FLATHEAD BASIN FOREST PRACTICES
WATER QUALITY AND FISHERIES
COOPERATIVE PROGRAM

FISHERIES HABITAT AND FISH POPULATIONS

BY THOMAS WEAVER AND JOHN FRALEY

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FLATHEAD BASIN FOREST PRACTICES
WATER QUALITY AND FISHERIES COOPERATIVE

FISHERIES HABITAT AND FISH POPULATIONS

Final Report

June 1991

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EXECUTIVE SUMMARY

We evaluated fish populations and fish habitat at 29 tributary sites as part of the Flathead Basin Forest Practice, Water Quality and Fisheries Cooperative. We selected variables which index the quality of spawning/incubation habitat and rearing habitat, adult spawner escapement, and juvenile population levels. We compared results of these evaluations with results from the activity assessment module to determine if significant relationships existed.

Field testing showed a strong relationship between the percentage of fine sediment (<6.35 mm) in the incubation environment and fry emergence success by westslope cutthroat and bull trout. Most mortality resulted from entombment of alevins in higher levels of material <6.35 mm. Freeze coring showed egg bearing strata in natural westslope cutthroat trout redds contained less fine material and larger geometric mean particle sizes and Fredle numbers that the strata above them. We simulated these conditions in the field testing.

McNeil core sampling provides an adequate monitoring tool once a period of record exists at a site. Results from McNeil coring were significantly related to both the Sequoia index and H_2OY model. Approximately 30 percent of streambed materials are <6.35 mm in natural spawning area conditions in the Flathead Drainage.

The relationships between substrate score and both the Sequoia index and H_2OY model output were significant and negative. The relationship between substrate score and juvenile bull trout density was significant, indicating that substrate scoring is a valid monitoring tool for bull trout rearing habitat.

We found a significant relationship between the percentage of material <4.75 mm observed in modified Whitlock-Vibert box samples and levels found in McNeil core samples collected at box planting locations. However, we observed significant differences in eight of 12 comparisons of the mean percentage of material <4.75 mm found in boxes versus cores. More work is required before this technique may be substituted for McNeil sampling.

Redd counts indicate annual spawning escapement has been relatively stable during the past 10 years. Natural population fluctuations and behavioral differences between the trout species present in our study area make interpretation of fish population data difficult. Densities of bull trout in study streams ranged from 0.4 to 11.8 fish ≥ 75 mm/100 m^2. Densities of westslope cutthroat trout ranged from 1.4 to 41.4 fish ≥ 75 mm/100 m^2.

We recommend continued monitoring using procedures described in this report. Adjustments on the Whitlock-Vibert box sampling and fish population estimation work are needed. Future research should include development of an index for instream cover for evaluating westslope cutthroat rearing potential. We urge land managers to use extreme caution in managing high risk watersheds and suggest deferment of ground disturbing activities until recovery is documented. We should expand the fisheries sampling program to a greater number

of high risk watersheds for future comparisons of this type. Land managers should use extreme caution in watersheds where spawning area gravel exceeds 40.0 percent <6.35 mm. Conduct sediment source surveys in these drainages to identify problem areas. These areas should be treated to prevent additional sediment delivery to stream channels.

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INTRODUCTION

Nearly one-third of the six million acres of the Flathead Basin watershed consists of commercial timber land (Flathead Basin Steering Committee 1983). Forest management activities such as road building and logging can change runoff pattern and introduce sediment into streams draining these forested uplands. Spawning and rearing of trout in tributary streams is the use most sensitive to adverse impacts from increased sediment (Montana Environmental Quality Council 1989). Chapman and McLeod (1987) and Everest et al. (1987) recognized the uncertainty in quantifying sediment effects on fisheries without looking at all aspects of the watershed. They urged an integrated approach combining watershed and fisheries concerns to address key questions associated with land use impacts.

The Flathead Basin Forest Practices/Water Quality and Fisheries cooperative was established to launch an integrated approach to address concerns of forest practices and the aquatic environment (Flathead Basin Commission 1988). Cooperators include the Flathead Basin Commission, Montana Department of State Lands, Plum Creek Timber Co. Inc., Flathead National Forest, Montana Department of Health and Environmental Science, Montana Department of Fish, Wildlife and Parks, University of Montana School of Forestry, and the University of Montana Biological Station. The Cooperative seeks to improve forest management through application of state-of-the-art information to prevent or mitigate adverse impacts on water quality and fisheries. Specific objectives of the cooperative are (1) evaluate and monitor impacts on water quality and fisheries, and (2) establish a process to use the information gathered and develop further procedures to protect the aquatic environment, if necessary.

The cooperative program consisted of nine interconnected study modules which addressed historical flow records, watershed risk, riparian guidelines, field audits, stream assessments, water quality, and fisheries. This document is the final report on the fisheries study module.

The fisheries study module (Montana Department of Fish, Wildlife and Parks 1989) concentrated on tributary fisheries habitat and fish populations. Westslope cutthroat trout and bull trout are native to the Flathead system. Montana recognizes these fish as species of special concern, and affords them special protection. Sediment originating from road building and other land management activities can reduce embryo survival to emergence of both species and decrease the available substrate spaces used for rearing by bull trout (Fraley, et al. 1989, Weaver 1990). Habitat degradation can also affect rainbow and brook trout and other fish species by filling in pools and altering food habits.

The approach of this module was to build on existing information to evaluate the effects of forest practices on important fish habitat and fish populations. Also, we provide an evaluation of fisheries monitoring tools and provide a framework for monitoring important fish and habitat valuables. Specific objectives included:

1. Evaluate the relationship between westslope cutthroat and bull trout embryo survival to emergence and the percentage of fine material in the substrate (results should show any link between substrate parameters and embryo survival, and identify threshold sediment levels).

2. Determine the resolution capabilities of several methods measuring fisheries habitat quality (results should validate methods of measuring habitat quality that can be used in a long-term monitoring program).

3. Evaluate the cause and effect relationship between forest practices and fisheries at sites around the basin.

Information generated in meeting these objectives will enable us to recommend an effective, monitoring plan for fisheries habitat and fish populations relative to forest practices in the Flathead Basin.

STUDY AREA

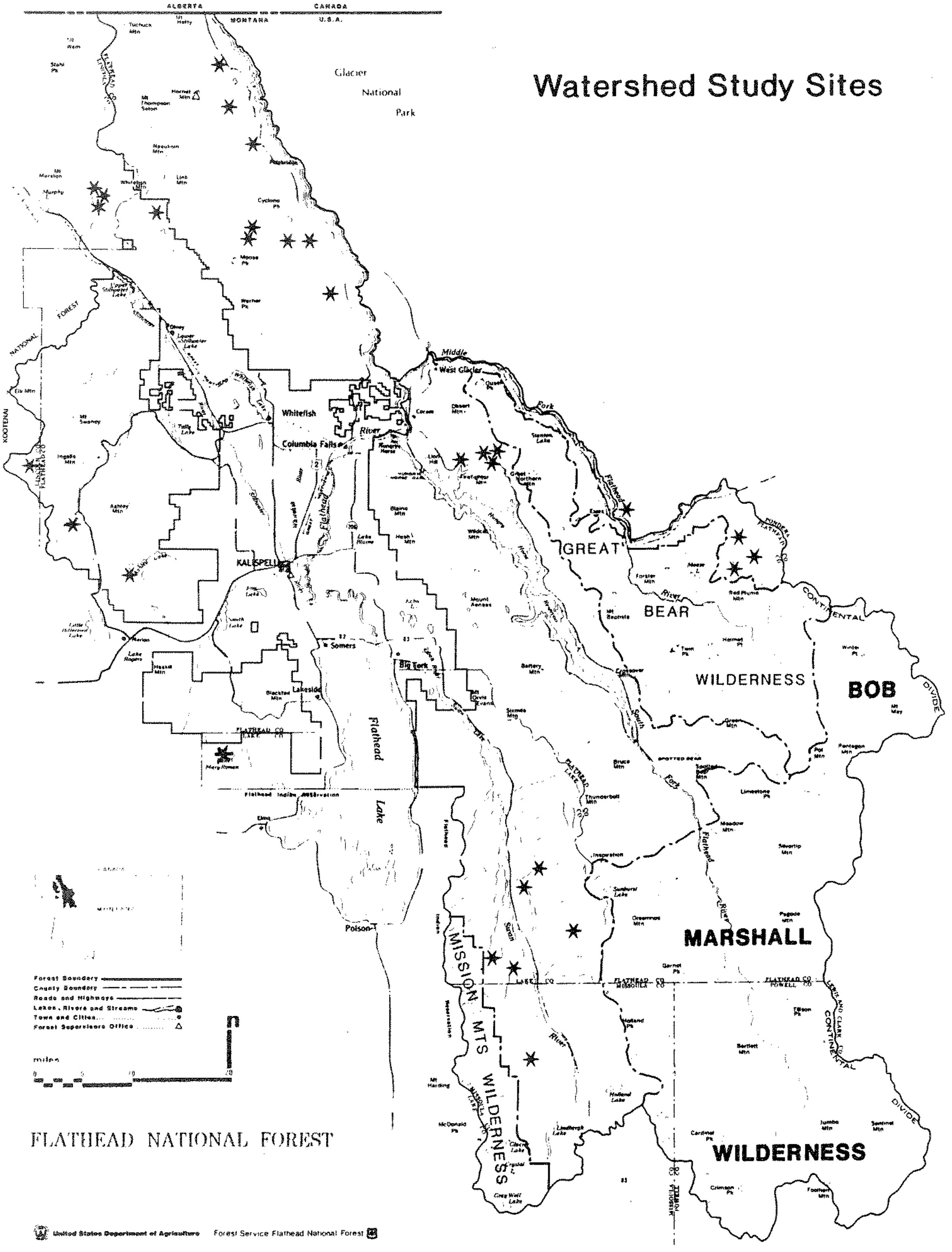
The Flathead Lake and River system is a headwater drainage of the Columbia River Basin (Figure 1). Flathead Lake is the largest natural lake west of the great lakes. The Flathead River enters the north end of Flathead Lake. The upper three meters of the lake is regulated by Kerr Dam. The South, Middle, and North Forks of the Flathead River drain areas of approximately equal size in portions of the Great Bear and Bob Marshall Wildernesses, Glacier National Park, State Lands, the Flathead National Forest, and private lands. The South Fork is regulated by Hungry Horse Dam. The Stillwater/Whitefish River enters the Flathead River 30 km upstream from Flathead Lake.

The Swan River enters Flathead Lake near the mouth of the Flathead River. The Swan River drains portions of the Flathead National Forest and Mission Mountain Wilderness, State Forest lands and private lands. Swan Lake is located 10 km upstream from Flathead Lake.

Migratory bull trout and cutthroat trout from Flathead Lake originally used tributaries of all forks of the Flathead River and Swan River; dams now block access to the South Fork and Swan River. Hungry Horse Reservoir behind Hungry Horse Dam and Swan Lake support isolated bull trout populations. Bull trout and cutthroat trout, species of special concern, coexist with 23 other species of fish in the Flathead Lake and River system (Leathe and Graham 1982).

Bull trout, cutthroat trout, and other species rely on clean, unembedded gravels and cobbles, and instream cover in many basin tributaries for spawning and rearing (Fraley and Graham, 1982; Fraley and Shepard 1989). Bull trout are particularly selective in their requirements; they spawn in only 28 of the hundreds of available tributaries. In fact, 12 tributaries in the North and Middle Forks of the Flathead and the Swan rivers support about half of all spawning of bull trout from Flathead and Swan lakes.

Watershed Study Sites



In this study module, we concentrated on 29 tributaries. These tributaries were located in the following drainages: Swan, Stillwater/Whitefish, North Fork, Middle Fork, and South Fork of the Flathead River. These tributaries were chosen by the study team to be representative of the variety of geography, habitat, land ownership and fisheries conditions in the basin.

METHODS

EMBRYO INCUBATION STUDIES

Westslope Cutthroat Trout

Since 1986, the Montana Department of Fish, Wildlife and Parks (MDFWP) has monitored westslope cutthroat trout spawning area gravel composition in the Flathead River drainage by hollow core sampling (McNeil and Ahnell 1984, May and Weaver 1986). During the course of this monitoring, field crews have sampled over 30 natural redds; 13 samples included actual westslope cutthroat trout egg pockets. We gravimetrically analyzed these samples and described spawning gravel composition using techniques developed by Tappel and Bjornn (1983) (Table 1). Cumulative particle size distributions from these samples plotted approximately linearly on log-probability paper; slopes ranged from 0.411 to 0.636.

Table 1. Slope, intercept and coefficient of determination (r^2) for regression lines developed from transformed gravimetric analysis (Tappel and Bjornn 1983) of hollow core samples of streambed substrate including egg pockets in 13 natural westslope cutthroat trout redds.

Sample number	Slope	Intercept	r^2
1	0.541	-1.518	0.97
2	0.532	-1.368	0.99
3	0.455	-1.355	0.99
4	0.636	-1.486	0.99
5	0.602	-1.881	0.97
6	0.565	-1.558	0.99
7	0.599	-1.495	0.99
8	0.421	-1.626	0.99
9	0.532	-1.198	0.97
10	0.411	-1.223	0.99
11	0.509	-1.231	0.99
12	0.632	-1.461	0.99
13	0.619	-1.599	0.99
Mean	0.543	-1.461	0.985
SE	0.077	0.191	0.009

We prepared six gravel mixtures to cover the particle size range observed in the natural egg pocket samples. To do this, we gravimetrically separated natural streambed material into ten size classes ranging from 25.4 mm to 0.42 m (Table 2). We remixed this material forming six different mixtures with levels of material <6.35 mm ranging from 0 to 50 percent dry weight (Table 2). We chose this size class for use in referencing the various mixtures because it is common in the literature and it includes the size range of material typically generated by land management activities.

Table 2. Size composition of gravel mixtures used in westslope cutthroat embryo survival tests expressed as percentage of mixture smaller than given particle sizes.

