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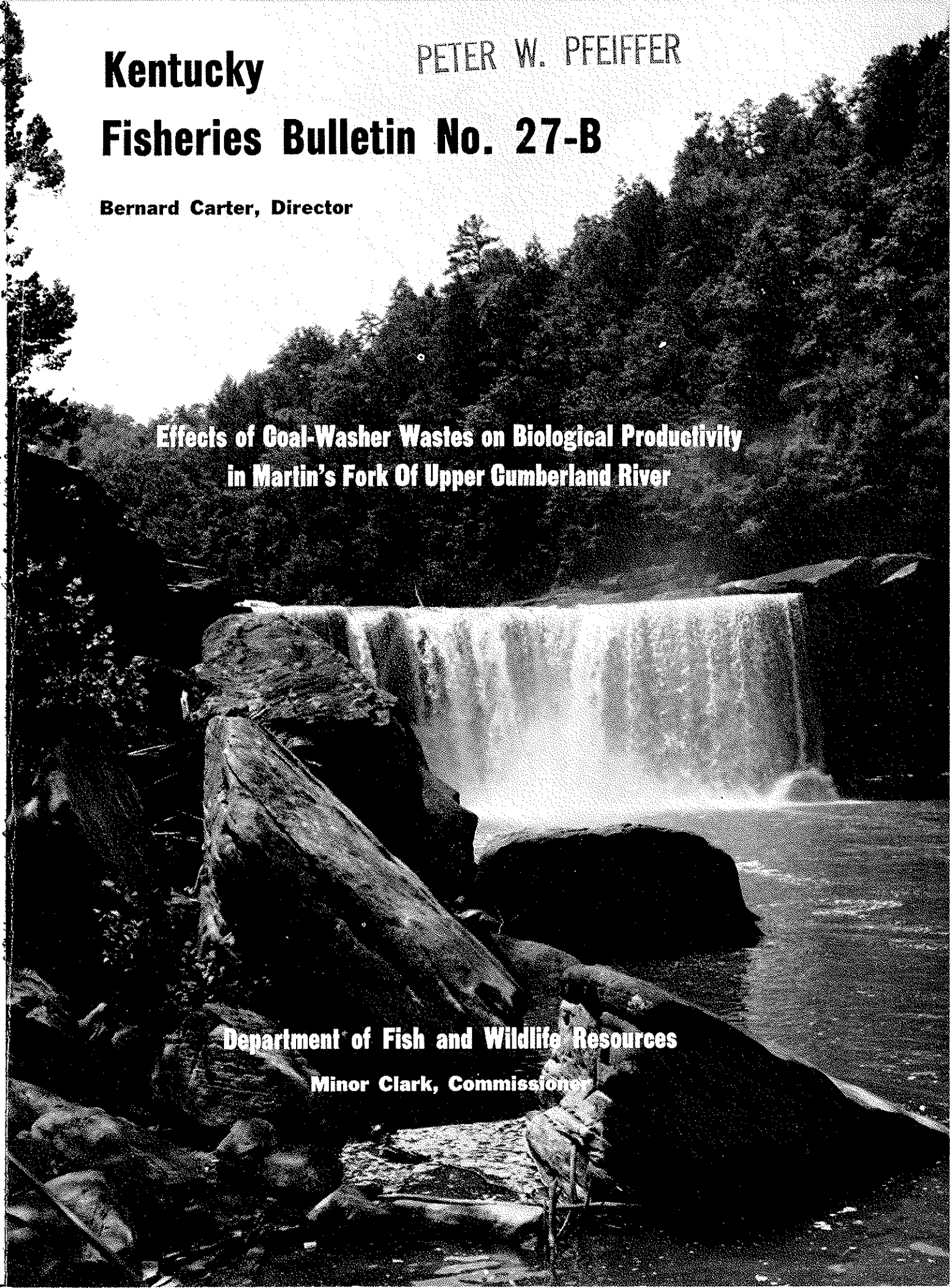
Bernard Carter, Director



Effects of Coal-Washer Wastes on Biological Productivity in Martin's Fork Of Upper Cumberland River

Department of Fish and Wildlife Resources

Minor Clark, Commissioner

EFFECTS OF COAL-WASHER WASTES ON BIOLOGICAL PRODUCTIVITY IN MARTIN'S FORK OF THE UPPER CUMBERLAND RIVER

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EFFECTS OF COAL-WASHER WASTES ON BIOLOGICAL PRODUCTIVITY IN MARTIN'S FORK OF THE UPPER CUMBERLAND RIVER

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ABSTRACT

Intermittent coal-washer waste pollution has been and continues to be a chronic stream pollution problem in the coal-producing areas of Kentucky despite passage of "model" anti-pollution laws. The effects of coal-washer wastes — primarily coal dust and "fines" — on the water quality, macro-invertebrate bottom fauna, and fish fauna of a stream in Harlan County were determined and evaluated by a study that began in the summer of 1961 and continued through 1963. Martin's Fork of the upper Cumberland River was intermittently polluted by washer wastes emanating from two coal mines three miles apart on the watershed.

Turbidity at the five sampling stations in the polluted section fluctuated widely, dependent upon coal-washing schedules. The range was from 0 to 700 ppm. Practically all the other chemical characteristics monitored in the polluted section exceeded the values found in the clean-water section above the washer effluent.

A moderately diverse macro-invertebrate bottom fauna was found in both the clean-water and polluted sections; however, the quality of the fauna as potential fish food was distinctly poorer in the polluted section. Annual mean productivity in the clean-water section varied from 42 to 81 organisms per square foot and from 0.69 to 1.58 cubic centimeters per square foot. The overall 3-year mean was 52 organisms and 0.82 cc. The range in the polluted section was from 19 to 183 organisms and from 0.17 to 4.26 cc per square foot. The overall 3-year mean was 52 organisms and 0.59 cc, the same and about three-fourths, respectively, of the clean-water production rate.

Population sampling showed that the fish fauna of Martin's Fork is meager, compared to many other streams in Kentucky having more diverse habitat types. Only 37 of the more than 178 species known to occur in the state were found. Specimens of redeye bass, Micropterus coosae, a species not known to occur in Kentucky, were found in the upper reaches of Martin's Fork. From 3 to 13 of the 25 to 31 fish species found each year in the clean-water section occurred there exclusively. The polluted section supported annually between 19 and 25 species, from 1 to 6 being found there exclusively each year. The average annual standing crop in the clean water ranged between 35 and 53 pounds per acre. The polluted section supported a standing crop that ranged between 62 and 103 pounds per acre. Harvestable-size channel catfish primarily, and intermediate-size suckers secondarily, were responsible for the greater biomass in the polluted section.

INTRODUCTION

Enlightened stream fishery management entails more than regulation of size, creel, and season limits, artificial replenishment, population sampling, creel surveying, or habitat alteration. It demands constant vigilance to the ever-growing threat of stream pollution. The situation faced today by most states is not one of adding more miles of fishable streams to their inventories but, instead, one of trying to prevent further losses to pollution. Intermittent coal-washer waste pollution has been and continues to be a chronic stream pollution problem in the coal-producing areas of Kentucky despite passage of "model" anti-pollution laws. The effects of coal-washer wastes -- primarily coal dust and "fines" -- upon biological productivity were largely unknown. This bulletin reports the results from the second phase of a Dingell-Johnson project (F-18-R:1-4) that investigated the effects of (1) oilfield brines in Green River, and (2) coal-washer wastes in Martin's Fork of the upper Cumberland River. The specific objectives sought from this second phase of the project that began in the summer of 1961 and continued through December 1963 were:

1. To determine the effects of coal-washer wastes on the water quality.
2. To determine and evaluate the effects of coal-washer wastes on the macro-invertebrate bottom fauna.
3. To determine and evaluate the effects of coal-washer wastes on the fish fauna.

ACKNOWLEDGEMENTS

Although many published titles bear the name of a single author, it has been my experience that few publications are the result of only one person's efforts. Certainly this is true of this particular report. Much credit is due Charles Gorham, my full-time Fishery Aide, for a job well done in both the field and laboratory. Few tasks in fishery biology are more tedious and eye-straining than collecting, sorting, and processing macro-invertebrate

bottom samples — and some 92,000 bottom organisms resulted from this and other phases of the project. The conscientious work of Tommy Brady, Summer Aide for three consecutive summers, who helped "pick bugs" and cheerfully performed all other tasks assigned him, is gratefully acknowledged. Although they worked on this particular project only one year and one summer, respectively, my thanks go also to Billy Sayle, former Fishery Aide, and to Robert Rash, Summer Aide. Finally, I wish to express my appreciation to William R. Turner, former staff member, for his assistance in fish and insect taxonomy. He either identified or confirmed the identity of all preserved fish, and was especially helpful in matters pertaining to Coleoptera.

METHODS AND EQUIPMENT

No difficulty was encountered in locating suitable data stations on Martin's Fork of the upper Cumberland River since paved highways closely parallel practically its entire length. The coding system used to identify data stations employs plus (+) and minus (-) signs before the mileage number. Station -19.7, for example, indicates that the location was 19.7 miles upstream from the uppermost source of coal-washer waste pollution. Station +0.1 means the location was 0.1 mile downstream from the uppermost pollution source. Although Martin's Fork was intermittently polluted by coal-washer wastes entering the stream channel at two locations three miles apart, the uppermost source was Turtle Creek. Consequently, the mouth of Turtle Creek was designated as the 0.0-mile reference point for station identification purposes.

