BENTHIC MACROINVERTEBRATES IN COLD TAILWATERS AND NATURAL STREAMS IN THE STATE OF ARKANSAS

By ROBERT E. BLANZ, CARL E. HOFFMAN, RAJ V. KILAMBI, and CHARLES R. LISTON

University of Arkansas
Department of Zoology
Fayetteville, Arkansas

1969

ABSTRACT

The results of a 1965-66 study of the physico-chemical factors, benthic macroinvertebrates, plankton, and fishes of three cold tailwaters (Bull Shoals, Norfork and Beaver) were published in the Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners by Brown, Liston, and Dennie (1967). The data presented here are an extension of this work and compare the macroinvertebrates of two natural streams (Buffalo and Kings rivers), two old tailwaters (Bull Shoals and Norfork), and a new tailwater (Beaver, impounded in 1963).

The dominant groups of benthic macroinvertebrates in the older tailwaters, Bull Shoals and Norfolk, were Isopoda, Chironomidae, Amphipoda, and Oligochaeta. The 1967-68 data show that the Beaver Tailwater just below the dam had fewer organisms per square foot than comparable stations below the older Bull Shoals and Norfork tailwaters and the same stations on the Beaver tailwater during the 1965-66 study. The data also indicate that Chironomidae have become relatively more abundant at all stations in the Beaver tailwater since the earlier study. Isopoda have increased at the first station below Beaver Dam while Oligochaeta decreased at all stations.

Trichoptera, Coleoptera, Ephemeroptera, and Gastropoda were abundant in one or both natural streams. The Coleoptera dominated the Buffalo River samples and Ephemeroptera and Trichoptera were most abundant in the Kings River.

INTRODUCTION

Part of the White River drainage system in northern Arkansas has been transformed into a series of large sprawling reservoirs and cold tailwaters by three hydroelectric dams. These tailwaters still resemble natural free-flowing streams, but certain changes are obvious. Water used for generating electricity is drawn from the depths of these reservoirs, and as a result water temperatures in the tailwaters remain quite low throughout the year. Seasonal variations in flow have been replaced by daily fluctuations caused by power generation.

Each of these cold tailwaters offers an unique opportunity to study the changes in a stream brought about by the construction of dams. The tailwater below Beaver Dam, which was completed in 1963, provides a chance to follow such changes. Tailwaters below Norfork and Bull Shoals dams, completed in 1944 and 1951 respectively, provide study areas that should have become biologically stabilized. The Beaver Dam tailwater also differs from the other two in that it empties into a reservoir a few miles below the dam. The Norfork Dam tailwater covers 4.5 miles before entering the Bull Shoals tailwater; the latter might be considered to end at the first lock at Batesville, some 120 miles below Bull Shoals Dam.

The objectives of the bottom fauna studies are as follows: (1) to study changes in benthic communities that have resulted from the creation of a cold tailwater below Beaver Dam; (2) to study established benthic communities in the old cold tailwaters of Bull Shoals and Norfork dams; (3) to study seasonal benthic population fluctuations and patterns in the cold tailwater below Beaver Dam; and (4) to compare presumed polythermic benthic species in the Buffalo River and Kings River with those found in cold tailwaters.

DESCRIPTION OF STUDY AREAS

The White River originates in the Ozark Mountains in western Arkansas and flows in a northeasterly direction. It enters Missouri from Carroll County and re-enters Arkansas in Boone County. The stream flows southeasterly from Missouri uniting with the Arkansas River near its confluence with the Mississippi River. It is 690 miles long and drains an area of 28,000 square miles.

The Buffalo River arises in the western part of Newton County, Arkansas and empties into the White River a few miles below Buffalo City in Marion County, Arkansas. It is approximately 140 miles long and drains an area of 1,383 square miles.

The North Fork River, a tributary of the White River, begins in southern Missouri and courses south to its confluence with the White River in Baxter County, Arkansas. It is about 70 miles long.

The studied stream sections lie in the Ozark Plateau. The most abundant rocks in this region are limestone, dolomite, sandstone, and shale, with the first two predominating (Branner, 1927). River basins are narrow and steep-sided, and entrenched meanders are numerous. Many stream bends have limestone bluffs on the outside with gradual slopes on the inside. Stream beds consist primarily of bedrock, rubble, gravel, and sand, with silt in areas of slight current. Ozark streams are typically spring-fed, clear, broken by numerous rapids and riffles, and, if undamed, subject to extreme seasonal variation in temperature and flow.

Higher forms of aquatic vegetation are generally scarce along the stream sections studied. Water cress (*Nasturtium officinale* Linnaeus), water weed (*Anacharis* Sp.), and arrowhead (*Sagittaria* Sp.) occur in scattered areas. Lower aquatic plants such as filamentous green and blue-green algae are rather abundant in some sections.