Mixture (= % <6.35 mm)	Particle size (mm)									
	>25.4[a]	25.4	19.0	12.7	9.52	6.35	4.76	2.00	0.85	0.42
0	93	7	6	4	3	0	0	0	0	0
10	71	29	26	22	14	10	7	3	1.5	0.5
20	52	48	40	32	26	20	15	7	2	1
30	39	61	54	44	36	30	24	12	5	2
40	30	70	63	54	47	40	32	18	8	4
50	21	79	74	67	59	50	43	25	13	7
Mean and range observed in natural egg pocket samples (n = 13):										
	35.4	64.6	51.5	45.8	39.3	30.6	26.1	16.2	6.8	3.1
	20.2 to 61.5	38.5 to 80.8	32.5 to 68.3	29.3 to 56.1	24.9 to 47.6	18.3 to 39.1	16.9 to 34.9	8.9 to 21.2	5.9 to 19.3	2.9 to 12.5

[a] We used the portion of this material larger than 50.8 mm as centrum particles for egg pockets.

We designed these gravel mixtures so that log-probability plots of cumulative particle size distributions were approximately linear and as similar as possible to the mean slope of plots from the 13 natural egg pockets. We included material larger than 25.4 mm in all six gravel mixtures. We used the largest of this material as centrum particles for egg pockets as described by Chapman (1988). We recently documented the presence of these larger particles in natural westslope cutthroat trout egg pockets sampled by freeze coring (MDFWP unpublished data). These larger particles are difficult to obtain using a standard 152 mm hollow core sampler. We predetermined that 31.78 kg of dry material adequately filled each incubation cell and weighed out three identical replicates of each gravel mixture, bagged them separately and transported them to the test stream.

We chose a section of Langford Creek (48° 35'N, 114° 11'W), a tributary to lower Big Creek in the North Fork of the Flathead River drainage as our study site. The stream section had good access and contained large areas of spawning gravel with water depths, gradients, and velocities typically used by spawning adfluvial westslope cutthroat trout (MDFWP unpublished data). Depths over our artificial redds ranged from 10.0 cm to 25.0 cm and velocities ranged from 0.1 to 0.3 m/sec. at the time of egg planting. Langford Creek supports high densities of juvenile cutthroat trout (40/100 m^2; MDFWP 1982). We observed actively spawning cutthroat trout in the study area just prior to setting up this test.

We prepared 18 cells for the test. The field crew used a hinged plywood deflector to create low water velocity areas in which we excavated pits in the streambed approximately 0.75 m in diameter by 0.20 m deep. We placed light gauge aluminum rings 0.46 m in diameter by 0.20 m high in the center of each pit and filled in the displaced gravel around them. These rings provided open spaces in the streambed where we placed the emergence traps (Fraley et al. 1986) during the egg planting process.

In preparation for egg planting, we randomly assigned one of the six gravel mixtures to each incubation cell. We located a relatively flat spot on the streambank near the center of the test site and laid two full sheets of plywood on the ground at this point. This landing served as a work surface where gravel mixing took place.

The timing of this test was somewhat later than the natural regime. We initially set up the experiment on July 13, using green eggs. However, high mortality forced us to rework the test one month later than planned, using eyed eggs.

We stocked the incubation cells on August 10. The egg planting process involved sitting the external frame of our emergence traps on the aluminum rings with the fiberglass screen enclosure extending down into the void in the bed material. We emptied a bag containing one replicate of the assigned gravel mixture onto the plywood. The largest particles were selected by hand and placed inside the emergence trap through the capture bag. We arranged these centrum particles inside the trap to provide protection and dispersal of the eggs. We added 50 eyed embryos among the centrum particles through a 1.0-m length of 76.1-mm diameter PVC pipe inserted through the capture bag. Egg planting depth ranged from 12.7 to 17.8 cm. We observed egg pockets within this depth range while hollow core and freeze core sampling in natural westslope cutthroat trout redds (MDFWP unpublished data). We mixed the rest of the gravel on the plywood with a flat-tipped shovel, placed it in buckets and carried it to the cell. We carefully bridged the interstices in the centrum particles with the mixture then added the remaining gravel through the PVC pipe. Once the cell was full, we closed the capture bag with a locking nylon tie strip and removed the aluminum ring. As we removed the rings,the surrounding streambed material collapsed around the traps so that only the external frame and the upper portion and capture bag remained above the gravel surface. Researchers formed a pit or depression immediately upstream of the sealed traps, mimicking the appearance of natural spawning sites.

We placed 273 eyed embryos in a heath tray plumbed with creek water. We used all handling procedures used to stock the incubation cells. The only difference was that no gravel was added over the eggs in the heath tray. We measured dissolved oxygen content and water temperature at egg pocket depth during the incubation period using perforated standpipes (Terhune 1958) located at the downstream edge of each incubation cell.

We began checking the traps for emergent fry during late August when fry in the Heath tray "buttoned up." Once fry emergence began, we checked the traps every second or third day. We captured, counted, weighed (nearest .001 g) and measured (nearest mm) emerging fry. We used regression analysis to test for significant relationships between emergence success and the percentage of materials <6.35 mm. We compared fry size from the various gravel compositions using Kruskal-Wallis tests.

Bull Trout

Since 1981, the Montana Department of Fish, Wildlife and Parks (MDFWP) has monitored bull trout spawning gravel quality in the Flathead River drainage by hollow core sampling (McNeil and Ahnell 1964). During the course of this monitoring, field crews have sampled a number of natural redds; 6 samples included actual bull trout egg pockets. We gravimetrically analyzed these egg pocket samples and described spawning gravel composition using techniques developed by Tappel and Bjornn (1983) (Table 3). Cumulative particle size distributions of material <25.4 mm in these samples plotted approximately linearly on log-probability paper with a mean slope of 0.545. Slopes ranged from 0.498 to 0.580.

Table 3. Slope, intercept and coefficient of determination (r^2) for regression lines developed from transformed gravimetric analysis (Tappel and Bjornn 1983) of hollow core samples of streambed substrate including egg pockets in six natural bull trout redds.

Sample number	Slope	Intercept	r^2
1	0.555	-1.482	0.966
2	0.580	-1.131	0.997
3	0.579	-1.336	0.999
4	0.552	-0.976	0.995
5	0.509	-1.275	0.996
6	0.498	-1.197	0.998
Mean	0.546	-1.233	0.992
SE	0.035	0.174	0.013

We prepared six gravel mixtures to cover the particle size range observed in the natural egg pocket samples. To do this, we gravimetrically separated natural streambed material into ten size classes ranging from 25.4 mm to 0.42 m (Table 4). We remixed this material forming six different mixtures with levels of material smaller than 6.35 mm ranging from 0 to 50 percent dry weight (Table 4). We chose this size class for use in referencing the various mixtures because it is common in the literature and it includes the size range of material typically generated by land management activities.

Table 4. Size composition of gravel mixtures used in bull trout embryo survival tests expressed as percentage of mixture smaller than given particle sizes.

Mixture (= % <6.35 mm)	Particle size (mm)									
	>25.4[a]	25.4	19.0	12.7	9.52	6.35	4.76	2.00	0.85	0.42
0	93	7	6	4	3	0	0	0	0	0
10	71	29	26	22	14	10	7	3	1.5	0.5
20	52	48	40	32	26	20	15	7	2	1
30	39	61	54	44	36	30	24	12	5	2
40	30	70	63	54	47	40	32	18	8	4
50	21	79	74	67	59	50	43	25	13	7

[a] We used the portion of this material >50.8 mm as centrum particles for egg pockets.

We designed these gravel mixtures so that log-probability plots of cumulative particle size distributions were approximately linear and as similar as possible to the mean slope of plots from the six natural egg pockets. We included material larger than 25.4 mm in all six gravel mixtures. We used the largest of this material as centrum particles for egg pockets as described by Chapman (1988). We recently documented the presence of these larger centrum particles in natural bull trout redds sampled by freeze coring (MDFWP unpublished data). These larger particles are difficult to obtain using a standard 152 mm hollow core sampler. We predetermined that 31.78 kg of dry material adequately filled each incubation cell and weighed out three identical replicates of each gravel mixture, bagged them separately and transported them to the test stream.

We chose a section of Coal Creek (48° 41'N, 114° 18'W), a tributary to the North Fork of the Flathead River as our study site. The stream section had good access and contained large areas of spawning gravel with water depths, gradients, and velocities typically used by spawning adfluvial bull trout (MDFWP unpublished data). Depths over our artificial redds ranged from 15.0 cm to 30.0 cm and velocities ranged from 0.2 to 1.0 ft/sec at the time of egg planting. Coal Creek supports high densities of juvenile bull trout (15/100 m^2; MDFWP 1982). We observed spawning by bull trout in the study area during ten years of annual redd counts.

We prepared 24 cells for the test. The field crew used a hinged plywood deflector to create low water velocity areas in which we excavated pits in the streambed approximately 0.75 m in diameter by 0.20 m deep. We placed light gauge aluminum rings 0.46 m in diameter by 0.20 m high in the center of each pit and filled in the displaced gravel around them. These rings provided open spaces in the streambed where we placed our artificial gravel mixtures containing egg bags or gravel filled emergence traps (Fraley et al. 1986) during the egg planting process.

In preparation for egg planting, we randomly assigned one of the six gravel mixtures to each incubation cell. We located a relatively flat spot on the streambank near the center of the test site and laid two full sheets of plywood on the ground at this point. This landing served as a work surface where gravel mixing took place.

We stocked sealed egg bags containing 100 green bull trout eggs into the incubation cells on October 4. This process involved placing recently fertilized eggs into fiberglass mesh bags containing test gravel and burying them with our test mixtures inside the aluminum rings. Once the rings were filled with gravel, we removed them from the stream. Prior to egg planting, we placed one perforated standpipe (Terhune 1958) in the center of each cell so that we could measure dissolved oxygen content in the egg incubation environment. We excavated a single egg bag from each gravel mixture on five separate dates to test for mortality and to monitor embryo development. We measured dissolved oxygen content during each excavation.

We maintained eggs remaining after the sealed bags were filled in a Heath incubator plumbed with creek water. On December 18 and 19, we stocked the remaining 18 incubation cells with these eggs. The eggs were strongly eyed at this time. The egg planting process involved placing the external frame of our emergence traps on the aluminum rings with the fiberglass screen enclosure extending down into the void in the bed material. We emptied a bag containing one replicate of the assigned gravel mixture onto the plywood. The largest particles were selected by hand and placed inside the emergence trap through the capture bag. We arranged these centrum particles inside the trap to provide protection and dispersal of the eggs. We added 100 eyed embryos among the centrum particles through a 1.0-m length of 76.1-mm diameter PVC pipe inserted through the capture bag. Egg planting depth ranged from 15.2 to 17.8 cm. We observed egg pockets within this depth range while hollow core sampling in natural bull trout redds (MDFWP unpublished data). We mixed the rest of the gravel on the plywood with a flat-tipped shovel, placed it in buckets and carried it to the cell. We carefully bridged the interstices in the centrum particles with the mixture then added the remaining gravel through the PVC pipe. Once the cell was full, we closed the capture bag with a locking nylon tie strip and removed the aluminum ring. As we removed the rings,the surrounding streambed material collapsed around the traps so that only the external frame and the upper portion and capture bag remained above the gravel surface. Researchers formed a pit or depression immediately upstream of the sealed traps, mimicking the appearance of natural spawning sites.

We placed the remaining eyed embryos in an emergence trap containing centrum particles using all handling procedures used to stock the incubation cells. The only difference was that no gravel was added over the eggs in this trap. We measured dissolved oxygen content and water temperature at egg pocket depth during the incubation period using perforated standpipes (Terhune 1958) located at the downstream edge of each incubation cell.

We began checking the traps for emergent fry during late April. Weaver and White (1995) observed first emergence at this time in previous tests. In general, researchers checked traps every second or third day. We captured and counted emerging fry. We used regression analysis to test for significant relationships between emergence success and the percentage of materials <6.35 mm.

FREEZE CORING IN SPAWNING SITES

In a review on the utility of existing predictors of salmonid response to fine sediment, Chapman (1988) pointed out that most researchers have failed to duplicate the location, structure and substrate composition of natural egg pockets. He concluded that these studies do not accurately model survival to emergence and that quantitative predictors depend on careful definition of egg pocket structure through field sampling. Chapman (1988) recommended extraction of intact egg pockets by freeze coring to define vertical stratification and particle size distribution.

Field crews used a tri-probe freeze core sampler (Lotspeich and Reid 1980) to obtain samples from natural westslope cutthroat and bull trout spawning sites. Sampling involved driving the hollow probes into the gravel in the redd. A tripod with a hoist affixed at the top was centered over the sampler. The crew poured liquid nitrogen into the probes individually. Addition of sufficient liquid nitrogen to freeze the sample required approximately five minutes. We jacked the frozen samples out of the streambed and placed them horizontally across a slotted chamber. As the samples melted, they were stratified into 10.0 cm depth increments.

We oven dried the samples and sieve separated them into 13 size classes ranging from >76.1 mm to <0.063 mm (Table 5) We compared the percentage of material <6.35 mm in diameter, the geometric mean particle size (Platts et al. 1979) and the Fredle Index (Lotspeich and Everest 1980) of strata containing eggs with those having no eggs.

STREAMBED CORING

Measurements of the size range of materials in the streambed are indicative of spawning and incubation habitat quality. In general, research has shown negative relationships between fine sediment and incubation success of redd constructing salmonids (Chapman 1988).

In 1981, field crews began collecting streambed samples from known spawning areas in Flathead Basin tributaries. Results of these investigations are summarized and discussed in annual reports (Shepard and Graham 1982, 1983a; Weaver and White 1984, 1985; Weaver and Fraley 1985, 1986, 1988; Weaver 1989, 1990). For this study, the site selection committee recommended

Table 5. Mesh size of sieves used to gravimetrically analyze freeze core (Lotspeich and Reid 1980) and hollow core (McNeil and Ahnell 1964) streambed substrate samples collected from Flathead River Basin tributaries from 1989-1991.

76.1 mm	(3.00 inch)
50.8 mm	(2.00 inch)
25.4 mm	(1.00 inch)
18.8 mm	(0.74 inch)
12.7 mm	(0.50 inch)
9.52 mm	(0.38 inch)
6.35 mm	(0.25 inch)
4.76 mm	(0.19 inch)
2.00 mm	(0.08 inch)
0.85 mm	(0.03 inch)
0.42 mm	(0.016 inch)
0.063 mm	(0.002 inch)
Pan	(<0.002 inch)

continued sampling of these areas and specified additional streams necessary to cover the range of land management activity present basin-wide (Table 6).

