Branson
et al
1984

Trans. Ky. Acad. Sci., 45(1-2), 1984, 55-72

Small-Stream Recovery Following Surface Mining in East-Central Kentucky

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ABSTRACT

Analyses of physio-chemical, piscine and macrobenthological data secured from two small-stream drainages affected by surface mining in eastern Kentucky are presented. Adverse pH values were not encountered during the study. Stream magnesium, calcium, manganese and sulfate concentrations increased rapidly during the onset of mining and continued to increase until 1982. The bottom sediments in both streams have remained very heavy throughout the study.

The creek chub, *Semotilus atromaculatus*, has greatly increased its populations in the headwaters while populations of other piscine species have remained virtually unchanged. Although active mining has ceased in the Leatherwood Creek drainage, fish population recovery has been minimal. A few species have been successful in re-establishing small populations, but many species are still absent. A second impulse of mining started in 1979 in Bear Branch probably resulted in a setback of recovery in that stream.

None of the macrobenthological data have been published previously. Analysis of these data demonstrated a decrease in the total taxa and mean diversity of Leatherwood Creek and Bear Branch from June 1968 to October 1970 followed by a modest increase in these 2 features from October 1970 to July 1982. The population level in most taxa remains low and mollusca have been extirpated in both streams. Mean diversity indices may be misleading, principally because of habitat changes that allow groups of organisms like the Heteroptera to replace other groups.

INTRODUCTION

To evaluate the impact of surface mining on the fish faunas of first and second order streams in east-central Kentucky, Branson and Batch (1) conducted a 17-month study from 1967 through 1969. The study area is located in Breathitt County, Kentucky and includes Leatherwood Creek and Bear Branch. Six stations were established on each stream (Fig. 1). The principal aim of the study was to document the effects of surface mining activities on benthos and fish fauna. Another objective was to trace changes in stream chemistry. Settleable solids were considered to be one of the most important features relating to changes in fish and benthos.

Results of the aforementioned study (1) indicated that fishes were progressively eliminated from headwaters downstream and that the benthic food organisms were reduced in number and kind, often by as much as 90%. Reproduction in darters and most minnows was curtailed.

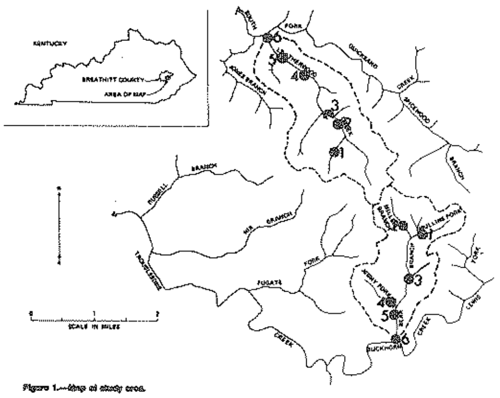

FIG. 1. *Proximity map of the study area, Breathitt County, Kentucky.*

Semotilus atromaculatus seemed to be resistant to silt and turbidity, principally because of its ability to feed off the water surface. Although considerable data on the benthos were collected and analyzed they have not been previously published. These data, and new information gleaned during

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the present study, are presented here.

A follow-up study, conducted during 1972, indicated no tendency toward recovery by the fish fauna (2). In fact, further degradation and elimination of species had occurred. With many of the competing species gone, the creek chub population expanded, a phenomenon observed also in Tennessee (3).

The mining history of this area and streams, including normal and mining-induced chemical and physical features, were discussed and analyzed by Bryan and Hewlett (4), Curtis (5, 6, 7), and Dyer and Curtis (8).

In the interim, several other studies with direct bearing on the problem of coal mining and the environment have appeared, particularly with reference to benthic organisms. Because of their limited mobility, benthic organisms may be better indicators of mine pollution than fishes (9). Increased sedimentation not only degrades habitat for fishes, particularly during increased water temperatures (10), but it also often severely alters or eliminates benthic organisms dependent upon a clean-gravel habitat. Sediments often fill the interstices of gravel to depths of one meter or more, replacing a cobble-gravel habitat with a silty sand one (11). In the case of the streams we studied, the silt load during active mining was observed to reach 46,400 ppm (5). Highest yields of sediment from surface mining normally comes during the first 6 months after mining (7).

Sedimentation poses direct problems for benthic organisms (12). It has been known that insect drift downstream is the major means of recolonization of both natural and altered streams (13); upstream migration of insects being only 5-30% as important in repopulating a decimated area (14). Changing the bottom from a cobble-gravel habitat to a sandy one, however, may preclude active recolonization by upstream migration in larval insects such as stoneflies like *Pteronarcys* and *Acroneuria* because of the unstable sand. By contrast, caddisflies with heavy cases *(Dicosmoecus)* are more successful in moving upstream on sand (15). Such phenomena can produce unbalanced benthic faunas by allowing resistant forms to control a given habitat.

The objectives of this study were to collect data on fish populations and benthos invertebrates to compare with data collected in the original studies made in 1967-1969, and to trace changes in water chemistry following surface mining and reclamation activities.

MATERIALS AND METHODS

As in the previous studies, the fish populations at each station were sampled by 30 minutes of intensive seining. During all sampling visitation, invertebrates were hand-collected from representative, random sections at each sampling site, care being exercised to include all habitat conditions.

Mean diversity "d" indices were calculated using the machine formula method of Lloyd, Zar and Karr (16) see also, Weber (17), an index that is compared with a hypothetical maximum "d" based upon arbitrarily selected distributions (18) related to MacArthur's (19) broken-stick model. This model results in a distribution frequently encountered in nature (17), i.e., a few abundant species and a progressively large number of species that are less abundant. Since in nature the members of a given local community are highly unlikely to be equally abundant, Lloyd and Ghelardi (20) proposed the concept of "equitability" "e" and presented a table for its determination (17) using a number of species in a sample "s" with the number of species expected "s′" from a community that conforms to MacArthur's (19) model: $e = \frac{s'}{s}$. Our calculations of "e" follow these authors' recommendations.

The physio-chemical measurements were made by standard methods in the laboratories of the Northeastern Forest Experiment Station, USDA, Forest Service, Berea, Kentucky. Samples were collected at monthly intervals.

RESULTS

Water Quality

Determinations of water quality have been made since late 1967 in Leatherwood Creek and since the spring of 1968 in Bear Branch (5). Although many individual substances and elements were monitored by the Northeastern Forest Experiment Station at Berea, Kentucky, we are reporting the results only for the substances that readily indicate the influence of surface mining on water quality or substances that may be implicated as partially responsible for the perturbation of biotic communities.

Low pH is often a serious problem in waters affected by surface mining, primarily due to the formation of hydrosulfuric acid following the oxidation of various pyritic materials (21). However, adverse pH was never encountered at any of our study stations (Figs. 2-5).

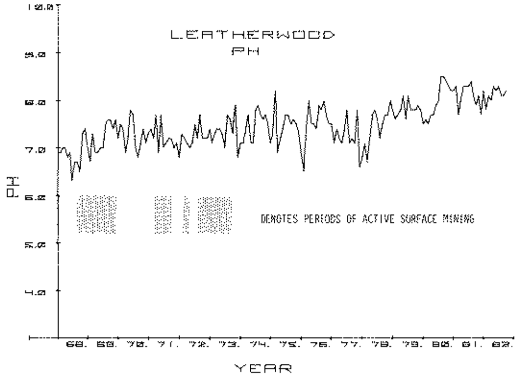

FIG. 2. pH in Leatherwood Creek.

