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Some Ecological Factors Affecting the Occurrence of Water Willow *Justicia americana* in Jessamine Creek, Kentucky

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Abstract

Efforts were made to determine what environmental conditions are conducive to the occurrence of water willow *Justicia* (= *Dianthera*) *americana* beds along the course of Jessamine Creek, which had been receiving about 650,000 gal/day (2,460 m^3/day) of secondary sewage effluent through 2 tributaries. There were no beds of water willow in the upper or lower extremities of the stream; beds were present only in a 12.7-km stretch downstream from the point where the sewage effluent first entered the main stream, and more than half the dense stands occurred within the uppermost 3.2 km of that stretch. Elevations in that stretch fell 70.1 m, yet the size of the beds did not seem affected by elevational changes. East or west flow seemed conducive to development of more extensive and dense beds. NPK did not appear limiting. Depth of gorge and length of available sunlight did seem to affect size and density of beds. Minor flooding seemed to increase riffle and patch size where beds already occurred; however, heavy flooding may have had an adverse effect on some stands. From 1971 to 1974, species composition and diversity of benthos and other animals more than doubled at one station where samples were taken both years.

Introduction

Jessamine Creek flows through one of the outstanding scenic gorges within the Blue Grass Physiographic Region of Kentucky (Dearinger 1968). Its course lies entirely within the Inner Blue Grass Subregion, centered around the city of Lexington in Fayette County. The stream originates 6.4 km south of the Fayette County line in Jessamine County, and empties into the Kentucky River without ever leaving Jessamine County. Jessamine Creek is a fifth-class stream (Kuehne 1962), and has cut its way through nearly 122 m of limestone to maintain its flow into the river. It is 30.9 km long, and for the last 9.7 km the stream flows through a narrow, heavily wooded valley with high cliffs on one or both sides.

Sewage disposal plants release effluents into 2 tributaries of the stream, Town Fork and Wilmore Branch (Fig. 1). In the last 5 years, a number of industries have moved into the drainage basin.

For the past 18 years, I have been interested in the water quality and biota of Jessamine Creek. I have seen darter (*Etheostoma*) and stonefly (Plecoptera) populations eliminated from parts of the stream, and the bottom become extremely slippery in riffles; yet, in the last 5 years, stream conditions have improved with reference to desirable fauna, and it appears that the changing flora may have been related to the improvement, since there has been a rapid extension of beds of water willow *Justicia* (= *Dianthera*) *americana* in