We selected the original study areas based on annual observations of natural spawning. We only sampled in spawning areas used by adfluvial westslope cutthroat and bull trout. During the period of study, these fish have spawned in the same general areas, so sampling locations remained similar. Field crews often sampled natural redds. Since crews did not have an opportunity to document spawning in several of the additional streams, we selected these study areas based on their physical characteristics using experience gained during past annual samplings.

Researchers used a standard 15.2 cm hollow core sampler (McNeil and Ahnell 1964) to collect four samples across each of three transects at each study area. We located actual coring sites on the transects using a stratified random selection process. The total width of stream having suitable depth, velocity, and substrate for spawning was visually divided into four equal cells. We randomly took one core sample in each cell. In some study areas we deviated from this procedure, due to limited or discontinuous areas of suitable spawning habitat.

Table 6. List of study streams showing activities scheduled for each stream included as part of the Flathead Basin Commission Cooperative Forest Practice, Water Quality, and Fisheries Study.

Area/Drainage: Stream	Fish Monitoring Activity				
Stillwater					
Fitzsimmons Creek	MN	WV	SS	--	P
Chepat Creek	MN	WV	SS	--	P
Swan River					
Elk Creek	(MN)	(WV)	(SS)	(RC)	(P)
Goat Creek	(MN)	WV	SS	(RC)	(P)
Squeezer Creek	(MN)	WV	SS	(RC)	P
Lion Creek	(MN)	WV	SS	(RC)	(P)
Jim Creek	(MN)	WV	SS	RC	P
Piper	MN	WV	SS	RC	P
Island Unit					
Freeland Creek	MN	WV	SS	RC	P
Tally Lake					
Fish Creek	(MN)	WV	SS	RC	P
Hand Creek	(MN)	WV	SS	--	P
Swift Creek	MN	WV	SS	RC	P
Sheppard Creek	MN	WV	SS	--	P
Squaw tributary	MN	--	SS	--	P
North Fork					
Big Creek	MN	WV	SS	RC	(P)
Coal Creek DH	(MN)	WV	(SS)	(RC)	(P)
NF Coal Creek	(MN)	(WV)	(SS)	(RC)	(P)
SF Coal Creek	(MN)	(WV)	(SS)	(RC)	(P)
Cyclone Creek	MN	WV	SS	RC	P
Red Meadow Creek	(MN)	WV	SS	--	(P)
Whale Creek	(MN)	WV	SS	(RC)	(P)
Trail Creek	(MN)	WV	SS	(RC)	P
Middle Fork					
Granite Creek	(MN)	WV	SS	(RC)	--
Challenge Creek	(MN)	WV	SS	(RC)	(P)
Ole Creek	--	--	SS	(RC)	(P)
Morrison Creek	(MN)	WV	(SS)	(RC)	(P)
South Fork					
Hungry Horse Creek (2)	(MN)	WV	(SS)	(RC)	(P)
Margaret Creek	(MN)	WV	(SS)	(RC)	(P)
Tiger Creek	(MN)	WV	(SS)	(RC)	(P)
Emery Creek	(MN)	WV	(SS)	(RC)	(P)

Fish Monitoring Activity Codes:

( )	Denotes Montana Dept. of Fish, Wildlife & Parks (MDFWP) and/or Flathead National Forest (FNF) work supported by other funding.
___	Denotes MDFWP work contracted by FNF.
MN	McNeil gravel core samples (12 cores at each site; 4 cores on each of 3 transects).
WV	Whitlock-Vibert box sediment samples (measures materials 4.75 mm; 4 boxes on each of 3 transects).
SS	Substrate scores (15 transects in a 150 m stream section).
RC	Redd counts (total number of spawning sites in a stream section).
P	Fish population estimates (electrofishing estimates for a 150 m stream section).

Sampling involved working the corer into the streambed to a depth of 15.2 cm. We removed all material inside the sampler and placed it in heavy duty plastic bags. We labeled the bags and transported them to the Flathead National Forest Soils Laboratory in Kalispell, Montana, for gravimetric analysis. We sampled the material in suspension inthe water inside the corer using an Imhoff settling cone (Shepard and Graham 1982). We allowed the cone to settle for 20 minutes before recording the amount of sediment per liter of water. After taking the Imhoff cone sample, we determined total volume of the turbid water inside the corer by measuring the depth and referring to a depth to volume conversion table (Shepard and Graham 1982).

The product of the cone reading (mg of sediment per liter) and the total volume of turbid water inside the corer (liters) yields an approximation of the amount of fine sediment suspended inside the corer after sample removal. We then applied a wet to dry conversion factor developed for Flathead tributaries by Shepard and Graham (1982), yielding an estimated dry weight (g) for the suspended material.

We oven dried the bagged samples and sieve separated them into 13 size classes ranging from >76.1 mm to >0.063 mm in diameter (Table 5). We weighed the material retained on each sieve and calculated the percent dry weight in each size class. The estimated dry weight of the suspended fine material (Imhoff cone results) was added to the weight observed in the pan, to determine the percentage of material >0.063 mm. We summed these percentages, obtaining a cumulative particle size distribution for each sample (Tappel and Bjornn 1983).

We refer to each set of samples by using the median percentage >6.35 mm in diameter. This size class is commonly used to describe spawning gravel quality, and it includes the size range typically generated during land management activities. We examined the range of median values for this size class observed throughout the basin and compared these values with results from the activity assessment and water yield models.

Field crews also used McNeil coring to obtain measures of particle size composition above and below an area in West Jim Creek where management related sediment sources could potentially change streambed composition. We selected this study area based on visual observations made as development progressed. Water quality monitoring showed elevated turbidity levels below this area during the first spring runoff period following development (Water Quality Bureau 1990). A subsequent audit of best management practicies (BMPs) conducted under another study model identified several areas of major BMP departure at the site (Ehinger and Potts 1990).

Crews collected McNeil core samples immediately above and below the sale area before spring runoff of 1989. The same areas were sampled again in November, 1989 and in April, 1990. We used the site selection and sampling procedures for McNeil core sampling described previously. We examined the percentage of fine material present during each sampling to test for any changes.

WHITLOCK-VIBERT BOX SAMPLING

The modified Whitlock-Vibert (W-V) box technique may be an alternative method for measuring accumulated fine sediment (Reiser et al. 1987; Wesche et al. 1989). Reiser et al. (1987) reported using Whitlock-Vibert boxes to determine the percentage of fine material in streambed gravel. They standardized weight and pore space inside the boxes by filling them with glass marbles. The marble filled boxes were placed in a saturation chamber, which they filled to overflowing and weighed. They they buried the boxes in the streambed. After the test period they excavated the boxes now containing fine sediment and repeated the saturated weighing procedure. They stated that the difference between these two weights was the weight of the sediment trapped in the box. Comparison of amounts of fine sediment (<4.75 mm) in W-V boxes with results of McNeil core samples collected adjacent to box planting sites showed a relationship existed (Reiser et al. 1987; Wesche et al. 1989). Potential advantages of this new technique include an onsite analysis capability, using lightweight, transportable apparatus. It would allow a continuous period of record for a greater range of stream conditions and it is not consumptive of spawning gravel.

We tested this procedure at the sites specified in Table 6. Field crews weighed and planted marble filled W-V boxes as described by Reiser et al. (1987). Upon box removal we found two disadvantages to their analysis procedure. First, the saturation chamber must be level when filled with water and weighed. This is very difficult to perform in the field. Second, and most important, the difference between the saturated weights of the empty and filled (with sediment) boxes is not the sediment weight. The actual sediment weight is this difference plus the weight of the volume of water displaced by the sediment. To quantify this volume of water in the field is impractical. This is because the box, when removed from the streambed, will contain water trapped between the sediment particles. Only an oven-dried sample can be used to determine the volume of water displaced.

Project personnel developed a new method for analyzing W-V boxes based upon Archimedes Principle:

$$\text{Dry Weight} - \text{Submerged Weight} = \text{Weight of Water Displaced}$$

The relationship between the dry weight and the weight of the water displaced is the specific gravity:

$$\text{Specific Gravity} = \frac{\text{Dry Weight}}{\text{Weight of Water Displaced}}$$

In theory, this relationship is absolutely linear (Newman 1967). In our procedure we find the submerged weight of the box and sediment and use it to predict the dry sediment weight. Knowing the dry sediment weight and the sediment density, we can calculate percent fines trapped by the W-V box.

To find submerged weights we built a five-sided submersion chamber with a monofilament sling to suspend it from a balance (Figure 2). We placed a W-V box into the submersion chamber and then into a five gallon bucket filled with water. Water temperature was kept between 10.5-12.0° C, because specific gravity of water changes with temperature. Next, we dried each sample to obtain the dry sediment weight. We used this weight to assess the submerged/dry weight relationship. If predictions prove accurate, we will only need to dry the first series of samples from a drainage to develop both the predictive equation and the sediment density. In the future, we can predict the dry sediment weight from the submerged weight taken in the field.

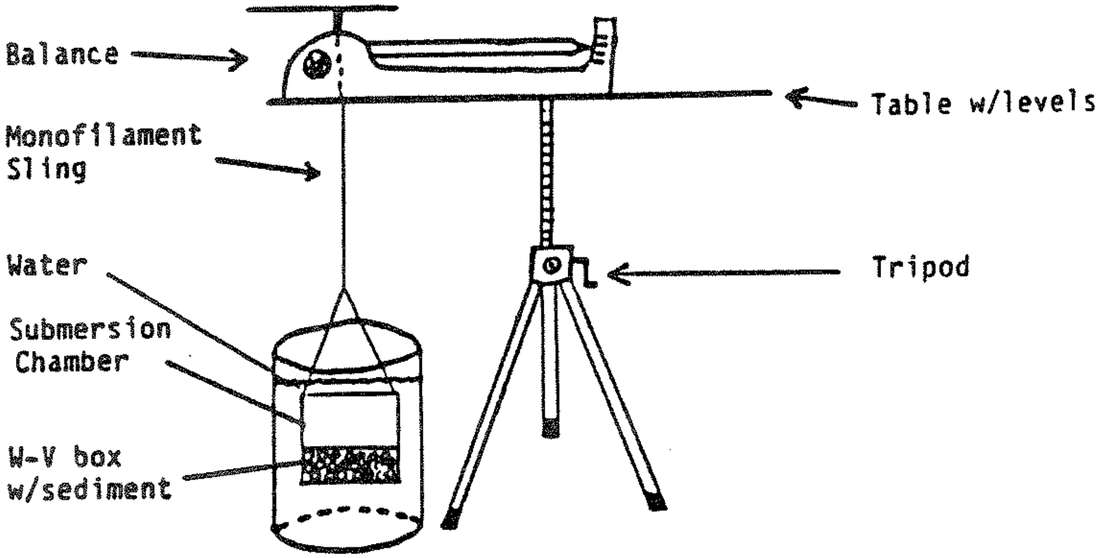


Figure 2. Diagram of apparatus and set up used to obtain submerged weights for individual Whitlock-Vibert box sediment samples in the laboratory or field.

To determine the percent fines trapped in the W-V boxes we found the sediment density. We pooled and mixed all dry sediment samples from a drainage. We weighed a sample of known volume and returned it to the pool. This procedure was repeated six times in calculating sediment densities:

$$\frac{\text{Sediment Weight}}{\text{Volume}} = \text{Sediment Density (g/cc)}$$

We found the mean sediment density for a drainage and used it to calculate the percent fines trapped by each W-V box. We divided the sediment dry weight by the sediment density obtaining volume and divided this by the volume of a W-V box (645.3 cc) to find the percentage of the box filled with sediment:

$$\text{Percent Fines} = \frac{\dfrac{\text{Sediment Dry Weight}}{\text{Sediment Density}}}{645.3} \text{ X } 100$$

We compared data from individual W-V boxes with corresponding McNeil cores using regression analysis, to determine whether a significant correlation existed. We also compared the mean percentage <4.75 in the boxes with mean percentage <4.75 from McNeil coring at each sample area.

SUBSTRATE SCORING

Juvenile bull trout rear for up to three years in Flathead Basin tributaries. Snorkel and electrofishing observations during past studies indicate juvenile bull trout are extremely substrate oriented and can be territorial (Fraley and Shepard 1989). It is possible that this combination of traits could cause partitioning of suitable rearing habitat, resulting in a maximum carrying capacity for each stream. We monitor substrate related habitat potential by calculating substrate scores (Crouse et al. 1981; Leathe and Enk 1985). Substrate scoring involves visually assessing the dominant and subdominant streambed substrate particles, along with embeddedness in a series of cells across transects. Surveyors assign a rank to both the dominant and subdominant particle size classes in each cell (Table 7). They also rank the degree to which the dominant particle size class is embedded (Table 7). The three ranks are summed, obtaining a single variable for each cell. All cells across each transect are averaged and a mean of all transects in a section results in the substrate score.

We scored each 150 m electrofishing section using equally spaced transects. Cell width varied depending of wetted width, allowing a minimum of five evaluations for any transect.

Maximum cell width in this study was 1.0 m. Lower scores indicate poorer quality rearing habitat; higher values indicate good conditions.

We examined the range of substrate scores obtained throughout the basin and compared these values with results from the activity assessment and water yield models using regression analysis. We also used regression analysis to compare juvenile bull trout densities to substrate scores in the important rearing areas.

Table 7. Characteristics and associated ranks for computing substrate score (modified by Leathe and Enk 1985 from Crouse et al. 1981).

Rank	Characteristic
	Particle Size Class[1]
1	Silt and/or detritus
2	Sand (<2.0 mm)
3	Small gravel (2.0 - 6.4 mm)
4	Large gravel (6.5 - 64.0 mm)
5	Cobble (64.1 - 256.0 mm)
6	Boulder and/or bedrock (>256.0 mm)
	Embeddedness
1	Completely embedded or nearly so
2	3/4 embedded
3	1/2 embedded
4	1/4 embedded
5	Unembedded

[1]Used for both dominant and subdominant particle ranking.

REDD COUNTS

A reliable census of annual spawning escapement by adult fish is a valuable element of any fisheries monitoring program. These data are frequently used as measures of anticipated production in succeeding generations. They also provide an index of success in regulating the fishery. Observations during past studies indicate that migratory fish populations in the Flathead consistently use the same stream sections for spawning (Fraley and Shepard 1989). Field crews monitor the number of spawning sites in identical stream sections annually. These counts provide information on trends in escapement into upper basin tributaries.

