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Impacts of Channel Modification and Habitat Mitigation on the Fisheries at Poor Fork Cumberland River, Caney Creek, and Right Fork Beaver Creek

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ABSTRACT

This project documents the impacts of channelization on the fishery resource and attempts to quantify the effectiveness of those mitigation measures placed in the new channels in three steams in two different physiographic regions. Results are based on sampling of the fish standing crop, macroinvertebrate populations, and water quality of each stream. Mitigation measures were effective in replacing instream habitat that was lost during construction, but their effectiveness was dependent upon proper design and placement of the structures. Significant differences were documented in the total poundage of fish when channelized sections were compared to natural and mitigated sections. However, when natural sections and mitigated sections were compared, based on total poundage of fish, there was no trend. The use of flood by-pass channels to accomplish flood control objectives was effective but reduced flood flows through the old channel resulted in an excess amount of debris deposited. Diversity and equitability values for both fish and macroinvertebrates were highly variable for the three streams and exhibited no apparent trend. However, some recovery of macroinvertebrate populations was noted in the mitigated areas in one stream. Water quality parameters exhibited no trends except for dissolved oxygen in the natural areas of one stream, which were always depressed.

INTRODUCTION

Channelization, channel modification, and channel re-alignment have been used extensively throughout recent history for wetland drainage, flood control, agricultural development, highway construction, and urban development. Numerous studies have shown the detrimental impacts of channelization and have successfully quantified some of these impacts.

Some of the adverse impacts of channelization include:

(1) removal of natural diverse substrate
(2) increased sediment loads
(3) creation of shifting bedload
(4) elimination of shifting currents
(5) lowering and widening of stream channels and draining of adjacent wetlands
(6) reduces stability of banks and causes cave-ins of trees and other vegetation
(7) seasonal periods of reduced or no flow

Tarplee, Louder, and Weber (1971) concluded from a study of channelized North Carolina Coastal Plain streams that channelization resulted in higher stream temperatures, reduction of in-stream cover, reduction in fish production, loss of macroinvertebrate production, and reduced species diversity. Other authors have noted impacts to riparian vegetation and wildlife, water quality, and non-game species (Carothers and Johnson 1975; Bulky et al. 1976; Schoof 1980; and Simpson et al.1982).

The impacts associated with channelization can be long term, especially if the channel is maintained, but some systems have been found to recover in as few as 15 years if no further alteration occurs (Tarplee et al.1971). However, Bayless and Smith (1964) found no significant recovery of streams 40 years after channelization occurred and Golden and Twilley (1976) attributed depressed fish populations in the Big Muddy Creek watershed in Kentucky to channelization which had occurred 45 years prior.

In recent years, there have been attempts to replace in-stream habitat lost during channelization with artificial structures designed and placed specifically for the affected stream. The success of this has been varied and often depends on proper placement. In some cases, the structure was found to be detrimental to both invertebrate and fish populations (Simpson et al. 1982). In other cases, the use of artificial structures resulted in a shift from resident species to pioneer species (Simpson et al,1982). Woods and Griswold (1981) found that channelized sections of the Olentangy River in Ohio with mitigation features contained similar diversity and density of macrobenthic communities as the natural sections. However, both mitigated channels and natural sections were greater in macroinvertebrate diversity and density than unmitigated channel sections.

The purposes of this study were to:

(1) compare channelized sections with "improved channelized" sections and natural sections and to determine the relative degree of damage, if any, within each;
(2) compare channelized sections with natural sections that were skirted by floodways;
(3) determine the relative importance of the respective mitigation measures in providing fish and wildlife habitat in channelized streams; and,
(4) provide a basis for departmental recommendations concerning future utilization of stream improvement structures.

Three streams in different physiographic regions of Kentucky were selected for study to determine the effectiveness of mitigation measures. Those streams were Poor Fork Cumberland River (southeastern Kentucky), Caney Creek (western Kentucky), and Right Fork Beaver Creek (eastern Kentucky).

STUDY AREA

Poor Fork Cumberland River is an order IV stream (Kuehne 1963) located in the Eastern Coalfield Region of Kentucky (Harlan County). Poor Fork rises near the Kentucky-Virginia state line in southwestern Letcher County and flows southwest toward the city of Harlan where it joins with Clover Fork to form the Cumberland River (Figure 1). Average gradient of the stream is 11.16 ft/mile. The sport fishery of Poor Fork had been considered to be excellent until the 1950's when pollution from coal mining activities severely degraded the water quality (Carter and Jones 1969). However, with the passage of the 1977 Federal Surface Mining Act and the Commonwealth of Kentucky enacting its own mining regulations, water quality and the sport fishery have been improving at Poor Fork, which is reflected in the declining numbers of pollution reports received by the Department of Fish and Wildlife Resources. Table 1 contains the site descriptions and physical characteristics of the stream.

Construction began on the building of US 119 in the winter of 1974 and, concurrently, new sections of Poor Fork Cumberland River were also being constructed. The work was completed in sections until it was finished in the fall of 1978. As the new channel was being constructed, the mitigation features, consisting of artificial riffles, random boulders, and dumped stone deflectors, were also installed.

Caney Creek is an order IV stream located in the Western Coalfield Region of Kentucky (Grayson and Ohio counties). Caney Creek rises in central Grayson County and flows west into Ohio County, then northward until it merges with Rough River (Figure 2). Caney Creek, a fairly low gradient stream (1.62 ft/mile), was considered to be fair for sport fishing potential (Laflin 1980). The most significant sources of pollution in the watershed were non-point source from agricultural activities, which were considered to remain relatively constant throughout the course of the study. Table 1 contains the site descriptions and physical characteristics of the stream.

Channelization of Caney Creek began in the spring of 1971 at the mouth of the stream. Work proceeded upsteam to a point upstream of US 62 in Grayson County until it was completed in the spring of 1981. The sections containing the instream mitigation of artificial riffles and randomly placed boulders were the last sections to be completed.

Right Fork Beaver Creek is an order IV stream located in the eastern coalfield of Floyd and Knott counties. The stream begins in northern Knott County and flows north where it confluences with Left Fork Beaver Creek near Martin in Floyd County, Kentucky (Figure 3). Average gradient for the stream is 5.77 ft/mile. The sportfish potential for the stream was considered fair, with panfish dominating the creel (Evenhuis 1973). The major sources of pollution in the system have been a result of coal mining activities. Similar to Poor Fork, the problem with pollution has appeared to be reduced in recent years due to the passage of various federal and state laws, as evidenced by the reduced number of pollution reports received by the Department of Fish and Wildlife Resources. However, it was noted during the study that excessive sediment from upstream road construction activities was a major pollution problem in the watershed. Table 1 contains site descriptions and physical characteristics of the stream.