Major uses of land bordering the stream sections studied are for beef cattle grazing and timber production. Forests consist of mixed hardwoods and scattered pockets of evergreens. Willows (*Salix* Sp.) are common along stream banks.

Figure 1 indicates the locations of the collecting stations. B1, B2, and B3 were approximately 0.25, 1.9, and 3.5 miles, respectively, below Beaver Dam. Bull Shoals tailwater stations were designated BS, C1, and C2. Station BS was approximately 0.75 of a mile below Bull Shoals Dam; C1 and C2, located on opposite sides of the stream, were approximately 20 miles below the dam. Norfork tailwater stations, N1 and N2, were located approximately 0.25 and 3.5 miles, respectively, below the dam. Stations B1, BS, and N1 were chosen to compare quantitative differences between the stations nearest the dams. Stations C1 and C2 were selected to show quantitative results before the Buffalo River enters the White River tailwater below Bull Shoals Dam. The Buffalo River was studied using stations C5 and C6; both were nearly 0.75 of a mile upstream from its confluence with the White River and on opposite sides of the stream from each other. Kings River stations were KR1 and KR2. KR1 was approximately 0.25 of a mile upstream from the Highway 68 bridge or 0.50 of a mile east of Marble, Arkansas. Station KR2 was located beneath the same bridge.

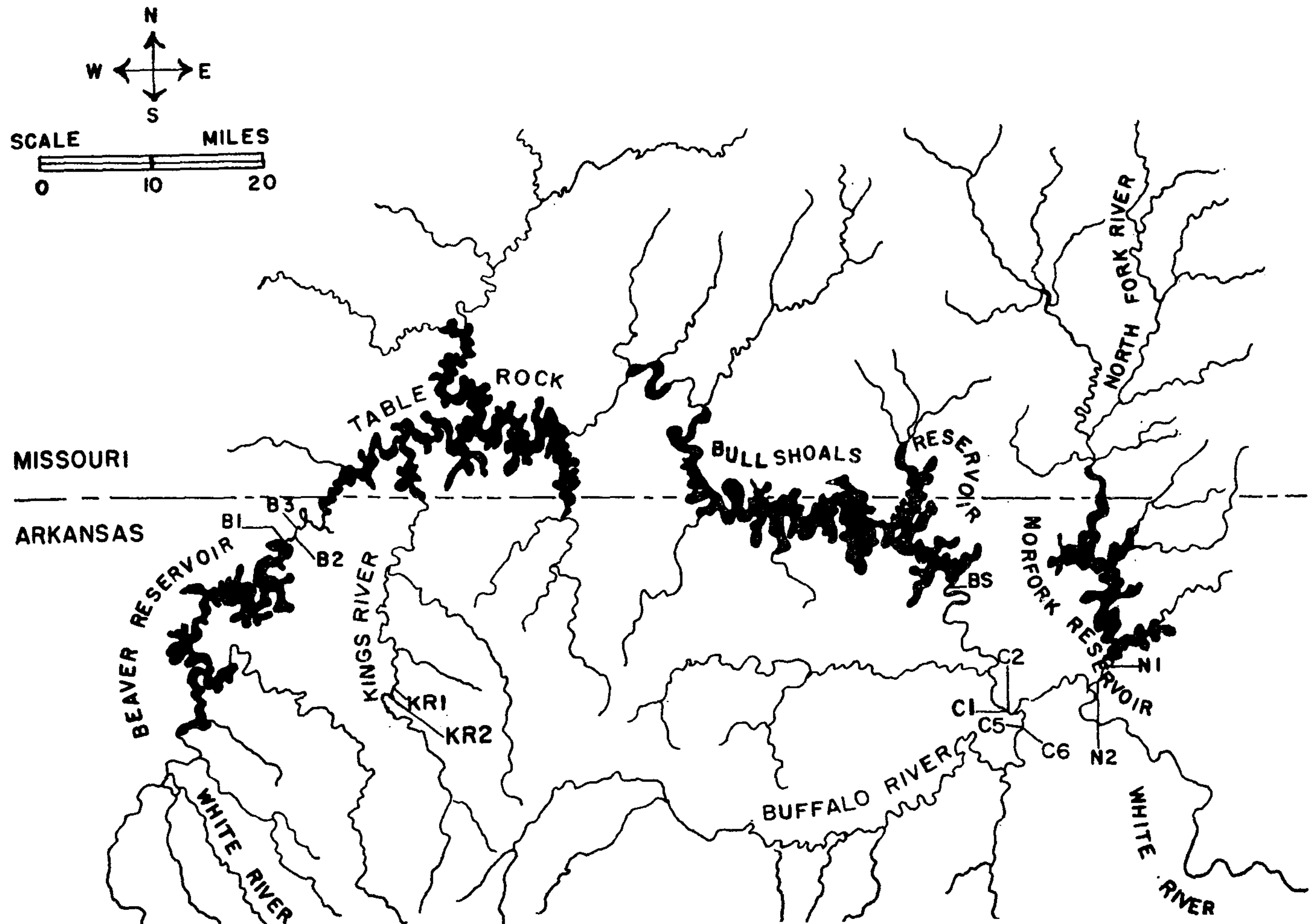


FIGURE 1. Map of study area

METHODS AND MATERIALS

Sampling Techniques

Sampling stations were established during July and August, 1965 in the tailwaters below Beaver, Bull Shoals, and Norfork reservoirs, and near the mouth of the Buffalo River. These stations are shown in Figure 1.