We conduct preliminary surveys to determine appropriate timing for final counts. Final inventories begin after we observe numerous completed redds, few adult fish, and little evidence of active spawning during the preliminary surveys. Timing of final counts is critical, because as redds age, they loose the characteristic "cleaned" or "bright" appearance becoming more difficult to identify.

Experienced field crews conduct surveys by walking the channel within these known spawning areas. They visually identify redds by the presence of a pit or depression and associated tail area of disturbed gravel.If timing is proper, identification of redds presents little problem. We classify redds based on the following criteria:

1. Definite - no doubt. The area is definitely "cleaned" and or pit and tail area are recognizable. Not in an area typically cleaned by stream hydraulics.

2. Probable - An area cleaned that may be due to stream hydraulics but a pit and tail are recognizable, or an area that does not appear clean but has a definite pit and tail.

We call the upper boundary of the survey section pace zero and keep track of paces while walking down through the section. When the surveyors encounter a redd, they record its certainty class along with its location in paces from the start of the survey. Surveyors record distinct landmarks by noting the pace number at the location of each landmark.

We include both classes of redds in final totals, which we compare annually as an index of spawner escapement. Field crews have not had an opportunity to locate the spawning areas in several of the additional streams recommended by the site selection committee. No redd counts were conducted in these streams (Table 2).

POPULATION ESTIMATION

We evaluated fish populations at 28 sites around the Flathead Basin (Table 2). A period of record exists for several sections. Field crews used equipment and procedures outlined by Shepard and Graham (1983b) in determining populations estimates and densities for 150 m long stream sections. We examined the range of estimates obtained from these efforts. We compared total trout density (#/100 m^2) in each section with results from the activity assessment and water yield modeling. Since juvenile bull trout are so highly substrate oriented, we compared juvenile bull trout density (#/100 m^2) with substrate scores also. Estimates were made using age one and older fish ($\geq$75 mm total length).

DATA ANALYSIS

Project personnel constructed data base files analyzed using Statgraphics 4.0. We compared mean egg pocket versus non-egg pocket strata from the freeze coring and the mean percentage of substrate <4.75 mm in W-V boxes versus the associated McNeil cores using paired t-tests. We tested for changes in the median percentage of streambed material <6.35 mm in McNeil cores using two tailed Mann-Whitney tests. Total fish density and juvenile bull trout density were compared with substrate scoring results using linear regression analysis. To demonstrate the linkage between land management activities and fisheries we used linear regression analysis. We used arcsine transformations on the output from the Sequoia index and H_2OY model. This is a standard procedure used when data are percentages and the values are limited in range. We evaluated the McNeil coring data and the substrate scores as percent differences.

$$X = \frac{\text{observed value - minimum value}}{\text{minimum value}} (100)$$

This was necessary to expand the range of the data.

RESULTS AND DISCUSSION

EMBRYO INCUBATION STUDIES

Westslope Cutthroat Trout

All but two of the embryos in the heath tray hatched within two days after we stocked the incubation cells. We made no adjustment for planting mortality since hatching success exceeded 99 percent. Fry emergence began on September 2 and continued for 22 days. Emergence peaked on day three (September 5) and we recorded 70 percent of the total number of emerging fry over the following week. Ninety-six percent of all observed emergence occurred during the first two weeks. We did not statistically test for differences in timing of emergence between gravel mixtures.

We observed a significant inverse relationship between the percentage of material <6.35 mm and emergence success ($P < 0.005$; $r^2 = 0.72$) (Figure 3). Mean emergence success ranged from 76 percent in the mixture containing no material <6.35 mm, to 4 percent in the mixture containing the most fine sediment (Table 8).

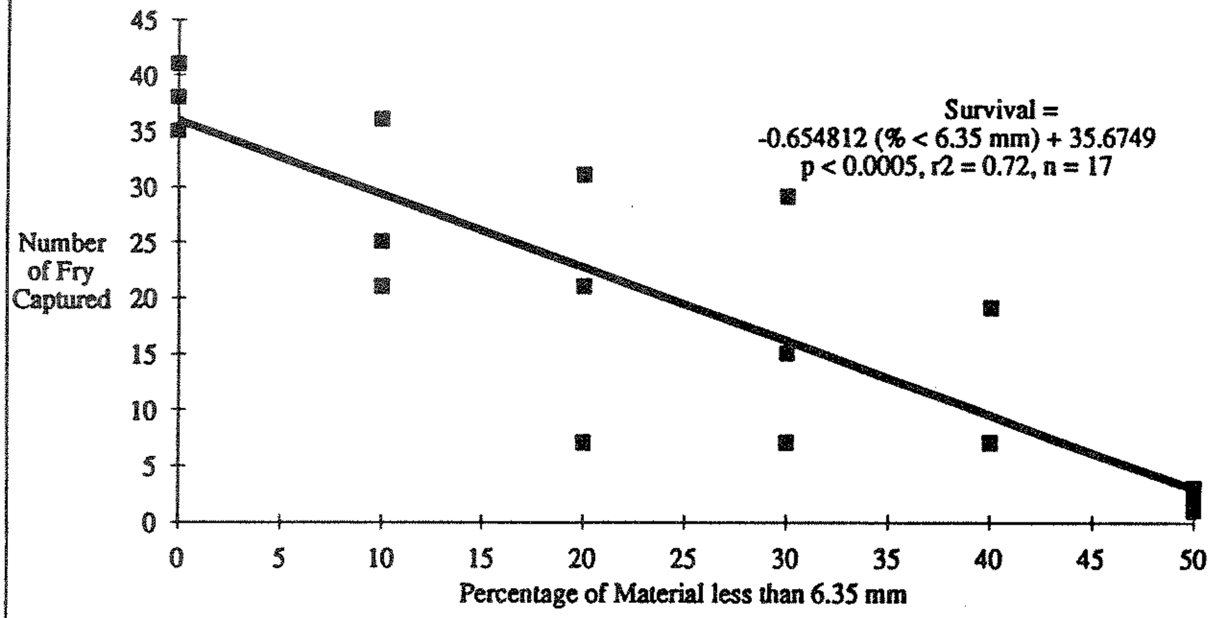
We recorded the highest survival in one of the control cells (82 percent). It is possible that some embryos were damaged when filling the cells, although we took care in bridging interstices in egg pocket centrums. Chapman (1988) suggests that once fertilized eggs are deposited in an egg pocket, digging by the female results in a bridging over of the centrum components and then in a mix of gravels over this area. Green eggs are resilient for up to 24 hours after spawning; however, our use of strongly eyed eggs may have resulted in higher mortality from crushing as we filled the cells with gravel. We could not quantify this potential mortality from our heath tray results.

Table 8. Number of fry successfully emerging from each replicate of six gravel mixtures and dissolved oxygen content (in parenthesis) at each incubation cell location.

Replicate	Gravel mixture (= % <6.35 mm)					
number	0	10	20	30	40	50
1	38 (8.0)	21 (8.1)	7 (7.8)	7 (7.8)	7 (8.0)	3 (8.0)
2	41 (8.4)	25 (8.0)	31 (8.1)	29 (8.3)	[a] (--)	1 (8.0)
3	35 (8.2)	36 (8.2)	21 (8.0)	15 (8.0)	19 (8.1)	2 (8.1)
Total number:	114	82	59	51	26	6
Mean % success:	76	55	39	34	26	4

[a] Replicate was not completed.

Figure 3. Relationship between numbers of westslope cutthroat trout fry successfully emerging from replicates of six gravel mixtures and the percentage of material smaller than 6.35 mm in each mixture



Some emergent fry may have avoided capture by retreating into voids in the gravel inside the traps during sampling. The greatest potential error from this would have occurred in the cells with the lower sediment concentrations; greater pore space would provide more space for refugia. We believe escape from the emergence traps was negligible. Phillips and Koski (1969) reported mean trap efficiency of over 99 percent for the type of trap used for this study. In an effort to document fry entombment, personnel inspected contents of several traps after removal, but found no live or dead alevins. Therefore, we made no adjustment for avoidance.

We observed some significant differences when comparing survivals between mixtures. Survival in the zero percent mixture was significantly greater than in all other mixtures except the ten percent mixture. Emergence success in the 10 percent mixture was significantly greater than in the 40 and 50 percent mixtures. Fry emergence in the 20, 30, and 40 percent mixtures were all significantly greater than in the 50 percent mixture.

Considerable variation existed between individual replicates of each gravel mixture. This variation was greatest in the mixtures containing 20 and 30 percent materials <6.35 (Table 8). Dissolved oxygen varied from 7.8 to 8.4 mg/l at the incubation cell locations (Table 8). Emergence success was significantly related ($P < .005$ $r^2 = 0.43$) to dissolved oxygen content. There was no relationship between dissolved oxygen content and the percentage of material <6.35 mm.

Although we observed a high degree of negative correlation between emergence success and percentage of materials less than 6.35 mm, variation among replicates of individual gravel mixtures suggest that other factors may have influenced test results. We treated all cells equally during the planting process. Dissolved oxygen levels were within the required range for incubating salmonids (Reiser and Bjornn 1979). In reviewing salmonid oxygen requirements, Davis (1975) showed a mean threshold of incipient oxygen response during incubation of 8.1 mg/L. We observed the lowest dissolved oxygen concentrations (7.8 mg/L) in incubation cell numbers 4 and 5 (Table 8). These cells were located close to each other and contained 20 and 30 percent fines (<6.35 mm) respectively. Oxygen levels in all other cells measured 8.0 mg/L or greater. We observed seven emerging fry in each of these two cells; considerably less than the remaining two replicates of each mixture (Table 8). It is possible that part of this variation resulted from site specific differences in the intergravel environment around cells 4 and 5. Depths and velocities over cells four and five may have caused differences in the intergravel environment. Differential handling mortality could have also contributed to the observed variation between replicates.

No significant differences in the length or weight of emergent fry existed over the range of gravel mixtures tested. Fry with the greatest mean weight came from the zero percent mixture followed by those from the 30 percent and 20 percent mixtures respectively. We recorded the lowest mean fry weight from the mixtures containing 10 and 40 percent material <6.35 mm. Regressions of fry weight from each cell location on dissolved oxygen content were not significant.

Irving and Bjornn (1984) conducted similar tests relating cutthroat trout embryo survival to substrate composition in laboratory channels. They provided the following equation relating survival to gravel size: Percent survival = $102.83 - 0.838 (Sq_{.5}) - 9.29 (So_{.85}) + 0.386 (S_{0.85})^2$. We predicted survival to emergence for each of our gravel mixtures using this equation. Results are 100, 73, 64, 36, 14, and 0 percent survival from the 0, 10, 20, 30, 40, and 50 percent mixtures, respectively. We observed lower survival than predicted in the 0, 10 and 20 percent mixtures; similar survival from the 30 percent mixture and higher survival in the 40 and 50 percent mixtures. Emergence success in the laboratory study was more strongly influenced by the smaller particle size classes.

Similar to this study, Irving and Bjornn (1984) reported using strongly eyed eggs; hatching occurred within five days after planting. They also observed peak emergence shortly after the first fry emerged. Irving and Bjornn (1984) observed earlier emergence from mixtures containing more fines; we did not observe this trend.

Several major differences exist between the experimental designs. Irving and Bjornn (1984) conducted laboratory tests and did not include the larger particle sizes or attempt to simulate egg pockets and structure of natural redds. Egg planting depth appeared deeper in the lab study and they adjusted for handling mortality.

Through this study, we have made an effort to address the research requirements listed by Chapman (1988) as necessary to adequately index embryo survival to emergence. We simulated as closely as possible natural spawning sites, including proper depths, velocities, and gravel composition; we included egg pockets centrum particles, planted eggs at the natural depth of deposition and measured dissolved oxygen content in the incubation environment. The differences between these and earlier findings (Irving and Bjornn 1984) support the need for intensive study of natural spawning sites and simulation of conditions in the egg pocket.

The results of our studies indicate that any increases in fine materials in a streambed could significantly reduce the emergence success of westslope cutthroat fry. These results could be used by resource managers to develop substrate quality guidelines in steams subject to potential impacts from land management activities.

Bull Trout

We excavated the first series of sealed egg bags on November 11, 1989 (Table 9). Embryos had developed for 38 days. We observed no "eyed" eggs at this time. Survival ranged from 97 percent in the 50 percent mixture to 100 percent in the 20 percent and 40 percent mixtures. We pulled the second set of egg bags on February 20, 1990 (Table 9). These eggs had developed for 108 days. Eggs were strongly "eyed" at this time. survival ranged from 71 percent in the 20 percent mixture to 100 percent in the 30 percent mixture. The third set of egg bags came out on March 23, after 170 days of incubation (Table 9). Most eggs had hatched by this time although we observed several unhatched eggs which still appeared viable. Survival ranged from 73 percent in the 50 percent mixture to 95 percent in the 40 percent mixture. We excavated the fourth egg bag series on May 5 (Table 9). These embryos had incubated for 213 days. Most fry appeared "buttoned up" at this time. We noted remnants of yolk sacs still present on several fry. We found 3 and 6 dead fry in the 40 percent and 50 percent mixtures respectively. These fry probably died because they were unable to emerge from the sealed bags. It is likely that sediment related entombment in the emergence traps may have begun at about this time. We pulled the final set of egg bags on July 10 after 279 days in the gravel (Table 9). All fry found during this sampling were dead. Fungal growth was evident on the dead fry and many may have decomposed beyond recognition. Weaver and White (1985) reported similar developmental timing in field studies of bull trout incubation.

Table 9. Percent survival and dissolved oxygen concentrations measured in incubation cells containing sealed egg bags buried in known gravel mixtures at five samplings during the bull trout incubation period in Coal Creek.

	Gravel mixture (= % <6.35 mm)					
	% survival (D.O.)					
Date	0	10	20	30	40	50
11/20/89	99(8.1)	99(8.0)	100(8.2)	99(8.3)	100(8.3)	97(8.0)
2/20/90	89(8.4)	74(8.3)	71(8.2)	100(8.5)	99(8.7)	84(8.3)
3/23/90	89(7.9)	56(8.1)	74(7.7)	94(8.3)	9.5(8.5)	73(8.4)
5/5/90	92(7.8)	78(7.9)	69(7.5)	88(8.0)	89(8.0)[1/]	66(7.9)[1/]
7/10/90[2/]	86(7.4)	81(7.2)	82(7.2)	71(7.8)	87(7.8)	50(7.5)

[1/] Dead fry found in these egg bags

[2/] All fry found were dead during this sampling

We measured dissolved oxygen content in the various cells each time we excavated egg bags (Table 9). The cell containing the 40 percent gravel mixture consistently had the highest concentrations. The cell containing the 30 percent mixture also had consistently high concentrations. A small spring entered Coal Creek at the precise location of the 40 percent cell. The 30 percent cell was approximately 2.0 m downstream from this point. Both of these cells were within 2.0 m of the wetted edge of the channel during low winter flows. It is possible that the location of these cells may partially explain the differences in dissolved oxygen concentration observed.