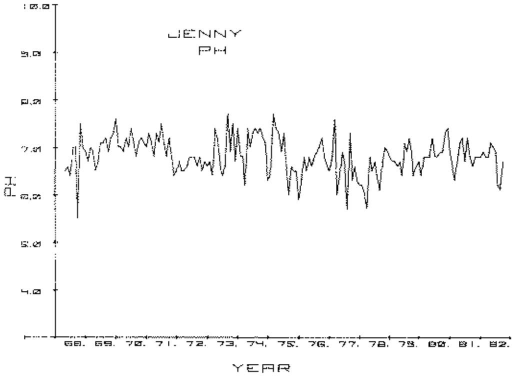

FIG. 3. pH in Jenny Fork of Bear Branch.

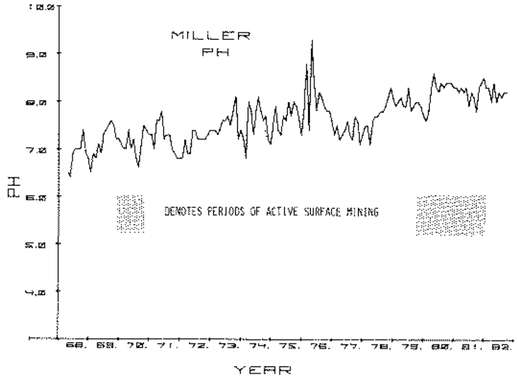

FIG. 4. pH in Miller Branch of Bear Branch.

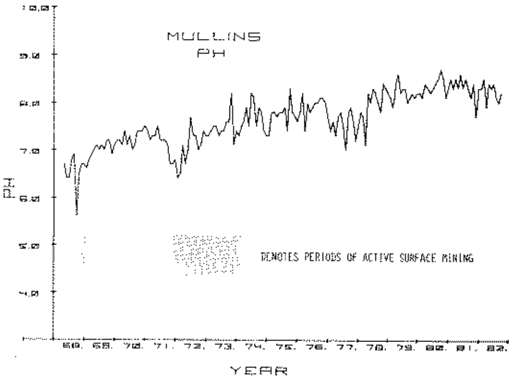

FIG. 5. pH in Mullins Fork of Bear Branch.

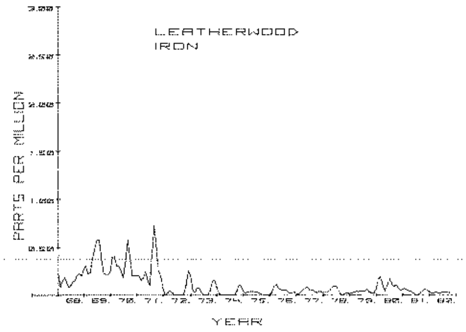

FIG. 6. Iron concentration in Leatherwood Creek.

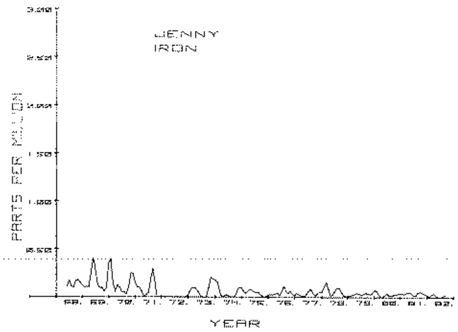

FIG. 7. Iron concentration in Jenny Fork.

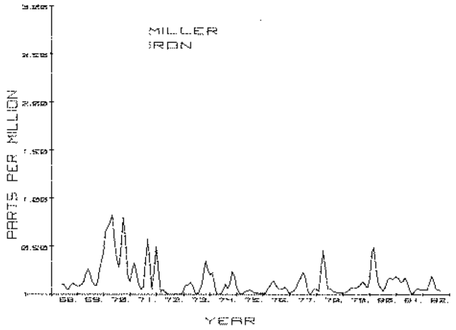

FIG. 8. Iron concentration in Miller Branch.

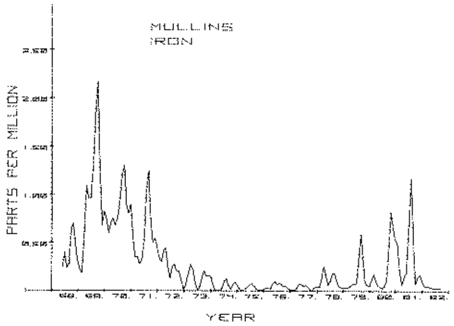

FIG. 9. Iron concentration in Mullins Fork.

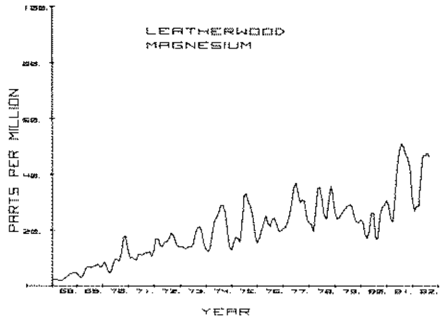

FIG. 10. Magnesium concentration in Leatherwood Creek.

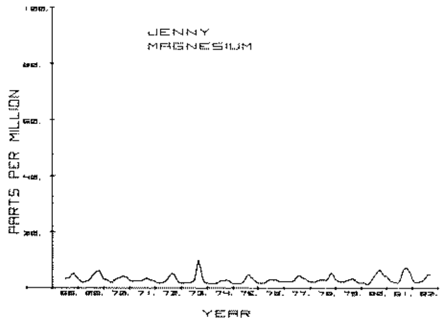

FIG. 11. Magnesium concentration in Jenny Fork.

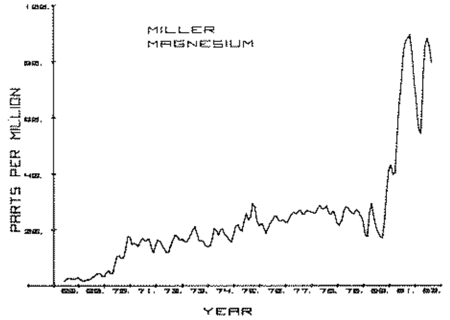

FIG. 12. Magnesium concentration in Miller Branch.

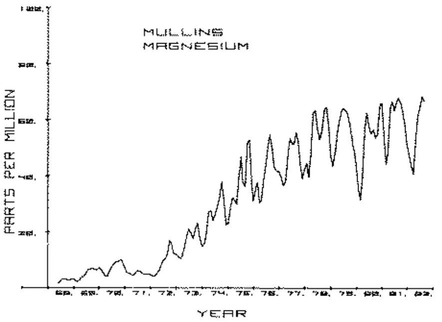

FIG. 13. Magnesium concentration in Mullins Fork.

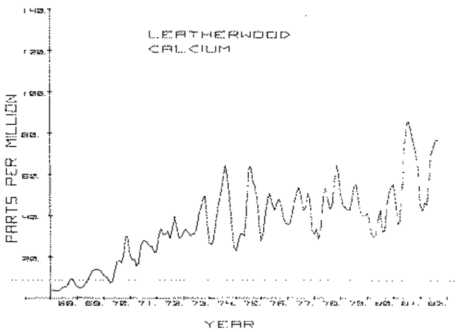

FIG. 14. Calcium concentration in Leatherwood Creek.