Water-Quality Determinations

Water-quality sampling stations on Martin's Fork coincided in location with the stations selected for bottom fauna sampling (Fig. 1). Water-quality determinations were made at 3 stations above the coal-washer pollution

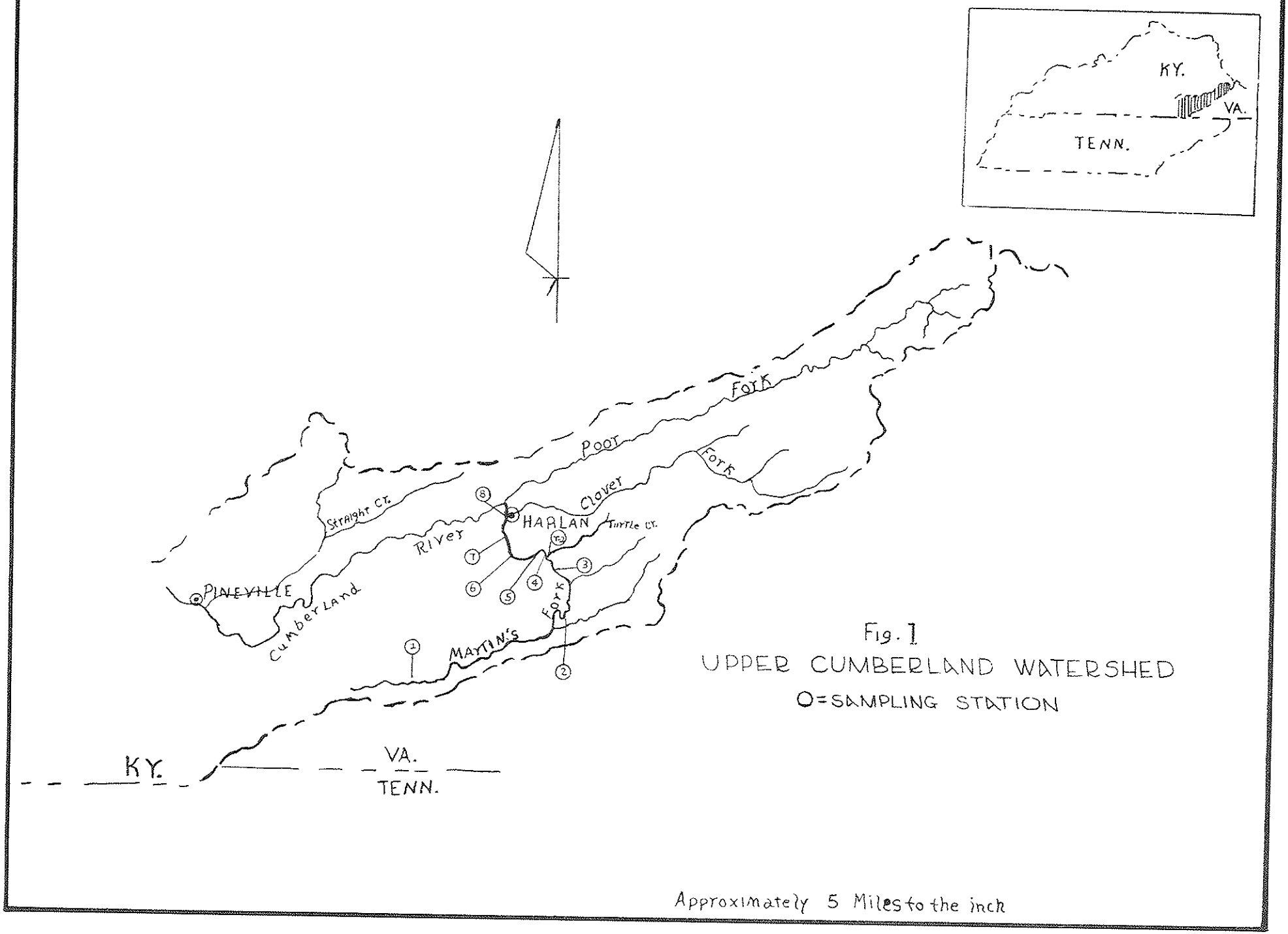

Fig. 1
UPPER CUMBERLAND WATERSHED
O=SAMPLING STATION

Approximately 5 Miles to the inch

(Stations-2.2, -8.2, and -19.7) and at 5 stations within the section affected by pollution (Stations +0.1, +2.8, +3.8, +5.6, and +7.8). A single data station on Turtle Creek was used during the life of the project. Water-quality analyses were performed seasonally in 1961, but beginning in June 1962 the stations were visited monthly. No determinations were made, however, during those months when the river stage was too high for bottom fauna sampling.

A portable, battery-powered colorimeter was used to make turbidity, sulfate, pH, ortho-phosphate, iron, and nitrate determinations. Separate kits were necessary for determining dissolved-oxygen content and total alkalinity. A battery-powered solubridge with paired conductivity cells enabled specific conductance values between 40 and 40,000 micromhos to be measured. The solubridge also measured water temperature.

Bottom Fauna Studies

Since only riffle areas in Martin's Fork and in Turtle Creek were sampled, the standard Surber square-foot bottom sampler (brass frame, canvas sides, and bolting-cloth bag) was used exclusively. Three square-foot samples were collected at each station. An attempt was made to randomly sample the bottom out from the left bank, in the center of the stream, and out from the right bank.

Each collected sample was thoroughly washed and strained through a square twinned-sieve constructed of 1/4"-mesh hardware cloth on the top half and 60-mesh bronze screen on the bottom half. All samples were sorted in the field at the station while the organisms were alive and mobile. Sorting was accomplished in a white-enameled pan of the type used by photography shops. A snow-white background that does not glare and reflect light is deemed highly essential for precise and thorough sorting of bottom samples which may contain organisms as small as water mites and larval diptera, to animals as large as crayfish and mussels. Sorted samples were preserved in vials of 80% ethyl alcohol.

In the laboratory, each sample was processed individually using essentially the techniques described by Ball (1948) and by Hunt (1953). The organisms were identified at least to order, counted, and the volume determined for each order by the water-displacement method. It has been established (Ball, 1948; Hunt, 1953; and others) that the specific gravity of most macroinvertebrates is so near that of water, that, for all practical purposes, 1.0 cubic centimeter of preserved volume is equal to 1.0 gram live weight. Despite its inappropriate-sounding title — *Aquatic Insects of California* — the excellent text edited by Usinger (1956) was the most helpful single volume in matters pertaining to aquatic insect identification.

Fish Fauna Studies

Fish population sampling areas in Martin's Fork were located above and below the sources of coal-washer pollution (Fig. 1). Emulsifiable rotenone (5%) was the only fish toxicant used during 1962 and 1963. A powdered form of potassium permanganate was used as the detoxifying agent. Sodium cyanide briquets were used upon occasion during 1961 as a fish toxicant, but only for spot-sampling and not for quantitative sampling, since NaCN proved unsatisfactory for the latter use (Charles, 1964).

The stream sampling methods used in studying the fish population of Martin's Fork were those that have become more or less standardized, and are based on many years' experience by staff biologists of the Department. The same sampling procedure was followed, in essence, at each study site. The area was first blocked at each end with 1/2"-mesh nets to prevent escape of the resident fish population that might have been disturbed by subsequent operations. A steel tape was used to measure the length and width of the study area. Soundings were made to determine the average depth. All measurements and observations were recorded on a standard field form. Emulsifiable rotenone was applied through the propeller wash, via a Venturi-type boat

bailer. A concentration of 0.5 ppm to 1.0 ppm of 5% rotenone was used, since lesser concentrations have proved inadequate for a complete kill, and greater concentrations tend to cause all sizes of all species to become distressed simultaneously, rather than in an orderly manner dependent upon their size and tolerance to rotenone. Fish in distress must be netted soon after surfacing because many species, especially those lacking air-bladders, sink to the bottom after their initial surface-floundering. The task of dip-netting is made more difficult by having most of the fish in distress at the same time, and recovery efficiency is definitely impaired.

The $KMnO_4$ was either placed in burlap feed sacks or dribbled in a continuous pile across the riffle bottom downstream from the lower block net. Current action provided a fairly constant source of dissolved permanganate. A concentration of approximately twice that of the rotenone was sought.

After capture, all fishes were sorted according to species, measured in inch-groups (game fishes were processed individually), and weighed to the nearest 0.01 pound. Small species, as well as questionable larger specimens, were preserved in formalin, along with a representative collection of the entire sample, for later identification and study. Standardized field forms, designed to complement the Kentucky-version of the standard method of reporting fish population data (Surber, 1959), were used in recording measurable data.

The Kentucky-version of the standard method for reporting population study data divides all species into two major categories, Piscivorous or Non-piscivorous, based primarily upon their food habits (Appendix:Fig. 1). Each major category is sub-divided into three arbitrary groups. The piscivorous category is composed of (A) Game Fishes; (B) Food Fishes; (C) Predatory Fishes. The non-piscivorous breakdown is (D) Panfishes; (E) Commercial Fishes; (F) Forage Fishes. The individual species in all groups and both categories are further separated, according to total length, into fingerling, intermediate, and

harvestable sizes. The final, and most meaningful, items calculated for each species are the number per acre and pounds per acre. The resultant tabular data greatly facilitates comparison of population data between areas within the same drainage system, between streams within the state, or between other states, or even regions of the country.

DESCRIPTION OF MARTIN'S FORK

Geography and Topography

The Cumberland River, one of the major tributaries of the Ohio River, is located entirely within the borders of Kentucky and Tennessee. The basin is crescent-shaped, embracing a large part of southeastern Kentucky, the northern part of middle Tennessee, and a wide corridor across western Kentucky. The total area of the Cumberland Basin is 17,720 square miles, of which 10,160 square miles are in Tennessee and 7,560 are in Kentucky. The average width of the basin is about 50 miles and its axial length is approximately 350 miles.

The Cumberland River is formed in the mountains that lend their name to the river by the confluence of three headwater streams near the city of Harlan: Poor Fork, Clover Fork, and Martin's Fork. Some authorities maintain that Martin's Fork is tributary to Clover Fork, and that the confluence of the latter and Poor Fork form the Cumberland. Regardless, Martin's Fork rises in Bell County within the boundary of Cumberland Gap National Historical Park at an elevation of 3030 feet and joins Poor Fork at an elevation of 1175 feet, an average gradient over the 40-mile reach of 46 feet per mile. This is a deceptive average, however: the average gradient of the uppermost 10 miles is 145 feet per mile, the next 10 miles average 26 feet per mile, the next 10 average 8 feet per mile, and the last 10 miles has only a 6.5 feet per mile gradient. For comparison, Poor Fork drains 149 square miles, is 49 miles long, and has a gradient of 11.6 feet per mile; Clover Fork drains 103 square miles, is 35 miles long, and has a gradient of 10.7 feet per mile. From its

source Martin's Fork flows almost due east for about 10 miles, then heads northeastward for the next 10 miles. Here the course changes to due north for the next 10 miles and, after a 3-mile swing westward, continues northward to the confluence of the 3 forks near Harlan. All but the first few miles of Martin's Fork are located in Harlan County.

