COAL CREEK FISHERIES MONITORING
STUDY NO. II

Final Report
July, 1984

By
Thomas M. Weaver
and
Robert G. White

Montana Cooperative Fishery Research Unit
Biology Department
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Under Contract No. 53-0385-3-2685
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EXECUTIVE SUMMARY

This report summarizes data collected on the fish resource in Coal Creek during 1983. Water levels and temperatures followed patterns similar to those reported for the 1982 study. Preliminary spring peak flows, recorded annually during the past 3 years, may cue bull trout fry emergence. The dampened temperature and water level fluctuations in the Dead Horse Bridge area are due to extensive intergravel flow/ground water recharge and may strongly influence bull trout spawning site selection and embryo survival.

Fish habitat surveys revealed most parameters evaluated remained relatively constant between 1982 and 1983. The differences in wetted width, depth, overhead and instream cover were probably related to the higher discharges during this years study. A 15% increase in imbeddedness was observed in HS2 between the summers of 1982 and 1983.

Organic debris frequencies showed that recruitment of larger materials was highest in HS2. Logged debris was still present in the two upstream sections; however, frequency of occurrence was lower than in 1982. Instream debris photography illustrated woody debris in the Dead Horse section was considerably more stable than in the riparian sale area.

Core sampling in known bull trout spawning areas of Coal, Big, Whale and Trail Creek revealed Coal Creek's spawning area still contained a singificantly higher percentage of material smaller than 2 mm than the other creeks. A slight difference in substrate composition was observed between the 1982 and 1983 sampling in Coal Creek. Increases in material smaller than 6.35 mm were noted between 1982 and 1983 in Big and Trail Creeks.

Fish abundance estimates showed juvenile bull trout were most abundant in the Dead Horse Bridge area. Cutthroat greater than or equal to 75 mm were also most abundant in the Dead Horse section. Densities of age one and older fish generally declined slightly in most streams sampled, between the 1982 and 1983 estimates.

Bull trout spawning site inventories in North and Middle Fork drainages located 600 redds in 1983, compared to 1129, 704, 574 and 292 in 1982, 1981, 1980 and 1979, respectively. Sixty-nine percent of the 1983 redds were observed in the North Fork Drainage and 31% were found in the Middle Fork.

Bull trout embryo survival and development in Coal Creek showed that that eye-up occurred after 35 days and 200 temperature units. Hatching began after 113 days and 350 temperture units, while fry emergence occurred 223 days and 634 temperature units after fertilization. Survival to emergence in Coal Creek was 53%. An inverse relationship between emergence success and the

percentage of streambed material smaller than 635 mm was observed. Entombment of alevins was documented.

Survival to emergence in experimental channel tests ranged from 0% in the 50:29 gravel mixture to the 48% in the 10:6 mixture. A significant difference in survival was found between replicates of each substrate mix as well as between mixes. These findings made it inappropriate to develop a survival/sediment model at this time.

ACKNOWLEDGEMENTS

We wish to thank the following individuals and organizations who made this study possible. Personnel of the Montana Department of Fish, Wildlife and Parks and their Research and Special Projects Division were a principal force in this effort. Brad Shepard and Pat Graham proposed the original study and Nick Hetrick played a valuable role in data collection. Discussions with the Special Projects Biologists often yielded valuable insight into survey techniques or design of apparatus used. Fisheries Manager Jim Vashro, along with the Region One fisheries staff provided the equipment and field help necessary. Gary Anderson, Mike Hensler, Dennis Schuster, Jeff Holland and Tim Swant assisted in data collection. Bob McFarland aided in the statistical analyses.

The United State Forest Service, Flathead National Forest funded the study under the direction of Paul Brouha, Regional Fisheries Biologist and Hank Dawson, Flathead National Forest Fisheries Biologist. Sonny Danielson provided use of the Flathead National Forest's Soils Lab whenever required. Dick Call and Bonner Armstrong, of Glacier View Ranger District, also assisted by providing much needed equipment and information.

Ron Spoon and Bill Schrader of the Montana Cooperative Fishery Research Unit assisted whenever their services were required. Bill was responsible for setting up the artificial incubation environment and helped monitor fry emergence. Gee King did the graphics and typed the drafts. Gisela Knupp typed the final manuscript.

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INTRODUCTION

In 1979, a study was initiated by the Montana Department of Fish, Wildlife and Parks (MDFWP) to collect baseline fish population and aquatic habitat information from major tributaries to the North and Middle Forks of the Flathead River. The Flathead River Basin Study was funded by the Environmental Protection Agency and annual reports identified "critical" spawning and rearing areas for the native populations of westslope cutthroat and bull trout (Graham et al. 1980, Fraley et al. 1981, Shepard et al. 1982). As part of the River Basin Study, a monitoring plan was designed and implemented to evaluate the effects of various land management activities on the fish resource of the upper Flathead Basin. During this monitoring effort, it was determined that Coal Creek, a tributary to the North Fork on Glacier View Ranger District, contained a significantly higher percentage of fine material in the streambed than other streams sampled. Coal Creek supported major bull trout spawning runs annually and contained areas critical for juvenile bull trout rearing. Migratory cutthroat trout were also documented in the Coal Creek drainage, along with resident cutthroat populations (Shepard et al. 1982). The effects of high levels of fine sediment on salmonid embryo survival are well documented and have been summarized by Cordone and Kelly (1971), Gibbons and Salo (1973) and Iwamoto et al. (1976).

Flathead National Forest (FNF), Glacier View Ranger District had scheduled a timber harvesting program in the Coal Creek Drainage to begin after 1981; however, in 1981 a spruce bark beetle infestation was identified in the upper drainage. Plans were changed in an attempt to control the infestation by salvaging beetle infested and high risk spruce from 600 acres in the riparian zone and then harvesting 11 million board-feet of primarily spruce, along both ridges of the upper drainage. Extensive road construction and reconstruction were required, creating the potential for further degradation of important spawning and rearing areas through increased sedimentation.

MDFWP and FNF met in the summer of 1981 to discuss a study to evaluate the present condition of the fish resource in Coal Creek. Funding became available, through the efforts of Regional Office, Supervisors Office and District personnel and a contract was begun by MDFWP for FNF in 1982. Initial findings were reported by Shepard and Graham (1983a).

In 1983, additional moneys were available from Forest Insect and Disease Control funds, allowing continuation of the study. The 1983 work was contracted to the Montana Cooperative Fisheries Research Unit at Montana State University.

The Coal Creek Fisheries Monitoring Study Number II was designed to collect additional comparable fish population and habitat data, to document the number of bull trout redds in known spawning areas on the District and to obtain information on bull trout embryo survival and fry emergence. The seven specific activities included under the contract were:

1. Assess aquatic habitat at three established sites in Coal Creek;

2. Document movement and recruitment of woody debris in two established sections of Coal Creek;

3. Determine substrate composition of known bull trout spawning areas in Coal, Big, Whale and Trail Creeks;

4. Document the number and location of bull trout redds in Coal, Big, Whale and Trail Creeks;

5. Complete fish abundance estimates by electrofishing at three established sites in Coal Creek;

6. Monitor embryo development and survival to emergence in Coal Creek and in a controlled incubation environment; and

7. Report results for the above work.

The following report summarizes data collected during the second year of the study and recommends future data needs in order to minimize the impacts of land management activities on the fish resource in the Coal Creek Drainage.

DESCRIPTION OF STUDY AREA

Coal Creek is a major tributary entering the North Fork of the Flathead River 38.9 km above the junction of the North and Middle Forks (Figure 1). Coal Creek drains an area of 211.5 km and is 31.2 km in length with an average channel gradient of 1.9 %. Major tributaries to Coal Creek include Cyclone, Dead Horse and the South Fork of Coal Creeks.

The parent material underlying the Coal Creek drainage is predominated by argillites and limestone. Quartzites and sandstone are also present. The material was classified by Martinson et al. (1982) as having a silty texture and moderately fast sediment transport capability. Valley walls adjacent to Coal Creek and its tributaries frequently have steep slopes, increasing erosion and sediment transport potential.

Land ownership in the Coal Creek Drainage is mixed between private holdings, which comprise approximately 11%, principally in the lower portion of the drainage, the Montana Department of State Lands controlling approxumately 19% in the mid portion and Flathead National Forest, which manages the remaining 70%, mostly in the upper basin and along the Wild and Scenic River corridor. Glacier View Ranger District is currently involved in acquiring fee title to 700 acres located south of Coal Creek, near the North Fork Road (210) crossing and scenic easements on 600 acres on the north side of the creek.

Between 1955 and 1982, an estimated 10.3 km^2 of state land have been clearcut and 1.2 km^2 have been partially cut. In 1983, approximately 5 million board-feet of timber was removed during the Coal Ridge Sale and a similar harvest is scheduled for 1984.

As of 1982, approximately 153 km of road existed on Forest Service land and 43.4 km existed on State land. Approximately 17 of the 19 km of new road planned during the Coal Ridge Sale had been completed as of May. 1984.

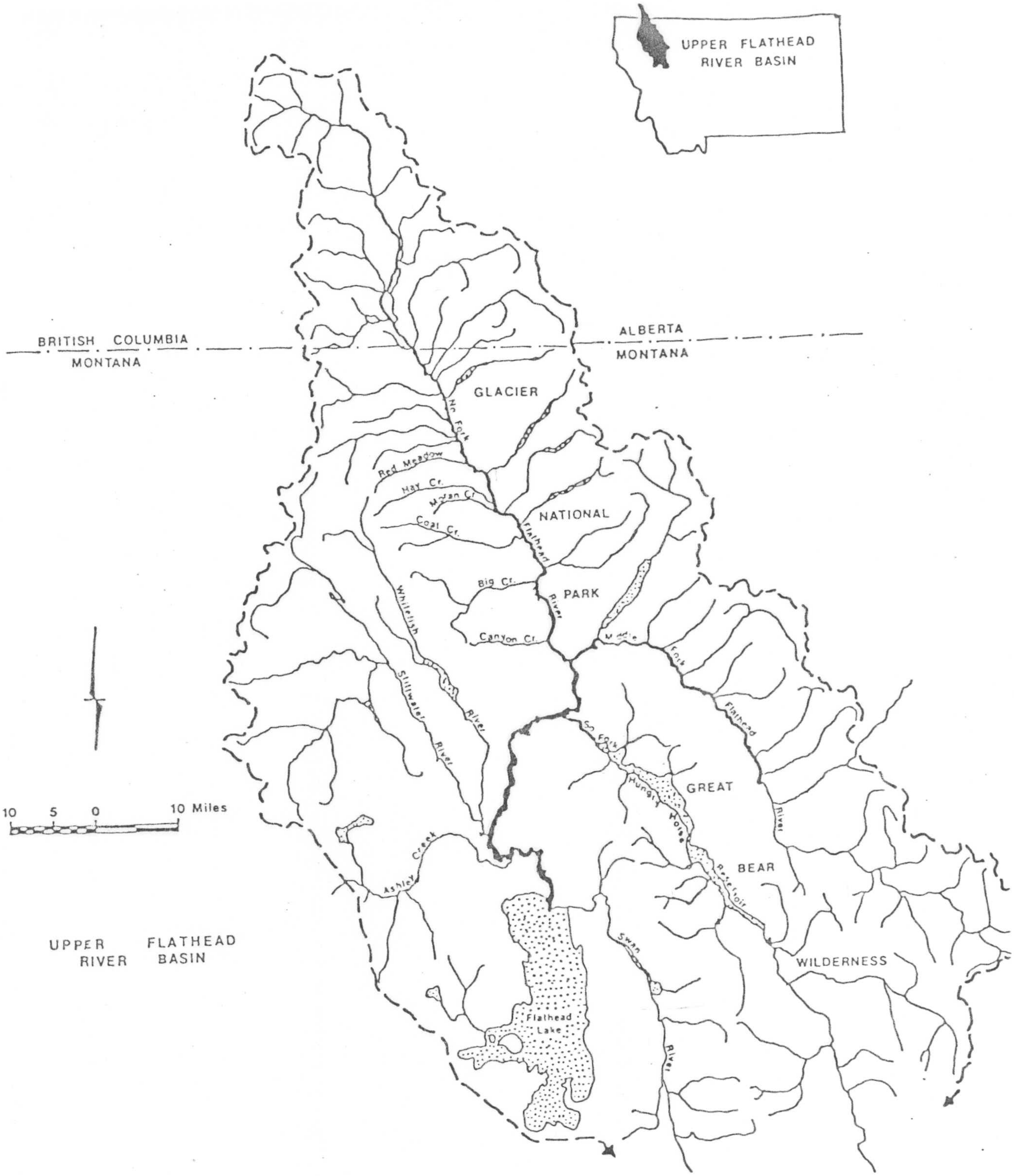

Figure 1. Map of the Upper Flathead Basin. Adapted from Montana Department of Natural Resources and Conservation (1977).

METHODS

HABITAT ASSESSMENT

Streamflow

Coal Creek's water levels were monitored throughout the study period at the following bridge crossings:

1. Coal Creek Road - 317 (SE¼, NW¼, SE¼, Section 36, Township 34 North, Range 21 West);
2. Dead Horse Road - 1693 (NW ¼, SE ¼, SW ¼, Section 28, Township 34 North, Range 21 West); and
3. South Fork Coal Creek Road - 317 (SE¼, NE¼, SW ¼, Section 24, Township 34, North, Range 22 West) (Figure 2).

Standard stage gages were installed on bridge abutments at each site and referenced to permanent benchmarks by MDFWP (Shepard and Graham 1983a). Water levels reported were standardized as gage height in feet. Water levels in eight other westside tributaries to the North Fork were monitored monthlty, at or near the North Fork Road (210) crossing. Natural fluctuations within and between drainages were compared to existing records.

At each bridge, point measurements of discharge and corresponding stage were made of a series of flows. These data were used to develop stage-discharge relationships. Flow measurements were also made in conjunction with major activities to document discharge during surveys. These point measurements were made with a Marsh Mcbirney current meter and topsetting rod, following procedures described in Hewlett and Nutter (1969).

Water Temperature

Continuously recording thermographs were placed near each of the three bridges listed and maintained weekly. Daily minimum and maximum temperatures were interpreted from charts. Operation of the unit at Cyclone Bridge began on 10 June 1983. The Dead Horse and South Fork Bridge thermographs were installed during early July. On 15 December, the units at Cyclone and the South Fork Bridges were removed. The Dead Horse thermograph was maintained throughout the winter to provide an approximate temperature record in the spawning area.

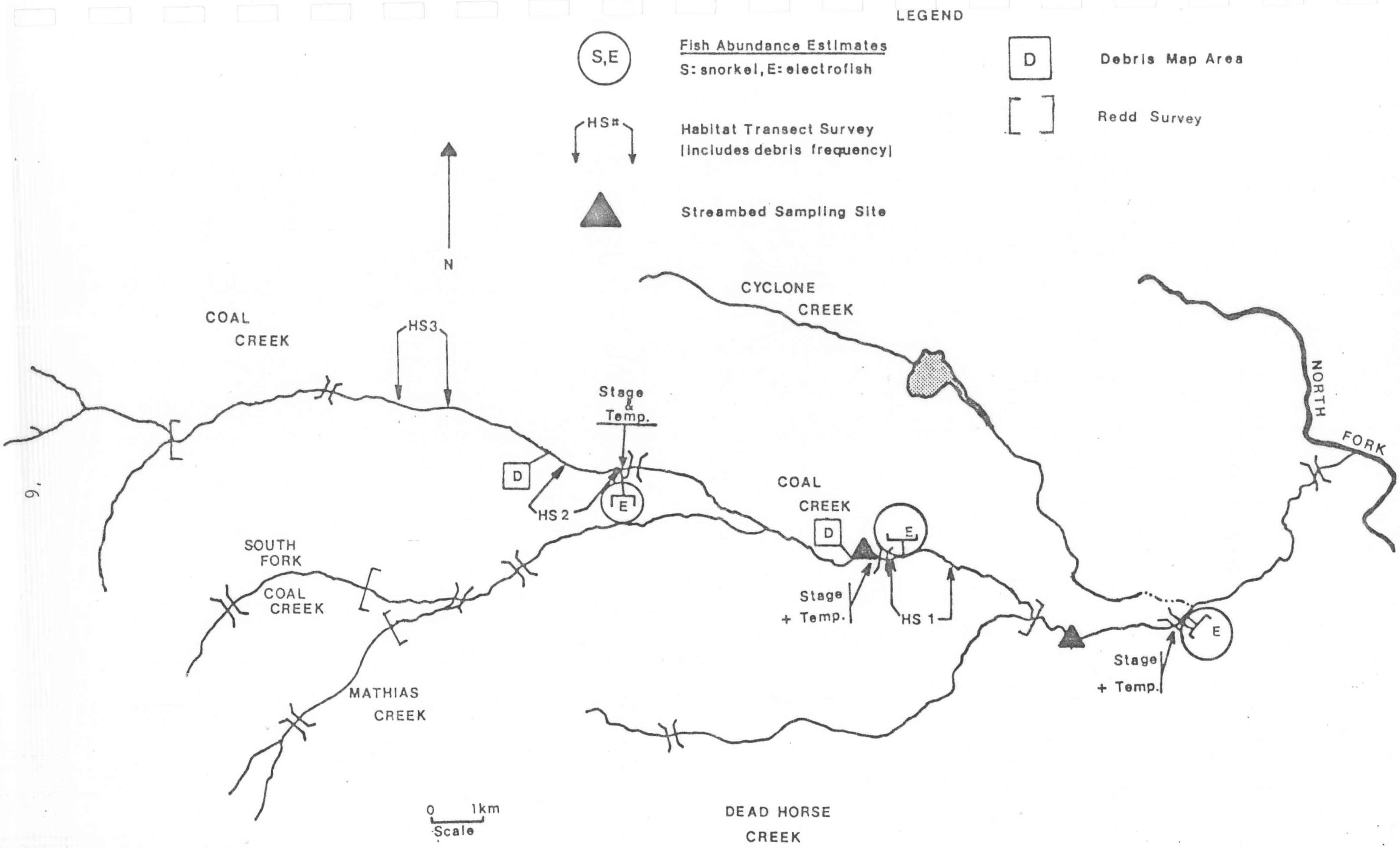

Figure 2. Drainage map of the Coal Creek drainage showing physical and biological sampling sites.

Line Transects

Aquatic habitat was evaluated using a line transect methodology similar to that described by Herrington and Dunham (1967) and used in previous surveys of Coal Creek (Shepard and Graham 1983a). Transects were located at 25 randomly selected sites per kilometer in the three established sections, located:

1. approximately 0.5 km below Dead Horse Bridge (HS1);

2. approximately 0.3 km above South Fork Bridge (HS2);

   and

3. above the Coal Ridge Lookout trailhead (HS3)

   (Figure 2).

Point estimates of the following parameters were made at 1 m intervals across each transect:

1. instream cover;

2. overhead cover; and

3. two predominant substrate size classes (Table 1).

For comparison with transect data, visual estimates of overall substrate composition, compaction, imbeddedness and D-90 were made along with visual estimates of total instream and overhead cover on each transect. Depth was recorded at each point and the maximum depth on the transect was noted. Wetted width and channel width were also measured across each transect. Terminology used during the habitat assessment process was defined by MDFWP (1983).

Line transect data were entered into files on the ICIS 850 computer located at the MDFWP Regional Headquarters in Kalispell, Montana. Computer programs developed by MDFWP were used for data entry and summarization by survey section. Summarized habitat data were compared to information previously collected.

Debris Frequency

All channel debris encountered in each 1 km habitat survey section was identified and recorded by type, size class and age class (Table 2). Approximate locations were obtained by counting paces throughout each section. The frequency of occurrence for debris classes was compared by section with existing information.

Table 1. Substrate size class, instream cover and bank cover criteria.

Substrate size class	
1. Particulate organic matter-silt or detritus	
2. Less than 2.0 mm in diameter - sand	
3. 2.0 to 6.4 mm in diameter - pea gravel	
4. 6.4 to 64.0 mm in diameter - pebble	
5. 64.0 to 254.0 mm in diameter - cobble	
6. Larger than 254.0 mm in diameter - boulder, bedrock	
Instream cover codes	
0. None	
1. Aquatic vegetation	
2. Logs	Below water surface
3. Debris	Below water surface
4. Boulders	Below water surface
5. Logs	Above water surface
6. Debris	Above water surface
7. Boulders	Above water surface
8. Man made structure	
Bank cover codes	
0. None	
1. Undercut bank, log or root mass	
2. Overhang <2 m above water surface	
3. Overhang from 2 m up to canopy overstory	
4. Overstory canopy	

Table 2. Criteria used to classify organic debris by size and age in Coal Creek.

Size	Diameter
Large	> 305 mm (>12 inch)
Medium	152-305 mm (6 to 12 inch)
Small	52-151 mm (2 to 6 inch)
Branches	<52 mm (<2 inch)
Jams	Accumulation of Debris
<u>Age</u>	
Old	Past years
New	This years (natural)
Logged	This year (cut)

INSTREAM DEBRIS MONITORING

MDFWP mapped the presence and location of woody debris in two sections of Coal Creek in 1982 (Shepard and Graham 1983a). One section was located within the riparian cut area, approximately 2 km above the South Fork Road Bridge. The other section was located downstream 0.5 km above Dead Horse Road Bridge.

During late July, semipermanent photopoints were established and the channel area in each section was photodocumented. Landmarks (ie., mature trees, boulders) identifying transects were marked with red paint. A tape was stretched from these numbered landmarks at approximately a 90 angle to the channel. The photographers location on this transsect was selected for maximum effectiveness and the distance from the landmark and compass heading of the lense were recorded (Table 3). An Olympus OM-1 with a Zuiko 50 mm lense and Kodak 100 ASA color print film were used.

To further monitor debris recruitment and movement, the sections were divided into five equal segments and debris in each segment was marked with a different colored paint. All debris in the 100 m immediately above each section was marked with a sixth color. Debris locations and channel configuration were compared to 1982 records.

SUBSTRATE COMPOSITION

Twenty substrate samples were collected from Coal Creek's bull trout spawning area. A standard 15.2 cm hollow core sampler (McNeil and Ahnell 1964) was used, following methods developed for Glacier View Ranger District by MDFWP (Shepard and Graham 1982). Coring sites were located across the five transects sampled during previous studies (Shepard and Graham 1982, Shepard and Graham 1983a (Appendix A).

Samples were placed in labeled bags and transported to the Flathead National Forest Soils Lab in Kalispell. After drying, each core sample was analyzed using the following sieve series:

76.10 mm (3.00 inch)

50.80 mm (2.00 inch)

16.00 mm (0.62 inch)

6.35 mm (0.75 inch)

2.00 mm (0.08 inch)

0.063 mm (0.002 inch)

pan

Table 3. Location of debris monitoring photopoints, Coal Creek, 1983.

Section	Date	Discharge (cfs)	Station Number	Distance Above Lower Rebar 1/	Photo Number	Landmark type	Distance From Landmark 2/ (M)	Compass Heading
			1	19.4 3/	1	Stump	3.5	275°
			2	43.2	2	Tree	0.0	110°
			3	65.9	3	Tree	1.0	315°
			--	--	4	--	11.0	110°
			--	--	5	--	11.0	80°
Dead Horse	7-28-83	82.6	4	65.9	6	Tree	1.0	220°
			5	85.2	7	Tree	11.0	35°
			--	--	8	--	11.0	190°
			6	106.3	9	Rebar		
			--	--	10	--	5.0	335°
			1	12.0	1	Tree	2.0	310°
			2	34.1	2	Tree	4.0	110°
			--	--	3	--	4.0	280°
Riparian Cut	7-30-83	35.8	3	96.6	4	Tree	3.0	245°
			--	--	5	--	6.0	90°
			4	113.8	6	Rock	0.0	100°
			5	133.8	8	Rock	2.5	85°

[1] All measurements above the lower rebar were made along the shortest route.

[2] These measurements were made from the landmark of a 90° angle to the channel.

[3] These measurements are distance below the lower rebar.

All material retained on each sieve was weighed and the percent dry weight in each size class was calculated and compared to existing records.

To compare the substrate composition of Coal Creek with other westside tributaries, core samples were also collected from bull trout spawning areas in Big, Whale and Trail Creeks. Twelve samples were taken from established transects in both Whale and Trail Creeks (Shepard and Graham 1983a). A single coring site in Whale Creek required relocation due to excessive depth and velocity. One site in Trail Creek was also relocated, allowing a natural redd to be sampled.

Channel changes in the Big Creek sampling area forced the relocation of two transects and adjustment of the coring sites on the third transect. The location of all substrate sampling areas are mapped in Appendix A.

A Kruskal-Wallis test was run to deterime if substrate composition differed between the creeks sampled (Lund 1979). Percentages of material less than 2 mm in cores from undisturbed streambed in the four creeks were compared between creeks, using a Mann-Whitney multiple comparison test.

BULL TROUT SPAWNING SITE SURVEYS

Bull trout spawning activity was closely monitored in the Coal Creek drainage. Preliminary surveys were conducted frequently from mid-August through early October. Final redd counts began on 10 October 1983. Redds were identified and pace located while walking along the stream channel. Areas surveyed were identical to those inventoried during the 1982 study, excluding the section below the mouth of Dead Horse Creek.

To compare Coal Creek's spawning run with runs in other tributaries, weekly preliminary surveys and final redd counts were conducted in the Big, Whale and Trail Creek drainages. Areas surveyed were those recommended for monitoring by MDFWP (Shepard and Graham 1983a). The lower 6.30 km of Hallowatt Creek and 4.00 km of Shorty Creek were also surveyed.

FISH ABUNDANCE

During late summer, fish abundance estimates were completed in the three 150 m sections established by MDFWP (Shepard and Graham 1983a). The sections were blocked off at each end with 12.7 mm wire mesh, anchored to the streambed by metal fence posts. Fish were captured using a bank electrofishing unit.

Total length and weight of all trout and whitefish captured was recorded and sculpins were counted. Trout between 75 and 100 mm were marked with a fin clip and those larger than 100 m were given a numbered tag.

Two-catch population estimates (Seber and LeCren 1967) were computed for the Cyclone Bridge and South Fork Bridge sections. Both two-catch and mark-recapture estimates (Vincent 1971) were made in the section below Dead Horse Bridge. Estimates, including 95% confidence intervals, were computed for cutthroat and bull trout 75 mm and longer. Smaller fish were able to escape through the block fences making estimation impossible. Estimates and densities were compared to existing information.

EMBRYO SURVIVAL AND FRY EMERGENCE

Field Study

Embryo survival work in Coal Creek began in early September with the construction of eight artificial redds. A run, located 0.3 km above Dead Horse Bridge, having approximately the mean depth and velocity reported for bull trout redds in the Flathead Drainage by Fraley et al. (1981) was selected. Construction involved digging depressions in the streambed with a Pulaski and shovel and mounding the disturbed material immediately downstream. The mounds, or tailspin areas of completed redds were approximately 2 m in length. Artificial redd arrangement within the stream channel is illustrated in Figure 3. Subsequent to construction, a core sample was removed from the tailspin area of each artificial redd, using a hollow core sampler (McNeil and Ahnell 1964). After core sampling was completed, four egg planting sites were prepared in each of the upstream artificial redds. Each site consisted of a closed bottomed, wire screen cylinder approximately 15.2 cm in height and 15.2 cm in diameter burried in the tailspin. The gravel displaced was carefully filled in a round the cylinder so when positioned, the top of the wire screen was even with the tailspin surface, forming holes for egg bag planting (Figure 4).

Adult bull trout were captured above Dead Horse Bridge on 12 September 1983 at approximately 0100 h. A lantern was used to locate the spawners which were easily captured with a dip net The fish were held in covered live cars until morning. At approximately 1000 h, one male and one female were anesthetized. Eggs were taken dry, then fertilized in a stainless steel bowl. The fish were released after a short recovery period.

The gametes were mixed thoroughly and allowed to sit for several minutes. The eggs were then washed several times with creek water and transferred to a water cooler containing creek water. The cooler was covered and left immobile for 1 hr, allowing eggs to water harden.