Construction on Right Fork Beaver Creek was similar to that of Poor Fork Cumberland River. Construction of Hwy. 80 and the new channel sections of the stream began near the mouth and proceeded upstream. The work was begun in the winter of 1978 and was completed in the summer of 1981. As with the other sections, the mitigation measures, consisting of artificial riffles, randomly placed boulders, gabion dams, and gabion deflectors, were placed in the appropriate sections as they were constructed.

METHODS

Sampling stations were established within natural areas, areas channelized without mitigation, and channelized areas with mitigation measures within each stream system. Four sampling sites were established on Poor Fork, three on Right Fork Beaver Creek and four on Caney Creek. A fifth station was later established on Caney Creek in 1981. Table 1 describes the sample sites. Sampling began in 1977 at Poor Fork and Caney Creek and in 1979 at Right Fork Beaver Creek; each stream was sampled for 5 years thereafter. Caney Creek was also sampled in 1982, 1984, and 1986.

Fish population standing crops were determined at each site through the use of a fish toxicant in a confined area. The length, average width, and depth of each sampling station were determined to calculate area and volume. Small-mesh block nets were stretched across the upper and lower limits of the study areas. Emulsifiable rotenone (5%) was utilized to collect the fish at an application rate of 1 mg/l. In order to prevent downstream fish kills, potassium permanganate was applied to the stream below the downstream block net to oxidize the rotenone as it passed from the sampling area. When all fish were collected, potassium permanganate was distributed throughout the area. Fish were collected with dip nets until no dead or stressed fish were observed. The fish were then identified, sorted into inch groups, and weighed to the nearest .01 lb.

The only station where a variance in this technique occurred was Station 1 at Caney Creek. Due to high levels of organic material and high water levels caused by downstream blockages, rotenone could not be used. A modified seining technique was utilized at this station. This technique involved the use of small meshed block nets which were set at the lower and upper limits of the sampling site and each end was pulled towards each other. This technique has been previously described by Davis et al. (1987).

Small specimens and those not readily identified at all stations were preserved in 10% formalin and later identified, sorted into length groups, and weighed to the nearest gram at the laboratory.

Data obtained were used to determine standing crop, species composition, and diversity indices at each sampling station. Diversity indices ($\bar{d}$) were calculated using the Lloyd, Zar and Karr (1968) machine formula of the Shannon-Weaver (1949) equation $d=c/n\ (N\log_{10} N - n_i \log_{10} n_i)$ where C=3.321928 (a constant), N is the total number of individuals and n_i is the total number of individuals in the ith species. Values less than 1.0 indicate degraded conditions, those from 1.0 to 3.0 indicate moderate degradation, and those greater than 3.0 indicate unpolluted conditions (Wilhm and Dorris 1968).

The diversity index ($\bar{d}$) lacks the sensitivity to demonstrate differences between slight to moderate degradation (Weber 1973). Lloyd and Ghelardi (1964) developed an equation which compares d with the type of distribution frequently observed in nature; that of few relatively abundant species and numerous species represented by only a few individuals. The formula $e=s'/s$ compares the number of species in a sample (s) with the number of species expected from natural communities (s') based on tabulated values of d. Equitability (e) has been found to be sensitive to slight levels of degradation and ranges from 0 for polluted conditions to 1 for clean water.

Benthic macroinvertebrates were collected at most sampling stations using a Surber stream sampler in riffles and an Eckman or Petite Ponar dredge in pools. The only variation was that riffle samples were not collected at Stations 1, 2, and 4 on Caney Creek. At least three samples were collected, and more if it was anticipated, at each station since Weber (1973) states that at least 100 individual are needed to confidently compute diversity indices and equitability values. Samples were preserved in 10% formalin and later sorted, identified to the lowest taxon possible, and counted. Data obtained were used to determine density per square foot, diversity indices, and equitability.

A Student's t-Test, outlined by Zarr (1974), was utilized to determine significance of difference between fish standing crop data.

RESULTS

Summarized fish standing crop data for all three studies are presented in Tables 2, 6, and 10. Standing crop values ranged from 47.62 to 218.43 lb/acre in Poor Fork, 3.90 to 270.05 lb/acre in Caney Creek and 4.62 to 68.69 lb/acre in Right Fork Beaver Creek.

Significant differences were observed between fish standing crops in the non-mitigated channelized sections and natural sites of Caney Creek ($P<0.001$) and Right Fork Beaver Creek ($0.02<P<0.01$). The fish standing crops at the mitigated channelized sites were not statistically different from the natural sites at Poor Fork ($0.50<P<0.20$), Caney Creek, and Right Fork Beaver Creek ($0.10<P<0.05$). However, there was no significant difference between fish standing crops in the mitigated channel sites and the channelized sites in Caney Creek and Right Fork Beaver Creek ($0.50<P<0.20$).

Diversity and equitability values for fish standing crops for all three streams are presented in Tables 3, 7, and 11. Although no notable difference for those values existed between the types of sites, the fish assemblage was different in the non-mitigated channelized areas from the natural areas. At Caney Creek, these degraded sites were composed of predatory fish such as longnose gar and an abundance of forage fish such as gizzard shad. In some years these fish comprised as much as 40% of the entire sample, which was not typical of natural sections. In almost all samples, the fish standing crops of all groups of fish were greater in the natural sections of Right Fork Beaver Creek than what was found in the channelized sections. In Poor Fork there was little difference between the natural sections and the mitigated channelized section, except that commercial fishes (i.e. carp) were generally greater in the mitigated sections.

Diversity, equitability, and density values for benthic macroinvertebrates for all three streams are presented in Tables 4, 8, and 12. As with the fish standing crops, no notable trends were evident. Some minor increases in value are indicated in all three studies, but the difference is slight and may be a result of small sample size.

Water quality data for all three streams similarly failed to differentiate the three areas (Tables 5, 9, and 13). The only trend evident is the continued degradation of dissolved oxygen values at the natural sites at Caney Creek. Dissolved oxygen values ranged from 1.6 to 6.0 mg/l in the natural sites and 5.2 to 11.5 mg/l in the channelized areas. Dissolved oxygen levels were significantly lower at the natural sections when compared to the channelized sections ($P<0.0001$).

DISCUSSION

Findings from this report compares favorably to that reported by Bayless and Smith (1964), Tarplee et al. (1971) and Simpson et al. (1982), in which channelization has an extremely detrimental impact on fish populations by the habitat destruction for many fish species. In all three study streams, there was virtually no instream habitat in channelized sections without mitigation. Channelized Site 1 in Caney Creek was modified from a lotic to a lentic environment due to downstream log jams that reduced water flow. This flow reduction resulted in a slight change to fish species that inhabit slower moving waters.

Placement of mitigation measures such as artificial riffles, gabion deflectors, gabion dams, and randomly spaced boulders replaced some of the habitat that was lost during construction. The placement of these structures helped to create microhabitats, which is important for a significant fishery to re-establish. The physical presence of these structures also increased habitat by the deflection of stream flow.