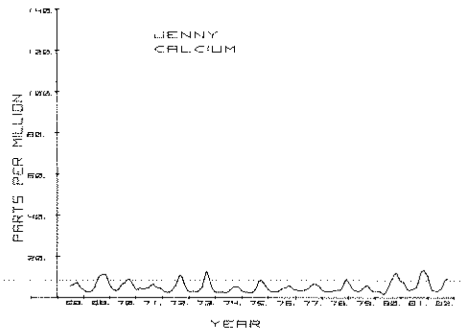

FIG. 15. Calcium concentration in Jenny Fork.

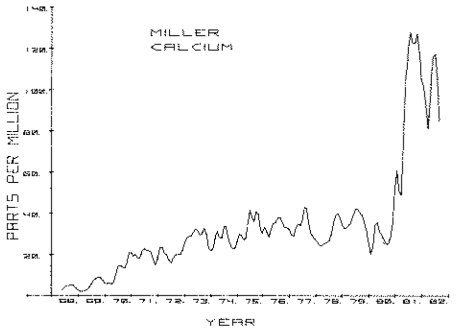

FIG. 16. Calcium concentration in Miller Branch.

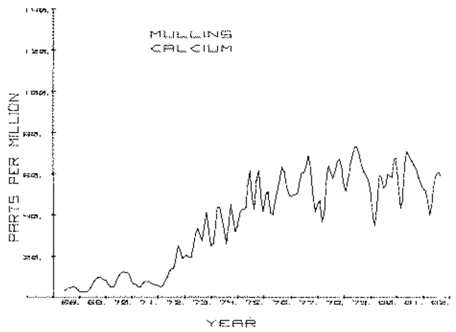

FIG. 17. Calcium concentration in Mullins Fork.

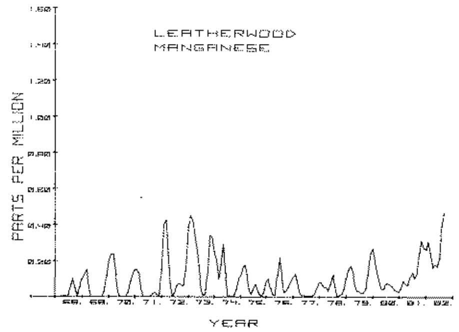

FIG. 18. Manganese concentration in Leatherwood Creek.

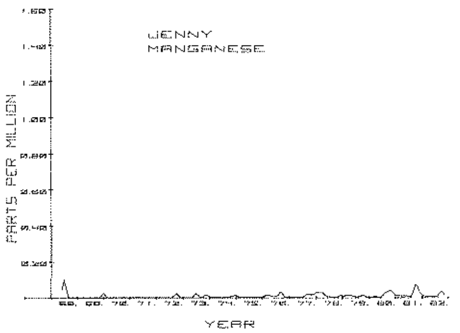

FIG. 19. Manganese concentration in Jenny Fork.

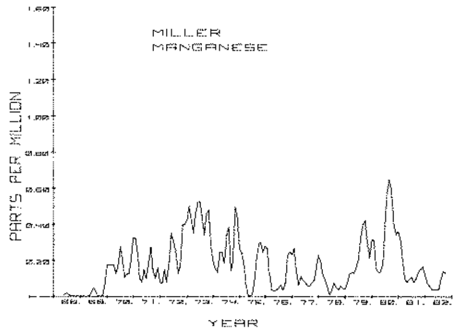

FIG. 20. Manganese concentration in Miller Branch.

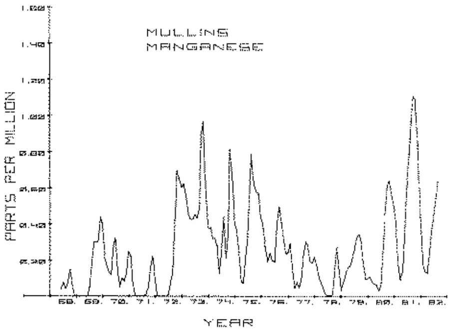

FIG. 21. Manganese concentration in Mullins Fork.

During mining or other surface disturbances such as haul-road construction and use, sulfates are readily produced, often in the form of calcium, magnesium and iron complexes (22). Hence measurements of those substances as well as of specific conductivity are important to an understanding of the degradation process. Figures 6-9 illustrate an initial increase from less than 0.5 ppm of iron in the study streams to approximately 1.0 ppm in Leatherwood Creek and Miller Branch and to over 2.0 ppm in Mullins Fork following the onset of mining with a sharp decline post 1972. A second peaking occurred in Mullins Fork in 1978-1981. Jenny Fork, never mined and only moderately disturbed otherwise, experienced no marked increases in iron content. Concentrations of iron by itself at these levels probably do not pose any threat to aquatic bota in eastern Kentucky. The same type of unqualified statement cannot be made concerning calcium, magnesium and sulfates. The composition of the macrobenthos, because of limited mobility, may reflect long-term, cumulative responses to degrading influences (22). In this regard, it has been observed that, following surface mining, calcium, magnesium, manganese and sulfate concentrations tend to increase in a systematic fashion with the passage of time (23, 6). Thus, the streams discussed herein exhibited a nearly classical picture with regard to magnesium (Figs. 10-13), calcium (Figs. 14-17) and manganese (Figs. 18-21) concentrations during mining and up to the present. Unmined Jenny Fork exhibited only normal seasonal cycles.

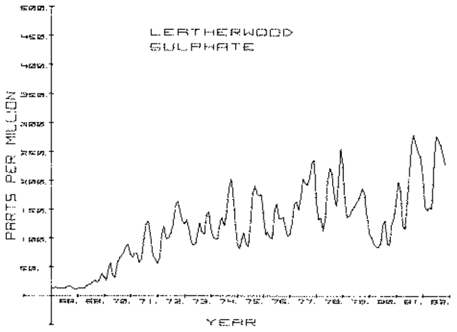

FIG. 22 Sulphate concentration in Leatherwood Creek.

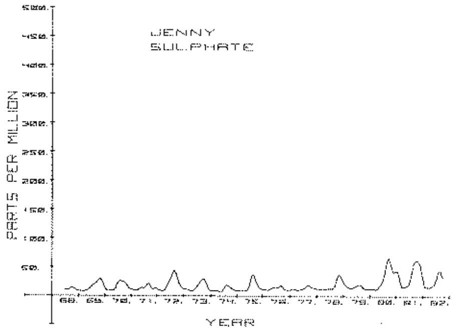

FIG. 23. Sulphate concentration in Jenny Fork.

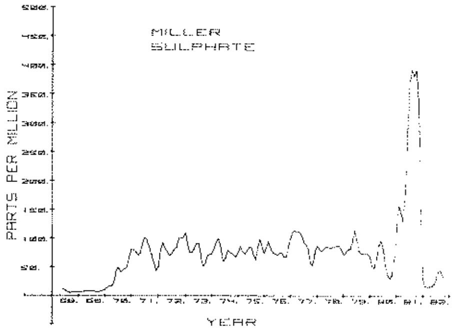

FIG. 24. Sulphate concentration in Miller Branch.

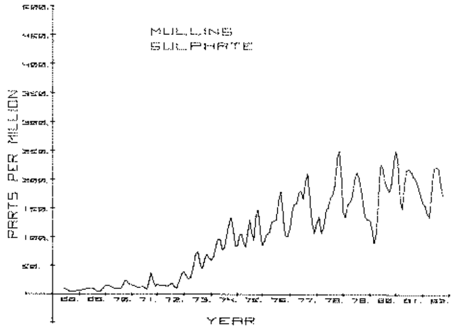

FIG. 25. Sulphate concentration in Mullins Fork.

