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IMPACTS OF A FIRE-FLOOD EVENT ON PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF A SMALL MOUNTAIN STREAM

by

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APPROVAL

of a thesis submitted by

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Date 22 July, 1988

VITA

Mark Anthony Novak, son of Ernest and Mary Ann Novak, was born in Oklahoma City, Oklahoma, on 26 November, 1959. He attended Adlai Stevenson High School and Henry Ford II High School, Sterling Heights, Michigan, and graduated from the latter in June 1977. In September 1978 he entered Western Michigan University, Kalamazoo, Michigan, and received a Bachelor of Science degree in Biology and Geography in June 1983. He began graduate studies and research toward a Master of Science degree in Fish and Wildlife Management at Montana State University in August 1984.

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My thanks, especially, to my wife Lisbeth, for her support and patience during my graduate studies and to my parents and family for their constant encouragement.

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ABSTRACT

A forest fire burned 4811 ha of the lower Beaver Creek drainage and was followed by an intense convectional rainstorm causing extensive soil erosion. Runoff from the event caused physical and biological degradation of the stream. This study evaluated recovery of trout and aquatic macroinvertebrates, use of the stream by spawning adfluvial rainbow trout, emigration of young-of-the-year rainbow trout to the Missouri River, and changes in substrate composition. Two months after the fire and flood trout populations in the impacted portion of the stream were nearly eliminated; within 2 years, numbers of age-0 to age-III rainbow trout had increased to 5978/ha (68.68 kg/ha), compared to an abundance of 3841/ha (49.34 kg/ha) before the event. The resident brown trout stock did not recover during the period of the study. Numbers of adfluvial rainbow trout spawners using Beaver Creek did not differ significantly from pre-event years, however, there was a large increase in recruitment of young-of-the-year rainbow trout to the Missouri River. Fine sediments <0.85 mm increased significantly ($P<0.05$) in riffle areas following the event; fine sediments decreased 7.7% in riffle areas in 2 years. Adult rainbow trout selected spawning sites containing significantly less fine sediments ($P<0.05$) than were measured in randomly sampled riffles. The benthic community was assumed to have been severely reduced by scouring of the substrates during the flood. The benthic community had recovered by fall 1986, however, percent occurrence of several taxa was lower in the impacted area due to greater embeddedness of cobble substrates.

INTRODUCTION

The North Hill Fire in Helena National Forest began on 27 August, 1984 approximately 30 km north of Helena, Montana (Figure 1). Sixty-four-kilometer-per-hour winds drove the fire rapidly to the northeast and across the Missouri River near the mouth of Beaver Creek. By 30 August, the fire had advanced approximately 20 km into the Gates of the Mountains Wilderness Area and affected 11,000 ha, including 26% (4811 ha) of the lower Beaver Creek drainage. On 31 August an intense convectional rainstorm moved over the burn area depositing 32.5 mm of precipitation in 20 minutes (Putnam 1985). Runoff from the burn area caused a flood exceeding that of a 100-year event. This study was initiated to assess the effects of the fire-flood event on biota and habitat of Beaver Creek.

Fire is a natural occurrence; suppression of such natural perturbations by man results in build-up of fuel on the forest floor, increasing the potential severity of fire events. In some landform types, fire may be the major contributor to landform shaping processes and cartographic characteristics (Swanston 1971). In pyrolytic ecosystems, fire is a major factor in nutrient cycling and energy flow,

STUDY AREA

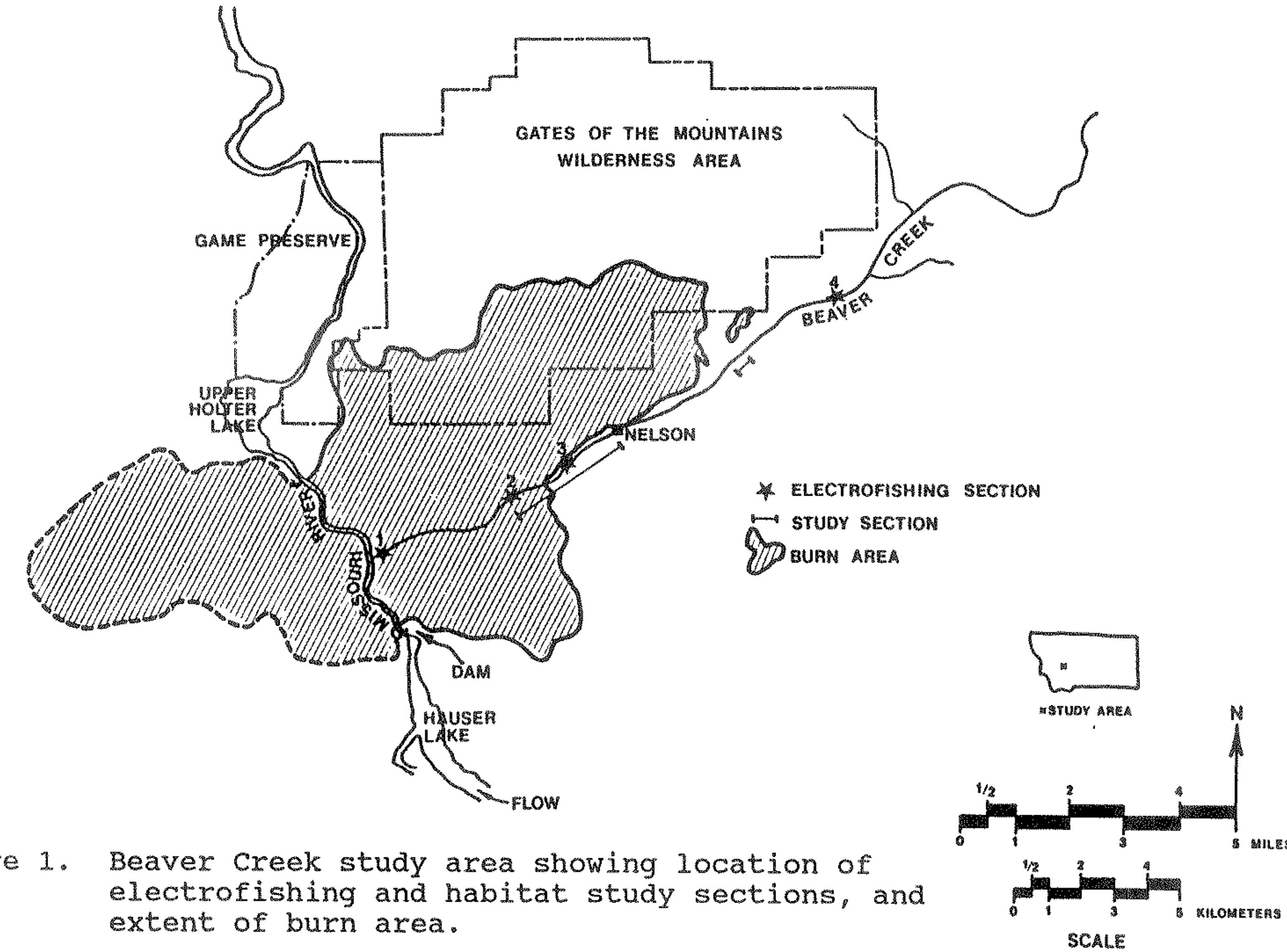

Figure 1. Beaver Creek study area showing location of electrofishing and habitat study sections, and extent of burn area.

and is required for sustained productivity in both aquatic and terrestrial communities (Wright and Heinselman 1973).

Fire causes recession of terrestrial seral stages, and disrupts community diversity and stability (Cooper 1960; Biswell 1974). However, effects of wildfire on the biota of streams have been reported to be negligible (Albin 1979). Despite drastic changes in the terrestrial community of two Yellowstone Lake tributaries, Albin found no changes in fish or aquatic invertebrates directly attributable to fire.

Burning of forests destroys vegetative and litter cover, alters the physical properties of topsoil, and may expose mineral soils lower in the profile (Swanston 1980). These alterations result in increased water yield and stormflow discharge from affected watersheds. Hydrophobic soils, formation of water repellent layers due to vaporization of organic substances and fusion of soil particles, have been verified in a variety of ecosystems following fires (Debano 1969; Megahen and Molitor 1975; Campbell et al. 1977). The relative importance of soil hydrophobia on increased soil erosion and mass-movement processes is not well known, however, a relationship between fire and sediment yield from affected watersheds has been confirmed (Krammes 1960; Rice 1973; Swanson 1978). Increased discharge and accelerated erosion rates depend on the intensity, severity and frequency of burning, as well as the extent to which a particular watershed is affected (Anderson et al. 1976).

Flooding in trout streams may decrease trout numbers, reduce aquatic macroinvertebrate abundance, and reduce availability of nutriment resources (Allen 1951; Elwood and Waters 1969; Hoopes 1974, 1975). An initial reduction in trout numbers is exacerbated by potential loss of year-classes due to destruction of trout redds and young-of-the-year, as well as delayed mortality of older trout resulting from habitat degradation (Allen 1951; Hanson and Waters 1974; Hoopes 1975). Macroinvertebrates, though severely depressed by extreme discharge, are able to repopulate a denuded stream reach in relatively rapid succession (Allen 1951; Waters 1964; Hoopes 1974).

Combined impacts of wildfire and intense rainfall events on stream habitat and fish populations can be devastating. Resulting debris avalanches, debris flows and debris torrents constitute the most damaging of soil mass-movement processes to stream channels (Swanston 1980). Debris torrents of soil, rock, and organic debris-laden water pose the greatest threat to stream habitat and biota, but have received little study (Frederikson 1963, 1965; Morrison 1975; Swanson et al. 1976).

Intense heat from the North Hill Fire created hydrophobic soil conditions resulting in immediate overland water flow, and sheet erosion developed within meters of ridgetops. Flows progressed downslope causing rill and gulley erosion in first-order drainages, and severe scouring in second and third-order drainages.

Excessive erosion occurred on 1500 ha, with erosion rates of 871 Mg/ha at some sites (Shultz et al. unpub. data.). Several debris torrents reached Beaver Creek resulting in >50% suspended sediments immediately following the flood (Bill Putnam, Forest Hydrologist, pers. comm.). As the flood receded, trout were stranded in isolated backwater pools and puddles (Len Walsh, Fishery Biologist, pers. comm.). Severe scouring of the stream bottom and banks, along with heavy deposition of sediment and charred debris resulted in physical and biological debasement of the stream.

In spring 1984, the Montana Cooperative Fishery Research Unit completed a 2-year study on Beaver Creek as part of a larger project on the Missouri River (White et al. 1984; Carty 1985; Spoon 1985). That study investigated spring and fall trout population abundance, amount of spawning use, location of spawning habitat, substrate composition of spawning areas and recruitment of young-of-the-year trout to the Missouri River. Sampling sites encompassed areas within and above the fire-flood impacted portion of Beaver Creek.

The following objectives were established to study effects of the fire-flood event on habitat, trout populations and aquatic macroinvertebrates of Beaver Creek:

1. Compare relative abundance and age-structure of brook, brown, and rainbow trout populations to pre-fire population data.

2. Determine if spawning activity and distribution of adfluvial brown trout and rainbow trout from the Missouri River and Holter Reservoir changed.

3. Ascertain effects of watershed erosion on streambed substrate particle-size composition.

4. Compare recruitment of young-of-the-year rainbow trout to the Missouri River to pre-fire recruitment data.

5. Investigate the effects of the flood on the benthic community.

Information presented in this thesis was collected between November, 1984 and November, 1986.

DESCRIPTION OF STUDY AREA

Beaver Creek, the only perennial tributary to the Missouri River between Hauser Dam and Upper Holter Reservoir, has a drainage area of 18,715 ha. The stream is approximately 27 km long, has an average gradient of 1.72% and flows into the Missouri River 2.7 km downstream from Hauser Dam (Figure 1). From its headwaters in the Big Belt Mountains to the town of Nelson, the stream flows through a narrow limestone canyon, below which it meanders through a broader floodplain. The confluence of Beaver Creek and the Missouri River is a popular recreation area, with the Beaver Creek fishery valued at $24,000 annually (Putnam 1985).

Most of the Beaver Creek drainage is administered by the U.S. Forest Service, Helena National Forest. A Forest Service road parallels 19 km of Beaver Creek, with much of the watershed north of this road included in the Gates of the Mountains Wilderness Area; 5 km of the stream flows through private land.

A Montana Department of Fish Wildlife and Parks survey in 1973 indicated 24% of Beaver Creek had been altered by road and pipeline construction, channelization and dewatering. Before acquisition by the U.S. Forest Service in 1974, the lower 3.2 km of stream had been completely dewatered for several years to irrigate private land (Hill and Wipperman 1976).

Beaver Creek flows through ponderosa pine-grassland vegetation, with riparian areas dominated by red osier dogwood (*Cornus stolinifera*) and willow (*Salix* spp.). Extensive beaver activity throughout the stream perpetuates the presence of ponds in various stages of senescence. A list of fish species occurring in Beaver Creek is given in Table 1, and a list of aquatic macroinvertebrates known to inhabit the stream is presented in Appendix A.

Table 1. Fish species known to inhabit or spawn in Beaver Creek.

Family	Common Name	Species
Catostomidae	longnose sucker	*Catostomus catostomus*
	white sucker	*Catostomus commersoni*
Cottidae	mottled sculpin	*Cottus bairdi*
Cyprinidae	fathead minnow	*Pimephales promelas*
	longnose dace	*Rhynichthys cataractae*
Salmonidae	brook trout	*Salvelinus fontinalis*
	brown trout	*Salmo trutta*
	cutthroat trout	*Salmo clarki*
	rainbow trout	*Salmo gairdneri*
	cutthroat X rainbow trout	hybrid
	mountain whitefish	*Prosopium williamsoni*

Average weekly discharge (Figure 2) recorded at the U.S.F.S. gauging station for April through November (the gauging station is not operated December through March) is lowest in November (0.21 m^3/s) and greatest in May (1.39 m^3/s), with an annual average of 0.52 m^3/s. The drainage continued to exhibit effects of soil instability during the course of the study, as debris torrents were associated with heavy rain and spring runoff.

Average weekly water temperatures during the study ranged from 0.8 C in December/January to 15.1 C in July (Figure 3). Several gaps in temperature data resulted from thermograph malfunction following runoff events. Ice and snow cover was extensive on Beaver Creek during winter.

Three electrofishing sections corresponding to Spoon's (1985) sections 2, 3 and 4 were evaluated. Sections 2 and 3 were 4.8 km and 6.4 km upstream from the mouth of Beaver Creek, respectively, and located in the impacted portion of the stream; section 4 served as a nonimpacted reference and was 19.0 km upstream from the mouth (Figure 1). Two habitat study sections were established; the impacted section, approximately 3.2 km of stream from Nelson downstream to electrofishing section 2 and, a nonimpacted section approximately 0.51 km long and beginning 13 km upstream from the confluence of Beaver Creek with the Missouri River. Physical parameters of electrofishing and habitat study sections are given in Table 2.