Woody debris was conspicuously absent from channelized sections. Angermeir and Karr (1982) documented that wood debris provides diverse habitat for fish residence (especially for large fish) and attachment for aquatic macroinvertebrates. The absence of this material resulted in the loss of large piscivorous fish and a decrease in surface area available for the production of macroinvertebrates. The lack of this type of habitat could explain why the mitigated channelized sites usually approached but seldom equaled the fish standing crops of natural sections.

The design and placement of those mitigative structures is equally important as their presence. Bulkley et al. (1976) reported the placement of instream structure is critical because improper construction may result in other damages to the fishery from things such as bank sloughing. The authors noted that while mitigation measures were working as planned at all study sites, there were some features in other sections not studied in Right Fork Beaver Creek that were not functioning. Some riffles were functioning as dams while some were inundated by several feet of water, thus providing very little benefit for the species they were intended to impact.

The mitigation features at all study sites were functioning as planned and were beneficial to the fishery resources. The standing crops of fish in the mitigated sections compared favorably with the natural sections. In Poor Fork, the standing crop of fishes in the mitigated channelized sections generally equaled or exceeded the standing crop in the natural sites. However, at Caney Creek and Right Fork Beaver Creek, the mitigated channelized sections (Stations 5 and 2, respectively) did not equal those in the natural sites but they were statistically similar ($0.10<P<0.05$ for both streams).

Diversity and equitability values for fish standing crops were highly variable for all three study streams. The values indicated a slight degradation in the environment, but there was no discernible difference between the natural, mitigated channelized, and channelized sites. This inconsistency was apparently due to the insensitivity of the equitability test or infrequent sampling.

The diversity, equitability, and density values for benthic macroinvertebrates at all three streams were also highly variable and did not exhibit any particular trends. It was noted that diversity and equitability values for riffle areas in the mitigated sections of Poor Fork were low at the beginning of the study and improved as the study progressed. At the conclusion of the 5 year study, the values between mitigated and natural sections were similar, which indicated a recovery in the mitigated sections. Contrarily, the diversity and equatability values for the pool sections of the mitigated sites of Poor Fork remained low throughout the study. This is probably a result of favorable habitat not developing in these areas due to an increase in velocities through the new sections (Angermeir and Karr 1982). The lack of sediment and woody debris in these sections prevents invertebrates from burrowing or attaching themselves.

The diversity, equitability, and density values for Caney Creek and Right Fork Beaver Creek demonstrate no apparent trends. There does appear to be some recovery in these values in the channelized areas but the change, if any, is slight. A possible reason for this lack of definitive information is that, frequently, only a few organisms were sampled at each site. Weber (1973) stated that it is necessary to sample at least 100 organisms per site or any equitability analysis would be doubtful. Therefore, since fewer than 100 organisms per site were frequently collected, a large variability of the data could be possible.

Water quality data at the three streams did not exhibit any trends except for dissolved oxygen levels at Caney Creek. The natural sections, which were by-passed by a high flow diversion channel, had more log jams than the other sections which resulted in slow stream flows. The cause for these log jams could be a result of reduced flood flows which tends to scour channels and remove these jams. It is hypothesized that the slower water allowed for a greater accumulation of organic material and increased the oxygen demand.

The deleterious effects of channelization have not been offset in these study streams; recovery was facilitated by the placement of instream mitigation structures. This compares favorably to that found by Bulkley et al. (1976) and Simpson et al. (1982) who both found that recovery of channelized streams can be facilitated by the placement of mitigation structures.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions that can be extracted from this report are:

(1) channelization reduces fish populations through the reduction of instream habitat;

(2) mitigation measures such as artificial riffles, gabion deflectors, gabion dams, and randomly placed boulders are effective in replacing lost habitat and improving the production and survival of fish and macroinvertebrates;

(3) the effectiveness of mitigation structures is dependent upon the proper design and construction of those structures;

(4) flood control benefits can be accomplished by the construction of floodways that carry only flood water, while normal flows are maintained through natural stream channels, without impacting the local aquatic resources. It is also important not to reduce flows below the flushing capacity of log jams in low gradient habitats.

The following recommendations have been proposed for review guidelines for future channelization projects:

(1) Oppose the use of channelization unless no other alternative can be found to accomplish proposed project goals and no significant resources (i.e. sport fishery, production area, or rare or endangered species) are present.

(2) Whenever a stream is to be channelized, instream habitat should be replaced utilizing artificial riffles, gabion or dumped stone deflectors gabion dams, randomly placed boulders, or other types of structures. The type and amount of structure placed should be similar to that lost. Riffles should be replaced that replicate the pool/riffle ratio prior to channelization.

(3) Channel morphology of the new sections should be similar to the old sections.

(4) Mitigation features should be monitored for at least 3 years after construction by the construction agency to ensure the habitat structure is functioning as planned. If structure is not adequate, then correctional measures should be made.

(5) Riparian zone vegetation should be replaced to provide shade to reduce water temperatures and provide future woody debris as instream habitat.

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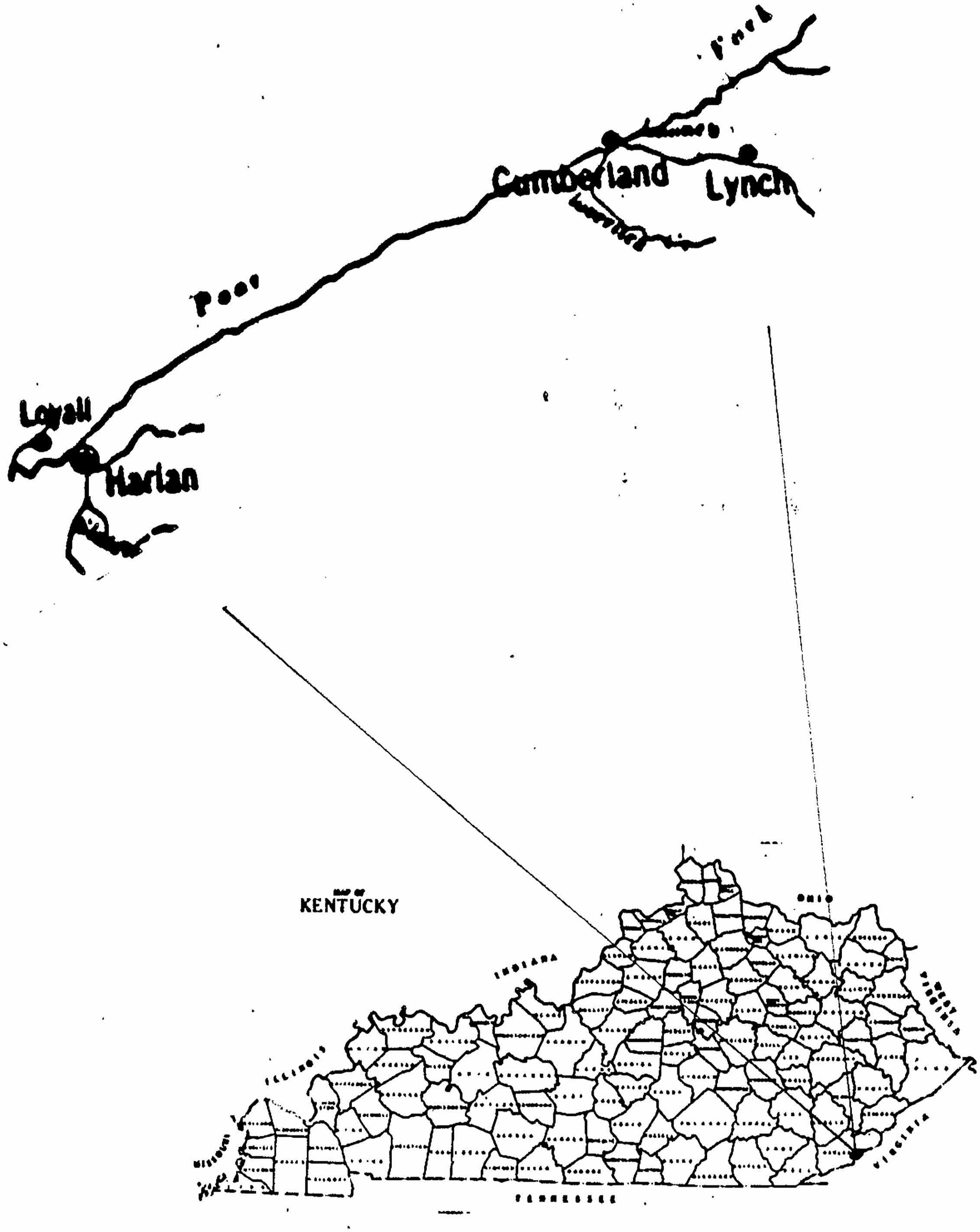

