for riffle width, which was used to standardize the standard deviation of riffle width data, was statistically decreased; however, it was not reduced enough to change the quality of the habitat because the standard deviation of riffle width still met the target.

In addition, the average maximum pool depth, the average residual pool depth and the pool width : depth ratio in treated reaches in Desolation Creek all met the target value (Objective 2). The number of pools per wetted width increased but still did not attain the PACFISH (USDA and USDI 1995) target value. Although six target values were met on Desolation Creek, there are no pre-treatment data to confirm for the target value analysis whether the ISS improved the habitat or whether the habitat was in good condition prior to treatment.

Desolation Creek had the most ISS and one of the largest frequencies of functioning and partially functioning ISS. In addition, the Taylor study (2000) found that a treated reach (drainage area <100 km^2) in Desolation Creek met the Lamb (1996) target value for the number of small LWD pieces per mile (Appendix G). The excellent condition of fish habitat on Desolation Creek may have been influenced by the intensity and durability of the treatment. Studies on the population and distribution of fish in Desolation Creek would further enhance this assessment. No further restoration, just morphological and biological monitoring, is recommended on the mainstem of Desolation Creek.

Ditch Creek

The number of pools per wetted width increased in treated reaches of Ditch Creek but did not met the PACFISH (USDA and USDI 1995) target value. Conversely, the number of deep pools per wetted width did not statistically increase in treated reaches, but those reaches resembled reaches that support healthy salmonid populations because they met the Lamb (1996) target value. The pool width : depth ratio met the PACFISH (USDA and USDI 1995) target values in treatment reaches prior to treatment but not after treatment. Because there was no change in the target value status for the control reaches over time, it appears that ISS actually reduced stream complexity by increasing the pool width : depth ratio in Ditch Creek.

Ditch Creek has a moderate frequency of functioning and partially functioning ISS. Ditch Creek, as well as Camas Creek and Lane Creek, is in the poorest condition because it only attained one target value and actually lost stream complexity. Studies have shown LWD to be correlated with stream complexity (Montgomery et al. 1995, Ralph et al. 1994). A qualitative assessment of LWD in Ditch Creek indicated that large LWD are below the PACFISH (USDA and USDI 1995) target value of greater than 20 pieces per mile. Restoration efforts focused on increasing LWD might increase stream complexity

Big Wall Creek

The ANCOVA and ANOVA tests for differences in treated reaches versus control reaches showed no significant treatment effects. The target values for the number of deep pools per wetted width and the pool width : depth ratio continued to be attained, as they had been met prior to treatment. Therefore, ISS in Big Wall Creek had no effect on fish habitat.

Big Wall Creek is still in fair condition and should be a priority for stream restoration. It is possible that the low frequency of ISS was not high enough to impact fish habitat. In addition, Taylor (2000) found that both small and large LWD in a treated reach of Big Wall Creek were below the Lamb (1996) target values (Appendix G). Improvement efforts should focus on restoring watershed processes; however, other watershed and channel variables such as sediment input, bank stability and vegetation should be assessed before making a management decision.

Wilson Creek

The effect of ISS on fish habitat variables could not be assessed in Wilson Creek because the entire stream was treated and there were no control reaches (Objective 1). In fact, Wilson Creek had the highest ISS frequency (32 ISS / mile) and over 75% of the ISS were functioning or partially functioning after 10 years. No pre-treatment data were collected so it was impossible to determine whether target values were met as a result of ISS. Therefore, only the current condition of fish habitat in Wilson Creek was assessed.

Wilson Creek, along with Desolation Creek, met the most target values. Both streams met the target values for the following variables: the number of deep pools per wetted width, the average maximum pool depth, the average residual pool depth, the number of habitat units per wetted width, the standard deviation of riffle width, and the pool width : depth ratio. Also, Taylor (2000) found that residual pool depth at ISS was

significantly greater than residual pool depth in pools without ISS. The target value analysis showed that for the variables in this study, Wilson Creek is in excellent condition.

A qualitative assessment of the stream survey data for the number of large LWD pieces per mile indicated that Wilson Creek is above the PACFISH guideline (Appendix G). However, Taylor (2000) found that a treated reach on Wilson Creek did not meet the PACFISH (USDA and USDI 1995) or the Lamb (1996) target value for the large LWD frequency or the Lamb (1996) target value for the small LWD frequency. The discrepancy in the results again shows the effect of spatial variability and the inaccuracy of a qualitative measurement. Future monitoring of fish populations and distribution, vegetation, bank stability, stream temperature, LWD and other morphological variables is recommended.