One hundred eggs were placed in each of 32 fiberglass screen bags, along with enough stream gravel to fill the bags. Egg bags had dimensions of 15.2 x 7.6 cm. A strip of blue flagging was attached to each bag to facilitate relocation. Half of the bags were stapled closed, to prevent escape of fry after hatching. Four sealed bags were planted approximately 15 cm deep in each of

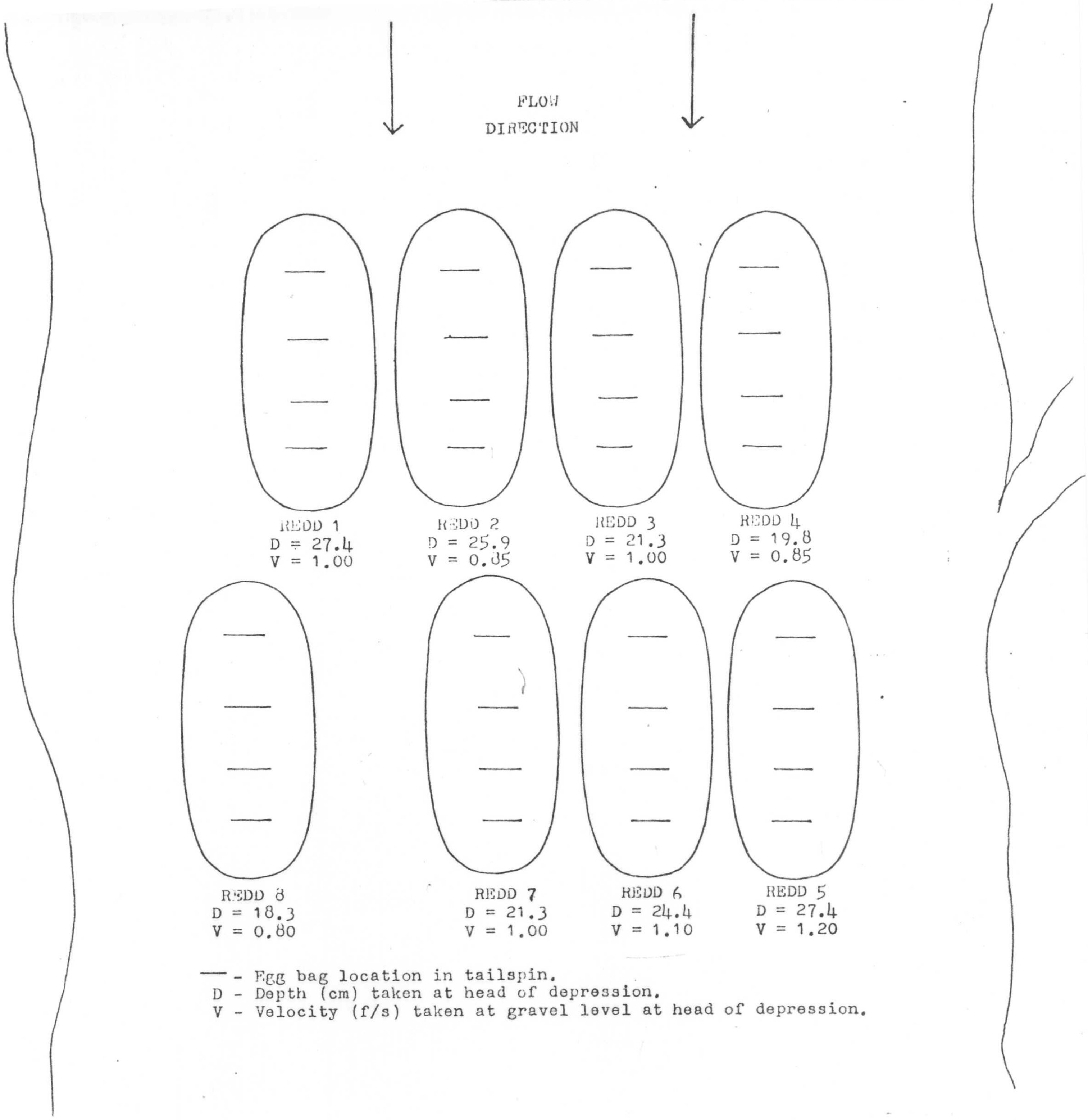

Figure 3. Diagram of artificial redd arrangement and numbering, including point measurements of depth and velocity.

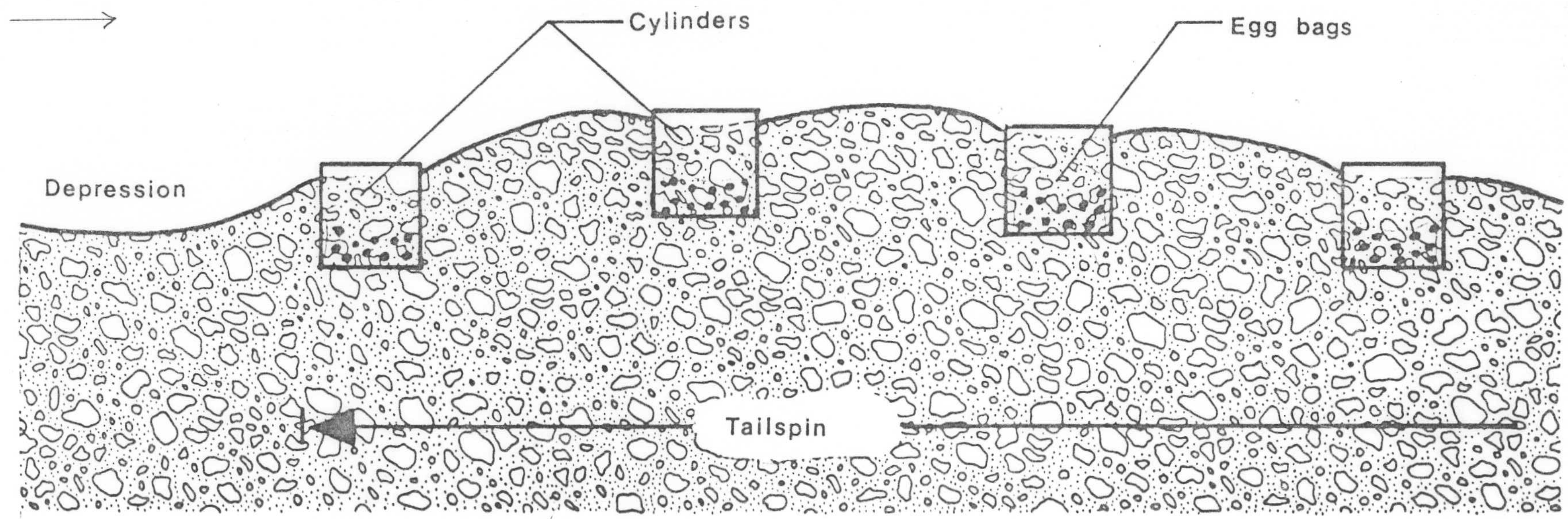

Figure 4. Cross-section of an artificial redd showing wire mesh cylinders and egg bags in place prior to burial.

the downstream redds. The remaining egg bags were left open and planted in the previously prepared sites in the upstream redds. Care was taken to make sure the top of each open bag remainded uppright as the screen cylinders were filled with gravel. After egg planting was complete, additional gravel was added on each tailspin and they were covered with 12.7 mm wire mesh, to prevent natural spawning from disturbing the area. The wire mesh was removed when natural spawning subsided.

One egg bag was excavated from each of the downstream redds on four separate dates, to document embryo survival and development. During these samplings, each egg bag was carefully opened and emptied into a white lab tray containing water. Live and dead embryos were enumerated and preserved in a 10% formalin solution. A subsample of the sac-fry in each bag was randomly selected and each fry measured to the nearest millimeter total length. Embryo survival was expressed as percent survival for each sampling time throughout the experiment.

The upstream redds were left undisturbed until late February, when emergence traps were placed over all egg bags. Trap design was similar to that described by Phillips and Koski (1969) and had been used in the Flathead Drainage by MDFWP (Fraley and McMullin 1983). Trap frames measured 30.5 cm square and were covered with 1.6 mm mesh nylon netting. The sample socks were approximately 0.5 m in length and were closed with an overhand knot near the end (Figure 5).

During trap placement, enough gravel was removed from the tail-spins to expose the tops of the wire screen cylinders. This allowed traps to be located effectively. Once in position, the flaps of netting extending pasts the iron frame were tucked down into the gravel, sealing the traps. Traps were generally checked and cleaned twice weekly throughout March and three times weekly in April, until emergence began.

When emergence was first observed, the knots in the samplers were untied and replaced with locking nylon tie straps. Sampling involved cutting the nylon tie with a small pair of snips and placing the opened sampler entirely inside a slightly larger elongated dip net. The dip net was also 1.6 mm mesh and had a 30.5 cm long, 5.1 cm square wooden handle. This allowed the net to be held in position with a knee, freeing both hands to close the sampler when finished. A subsample of the fry removed from the traps during the first 2 days of emergence was measured to the nearest millimeter total length and preserved in a 10% formalin solution. All other emergent fry were counted and released.

When emergence ended, the traps were removed and egg bags excavated. During egg bag removal, a sein was positioned immediately downstream from each site to catch any dead eggs or alevins dislodged. Contents of each egg bag was emptied into a white lab tray where alevins or dead eggs present were enumerated and recorded. All alevins present in the egg bags at the time of excavation were measured and preserved.

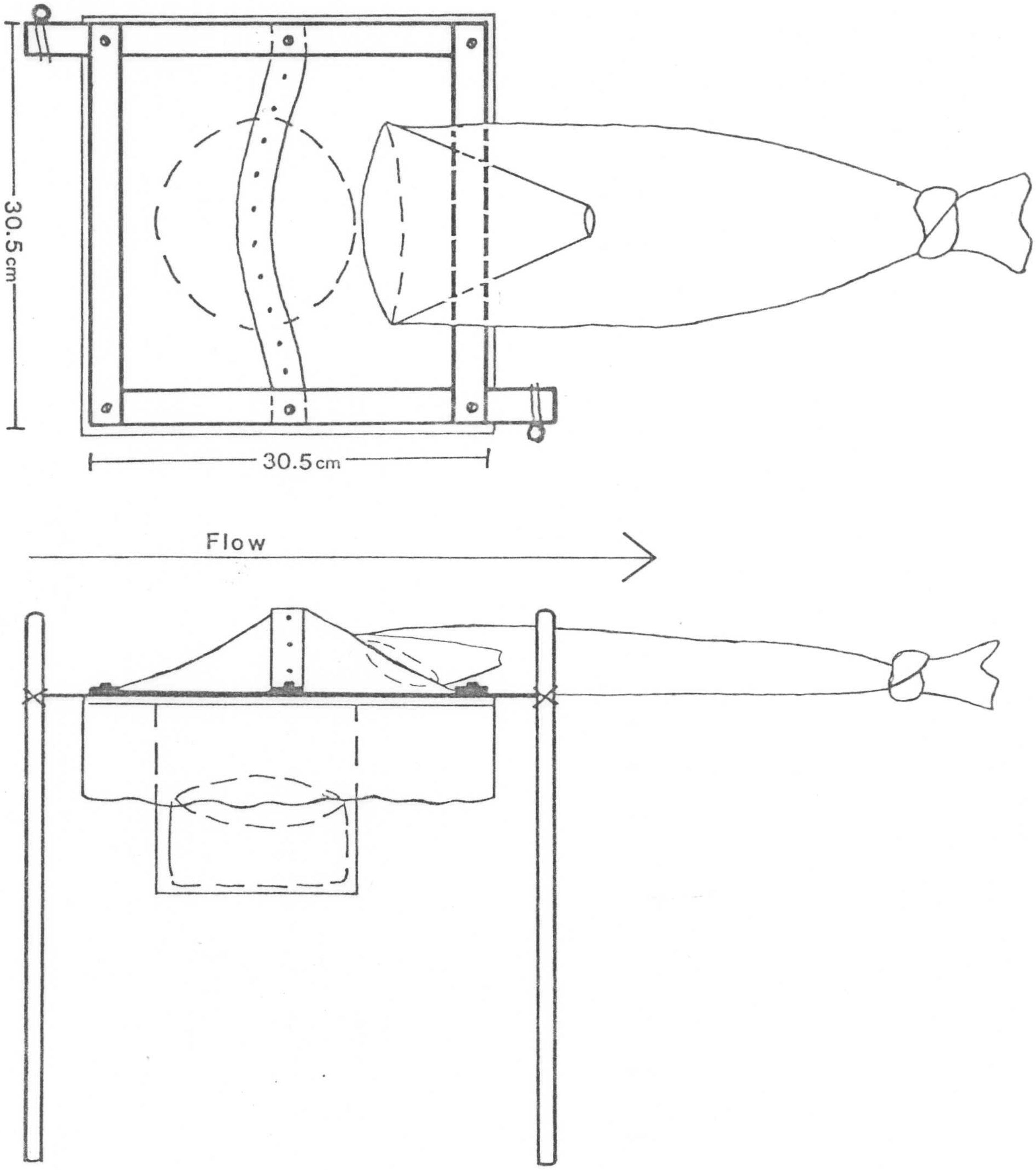

Figure 5. Diagram of fry trap showing a top view and a cross sectional view of a positioned trap.

Hollow core samples (McNeil and Ahnell 1964) were collected from each site subsequent to egg bag removal. The relationship between the percentage of material smaller than 6.35 mm and successful fry emergence was examined. Fry emergence success was expressed as percent of viable embryos which successfully emerged. The number of viable embryos was considered equal to the percent survival in the first series of closed bags excavated.

Experimental Channels

During late summer, 1983 an artificial incubation environment was set up at the Bozeman Fish Cultural Development Center, where testing was conducted to assess bull trout embryo survival to emergence, in six different gravel mixtures. Approximately 2,500 kg of streambed material was dried and sorted into size groups by sieving. Gravels were then recombined by weight to provide experimental mixtures which were similar in overall size distribution to natural spawning gravels (Tappel 1981, Shepard and Graham 1982) (Table 4).

Each experimental gravel mixture was designated by the percentage of material smaller than 9.50 mm and the percentage smaller than 2.00 mm. As an example, in the mixture 10:6, 10% of the material was smaller than 9.50 mm and 6% was less than 2.00 mm.

Three 1.2 m wide by 2.4 m long channels were each subdivided into eight 1.2 m long by 0.3 m wide by 0.3 m deep chambers, providing space for four replicates of the six gravel mixtures. Gravel mixtures were randomly assigned to the incubation chambers. Water flow and gradient through each chamber was regulated by a valve at the inlet.

Four aluminum cylinders were placed in each chamber and gravel was carefully filled in around them to a depth of approximately 15.2 cm. The cylinders were left in place forming sites for egg planting (Figure 6).

Adult bull trout were captured above Dead Horse Bridge on 20 September 1983. Capture and spawning procedures were identical to those described previously. Fish spawned were retained along with a sample of both male and female gametes for disease testing. After water hardening, these eggs were placed on two trays in a shipping container packed with creek water ice, trucked to Kalispell, and flown to Gallatin Field, Bozeman, Mt.

Upon arrival at the Development Center, 50 eggs were placed in each of 92 fiberglass screen bags containing the gravel mixtures being tested. One open topped bag was placed upright inside each cylinder and covered with the gravel mixture. When all four cylinders in each chamber were full, the cylinders were pulled out and the inlet valve was opened, flooding the chamber. Water level was kept just below the gravel surface to maintain a constant gradient of 2%. Water temperature was monitored continuosly by a recording thermograph.

Table 4. Size composition of gravel mixtures used in controlled channel incubation test.

Gravel Mixture Designation	Percentage of mixture smaller than given particle size (mm).					
	50.8	25.4	12.7	9.50	6.35	2.00
0:0	100	73.4	4.2	0	0	0
10:6	100	76.3	13.8	10.0	9.9	5.9
20:12	100	79.0	23.4	20.0	19.8	11.7
30:18	100	81.6	32.9	30.0	29.6	17.6
40:23	100	84.2	42.5	40.0	39.5	23.4
50:29	100	86.8	52.1	50.0	49.4	29.3

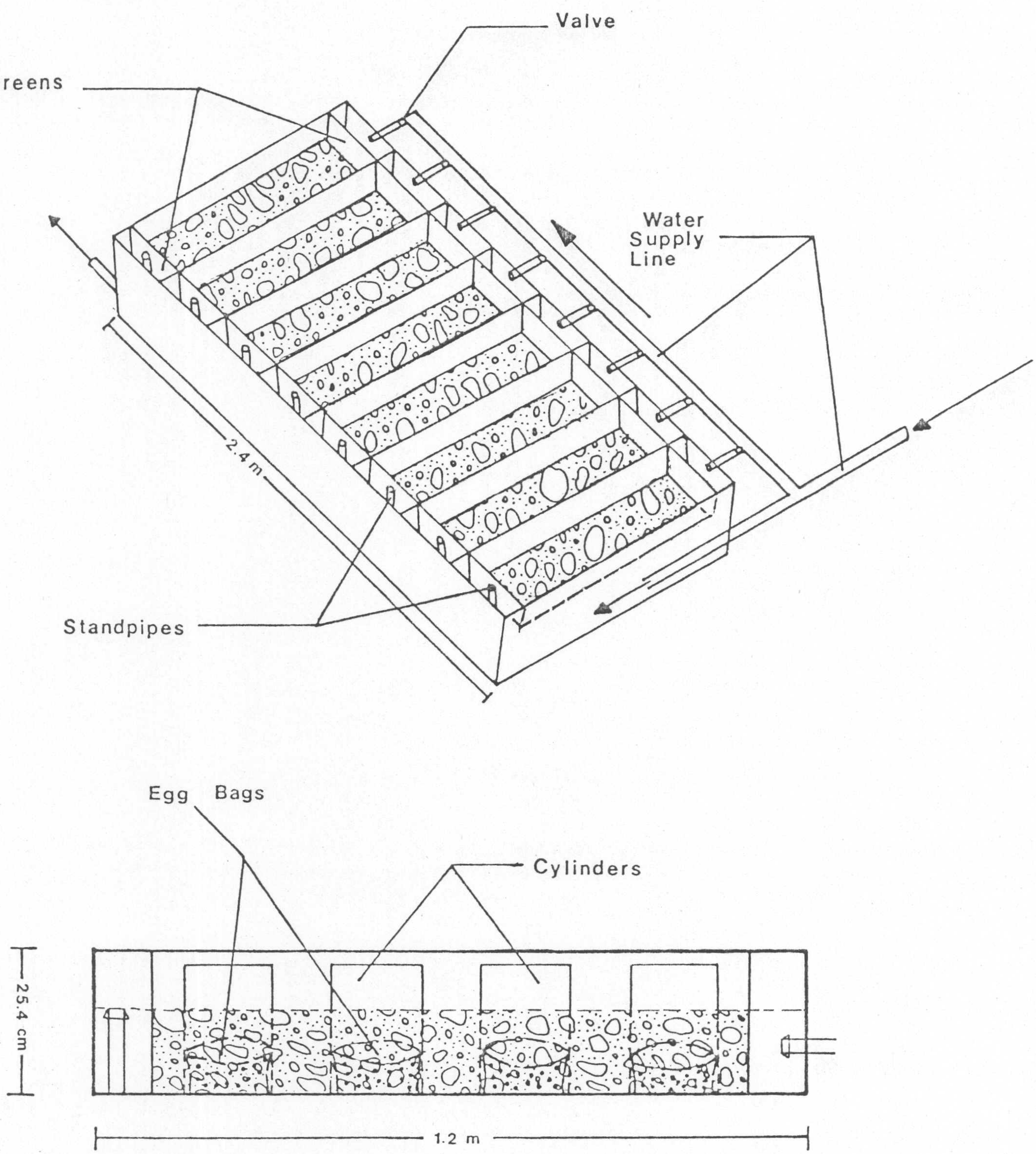

Figure 6. Diagram of incubation chambers showing egg planting sites.

Eggs from the first tray were used in the chambers containing the 50:29, 40:23, 30:18 and 20:12 gravel mixtures. The 10:6 and 0:0 mixtures were stocked with eggs from the second tray. Excess eggs on each tray were placed in separate compartments of a Heath stack incubator.

When the first emergent fry were observed, flows were increased to levels above the gravel surface. Fry in each chamber were captured, enumerated and preserved in 10% neutral buffered formalin. A subsample of the captured fry were weighed and measured.

When emergence was complete, the egg bags were removed and the number of dead eggs in each was determined. The percentage of embryos in the Heath stack incubator from egg tray number one surviving to the eyed stage, determined the number of viable embryos in the four gravel mixtures planted with eggs from this tray. Similarly, the percent survival to the eyed stage from tray number two was applied to the two mixtures stocked with these eggs. Emergence success was expressed as percent of viable embryos which successfully emerged during the test.

The Chi-square index was calculated to test the null hypothesis that the number of successfully emerging fry was not different between the six gravel mixtures. A one way analysis of variance was also calculated comparing successful emergence between gravel mixtures.

RESULTS AND DISCUSSIONS

HABITAT

Streamflows

During 1983, Coal Creek's water levels followed patterns similar to those reported in 1982 (Shepard and Graham 1983a) (Figures 7, 8 and 9). Flows began rising in early April, peaking on about April 25, then declining during the last week of the month. By early May , water levels were again rising, reaching the annual peak on about 31 May 1983. Peak flow in Big Creek at the Big Creek Work Center occurred on 27 May (files, USGS, Kalispell, Montana). Low autumn flows were recorded during late September and early October, coinciding with the bull trout spawning period. In late October, water levels at all three sites increased, reaching an autumn peak on 11 November. By late February 1984, flows had dropped to slightly below the lowest levels during the previous autumn.

A mid-April peak was again observed in 1984. At Dead Horse Bridge, a gage reading of 1.67 feet (approximatelay 250 cfs) was recorded on 19 April. Wading was difficult and bed movement was observed at this level. By 27 April the gage height had dropped to 1.07 feet (approximately 115 cfs). During this decline, most of our fry emerged from the artificial redds. A preliminary peak has been documented annually since 1982; prior to this no records are available from this area. Preliminary spring peaks may influence fry emergence by providing an environmental cue for fry activity.

The stage gage on the South Fork Road Bridge was burried under ice and snow from late November 1983 through March 1984 and readings are not available for this period. Seasonal water level fluctuations in other westside tributaries to the North Fork from 1979 through 1983 are presented in Appendix B.

Stage-discharge relationships developed for each site by MDFWP in 1982 were expanded to include data collected during this study (Figure 10).

Water Temperatures

Mean weekly minimum and maximum water temperatures during 1983 also followed trends similar to those reported for 1982 (Shepard and Graham 1983a) (Figures 11, 12 and 13). The difference between mean weekly minimum and maximumtemperature was much greater at Cyclone Bridge than at the other two sites and daily fluctuations were also more pronounced. Water temperatures peaked on 6 August 1983 at all three sites with Cyclone reaching 14.5^{o} C and the Dead Horse and South Fork reaching 12.6 and 12.9^{o} C respectively. The daily maximum temperature dropped below 9^{o} C during the first week of September and approached 0^{o} C the first week in December. Temperature at Cyclone and the South Fork Road Bridges was a constant 0 for over 15 days prior to

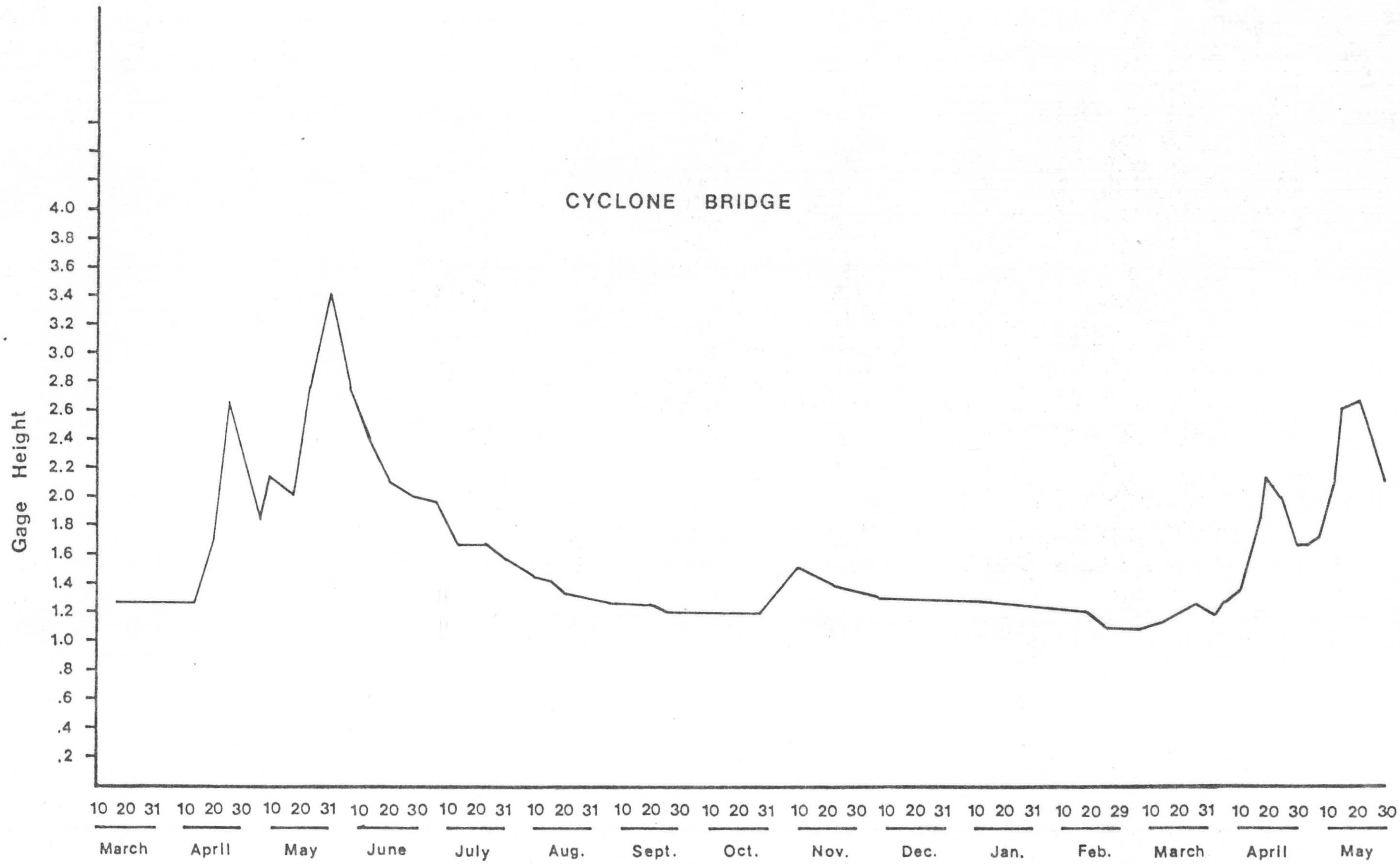

Figure 7. Gage height (in feet) of Coal Creek at the downstream bridge on Coal Creek Road (317) from 16 March]983 to 28 May, 1984.