The entire 120 square miles of the Martin's Fork basin is composed of rugged, steep mountains and deep, narrow valleys. The watershed lies within an area of Paleozoic limestones and hard shales. These are overlain by sandstones, shales, and coals of the Coal Measures. The overburden is residual, having been formed by the decay of these rock formations. Pronounced stratal folding is present, accompanied by the major Pine Mountain fault which extends from Jellico, Tennessee through Loyall (near Harlan), Kentucky.

Hydrologic Conditions

Although the U. S. Geological Survey, in cooperation with other state and federal agencies, has a vast network of gaging stations on the many watersheds in Kentucky, unfortunately there is none on Martin's Fork (there is one on Poor Fork, and one on Clover Fork, and one below the confluence of all three forks). Recorded under the Low-flow partial-record stations heading for the 1961 water year (October 1960 - September 1961) is a single discharge measurement made on September 12, 1961 (USGS, 1961). At this station, 1.0 mile above the mouth, Martin's Fork was discharging a base flow of 6.14 cubic feet per second. Base flow is defined as flow primarily from ground-water storage.

Beginning with the 1961 water year, streamflow records and related data have been released by the Geological Survey in annual reports on a State-boundary basis. Hydrologic conditions were first summarized in the 1962 water year report (*Surface Water Records of Kentucky*, USGS, 1962). This

report states "Runoff for the 1962 water year was excessive (in the upper 25 percent of record) over most of the State. During October and November streamflow was slightly below median. However, beginning in December flows were either excessive or well above median through April. During floods which began near the end of February and extended into March, record peak flows were established at several locations in the middle reaches of the Kentucky River and its tributaries, mainly the Red River; and in the Green and Barren River basins. Both March and April were excessive. May and August were dry months; runoff in the central and western parts of the State were deficient (in the lower 25 percent of record). June flows were above median. July and September were marked by wide ranges in runoff conditions. July was wet, or above median, in the eastern part of the State but was generally dry in other sections. September flows were below median in the eastern part of the State but well above median elsewhere in the State".

It was reported the following year (USGS, 1963) that "Runoff for the 1963 water year was below median over most of the State. During October and November streamflow was excessive, having near median flow in December. Streamflow was generally deficient for most parts during the months of January, February, April, and May. March flow was excessive due to major floods during the period March 11 - 14 which approached those of period of record at many gaging stations in southeastern Kentucky. New maximum discharges were established at five gaging stations [one of which was the Cumberland River at Harlan, 2.0 miles downstream from the confluence of Poor Fork and Martin's Fork]. June, July, and August flows were near median. September was dry and deficient in some parts. This month marked the start of a serious drought which lasted throughout the fall of 1963".

Under Hydrologic Conditions (USGS, 1964); "With the exception of March, runoff for the 1964 water year was, in general, below median over most of

the State. Drought conditions which started in July 1963 continued through February 1964...". Project field work terminated in January 1964.

EFFECTS OF WASHER WASTES ON WATER QUALITY

Unpolluted Section Water Quality Characteristics

The upper reach of Martin's Fork above the inflow of Turtle Creek was usually clean, clear, and relatively sterile (Tables 1 and 2). Although a state highway closely parallels the lower three-fourths of the stream, the headwaters are sparsely populated; littering here, compared to the lower reach, was practically non-existent. Turbidity was often completely absent and usually very low. Since the section was free from coal-washer wastes, the higher turbidity values recorded some months were caused by run-off from strip-mining operations. Total alkalinity ranged between 21 and 164 ppm at the 3 sampling stations during 1962-63, averaging about 26, 37, and 77 ppm annually, following the usual pattern of increasing downstream values. Specific conductivity was so low at the uppermost station each year that it failed to deflect the needle of the solubridge, whose scale began at 40 micromhos. Conductance values ranged as high as 480 micromhos in this section; however, the annual means at the other 2 stations averaged between 36 to 52 and 88 to 281 micromhos.

Sulfate values fluctuated from 10 to 190 ppm, averaging annually about 38, 82, and 128 ppm at the 3 stations. Dissolved oxygen was never found to be in short supply; in fact, dissolved oxygen readings tended to be rather high at all 3 stations each year, averaging between 7.1 and 8.5 ppm. The water in this section was somewhat acidic, the lowest pH value recorded being 4.1 and averaging less than 7.0 each year at each station. The other chemical characteristics that were monitored (ortho-phosphate, iron, and nitrate) showed such widely fluctuating values as to cast suspicion upon

Table 1. Chemical characteristics, in parts per million, of Martin's Fork water analyses made monthly (June through December) during 1962. Upper values are the maximum, middle values are the mean, and lower values are the minimum recorded at the various stations.

Station	-19.7	-8.2	-2.2	Turtle Creek	+0.1	+2.8	+3.8	+5.6	+7.8
	295	280	180	1300	110	450	600	675	510
Turbidity	63	81	95	438	68	149	217	208	171
	0	4	1	20	1	4	5	0	0
Total	28	48	116	287	150	123	123	116	143
alkalinity	27	39	71	185	83	88	91	89	106
	27	27	41	103	48	55	55	55	48
Specific	*	52	135	800	225	210	190	185	475
conductivity	*	52	88	625	143	195	185	183	352
(micromhos)	*	*	*	450	60	180	180	180	290
	80	100	190	550	400	300	190	190	225
Sulfate	40	83	127	386	160	158	140	135	149
	20	65	58	150	75	70	92	62	100
Dissolved	10.5	10.9	10.0	9.8	10.1	11.0	10.2	10.1	10.8
oxygen	8.2	8.1	7.1	8.0	8.1	8.6	8.0	8.0	8.9
	7.0	6.7	5.3	7.2	6.2	7.1	6.9	5.8	7.1
	6.5	7.0	7.2	7.5	7.6	7.3	7.4	7.5	7.6
pH	6.3	6.7	6.9	7.2	7.2	7.1	7.0	7.0	7.1
	6.1	6.3	6.5	6.6	7.0	6.8	6.9	6.4	6.4
Ortho-	3.0	1.0	2.5	8.0	2.3	2.2	4.1	1.7	2.5
phosphate	1.5	0.8	1.5	3.5	1.1	1.1	2.3	1.2	1.2
	0.2	0.3	0.5	1.3	0.6	0.4	1.0	0.6	0.4
	1.30	1.60	1.20	1.50	1.00	1.25	1.55	1.30	0.90
Iron	0.50	0.83	0.91	0.65	0.69	0.79	1.03	0.92	0.49
	0.15	0.50	0.42	0.20	0.48	0.50	0.48	0.60	0.22
	0.70	0.40	0.80	1.50	1.39	2.10	1.35	1.90	2.80
Nitrate	0.34	0.28	0.51	0.70	0.66	0.70	0.64	0.91	1.15
	0.10	0.05	0.27	0.05	0.10	0.20	0.17	0.05	0.45

* Value below scale (40 micromhos) on solubridge.

Table 2. Chemical characteristics, in parts per million, of Martin's Fork water analyses made monthly (except February and March) during 1963. Upper values are the maximum, middle values are the mean, and lower values are the minimum recorded at the various stations.

Station	-19.7	-8.2	-2.2	Turtle Creek	+0.1	+2.8	+3.8	+5.6	+7.8
	20	122	425	585	700	360	370	350	640
Turbidity	5	20	85	189	118	94	143	79	108
	0	2	0	15	10	8	8	15	2
Total	41	54	164	328	138	205	192	192	239
alkalinity	26	36	84	174	91	90	99	100	134
	21	27	34	96	48	41	55	55	75
Specific	*	205	480	950	575	600	550	575	710
conductivity	*	147	281	607	323	315	338	333	473
(micromhos)	*	87	120	400	130	150	150	100	210
	95	140	170	190	180	180	180	190	190
Sulfate	37	82	128	181	139	133	123	134	169
	10	40	71	160	90	75	65	67	110
Dissolved	11.6	10.8	11.8	9.7	11.4	9.6	11.8	11.5	11.4
oxygen	8.5	8.1	8.0	7.7	8.2	8.1	8.2	8.4	8.0
	7.1	6.7	5.9	6.4	6.4	6.5	6.7	7.2	6.2
	6.7	7.0	7.5	7.9	7.7	7.7	7.8	7.7	7.8
pH	6.1	6.4	6.8	7.3	7.1	7.1	7.2	7.2	7.3
	4.1	5.4	5.9	7.0	6.7	6.6	6.6	6.6	6.7
Ortho-	3.9	2.8	2.2	6.4	5.0	3.1	5.5	3.8	3.8
phosphate	1.6	1.3	1.4	3.0	2.1	1.7	2.3	1.9	1.8
	0.4	0.3	0.6	1.0	0.7	0.6	0.5	1.2	1.0
	0.42	1.10	0.88	0.78	1.00	1.10	1.25	0.98	0.81
Iron	0.23	0.49	0.50	0.45	0.60	0.60	0.67	0.63	0.36
	0.10	0.22	0.26	0.20	0.28	0.29	0.30	0.32	0.18
	0.80	0.55	3.70	2.10	1.12	2.10	1.10	0.90	0.85
Nitrate	0.30	0.31	1.02	0.29	0.70	0.75	0.57	0.47	0.40
	0.00	0.05	0.22	0.45	0.30	0.05	0.10	0.25	0.20

* Value below scale (40 micromhos) on solubridge.

their validity. They are, nonetheless, included in the water-quality tables along with the other determinations.