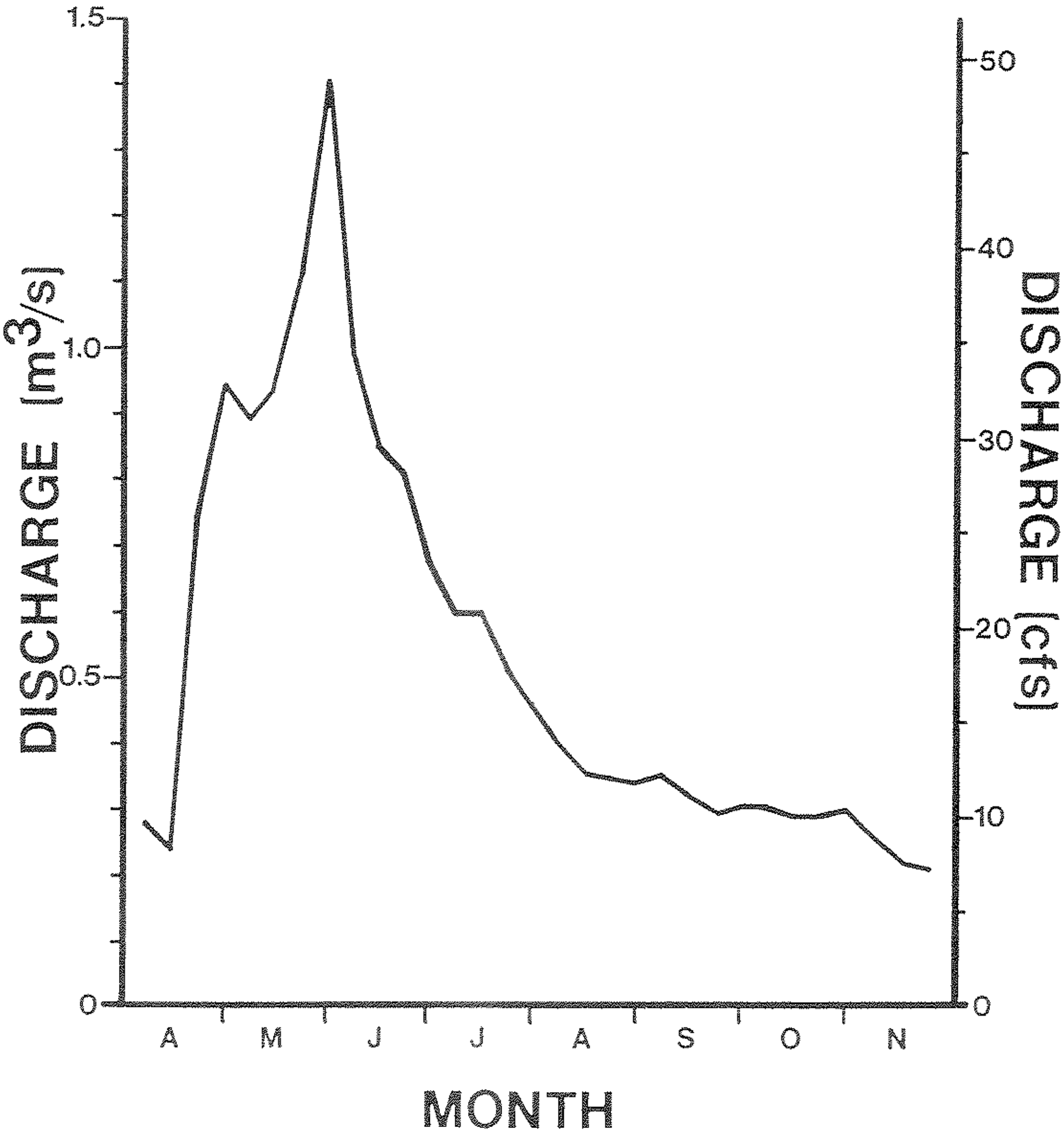

Figure 2. Mean weekly discharge of Beaver Creek 1980-1986. (U.S. Forest Service, unpublished data)

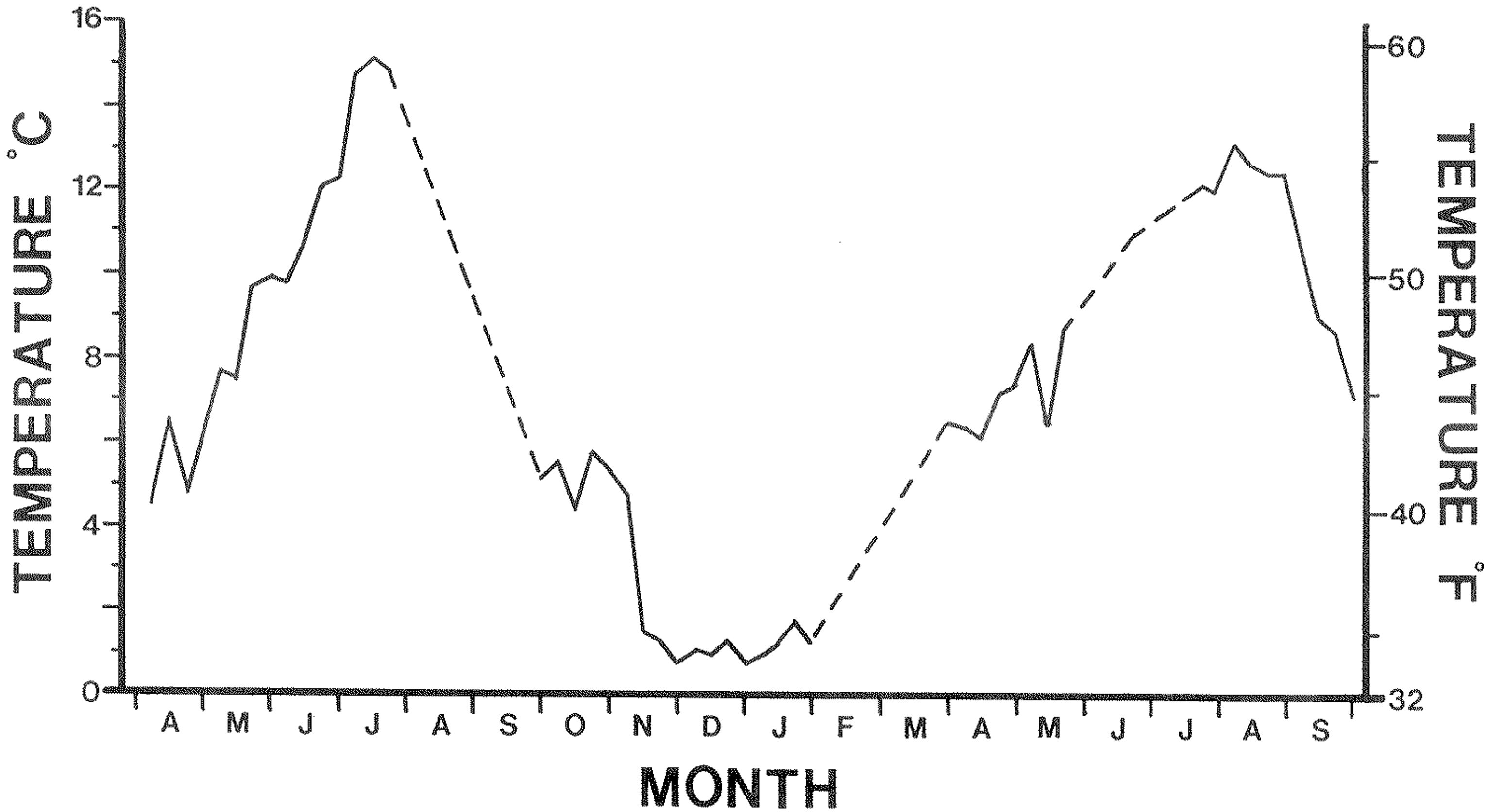

Figure 3. Mean weekly water temperature of Beaver Creek 1985-1986.

Table 2. Physical parameters of impacted and nonimpacted habitat sections and electrofishing sections*, Beaver Creek study area.

Section	Length (m)	Width (m)	Depth (m)	Water velocity (m/s)	Area (ha)	Slope (%)
			Habitat Sections			
Impacted	3200	4.48	0.13	0.31	1.43	1.5
Nonimpacted	510	3.24	0.08	0.20	0.26	2.4
			Electrofishing Sections			
2	305	4.41	--	0.43	0.13	1.3
3	305	3.98	--	0.54	0.13	1.1
4	305	3.53	--	0.12	0.11	1.5

*Electrofishing sections 2 and 3 impacted, section 4 nonimpacted.

Two young-of-the-year trapping stations were established. Station 1, 125 m upstream of the outlet of Beaver Creek (Carty 1985), and station 2, 12.8 km upstream of the outlet and located immediately above the impacted portion of the creek (Figure 4). Three sites were selected for monitoring aquatic macroinvertebrate recolonization. Sites 1 and 2 were in the impacted habitat section, and site 3 was in the nonimpacted habitat section (Figure 4). Sites selected were riffle areas with similar depths and velocities (Table 3).

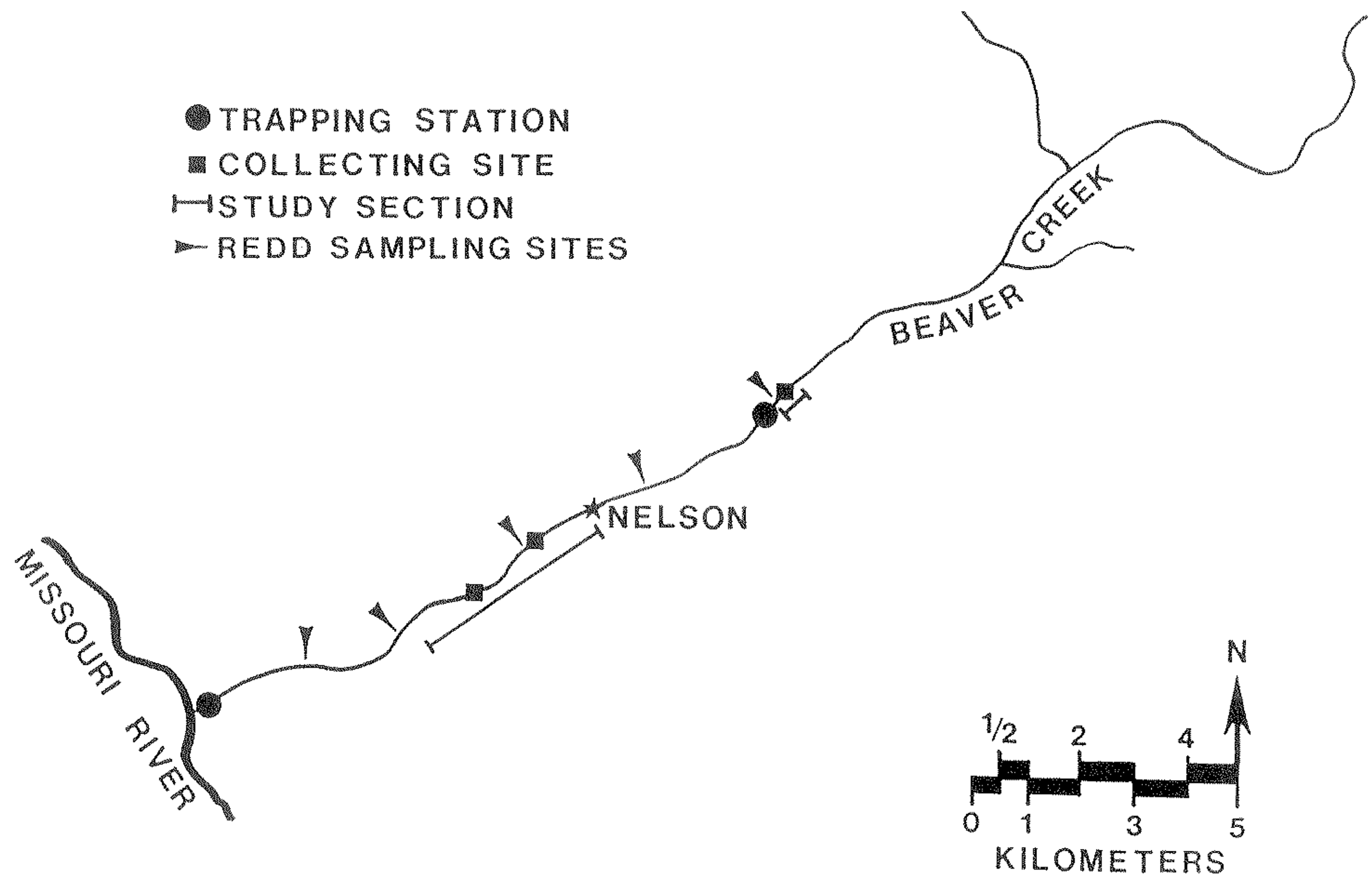

Figure 4. Locations of young-of-the-year trapping stations, aquatic macroinvertebrate collecting sites, and trout redd sampling sites, Beaver Creek study area.

Table 3. Physical parameters of aquatic macroinvertebrate sampling sites*, Beaver Creek study area.

Site	Mean substrate size (mm)	Depth (m)	Water velocity (m/s)	Width (m)
1	43.1	0.12	0.43	4.0
2	37.9	0.10	0.35	4.3
3	44.1	0.06	0.19	3.7

*Sites 1 and 2 impacted, site 3 nonimpacted

METHODS

Population Estimates

Trout population estimates were conducted each fall and spring, beginning October, 1984 and ending October, 1986 using the two-pass method (Seber and LeCren 1967; Seber 1973; Leathe 1983) or the Zippin method (Moran 1951; Zippin 1958; Platts, Megahan and Minshall 1983). Two or more passes through a section were conducted to obtain an acceptable probability of capture (p) for calculating population estimates. Equations used for the two-pass method were:

probability of capture, $p = \frac{n_1 - n_2}{n_1}$;

population estimate, $N = \frac{(n_1)^2}{n_1 - n_2}$;

standard error, $SE(N) = \frac{n_1 n_2 \sqrt{n_1 + n_2}}{(n_1 - n_2)^2}$.

Equations used for the Zippin method were:

population estimate, $N = \frac{T}{Q}$,

where T = total number of fish collected and Q = proportion of fish captured during all removals;

standard error, $SE(N) = \frac{N(N-T)T}{T^2 - N(N-T)\frac{(kP)^2}{1-P}}$,

where P = estimated probability of capture during a single removal and, k = the number of removals. (Values for Q and P were determined from standardized graphs.)

Population estimates and estimated biomass were calculated by age-class for brook, brown and rainbow trout; 80% confidence intervals (80% CI) were calculated for population estimates using the equation, 80% CI = $N \pm 1.282\,[SE(N)]$ (Neter, Wasserman, and Kutner 1985). In nonimpacted section 4, rainbow and cutthroat trout were combined due to extensive hybridization and are referred to as rainbow-cutthroat trout.

Trout were sampled with a bank electrofishing unit consisting of a 1500 watt, 115 volt AC generator and Coffelt rectifying unit (Model VVP-2C). Three, 305-m sections were electrofished working upstream with a hand-held positive electrode attached to a 152-m length of cord; a stationary negative electrode was used.

A three or four person crew conducted surveys with one person operating the positive electrode and using a small dip net while two people collected fish with long handled dip nets; a fourth person (when present) moved equipment and fish. Measurements of total length (mm) and weight to the nearest 5 gm were recorded for all trout collected, and scale samples were obtained from 10 fish per centimeter group in each section. Trout collected during the first pass through a section were held in live-cars during subsequent passes.

Spawning Surveys

Brown trout and rainbow trout spawning activity was measured by conducting redd counts while wading upstream or walking stream banks. Brown trout redd counts were conducted in the 3.2 km impacted study section in fall of 1985 and 1986. Rainbow trout redds were counted twice each spring; once at peak spawning in mid-May and again near the end of spawning in mid-June. Redds were counted in the entire 19.2 km of stream accessible to rainbow trout each year.

Substrate Sampling

Subsurface Core Analysis

Streambed substrate composition was determined from samples collected using a modified McNeil sampler (McNeil 1964). Substrate samples were obtained during March 1985 and 1986 prior to spring runoff. The 178 mm diameter tube of the sampler was embedded in the substrate to a depth of approximately 190 mm and the enclosed sample extracted and stored for later particle size analysis. Total suspended sediment in each sample was obtained by measuring the volume of sediment in a 1.0 L sample, multiplying that value by the total volume in the core-tube, and correcting for dry weight (Shepard and Graham 1983). Three core samples at one-quarter, one-half and three-quarters distance from the left wetted edge were taken from each of seven run-riffle transects in the impacted section and from three run-riffle transects in the nonimpacted section. Fifteen spawning sites were sampled by coring at the upstream lip of three redds in each of five spawning areas (Figure 4); a substrate sample was also obtained from one artificial redd in each spawning area.

Substrate samples were dried in a forced-air oven at 150 C for 4 h. A Tyler Ro-Tap sieve shaker and U.S. Standard Testing Sieves were used to separate samples for particle-size composition. Twelve standard sieves ranging in size from 76.1 mm to 0.074 mm were used and the shaker was operated for 5 min per sample. Materials in each sieve were weighed to the nearest 5.0 gm and percentage of the total sample weight was calculated. Substrate particle-size distributions were analysed by assigning sieve sizes to 10 classes (Table 4).

Ocular Substrate Analysis

Substrate surface of the streambed was evaluated visually at randomly located transects in impacted and nonimpacted study sections (Spoon 1985). Ocular substrate analysis was conducted in March 1985 and 1986 prior to spring runoff. Sixty-two impacted and 10 nonimpacted, permanent transects were established at 75-pace intervals by walking upstream in mid-channel. Rebar stakes were driven into the streambanks and a measuring tape stretched across the stream channel perpendicular to flow. Ocular analysis was conducted in 1.0-m increments along the tape and substrate classes were assigned percentages according to estimated surface area each class comprised. A modified version of the Wentworth particle-size scale (Table 5) was used for substrate classification.

Table 4. Sizeclass* assignments of sieve sizes for substrate particle size distribution analysis.

Sizeclass	Sieve Size (mm)
1	<0.074
2	0.074
3	0.42
4	0.85
5	2.00
6	4.76
7	6.35
8	9.52, 12.7
9	15.9, 25.4
10	50.8, ≥76.1

*The ANOVA program in MSUSTAT limits the user to comparison of 10 variables.

Mean particle size for each site was calculated by the equation,

Summation (class midpoint x class %)= mean at site, for all classes present at a transect (Spoon 1985).

Table 5. Streambed substrate size classification (from Spoon 1985).

Substrate Class	Size (mm)	Midpoint (mm)
Fines	<2.0	1.0*
Gravel	2.0-64.9	33.0
Cobble	6.5-249.9	160.0
Boulder	>250.0	300.0*

*approximate midpoint

Predicted Survival to Emergence

Percentage of substrate less than 9.52 mm and 0.85 mm was used to predict rainbow trout embryo survival to emergence using the equation described by Irving and Bjornn (1984), Percent survival = $113.58 - 10.77(S_{0.85}) - 0.007(S_{9.5}) + 0.301(S_{0.85})^2$; where $S_{9.5}$ is percent composition less than 9.5 mm, and $S_{0.85}$ is the percent composition less than 0.85 mm. Survival to emergence was predicted for substrates sampled in the impacted and nonimpacted sections, and natural and artificial redds.

Artificial Redds

Five artificial redds were constructed in spring 1985 and 1986 to measure survival of trout larvae to time of emergence. Sites were selected by the presence of adfluvial rainbow trout redds. Four redds in the impacted section were 2.5, 4.0, 7.5 and 11.0 km upstream from the mouth of Beaver Creek (Figure 4); one redd was located in the nonimpacted habitat section. Artificial redds were built to approximate length and width of natural redds (Spoon 1985). Redds were constructed by driving two rebar stakes into the streambed to delineate total length, and substrates were worked loose and cleaned of fine sediments with a pick-axe and shovel. Redds were formed progressing upstream to create a tailspill, egg pocket and depression.