Figure 1. Locality map for Poor Fork Cumberland River, Harlan County, Kentucky.

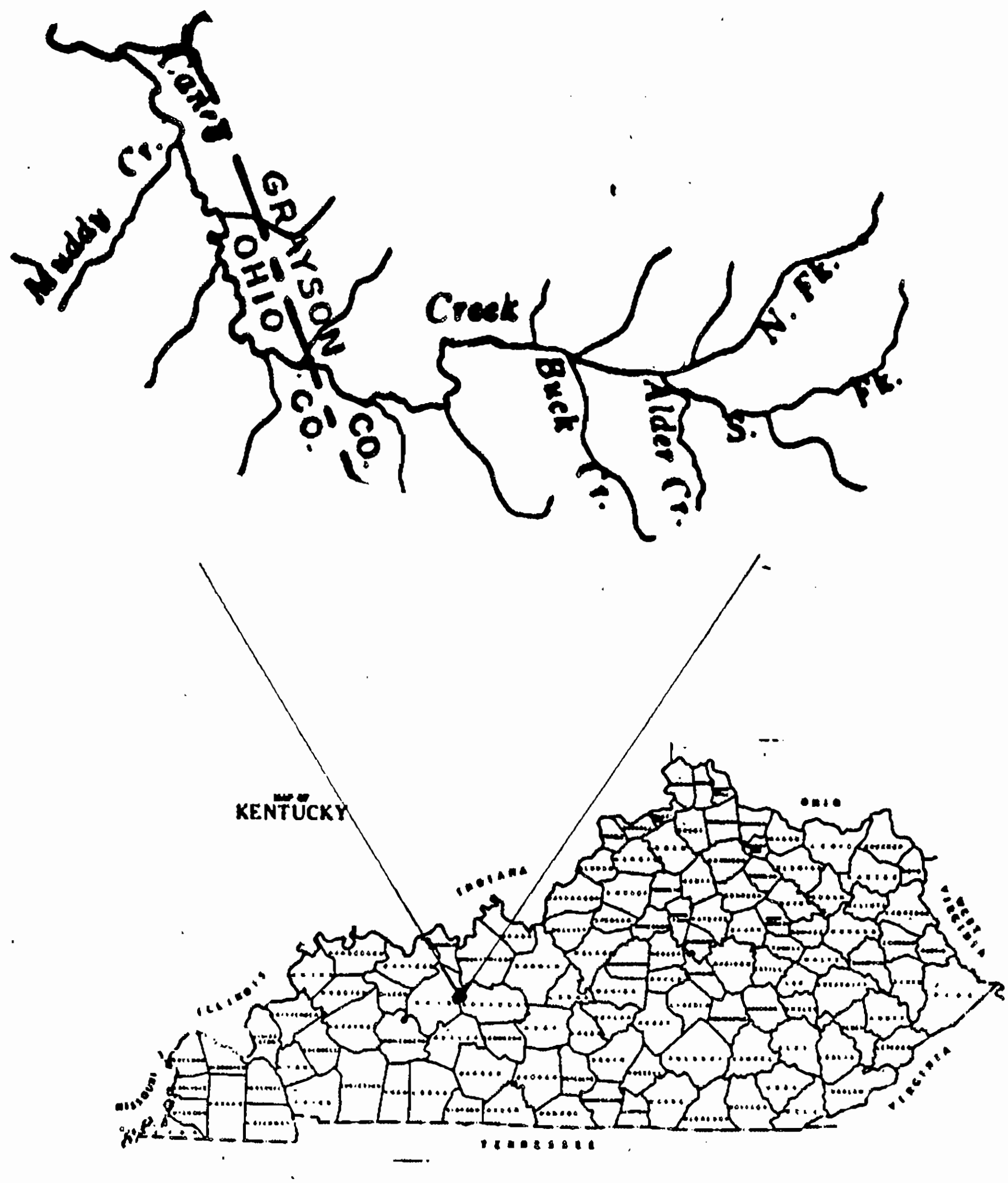

Figure 2. Locality map for Caney Creek, Grayson and Ohio counties, Kentucky.