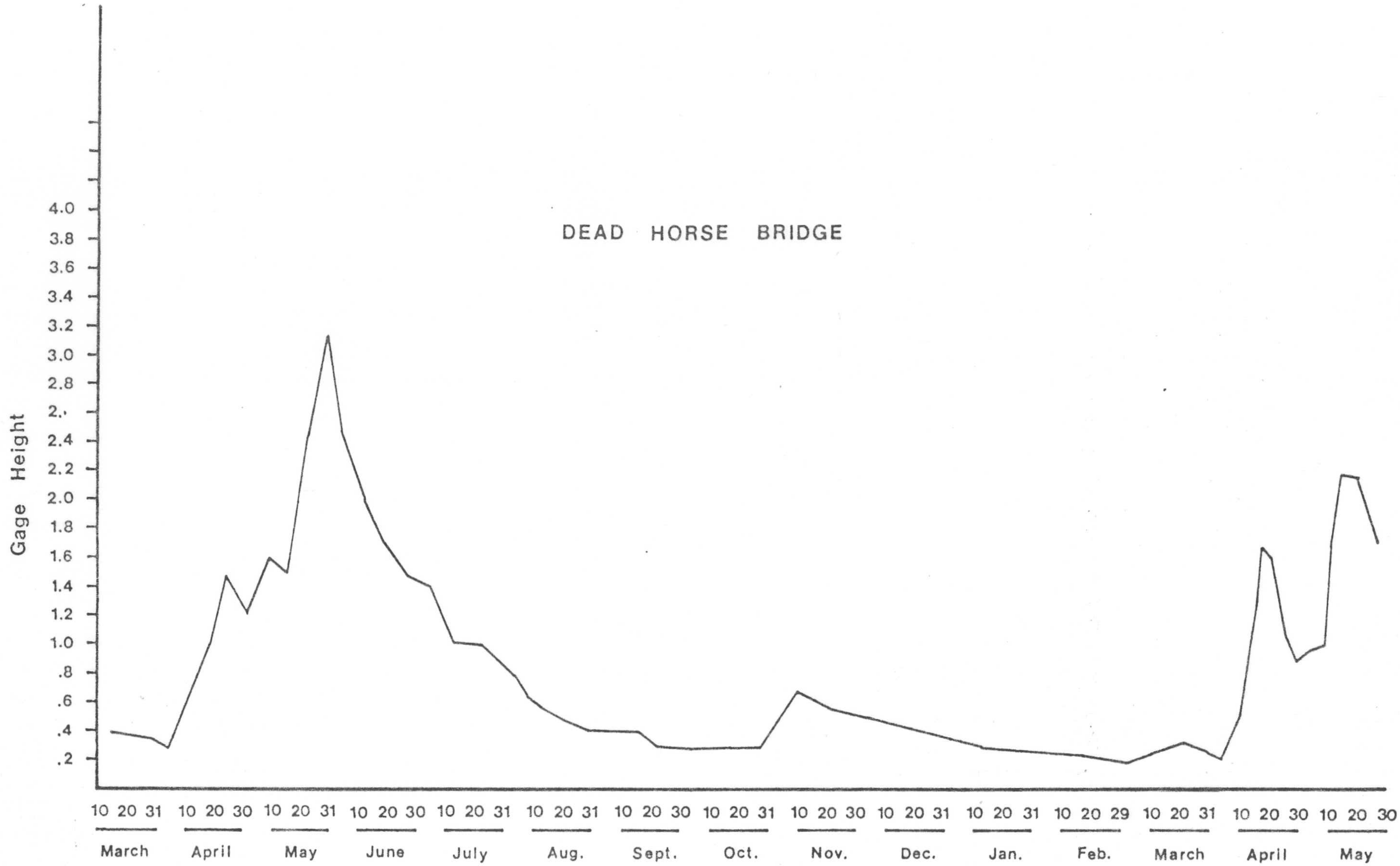

Figure 8. Gage height (in feet) of Coal Creek at the Dead Horse Creek Road Bridge (1693) from 16 March 1983 to 28 May, 1984.

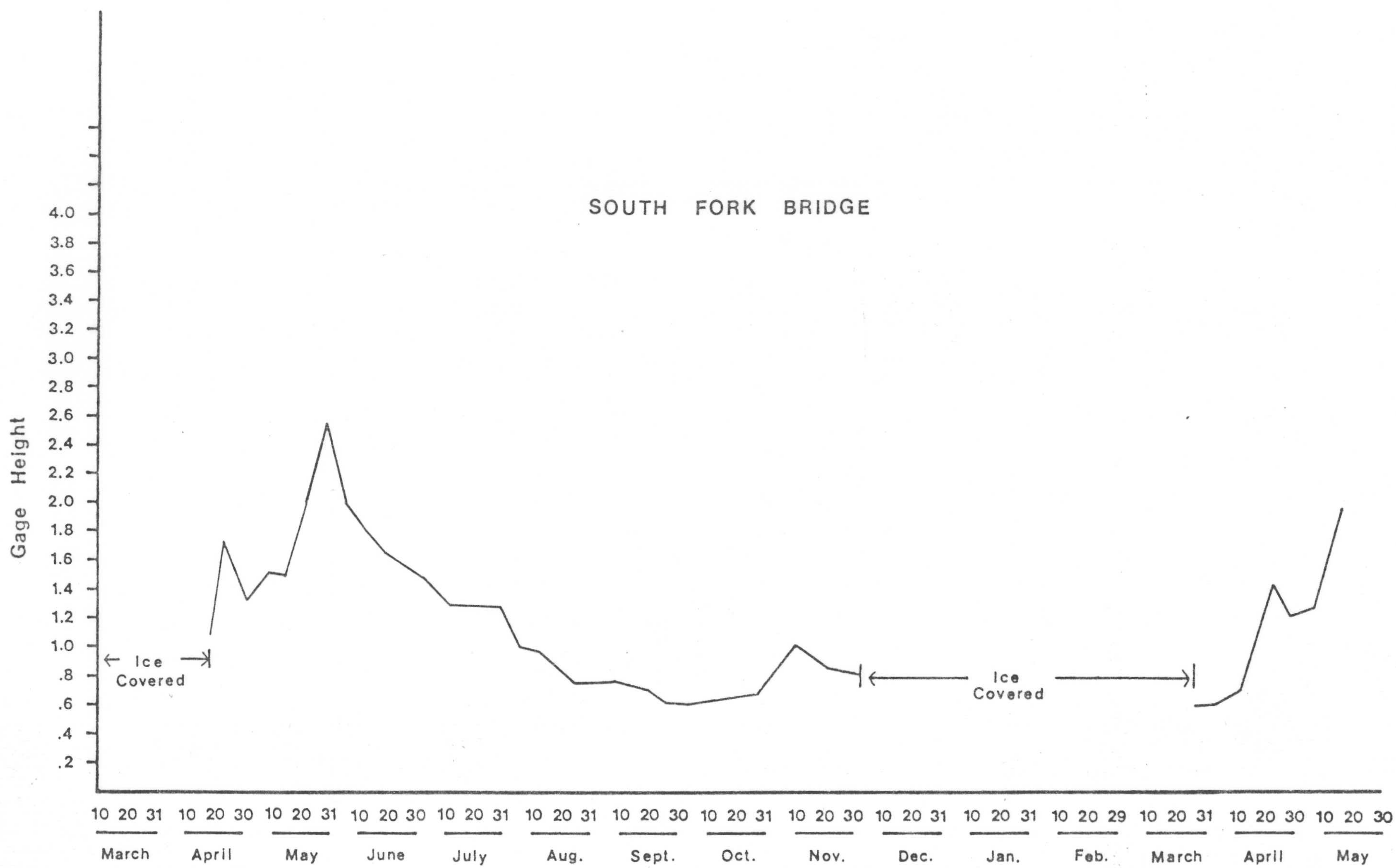

Figure 9. Gage height (in feet) of Coal Creek at the South Fork of Coal Creek Road Bridge (317) from 16 March 1983 to 28 May, 1984.

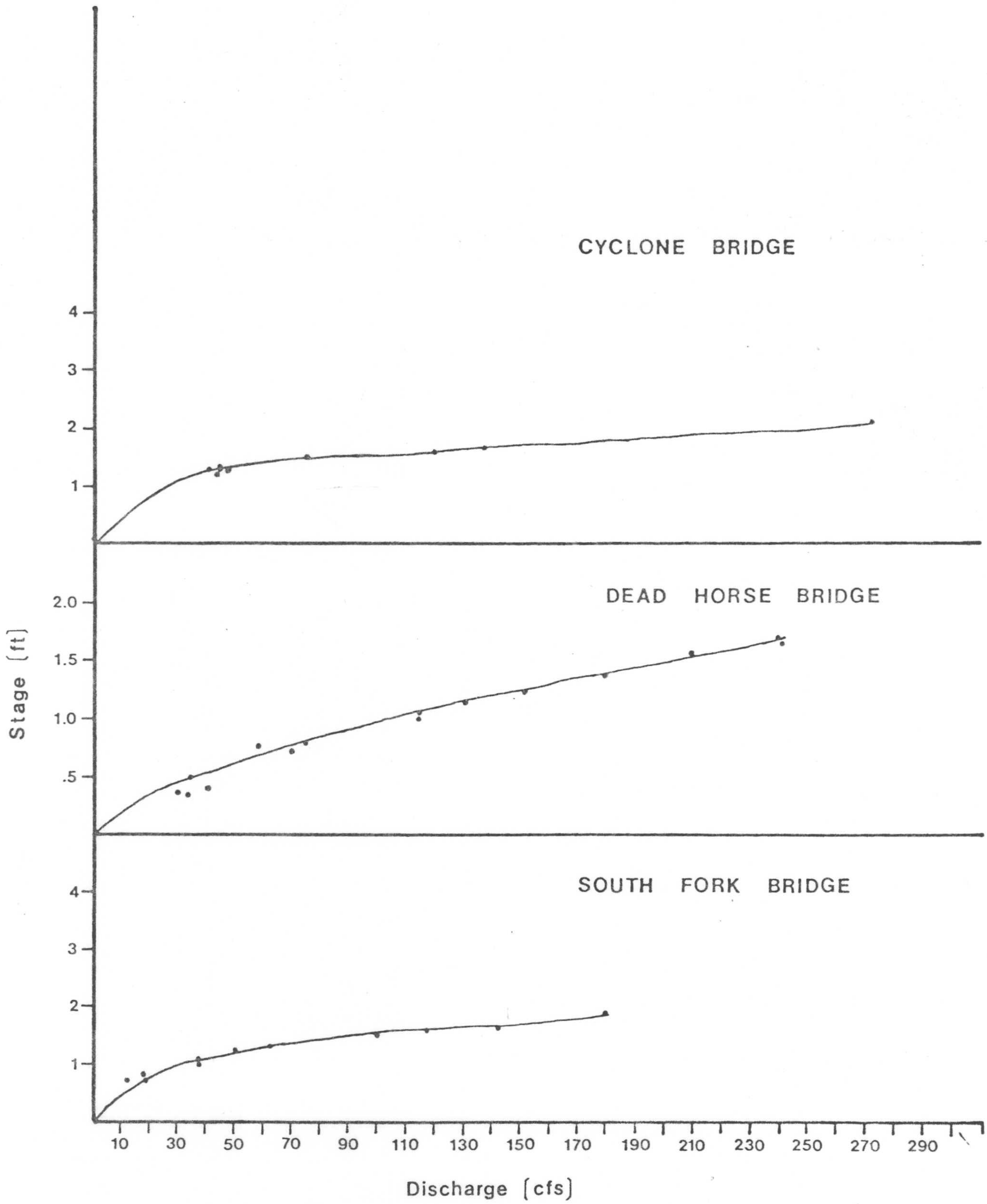

Figure 10. Stage discharge relationships for the three bridge crossings on Coal Creek. Points are measured discharges.

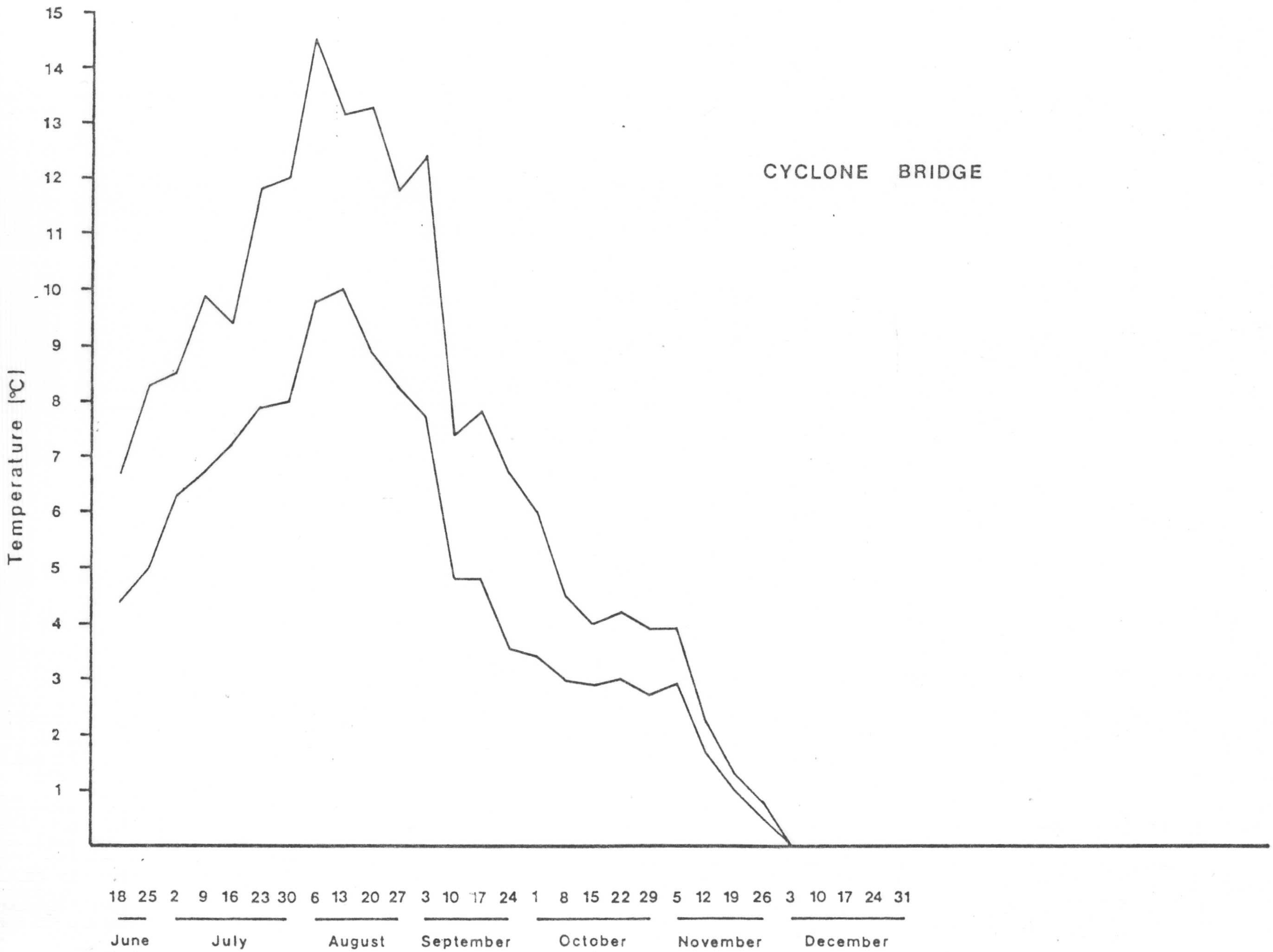

Figure 11. Mean weekly minimum and maximum water temperatures at the downstream bridge on the Coal Creek Road (317) from 10 June to 15 December, 1983.

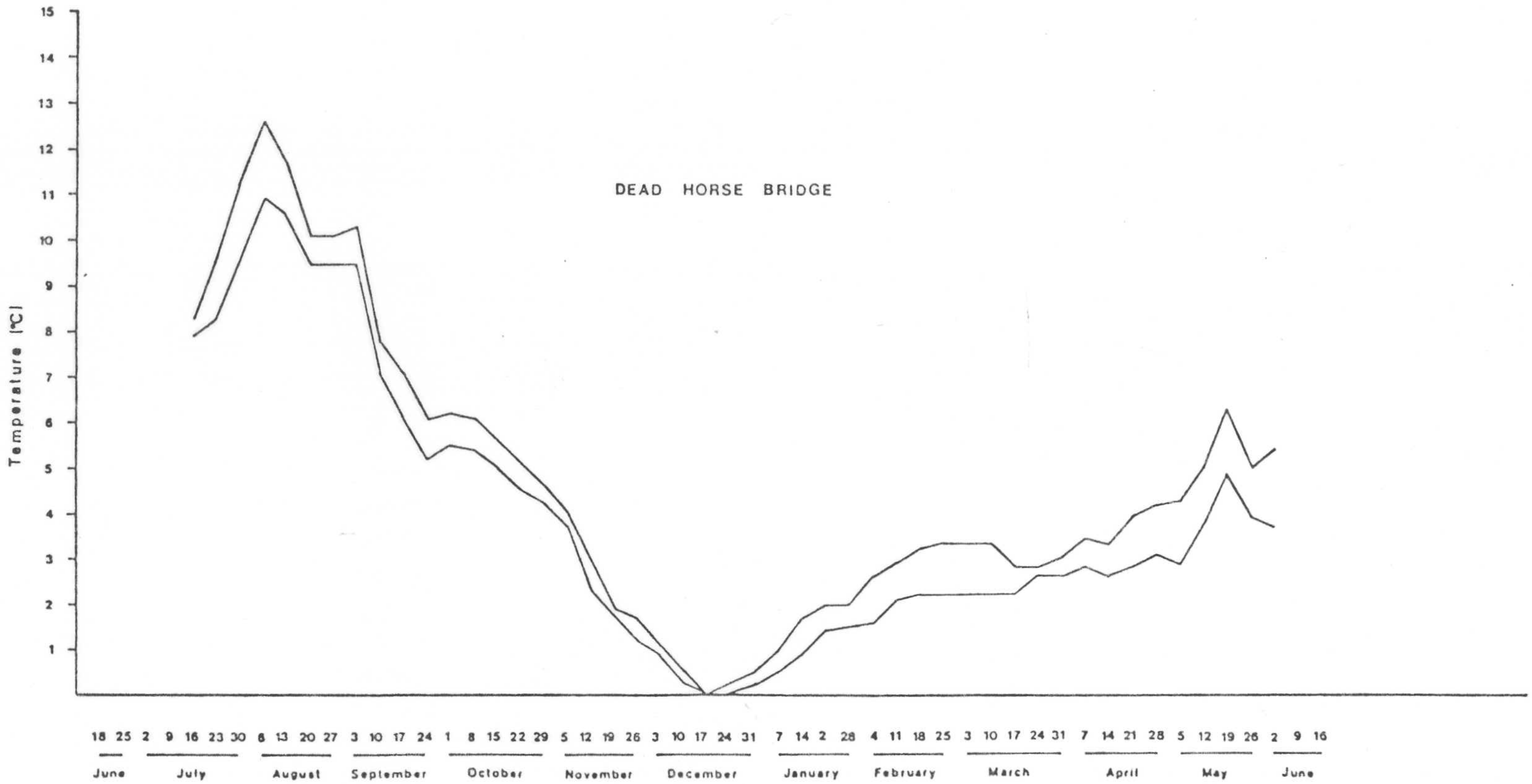

Figure 12. Means weekly minimum and maximum water temperatures at the Dead Horse Creek Road Bridge (1693) from 13 July 1983 to 4 June, 1984.

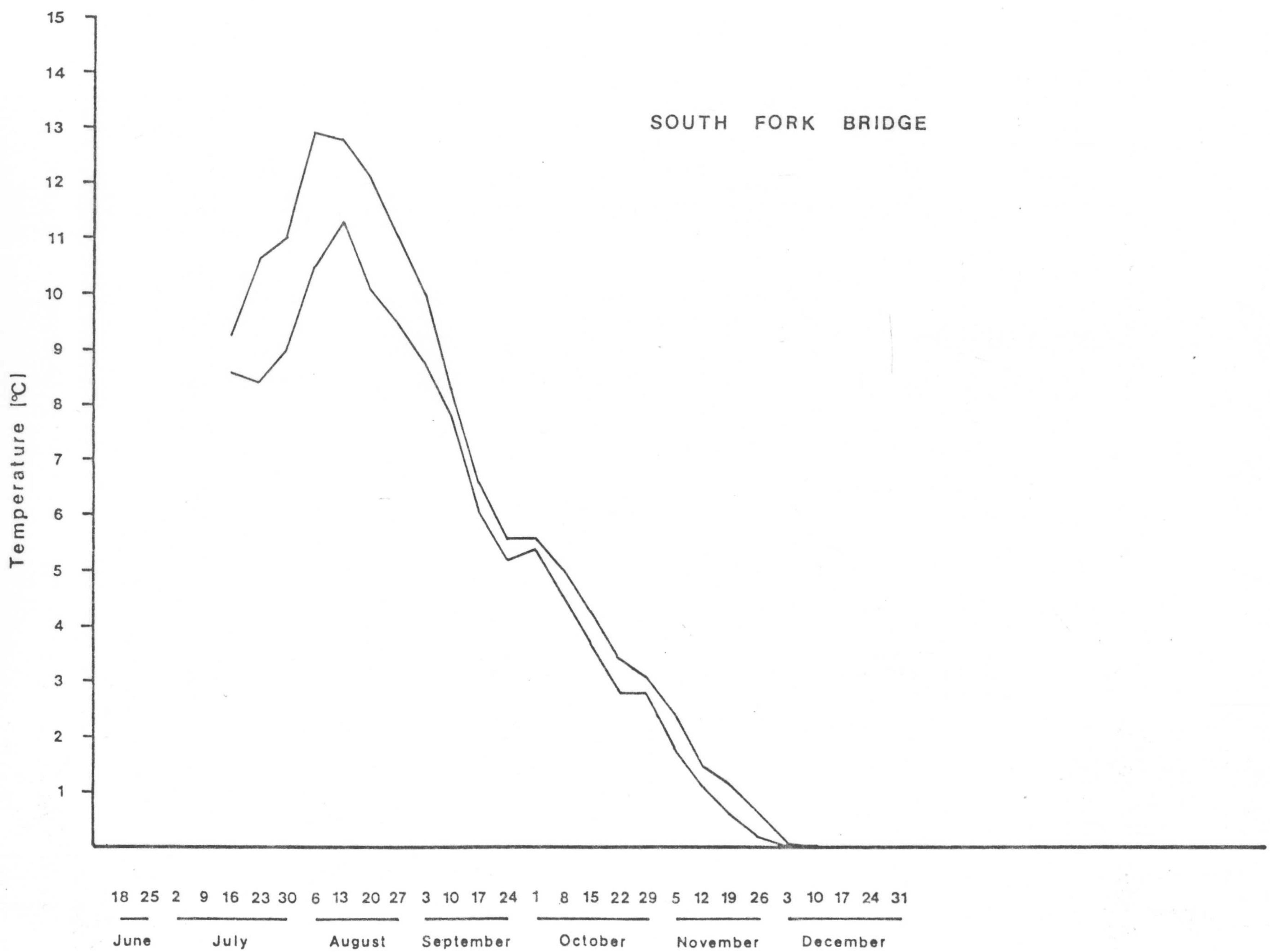

Figure 13. Mean weekly minimum and maximum water temperatures at the South Fork of Coal Creek Road Bridge (317) from 13 July to 15 December, 1983.

thermograph removal. The Cyclone Bridge area was completely frozen over at this time and 15 cm of surface ice was observed during thermograph removal. Anchor ice was also abundant throughout the Cyclone Bridge section.The South Fork Bridge section has been snow covered annually during the past 3 years.

Minimal surface ice formed in the Dead Horse Bridge section even though air temperatures approached -35°C during December. Water temperatures here approached 0° C for about 1 week before slight fluctuations were again noted. A steady increase began around January 1984. We believe the dampened temperature and water level fluctuation in the Dead Horse Bridge area were due to extensive intergravel flow, which may strongly influence bull trout spawning site selection and embryo survival.

Line Transects

Averages of physical habitat measurements differed slightly between 1982 and 1983 (Tables 5, 6 and 7). Mean channel width during 1983 was approximately 2 m greater in HS1 and HS2 and 1 m narrower in HS3, than measurements recorded during the summer 1982 surveys. These small differences were probably due to the change in field personnel and the subjective nature of determining channel boundaries. Random site selection may have resulted in the variation in some parameters. Wetted width was approximately 1 m wider in each section during 1983. The differerence in wetted width and average depth can be attributed to the higher discharges during the 1983 surveys. The maximum depth and D-90 measurements reported for HS3 during the summer of 1982 were substantially greater than those recorded during this study; however, the measurements reported for the spring 1982 survey are extremely similar to 1983 values. The difference in the D-90 measurements between spring and summer surveys during 1982 is mentioned briefly, but not explained by Shepard and Graham (1983a). The increased number of run and multiple channel habitat units observed during 1983 may also be explained by the higher discharges during this year's surveys.

Point estimates of substrate composition showed all study sections remained relatively stable (Table 8). The difference between mean particle size percentages obvserved during summer of 1982 and 1983 averaged 5% or less. The visual estimates of overall substrate composition during 1983 were quite similar to the mean perecentages from the point estimates (Table 9). In HS1, the average difference between the two methods was less than 2% and in HS2 and HS3 average difference was approximately 5%. Shepard and Graham (1983a) reported similar results from a comparison of these methods. A 13% increase in imbeddedness was reported for HS3 between spring and summer of 1982 (Shepard and Graham 1983a). This year, a 15% increase over the summer 1982 figure was observed in HS2, while imbeddedness in the other two sections changed little.

Table 5. Comparison of mean physical habitat measurements in the Dead Horse Bridge section (HS1) of Coal Creek collected during the summers 1982 and 1983.

Habitat Unit	No.	Date	Flow (cfs)	Channel Width (M)	Wetted Width (M)	Average Depth (cm)	Maximum Depth (cm)	D-90 (cm)
Pool	5	7-30-82	76	19.7	16.4	65.8	195	21.6
Riffle	10	7-30-82	76	23.3	19.8	33.5	78	18.6
Run	9	7-30-82	76	23.6	16.9	46.0	115	23.3
Pocket water	0	7-30-82	76	--	--	--	--	--
Multiple channels	1	7-30-82	76	23.7	21.7	23.0	141	24.0
AVERAGE				22.7	18.2	44.0	195	21.1
Pool	2	7-25-83	115	22.1	22.1	80.0	160	20.0
Riffle	4	7-25-83	115	28.3	20.6	35.2	150	18.8
Run	14	7-25-83	115	22.9	16.8	42.4	100	20.1
Pocket water	0	7-25-83	115	--	--	--	--	--
Multiple channels	5	7-25-83	115	25.8	15.3	39.8	130	18.2
AVERAGE				24.3	19.5	40.2	160	19.3

Table 6. Comparison of mean physical habitat measurements in the South Fork Bridge section (HS2) of Coal Creek collected during the summers of 1982 and 1983 .

Habitat Unit	No.	Date	Flow	Channel width (M)	Wetted width (M)	Average depth (cm)	Maximum Depth (cm)	D-90 (cm)
Pool	2	7-29-82	39	17.7	15.6	47.0	88	23.1
Riffle	5	7-29-82	39	13.9	10.8	27.8	88	39.2
Run	9	7-29-82	39	14.9	10.8	39.3	100	39.2
Pocket water	9	7-29-82	39	11.6	10.1	31.7	85	68.2
Multiple channels	0	7-29-82	39	--	--	--	--	--
AVERAGE				13.7	10.9	34.9	100	48.6
Pool	1	7-27-83	63	12.9	12.9	58.0	90	48.0
Riffle	3	7-23-83	63	16.3	12.8	30.7	65	42.3
Run	11	7-27-83	63	14.5	9.8	35.5	100	41.4
Pocket water	7	7-27-83	63	11.4	9.5	31.8	65	43.0
Multiple channels	3	7-27-83	63	25.7	15.8	29.6	80	37.0
AVERAGE				16.2	12.2	37.1	100	42.3

Table 7. Comparison of mean physical habitat measurements in the Riparian Cut section (HS3) of Coal Creek collected during the summers of 1982 and 1983.

Habitat Unit	No.	Date	Flow	channel width (M)	Wetted width (M)	Average depth (M)	Maximum depth (cm)	D-90 (cm)
Pool	4	7-29-82	39	15.1	9.7	42.5	109	50.5
Riffle	5	7-29-82	39	15.4	10.3	21.2	45	36.4
Run	8	7-29-82	39	15.2	9.0	25.6	57	43.5
Pocket water	6	7-29-82	39	12.5	9.8	25.0	51	56.3
Multiple channels	2	7-29-82	39	15.1	10.5	18.5	54	40.0
AVERAGE				14.6	9.7	26.7	109	46.0
Pool	0	7-28-83	43	--	--	--	--	--
Riffle	11	7-28-83	43	12.9	10.9	18.3	51	31.9
Run	6	7-28-83	43	12.4	7.9	27.7	50	27.7
Pocket water	4	7-28-83	43	16.3	11.3	23.8	46	24.5
Multiple Channels	4	7-28-83	43	15.0	11.2	26.5	70	23.0
AVERAGE				13.7	10.8	227	70	29.3

Table 8. Estimates of substrate composition, D-90 and percent imbeddedness by habitat unit from three study sections of Coal Creek during 1983.