Turtle Creek Water Quality Characteristics

A more apt name for this stream would be "Turtle Ditch" or even "Turtle Sewer", because it usually resembled the image conjured up by one or the other of these derisive-but-true appellations. During periods of coal-washing operations at the coal mine located on this tributary to Martin's Fork, the water resembled India ink. Fortunately for the macro-invertebrates, the fish, and the biologists, coal washing was not done every day — in fact, no readily-recognized washing schedule was followed. However, the finely-divided coal (dust and "fines") overlaid the stream channel like a black blanket, waiting for a rise to flush it on into Martin's Fork. The extremely high turbidities encountered in Turtle Creek (and in Martin's Fork below this point) often interfered with water-quality analyses; even with appropriate dilutions of distilled water, erratic determinations were often suspected. Turbidity values ranged between 20 and 1300 ppm in 1962, averaging 438 ppm. In 1963 the range was 15 to 585 ppm, the average being 189 ppm. Practically all of the other chemical characteristics, except dissolved oxygen, exceeded the values found at all the sampling stations on Martin's Fork (Tables 1 and 2). Particularly high was the specific conductivity. The range was 450 to 800 micromhos in 1962, averaging 625; in 1963 the range was 400 to 950, averaging 607 micromhos.

Polluted Section Water Quality Characteristics

The first sampling station in this section was located 0.1 mile below the mouth of Turtle Creek. The next station was 2.8 miles below the mouth but above the second source of coal-washer wastes. The last 3 stations, in relation to the inflow of Turtle Creek, were 3.8, 5.6, and 7.8 miles downstream

and were subject to washer pollution from the second coal mine. Approximately 1.3 miles downstream from the last station, Martin's Fork and Poor Fork unite to become the Cumberland River. Washer wastes from the second mine were held in settling ponds that paralleled the stream bank. These ponds continually leaked their black water into Martin's Fork and -- for some strange reason -- the retaining dikes invariably broke through only when a combination of factors occurred: a rising river stage and a nearly-filled settling pool. Bulldozers quickly repaired the hole in the dike (after the pool had drained out completely) and the cycle began all over again.

While this section of Martin's Fork usually exhibited varying degrees of turbidity, caused not only by washer wastes but by silt and pollution from strip mining on the upper watershed as well, it did upon occasion run clear (Tables 1 and 2), and surprisingly, even when the water appeared to be an opaque, dirty gray-black, more light than supposed could and did penetrate it, as proven by the colorimetric values. The turbidity averaged between 68 and 217 ppm at the 5 stations in 1962. The following year the range was between 79 and 143 ppm. Total alkalinity in the section was fairly constant, especially in 1962 when the monthly means ranged between 83 and 106 ppm. Specific conductivity also showed a fairly constant monthly mean, except at the lowermost station which received slugs of raw sewage from the city of Harlan along the right bank and from the community of Georgetown along the left bank. Dissolved oxygen was always plentiful, even during periods of low summer flow. The pH averaged around neutral, to a few tenths above it.

EFFECTS OF WASHER WASTES ON BOTTOM FAUNA

The macro-invertebrate bottom fauna of Martin's Fork was moderately diverse in taxonomic composition but, typical of low-alkalinity mountain

streams, productivity was low. Nineteen major taxonomic categories of bottom-dwelling organisms were identified from the 431 square-foot riffle samples taken during 1961 - 1963. Annual mean productivity in the unpolluted section (derived from the examination of 161 bottom samples, collected at 3 stations, which contained nearly 8500 organisms having a total volume of 132 cubic centimeters) varied from 42 to 81 organisms per square foot and from 0.69 to 1.58 cc per square foot. Annual productivity in the polluted section (derived from the examination of 270 bottom samples, collected at 5 stations, which contained nearly 14,000 organisms having a total volume of 158 cubic centimeters) ranged from a low mean of 19 organisms at Sta. +3.8 (below the second coal washer) in 1962, to a high of 183 organisms at Sta. +2.8 (above the second coal washer). The lowest mean volume, 0.17 cc, was recorded at Sta. +7.8 in 1963; the highest mean volume was 4.26 cc at Sta. +7.8 in 1961. At this point, however, an explanation regarding the analysis and evaluation of the bottom sample data is in order.

Early in the field work while collecting and sorting bottom samples from the Green River phase of the project (Charles, 1964), and later in the laboratory while counting and determining the volume of the organisms, it became apparent that comparison of *total* productivity between the unpolluted and polluted sections of both Green River and Martin's Fork would be misleading, although basically correct. This situation stemmed from the fact that gastropods (snails) in the polluted section of Martin's Fork occurred in such abundance that their numbers, and particularly their bulk, obscured any effect that pollution may have been exerting on the other macro-invertebrates. Excepting larger decapods (crayfish), and pelecypods (mussels), practically all the other macro-invertebrates are equally available at any stage in their life cycles as forage for most all size-classes of fishes. This is not true of the snails and mussels, since many are too large for ingestion even by harvestable-size fishes, and to what extent the various fish species utilize smaller snails

and mussels is not well known. Fresh-water drum, which are known to utilize them, do not occur in the fish fauna of Martin's Fork, and the redhorses, which probably utilize them, are only a minor component of the population. To illustrate the disparity between total productivity (all macro-invertebrates included) and modified productivity (snails and mussels excluded), the mean total productivity of Sta. +5.6 (below both coal washers) in 1962 was 49 organisms and 2.15 cc, per square foot. Excluding the snails and mussels, these mean values became 27 organisms and 0.21 cc per square foot. Unless specifically stated otherwise, modified productivity values are used in this report, both in the text and in the tables. Also, all macro-invertebrate productivity values were computed and are reported on a per-square-foot basis.

Unpolluted Section Bottom Fauna

Productivity in the clean-water section varied from a mean of 81 organisms and 1.58 cc in 1961, to 42 organisms and 0.69 cc in 1962, to 57 organisms and 0.85 cc in 1963. The overall 3-year mean for the clean-water section was 52 organisms and 0.82 cc (Table 3).

Each year the same insect orders, Ephemeroptera (mayflies), Megaloptera (Corydalidae: helgrammites), Plecoptera (stoneflies), Trichoptera (caddisflies), Coleoptera (beetles), and Diptera (true flies), dominated the benthos by comprising 92-93% of all the organisms in the combined samples (Appendix: Table 1). Individually, the other 11 taxonomic groups (with the exception of Gastropoda) seldom comprised as much as 1% of the benthos. Mayfly nymphs predominated over all the other groups each year: 47 to 57% of all the macro-invertebrates belonged to this single order. True or two-winged fly larvae and pupae were most often the second most abundant group, accounting for 12 to 20% of all organisms collected. Caddisfly nymphs and adult and immature beetles alternated for third and fourth rank, ranging respectively between 6 and 16%, and between 7 and 11% of the sampled benthos. Stoneflies, by

accounting for 0.3 to 4% annually, ranked fifth in relative abundance. Dobson fly larvae (helgrammites) usually ranked sixth, fluctuating between 1.7 and 2.5% of the numerical total. As discussed previously, and as mentioned above, snails were the exception: they comprised from 0.5 to nearly 5% of the benthos each year.

Excepting Gastropoda and Pelecypoda, the top-ranking taxonomic groups in point of volume were Corydalidae, Decapoda, Ephemeroptera, and Trichoptera. Collectively, these groups accounted for never less than 59% nor more than 82% of the total volume each year (Appendix: Table 1). Helgrammites annually made up from 6 to 26% of the total bulk; crayfish made up from 15 to 58%; mayflies made up from 6 to 14%; and caddisflies made up from 4 to 6%. Individually, the other 11 groups seldom contributed as much as 3% to the total volume recorded from the clean-water samples.

The presence of a diverse bottom fauna existing in moderate abundance, both numerically and volumetrically, typified the normal macro-invertebrate complex to be expected in a stream of this type. Thus, the productivity values derived were considered to be a valid index against which the effects of intermittent coal-washer pollution could be measured.

Polluted Section Bottom Fauna

The annual mean productivity of macro-invertebrates within the polluted section fluctuated from 110 organisms and 1.97 cc in 1961, to 34 organisms and 0.56 cc in 1962, to 60 organisms and 0.56 cc in 1963 (Table 4). The overall 3-year mean for this section was 52 organisms and 0.59 cc, the same and about three-fourths, respectively, of the overall mean number and volume recorded from the clean-water section. Annual mean productivity at the individual stations is shown in the Appendix: Table 4.

The composition and relative abundance of the bottom fauna in the polluted section of Martin's Fork differed greatly from the fauna in the

Table 3. Mean annual productivity of macro-invertebrates* in the clean-water section of Martin's Fork, 1961 - 1963. Productivity was determined by sampling monthly (1962 and 1963) 3 square feet of riffle at 3 stations located upstream from coal-washer pollution.

Year	Sq. ft. sampled	Number of organisms	Volume (cc)	Mean number per sq. ft.	Mean volume per sq. ft.
1961	8	651	12.64	81	1.58
1962	63	2653	43.23	42	0.69
1963	90	5139	76.36	57	0.85
Total	161	8443	132.23		
Mean (all years combined)				52	0.82

* Gastropoda and Pelecypoda deleted.

Table 4. Mean annual productivity of macro-invertebrates* in the polluted section of Martin's Fork, 1961 - 1963. Productivity was determined by sampling monthly (1962 and 1963) 3 square feet of riffle at 5 stations located downstream from the 2 sources of coal-washer pollution.

Year	Sq. ft. sampled	Number of organisms	Volume (cc)	Mean number per sq. ft.	Mean volume per sq. ft.
1961	15	1645	29.50	110	1.97
1962	105	3532	59.03	34	0.56
1963	150	8765	69.52	60	0.56
Total	270	13,942	158.05		
Mean (all years combined)				52	0.59

* Gastropoda and Pelecypoda deleted.

unpolluted section. From 14 to 18 major taxonomic groups of macro-invertebrates were represented each year in this section (Appendix: Table 2). Relative abundance among the groups, expressed as a percentage of the total number and of the total volume, shifted from year to year. During 2 years of the 3-year period, dipteran larvae and pupae were the most abundant single group in the polluted section, accounting for 33% and 48% of the benthos. Since larval and pupal flies are so small, however, this group accounted for only 2% and 8% of the total volume those years. The only year in which oligochaetes (aquatic earthworms) were the most abundant organisms, they comprised 28% of the total number, but only 4% of the bulk. Mayflies were the next ranking in order of abundance. This group annually made up between 20 and 30% of the population, but only from 4 to 7% of the total volume. In 2 years of the 3, snails were the next most abundant macro-invertebrates, accounting for 14% and 20% of all organisms. Because of their dense shells they accounted for 46% and 52% of the total volume those same years. Caddisflies were relatively abundant in the polluted section only one year, when they comprised 23% of the population and 3% of the bulk. During each of the 3 years, between 88 and 93% of the bottom fauna in this section was accounted for by 4 taxonomic groups, although not the same 4 each year.

