Aquatic Macroinvertebrate Surveys in the Clark Fork River,1986 to 1988

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Abstract

The Montana DHES conducts aquatic macroinvertebrate surveys as part of its environmental surveillance of the Clark Fork River. Since 1986, annual collections have consisted of four modified Hess samples from each of 25 stations between the headwaters of Silver Bow Creek and Thompson Falls Reservoir. The purpose of these studies are to monitor the integrity of macroinvertebrate assemblages in the river, to detect changes in water quality and to provide information useful for water-quality management decisions.

Macroinvertebrates provided assessments of metals and organic pollution as well as cumulative environmental stress in the Clark Fork drainage. Metals pollution remained the principle agent of perdition in Silver Bow Creek while degradation from both metals and organic pollution were widespread in the upper reaches of the Clark Fork River. The biological impacts of heavy metal contamination were significantly reduced below the Warm Springs Ponds compared with conditions in Silver Bow Creek. Nevertheless, metals clearly limited the number of macroinvertebrate species in the Clark Fork River downstream at least as far as Bonita. Impacts attributable to metals were relatively uniform in the upper river from Warm Springs Creek to the confluence of the Little Blackfoot River. Further downstream, proximity to "clean water" tributaries appeared to be an important factor influencing the extent of metals impacts. Biologically significant metals pollution was not detected downstream from the Clark Fork River' s confluence with Rock Creek. Metals-related stress appeared more severe in 1987 than in other years. Among all river reaches, the healthiest benthic fauna was found from Milltown Dam to the confluence of the Bitterroot River. Downstream from the Bitterroot, nutrient enrichment impacted the aquatic community.

The 1988 drought appeared to accentuate biological responses to organic and nutrient enrichment. Symptoms of organic pollution were more distinct and widespread than in previous years. Macroinvertebrate densities during August 1988 were, on average, double those in 1986 and 87. Impacts attributed to organic enrichment were widespread with the greatest effects in the upper river below the Warm Springs Ponds, at Deer Lodge, Bonita and Turah and, in the lower river, from Harper's B ridge downstream to Alberton. The response of the fauna and the ability of Silver Bow Creek to assimilate organics was limited by the prevailing toxic environment.

Introduction

The Clark Fork River drains most of western Montana to the Columbia drainage. The upper Clark Fork River and Silver Bow Creek, a tributary, have been plagued by heavy metal contamination from mining for over 100 years. More recently, concerns have extended to the trophic status of the river, which has shifted due to increased nutrient loading and organic pollution. The Montana Department of Health and Environmental Sciences conducts annual aquatic macroinvertebrate surveys (6., 11, 13, 14) as part of its environmental surveillance. These surveys provide a general assessment of pollution impacts and

environmental conditions throughout much of the drainage by evaluating the integrity of indigenous macroinvertebrate assemblages.

Methods

Field and Laboratory Procedures

Benthic macroinvertebrates were collected by Montana Water Quality Bureau (WQB) staff during mid August of 1986,1987 and 1988. Each year, a 'modified Hess sampler (0.1 m2 diameter, 0.45 mm mesh netting) was used to obtain four samples at each of 25 stations between the headwaters of Silver Bow Creek (SBC) and Thompson Falls Reservoir (fig.1). Samples were preserved in ethanol containing rose bengal dye and, when needed, formalin. In the laboratory, macroinvertebrates were sorted from the debris, identified to the lowest practical taxonomic level, and counted. The Montana WQB maintains a reference collection of macroinvertebrates from this study.