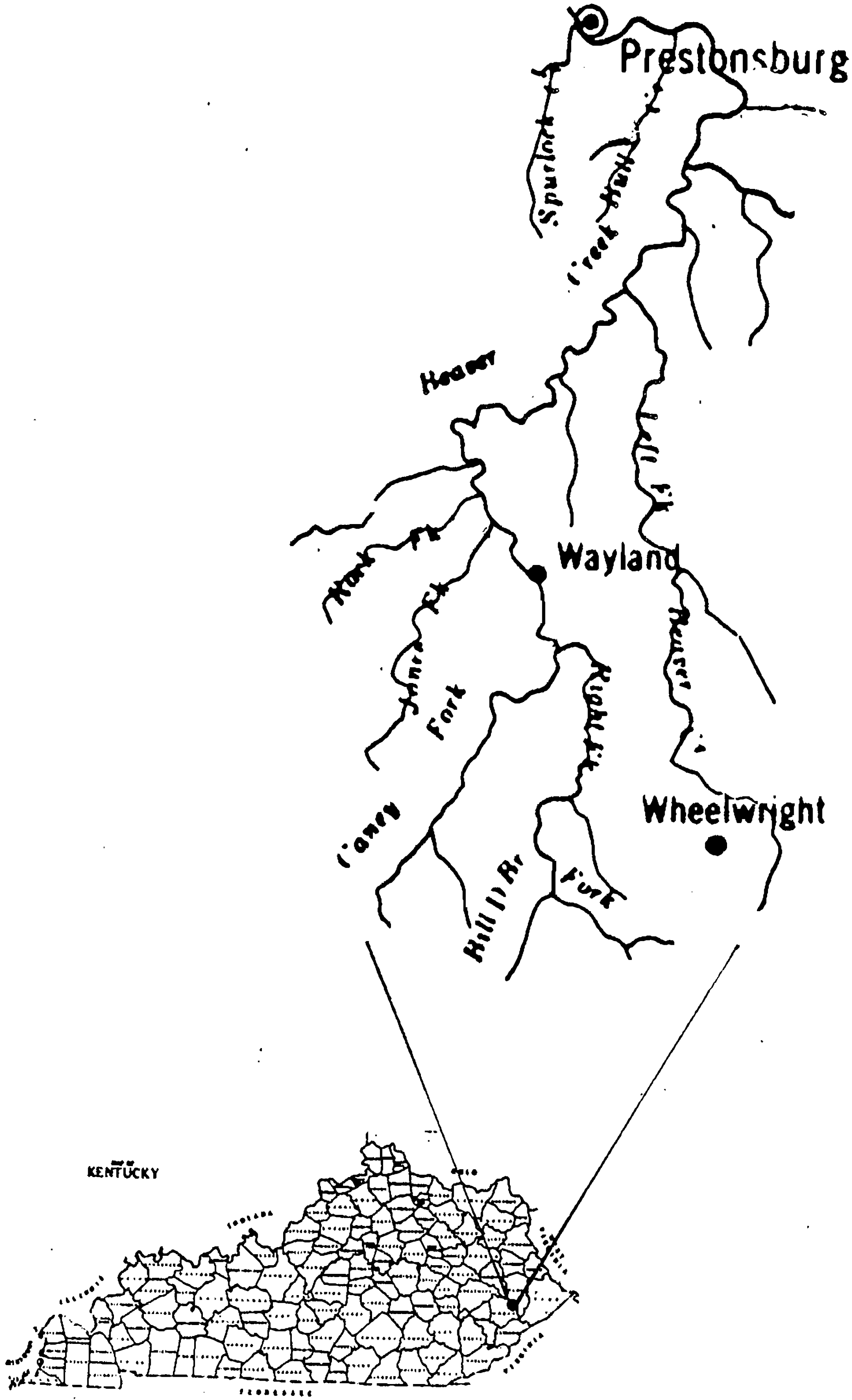

Figure 3. Locality map for Right Fork Beaver Creek, Floyd County, Kentucky.

Table 1. Locality and site description information for sampling stations on Poor Fork Cumberland River, Caney Creek, and Right Fork Beaver Creek.

STATION & LOCATION	COUNTY	CONDITION	AV.WIDTH (ft)	AV.DEPTH (ft)	AV.LENGTH (ft)
POOR FORK					
1 AT MOUTH OF LAKEY BRANCH	HARLAN	CHANNELIZED WITH ARTIFICAL RIFFLES, GABION DEFLECTORS AND RANDOMLY PLACED BOULDERS	55.26	1.20	348.25
2 AT MOUTH OF STATION BRANCH	HARLAN	NATURAL	74.23	1.26	456.33
3 2000 FEET UPSTREAM OF CLOVER BRANCH	HARLAN	SAME AS STATION 1	79.6	1.24	380.00
4 1000 FEET DOWNSTREAM OF ALECS BRANCH	HARLAN	NATURAL	48.1	1.28	391.17
CANEY CREEK					
1 2000 FEET DOWNSTREAM OF HWY. 62 BRIDGE	OHIO	CHANNELIZED, IMPOUNDED AND NO MITIGATION	91.85	2.46	250.00
2 200 FEET BELOW McGRADY CREEK ROAD	OHIO	NATURAL	33.54	1.51	264.00
3 AT MOUTH OF McGRADY CREEK	OHIO	NATURAL	24.94	1.15	260.00
4 1000 FEET UPSTREAM OF HWY. 878 BRIDGE	OHIO	CHANNELIZED, NO MITIGATION	39.60	0.57	300.00

5 1 MILE ABOVE MOUTH OF COW CREEK	OHIO	CHANNELIZED WITH ARTIFICIAL RIFFLES AND RANDOMLY PLACED BOULDERS	85.50	1.24	200.00
RIGHT FORK BEAVER CREEK					
1 0.75 MILE ABOVE MOUTH OF GOOSE CREEK	FLOYD	NATURAL	30.06	0.96	217.40
2 JUST DOWNSTREAM OF HENRYS BRANCH	FLOYD	CHANNELIZED WITH ARTIFICIAL RIFFLES, RANDOMLY PLACED BOULDERS AND GABION DAM	46.16	1.39	313.00
3 JUST UPSTREAM OF WARCO	FLOYD	CHANNELIZED WITH NO MITIGATION	37.80	1.06	436.40

Table 2. Summarized values of fish standing crops and total species from 1977 through 1981* at stations in Poor Fork Cumberland River, Harlan County, Kentucky

STANDING CROP (lb/acre)	SAMPLING STATION 1(C)	2(N)	3(C)	4(N)
GAME FISHES				
1977	6.24	7.04	7.78	3.42
1978	ND*	ND	ND	ND
1979	0.19	trace	ND	ND
1980	11.58	6.00	14.85	11.90
1981	0.85	2.93	3.73	6.13
AVERAGE	4.71	3.99	8.79	7.15
FOOD FISHES				
1977	34.07	16.45	6.37	39.86
1978	ND	ND	ND	ND
1979	-	-	ND	ND
1980	21.16	21.23	3.08	107.71
1981	8.79	3.89	11.25	4.56
AVERAGE	16.01	10.39	6.90	50.71
PANFISHES				
1977	1.34	1.17	4.41	3.17
1978	ND	ND	ND	ND
1979	-	-	ND	ND
1980	6.02	1.88	5.88	7.37
1981	1.05	3.18	2.40	4.05
AVERAGE	2.10	1.56	4.23	4.86
COMMERCIAL FISHES				
1977	88.80	17.49	59.38	13.19
1978	-	-	-	-
1979	3.01	0.14	ND	ND
1980	59.80	26.58	41.05	74.72
1981	49.76	24.41	68.16	27.06
AVERAGE	50.35	17.16	56.20	38.33
FORAGE FISHES				
1977	21.86	5.47	3.88	9.25
1978	-	-	-	-
1979	8.21	2.35	ND	ND
1980	51.01	16.11	33.99	16.73
1981	30.33	13.55	21.68	34.99
AVERAGE	27.86	9.37	19.85	20.32
TOTAL				
1977	152.31	47.62	81.82	68.89
1978	-	-	-	-
1979	11.41	2.89	ND	ND

