The Lower East Fork Lewis River Subbasin: A Summary of Habitat Conditions, Salmonid Distribution, and Smolt Production

Photo courtesy of American Rivers

Project No. 99-1113P
June 2001

Washington Department of FISH AND WILDLIFE

The Lower East Fork Lewis River Subbasin: A Summary of Habitat Conditions, Salmonid Distribution, and Smolt Production

WDFW Contract to the Lower Columbia Fish Recovery Board #33000422 (HAB) & #33000424 (FISH)

Prepared by:

Dan Rawding[1]
Ned Pittman[2]
Christopher Stearns[2]
Steven VanderPloeg[1]
Brian McTeague[2]

Abstract

Two rotary screw traps were installed in the mainstem of the EF Lewis River near the mouth of Mason Creek (RM 7) and below Lucia Falls (RM 21) to estimate natural salmonid smolt production in the spring of 2000. Chinook salmon, chum salmon, coho salmon, steelhead, and cutthroat smolts were collected at the lower trap. The smolt catch at the upper trap was composed of mostly steelhead, with a few cutthroat, supporting the contention that the only anadromous salmonid ascending Lucia Falls in substantial numbers are steelhead. A Petersen estimator was used to develop smolt yield using trap efficiencies to estimate spring juvenile population estimates for these reaches. The wild steelhead smolt yield was 12,481 for the area above Lucia Falls and 27,097 for the area above the lower trap. Estimates for coho salmon, chum salmon, and sea-run cutthroat trout above the lower trap were 5,716, 2,060, and 1,068 respectively. One method of examining the salmonid habitat quality on the EF Lewis River is to compare the historic or expected number of salmon and steelhead based on habitat models with the observed fish abundance from this project. Habitat quality can be inferred from distribution of the species in the watershed. The preferred historical habitat for chum salmon occurred in the mainstem below Daybreak Park. Since the current chum salmon abundance is only 1% of historic abundance, the habitat in this reach can be classified as severely degraded. Coho salmon and sea-run cutthroat trout primarily utilize small tributaries for spawning and rearing, including McCormick, Breezee, Lockwood, Mason, Mill, lower Rock, and other unnamed tributaries below Lucia Falls. Coho salmon are believed to be at less than 32% of modeled production for good habitat. Therefore, the lower tributary habitat would be classified as substantially degraded. Steelhead are the most broadly distributed anadromous fish in the EF Lewis River basin and redds have been observed in the mainstem from RM 7 to the headwaters. However, steelhead tend to spawn and rear in the middle to upper reaches of the basin and larger tributaries such as Green Fork and upper Rock Creek. The measured steelhead production was similar to the average estimated production in western Washington in the 1980's. Therefore, the habitat in the middle and upper basin would be classified as slightly to moderately degraded.

Available habitat information was gathered and summarized across the following categories: access, floodplain connectivity, bank stability, large woody debris (LWD), pools, side channels, substrate fines, riparian conditions, water quality, water quantity, and biological processes. Additionally, the Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) methodology was utilized to summarize aquatic habitat by type and gradient/confinement. Anadromous species are limited (mostly) to lower gradient reaches of the system resulting in a large portion of the small tributary habitat being inaccessible and unused by these fish. This investigation suggested that salmonid habitat has been severely degraded within the lower

East Fork Lewis River subbasin. Access to migrating salmonids has been limited due to human activities within approximately 67% of East Fork Lewis River tributaries resulting in a significant loss of available habitat. Alteration of the channel from a multi-thread configuration to a single thread has significantly reduced winter rearing habitat for coho salmon and spawning habitat for chum salmon. A subbasin-wide lack of LWD has resulted in low pool quality and frequency. Avulsions to abandoned gravel pits within the floodplain have replaced high quality chinook spawning habitat with large deep pools that provide habitat more suitable for exotic species that have been introduced within the subbasin. Water quality and quantity has been impaired due to several factors including; high road density, gravel mining, agriculture, and timber harvest. Bank stability has been defined as a source of excessive fine sediments in several areas with such things as lack of riparian vegetation and channel stabilization projects identified as the source of these problems. Biological processes seem to be drastically altered within the subbasin as estimation of the number of coho salmon required to meet the nutritional needs of the stream is approximately 87.5% greater than the largest known run size.

Salmonid distribution was mapped on a SSHIAP hydrolayer using the Washington Conservation Commission (WCC) Limiting Factors Analysis (LFA) data generated in year 2000. Fish passage barrier layers used for mapping include: WDFW SSHEAR database of fish passage barriers, StreamNet, DNR fish passage barriers, DOE dams data, and an enhanced layer created by SSHIAP for the anadromous zone.

Short-term habitat restoration projects should focus on maintaining and improving chum salmon populations through the construction of off-channel spawning areas in the lower mainstem. Coho salmon restoration activities for the short-term should focus on activities that create slow water off-channel rearing areas in the mainstem, and work in the tributaries should include removing blockages, reducing water temperatures, maintaining summer flows, and creating slow water habitat. The steelhead populations are in relatively good shape compared to the salmonids mentioned above. The lower tributary coho projects will benefit sea-run cutthroat and steelhead as well because their habitats often overlap in these small systems. Nutrient enhancement would benefit all species. Long-term restoration activities are needed to maintain populations. These activities should address ecosystem function and begin in the headwaters. Projects should focus on restoring the historic hydrograph, sediment transport, riparian and floodplain function, water quality, and water quantity, to create the historic habitat diversity required by salmonids. Specific projects that meet these needs include: decommissioning roads so densities are less than 2 miles per square mile to reduce sediment transport and peak flows; riparian plantings and fencing to improve shade, large woody debris recruitment, and bank stability; removal of dikes and development of historic overflow channels to restore floodplain connectivity and create habitat diversity; and upland management in all sub basins to keep maximize hydrologic maturity.

[1] Washington Department of Fish and Wildlife, Fish Management Program, 600 Capitol Way North, Olympia, WA 98501-1091. Phone and e-mail for Dan: (360) 906-6747; rawdidr@dfw.wa.gov. Phone and e-mail for Steven (currently Habitat Division): (360) 906-6720; vandesmv@dfw.wa.gov.

[2] Washington Department of Fish and Wildlife, Habitat Division, 600 Capitol Way North, Olympia, WA 98501-1091. Phone and e-mail for Ned: (360) 902-2568; pittmnrp@dfw.wa.gov. Phone and e-mail for Christopher: (360) 906-6757; stearcls@dfw.wa.gov. Phone and e-mail for Brian: (360) 902-2771; mcteabjm@dfw.wa.gov.

Table of Contents:

Suggested Citation:

Rawding, D., N. Pittman, C. Stearns, S. VanderPloeg, and B. McTeague. 2001. The lower East Fork Lewis River subbasin: a summary of habitat conditions, salmonid distribution, and smolt production. Prepared *by* the WA Dept. of Fish and Wildlife Fish Management and Habitat Science Programs *for* the Lower Columbia Fish Recovery Board. Project No. 99-1113P. WA Dept. of Fish and Wildlife, Olympia.

THE RELATIONSHIP BETWEEN THE 2000 JUVENILE SALMON AND STEELHEAD SMOLTS YIELD AND SALMONID HABITAT IN THE EAST FORK LEWIS RIVER

2000 Annual Report

May 2001

Prepared by:

Dan Rawding
Steven VanderPloeg

Washington Department of Fish and Wildlife
Fish Management Program
600 Capitol Way
Olympia, WA 98195

Introduction

Historically, the EF Lewis River was one of the most productive salmonid watersheds in southwest Washington supporting summer and winter steelhead (*Oncorhynchus mykiss*), rainbow trout, fall chinook (*Oncorhynchus tshawytscha*), chum salmon (*Oncorhynchus keta*), coho salmon (*Oncorhynchus kisutch*), and coastal cutthroat trout (*Oncorhynchus clarki*). A series of falls are present on the EF Lewis River beginning with Lucia Falls at RM 21, which is a barrier for all anadromous salmonids except steelhead. After Moulton Falls at RM 25 is Horseshoe Falls (RM 30), which is a partial to complete barrier for winter steelhead depending on the water year. Finally, there is Sunset Falls at RM 33, which was notched to improve summer steelhead passage in the 1980's. It is believed that Sunset Falls represents a barrier for all species except summer steelhead. Larger steelhead were once abundant on this river and a state record, 32 lbs. 12 oz., winter steelhead was caught from the EF Lewis River. Complete counts of adult anadromous salmonids are not available but index counts are available for fall chinook, winter steelhead, and summer steelhead. Due to declining abundance in index reaches, genetic and ecological risks from hatchery fish, loss of productivity and capacity from degraded habitat, and the potential of overharvest, the National Marine Fisheries Service (NMFS) listed EF Lewis River chinook salmon, chum salmon, and steelhead under the Endangered Species Act (ESA) in 1998 and 1999. In addition, NMFS proposed to list coastal cutthroat trout and has listed coho salmon as a candidate species under ESA.

Although WDFW adult counts show a negative trend in steelhead abundance, these data are not sufficient to indicate the cause for the decline. Wild salmonids typically spend up to three years as juveniles in freshwater and two or three years in the ocean. Cooper and Johnson (1992) indicated that the decline in steelhead abundance for Washington steelhead in 1988-89 was due to low ocean productivity. Nehlsen et al. (1991) and the Independent Science Group (ISG 1996) indicated that the declines in Columbia River salmon and steelhead are largely due to habitat losses. Therefore, separate estimates of smolts and adults are needed to determine if changes in freshwater or ocean conditions are responsible for the change in wild salmon abundance. The objectives for 2000 were to develop annual estimates of juvenile salmonid production for the EF Lewis River basin and the area above Lucia Falls, and to collect juvenile steelhead life history information during the outmigration. This data will be used to help determine factors for decline, develop a watershed recovery plan based on a science-based assessment, and to determine if watershed restoration activities are effective at recovering steelhead. This was the initial year of this project.

Study Area

The EF Lewis River is located near Vancouver, Washington. This fifth order stream drains 212 square miles and enters the mainstem Lewis River at RM 3. The Lewis River enters the Columbia River below Vancouver, Washington at River Mile RM 87. The watershed provides habitat for the salmonids listed above, mountain whitefish (*Prosopium williamsoni*), lamprey (*Lampetra spp*) suckers (*Catastomas spp*), sculpins (*Cottus spp*) stickleback (*Gasterosteus aculeatus*), peamouth (*Mylocheils caurins*), reside shiner (*Richardsontius balteatus*), leopard dace (*Rhinichthys falcatus*), northern pikeminnow (*Ptychocheilus oregonensis*), and smallmouth bass (*Micropterus dolomieui*). The upper portion of the watershed, above Sunset Falls lies within the Gifford Pinchot National Forest. The President's Forest Plan categorizes this basin as a "Tier 1, key watershed" that provides habitat for anadromous salmonids. The USFS manages 32 % the watershed for multi-use benefits. The lower portion the EF Lewis River basin consists of non-federal lands managed for timber harvest, residential development, agriculture, gravel mining, and recreation.

Methods

Fish Capture

Prior to the start of the smolt outmigration, two rotary screw traps were installed in early April. The traps were fished until the end of the smolt migration in mid-June. A trap with 5-foot diameter cone was located in the middle EF Lewis River below Lucia Falls at RM 21. The trap in the lower EF Lewis River at RM 7, just upstream of the Mason Creek mouth, had a larger 8-foot diameter cone. Trap locations were chosen based on the objectives listed above. The lower EF Lewis River site was located just below the first spawning sites to determine smolt yield for the entire basin. Site selection was based on access, suitable anchor sites, and stream conditions that produce acceptable trap efficiencies. The traps were fished near the head of a pool, just below a narrow section of fast turbulent flowing water when available. Traps were positioned so that stream flow entered in a straight line. We generally tried to fish in water velocities greater than 1.5 meter/second producing cone revolutions of greater than 6 revolutions per minute (rpm) on the 5 ft. traps and greater than 4 rpm on the 8 ft. traps.

All traps were fished 24 hours/day throughout the smolt outmigration period. A total of 6 days of fishing time was lost at the Lucia Falls trap due to logs in the trap and mechanical malfunction. At the lower trap site, a total of 8 days was lost due to debris in the trap, and mechanical malfunction. Traps were checked daily in the morning; fish were removed from the live well and placed into aerated coolers. Salmonid juveniles were sorted by species composition and life history stage. Wild salmonids were classified as parr, pre-smolt, or smolt. The criteria for parr included well-developed parr marks and heavy spotting across the dorsal surface. Pre-smolts were those fish that had faint parr marks, less prominent dorsal spotting, silvery appearance, and no dark caudal fin margin. Smolts consisted of those salmonids with deciduous scales, silver appearance, and a dark band on the outer margin of the caudal fin. Since smoltification is a process that steelhead undergo along their downstream migration and these EF Lewis River steelhead are more than 90 miles from the ocean, we felt it necessary to classify fish as pre-smolts. For smolt production estimates, smolts and presmolts were pooled. In all cases, captured juveniles were anesthetized with MS-222 (~ 40 mg/l) before handling, sampled as quickly as possible and were allowed to recover fully before being released into the river. Fork lengths (mm) were obtained on pre-smolts and smolts. Others fish species were identified and enumerated. Water temperatures were recorded at all trap sites. Stream discharge was obtained from USGS stream gauge stations on the EF Lewis River (RM 19) at Heisson.

Juvenile Production Estimates

The number of juvenile outmigrants was estimated by using a trap efficiency method of releasing marked fish upstream of the trap (Thedinga et al. 1994). Captured juvenile steelhead were marked with a Panjet inoculator (Hart and Pitcher 1969). Our marking schedule rotated every week and used different fin combinations to distinguish between traps. This allowed us to identify fish based on trap site and marking period. Trap efficiency is estimated using a modification to the Petersen estimate from the equation:

$$e = (R+1)/(M+1) \qquad (1)$$

where e is the estimated trap efficiency, M is the number of marked fish released upstream of the trap, and R is the number of marked fish recaptured. The number of migrants at each trap was determined from the equation:

$N = U/e$ (2)

where N is the estimated number of outmigrants, U is the total unmarked catch, and e is the trap efficiency. The variance for each N was determined by a bootstrapping method (Efron and Tibshirani 1986) with 1,000 iterations from a Fortran program (Murphy et al. 1996). Confidence limits were calculated from the equation:

95% CL = 1.96 */V (3)

where V is the variance determined from bootstrapping.

A series of Chi Square tests were performed to determine if there was a statistical difference between mark groups. If no difference was noted between adjacent mark periods, groups were further pooled. When the significant differences between adjacent mark periods were noted, then samples taken in that period could not be pooled and trap efficiency estimates, population estimates, and variances were individually calculated for the mark period. At the lower trap we had marks available from that trap and the upriver trap. First, we performed a Chi Square test to detect seasonal differences between traps. If there were no significant differences then marks from all traps would be pooled and another Chi Square test on mark groups was conducted. If there was no difference between adjacent mark periods, groups were pooled to tighten the confidence limits. When the differences were significant, trap efficiency estimates, population estimates, and variances were calculated for the mark period by trap.

Murphy et al. (1996) listed the standard assumptions of the Petersen method (Seber 1982) that apply in trap efficiency experiments: (1) the population is closed; (2) all fish have the same probability of capture in the first sample; (3) marking does not affect catchability; (4) the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly; (5) fish do not lose their marks; and (6) all recaptured marks are recognized. During the smolt trapping season, we took steps to reduce the possibility that these assumptions were violated. When possible we conducted experiments to determine the bias caused by violations of these assumptions and develop correction factors.

Results

Migration Characteristics

Since trap catches were low for the first few days the traps were operated, it was assumed that smolt migration was not substantial prior to the period of trap installation. Smolt migration began in April, peaked by early May, and continued through mid-June (Figure 1). Steelhead smolt lengths ranged from 113-268 mm. The mean smolt lengths from Lucia and lower traps were 176 and 175, respectively. The length frequency distribution by key production area is shown in Figure 2. Parr lengths ranged from 47 to 159 mm. Mean parr length averaged 96 mm at the lower trap to 112 mm at Lucia

Falls trap (Table 2). Mean chum salmon and coho salmon lengths were 130 and 63, respectively (Table 3 &4)

Table 1. Summary of steelhead smolt length data by trap site in the EF Lewis River basin, Spring 2000.

Site	New Smolts (mean)	New Smolts Standard Deviation (S.D.)	New Smolts Range	Recap Smolts (mean)	Recap Smolts S.D.	Recaptured Smolts Range
Lucia Falls	176	17.51	117-268	174	17.10	144-252
Lower	175	16.21	113-245	174	14.19	126-233

Table 2. Summary of steelhead parr length data by trap site in the EF Lewis River basin, Spring 2000.

Trap Site	Mean Fork Length (mm)	Standard Deviation	Range (mm)
Lucia	112	20.62	55-159
Lower	96	28.10	47-157

Table 3. Summary of coho smolt length data by trap site in the EF Lewis River basin, Spring 2000.

Trap Site	Mean Fork Length (mm)	Standard Deviation	Range (mm)
Lower	130	14.30	72-197

Table 3. Summary of coho smolt length data by trap site in the EF Lewis River basin, Spring 2000.

Trap Site	Mean Fork Length (mm)	Standard Deviation	Range (mm)
Lower	130	14.30	72-197

Smolt and Parr Yield

A total of 3,013 wild steelhead smolts were trapped in 2000. We marked 2,415 smolts with alcian blue dye for trap efficiency tests. Trap efficiencies varied during the 2000 outmigration. Chi-Square test indicated that there was no difference in recovery rate for marks released from the lower trap and recovered at the lower trap and marks released at the Lucia Falls and recovered at the lower trap (Figure 3). Therefore, both mark groups were pooled to calculate the lower trap efficiency. Seasonal differences existed at both traps and we developed trap efficiencies by similar marks at both sites. The estimate wild steelhead smolt yield from the area above the lower trap was 27,097 and from the area above Lucia Falls the yield was 12,481. Wild steelhead smolt yields with 95% confidence limits by trap are listed in the Table 5 and 6.

Table 5. Wild steelhead smolt yield for the area above the lower trap (RM 7) on the EF Lewis River, spring 2000.

Period	Catch	Marks	Recaptures	Trap Efficiency	Population Estimate	95% Con. Int.
4/2 - 4/9	0	20	1	2.78%	0	
4/10 - 4/16	69	72	1	2.73%	2139	
4/17 - 4/21	47	200	5	2.73%	1457	
4/22 - 4/29	271	436	47	10.98%	2397	
4/29 - 5/6	515	670	35	5.37%	9406	
5/7 - 5/15	157	277	4	2.16%	5416	
5/16 - 5/21	306	388	39	7.15%	4197	
5/22 - 5/28	91	240	8	7.15%	1248	
5/29 - 6/4	45	78	5	7.15%	617	
6/5 - 6/11	16	32	0	7.15%	219	
6/12 - 6/18	0	2	0	7.15%	0	
6/19 - 6/24	0	0	0	7.15%	0	
	1517	2415	145	5.60%	27097	+/- 7583

Table 6. Wild steelhead smolt yield for the area above the Lucia Falls trap (RM 21) on the EF Lewis River, spring 2000.

Period	Catch	Marks	Recaptures	Trap Efficiency	Population Estimate	95% Con. Int.
4/2 - 4/9	25	20	1	12.48%	197	
4/10 - 4/16	114	61	7	12.48%	896	
4/17 - 4/23	157	157	21	12.48%	1234	
4/24 - 4/30	188	168	20	12.48%	1478	
5/1 - 5\6	450	218	28	12.48%	3538	
5/7 - 5/13	229	125	9	7.94%	2840	
5/14 - 5/21	110	94	11	12.63%	788	
5/22 - 5/28	157	152	37	24.84%	618	
5/29 - 6/4	44	36	1	7.27%	594	
6/5 - 6/11	19	16	2	7.27%	257	
6/12 - 6/18	3	2	0	7.27%	41	
6/19 - 6/20	0	0	0	7.27%	0	
	1496	1049	137	11.99%	12481	+/- 2741

Other Salmonids

Chinook salmon, coho salmon, chum salmon, and sea-run cutthroat trout were also trapped. Species specific trap estimates were not determined for these species due to few fish available for marking or the inability to trap over the entire run. Trap efficiency is commonly related to size of fish. Steelhead smolts are larger (175mm) stronger swimmers and typically have the lowest trap efficiency because once they detect the trap, they are capable of swimming away from it. Cutthroat trout are of similar size and are likely to have the same trap efficiency as steelhead (WDFW, unpublished data). Coho salmon smolts average 130mm in length at the lower trap, which is 45mm shorter than the average steelhead smolts. Coho salmon trap efficiencies tend to be near twice that of wild steelhead (Dave Seiler, WDFW pers. comm.). Chum salmon lengths on the EF Lewis River averaged 69mm, only 53% of coho salmon smolts. On the Skagit River chum salmon efficiencies were about twice the trap efficiency estimate for coho salmon (Steve Neuhauser, WDFW pers. comm.). However, the chum salmon estimates should be adjusted to 2060, since we only trapped the last 10% of the run based on lower Columbia River juvenile chum salmon outmigration timing (Tom Hoffman, USFWS pers. comm.).

Based on these estimates of trap efficiencies, we estimated that 5,716 coho salmon, 2,060, chum salmon, and 1,068 sea-run cutthroat trout passed the lower trap. No chinook, chum, or coho salmon smolts were caught at the Lucia Falls trap confirming that in most years this is a barrier to all anadromous salmonids but steelhead. In addition, 168 cutthroat smolts were estimated to have passed the Lucia Falls trap. Since coho salmon do not pass Lucia Falls, we believe that in most years sea-run cutthroat do not pass the falls, so the cutthroat smolts that were counted at Lucia Falls are believed to be offspring of resident coastal cutthroat.

Table 7. Smolt population estimates at the Lower EF Lewis River Trap

Species	Measured Seasonal Trap Efficiency	Estimated Trap Efficiency	Trap Catch	Population Estimate
Steelhead	5.41%		1517	27097
Cutthroat		5.41%	53	1020
Coho		9.88%	565	5716
Chum		28.61%	69	2060

Table 8. Smolt population estimates at the Lucia Falls EF Lewis River Trap

Species	Measured Seasonal Trap Efficiency	Estimated Trap Efficiency	Trap Catch	Population Estimate
Steelhead	11.99		1496	12,481
Cutthroat		10.69%	18	168
Coho			0	0
Chum			0	0
Chinook			0	0

Discussion

Data Accuracy

In 2000 a total of 117,617 hatchery steelhead smolts were released at Daybreak and Lewisville parks, 3 and 6 miles above the lower trap site. We were able to differentiate between hatchery and wild steelhead at the trap because all hatchery steelhead are adipose fin clipped. We estimate that 106,836 hatchery steelhead smolts migrated past the trap, leaving a difference of 10,781 or 9% of the release. The lower 95% confidence interval for the hatchery steelhead estimate is 79,004 smolts. If we used this lower bound as the population estimate, we would expect 38,613 (36%) hatchery steelhead not to migrate past the trap. Other steelhead trapping efforts indicate that a portion of hatchery steelhead released above a trap never migrate past the trap (Seiler et al. 1997). These fish either residualize or there is mortality between the hatchery release site and the trap site. Previous adult snorkel surveys in the EF Lewis River in July documented the presence of residualized hatchery steelhead, identified by the absence of the adipose fin, confirming that hatchery steelhead do residualize above the trap. Our estimate of residualism and mortality appear to be in the range observed for hatchery steelhead in other basins.

Table 9. Hatchery steelhead smolt yield above the lower trap on the EF Lewis River, spring 2000.