Habitat Unit	No.	SUBSTRATE Point Estimate (%) Organic Sand & Silt	Small Gravel	Large Gravel	Cobble	Boulder	D-90 (cm)	Imbeddedness (%)
Below Dead Horse Bridge (HS1)								
Pool	2	69	19	9	3	0	20	38
Riffle	4	11	32	38	15	2	19	31
Run	14	19	22	38	18	3	20	27
Pocket water	0	--	--	--	--	--	--	--
Other	5	17	22	41	20	0	18	32
Average		22	23	36	17	2	20	30
Above South Fork Bridge (HS2)								
Pool	1	0	0	17	30	54	48	38
Riffle	3	6	3	24	41	26	42	21
Run	11	12	10	27	35	16	41	31
Pocket water	7	4	6	26	34	30	43	42
Other	3	14	22	36	27	1	37	58
Average		9	9	27	34	21	42	36
Riparian Cut Area (HS3)								
Pool	0	--	--	--	--	--	--	--
Riffle	11	10	14	40	34	2	32	33
Run	6	6	10	39	33	12	28	43
Pocket water	4	14	21	28	26	10	34	45
Other	4	15	19	33	24	8	23	60
Average		10	15	37	31	6	29	42

Table 9. Comparison of point and visual estimates describing substrate composition in three study sections of Coal Creek during 1983.

Habitat Survey Section	HS1		HS2		HS3	
	POINT	VISUAL	POINT	VISUAL	POINT	VISUAL
Substrate Class						
Organic, Silt Sand	22	24	9	15	10	20
Small Gravel	23	24	9	16	15	19
Large Gravel	36	32	27	21	37	25
Cobble	17	17	34	29	31	30
Boulder	2	3	21	19	6	6

Overhead cover was moderate in HS1 and HS3 and abundant in HS2 (Table 10). Average percentages from point estimates in 1983 generally agreed with the 1982 averages. A 14% increase in overhang less than 2 m above the water's surface was recorded in 1983 in HS1. This was probably due to the higher discharge and wider wetted widths during 1983. Instream cover was moderate in HS1 and HS3 and abundant in HS2 (Table 10). Most instream cover was provided by submerged logs, debris and boulders. In HS3, submerged log cover increased 6% while submerged debris cover decreased by 10% from the summer 1982 survey. The decrease in submerged boulder cover in all three study sections may also be discharge related. Higher flows made identification of deeply submerged cover more difficult. Visual estimates of total overhead cover underestimated results of the point sampling by 24%. Instream cover was underestimated by 21% when using the visual method. Shepard and Graham (1983a) reported a significant ($p<0.05$) difference between the two methods.

Organic Debris

The number and percentage of debris by size and age class in HS1 during summer 1983 (Table 11) was extremely close to that observed in 1982 (Shepard and Graham 1983a). In HS2 and HS3 the number and percentage of debris in the old large and old medium classifications also remained similar to the summer 1982 surveys; however, numbers and percentages in the old small, old branches and logged branches classifications were much smaller during this year's surveys. We believe this was due to the consolidation of logged branches and smaller natural debris on existing jams. A single new debris jam was recorded in HS3, probably resulting from this type of accumulation on existing large and medium materials. Both HS2 and HS3 still contained some logged branches, but considerably fewer than during the summer of 1982.

INSTREAM DEBRIS MONITORING

Photographs of the two debris monitoring sections showed that all types of organic debris were common in both areas (Appendix C, Figures 1 to 9). The section located in the sale area contained a higher frequency of debris than the section above Dead Horse Bridge and a greater percentage appeared newly recruited. Logging debris was also observed more frequently in the upper section.

The Dead Horse Bridge section changed little between surveys conducted during the summers of 1982 and 1983 (Shepard and Graham 1983a) (Appendix C Figures 1 to 5). The downstream portion of this section remained stable. Photo number eight showed an open gravel bar on which several logs, one with the rootball attached, were documented during 1982. (Appendix C, Figure 4). Photos nine and ten showed an increase in submerged and partiallay submerged logs just downstream and across the channel. (Appendix C, Figure 5).

Table 10. Estimated percentages of overhead and instream cover by habitat unit in the three study sections of Coal Creek during 1983.

		POINT ESTIMATES (%)													VISUAL (%)	
		Overhead cover						Instream Cover								
			Under	Overhang				Aquatic	Over - water			In - water				
Habitat Unit	No.	None	cut	<2m	>2m	Canopy	None	Vegetation	log	debris	boulder	log	debris	boulder	Overhead	Instream
Below Dead Horse Bridge (HS1)																
Pool	2	0	0	100	0	0	12	6	6	19	0	50	6	0	75	60
Riffle	4	80	0	18	0	2	70	2	3	2	0	20	2	2	13	18
Run	14	80	1	11	5	3	77	1	4	1	0	6	4	8	5	11
Pocket water	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other	5	63	4	15	9	9	70	0	9	5	0	1	14	0	8	14
Average		70	2	20	5	4	69	1	5	4	0	11	6	5	13	17
Above South Fork Bridge (HS2)																
Pool	1	67	0	33	0	0	0	0	0	0	0	42	0	58	10	50
Riffle	3	66	0	34	0	0	40	0	0	3	3	29	9	17	16	27
Run	11	65	2	23	9	1	62	0	3	4	1	2	11	17	10	15
Pocket water	7	40	0	45	3	11	45	0	0	0	0	9	8	38	16	26
Other	3	33	3	41	3	20	59	0	0	3	0	3	36	0	13	15
Average		54	1	34	5	6	51	0	1	2	1	10	13	22	13	21
Riparian Cut Areas (HS3)																
Pool	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Riffle	11	76	2	16	1	6	74	0	0	0	6	9	9	1	5	6
Run	6	69	2	18	2	9	64	0	0	4	0	13	0	18	7	9
Pocket water	4	76	0	21	3	0	50	0	10	0	0	5	8	26	7	19
Other	4	56	5	20	8	10	80	0	3	3	0	5	10	0	10	8
Average		71	2	18	3	6	69	0	2	1	8	9	4	8	7	9

Table 11. Number and percent (in parentheses) of organic debris by type and age in the three habitat sections of Coal Creek during summer 1983.

Area	Size	Old	New	Logged	Total
Below Dead Horse Bridge (HS1)					
Large		93 (42)	2 (20)	0 (0)	95 (41)
Medium		60 (27)	3 (30)	0 (0)	63 (27)
Small		19 (9)	4 (40)	0 (0)	23 (10)
Branches		36 (16)	1 (10)	0 (0)	37 (16)
Jams		12 (5)	0 (0)	0 (0)	12 (5)
	Total	220 (96)	10 (4)	0 (0)	230 (100)
Above South Fork Coal Creek Bridge (HS2)					
Large		170 (51)	5 (29)	0 (0)	175 (49)
Medium		96 (29)	7 (41)	1 (12)	104 (29)
Small		39 (12)	1 (6)	1 (12)	41 (11)
Branches		20 (6)	4 (24)	6 (75)	30 (8)
Jams		10 (3)	0 (0)	0 (0)	10 (3)
	Total	335 (93)	17 (5)	8 (2)	360 (100)
Above Coal Ridge Lookout Trailhead-Riparian Cut (HS3)					
Large		150 (39)	0 (0)	0 (0)	150 (38)
Medium		118 (31)	4 (31)	0 (0)	122 (31)
Small		76 (20)	8 (61)	0 (0)	84 (21)
Branches		30 (8)	0 (0)	2 (100)	32 (8)
Jams		10 (3)	1 (8)	0 (0)	11 (3)
	Total	384 (96)	13 (3)	2 (1)	399 (100)

Photos of the upstream section indicated less stability (Appendix C, Figure 6 to 9). Number one and two showed that a jam present in summer of 1982 had opened, with the larger material swinging toward the downstream right bank (Appendix C, Figure 6).

Smaller materials exited the section entirely. Photo number four (Appendix C, Figure 7), depicted a new tree on the gravel bar below the upper end of the section, along with a new accumulation of branches hanging over the upstream jam. Photo six was the downstream view of the gravel bar (Appendix C, Figure 8), and number eight showed the extent of the new debris accumulation at the upstream end of the study section (Appendix C, Figure 9).

SUBSTRATE COMPOSITION

The bull trout spawning area in Coal Creek contained similar percentages of fine material in 1982 and 1983 (Figure 14). Last year's sampling showed median percentages of material smaller than 6.35 mm and 2.00 mm in undisturbed areas to be 38 and 17 respectively, while this study found 37% smaller than 6.35 mm and 18% smaller than 2.00 mm.

Results of the Kruskal-Wallis test revealed median percentages of material smaller than 16 mm was significantly different between the four creeks sampled ($p < .003$).) Median percentages of material smaller than 6.35 mm and 2.00 were also significantly different between Creeks. ($p < .0001$ and $p < .0003$ respectively). A Mann-Whitney multiple comparison test showed Coal Creek contained a significantly higher percentage of material smaller than 2.00 mm than did Whale ($p < 0.01$), Trail ($p < 0.001$) and Big ($p < 0.001$) Creeks.

Between 1982 and 1983, a 5% increase in material smaller than 6.35 mm was observed from undisturbed sites in Trail Creek. This size class also increased by 2% in Big Creek's spawning area. Undisturbed sites in Whale Creek experienced a 4% decrease in the amount of material smaller than 6.35 mm from the 1982 level. A comparison of the mean percentages of material smaller than 6.35 mm and 2.00 mm in the four creeks sampled during 1981, 1982 and 1983 is presented in Table 12. Comparisons of substrate composition for each site sampled during 1983 are presented in Appendix D, Figures 1 to 5.

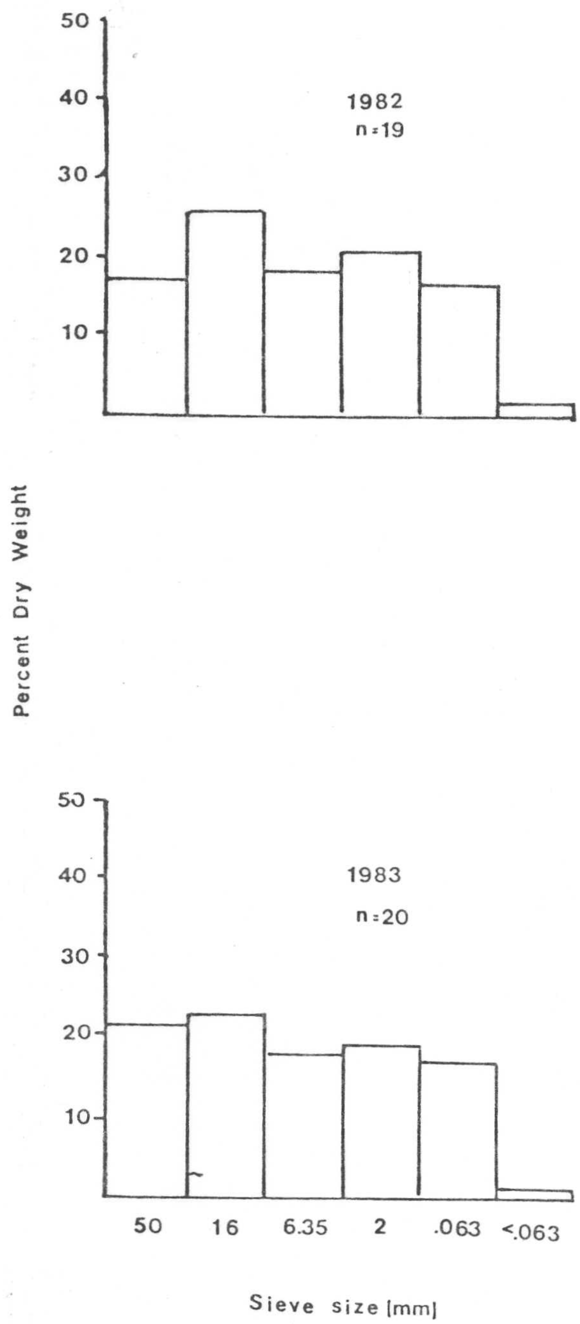

Figure 14. Composite graphs of undisturbed streambed samples in Coal Creek during 1982 and 1983.

Table 12. Comparison of the mean percentages of material smaller than 6.35 mm and 2.00 mm from undisturbed sites in Coal, Whale, Trail and Big Creeks during 1981, 1982 and 1983.

Creek / Year	n	Percent smaller than 6.35 mm	Percent smaller than 2.00 mm
Coal Creek			
1981	10	33	16
1982	19	38	17
1983	20	37	18
Whale Creek			
1981	6	22	7
1982	8	35	15
1983	11	34	12
Trail Creek			
1981	12	23	10
1982	16	22	10
1983	10	27	13
Big Creek			
1981	6	22	8
1982	9	28	9
1983	11	28	11

FISH ABUNDANCE

Electrofishing estimates from the three sections of Coal Creek were generally lower than the estimates reported for 1982 (Table 13). As in 1982, estimates only included fish 75 mm or longer in total length. Bull trout estimates decreased in the Dead Horse and Cyclone Bridge sections while remaining constant in the South Fork Bridge area. Estimates of cutthroat numbers decreased in the Cyclone and South Fork Bridge sections. A similar declining trend was observed in most streams electrofished in the North Fork Drainage during 1983. Densities calculated from two-pass population estimates during 1983 also show declines from 1982 levels (Table 14).

Largest fluctuations occurred in the Dead Horse section where estimated cutthroat abundance increased by 467% between the summers of 1982 and 1983 (Table 13). This increase was due to an experimental westslope cutthroat plant by MDFWP in September of 1982. In this experiment over 90,000 westslope cutthroat averaging approximately 51 mm in length were planted just upstream from Dead Horse Bridge. Approximately one third of these fish were batch marked with a fluorescent green pigment. Annual electro fishing work in Coal Creek should provide valuable information concerning carrying capacity, competition, movement and growth.

During the 1983 electrofishing in the Dead Horse section, all cutthroat $\geq$100 mm captured during the recapture effort were placed under a Ultra Violet lamp and 20% were observed to have the green mark. Cutthroat in this size group from the Cyclone shocking section were also examined, but no marks were observed.

Overall fish density and total numbers estimated in the Dead Horse section changed little between 1982 and 1983, suggesting that this section was at or near carrying capacity prior to the plant. The shift in species composition indicated that juvenile bull trout may have been displaced by cutthroat.

Growth of tagged fish recaptured during spring 1983 electrofishing varied between the three sections. Two cutthroat and four bull trout were recaptured in the South Fork Bridge Section. The cutthroat showed average increases of 24.5 mm in length and 5.5 g in weight while bull trout growth averaged 11 mm in length and 4 g in weight. The time span between the two samplings was 40 days. Two bull trout were recaptured from the Dead Horse section and showed an average increase of 33.5 mm in length and 12.5 g in weight. The single cutthroat recaptured from the Cyclone Bridge sectio had grown 25 mm and weighed 13 g more. The time span between these estimates was approximately 150 days.

Table 13. Comparison of fish numbers and associated 95% confidence intervals for cutthroat and bull trout greater than or equal to 75 mm total length, from the three study section of Coal Creek during August of 1982 and 1983.

Section	Date	Flow (cfs)	Estimation technique	$\hat{N}$	95% C.I.	$\hat{P}$
Cutthroat trout						
Cyclone Br.	8-10-82	75.9	Two-Pass	41	±18	.55
	8-24-83	45.9	Two-Pass	17	± 7	.64
Dead Horse Br.	8- 5-82	58.8	M&R	12	± 9	2 1/
	8-23-83	41.6	M&R	56	±15	3 1/
South Fork Br.	8- 4-82	31.2	Two-Pass	32	± 6	.74
	8-28-83	18.8	Two-Pass	23	± 2	.84
Bull trout						
Cyclone Br.	8-10-82	75.9	Two-Pass	50	±43	.40
	8-24-83	45.9	Two-Pass	34	± 7	.71
Dead Horse Br.	8- 5-82	58.8	M&R	130	±36	2 1/
	8-23-83	41.6	M&R	99	±33	1 1/
South Fork Br.	8- 4-82	31.2	Two-Pass	17	± 9	.60
	8-25-83	18.8	Two-Pass	18	± 3	.78

1/ These numbers are motalities recorded between marking and recapture efforts.

Table 14. Comparison of two-pass population estimates and densities (number per 100 m^2) of cutthroat and bull trout greater than or equal to 75 mm total length during summer 1981, spring and summer 1982 and summer of 1983.

Creek Section	Date	Flow (cfs)	Surface area (m)	$\hat{N}$	95% C.I.	$\hat{P}$	Density (#/100 m^2)
Cutthroat trout							
Coal Creek							
Cyclone Br.	4-20-82	64.6	1863	31	± 4	0.79	1.7
	8-10-82	75.9	1809	41	±18	0.55	2.3
	8-24-83	45.9	1610	17	± 7	0.64	1.1
Dead Horse Br.	4-14-82	28.1	1621	12	± 1	0.90	0.7
	8- 5-82	58.8	1745	7	± 2	0.80	0.4
	8-23-83	41.6	1705	44	±10	0.66	2.6
South Fork Br.	5-11-82	100.4	--	18	± 2	0.87	--
	8- 4-82	31.2	1268	32	± 6	0.74	2.5
	8-25-83	18.8	1180	23	± 2	0.84	2.0
Langford Creek	8- 8-81	--	297	93	±15	0.66	31.3
	7-16-82	4.4	352	87	± 9	0.73	24.7
	7-21-83	3.8	519	144	±14	0.70	27.7
Cyclone Creek	7-23-81	--	569	177	±21	0.65	31.1
	7-19-82	11.5	721	131	± 3	0.90	18.2
	7-20-83	12.6	706	68	±11	0.67	9.6
Bull trout							
Coal Creek							
Cyclone Br.	4-20-82	64.6	1863	30	± 6	0.71	1.6
	8-10-82	75.9	1809	50	±43	0.40	2.8
	8-24-83	45.9	1610	34	± 7	0.71	2.1
Dead Horse Br.	4-14-82	28.1	1621	65	±34	0.47	4.0
	8- 5-82	58.8	1745	102	±51	0.43	5.8
	8-23-83	41.6	1705	53	± 7	0.75	3.1
South Fork Br.	5-11-82	100.4	--	15	± 5	0.70	00
	8- 4-82	31.2	1268	17	± 9	0.60	1.3
	8-25-83	18.8	1180	18	± 3	0.78	1.5
Morrison Creek	9- 1-82	3.6	603	93	± 5	0.83	15.4
	8-18-83	3.9	612	62	±11	0.70	10.1

Length frequency distributions for cutthroat illustrate the larger number of young of the year fish during the summer 1983 electrofishing in the Cyclone and South Fork Bridge sections (Figures 15 and 16). The predominance of larger cutthroat in the South Fork Bridge section is indicative of a resident population. Five distinct size classes were observed in the Cyclone Bridge area. The increase in small cutthroat due to the experimental plant at Dead Horse Bridge was also evident (Figure 17).

The 1983 bull trout length frequencies were similar to the 1982 findings except for the large increase in young of the year fish recorded (Figures 15, 16 and 17). The 1982 bull trout spawning run was the strongest of the past 5 years.

BULL TROUT SPAWNING SITE SURVEYS

The 1983 bull trout spawning site counts were generally lower than those recorded during 1982; however, redd numbers in the major spawning tributaries during 1983 remained higher that the 5 year average figures (Table 15). Six hundred redds were enumerated during the basin wide surveys. The North Fork Drainage contained 414 (69%) and the Middle Fork Drainage had 186 (31%). The Canadian portion of the North Fork was partially surveyed dur ng 1983 by helicopter. The portion of the Middle Fork Drainage inventoried in 1983 included only the known spawning tributaries located downstream from Schafer Meadows. We estimate that the numbers reported reflect approximately 85% of all redds in the U. S. portion of the North Fork Drainage and 60% of the Middle Fork total during 1983. Tributaries which have shown the highest level of bull trout spawning during the past 5 years are presented in order of importance in Table 16. The 1983 redd frequency distributions are presented in Appendix E, Figures 1 to 5 and illustrate that similar stream sections were selected again this year. Many redds were observed in the exact sites recorded during the 1982 surveys.

In the Coal Creek drainage, 94 redds were enumerated in 1983. Seventy nine of these were observed in main Coal Creek, 12 in Mathias Creek and 3 in the South Fork of Coal Creek (Figures 18, 19 and 20). During the 1981 survey, the South Fork of Coal Creek contained 24 redds. The upstream portion of the South Fork's spawning area was located in a section where the cumulative effects of logging, wind throw and increased beaver activity have created channel instability. Redd numbers in main Coal Creek increased from a previous high of 67 in 1982 to 73 this year.

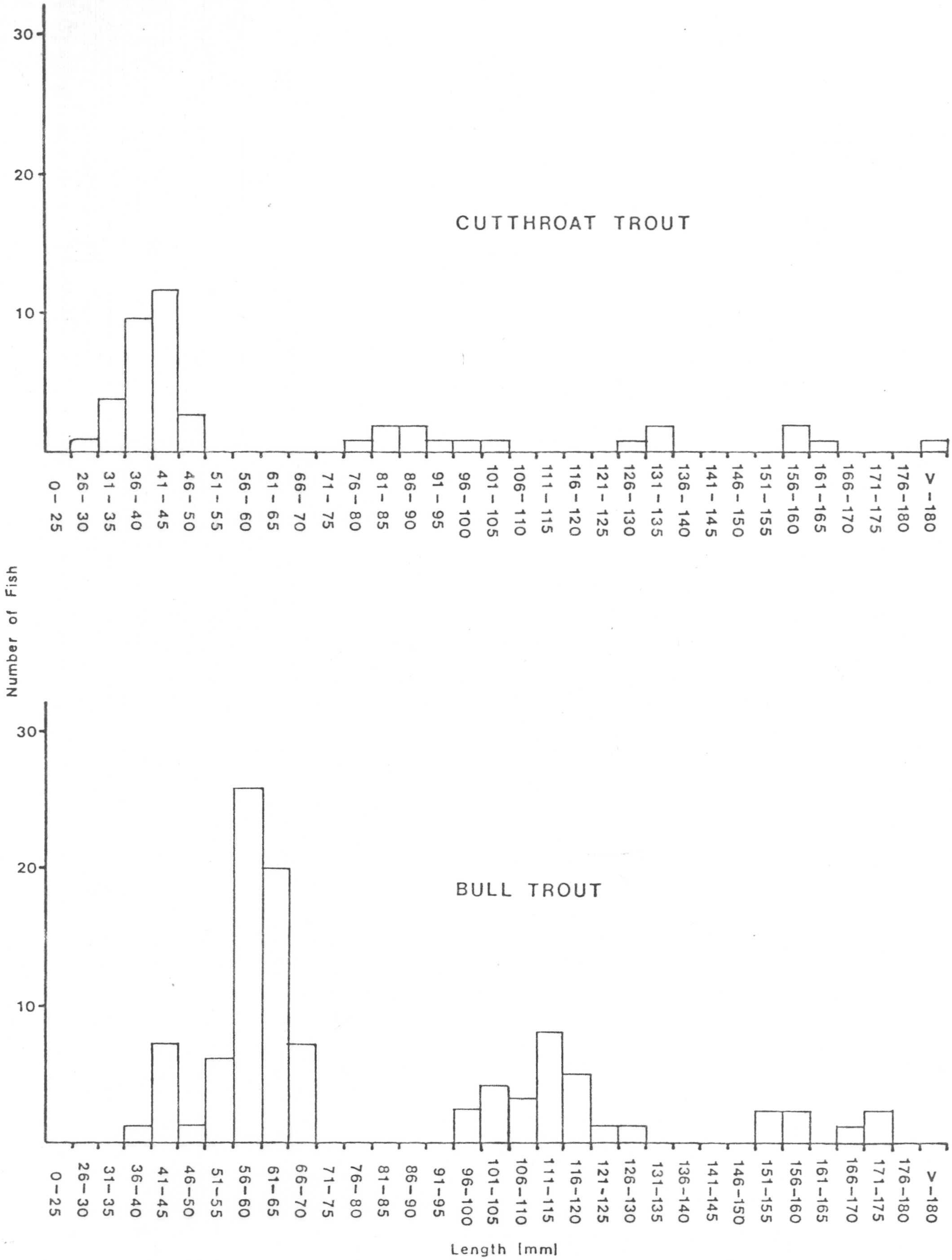

Figure 15. Length frequency distribution for cutthroat and bull trout captured during the electrofishing of the Cyclone Bridge section during August 1983.

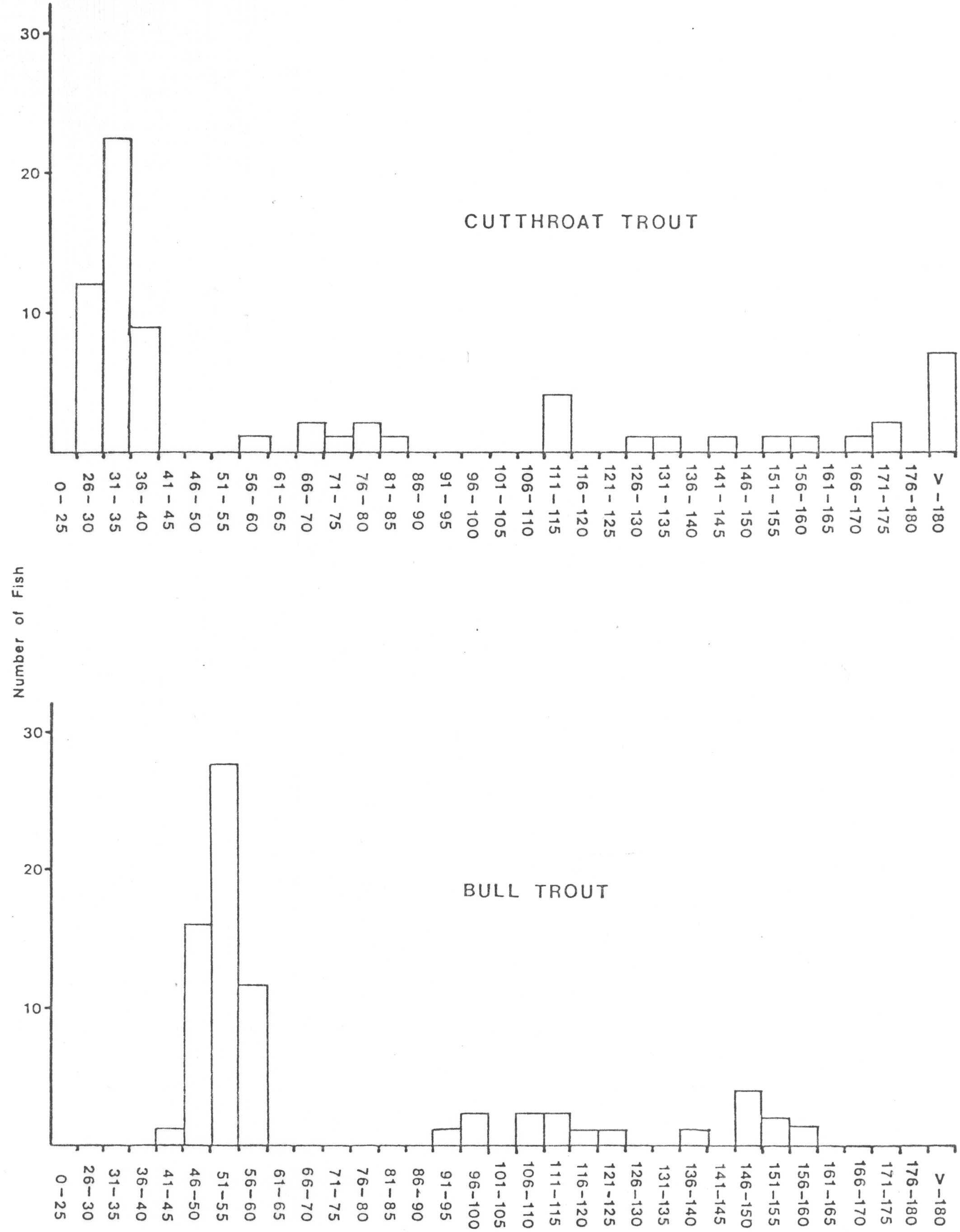

Figure 16. Length frequency distribution for cutthroat and bull trout captured during the electrofishing of the South Fork Bridge section during August 1983.