In order to assure random sampling each station below Beaver Dam was sub-divided into areas and assigned a number. The specific area of a station sampled on each collecting trip was determined by drawing a number from a hat.

Beginning July, 1965 through December, 1966 collecting trips were made weekly to the tailwater below Beaver Reservoir, and monthly to both the tailwaters below Bull Shoals and Norfork reservoirs, and to the Buffalo River. In the 1967-68 study, collecting trips were made bimonthly to the Beaver tailwater and to the Kings River.

To differentiate between the three Beaver stations during the 1965-66 and 1967-68 investigation periods, the earlier samplings are referred to as B1L, B2L, and B3L; the latter are referred to as B1, B-2 and B3.

On each collecting trip, air and water temperatures were taken with mercury thermometers. The thermometer used for taking water temperatures was calibrated to one-tenth degree Celsius, while the one used to take air temperatures was calibrated to one degree Celsius. Time of day, weather conditions, general water conditions, depth, length and width measurement, and riffle speeds were recorded at each site on each collecting trip. Riffle speed was calculated using a float traveling a specified distance. In general, turbidity was low in all study areas and was, therefore, not routinely measured since it was not considered to be a limiting factor. Chemical qualities of the water at each station were analyzed and were presented in detail by Dennie (1967), Liston (1967), Brown, Liston, and Dennie (1967).

A Surber Square Foot Sampler, as described by Lagler (1956), was used for bottom fauna collections. This sampler consists of a collapsible metal frame and a tapered nylon net. In use, the metal frame is placed on the substrate and organisms are dislodged from within the square foot area by washing the bottom material with the hand. The current carries the organisms and detritus into the tapered net, and the material is concentrated by rigorously swishing the net back and forth through the water. The organisms and detritus were placed in quart jars containing 5% formalin. These samples were transported back to the laboratory, separated from the detritus, sorted according to taxonomic category, counted, and weighed to the nearest milligram on an analytical balance. Organisms were separated in a white porcelain pan illuminated by a fluorescent light equipped with a built-in magnifying glass. Wet weight was determined after placing the organisms on filter paper and allowing the formalin to drain off. The organisms were then placed into a 70% ethanol solution and stored for later study.

Identification mainly consisted of separating the organisms into classes, orders, and families. Some of the dominant forms have been identified at the generic level (Blantz, 1969).

RESULTS AND DISCUSSION

General

The relative abundances of the dominant taxa in the Beaver, Bull Shoals, and Norfork tailwaters along with the Kings and Buffalo rivers are presented in Figure 2 and Table II. The percentages of dominant taxa in the Kings and Buffalo rivers are given to show the conditions in natural streams in Arkansas. The figure and table show that, with the exception of Bull Shoals station 2 (C1 and C2), the older tailwaters in general yielded more organisms per square foot than the new tailwater and the natural streams. The data also show that the dominant organisms in the old tailwaters and those in the natural streams differ from each other.