Period	Catch	Marks	Recaptures	Trap Efficiency	Population Estimate	95% Con. Int.
4/2 - 4/9		0	0			
4/10 - 4/16	0	0	0			
4/17 - 4/21	751	149	6	5.28%	14157	
4/22 - 4/29	2170	1290	69	5.28%	40906	
4/29 - 5/6	2128	617	47	7.77%	26872	
5/7 - 5/15	528	263	5	2.27%	22792	
5/16 - 5/21	106	89	12	9.64%	1080	
5/22 - 5/28	47	32	3	9.64%	479	
5/29 - 6/4	42	36	0	9.64%	428	
6/5 - 6/11	11	8	0	9.64%	112	
6/12 - 6/18	1	0	0	9.64%	10	
6/19 - 6/24	0	0	0	9.64%		
	5784	2484	142	5.41%	106836	+/- 27832

Data Precision

The need for accurate and precise population estimates has been well documented by fisheries managers (Walters and Ludwig 1981, Knudsen 1997). Organizations that fund habitat restoration programs are equally concerned with the development of accurate population estimates to assess the effectiveness of protecting and restoring habitat. Robson and Regier (1964) indicated that precision of population estimates as measured by 95% confidence intervals for population estimates, should be less than 10% for research and less than 25% for management. Rawding (1997) proposed that the steelhead smolt-monitoring program on the Wind River should strive to attain 95% confidence limits that are within 20% of the point estimate of the population. It is unlikely that lower 95% confidence intervals can be obtained for steelhead in southwest Washington due to small population size and low trap efficiencies. An alternate way of describing confidence limits is the coefficient of variation, which can be approximated as ½ of the 95% confidence interval or can be expressed from the equation:

$$CV = SD/N \qquad (4)$$

where CV is the coefficient of variation, SD is the standard deviation, and N is the population estimate. The 95% confidence intervals mentioned above are equivalent to coefficients of variation of 5%, 13%, and 10%, respectively. The coefficient of variation for steelhead at Lucia Falls was 11% and the coefficient of variation at the lower EF Lewis River trap was 14%. These are just above the range recommended by Rawding (1997) and near those recommended by Robson and Regier (1964) for management. Mechanical problems at both sites and high flows reduced trap efficiency, and capture rates during the season; without these problems coefficients of variation at both sites would have likely approached 8%.

Trap Efficiency Bias

The Petersen estimator can provide accurate and precise population estimates if the following conditions are met: (1) the population is closed; (2) no mark loss; (3) all marked fish are properly recognized; (4) marking has no effect on catchability; and (5) all fish have the same probability of being tagged in the first sample or all fish have the same probability of being captured in the second sample.

(1) Closed Population - Closure usually implies that no animals enter or leave between the two sample periods. However, as long as the mortality rate is the same for marked and unmarked animals, the Petersen estimate is still valid (Arnason et al. 1996). Trap efficiency studies are designed to minimize mortality so the assumption of a closed population is usually met. We incorporated procedures to minimize mortality from sampling and handling stress, released fish close to the trap to minimize natural mortality between the release site and the trap, and evaluated the short-term survival of marked fish. Prior to sampling juveniles were anesthetized with MS-222 (~ 40 mg/l). Fish were sampled as quickly as possible and were allowed to recover fully before being released into the river. These procedures helped reduce stress and decrease delayed mortality. The release sites for marked fish are located approximately 1 to 3 miles above the trap to minimize natural mortality but still allow unmarked and marked fish to mix randomly. Predation on juvenile steelhead in the EF Lewis River is assumed to be low due to the inactivity of piscivorous fishes above the lower traps in cold water, and low abundance of natural predators such as river otter (*Lutra canadensis*), mink (*Mustala vison*), and common mergansers (*Mergus merganser*). The moderate stream gradient (~2%) and boulder substrate combine to create substantial cover for juvenile steelhead reducing the effectiveness of these predators.

The survival of juvenile steelhead was tested as part of a Hemlock Dam fish passage study on the Wind River in 1997. Hemlock Dam is located at RM 2 on Trout Creek and the USFS and USGS-CRRL developed a study to determine the passage routes and survival of steelhead passing Hemlock Dam. A total of 20 steelhead smolts captured at the Trout Creek screw trap were implanted with radio tags. These fish were handled in the same manner as fish used for our mark-recapture estimates. A total of 19 radio tagged smolts passed Hemlock Dam (Adams and Wieman, unpublished). Based on mobile radio tracking, it was determined that the single fish not passing the dam had likely regurgitated the tag. These results indicate that the survival of marked fish was 100%. In 2000 we tested the short-term survival of 33 steelhead smolts by holding them for a 24-hour period in the Lucia Falls live well. The results indicated that survival was 100%, which is the same as Wind River studies (Rawding 1997, and Rawding et al. 1999). The short-term survival for juvenile steelhead in the Situk River, Alaska used for trap efficiency studies was greater than 99% (Thedinga et al. 1994). Therefore, we assumed the survival of marked steelhead was 100% or equal to that of unmarked steelhead and we did not apply a correction factor to account for mortality bias between marked and unmarked fish.

(2) No Mark Loss - If undocumented mark loss occurs, it can lead to an underestimate of trap efficiency. Juvenile steelhead were tatooed with a Panjet inoculator (Hart and Pitcher 1969). Mark retention in juvenile chinook and coho salmon of 100% has been reported for fish held for more than 5 weeks in the hatchery (Hillman and Miller 1989, Thedinga and Johnson 1995). Rawding (1997) indicated similar results on the spring chinook held at Carson National Fish Hatchery. Short-term mark retention tests were conducted in 2000 using steelhead. A total of 109 marked steelhead smolts were held for 24 hours in live boxes, with 98.17% mark retention. The mark loss was due to the intermittent malfunction of the marking tool in 2000. The mark retention was calculated from the equation:

$$S = g/h \qquad (5)$$

Where S is the mark retention, g is the observed number of good marks, and h is the number of live fish held for testing. The number of marks available in each period was corrected by multiplying the number of marks by the mark retention estimate.

(3) Proper Mark Recognition - In some cases recaptured marks are not recognized leading to an underestimate of trap efficiency. This usually occurs when trap catches are high and samplers must examine many fish. Over the course of the season we handled a total of 5,815 juvenile steelhead, which is low compared to other juvenile trapping projects (Thedinga et al. 1994 and Sieler, 1997). Samplers checked for marked fish over a white background, where marks are more visible. Rawding et al. (2001) found that when double marks were used (alcian blue tattoo and CWT), samplers were 100% in the detection of the alcian blue mark. Based on the low number of fish caught and previous mark detection, we used 100% mark recognition for this experiment.

(4) Equal Catchability - Potentially marked fish may be attracted or repelled from the trap, resulting in positively or negatively biased trap efficiency. To test for this bias, we compared lower EF Lewis River trap efficiencies for fish marked at the lower and upper traps and recaptured at the lower EF Lewis River trap. Our hypothesis was that marked fish from the lower EF Lewis River should be recaptured at a lower rate than upriver marks if they avoid the trap or at a higher rate if they are attracted to the trap. Rawding (1999) reported that lower Wind River trap efficiencies during similar periods did not significantly vary between smolts marked at Trout Creek, Panther Creek, upper Wind River, and the lower Wind River trap sites. In 2000, no significant differences were detected for marks originating at the Lucia Falls or lower trap over similar periods (Figure 2). Although these tests had low statistical power, they indicate that trap rejection or attraction is not a major concern at

the lower EF Lewis River site. Due to the high velocities at the upriver trap, we believe that trap rejection or attraction is not a factor.

(5) All fish have the same probability of capture in the first sample and the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly. This assumption is difficult to validate using sample data alone and is likely to cause most of bias in the Petersen estimator. The probability that all fish have the same likelihood of capture in the first sample may not always be met due to differences in migrational patterns and trap efficiencies between different species, the same species at different lengths, life history stages, physiological development, and hatchery and wild origin fish of the same species (Thedinga et al.1994, Nicholson 1998, Seiler et al. 1997). To increase the same probability of first sample capture, trap efficiencies should be developed for homogeneous groups. To address this concern we separated steelhead into two homogeneous groups of steelhead parr and smolts and developed a separate estimate for each group.

To increase the probability of random mixing of marked and unmarked fish, release sites were located at least one mile upstream of the traps. The lower EF Lewis River release site is located at least 3 miles upstream due to limited access. Factors such as changing stream flow, life history stage, water temperature, and photoperiod can influence fish migration and recapture rate (Seiler et al. 1997, Nicholson et al. 1998). It is possible that these factors combine to create trap efficiencies that change instantaneously. Some researchers have suggested that due to low numbers of daily recaptures and for the most part the slow change in these environmental conditions (flow and temperature), that it is appropriate to use weekly estimates (Dempson and Stansbury 1991, Thedinga et al. 1994, Nicholson 1998). In 2000, our marking schedule for smolts rotated every week and used three different fin combinations to distinguish between traps. This allowed us to identify fish based on trap site and marking period. Since the number of fin mark combinations is limited, the same marks were repeated every 21 days. Previous years' data indicated that the maximum migration time for Wind River steelhead juveniles between traps was 3 weeks, so the three week rotation is consistent with our objective of identifying fish by trap site and marking period (WDFW, unpublished data).

Seiler et al. (1997) proposed an alternative to the weekly trap efficiency method by developing an equation that defines the relationship between trap efficiency and flow through the use of marked fish over the entire range of observed discharge. Due to the single releases of a large number of marked fish required to develop this equation, this methodology is usually used for more abundant anadromous salmonids such as chum, pink, coho, chinook, and sockeye salmon. It has limited use when sampling smaller populations such as EF Lewis River steelhead, because not enough fish can be captured and marked in a single day to routinely achieve the five or more recaptures recommended by Schwarz and Taylor (1998).

Quality of Habitat

One method of examining the salmonid habitat quality on the EF Lewis River is to compare the historic or expected number of salmon and steelhead based on habitat models with the observed fish abundance from the 2000 smolt trapping. Habitat quality can be inferred from distribution of the species in the watershed. On the EF Lewis River the preferred historical habitat for chum salmon occurs in the mainstem below Daybreak Park. Coho salmon and sea-run cutthroat trout seek out small tributaries for spawning and rearing, including McCormick, Breezee, Lockwood, Mason, Mill, lower Rock, and other unnamed tributaries below Lucia Falls. Steelhead are the most broadly distributed anadromous fish in the EF Lewis River basin and redds have been observed in the mainstem from the mouth of Mason Creek to the headwaters. In the EF Lewis River, steelhead tend to spawn and rear in the middle to upper reaches of the basin and larger tributaries such as Green Fork and upper Rock Creek. Many factors effect smolt production including the quality of habitat, number of spawners, reproductive success of the spawners, and ecological interactions with other fish in the basin. Because these factors are intrinsically variable and poorly documented in the EF Lewis River, the smolt production data is not presented here to validate the models, but as a gross measure of habitat quality within the basin. Therefore, the smolt production in a given stream reach can be higher than the model predicted due to excellent habitat, lack of competition from other species, or if escapements are managed for the maximum number of spawners. In this analysis, we assumed that stream reaches with smolt production equal to or greater than the historic or model outputs are likely candidates for habitat protection, while reaches with smolt production lower than the historic model outputs are likely candidates for stream restoration.

Chum Salmon

Chapman (1986) estimated that chum salmon run size in the Columbia River exceeded 449,000 fish based on cannery records. Rawding (in prep) estimated current Columbia River chum salmon run size between 4,000 and 8,000, only 1% of historic run size. Bryant (1949) indicated that approximately 3,000 chum salmon spawned in the Lewis River basin, with an annual run size of 10,000 fish. Since Merwin Dam had been constructed in 1931, prior to this estimate, it is likely that a significant portion of the chum salmon originated from the EF Lewis River. WDF surveyed the EF Lewis in the 1960's and determined that most chum salmon spawned in a side channel below Daybreak Park. A peak spawning ground count exceeded 100 chum salmon on December 2, 1963. Based on survey length, timing, and fish detection rates it is likely that run size and spawning ground escapements exceeded 200 chum salmon during the early 1960's. Based on the screw trap catch of 69 smolts, at least two spawners must have been successful in 1999. Based on average outmigration timing, fecundity, and egg to smolt survival rates, we might expect that up to 10 chum spawned above the trap in 1999. Similar to the decline of chum salmon in the Columbia Basin, it appears that chum salmon in the EF Lewis River have also declined from thousands to less than ten fish, which is less than 1% of the historic abundance in the EF Lewis River.

Life stages and key habitat description for each life stage for chum salmon in the EF Lewis River are presented in Tables 11 and 12. The key habitats for the chum salmon incubation stage are side channels with upwelling sites. This habitat is important because it maximizes egg to fry survival by providing a stable incubation environment that minimizes the effects from scour and sedimentation. On the EF Lewis River the preferred historical habitat for chum salmon based on spawning ground surveys was in the side channels to the mainstem from Mason Creek to Daybreak Park (WDFW, unpublished data). Norman et al. (1998) shows extensive channel braiding from RM 7 to RM 10, with up to nine side channels in 1854. The number of side channels was reduce to six by 1937 (Figure 4). Currently, only one side channel is present in the lower EF Lewis River. The reduction in key side channel habitat, from 9 to 1 side channels (89%), corresponds to the 99% reduction in historic chum salmon abundance. Habitat below Daybreak Park for chum salmon would be rated as severely degraded.

Table 10. Definition of chum salmon life stages and corresponding time periods in the EF Lewis River Basin.

LIFE STAGE	DESCRIPTION	MONTH
Pre-spawning adult	Upstream adult migration and holding prior to spawning.	Oct-Jan
Spawning	Spawning period, including establishment and defense of redd sites.	Nov-Jan
Incubation	Egg deposition to fry emergence	Nov-Mar
Fry colonization and rearing	Fry emergence & distribution through winter & spring rearing.	Feb-Jun
Smolt to smolt	Onset of seaward migration.	Feb-Jun

Table 11. Descriptions of key habitat used by chum by life stage within the EF Lewis Basin.

LIFE STAGE	KEY HABITAT
Pre-spawning adult	Large deep pools with sufficient connecting flow for adult migration.
Spawning	Riffles & tail outs containing a mixture of gravel and small cobble with flow of sufficient depth for spawning. This species shows a strong preference for spawning in upwelling sites and side channels.
Incubation	Riffles & tail outs described for spawning with sufficient flow for egg and alevin development. Side channels and upwelling areas provide a more stable incubation environment by limiting scour from floods, and sedimentation.
Fry colonization and rearing	As fry emerge they use shallow & relatively slow velocity areas within the stream channel, often associated with stream margins.
Smolt to smolt	Sufficient flow for free movement of smolts downstream

Coho Salmon

Adult coho salmon abundance has not been measured in the EF Lewis River. A recent paper by Bradford et al. (2000) suggested that the spawning density needed to seed coho salmon rivers ranged from 4 to 44 females per kilometer, with an average of 19 females per kilometer. He noted that the average number of smolts per females for carrying capacity was 85, and it ranged from 38 to 144 smolts per female. We applied the average of 19 females per kilometer, and 85 smolts per female to EF Lewis River stream length estimates used in the steelhead model. The estimated coho salmon smolt production is 78,000 fish for the EF Lewis River.

WDFW has measured smolt production in a variety of rivers and creeks annually since the 1970's (Seiler et al. 1997). To standardize smolt production the smolt yield has been divided by the drainage area to estimate smolts per square mile. Average annual estimates range from over 1000 smolts per square mile in productive habitats to less than 400 smolts per square mile in less productive habitats. Since coho salmon are restricted to the area below Lucia Falls, we subtracted the area above the falls from the area at the mouth, and estimated the drainage area is 87 square miles. Applying the lower estimate of 400 smolts per square mile yields an expected estimate of 35,000 smolts for the EF Lewis River. If we applied the higher estimate of 1000 smolts per square mile we obtain an estimate of 87,000 smolts.

The current coho salmon estimate was 5,700 smolts, assuming the trap efficiencies were double that for steelhead and the population estimate may reach 11,400 if 50% of the smolts overwintered below the trap site. These are compared to the two coho models and present production is between 7% and 32% of the modeled production (Table 13). For comparison, the same model was run on Cedar Creek where we have monitored coho production since 1998. In the least productive model, the observed Cedar Creek production exceeds the estimate. But in the moderate to high productive models the observed Cedar Creek production is less than 50% of the predicted output. The Cedar Creek coho data is presented here to demonstrate that at least the lower production model estimates can be achieved by coho salmon in lower Columbia River tributaries and the lower goal should be achievable in fair habitat. Since the EF Lewis River coho salmon smolt production is less than 1/3 of the lower production model, habitat used by coho salmon in the EF Lewis would be rated as substantially degraded.

Coho salmon typically enter the EF Lewis River as adults in the fall, and move into the tributaries to spawn in the fall to early winter. Eggs incubate in the tributaries and emergence takes place in late

Table 12. Estimates of current and modeled coho salmon smolt production in the EF Lewis River and Cedar Creek.

	Current Estimate	Bradford Model	WDFW Model (400 per Sq. M.)	WDFW Model (1000 per Sq. M.)
EF Lewis Estimate	5,700 – 11,400	78,000	35,000	87,000
EF Lewis / Model		7% - 14%	16% - 32%	7-13%
Cedar Creek 98-00	20,000– 38,000	78,000	22,000	55,000
Cedar/Model		26-49%	91% - 173%	36-69%

winter or early spring. Some fish continue to rear near their spawning site and others migrate primarily downstream to find suitable habitat. After the juveniles overwinter, they migrate to the ocean as smolts in the spring. Coho salmon abundance has decreased due to lack of habitat diversity, floods, sedimentation, high water temperature, and summer low flow. Nickelson et al. (1993) listed the preferred habitats for coho salmon juveniles by life stage, which were always associated with pools. Alcove and backwater pools were preferred habitat for spring fry. In the summer, parr preferred any pool habitat and by winter parr showed a preference for only slow water pools such as dammed pools and beaver ponds. Figure 4 from Norman et al. (1998) indicates that off-channel rearing areas, created by oxbows and beaver activity would have been abundant between RM 7 and RM 10 in the EF Lewis River in 1854. In Limiting Factors Analysis (LFA) the TAG "estimated that 50% of the off-channel habitat and associated wetland within the lower EF Lewis River have been disconnected from the floodplain" (Wade 2000). The current single thread channel demonstrates the loss off-channel habitat complexity and reduces the juvenile overwintering and rearing habitat (Cederholm and Scarlet 1981, Petersen 1982, Bjornn and Reiser 1991) and ultimately the capacity of the EF Lewis River to produce coho smolts. The lack of large woody debris and few high quality pools in the tributaries indicate the lack of habitat complexity, and also limits production in the tributaries (Wade 2000).

In 50% of the sites, where smolt production is monitored in western Washington, Seiler (2001) indicated that high winter flows during incubation correlated negatively with coho smolt abundance. High flows can scour salmon eggs and/ or transport sediment that suffocates or entombs eggs. High road densities have increased the stream channel network and have led to increased flows in the EF Lewis River. The average road density for the entire watershed is high (4.13 miles/square mile) and higher in the lower river tributary sub-basins, where coho spawn. Since roads also rout sediment, NMFS used road densities as a surrogate measure for sediment. When road densities are in excess of 3 (miles/square mile) sediment in spawning gravels is estimated be in excess of 17% fines less than 0.85mm.

The NMFS indicated that when waters temperatures are elevated above 15 to 17.8 degrees Celsius, they are rated as poor for salmon. Reeves et al. (1989) indicated that when minimum water temperatures exceed 20 degrees for two weeks or more, summer coho salmon parr production is minimal. Temperature monitoring in Cedar Creek, a NF Lewis River tributary, are believed to be typical of lower EF Lewis River tributaries. These data show that maximum stream temperatures often exceed 18 degrees and in some years minimum temperatures exceeded 20 degrees for a week. Wade (2000) cited (Maul, Foster, and Alongi, Inc. 1999) that minimum temperatures discharged from Stordahl's pond exceeded 20 degrees for 6 weeks in 1999. Those juvenile coho rearing in the mainstem are also subject to warm water. Water temperatures in August 1998 exceeded 20 degrees (Wade 2000). Seiler (2001) also indicated that summer low flows negatively affect coho salmon production in 50% of the streams monitored for smolt production. Loranger (1999) indicated that rearing and spawning habitat was severely limiting in primary coho tributaries of McCormick, Breeze, Lockwood, and Mason Creeks due to low flow.

Blockages in the lower portions of the McCormick, Breeze, Lockwood, Mason, and Dean creeks limit coho salmon access. It is unclear if historically coho had access to Farhger Lake and its wetland complex. If they historically did use this habitat, these wetland habitats would have been among the most productive habitat for coho salmon in the basin.

Steelhead

Gibbons et al. (1985) developed a Parr Production Index (PPI) model to estimate summer carrying capacity of age 1+ steelhead parr based on measured stream gradient zones for western Washington rivers that were seeded at or above Maximum Sustainable Harvest and under average 1980's habitat conditions. Using the 40% steelhead parr to smolt survival from Johnson et al. (1988), these parr production estimates from PPI were converted into smolt production estimates. Smolt production estimates using both of these models are shown in Table 14.

The accuracy of this model for the EF Lewis River is unknown, due to lack of a long-term data series. One way to compare the applicability of wild steelhead production estimates from this model

Table 13. Comparison of WDFW smolt model outputs with observed EF Lewis River smolt production, 2000.

Production Zone	2000 Smolt Estimate	Smolt Production Goal using PPI	Difference
EF Lewis Basin		26,490	
EF Lewis > Mason Cr	27,097	24,954	+8.6%

is to examine predicted and observed steelhead production data. WDFW has monitored steelhead smolt production on the Kalama River from 1978 through 1984, and on Cedar Creek, a tributary to the NF Lewis from 1998-2000. The Quinalt Indian Nation (QIN) has monitor wild steelhead production on the Clearwater River a tributary to the Queets River from 1984 to the present. Predicted parr production was taken from Gibbons et al. (1985). Since not all traps were located at the mouth of the stream the parr production above the trap was recalculated. This simple model does well in estimating steelhead smolt production in western Washington rivers (Table 15). The model tended to predict smolt production well when escapements were near WDFW escapement objectives. Examples of this would be the Clearwater and Kalama data sets. The model tended to underestimate small streams such as Cedar Creek and Wind River tributaries such as Panther and Trout Creeks. However, since we are trying to determine an estimate for a larger basin this isn't an issue. Steelhead are the most broadly distributed anadromous fish in the EF Lewis River basin. Redds have been observed from the mainstem above Mason Creek (RM 7) to the headwaters above the last

Table 14. Comparison of predicted (Gibbons et al. 1985) and actual wild steelhead smolt production estimates.

Basin	Years Monitored	Average	Predicted	Difference
Clearwater River	1984 – 99	19,900	20,500	-3%
Kalama River	1978 – 84	28,300	26,100	+8%
Cedar Creek	1998 – 00 prelim	4,000	4,800	-17%
EF Lewis River	2000 prelim	27,100	25,000	+8%
Wind River	1997-00 prelim	21,000	23,000	-9%

road (RM 40). Based on the 2000 trapping project 45% of the smolts steelhead originated from the area above Lucia and 55% below the falls. Most of this stream reach between Lucia Falls and lower Rock Creek is dominated by a canyon, which is a Rosgen "B" channel characterized by riffles with infrequent pools and a moderate slope (2-4 percent) (Rosgen 1994). The substrate in this reach consists almost entirely of bedrock, large boulders, and large cobble. Rich et al. (1992) indicated that undisturbed B channels would provide excellent steelhead 1+ parr-rearing habitat. A similar canyon type habitat extends to the limit of anadromous distribution in the headwaters. Except for the scour from high flows and past splash damming, the habitat in this reach is likely the least altered relative to historic conditions.