Data Analysis and Interpretation

Six measures of community structure and function were calculated as the primary method of impact assessment: taxa richness, total density, Shannon diversity (25), EPT (Ephemeroptera, Plecoptera and Trichoptera) species richness (19), the percent relative abundance of the numerically dominant taxon (19) and the percent relative abundance of filter feeders. Each index provided a different measure of the benthic fauna. Since macroinvertebrates exhibit different responses to various types of environmental stress, some measures were better estimators of organic enrichment while others were more sensitive to toxic pollutants or sediment deposition. Taxa and EPT richness, or the number of species present, are probably the best measures of toxic conditions from heavy metal pollution (11). Total macroinvertebrate density and the relative abundance of filter feeding insects provided measures of organic and nutrient enrichment. Benthic community density increases in response to nutrient and/or organic enrichment but will decline in response to severe toxic pollution or moderate habitat degradation. Filterers typically comprise a major component (25 to 50%) of the summer macroinvertebrate fauna in Montana rivers; however, relative abundances of greater than about 50% indicate organic/nutrient enrichment (l0). Shannon diversity and the relative abundance of the numerically dominant taxon were used to measure cumulative impact to benthic community substructure. By analyzing several indices, the accuracy and sensitivity of the overall evaluation was improved. Statistical comparisons or these indices included analysis of variance (ANOVA) and Newman-Keuls multiple range test (26). Between sample mean squares were used to test differences among stream reaches.

To provide an overview of heavy metal and organic pollution, the study area was divided into seven stream reaches (table 1) based on Community Similarity Coefficients and the geographic proximity of stations (13). For comparison, the lower Blackfoot River was included as a control reach. The Blackfoot River is a tributary to the Clark Fork River and, at the seven stations incorporated into this analysis, was considered free of significant environmental degradation (10). Blackfoot River data from August, 1988 (10) were used as an estimate of the Clark Fork River's potential to support aquatic life.

Results and Discussion

Pollutants

Metals, including copper, cadmium, iron, lead, zinc and arsenic, contaminate Silver Bow Creek and much of the Clark Fork River, Elevated metal concentrations are found throughout the upper basin in water (8). sediments (2, 16). benthic insects (1) and fish (!8), The distribution. exposure and concentration patterns of most metals appeared similar. with copper considered the metal of greatest biological significance (7, l7), The mean copper concentration and the frequency of copper concentrations exceeding chronic and acute aquatic life criteria were used to summarize metal pollution in each stream reach during this study (table 2).

Plant nutrients comprise another major category of pollutants in the Clark Fork River drainage. By stimulating algal growth, nitrogen and phosphorus can have a profound influence on the abundance and composition of macroinvertebrate assemblages. The mean concentrations of Total Soluble Inorganic Nitrogen (TSIN) and Orthophosphate (OP) at one station in each stream reach from July 1986 to August 1988 are presented in table 2. Other papers in these proceedings consider nutrients (2) and algal growth (2:4) in more detail. Ammonia concentrations toxic to most aquatic life occur frequently in Silver Bow Creek (8).

Faunal Description

In general, the Clark Fork River supported an abundant benthic fauna that, during August. was dominated by hydropsychid caddis flies. Caddis flies accounted for approximately 55% of the macroinvertebrates collected while dipterans ac- counted for approximately 30%. Dipterans were relatively more abundant in Silver Bow Creek (fig. 2). Overall, mayflies comprised slightly less than 10% of the fauna while stoneflies and beetles each contributed less than five percent. The amphipod, Hyalella azteca, was a major faunal component in the Warm Springs Ponds during 1986 and 1988.

With a study area consisting of 25 stations scattered over 471 km (294 miles) of river, it was not surprising to find 165 taxa among the more than 300,000 macroinvertebrates collected. Dipterans accounted for 59 taxa, including 43 midges. Caddis flies, mayflies, beetles and stoneflies were also well represented with 30, 23, 15 and 12 taxa, respectively. One to three taxa in the insect orders Hemiptera, Lepidoptera, Megaloptera and Odonata were also collected. Non- insects, although minor components of the fauna, accounted for an additional 20 taxa.

Chronic Pollution

The integrity of the aquatic communities in Silver Bow Creek (SBC) and most reaches of the Clark Fork River (CFR) were impaired when compared with those in the Blackfoot River (table 1). Impacts were most severe in Silver Bow Creek. Where macroinvertebrate density, taxa richness, EPT richness and Shannon diversity were significantly lower and the percent contribution of the dominant taxon was significantly higher than for all other stream reaches. Varying degrees of environmental stress were indicated by one or more indices in the Warm Springs Ponds outflow (WSP) and all reaches of the Clark Fork River.