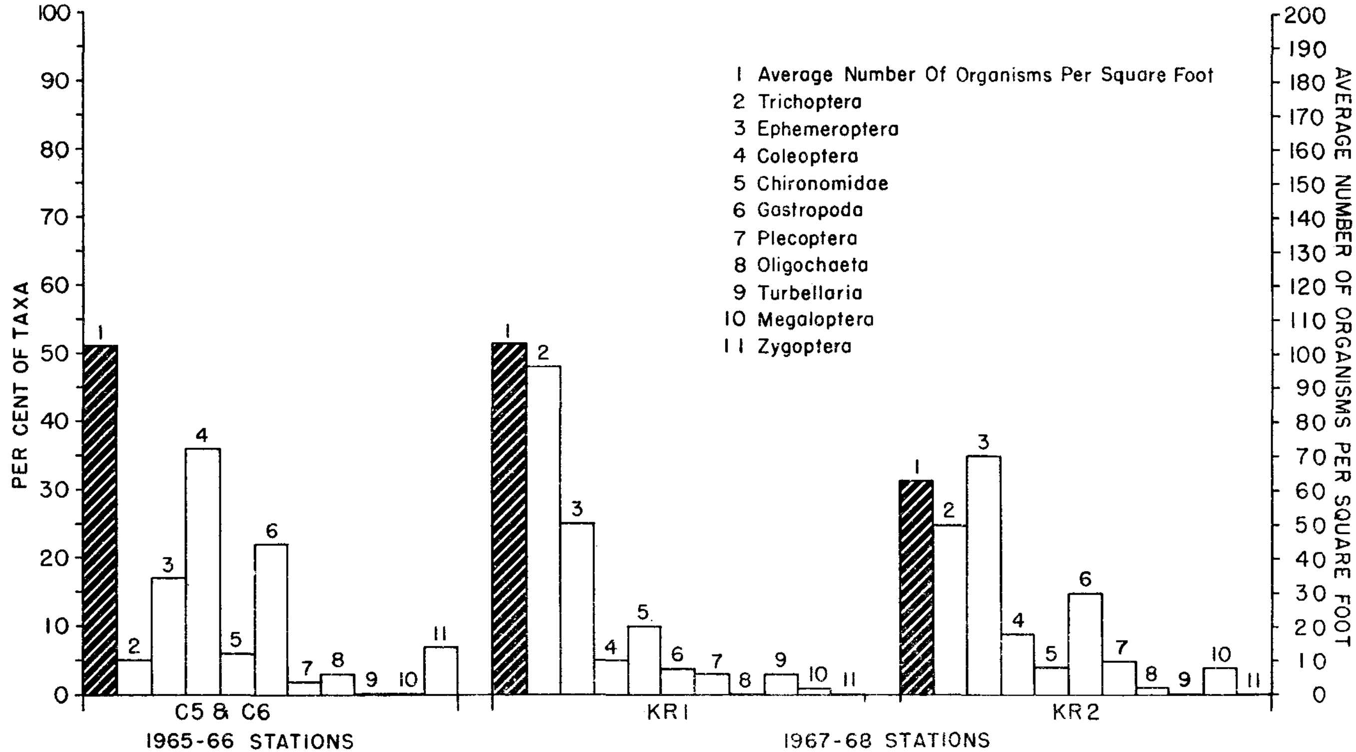
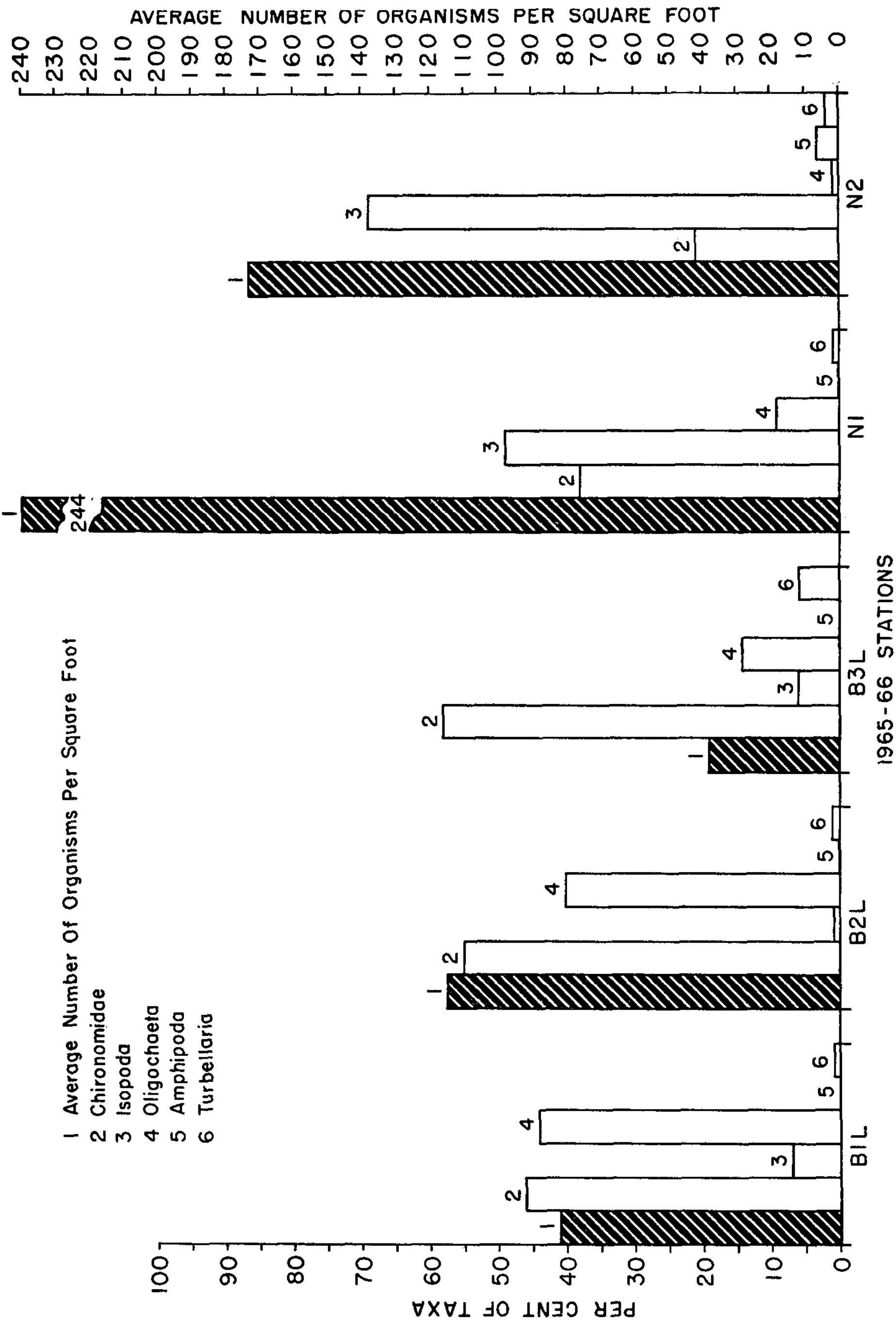