Adfluvial rainbow trout spawners were collected in Beaver Creek using a Coffelt backpack electrofishing unit (model BP-1C) to obtain eggs and sperm. A section of stream was electrofished until adequate numbers of males and females were collected. Fish were held in livecars in the creek, were not sedated, and were released after spawning was completed.

Equal numbers of male and female rainbow trout were spawned to inseminate 5000 eggs. Eggs and sperm were combined in a bowl and allowed to stand for 5-10 min, after which the eggs were rinsed of excess sperm. Eggs were kept chilled in a dark container and allowed to water harden for 3-4 h, or overnight when possible.

Two-hundred water hardened eggs were placed in egg bags with gravel mixtures from the artificial redds; egg bags were constructed of 1 mm mesh plastic-fiber window screen. Egg bags were stapled shut, marked with flagging, and four bags were buried in each artificial redd approximately 15 cm deep. Temperature units and number of days required for eggs to hatch were calculated (Carlander 1969; Leitritz and Lewis 1976); egg bags were retrieved and numbers of fry surviving to time of emergence counted. In 1986, trout egg fertilization success and handling mortality was assessed by incubating approximately 850 eggs in a Heath tray in the laboratory. These data were used to correct survival to emergence in the 1986 field tests.

Young-of-the-year Trapping

Young-of-the-year (YOY) emigration was monitored from late June through late August, 1985 and 1986. Three traps placed side-by-side were used at the two sampling stations to capture downstream migrants; each trap consisted of a nylon net funnel (3 mm mesh) with a live box attached to its downstream end. Small mesh leads (3 mm mesh) were secured to the outside traps in an attempt to collect all emigrating fry. Leads were placed along rock berms extending upstream diagonally from trap openings to the stream bank and the lower edge buried approximately 10 cm in the substrate.

Traps were checked each morning and evening, except during high flows when they were also checked at mid-day. The number of each species of trout captured was recorded for each trap and lengths of a subsample of the fish were measured to the nearest 1.0 mm TL at each trap check. All captured YOY were released downstream from trap stations.

In 1986, 1,682 YOY rainbow trout were stained to monitor downstream migration from station 2 to the Missouri River (station 1); 741 YOY were stained and released 50 m upstream of station 1 to measure trap efficiency. Young-of-the-year were stained in 6.0 L of a 1:30,000 solution of histological die (Bismarck Brown Y) for 3 to 4 h and released. Twenty-five stained YOY were held in live-cars after each release to monitor mortality due to staining and handling, and to determine length of time die was retained.

Aquatic Macroinvertebrate Recolonization

Macroinvertebrates were sampled using modified Hester-Dendy (1962) multiplate artificial-substrate collectors, and a Surber sampler. Each multiplate collector consisted of seven pressed hardboard plates measuring 12.2 x 12.2 cm, with plates separated by 0.60 cm thick spacers; surface area of each collector was 0.20 m^2. Three collectors were placed at each of the three sampling sites at one-quarter, one-half and three-quarters distance from the left wetted edge, with the plates positioned parallel to flow. Collectors were anchored to the stream bottom with steel rods, and buried to the level of surrounding substrates.

At approximately 30 d intervals, all material on each collector was removed, placed in a bottle containing Kahle's solution and labeled appropriately. Samples were screened in the laboratory using 6.30 mm and 0.589 mm U.S. Standard Sieves.

Aquatic macroinvertebrates present in each sample were hand picked, washed and preserved in 90% ethanol. Macro-invertebrates were identified to species or lowest possible taxon using keys by Pennak (1978) and Merritt and Cummins (1984). Number of individuals in each taxon was recorded, and percent occurrence (percentage of samples in which taxa occurred) was calculated.

Bottom samples of macroinvertebrates were collected at each site in July, September, and November, 1985 and March and June, 1986. Three 0.09 m^2 Surber samples with 0.1 mm mesh netting were taken at each site at one-quarter, one-half, and three-quarters distance from the left wetted edge. Each sample was fixed, screened, preserved and identified in the same manner as those from artificial substrate collectors.

Discharge and Temperature Monitoring

Discharge information was obtained from the U.S. Forest Service gauging station located 2.4 km upstream of the mouth of Beaver Creek. Water temperatures were recorded continuously with a submersible Ryan 90-day thermograph (Model J) installed 100 m downstream of the U.S. Forest Service gauging station in March, 1985 and removed in November, 1986. Measurable temperature range of the thermograph was -5 to 25 C; the thermograph was accurate to within 0.8 C and 3 min/d.

Statistical Testing

Statistical tests were conducted using methods in Neter, Wasserman and Kutner (1985). Statistical analyses on stream bottom substrate and aquatic macroinvertebrates were performed on a personal computer using MSUSTAT (Lund 1987). All statistical tests were conducted at 0.05 and 0.01 levels of significance.

Substrate distributions were analyzed using ANOVA; sample size of nonimpacted substrates was inadequate for comparison of distributions between years and comparisons with redd sites. Due to non-symmetry of substrate distributions (distributions were not symmetric about the means), mean substrate sizes were analyzed by non-parametric methods using the Kruskal-Wallis Rank Test.

Analysis of visual surface substrate measurements was conducted using ANOVA. A Chi-Square value was calculated for each aquatic invertebrate taxon sampled from artificial-substrate collectors and surber samples to analyse differences in percent occurrence at sampling sites.

RESULTS

Trout Populations

Abundance

Trout abundance decreased dramatically in the impacted portion of Beaver Creek from fall 1983 to fall 1984, when a total of eight brook trout and four rainbow trout were collected in sections 2 and 3, respectively (Figures 5 and 6; Appendix B Tables 13 and 14). In the nonimpacted section, brook trout and rainbow-cutthroat trout estimates were 40.6% and 84.9% lower, respectively, than fall 1983 but relative differences were not as pronounced as in the impacted area (Figure 7; Appendix B Table 15).

Spring 1985 trout populations were similar to fall 1984 populations in the impacted sections (Appendix B Tables 13 and 14). In the nonimpacted section, estimates of brook trout and rainbow-cutthroat trout decreased 26.3% and 61.2%, respectively (Appendix B Table 15).

By fall 1985, a dramatic increase in trout numbers had occurred in impacted sections of Beaver Creek. Ninety-seven percent of the increase was in the rainbow trout population (Figures 5 and 6; Appendix B Tables 13 and 14).

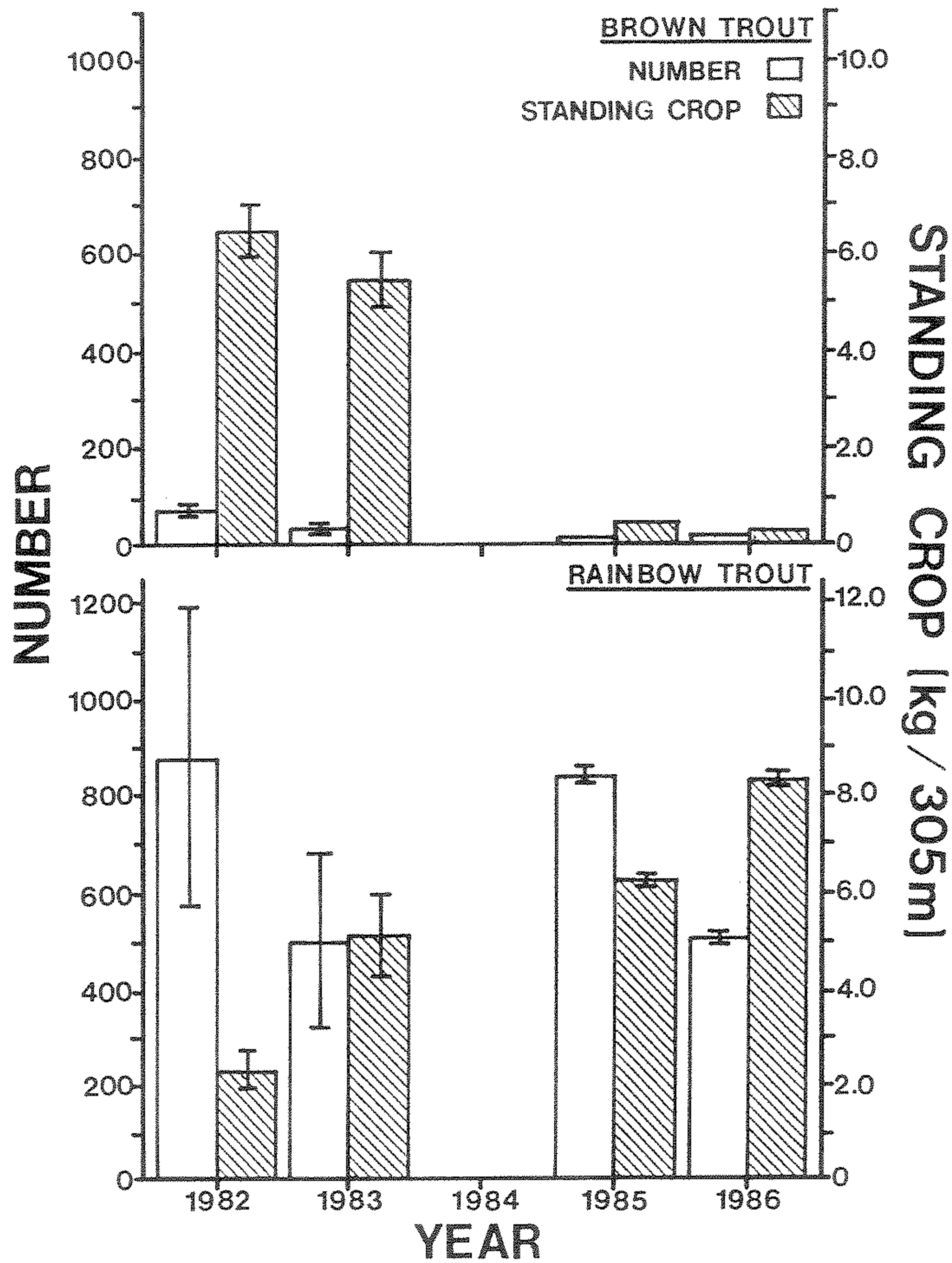

Figure 5. Number and standing crop of brown trout and rainbow trout, impacted section 2, fall 1982 (pre-fire) through fall 1986. (Vertical bars are 80% confidence intervals)

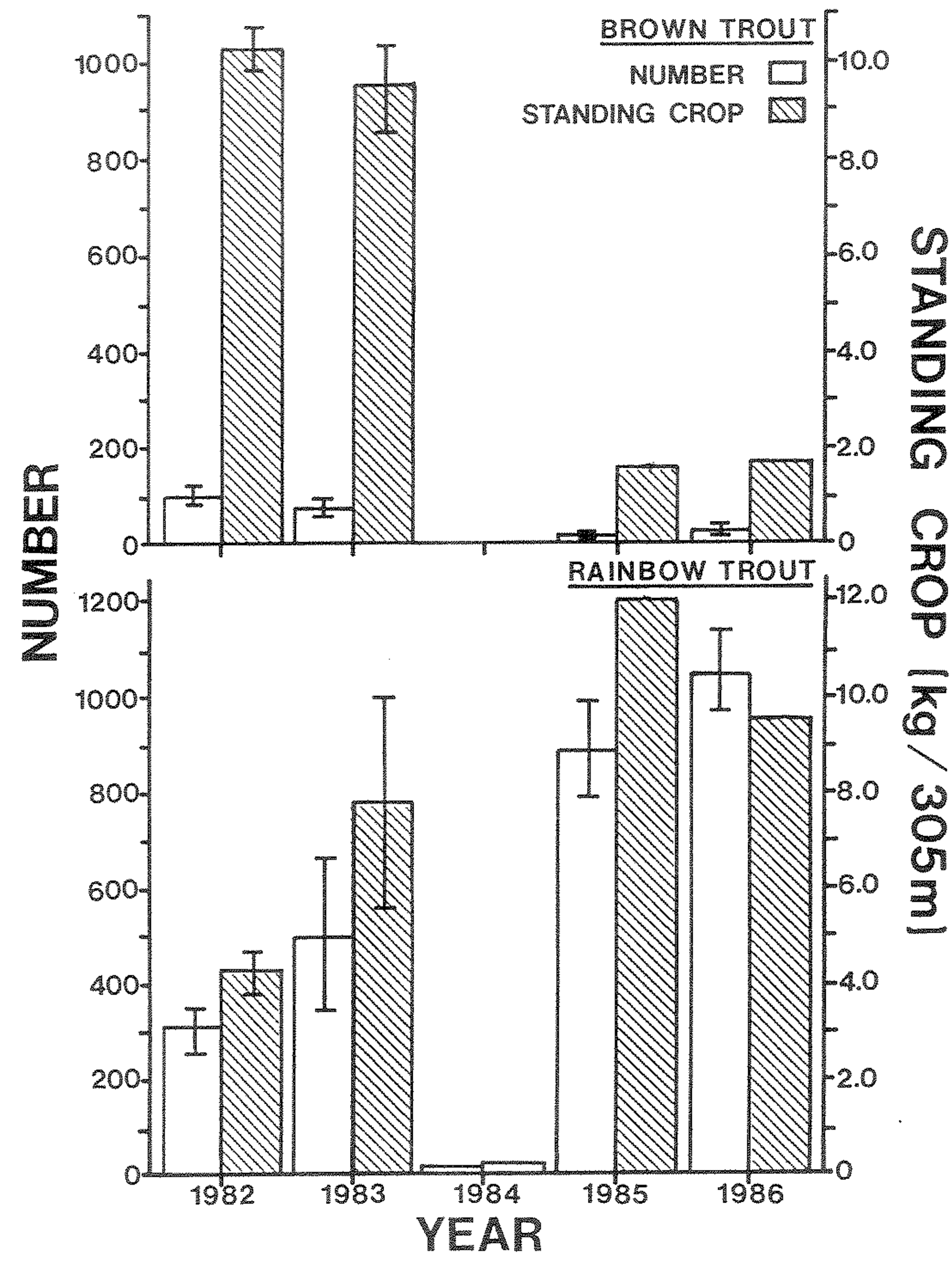

Figure 6. Number and standing crop of brown trout and rainbow trout, impacted section 3, fall 1982 (pre-fire) throughfall 1986. (Vertical bars are 80% confidence intervals)

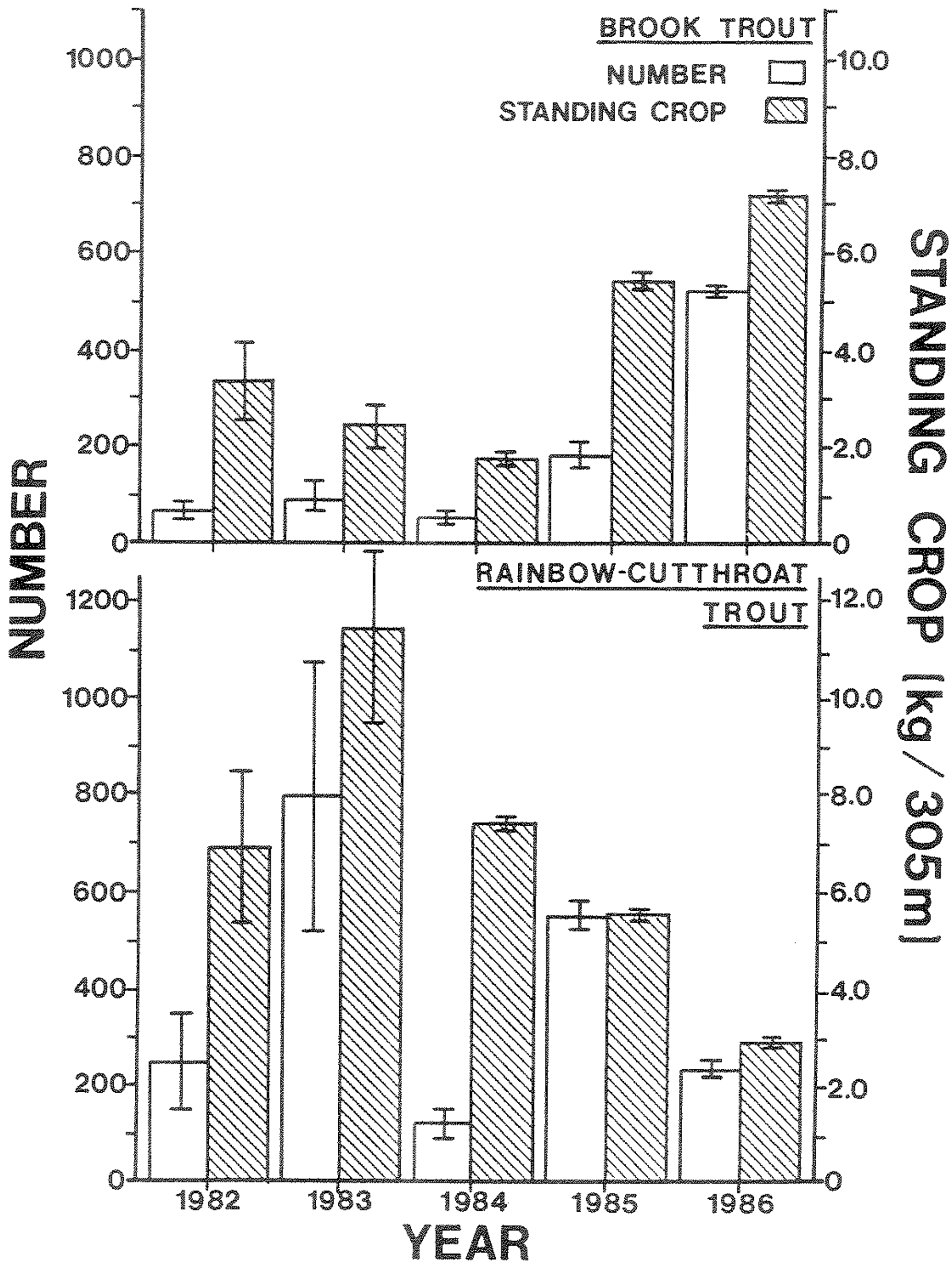

Figure 7. Number and standing crop of brook trout and rainbow-cutthroat trout, nonimpacted section 4, fall 1982 (pre-fire) through fall 1986. (Vertical bars are 80% confidence intervals)

In the nonimpacted section, rainbow-cutthroat trout numbers increased 91%, and brook trout had increased 77.3% (Figure 7; Appendix B Table 15).