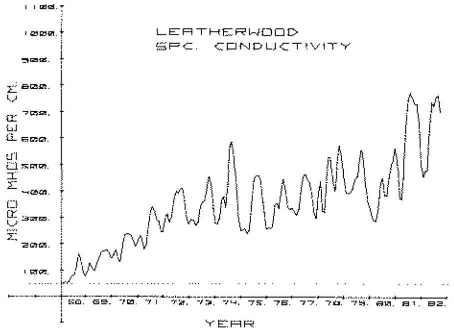

FIG. 26. Specific conductivity in Leatherwood Creek.

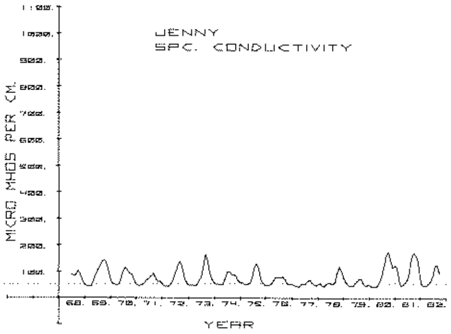

FIG. 27. Specific conductivity in Jenny Fork.

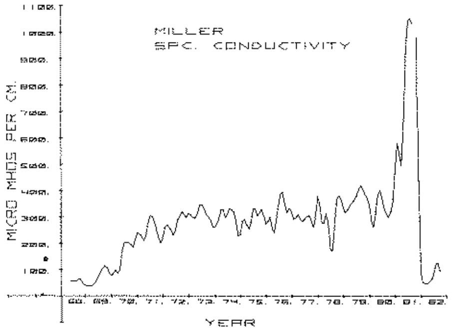

FIG. 28. Specific conductivity in Miller Branch.

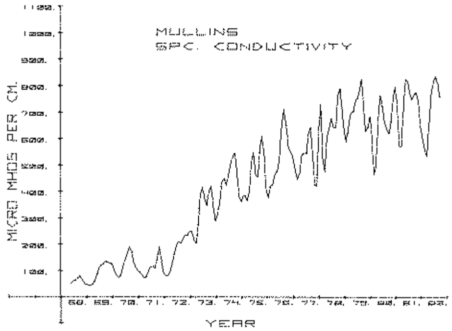

FIG. 29. Specific conductivity in Mullins Fork.

Sulfate is probably the most useful indicator of the condition of a stream and its concentration reflects the extent of watershed disturbance. Following a log phase of sulfate generation at the onset of mining, a long-term production of the substance continues from disturbed watersheds (23). In general, high sulfate and hardness components are associated with poor biotic populations (22).

As can be seen in figures 22-25, again with the exception of Jenny Fork, there was a significant increase in sulfate production with the onset of mining and a continuous generation of the substance thereafter. However, sulphate concentrations seldom exceeded the levels established for drinking water standards. Specific conductivity measurements covering the same period reflect a similar trend (Figs. 26-29).

All of these components demonstrated periodic variations of relatively large magnitude, a feature also reported by other investigators (23). This phenomena may be, in part, correlated with peak and mean daily discharge of the streams involved. In that regard, figures 30-33 are of specific interest.

Discharge is also of importance when dealing with erosion and subsequent stream sedimentation. Disturbed soil materials are usually very susceptible to erosion, especially during storms (5, 6, 24, 25, 26). Curtis (5) measured 9,600 to 46,400 ppm of suspended solids in one of the tributaries to Leatherwood Creek following the onset of mining as contrasted with 150 ppm for unmined watersheds in the same general area. The sediment remained high after cessation of mining, as indicated by Branson and Batch (1).

Although this study does not report new measurements of settleable solids, field visual observations indicate that the study streams are still heavily silted; the bottom and sides of the streams have silt deposits that are in many areas more than 45 cm deep.

Periodic turbidity measurements of the study streams give little insight into the sediment problem. Though the measurements spike at 600-700 JTU (Jackson Turbidity Units) following rain storms (Figs. 34-36), the readings quickly return to low levels. Jenny

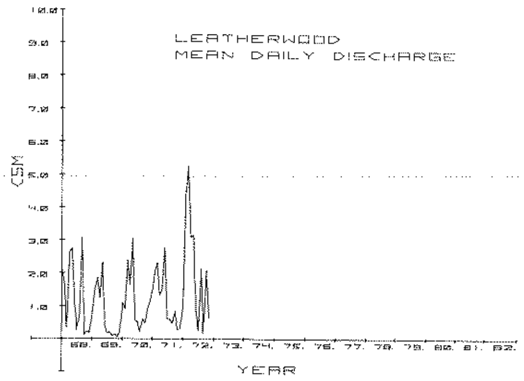

FIG. 30. Mean daily discharge in Leatherwood Creek.

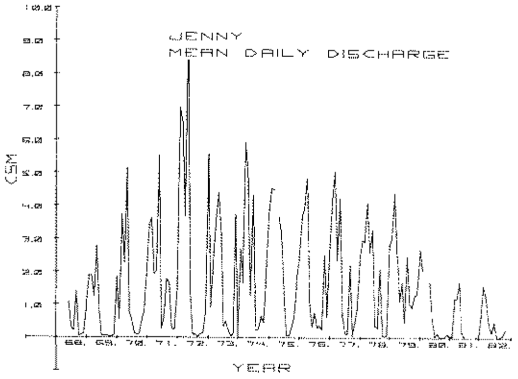

FIG. 31. Mean daily discharge in Jenny Fork.

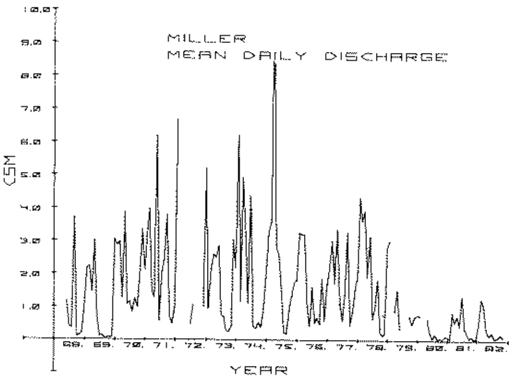

FIG. 32. Mean daily discharge in Miller Branch.

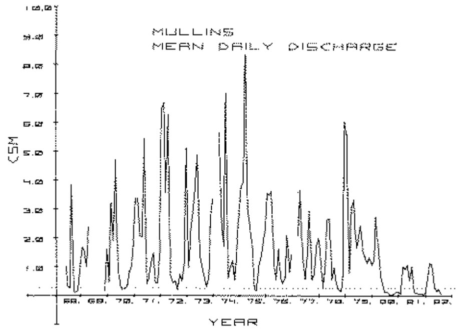

FIG. 33. Mean daily discharge in Mullins Fork.

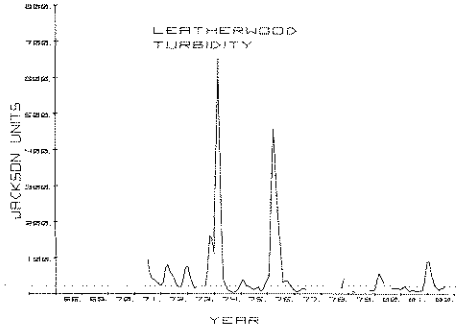

FIG. 34. Turbidity measurements in Leatherwood Creek.