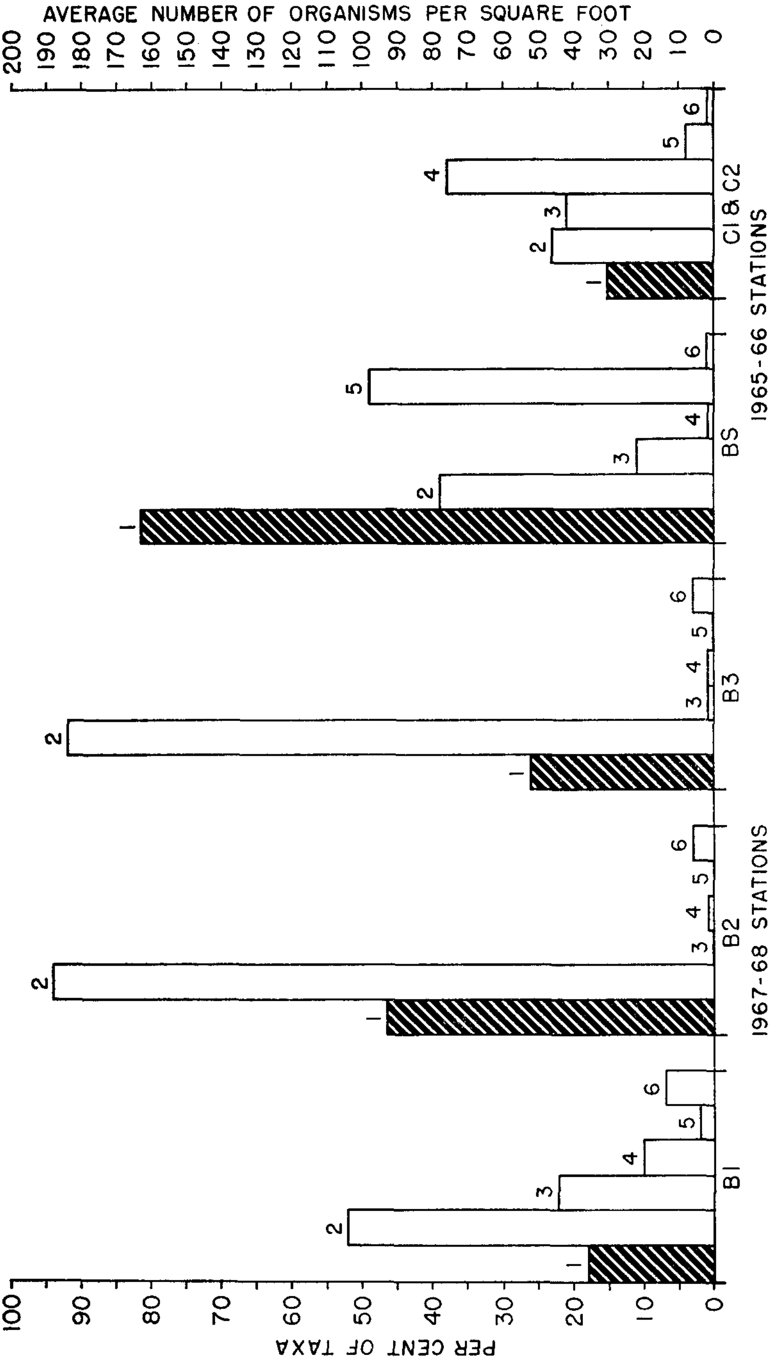