In spring 1986, trout numbers had decreased in all electrofishing sections compared to fall 1985. Rainbow trout abundance decreased 65% (Appendix B Table 13), and brook trout and brown trout combined decreased 43% in impacted section 2. In impacted section 3, rainbow trout and brown trout numbers decreased 67% and 25%, respectively (Appendix B Table 14). Spring 1986 population estimates for nonimpacted section 4 showed decreases of 94% and 25% for rainbow-cutthroat trout and brook trout, respectively (Appendix B Table 15); two brown trout were collected.

Fall 1986 population estimates showed increased total trout abundance over spring estimates in each section. In impacted section 2, brook trout and brown trout combined decreased 47.6%, but the rainbow trout population increased 42.5% (Figure 5; Appendix B Table 13). In impacted section 3, rainbow trout and brown trout increased 72.1% and 57.1%, respectively (Figure 6; Appendix B Table 14); five brook trout were captured. Brook trout and brown trout estimates in nonimpacted section 4 (Figure 7; Appendix B Table 15) increased 73.5% and 93.5%, respectively, and 61.0% for rainbow-cutthroat trout.

Age-structure

Most age-classes of trout were eliminated in the impacted portion of Beaver Creek (Figures 8 and 9). Successful spawning of adfluvial rainbow trout in spring 1985 resulted in large numbers of YOY rainbow trout during fall in impacted sections (Figures 8 and 9). Age-0 fish comprised approximately 92% of the rainbow trout population; the remaining 8% were largely age-I fish. By fall 1986, age-structure of rainbow trout populations in impacted sections was returning to pre-event proportions with approximately 70% age-0, 26% age-I and 4% age-II and older (Figures 8 and 9).

Age structure of the brown trout population in impacted sections of Beaver Creek indicated little recruitment of YOY, or older fish, by fall 1986. Only two brown trout age-II and older were present in section 2; in section 3 an estimated, five age-0, four age-I and five age-II and older fish were present (Figures 8 and 9; Appendix B Tables 13 and 14). Age structures of brook trout, brown trout and rainbow-cutthroat trout in the nonimpacted section of Beaver Creek were similar to those of previous years (Figure 10; Appendix B Table 15).

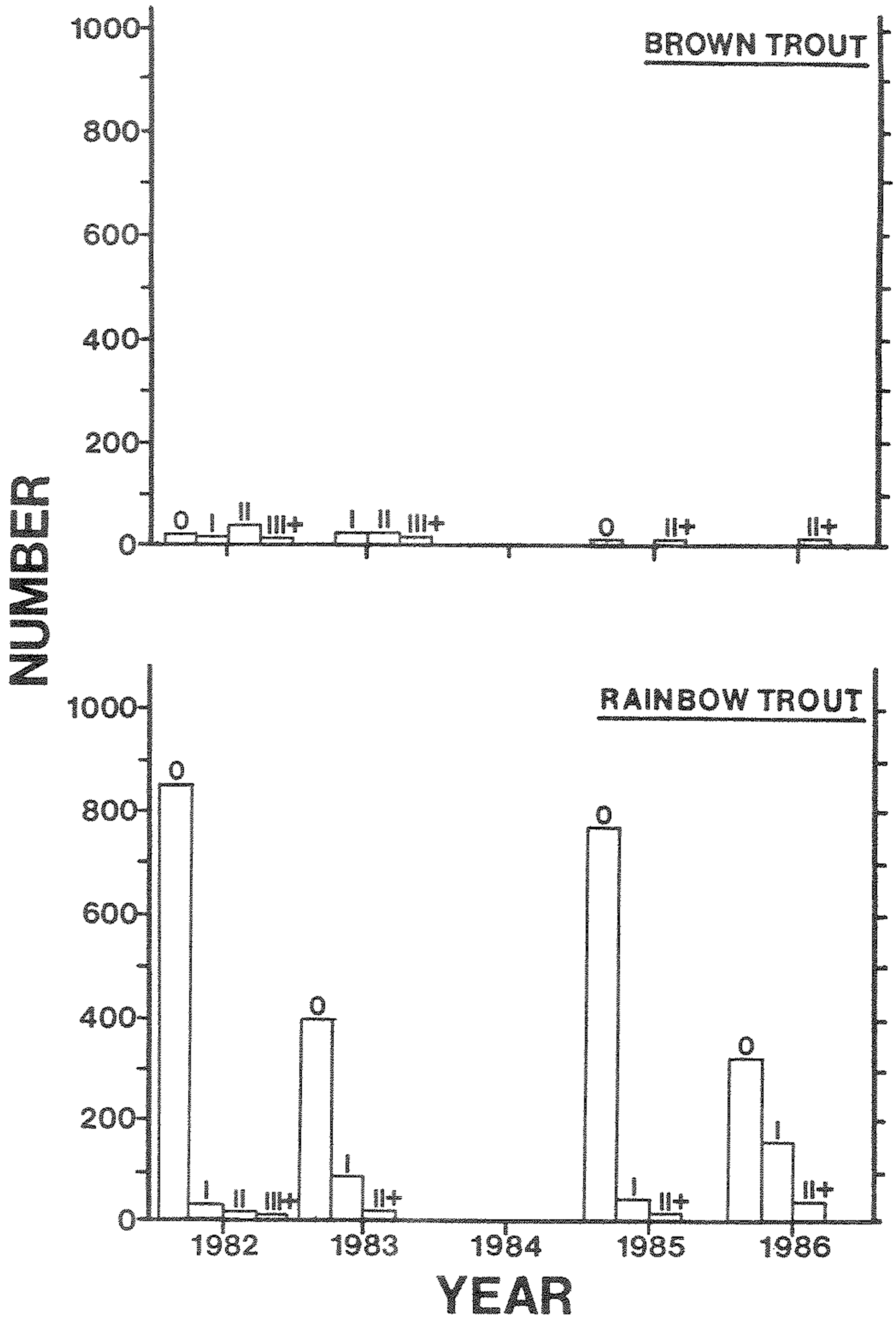

Figure 8. Brown trout and rainbow trout age-class distributions, impacted section 2, fall 1982 (pre-fire) through fall 1986.

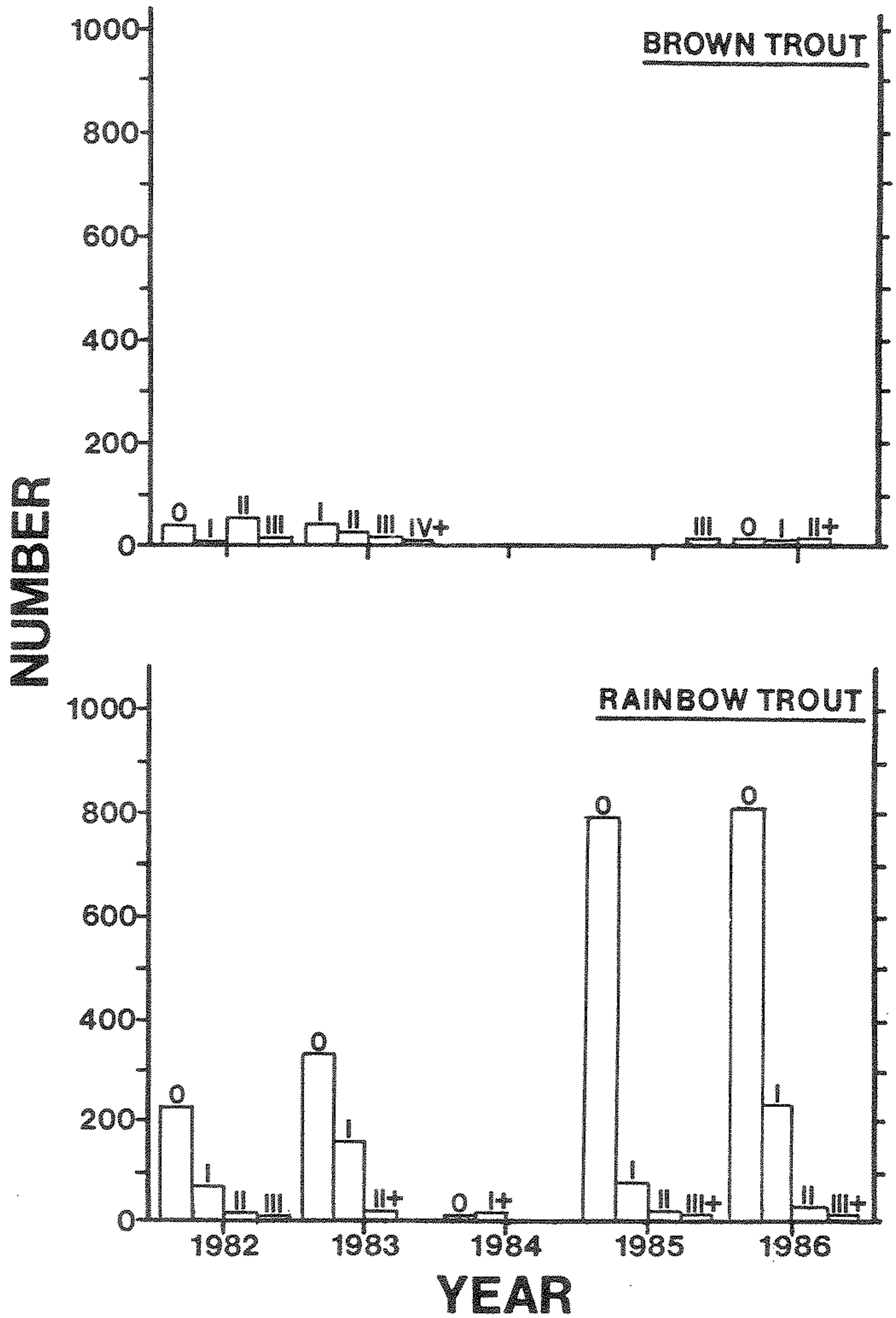

Figure 9. Brown trout and rainbow trout age-class distributions, impacted section 3, fall 1982 (pre-fire) through fall 1986.

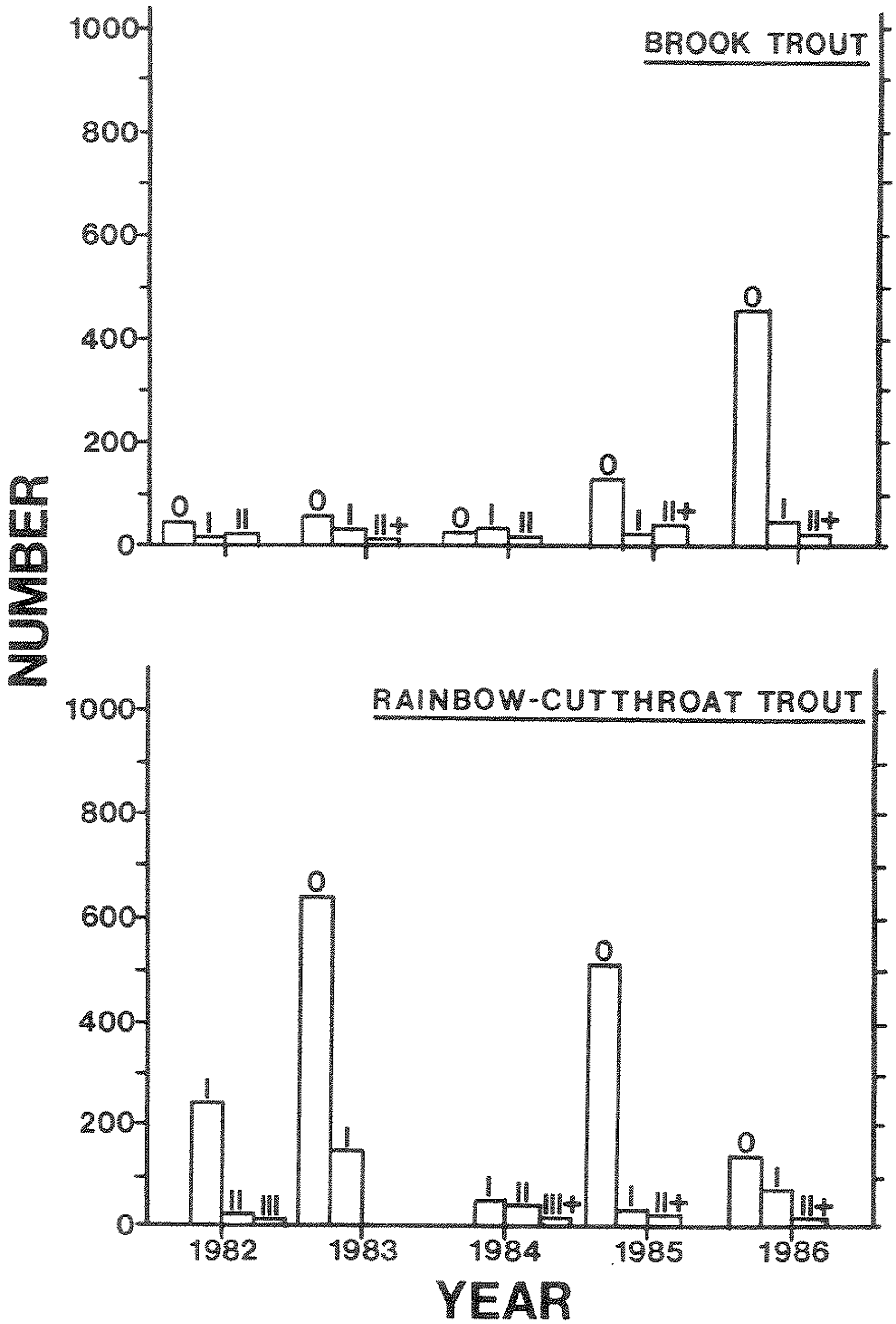

Figure 10. Brook trout and rainbow-cutthroat trout age-class distributions, nonimpacted section 4, 1982 (pre-fire) through fall 1986.

Spawning Surveys

Brown Trout

Spawning areas in the impacted portion of Beaver Creek known to be used previously (Spoon pers. comm.), showed no evidence of spawning by resident brown trout in fall 1985 and 1986. Fifteen adfluvial brown trout redds were observed in the impacted habitat section in fall 1985. Adfluvial brown trout were unable to access Beaver Creek in fall 1986 due to a large beaver dam near the mouth of the creek. Six redds were observed between the dam and the Missouri River (approximately 100 m), and no redds were found in the impacted habitat section.

Rainbow Trout

Adfluvial rainbow trout used Beaver Creek extensively for spawning each spring (Figure 11). Seven-hundred-twenty-two and 640 redds were observed in 1985 and 1986, respectively. A beaver dam near the mouth of Cottontail Gulch, 19.2 km upstream of the confluence with the Missouri River, functioned as the migration barrier in 1985 and 1986.