It appears that successful incubation may be more strongly related to intergravel dissolved oxygen content than the percentage of fine sediment. In natural situations these two variables are probably more highly correlated than in our test. The relatively small size of our incubation cells probably does not allow gravel composition to greatly affect permeability and dissolved oxygen content has been shown to be largely a function of permeability (Chapman 1988).

We observed a handling mortality of 7.8 percent based on results from the cell stocked with the remaining eggs and centrum particles with no gravel mixture covering the egg pocket. We opened this cell on March 23, 1990. All embryo present were in the sac fry stage at this time.

Fry emergence began on May 9 and continued for 57 days. Stream flow was too high for us to check the traps during a 14 day period between June 18 and July 2. We captured 179 fry during the first sampling following the high flows. We did not statistically test for differences in emergence timing between the various gravel mixtures. Weaver and White (1985) reported the coincidence of fry emergence with high spring flows also. However, they reported the bulk of observed emergence (83 percent) occurred during the first 4 days. This probably resulted from a shallower egg planting depth than we used in this study. We planted eggs within the range of egg deposition depths observed during McNeil core sampling in bull trout redds.

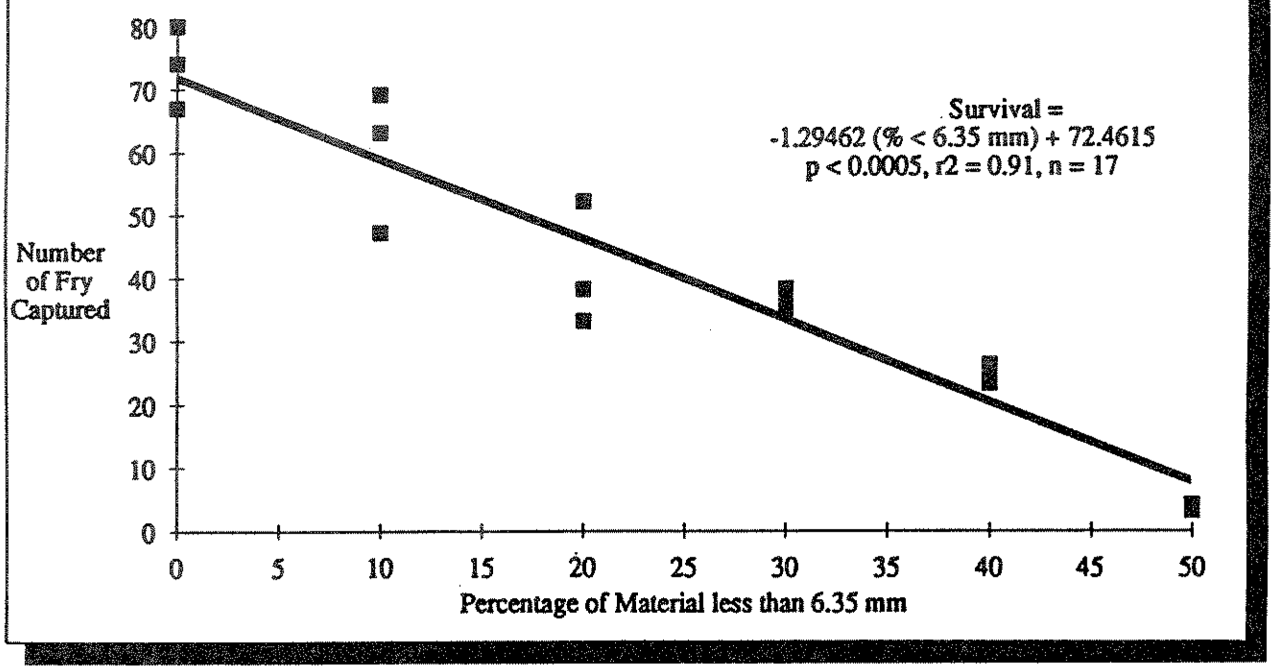
We observed a significant inverse relationship between the percentage of material <6.35 mm and emergence success ($P < 0.005$; $r = -0.95$) (Figure 4). Mean adjusted emergence success ranged from 79 percent in the mixture containing no material <6.35 mm, to 4 percent in the mixture containing the most fine sediment (Table 10).

We observed some significant differences when comparing survivals between mixtures. Survival in the zero percent mixture was significantly greater than in all other mixtures except the 10 percent mixture. emergence success in the 10 percent mixture was significantly greater than in the 40 percent and 50 percent mixtures. Fry emergence in the 20 percent, 30 percent, and 40 percent mixtures were all significantly greater than in the 50 percent mixture.

Table 10. Number of bull trout fry successfully emerging from each replicate of six gravel mixtures stocked into artificial incubation cells in Coal Creek.

	Gravel Mixture (= % <6.35 mm)					
Replicate Number	0	10	20	30	40	50
1	67	69	52	35	25	4
2	74	47	33	37	26	3
3	80	63	38	38	23	--
Total Number	221	179	123	110	74	7
Mean Adjusted Emergence Success	79	64	44	39	26	4

Figure 4. Relationship between number of bull trout fry successfully emerging from replicates of six gravel mixtures and the percentage of material smaller than 6.35 mm in each mixture



We pulled the emergence traps out on July 13-15 and checked for entombed fry. We measured dissolved oxygen content at each site just prior to trap removal (Table 11). We found two live fry during these efforts. Both came from the zero percent <6.35 mm mixture. We counted approximately 26 dead eggs. Most of these were fragments and the actual number was difficult to determine. We observed 53 dead fry. Most of these (68 percent) were found in the 50 percent mixture. In cell number seven (50 percent), we found almost one quarter of the total number planted. We found dead fry in the 30 percent and 40 percent mixtures also (4 and 13 respectively). Since we observed dead fry in the sealed egg bags as early as May 5, we suspect that many more may have decomposed beyond recognition by the mid-July examination. It appears that entombment is responsible for the majority of the observed mortality.

Through this study, we have made an effort to address the research requirements listed by Chapman (1988) as necessary to adequately index embryo survival to emergence. We simulated as closely as possible natural spawning sites, including proper depths, velocities, and gravel composition; we included egg pocket centrum particles, planted eggs at the natural depth of deposition, and measured dissolved oxygen content in the incubation environment. The differences between these and earlier findings (Weaver and White 1985) support the need for intensive study of natural spawning sites and simulation of conditions in the egg pocket.

Table 11. Number of live fry, dead eggs, dead fry, and dissolved oxygen content observed during the examination of emergence trap contents during mid July.

Cell Number	Gravel Mixture	Live Fry	Dead Eggs	Dead Fry	D.O.
1	0	1	0	0	7.6
2	30	0	3	2	7.7
3	10	0	0	0	7.8
4	50	0	5	13	7.4
5	40	0	2	6	7.3
6	20	0	0	0	7.6
7	50	0	10	23	7.4
8	0	0	0	0	7.5
9	30	0	3	0	7.2
10	40	0	0	4	7.8
11	10	0	0	0	7.3
12	20	0	0	0	7.5
13	40	0	3	3	7.5
14	10	0	0	0	7.8
15	20	0	0	0	7.6
16	0	1	0	0	7.8
17	30	0	0	2	7.4
18	50	--	--	--	--
Totals		2	26	53	

The results of our studies indicate that any increases in fine materials in spawning areas could significantly reduce the emergence success of bull trout fry. These results could be used by resource managers to develop substrate quality guidelines in streams subject to potential impacts from land management activities.

FREEZE CORING IN SPAWNING SITES

Westslope Cutthroat Trout

Project personnel collected six frozen core samples from four adfluvial westslope cutthroat trout redds in Hungry Horse Creek. Sampling depths ranged from 30.0 to 38.0 cm; dry weights of samples ranged from 16.7 to 20.1 kg. We detected eggs in three of these samples. In all three samples we found the eggs in the second chamber, indicating an egg deposition depth >10.0 cm but <20.0 cm deep. We observed an undisturbed layer of large angular particles (mostly >50.8 mm and some >76.1 mm) in the frozen samples beginning around 17.8 cm below the surface and extending downward. It is likely that these particles prevented deeper excavation by the fish and formed the "floor" of the redds. Eggs deposited on and around these particles were covered by a mixture of particles of up to 50.8 mm in diameter.

Two of the samples contained less than 25 eggs; the third sample contained 63 eggs. Eggs were in the eyed stage at this time. We have no way to determine whether the sampler was centered on egg pockets or if we only sampled portions of them.

In all three samples, less fine material (percent <6.35 mm) was present in the strata containing the eggs than in the one immediately above it (Table 12). Geometric mean particle size and Fredle index were greater in the egg pocket strata (Table 12). A comparison of the mean values for egg pocket strata and the 10.0 cm strata above it showed significant differences ($P < 0.05$) existed in both geometric mean particle size and Fredle index.

This difference may have resulted from the larger particles in and below the floor of the redds. When these larger particles broke away during thawing, we placed them in the chamber over which the larger portion of the particle hung. We may have biased the sample by not being able to completely separate these particles into the proper strata when they overlapped the boundary. It is also possible that the female fish cleaned the substrate in the egg bearing strata in the process of redd construction during spawning. Chapman (1988) provides a thorough discussion of redd construction and conditions in the redd during incubation.

Although embryos may incubate in egg pockets having greater geometric mean particle size and less fine sediment, emerging fry must migrate up through the material covering the egg pocket to successfully reach the stream. We know a major portion of the mortality in the incubation testing resulted from fry entombment. After combining strata, the three frozen core samples containing egg pockets averaged 26.8 percent <6.35 mm. The median value obtained from the 1989 McNeil coring of undisturbed gravel in Hungry Horse Creek's spawning area was 29.2 percent <6.35mm ($n=12$).

Table 12. Cumulative particle size distributions (Tapel and Bjornn 1983), geometric mean particle size (dg) (Platts et al. 1979) and Fredle index (fi) (Lotspeich and Everest 1980) by depth strata from three freeze core samples from westslope cutthroat trout redds where eggs were observed in samples.

Sample No.	Depth Strata	% < Given Sieve Size											dg	f_i
		Sieve Size (mm)												
		76.1	50.8	25.4	19.0	12.7	9.52	6.35	4.76	2.00	0.85	0.42		
1	Top 10.0cm	100.0	100.0	75.1	66.2	49.9	40.9	32.6	27.9	15.6	7.1	2.9	13	5.2
	2nd 10.0cm	100.0	67.7	43.5	37.4	29.9	26.1	20.8	17.7	9.9	4.5	2.3	28	9.6
2	Top 10.0cm	100.0	89.5	69.1	61.1	48.3	40.7	32.3	26.9	15.6	7.4	2.4	14	4.3
	2nd 10.0cm	85.2	67.1	46.6	39.7	32.3	28.3	22.1	18.3	11.0	5.2	2.4	25	8.6
3	Top 10.0cm	100.0	100.0	72.5	63.2	48.9	39.4	31.3	25.8	13.8	5.8	2.4	13	5.2
	2nd 10.0cm	100.0	72.4	50.9	44.3	35.4	30.9	25.0	20.5	12.0	5.3	2.5	23	7.3
Mean	Top 10.0cm	100.0	96.5	72.2	63.5	49.0	40.3	32.1	26.9	15.0	6.8	2.6	13.3	4.9
	2nd 10.0cm	95.1	69.1	47.0	40.5	32.5	28.4	22.6	18.8	11.0	5.0	2.4	25.3	8.5

Bull Trout

Field crews collected four frozen core samples from two adfluvial bull trout redds in Lion Creek. Sampling depths ranged from 30.0 to 38.0 cm; dry weights of samples ranged from 15.3 to 18.3 kg. We found no eggs in these samples.

We took the first two cores from the tail area of a redd 1.4 m long and 0.9 m wide. Cores were located approximately 15.0 and 30.0 cm downstream from the center of the depression. Larger particles (50.8 - 76.1 mm) were noted between 8.0 and 25.0 cm in one sample. The floor of this redd was about 25.0 cm deep. The second pair of cores came from a redd 2.3 m long and 1.8 m wide. We sampled two locations side by side, approximately 25.0 cm downstream from the depression. The floor of this redd appeared to be 18.0 to 21.0 cm deep.

Even though we obtained no information on egg pockets, several notable observations were made. Everest et al. (1987) reported that some fish spawning in higher levels of fine sediment may build larger redds, but deposit eggs at a shallower depth. The floor of the second and much larger redd did appear shallower and sieve analysis showed the percentage of material <6.35 mm was greater in these samples 21.2 and 18.9 percent in the smaller redd, 24.2 and 30.3 percent in the larger redd). The median value obtained from the 1989 McNeil coring of undisturbed gravel in Lion Creek's spawning area was 39.0 percent <6.35 mm (n = 12). We have noted many extremely large redds during annual redd counts in Lion Creek.

Adfluvial bull trout redds are much larger than the cutthroat trout redds we sampled. This greater area of disturbed gravel makes it more difficult to obtain egg pocket samples. We feel this effort should continue to further refine bull trout embryo survival modeling. Data from even a small number of bull trout egg pockets would help our predictive ability.

STREAMBED CORING

Median percentages of streambed material <6.35 mm ranged from 24.8 percent in Chepat Creek to 50.3 percent in Jim Creek (Table 13). These 29 values averaged 36.3 percent. The maximum variability observed within individual streams was about 20 percentage units. As an indication of natural sediment levels, we averaged the core sampling results for the nine sites where the Sequoia index (Potts and McInerny 1990) was 0.00 or no disturbance. This calculation resulted in an average value of 31.7 percent. Of these nine watersheds, we know of significant natural sediment sources with high levels of channel storage above the study areas in Elk and Lion creeks. The Sequoia index does not consider natural sediment sources or other natural phenomena which may alter streambed conditions. Eliminating these two sites from calculations of the average condition in "undisturbed" watersheds results in a value of 29.8 percent.