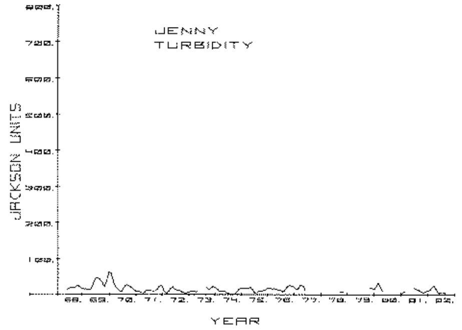

FIG. 35. Turbidity measurements in Jenny Fork.

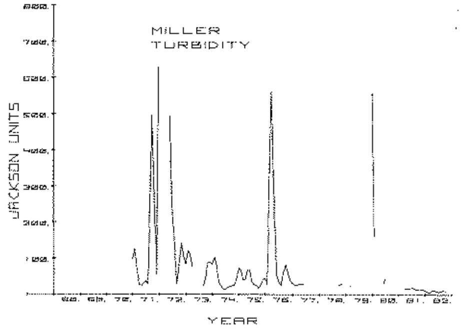

FIG. 36. Turbidity measurements in Miller Branch.

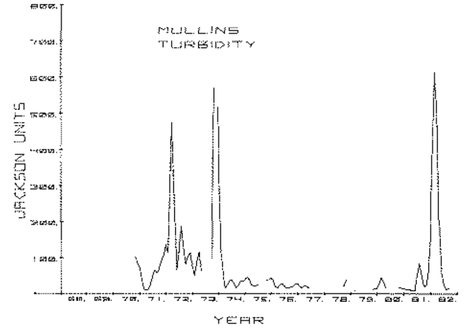

FIG. 37. Turbidity measurements in Mullins Fork.

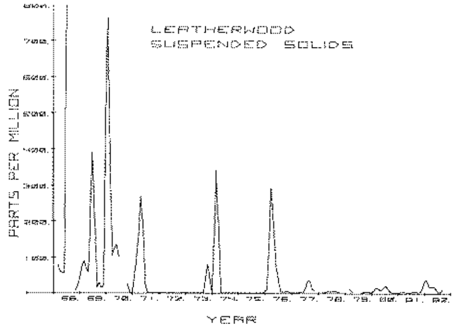

FIG. 38. Suspended solids in Leatherwood Creek.

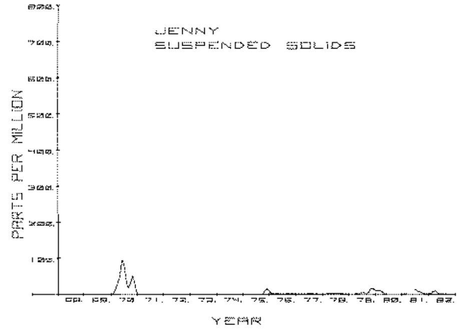

FIG. 39. Suspended solids in Jenny Fork.

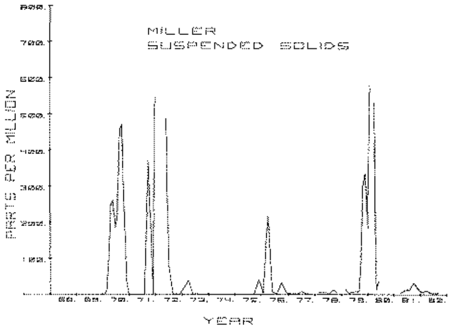

FIG. 40. Suspended solids in Miller Branch.

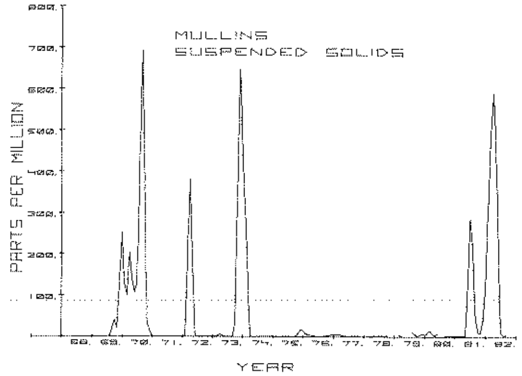

FIG. 41. Suspended solids in Mullins Fork.

Fork (Fig. 37), however, did not exhibit the degree of fluctuation exhibited by the other streams.

Suspended solids also exhibited fluctuations associated with rain storms during the study period (Figs. 38-41) but each stream quickly returned to pre-storm conditions as the transported materials settled to the bottom.

Many of these physical and chemical conditions adversely affect stream biotas. Matter, Ney and Maughan (22) reported a general trend toward poor biotic populations associated with streams impacted by high sulfate and hardness concentrations produced by mining. In addition, siltation often severely affects aquatic biota and its microdistribution in relation to stream velocity, substrate particle size, silt and detritus (27). Fishes are usually displaced downstream or eliminated by heavy siltation (1). Both suspended solids and sediments cause negative responses in macroinvertebrate populations.

Most species, however, are more or less uniformly affected; hence, diversity indices may not be altered (28) although abundance may be greatly lowered (22). There are, of course, exceptions. For example, certain mayflies (*Tricorythodes*) and beetles (*Stenelmis*) are resistant to siltation and tend to increase any time competitors are removed (28). Particle size of sediments is apparently of importance in considering the impact upon the benthos, with sand and fine silt having the greatest impact (27, 15). Most of the sediments deposited in our study areas are in the sand and silt categories. Siltation influences may often be long-term. Vaughan, Talak and Anderson (29) indicated that aquatic invertebrate populations in Tennessee may require 20 or more years to return to a predisturbance level. In other instances following drastic land disturbance, the benthos have remained disturbed for 50 years (30).

Recolonization of disturbed portions of streams comes from 4 principal sources: drift, 41%; upstream migration in the water, 18%; upstream migration in the substrate, 19%; and aerial migration with subsequent reproduction, 28% (31, 32, 33). If the disturbance occurs downstream from a non-impacted headwater where the substrate is suitable, drift may allow rapid recolonization. Headwater disturbance significantly increases drifting downstream of invertebrates which may serve to hasten recolonization of previously disturbed downstream sites (28, 34). If a whole drainage is disturbed, other mechanisms must effect the repopulation of a stream. This is essentially the situation in the case of the streams herein discussed.

Fishes

Table 1 summarizes the fish data from the first two study periods (1, 2) and those gleaned during the present investigation. It is not intended that the data from similar numbered stations be compared by watershed and to do so could be misleading. For example, Station 4 on Leatherwood represents a point well downstream draining some 1200 acres while Station 4 on Bear Branch represents a headwater drainage of less than 300 acres. Stations 3, 5, and 6 are somewhat comparable. Study of the table indicates no change in the fish fauna at Station 1 in either stream, and no change at Station 2 in Bear Branch. However, in Leatherwood Creek *Semotilus*, *Campostoma*, *Ericymba*, and *Etheostoma flabellare* have all successfully invaded or reinvaded the area even though the last 3 species are present in small numbers only. *Semotilus*, which is more or less resistent to sedimentation of its habitat (1, 35), is the dominant species at

TABLE 1.—FISH DATA FOR SIX SITES EACH IN LEATHERWOOD CREEK AND BEAR BRANCH, BREATHITT COUNTY, 1968-1982. UPPER ROW OF SYMBOLS FOR EACH SPECIES REPRESENT LEATHERWOOD CREEK OBSERVATIONS, THE LOWER ROW REPRESENTS BEAR BRANCH OBSERVATIONS. - INDICATES LACKING; + INDICATES PRESENT. THE LAST ENTRY IN EACH ROW IS THE 1982 OBSERVATION; THE OTHER ENTRIES REPRESENT THE OBSERVATIONS MADE PREVIOUSLY (1, 2).