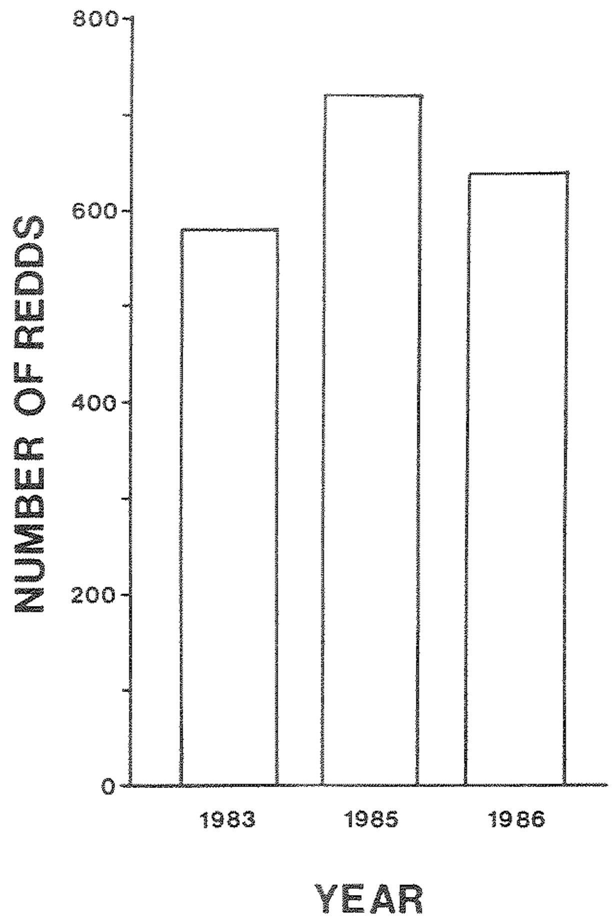

Figure 11. Rainbow trout redd counts for spring 1983 (pre-fire), 1985 and 1986. (No spawning survey conducted in 1984)

Substrate Composition

Substrate composition in 1985 (Figure 12) for size classes 1-8 (Table 4) was significantly different for impacted and nonimpacted sections ($P<0.05$), and for the impacted section and redd sites ($P<0.05$). Significant differences in substrate composition persisted in 1986 (Figure 13) between impacted and nonimpacted sections

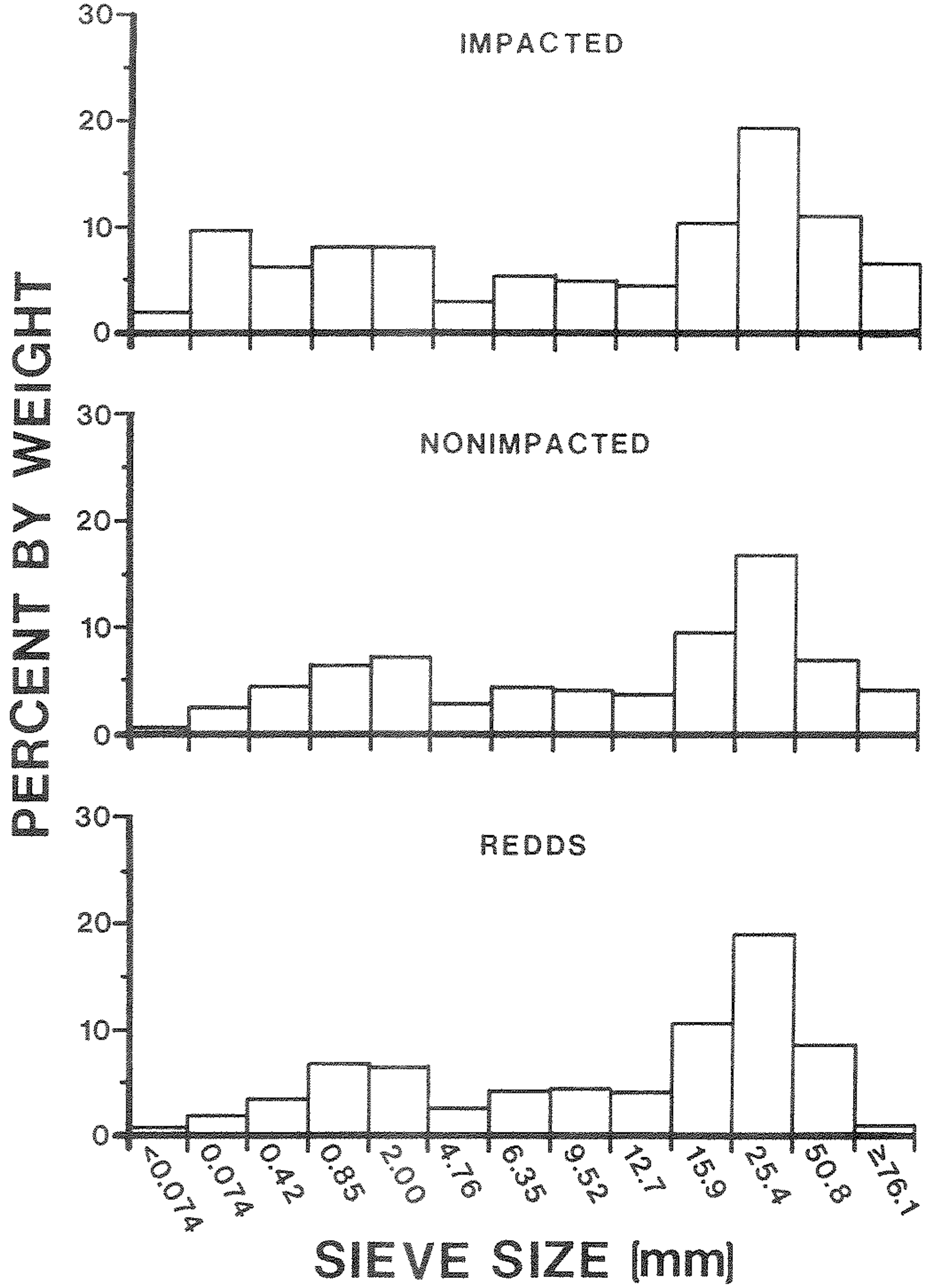

Figure 12. Substrate composition (%) at given sieve sizes for impacted and nonimpacted habitat sections, and redd sites, 1985.

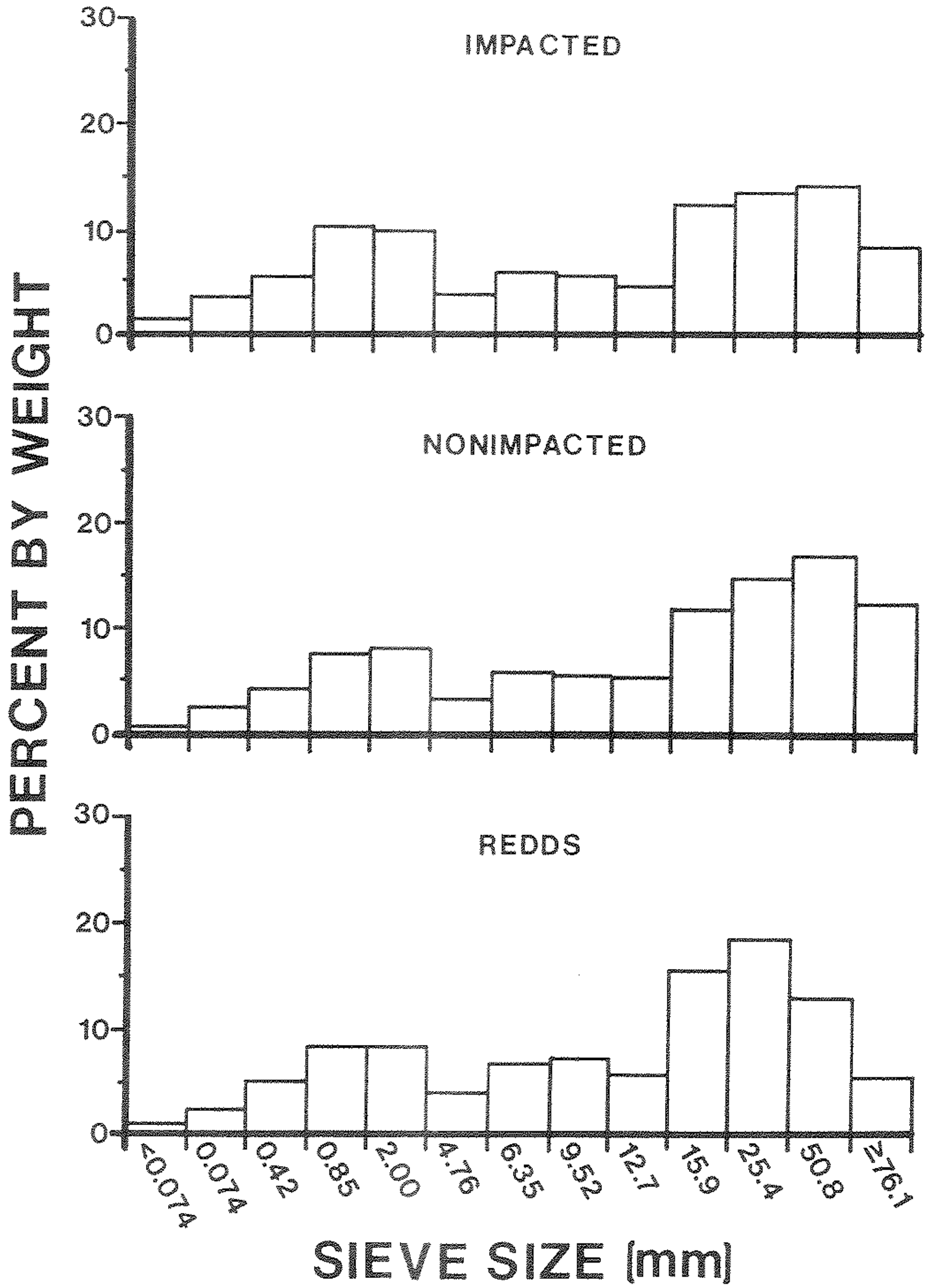

Figure 13. Substrate composition (%) at given sieve sizes for impacted and nonimpacted habitat sections, and redd sites, 1986.

(P<0.05), and the impacted section and redd sites (P<0.01). Comparison of distributions for size classes 1-8 between 1985 and 1986 indicates a significant decrease in fine sediments (P<0.01) in the impacted section, and no significant decrease at redd sites.

In 1985, comparison of mean substrate particle sizes (Table 6) for impacted and nonimpacted habitat sections, and for the impacted section and redd sites showed no significant differences; similar results were obtained in 1986. There were no significant differences in mean particle size between 1985 and 1986 for the impacted section, nonimpacted section or redd sites. However, particle size distributions differed between years (Figures 12, 13 and 14).

Table 6. Mean substrate particle size (mm) for impacted and nonimpacted habitat sections, and at redd sites, 1985 and 1986. (standard error in parentheses)

Type	1985	1986
Impacted	26.9 (3.2)	30.0 (3.7)
Nonimpacted	27.7 (3.2)	37.3 (5.0)
Redds	23.7 (3.1)	28.2 (3.1)

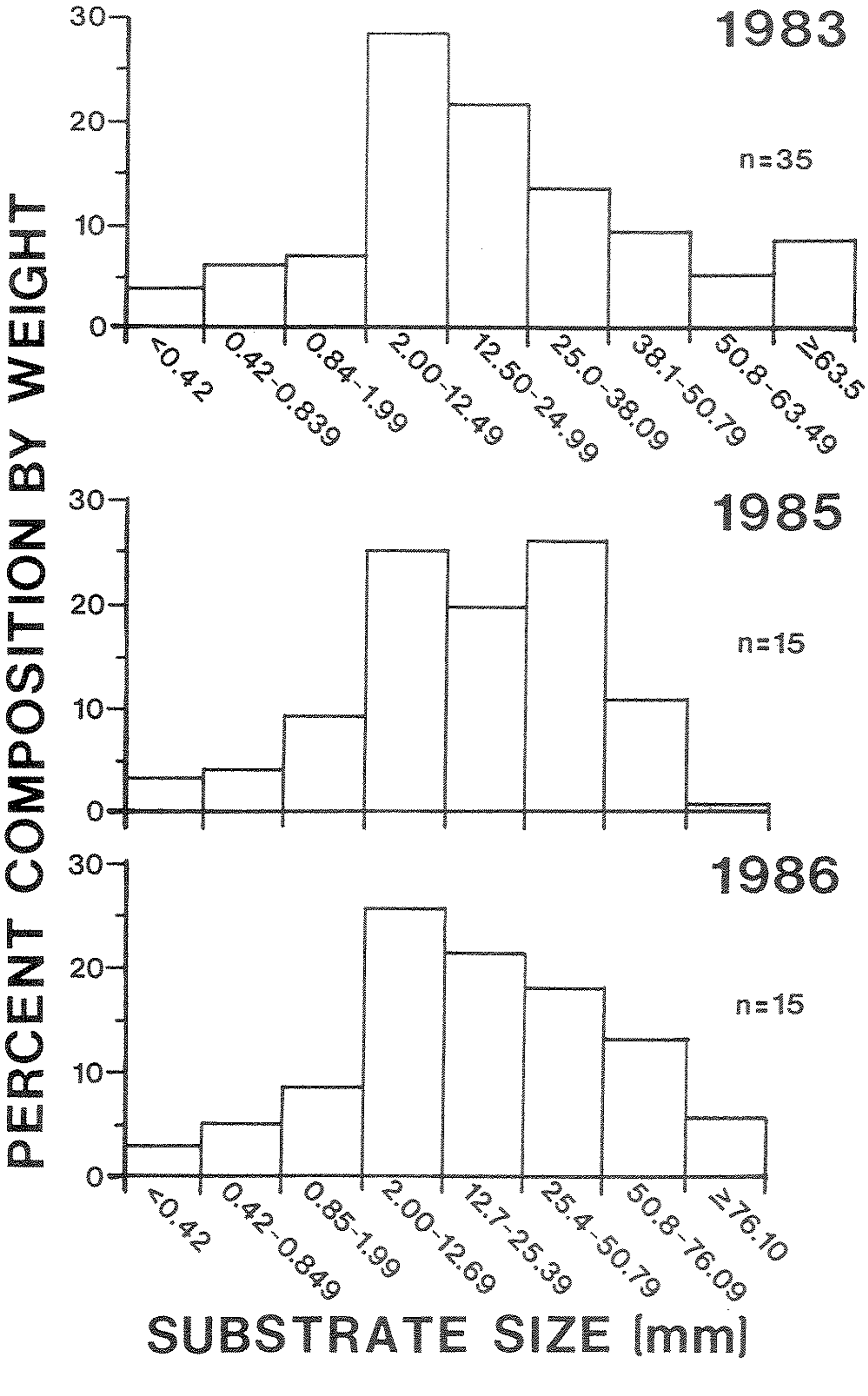

Figure 14. Substrate composition (%) at rainbow trout redds, 1983 (pre-fire; from Spoon 1983), 1985 and 1986.

In 1985, there were 8.8% more fine sediments <0.85 mm in the impacted habitat section than the nonimpacted habitat section (Table 7); fine sediments decreased to 2.9% greater in 1986. Quantities of fine sediments in the impacted section were 10.2% greater than at redd sites in 1985, and decreased to 2.2% greater in 1986. Substrates <6.35 mm were 6.5% greater in the impacted section than the nonimpacted section in 1985 (Table 7). In 1986, materials <6.35 mm decreased 3.4% in the impacted section but were 7.4% greater than the nonimpacted section. Substrates <6.35 mm were 8.0% greater in the impacted section than at redd sites in 1985, and decreased to 6.8% in 1986.

Table 7. Cumulative substrate composition* (%) less than given sieve size, 1985 and 1986.

Year	Sieve size (mm)					
	6.35	4.76	2.00	0.85	0.42	0.074
		Impacted				
1985	37.9	34.7	26.5	18.3	11.8	2.1
1986	34.5	30.7	20.7	10.6	5.0	1.5
		Nonimpacted				
1985	31.4	27.5	18.0	9.5	3.8	0.5
1986	27.1	23.7	15.4	7.7	3.3	0.7
		Redd Sites				
1985	29.9	26.4	17.2	8.1	3.5	0.9
1986	27.7	24.3	16.2	8.4	3.3	0.7

*Particle-size distributions at all sieve sizes used are given in Appendix C.

Based on visual estimates, there were significantly more fines ($P<0.01$) and less gravels ($P<0.01$) in the impacted section than the nonimpacted section in 1985 (Table 8). In 1986, significantly more fines ($P<0.01$) were present in the impacted section, while quantities of gravel between sections were not significantly different. Visual estimates of fine sediments at impacted transects decreased 14.9% ($P<0.01$) from 1985 to 1986, while estimates of gravels increased 12.6% ($P<0.01$). At nonimpacted transects, fine sediments showed no significant change, but gravels decreased 22.6% ($P<0.01$) from 1985 to 1986.

Table 8. Average percentages of substrates at impacted and nonimpacted transects based on visual estimates, 1983 (data from Spoon 1985), 1985 and 1986.

Year	Section	Substrate Class			
		Fine	Gravel	Cobble	Boulder
1983	Impacted	13.2	45.9	38.3	2.6
1985	Impacted	43.1	49.2	7.1	0.6
	Nonimpacted	11.2	71.7	12.4	4.7
1986	Impacted	28.2	61.8	9.1	0.9
	Nonimpacted	6.1	49.1	33.7	11.1

Predicted Survival to Emergence

Predicted survival of rainbow trout to emergence was greater in the nonimpacted section and at redd sites than the impacted section in 1985 and 1986 (Table 9). Predicted survival was highest for substrates at preferred spawning sites in 1985 and in the nonimpacted habitat section in 1986. Predicted survival to emergence increased in the impacted and nonimpacted sections in 1986, and showed little change at redd sites.

Table 9. Predicted survival to emergence (%) of rainbow trout embryos, for 1985 and 1986, using Irving and Bjornn's (1984) survival equation.

Year	Impacted section	Nonimpacted section	Natural redds	Artificial redds
1985	3.3	28.1	36.9	36.7
1986	21.3	40.8	35.9	27.2

Artificial Redds

Rainbow trout survival to time of emergence in 1985 was less than 1% in artificial redds in the impacted area, and 37.5% in the nonimpacted redd (Table 10); no correction was made for mortality from handling or incomplete fertilization. In 1986, corrected survival to emergence was 40.2% for artificial redds in the impacted area and 52.5% in the nonimpacted redd, but the difference was not significant.

Table 10. Rainbow trout survival (%) to time of emergence in artificial redds*, 1985 and 1986.

Year	Redd				
	1	2	3	4	5
1985	0	0	0	0.5	37.5
1986	0	12.0	85.0	64.0	52.5

*Redds 1-4 impacted, redd 5 nonimpacted.

Young-of-the-year Recruitment

In 1985, 25,504 YOY rainbow trout were captured at the mouth of Beaver Creek (station 1) during 62 trap-days (mean of 411 YOY/d), and 10,529 YOY were captured at station 2 during 59 trap-days (mean of 178 YOY/d; Figure 15). Trapping conditions were ideal with no high discharge events during the peak migration period in mid-July.