1980	149.57	71.80	98.85	218.43
1981	90.78	47.96	107.22	76.89
AVERAGE	101.02	42.47	95.97	121.40
TOTAL SPECIES COLLECTED				
1977	20	25	21	24
1978	ND	ND	ND	ND
1979	11	12	ND	ND
1980	23	23	23	24
1981	25	23	23	24
AVERAGE	20	21	22	24

* No stations were sampled in 1978 and Stations 3 and 4 were not sampled in 1979 due to low water temperatures.
Fish populations were not determined(ND)
C-Channelized with mitigation
N-Natural

Table 3. Diversity index ($\bar{d}$) and equitability (e) values for fish standing crops collected from 1977 through 1981 at stations on Poor Fork Cumberland River, Harlan County, Kentucky. Fish were not sampled in 1978 or at Stations 3 and 4 in 1979; the d and e values were not determined at Stations 1 and 2 in 1979.

SAMPLE STATION	1977	1980	1981
1(CHANNELIZED)			
$\bar{d}$	3.26	3.28	2.61
e	0.70	0.61	0.32
2(NATURAL)			
$\bar{d}$	3.40	2.26	2.40
e	0.60	0.26	0.30
3(CHANNELIZED)			
$\bar{d}$	3.82	2.30	2.91
e	1.00	0.30	0.48
4(NATURAL)			
$\bar{d}$	3.41	2.37	2.66
e	0.60	0.29	0.38

Table 4. Diversity index ($\bar{d}$), equitability (e) and density (#/ft2) values for benthic macroinvertebrates collected from 1977 through 1981 at station on Poor Fork Cumberland River, Harlan County, Kentucky.

SAMPLE STATION	RIFFLE $\bar{d}$	RIFFLE e	RIFFLE #/ft2	POOL $\bar{d}$	POOL e	POOL #/ft2
1(CHANNELIZED)						
1977	1.06	0.62	297.00	2.40	0.54	457.00
1978	2.19	0.55	36.65	0.18	0.20	152.16
1979	2.50	0.55	36.65	1.17	0.50	22.10
1980	2.32	.033	29.25	0.91	0.22	229.00
1981	3.25	0.87	29.25	1.05	0.18	149.33
2(NATURAL)						
1977	1.78	0.40	77.00	1.39	0.54	83.00
1978	2.14	0.43	58.66	1.14	0.75	23.35
1979	2.17	1.20	3.75	3.41	0.27	32.00
1980	1.81	0.31	218.00	0.97	0.40	247.43
1980	3.18	0.81	17.00	1.31	0.33	63.11
3(CHANNELIZED)						
1977	0.59	0.25	142.00	0.27	0.26	122.00
1978	1.53	0.50	26.62	0.75	0.25	41.78
1979	1.99	0.50	17.75	0.24	0.65	35.57
1980	1.99	0.50	17.75	0.24	0.65	408.50
1981	2.31	0.70	26.50	0.40	0.13	303.55
4(NATURAL)						
1977	2.35	0.80	24.00	1.37	0.60	145.00
1978	2.52	0.73	95.66	1.13	0.23	81.28
1979	2.62	1.14	5.00	0.85	0.29	49.02
1980	2.41	0.44	92.00	1.00	.033	188.00
1981	1.84	0.63	0.31	1.70	0.31	169.33

Table 5. Water quality parameters measured from 1977 through 1981 at stations on Poor Fork Cumberland River, Harlan County, Kentucky.

SAMPLE STATION	WATER TEMP. (°C)	DISSOLVED OXYGEN (mg/l)	pH	ALKALINITY (mg/l)	TOTAL HARDNESS (mg/l)	TURBIDTIY (FTU)
1(CHANNELIZED)						
1977	24.5	9.0	8.3	ND*	ND	ND
1978	15.0	12.6	ND	ND	ND	ND
1979	19.4	ND	ND	ND	ND	ND
1980	24.0	7.7	8.2	210	100	19
1981	21.0	8.6	7.4	90	95	43
2(NATURAL)						
1977	25.0	9.8	8.5	ND	ND	ND
1978	15.0	13.2	ND	ND	ND	ND
1979	20.0	ND	ND	ND	ND	ND
1980	25.0	8.7	8.3	190	100	40
1981	25.0	8.8	7.8	105	95	61
3(CHANNELIZED)						
1977	25.0	10.9	8.3	ND	ND	ND
1978	15.0	13.5	ND	ND	ND	ND
1979	ND	ND	ND	ND	ND	ND
1980	27.0	10.5	8.3	200	100	15
1981	23.0	8.4	7.9	115	105	30
4(NATURAL)						
1977	23.0	10.4	8.2	ND	ND	ND
1978	15.0	13.4	ND	ND	ND	ND
1979	ND	ND	ND	ND	ND	ND
1980	29.0	11.2	8.5	200	100	21
1981	23.0	8.5	7.5	105	105	60

* Not determined

Table 6. Summerized values for fish standing crops and total species from 1977 through 1986* at stations on Caney Creek, Ohio County, Kentucky

STANDING CROP (lb/acre)	SAMPLING STATION 1(C)	2(N)	3(N)	4(C)	5(MC)
GAMEFISHES					
1977	14.57	10.70	7.26	8.41	ND
1978	11.65	10.70	0.60	5.57	ND
1979	5.77	4.81	14.35	0.26	ND
1980	4.43	7.46	1.41	0.18	ND
1981	1.94	16.99	34.83	0.02	2.67
1982	3.43	6.45	7.87	0.09	2.26
1984	6.09	4.87	9.09	4.32	3.81
1986	1.41	11.33	13.03	0.09	6.98
AVERAGE	6.16	9.16	11.05	2.36	3.93
FOOD FISHES					
1977	-	2.11	5.34	4.06	ND
1978	3.67	-	13.92	9.90	ND
1979	1.44	-	28.68	trace	ND
1980	0.09	1.22	31.08	1.06	ND
1981	0.06	25.53	64.64	0.03	2.10
1982	1.52	-	15.30	0.05	1.27
1984	-	-	-	1.11	13.91
1986	-	11.77	21.21	-	12.81
AVERAGE	0.85	5.08	22.50	2.03	7.52
PREDATORY FISHES					
1977	trace	-	-	-	ND
1978	7.02	-	-	0.31	ND
1979	10.46	-	-	-	ND
1980	53.88	-	-	-	ND
1981	1.05	-	-	-	-
1982	24.52	-	0.11	-	-
1984	1.92	-	-	-	-
1986	-	-	-	-	-
AVERAGE		-	0.01	0.04	-
PANFISHES					
1977	25.53	34.09	34.37	23.63	ND
1978	2.75	29.13	16.01	1.55	ND
1979	10.83	33.61	34.37	9.37	ND
1980	1.35	21.46	46.62	2.65	ND
1981	1.27	41.43	62.26	0.78	8.35
1982	.028	41.10	20.12	4.59	7.36
1984	1.32	28.10	74.36	37.95	13.13
1986	1.06	85.48	71.31	0.74	26.55
AVERAGE	4.72	39.80	47.22	9.35	13.85