FIGURE 2. Dominant taxa at each station for both the 1965-66 and the 1967-68 studies. Expressed as per cent of total organisms collected at the respective stations (contains 3 pages)


AVERAGE NUMBER OF ORGANISMS PER SQUARE FOOT
PER CENT OF TAXA
1965-66 STATIONS
BIL
B2L
B3L
NI
N2
244
1 Average Number Of Organisms Per Square Foot
2 Chironomidae
3 Isopoda
4 Oligochaeta
5 Amphipoda
6 Turbellaria



AVERAGE NUMBER OF ORGANISMS PER SQUARE FOOT
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
PER CENT OF TAXA
100 90 80 70 60 50 40 30 20 10 0
B1
1967-68 STATIONS
B2
B3
BS
1965-66 STATIONS
C1 & C2
1 2 3 4 5 6

The most striking physical difference between the natural streams and the tailwaters was temperature (Table I). The Buffalo and Kings rivers exhibited a higher average and a wider range of temperatures than did the cold tailwaters. In general, the tailwaters reflect the current condition of the water at the level of intake. As the water moves downstream, it is influenced to some extent by local conditions.

Natural Streams

Buffalo and Kings Rivers

During the period from 1965-68, bottom organisms from two natural streams, the Buffalo and Kings rivers, environments unaltered by man-made activities, were studied for biotic productivity and composition to compare with cold tailwaters. The Buffalo River station (C5 and C6) average 102 organisms per square foot, while station number 1 on the Kings River (KR1) had 103 organisms per square foot. Station number two on the Kings River (KR2), having a slower riffle speed (Table I), yielded a lower average, 63 organisms per square foot.

The dominant organisms in the Buffalo River were Coleoptera (36%), Gastropoda (22%), and Ephemeroptera (17%). In the Kings River, the dominant organisms at station KRI were Trichoptera (48%), Ephemeroptera (25%), and Coleoptera (5%). At station KR2 in the Kings River, organisms in order of abundance were Ephemeroptera (35%), Trichoptera (25%), Gastropoda (15%), and Coleoptera (9%). Figure 2 and Table II show that the natural streams supported a greater variety of organisms and a minimal number of Chironomidae.

Tailwaters

Norfork and Bull Shoals

A total of 41 one square foot bottom samples was taken and analyzed from Bull Shoals and Norfork tailwaters. A total of 6,120 organisms weighing 24.8 grams was taken from the old tailwaters.

Amphipoda (49%), Chironomidae (38%), Isopoda (11%) were dominant taxa at station number 1 (BS) of the Bull Shoals tailwater (Figure 2). Oligochaeta (38%), Chironomidae (23%), and Isopoda (21%) were the dominant taxa at the second station (C1 & C2) of the Bull Shoals tailwater. The average number of organisms at station 1 (BS) was 163 per square foot while the second station (C1 & C2) averaged only 30 per square foot. Consistently higher numbers of organisms per sample were collected directly below Bull Shoals Dam than at station (C1 & C2) located approximately twenty miles downstream from the dam.

Three dominant groups of bottom organisms were taken from station 1 (N1) from the Norfork tailwater. These were as follows: Isopoda (49%), Chironomidae (38%), and Oligochaeta (9%). The second station (N2) had two dominant taxa, namely, Isopoda (69%), and Chironomidae (21%). This tailwater appeared to be somewhat similar at both stations with two exceptions, such as, the abundance of total organisms and the per cent of Oligochaeta (Figure 2). The Norfork tailwater also exhibited greater benthic productivity than other cold tailwaters studied. Samples taken from the stations directly below Bull Shoals and Norfork dams yielded consistently higher numbers of organisms and wet weights per sample than did the samples from comparable distances below Beaver Reservoir.

Beaver Tailwater

In this investigation, July 1965-66 and 1967-68, an attempt was made to determine the development of the benthos of the Beaver tailwater. Stations were identical in location in both studies of this tailwater; however, the stations of the earlier study have been referred to as B1L, B2L, and B3L for clarity. Using the studies of the established tailwaters of Bull Shoals and Norfork reservoirs as a base, the data obtained in

1967-68 may be compared to the data of the older tailwaters (Figure 2). Station BS, below Bull Shoals Reservoir, is comparable to B1; B2 is comparable to N2 below Norfork Dam and, to a limited degree, to C1 and C2 in the White River below Bull Shoals Dam.

In the 1965-66 study a total of 13,303 organisms in 168 samples was taken from the three Beaver tailwater stations for an average of 79.2 organisms per square foot. From the same stations the 1967-68 study yielded 3,694 organisms in 63 samples for an average of 58.6 per square foot. The 1967-68 study had fewer organisms per square foot at B1 and B2 than did the 1965-66 investigation (Table II).

The relative abundances of dominant taxa in the Beaver, Bull Shoals, and Norfork tailwaters, along with the Kings and Buffalo rivers, are presented in Figure 2. The percentages of dominant taxa in the tailwaters and the Kings and Buffalo rivers are given to show the conditions in the older tailwaters and natural streams in Arkansas.