Turtle Creek Bottom Fauna

Productivity in this tributary to Martin's Fork averaged less each year than that at most of the polluted section stations, and much less than that of the clean-water section of Martin's Fork (Table 5). The overall 3-year mean was 64 organisms and 0.16 cc per square foot.

Based on the examination of only 3 square feet of riffle in 1961, Turtle Creek supported only 4 major taxonomic groups of macro-invertebrates (aquatic earthworms, sowbugs, crayfish, and two-winged fly larvae and pupae) at the rate of 7 organisms and 0.53 cc per square foot (Appendix: Table 3).

If the single crayfish recovered is deleted, the volumetric value becomes 0.03 cc.

The following year, when 21 square-foot samples were taken, 7 taxonomic groups were represented (new: nemas, mayflies, dobson flies, caddisflies, and beetles). Productivity averaged 50 organisms and 0.09 cc, with true flies being the most abundant (94%) group and also accounting for most (61%) of the volume in 1962.

The final year, 1963, 30 square feet of riffle were sampled. Ten taxonomic groups were recovered (new: snails and water mites) at a mean rate of 80 organisms and 0.17 cc. Dipterans again dominated the fauna of this tributary by comprising 91% of the population. The dense-shelled crayfish made up 37% of the total bulk.

Table 5. Mean annual productivity of macro-invertebrates* in Turtle Creek (uppermost of the 2 sources of coal-washer wastes to Martin's Fork), 1961 - 1963. Productivity was determined by sampling monthly (1962 and 1963) 3 square feet of riffle at a single station.

Year	Sq. ft. sampled	Number of organisms	Volume (cc)	Mean number per sq. ft.	Mean volume per sq. ft.
1961	3	20	1.60	7	0.53
1962	21	1058	1.91	50	0.09
1963	30	2386	4.96	80	0.17
Total	54	3464	8.47		
Mean (all years combined)				64	0.16

* Gastropoda and Pelecypoda deleted.

EFFECTS OF WASHER WASTES ON FISH FAUNA

The fish fauna of Martin's Fork is meager, compared to many other streams in Kentucky having more diverse types of habitat. While the checklist of fishes known to occur in the state comprises 26 families, 67 genera,

and 178 species, only 37 species representing 18 genera from 6 families were identified from the 1961 - 1963 Martin's Fork population studies. However, 1 of the 37 species was then and still remains unique, having never been found in the state before, and occurring only in Martin's Fork. Specimens of redeye bass, *Micropterus coosae* Hubbs and Bailey, were first collected on August 24, 1961 by project personnel spot-sampling with sodium cyanide. The location was 30.5 miles upstream from the mouth. Extensive spot-sampling in the Poor and Clover Forks of the Cumberland River failed to disclose the presence of redeye bass in these tributary headwater streams. Whether the redeye bass, restricted to the upper reaches of Martin's Fork, represents a relict population, or was stocked there by resourceful citizens, remains a moot question. Table 6 lists all the species collected from Martin's Fork and shows their occurrence either above or within the polluted section.

Unpolluted Section Fish Fauna

Thirty-one species of fishes, listed below, were identified from the 1961 spot-sampling and population studies conducted in the unpolluted section of Martin's Fork above the mouth of Turtle Creek. The 13 starred (*) species occurred exclusively in the unpolluted section and were not found in the polluted section that year.

Stoneroller	Northern hog sucker	Smallmouth bass
*Goldfish	Black redhorse	Spotted bass
Carp	*Black bullhead	*Largemouth bass
*Emerald shiner	Yellow bullhead	*Cumberland snubnose darter
Common shiner	Channel catfish	*Greenside darter
Rosyface shiner	*Flathead catfish	*Rainbow darter
Spotfin shiner	Rock bass	*Stripetail darter
*Mimic shiner	*Green sunfish	*Arrow darter
Bluntnose minnow	Bluegill	Blackside darter
Creek chub	Longear sunfish	
White sucker	*Redeye bass	

As often happens, fewer species were found in the clean-water section the following year, and the number of species occurring exclusively in that section, listed below, was also less than the year before.

Table 6. List of fishes collected from Martin's Fork of the Cumberland River, 1961 - 1963. This list comprises 6 families, 18 genera, and 37 species. Symbols denote occurrence above (-) the polluted section and in (+) the polluted section.

PETROMYZONTIDAE			
	+	*Lampetra* species	(Unidentified ammocetes)
CYPRINIDAE			
-	+	*Campostoma anomalum* (Rafinesque)	Stoneroller
-		*Carassius auratus* (Linnaeus)	Goldfish
-	+	*Cyprinus carpio* Linnaeus	Carp
-	+	*Ericymba buccata* Cope	Silverjaw minnow
-	+	*Notropis atherinoides* Rafinesque	Emerald shiner
-	+	*Notropis cornutus* (Mitchill)	Common shiner
-	+	*Notropis rubellus* (Agassiz)	Rosyface shiner
-	+	*Notropis spilopterus* (Cope)	Spotfin shiner
-	+	*Notropis volucellus* (Cope)	Mimic shiner
-	+	*Notropis whipplei* (Girard)	Steelcolor shiner
-	+	*Pimephales notatus* (Rafinesque)	Bluntnose minnow
	+	*Pimephales vigilax* (Baird and Girard)	Bullhead minnow
-	+	*Semotilus atromaculatus* (Mitchill)	Creek chub
CATOSTOMIDAE			
-	+	*Catostomus commersoni* (Lacepede)	White sucker
-	+	*Hypentelium nigricans* (LeSueur)	Northern hog sucker
-	+	*Moxostoma anisurum* (Rafinesque)	Silver redhorse
-	+	*Moxostoma duquesnei* (LeSueur)	Black redhorse
ICTALURIDAE			
-	+	*Ictalurus melas* (Rafinesque)	Black bullhead
-	+	*Ictalurus natalis* (LeSueur)	Yellow bullhead
-	+	*Ictalurus punctatus* (Rafinesque)	Channel catfish
-		*Pylodictis olivaris* (Rafinesque)	Flathead catfish
CENTRARCHIDAE			
-	+	*Ambloplites rupestris* (Rafinesque)	Rock bass
-	+	*Lepomis cyanellus* Rafinesque	Green sunfish
-	+	*Lepomis macrochirus* Rafinesque	Bluegill
-	+	*Lepomis megalotis* (Rafinesque)	Longear sunfish
* -		*Micropterus coosae* Hubbs and Bailey	Redeye bass
-	+	*Micropterus dolomieui* Lacepede	Smallmouth bass
-	+	*Micropterus punctulatus* (Rafinesque)	Spotted bass
-	+	*Micropterus salmoides* (Lacepede)	Largemouth bass
PERCIDAE			
-		*Etheostoma atripinne* (Jordan)	Cumberland snubnose darter
-	+	*Etheostoma blennioides* Rafinesque	Greenside darter
-	+	*Etheostoma caeruleum* Storer	Rainbow darter
-	+	*Etheostoma kennicotti* (Putnam)	Stripetail darter
-		*Etheostoma sagitta sagitta* (Jordan and Swain)	Arrow darter
	+	*Percina caprodes* (Rafinesque)	Logperch
-	+	*Percina maculata* (Girard)	Blackside darter

* A new species for the state: first collected on August 24, 1961, 30.5 miles upstream from mouth.

Goldfish	Flathead catfish	Cumberland snubnose darter
Emerald shiner	Largemouth bass	

The four previously-found species absent from the 1962 studies were carp, mimic shiner, redeye bass, and arrow darter. Since no spot-sampling with sodium cyanide was done in the headwaters of Martin's Fork that year, the latter two species were not to be expected since they are restricted to that area.

The number of species recovered from the unpolluted section during 1963 dropped to 25. Missing were:

Goldfish	Flathead catfish	Cumberland snubnose darter
Carp	Green sunfish	Stripetail darter
Black bullhead	Redeye bass	Arrow darter

However, three species were found there for the first time: silverjaw minnow, steelcolor shiner, and silver redhorse, while the number of species occurring exclusively in the unpolluted section fell to three: mimic shiner, greenside darter, and blackside darter.

The 1961 fish population composition and the average standing crop (biomass) values were determined by sampling 2.55 acres (2 areas: Stations -0.1 and -6.7). The clean-water section supported 332 fpa and 35 ppa (fishery topics require the repeated usage of "fish per acre" and "pounds per acre" — hence the abbreviations fpa and ppa for these terms). The A_t value (the percentage of the biomass comprised by harvestable-size fishes) was 48. These data are summarized in Table 7, which also shows that all fish groups in both the piscivorous and non-piscivorous categories were represented by all size-classes, except no fingerling food fishes and no predatory fishes of any size-class were recovered (species belonging to the predatory group do not occur in Martin's Fork).

The 1962 productivity values for the section were derived by sampling 1.87 acres at the same 2 locations used in 1961. The population that year

Table 7. Composition of the 1961 standing fish crop in the unpolluted section of Martin's Fork, determined by sampling 2.55 acres (2 areas) with rotenone.