COMMERCIAL FISHES					
1977	10.88	53.76	169.94	59.82	ND
1978	47.49	79.99	74.05	17.84	ND
1979	31.23	176.26	89.49	25.92	ND
1980	11.48	75.7	33.45	0.55	ND
1981	25.50	75.48	97.57	-	6.50
1982	4.18	22.47	131.82	trace	14.85
1984	45.87	19.25	7.38	16.41	5.34
1986	34.65	68.47	83.82	0.13	41.73
AVERAGE	22.73	54.71	77.82	11.86	17.11
FORAGE FISHES					
1977	11.63	16.90	13.76	22.88	ND
1978	28.61	20.78	4.08	22.30	ND
1979	37.69	30.01	6.66	16.79	ND
1980	23.77	15.04	8.59	6.79	ND
1981	88.34	189.08	270.05	3.07	49.45
1982	31.42	15.15	8.89	5.36	33.07
1984	26.45	5.03	14.69	23.65	25.61
1986	17.61	15.13	34.76	6.16	89.49
AVERAGE	33.86	21.26	12.21	11.76	44.50
TOTAL					
1977	60.61	117.56	230.67	118.80	ND
1978	101.19	140.60	108.66	57.57	ND
1979	97.29	131.81	153.92	61.59	ND
1980	95.00	131.81	153.92	61.59	ND
1981	88.34	189.08	270.05	3.90	49.45
1982	65.35	85.17	184.11	10.09	58.81
1984	81.65	57.25	105.52	83.44	61.80
1986	54.73	192.18	224.13	7.12	177.56
AVERAGE	80.68	130.01	170.82	37.40	86.91
TOTAL SPECIES COLLECTED					
1977	26	24	24	17	ND
1978	16	25	22	14	ND
1979	20	25	23	16	ND
1980	22	22	27	24	ND
1981	17	22	25	15	22
1982	18	20	31	17	21
1984	11	10	14	30	15
1986	17	26	24	15	25
AVERAGE	18	22	24	19	21

*-Sampling began at Station 5 in 1981
ND-Not determined
C-Channelized
N-Natural
MC-Mitigated Channel

Table 7. Diversity index ($\bar{d}$) and equitability (e) values for fish standing crops collected from 1977 through 1986 on Caney Creek, Ohio County, Kentucky.

SAMPLE STATION	1977	1978	1979	1980	1981	1982	1984	1986
1(CHANNELIZED)								
$\bar{d}$	3.07	1.94	2.49	3.04	2.24	2.93	2.71	2.44
e	0.46	0.31	0.40	0.55	0.35	0.61	0.82	0.41
2(NATURAL)								
$\bar{d}$	3.29	3.31	3.55	3.43	3.25	2.92	2.39	2.89
e	0.58	0.56	0.61	0.73	0.64	0.55	0.70	0.38
3(NATURAL)								
$\bar{d}$	3.00	3.27	2.95	3.20	3.23	3.36	2.16	3.11
e	0.48	0.64	0.46	0.48	0.52	0.48	0.43	0.50
4(CHANNELIZED)								
$\bar{d}$	3.30	2.84	2.97	3.00	1.67	1.56	3.14	2.27
e	0.82	0.71	0.50	0.46	0.27	0.24	0.43	0.50
5(CHANNELIZED WITH MITIGATION)								
$\bar{d}$	ND	ND	ND	ND	2.92	1.66	2.13	2.74
e	ND	ND	ND	ND	0.50	0.19	0.40	0.36

ND-Not determined

Table 8. Diversity index ($\bar{d}$), equitability (e), and density (#/ft2) values for benthic macroinvertebrate collected from 1977 through 1986 at stations on Caney Creek, Ohio County, Kentucky.

SAMPLE STATION	RIFFLE			POOL		
	$\bar{d}$	e	#/ft2	$\bar{d}$	e	#/ft2
1(CHANNELIZED)						
1977		n.s.*		0.29	0.33	23.56
1978		n.s.		1.38	0.60	8.64
1979		n.s.		2.48	0.61	104.42
1980		n.s.		1.09	0.21	81.19
1981		n.s.		1.74	0.36	89.33
1982		n.s.		3.68	1.05	32.67
1984		n.s.		0.97	0.50	48.68
1986		n.s.		1.58	1.00	3.00
2(NATURAL)						
1977		n.s.		0.32	0.14	309.17
1978		n.s.		2.30	0.70	68.64
1979		n.s.		2.10	0.35	382.53
1980		n.s.		2.21	0.35	360.89
1981		n.s.		1.41	0.30	306.22
1982		n.s.		2.15	0.35	82.98
1984		n.s.		0.58	0.29	610.40
1986		n.s.		1.62	0.01	238.00
3(NATURAL)						
1977	0.66	0.33	74.51		n.s.	
1978	0.94	0.20	17.00	1.84	0.69	121.44
1979	0.52	0.20	17.00	2.10	0.54	74.41
1980	1.70	0.27	383.50	1.86	0.28	96.00
1981	2.58	0.36	265.00	0.61	0.20	219.56
1982	2.00	0.25	442.99	3.05	0.80	22.65
1984	2.78	0.77	23.84	2.12	0.67	95.35
1986	3.22	0.07	46.50	2.80	0.10	92.00
4(CHANNELIZED)						
1977		n.s.		0.07	0.20	303.84
1978		n.s.		1.39	0.44	76.91
1979		n.s.		1.12	0.43	134.02
1980		n.s.		1.40	0.18	168.89
1981		n.s.		2.13	0.50	52.44
1982		n.s.		1.81	1.00	18.67
1984		n.s.		2.86	0.63	96.80
1986		n.s.		2.27	0.10	62.00

5(CHANNELIZED WITH MITIGATION)						
1977		n.s.			n.s.	
1978		n.s.			n.s.	
1979		n.s.			n.s.	
1980		n.s.			n.s.	
1981	1.78	0.27	225.00	2.66	0.64	109.78
1982	2.91	0.69	46.99	0.76	0.40	19.67
1984	3.33	0.74	80.31	0.93	0.67	111.33
1986	3.15	0.41	7.25	0.00	0.00	0.00

*-Not sampled

Table 9. Water quality data for parameters measured from 1977 through 1986 at stations on Caney Creek, Ohio County, Kentucky.