Fewer YOY migrants were captured in 1986; 13,527 at station 1 during 58 trap-days (mean of 233 YOY/d), and 3,117 at station 2 during 41 trap-days (mean of 76 YOY/d; Figure 16). Three peak discharge events occurred early in the 1986 trapping season and probably lowered trapping success at station 1 since flow went over the trap leads.

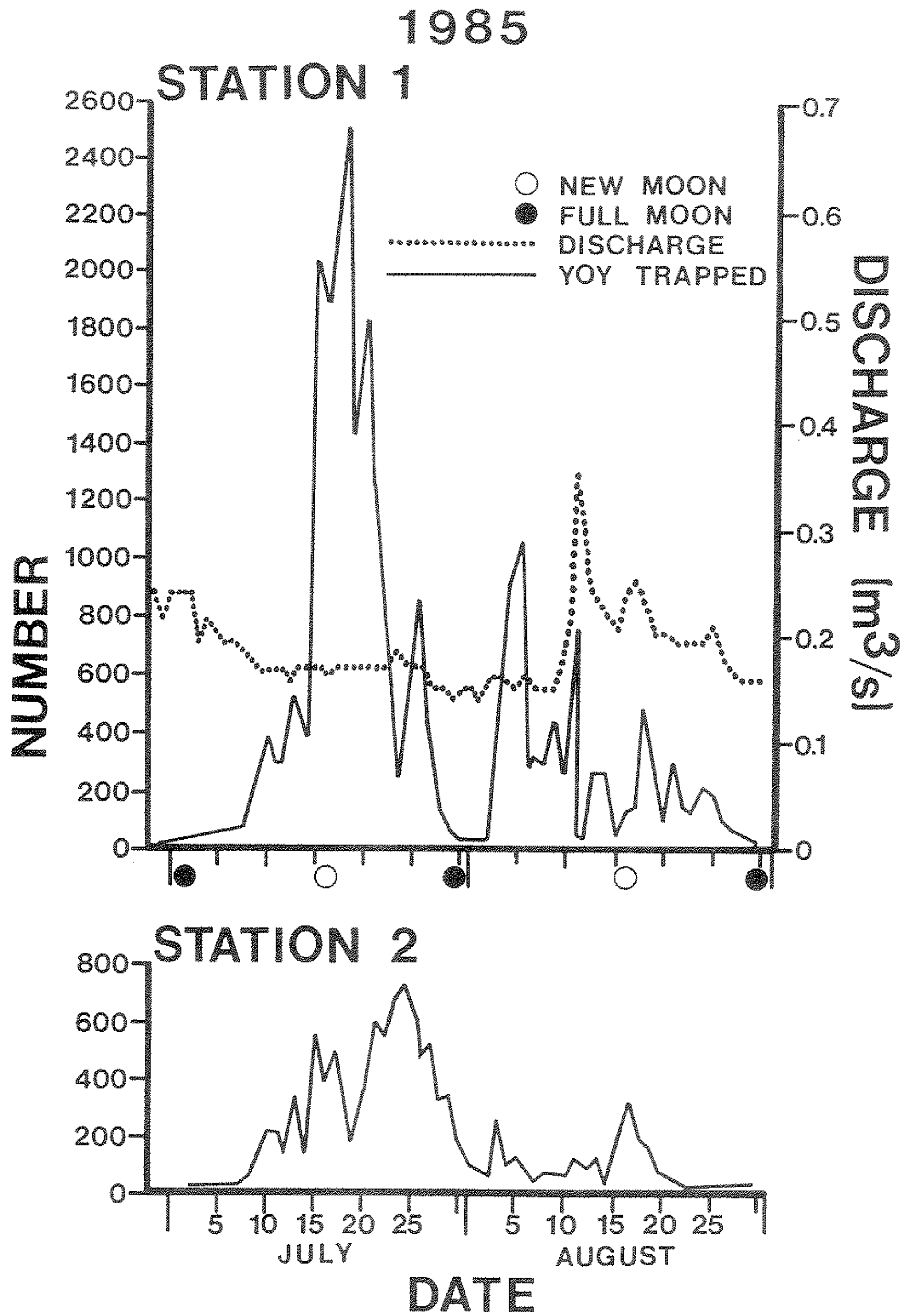

Figure 15. Total numbers of young-of-the-year rainbow trout trapped at stations 1 and 2, maximum daily discharge, and date of new and full moons for 1985.

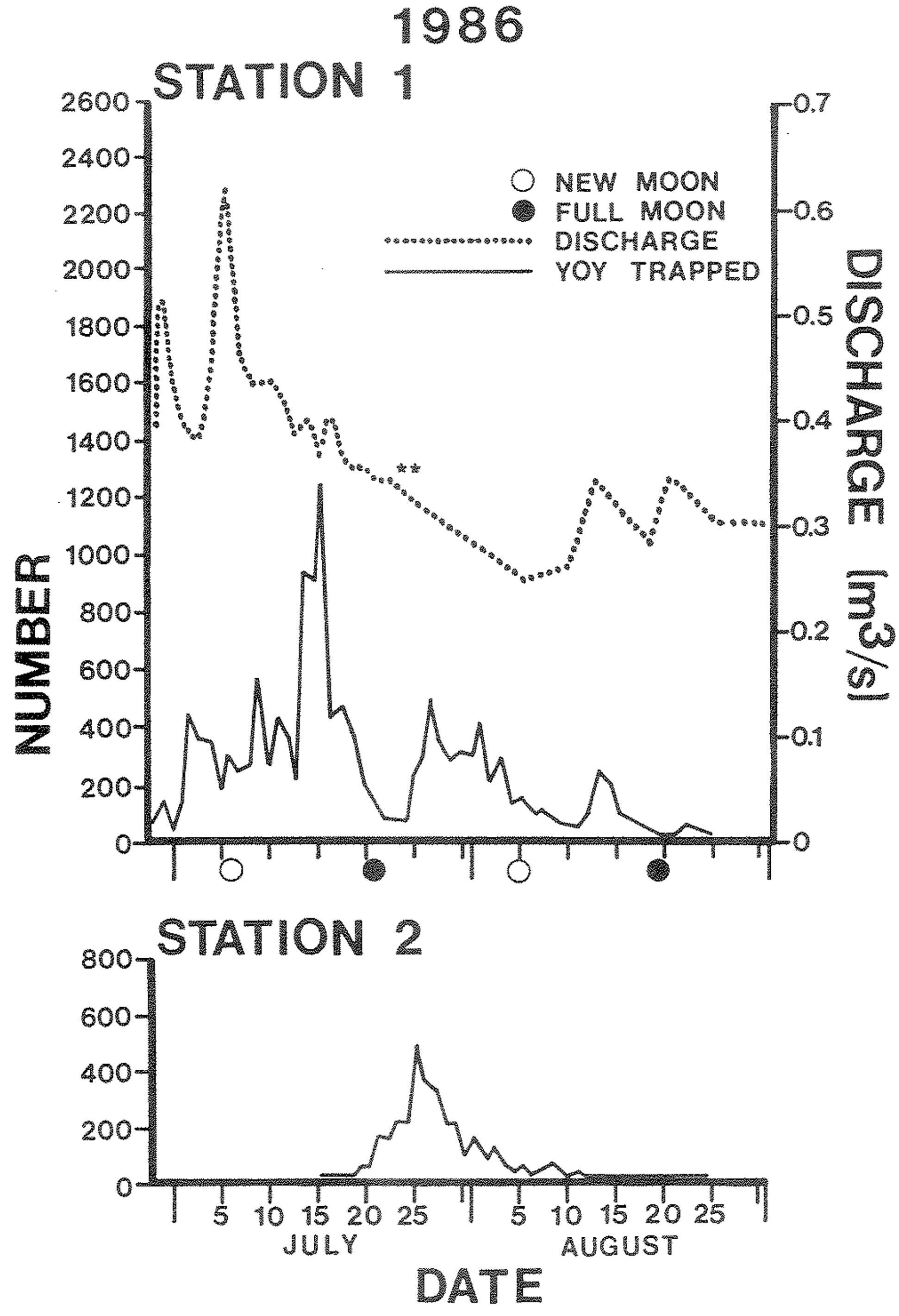

Figure 16. Total numbers of young-of-the-year rainbow trout trapped at stations 1 and 2, maximum daily discharge, and dates of new and full moons for 1986. (**discharge for 23 July-31 August estimated from 1980-1986 average and field notes)

Peak YOY capture occurred during July in 1985 and 1986. Young-of-the-year ranged from 23 mm (newly emerged) to 85 mm total length, with daily mean length ranging from 23 mm to 59 mm.

Observation of stained YOY rainbow trout showed positive identification for 2 to 4 d after marking; no mortality due to staining was observed in control groups. Batch marking of YOY rainbow trout in 1986 indicated that trapping efficiency was 31% at station 1. No correction was applied to total numbers of YOY rainbow trout captured at stations 1 and 2. Recapture of stained YOY released at station 2 indicated 2% of downstream migrants reached the mouth of Beaver Creek in 1986.

Aquatic Macroinvertebrate Recolonization

To avoid sampling selectivity, both artificial-substrate and Surber samples were used to follow recolonization of aquatic macroinvertebrates. Eighty-eight percent of the taxa collected at sampling sites 1, 2 and 3 were obtained with both artificial-substrate collectors and Surber samples. A list of percent occurrence at sites 1, 2 and 3, and Chi-Square values for taxa occurring in a minimum 10% of samples is presented in Appendix D.

Ninety-three percent of the taxa sampled at nonimpacted site 3 occurred in samples obtained at impacted sites 1 and 2 (Appendix A). An additional seven taxa were sampled at sites 1 and 2 which did not occur in samples at site 3. Sixty-two percent of Ephemeroptera and Plecoptera taxa sampled, which require second and third-order headwater lotic habitats with clean, rocky-bottoms (Edmunds 1984; Harper 1984) had significantly higher percent occurrence in artificial-substrate and Surber samples taken at nonimpacted site 3 (Table 11).

Table 11. Percent occurrence of Ephemeroptera and Plecoptera taxa from artificial-substrate collectors and Surber samples at sites 1, 2, and 3, and Chi-Square values.

Taxa	Site 1	Site 2	Site 3	X^2
Artificial-substrate collectors				
EPHEMEROPTERA				
Baetis tricaudatus	36.4	30.3	57.6	44.6**
Drunella coloradensis	6.1	6.1	21.2	16.6**
Ephemerella infrequens	6.1	3.0	3.0	0.6
Cinygmula spp.	6.1	12.1	30.3	34.6**
Epeorus spp.	3.0	0.0	18.2	20.6**
Rhithrogena spp.	21.2	15.2	33.3	18.6**
PLECOPTERA				
Capnia spp.	6.1	15.2	12.1	4.6
Triznaka signata	36.4	36.4	15.2	32.6**
Prostoia besametsa	6.1	12.1	9.1	2.0
Zapada centripes	18.2	15.2	27.3	8.6*
Doroneuria theodora	3.0	0.0	15.2	14.0**
Hesperoperla pacifica	66.7	54.5	75.8	24.6**
Isoperla fulva	24.2	24.2	15.2	6.0*

(Table 11. continued)

Taxa	Site 1	Site 2	Site 3	X^2
Surber samples				
EPHEMEROPTERA				
Baetis tricaudatus	26.7	40.0	60.0	12.6**
Drunella coloradensis	20.0	13.3	33.3	4.6
Ephemerella infrequens	13.3	0.0	13.3	2.6
Cinygmula spp.	26.7	6.7	40.0	12.6**
Epeorus spp.	0.0	0.0	40.0	24.0**
Rhithrogena spp.	0.0	26.7	60.0	40.6**
PLECOPTERA				
Capnia spp.	13.3	13.3	6.7	0.6
Triznaka signata	20.0	26.7	26.7	0.6
Prostoia besametsa	20.0	6.7	20.0	2.6
Zapada centripes	20.0	6.7	40.0	12.6**
Doroneuria theodora	0.0	0.0	26.7	10.6**
Hesperoperla pacifica	6.7	6.7	53.3	32.6**
Isoperla fulva	20.0	13.3	20.0	0.6

*$P<0.05$
**$P<0.01$

DISCUSSION

Trout Populations

Habitat characteristics and biota of Beaver Creek were severely damaged following the North Hill fire and flood. Decreased trout abundance probably resulted from mortality during the flood, fish moving downstream to the Missouri River, or fish becoming stranded in backwater areas in an attempt to avoid the debris torrent in Beaver Creek. Fish movement out of the impacted area of the stream may have occurred prior to electrofishing surveys in fall 1984 due to habitat degradation following the flood.

Hall and Knight (1981) reviewed several studies which illustrated the impacts of floods on salmonid populations. Generally, floods affect incubating eggs and young most severely. The magnitude of impact, however, can vary with severity of the event, species involved, time of year, and physical characteristics of the stream.

In the impacted portion of the creek, the initial debris torrent and subsequent sediment deposition reduced trout numbers 99% and biomass 98%, from fall 1983. Numbers of age-0, age-I and age-II trout were nearly eliminated, and there was complete loss of age-III and older fish (Appendix B Tables 13 and 14).

Similar results were found in Valley Creek, Minnesota where severe flooding nearly eliminated the brook trout population (Elwood and Waters 1969). Elwood and Waters found that young-of-the-year were affected immediately, while numbers of fish in older age groups were reduced in following months due to habitat degradation caused by the flooding. In the Horokiwi stream, New Zealand (Allen 1951) numbers of brown trout decreased 50% to 75% in most age-classes after severe flooding, and more than 80% mortality of eggs and fry was estimated. Hoopes (1975), and Seegrist and Gard (1972) also found the effects of flooding to be most severe on young-of-the-year trout.

Lower trout abundance in nonimpacted section 4 during fall 1984 and spring 1985 was probably not related to the fire-flood event. Extensive beaver activity necessitated shifting Spoon's (1985) electrofishing section 4 downstream approximately 150 m. A large beaver pond (approximate surface 300 m^2 and maximum depth of 2.0 m) flooded an adjacent willow thicket creating extensive overhead cover. Security cover afforded by such a large pond and the lack of a spillway over the dam may have influenced fish distribution downstream. The beaver dam forming this pond functioned as the upper boundary of the nonimpacted electrofishing section, and as the migration barrier to adfluvial spawners in spring 1985 and 1986.

Hall and Knight (1981) reported salmonid biomass in streams varying naturally from near 0 to 60 g/m^2. Fall biomass in nonimpacted section 4 of Beaver Creek ranged from 8.4 g/m^2 to 10.3 g/m^2, a variation of 2.0 g/m^2 during the study. This is compared to a range in biomass in the impacted sections of Beaver Creek of 2.4 g/m^2 to 161.5 g/m^2, a variation of 159.0 g/m^2; this is well in excess of the natural range reported by Hall and Knight (1981).

As fish populations began to recover, marked changes in the relative abundance of brown trout and rainbow trout occurred in impacted sections of Beaver Creek. Before the flood, rainbow trout composed 89% of the trout population, while biomass of rainbow and brown trout was approximately equal (Figures 5 and 6; Appendix B Tables 13 and 14). By fall 1986, rainbow trout composed 98% of the population by number, and 82% by biomass in impacted sections; rainbow trout numbers and biomass were 55% and 38% greater, respectively, than fall 1983. By fall 1986, age-class structure of the rainbow trout population was similar to pre-event composition (Figures 8 and 9).

The brown trout population in the impacted portion of Beaver Creek had not recovered by fall 1986. Brown trout numbers in impacted sections 2 and 3 were 85% lower than fall 1983 (White et al. 1985), and age-class composition had not recovered. This was reflected by a reduction in biomass of 94.5% and 81.2% in sections 2 and 3, respectively, from fall 1983 (Appendix B Tables 13 and 14).

Seegrist and Gard (1972) found similar changes in species composition after flooding in Sagehen Creek, California. They hypothesized that much of the variation in year-class strength of brook trout and rainbow trout could be attributed to destruction of redds during flood events. Immigration of rainbow trout into Valley Creek, Minnesota after flooding and loss of two year-classes of brook trout, resulted in strong recruitment of rainbow trout fry (Hanson and Waters 1974); rainbow trout constituted a significant proportion of the total salmonid population and production in post-flood years.

Spawning Surveys

Rapid recovery of the rainbow trout population in Beaver Creek was due to the large spawning runs of adfluvial rainbow trout from the Missouri River and Holter Reservoir. Although some spawning by adfluvial brown trout occurs in Beaver Creek, access during the fall spawning period is restricted due to the combination of beaver dams and low fall flows (Spoon 1985).

The flood breached all beaver dams in the impacted portion of Beaver Creek which improved upstream migration of spawners in 1985. However, construction of 31 beaver dams by spring 1986 slowed upstream movement of spawning rainbow trout; rainbow trout redds were observed upstream of electrofishing section 3 three weeks later in 1986 than 1985. A beaver dam constructed near the mouth of Beaver Creek during September 1986 restricted access of brown trout that fall; no brown trout redds were found upstream of the dam.

Most of the 666 brown trout redds observed by Spoon (1985) in Beaver Creek from 1981 to 1983 were thought to be constructed by resident brown trout. In 1981, Spoon (1985) identified nine adfluvial brown trout redds near the mouth of Beaver Creek. It is unknown if the 15 redds observed during this study in fall 1985 is a significant increase over previous years. Although there were few obstacles to upstream movement, average discharge during the spawning period in 1985 (0.25 m^3/s) was similar to that during Spoon's study, indicating that flow-related access into Beaver Creek probably did not improve.