Silver Bow Creek (SBC and WSP)

Prior to 1975, aquatic macroinvertebrates were absent from Silver Bow Creek. Chadwick et al. (5) documented the establishment of a metals-tolerant benthic fauna between 1975 and 1983. Macroinvertebrate colonization was concurrent with the effective secondary treatment of the effluent from the Anaconda Minerals Company metal concentrator and with cessation of sludge discharge by the Butte sewage treatment plant ill). Chironomids and empidids, the earliest colonizers, were present throughout Silver Bow Creek by 1981. A few additional species, including hydropsychids, were established in the lower reach by 1983. The biological recovery in Silver Bow Creek stagnated during the 1980's. The macroinvertebrate fauna has remained virtually unchanged since the early eighties, and no new species have established populations in Silver Bow Creek in recent years. Silver Bow Creek remains the most impaired reach of the Clark Fork River drainage. The impoverished macroinvertebrate fauna was limited to a few metals tolerant species including Cricotopus spp., Cardiocladius sp.,Pagastia sp., Simulium vittatun and Hydropsyche slossonae. Mayflies and stoneflies were conspicuously absent. Severe environmental stress and pervasive heavy metal contamination were indicated by the low macroinvertebrate density, taxa richness, EPT richness and Shannon diversity as well as the high relative abundance of the numerically dominant taxon (fig. 3). Despite extremely high nutrient concentrations (Table 2), Silver Bow Creek's macroinvertebrate fauna exhibited few indications of organic or nutrient pollution. The stream's ability to assimilate nutrients and the fauna's ability to respond to organics appeared limited by the prevailing toxic environment.

The Warm Springs Ponds provide additional treatment of Silver Bow Creek water prior to its entering the Clark Fork River (table 2). The macroinvertebrate fauna in the Warm Springs Pond #2 outflow was typical of a lake outflow assemblage. At this site, the mean macroinvertebrate density increased nearly eight fold, and taxa richness was double that in Silver Bow Creek. Both were good indications of reduced toxicity. While the severity lessened, biological impairment by metals remained apparent. Taxa richness and, particularly, EPT richness were significantly lower than in downstream reaches (table 1). Nutrients transported by Silver Bow Creek had a substantial impact on the biota as indicated by the high macroinvertebrate density and the large percentage of filterers in the Warm Springs Pond #2 outflow (fig. 3). During August, the most abundant taxa were Cheumatopsyche sp., Hydropsyche vexa, Simulium spp. and Hyalella azteca. Cumulative environmental stress was moderate to severe at this site.

Upper Clark Fork River (CFR 1 and 2)

The biological integrity of the upper Clark Fork River was much improved compared to historic conditions in this reach and existing conditions in Silver Bow Creek. Investigators in the 1950's (1, 22) and 1960's (21) reported sparse insect populations and the virtual absence of mayflies, stoneflies and caddis flies in the Clark Fork River upstream from the confluence of the Little Blackfoot River. Impact from metals contamination diminished substantially during the 1970' s (4) Nevertheless, degradation from both metals and organic pollution remain evident in CFRl, and cumulative impact appeared moderate to severe.

In CFR 1, metal pollution was manifest as low taxa richness. EPT richness, in particular, remained suppressed (fig. 3). As indicated by the preponderance of filter feeders, organic/nutrient enrichment from the Butte WWTP (via the Warm Spring Ponds), the Deer Lodge WWTP and natural sources exert a major influence on the biota. Hydropsyche occidentalis dominated the benthic fauna in this reach during

August. Community structure was skewed due to the high relative abundance of this species. Partial dewatering and high water temperatures may have also stressed organisms in this stream reach.

Downstream from the confluence of the Little Blackfoot River (CFR2) was clearly a transition zone with regard to heavy metals and other pollutants (table 2). Impacts were apparent at some stations but not others. During 1986 and 1988, taxa richness and Shannon diversity were significantly higher at stations 11 (CFR at Gold Creek Bridge) and 13 (CFR at Turah) than at station 12 (CFR at Bonita). For the reach as a whole, cumulative impacts attributable to metals were slight. Taxa richness and EPT richness were not significantly different from downstream Clark Fork River reaches; although, both indices were significantly lower than for the Blackfoot River (Table 1).