Big, Coal, Granite, and Challenge creeks all had relatively high median percentages of fine material considering Sequoia results (Table 13). A period of record exists for all five of these areas. Effects of the 1964 flood are still evident in Granite and Challenge creeks. As with Elk, Squeezer, and Lion creeks, model predictions are probably not reflective of the current conditions in these watersheds. The median percentage of material <6.35 mm in Big Creek's spawning area has increased from 21.6 percent in the 1981 sampling to the current level of 48.0 percent. Significant increases ($P < 0.05$) occurred between 1987 and 1988, then again between 1988 and 1989. Sediment source surveys have resulted in identification of both natural and old management related sources. Management related sediment sources resulting from timber harvest which occurred over ten years ago are still influencing spawning gravel composition in Coal Creek also.

We are unable to determine why Fish, Hand, Sheppard, and a Squaw tributary all had relatively low median percentages of fine material considering the Sequoia model output (Table 13). With the exception of Fish Creek, only a single year of coring data are available for these areas. Field crews have sampled Fish Creek annually since 1985. The median percentage of material <6.35 mm has remained relatively stable and similar to the value reported in Table 13.

Table 13. Comparison of results from streambed core sampling, substrate scoring, activity assessment (Sequoia) and water yield (H_2OY) modeling on selected tributaries in the Flathead River Basin.

Creek	McNeil Core Sampling (Median % <6.35 mm)	Substrate Score	Sequoia index (% Disturbed)	H_2OY output (% Over Natural)
Elk	37.8	12.5	0.00	0.00
Goat	31.9	10.2	0.01	0.90
Squeezer	42.2	9.1	0.04	0.46
Lion	39.0	9.9	0.00	0.00
Jim	50.3	9.0	13.00	4.26
Piper	31.0	13.2	0.00	0.00
Freeland	45.7	8.8	30.90	NA
Fish	34.2	10.1	22.60	16.78
Hand	36.6	10.3	9.50	1.55
Squaw tributary	32.8	10.8	11.10	3.62
Sheppard	33.8	10.8	15.70	10.24
Big	48.0	11.8	3.00	3.32
Cyclone	31.0	11.3	NA	NA
Coal	39.8	9.6	2.30	1.58
North Coal	37.8	12.3	6.70	3.03
South Fork Coal	36.1	11.8	3.90	1.70
Red Meadow	40.1	11.8	3.40	1.83
Whale	35.4	11.5	1.20	1.27
Trail	30.8	13.1	2.30	0.65
Granite	43.2	NA	1.90	1.72
Challenge	43.5	12.4	2.50	1.03
Morrison	39.2	13.0	2.50	1.30
Ole	NA	12.8	0.00	NA
Hungry Horse	29.2	11.4	0.00	0.50
Tiger	30.2	11.8	0.00	0.11
Margaret	33.6	10.9	0.00	1.64
Emery	36.4	11.6	2.00	3.14
Fitzsimmons	31.2	12.7	0.00	NA
Chepat	24.8	12.6	0.00	NA
Swift	28.4	12.8	0.00	NA

Researchers have collected McNeil core samples in selected spawning areas annually during the past ten years. This period of record gives an idea of how spawning area gravel composition changes from year to year. The average annual change in median percentage ($n = 12$) of material smaller than 6.35 mm in samples from Big, Coal, and Whale creeks has been 4.8 percentage units; changes ranged from 0.1 to 10.7 percentage units. These drainages are mainly roaded timber lands. The average annual change in the Trail Creek samples during this same ten year period was 2.1 percentage units (range = 0.2 to 5.2). The Trail Creek spawning area is not subject to the ground-disturbing activities in the drainage above, which are occurring in Big, Coal, and Whale creeks. The average annual change observed in "undisturbed watersheds" (Sequoia index = 0.0) where we have completed five annual samplings is 3.0 percentage units (range = 0.4 to 5.5).

To demonstrate the linkage between land management activities and spawning gravel composition we used simple linear regression analysis. We used arcsine transformations on the output from the Sequoia index and H_2OY model. This is a standard procedure used when data are percentages and the values are limited in range. We evaluated the McNeil coring data as percent differences.

$$X = \frac{\text{observed value - minimum value}}{\text{minimum value}} (100)$$

This was necessary to expand the range of the data.

Results showed significant relationships ($p < 0.05$) between McNeil coring results and output from both Sequoia and H_2OY models. The correlation with the Sequoia index was slightly stronger than with the H_2OY model (Figure 5 and 6). Although these relationships are significant, considerable scatter exists. There are several reasons which may explain a portion of this scatter. First, to keep this analysis as simple as possible we elected to use linear regression techniques. By including more variables in a multiple regression analysis it is likely we could have a better fit. However, correlation between independent variables could cloud the assessment of cause and effect. The Sequoia index assumes a ten year recovery period. It does not take into account older problems still having a major influence on the percentage of fines in spawning gravel in several watersheds. Sequoia does not consider catastrophic events such as fires or floods. The channel morphology and percentage of fine material in several of our spawning areas are still showing effects of the 1964 flood. By eliminating the watersheds where assumptions dealing with recovery rates and natural events are not reflective, the fit improved ($r = 0.65$; $n = 21$).

High levels of fine sediment can reduce embryo survival by decreasing gravel permeability and the availability of dissolved oxygen for developing embryos. Reduced permeability also slows the rate of metabolic waste flushing from the incubation environment. Fine sediments can physically interfere with emergency by filling the interstitial spaces through which fry emerge.

Figure 5. Relationship between the arcsine transformations of Sequoia model output and transformed McNeil core results for 28 watersheds in the Flathead River Basin during 1989

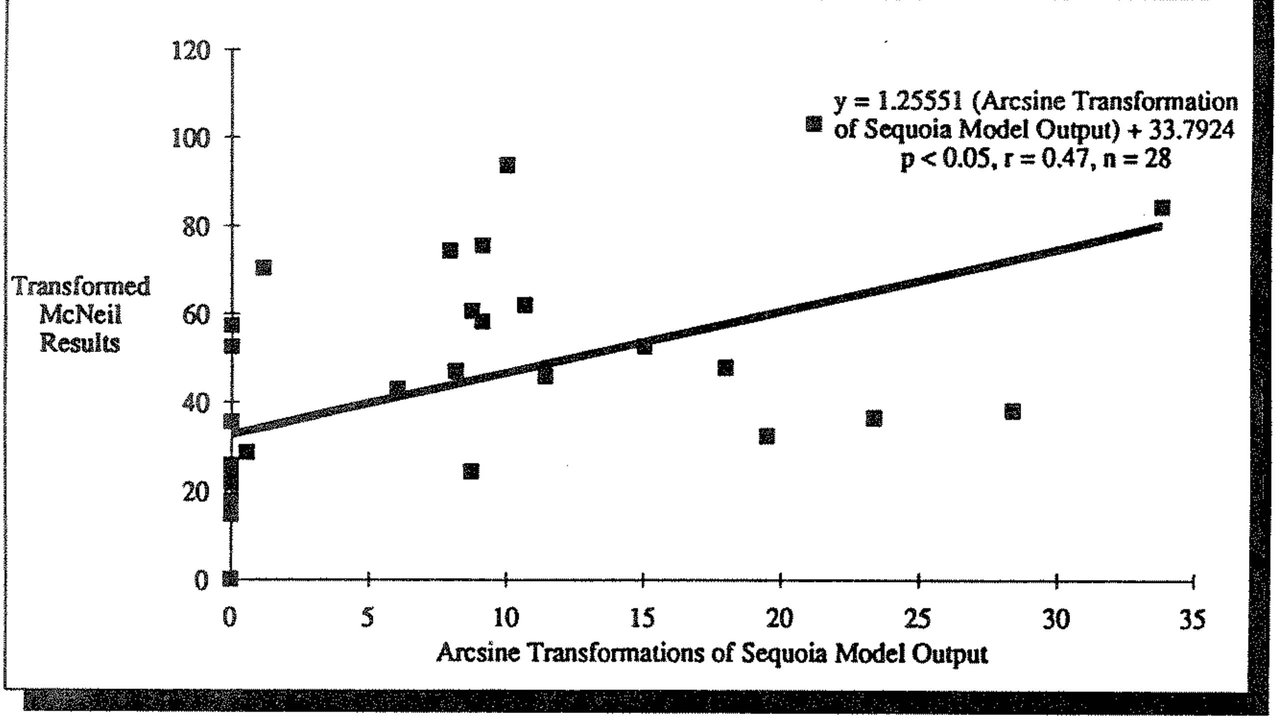
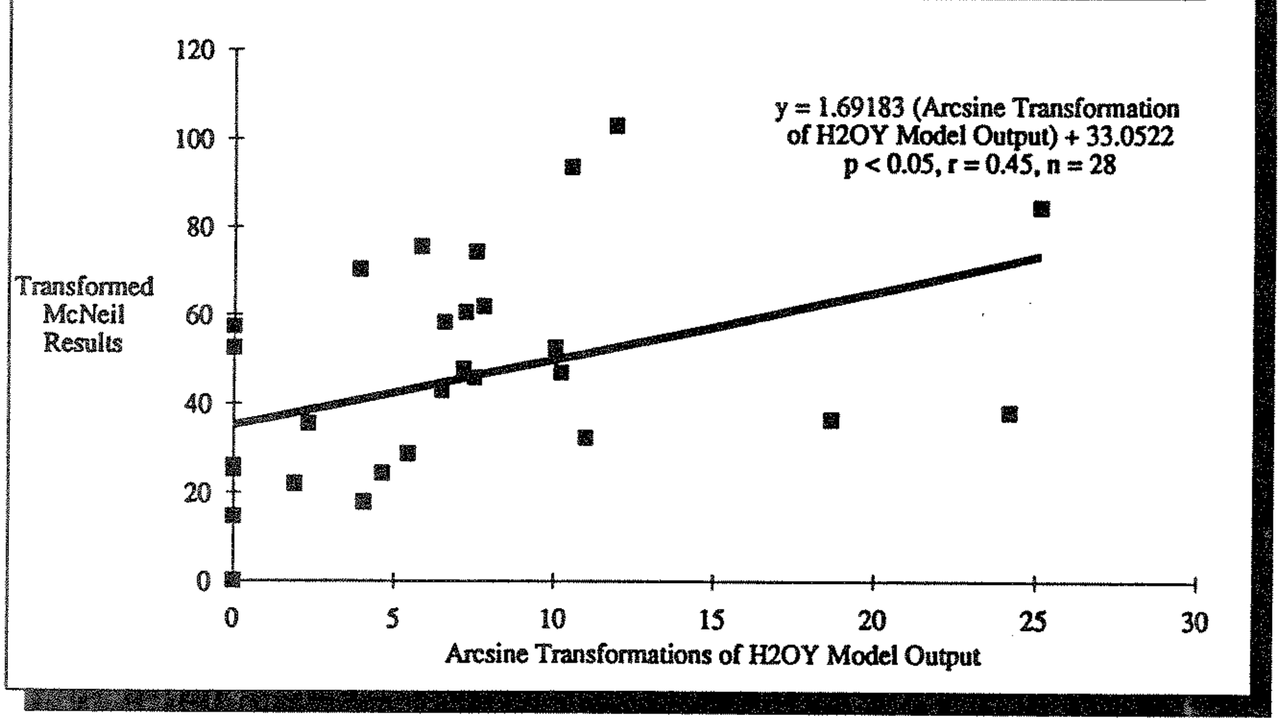


Figure 6. Relationship between the arcsine transformations of H2OY model output and transformed McNeil core results for 28 watersheds in the Flathead River Basin during 1989



The median percentage of material <6.35 mm in the McNeil core samples collected above the timber sale area in West Jim Creek has shown no statistical change during the sampling period (Table 14). We observed no change in Lion Creek, the neighboring drainage paired for comparison. The median percentage of this size class increased significantly ($P < 0.05$) between the April, 1989 and November, 1989 samplings at the site below the West Jim sale area (Table 15). Although some flushing appears to have occurred at this site between the November, 1989 and April, 1990 sampling, the change was not significant (Table 15). The observed increase in the median value of approximately 21 percent was the largest annual increase we have observed for a sampling area in 10 years of sampling. Results from water quality monitoring (Water Quality Bureau 1990) and BMP audits (Ehinger and Potts 1990) support the conclusion that observed changes resulted from the development activities.

Table 14. Percentages of streambed material <6.35 mm in McNeil core samples collected ABOVE the selected cutting unit prior to 1989 runoff after 1989 runoff and approximately 1 year after the initial sampling.

4/9/89	11/7/89	4/16/90
26.1	29.4	29.8
35.1	34.5	30.9
38.7	38.7	32.4
40.0	39.4	33.6
41.4	39.4	36.0
41.4	39.4	37.6
42.6	41.1	42.8
43.5	43.8	45.8
47.6	44.4	46.9
51.5	50.2	49.8
52.5	56.1	57.0
63.0	67.4	62.4
$\bar{x} = 43.6$	$\bar{x} = 43.6$	$\bar{x} = 42.1$
6n - 1 = 9.34	6n - 1 = 10.16	6n - 1 = 10.58
Median = 42.0	Median = 40.2	Median = 40.2

Mann-Whitney ----	4/18/89 vs 11/7/89	11/7/89 vs 4/16/90
Test Results	No Significant Change	No Significant Change

The same personnel used the same equipment in the same manner during all samplings. Although the sites were probably in different riverine-riparian habitat types, we sampled spawning gravel areas having similar depths and velocities at each site. Our sites were the closest areas of suitable spawning gravel above and below the development activity. Our sample size may not have been large enough for 95 percent assurance, but the decreasing variability at the site below the West Jim sale area suggests that the substrate here had become more homogeneous. This is likely due to deposition, and it reduces the number of samples required to obtain a specified level of assurance. It is impractical to collect enough McNeil cores to obtain 95 percent assurance levels at all sampling sites, so we lean heavily on the period of record in determining extreme changes. Spring runoff during 1989 was well within the range of timing and intensity observed during 18 years on record. A late fall rain on snow event in November, 1989, resulted in unseasonably high flows. Our November 7, 1989, sampling occurred before this event.

Table 15. Percentages of streambed material <6.35 mm in McNeil core samples collected BELOW the selected cutting unit prior to 1989 runoff, after 1989 runoff and approximately 1 year after the initial sampling.