TABLE 1.—COLLECTING STATIONS

SPECIES	1	2	3	4	5	6	SPECIES	1	2	3	4	5	6
Semotilus	-------	++-+--+	++++--+	+++++++	+++++++	+++++++	*Percina*	-------	-------	-------	-------	-------	-------
atromaculatus	++++++	++++++	++++++	+--+--	+-++++	++++++	*maculata*	------	------	--+---	------	------	------
Campostoma	-------	+-----+	+-----+	+++++++	+++++++	+++++++	*Etheostoma*	-------	+-----+	++----+	++++-++	-+++-++	++++-++
anomalum	------	------	++++--	------	++++-+	+++-++	*flabellare*	------	------	++----	--+---	+-+++-	++++++
Ericymba	-------	------+	+-----+	-+++-++	+---+++	+++++++	*Etheostoma*	-------	-------	+------	++-----	------+	+++++++
buccata	------	------	+-++--	------	++++--	+++--+	*caeruleum*	------	------	------	------	--++--	++++++
Notropis	-------	-------	-------	-------	-------	-------	*Etheostoma*	-------	-------	+------	-+-----	-------	++-----
ardens	------	------	+-----	------	------	++-+++	*nigrum*	------	------	------	------	++----	++++++
Notropis	-------	-------	-------	+------	+----+-	+++-+++	*Etheostoma*	-------	-------	-------	-------	-------	+------
chrysocephalus	------	------	------	------	+----+	+++-++	*variatum*	------	------	--+---	------	------	++++++
Notropis	-------	-------	-------	-------	+------	+------	*Etheostoma*	-------	-------	+------	-+-----	--+--++	---+---
photogenis	------	------	------	------	------	----+-	*sagitta*	------	------	+-----	------	--++--	++--+-
Notropis	-------	-------	-------	-------	+------	++---+-	*Etheostoma*	-------	-------	-------	-------	-------	-------
volucellus	------	------	------	------	------	--+---	*blennioides*	------	------	------	------	------	+-++--
Notropis	-------	-------	-------	-------	-------	------+	*Etheostoma*	-------	-------	-------	-------	-------	-------
rubellus	------	------	------	------	------	-----+	*baileyi*	------	------	------	------	------	--+++-
Pimephales	-------	-------	-------	-------	+------	++-++++	*Catostomus*	-------	-------	-------	-------	-------	------+
notatus	------	------	--++--	------	--++-+	++++++	*commersoni*	------	------	------	------	-----+	------
Nocomis	-------	-------	-------	-------	-------	-------	*Micropterus*	-------	-------	-------	-------	-------	------+
micropogon	------	------	------	------	--++--	++++++	*dolomieui*	------	------	------	------	------	-----+
Hypentelium	-------	-------	-------	-------	------+	------+	*Lepomis*	-------	-------	-------	-------	-------	-------
nigricans	------	------	------	------	------	++---+	------	------	------	------	------	------	-----+
Percina	-------	-------	-------	-------	-------	-------							
caprodes	------	------	------	------	------	+-----							

all stations in both streams.

At Station 3 on Bear Branch, *Campostoma*, *Ericymba*, *Pimephales notatus*, *Percina maculata*, *Etheostoma flabellare*, *E. variatum*, and *E. sagitta* have not returned to the fauna. *Semotilus*, *Campostoma*, *Ericymba*, and *E. flabellare* were present at Leatherwood Creek Station 3, but *Etheostoma caeruleum* continues to be absent.

Water volume, current, and oxygen content is higher at stations 5 and 6 than at the other stations, resulting in a slightly better habitat at these stations, and while large quantities of sediments are present, particularly along the margins of the streams and in pools, recovery in the fish faunas have been modest. For example, at Station 5 in Bear Branch, *Catostomus commersoni* was observed for the first time and *Notropis chrysocephalus* rejoined the fauna. *Etheostoma flabellare*, a clean-water fish dropped out of the fauna and *Nocomis micropogon*, *Etheostoma caeruleum*, *E. nigrum*, and *E. sagitta* continue to be absent. Similarly, at Leatherwood Station 5 *Notropis chrysocephalus* has apparently dropped out of the fauna, and *N. photogrenis*, *N. volucellus*, and *Pimephales notatus* are still missing. At the same station, *Hypentelium nigricans* and *Etheostoma caeruleum* were observed for the first time since the onset of mining, and *E. sagitta* has rejoined the fauna.

Stations 6, located at the mouth of the respective watersheds, are under the influence of normal longitudinal succession which reflects expansion of the habitat. Normally, such sites are kept relatively clear of sediments because of the higher flows, especially during storms. However, in both streams there are some thick bars and lens-shaped deposits of sediments.

At these two sites, some piscine changes were evident. In Bear Branch Station 6, *Lepomis megalotis*, *Micropterus dolomieui* (2 juveniles), and *Notropis rubellus* were collected for the first time, and *Ericymba* and *Hypentelium nigricans* have rejoined the fauna. However, *Notropis photogenis*, *Etheostoma sagitta*, and *E. baileyi* dropped out of the fauna, giving a net positive change of one species. *Notropis volucellus*, *Percina caprodes*, and *Etheostoma blennioides* continue to be absent.

In Leatherwood Station 6, 3 species—

Catostomus commersoni, Notropis rubellus, and *Micropterus dolomieui* — were observed for the first time, and *Hypentelium nigricans* has rejoined the fauna. However, *Notropis ardens, N. photogenis, N. volucellus, Etheostoma nigrum, E. variatum,* and *E. sagitta* apparently have not been able to reinvade the stream.

Many of these species, such as the bass, suckers, and some of the minnows and darters, are usually found at the mouths of small streams because of the proximity of the larger streams into which the tributaries flow. In this case, however, the larger streams have also been heavily impacted by mining. South Fork of Quicksand Creek, receiving Leatherwood Creek, and Buckhorn Creek, to which Bear Branch is tributary, are both choked with sediments and fine silt. Both streams' faunas have also been decimated, so they are no longer capable of providing parent populations of fishes for repopulation of the study streams. Since Bear Branch has recently been redisturbed (see Figs. 2-1) the faunal recovery of that stream has been slower than that of Leatherwood Creek.

Stations 1 and 2 of both watersheds and Station 4 of Bear Branch are on small, first order streams that may be ephemeral. Thus, the diversity and populations of fishes found in larger streams are not to be expected here.

Macrobenthos

None of the Leatherwood Creek and Bear Branch data on macrobenthos have been published previously (Tables 2 and 3). Thus, these data provide us with considerable new insight into the long-term influences of surface mining on the aquatic fauna in eastern Kentucky.

TABLE 2.—MACROBENTHOS OBSERVATIONS IN LEATHERWOOD CREEK, BREATHITT COUNTY, KENTUCKY, 1968 - 1982. COLLECTING DATES HEAD EACH COLUMN BELOW WHICH ARE GIVEN THE NUMBER OF SPECIMENS COLLECTED (COLLECTION SITE(S) IN PARENTHESES). TOTAL TAXA, TOTAL NUMBER COLLECTED, MEAN DIVERSITY INDICES, MAXIMUM DIVERSITY INDICES, AND EQUITABILITIES ARE PRESENTED AT THE END OF EACH COLUMN.