SAMPLE STATION	WATER TEMP. (°C)	D.O. (mg/l)	pH	ALKALINITY (mg/l)	TOTAL HARDNESS	TURBIDITY (FTU)
1(CHANNELIZED)						
1977	30	8.0	6.8	75	n.s.*	n.s.
1978	26	8.2	7.4	57	55	79
1979	n.s.	10.0	8.2	50	20	39
1980	26	8.8	6.4	30	60	39
1981	24	8.5	7.6	40	45	37
1982	28	5.2	7.4	50	60	42
1984	27	6.7	6.7	42	68	25
1986	27	7.3	7.2	46	50	n.s.
2(NATURAL)						
1977	19	2.8	6.5	85	n.s.	n.s.
1978	23	4.6	8.8	42	51	105
1979	n.s.	5.0	7.0	60	80	48
1980	17	2.3	6.9	40	60	100
1981	22	2.7	6.4	55	40	40
1982	30	1.6	7.1	70	70	18
1984	24	3.2	6.4	64	66	30
1986	24	3.0	6.2	81	73	n.s.
3(NATURAL)						
1977	19	5.1	6.5	85	n.s.	n.s.
1978	23	6.0	7.2	40	56	150
1979	n.s.	4.0	7.4	50	20	110
1980	13	4.0	7.4	50	20	110
1981	24	4.4	6.8	45	45	40
1982	29	4.2	7.8	60	70	50
1984	26	2.8	6.2	55	74	30
1986	26	4.0	6.4	45	54	n.s.
4(CHANNELIZED)						
1977	26	8.0	7.3	50	n.s.	n.s.
1978	23	8.2	8.0	35	70	95
1979	n.s.	10.0	6.4	50	80	45
1980	28	8.8	7.1	30	60	78
1981	29	10.2	7.2	82	90	36
1982	34	9.0	8.3	90	90	25
1984	27	6.8	7.4	111	105	30
1986	35	11.5	7.5	61	117	23

5(CHANNELIZED WITH MITIGATION)						
1977	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1978	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1979	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1980	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1981	31	10.1	8.1	40	40	36
1982	32	6.6	n.s.	65	80	55
1984	26	7.0	6.1	31	61	70
1986	25	5.2	6.6	67	60	n.s.

*-Not sampled

Table 10. Summerized values for fish standing crops and total species collected from 1980 through 1983 at stations in Right Fork Beaver Creek, Floyd County, Kentucky.

STANDING CROP (lb/acre)	SAMPLING STATIONS 1(N)	2(MC)	3(C)
GAME FISHES			
1980	11.69	0.59	1.26
1981	8.34	4.99	0.03
1982	0.20	0.08	0.15
1983	13.17	5.08	1.44
AVERAGE	8.35	2.69	0.72
FOOD FISHES			
1980	0.17	13.01	4.33
1981	1.87	12.26	0.15
1982	-	0.10	0.03
1983	1.00	0.01	2.57
AVERAGE	0.76	6.35	1.77
PANFISHES			
1980	21.18	1.12	7.68
1981	1.97	2.31	0.09
1982	5.72	2.13	2.34
1983	7.33	4.88	6.11
AVERAGE	9.02	2.61	4.06
COMMERCIAL FISHES			
1980	22.18	3.37	15.69
1981	45.08	21.26	1.35
1982	4.84	1.51	1.12
1983	21.75	3.70	6.11
AVERAGE	23.46	7.46	6.07
FORAGE FISHES			
1980	13.47	9.95	4.38
1981	10.74	6.81	3.00
1982	15.97	6.23	5.04
1983	19.65	6.85	6.21
AVERAGE	14.96	7.46	4.66
TOTAL			
1980	68.69	28.04	33.34
1981	68.00	47.63	4.62
1982	26.73	10.05	8.69
1983	62.90	20.52	22.44
AVERAGE	56.58	26.56	17.27

TOTAL SPECIES COLLECTED			
1980	28	30	27
1981	26	28	26
1982	27	24	31
1983	28	27	31
AVERAGE	27	27	29

N-Natural
MC-Mitigated Channel
C-Channelized with no mitigation

Table 11. Diversity index ($\bar{d}$) and equitability (e) values for fish standing crops collected from 1980 through 1983 at Right Fork Beaver Creek, Floyd County, Kentucky.

SAMPLE STATION	1980	1981	1982	1983
1(NATURAL)				
$\bar{d}$	3.64	4.15	3.51	3.53
e	0.64	1.00	0.59	0.61
2(MITIGATED)				
$\bar{d}$	3.52	3.96	3.68	3.84
e	0.57	0.82	0.79	0.78
3(NO MITIGATION)				
$\bar{d}$	3.39	3.61	4.06	3.55
e	0.56	0.69	0.77	0.55

Table 12. Diversity index ($\bar{d}$) and equitability (e) values for benthic macroinvertebrate samples from riffle and pool areas from 1979 through 1983 at stations on Right Fork Beaver Creek, Floyd County, Kentucky.

SAMPLE STATION	$\bar{d}$	e	#/ft2	$\bar{d}$	e	#/ft2
1(NATURAL)						
1979	0.47	0.15	20.40	2.02	0.55	22.41
1980	3.02	0.92	9.67		n.s.*	
1981	3.02	0.79	30.00	1.32	0.38	192.88
1982	2.90	0.71	19.32	2.15	0.86	44.00
1983	3.15	0.87	25.00	2.20	0.60	73.60
2(MITIGATED)						
1979	1.05	0.22	58.20	1.27	0.75	1.27
1980	2.58	0.73	5.00		n.s.	
1981	1.68	0.24	111.00	1.28	0.23	155.11
1982	2.42	0.58	48.33	1.85	0.55	81.60
1983	2.79	0.67	33.00	1.70	0.29	211.20
3(NO MITIGATION)						
1979	2.45	0.58	17.68	1.20	0.50	1.20
1980	1.02	0.29	113.29	1.72	0.40	177.72
1981	2.74	0.75	19.33	1.48	0.44	39.61
1982	1.77	0.80	12.66	2.73	1.00	30.40
1983	2.15	0.43	35.20	2.66	1.00	38.40

*-Not sampled

Table 13. Water quality data for prameters measured from 1980 through 1983 at stations on Right Fork Beaver Creek, Floyd County, Kentucky.

SAMPLE STATION	WATER TEMP. (°C)	D.O. (mg/l)	pH	ALKALINITY (mg/l)	TOTAL HARDNESS (mg/l)	TURBIDITY (FTU)
1(NATURAL)						
1980	19	6.3	6.6	220	190	28
1981	21	7.6	8.1	135	210	47
1982	24	6.1	7.1	130	180	10
1983	24	6.9	7.8	90	130	66
2(MITIGATION)						
1980	29	10.6	6.7	120	215	35
1981	25	6.8	7.1	135	220	40
1982	27	7.2	8.2	110	160	10
1983	29	8.2	7.8	110	140	23
3(NO MITIGATION)						
1980	26	10.1	6.9	140	160	78
1981	24	6.9	7.6	60	220	25
1982	26	6.7	7.2	170	180	10
1983	26	6.0	7.8	100	130	50