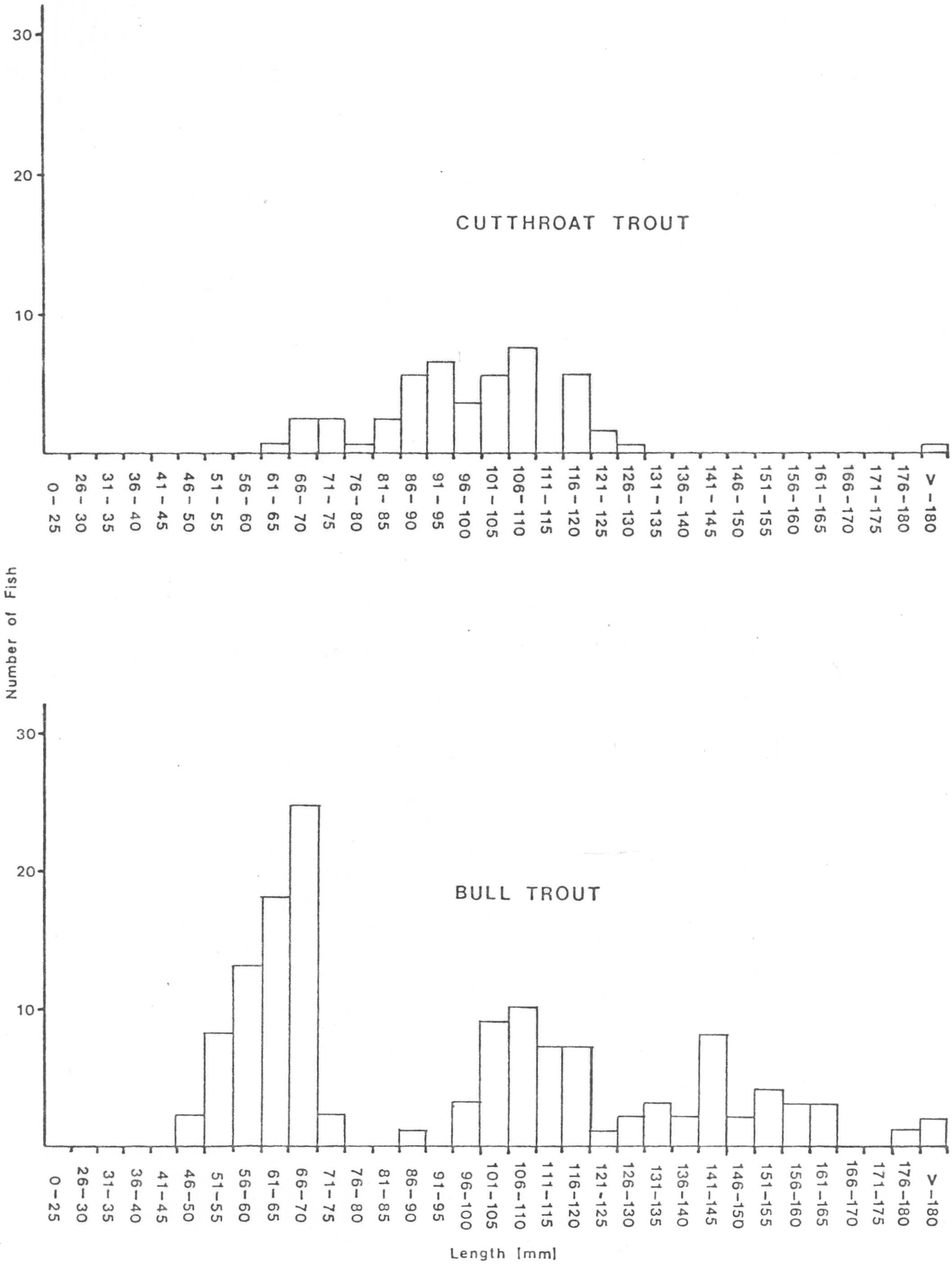

Figure 17. Length frequency distribution for cutthroat and bull trout captured during the electrofishing of the Dead Horse Bridge section during August 1983.

Table 15. Numbers of bull trout redds in North Fork tributaries surveyed during the past five years.

Creek	1979	1980	1981	1982	1983
Starvation	*	1	1	*	*
Trail	35	31	82	99	56
Whale	69	51	118	284	172
Red Meadow	0	6	19	*	*
Coal	50	60	64	121	94
Big	14	23	38	76	55
	168	268	467	736	414

Table 16. Tributaries in the upper Flathead Basin which have contained the greatest number of bull trout redds during 1979, 1980, 1981, 1982 and 1983.

Rank	Creek	Drainage	Annual average	Years surveyed
1	Whale	N.F.	139	5
2	Morrison	N.F.	83	4
3	Coal	N.F.	78	5
4	Howell	N.F.	74	3
5	Trail	N.F.	61	5
6	Strawberry	M.F.	55	3
7	Schafer/Dolly Varden	M.F.	42	4
8	Big	N.F.	41	5
9	Ole	M.F.	31	4
10	Granite	M.F.	30	4

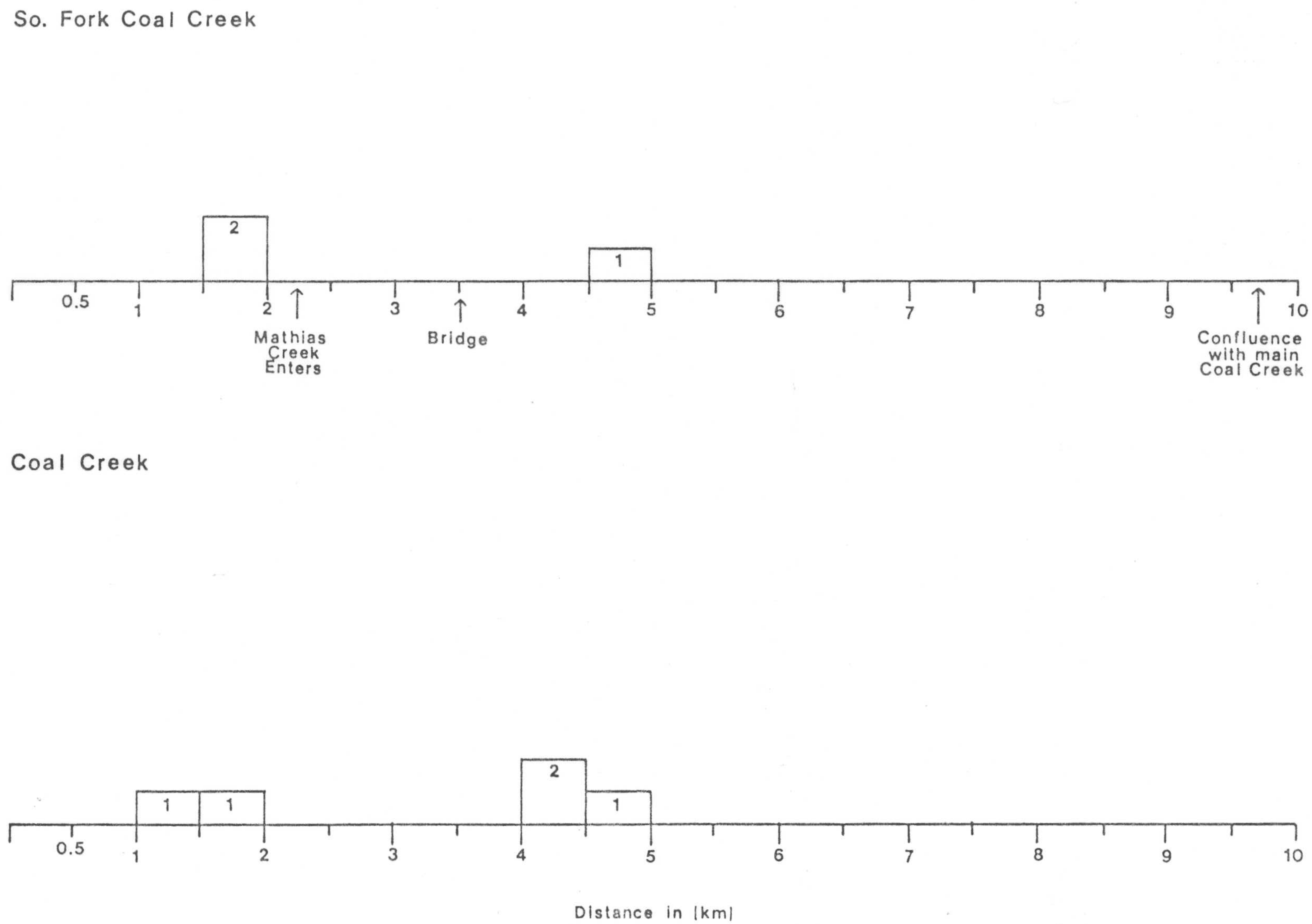

Figure 18. Bull trout redd frequency distributions in the South Fork of Coal Creek (top) and the upstream portion of main Coal Creek (bottom) during 1983.

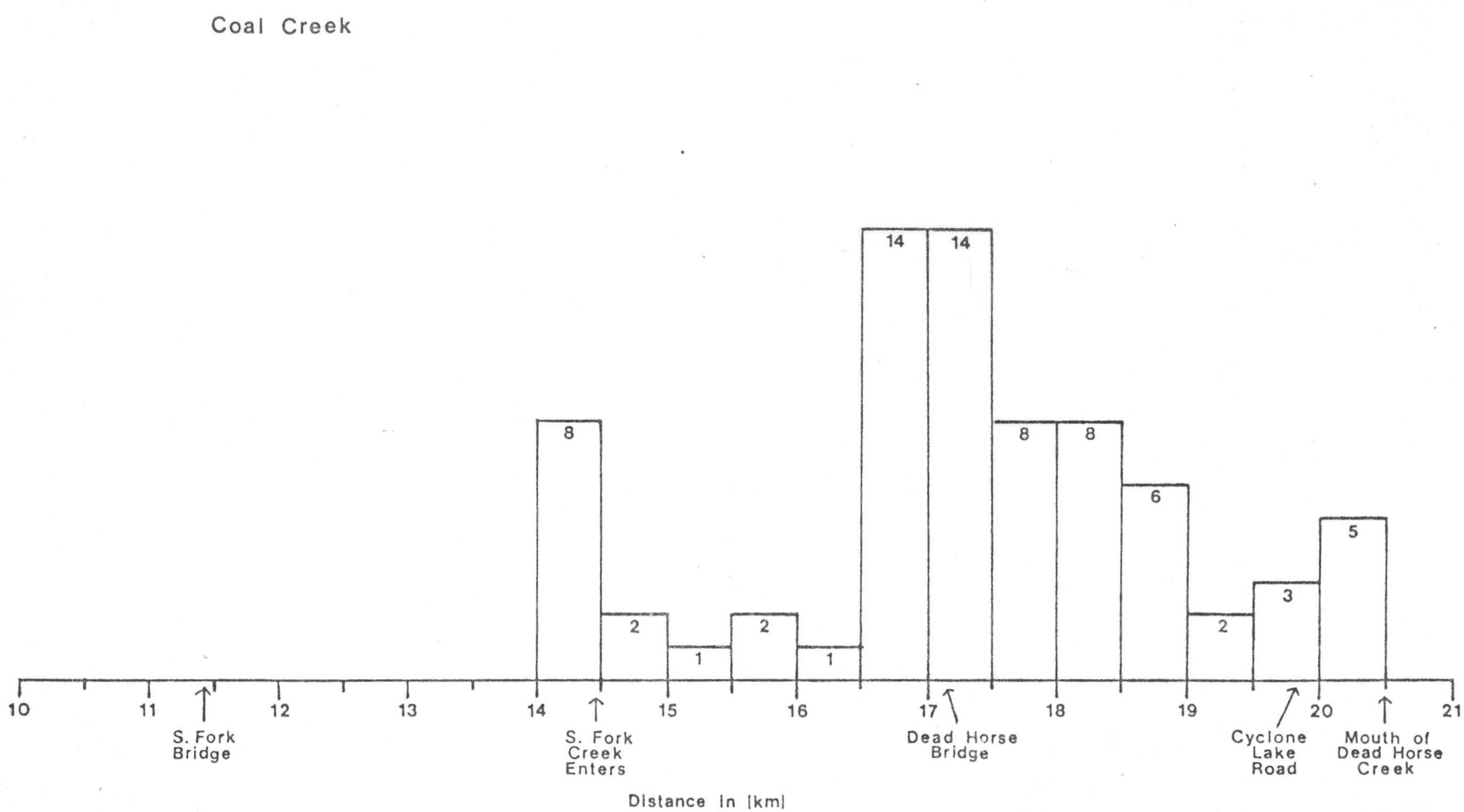

Figure 19. Bull trout redd frequency distribution in main Coal Creek downstream from the South Fork Bridge during 1983.

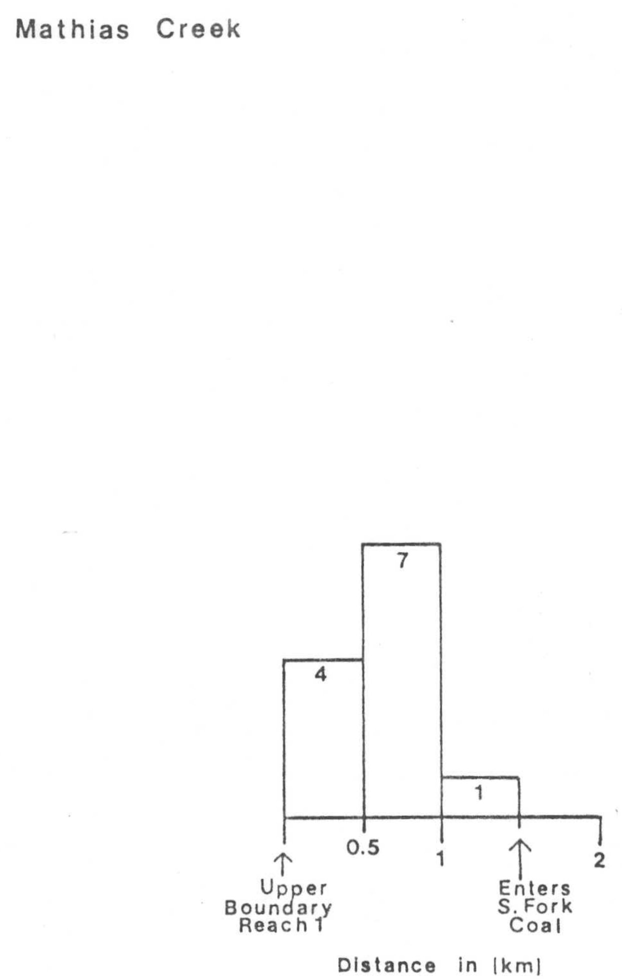

Figure 20. Bull trout redd frequency distribution in Mathias Creek during 1983.

Spawning activity in Coal Creek began on 30 August 1983 and proceeded very slowly until approximately 21 September, when activity increased sharply. Similar timing was observed in the other three creeks. Final redd counts in Coal Creek began on 10 October. Throughout early September, most spawning activity took place at night. During the nocturnal observations increased levels of juvenile bull trout activity were also noted.

A short portion of the high use spawning area above Dead Horse Bridge was surveyed almost daily throughout September. During these surveys, a complete appearing redd was recorded after 3 nights of activity. This redd remained unoccupied and showed no change in appearance for approximately 1 week before activity began a second time. Observation after dark revealed a different female working the site. This same pattern was observed a third time with another different pair using the same location approximately 10 days later.

EMBRYO SURVIVAL AND FRY EMERGENCE

Field Study

Substrate of eight artificial redds prior to planting egg bags contained an average of 42%, by weight, of material smaller than 6.35 mm (range 36-50%) and 19% smaller than 2.00 mm (range 15-23%) (Table 17). These percentages are higher than mean percentages from core samples of undisturbed streambed in the same area and may reflect our inability to clean the gravels effectively during redd construction. Since only a single core sample was removed from the tailspin area of each artificial redd, these preplanting samples may not reflect the actual substrate composition surrounding the egg bags. We have adjusted future sampling procedures so substrate composition surrounding the egg bags can be more accurately determined,

Survival and Development

The first series of sealed egg bags was removed from the artificial redds on 24 October, 1983. Embryos had developed for 42 days and received approximately 236 temperature units to this point. Live embryos were in the eyed stage and we estimate eye-up occurred after about 35 days of incubation and 200 temperature units. Seventyone percent survival was observed to the eyed stage and this figure was used to determine the number of viable embryos in the emergence portion of the field study. (Table 18).

On 13 January, 1984, the second set of sealed bags were removed. Approximately 371 temperature units had accumulated during 123 days of incubation. Live embryos were in the alevin stage, averaging 19.3, mm in length (n=40). Hatching probably occurred around 3 January, after 113 days and 350 temperature units. A 62% survival to hatch was recorded during this sampling (Table 18).

The third series of sealed bags was excavated on 20 February. Approximately 454 temperature units had accumulated during the 161 days since planting. Alevins averaged 23.6 mm in length (n = 40) with a survival rate of 64%.

On 6 March, the remaining sealed bags were removed from artificial redd numbers six and eight. Alevins averaged 26.6 mm in length (n=20) after approximately 497 temperature units and 177 days of incubation. A 60% survival rate was recorded from these two bags (Table 18).

Since the timing and duration of the bull trout fry emergence period was not known, the two remaining sealed bags were used as indicators of the proper timing of emergence trap removal. The final sealed bag in artificial redd number five was excavated on 2 April, after 215 days and approximately 570 temperature units. Alevins averaged 26.8 mm in length (n=30) with 79% survival and yolk-sacs were nearly absorbed. On 13 May, the last sealed egg

Table 17. Percentages of material smaller than 6.35 mm and 2.00 mm from the artificial redds in Coal Creek during fall of 1983.

Artificial Redd No.	Percent smaller than 6.35 mm	Percent smaller than 2.00 mm
1	37	15
2	44	19
3	42	18
4	36	15
5	40	19
6	42	18
7	50	23
8	43	22
Mean	42	19

Table 18. Bull trout embryo survival and development from the artificial redds in Coal Creek during fall and winter of 1983 and spring of 1984.

Sampling Date	Redd Number	Egg Bag Result # Live	Egg Bag Result # Dead	Total	Days	T.U.
	5	80	20	100		
10-24-83	6	90	10	100	236	42
	7	56	44	100		
	8	57	43	100		
Mean		70.8	29.2			
	5	91	5	96		
1-13-84	6	80	14	94	371	123
	7	35	56	91		
	8	42	52	94		
Mean		62.2	31.8			
	5	80	5	85		
2-20-84	6	64	31	95	454	161
	7	54	36	90		
	8	58	35	93		
Mean		64	26.8			
4-2-84	5	79	18	97	570	215
3-6-84	6	72	20	92	497	177
5-13-84	7	68	15 1/	83	710	256
3-6-84	8	48	47	95	497	177

1/ Five of these dead embryos were in the alevin stage.

bag was removed from artificial redd number seven. A 68% survival rate was observed but five alevins examined had died prior to egg bag removal. Approximately 710 temperature units had accumulated during the 256 days since planting (Table 18).

Fry Emergence

Fry emergence was first observed on 23 April, 1984. During the 3 preceeding days, high discharge prevented emergence trap sampling and bed movement was observed. Most emergence (83%) was recorded in a 4 day period during the declining limb of the preliminary spring peak flow (23-27 April) (Figure 8). Approximately 634 temperature units had accumulated during the 223 day incubation period. Threehunderd fifteen fry with an average length of 27.2 mm (n=50) were capture during the first day of sampling. Over half of these emergent fry were dead, indicating that emergence probably began while flows were too high for sampling.

On 23 April 1983, emergence traps which had been dislodged by high flows were removed along with the associated egg bags. Live alevins were still present in two of three bags (Table 19) and averaged 27.1 mm in length (n = 16). Core samples from the exact location of each egg bag were collected immediately following bag removal. All remaining emergence traps were anchored to the substrate with rebar. By 18 May, emergence had slowed to less than 10 fry per week and since annual peak flows during past years had occurred in late May, we removed seven of the remaining emergence traps, excavated egg bags and collected substrate samples. During this sampling, 88 live and 46 dead alevins were observed in the egg bags (Table 19). The remaining six traps were monitored until 28 May when four were removed. Flows had remained fairly stable during this 10 day period and only two fry had emerged. Egg bags contained 13 live and 24 dead alevins (Table 19). The remaining two traps were monitored until 18 June but no emergence was observed. Upon excavation, 27 partially decomposed alevins were enumerated, showing that entombment and crushing may have occurred. Overall emergence success in Coal Creek during this study was 53%. (Table 19).

In gravels containing high levels of fine sediment, most researchers cited by Cordone and Kelly (1961), Gibbons and Salo (1973), and Iwamoto et al. (1978) attributed low emeregence success to decreased gravel permeability or entrapment of alevins. The level of intergravel flow in the Dead Horse Bridge areas may partially mitigate the effects of the high percentage of fine material, as indicated by the relatively constant survival rate in the sealed bags. To evaluate this, ground water sampling locations in Coal Creek were selected and preliminary work was initiated to determine apparent velocities, dissolved oxygen content and temperature of the intergravel flow in Coal Creek.

Table 19. Numbers of emergent fry and live and dead embryos observed during the bull trout fry emergence work in Coal Creek in spring of 1984.

Artificial Redd	Egg Bag	Number Emerged	Number in Egg Bags: live alevins	dead alevins	dead eggs	Total
	1 4/	73	--	5	9	87
1	2 4/	16	--	22	31	69
	3 3/	27	4	11	19	61
	4 3/	10	4	6	39	59
	1 3/	64	1	3	21	89
2	2 3/	35	4	4	25	68
	3 1/	42	19	--	11	72
	4 1/	31	2	--	29	62
	1 2/	20	20	6	26	72
3	2 2/	57	1	7	13	78
	3 1/	53	--	--	24	77
	4 2/	54	2	1	22	79
	1 2/	77	--	--	7	74
4	2 2/	5	24	10	19	58
	3 2/	12	36	14	26	88
	4 2/	22	--	1	68	91
		598	117	90	389	1194
Percent (of viable)		53	10	8		

1/ Removed on 23 April, 1984

2/ Removed on 18 May, 1984

3/ Removed on 28 May, 1984

4/ Removed on 18 June, 1984

When comparing emergence success with percentages of material less than 6.35 mm an inverse relationship is evident (Figure 21). From the 16 samples collected, an average coefficient of determination (r^2 of 0.874 was obtained for the regression lines through the data. Salmonid embryo survival has been negatively correlated with fine sediment by other researchers. McNeil and Ahnell (1964) found pink salmon (*Oncorhynchus gorbuscha*) fry emergence was inversely related to the percentage of subtrate smaller than 0.83 mm. Tagart (1976) reported survival to emergence of coho salmon (*O. kisutch*) in natural redds decreased when more than 20% of the substrate was smaller than 0.85 mm. Koski (1966) found that coho salmon embryo survival was best in low percentages of material smaller than 3.3 mm. In laboratory tests, Hall and Lantz (1969) reported an inverse relationship between material smaller than 3 mm and coho and steelhead (*Salmo gairdneri*) fry emergence. Bjornn (1969) showed that emergence of chinook salmon (*O. tshawytscha*) and steelhead trout was impeded whem more than 20% of the spawning gravel was smaller than 6.35 mm. Tappel (1981) conducted laboratory tests which revealed that over 90% of the variability in chinook salmon and steelhead trout embryo survival to emergence was correlated with changes in substrate size composition.

Experimental Channels

Eyed eggs were first observed in the Heath incubator on 1 Novembert 1983. Eye-up, however, had occurred sometime earlier. By 1 November, embryos had incubated for 42 days and received approximately 336 temperature units. A 70% survival to the eyed stage was observed for the embryos in lot number 1 and 86% for lot number 2. These survival values were applied to the gravel mixtures stocked from each lot to obtain the total number of viable eggs in each mix.

By 21 November, 62 days and 504 temperature units after planting, approximately 25% of the eggs in the Heath incubator had hatched. The first emergent fry were observed in the channels on about 1 January,1984. Approximately 825 temperature units had accumumulated during the 103 days of incubation to this point. Most emergence occurred between 1 January to 16 January. No difference in the timing of emergence was observed between the gravel mixtures.

On 3 March, egg bags were removed from the channels and dead eggs enumerated. A single alevin remained in one egg bag in the 10:6 mixture; all others had emerged or died. No fry emergence was observed from the 50:29 mixture (Table 20). Only 1% of the fry emerged from the 40:23 mixture. Twenty one percent of the viable embryos in the 30:13 mixture emerged while 38% emerged from the 20:12 and 0:0 mixtures. The highest survival recorded was 48% in the 10:6 mixture (Table 20).

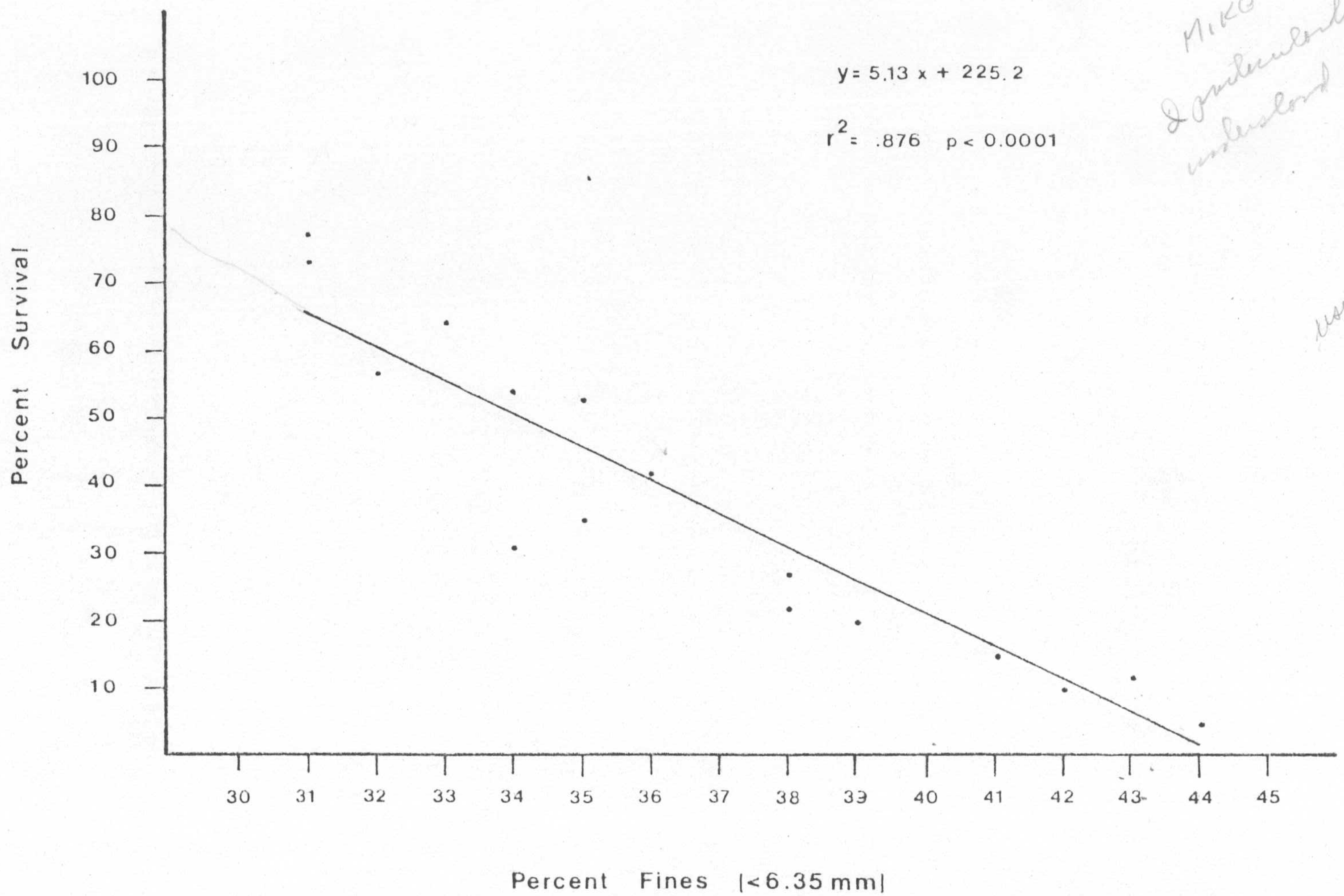

Figure 21. Relationship between bull trout survival to emergence and the percentage of substrate smaller than 6.35 mm in diameter from the artificial redds in Coal Creek during 1983-84.