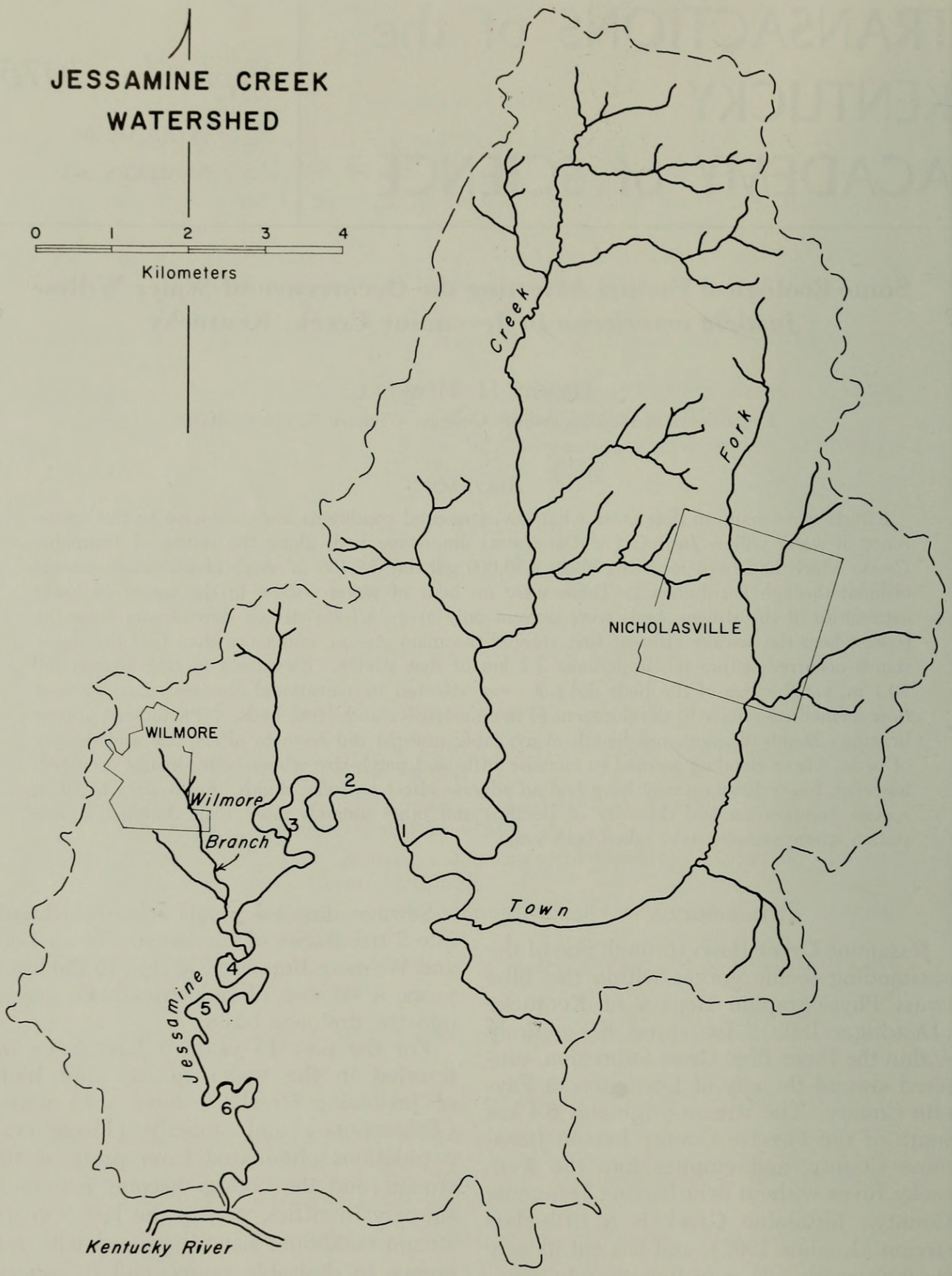

FIG. 1. Map of Jessamine Creek watershed showing the locations of the sampling stations (indicated by numbers), Town Fork, and other principal tributaries.

spring and summer along the course of the stream, and the presence of huge mats of filamentous algae during the winter. This paper discusses the results of data gathered largely from 1 July through 15 October 1974, in what was an effort to determine the ecological role of the extensive patches of water willow in Jessamine Creek, and to see if they could possibly be contributing to the improvement of water quality.

Water willow is one of the most commonly occurring angiosperms in the shallow waters of lakes, ponds, and streams in eastern United States and southern Canada (Fassett 1969). It is an emergent perennial herb, rather frequently found in dense and extensive stands. Numerous workers have studied the production, mineral nutrient absorption, and assimilation of aquatic flowering plants. Westlake (1963) and Boyd (1968, 1969) have summarized the rather extensive literature. Boyd (1969), in particular, found that stands of water willow in lentic and lotic situations in Alabama had high biomass productivities and mineral uptake during spring and early summer, with standing crops that averaged 3.75 times higher in the 2 lakes studied than in the 3 streams. Krumholz (1971), Krumholz and Neff (1972), White (1974), and Woodling (1970, unpublished master's thesis, University of Louisville, Louisville, Kentucky) all sensed the need for an intensive study of the large *Justicia* beds in the Salt River, Kentucky, to ascertain their contribution to the overall economy of the river.

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RECENT INVESTIGATIONS IN THE STUDY AREA

Since 1963, 18 undergraduate students at Asbury College have conducted brief independent investigations on Jessamine Creek, most work being done since 1970. One of the chief conclusions gathered from those reports is that total and fecal coliform counts increased below the Wilmore and Nicholasville sewage outfalls, with more rapid recovery in Wilmore Branch than in Town Fork, even though a higher count had been present below the Wilmore plant. In all reports, the total coliforms usually were higher than 5,000/100 ml.

In 2 unpublished reports by M. W. Jones, chemical analyses were run on water samples from selected stations; other than below the outfalls, orthophosphate ranged from 1.12 to 4.25 mg/l, and nitrate nitrogen from 4.25 to 7.08 mg/l. Other parameters determined were pH, sulfate, metaphosphate, conductivity, alkalinity, hardness, total dissolved solids, and dissolved oxygen. None of those factors were considered critical.