Nutrient loading clearly impacted this reach of the Clark Fork River. Macroinvertebrate densities were, on average, higher than elsewhere in the drainage (fig. 3), an indication that large amounts of nutrients were assimilated in this reach. The benthic fauna was comprised of taxa tolerant to organic and nutrient enrichment including H. occidentalis, Simulium spp., Polypedilum sp. and numerous species of Orthocladinae midges.

Middle Clark Fork River (CFR 3, 4 and S)
Historically pollution has had a less dramatic impact on the biota in the middle reaches of the Clark Fork River than in the headwaters (1, 21, 22). Organic wastes from the Missoula WWTP t the Stone Container Mill and metals-laden sediment flushed from Milltown Dam have been the pollutants of concern (23). With improved wastewater treatment at the mill (1975) and the Missoula WWTP (1978), recent impacts from these sources have primarily been limited to nutrient enrichment (Qt 2J)

Significant heavy metal pollution, as measured by taxa and EPT richness (Fig 3), was not indicated downstream from Milltown Dam during this study. Among all reaches of the Clark Fork River, the highest biological integrity was found from Milltown Dam downstream to the confluence of the Bitterroot River (CFR3) and from Superior downstream to the confluence of the Flathead River (CFR5). As measured by Shannon diversity and the contribution of the dominant taxon, environmental stresses were significantly less in these two reaches than elsewhere in the Clark Fork River. Values of these indices, along with taxa and EPT richness, approached those for the reference reach on the Blackfoot River. The higher relative abundance of filter feeders in the middle Clark Fork River compared to the Blackfoot River indicated higher nutrient levels in the former.

A slight to moderate impact of nutrient enrichment was evident in reach CFR4, from the confluence of the Bitterroot River to Alberton. Shannon diversity was significantly lower in this reach than in adjacent reaches. Additional evidence of nutrient-related impacts included the higher macroinvertebrate densities, percentage of filter feeders and contribution of the dominant taxon compared with adjacent reaches. Hydropsyche occidentalis was abundant throughout the middle Clark Fork River and was the most abundant species in August samples from reach CFR4. Interestingly, it was replaced by H. cockerelli as the most numerous species in reach CFR3 and by Cheumatopsyche sp. As the dominate in reach CFR5.

Spatial and Temporal Variation

Understanding temporal and spatial variation can increase our understanding of the underlying conditions and mechanisms influencing aquatic communities. In addition, knowledge of annual variation is a prerequisite to successfully predicting and assessing long-term trends.

Drought conditions prevailed during 1987 and 1988 with near record low stream flows during much of 1988. The drought affected many facets of the environment and, consequently, had a major influence on aquatic communities in the Clark Fork River drainage. For instance, the effects of organic/nutrient enrichment were more apparent in 1988 than in other years. Among the 16 stations on the Clark Fork's mainstem, macroinvertebrate density averaged 27,000 organisms per square meter during 1988, nearly triple the density estimates for 1986 and 1987. The increase in macroinvertebrate density was not uniform among locations, rather pronounced increases in macroinvertebrate density occurred at some stations (Fig. 4) and stream reaches (fig. 3). Nutrients in municiple discharges were relatively more important during periods of low streamflows (8) and, in reaches were these nutrients were assimilated, macroinvertebrates were quite abundant. Based on total macroinvertebrate density, nutrient and organic enrichment had its greatest impact in the Clark Fork River at Deer Lodge, Bonita, Turah and Harper’s Bridge (st. 09,12, 13 and 20, respectively). The relatively high macroinvertebrate densities in Silver Bow Creek (st. 01), the Warm Springs Pond #2 effluent (st. 04) and the Clark Fork River stations 07, 22 and 24 also indicated widespread nutrient enrichment. A dramatic reduction in total macroinvertebrate density at station 11 in 1988 was attributed to excessive sediment deposition during the drought.