Table 20. Bull trout fry emergence success in the experimental channels during January and February, 1984.

Sediment Mix	Channel Number	Number Emerged (%)	Number dead eggs	Total	Lot Number
	1	68	124	192	2
0:0	21	91	97	188	2
	22	37	128	165	2
Total %		196 (38)			
	8	100	100	200	2
10:6	13	99	100	199	2
	15	73	127	200	2
	24	58	125	183	
Total %		330 (48)			
	4	68	133	201	1
20:12	11	42	138	180	1
	14	83	116	199	1
	19	21	164	185	1
Total %		214 (38)			
	7	29	161	190	1
30:18	10	50	148	198	1
	12	17	180	197	1
	23	21	168	189	1
Total %		117 (21)			
	2	2	179	181	1
40:23	5	1	184	185	1
	16	3	175	178	1
	18	0	183	183	1
Total		6 (1)			
	3	0	163	163	1
50:29	6	0	162	162	1
	9	0	165	165	1
	17	0	174	174	1
Total(%)		0 (0)			

Table 21. Analysis of varience test comparing the total number of emerging bull trout fry from the six gravel mixtures in the controlled incubation environment during 1983-84.

Mixtures compared	Mean	Difference	p Value
50:29 - 40:23	1.500	1.500	.9088
50:29 - 30:18	29.25	29.25	.0367*
50:29 - 20:12	53.50	53.50	.0001*
50:29 - 10:6	65.33	65.33	.0001*
50:29 - 0:0	82.50	82.50	.0001*
40:23 - 30:18	29.25	27.75	.0462*
40:23 - 20:12	53.50	52.00	.0001*
40:23 - 10:6	65.33	63.83	.0001*
40:23 - 0:0	82.50	81.00	.0001*
30:18 - 20:12	53.50	24.25	.0774
30:18 - 10:6	82.50	53.25	.0001*
30:18 - 0:0	65.33	36.08	.0191*
20:12 - 10:6	82.50	29.00	.0382*
20:12 - 0:0	65.33	11.83	.4076
10:6 - 0:0	82.50	17.17	.2348

*Significant at 0.95 level

Table 22. Average lengths and weights of bull trout fry after emergence from the experimental channels during January of 1984.

Gravel Mixture	n	Length (mm)	Weight (mg)
0:0	37	26.1	122
10:6	100	25.7	115
20:12	93	25.8	116
30:18	36	25.8	110
40:23	--	--	--
50:29	--	--	--
Coal Creek	50	27.2	--
Level of significance 1/		p=.0522	p=.0001*

1/ Fry from Coal Creek are excluded from this value.

* Significant at 0.95 level

Table 23. Mann-Whitney test comparing legnths and weights of bull trout fry emerging from the 0:0, 10:6, 20:12 and 30:18 gravel mixture during the controlled incubation experiment.

Mixture compared	p value length	weight
0:0 - 10:6	.0066*	.0001*
0:0 - 20:12	.0190*	.0005*
0:0 - 30:18	.0662	.0001*
10:6 - 20:12	.5486	.4837
10:6 - 30:18	.6394	.0071*
20:12 - 30:18	.9704	.0024*

*Significant at 0.95 level

5. Coal Creek's bull trout spawning area contained a significantly higher percentage of material smaller than 2.00 mm than found in spawning areas in Whale, Trail and Big Creeks. Percentage of material smaller than 6.35 mm in Coal Creek changed little from 1983 while increases in this size class were documented in Trail and Big Creeks.

6. Overall fish densities declined slightly in the upper Flathead Basin between the summers of 1982 and 1983.

7. The 1983 bull trout spawning run was smaller than the 1982 run, but was larger than the 5 year average (1979-1983).

8. Due to the long incubation period (223 days), bull trout embryos are highly susceptible to the effects of increased levels of fine material in the streambed. Entombment of alevins was observed during the field study and may be a major cause of mortality in Coal Creek.

9. Laboratory tests showed an inverse relationship between the percentage of fine material and bull trout embryos survival to emergence. Large variation in emergence success between replicates of most gravel mixtures, however, made it inappropriate to use these data to develop a sediment/survival model.

RECOMMENDATIONS

1. Logging and roading in riparian areas must be done with extreme care.

   A. Only salvage or intensively selective prescriptions should be considered.

   B. Logging should occur in winter when at least 1 m of snow cover is present.

   C. All skidding should be done over the snow using wide tracked caterpillar tread machines.

   D. No skid road should be constructed in riparian areas.

   E. Avoid skidding timber over natural water courses. All water courses should be flagged during sale layout to allow skidder operators to locate these areas even when snow covered.

   F. Closely supervise the contractor to insure road construction is completed in a proper and timely manner.

   G. Prohibit road construction activities in live stream channels.

H. Due to the adfluvial nature of the fishery, the cumulative effects from all timber development activities proposed under the 5 year plan should be assessed.

2. Monitoring effects of forest management activities on the fish resources of the Flathead National Forest should be continued. Future planning requires monitoring of past and present activities so impact can be predicted and mitigated. A commitment must be made for long term monitoring under various forest management activities if multiple-use management is to continue.

A. Continue monitoring the fish resource in Coal Creek through the course of the Coal Beetle Salvage Sale to assess the immediate impacts of timber harvest. After this period, monitoring should be conducted at 3 to 5 year intervals to document long-term changes and possible recovery.

B. Rephotograph the debris monitoring sections to document channel changes and debris movement.

C. Continue recording water levels and temperatures in Coal Creek to obtain long-term records for assessing changes in flow and temperature regimes associated with development.

D. Determine the extent of inter-gravel flow/ground water recharge in the high use spawning area near Dead Horse Bridge.

E. Continue to monitor the substrate composition in bull trout spawning areas of Coal, Whale, Trail and Big Creeks.

F. Determine what, if any, effect the beetle salvage sale on South Fork of Coal Creek has on downstream spawning and rearing areas.

G. Confirm the relationship between bull trout egg to fry survival and streambed composition.

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APPENDIX A

Maps showing the locations of the 1983 substrate monitoring transects in Coal, Big, Whale and Trail Creeks and measurements to actual coring sites on each transect are listed.

Table 1. Core sample site locations and distance between rebar stakes on each transect. Distances are meters from the left rebar when facing downstream.

Creek	Transect Number	1	2	3	4	Right rebar
Whale	1	4.8	5.8	11.1	12.0 1/	18.9
	2	5.2	6.8	11.9	13.5	18.3
	3	3.7	6.3	7.7	8.8	22.5
Coal	4	9.4	10.6	11.7	13.1	15.8
	5	9.0	10.9	12.4	13.3	15.3
	6	8.4	9.3	10.8	12.4	15.0
	7	6.2	8.2	18.8	12.6	20.6
	8	6.4	7.9	10.0	11.5	20.7
Big	9 2/	6.0	9.1	10.5	11.5	18.3
	10 2/	6.2	7.6	8.6	10.4	17.0
	11	6.1 1/	11.1 1/	13.8 1/	14.0 1/	25.5
Trail	12	5.1	7.4	8.3	13.6	15.9
	13	6.4 1/	7.1	9.8	12.1	18.4
	14	7.5	9.7	11.8	15.6	19.9

1/ These sites were relocated during 1983.

2/ These transects were relocated during 1983.

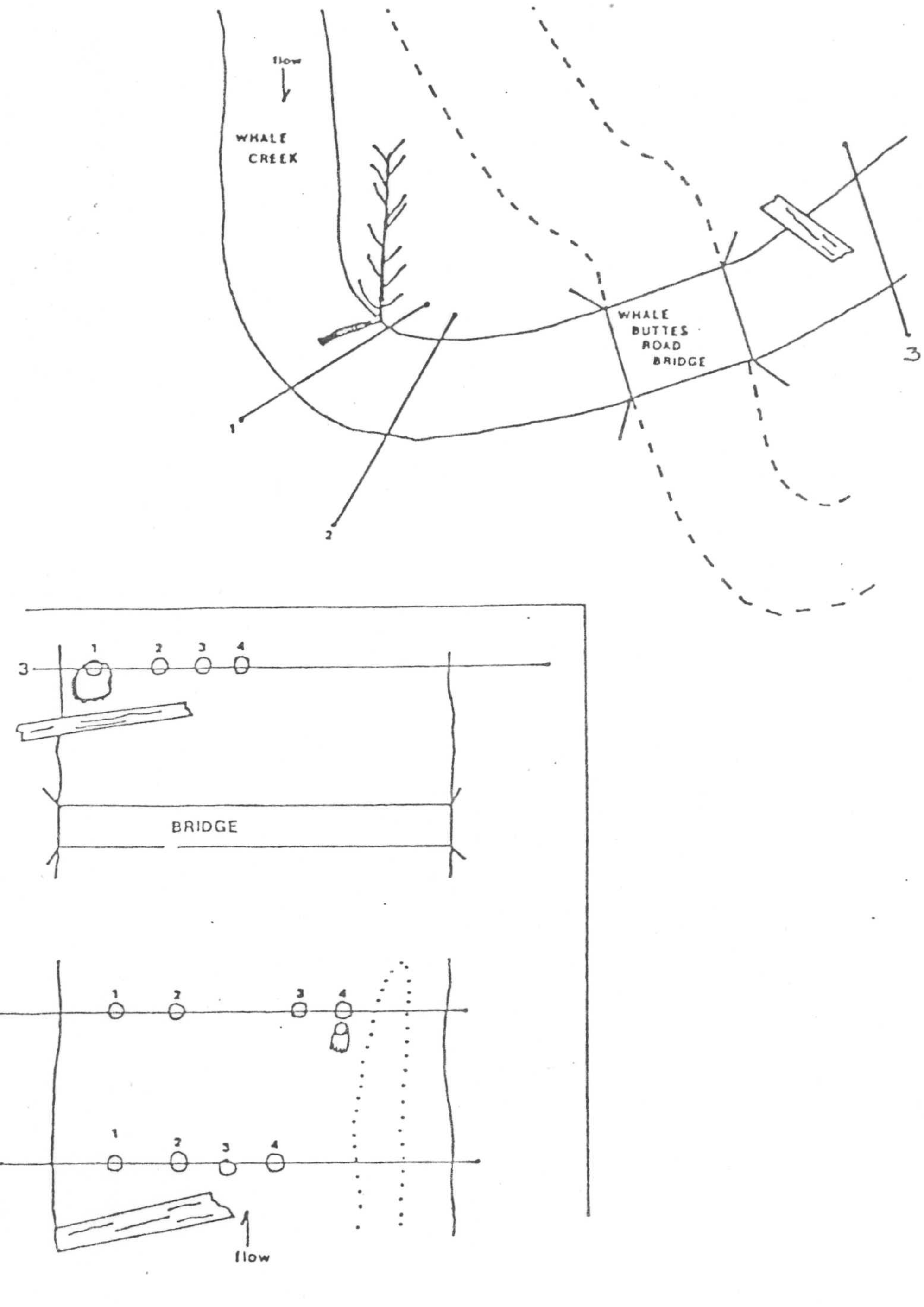

Figure 1. Substrate monitoring transect locations and coring sites on each transect in the Whale Buttes Road Bridge sampling area during fall of 1983.

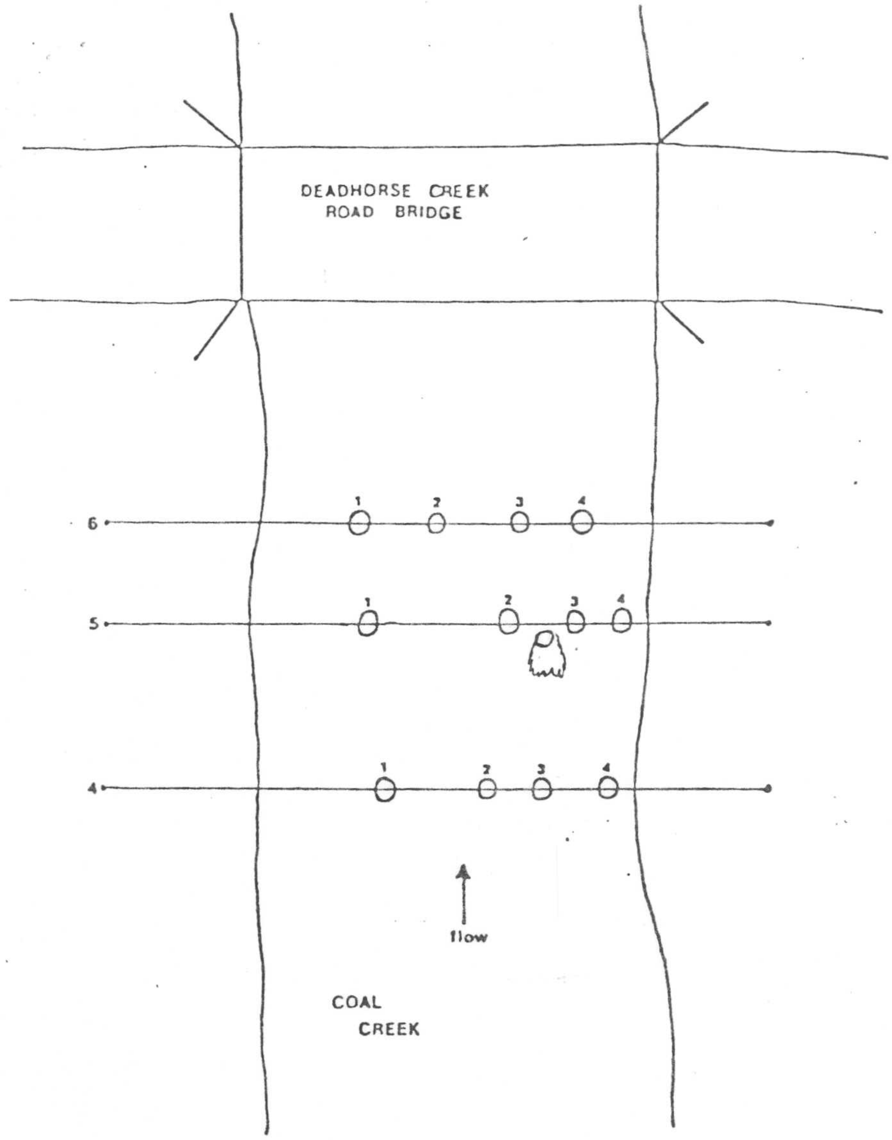

Figure 2. Substrate monitoring transect locations of coring sites on each transect in the Cyclone Road sampling area of Coal Creek during fall of 1983.

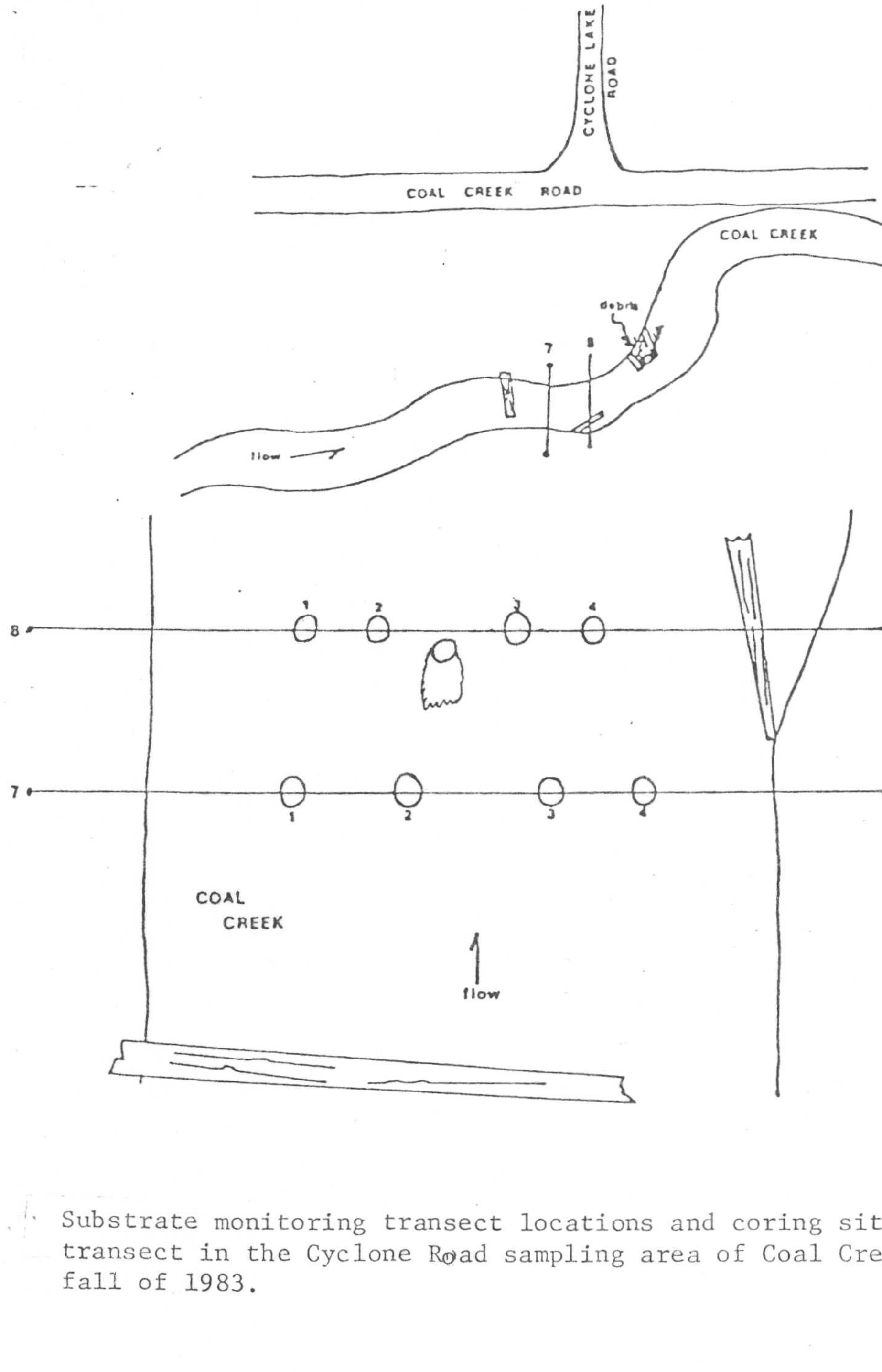

Figure 3. Substrate monitoring transect locations and coring sites on each transect in the Cyclone Road sampling area of Coal Creek during fall of 1983.

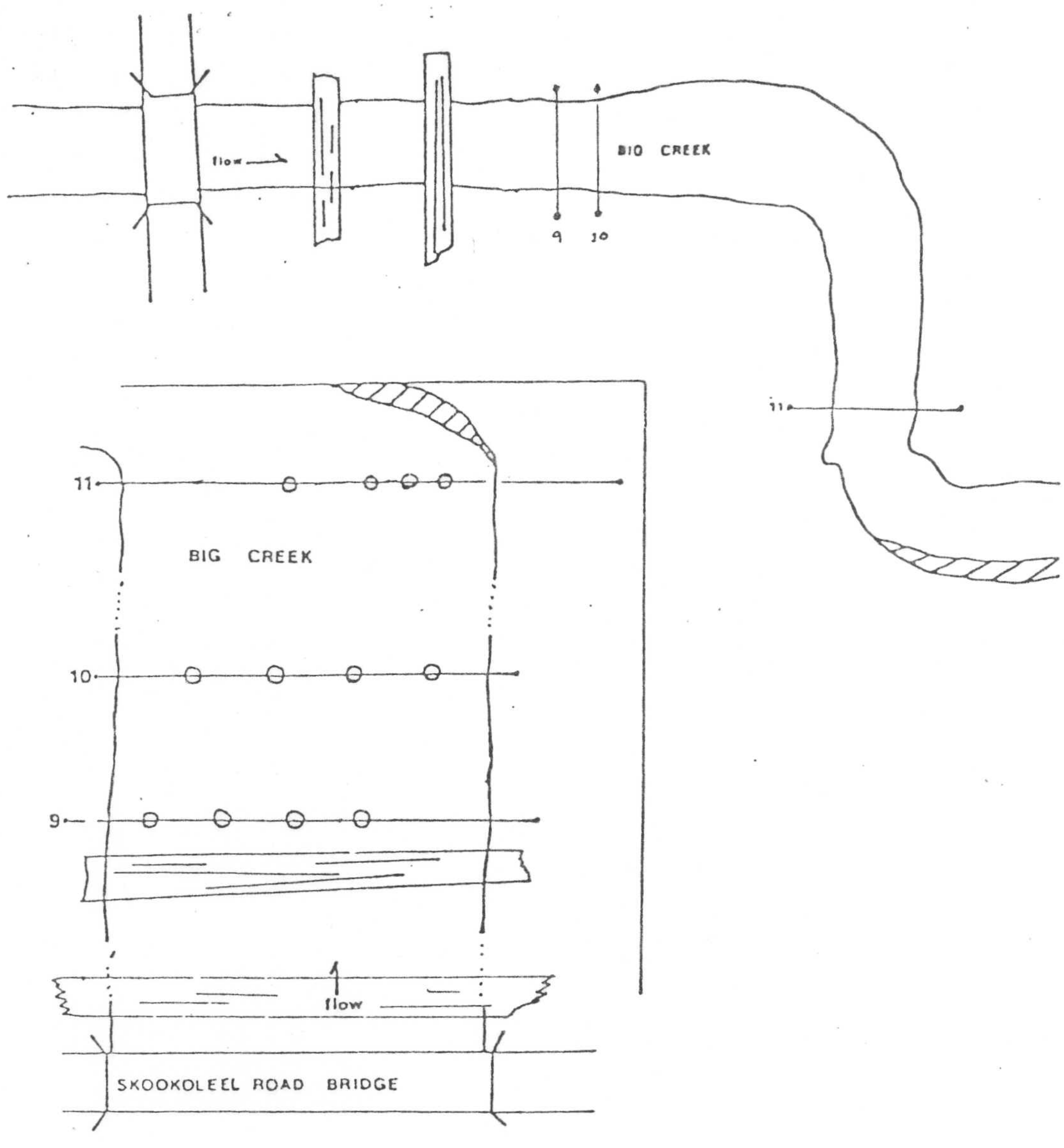

Figure 4. Substrate monitoring transect locations and coring sites on each transect in the Skookoleel Bridge sampling area of Big Creek during fall of 1983.

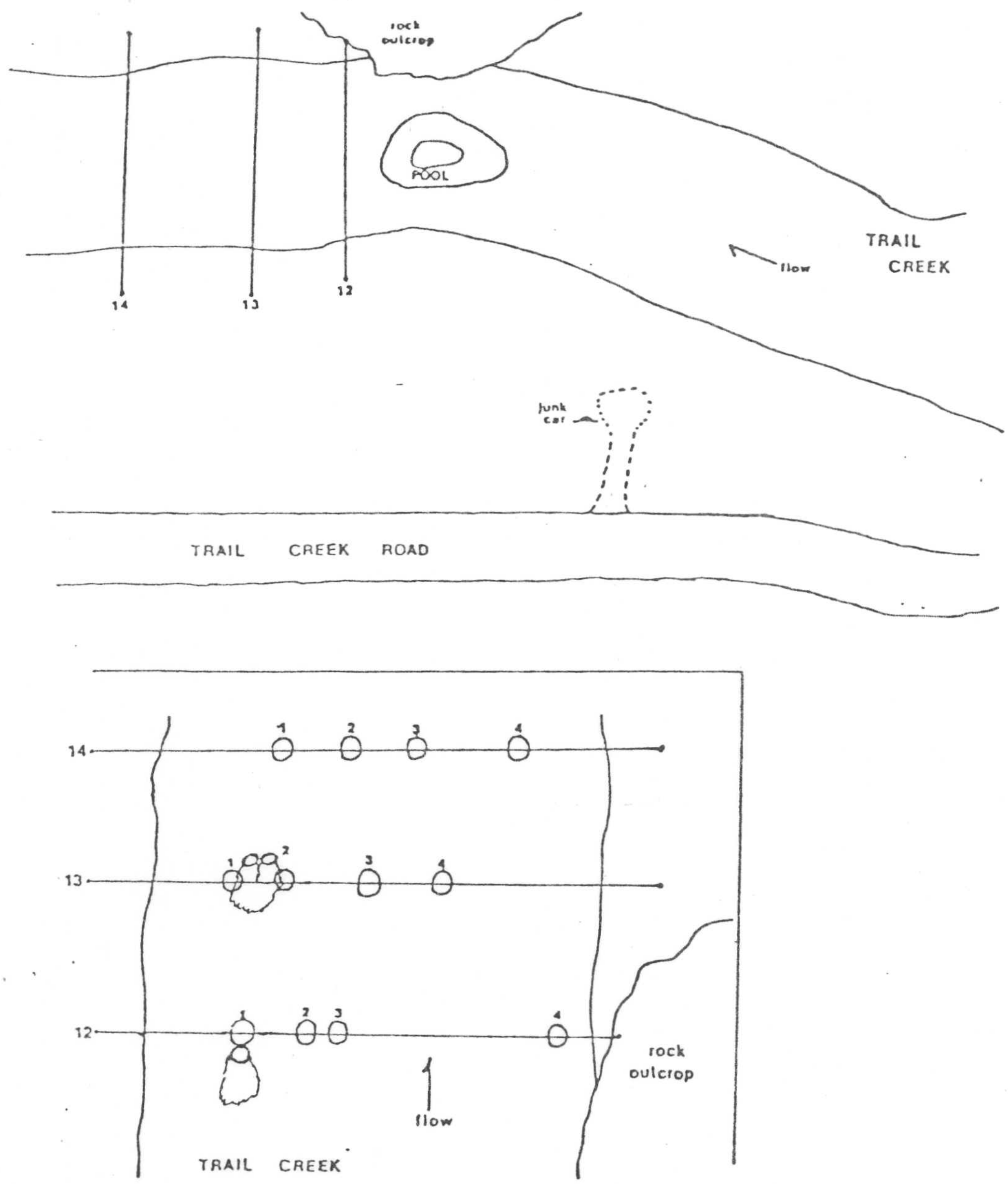

Figure 5. Substrate monitoring transect locations and coring sites on each transect in the junk car sampling area of Trail Creek during fall of 1983.

APPENDIX B

Seasonal water level fluctuations in selected tributaries to the North Fork of the Flathead River during portions of 1979, 1980, 1981, 1983 and 1983.