One of the most comprehensive studies was done in the fall of 1973 by Barcelo, who used stationary periphyton samplers to study the extent of colonization on glass slides placed in riffles for 4 exposure periods. She identified 46 genera in the samples, mostly diatoms. The dry weight per slide ranged from 0.5 to 13.3 mg, and the ash-free weights ranged from 0.1 to 9.6 mg. The ash-free weights averaged 57.5 percent of the dry weight, and at the station below the sewage outfalls, the weights were more than double those upstream from the outfalls.

In the summer of 1971, I had the assistance of 2 college seniors and 2 high school students under the National Youth Corps Program, and a paper entitled "Some of the effects of domestic sewage discharged into Hickman and Jessamine Creeks in Jessamine County, Kentucky" by Howell and Jones was presented to the Kentucky Academy of Science that fall, and again in March 1972 to the Midwest Benthological Society. The information used came from 8 riffle stations on Hickman Creek and 13 on Jessa-

TABLE 1.—RELATIVE ABUNDANCE, NUMBER OF STEMS PER SQUARE METER, PATCH SIZE (m^2), DIRECTION OF STREAM FLOW, AND TYPE OF VEGETATIONAL COVERAGE OF SURROUNDING SHORES, FOR WATER WILLOW BED AT EACH STATION IN JESSAMINE CREEK, KENTUCKY

Station Number	Relative Abundance	Number of Stems	Size of Patch	Direction of Flow	Shoreline Vegetation
1	Sparse to very thick	64–334	367	W & NW	Open field
2	Thick to very thick	360–476	1800	W	Open field
3	Medium thick	256[1]	232	S	Open field
4	Medium thick	252	203	W	Woods with little overhang
5	Sparse	–[2]	900	SW	Partial canopy
6	Sparse	60[1]	200	W	Partial canopy

[1] Floods made accurate count difficult.
[2] Too much flood damage to estimate.

mine Creek, and included data on water chemistry, coliforms, benthos, and fishes. Hickman Creek was judged more polluted than Jessamine Creek largely on the basis of the diversity of benthos and fishes. Hickman Creek was receiving about 1.3 million gal/day (4,920 m^3/day) of sewage effluent from the Lexington area, and Jessamine Creek was receiving about 650,000 gal/day (2,460 m^3/day) from Nicholasville and Wilmore.

In addition to the above-mentioned investigations, studies on the flora of the county have been made by members of the Department of Botany at the University of Kentucky. A master's thesis entitled "Vascular plants of Jessamine County, Kentucky" was written in 1941 by MacFarland, who listed 661 species including a number of rare species from the gorge. In 1974, MacGregor, a graduate student, presented a paper to the Academy on "The flora of Jessamine Gorge." He listed 344 species as occurring in the gorge, with 68 species being considered rare or near rare. The U. S. Army Corps of Engineers (1974) compiled a thorough study of the environmental resources of the Lexington Urban Area, and in the section dealing with flora, some special notes from Meijer (1974) were included, with comments on 15 rare species from the gorge.

METHODS

To determine the extent of water willow and other angiosperm beds in Jessamine Creek, the creek bed was cruised for its entire length, including Town Fork and Wilmore Branch. Whenever a patch of plants or an algal mat was found, its location was plotted on a 7.5-min topographic map. The size of each patch in square meters was determined from the length and average width. Relative density of the emergent stalks was recorded as very thick, thick, medium, or sparse. The direction of stream flow was recorded as N, S, E, W, NW or SE, NE or SW, along with the extent of overhead cover, whether there were open fields along banks, partial canopy, or full canopy. The presence or absence of noticeable current, the depth of water, and the type of substrate were also recorded.

After cruising the stream, 6 collecting stations were established (Fig. 1) at which detailed studies of water willow communities were made using 0.25-m^2 square metal frames to determine the average numbers of emergent stems per square meter and the average wet and dry weights of harvested stems. When collecting stems, an effort was made to collect benthos from around the roots. In addition, total dissolved solids using a Hach meter, total coliforms using the Millipore technique, and other chemical tests were determined as time permitted. Efforts were made to determine the size and composition of the fish, snake, and crayfish populations in and around the water willow beds.