TABLE 2.—LEATHERWOOD CREEK

	6/1/68	10/26/68	5/17/69	11/1/69	10/3/70	8/14/71	12/2/72	7/31/82
	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)
Ephemeroptera								
Baetis			27 (2,3,4,5,6)	4 (1,4		1 (5)		10 (4,5)
Epeorus	1 (2)		13 (2,3,4,5)					
Stenacron			4 (1,2)	3 (2)		6 (3)	2 (3)	3 (4)
Stenonema	9 (1,2,4)	49 (3,4,6)	19 (4,6)	74 (2,4,5,6)	14 (3,4,6)	11 (3,5,6)	58 (3,4,5,6)	4 (4,6)
Isonychia		22 (6)	5 (6)	2 (6)	2 (6)	7 (3,6)	2 (3,4)	26 (4,5,6)
Paraleptophlebia			4 (2)					
Ephemera	1 (2)			1 (6)				1 (4)
Dannella			1 (4)	1 (1)				
Drunella	13 (1,2,4)		1 (5)					
Ephemerella			3 (2,6)					
Odonata								
Boyeria	9 (1,2,4)	1 (6)						
Lanthus			1 (4)					1 (6)
Cordulegaster	1 (1)							
Calopteryx								1 (3)
Plecoptera								
Amphinemura	1 (1)		3 (3,5)					
Allocapria							2 (3,4)	
Leuctra	1 (1)							
Peltoperla			1 (1)					
Isoperla			3 (5,6)					
Remenus	2 (1,2)							
Yugus	11 (1,2)	1 (6)		3 (4)		2 (3)	1 (4)	1 (5)

TABLE 2.—LEATHERWOOD CREEK (CONTINUED)

	6/1/68	10/26/68	5/17/69	11/1/69	10/3/70	8/14/71	12/2/72	7/31/82
	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)
Plecoptera (Continued)								
Acroneuria	1 (3)							
Acroneuria carolinensis	18 (1,2,3)	54 (3,4,5,6)	10 (2,4,5,6)	13 (4,5,6)	2 (4)			5 (4,5)
Eccoptura	4 (1,4)							
Heteroptera								
Gerris								9 (4,5)
Trepobates						3 (3,6)		4 (4,5)
Microvelia								1 (5)
Rhagovelia					9 (3)			
Megaloptera								
Corydalus cornutus		3 (6)			1 (6)	2 (3,6)	2 (3)	9 (3,4)
Trichoptera								
Diplectrona	9 (1,2)	18 (3,4,6)	2 (2,5)	1 (1)				
Cheumatopsyche	2 (2)	21 (3,4,6)		7 (4,5,6)		12 (3,4,6)	10 (3,4)	58 (3,4,5)
Hydropsyche		4 (3,6)		7 (4,5,6)		12 (3,4,6)	10 (3,4)	58 (3,4,5)
Ceratopsyche						3 (3)	4 (3)	5 (5)
Chimarra								70 (4,5)
Hydroptila								1 (4)
Rhyacophila		1 (6)						
Neophylax	1 (1)							
Coleptera								
Haliplus		1 (6)		2 (6)				
Hydrophilus				1 (6)				
Hydroblus								1 (4)
Psephenus		2 (3,6)						
Helichus	1 (2)	2 (3,6)	1 (2)	4 (4,5,6)	1 (6)	1 (6)	1 (3)	
Optioservus								1 (4)
Diptera								
Tipula	12 (1,2,3,4)	26 (1,3,6)	2 (3,4)	4 (4,5,6)			40 (4,5,6)	4 (3,4)
Eriocera	3 (1,2)							
Dixa				2 (1)				
Chironomidae								2 (4)
Pentaneura			1 (5)				3 (4)	
Simulium				1 (1)		1 (6)		3 (3,4)
Hemerodromia								1 (4)
Decapoda								
Cambarus bartonii	27 (1,2,3,4,5)	18 (1,3,4,6)	30 (2,3,4,5,6)	13 (2,3,4,5,6)	4 (4,6)	3 (5,6)	2 (5,6)	15 (3,4)
Orconectes putnami	55 (3,4,5)	18 (3,4,6)	13 (4,5,6)	26 (4,5,6)	13 (4,5,6)	29 (3,4,5,6)	6 (4,5,6)	48 (3,4,5,6)
Total Taxa	21	16	20	18	8	13	14	27
Total Number	182	241	144	162	46	81	135	293
Diversity Index (Mean)	3.371	3.181	3.478	2.790	2.438	2.940	2.439	3.463
Diversity Index (Max.)	4.392	4.000	4.322	4.170	3.000	3.700	3.807	4.755
Equitability	.705	.804	.800	.535	.923	.828	.528	.586

In general, analysis of the benthos demonstrated a decrease in total taxa and mean diversity index in Leatherwood Creek between June 1968 and October 1970 with an increase in both from October 1970 to July 1982, with the exception of a slightly lowered diversity index in December 1972. Concomitant changes in equitability were also obvious (Table 2).

Similar changes were noted in Bear Branch (Table 3) from March and April 1969 to November 1970, i.e., decreases in total taxa and mean diversity index, with a tendency toward an increase in total taxa and mean diversity index and equitability from November 1970 through October 1982.

In both watersheds, however, the numbers of individuals within given taxa tended to be lower in 1982 than previously. The population diversity remains lower in Bear Branch than it was in 1969, but in Leatherwood it is higher (Tables 2 and 3). Mayflies (Ephemeroptera) tend to be microhabitat specialists (36), the nymphs often burrowing deeply into the substrata (37) where they are subject to decimation by heavy siltation. Furthermore, the feeding activities, i.e., shredding/chewing of vegetation, collecting, or scraping/grazing, are often depreciated by sediments. Certain mayflies, like the various species of *Stenonema*, are moderately resistant to sediment pollution (38). Although some genera of mayflies (*Baetis, Stenonema, Isonychia,* and others) were able to persist during and after mining, others like *Ameletus, Leptophlebia, Paraleptophlebia, Ephemera, Dannella* and *Ephemerella* were apparently eliminated from the fauna of Bear Branch. Some of these same genera, mostly the collector/gatherers or deposit feeders, are also still missing from Leatherwood Creek. The Odonata were likewise seriously decimated by mining pollution in both streams. In fact, in Leatherwood Creek only *Lanthus* and *Calopteryx* were found in the fauna; both are lotic climbers and detritus feeders. In Bear Branch, *Boyeria, Lanthus, Progromphus* and *Cordulegaster* have returned, probably because of the increased amount of sediments suitable for burrowing.

The Plecoptera are, in general, particularly sensitive to sedimentation as demonstrated by Tables 2 and 3. Many genera eliminated from the fauna during mining have not yet successfully recolonized. The genera *Yugus, Peltoperla* and some *Acroneuria* have become re-established at low levels.

Megalopterans (*Corydalus, Nigronia, Sialis*), living among coarse rubble and stones, are active hunters and, hence, are resistant to sediment and acid pollution (38). Our data confirm this.

The Heteroptera (water strides and associated genera) poses an interesting phenomenon. From 1968 through 1970, intensive collecting failed to turn up specimens of any member of this order. It is doubtful that this is an artifact of collecting since the gerrids, at least, are a very obvious member of the fauna when present. We hypothesize that the influence of sedimentation, by slowing the current, producing several sluggish, ooze-filled pools, and otherwise disturbing the normal conditions changed the habitat enough to allow these organisms to colonize both streams. In any case the addition of these organisms to the fauna of both streams helped to counteract the tendency toward lowered diversity indices created by the absence of mayflies, stoneflies, and other insects.