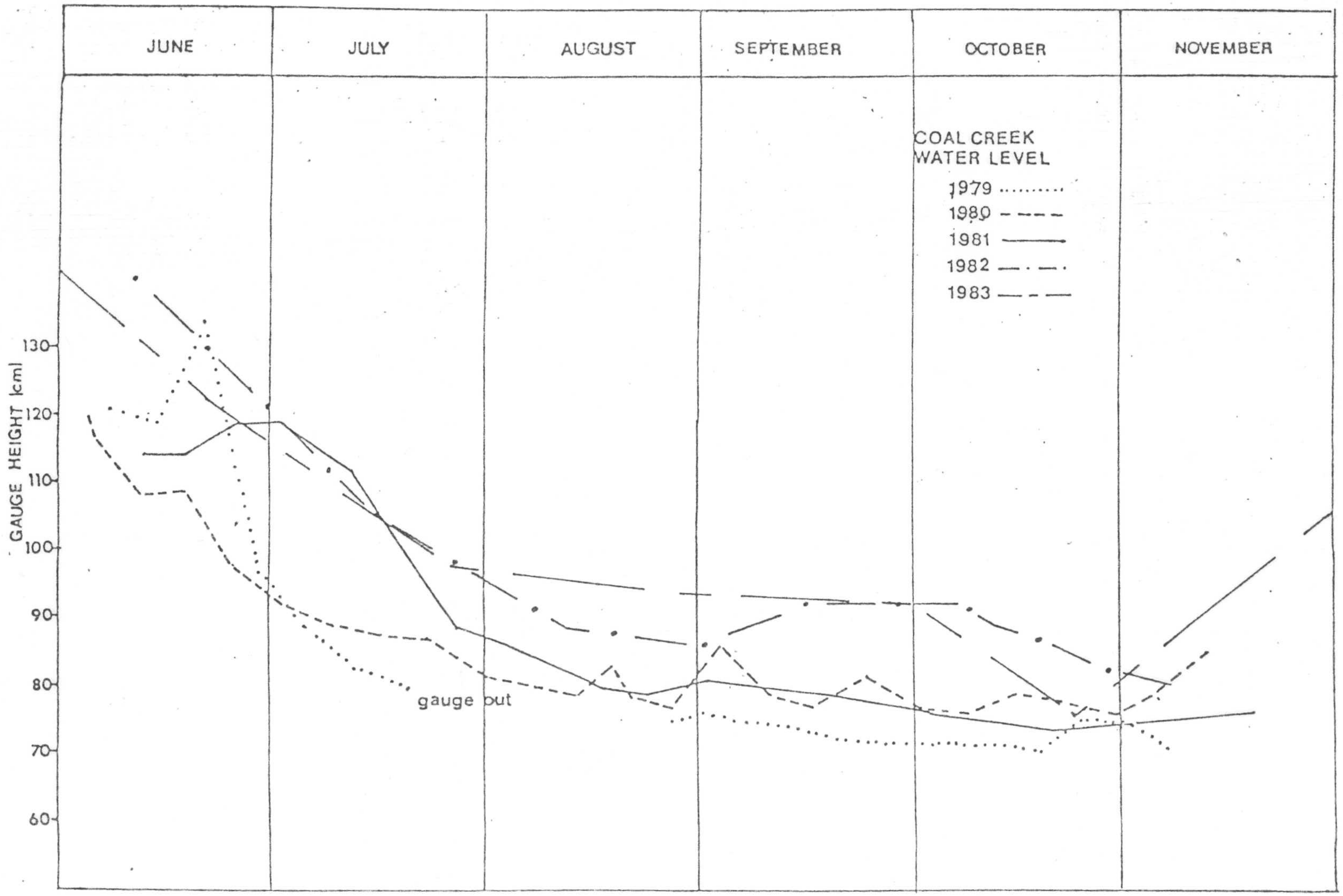

Figure 1 . Seasonal water level fluctuations in Coal Creek at the North Fork Road bridge during summer and fall 1979, 1980, 1981, 1982 and 1983.

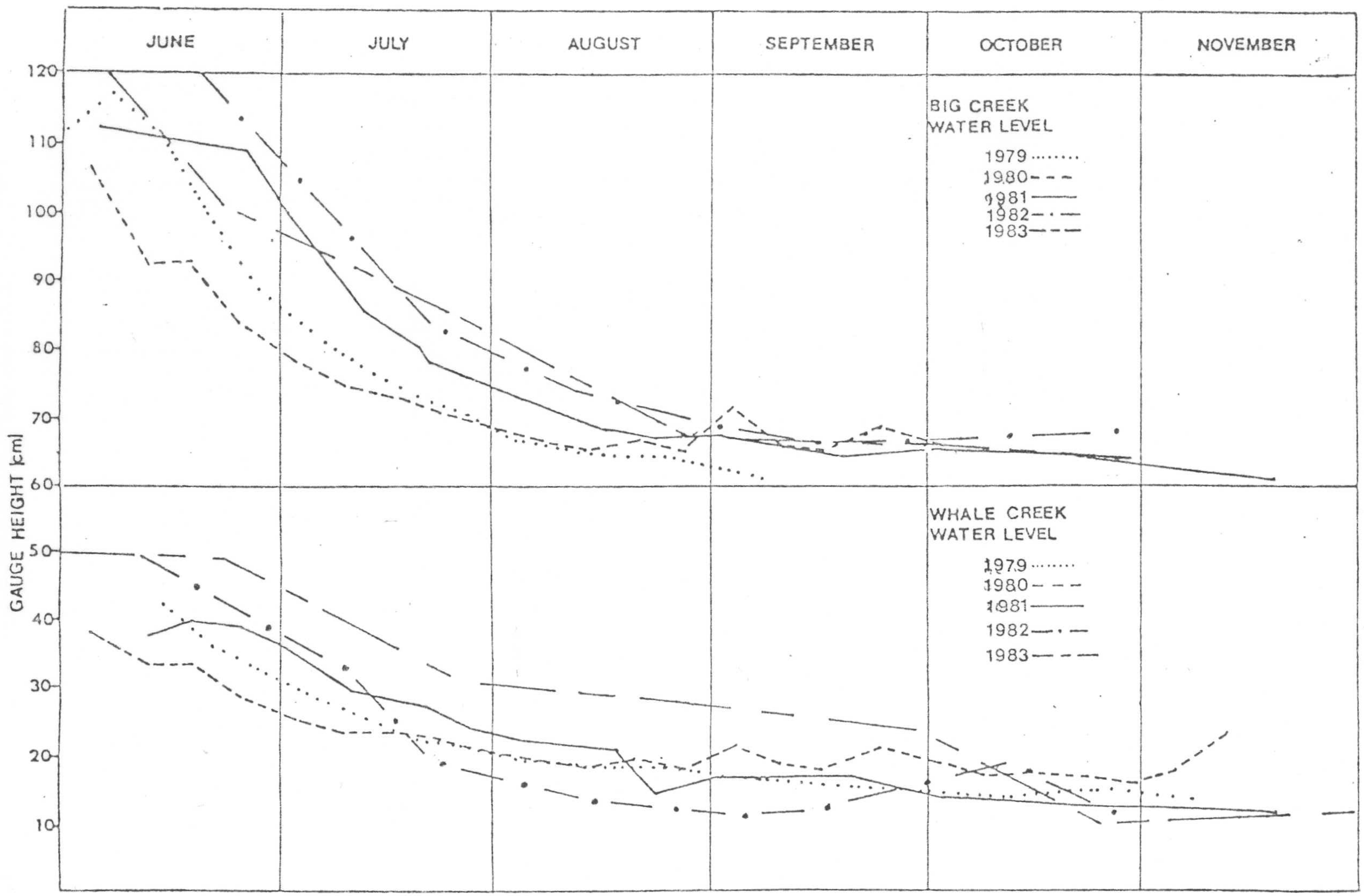

Figure 2 . Seasonal water level fluctuations in Big Creek (top) and Whale Creek (bottom) during the summer and fall 1979, 1980, 1981, 1982 and 1983.

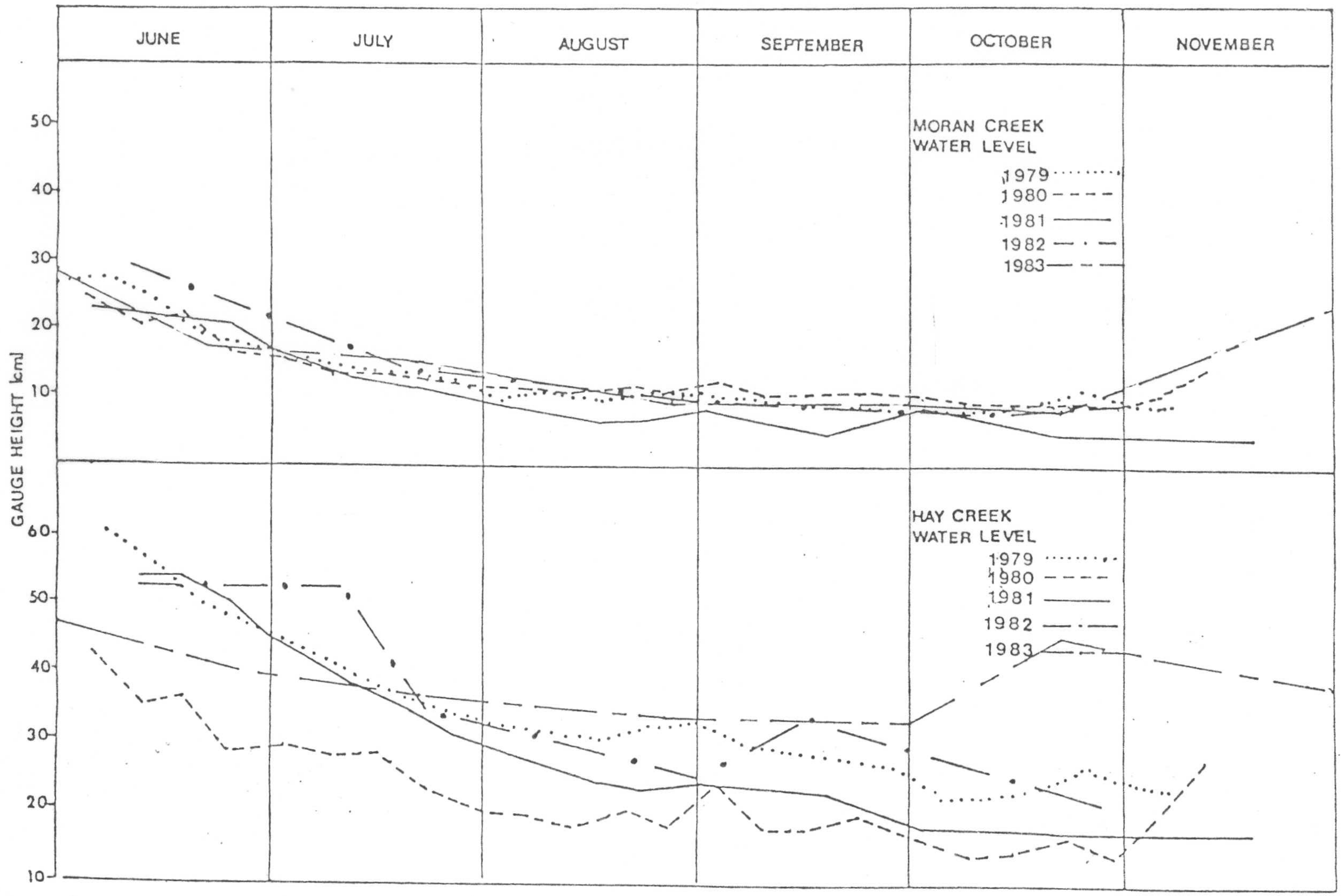

Figure 3. Seasonal water level fluctuations in Moran Creek (top) and Hay Creek (bottom) during the summer and fall 1979, 1980, 1981, 1982 and 1983.

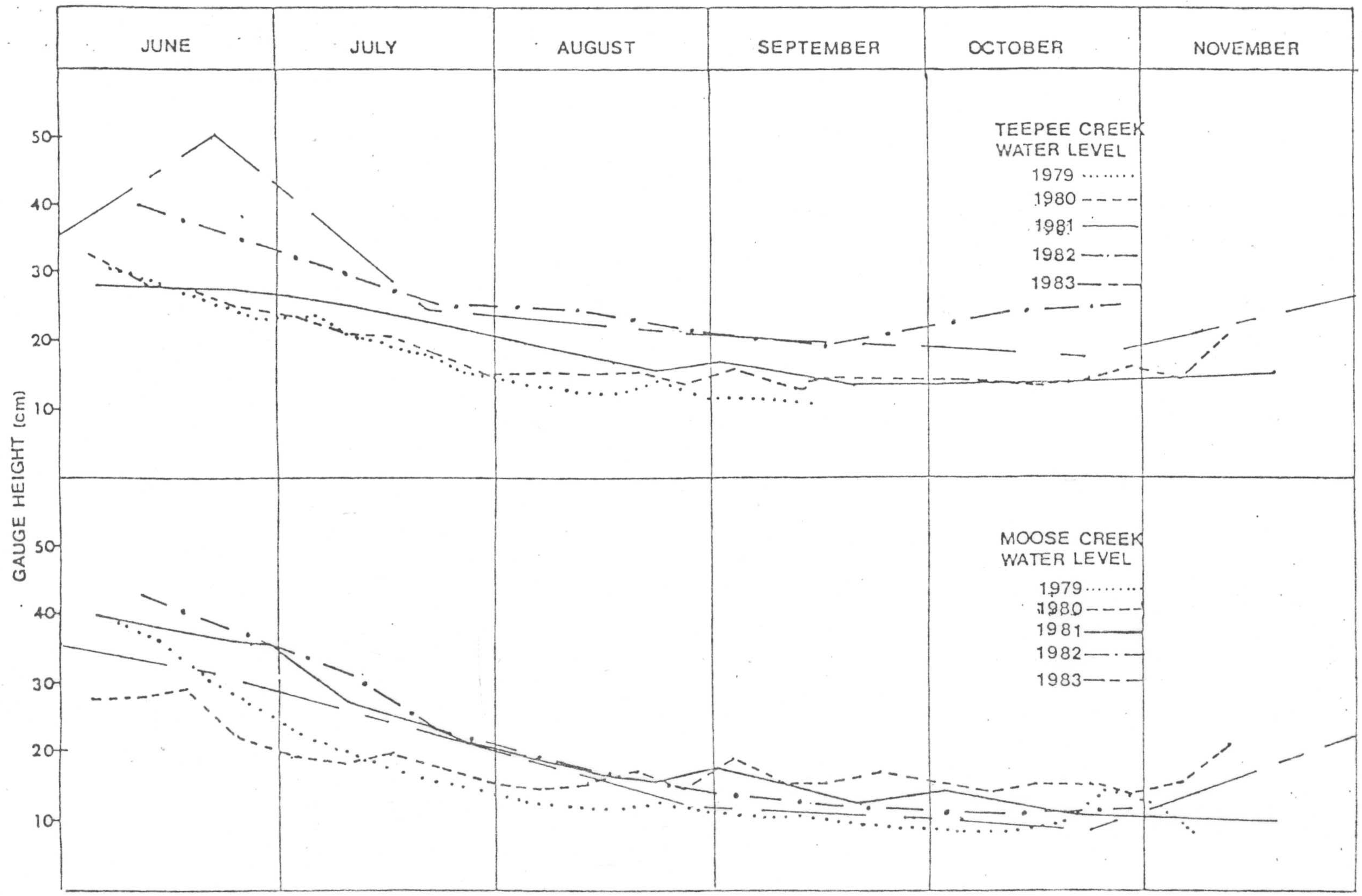

Figure 4. Seasonal water level fluctuations in Teepee Creek (top) and Moose Creek (bottom) during summer and fall 1979, 1980, 1981, 1982 and 1983.

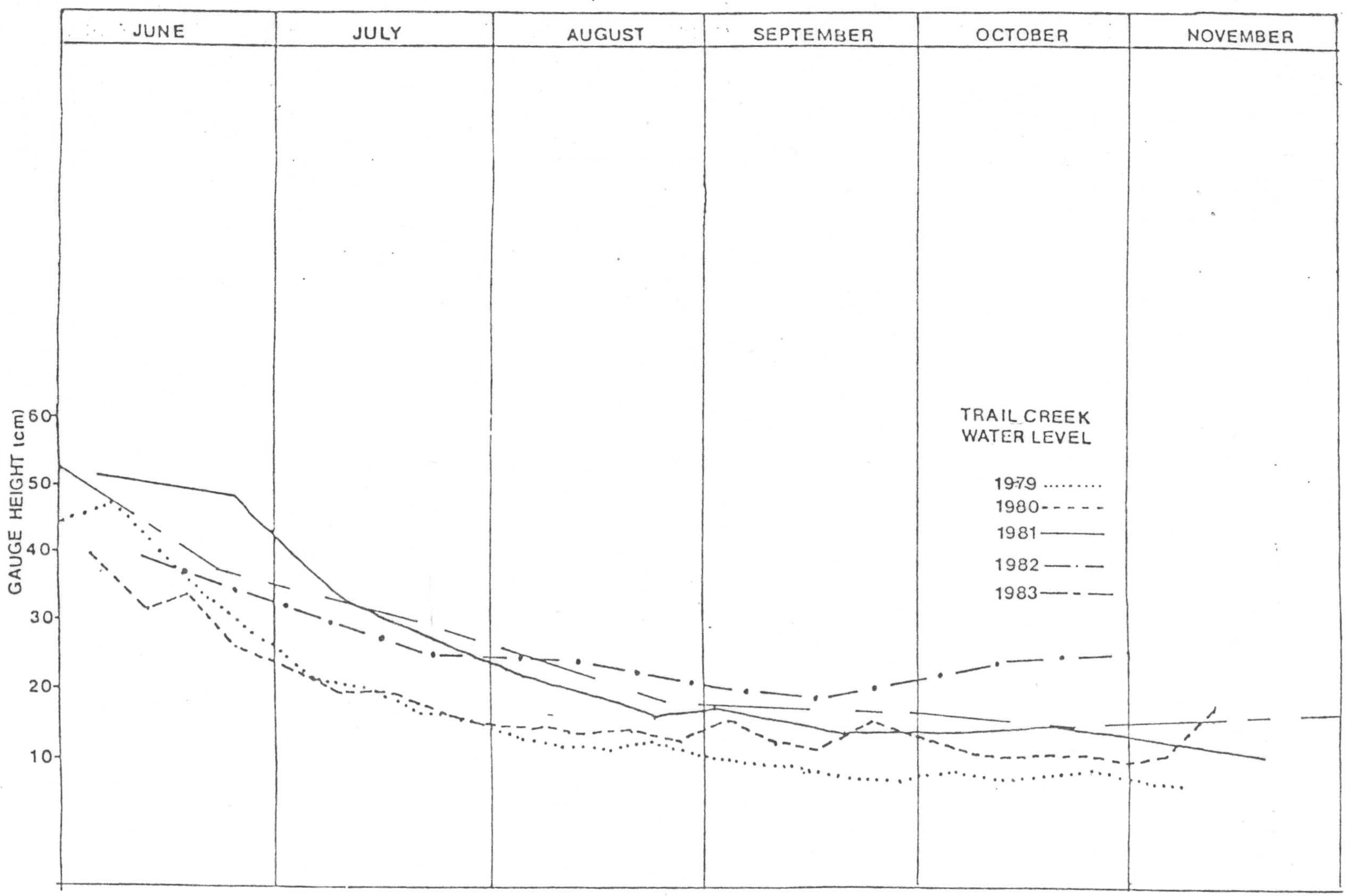

Figure 5. Seasonal water level fluctuations in Trail Creek during the summer and fall 1979, 1980, 1981, 1982 and 1983.

APPENDIX C

Photographs documenting channel areas of the two instream debris monitoring sections during 1983.

Figure 1. Photographs number 1 and 2 of the Dead Horse Bridge debris monitoring section.

Figure 2. Photographs number 3 and 4 of the Dead Horse Bridge debris monitoring section.

Figure 3. Photographs number 5 and 6 of the Dead Horse Bridge debris monitoring section.

Figure 4. Photographs number 7 and 8 of the Dead Horse Bridge debris monitoring section.

Figure 5. Photographs number 9 and 10 of the Dead Horse Bridge debris monitoring section.

Figure 6. Photographs number 1 and 2 of the Riparian Sale area debris monitoring section.

Figure 7. Photographs number 3 and 4 of the Riparian Sale area debris monitoring section.

Figure 8. Photographs number 5 and 6 of the Riparian Sale area debris monitoring section.

Figure 9. Photographs number 7 and 8 of the Riparian Sale area debris monitoring section.

APPENDIX D

Substrate composition for each site sampled during fall of 1983, in the four North Fork tributaries.

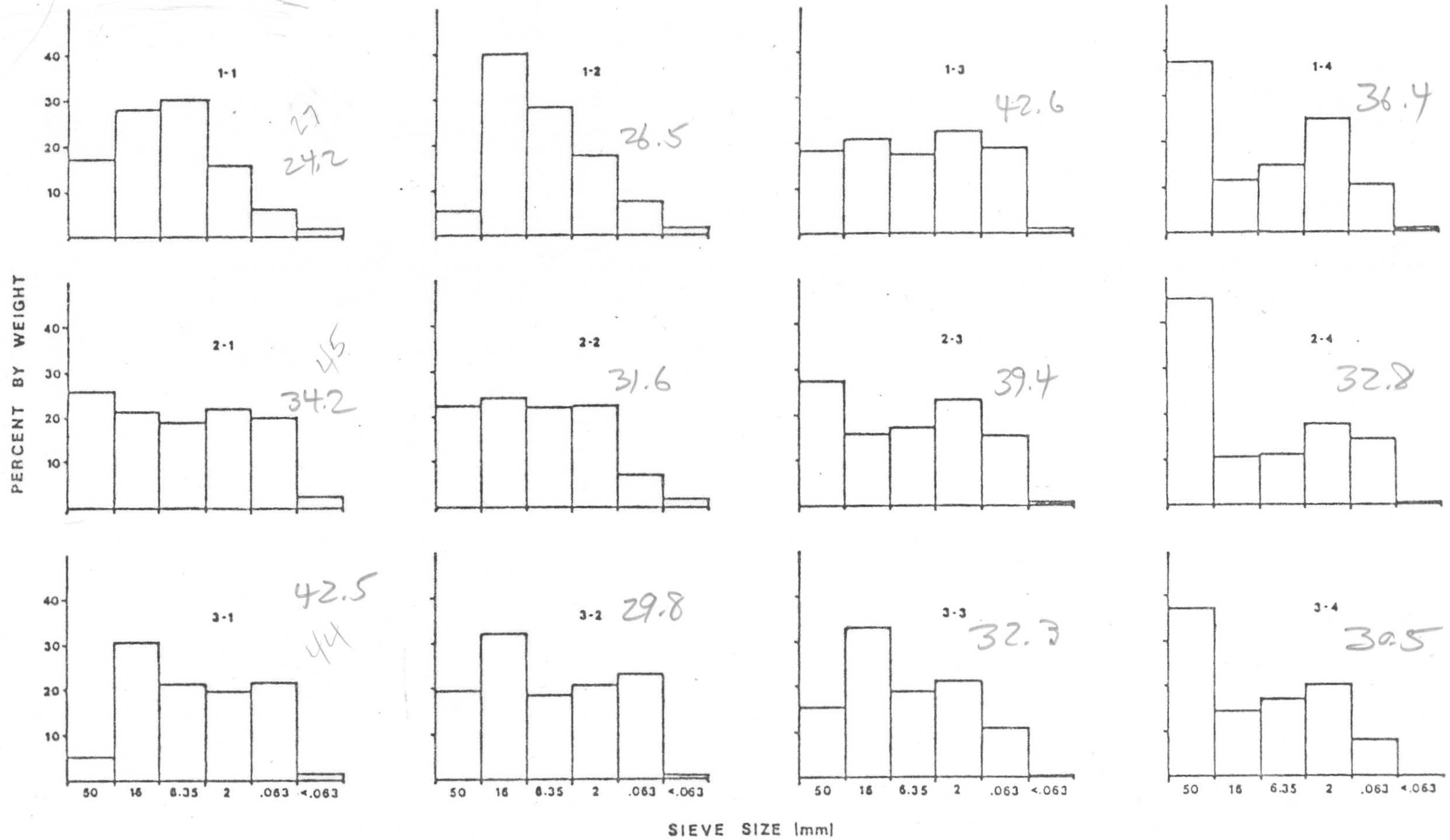

Figure 1. Substrate composition by dry weight from transects 1, 2, and 3 in Whale Creek during November 1983.

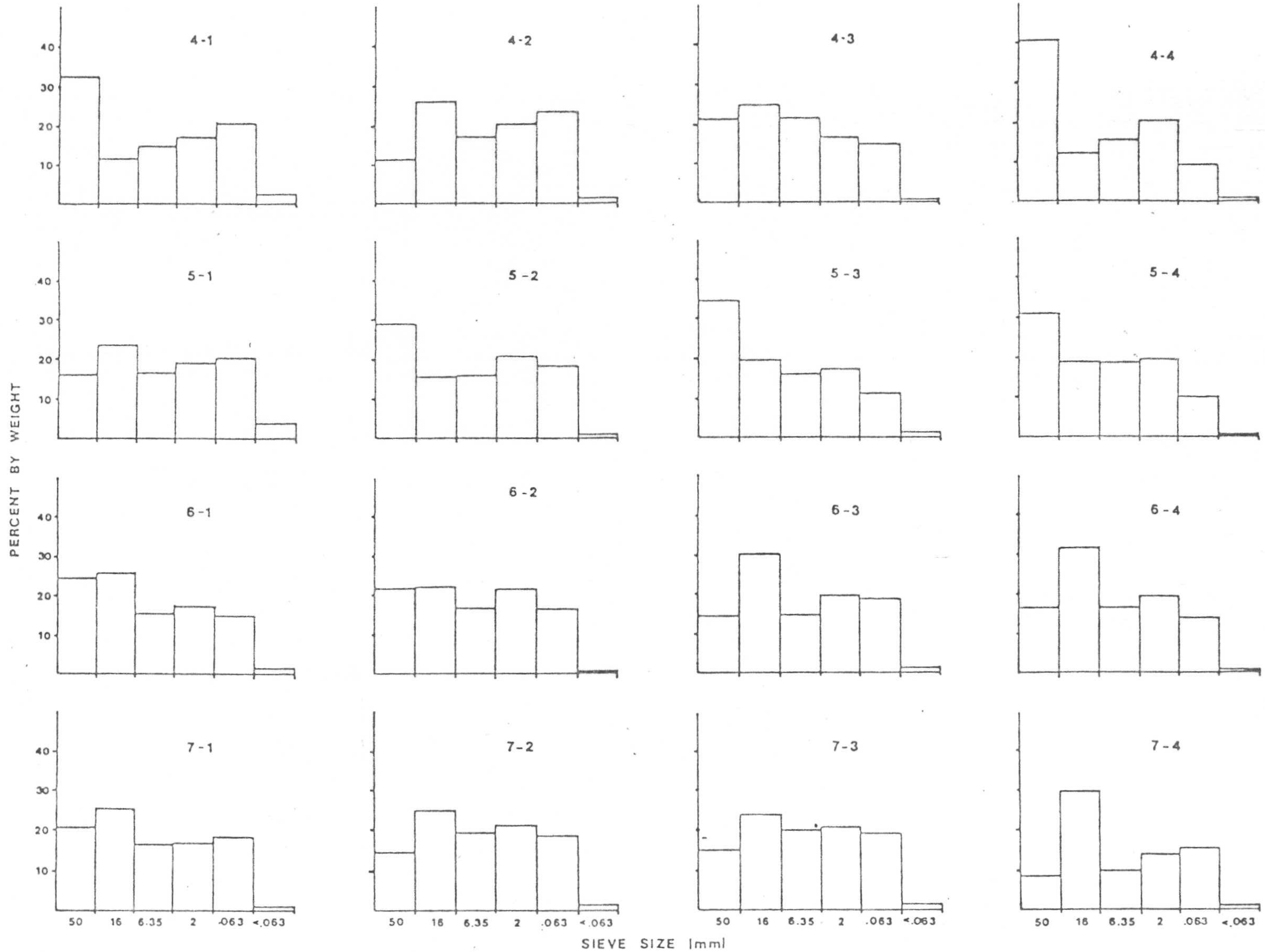

Figure 2. Substrate composition by dry weight from transects #4, #5, #6 and # 7 in Coal Creek during November 1983.