A substantial reach within the section below the canyon and in the tributaries below Lewisville is composed of Rosgen "C" channel . These channels typically meander through a valley and are characterized by deposition of fine materials and lower velocity, with gradients of less than 1.5 percent (Rosgen 1994). The 1+ parr steelhead rearing habitat quality in this reach is likely less than that of the canyon due to steelhead preference for B channels (Scully and Petrosky 1991) and habitat degradation. However, chum, chinook, and coho salmon prefer this habitat. Anadromous habitat below Lewisville is most impacted by human activities. Wade (2000) summarized the EF Lewis River LFA: "Elevated water temperatures are considered a major problem in many tributaries and especially within the lower East Fork. The recent avulsion of the East Fork into abandoned gravel pits increased already high rates of erosion and channel instability in the lower river and led to a significant loss in spawning habitat for fall chinook. Diking and development within the floodplain has largely disconnected the river and reduced over-winter habitat and low flows appear to limit the amount of available rearing habitat in the summer for juvenile salmon and steelhead." The measured steelhead production was similar to the average estimated production in western Washington in the 1980's. Therefore, the habitat in the middle and upper basin would be classified as slightly to moderately degraded.

Steelhead primarily spawn and rear in the middle to upper mainstem although some use occurs in the tributaries. Since steelhead production is high compared to coho and chum salmon, habitat focus in the reaches preferred by this species should be on protection rather than restoration. The exception may be in the lower river tributaries and mainstem, where habitat complexity would improve steelhead production. Restoration activities in fifth order watersheds, which is the size of the EF Lewis River mainstem, have not been very successful because high flows in the winter tend to alter the placement of instream structure. However, restoration projects such as boulder and/or LWD placement smaller tributaries have been effective. When these projects have been combined with nutrient enhancement, their effectiveness has been improved (McDubbing and Ward 2000).

Habitat Protection and Restoration Opportunities

One way of looking at habitat protection and restoration is by species distribution. In this analysis chum salmon, in the mainstem below Daybreak Park, currently support 1% of the historical production. The lower river tributary habitats used by coho salmon, support less than 32% of that which good habitat should support. Finally, the middle to upper river mainstem and larger middle and upper tributary habitats are in the best shape because they produce average steelhead smolt production for western Washington streams. Following the guidelines above, the focus of middle and upper habitats should be habitat protection, since the dominant species, steelhead, are doing relatively well. The mainstem habitat below Daybreak Park and in the tributaries below Lucia Falls should be restored because the dominant species in these areas are less than 1% and 32% of expected abundance levels. One method of prioritizing restoration activities is to prioritize long and short-term projects based on the likelihood or certainty the projects will increase freshwater production for the target species. Long-term projects are needed to maintain and restore ecological function to the watershed, to meet the requirements of the ESA, which is self-sustaining wild populations. Short-term projects can be used to assist populations in remaining above the danger zone until natural riverine processes are restored.

Habitat protection can be achieved through long-term restoration activities, which are needed to maintain populations. These activities should address ecosystem function, begin in the headwaters on the mainstem or tributaries and proceed downstream. The focus of these projects should be to restore the historic hydrograph, sediment transport, riparian and floodplain function, water quality, and water quantity, to create the historic habitat diversity required by salmonids. Projects that meet these needs include: decommissioning roads so densities are less than 2 miles per square mile to reduce sediment transport and peak flows; riparian plantings and fencing to improve shade, large woody debris recruitment, and bank stability; removal of dikes to allow the recreation of historic overflow channels to restore floodplain connectivity and create habitat diversity; and upland management in all sub-basins to maximize hydrologic maturity.

Some of the most successful short-term restoration projects that have shown immediate benefits salmonids include: removing man-made blockage so fish can access historically productive habitat, adding nutrients to increase the productivity and capacity of the basin to produce salmonids, creating off-channel spawning and rearing areas for chum and coho salmon, and the placement of instream structures to create pool habitat. To effectively complete these projects physical habitat surveys and a hydrological studies should be conducted in the high priority habitat in lower tributaries and the mainstem below Daybreak Park, so site specific restoration projects can be identified. Without the site specific information, only an unprioritized restoration project list can be developed.

Salmon passage is blocked in some of the lower river tributaries. Immediately opening up this habitat would potentially increase coho salmon production if minimum summer water temperatures are below 20 degrees, and the summer flows are not sub-surface. If flow and temperatures are below the acceptable level, then other habitat restoration projects should be considered. WDFW is compiling all the blockages on EF Lewis River tributaries and the information will be available in a GIS format. The LFA lists blockages on McCormick, Brezee, Lockwood, and Mason creeks (Wade 2000). The lower Rock Creek/Fargher Lake complex, was potentially the most productive coho habitat in the EF Lewis River Basin. Physical habitat surveys should be conducted to determine if suitable habitat still exists in the lake/wetland complex and determine if coho salmon blockages still prevent coho from accessing this area.

The lack of spawning adult salmon and their carcasses has led to a deficiency in nitrogen and phosphorus in the EF Lewis River. In 1997 WDFW initiated a nutrient enhancement project with hatchery salmon and steelhead from the Lewis River Hatchery. Since that time Fish First, Southwest Washington Anglers, Clark-Skamania Flyfishers, the Lower Columbia Fish Enhancement Group, other volunteer organizations, and private citizens distributed carcasses in the EF Lewis River. This work should continue and the number of carcasses increased to the upper limit of the WDFW guidelines.

Limiting factors for chum salmon often indicate a lack of off-channel spawning habitat and for coho salmon often include the lack of off-channel rearing habitat. Norman et al. (1998) indicate that this habitat was historically abundant below Daybreak Park in the mainstem and in the lower portions of Mason and Dean creeks but is currently lacking. A hydrologic study to reestablish dimension, pattern, and profile based on pre-disturbance reach should be conducted. This survey should also focus on identifying groundwater sources. Survey and study results should then be used to create off-channel rearing and spawning sites in these reaches.

Pools and large woody debris have been identified as lacking in the lower EF Lewis River tributaries (Wade 2000). Placement of instream structures, such as large woody debris, has improved pool habitat and the production of salmonids from the modified reaches. We recommend that results from the physical habitat surveys and hydrologic surveys be used to identify reaches that would benefit from these restoration activities.

Importance of Smolt and Parr Production Data

The juvenile outmigrant monitoring indicates that parr and smolt production from basins is variable between years (Rawding et al. 2001). Juvenile production estimates are a function of adult escapement, reproductive success of hatchery and wild spawners, capacity and productivity of habitat, and natural environmental change. Accurate measurement of these parameters in all basins is needed to discern effects of habitat modification funded by the Lower Columbia Fish Recovery Board on natural salmonid production. Reeves et al. (1992) indicated that it could take ten years or more before full biological and physical responses to instream habitat restoration projects are realized. This year of data will help establish a baseline to measure the effect of habitat improvements. However, due to the variability in smolt production, at least three years of smolt production data should be collected to establish a baseline.

Smolt and parr production data has been very useful in other areas. First, the data collected from juvenile steelhead monitoring is being used to develop a description of movements of wild Wind River summer steelhead adults and juveniles through time and space (Rawding 1999). A draft report in preparation to provide scientific background to use summer steelhead as an indicator species to assess environmental conditions of the Wind River based on the assumption that this species is sensitive to a wide variety of ecosystem conditions. The assessment will be completed through an Ecosystem Diagnosis and Treatment approach following the principles in Lestelle at al. (1996).

Smolt monitoring is an important element for an extinction risk assessment. Wild adult steelhead run size and escapement data indicate that Lower Columbia River steelhead stocks are not able to replace themselves at low abundance levels or not replace themselves at all (Busby et al. 1997). This situation is unhealthy and indicates a high risk for extinction of salmonids (Chilcote 1998). However, EF Lewis River steelhead smolt data indicate that freshwater production is adequate for adult replacement or even rebuilding given average survival in the Columbia River mainstem and ocean productivity. When smolt and adult data are analyzed together, they indicate that wild steelhead spawner abundance is being greatly influenced by factors outside of the sub-basin such as survival in the Columbia River migration corridor and/or in the ocean (Rawding in prep). Fisheries agencies have initiated captive broodstock (e.g., IDFG - Redfish Lake sockeye) or supplementation (e.g., WDFW - upper Columbia River steelhead) programs to prevent extinction of anadromous salmonid populations. However, the effectiveness of captive broodstock and supplementation programs to recover at risk populations is unproven and these programs present significant risks (Miller et al. 1990). Therefore, WDFW has advocated a cautious approach for supplementation (WDFW 1997). Since adult monitoring on the EF Lewis River has not been extensive, the smolt monitoring data help evaluate risks to listed wild salmonid population in this basin. Given the current level of natural steelhead smolt production in EF Lewis River, we feel that intervention through supplementation or captive broodstock programs is not presently needed. However, a more detailed analysis need for other species. Therefore, continued smolt production monitoring along with adult monitoring is needed to update risk assessments for EF Lewis River salmonids.

Conclusions and Summary

The estimated wild steelhead, coho salmon, chum salmon, and cutthroat trout smolt yield from the EF Lewis River above Mason Creek was 27,097, 5,716, 2,060, and 1,020 juveniles. At Lucia Falls the wild steelhead and sea-run cutthroat estimate was 12,481 and 168 smolts.

A total of 117,617 hatchery steelhead smolts were released into the EF Lewis River above the lower trap. We estimated that 106,836 (+/- 27,832) hatchery fish emigrated past the trap. Our estimate is 9% less than the hatchery release and this difference can be accounted for by mortality between the release site and the trap and residualism.

The precision of our estimates as measured by the coefficient of variation was 14% at the lower trap and 11% at the Lucia Falls trap. These estimates would be improved to 8% if mechanical malfunctions during trapping season can be reduced or eliminated.

A comparison of present abundance of chum salmon to historical data, suggest that present run size levels are 1% of the historic level. We believe that low egg to fry survival of chum salmon in this basin is the most likely cause for the continued low abundance of chum salmon. Limiting Factor Analysis indicated that approximately 50% of the off-channel habitat has been disconnected from the floodplain. The conversion of the EF Lewis River from a braided to a single channel eliminated the side spawning channel habitat that protected eggs from scour and sedimentation.

Current coho smolt abundance is 7% to 32% of predicted coho salmon abundance based on three coho models. Since these fish utilized the lower tributaries, coho abundance has been reduced by blockage, high water temperatures, lack of large woody debris and pools, increased peak flow, and sedimentation. Coho salmon juveniles often overwinter in off-channel and backwater mainstem areas. The loss of these habitat types is likely limiting winter carrying capacity.

Wild winter steelhead smolts are five times more abundant than coho salmon smolts, and 13 times more abundant than chum salmon smolts. The observed smolt productions were similar to the predicted output from a WDFW model. EF Lewis River steelhead productivity remains similar to other western Washington basins because the major spawning and rearing areas in the middle and upper basin have undergone less habitat destruction than the habitat in the lower basin, which are more intensively utilized by chum and coho salmon.

Habitat projects that: 1) protect functioning habitat in the middle and upper basin to maintain the wild summer and winter steelhead populations, 2) recover mainstem off-channel spawning and rearing areas below Daybreak Park RM (10) to rebuild coho and chum salmon populations, 3) open blockages, 4) increase nutrients, and 5) restore ecological process should be give the highest priority.

Smolt production is influenced by the number and composition of adult spawners, along with habitat quality and quantity. Smolt production is variable. These variations in smolt production make it difficult to discern short-term effects of habitat restoration. Additional baseline, long-term smolt, adult, habitat, and environmental monitoring are necessary better prioritize habitat protection and restoration projects, to determine the effects of restoration activities, and to assess extinction risk.

Smolt trapping should continue at the sites identified in this report. We demonstrated the ability to develop accurate and unbiased estimates of steelhead for the basin. Since coho rear downstream on the lower trap site we suggest in addition to trapping smolts these fish should also be CWT. Adult sampling of coho jacks and adults will allow smolt estimates to be estimated through back calculation. To develop chum and chinook salmon estimates, we recommend that monitoring begin in February and extend through July. In addition, the rotary traps should be modified to eliminate the possibility that fry exit the live box via the debris drum.

Acknowledgments

We would like to thank the following people who assisted with this project. The sampling crew including Steven VanderPloeg, Julie Grobelney, Michelle Smith, and Josh Holowatz collected data and installed and removed traps. Cameron Sharpe (WDFW) provided assistance with statistical analysis. Michael Murphy (NMFS-Auke Bay) provided the Fortran program for the calculation of trap efficiencies, population estimates, and variances. Clark County Parks Department provided access to the Lucia Falls trap site and the south bank of the lower trap site. Dean Swanson provide the primary access to the lower trap site and provided cable to secure the lower trap. Part of this study was funded by Lower Columbia Fish Recovery Board and we would like to thank Jeff Breckel for his support of this project.

References

Adams, N., and K. Wieman. 1998. Passage of radio tagged steelhead smolts at Hemlock Dam in 1997. Unpublished draft.

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapement and other popul ations. Canadian Tech. Report of Fisheries and Aquatic Science 2106. 37p.

Beecher, H. A., T. H. Johnson, and J. P. Carlton. 1993. Predicting microdistribution of steelhead (Oncorhynchus mykiss) parr from depth and velocity preference criteria: test of an assump tion of the Instream Flow Incremental Methodology. Canadian Journal of Fisheries and Aquatic Sciences 50:2380-2387.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 in W.R. Meehan, editor. Influence of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19. Bethesda, MD.

Bradford, M.J., R.A. Myers, and J.R. Irvine. 2000. Reference points for coho salmon (Oncorhynchus kisutch) harvest rates and escapement goals based on freshwater production. Canadian Journal of Fisheries and Aquatic Sciences 57:677-686.

Bryant, F. G. 1949. A survey of the Columbia River and its tributaries with special reference to its fishery resources. 2: Washington streams from the mouth of the Columbia River to and including the Klickitat River (Area 1). U.S. Fish and Wildlife Service. Spec. Sci. Rep. No. 62.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Oregon, and California. U.S. Dept of Commerce, NOAA Tech. Memo. NMFS-NWDSC-27, 261p.

Cederholm, C.J. and W.J. Scarlet. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-81. Pages 98-110 in E.L. Brannon and W.O. Salo editors. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington. Seattle, WA.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Publications in Statistics 1:131-160.

Chapman, D.G. 1986. Salmon and steelhead abundance in the Columbia River in the Nineteenth Century. Amer. Fish. Soc. 115:662-670.

Chilcote, M. 1998. Conservation status of Oregon steelhead populations. Oregon Department of Fish and Wildlife. Portland, OR.

Cooper, R., and T. H. Johnson. 1992. Trends in steelhead abundance in Washington and along the Pacific Coast of North America. Washington Dept. of Wildlife. Fisheries Management

Division, Report No. 92-20. 90p.

Cramer, S. P., and 9 coauthors. 1997. Synthesis and analysis of the Lower Columbia River Steelhead Initiative. S.P. Cramer and Associates, Inc.

Efron, B., and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1:54-77.

Dempson, J. B., and D. E. Stansbury. 1991. Using partial counting fences and a two sample stratified design for mark recapture estimation of an Atlantic salmon smolt population. North American Journal of Fisheries Management 11:27-31.

Gibbons, R. G., P. K. Hahn, and T. H. Johnson. 1985. Methodology for determining MSH steelhead spawning escapement requirements. Washington State Game Department, Fisheries Management Division. 85-11. 22p.

Hart, P. J., and T. J. Pitcher. 1969. Field trials of fish marking using a jet inoculator. Journal of Fish Biology 1: 383-386.

Hillman, T. W., and M. D. Miller. 1989. Use of jet inoculator to mark juvenile chinook salmon for assessment of permanence station. Don Chapman Consultants Inc.

ISG (Independent Science Group). 1996. Return to the river: Restoration of salmonid fishes in the Columbia River ecosystem. No. 96-6. Northwest Power Planning Council, Portland, OR.

Keefer, M. L., D. J. Anderson, R. W. Charmicheal, and B.C. Johnson. 1996. Early life history study of Grande Ronde River basin chinook salmon. Bonneville Power Administration.

Knudsen, E. E. 1997. Managing Pacific salmon escapements: the gaps between theory and reality. U.S. Geological Survey, Biological Resources Division. Proceedings from the Sustainable Fisheries Conference. Anchorage, AK. In press.

Lestelle, L. C., L. E. Mobrand, J. A. Lichatowich, and T. S. Vogel. 1996. Applied ecosystem analy sis--a primer, EDT: the ecosystem diagnosis and treatment method. Project No. 9404600. Prepared for: Bonneville Power Administration, Portland, OR.

Loranger, T. 1999. Unpublished letter summarizing the results of possible water quantity impacts to salmonids within the EF Lewis River using "instream flow incrementatl methodology" and "toe width method" (Ecology publication # 99-151)

McDubbing, D.J.F., and B. R. Ward. 2000. Stream rehabilitation in British Columbia's watershed restoration program: juvenile salmonid response in the Keogh and Waukwass rivers 1998. Watershed Restoration Project Report No. 12. 20pp.

Miller, W. H., T. C. Coley, H. L. Burge, and T. T. Kisanuki. 1990. Analysis of salmon and steelhead supplementation: Emphasis on unpublished reports and present programs. Part 1 in Analysis of Salmon and Steelhead Supplementation. Technical Report. Bonneville Power Administration. Portland, OR.

Murphy, M. L., J. F. Thedinga, and J. J. Pella. 1996. Bootstrap confidence intervals for trap efficiency estimates of migrating fish. National Marine Fisheries Service, Juneau, AK.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4-21.

Nicholson, T.E., M.F. Solazzi, S.L. Johnson, and J.D. Rogers. 1993. Approach to determining stream carrying capacity and limiting habitat for coho salmon (Oncorhynchus kisutch) in L. Berg and P. Delany, editors. Proceeding of the 1992 Coho Workshop. Nanaimo, B.C.

Nicholson, T. E. 1998. ODFW coastal salmonid population and habitat monitoring program, draft. Oregon Department of Fish and Wildlife. Corvallis, OR.

Norman, D.K., C.J. Cedarholm, W.S. Lingley. 1998. Floodplains, salmon habitat, and sand and gravel mining. Washington Geology. Vol. 26, No. 2/3, pages 3-20.

Petersen, N.P. 1982. Immigation of juvenile coho salmon (Oncorhynchus kisutch) into riverine ponds. Canadian Journal of Fisheries and Aquatic Sciences 39:1308-1310.

Rawding, D. J. 1997. Wind River smolt monitoring program. Washington Department of Fish and Wildlife, Vancouver, WA. Unpublished draft.

Rawding, D. 1999. A description of life history trajectories and classification of key habitat for wild summer steelhead in the Wind River basin. Washington Department of Wildlife, Vancouver, WA. Unpublished Draft.

Rawding, D, P.C. Cochran, and T. King. 1999. Wind River steelhead smolt and parr production monitoring. Wash. Dep. Fish and Wild. Olympia, WA. 22p

Rawding, D, and P.C. Cochran. 2001. Wind River steelhead smolt and parr production monitoring. Wash. Dep. Fish and Wild. Olympia, WA. 22p.

Rawding, D. (In prep). Variation in the Kalama River wild summer and winter steelhead stock-recruitment relationship. Wash. Dep. Fish and Wild. Olympia, WA. (working paper)

Rawding D. (In prep). Lower Columbia River chum salmon. Wash. Dep. Fish and Wild. Olympia, WA. (working paper)

Reeves, G.H., F.H. Everest, and T.E. Nicholson. 1989. Identification of physical limiting factors for coho salmon in western Oregon and Washington. USDA Forest Service, Gen. Tech. Rep. PNW-GTR-245. Portland, OR. 18pp.

Reeves, G. H., K. M. Burnett, F. H. Everest, J. R. Sedell, D. B. Hohler, and T. L. Hickman. 1992. Responses of anadromous salmonid populations and physical habitat to stream restoration in Fish Creek, Oregon, 1983-90. U.S. Department of Energy, Bonneville Power Administration, Division of fish and Wildlife, Portland, OR. Project No. 84-11. Contract No. DE-AI 79-84 BP 16726.

Rich, B. A., R. J. Scully, and C. E. Petrosky. 1992. Idaho habitat/natural production monitoring. Idaho Department of Fish and Game. Annual report for 1990. Bonneville Power Adminis tration. Project 83-7.

Robson, D.S., and H.A. Regier .1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 98: 3: 215-26.

Rosgen, D. L. 1994. A classification of natural rivers. Elsevier Science, B.V. Amsterdam. Catena 22:169-199.

Schwarz, C. J., and C. G. Taylor. 1998. Use of the stratified- Petersen estimator in fisheries man agement: estimating the number of pink salmon (Oncorhynchus gorbuscha) spawners in the Fraser River. Canadian Journal of Fisheries and Aquatic Sciences 55:281-296.

Scully, R. J., and C. E. Petrosky. 1991. Idaho habitat/natural production monitoring. Idaho Depart ment of Fish and Game. Annual report for 1989. Bonneville Power Administration. Project 83-7.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Charles Briffin and Company, London.

Seiler, D., and five co-authors. 1997. Wild salmon production and survival evaluation. Annual Report No. RAD97-03. Washington Department of Fish and Wildlife, Olympia.

Seiler, D.. 2001. Wild coho salmon forecast for Puget Sound and Washington Coastal Systems. Wash. Dep. Of Fish and Wild., Science Div. Olympia, WA . 26p.

TAC (Technical Advisory Committee). 1991. 1991 - All species review: Columbia River Fish Management Plan.

Thedinga, J. F., S. W. Johnson, K V. Koski, J. M. Lorenz, and M. L. Murphy. 1994. Determination of salmonid smolt yield with rotary screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

Thedinga, J. F., and S. W. Johnson. 1995. Retention of jet-injected marks on juvenile coho and sockeye salmon. Transactions of the American Fisheries Society 124:782-785.

USFS (U.S. Forest Service). 1995. EF Lewis River basin watershed analysis. Mt. St. Helens Ranger District, Carson, Washington.

Wade, G. 2000. Salmon and steelhead limiting factors, Water Resource Area 27. Washington State Conservation Commission. Olympia, WA. 120pp.

Walters, C. J., and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. Canadian Journal of Fisheries and Aquatic Sciences 38:704-710.

WDFW (Washington Department of Fish and Wildlife). 1997. Stock status update for steelhead in the lower Columbia River , Washington. Washington Department of Fish and Wildlife, Olympia, WA.

WDFW (Washington Department of Fish and Wildlife). 1997. Final environmental impact state ment for the Wild Salmonid Policy. Washington Department of Fish and Wildlife, Olympia, WA.

WDW (Washington Department of Wildlife), and Washington Department of Fisheries. 1990. Kalama River subbasin salmon and steelhead production plan. Columbia Basin System Planning, Northwest Power Planning Council, Portland, OR.