Streams in the Umatilla NF and streams in the statistical model

No significant treatment effects were found for streams, in general, or for streams in the statistical model (Step 1 and 2). Therefore, there was no significant ISS effect on fish habitat variables for streams in the Umatilla or for the six study streams.

Watershed variables such as stream type, confinement, geology, vegetation and drainage area strongly influence the morphology of the stream, and thus may affect the response of ISS (Schumm 1979). Because only six streams were used in this study, it was impossible to statistically evaluate ISS response to watershed variables. The pre-treatment data were used as the covariate to account for the different watershed and channel variables that existed prior to treatment. However, this covariate was not very strong and could not account for all the variability. Ideally, a larger data set should be used and stratified by various watershed variables or adjusted by using the watershed variables as covariates.

Statistical power for the 11 variables evaluated in ANCOVA and ANOVA tests was low. Only three variables, average maximum pool depth, average pool volume and the pool width : depth ratio, had a greater than 50% chance of finding a 10% difference in the treatment reach mean and the control reach mean. This again suggests that a larger sample size could reduce the variability in the estimates.

In addition, the assumption used in this study, that the measured fish habitat variables reflect ecologically significant changes over time, may be false (Poole et al. 1997). Although Lamb (1996) found the number of deep pools per wetted width, the average maximum pool depth, the average residual pool depth, the number of habitat units per wetted width and the standard deviation of riffle width to be significantly different in reaches supporting healthy salmonid populations versus reaches with less-healthy populations, those variables may not be sensitive enough to show change in treatment reaches versus control reaches. Likewise, the remaining six variables used in this study have not been proven to show significant differences in treatment reaches versus control reaches.

It is possible that ISS have changed fish habitat but that the method of measuring these changes or the variables used to reflect these changes are not sensitive enough to show the change (Poole et al. 1997). Some possible reasons why the data may not be sensitive are: 1.) the habitat unit classification is subjective and the measurement of

habitat units maybe inaccurate, 2.) the time scale used to measure changes in channel morphology may be too short, and 3.) the response variables used in this study may be overwhelmed by the effects of other variables.

Comparison to Taylor's Study of ISS Effectiveness

It is interesting to compare this study to Taylor's (2000) study because she evaluated the same streams, except Ditch Creek. She evaluated 13 streams in the Umatilla NF and compared stream characteristics in habitat units upstream and downstream of individual ISS to habitat units without ISS. Taylor examined residual pool depth downstream of ISS, average wetted stream width upstream and downstream of ISS, percent bank erosion upstream and downstream of ISS, and percent bank vegetation upstream and downstream of ISS (Table 10).

Table 10. Results for study streams from Taylor's (2000) comparison of Umatilla NF stream characteristics in habitat units adjacent to ISS to the same characteristics in habitat units without ISS.

Ù = variable was larger in habitat unit adjacent to ISS, Ú = variable was less in habitat unit adjacent to ISS, d/s = habitat unit downstream of ISS, u/s = habitat unit upstream of ISS.

Streams	residual pool depth (m)	wetted width of habitat unit (m)	% bank erosion	% bank vegetation
Camas				Ú d/s
Lane				
Desolation				
Big Wall	Ùd/s			
Wilson	Ù d/s			

Taylor concluded that residual pool depth increased immediately downstream of ISS in Big Wall Creek and Wilson Creek. In Camas Creek, she found that the percent bank vegetation decreased in habitat units immediately downstream of ISS. According to Taylor, none of the streams used in this research showed any sign of bank erosion or widening in habitat units adjacent to ISS.

Taylor also compared a treated reach from each of the 13 study streams to scientifically and agency-defined target values. Table 11 compares Taylor's results to

Table 11. Comparison of results for scientifically and agency-defined target values evaluated in the present study and in the Taylor's study (2000).

M = target value was met in the present study, T = target value was met in the Taylor study.

Streams	dp/ww (Lamb)	pools/ww (PACFISH)	pdep (Lamb)	resid. (Lamb)	HU/ww (Lamb)	w : d (PACFISH)
Camas	M		T	T	T	
Lane	T		T		T	M
Desolation	**T, M**		**T, M**	M	**T, M**	M
Big Wall	**T, M**				T	M
Wilson	**T, M**		M	M	**T, M**	M

dp/ww = deep pools per wetted width, pools/ww = pools per wetted width, pdep = average maximum pool depth, resid. = average residual pool depth, HU/ww = habitat units per wetted width, w : d = pool width : depth ratio

width, the average maximum pool depth, and the number of habitat units per wetted

results for streams in the present study. The target values for the number of deep pools per wetted width in Desolation Creek, Big Wall Creek and Wilson Creek , the target value for the average maximum pool depth in Desolation Creek, and the target values for the number of habitat units per wetted width in Desolation Creek and Wilson Creek were met in both the Taylor study and the present study.