RESULTS

By the end of July, 59 vegetational patches had been mapped. Extremely

TABLE 2.—NUMBERS AND SIZES OF PATCHES OF WATER WILLOW BETWEEN STATIONS IN JESSAMINE CREEK, TOGETHER WITH DISTANCES AND DIFFERENCES IN ELEVATION (MSL) BETWEEN STATIONS

Between Stations	No. Patches Between Stations	Distance Between Stations		Total Size of Patches (m^2)	Elevations (meters)	Fall in Stream	
		mi	km			m/km	Ft/mi
1–2	19	0.74	1.20	4,330	241.1–237.4	3.04	16.1
2–3	10	0.89	1.43	3,910	237.4–225.6	8.29	43.9
3–4	20	2.74	4.41	3,154	225.6–199.7	5.86	30.9
4–5	9	1.83	2.95	1,768	199.7–183.9	5.36	28.4
5–6	5	2.31	3.72	202	183.9–164.2	5.31	28.1
Totals	63	8.51	13.71	13,364	241.1–164.2		

heavy rains fell on the watershed the first 2 weeks in August, and by the end of the month there was an excess of 7.95 inches (20.19 cm) over the average rainfall of 3.50 inches (8.89 cm). September had one of the highest rainfalls on record, with an excess of 6.47 inches (16.43 cm). The lower 4.83 km of the creek was not visited until late August and September; flood damage had been extensive. Station 6 was selected on 22 September. The upper reaches of Jessamine Creek above Town Fork were not visited until October.

There were no beds of water willow in Town Fork, Wilmore Branch, or in Jessamine Creek above the mouth of Town Fork even though there were suitable riffle sites for such beds. There were occasional patches of lizard's tail *Saururus cernuus* upstream from the mouth of Town Fork, primarily along the margins of pools. Although there were no beds of water willow in Jessamine Creek upstream from the mouth of Town Fork, there were 63 beds downstream from that point. The extremely high floodwaters could have eliminated a few small beds before the lower reaches of the stream were surveyed.

The 6 stations for intensive study were selected because of the sizes of water willow beds and ease of access. At Station 1, 5 small beds were lumped together. The densest and largest beds were at or near Station 2, and although it cannot be stated conclusively because of the severe flooding, the density of the stands appeared to diminish downstream. The abundance, coverage, direction of flow, and adjoining riparian vegetation at each station are shown in Table 1. At Station 2, driftage was found almost 2 m above normal pool level, and at Station 4 it was nearly 3 m above normal pool level. The abundance and distribution of water willow beds in relation to declivity in Jessamine Creek are shown in Table 2, and Fig. 2 shows the profile of the stream and the relationship between station locations and declivity. Assuming that the portion of the stream that contains water willow beds is 13,720 m (8.52 miles) long and the average width is 10 m, the beds covered nearly 10 percent of the total streambed. Those beds covered 36 percent of the streambed between Stations 1 and 2, 27 percent between Stations 2 and 3, and only 7 percent between Stations 3 and 4. At the first 4 stations, the beds covered 60–95 percent of the streambed. The declivity of the streambed did not appear to influence the location of the beds.

At Station 1 and in several vegetational beds downstream, there was a mixture of water willow and lizard's tail. In 4 of 8 mixed beds, lizard's tail comprised 50 percent of the total coverage, in 3 other beds, lizard's tail was the only plant. Seven of the 11 beds of lizard's tail were along the stream bank.

An east or west flow may be conducive to enlarging the size of beds, since nearly 60 percent of all beds occurred in such locations (Table 3). Flow in either of those directions normally allows greater exposure to direct sunlight, especially in the gorge