	4/9/89	11/7/89	4/16/90
	25.5	----	29.1
	25.9	26.8	40.2
	29.5	33.3	46.0
	32.1	44.4	46.6
	36.7	46.2	47.2
	41.4	50.0	47.5
	43.0	51.2	49.0
	43.7	56.8	50.3
	45.3	58.3	55.2
	49.3	58.5	57.9
	49.4	60.9	60.6
	68.9	64.0	61.7
	$\bar{x}$ = 40.9	$\bar{x}$ = 50.0	$\bar{x}$ = 49.3
	6n - 1 = 12.2	6n - 1 = 11.7	6n - 1 = 9.08
	Median = 42.2	Median = 51.2	Median = 48.2
Mann-Whitney ----	4/18/89 vs 11/7/89		11/7/89 vs 4/16/90
Test Results	Increase significant at the 5 percent level		No significant change

Other researchers have observed similar increases in the percentage of fine materials following land development (Everest et al. 1987). We believe McNeil core sampling is reflective of streambed conditions in the specific sampling sites. Once a period of record exists, annual sampling provides an adequate monitoring tool. However, more cost efficient methods would allow us to increase the level of this activity basin-wide.

WHITLOCK-VIBERT BOX SAMPLING

Field crews planted a total of 380 W-V boxes during the study. We recovered 182, for a recovery rate of 48 percent. Reiser et al. (1987) reported a 58 percent recovery rate for marble filled boxes in a similar field test. Most of our box loss occurred during a November, 1989 precipitation event. We noted substantial movement of streambed material at this time. We lost all W-V boxes planted in several South Fork and Middle Fork Flathead tributaries. Some box displacement and loss occurred in the North Fork Flathead and Swan River drainages as well. In all, we probably lost well over 100 W-V boxes during this event.

Box loss often resulted when the channel degraded at the planting site. Boxes displaced in this manner were often found along the streambank a short distance downstream. Box loss also resulted from deposition of large amounts of material on our transects. We observed up to 15.2 cm of material on several boxes given up for lost but discovered during the McNeil coring procedure. A channel change at one study site resulted in complete dewatering of our boxes in an area of historic spawner use. Unknown persons altered several sites after discovering the boxes in the streambed. We lost boxes due to bull trout spawning at box planting sites in several streams. We lost boxes when cattle walking in the channel stepped on them.

Of the 182 boxes recovered, we analyzed 109 in the laboratory for fine sediment accumulation and density. The overall linear regression of both the submerged weight of the W-V box and the percent <4.75 mm in the W-V box against the percent <4.75 in the associated McNeil core sample showed significant relationships ($P < 0.05$), although considerable scatter existed ($r = 0.48$). When we compared the mean percentage <4.75 mm in the W-V boxes with the mean from McNeil coring at each study area, we observed significant differences ($P < 0.05$) in eight of the 12 comparisons (Table 16).

Wesche et al. (1989) conducted similar tests using W-V boxes and McNeil cores in both the laboratory and field. They observed no significant difference between the mean percentage <3.35 mm in substrate filled W-V boxes versus McNeil cores. To this point, we have only tested using the percentage of material <4.75 mm. We have observed materials up to this size inside boxes. The slotting in the W-V boxes (3.35 mm wide x 13.0 mm long) allows particles >3.35mm to enter the box. We will recalculate and test using the smaller size classes to determine how the elimination of larger particles changes results.

Table 16. Comparison of mean percent fine sediment in modified Whitlock-Vibert boxes and McNeil Core samples collected at the same sites in Flathead Basin tributaries during 1989-1990.

		Mean % Fines <4.75 mm	
Stream	Sample Size	McNeil	W-V
Big 1990	8	41.8	23.0
Challenge 1990*	4	40.3	30.5
Cyclone 1990	12	26.7	6.1
Freeland 1990*	8	41.8	36.4
Goat 1989*	8	28.2	33.2
Goat 1990*	6	35.0	30.9
Jim 1989	12	37.1	25.2
Lion 1989	11	34.1	19.0
Lion 1990	10	36.7	24.3
Morrison 1990	6	40.3	28.8
S. F. Coal 1990	11	29.3	29.3
Squeezer 1989	12	34.9	27.2

*No significant difference between means at alpha = 0.05

Based on these findings, we seriously question whether W-V boxes are suitable for monitoring streambed conditions at this time. However, we believe the potential advantages of this technique over presently used methods warrant greater effort at developing a W-V box program for the Flathead Drainage. Questions relating to box planting, box loss, and best marble size will require more evaluation. A change in box design to use perforations 6.35 mm in diameter would yield more usable results and eliminate questions about which particle size to use.

SUBSTRATE SCORING

Substrate scores ranged from 8.8 in Freeland Creek to 13.2 in Piper Creek (Table 13). Shepard et al. (1984) and Leathe and Enk (1985) felt that scores above 11.0 generally indicated good rearing habitat quality. They specified 9.0 as the minimum critical standard. Based on these values, Jim and Freeland creeks are at or below the minimum recommended level. Squeezer, Lion, and Coal creeks at Dead Horse Bridge scored between 9.0 and 10.0 (Table 13). Sixty-two percent of the scores basin-wide were 11.0 or higher.

The linear regression of substrate scores against the Sequoia model output yielded a significant negative relationship ($P < 0.05$; $r = -0.48$; $n = 28$) (Figure 7). Eliminating the watersheds where the Sequoia index is questionable increased the amount of observed variability accounted for by the regression. We also obtained a significant negative relationship ($P < 0.05$; $r = -0.53$; $n = 28$) between substrate scores and H_2OY predictions (Figure 8)

Linear regression of juvenile bull trout densities ($\#/100m^2$) against substrate score showed a significant positive relationship ($P < 0.05$; $r = 0.54$; $n = 15$) (Figure 9). During winter, long portions of stream channel are completely ice and snow covered. Field crews have also observed extensive areas of anchor ice. In other areas, upwelling ground water keeps certain sections open, even during extreme conditions. These open areas may support the majority of the winter rearing in streams where they occur. It is likely that if we could obtain estimates of juvenile bull trout densities during this winter period instead of late summer, a stronger relationship may result.

REDD COUNTS

We completed rainbow trout spawning site inventories on Freeland and Fish Creek drainages (Table 17). The number of spawners using these two streams during spring of 1989 appeared similar to observations made during past years.

Table 17. Summary of 1989 rainbow trout spawning site inventories.

		Redd Numbers
Creek		1989
Fish	(Ashley Lake)	27
Freeland	(Lake Mary Ronan)	200
Hillburn	(Lake Mary Ronan)	19

We completed westslope cutthroat trout spawning site inventories on all proposed streams (Table 18). In the South Fork drainage, redd numbers in Hungry Horse Reservoir tributaries were up during 1989. Our index stream in the Middle Fork drainage contained fewer redds in 1989 than observed during 1982 surveys when we documented 24 redds. Since we made no previous counts in Cyclone Creek in the North Fork drainage, comparison with existing data is not possible.

Figure 7. Relationship between the arcsine transformations of Sequoia model output and transformed substrate scores for 28 watersheds in the Flathead River Basin during 1989

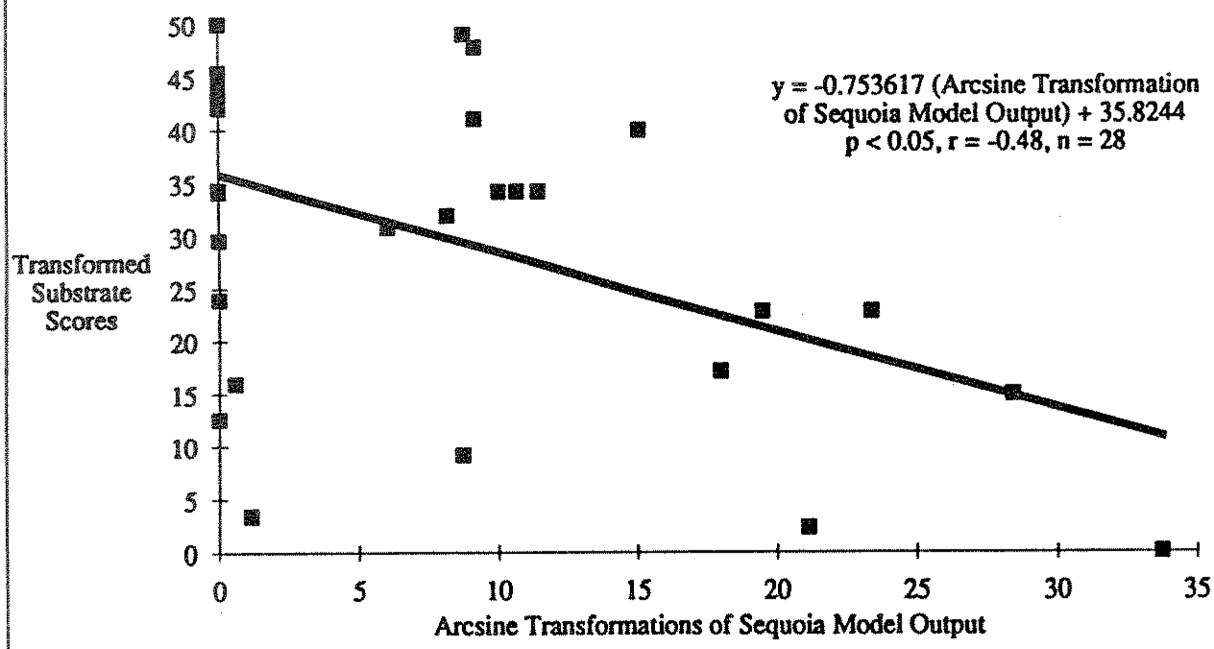


Figure 8. Relationship between the arcsine transformations of H2OY model output and transformed substrate scores for 28 watersheds in the Flathead River Basin during 1989

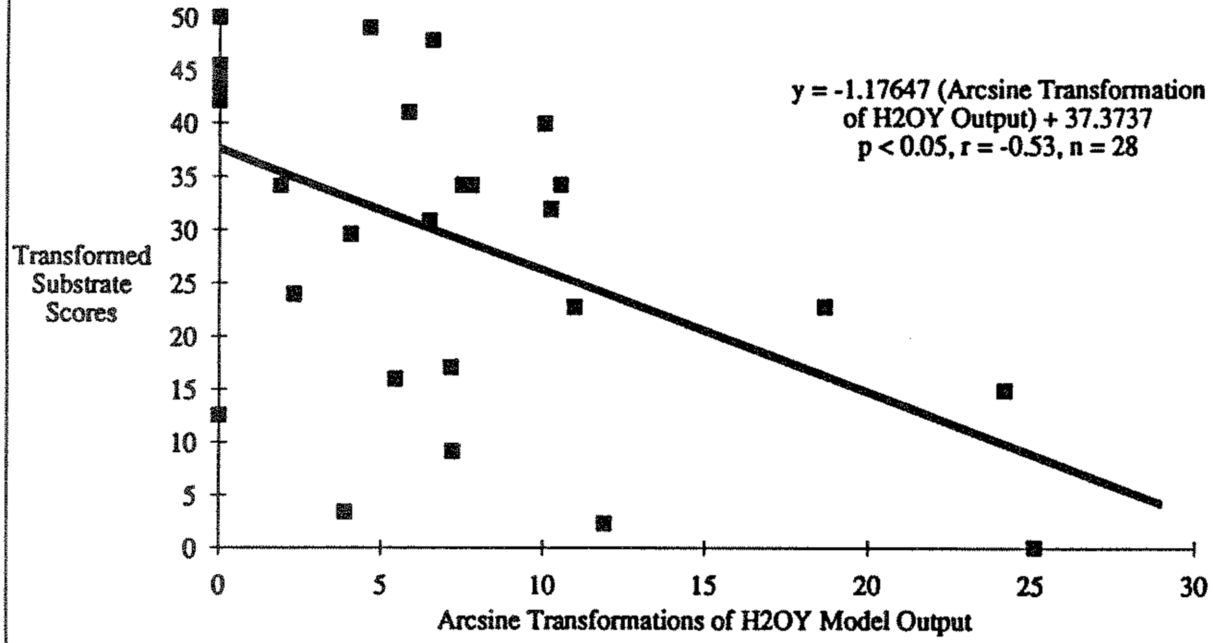


Figure 9. Relationship between transformed substrate scores and juvenile bull trout densities (number of trout less than 75 mm per 100 m2) for 15 tributary reaches in the Flathead River Basin during 1989

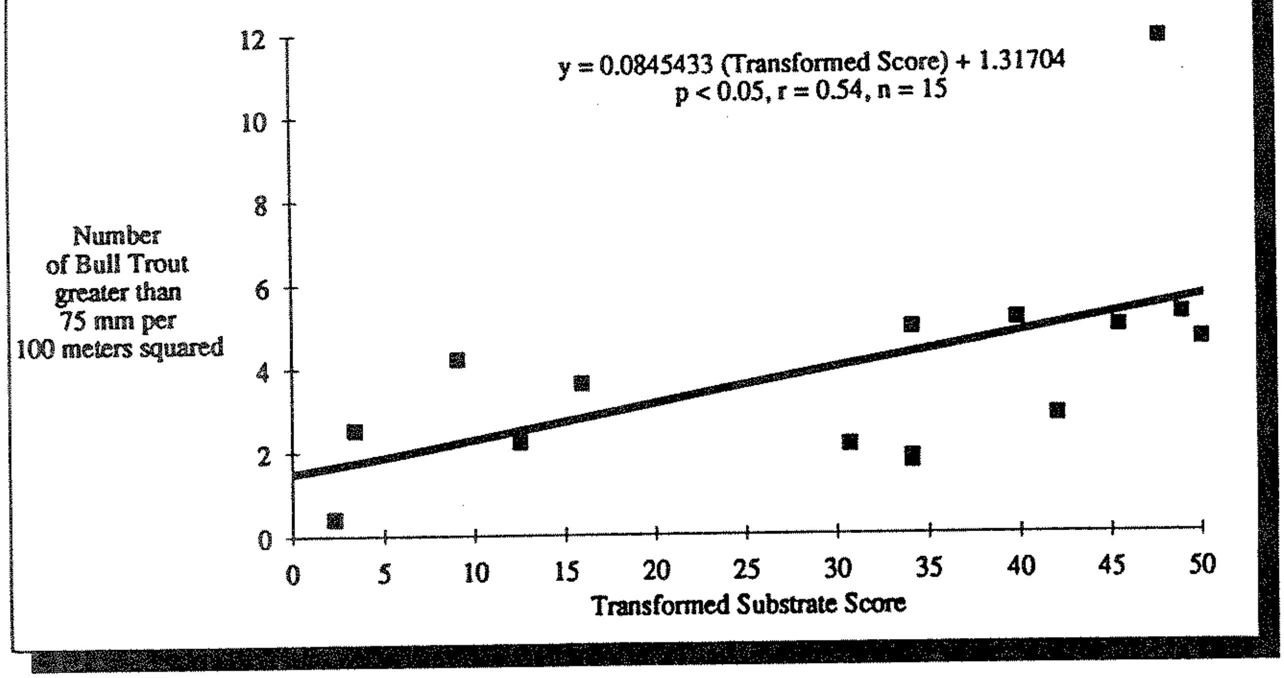


Table 18. Summary of westslope cutthroat trout spawning site inventories from 1986-1987.