Rainbow trout redd counts in 1985 and 1986 were higher than observed by Spoon (1985; Figure 11) but, due to optimum spring runoff conditions, water clarity improved redd identification. Also, a large beaver dam with no spillway restricted spawning rainbow trout to 10.5 km of Beaver Creek during Spoon's study, which resulted in considerable redd superimposition below the migration barrier (Spoon 1985).

Spawning adfluvial rainbow trout gained access to 19.2 km of stream in 1985 and 1986. Upstream migration was restricted by a large beaver dam with no spillway. The 1985 and 1986 redd counts are believed to be under-estimates due to high turbidity caused by a cattle drive along the stream during the last count in 1985, and to redd superimposition below two beaver dams in 1986. A higher redd count in the nonimpacted area in 1986 (168) compared to 1985 (117), may indicate a greater density of spawning rainbow trout competing for optimal spawning areas.

Substrate Composition

Significantly more fine sediments were present in the impacted portion of Beaver Creek compared to the non-impacted area after the fire-flood event (Figures 12 and 13; Table 7). Visual substrate analysis indicated significantly more fine sediments ($P<0.01$), less cobble ($P<0.01$) and less boulder ($P<0.01$) substrates in the impacted section in spring 1985 than fall 1983 (data from Spoon 1985; Table 8); percentage of gravel was not significantly different. Decreased quantities of fine sediments in core samples and at visual transects in 1986 probably resulted from natural flushing of fine sediments during spring runoff (Heede 1980). An intense revegetation program by the U.S. Forest Service (Putnam 1985) should accelerate stabilization of soils in the burned area, but continued influxes of sediment can be expected following heavy rain and snowmelt runoff in the immediate future.

Preferred spawning areas in Beaver Creek had particle-size distributions within the acceptable range (6.0-52.0 mm) for rainbow trout spawning (Reiser and Bjornn 1979). Mean substrate particle-sizes at redd sites in 1985 and 1986 (Table 6) were similar to the 22.4 mm mean particle-size reported by Spoon (1985), although particle-size distributions differed between years (Figure 14).

Particle-size distribution and permeability of spawning substrates influence development and emergence of salmonid fry. McNeil and Ahnell (1964) found that stream substrates with high permeability (24,000 cm/h) were more suitable spawning areas than those with low permeability (1300 cm/h). Streams with high embryo survival had substrates with less than 5% fine sediments (<0.833 mm), while embryo survival was relatively low in streams with more than 15% of the substrate <0.833 mm. In 1985 and 1986, amount of fine sediments <0.85 mm at redd sites in Beaver Creek was approximately 8.0% (Table 7), indicating good conditions for survival to hatching.

Successful emergence of salmonid fry is reduced when materials <6.4 mm comprise more than 20-25% of the spawning substrates (Reiser and Bjornn 1979). Substrates at redd sites in impacted and nonimpacted areas of Beaver Creek had approximately 28.0% (Table 7) of materials <6.35 mm in 1985 and 1986, suggesting reduced emergence success.

In 1985, cumulative substrate composition (Table 7) at random transects in the impacted section showed quantities of fine sediments <0.85 mm were large enough to lower survival to hatching, and materials <6.35 mm could have lowered emergence success. Areas of high quality spawning substrate were probably limited in Beaver Creek following the fire-flood event. Thus, some fish likely spawned in substrates containing greater amounts of fine sediments in the impacted portion of Beaver Creek in 1985. In 1986, fine sediments <0.85 mm and materials <6.35 mm decreased 7.7% and 3.4%, respectively, indicating better survival to hatch, but little improvement in emergence success.

Based on predicted embryo survival to emergence (Table 9), hatch and emergence success were greatest in substrates sampled at redd sites in impacted and non-impacted areas of Beaver Creek. Predicted survival to emergence at random sites in the impacted area of the creek increased 18.0% in 1986, compared to 1985, indicating substrates were more conducive to successful embryo development, and emergence success may have increased. Differences between predicted survival to emergence at artificial redd sites in 1985 and 1986 (approximately 30%), and observed survival to time of emergence in artificial redds (42.7% in 1986) may represent mortality during emergence.

Young-of-the-year Recruitment

Large numbers of YOY rainbow trout in Beaver Creek during 1985 and 1986 resulted from continued reproductive success of adfluvial spawners in the impacted portion of the stream. Near elimination of the resident brown trout population and limited spawning by adfluvial brown trout in Beaver Creek diminished recruitment of YOY.

The lower number of YOY rainbow trout captured at station 1 in 1986 than 1985 probably resulted from higher intercohort and interspecific predation as fish populations recovered in the impacted portion of the creek. Fewer YOY trapped above the impacted area (station 2) in 1986 may have resulted from lower survival to emergence of rainbow trout due to increased density of spawners. Johnson (1965) found that with increased densities of spawning salmon, more fish are forced to spawn in marginal substrates. Greater densities of incubating eggs, even in the most desirable substrates, may lead to increased mortality before hatching due to lower oxygen levels, excessive metabolite (NH_3) concentrations, and pathogens.

Carty (1985) trapped YOY at the mouth of Beaver Creek in summer 1983 and captured 6,224 YOY rainbow trout during

70 trap-days (mean of 89 YOY/d). Carty's total capture was much lower than during this study and probably resulted from differences in predation, flow regimes, trap design, and techniques. Interspecific predation on YOY was probably much higher prior to the fire-flood event when there were more age-III and older brown and rainbow trout in the impacted area of Beaver Creek. Carty (pers. comm.) used four traps, did not use leads or rock around trap openings, and lost use of his traps for 4 d in mid-July due to damage during a peak discharge event. Peak migration may have occurred during the period that Carty (1985) lost use of his traps and, therefore, lowered his total capture. Also, lower survival to emergence may have occurred during Carty's study due to redd superimposition below the migration barrier and increased embryo mortality before hatching.

Mortality has been shown to be greatest in YOY salmonids during the first few months of life, with less than 10% survival (Ricker 1954; Johnson 1965; Chapman 1966; McFadden 1969). Survival of YOY emigrants is influenced by environmental factors, competition and predation (Chapman 1966). Since YOY rainbow trout emigrated soon after emergence in Beaver Creek, intracohort competition would not be expected to have caused high mortality; water quality and other environmental factors appeared suitable for good survival. Intercohort and interspecific predation would have reduced survival in the nonimpacted area of Beaver Creek, but was probably minimal in the impacted portion in 1985 since there were few age-III and older brown and rainbow trout. Predation was not absent in the impacted area, however, as belted kingfishers (Megaceryle alcyon) and common mergansers (Mergus merganser) were often observed feeding in the creek downstream of Nelson.

Alexander (1979) estimated a minimum 3.3% of total annual production was consumed by mergansers and kingfishers preying on age-0 and age-I brook and brown trout in the Au Sable River, Michigan. It is likely that mortality due to avian predation would have remained static in Beaver Creek or possibly decreased with an increase in recruitment following the fire-flood event.

Aquatic Macroinvertebrate Recolonization

It is assumed that the influx of sediment and debris from the burn area in combination with the high discharge experienced in Beaver Creek severely reduced the benthic community. Flooding in streams displace organisms and reduce the invertebrate fauna by increased discharge and, abrasion of larger substrates by fine sediments (Hynes 1972). Hynes (1972) indicated that high flows alone are not of great detriment to the benthic community since temporary shelter is available in substrate interstices. Tebo (1955) found that flooding reduced benthic organisms

73.2% in a heavily sedimented section of stream, as compared to a 22.2% decrease in a control section immediately upstream. Hoopes (1974) found a significant decrease in number of taxa and total numbers of benthic macroinvertebrates in a Pennsylvania stream after severe flooding. In both cases discharge was high enough to completely resort the bottom substrates, and severe scouring of larger substrates occurred. Thus, spates of a magnitude large enough to dislodge the armor layer, resort substrates, and scour the larger substrates, seriously reduces the benthic community of streams.

By fall 1986, aquatic invertebrate taxa present at impacted sites 1 and 2 were similar to those present at nonimpacted site 3, indicating the benthic community in the impacted portion of Beaver Creek had recovered. However, significantly greater percent occurrence of eight Ephemeroptera and Plecoptera taxa at nonimpacted site 3 (Table 11) indicates density of the benthic community was lower in the impacted area.

Bjornn et al. (1977) found that streambeds with cobbles more than two-thirds embedded by fine sediments lowered the diversity and density of the benthic insect community by restricting the capacity for subsurface habitation and reducing streambed permeability. Cobbles embedded in a coarser matrix (e.g., pebble) generally supported a more diverse benthic community with greater densities. Substrates classified as two-thirds to fully embedded corresponded to manual-core samples containing 30% or more materials <6.35 mm. Cumulative substrate composition in impacted and nonimpacted sections of Beaver Creek (Table 7) indicate cobble substrates were more than two-thirds embedded. Greater amounts of fine sediments ≤2.00 mm in the impacted section than the nonimpacted section (Figures 12 and 13), indicate a higher degree of embeddedness in substrate interstices and lower permeability at collecting sites 1 and 2 than at site 3 in the nonimpacted section.

Tests conducted in experimental stream channels by Bjornn et al. (1977) showed that *Epeorus albertae* and *Baetis bicaudatus* were intolerant to high levels of sedimentation. When cobbles in treatment channels were more than two-thirds embedded, numbers of *E. albertae* and *B. bicaudatus* were 94% and 52% lower, respectively, compared to control channels without sediment. In Beaver Creek, percent occurrence of *Epeorus* spp. and *Baetis tricaudatus* at impacted sites 1 and 2 was significantly lower than at nonimpacted site 3 (Table 11), and probably resulted from cobble substrates in the impacted section being more fully embedded by fine sediments.

It is likely that recolonization of the impacted portion of Beaver Creek had occurred before initiation of sampling in June 1985, 9 months after the fire-flood event.

Colonization of newly excavated stream channels begins as rapidly as the first day (Williams and Hynes 1977) to within a week (Leonard 1942). Recovery of denuded populations may occur as rapidly as 10-14 d in experimental plots (Waters 1964), although most research indicates recovery in 3-5 months when large stream segments are affected (Surber 1937; Leonard 1942; Kennedy 1958; Larimore, Childers and Heckrotte 1959; Hoopes 1974; Williams and Hynes 1977).

Colonization of lotic habitats occurs via downstream drift, upstream migration, migration within the substrate and aerial dispersal of adults (Kennedy 1958; Larimore, Childers and Heckrotte 1959; Waters 1964; Leudtke and Brusven 1976; Williams and Hynes 1977). Downstream drift has been shown to be a sufficient mechanism for recovery of depleted populations (Waters 1964), whether the reduction is normal (a result of emergence or behavioral drift), or induced (a result of flooding; Waters 1961).

Recolonization of aquatic invertebrates occurred in the impacted area of Beaver Creek from fall 1984 to spring 1985. Adult dispersal and reproduction is minimal during fall and winter in temperate headwater streams (Anderson and Wallace 1984) and probably did not add appreciably to recolonization. Migration of invertebrates within the substrates is unlikely due to the degree of embeddedness in the impacted area. Upstream migration from the Missouri

River probably occurred, although habitat and water quality of Beaver Creek may not be suitable for many large river taxa. Thus, downstream drift was likely the major source of ingress, and increased flows associated with rain and snowmelt probably increased the drift rates of many taxa (Anderson and Lehmkuhle 1967), accelerating the recovery of the benthic community.

SUMMARY

1) Habitat characteristics and biota of Beaver Creek were severely damaged following the 1984 North Hill fire and flood.

2) Numbers and biomass of trout were seriously reduced. Age-0, age-I and age-II trout were nearly eliminated, and there was complete loss of age-III and older fish.

3) By fall 1986, abundance and biomass of rainbow trout in the impacted portion of Beaver Creek were much greater than prior to the event, and age-class structure was similar to 1983. In 1986, brown trout abundance and biomass in the impacted area were much lower than in fall 1983, and age-class structure had not recovered.

4) Rapid recovery of the rainbow trout population in Beaver Creek was due to spawning of adfluvial rainbow trout from the Missouri River and Holter Reservoir. Although some spawning by adfluvial brown trout occurred in Beaver Creek, access in fall is restricted due to the combination of beaver dams and low fall flows.

5) Significantly more fine sediments were present in the impacted section of Beaver Creek than in the non-impacted section after the fire-flood event. Lower quantities of fine sediments in 1986 probably resulted from natural flushing of fine sediments during spring runoff.

6) Spawning rainbow trout selected redd sites containing significantly fewer fine sediments than were measured in randomly sampled riffles. Predicted survival to emergence of rainbow trout embryos was highest in substrates sampled at redd sites, and lowest in riffle areas in the impacted area of Beaver Creek.

7) Large numbers of YOY rainbow trout in Beaver Creek during 1985 and 1986 resulted from continued reproductive success of adfluvial spawners in the impacted portion of the stream. Near elimination of the resident brown trout population in Beaver Creek and limited spawning by adfluvial brown trout diminished recruitment of YOY.

8) Total capture of YOY rainbow trout emigrating to the Missouri River in 1985 and 1986 was much higher than 1983 and probably resulted from lower interspecific and intercohort predation.

9) The abundance of benthic organisms in the impacted area of Beaver Creek was assumed to have been severely reduced during the flood event. Invertebrate taxa present at impacted and nonimpacted sampling sites were similar 9 months after the flood.

10) Percent occurrence of several invertebrate taxa remained lower at sampling sites in the impacted area compared to the nonimpacted area in fall 1986. This was probably due to greater embeddedness of cobble substrates by fine sediments, restricting the capacity for subsurface habitation and reducing streambed permeability.

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APPENDICES

Appendix A

Aquatic Macroinvertebrate Species List

Table 12. Aquatic macroinvertebrate taxa collected at sample sites and random locations* in Beaver Creek. a = adult, l = larvae, p = pupae; + = present, - = absent at sample site.

Taxa	Site		
	1	2	3
ANNELIDA			
OLIGOCHAETA	+	+	+
COLEOPTERA			
Dytiscidae			
Agabus spp. (a)	N/A	N/A	N/A
Hydaticus spp. (a)	N/A	N/A	N/A
Megadytes spp. (a)	N/A	N/A	N/A
Elmidae			
Cleptelmis ornata (a)	+	+	+
Heterlimnius corpulentus (l)	+	+	+
Optioservus quadrimaculatus (a)	+	+	+
Optioservus spp. (l)	+	+	+
Narpus concolor (l)	+	+	+
Zaitzevia parvula (a,l)	+	+	+
Gyrinidae			
Gyrinus spp. (a)	N/A	N/A	N/A
Haliplidae			
Brychius horni (a)	+	-	-
Brychius spp. (l)	+	+	+
Hydrophilidae (a)	+	-	-
DIPTERA			
Chironomidae (l,p)	+	+	+

(Table 12. continued)

Taxa	Site 1	Site 2	Site 3
Empididae (l,p)	+	+	+
Muscidae (l)	+	-	-
Pelecorhynchidae (l)	+	-	+
Psychodidae			
Pericoma spp. (l)	+	+	+
Simuliidae (l)	+	+	+
Tipulidae			
Antocha spp. (l)	+	+	+
Dicranota spp. (l)	+	+	+
Hexatoma spp. (l)	+	+	-
Limnephila spp. (l)	+	+	-
Pseudolimnephila spp. (l)	+	+	-
Tipula spp. (l)	-	-	+
EPHEMEROPTERA			
Baetidae			
Baetis tricaudatus (l)	+	+	+
Ephemerellidae			
Drunella coloradensis (l)	+	+	+
D. doddsi (l)	-	-	+
D. flavilinia (l)	+	-	+
D. grandis (l)	+	-	+
Ephemerella infrequens (l)	+	+	+
Serratella tibialis (l)	+	+	+

(Table 12. continued)

Taxa	Site 1	Site 2	Site 3
Heptageniidae			
Cinygmula spp. (l)	−	+	+
Epeorus spp. (l)	+	+	+
Heptagenia spp. (l)	+	+	+
Rhithrogena spp. (l)	+	+	+
Leptophlebiidae			
Leptophlebia spp. (l)	+	−	−
Paraleptophlebia spp. (l)	−	+	+
Siphlonuridae			
Ameletus spp. (l)	+	−	+
Tricorythidae			
Tricorythodes minutus (a)	N/A	N/A	N/A
HEMIPTERA			
Belastomatidae			
Lethocerus spp. (a)	N/A	N/A	N/A
Corixidae (a)	N/A	N/A	N/A
Gerridae			
Gerris spp. (a)	N/A	N/A	N/A
Notonectidae			
Notonecta spp. (a)	N/A	N/A	N/A

(Table 12. continued)

Taxa	Site 1	Site 2	Site 3
MOLLUSCA			
GASTROPODA			
Lymnaeidae			
Stagnicola spp.	+	-	-
Lymnea spp.	-	+	+
Physidae			
Physa spp.	+	+	-
Planorbidae			
Helisoma spp.	-	+	-
PLECOPTERA			
Capniidae (l)	-	+	+
Capnia spp. (l)	-	+	+
Chloroperlidae			
Alloperla spp. (l)	-	+	-
Paraperla fontalis (l)	N/A	N/A	N/A
Triznaka signata (l)	+	+	+
Utaperla sopladora (l)	N/A	N/A	N/A
Nemouridae			
Prostoia besametsa (l)	+	+	+
Zapada centripes (l)	+	+	+
Perlidae			
Doroneuria theodora (a,l)	+	+	+
Hesperoperla pacifica (l)	+	+	+
Perlodidae			
Isoperla fulva (l)	+	+	+
Skwala spp. (l)	-	+	+

(Table 12. continued)

Taxa	Site 1	Site 2	Site 3
Pteronarcyidae			
Pteronarcys californica (l)	+	+	+
TRICHOPTERA			
Brachycentridae			
Brachycentrus americanus (l,p)	+	+	+
Micrasema spp. (l)	+	-	-
Glossosomatidae			
Glossosoma alescences (p)	+	+	+
Glossosoma spp. (l)	+	+	+
Hydropsychidae			
Arctopsyche grandis (l,p)	+	+	+
Hydropsyche spp. (l)	+	+	+
Lepidostomatidae			
Lepidostoma spp. (l,p)	+	+	+
Limnephilidae			
Dicosmoecus spp. (l)	+	+	+
Grensia spp. (l)	+	+	+
Limnephilus spp. (l)	+	+	+
Neophylax spp. (l)	+	+	+
Onocosmoecus spp. (l)	+	+	+
Philopotamidae (p)	-	-	+
Rhyacophilidae			
Rhyacophila angelita (l)	+	+	+

*N/A = Taxa sampled at random sites, not from artificial substrate collectors or Surber samples.