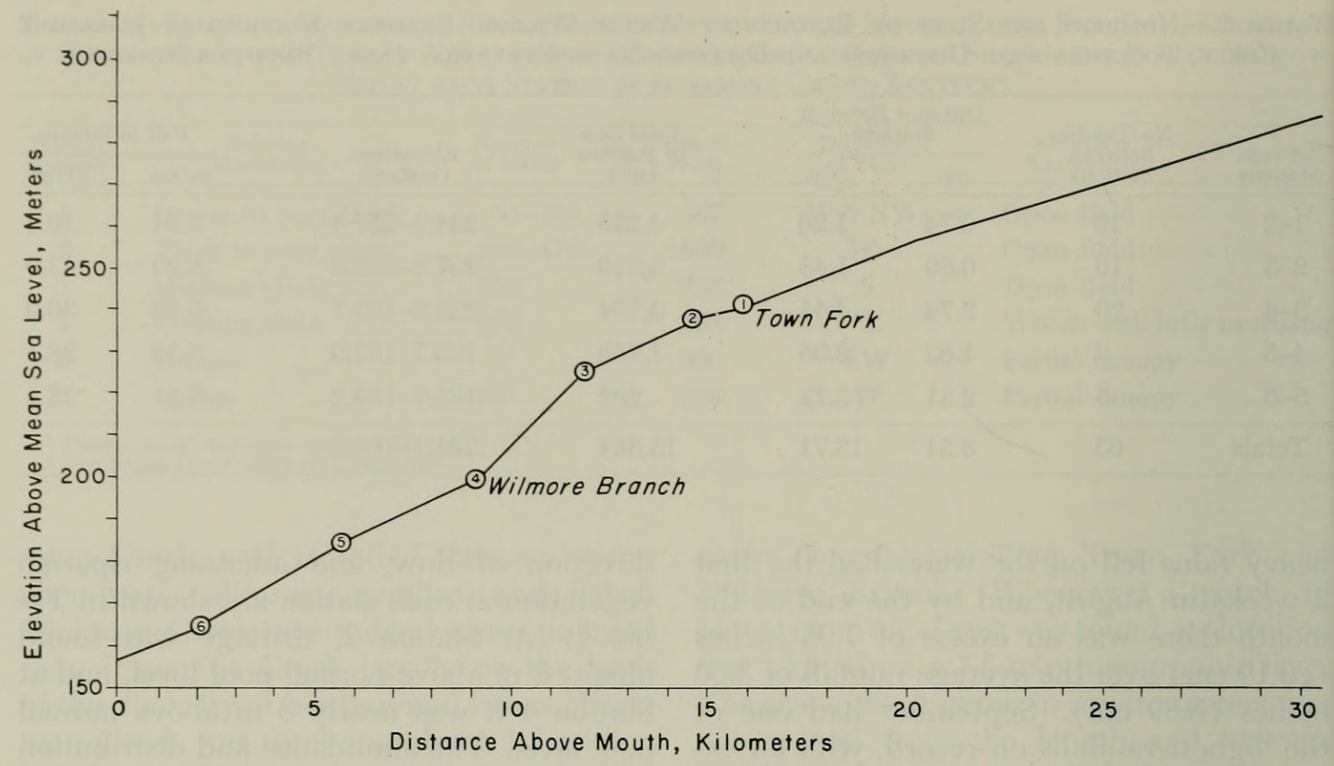

FIG. 2. Profile of Jessamine Creek showing the locations of the sampling stations and the points of confluence of Town Fork and Wilmore Branch.

portion. Only 23 percent of the water willow coverage was in areas of north–south flow.

In all larger beds, the water willow grew in riffle areas where the water was 2.5–7.5 cm deep. Of the 63 beds recorded, only 14 (22 %) were in shallow water along the banks of pools; the remaining 49 beds were in riffles and the coverage ranged from 2 to 1,800 m^2. The pattern of flow within each bed varied greatly. In a few beds it was almost impossible to see any flowing water without separating the dense willow shoots. Usually, in naturally occurring separations, larger volumes of water imparted a braided appearance to the stream. Horizontal runners attached the plants to the substrate, and almost any combination of boulders, rubble, gravel, sand, and silt was found associated with the beds.

The wet weight of the standing crop on 1 August in a medium dense bed at Station 4 was 2,917 g/m^2; the dry weight was 522 g/m^2. The latter figure falls within the range cited by Boyd (1969) in 3 Alabama streams (322–802 g/m^2 dry wt). Production from a dense stand in Jessamine Creek was not determined.

High waters had a very adverse effect on beds of water willow. All stems were bent

TABLE 3.—SUMMARIES OF WATER WILLOW COVERAGES IN SQUARE METERS ARRANGED ACCORDING TO DIRECTION OF STREAM FLOW. NUMBERS IN PARENTHESES INDICATE NUMBERS OF PATCHES

Stations	No. of Patches	E or W	N or S	NE or SW	NW or SE
1–2	19	3689 (8)	266 (3)		876 (8)
2–3	10	3213 (4)	97 (3)	5 (2)	600 (1)
3–4	20	180 (6)	2528 (8)	214 (5)	232 (1)
4–5	9	593 (5)	155 (2)	900 (1)	120 (1)
5–6	5	198 (3)	15 (1)		4 (1)
Totals	63	7873 (26)	3061 (17)	1119 (7)	1332 (12)

double with the exception of those at the upper ends of large beds where the stems brought about retardation of the current and rapid deposition of sediment that held the stems upright. Stems not broken, frequently became upright after flow receded to near normal for a few days. At the upper end of Station 2, 30.48 cm of sediment was deposited on top of the earlier exposed horizontal runners; at the lower end of the same bed, 10.16 cm of sediment had been deposited. The smaller volume of floodwater at Stations 1 and 2 allowed the beds there to survive the floods with less destruction.