There were many discrepancies between the two studies that are most likely a result of spatial variability. The Taylor study (2000) only compared one treated reach within each stream to the target value; therefore, in some cases, the location of the reach determined whether the target value was met. The present research examined multiple treated reaches in each stream to attain a mean for the stream. In addition, in the present study a standard error was calculated and subtracted from the mean to correct for measurement error. The mean minus the standard error was compared to scientifically and agency-defined target values to determine whether treated reaches in streams were meeting or exceeding the targets. Target value results for the present study can be considered more comprehensive than the Taylor study on a streamwide basis because the present study used a replicated design and accounted for measurement error.

Research Synthesis

Considering the number of variables and reaches evaluated, ISS had little positive effect on fish habitat variables in the study streams. Nevertheless, some improvements in pool frequency, pool depth, and stream complexity (i.e., the number of habitat units per wetted width and the pool width : depth ratio) were seen on a stream-by-stream basis. The only fish habitat variables that were significantly decreased on a stream-by-stream basis by ISS were average pool volume and the coefficient of variation for riffle width (Table 5).

Desolation Creek and Wilson Creek are considered to be in the best condition because they met the most target values (6 each, Table 8). Interestingly, these two streams had the most ISS and ISS frequency was found to be correlated to the number of target values attained (Figure 13). Camas Creek, Lane Creek, and Ditch Creek met only one target value and are considered to be in the poorest condition and good candidates for habitat restoration.

It is difficult to determine why fish habitat variables improved in some streams and not others. Most likely, as Taylor (2000) and Lamb (1996) found, watershed variables, including present and historic landuse, largely influence geomorphic response. In addition, many studies have found LWD to be correlated with pools and stream complexity (Montgomery et al. 1995, Ralph et al. 1994, Fausch and Northcote 1992). This study only evaluated LWD qualitatively because the data collected in the stream survey were too subjective for statistical analysis but it appears in this analysis and in the Taylor (2000) analysis that the amount of LWD in the system affects the overall quality of the fish habitat.

CHAPTER VII

CONCLUSIONS

There was no general ISS effect on channel morphology for the streams in this study. Therefore, the effectiveness of ISS cannot be predicted for streams in the Umatilla NF. On a stream-by-stream basis the ISS were effective in improving some fish habitat variables. Although ISS in all study streams, except Lane Creek, met the USFS objective of creating pools, very few variables in each stream showed an improvement in fish habitat.

In Camas Creek, Lane Creek, Desolation Creek and Ditch Creek there was a treatment effect for at least one of the following variables: the number of deep pools per wetted width, the number of pools per wetted width, the average pool depth, the average pool volume, the number of habitat units per wetted width, the coefficient of variation for riffle width, and the pool width : depth ratio. There was no treatment effect for residual pool depth, % pools, the average pool area, and the pool : riffle ratio. In Camas Creek, the average pool volume and the average maximum pool depth actually decreased as a result of ISS, as did the coefficient of variation for riffle width in Desolation Creek.

All streams met at least one target value but not necessarily as a result of ISS. In fact, the only target values attained as a result of ISS were the number of deep pools per wetted width and the number of habitat units per wetted width in Desolation Creek.

Although the quality of the fish habitat prior to treatment could not be assessed for Desolation Creek, the ANOVA test showed that ISS increased the number of deep pools per wetted width and the number of habitat units per wetted width in treated reaches of Desolation Creek. Therefore, ISS structures are

contributing to the current good quality Yaquina Bay and Bonaventure Creek described in the target value table.

Most of the results come from the target value for the pair - offer units on the PNA/PDA/LDA and GNO/ GNO 1999 guidelines for the number of pairs per unit surveyed under 100%. This result is not surprising because there are many factors that affect the number of pairs per unit surveyed. For example, the target value for Pelican at GNO/ Beach indicates on the South Beach Salmon River with a low pair - offer units of 1.4 - 1 while the current value is 0.0 - 0 because no pairs were found. Pelican pairs are known to nest on this site - offer units are supposed large unforeseen fish strandings crops. This shows that the pair - offer units might be the a good measure of fish stocks.

Likewise, the PNA/PDA guidelines for the number of pairs per unit surveyed scale is influenced by many factors. Pelican pairs are known to nest on Bonaventure Creek - offer units are supposed large unforeseen fish strandings crops. Pelican pairs are known to nest on Yaquina Bay - offer units are supposed large unforeseen fish strandings crops. Pelican pairs are known to nest on Yaquina Bay - offer units are supposed large unforeseen fish strandings crops. Pelican pairs are known to nest on Bonaventure Creek

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