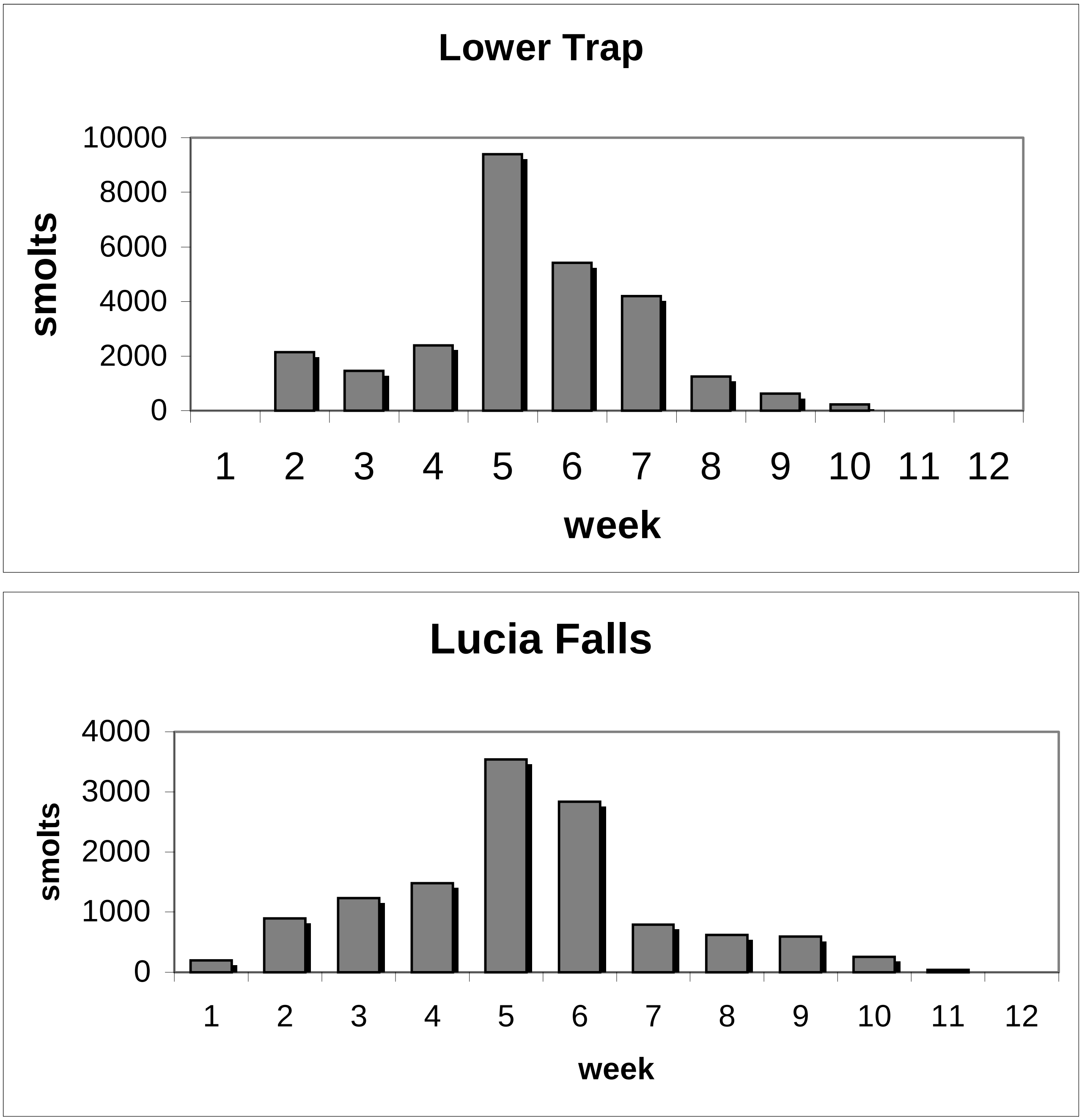


Figure 1. Timing of wild steelhead smolts at the Lower and Lucia Falls traps (note Week 1 corresponds to April 2, 2000).

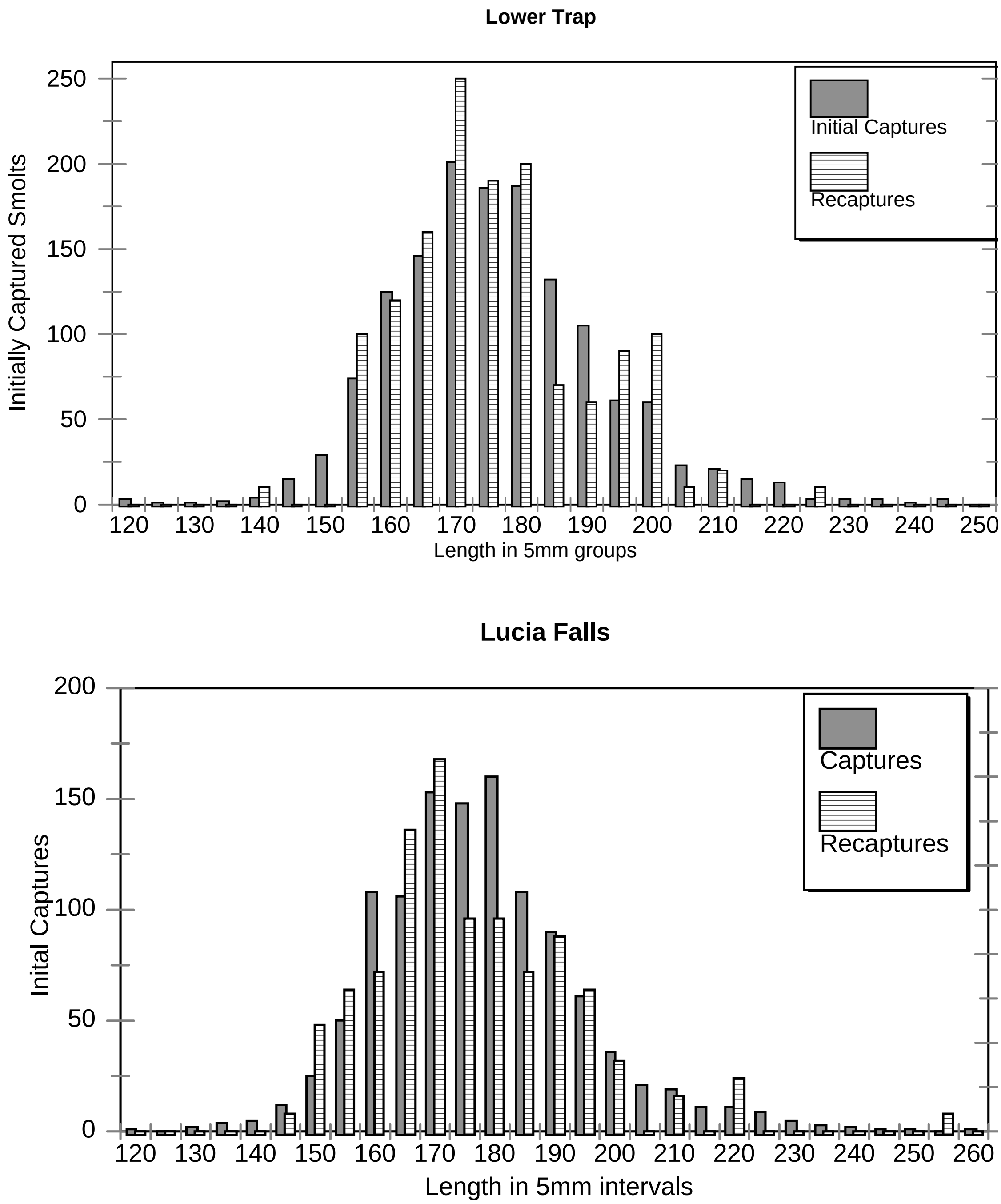
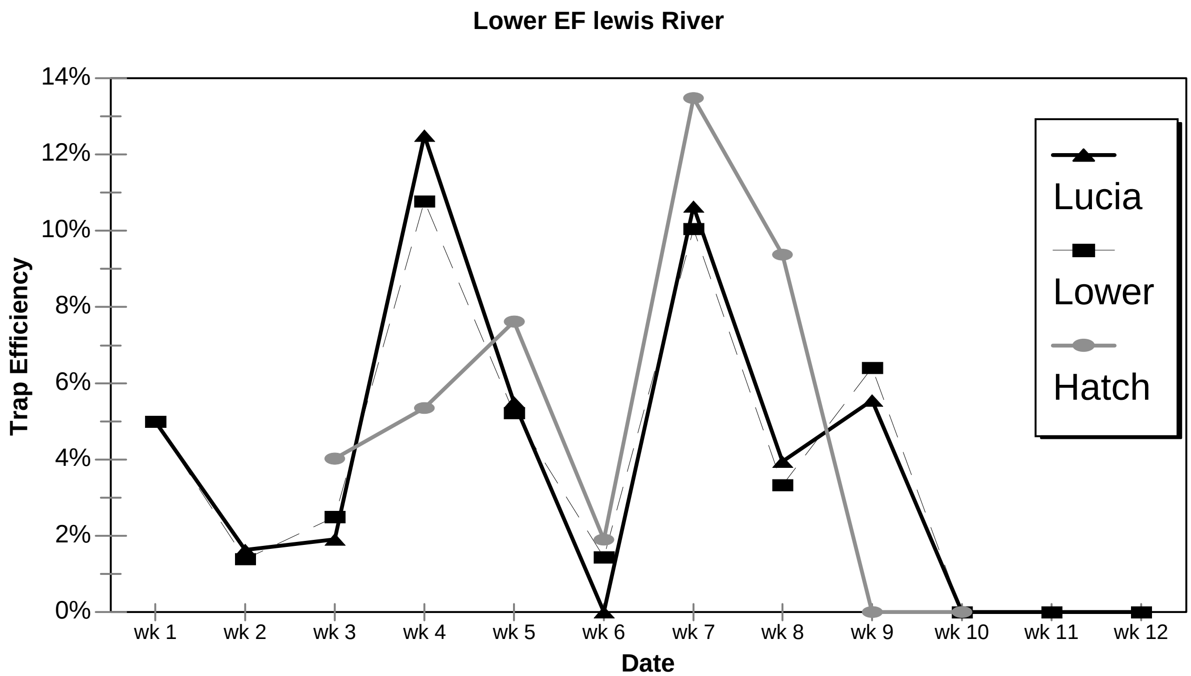


Figure 2. Length frequency of initially captured and recaptured steelhead smolts at the lower and Lucia Falls traps on the EF lewis River, spring 2000.



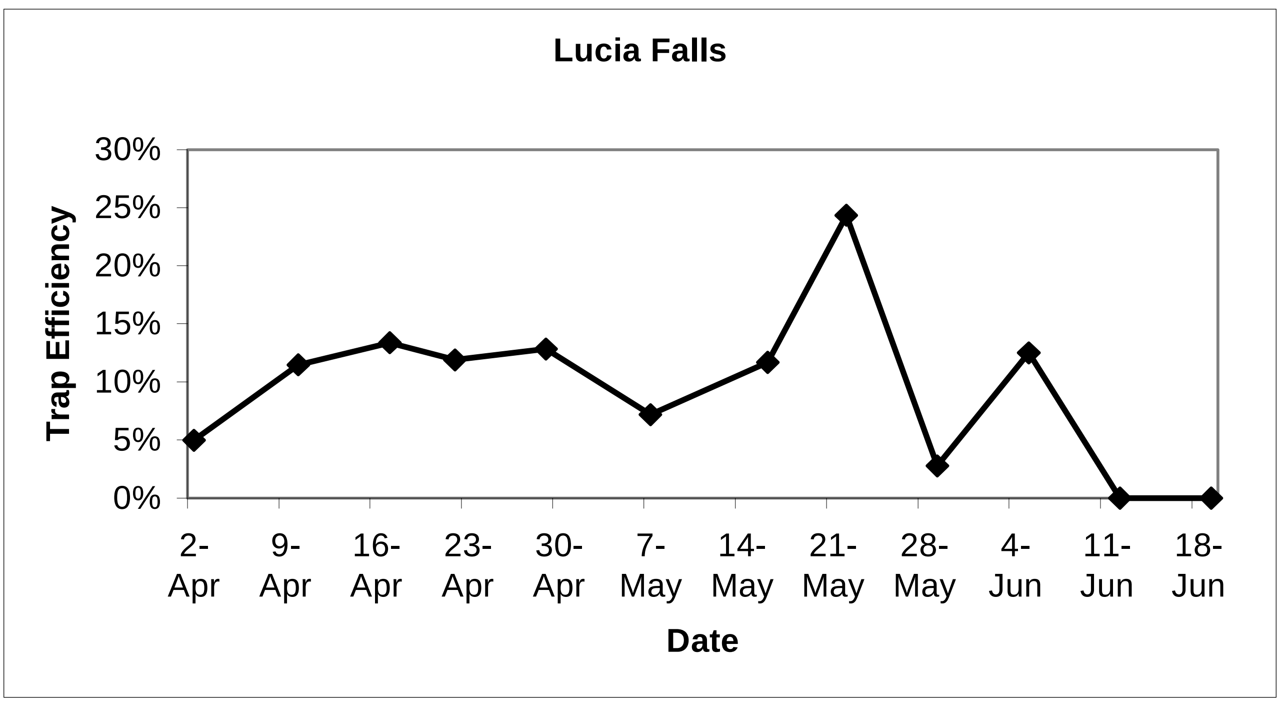


Figure 3. Weekly trap efficiencies for steelhead smolts at the Lucia Falls and lower EF Lewis River trap, Spring 2000.

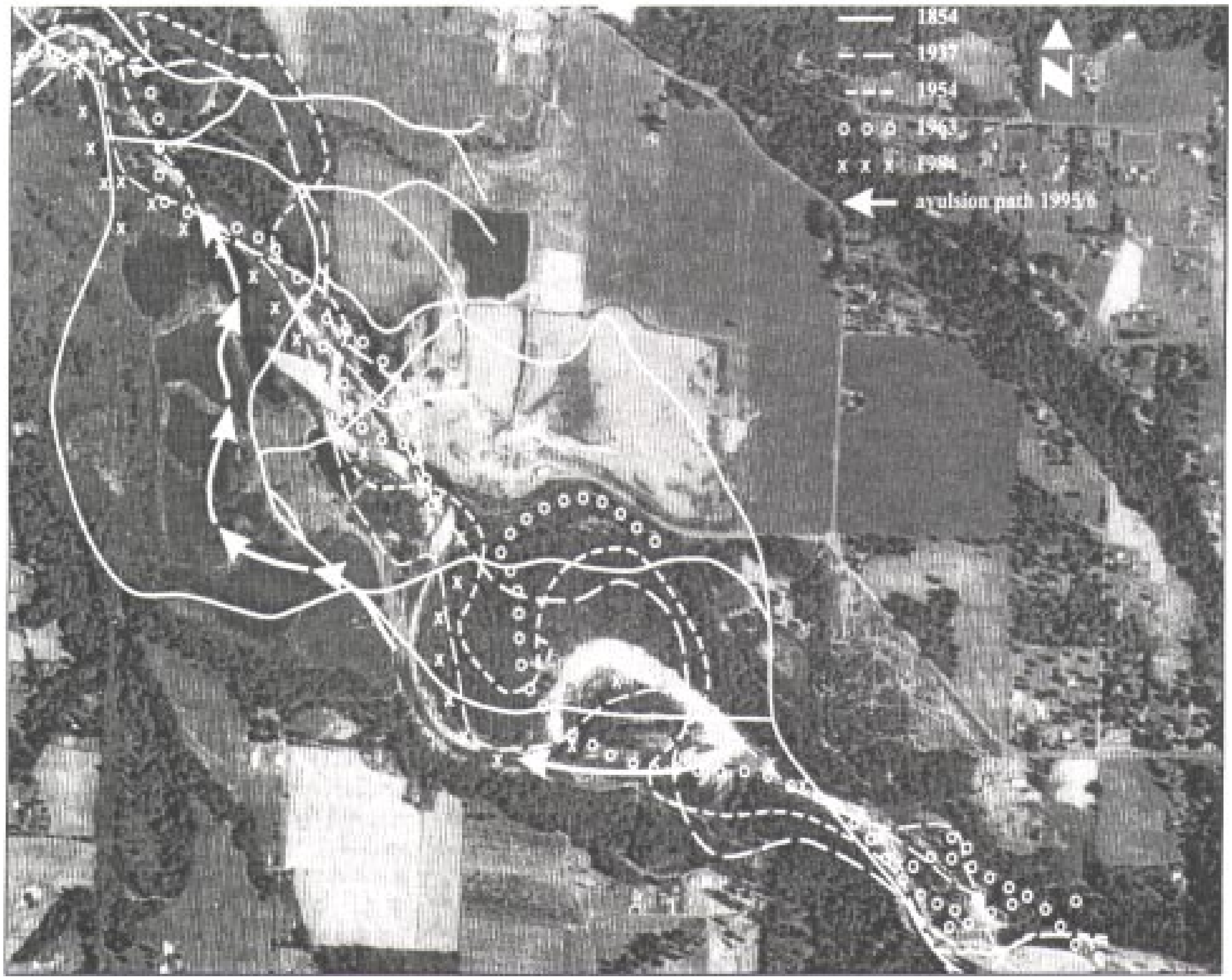


Figure 4. Arial photo (1996) showing the present and historic channels in the lower EF Lewis River from Norman et al. (1998).

Salmonid Habitat and Distribution: A Summary of the Limiting Factors to Salmonid Production in the lower East Fork Lewis River Subbasin (RM 0 to RM 32.7) with Distributions of Selected Anadromous Species

Prepared By:
Ned Pittman,
Christopher Stearns,
and
Brian McTeague

Wade (2000) reports on the limiting factors to salmonid (*Oncorhynchus spp.*) production in the East Fork Lewis River subbasin across several categories, these categories include: Access, floodplain connectivity, bank stability, large woody debris (LWD), pools, side channels, substrate fines, riparian conditions, water quality, water quantity, and biological processes (Table 1). The Limiting Factors process included assistance from the WRIA 27 Technical Advisory Group (TAG). The following is a summary of these findings along with additional information generated by the Salmon and Steelhead Inventory and Assessment Program (SSHIAP) and these authors.

Habitat

SSHIAP has identified approximately 119.6 miles of anadromous habitat within the East Fork Lewis River subbasin. This value may be further broken down by known and presumed use (97.82 miles), historical use (17.88 miles), and potential for use (3.9 miles). The preceding data is considered DRAFT as fish distribution within the subbasin is being reviewed at this time.

SSHIAP habitat types (Table 2) were identified by stream segment throughout the anadromous zone of the East Fork Lewis River subbasin. Information generated by this effort is presented within Figure 1.

Figure 1. SSHIAP Habitat Type: East Fork Lewis River Subbasin

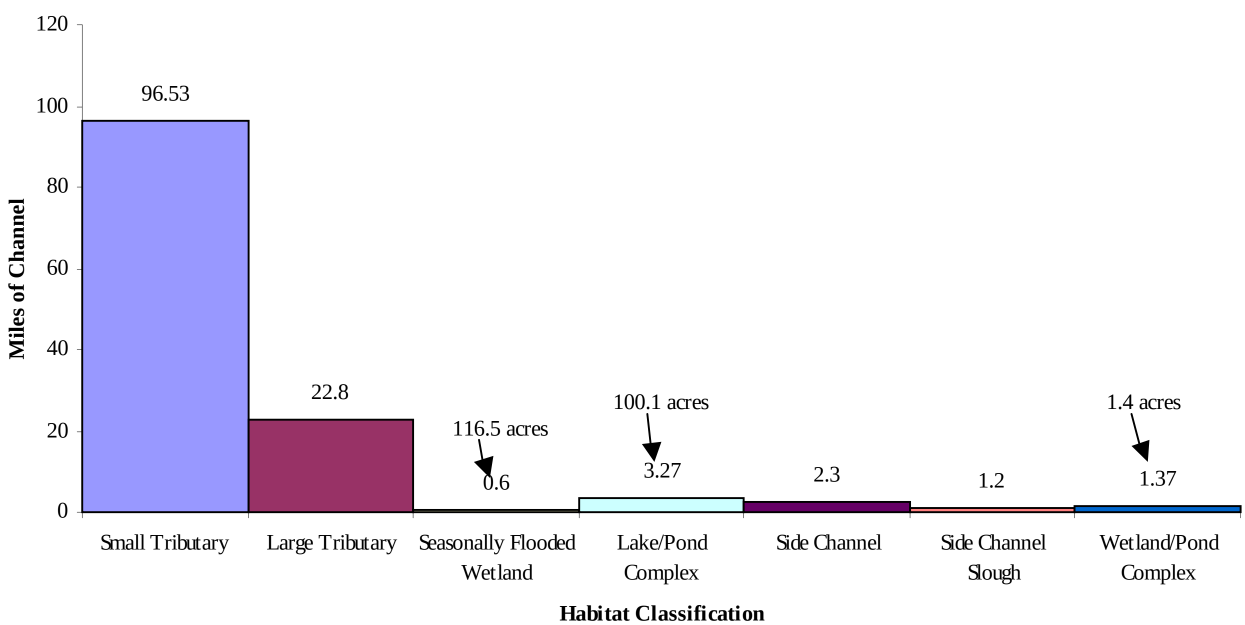


Table 1. Summary of habitat limiting factors within the East Fork Lewis River basin (Adapted from Wade 2000)												
Stream Name	WRIA #	Fish Passage	Floodplain Connectivity	Bank Stability	LWD	Pools Ratio (pools/mile)	Side Channels	Substrate Fines	Riparian	Water Quality	Water Quantity	Biological Processes
Lower mainstem (to RM 6)	27.0173	G(2)	P (2)	P (2)	P (2)	NA	P (1)	P (2)	P (3)	P (1)	P (1)	P (1)
McCormick Creek	27.0182	P (1)	F (2)	ND	ND	ND	ND	P (2)	P (3)	P (1)	P (1)	P (1)
Brezee Creek	27.0186	P (1)	ND	ND	ND	ND	ND	F (2)	F (3)	ND	P (2)	P (1)
Lockwood Creek	27.0189	P (1)	P* (2)	P (2)	F (2)	ND	P (2)	P (2)	P (3)	P (1)	P (1)	P (1)
Mason Creek	27.0200	P (1)	P (2)	P (2)	P (2)	ND	ND	P (2)	P (3)	P (1)	P (1)	P (1)
mainstem (RM 6 to 16.2)	27.0173	G(2)	P (1)	P (1)	P (2)	P (1)	P (1)	P (2)	P (3)	P (1)	P (1)	P (1)
Dean Creek	27.0214	P (1)	P (2)	P (1)	P (2)	ND	ND	P (1)	P (3)	P (1)	P (1)	P (1)
Mill Creek	27.0218	G(2)	NA	ND	P (2)	P (2)	ND	P (2)	P (3)	ND	ND	P (1)
Rock Creek (lower)	27.0222	G(2)	NA	P (2)	P (2)	P (2)	ND	P (2)	P (3)	P (1)	ND	P (1)
mainstem (RM 16.2 to 32)	27.0173	G(2)	NA	F (2)	P (2)	F (2)	F (2)	F (2)	P (3)	P (1)	P (1)	P (1)
Rock Creek (upper)	27.0254	G(2)	NA	F (2)	P (2)	F (2)	F (2)	G(2)	P (3)	P (1)	F (2)	P (1)
Cedar Creek	27.0260	G(2)	NA	F (2)	P (2)	F (2)	P (2)	F** (2)	P (3)	P (2)	F (2)	P (1)
mainstem (RM 32 to headwaters)	27.0173	G(2)	NA	F (1)	P (1)	P (1)	P (2)	F** (1)	P (1)	P (1)	P (1)	P (1)
King Creek	27.0272	G(2)	NA	ND	P (1)	ND	ND	F (1)	F (1)	ND	F(1)	P (1)
Slide Creek	27.0284	G(2)	NA	ND	P (1)	P (1)	ND	F (1)	P (1)	ND	P (1)	P (1)
Green Fork	27.0287	G(2)	NA	ND	P (1)	ND	ND	F (1)	F (1)	ND	F (1)	P (1)
P = "Poor" as defined in Appendix ? (Salmonid Habitat Condition Rating Standards)							(1) Documented by quantitative studies or published reports					
F = "Fair" as defined in Appendix ? (Salmonid Habitat Condition Rating Standards)							(2) Personal and professional experiences of TAG members					
G = "Good" as defined in Appendix ? (Salmonid Habitat Condition Rating Standards)							(3) Riparian habitat conditions rated by aerial photo analysis					
ND = No Data for this specific habitat condition in this subbasin							* Rehabilitation practices are planned to address this problem					
NA = Not Applicable to this subbasin							** Lack of suitable spawning gravel					

Table 2. Stream segment habitat types recognized under the SSHIAP methodology.