As measured by taxa richness, chronic heavy metal impacts in Silver Bow Creek and the upper Clark Fork River appeared to be reduced in 1988 when compared with 1986 and 1987 (fig. 4). During 1987 and 1988, low streamflows resulted in reduced metals concentrations and loading in these stream reaches (8) and mean taxa richness was significantly higher for both years than in 1986. However, for 1987, a statistically significant interaction between year and location was noted, with taxa richness being relatively low at upstream stations but relatively high at downstream sites. This was attributed to runoff from a rainstorm on July 3, 1987, which resulted in elevated metals concentrations and/or pH fluctuations sufficient to kill several thousand salmonids in the Mill-Willow Bypass and upper Clark Fork River. Impacts attributable to an episode of acute toxicity were evident during August of 1987, in Silver Bow Creek, the Warm Springs Pond effluent, the Mill-Willow Bypass and the upper Clark Fork River.

Surprisingly, the impact was most evident in the Warm Springs Pond #2 outflow. The ponds are generally effective in reducing metals toxicity (table 2) cause they are well buffered and have a relatively long retention time. Prevailing conditions allowed a large population of Hyalella azteca, a relatively intolerant species, to became established in the ponds. Subsequently, when the buffering capacity of the ponds was overwhelmed, the H. azteca population was severely diminished (fig. 2) and community structure was greatly altered (fig. 3).

Impacts from metal pollution were also more severe in Silver Bow Creek during 1987. Simulium vittatum and Hydropsyche slossonae appeared to be the species least tolerant of heavy metals in Silver Bow Creek, and both were severely reduced in abundance during 1987. In other years, these species comprised most of macroinvertebrate fauna and nearly all of the filter feeders in Silver Bow Creek. Their demise was registered by the relative abundance of orders, filterers and total number of macroinvertebrates (fig. 3).

At most stations in the upper Clark Fork River, community level indices exhibited little response to the episodic perturbation, although taxa considered relatively intolerant of heavy metals suffered significantly reduced densities and restricted distributions during 1987. Micropseclra sp., Arclopsyche grandis, and Hexaloma sp. were considered the best indicator species of changes in the severity of metals pollution in the upper Clark Fork River (H). Measures of the macroinvertebrate fauna as a whole showed only subtle changes. This was probably due to chronic metals pollution, which had already limited relatively intolerant species to a minor component of the fauna.

Conclusions

Silver Bow Creek and the Warm Springs Ponds

1. Silver Bow Creek remained severely polluted by heavy metals. The macroinvertebrate fauna was impoverished and restricted to a few tolerant species.
2. Biological impacts of heavy metal contamination were significantly reduced below the Warm Springs Ponds, however, the capacity of the ponds to reduce metals toxicity in the outflow appeared to be overwhelmed by a rainstorm induced pulse of metals-laden runoff during July, 1987.
3. Indications of organic/nutrient enrichment were minimal in Silver Bow Creek. Apparently, the stream's ability to assimilate nutrients and the faunas ability to respond to this form of pollution were limited by the prevailing toxic environment.
4. Nutrients transported by Silver Bow Creek contributed to the high macroinvertebrate densities in the Warm Springs Ponds discharge. Nutrients transported to the Warm Springs Ponds had a major impact on the downstream fauna.

Upper Clark Fork River

5. The biological integrity of the upper Clark Fork River was much improved compared to that of Silver Bow Creek. However, degradation from both metals and nutrients were pervasive. Cumulative impacts were severe in CFR 1 and moderate in CFR2.
6. Impacts attributed to organic enrichment were most severe below Warm Springs Creek, and at Deer Lodge, Bonita and Turah (stations 07, 09, 12 and 13, respectively).
7. Impacts from metals were relatively uniform from the Mill- Willow Creek Bypass downstream to the confluence of the Little Blackfoot River (CFRI).
8. Metals pollution appeared intermittent and less significant from the Little Blackfoot River to Milltown Dam (CFR2). In this reach, station 12 (CFR at Bonita) appeared to be more severely impacted than other stations.
9. Biological impacts attributable to metals were not detected downstream from the Clark Fork River's confluence with Rock Creek.