GROUP	FINGERLING (per acre)		INTERMEDIATE (per acre)		HARVESTABLE (per acre)		TOTALS (per acre)		PERCENT OF POPULATION	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Weight
Game Fishes	6	tr.	11	1.8	2	3.2	19	5.1	5.7	14.6
Food Fishes	-	-	2	0.5	4	4.4	6	4.9	1.8	14.1
Predatory Fishes	-	-	-	-	-	-	-	-	-	-
Totals (Piscivorous)	6	tr.	13	2.3	7	7.7	25	10.0	7.5	28.7
Panfishes	12	0.1	86	3.6	5	0.9	102	4.6	30.9	13.2
Commercial Fishes	4	tr.	22	6.1	9	8.0	34	14.0	10.3	40.4
Forage Fishes	108	0.5	62	5.5	tr.	0.1	170	6.2	51.3	17.7
Totals (Non-Piscivosous)	123	0.6	170	15.1	14	9.0	306	24.8	92.5	71.3
GRAND TOTALS	129	0.7	182	17.4	20	16.7	332	34.8	100.0	100.0

Standing crop = 332 fish per acre; 35 pounds per acre. A_t = 48.0

averaged 672 fpa and 37 ppa, with an A_t value of 43. Missing from the population were fingerling- and intermediate-size food fishes and "harvestable"-size forage fishes (Table 8).

The 1963 productivity values were derived by sampling 2.00 acres at the same 2 locations used in 1961 and 1962. The population increased to 996 fpa and 53 ppa, with a lower A_t value of 25. All groups were represented by all size-classes (Table 9).

During the 3-year investigation the game fish group (smallmouth, spotted and largemouth bass) in the unpolluted section of Martin's Fork varied from 19 to 34 fpa, or from 3 to 6% of the population. Annually, the group fluctuated between 5.1 and 5.5 ppa, or from 10 to 15% of the standing crop. Game fishes accounted for 2 of the 20 harvestable-size fish per acre in the 1961 population. They accounted for 3 of the 23 in 1962, and for 5 of the 21 in 1963.

The food fishes (primarily channel catfish) comprised between 0.3 and 2% (2 - 6 fpa) of the population, and between 3 and 14% (1.5 - 4.9 ppa) of the biomass each year. From one to four harvestable-size catfish per acre were available in the clean-water section.

The panfish group (rock bass, bluegill, green and longear sunfish) was an important segment of the population. The panfishes comprised from 6 to 31% (55 - 102 fpa) of the population each year. Their contribution to the biomass ranged from 7 to 17% (3.6 - 6.2 ppa). Wider fluctuation was recorded in harvestable panfishes from year to year than in the same size-class of the other groups: the number per acre varied from 5 to 13.

The commercial fish group (suckers, redhorses, and bullheads) constituted between 10 and 16% (34 - 111 fpa) of the population, and between 40 and 50% (14 - 27 ppa) of the biomass. Harvestable fish of this group occurred at the rate of 5 to 9 per acre.

Table 8. Composition of the 1962 standing fish crop in the unpolluted section of Martin's Fork, determined by sampling 1.89 acres (2 areas) with rotenone.

GROUP	FINGERLING (per acre)		INTERMEDIATE (per acre)		HARVESTABLE (per acre)		TOTALS (per acre)		PERCENT OF POPULATION	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Weight
Game Fishes	15	0.2	15	2.1	3	3.1	34	5.4	5.0	14.4
Food Fishes	-	-	-	-	2	4.0	2	4.0	0.3	10.9
Predatory Fishes	-	-	-	-	-	-	-	-	-	-
Totals (Piscivorous)	15	0.2	15	2.1	5	7.1	36	9.4	5.3	25.3
Panfishes	3	tr.	65	2.8	13	3.4	82	6.2	12.1	16.6
Commercial Fishes	14	0.3	91	10.8	5	5.3	110	16.3	16.3	44.0
Forage Fishes	333	1.5	111	3.7	-	-	444	5.2	66.2	14.1
Totals (Non-Piscivorous)	350	1.8	267	17.3	18	8.7	636	27.7	94.6	74.7
GRAND TOTALS	365	2.0	282	19.4	23	15.8	672	37.1	100.0	100.0

Standing crop = 672 fish per acre; 37 pounds per acre. A_t = 42.6

Table 9. Composition of the 1963 standing fish crop in the unpolluted section of Martin's Fork, determined by sampling 2.00 acres (2 areas) with rotenone.

GROUP	FINGERLING (per acre)		INTERMEDIATE (per acre)		HARVESTABLE (per acre)		TOTALS (per acre)		PERCENT OF POPULATION	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Weight
Game Fishes	11	0.1	11	2.0	5	3.5	26	5.5	2.6	10.3
Food Fishes	2	tr.	1	0.1	1	1.4	3	1.5	0.3	2.8
Predatory Fishes	-	-	-	-	-	-	-	-	-	-
Totals (Piscivorous)	12	0.1	11	2.0	5	4.9	28	6.9	2.8	13.0
Panfishes	15	0.1	33	1.6	7	2.0	55	3.6	5.5	6.9
Commercial Fishes	34	0.7	70	19.8	8	6.0	111	26.5	11.2	49.8
Forage Fishes	520	2.9	281	12.9	2	0.4	802	16.1	80.5	30.3
Totals (Non-Piscivorous)	568	3.7	384	34.3	16	8.3	968	46.2	97.2	87.0
GRAND TOTALS	580	3.7	395	36.3	21	13.2	996	53.2	100.0	100.0

Standing crop = 996 fish per acre; 53 pounds per acre. A_t = 24.8

Fishes comprising the forage fish group (primarily shiners and darters) were more abundant each year than the combined population of all the other groups. Forage fishes never accounted for less than 51% (170 fpa) nor more than 81% (802 fpa) of the population. They contributed between 14 and 30% (5.2 - 16.1 ppa) to the annual biomass. Only 2 of the 802 forage fish per acre, recorded in 1963, were "harvestable" size (larger than optimum for utilization by piscivorous species).

Polluted Section Fish Fauna

The 19 species listed below were found in the 1961 population study conducted in Martin's Fork below the mouth of Turtle Creek. The only species which occurred exclusively in the polluted section that year was the silverjaw minnow.

Stoneroller	Creek chub	Bluegill
Carp	White sucker	Longear sunfish
Silverjaw minnow	Northern hog sucker	Smallmouth bass
Common shiner	Black redhorse	Spotted bass
Rosyface shiner	Yellow bullhead	Blackside darter
Spotfin shiner	Channel catfish	
Bluntnose minnow	Rock bass	

Population sampling was more extensive in the polluted section during 1962; the number of species occurring there rose to 25. The six species listed below were not recovered from that section the previous year. Three species (carp, silverjaw minnow, and mimic shiner) occurred exclusively in the polluted section in 1962.

Mimic shiner	Greenside darter
Black bullhead	Rainbow darter
Green sunfish	Stripetail darter

The number of species recorded from the polluted section rose to 28 during 1963. Five species were found there for the first time: *Lampetra* sp.(?), steelcolor shiner, bullhead minnow, silver redhorse, and logperch. The six species listed below occurred exclusively in the polluted section during 1963.

Lampetra sp.(?)	Black bullhead
Carp	Green sunfish
Bullhead minnow	Logperch

Fish population sampling in the polluted section during 1961 was restricted to only one 0.55-acre area (Station +4.3) in deference to a public relations situation caused by earlier extra-territorial fish kills. The pool sampled was supporting 513 fpa and 99 ppa, with an A_t value of 68. Several size-classes of the various fish groups were absent; no predatory fishes of any size-class were taken in this or subsequent studies in the polluted section (Table 10).

The 1962 productivity values were derived from sampling 1.98 acres (Stations +1.8, +4.3, and +4.5). The standing crop averaged 635 fpa and 62 ppa, with an A_t value of 58. All size-classes were represented except for "harvestable"-size forage fishes (Table 11).

The same areas used in 1962 were again sampled to obtain the 1963 productivity values, although the acreage covered (2.07) was slightly greater. All size-classes of all fish groups were represented at the rate of 835 fpa and 103 ppa. The A_t value was 44 in 1963 (Table 12).

Relative abundance of the game fish group in the polluted section (primarily spotted bass) during the 3-year study varied from 13 to 31 fpa, or from 3 to 4% of the population each year. Game fishes occurred at the rate of from 1.4 to 6.3 ppa, or from 1 to 6% of the annual biomass. No harvestable-size game fishes were recovered here in 1961; in 1962 the group accounted for 3 of the 42 fish per acre this size, and for 6 of the 44 per acre in 1963.

Channel catfish, the only member of the food fish group found in the polluted section, comprised each year between 4 and 15% (28 - 75 fpa) of the population, and between 31 and 58% (26 - 58 ppa) of the biomass. Most of the catfish occurring in this section were of harvestable size.

Table 10. Composition of the 1961 standing fish crop in the polluted section of Martin's Fork, determined by sampling 0.55 acre (1 area) with rotenone.

GROUP	FINGERLING (per acre)		INTERMEDIATE (per acre)		HARVESTABLE (per acre)		TOTALS (per acre)		PERCENT OF POPULATION	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Weight
Game Fishes	9	0.1	4	1.3	-	-	13	1.4	2.5	1.4
Food Fishes	-	-	4	0.3	71	57.7	75	58.0	14.5	58.3
Predatory Fishes	-	-	-	-	-	-	-	-	-	-
Totals (Piscivorous)	9	0.1	7	1.6	71	57.7	88	59.4	17.0	59.7
Panfishes	4	tr.	111	6.0	9	2.0	124	8.1	24.1	8.1
Commercial Fishes	9	0.1	42	15.1	11	8.2	62	23.4	12.1	23.5
Forage Fishes	156	0.4	84	8.3	-	-	240	8.7	46.8	8.7
Totals (Non-Piscivorous)	169	0.5	236	29.4	20	10.2	426	40.2	83.0	40.3
GRAND TOTALS	178	0.6	244	30.9	91	67.9	513	99.4	100.0	100.0

Standing crop = 513 fish per acre; 99 pounds per acre. A_t = 68.3

Table 11. Composition of the 1962 standing fish crop in the polluted section of Martin's Fork, determined by sampling 1.98 acres (3 areas) with rotenone.