SSHIAP database code	Habitat type	Description
1	Small Tributary	Stream with summer low flow wetted width <6m, OR basin area <23mi^2 (≈1/2 of a USGS 7.5' quad).
2	Large Tributary	Stream/river with summer low flow wetted width ≥6m. OR basin area >23mi^2.
3	Side Channel	Persistent secondary channel, typically with a vegetated island or other persistent landform separating it from the main channel.
4	Side Channel Slough	Channel branching off the mainstem with >90% pools.
5	Distributary Slough	Channel with >90% pools that branch off a mainstem and flow as part of or into an estuary.
6	Lake/Pond	Habitat with standing water all year. Shown as unbroken blue on USGS topos; verified with aerial photos.
7	Wetland/Pond Complex	Wetland with associated, perennial surface water pond(s). Shown as blue with grass symbols or unbroken blue on USGS topos; verified with aerial photos.
8	Seasonally Flooded Wetland	Wetland that holds water for only a portion of the year. Often have perennial surface water channels and are identifiable with aerial photographs. Shown in white with grass symbols on USGS topos.

A large part of the aquatic habitat in the East Fork Lewis River subbasin is described as small tributary (Figure 1), however the overall habitat (within the anadromous zone) remains relatively low gradient with only about 7.2% of anadromous miles > 4% in slope (Figure 2; Table 3).

Figure 2. East Fork Lewis River Gradient/Confinement Classes

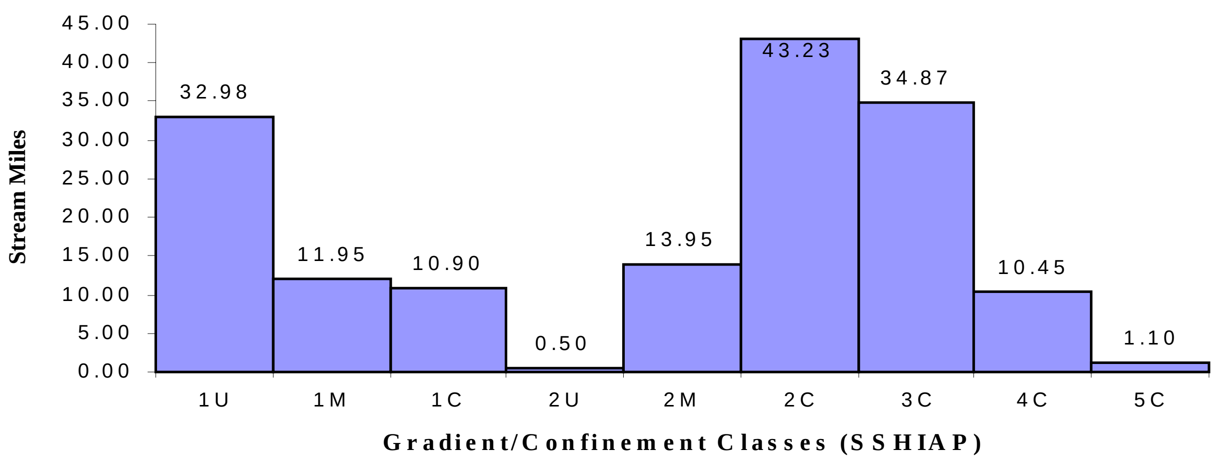


Table 3. Selected gradient/confinement classes recognized under the SSHIAP methodology.

Gradient/Confinement Code	Gradient	Confinement
1U	<1%	Unconfined – floodplain width ≥ 4 channel widths
1M	<1%	Moderately Confined - floodplain width ≥ 2 and < 4 channel widths
1C	<1%	Confined – floodplain < 2 channel widths
2U	1-2%	Unconfined – floodplain width ≥ 4 channel widths
2M	1-2%	Moderately Confined - floodplain width ≥ 2 and < 4 channel widths
2C	1-2%	Confined – floodplain < 2 channel widths
3C	2-4%	Confined – floodplain < 2 channel widths
4C	4-8%	Confined – floodplain < 2 channel widths
5C	8-20%	Confined – floodplain < 2 channel widths

Access

The only limits to anadromous access along the mainstem East Fork Lewis River are Lucia Falls and other natural falls (Moulton, Horseshoe, and Sunset) that lie upstream of these (Wade 2000). The uppermost, Sunset falls (RM 32.7), was notched in 1982 opening up a significant amount of previously non-anadromous habitat in the upper watershed (Wade 2000). Steelhead (*O. mykiss*) (Wade 2000) and anadromous form cutthroat (*O. clarki*) (Bond Richards, landowner, pers. comm.) are the only species that consistently access areas upstream of Lucia Falls.

There are a number of passage problems on tributaries to the East Fork Lewis River. Wade (2000) provides a list of these passage problems as summarized below (includes the entity that identified the problem):

- McCormick Creek – Partial to total barrier culvert at the 319th Street crossing (Clark County Public Works) blocks 2.3 miles of potential habitat for winter steelhead and coho (*O. kisutch*).
- Breezee Creek – impassable culvert (Clark County Public Works) at RM 0.4 (County Road 42 or Lockwood Road) blocks 5.7 miles of potential habitat for winter steelhead and coho.
    - Passable barrier (Clark County Conservation District), a dam 500 ft above blocks 0.8 miles potential winter steelhead and coho habitat on Riley Creek (tributary to Lockwood Creek).

    - A partially blocking/impassable culvert (Clark County Public Works) has been located at the Taylor Valley Road crossing on a tributary to Lockwood Creek. A series of cascades below this culvert may limit fish distribution themselves, it is recommended that a survey for coho above the cascades be completed prior to any repair or modifications to the culvert.

- Mason Creek – Passable culvert (Clark County Public Works) under N.E. 102nd needs additional assessment to determine its status.
    - 3 impassable culverts on Mason Creek tributary (Clark County Public Works): one at Underwood Road crossing, one at Peart Road crossing, one in between these two roads. 1.57 miles of potential habitat affected
    - Impassable culvert (Clark County Public Works), at Dunn Road crossing on tributary to Brezee Creek (blocks 1.8 miles potential winter steelhead and coho habitat.
    - Impassable culvert (Clark County Public Works), at 359th Street crossing.
    - Passable blockage culvert (Clark County Public works) at Dunn Road crossing on left fork of Brezee tributary.
- Lockwood Creek – Culvert improvements at the Lockwood road crossing may need modifications or consistent maintenance to provide full passage to all species (TAG members). Impassable culvert (Clark County Public Works) at Finalburg Road crossing
- Dean Creek (unnamed 27.0210) – two barrier culverts (need assessment) one near mouth may block 2.2 miles of habitat, another on private property may block 0.8 miles of habitat for winter steelhead, cutthroat, and coho (TAG Members).
    - potential low-flow and thermal barrier passage problems near the mouth (TAG Members).
    - mid- and late-summer flow is often subterranean in heavy gravel deposits just downstream of J.A. Moore Rd (TAG Members).
- Unnamed RB tributary (27.0201) at RM 3.1 – Passable barrier (Clark County Conservation District) at Moore Rd. crossing.
    - Impassable culvert (Clark County Conservation District).
    - Impassable culvert (Clark County Public Works).
    - Impassable culvert (Clark County Public Works) at Road No. 3 crossing.
- Mill Creek – impassable culvert (Clark County Conservation District) at the N.E. 239th St. crossing.
- Unnamed LB tributary (27.0219) – impassable barrier (Clark County Conservation District).
    - impassable barrier (Clark County Conservation District).
    - impassable barrier (Clark County Conservation District).
- Unnamed LB tributary (27.0220) – impassable culvert (Clark County Public Works) at Pender Rd. crossing.
- Unnamed RB tributary (27.0242) – impassable barrier (Clark County Public Works).
- Big Tree Creek – impassable culvert (Clark County Public Works) affects 0.23 miles of potential winter and summer steelhead habitat.
- Upper rock Creek – impassable culvert (Clark County Public Works) at Dole Valley Road crossing falls outside known anadromous distribution.
- Slide Creek – passable barrier (Clark County Conservation District) at Gumboot Road crossing.

- Green Fork – impassable culvert at Green Fork Rd. crossing (Clark County Conservation District) affects 0.3 miles of potential winter and summer steelhead habitat.
    - impassable culvert (Clark county Conservation District) at second Green Fork Road Crossing.

In all, approximately 67% of anadromous fish bearing tributaries to the East Fork Lewis River are affected by barrier culverts along their mainstems and/or tributaries. The Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) identified 29 barrier culverts (anadromous zone) within the East Fork Lewis River subbasin (Table 4).

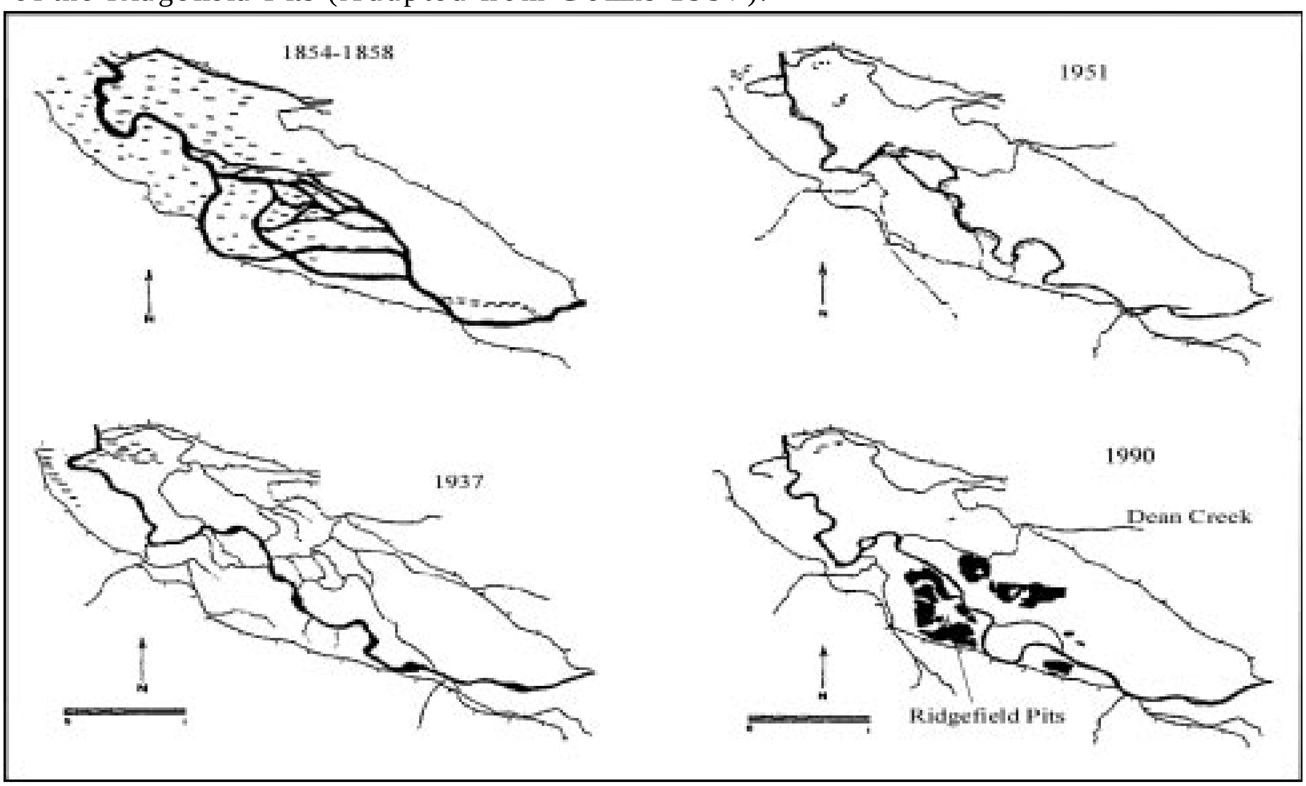
Table 4. Barrier culverts within the East Fork Lewis River subbasin (data from SSHIAP).

Status	# of Culverts	Miles Blocked
Impassable	22	33.2
Passable	7	9.1 partial block
Total	29	42.3 affected

Floodplain Connectivity

TAG members estimate that over 50% of the off-channel habitat and associated wetlands within the floodplain of the lower East Fork Lewis River have been disconnected from the river (Wade 2000). Historically, the lower East Fork Lewis River was comprised of a multi-threaded sinuous channel (Figure 3). Although the East Fork remains largely sinuous in character, the channel has been converted from a multi-threaded pattern to a single channel due to floodplain modifications (Figure 3). This conversion to a single thread morphology has substantially reduced the complexity of habitat and largely eliminated off-channel habitats (Norman et al. 1998). Off-channel habitats have been shown to be important as a rearing and over-wintering area for coho salmon (*O. kisutch*) (Peterson 1982; Swales and Levings 1989; Bjornn and Reiser 1991).

Figure 3. Historic channel patterns of the East Fork Lewis River in the vicinity of the Ridgefield Pits (Adapted from Collins 1997).



Wade (2000) further reports that diking, ditching and the draining of wetlands has occurred on a number of floodplain properties as a result of efforts to protect and enhance agricultural, residential, and mining activities. Areas of concern include:

- LaCenter Bottoms (RM 3.3 to RM 4.5)
  - Dikes disconnect the river from the floodplain along the north side of the river; and
  - Extensive ditching and draining of the floodplain.
- Lockwood Creek
  - Dikes run along the lower reaches of this tributary.
- County owned properties (RM 4.5 to RM 7)
  - A number of dikes disconnect the river from the floodplain along the south side of the river; and
  - Ditching has occurred that drains wetlands and wall base channels in this area.
- Ridgefield Pits (near RM 8)
  - Remnant/discontinuous dikes along the north side of the river disconnect the channel from the floodplain.
- County property (referred to as the Zimmerly property) (near RM 7)
  - Remnant dikes reduce the connection between the channel and floodplain habitats.
- Near RM 7.2
  - Dikes along the north side of the river protect private properties from flooding while contributing further to the disconnect between channel and floodplain.
- County gravel pit (near RM 9.4)
  - Dikes in place to protect the gravel pit further contribute to floodplain disconnect.
- RM 9
  - Remnant dikes remain in mid-channel after the 1995 avulsion into this gravel pit.
- Daybreak Park (near RM 12)
  - Daybreak dike on the south side of the river upstream of the park has disconnected a large overflow channel with floodplain habitat from the river.

Area SSHIAP biologists have provided the following updates to this information (Christopher Stearns, WA. Dept. Fish and Wildlife, pers. comm.):

- Mainstem dike from RM 0.3 to RM 0.7.
- Mainstem dike from RM 12.7 to RM 12.9.
- A total of 0.4 miles of diking has now been removed on lower Lockwood Creek, lowering the known total length of diking to 6.2 miles (currently identified) in the East Fork Lewis River subbasin.
- Three other dike removal projects are under review and expected to begin in July 2001 with completion dates within 2 years.
  - Removal of 2/3 of the Schriber levee (approximately 0.4 miles).
  - Removal of the Schaefer levee at RM 5.8.
  - Removal of a 0.6 mile levee along the power line adjacent to left bank tributary #27.0210.

Washington Department of Natural Resources Geologist, Carol Serdar, reports that there are 6 active permitted surficial mining sites within the East Fork Lewis River subbasin. At least 350 acres of this active mining is located within the floodplain of the East Fork mainstem (Figure 4). These sites are thought to contribute fine sediment and elevated water temperature to the lower mainstem of the East Fork (Carol Serdar, WA. Dept. Natural Resources, pers. comm.).

Figure 4. Gravel mining operation adjacent to the East Fork Lewis River mainstem. The 1996 avulsion to the Ridgefield Pits appears in the upper right of the photograph. (Photograph courtesy of the *Friends of the East Fork*).

Bank Stability

Wade (2000) classified bank stability as “poor” along the mainstem East Fork Lewis River from it’s mouth to RM 16.2 (Table 1, Appendix A), citing highly erodible non-cohesive silts, sands, and gravels as conducive to high rates of lateral channel migration (Figure 5). West Consultants (2000) estimated both the lateral and longitudinal migration rates of the East Fork of the Lewis River channel from RM 7 to RM 10 (Table 5), their findings indicate a highly dynamic channel that is under a state of constant change.

Table 5. Channel migration rates in the vicinity of the Ridgefield Pits (From West Consultants 2000).

Location	Type of Migration	Average Migration (feet/year)
RM 7.0 - RM 7.5	Lateral (side to side)	25
	Longitudinal (up/down valley	25
RM 7.5 - RM 8.0	Lateral (side to side)	NA
	Longitudinal (up/down valley	42
RM 8.0 - RM 9.0	Lateral (side to side)	30
	Longitudinal (up/down valley	27
RM 9	Lateral (side to side)	5 and 100*
	Longitudinal (up/down valley	NA
RM 9 - RM 9.3	Lateral (side to side)	6
	Longitudinal (up/down valley	9
RM 9.3 - RM 10	Lateral (side to side)	6
	Longitudinal (up/down valley	36

* Short-term channel migration between 1996 and 1998.

Figure 5. Highly erodible bank adjacent to gravel mining operation near RM 8 (Photograph courtesy of the *Friends of the East Fork*).

The historic braided channel patterns seen in Figures 3 and 7 generally form within a narrow range of geologic and hydrologic conditions (Dunne and Leopold 1978). These authors contend that braided channel patterns usually develop where flood discharges are high and fluctuate rapidly; where sediment transport rates along the streambed are high; and where the channel gradient is steep, and the stream banks are formed in weak, noncohesive sand and gravel. This observation suggests that the loss of the braided channel pattern near the Ridgefield Pits reflects the bank hardening/diking efforts in this area designed to keep the channel in its present location.

From RM 8 (Ridgefield Pits) to RM 9.5 there is a considerable amount of mass wasting occurring along the steep and unstable south bank of the East Fork Lewis River mainstem (Figure 6) (Wade 2000). It has been suggested that the Daybreak Bridge (RM 10) acts to fix the river in its present location and helps to direct flow toward this south valley wall (West Consultants 2000). Dyrland (1999 pers. comm., cited by Wade 2000) further suggests that dikes protecting county-owned gravel pits along the north bank may further exacerbate erosion along the south cliffs. Norman (1998) adds that the avulsion of the East Fork Lewis River into the Ridgefield Pits has increased the rate of erosion along the already generally unstable south banks. Whatever the cause, or combination of causes, Wade (2000) reports that TAG members concurred that this mass wasting is contributing excessive fine sediments to fall chinook spawning grounds located downstream.

Figure 6. Excessive mass wasting occurring along the south bank (RM 8-9.5) (Photograph courtesy of the *Friends of the East Fork*).

Bank Stability was classified as “fair” from RM 16.2 to the Gifford Pinchot National Forest Boundary (Table 1, Appendix A) (Wade 2000). Much of this particular reach is highly confined by bedrock on both sides of the channel.

Large Woody Debris (LWD)

Large woody debris (LWD) concentrations within the East Fork Lewis River (below Sunset Falls) and its tributaries were rated as “poor” (Table 1, Appendix A) (Wade 2000). The exception to this finding was Lockwood Creek where the Limiting Factors Analysis found LWD concentrations to rate as “fair” (Table 1, Appendix A) (Wade 2000). This author further reports that both Rock Creeks (upper and lower) and Cedar Creek are very limited in LWD abundance. These particular “sediment supply limited” streams (USFS 1999) may require supplementation of LWD to capture and concentrate sparse spawning gravels (Wade 2000).

In response to the 1902 Yacolt Burn, large-scale salvage logging operations began in the East Fork Lewis River subbasin in the 1930’s. Continuing for over 3 decades, much of the riparian area (including LWD within the stream channel) was logged and removed (Wade 2000). Removal of LWD from the stream channel continued in the 1980’s when all debris jams were mistakenly interpreted as barriers to fish passage (USFS 1999).

Work done by the United States Forest Service (USFS) upstream of Sunset Falls may best summarize the decrease in LWD abundance throughout the East Fork Lewis River subbasin (Table 6). These findings display a 68.2% decrease in LWD concentrations over a 15 year period regardless of an extended survey length in the most recent effort.

Table 6. Changes in large woody debris (LWD) abundance along the East Fork Lewis River channel (upstream of Sunset Falls) (From USFS 1999).

Stream Survey Year	*Survey Length (miles)	LWD pieces/mile
1983	4.2	39
1993	5.0	29.3
1998	5.2	12.4

*All surveys begin at Sunset Falls and move upstream.

Wade (2000) further reports that potential recruitment of LWD within the subbasin is of concern, citing the lack of a large coniferous component due to slow recovery from past fires and snag removal activities. It has been shown that in young forest stands, input of LWD large enough to be stable in streams with channel widths greater than about 15 m remain low for at least the first 60 years of riparian forest re-growth (Grette 1985; Long 1987). However, work done on the Nisqually River indicates that a fast growing species, black cottonwood (*Populus trichocarpa*), commonly forms key pieces (i. e., those pieces of LWD that become stable and act as a backbone to form jams) (Collins and Montgomery 2000). These authors further suggest that self-sustaining restoration can occur within 40-80 years, thus potentially earlier than previously assumed.

Pools

The lower 6 miles of the East Fork Lewis River is described as a tidally influenced backwater of the Columbia River (Hutton 1995). Although not directly stated, it is inferred that this reach is completely lacking in pool habitat.

Wade (2000) rated the number of pools/mile and pool quality as “poor” (Table 1, Appendix A) along the east Fork Lewis River mainstem from RM 6 to the lower Rock Creek confluence at RM 16.2. Only 3 large pools were located from RM 7 to RM 10.2 (Daybreak Park) during a 1996 instream habitat survey (EnviroScience 1996). Friends of the East Fork Board Member, Richard Dyrland, reports that the width to depth ratios of the river channel in areas below the Ridgefield Pits have increased over the past 10 years as the few pools in this area fill with sediments (Wade 2000).

The river's 1996 avulsion into the Ridgefield Pits has been construed by some as the addition of pool habitat to the channel (Figure 7). However, the conditions within the abandoned gravel pits are more pond-like and produce instream habitat conditions that may have harmful effects on native salmonid species. These include: increased water temperatures, enhanced habitat for predatory warm water species, and the potential disorientation of smolts in the slack water areas (Norman et al. 1998). Furthermore, the abandonment of about 3200 ft of known steelhead and salmon spawning habitat due to this avulsion (Norman et al. 1998), is likely more detrimental to salmonid production than any gain contributed by the deeper-water habitat created within the pits.