Drainage	Creek	Redd Numbers			
		1986	1987	1988	1989
South Fork:	Hungry Horse	93	28	123	118
	Margaret	18	10	37	43
	Tiger	10	7	46	61
	Emery	88	74	108	129
Middle Fork:	Challenge	--	--	--	19
North Fork:	Cyclone	--	--	--	31

We conducted bull trout spawning site inventories in established monitoring areas basin-wide (Table 19). We identified 244 and 158 bull trout redds in North and Middle Fork Flathead tributaries, respectively. Based on these counts, the Flathead Lake run was approximately 9 percent above the 10-year average figure (Figure 10). We counted 371 redds in Swan River tributary monitoring areas during 1989. Based on this number, the run out of Swan Lake was approximately 57 percent above the seven-year average (Figure 11).

Table 19. Summary of annual bull trout spawning site inventories between 1979-1989.

Drainage/ Stream	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
		Redd Numbers									
North Fork:											
Big	10	20	18	41	22	9	9	12	22	19	24
Coal	38	34	23	60	71	53	40	13	48	52	50
Whale	35	45	98	211	141	133	94	90	143	136	199
Trail	34[a]	31[a]	78	94	56	32	25	69	64	62	51
Total	**117**	**130**	**217**	**406**	**280**	**227**	**168**[b]	**184**	**277**	**269**	**244**
Middle Fork:											
Morrison	25[a]	75	32[a]	86	67	38	99	52	49	50	63
Granite	14	34	14[a]	24	31	47	24	37	34	32	31
Lodgepole	32	14	18	23	23	23	20	42	21	19	43
Ole	--	19	19	51	35	26	30	36	45	59	21
Total	**71**	**142**	**83**	**194**	**156**	**134**	**173**[b]	**167**	**149**	**160**	**158**
Flathead Drainage Total	**188**	**272**	**300**	**600**	**436**	**361**	**341**	**351**	**426**	**429**	**402**
Swan:											
Elk	--	--	--	56	91	93	19	53	162	201	186
Goat	--	--	--	33	39	31	40	56	31	46	34
Squeezer	--	--	--	41	57	83	24	55	64	9[b]	67
Lion	--	--	--	63	49	88	26	46	33	65	84
Total	**--**	**--**	**--**	**193**	**236**	**295**	**109**	**210**	**290**	**321**	**371**

[a] Counts may be underestimated due to incomplete survey.

[b] High flows may have obliterated some of the redds.

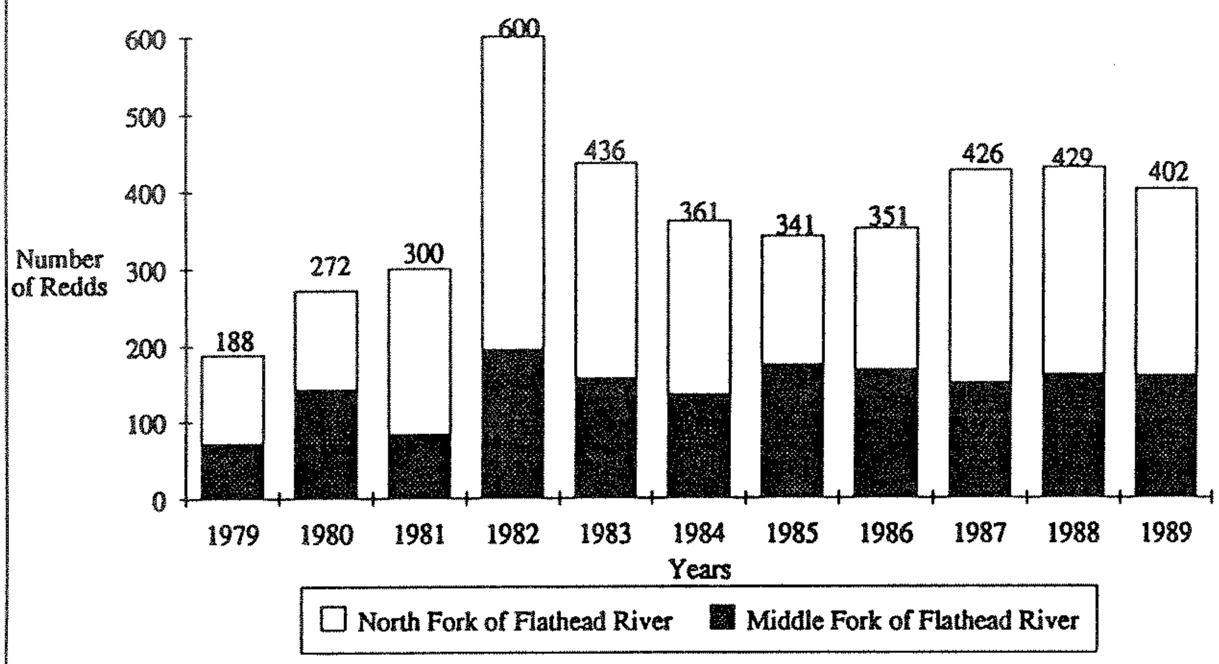


Figure 10. Summary of annual bull trout redd counts in the North and Middle Forks of the Flathead River Drainage from 1979 through 1989.

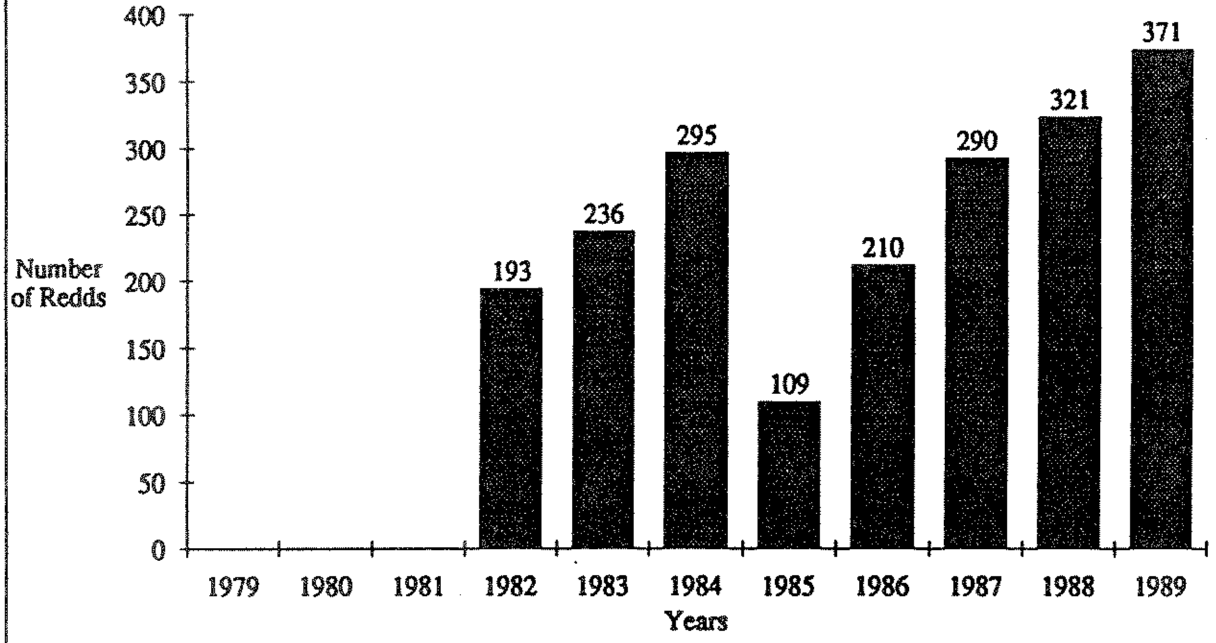


Figure 11. Summary of annual bull trout redd counts in the Swan River Drainage from 1982 through 1989.

Unmonitored sections exist in several of these tributaries and other streams are utilized by spawning bull trout. Our numbers do not represent the total annual spawning run. We estimate our annual counts represent about 35 percent of the annual Flathead Lake spawning escapement and about 75 percent of the Swan Lake run.

POPULATION ESTIMATION

Mean total fish density for the 28 electrofishing areas was 13.1 trout $\geq$75 mm/100m^2 of stream surface area. Densities ranged from 2.1 in Jim Creek to 75.8 in Freeland Creek (Table 20). Tributary streams to large lakes which support rearing populations of rainbow trout (Freeland and Fish Creeks) and westslope cutthroat trout (Hungry Horse, Tiger, Margaret, and Emery creeks) had the highest densities. Eastern brook trout populations in Sheppard and Hand Creek were also higher density (Table 20). Piper Creek was the only stream where we observed estimatable numbers for all three trout species present.

Linear regression analysis showed significant positive relationships ($P < 0.05$) between total fish density and model output from both Sequoia and H_2OY. However, we expected any relationship observed here to be negative. Behavioral differences exist between the trout species present in our study streams, making interpretations difficult. Rainbow and cutthroat trout have a greater tendency to school or tolerate high density situations. In our test streams rainbow and cutthroat trout populations consisted of one and two year old fish which occupy streams for a portion of their life history prior to moving into large lakes. Eastern brook trout in our test streams are generally stream residents, spending their entire life in these areas. There is a tendency for resident brook trout populations to overpopulate the available habitat. Weaver (1990) reported the average annual and maximum fluctuation in populations statistics (Platts and Nelson 1988) observed at sites where a period of record exists.

Juvenile bull trout are much more substrate oriented than these other trout species (Fraley and Shepard 1989). Because of their close association with the streambed, we believe bull trout are better indicators of the influence of fine sediment. We compared juvenile bull trout densities with substrate scores and found a significant relationship ($P < 0.05$; $r = 0.54$; $n = 15$) existed (Figure 9). Approximately 30 percent of the variability we observed in juvenile bull trout densities can be explained by this relationship. Leathe and Enk (1985) reported a similar but somewhat stronger relationship for Swan River tributaries supporting juvenile bull trout.

We observed a mean juvenile bull trout density of 3.8 fish $\geq$75 mm/100 m^2. Densities ranged from 0.4 in Jim Creek to 11.8 in Morrison Creek (Table 21). Swan River tributaries supported juvenile bull trout at an average density of 2.7 fish $\geq$75 mm/100 m^2 while the North and Middle Forks averaged 4.6 fish/100 m^2. Eastern brook trout are present in the Swan River tributaries but not in the North and Middle Fork sections.

Information on juvenile bull trout densities and streambed conditions in winter rearing areas may show stronger relationships than we obtained using late summer electrofishing. It is possible that winter rearing habitat may control juvenile bull trout densities in our study streams. In general, these findings support the use of bull trout as an indicator species for future monitoring efforts.

Table 20. Comparison of total fish density number $\geq$75 mm/100 m_2 and juvenile bull trout density number $\geq$75 mm/100 m^2 calculated from electrofishing estimates at 28 sites around the Flathead Basin during 1989.

Stream	Area of Section	Total Fish Density # $\geq$75 mm/100 m^2	Juvenile Bull Trout # $\geq$75 mm/100 m^2
Elk	1605	3.0	2.8
Goat	930	6.6	3.6
Squeezer	960	9.9	2.5
Lion	1710	3.0	2.2
Piper	795	14.3	4.6
Jim	1155	2.1	0.4
Sheppard	795	15.6	
Hand	735	12.4	
Squaw tributary	345	5.2	
Fish	375	16.5	
Swift	1245	4.4	
Big	1695	5.0	4.9
Coal DH	1410	7.4	4.2
North Coal	900	10.6	5.1
South Coal	810	9.0	1.8
Red Meadow	1170	7.2	1.7
Whale	1545	2.4	2.1
Trail	915	5.5	5.2
Hungry Horse	810	14.3	
Tiger	555	41.4	
Margaret	465	25.6	
Emery	810	11.2	
Fitzsimmons	645	9.1	
Chepat	540	13.9	
Morrison	1095	11.8	11.8
Challenge	705	19.6	
Ole	810	5.5	4.9
Freeland	360	75.8	

CONCLUSIONS

1. Results indicated a direct linkage between ground-disturbing activity (Sequoia and H_2OY) and a measurable fisheries habitat parameter (percentage of material less than 6.35 mm) which is linked to embryo survival by westslope cutthroat and bull trout.

2. Findings also illustrated a direct linkage between ground-disturbing activity (Sequoia and H_2OY) and an index of fisheries habitat (substrate score) which is linked to juvenile bull trout rearing potential.

3. Spawning area gravel composition in the nine watersheds with no development averaged 31.7 percent material smaller than 6.35 mm. This size class comprised an average of 39.0 percent in the 17 watersheds where disturbed area exceeded one percent of the drainage. Forest management activities have had a quantifiable effect on streambed composition and fish populations in the Flathead Basin.

4. Monitoring streambed composition in known westslope cutthroat and bull trout spawning areas can provide fisheries information useful in making land management decisions. Once an initial sampling is complete, McNeil coring is an adequate tool for quantifying streambed particle size composition in spawning areas. We can detect changes in gravel composition.

5. Monitoring streambed substrate score in known bull trout rearing areas can provide fisheries information useful in making land management decisions. Substrate scores are not adequate indicators of rearing potential for fish species other than bull trout. Behavioral differences between the trout species present in our study area makes use of a single index impossible.

6. A significant relationship exists between substrate samples collected using modified Whitlock-Vibert boxes and McNeil core samples taken at the box planting sites. However, more work is required before the W-V box technique can replace McNeil coring in our streambed substrate monitoring program.

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