GROUP	FINGERLING (per acre)		INTERMEDIATE (per acre)		HARVESTABLE (per acre)		TOTALS (per acre)		PERCENT OF POPULATION	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Weight
Game Fishes	11	0.2	14	1.7	3	2.0	27	3.9	4.3	6.4
Food Fishes	3	tr.	5	0.6	21	25.7	28	26.3	4.5	42.7
Predatory Fishes	-	-	-	-	-	-	-	-	-	-
Totals (Piscivorous)	14	0.2	19	2.3	24	27.7	55	30.2	8.8	49.1
Panfishes	6	tr.	36	1.8	12	3.8	54	5.7	8.4	9.2
Commercial Fishes	17	0.3	159	16.2	6	4.3	181	20.8	28.5	33.7
Forage Fishes	233	0.9	112	4.1	-	-	345	5.0	54.3	8.1
Totals (Non-Piscivorous)	256	1.2	307	22.1	18	8.1	580	31.5	91.2	51.0
GRAND TOTALS	270	1.4	326	24.4	42	35.8	635	61.7	100.0	100.0

Standing crop = 635 fish per acre; 62 pounds per acre. A_t = 58.0

Table 12. Composition of the 1963 standing fish crop in the polluted section of Martin's Fork, determined by sampling 2.07 acres (3 areas) with rotenone.

GROUP	FINGERLING (per acre)		INTERMEDIATE (per acre)		HARVESTABLE (per acre)		TOTALS (per acre)		PERCENT OF POPULATION	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Weight
Game Fishes	10	0.1	16	2.8	5	3.4	31	6.3	3.8	6.1
Food Fishes	4	tr.	9	0.8	17	30.7	30	31.6	3.6	30.6
Predatory Fishes	-	-	-	-	-	-	-	-	-	-
Totals (Piscivorous)	14	0.1	25	3.6	23	34.1	61	37.9	7.3	36.7
Panfishes	8	tr.	69	2.9	14	4.2	90	7.2	10.8	6.9
Commercial Fishes	43	0.5	178	39.7	5	7.0	226	47.2	27.0	45.6
Forage Fishes	284	1.9	173	8.9	1	0.3	458	11.1	54.8	10.8
Totals (Non-Piscivorous)	334	2.4	419	51.5	21	11.5	774	65.4	92.7	63.3
GRAND TOTALS	348	2.5	444	55.1	44	45.7	835	103.3	100.0	100.0

Standing crop = 835 fish per acre; 103 pounds per acre. A_t = 44.2

The panfish group was as abundant in this section as it was in the clean-water section. The panfishes annually comprised from 8 to 24% (54 - 124 fpa) of the population. Their contribution to the biomass ranged from 7 to 9% (5.7 - 8.1 ppa). The number of harvestable-size panfish per acre varied from 9 to 14.

The commercial fish group was relatively more abundant each year in this section than the food fish group, and in 1963 commercial fishes contributed considerably more weight to the biomass than did the food fishes. Productivity of the group measured from 12 to 29% (62 - 226 fpa) of the population and from 24 to 46% (21 - 47 ppa) of the biomass. Relatively few of the commercial fishes were of harvestable size: from 5 to 11 per acre each year.

The forage fishes were usually as abundant in the polluted section as members of all the other groups combined. From 47 to 55% (240 - 458 fpa) of the population, and from 8 to 11% (5 - 11 ppa) of the biomass each year belonged to this group. Nearly all the members of the group were small enough to be considered forage size.

DISCUSSION

Complicating Factors

Other variable factors, both natural and man-induced, besides intermittent washer wastes affected biological productivity in Martin's Fork. One of the more important ones was the significant differential in total alkalinity between the clean-water and polluted sections. The correlation between high alkalinity and high macro-invertebrate productivity is a well-established biological principle. Consequently, a much greater bottom fauna production rate was to be expected in the polluted section.

A pig farm was located adjacent to Sta. +0.1, the uppermost station in the polluted section. Some of the pigs were penned but most of a large

herd, as well as a large flock of ducks and geese, had access to the river itself. The resulting organic enrichment undoubtedly affected biological productivity downstream.

The effluent from a hospital's sewage treatment plant entered Martin's Fork above Sta. +5.6. Whenever overtaxed or broken down, the plant bypassed raw sewage directly into the stream. Exposure to the effluent a few times while collecting square-foot bottom samples prompted a hasty relocation of that particular station to a riffle above the hospital outfall. Channel catfish were particularly abundant in the pools sampled below this outfall.

During the years of this study, the city of Harlan on the right bank and the community of Georgetown on the left bank had no sewage treatment plants. Their raw sewage entered Martin's Fork above Sta. +7.8.

At one time or another between June 1961 and December 1963, nearly the entire 9.3 miles of stream channel, from the mouth of Turtle Creek to the confluence with Poor Fork, were bulldozed smooth to hasten flood water past the city of Harlan. This operation unquestionably affected the macroinvertebrate and fish faunas.

Weather conditions and resulting streamflow, while equally affecting all sections of Martin's Fork, ran the gamut of extremes during the life of the project. The March 1963 flood broke all previous records; older residents in the area claimed that Martin's Fork in the summer and fall of 1963, especially during October, was lower than they had ever seen it before. The combination of bulldozing and flood water served to flush the finely-divided coal on down the stream channel.

Conclusions

Intermittent coal-washer waste pollution in Martin's Fork had a greater effect on the viewer's aesthetic sensibility than it had on biological productivity. The key word here is "intermittent", because the data from Turtle

Creek, where low streamflow allowed the washer wastes to accumulate on the bottom, clearly indicate what would have happened to the bottom fauna in Martin's Fork if the pollution had been constant. It follows that, since macro-invertebrates are near the bottom of the food chain, the fish fauna would also have suffered.

Comparison of the fish populations in the clean-water and polluted sections showed them to be essentially the same, except for a vast preponderance of harvestable-size channel catfish in the polluted section. It could be inferred that channel catfish are tolerant to washer wastes, and/or they were able to forage in the often-dirty water since they are tactile feeders. I believe the abundance of these large catfish was due, either directly or indirectly, to the hospital sewage outfall that entered upstream from the pools they inhabited. I think they were feeding directly on the effluent or on the smaller fishes which were feeding on it.

SUMMARY

1. Intermittent coal-washer waste pollution has been and continues to be a chronic stream pollution problem in the coal-producing areas of Kentucky despite passage of "model" anti-pollution laws. The effects of coal-washer wastes — primarily coal dust and "fines" — on the water quality, macro-invertebrate bottom fauna, and fish fauna of a stream in Harlan County were determined and evaluated by a study that began in the summer of 1961 and continued through 1963.

2. Martin's Fork of the upper Cumberland River was intermittently polluted by washer wastes emanating from two coal mines three miles apart on the watershed. The uppermost source of pollution to this 40-mile mountain stream was via a tributary, Turtle Creek, that enters Martin's Fork from the east

9.3 miles from its confluence with Poor Fork. The settling ponds of the second mine were parallel and adjacent to the west bank of Martin's Fork.

3. The upper reach of Martin's Fork above the mouth of Turtle Creek was usually clean, clear, and relatively sterile. Turbid water in this section was caused by run-off from strip-mining operations.

4. Coal washing at the mine on Turtle Creek resulted in turbidity as high as 1300 ppm. The water in this tributary often resembled India ink. Practically all the other monitored chemical characteristics, except dissolved oxygen, exceeded the values found at all the sampling stations on Martin's Fork.

5. Turbidity at the five sampling stations on Martin's Fork below the mouth of Turtle Creek fluctuated widely, dependent upon coal-washing schedules. The range was 0 to 700 ppm, the average consistently higher than in the clean-water section, but less than in Turtle Creek because of dilution. The same held true for most of the other chemical characteristics in this section: values higher than in the clean-water section but lower than in Turtle Creek.

6. A moderately diverse macro-invertebrate bottom fauna was found in both the clean-water and polluted sections of Martin's Fork. Nineteen major taxonomic categories of bottom-dwelling organisms were identified from the 431 square-foot riffle samples taken during 1961 - 1963. This diversity of macro-invertebrate forms was not found in Turtle Creek.

7. Although the number of taxonomic forms found in the polluted section was greater than that found in the clean-water section, the quality of the bottom fauna as potential fish food was distinctly poorer in the polluted section. The quality in Turtle Creek was extremely poor.

8. Annual mean productivity in the clean-water section varied from 42 to 81 organisms per square foot and from 0.69 to 1.58 cubic centimeters per square foot. The overall 3-year mean was 52 organisms and 0.82 cc.

9. Annual mean productivity in the polluted section varied from 19 organisms (below the second coal washer) to 183 organisms (above the second coal washer) and from 0.17 cc to 4.26 cc (both volumes from below the second coal washer). The overall 3-year mean was 52 organisms and 0.59 cc, the same and about three-fourths, respectively, of the clean-water production rate.

10. Productivity in Turtle Creek averaged less each year than that at most of the polluted section stations, and much less than that of the clean-water section. The overall 3-year mean production rate was 64 organisms and 0.16 cc.

11. Population sampling showed that the fish fauna of Martin's Fork is meager, compared to many other streams in Kentucky having more diverse habitat types. Only 37 of the more than 178 species known to occur in the state were identified from the population studies. Specimens of redeye bass, *Micropterus coosae*, a species not known to occur in Kentucky, were found in the upper reaches of Martin's Fork.

12. The number of fish species occurring exclusively in the clean-water section each year varied from 3 to 13. The total number of species found there ranged between 25 and 31.

13. The polluted section each year contained between 19 and 25 species of fish. The number of species occurring exclusively in that section varied between 1 and 6.

14. The unpolluted section supported an average annual standing crop that ranged between 35 and 53 pounds per acre. Annually, the percentage of the

biomass comprised of harvestable-size fish (A_t value) varied between 25 and 48%.

15. The polluted section supported an average annual standing crop that ranged between 62 and 103 pounds per acre. The annual A_t value varied from 44 to 68. Harvestable-size channel catfish primarily, and intermediate-size suckers secondarily, were responsible for the greater standing crop and A_t values in the polluted section.

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APPENDIX

Figure 1

Tables 1 - 4

Figure 1. Kentucky's standard method for reporting fish population data.