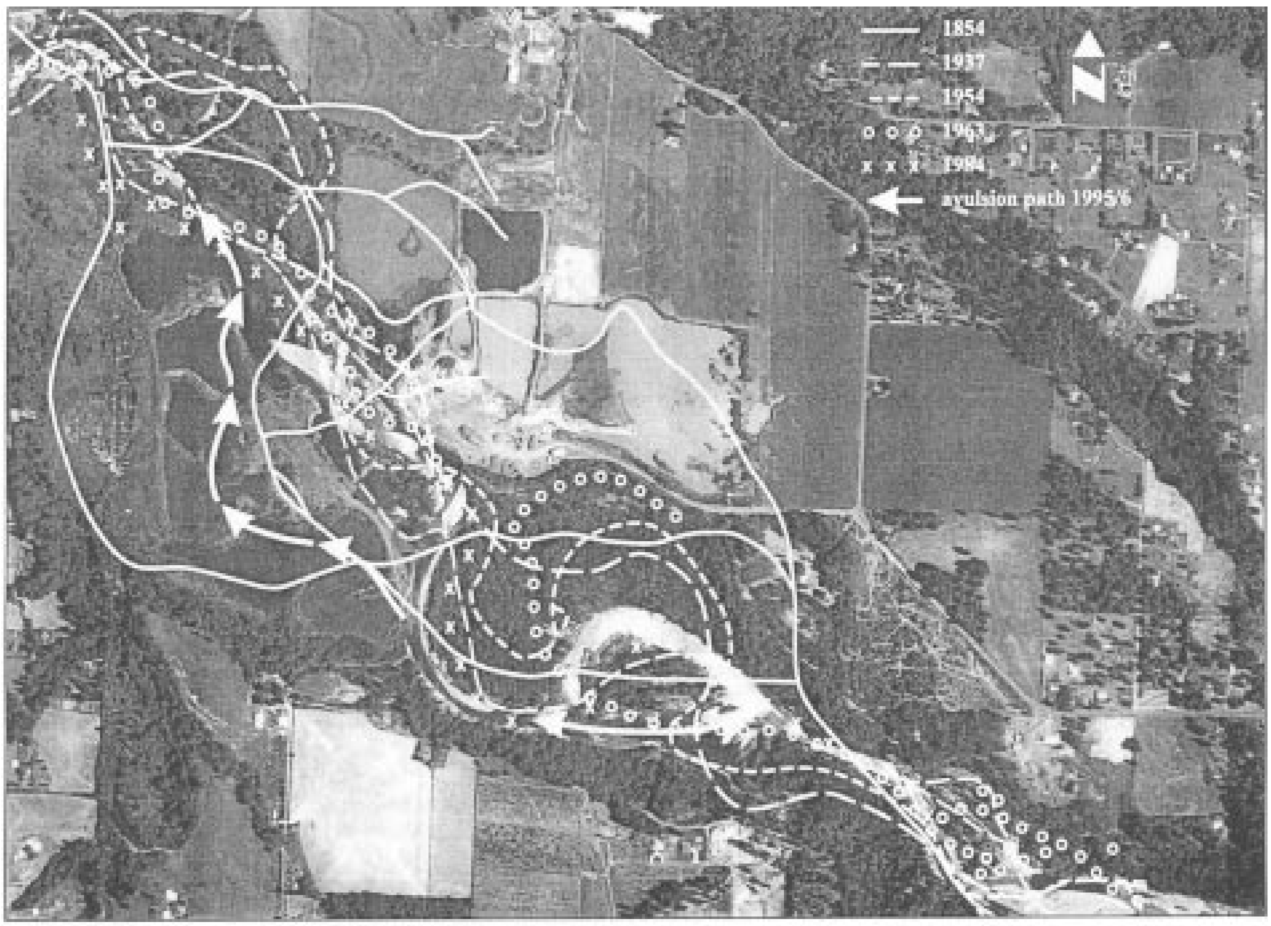


Figure 7. Aerial photograph (1996) showing historic channel locations and avulsions into gravel pits on the East Fork Lewis River near river mile 8 (Adapted from Norman et al. 1998).

The pools/mile ratio was rated as "fair" (Table 1, Appendix A) along the East Fork Lewis River channel from RM 16.2 (lower Rock Creek) to RM 32.7 (Sunset Falls), citing bedrock formations as the primary pool forming factor (Wade 2000).

Pool habitat in most tributaries to the lower East Fork Lewis River was not rated by the Limiting Factors Analysis due to a lack of data. The 2 tributaries that were rated by this analysis (upper Rock Creek and Cedar Creek) received ratings of "fair" (Table 1, Appendix A) relative to the number of pools/mile (Wade 2000).

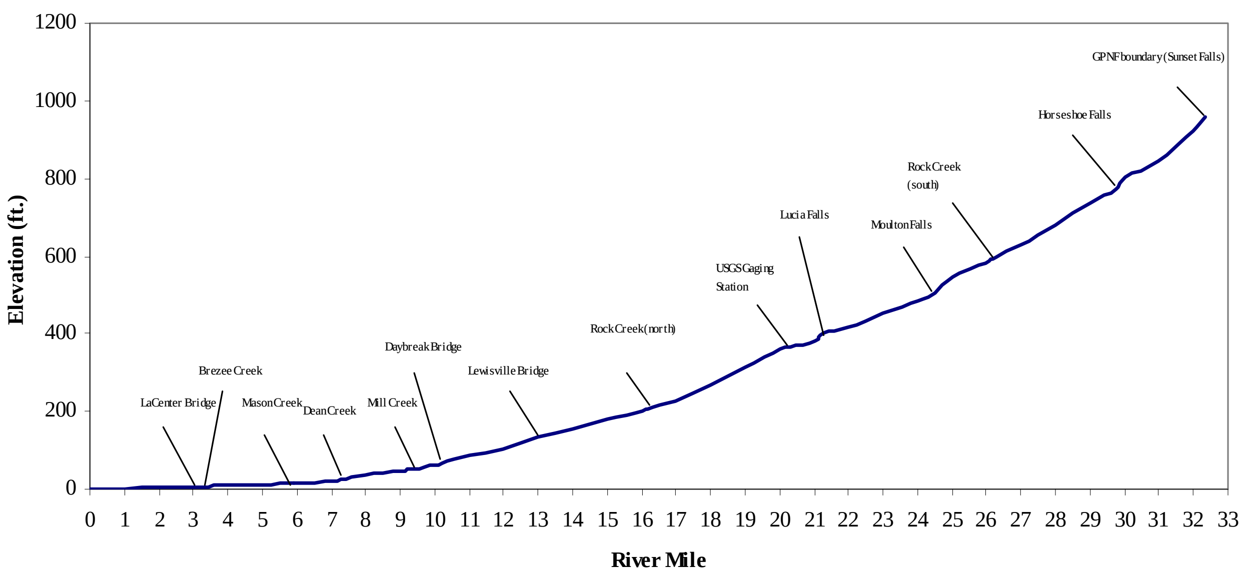
Side Channels

Wade (2000) classified side channel habitat as “poor” (Table 1, Appendix A) along the East Fork Lewis River channel from it’s mouth to RM 16.2 (lower Rock Creek). Collins (1997) reconstruction of historical habitat (Figure 3), demonstrates the conversion of the East Fork Lewis River channel from about RM 6 to RM 10. The 1854-1858 reconstruction indicates that the valley bottom was largely wetland habitat with the upper portion of this reach displaying a complex multi-threaded morphological pattern (See Figures 3 and 7). By 1937, the mainstem appeared as mostly a single-thread channel with a system of ephemeral floodplain sloughs that remained from the former braided channels (Collins 1997). The 1951 reconstruction indicates, by this time, a loss of most of these ephemeral floodplain sloughs (Figure 3). By 1990, several gravel pits occupied the locations of the historic channels (Figure 3). Conversion of the channel within this reach has substantially reduced the complexity of habitat and largely eliminated side channel and backwater habitats (Norman et al. 1998).

Substrate Fines

WEST Consultants (2000) describe the lower 6 miles of the East Fork Lewis River as a flat, tidally influenced silt and sand bed stream. From RM 6 to RM 10 the channel bed materials transition to sand and gravel (Wade 2000). A decrease in channel gradient near RM 10 (Figure 8) has been indicated as a depositional area for sediments delivered from upstream reaches (Wade 2000; WEST Consultants 2000).

Figure 8. Longitudinal Profile of the East Fork Lewis River (Mouth to Gifford Pinchot National Forest boundary)



Hutton (1995) describes the East Fork Lewis River channel from RM 10 to RM 32.7 (Sunset Falls) as primarily a transport reach where steep gradients and high velocities move fine materials to the depositional area previously discussed.

Due to a lack of direct sampling of spawning gravels within the East Fork Lewis River subbasin, Wade (2000) discusses road density as a surrogate measure for fine sediment inputs. The Washington Conservation Commission (WCC) adopted Properly Functioning

Conditions (PFC) standards as developed by the National Marine Fisheries Service (NMFS) as a measure of watershed health relative to road density (Appendices A and B). Thus, road densities >3 mi/mi^2 are considered to fall in the "poor" category (Appendix A). Work done by Lewis County GIS (1999, cited by Wade 2000) indicates an overall road density within the East Fork Lewis River subbasin of 4.13 mi/mi^2. This finding may indicate a high rate of fine sediment delivery to both the mainstem East Fork Lewis River and it's tributaries relative to land management practices.

Chronic mass-wasting has been observed in several areas of the East Fork Lewis River subbasin (Wade 2000). These include: the East Fork Lewis River south bank from RM 8 to RM 9.5 (Figure 6), the high cliffs on Mason Creek near the bridge at Anderson Road, lower Rock Creek above Rock Creek Road, upper Rock Creek near the Dole Valley Bridge, Lockwood Creek above Lockwood Creek Road and upstream of 379th Street. These mass-wasting sites are considered to be major contributors of fine sediments to the stream channels of the subbasin, particularly the south bank site on the mainstem where a combination of undercutting and overland runoff has been observed to actively erode these 75-100 ft high banks that are situated in an exposure of the Lower Troutdale geologic formation (WEST Consultants 2000). This particular formation has been shown to be comprised of 30% fine sediments (Carol Serdar, Washington Department of Natural Resources, pers. comm..) and is thought to contribute excessive fine sediments to fall chinook (*O. tshawytscha*) spawning grounds located downstream (Wade 2000).

Riparian Conditions

Wade (2000) describes riparian habitat as heavily impacted by grazing, farming, residential development, and gravel mining along the lower East Fork River below RM 10 (Daybreak Bridge). This author further describes what remains of the riparian overstory vegetation in this area as widely dispersed cottonwoods (*Populus spp.*), willows (*Salix spp.*), and Oregon ash (*Fraxinus latifolia*) with invasive species such as reed canary grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus discolor*), and Scotch broom (*Cytisus scoparius*) proliferating the disturbed areas.

There has been a significant amount of riparian restoration efforts conducted on some of Clark County's open space properties along the lower 10 miles of the East Fork Lewis River mainstem (Wade 2000). These include:

- Approximately 3.5 miles of shoreline has been replanted as of the summer of 2000 with a mix of native vegetation species,
- More than 4000 native trees and shrubs were planted within 20 acres of the riparian zone on the Storedahl property in 1998 with additional plantings planned for this year, and
- Riparian restoration efforts are planned and being assessed for the Ridgefield Pits.

In general, riparian conditions along the rest of the mainstem were characterized as "poor" (Table 1, Appendix A) (Wade 2000). The author suggests that (from a 1996 aerial photo analysis) roads and residential development parallel the river for much of its length with the removal of riparian vegetation and its replacement with lawns to the banks of the river as a common site. Some riparian sections of the steep south bank of the mainstem from Lucia Falls to upper Rock Creek were considered to remain generally intact with some mature conifers present. Wade (2000) further reports that most of the tributaries of the east Fork Lewis River also display "poor" (Table 1, Appendix A) riparian conditions with some upper sections of Brezee, Riley, Mason, Dean, and Cedar Creeks being the exceptions.

Work done by Lunetta et al. (1997) characterizes riparian conditions by seral stage (Table 7) within a 30 m buffer along response channels (i. e., those 0% to 4% in gradient) throughout much of western Washington State. These authors work summarized conditions at the Water Resource Inventory Area (WRIA) and Watershed Administration Unit (WAU) levels.

Ta ble 7. Seral stage classes considered for riparian analysis by Lunetta et al. 1997 (Modified from Lunetta et al. 1997).

Seral Stage Class	WDNR Classification	Description
Late	1	Coniferous crown cover ≥70% with >10% crown cover in trees ≥21 in. dbh
Mid	2	Coniferous crown cover ≥70% with <10% crown cover in trees ≥21 in. dbh
Early	3	Coniferous crown cover ≥10% and <70% and <75% hardwood tree cover/shrub cover
Other Lands	4	<10% coniferous crown cover (can contain hardwood tree/shrub cover; cleared forest land, etc.)
Non-Forest	15	Urban, agriculture, rangeland, barren, glaciers. Minimum mapping unit = 10/40 acres

For analysis of the lower East Fork Lewis River subbasin, this report concentrates on the WAU scale examination conducted by Lunetta et al (1997). Figures 9A-D portray the percent seral stage class within the 30 m response channel buffer for the lower East Fork Lewis River WAUs (to Snass Creek confluence). It is apparent that late-seral stage forest is nearly non-existent within the response channel buffers, constituting only a small proportion of the Rock Creek-Clark and Cold Creek WAUs by acreage (Figures 9A and B). This, along with the high proportion of mid-seral stage forest within the response channel buffer within these same WAUs may be an artifact of historic fires within the subbasin as mentioned previously (Figures 9A and B). Non-forest and other lands clearly dominate the 2 lowermost WAUs within this subbasin (Figures 9C and D). This finding reflects, in a large part, agricultural and gravel mining components present in the lower reaches of the subbasin.

Figure 9-A. Percent Seral Stage/Land Cover Acres Within Response Channel Buffer (Rock Creek Clark WAU) (From Lunetta et al. 1997)

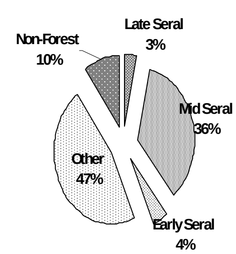
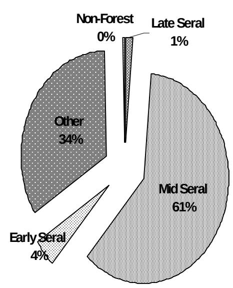
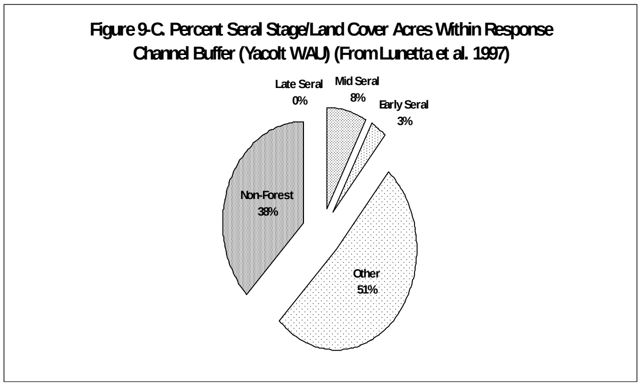
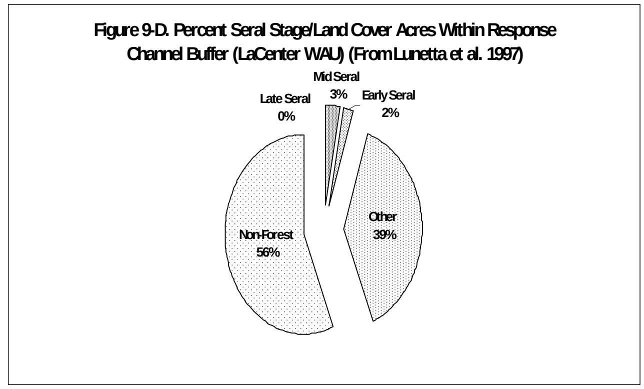


Figure 9-B. Percent Seral Stage/Land Cover Acres Within Response Channel Buffer (Cold Creek WAU) (From Lunetta et al. 1997)







Water Quality

Wade (2000) reports that water quality is of large concern within the East Fork Lewis River subbasin, rating all observed reaches with existing data as "poor" (Table 1). In 1996, the mainstem (mouth to Moulton Falls RM 24.6) was listed under section 303(d) of the Clean Water Act as an impaired waterbody as it was found to exceed standards for temperature, pH, and fecal coliform (WDOE 1996, cited by Wade 2000). However, the 1998 final section 303(d) listings only mention temperature and fecal coliform as concerns in the East Fork Lewis River mainstem (Beckett 2000). Beckett (2000) further indicates that East Fork Lewis River tributaries (Lockwood, McCormick, Rock [lower], Rock [upper], and Yacolt Creeks) exceed water quality standards (Section 303[d] listed) for fecal coliform while McCormick Creek is also listed relative to water temperature.

Table 8. Water quality exceedances in the East Fork Lewis River subbasin (Adapted from Hutton 1995).

Subbasin Monitoring Station	Percent of Measurements Exceeding State Criteria				
	Temp	DO	pH	Turbidity	Fecal Coliform
McCormick Creek at NW LaCenter Road	10%	0%	0%	45%	60%
Mainstem near LaCenter Bridge	25%	5%	0%	10%	25%
Lockwood Creek at Lockwood Creek Road	5%	0%	0%	10%	45%
Mason Creek at J.A. Moore Road	0%	0%	0%	0%	30%
Mainstem at Daybreak Park	20%	0%	0%	0%	0%
Rock Creek (lower) at NE Rock Creek Road	0%	10%	0%	30%	55%
Mainstem at Moulton Falls	0%	0%	0%	0%	25%
Yacolt Creek at County Road 16	0%	50%	11%	0%	35%
Rock Creek (upper) at Dole Valley Road	0%	0%	6%	0%	30%

Hutton (1995) measured water quality over a 20-month (1991-92) period at 9 stations within the East Fork Lewis River mainstem and various tributaries (Table 8). Key findings from this work include:

- Excessively high levels of fecal coliform are widespread within the basin,
- High turbidity and temperature were the second most widespread water quality problems within the subbasin, and
- Low monthly dissolved oxygen (DO) was a major issue in Yacolt Creek.

R2 Resources (2000) documented water temperatures exceeding 24°C in lower Dean Creek (below J. A. Moore Road) during July 1998. Wade (2000) suggests that a lack of canopy cover and possibly groundwater connections to large open water gravel processing pits on the adjacent Storedahl & Sons property contributed to the elevated water temperatures in this section of the creek. Maul Foster & Alongi, Inc. (1999) further documented elevated temperatures of discharge water from Storedahl & Sons processing ponds into Dean Creek. The results of these authors monitoring program displayed a mean outfall temperature of 22.24°C (range 20.8°C to 25.6°C) from Pond 5 into lower Dean Creek during a period from 14 July 1999 to 31 August 1999. Bell (1986, cited by Bjornn and Reiser 1991) indicates that upstream migration of Pacific salmon may be inhibited by water temperatures >20°C.

During this same monitoring program, Maul Foster & Alongi, Inc. (1999) documented a decrease in turbidity levels of outfall water from the Storedahl & Sons processing pits into lower Dean Creek. This decrease in turbidity was attributed to a new water processing system installed in an effort to improve the quality of water discharged from the pits. However, it should be pointed out that turbidity levels were only measured from approximately 15 May 1998 to 27 July 1998 and again from approximately 7 June 1999 to 30 September 1999. Results indicated that turbidity levels in 1999 were decreased from that of 1998 over most overlapping measurements even prior to the implementation of the testing program. In other words, long-term data is lacking to make a clear distinction of the results of this project, however preliminary results appear promising.

Wade (2000) suggests that farming operations in the Fargher lake area may be contributing to water quality problems in the lower Rock Creek subbasin (Table8). The author suggests that there is a need to further assess water quality within this creek and to investigate the possible connection between farming in the Fargher Lake area and water quality problems.

Turbidity (and possibly other unidentified water quality problems) was also noted as a problem in Cedar Creek where wastewater releases from the Larch Mountain Corrections Facility along with the roads leading to it are suspected as the primary causes (Wade 2000). According to Rick Marlow (WA. Dept. Natural Resources, pers. comm., cited by Wade 2000) there are over 200 cars/day using the L-1400 road to the facility. Wade (2000) reports that these roads are all gravel surfaced and become slurry during winter months under these heavy traffic conditions. Bjornn and Reiser (1991) suggest that high turbidity in salmon streams may delay migration, but that turbidity alone does not seem to affect the homing capabilities of salmonids very much.

Water Quantity

Caldwell et al. (1999) examined instream flows within the East Fork Lewis River subbasin. The purpose of this study was to provide information to determine minimum stream flows in WRIA 27 as is required by state law (Wade 2000). The Instream Flow Incremental Methodology (IFIM) was used to determine flow versus habitat relationships within the East Fork Lewis River channel while the Toe-Width Method was applied to 8 tributaries of the mainstem: Jenny Creek, McCormick Creek, Breezee Creek, Lockwood Creek, Mason Creek, Yacolt Creek, upper Rock Creek, and lower Rock Creek.

A flow exceedance probability hydrograph was developed for the East Fork Lewis River based on United States Geological Survey (USGS) flow data collected over the period from 1929-1993 at gage 14222500 at RM 20.2 (Figure 10). Flow exceedance probability graphs such as this are useful in assessing variances in streamflows at certain times of the year rather than relying on a single value such as mean monthly flow. Furthermore, the exceedance graph shows the range of flows one might expect on a given day or during a particular month (Caldwell et al. 1999).

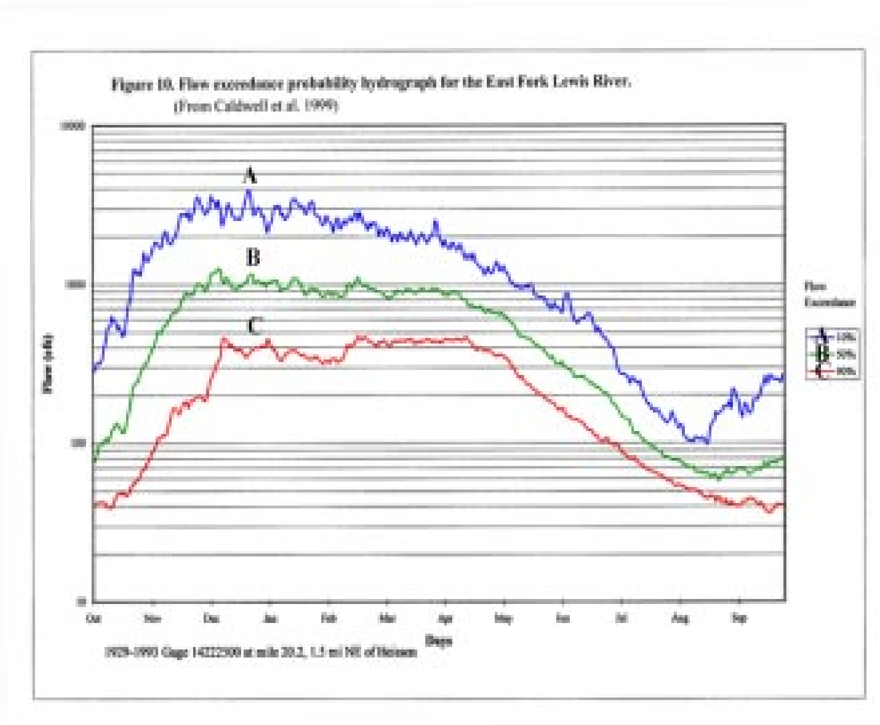


Figure 10. Flow exceedance probability hydrograph for the East Fork Lewis River. (From Caldwell et al. 1999)

Caldwell et al. (1999) explain that when a single number (such as mean monthly flow) is used to describe the flow in a stream, it gives a very distorted idea of the normal flow in the stream. A range, they say, such as the 10% to 90% flow exceedance values, best describes streamflow. While this flow range describes the flow one would expect to see 80% of the time in the stream, the 50% exceedance flow value (median flow) represents a flow mid-point that is exceeded half of the time on a particular day or not exceeded half of the time on a particular day (Caldwell et al. 1999).

Fish habitat versus flow curves were generated using IFIM for the East For Lewis River mainstem (Figure 11). These curves indicate instream flows that provide maximum spawning habitat for chinook, steelhead, and coho as well as maximum rearing habitat for chinook and steelhead (intersect of horizontal and vertical lines) (Caldwell et al. 1999).