Middle Clark Fork River

10. Among all river reaches, the healthiest benthic fauna was found from Milltown Dam to the confluence of the Bitterroot River (CFR3) and from Superior to the confluence of the Flathead River (CFR5). Slight nutrient enrichment was indic3led in these reaches.
11. No impacts were detected at stations immediately below designated mixing zones for me Missoula WWTP and the Stone Container kraft mill. Nutrients from these sources contributed to downstream impacts.

12. From the confluence of the Bitterroot River to Albel1on (CFR4), moderate impairment due to nutrient enrichment was indicated. Within this reach, the impact was most severe at Harper's Bridge (station 20).
13. During August 1988, construction at Milltown Dam did not appear to have a deleterious impact on the downstream benthic fauna.

Drought

14. The 1988 drought affected many facets of the environment and, consequently, had a major influence on aquatic communities in the Clark Fork River drainage. Reduced stream flows appeared to limited metals impact in Silver Bow Creek and the upper Clark Fork River, but created some localized sediment problems. Drought-related conditions accentuated biological responses to organic and nutrient enrichment.

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Figure 1: Clark Fork River basin study sampling locations.

Table 1

Table 1. Mean values and statistical comparisons* of indices characterizing macroinvertebrate assemblages in eight stream reaches in the Clark Fork drainage during August, 1986, 1987,1988.

stream reach	stations	n	density #/0.1m2	taxa richness	Shannon diversity	EPT richness	%RA dominant	%RA filterers
Silver Bow Cr.	00,01,02,03	44	300	9	1.8	2	57	32 a
WSP#2 discharge	04	12	2300 b,c	18	2.2 a	4	41 b	78 c
CFR1 (Mill-Willow to L. Blackfoot R.)	05, 07, 08, 09, 10	60	1500 a,b	26	2.5 a	11	51 c	68 c
CFR2 (L. Blackfoot R. to Milltown Dam)	11, 12, 13	36	2400 c	34 a	3.1	17 a	41 b	56 b
CFR3 (Milltown Dam to Bitterroot F.)	15, 16, 18	36	1100 a	37 a,b	3.4 b	19 b	33 a	59 b
CFR4 (Bitterroot R. to Alberton)	20, 22, 23	36	1900 b,c	35 a	2.9	17 a	46 b,c	71 c
CFR5 (Superior to Flathead R.)	24, 25	24	1300 a,b	34 a	3.4 b	17 a	30 a	56 b
Blackfoot R.** (North Fork to Rainbow Bend)	7 stations	28	2000 b,c	39 b	3.7	20 b	26 a	38 a

* One-way ANOVAs and Newman-Keuls tests. Means followed by common letters were not significantly different at $p = 0.05$.
** Blackfoot River data for August 1988 only, source: (10).

Table 2

Table 2. Mean concentrations of total soluble inorganic nitrogen (TSIN), orthophosphate (OP), total recoverable copper (Cu) and the frequency of copper concentrations exceeding EPA chronic and acute criteria at eight stations in the Clark Fork River drainage from July, 1986 to Aug. 1988.

stream reach	station	TSIN (ug/l)	OP (ug/l)	Cu (ug/l)	Freq. of aquatic criteria exceedence	
					Chronic	acute
Silver Bow Cr.	03	1640	265	198	100	100
WSP#2 discharge	04	281	58	17	41	14
CFR1	09	279	13	25	41	7
CFR2	12	57	13	<10	14	6
CFR3	15	46	12	<10	15	12
CFR4	20	102	15	<10	0	0
CFR5	24	65	13	<10	2	2
Blackfoot R.	14	35	7	<10	0	0

Figure 2: Relative abundance of aquatic macroinvertebrate orders at 21 locations in the Clark Fork River drainage during August 1986, 1987 and 1988.