SPECIES	FINGERLING SIZE			INTERMEDIATE SIZE			HARVESTABLE SIZE		
	Range	Number per acre	Pounds per acre	Range	Number per acre	Pounds per acre	Min. inch group	Number per acre	Pounds per acre
GAME FISHES									
Ohio muskellunge	0-4			5-23			24		
Chain pickerel	0-4			5-11			12		
Grass pickerel	0-4			5-9			10		
White bass	0-4			5-8			9		
Yellow bass	0-4			5-6			7		
Sauger	0-4			5-11			12		
Walleye	0-4			5-11			12		
Largemouth bass	0-4			5-9			10		
Smallmouth bass	0-4			5-9			10		
Spotted bass	0-4			5-9			10		
Black crappie	0-4			5-7			8		
White crappie	0-4			5-7			8		
TOTAL									
FOOD FISHES									
Blue catfish	0-4			5-9			10		
Channel catfish	0-4			5-9			10		
Flathead catfish	0-4			5-9			10		
TOTAL									

Figure 1. (continued)

SPECIES	FINGERLING SIZE			INTERMEDIATE SIZE			HARVESTABLE SIZE		
	Range	Number per acre	Pounds per acre	Range	Number per acre	Pounds per acre	Min. inch group	Number per acre	Pounds per acre
PREDATORY FISHES									
Skipjack herring	0-4			5-9			10		
Goldeye	0-4			5-9			10		
Mooneye	0-4			5-9			10		
Longnose gar	0-4			5-23			24		
Shortnose gar	0-4			5-23			24		
Spotted gar	0-4			5-23			24		
Bowfin	0-4			5-13			14		
American eel	-			8-15			16		
TOTAL									
PANFISHES									
Rock bass	0-2			3-5			6		
Bluegill	0-2			3-5			6		
Green sunfish	0-2			3-5			6		
Hybrid sunfish	0-2			3-5			6		
Longear sunfish	0-2			3-5			6		
Redear sunfish	0-2			3-5			6		
Warmouth	0-2			3-5			6		
TOTAL									

Figure 1. (continued)

SPECIES	FINGERLING SIZE			INTERMEDIATE SIZE			HARVESTABLE SIZE		
	Range	Number per acre	Pounds per acre	Range	Number per acre	Pounds per acre	Min. inch group	Number per acre	Pounds per acre
COMMERCIAL FISHES									
Sturgeons	0-7			8-23			24		
Paddlefish	0-7			8-23			24		
Buffalofishes	0-4			5-11			12		
Carpsuckers	0-4			5-11			12		
Hogsucker	0-4			5-11			12		
Redhorses	0-4			5-11			12		
White sucker	0-4			5-11			12		
Spotted sucker	0-4			5-11			12		
Carp	0-4			5-11			12		
Bullheads	0-4			5-8			9		
Drum	0-4			5-9			10		
TOTAL									

Figure 1. (continued)

SPECIES	FINGERLING SIZE			INTERMEDIATE SIZE			ABOVE FORAGE SIZE		
	Range	Number per acre	Pounds per acre	Range	Number per acre	Pounds per acre	Min. inch group	Number per acre	Pounds per acre
FORAGE FISHES									
Lampreys	0-3			4-7			8		
Gizzard shad	0-3			4-7			8		
Threadfin shad	0-3			4-7			8		
Shiners	0-3			4-7			8		
Misc. cyprinids	0-3			4-7			8		
Madtoms	0-3			4-7			8		
Topminnows	0-3			4-7			8		
Darters	0-3			4-7			8		
Orangespotted sunfish	0-3			4-7			8		
Brook silverside	0-3			4-7			8		
Sculpins	0-3			4-7			8		
TOTAL									
PISCIVOROUS TOTAL									
NON-PISCIVOROUS TOTAL									
GRAND TOTAL									

Table 1. Relative abundance of each major taxonomic group of macro-invertebrates occurring in riffle samples from Martin's Fork upstream from coal-washer pollution, 1961-63.

Year	1961		1962		1963	
Total number - volume	654 - 13.79		2788 - 63.68		5415 - 118.83	
Taxonomic group	Relative abundance (percentage of total number - total volume)					
Nemata (nemas)	1.8	tr.	0.1	tr.	tr.	tr.
Oligochaeta (earthworms)	2.9	3.1	0.7	0.4	0.4	0.1
Decapoda (crayfish)	0.9	58.2	0.4	14.7	0.4	22.8
Gastropoda (snails)	0.5	8.3	4.7	25.5	4.8	34.9
Pelecypoda (mussels)	-	-	0.1	6.7	0.3	0.8
Hydracarina (water mites)	0.2	tr.	0.1	tr.	0.3	tr.
Ephemeroptera (mayflies)	57.3	13.8	50.4	13.6	47.0	6.4
Odonata						
Anisoptera (dragonflies)	-	-	0.1	1.2	0.6	0.9
Zygoptera (damselflies)	0.2	0.6	0.3	0.1	0.5	0.1
Megaloptera						
Sialis (alderflies)	0.2	0.1	0.5	0.3	0.1	tr.
Corydalidae (dobson/fishflies)	1.7	6.5	2.5	26.0	2.5	25.3
Plecoptera (stoneflies)	0.3	0.4	4.0	1.0	4.2	0.7
Trichoptera (caddisflies)	6.1	3.7	12.7	6.2	15.8	4.0
Coleoptera (beetles)	8.1	3.5	6.6	1.8	11.2	1.6
Hemiptera (bugs)	-	-	tr.	tr.	-	-
Lepidoptera (caterpillars)	-	-	-	-	tr.	tr.
Diptera (true flies)	19.6	1.9	16.2	2.5	11.8	2.5
Unidentified	0.3	0.1	-	-	-	-

Table 2. Relative abundance of each major taxonomic group of macro-invertebrates occurring in riffle samples from Martin's Fork subjected to coal-washer pollution, 1961-63.

Year	1961		1962		1963	
Total number - volume	1907 - 54.39		4459 - 127.38		8964 - 84.53	
Taxonomic group	Relative abundance (percentage of total number - total volume)					
Turbellaria	-	-	tr.	tr.	-	-
Nemata	0.3	tr.	0.3	tr.	0.2	tr.
Oligochaeta	1.9	1.8	27.5	3.6	5.4	1.2
Hirundinae	-	-	tr.	tr.	-	-
Decapoda	0.4	39.0	0.4	22.0	0.2	39.5
Gastropoda	14.0	45.7	20.3	52.3	2.2	17.5
Pelecypoda	0.3	0.3	0.5	1.4	tr.	0.2
Hydracarina	0.4	tr.	0.3	tr.	0.9	tr.
Ephemeroptera	23.4	3.6	19.7	3.9	29.7	6.8
Odonata						
Anisoptera	-	-	0.2	0.5	0.1	0.3
Zygoptera	0.1	tr.	0.5	0.4	0.3	0.1
Megaloptera						
Sialis	tr.	tr.	0.2	0.3	tr.	tr.
Corydalidae	1.2	4.0	1.4	11.6	1.4	21.2
Plecoptera	tr.	tr.	1.1	0.2	2.3	0.7
Trichoptera	22.8	2.9	1.9	0.9	5.9	4.1
Coleoptera	2.5	0.6	5.0	1.0	2.9	0.4
Hemiptera	-	-	tr.	tr.	-	-
Diptera	32.7	2.1	20.6	2.0	48.4	7.8

Table 3. Relative abundance of each major taxonomic group of macro-invertebrates occurring in riffle samples from Turtle Creek, 1961-63.

Year	1961		1962		1963	
Total number - volume	20 - 1.60		1058 - 1.91		2453 - 5.73	
Taxonomic group	Relative abundance (percentage of total number - total volume)					
Nemata	-	-	0.1	tr.	tr.	tr.
Oligochaeta	10.0	tr.	3.4	7.3	1.3	1.9
Isopoda	15.0	3.1	-	-	-	-
Decapoda	5.0	93.8	-	-	tr.	36.7
Gastropoda	-	-	-	-	2.7	13.4
Hydracarina	-	-	-	-	0.4	tr.
Ephemeroptera	-	-	1.5	1.6	1.3	0.5
Odonata						
Anisoptera	-	-	-	-	tr.	0.9
Megaloptera						
Corydalidae	-	-	0.2	22.0	0.2	4.4
Trichoptera	-	-	0.4	2.1	2.9	11.2
Coleoptera	-	-	0.5	5.8	0.2	0.4
Diptera	70.0	3.1	94.0	61.3	90.9	30.7

Table 4. Mean annual productivity of macro-invertebrates* in the polluted section of Martin's Fork, 1961-63. Productivity was determined by sampling monthly 3 square feet of riffle at 5 stations located downstream from the 2 sources of coal-washer pollution (+ = miles below).

Year	Sq. ft. sampled	Number of organisms	Volume (cc)	Mean number per sq. ft.	Mean volume per sq. ft.
Station +0.1					
1962	21	558	9.33	27	0.44
1963	30	2081	7.67	69	0.26
Totals	51	2639	17.00		
Mean (all years combined)				52	0.33
Station +2.8					
1961	3	549	3.39	183	1.13
1962	21	593	27.43	28	1.31
1963	30	1438	31.11	48	1.04
Totals	54	2580	61.93		
Mean (all years combined)				48	1.15
Station +3.8 (downstream from second coal washer)					
1961	6	557	11.24	93	1.87
1962	21	404	10.57	19	0.50
1963	30	1641	11.59	55	0.39
Totals	57	2602	33.40		
Mean (all years combined)				46	0.59
Station +5.6					
1961	3	129	2.09	43	0.70
1962	21	563	4.45	27	0.21
1963	30	1390	14.16	46	0.47
Totals	54	2082	20.70		
Mean (all years combined)				39	0.38
Station +7.8					
1961	3	410	12.78	137	4.26
1962	21	1414	7.25	67	0.35
1963	30	2215	4.99	74	0.17
Totals	54	4039	25.02		
Mean (all years combined)				75	0.46

* Gastropoda and Pelecypoda deleted.