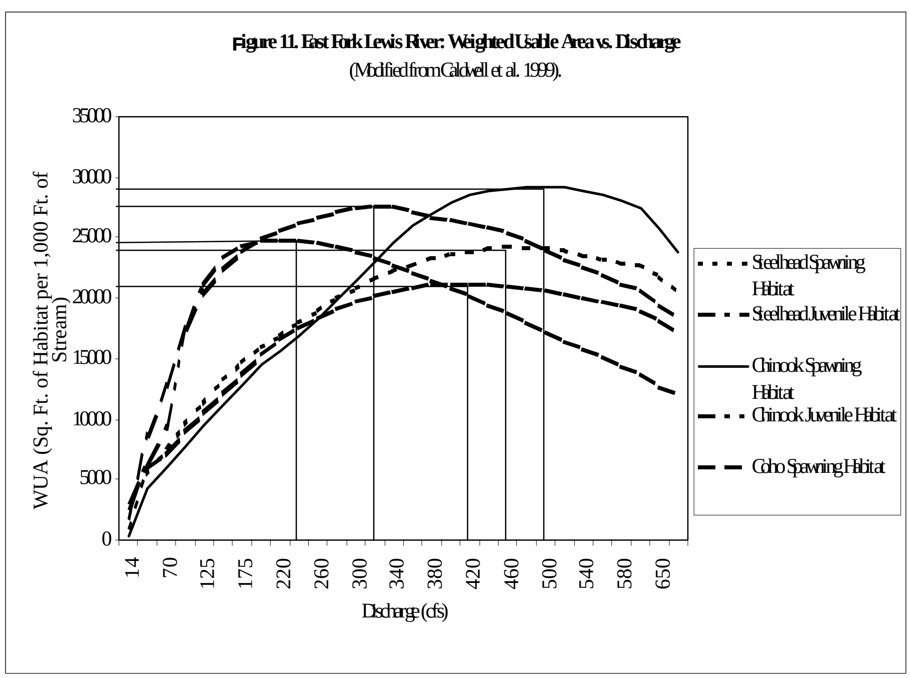


Figure 11. East Fork Lewis River: Weighted Usable Area vs. Discharge (Modified from Caldwell et al. 1999).

Table 9. Migration and spawning timing for selected East Fork Lewis River salmonid stocks (Adapted from WDF and WDW 1993).

Species/Stock	**Phase**	**Month**											
coho		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Terminal Run												
	River Entry												
	Spawning												
Fall chinook													
	Terminal Run												
	River Entry												
	Spawning												
Summer steelhead													
	Terminal Run					No Data							
	River Entry												
	Spawning												
Winter steelhead													
	Terminal Run					No Data							
	River Entry												
	Spawning												
Coastal cutthroat													
	Anad. River Entry												
	Anad. Spawning												
	Fluvial Spawning												
	Adfluvial Spawning												
	Resident Spawning												

Comparison of flow values generated by IFIM (Figure 11) with historical USGS flow data (Figure 10) and East Fork Lewis River salmonid stock spawning timing (Table 9) indicates that East Fork Lewis River fall chinook and early spawning coho may, at times, be spawning habitat limited by low flow conditions in the mainstem. However, low numbers of returning fish may preclude this finding.

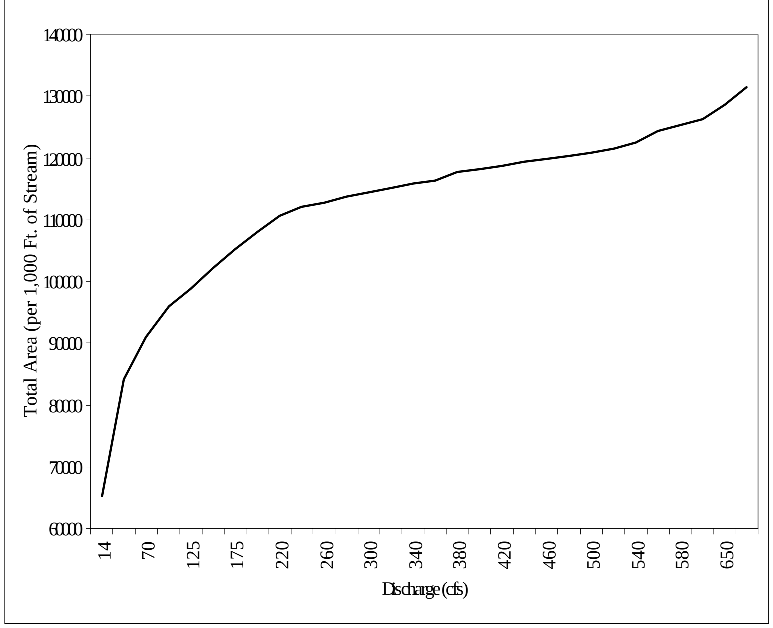


Figure 12. East Fork Lewis River: Total Wetted Area vs. Discharge
(From Caldwell et al. 1999)

The Caldwell et al. (1999) study further identified the relationship between wetted area and flow within the east Fork Lewis River mainstem (Figure 12). Their findings indicate that the total area values (Y-axis) can be divided by 1,000 to calculate the mean wetted width for any flow from 14 to 705 cfs.

Table 10 provides data regarding the percent of fish habitat (WUA) relative to optimum habitat (WUA) in the East Fork Lewis River mainstem. This data reflects the complications of setting minimum instream flows for a river channel. Setting minimum instream flows requires the ranking of importance of each fish species and lifestage as no specific flow will provide optimum conditions for those that coexist simultaneously within a river (Table 10) (Caldwell et al. 1999).

Table 10. Fish habitat (WUA) as a percent of optimum habitat (WUA) for the East Fork Lewis River (From Caldwell et al. 1999).

Discharge (cfs)	Steelhead Spawning Habitat	Steelhead Juvenile Habitat	Chinook Spawning Habitat	Chinook Juvenile Habitat	Coho Spawning Habitat
705	84%	81%	82%	48%	67%
650	90%	86%	88%	51%	70%
600	93%	90%	94%	55%	75%
580	94%	91%	96%	58%	77%
560	95%	93%	98%	61%	79%
540	97%	95%	99%	64%	81%
520	98%	96%	100%	66%	84%
500	99%	97%	100%	69%	86%
480	100%	98%	100%	73%	90%
460	100%	99%	99%	76%	92%
440	99%	100%	99%	78%	94%
420	98%	100%	98%	81%	95%
400	97%	100%	95%	84%	96%
380	96%	100%	92%	87%	97%
360	94%	99%	89%	89%	98%
340	92%	97%	84%	92%	100%
320	89%	95%	79%	94%	100%
300	86%	93%	73%	96%	99%
280	82%	90%	68%	98%	98%
260	78%	87%	63%	100%	97%
240	74%	83%	58%	100%	95%
220	70%	78%	54%	100%	93%
200	66%	73%	49%	100%	90%
175	60%	65%	44%	98%	86%
150	54%	57%	38%	94%	81%
125	47%	50%	32%	86%	74%
100	40%	42%	26%	71%	63%
70	31%	34%	20%	37%	46%
50	23%	27%	15%	26%	31%
14	4%	15%	1%	11%	6%

Caldwell et al. (1999) utilized the toe-width method to analyze available habitat within several tributaries to the East Fork Lewis River. These toe-width flows are presented in Table 11 and represent the optimal for the several categories of fish spawning and rearing

Table 11. Toe-width flows for several tributaries to the East Fork Lewis River (Adapted from Caldwell et al. 1999).

Stream Name	Average Toe-Width (ft)	Toe-Width Flow for Fish Spawning and Rearing (cfs)					
		chinook spawning	*coho spawning*	*chum spawning*	*steelhead spawning*	*steelhead rearing*	*salmon rearing*
Jenny Creek @ Pacific HWY/Clark Co. Rd.	15	39.1	19.1	39.1	35.9	7.7	6.9
McCormick Creek @ 11th Ave. crossing	12.3	30.6	14.7	30.6	28.5	5.8	5.2
Brezee Creek @ La Center, Co. Rd. 42 crossing	16	42.3	20.8	42.3	38.6	8.4	7.5
Lockwood Creek @ Co. Rd. 42	21.3	60.4	30.2	60.4	53.9	12.6	11.4
Mason Creek @ J.A. Moore Rd. crossing	17.3	46.6	23.0	46.6	42.3	9.4	8.4
Yacolt Creek @ confluence	35.5	113.7	59.0	113.7	97.4	26.1	23.7
Rock Creek (upper) ½ mile south of Dole	42.7	143.0	75.2	143.0	120.7	33.9	31.0
Rock Creek (lower) @ 319th St. Bridge	17.5	47.3	23.4	47.3	42.9	9.5	8.6

that are indicated (Hal Beacher, WA. Dept. of Fish and Wildlife, pers. comm.). For comparison, spot flow measurements taken by Washington Department of Ecology (DOE) staff are presented in Table12. It is apparent from this comparison that spawning habitat was very limited on these particular days within tributaries to the East Fork River during fall 1998. For example, within Lockwood Creek, coho spawning habitat was 4.6%, and 19.5% of optimal on dates 9 0ctober 1998 and 9 November 1998 respectively according to the results of this study (Tables 11 and 12).

Rearing habitat is also affected by flow in tributaries to the East Fork Lewis River (Caldwell et al. 1999). Results from the toe-with method indicate, for example, steelhead rearing habitat in Rock Creek (upper) was only 39.7% of optimal on 10 September 1998. Conversely, on dates 9 October 1998 and 9 November 1998, flow values were recorded at 81.7% and 90.5% greater (respectively) than optimal for steelhead rearing in this tributary.

Table 12. Spot flow measurements for several tributaries to the East Fork Lewis River (Adapted from Caldwell et al. 1999).

Tributary	Date and Discharge (cfs)		
	9/10/98	*10/9/98*	*11/9/98*
Jenny Creek @ Pacific HWY/Clark Co. Rd.	0.3	0.6	1.9
McCormick Creek @11th Ave. crossing	0.2	0.4	2.4
Brezee Creek @La Center, Co. Rd. 42 crossing	0.7	1.0	1.9
Lockwood Creek @ Co. Rd. 42	0.7	1.4	5.9
Mason Creek @J.A. Moore Rd. crossing	0.3	0.6	5.1
Yacolt Creek @ confluence	3.9	7.4	16.0
Rock Creek (upper) ½ mile south of Dole	5.0	22.9	24.0
Rock Creek (lower) @319th St. Bridge	0.2	1.9	6.3

Biological Processes

Wade (2000), using Washington Conservation Commission (WCC) protocol, examined the number of stocks meeting current escapement goals as a surrogate measurement of nutrient levels within the East Fork Lewis River subbasin. However, recent investigations suggest that current escapement goals do not approach the number of spawners necessary to provide salmon derived nutrients at levels necessary to support juvenile salmonids, over-wintering bald eagles, and nesting song birds (Michael 1998) or the nutritional needs of streams (Bilby et al. 2001).

Work done by Bilby et al. (2001) suggested that ecosystem benefits from marine derived nutrients level off at 0.15 kg/m^2 of stream habitat when considering spawning stocks of coho salmon in western Washington. Using this value, an ecosystem-based escapement goal was developed for the East Fork Lewis River coho. Assumptions for this goal are as follows: coho salmon spawning is limited to and fully covers those areas indicated in Appendix 3 of the 1992 SASSI report (WDF/WDW 1993), the average weight of coho salmon is 3.36 kg (Hal Michael, WA. Dept. Fish and Wildlife, pers. comm.), and other salmonid species bear no contribution to ecosystem needs based on coho. From this information, it was calculated that 40,391 coho salmon are needed to spawn and die within the East Fork Lewis River SASSI spawning area to satisfy the nutritional needs of the stream and the surrounding ecosystem.

Wade (2000) reports that the recent status of coho salmon within the East Fork Lewis subbasin is unknown due to incomplete and inconsistent survey data, thus current escapement is unavailable at this time. However, historical data indicates that only up to 5000 coho have been observed within the East Fork Lewis River subbasin (WDF 1951); or 12% of ecosystem needs. This data represents a period when the Lewis River system was considered one of the most important producers of coho salmon in the Columbia basin (WDF/WDW 1993).

Recent salmon carcass distribution efforts conducted by the conservation group Friends of the East Fork, while certainly adding some benefit, fall considerably short of providing complete nutrient needs to the system. Year 2000/2001 efforts distributed a total of 5350 coho salmon carcasses to the mainstem East Fork and it’s tributaries (Scott Anderson, WA. Dept. Fish and Wildlife, pers. comm.).

Conclusion

Salmonid habitat in the East Fork Lewis River subbasin has been drastically altered from its historical condition. LWD removal from stream channels across the Pacific northwest has left many of them (including the East Fork and its tributaries) lacking in both number and frequency of pools as well as a lack of quality spawning gravel in some instances. Pools are few in the East Fork mainstem, probably affecting rearing habitat for some species and migration for others depending upon the season. Recommendations include adding in-channel structures where appropriate as well as riparian enhancement and protection. The planting of fast growing trees like black cottonwood may provide LWD recovery in the lower basin within 40-80 years (Montgomery and Collins 2000).

Gravel mining within the subbasin has been identified as a source of fine sediments and high stream temperatures in the lower river. Proposed expansion of mining activities has led American Rivers to list the East Fork Lewis River as the tenth most endangered river in the United States for year 2001. Avulsion to old gravel mining operations has caused serious loss of quality spawning habitat replacing it with habitat most suitable for exotic species (Norman et al. 1998). These events likely contribute to excessive water temperatures in the lower system. Recommendations include strict monitoring of mining discharge to the main channel.

Disconnection from the floodplain and the confinement of the channel to a single thread may have supressed coho populations through the lack of quality winter rearing areas and chum salmon via the lack of suitable spawning locations. Reconnection of the channel to the historical floodplain may further be complicated by downcutting of the channel caused by several variables including the avulsions to abandoned gravel pits. Establishing connection between the main channel and off-channel rearing habitats should be considered high priority. Creation and/or enhancement of side-channel habitat is also highly recommended within this subbasin.

Man-made barriers to migration are a cause for alarm in the East Fork Lewis subbasin. Estimates generated by this effort suggest that 67% of East Fork tributaries have been affected. This loss of both spawning and rearing habitat has not been replaced by habitat gains made through the notching of Sunset Falls as summer steelhead are the only species that consistently migrate beyond this point. Repair or replacement of fish blocking culverts should be high priority within the lower East Fork subbasin. Prioritization of culvert "fixes" should first consider less successful species, such as coho that are limited to the area below Lucia Falls.

Riparian conditions have been affected by fires, timber harvest, road building, gravel mining, and agriculture. Late seral forests are nearly completely lacking in the lower East Fork subbasin, thus LWD recruitment is affected for a number of years. Lack of shading may further contribute to excessive water temperatures in the lower system. Retention of smaller size class trees that do get recruited to the channel may be affected by the lack of larger "key pieces" that act to form jams. Again, the planting and protection of existing riparian vegetation is viewed as important within this subbasin. Planting such species as black cottonwood may lead to quicker recovery than previously thought (Montgomery and Collins 2000).

Water quality in the subbasin is of high concern as temperature, turbidity, and fecal coliform levels have been observed at high levels consistently. Attempts to alleviate these problems in some areas have shown promise, but monitoring efforts have only been conducted for a couple of years.

Bank stability issues contribute to fine sediment accumulation within the channel. Highly erosive soils in the lower system have been identified as fine sediment sources to the now confined channel that has lost most of its ability to migrate. This lack of natural channel migration may further contribute to fine sediment problems as the static channel continues to collect particles of this size class. Furthermore, the incision of the channel resulting in disconnection from the floodplain has likely resulted in higher percentages of fines due to a lack of natural deposition to the floodplain. Erosion of stream banks seems to have been a naturally occurring phenomenon within reaches of the lower East Fork. The identification of human-induced or exacerbated bank erosion should continue within the subbasin.

Biological processes appear to be severely depressed within the East Fork Lewis River subbasin. Estimation of an ecologically-based spawning escapement for coho salmon exhibits a need for a much larger population than has even been recorded historically. Efforts to supplement marine derived nutrients within the system include the distribution of hatchery carcasses within several areas of the subbasin. However, these efforts may remain to fall short of the nutritional needs of the stream. Efforts to supply nutrients back to the system should continue at the peak level recommended by WDFW.

Literature Cited

Bell, M. C. 1986. Fisheries handbook of engineering requirements and biological criteria. U. S. Army Corps of Engineers, Office of the Chief of Engineers, Fish Passage Development and Evaluation Program, Portland, Oregon.

Bilby, R. E., B. R. Fransen, J. K. Walter, C. J. Cederholm, and W. J. Scarlett. 2001. Preliminary evaluation of the use of nitrogen stable isotope ratios to establish escapement levels for Pacific salmon. Fisheries 26: 6-14.

Bjornn, TC and DW Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* WR Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19. Bethesda, MD.

Caldwell, B., J. Shedd, and H. Beacher. 1999. East Fork Lewis River fish habitat analysis using the Instream Flow Incremental Methodology and Toe-Width method for WRIA 27. Open File Technical Report, Publication # 99-151. Washington State Department of Ecology. Olympia, WA. 48 pp.

Collins, B. D. and D. R. Montgomery. 2000. DRAFT Importance of archival and process studies to characterizing riverine geomorphic processes and habitat in the Puget lowland. Department of Geological Sciences, University of Washington, Seattle.

Dunne T, and L. B. Leopold. 1978. Water in environmental planning. W. H. Freeman and Company, New York. 818 pp.

EnviroScience, Inc. 1996. Fishery resource evaluation Daybreak Mine extension. Prepared for J. L. Stordahl and Sons, Inc. Clark County, WA.

Grette, G. B. 1985. The role of large organic debris in juvenile salmonid rearing habitat in small streams. Master’s thesis. University of Washington, Seattle.

Hutton, R. 1994. DRAFT East Fork Lewis River watershed characterization background report. Clark County Water Quality Division. Vancouver, WA. 92 pp.

Lewis County GIS. 1999. GIS fish distribution maps and analysis of various habitat conditions within WRIA 27. Lewis County, WA.

Long, B. A. 1987. Recruitment and abundance of large woody debris in an Oregon coastal stream system. Master’s thesis. Oregon State University, Corvallis.

Lunetta, R. S., B. L. Cosentino, D. R. Montgomery, E. M. Beamer, and T. J. Beechie. 1997. GIS-Based evaluation of salmon habitat in the Pacific Northwest. Photogrammetric Engineering and Remote Sensing 63: 1219-1229.

Maul Foster & Alongi Inc. 1999. Daybreak Quarry process water treatment report. Appendix G *in* Draft technical appendices: Working draft habitat conservation plan Daybreak Mine expansion and habitat enhancement project. Prepared for J. L. Storedahl and Sons, Inc. Clark County, WA.

Michael, J. H., jr. 1998. Pacific salmon spawner escapement goals for the Skagit River as determined by nutrient cycling considerations. N. W. Sci. 72: 239-248.

Norman, DK, CJ Cederholm, and WS Lingley, Jr. 1998. Flood plains, salmon habitat, and sand and gravel mining. Washington Geology 26: 3-20.

Peterson, NP. 1982. Immigration of juvenile coho salmon (Oncorhynchus kisutch) into riverine ponds. Can. J. Fish. Aquat. Sci. 39: 1308-1310.

R2 Resources. 2000. Working Draft: Daybreak Mine expansion and habitat enhancement project habitat conservation plan. Prepared for J. L. Storedahl and Sons. Clark Conty, WA.

Swales, S and CD Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (Oncorhynchus kisutch) and other juvenile salmonids in the Coldwater River, British Columbia. Can. J. Fish. Aquat. Sci. 46: 232-242.

United States Forest Service (USFS). 1999. East Fork Lewis River fish habitat rehabilitation project: environmental assessment. Gifford Pinchot National Forest.

Wade, G. 2000. Salmon and steelhead habitat limiting factors: water resource inventory area 27. Washington Conservation Commission, Olympia.

Washington Department of Fihseries (WDF). 1951. Lower Columbia River Fisheries Development Program (Lewis River Area). Washington Department of Fisheries, Olympia, WA.

Washington Department of Fisheries (WDF) and Washington Department of Wildlife (WDW). 1993. 1992 Washington State Salmon and Steelhead Stock Inventory: Appendix 3 – Columbia River Stocks. Washington Department of Fisheries and Washington Department of Wildlife, Olympia, WA.

West Consultants, Inc. 2000. Geomorphic analysis of the East Fork Lewis River in the vicinity of the Daybreak Mine expansion and habitat enhancement project. Appendix C *in* Draft technical appendices: Working draft habitat conservation plan Daybreak Mine expansion and habitat enhancement project. Prepared for J. L. Storedahl and Sons, Inc. Clark County, WA.

Appendix A. Salmonid habitat condition ratings (from Wade 2000)

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Access and Passage						
Artificial Barriers	% known/potential blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection or other	<1% gradient	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient	>66%	33-66%	<33%	WCC
Channel Conditions						
Fine Sediment	Fines <0.85 mm in spawning gravel	All - westside	>17%	11-17%	≤11%	WSP/WSA/NMFS/Hood Canal
	Fines <0.85 mm in spawning gravel	All - eastside	>20%	11-20%	≤11%	NMFS
Habitat Factor	**Parameter/Unit**	**Channel Type**	**Poor**	**Fair**	**Good**	**Source**
Large Woody Debris	pieces/m of channel length	≤4% gradient, <15 m wide (westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA
	key pieces/channel width*	<10 m wide (westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA
	*** Minimum size to qualify as a key piece**		**BFW (m) / Diameter (m) / Length (m)** **0-5 / 0.4 / 8** **6-10 / 0.55 / 10** **11-15 / 0.65 / 18**			
Percent Pool	% pool by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA
	% pool by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool by surface area	>15 m wide	<35%	35-50%	>50%	Hood Canal
Pool Frequency	channel widths/pool	<15 m wide	>4	2-4	<2	WSP/WSA
	channel widths/pool	>15 m wide	NA	NA	channel width / pools/mile / cw/po 50' / 26 / 4.1 75' / 23 / 3.1 100' / 18 / 2.9	NMFS
Habitat Factor	**Parameter/Unit**	**Channel Type**	**Poor**	**Fair**	**Good**	**Source**
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP/WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP
Sediment Input						
Sediment Supply	$m^3/km^2/yr$	All	>100 or exceeds natural rate*	NA	<100 or does not exceed natural rate*	Skagit
			*** Note: this rate is highly variable in natural conditions**			

Appendix B. Source documents for habitat ratings (from Wade 2000).

Code	Document	Organization
Hood Canal	Hood Canal/eastern Strait of Juan de Fuca Summer chum Habitat Recovery Plan, Final Draft (1999)	Point no Point Treaty Council, Skokomish Tribe, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Washington Department of Fish and Wildlife
ManTech	An Ecosystem Approach to Salmonid Conservation, vol. 1 (1995)	ManTech Environmental Research Services for the National Marine Fisheries Service, the US Environmental Protection Agency, and the US Fish and Wildlife Service
NMFS	Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast (1996)	National Marine Fisheries Service
PHS	Priority Habitat Management Recommendations: Riparian (1995)	Washington Department of Fish and Wildlife
Skagit	Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)	Skagit Watershed Council
WSA	Watershed Analysis Manual, v 4.0 (1997)	Washington Forest Practices Board
WSP	Wild Salmonid Policy (1997)	Washington Department of Fish and Wildlife

Appendix C. Species distribution and barrier maps.

Data Dictionary

KNOWN
Habitat that is documented to presently sustain fish populations (published sources, survey notes, first-hand sightings, etc.): or, habitat with records of fish use (which may or may not be known to have been extirpated for some reason). This includes habitat used by all life history stages for any length of time (i.e. intermittent streams which contain water during flood flows that provides refuge habitat for a period of hours or days).

PRESUMED
Habitat with no records of known fish use, but that is below any known natural barrier (including sustained 12% gradient) and otherwise conforms to species-specific habitat criteria.

POTENTIAL
Habitat above human-caused blockages or obstructions that could be opened to fish use and that is below any known natural barrier (including sustained 12% gradient) and otherwise conforms to species-specific habitat criteria.

DNR BARRIERS
WA Dept. of Natural Resources culverts that have been identified as fish passage barriers.

DOE DAMS
Dam locations from the WA Dept. of Ecology's database. These dams impound at least 10 acre feet of water during some portion of the year.