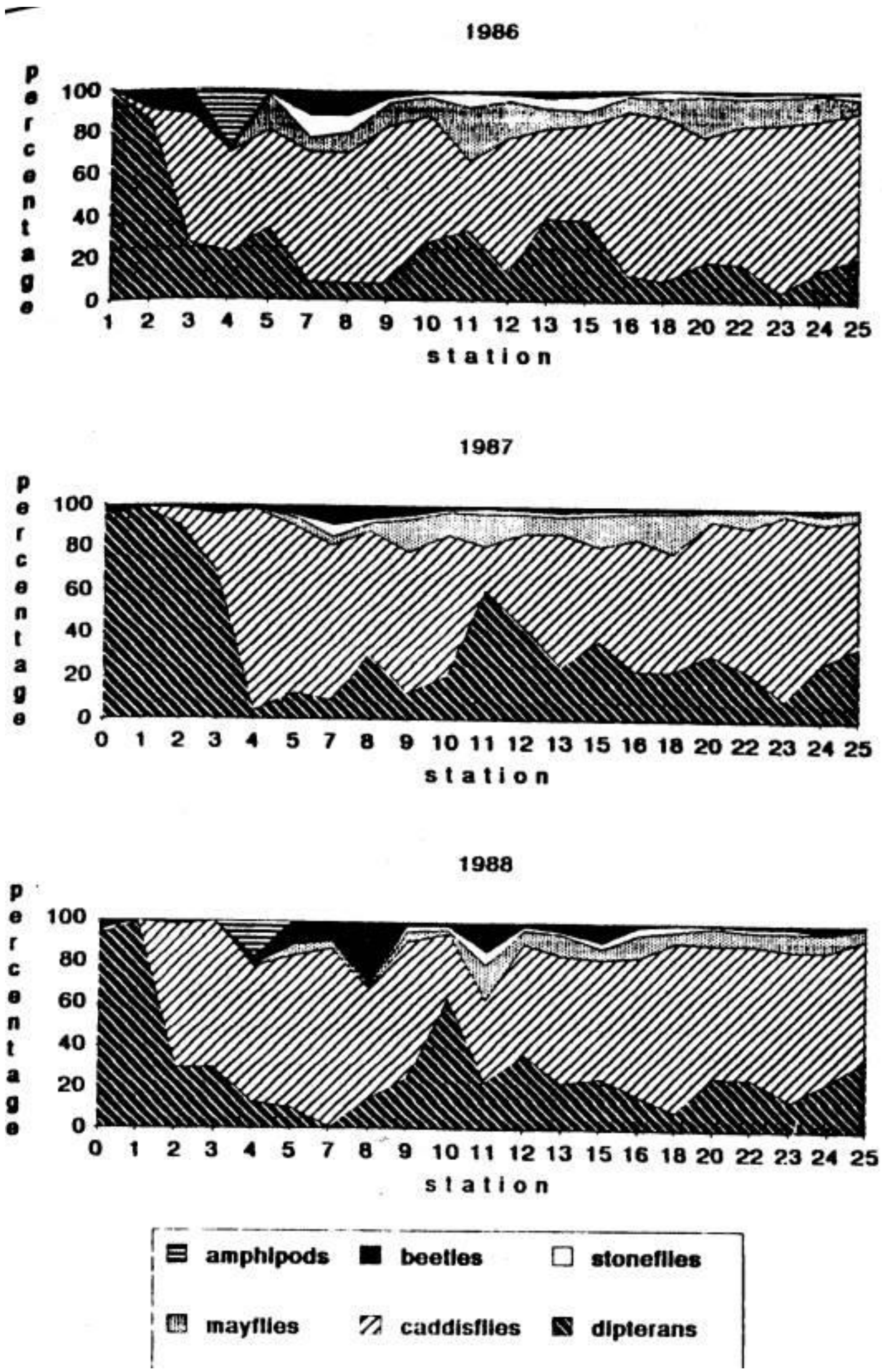

Figure 3: Mean values of indices characterizing macroinvertebrate assemblages in eight reaches of the Clark Fork River drainage during August of 1986, 1987 and 1988.