Representatives of the dipteran family Chironomidae have become more abundant at stations B2 and B3 (Figure 2). In the 1965-66 study this family comprised 55% at station B2L and 58% at B3L, compared to 94% and 92%, respectively, at the same stations in the 1967-68 study. In the older tailwaters and natural streams the percentages of Chironomidae were as follows: 38% at N1 and 21% at N2, 38% at BS and 23% at C1 and C2, 6% in the Buffalo river (C5 and C6), and 10% at KRI and 4% at KR2 (Figure 2, Table II). Aggus and Warren (1965) found that in streams Diptera (mostly Chironomidae) decreased in number with warmer temperatures. In comparing stations B1L and B1, Isopoda increased at station B1 in the Beaver tailwater while Oligochaeta decreased at all three Beaver stations (Figure 2).

According to Neel (1963), evidently a more stabilized substrate in natural streams permits attachment sites for a larger variety of organisms. Aquatic insects, especially those requiring long mating and egg-laying flights, appear to cope with controlled fluctuating power generations, while sedentary forms of organisms, such as claims and oligochaetes, find survival difficult under such conditions.

Seasonal occurrences of organisms are obscured by the relative constant temperatures of tailwaters. In addition, sporadic power generations may give false impressions as to seasonal cycles. Nevertheless, it appears that the late summer is the most productive season for natural streams and tailwater communities. However, low water conditions brought about by minimal power demands may be coincidental with these rises in tailwaters.

The same genera of Chironomidae present in the 1965-66 study also appeared in the latter samples. Specimens of *Cardiocladius* (Kieffer) were found abundant in the 1967-68 study.

The Beaver tailwater benthic community evidently is adversely affected in its development because of the turbulent substrate due to excessive power generations. Figure 2 presents the average number of organisms per square foot for the first station below each dam. Station B1, below Beaver Dam, contains fewer organisms than found below the older dams (BS and N1) and B1L (Table II). During January, February, and April of 1968, high water in the Kings River and large water discharges in the Beaver tailwater made sampling impossible; however, these missing samples do not seem to alter the overall picture. Monthly totals ranged from 35 to 450 organisms more in the older, established tailwaters than in B1.

The second station below each dam generally produced fewer organisms than the first station in the older tailwaters. B2 had fewer organisms than the older stations except for a large pulse of Chironomidae in the fall of 1968, although it was the most productive Beaver station. A more stabilized substrate, undoubtedly caused by controlled generation coupled with an expected spring pulse, might account for an increase in the older tailwater stations.

Kruskall-Wallis One Way Analysis of Variance provides some insight into the relationship of the sample stations with respect to the number of organisms per square foot. Stations assigned B1 and B1L, and B2 and B2L were significantly different between the two study periods at the 0.05 level. However, the difference between B3 and B3L was not significant for these same periods.

The Beaver tailwater benthic fauna, compared to the older tailwaters of Bull Shoals and Norfork, is not fully developed. However, it appears that more controlled water releases, allowing a more stablizing substrate to form, will eventually provide the Beaver tailwater with a rich benthic fauna. The presence of some of the taxa found in the older tailwaters along with the quick recovery potential displayed in the Beaver tailwater in the late summer of 1968 leads to this conclusion.

ACKNOWLEDGMENTS

The work upon which this publication is based was supported in part with funds provided by the Office of Water Resources Research, U. S. Department of the Interior, under grant number A-001-ARK as authorized under the Water Resources Research Act of 1964, P. L. 88-379 as amended by P. L. 89-404.

Special thanks are extended to Dr. Leo L. Van Scyoc, English Department, University of Arkansas, for reading and editing this manuscript.

LITERATURE CITED

Aggus, Larry R. and L. O. Warren. 1965. Bottom organisms of the Beaver Reservoir Basin: A pre-impoundment study. J. Kansas Entomol. Soc., 38:163-178.

Blanz, R. E. 1969. Physico-chemical factors and benthic macroinvertebrates in cold tailwaters and natural streams in the state of Arkansas. Unpublished Masters thesis, University of Arkansas. 77 pp.

Branner, G. C. 1927. An outline of the physical features of Arkansas. Arkansas Geol. Survey, Little Rock. 22 pp.

Brown, J. D., C. R. Liston, and R. W. Dennie. 1967. Some Physico-chemical and biological aspects of three cold tailwaters in northern Arkansas. Proc. S. E. Assoc. Game and Fish Comm., pp. 369-381.

Dennie, R. W. 1967. A limnological investigation of the tailwaters of three reservoirs in northern Arkansas: physical, chemical, and plankton. Unpublished Masters thesis, University of Arkansas. 87 pp.