Appendix B

Stock Density and Biomass of Trout Species in Beaver Creek

Table 13. Stock density and biomass of trout, impacted section 2 Beaver Creek, fall 1982 (pre-fire) through fall 1986. (80% confidence intervals in parentheses)

Date	Trout species	Age	Mean length (cm)	Mean weight (g)	Stock density (no./ha)	Biomass (kg/ha)
9/82[1]	Brown	0	8.1	5	92	0.31
		I	16.7	45	31	1.38
		II	25.4	167	262	42.85
		III and older	28.7	249	8	2.08
		Total			393(±38)	46.62
9/82[1]	Rainbow	0	6.6	5	6500	6.31
		I	14.2	31	200	6.62
		II	19.1	77	54	3.85
		III and older	20.6	92	8	0.69
		Total			6762(±310)	17.47
9/83[1]	Brown	0*	7.6	5	--	--
		I	16.6	45	92	4.34
		II	27.6	222	92	21.62
		III and older	31.5	322	31	9.00
		Total			215(±54)	34.96
9/83[1]	Rainbow	0	7.1	5	3076	9.77
		I	13.9	32	700	22.00
		II and older	21.8	109	69	7.62
		Total			3845(±1431)	39.39
10/84	Brook	0	8.6	5	38	0.23
		I and older	19.4	84	23	1.92
		Total			61(±0)	2.15
4/85[2]	Brook	I	10.3	10	31	0.31
		II	18.5	60	8	0.46
		Total			39	0.77
4/85[2]	Brown	II	20.5	110	8	0.85
9/85	Brook	0	10.5	15	8	0.15
		I	16.3	43	208	9.30
		II and older	25.1	162	38	6.23
		Total			254(±23)	15.68
9/85[2]	Brown	0	10.0	10	15	0.15
		II and older	23.5	165	15	2.46
		Total			30	2.61

(Table 13. continued)

Date	Trout species	Age	Mean length (cm)	Mean weight (g)	Stock density (no./ha)	Biomass (kg/ha)
9/85	Rainbow	0	7.9	5	6046	30.31
		I	14.3	33	362	10.92
		II and older	25.1	162	38	6.23
		Total			6446(±85)	47.46
3/86[2]	Brook	I and older	21.3	100	138	10.54
3/86[2]	Brown	I and older	24.2	143	23	3.31
3/86	Rainbow	I	6.7	7	1884	11.31
		II	15.0	34	277	7.69
		III and older	30.6	245	62	16.92
		Total			2223(±100)	35.92
9/86	Brook	0*	4.5	2	--	--
		I*	14.5	26	--	--
		II and older	23.2	177	69	11.08
		Total			69(±0)	11.08
9/86[2]	Brown	II and older	22.5	127	15	1.92
9/86	Rainbow	0	7.2	6	2438	14.61
		I	12.8	23	1223	23.84
		II and older	22.1	216	208	25.54
		Total			3869(±46)	63.99

[1]from White et al. 1984
[2]total number electrofished, no estimate calculated
*no estimate caculated for age group

Table 14. Stock density and biomass of trout, impacted section 3 Beaver Creek, fall 1982 (pre-fire) through fall 1986. (80% confidence intervals in parentheses)

Date	Trout species	Age	Mean length (cm)	Mean weight (g)	Stock density (no./ha)	Biomass (kg/ha)
9/82[1]	Brown	0	8.1	9	315	2.08
		I	14.7	32	15	0.69
		II	24.4	158	408	64.84
		III	28.8	254	46	11.54
		Total			784(±123)	79.15
9/82[1]	Rainbow	0	7.6	5	1623	6.61
		I	13.2	27	685	18.23
		II	20.8	104	46	4.92
		III	25.9	186	15	2.77
		Total			2369(±331)	32.53
9/83[1]	Brown	0*	7.6	5	--	--
		I	15.7	41	369	15.00
		II	25.6	213	154	32.77
		III	29.9	331	54	18.15
		IV and older	36.8	417	15	7.00
		Total			592(±85)	72.92
9/83[1]	Cutthroat	I	19.8	91	85	7.69
		II and older	22.8	154	15	2.46
		Total			100(±0)	10.15
9/83[1]	Rainbow	0	8.6	5	2538	16.38
		I	14.2	32	1246	37.00
		II and older	20.1	113	54	5.92
		Total			3838(±1284)	59.30
10/84[2]	Rainbow	0	8.8	10	8	0.77
		I and older	16.7	45	23	1.08
		Total			31	1.85
4/85[2]	Brown	III	27.5	230	8	1.77
4/85[2]	Rainbow	I	10.5	10	8	0.77
		II and older	18.5	60	15	0.92
		Total			23	1.69
10/85	Brown	II	25.6	193	61(±23)	12.46

(Table 14. continued)

Date	Trout species	Age	Mean length (cm)	Mean weight (g)	Stock density (no./ha)	Biomass (kg/ha)
10/85	Rainbow	0	6.7	8	6138	46.00
		I	15.3	38	38	25.69
		II	25.2	184	46	8.15
		III and older	39.8	317	23	12.46
		Total			6845(±808)	92.30
3/86[2]	Brown	II and older	28.2	223	46	11.61
3/86	Rainbow	I	7.1	5	1730	8.69
		II	14.9	27	323	8.69
		III and older	24.3	207	192	39.85
		Total			2245(±192)	57.23
9/86[2]	Brook	I and older	19.7	116	38	4.46
9/86	Brown	0	9.5	6	38	0.23
		I	18.5	64	31	2.00
		II and older	30.8	319	38	11.54
		Total			107(±31)	13.77
9/86	Rainbow	0	7.0	5	6240	18.61
		I	12.6	24	1715	30.61
		II	20.4	108	100	10.61
		III and older	35.3	440	31	13.54
		Total			8086(±631)	73.37

[1]from White et al. 1984
[2]total number electrofished, no estimate calculated
*no estimate calculated for age group

Table 15. Stock density and biomass of trout, nonimpacted section 4 Beaver Creek, fall 1982 (pre-fire) through fall 1986. (80% confidence intervals in parentheses)

Date	Trout species	Age	Mean length (cm)	Mean weight (g)	Stock density (no./ha)	Biomass (kg/ha)
9/82[1]	Brook	0	7.8	5	454	2.54
		I	19.3	91	82	7.00
		II	22.3	150	136	21.09
		Total			672(±154)	30.63
9/82[1]	Rainbow-Cutthroat	0*	8.6	9	--	--
		I	12.7	22	2136	48.45
		II	20.6	104	118	12.36
		III	25.9	191	9	2.09
		Total			2263(±936)	62.90
9/83[1]	Brook	0	8.1	5	609	3.27
		I	14.7	36	218	8.64
		II and older	24.8	208	45	10.27
		Total			872(±236)	22.18
9/83[1]	Rainbow-Cutthroat	0	8.8	9	5873	40.36
		I	15.5	45	1391	63.45
		II*	21.3	127	--	--
		III and older*	24.1	172	--	--
		Total			7264(±2554)	103.81
10/84	Brook	0	8.9	6	200	0.73
		I	15.3	32	218	7.64
		II	20.0	86	100	8.09
		Total			518(±73)	16.46
10/84[2]	Brown	0	7.0	5	18	0.09
10/84	Rainbow-Cutthroat	I	13.5	23	545	11.91
		II	20.2	91	491	40.73
		III and older	28.4	252	64	13.73
		Total			1100(±291)	66.37
4/85	Brook	I	9.8	10	182	1.64
		II and older	17.4	51	200	8.64
		Total			382(±64)	10.28
4/85[2]	Brown	II and older	27.5	230	18	4.18

(Table 15. continued)

Date	Trout species	Age	Mean length (cm)	Mean weight (g)	Stock density (no./ha)	Biomass (kg/ha)
4/85	Rainbow-Cutthroat	I	6.0	6	64	0.36
		II	13.3	20	154	2.54
		III and older	21.2	124	209	19.45
		Total			427(±82)	22.35
9/85	Brook	0	7.9	8	1254	7.54
		I	15.4	33	100	3.18
		II and older	27.7	144	327	38.18
		Total			1681(±209)	48.90
9/85[2]	Brown	III	32.5	320	9	2.91
9/85	Rainbow-Cutthroat	0	5.9	5	4690	23.45
		I	13.2	27	236	10.91
		II and older	21.4	124	145	16.45
		Total			5071(±327)	50.81
3/86	Brook	I	9.4	9	991	9.00
		II and older	19.2	86	254	16.00
		Total			1245(±218)	25.00
3/86[2]	Brown	I and older	20.5	130	18	2.36
3/86	Rainbow-Cutthroat	I*	6.0	3	--	--
		II	13.7	21	227	4.82
		III	20.5	106	64	5.91
		Total			291(±73)	10.73
9/86	Brook	0	8.4	6	4136	23.45
		I	15.8	36	436	17.09
		II and older	23.1	142	136	24.18
		Total			4708(±36)	64.72
9/86	Brown	0	7.3	5	236	0.91
		I and older	18.3	56	45	2.73
		Total			281(±27)	3.64

(Table 15. continued)

Date	Trout species	Age	Mean length (cm)	Mean weight (g)	Stock density (no./ha)	Biomass (kg/ha)
9/86	Rainbow-Cutthroat	0	7.0	4	1218	4.91
		I	12.9	16	718	14.00
		II and older	19.8	79	91	8.00
		Total			2027(±191)	26.91

[1]from White et al. 1984
[2]total number electrofished, no estimate calculated
*no estimate calculated for age group

Appendix C

Substrate Particle Size Distributions

Table 16. Substrate composition (%) at given sieve size for impacted and nonimpacted habitat sections and redd sites, Beaver Creek, 1985 and 1986.

Year	Sieve Size (mm)											
	≥76.1	50.8	25.4	15.9	12.7	9.52	6.35	4.76	2.00	0.85	0.42	≤0.074
					Impacted							
1985	6.5	11.0	19.3	10.3	4.4	5.2	5.4	3.2	8.2	8.2	6.5	11.8
1986	8.5	14.2	13.4	11.8	4.7	6.2	6.5	3.8	10.0	10.2	5.6	5.1
					Nonimpacted							
1985	6.2	9.4	22.5	12.7	5.2	6.2	6.4	3.9	9.5	8.5	5.7	3.8
1986	12.5	17.0	14.9	11.8	5.6	5.7	5.8	3.3	8.2	7.6	4.3	3.3
					Redd Sites							
1985	0.9	11.5	25.5	14.2	5.5	6.3	6.1	3.5	9.2	9.1	4.6	3.6
1986	5.5	13.0	18.6	15.6	5.6	7.1	6.7	3.7	7.9	7.9	5.2	3.2

Appendix D

Percent Occurance of Aquatic Macroinvertebrates at Sample Sites 1, 2, and 3, and Chi-Square Values

Table 17. Percent occurrence of aquatic macroinvertebrates at sites 1, 2, and 3, and Chi-Square values, from artificial-substrate collectors, Beaver Creek.

Taxa	Site			X^2
	1	2	3	
COLEOPTERA				
Elmidae	18.2	15.2	9.1	4.6
DIPTERA				
Chironomidae	30.3	42.4	57.6	40.6**
Simuliidae	15.2	3.0	12.1	8.6*
Antocha spp.	9.1	9.1	9.1	0.0
Dicranota spp.	6.1	6.1	6.1	0.0
Hexatoma spp.	15.2	24.2	0.0	32.6**
Limnephila spp.	9.1	6.1	0.0	4.6
Pseudolimnephila spp.	9.1	9.1	3.0	2.6
EPHEMEROPTERA				
Baetis tricaudatus	36.4	30.3	57.6	44.6**
Drunella coloradensis	6.1	6.1	21.2	16.6**
Ephemerella infrequens	6.1	3.0	3.0	0.6
Serratella spp.	12.1	18.2	9.1	4.6
Cinygmula spp.	6.1	12.1	30.3	34.6**
Epeorus spp.	3.0	0.0	18.2	20.6**
Rhithrogena spp.	21.2	15.2	33.3	18.6**
Paraleptophlebia spp.	3.0	12.1	18.2	12.6**
Ameletus spp.	3.0	0.0	9.1	4.6
PLECOPTERA				
Capnia spp.	6.1	15.2	12.1	4.6
Triznaka signata	36.4	36.4	15.2	32.6**
Prostoia besametsa	6.1	12.1	9.1	2.0
Zapada centripes	18.2	15.2	27.3	8.6*
Doroneuria theodora	3.0	0.0	15.2	14.0**
Hesperoperla pacifica	66.7	54.5	75.8	24.6**
Isoperla fulva	24.2	24.2	15.2	6.0*
Pteronarcys californica	42.4	30.3	6.1	74.6**

(Table 17. continued)

Taxa	Site 1	Site 2	Site 3	X^2
TRICHOPTERA				
Brachycentrus americanus	60.6	42.4	42.4	24.0**
Glossosoma spp.	60.6	57.6	60.6	0.6
Arctopsyche grandis	57.6	48.5	60.6	8.6*
Hydropsyche spp.	21.2	18.2	12.1	4.6
Lepidostoma spp.	24.2	27.3	12.1	14.0**
Dicosmoecus spp.	12.1	6.1	0.0	8.0*
Onocosmoecus spp.	24.3	12.1	0.0	32.0**
Rhyacophyla angelita	33.3	18.2	9.1	32.6**

*P-value <0.05
**P-value <0.01

Table 18. Percent occurance of aquatic macroinvertebrates at sites 1, 2, and 3, and Chi-square values, from Surber samples, Beaver Creek.

Taxa	Site 1	Site 2	Site 3	X^2
COLEOPTERA				
Elmidae	40.0	6.7	40.0	16.6**
Haliplidae	33.3	13.3	0.0	12.6**
DIPTERA				
Chironomidae	46.7	33.3	33.3	2.6
Empididae	13.3	13.3	20.0	0.6
Muscidae	13.3	0.0	0.0	2.6
Pelecorhynchidae	0.0	6.7	13.3	2.0
Psychodidae	6.7	0.0	26.7	8.6*
Simuliidae	0.0	6.7	13.3	2.0
Antocha spp.	13.3	20.0	40.0	8.6*
Dicranota spp.	20.0	6.7	0.0	4.6
Hexatoma spp.	20.0	0.0	0.0	6.0*
Limnephila spp.	13.3	6.7	6.7	0.6
Pseudolimnephila spp.	13.3	0.0	0.0	2.6
EPHEMEROPTERA				
Baetis tricaudatus	26.7	40.0	60.0	12.6*
Drunella coloradensis	20.0	13.3	33.3	4.6
D. flavilinea	0.0	0.0	13.3	2.6
D. grandis	6.7	0.0	6.7	0.6
Ephemerella infrequens	13.3	0.0	13.3	2.6
Serratella spp.	0.0	0.0	20.0	6.0*
Cinygmula spp.	26.7	6.7	40.0	12.6**
Epeorus spp.	0.0	0.0	40.0	24.0**
Heptagenia spp.	13.3	13.3	6.7	0.6
Rhithrogena spp.	0.0	26.7	60.0	40.6**
PLECOPTERA				
Capnia spp.	13.3	13.3	6.7	0.6
Triznaka signata	20.0	26.7	26.7	0.6
Prostoia besametsa	20.0	6.7	20.0	2.6
Zapada centripes	20.0	6.7	40.0	12.6**
Doroneuria theodora	0.0	0.0	26.7	10.6**
Hesperoperla pacifica	6.7	6.7	53.3	32.6**
Isoperla fulva	20.0	13.3	20.0	0.6

(Table 18. continued)

Taxa	Site 1	Site 2	Site 3	X^2
TRICHOPTERA				
Brachycentrus americanus	99.9	66.7	80.0	12.6**
Glossosoma spp.	80.0	73.3	86.7	2.0
Arctopsyche grandis	20.0	40.0	73.3	32.6**
Hydropsyche spp.	13.3	6.7	26.7	4.6
Lepidostoma spp.	6.7	20.0	20.0	2.6
Onocosmoecus spp.	33.3	6.7	6.7	10.6**
Rhyacophyla angelita	26.7	13.3	60.0	26.0**

*P-value <0.05
**P-value <0.01