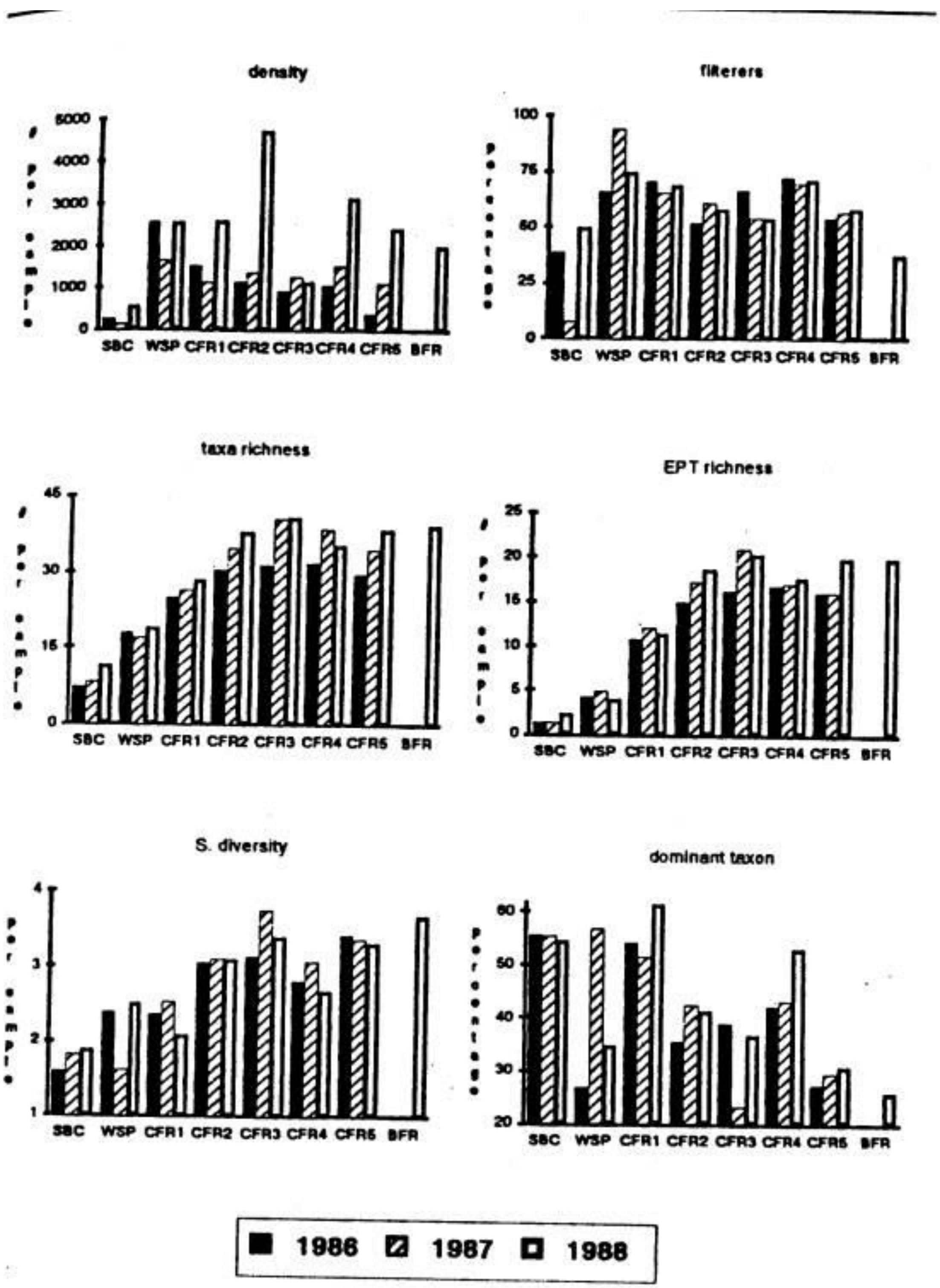

Figure 4: Mean macroinvertebrate density and taxa richness at 21 locations in the Clark Fork River drainage during August of 1986, 1887 and 1988.