Lagler, K. F. 1956. Freshwater fishery biology. Second Ed., Wm. C. Brown Co., Dubuque, Iowa. 421 pp.

Liston, C. R. 1967. A study of the riffle, benthic, macroinvertebrates occurring below three impoundments in northern Arkansas. Unpublished Masters thesis, University of Arkansas. 43 pp.

Neel, J. K. 1963. Impact of Reservoirs. In: Limnology of North America, University of Wisconsin Press, Madison. Pp. 575-593.

TABLE I. Averages and ranges of physical data for all the stations in both the 1965-66 (Liston, 1967) and the 1967-68 studies (Blanz, 1969)

Station		Current (Ft./Sec.)	Water Temp (°C)	Depth (In.)	Width (Ft.)
B1L[1]	A	2.7	8.2	5	34
	R	4.2 – 1.4	10.0 – 6.2		
B2L[1]	A	1.9	9.8	8	64
	R	3.0 – 1.1	16.2 – 5.1		
B3L[1]	A	3.8	11.2	11	26
	R	5.0 – 2.4	23.0 – 4.2		

Station		Current (Ft./Sec.)	Water Temp (°C)	Depth (In.)	Width (Ft.)
B1[2]	A	2.6	9.4	6	45
	R	5.6 – 0.5	10.5 – 6.0		
B2[2]	A	1.6	10.7	8	64
	R	2.5 – 1.1	15.0 – 5.0		
B3[2]	A	1.2	11.9	14	18
	R	4.0 – 0.3	17.9 – 6.5		
BS[1]	A	2.6	10.6	7	45
	R	3.2 – 1.8	15.4 – 7.1		
C1[1]	A	2.8	12.5	8	300
	R	3.6 – 1.4	17.3 – 5.7		
N1[1]	A	2.6	11.1		
	R	3.3 – 1.8	15.4 – 6.1	9	30
N2[1]	A	2.9	13.0		
	R	4.0 – 1.6	16.5 – 8.0	8	35
C5[1]	A	2.6	18.5	8	35
	R	3.7 – 1.0	32.0 – 1.0		
C6[1]	A	2.7	18.2	6	35
	R	4.3 – 1.5	32.9 – 1.0		
KR1[2]	A	4.1	16.1	11	31
	R	6.6 – 1.5	26.0 – 4.0		
KR2[2]	A	2.8	16.2	12.0	24
	R	5.0 – 1.2	26.3 – 6.0		

1 Study period from July 1965 to January 1966.
2 Study period from September 1967 to October 1968.

TABLE II. Average numbers, wet weights and percentages of dominant taxa at each station for both the 1965-66 (Liston 1967) and 1967-1968 (Blanz 1969) studies

DOMINANT TAXA EXPRESSED AS PER CENT OF TOTAL ORGANISMS

STATION	Symbol	Avg. No. Per Sq. Ft.	Avg. Wt. Per Sq. Ft.	Trichoptera	Ephemeroptera	Coleoptera	Chironomidae	Gastropoda	Plecoptera	Oligochaeta	Turbellaria	Megaloptera	Zygoptera	Others	No. of Samples
Buffalo River (1966)	C5 & 6	102	0.37	5%	17%	36%	6%	22%	2%	3%	P	P	7%	2%	19
King's River 1 (1968)	KR1	103	2.34	48	25	5	10	4	3	P	3	1	0	1	20
King's River 2 (1968)	KR2	63	2.74	25	35	9	4	15	5	1	P	4	P	1	20

DOMINANT TAXA EXPRESSED AS PER CENT OF TOTAL ORGANISMS

STATION	Symbol	Avg. No. Per Sq. Ft.	Avg. Wt. Per Sq. Ft.	Chironomidae	Isopoda	Oligochaeta	Amphipoda	Turbellaria	Others	No. of Samples
Beaver 1 (1966)	B1L	82	0.10 gms.	46%	7%	44%	0%	1%	2%	61
Beaver 1 (1968)	B1	36	0.07	52	22	10	2	7	7	20
Beaver 2 (1966)	B2L	115	0.16	55	1	40	0	1	3	55
Beaver 2 (1968)	B2	93	0.10	94	0	1	0	3	2	18
Beaver 3 (1966)	B3L	38	0.15	58	6	14	0	6	16	52
Beaver 3 (1968)	B3	52	0.05	92	1	1	0	3	3	25
Bull Shoals 1 (1966)	BS*	163	0.54	38	11	1	49	1	0	11
Bull Shoals 2 (1966)	C1 & C2*	30	0.23	23	21	38	4	1	13	11
Norfolk 1 (1966)	N1	244	1.03	38	49	9	0	1	3	10
Norfolk 2 (1966)	N2	173	0.67	21	69	1	3	2	4	9

* Referred to as BS1 and BS2 in Brown, Liston, and Dennie (1967).