FALLS and CASCADES
Natural falls and cascades that may present barriers to fish migration. This data is largely from the WDFW stream catalog.

STREAMNET BARRIERS
Barrier layer from the StreamNet database.

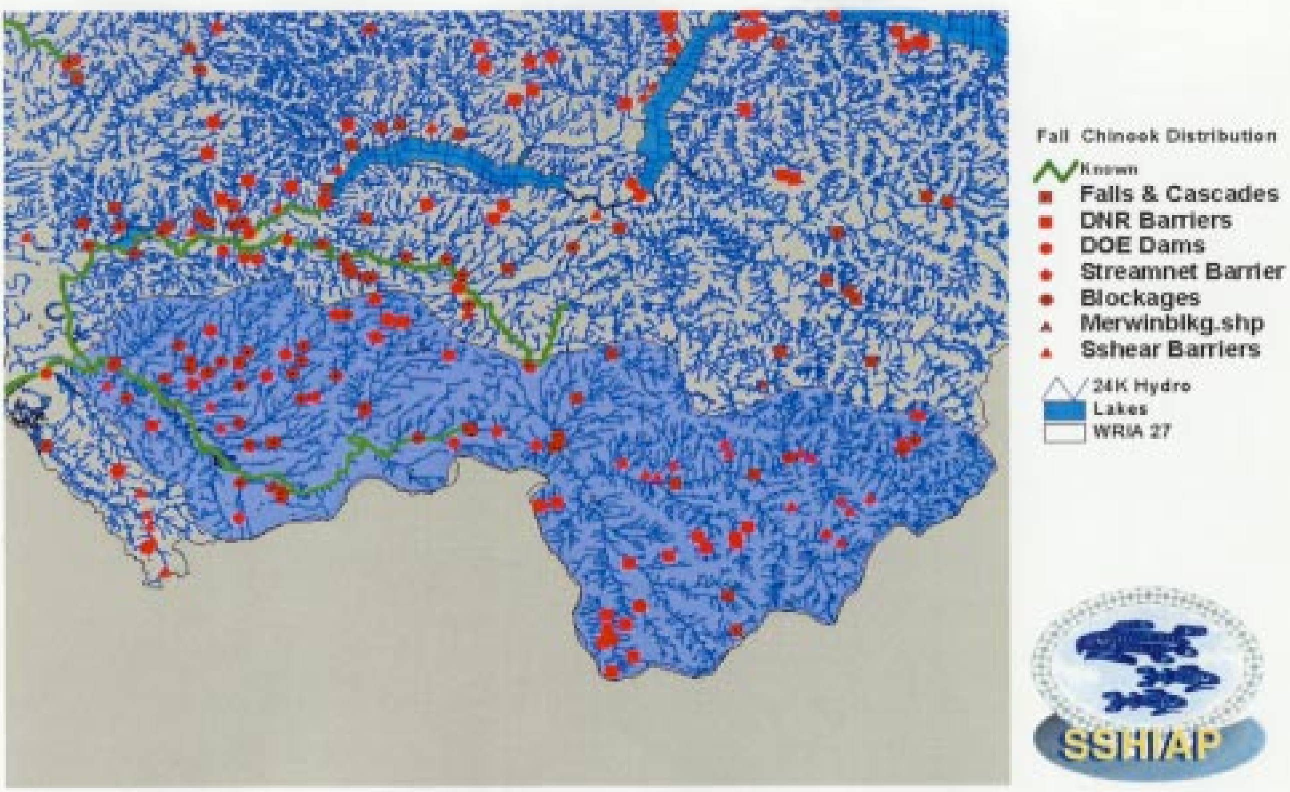
BLOCKAGES
SSHIAP layer consisting of barrier culverts within the anadromous zone.

MERWIN BLOCKAGES
Culvert barriers within the historical anadromous zone above Merwin Dam.

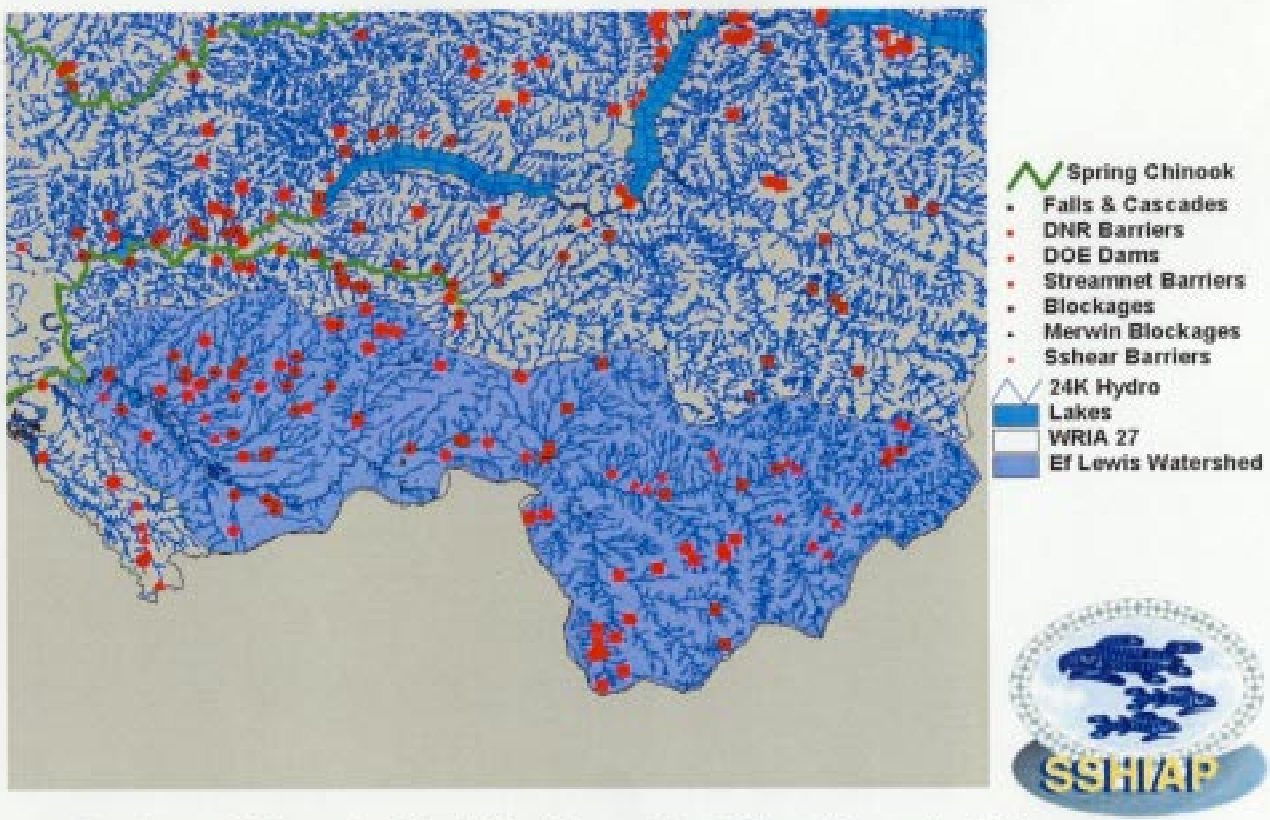
SSHEAR BARRIERS
Fish passage barriers from the WDFW SSHEAR database.

24K HYDRO
SSHIAP cleaned and routed hydrolayer.

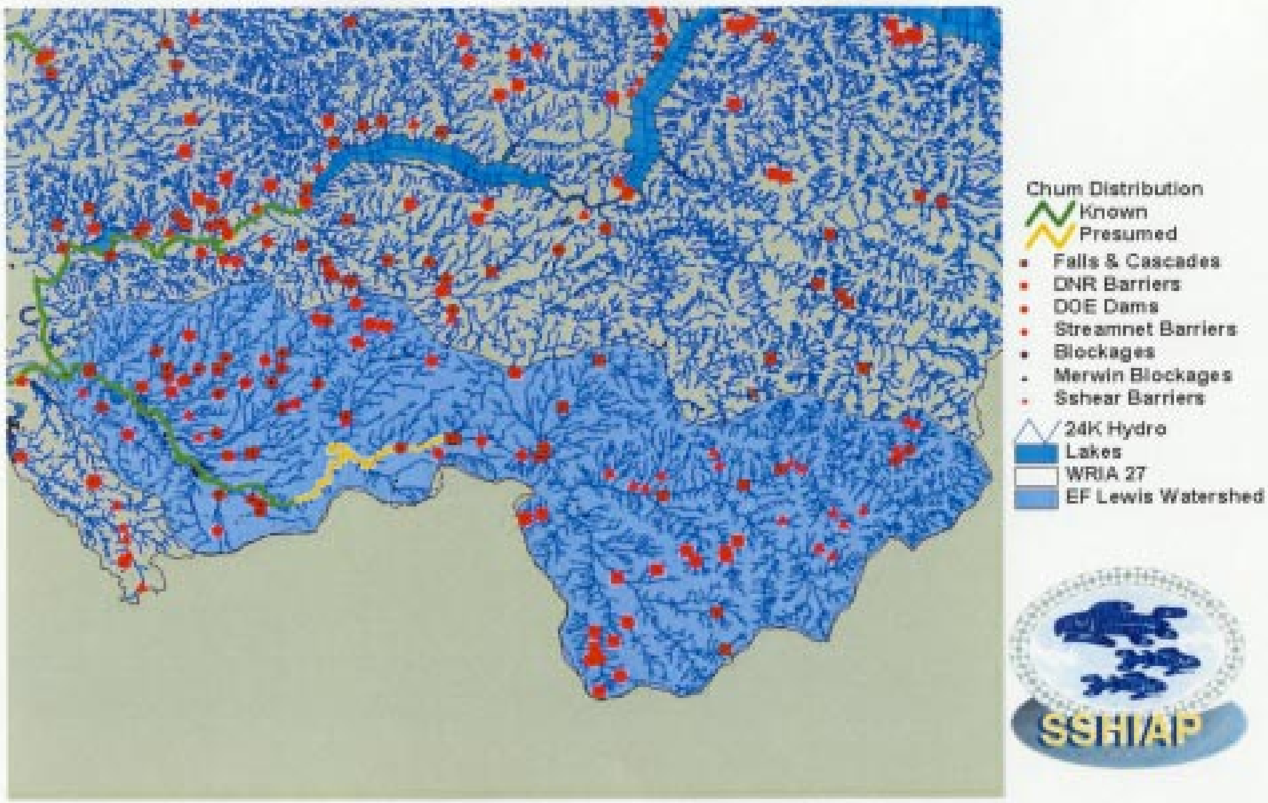
WRIA 27
WRIA boundaries.



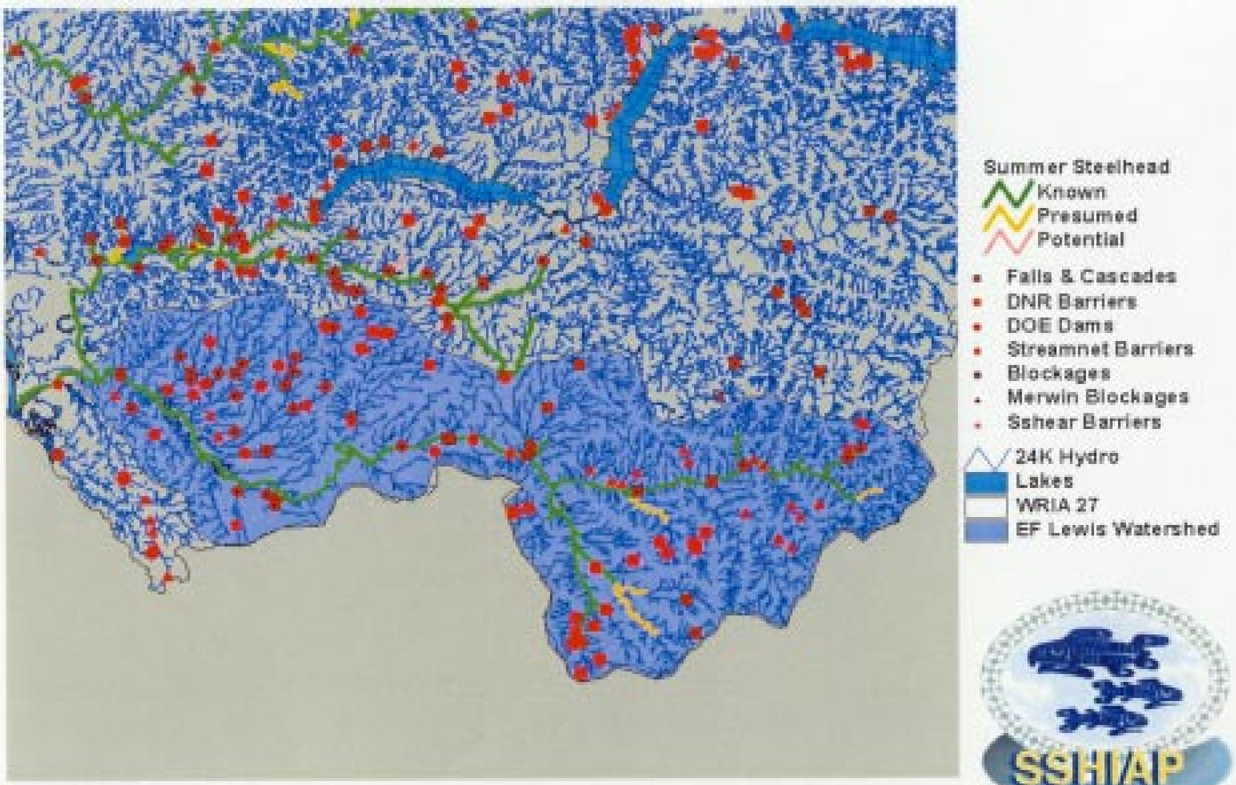
Fall Chinook Distribution: East Fork Lewis River



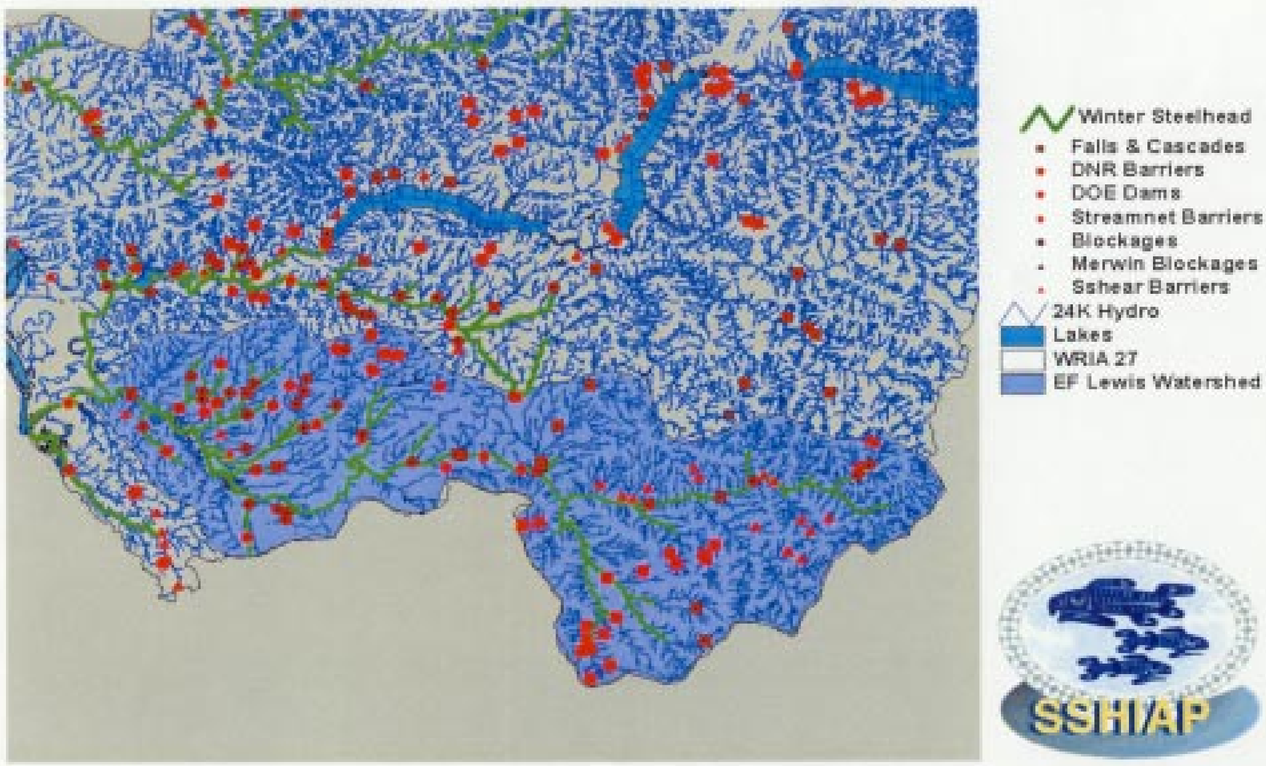
Spring Chinook Distribution: East Fork Lewis River



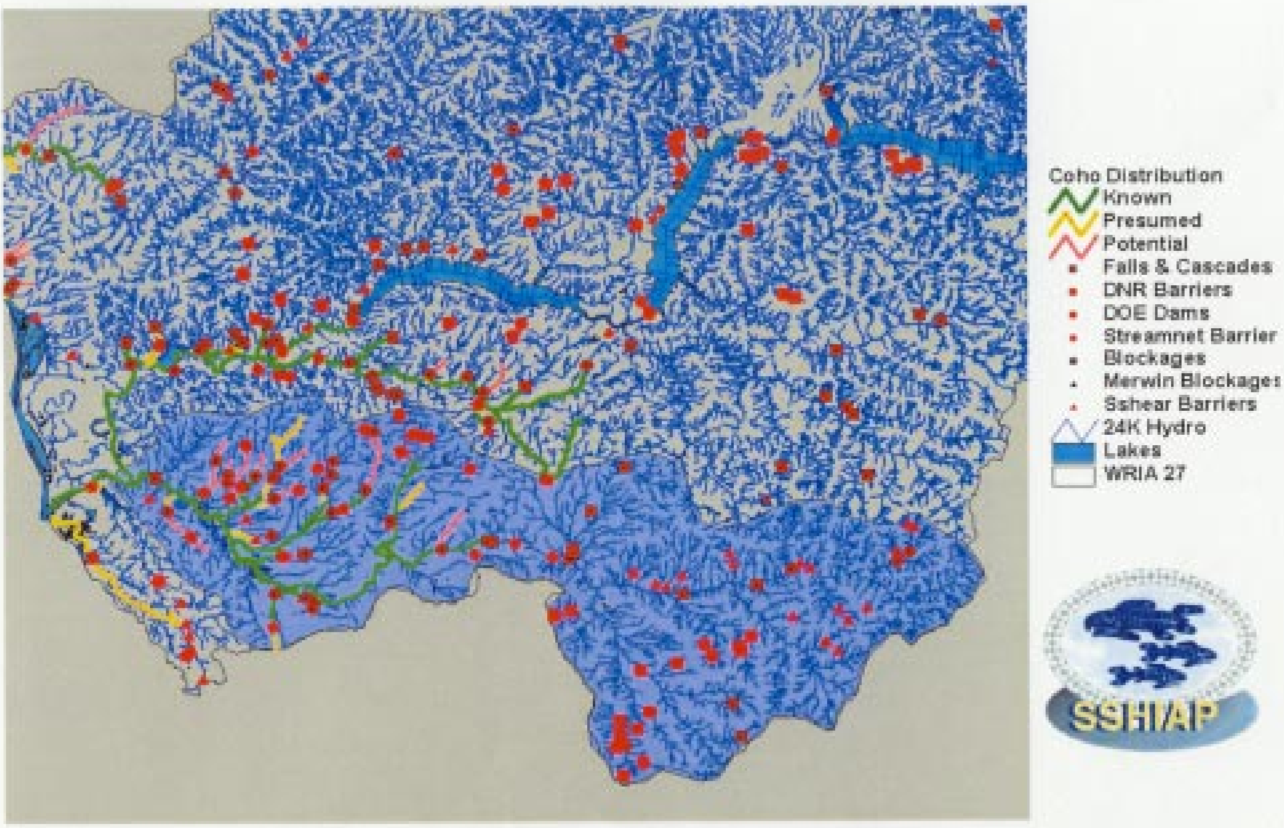
Chum Distribution: East Fork Lewis River



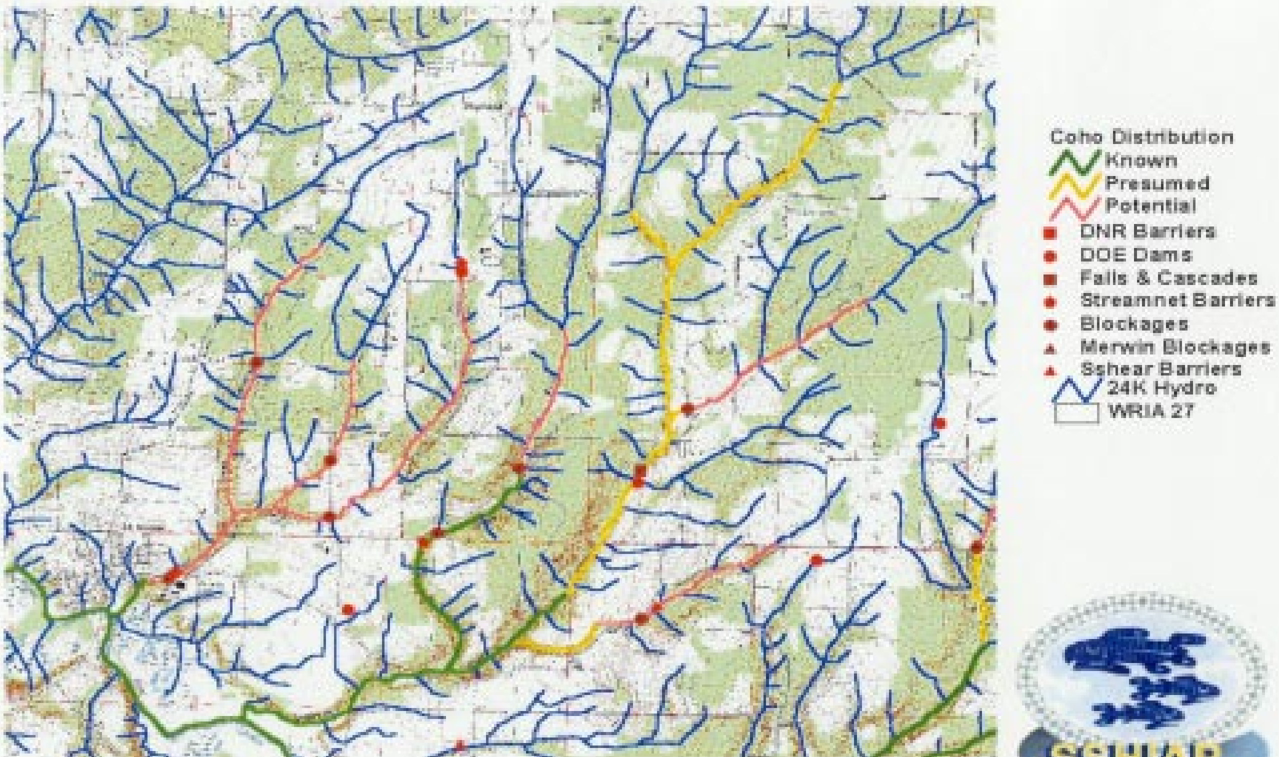
Summer Steelhead Distribution:East Fork Lewis River



Winter Steelhead Distribution: East Fork Lewis River



Coho Distribution: East Fork Lewis River



Coho Dist & Barriers: Lockwood Creek