Most streams show a consistently lower abundance and diversity of Trichoptera when impacted by mining pollution (22), although genera like *Cheumatopsyche* and *Hydropsyche* appear to be resistant to sedimentation pollution (38). These facts are supported by the data in Tables 2 and 3.

Although trichopterans often form a major component of invertebrate drift, especially at night, very little is known about their upstream migrations. Poole and Stewart (39) observed that various trichopterans use the loosely packed materials of the hyporheic zone as refuges from sedimentation and associated bottom scouring and thus are able to quickly recolonize streams following abatement of the sediment pollution.

The aquatic beetles (Coleoptera), though not abundant in Leatherwood Creek at the onset of the study, have been severely decimated in both streams. *Helichus* persisted in Leatherwood Creek through the mining period but was not found 10 years later. *Hydrobius* was the main genus observed in Bear Branch in 1982. It was not found in previous surveys.

TABLE 3.—MACROBENTHOS OBSERVATIONS IN BEAR BRANCH, BREATHITT COUNTY, KENTUCKY, 1968-1982. ALL OTHER DETAILS AS IN TABLE 2.

TABLE 3.—LEATHERWOOD CREEK

	3/21 & 4/26/69	12/12/69	11/7/70	9/4/71	9/9/72	8/1/82
	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)
Ephemeroptera						
Baetis	7 (3,4,5)			1 (6)	2 (3,6)	1 (6)
Centroptilum						1 (2)
Epeorus	48 (1,2,3,4)					
Stenacron	37 (1,2,4)	2 (1)	16, (1,4,5)	40 (1,2,3,4,5,6)	13 (3,4,6)	
Stenonema	48 (1,2,3,4,5)	53 (1,3,4,5,6)	40 (3,4,5)	24 (1,2,4,5,6)	29 (3,4,5,6)	1 (6)
Isonychia		1 (6)		7 (6)	2 (5,6)	2 (5,6)
Ameletus	7 (1,3,4)					
Leptophlebia	11 (2)	14 (1,2,4)	3 (4,5)			
Paraleptophlebia	3 (1,3)					
Ephemera	11 (3,4,5,6)	9 (3,4,6)	24 (2)			
24 (2,4)	2 (1,4)					
Ephemerella	21 (3,5)					
Odonata						
Boyeria	5 (1,3,5)	3 (1,3,6)		3 (3,5,6)		2 (2,6)
Hagenius					1 (6)	
Lanthus	1 (6)					4 (1,3)
Progomphus						1 (6)
Cordulegaster	1 (4)	2 (2)		1 (6)		1 (2)
Pantala					1 (2)	
Calopteryx	3 (3,6)	3 (1,4)	2 (2)	1 (2)	1 (6)	
Argia				1 (6)	2 (6)	
Plecoptera						
Ostrocerca		1 (6)				
Brachypterinae	3 (3)	6 (6)				
Allocapnia	2 (2)	3 (3,5)	2 (3,5)			
Leuctra	1 (1)					
Peltoperla	3 (4,5)			3 (3,5)		5 (4)
Isoperla	23 (1,2,3,4,5)	1 (6)				
Yugus	15 (1,2,3,4,5)	4 (6)	2 (4)			1 (4)
Alloperla	3 (6)					
Acroneuria				1 (3)	4 (6)	3 (1,2)
Acroneuria carolinensis	5 (1,3,4,5)	1 (5)	3 (3)			5 (3,5)
Eccoptura	2 (1)		1 (1)			
Heteroptera						
Gerris				2 (2,6)	4 (3,5)	9 (3,5)
Rheumatobates				1 (6)		
Trepobates					1 (3)	3 (5)
Microvelia						3 (3)
Rhagovelia				4 (3,6)		5 (1,2,3,6)
Megaloptera						
Corydalus cornutus	4 (6)			5 (1,6)	4 (5,6)	1 (5)
Nigronia	1 (4)					
Sialis						1 (3)
Trichoptera						
Diplectronia	9 (1,2,4)		1 (1)			1 (2)
Cheumatopsyche	14 (1,3,4,5)	5 (3,4,5)	38 (1,3,4,5)	8 (3,4,5,6)	19 (3,5)	13 (1,5,6)
Hydropsyche	2 (1,4)	1 (6)	2 (1,3)	2 (1,6)	1 (6)	1 (6)

TABLE 3.—MACROBENTHOS OBSERVATIONS IN BEAR BRANCH, BREATHITT COUNTY, KENTUCKY, 1968-1982. ALL OTHER DETAILS AS IN TABLE 2.

TABLE 3.—LEATHERWOOD CREEK (CONTINUED)

	3/21 & 4/26/69	12/12/69	11/7/70	9/4/71	9/9/72	8/1/82
	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)	NO. (STA)
Trichoptera (Continued)						
Ceratopsyche			2 (3)			
Chimarra				24 (6)	25 (3,6)	1 (1)
Wormaldia	1 (1)					
Polycentropus	1 (1)		1 (1)			
Rhyacophila	2 (1,4)					
Pychopsyche						1 (4)
Neophylax	97 (1,3,4)			4 (5)		6 (2,4)
Pseudostenophylax	17 (3,4,6)	7 (6)	1 (6)			
Coleoptera						
Laccophilus					3 (1,2,5)	
Tropisternus				1 (3)	1 (1)	
Hydrobius						6 (1,3,4)
Psephenus	11 (1,2,3)		4 (1,5)	4 (3,6)	2 (5)	6 (1,3,4)
Ectopria	7 (1,4,5)			4 (5,6)		
Helichus	1 (1)	1 (6)	2 (1,3)	13 (3,5,6)	24 (1,5,6)	1 (2)
Diptera						
Tipula	40 (1,2,3,4,5,6)	16 (2,3,4,5,6)	22 (1,3,4,5,6)	1 (6)	1 (3)	4 (3,6)
Dicranota						2 (3,4)
Hexatoma		2 (3,6)				
Bittacomorpha	1 (4)		1 (2)			
Dixa						1 (4)
Chironomidae						4 (1,24)
Pentaneura	1 (4)	1 (4)	4 (4)		11 (6)	
Simulium	6 (1,2)			1 (6)		
Atherix				1 (6)		
Heterondonta						
Sphaerium striatinum	2 (6)	8 (6)				
Mesogastropoda						
Pleurocera acuta	4 (6)	8 (6)		6 (6)	9 (6)	
Goniobasis semicarinata				4 (6)	6 (6)	
Basommatophora						
Ferrissia fragilis					1 (6)	
Helisoma anceps	1 (6)				2 (6)	
Decapoda						
Cambarus bartonii	44 (1,2,3,4,5,6)	5 (1,5,6)	9 (1,2,3,6)	29 (1,3,4,5,6)	2 (2,5)	21 (1,3,6)
Orconectes putnami	10 (5,6)	10 (6)	3 (5,6)	33 (2,3,5,6)	38 (2,5,6)	32 (1,2,3,5,6)
Total Taxa	45	26	22	29	27	32
Total Number	560	169	183	231	209	143
Diversity Index (Mean)	4.427	3.737	3.389	3.880	3.793	4.090
Diversity Index (Max.)	5.492	4.700	4.459	4.858	4.755	5.000
Equitability	.706	.743	.681	.739	.745	.779