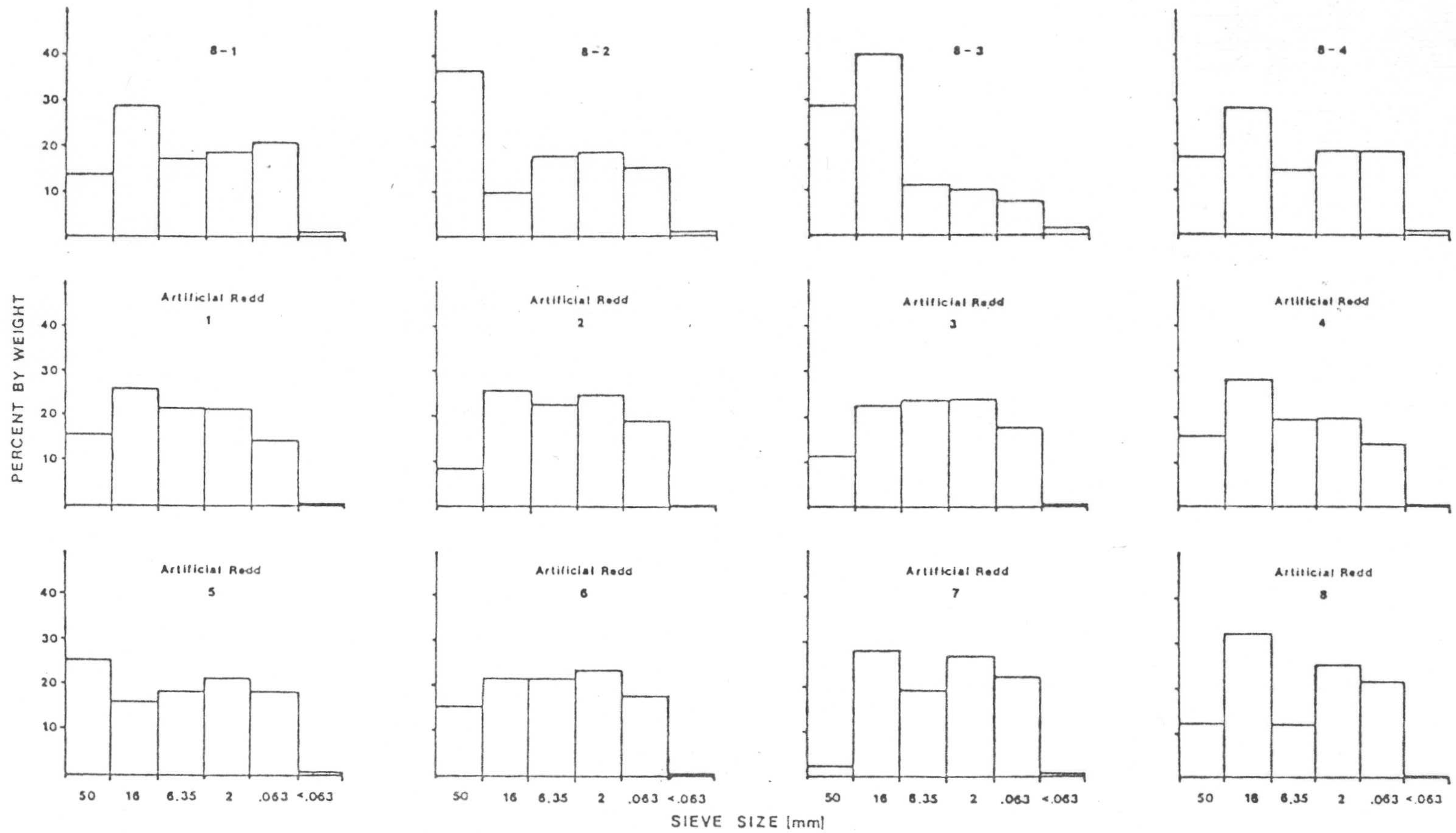

Figure 3. Substrate composition by dry weight from transect #8 and the artificial redds in Coal Creek during Fall of 1983.

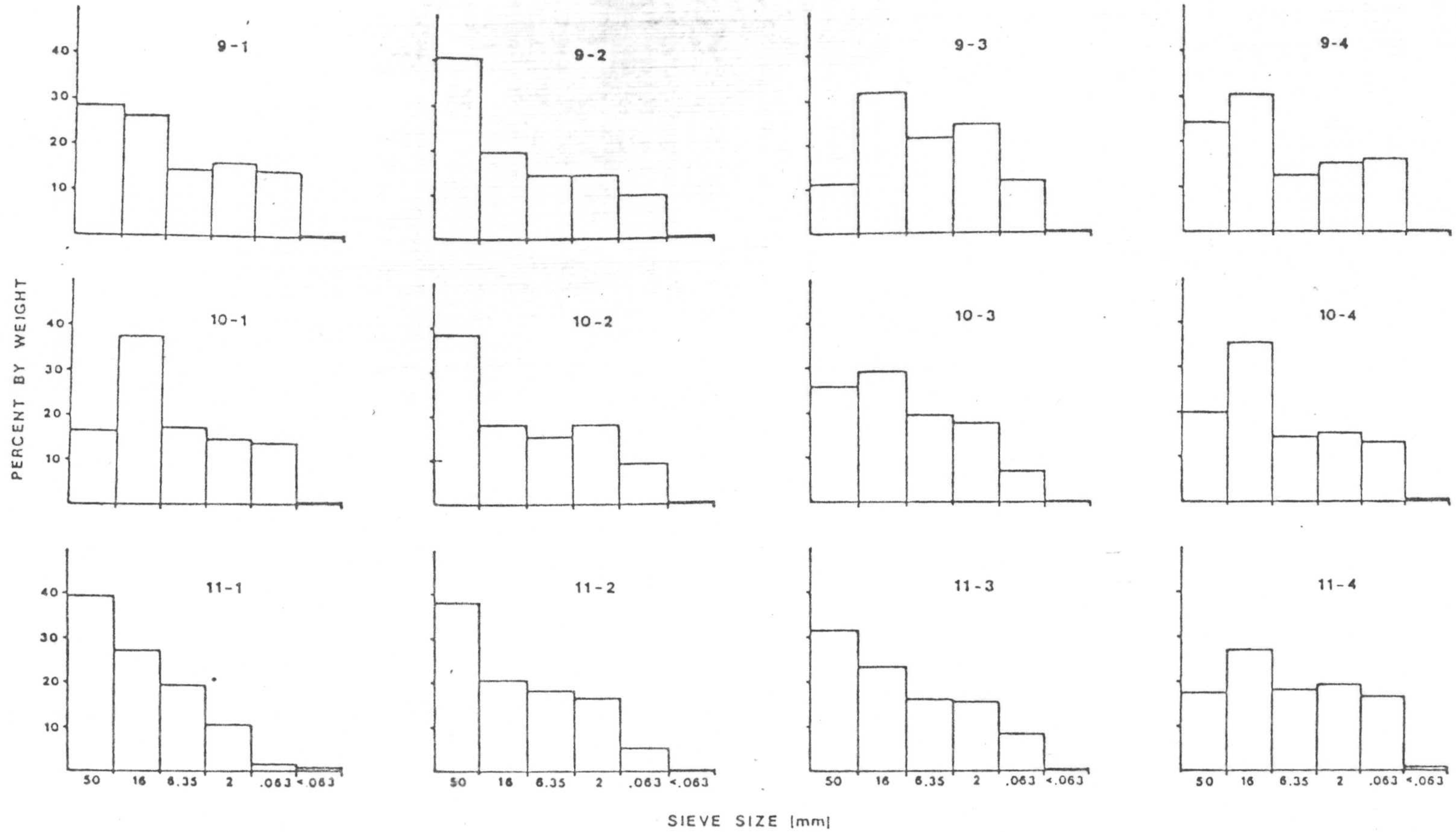

Figure 4. Substrate composition by dry weight from transects #9, #10 and #11 in Big Creek during November 1983.

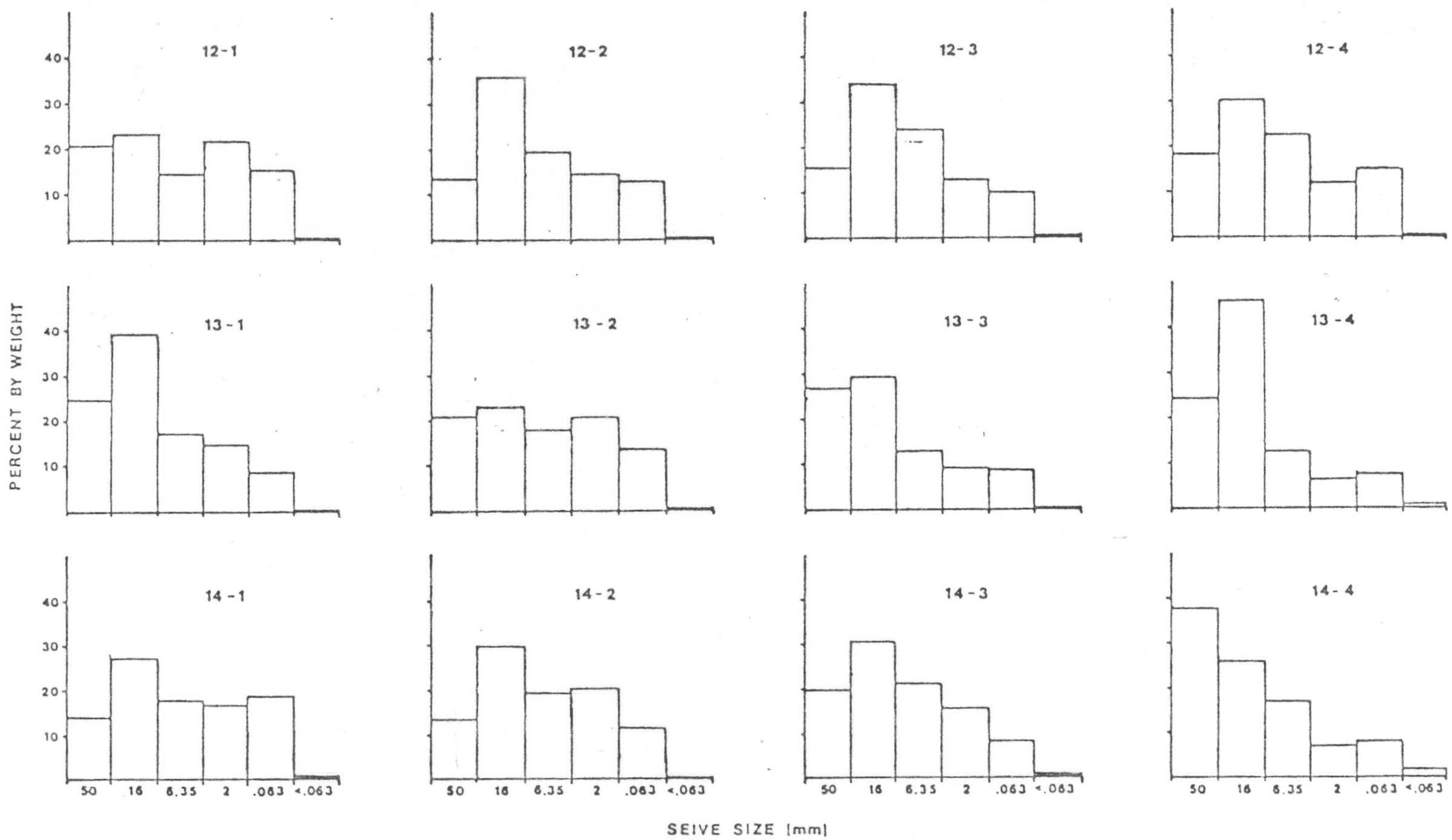

Figure 5. Substrate composition by dry weight from transects #13, #13 and #14 in Trail Creek during November 1983.

APPENDIX E

Bull trout redd frequency distributions for the Big, Whale and Trail Creek Drainages during 1983.

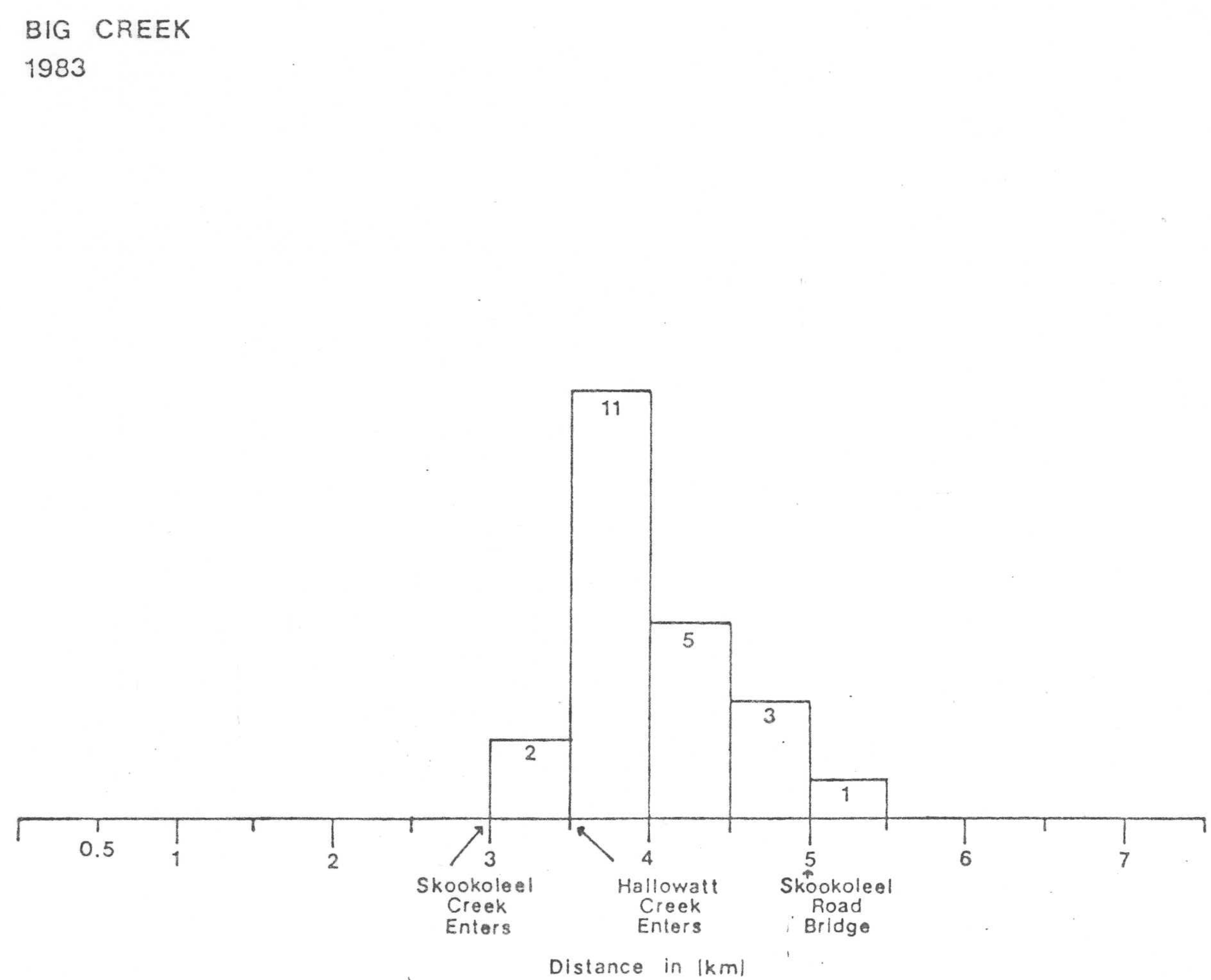

Figure 1. Bull trout redd frequency distribution in the Big Creek spawning areas during October 1983.

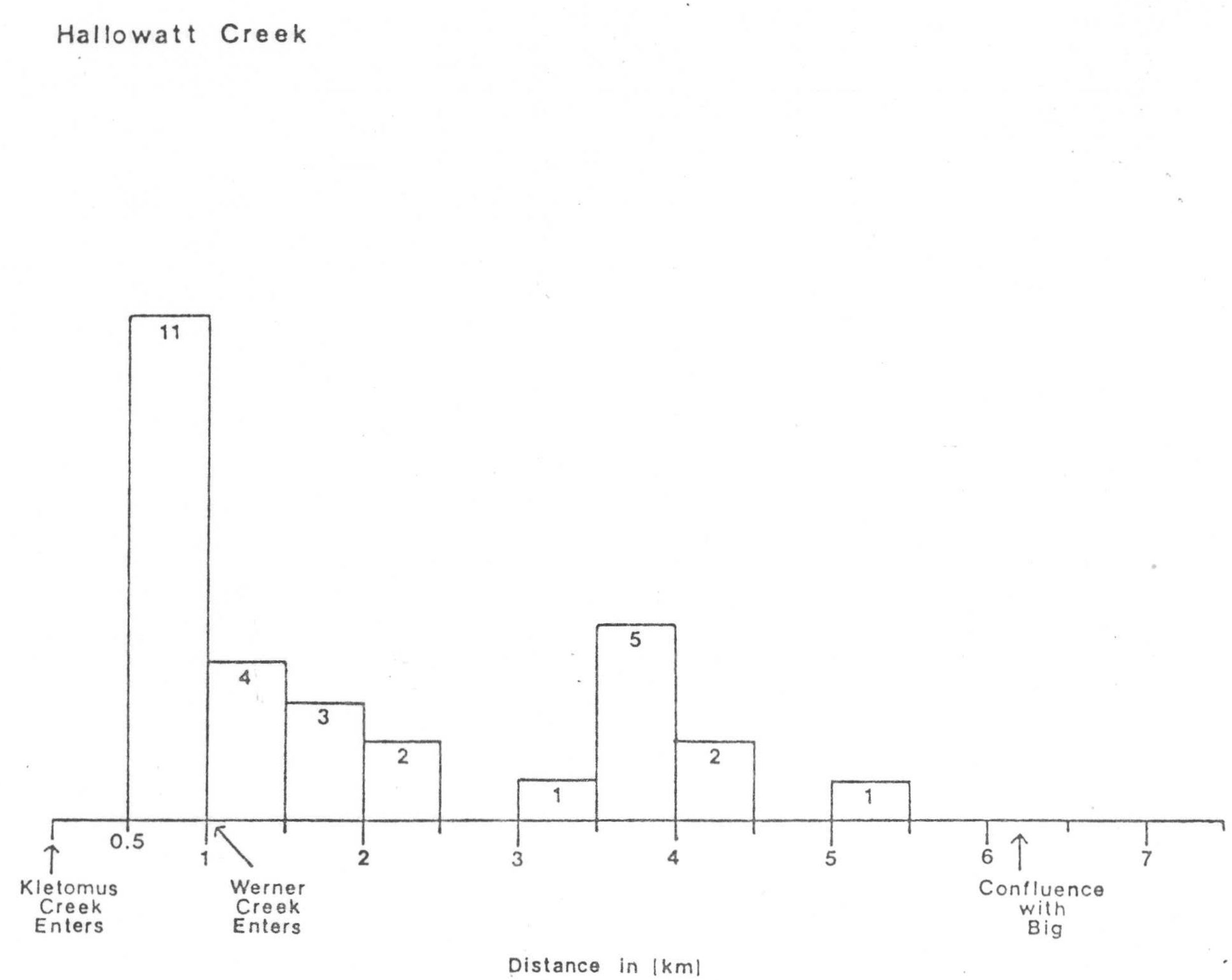

Figure 2. Bull trout redd frequwncy distribution in the Hallowatt Creek spawning area during October 1983.

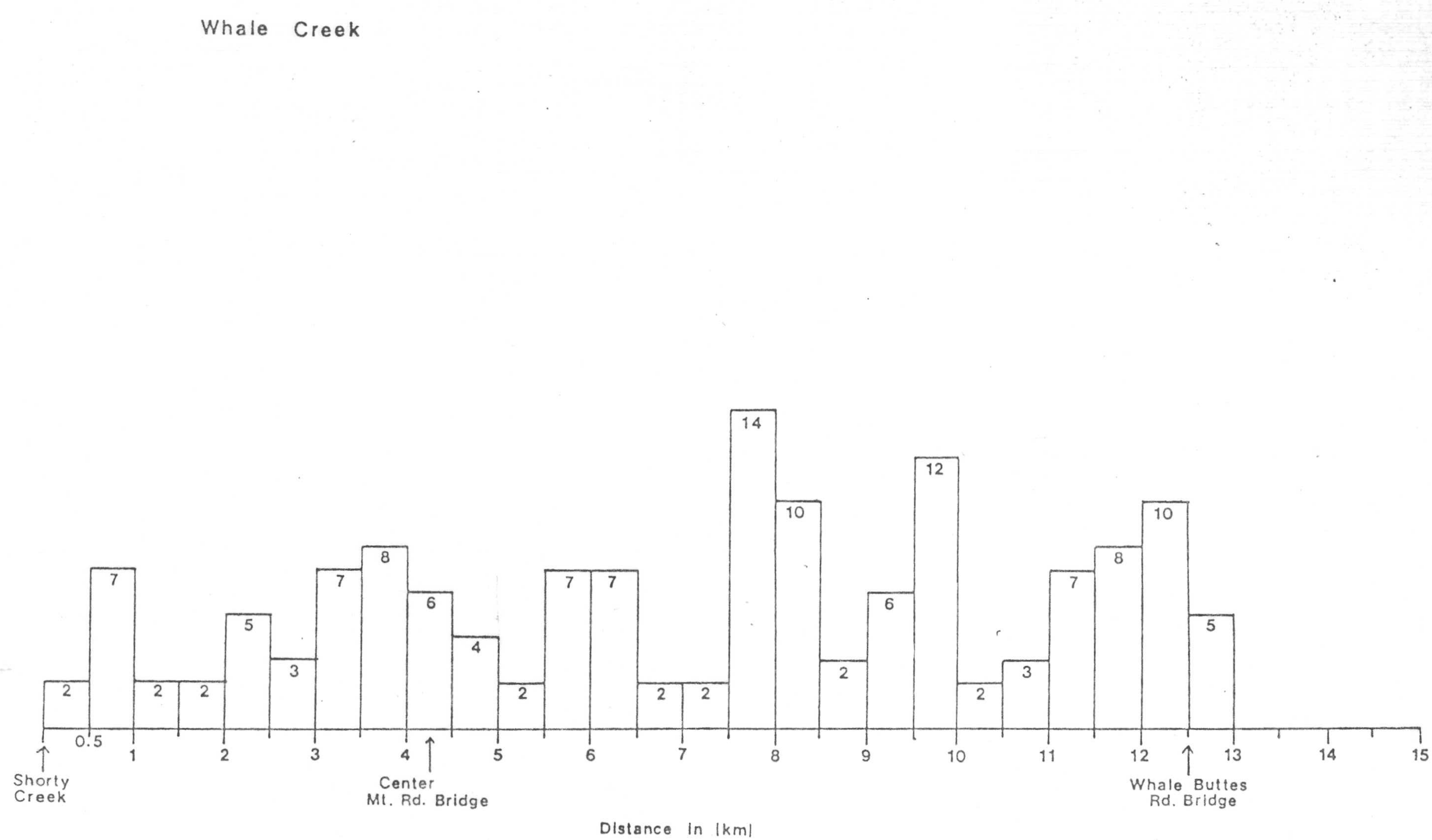

Figure 3. Bull trout redd frequency distribution in the Whale Creek spawning area during October 1983.

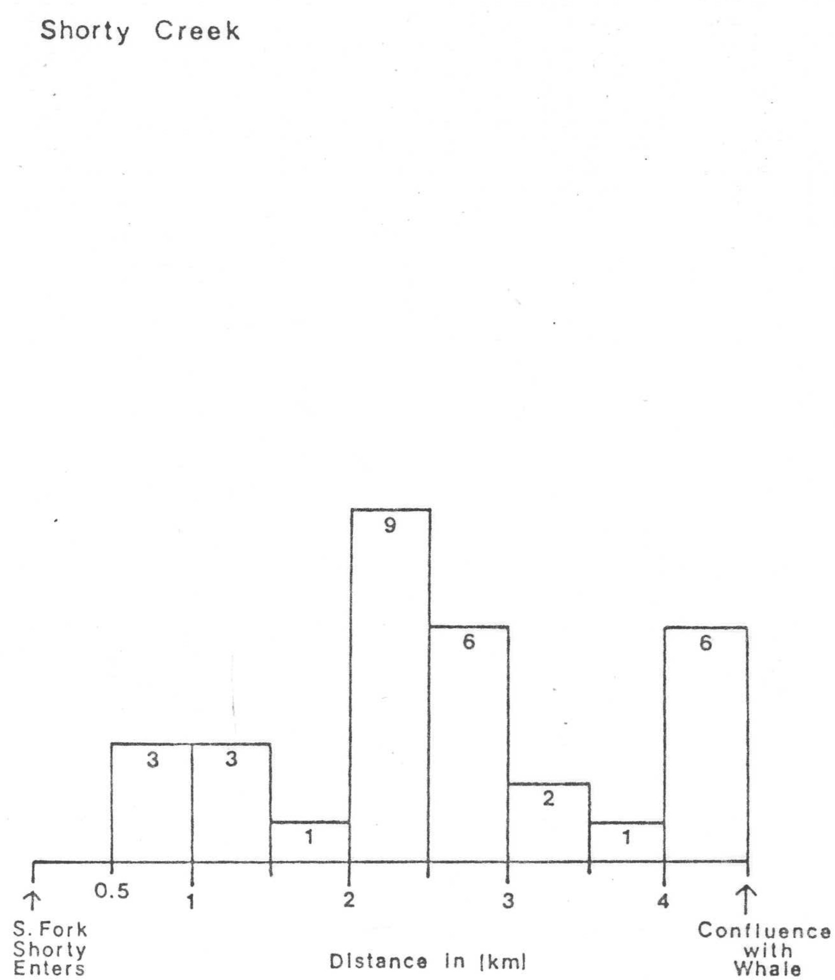

Figure 4. Bull trout redd frequency distribution in the Shorty Creek spawning area during October 1983.

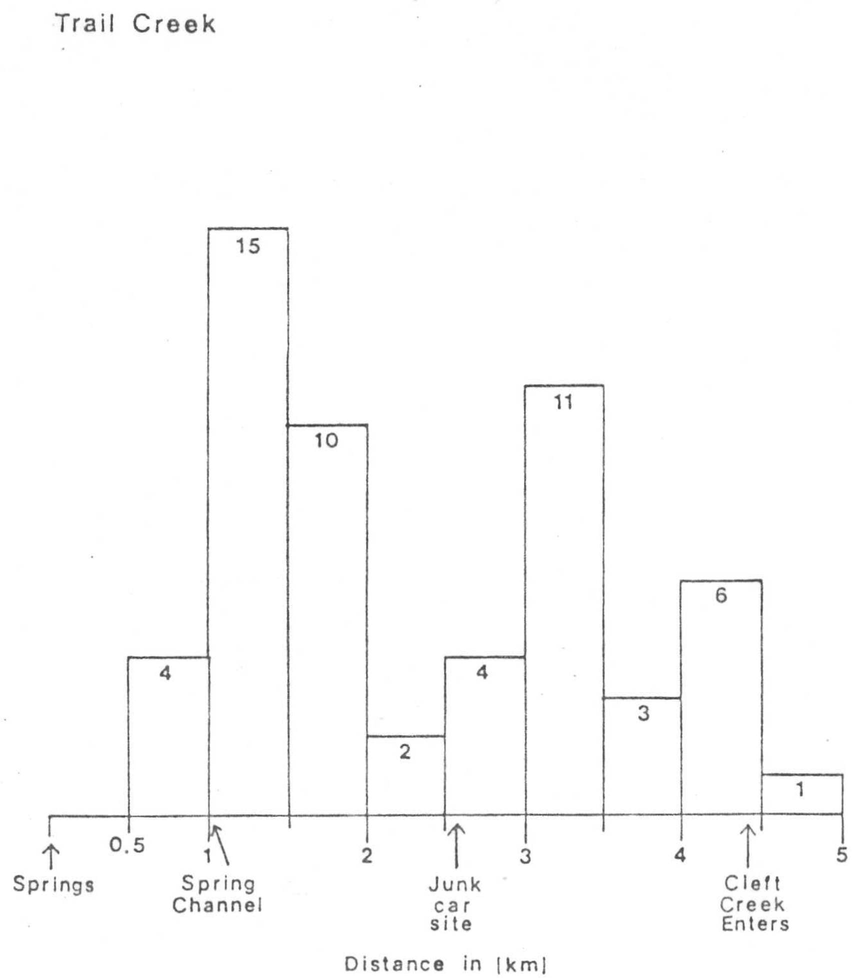

Figure 5. Bull trout redd frequency distribution in the Trail Creek spawning area during October 1983.