Only 2 quadrat samples for benthos were taken, and only a small part of the known fauna was collected. In the associated riffles, 3 species of darters, a sculpin, 2 cyprinids, a sucker, and a smallmouth bass were taken by agitating the rubble. In the pools below, 2 species of crayfish, *Orconectes rusticus* and *O. juvenilis*, were collected. Prior to the flooding, large numbers of crayfish were seen in the pools below the water willow beds. Below Station 2, 96 adult crayfish were collected with a 10-foot seine. In the 0.25-m^2 benthos quadrat in the water willow bed at Station 2, 4 small crayfish ($16/m^2$) were taken. The water willow beds possibly served as nurseries for small crayfish. Those same riffles, with their many rocks and rubble, may also serve as hiding places during winter, since no crayfish were found in any of the pools after the first frost.

In the gorge area between Stations 4 and 5 where water funneled quite rapidly over a bedrock strip, large crayfish were arrayed in a military spacing 20–25 cm apart, all facing upstream and remaining motionless. Were they waiting drift organisms, filter feeding, or carrying on some unknown physiological activity?

In May 1974, 3 *Natrix sipedon sipedon* were taken in a seine from a riffle at Station 3. Subsequent effort to census the *Natrix* population at 4 collecting stations was unsuccessful. About a dozen were seen during the season, most of them in pools.

From the 49 water samples collected from Stations 1 through 4 from 17 July through 6 August 1974, conductivity ranged from 452 to 616 μmhos/cm, with the higher figure at Town Branch just above its confluence with Jessamine Creek and the lower one from Jessamine Creek just above its confluence with the Kentucky River. Total and fecal coliform counts from the same samples are listed in Table 4.

TABLE 4.—MEAN TOTAL COLIFORM COUNTS PER 100 ML FOR JESSAMINE CREEK ABOVE AND BELOW CONFLUENCE WITH TOWN BRANCH, AND BETWEEN COLLECTING STATIONS, 15 JULY–5 AUGUST 1974

Station	Count
Jessamine Creek (above confluence)	7,962
Town Branch (above confluence)	31,928
Between Stations	
1–2	9,575
2–3	10,575
3–4	7,811

DISCUSSION

The occurrence of water willow in Jessamine Creek may be related directly to the increased urbanization within the county, particularly in and around Nicholasville where increased amounts of water are being shunted directly into the stream, thereby increasing its silt carrying capacity. Similarly, the increased sewage load has resulted in a higher BOD in the discharge (pers. comm. from operator). It appears that the existing beds are being extended at both ends of the area they now occupy. In the lower gorge, the larger volume of water tended to retard the extension of the beds because of the narrower floodplains and the increasingly scouring action of the current, and, perhaps, less exposure to direct sunlight.

No reasons could be found for the absence of water willow plants in the waters of Town Fork which carried the sewage effluent from Nicholasville, or in the relatively clean waters of Jessamine Creek above the mouth of Town Fork since there were many locations that appeared suitable so far as substrate is concerned. Chemical analyses provided no clues, but it may be

that data on BOD, and more specifically on dissolved organic materials would provide insight.

In many pool areas, the bottom is bedrock and establishment of water willow beds or other plant communities would be difficult; still, some of the smaller beds were found in cracks and fissures within the shallow pools less than 30 cm deep. As with several other streams in the Inner Blue Grass, the entire flow goes underground during the late summer and early fall, so that only dry riffles and occasional pools remain. Jessamine Creek disappears 0.8 km below Station 3 and remains underground for about 1.4 km.

It is not known how effective water willow plants are in removing the nutrients from sewage having undergone secondary treatment. Law and Kerr (1969), over a 60-week period in Oklahoma, used fescue and rye grasses in hydroponic culture tanks with nutrient rates of 8,664, 4,560, and 4,833 lb NPK/acre (1,590, 837, and 887 kg/ha), respectively, with gravel beds to ascertain the effectiveness of mineral removal. They reported that grasses were minor contributors to nutrient removal from wastes when compared to the total quantity of nutrients that passed through the tanks. They also concluded that there was greater reduction of COD (50%), BOD (85%), and total nitrogen (55%) than the NPK by passage through the tanks. Interestingly, removal in the control tanks on organic materials and total nitrogen was about the same as in the experimental tanks with the grasses. Such information allows for the possibility that an indirect benefit of the increasing sizes of the water willow beds may be the furnishing of increased size to the gravel beds where flora and fauna would tend to reduce COD, BOD, and total nitrogen as well as total bacterial counts.

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