COMPARISONS OF PRIMARY PRODUCTION AND LEAF LITTER DECOMPOSITION IN NATURAL AND CHANNELIZED PORTIONS OF A KANSAS STREAM

by

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

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INTRODUCTION

The small streams of the eastern Kansas Flint Hills were described by Jewell (1927) as transitional between typical woodland streams of the temperate deciduous forest biome and the true prairie streams of the temperate grassland biome. Like the former they are associated with a riparian forest and receive large amounts of allochthonous organic matter, but like the latter they have swift currents and are subject to flooding so that the bottoms are swept relatively clean of organic deposits.

Studies of small, first to fourth-order, streams of the temperate deciduous forest biome have resulted in accumulating evidence to support the contention that they are heterotrophic systems. That is, stream respiration exceeds photosynthesis and the detritus-based stream community is dependent upon the import of organic matter from the terrestrial community through which it flows (Nelson and Scott 1962; Hynes 1963; Egglishaw 1964; Minshall 1967; Triska 1970; Fisher 1971; Hall 1971; Fisher and Likens 1972; Cummins et al. 1973). The inference is that true prairie streams, which are not associated with a riparian forest, should tend to be autotrophic because of decreased import of organic matter and increased solar energy input. The streams of eastern Kansas, while transitional, should exhibit heterotrophic properties because of their association with a riparian forest.

Significant alteration of running water ecosystems by man disrupts their natural heterotrophic tendency (Cummins et al.

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1973). When streams are altered by straightening their channels and removing the associated riparian forest the stream ecosystem would be expected to shift to an autotrophic condition. Factors effecting this shift include a decrease in the allochthonous organic matter input to the stream, a reduction in the heterogeneous character of the stream and its channel which are responsible for the capture of the organic matter, and an increase in primary production as a result of reduced shading and consequent increased solar energy input.

Allochthonous organic matter has been documented as the predominant energy source in the energy budget of temperate woodland streams (Nelson and Scott 1962; Minshall 1968; Fisher 1971; Kaushik and Hynes 1971; Hall 1972; Cummins 1972,1973; Cummins et al. 1972,1973). Minshall (1967) concluded that allochthonous leaf material was the most important energy source in his study of Morgan Creek, Kentucky. Vannote (1970) determined that up to two-thirds of the annual energy requirements of primary consumer organisms in a woodland stream was provided by allochthonous detritus. Fisher and Likens (1972, 1973) calculated that 99% of the annual energy input to Bear Brook, in the northern hardwood forest of New Hampshire, was allochthonous, of which 28.8% was leaf litter. Thus, it has been established that a woodland stream in the temperate zone is heterotrophic, with the surrounding forest providing most of its total energy requirements.

A hearing before a subcommittee of the United States House of Representatives in 1971 established that stream channelization alters the physical characteristics of a stream as well as their biological systems. Tarplee et al. (1971) stated in a study of North Carolina coastal plain streams that 'channelized streams are extremely shallow, have a flat bottom and contain few deep pools, whereas, undisturbed natural streams are deeper and contain numerous deep pools.' Wolf, McMahon and Diggins (1972) concluded from a study of semi-natural and channelized portions of the Missouri River in South Dakota and Iowa, that while the diversity of organisms in both portions is nearly the same, the density of benthic organisms in the semi-natural portion is three times that of the channelized river portion. They also state that the channelized portion is only one-third as wide and has lost 60% of the habitat diversity found in the semi-natural portion. Congdon (1971) studied fish populations in channelized and unchannelized sections of the Chariton River in Missouri and calculated that channelization resulted in an 87% loss in the total standing crop and an 89% reduction in the standing crop of catchable-size fish.

Since channelization alters both the physical and biological nature of a stream, processes such as allochthonous organic matter processing should also be altered. Petersen and Cummins (1974) investigated winter rates of leaf litter weight loss for several tree species constituting detrital input to Augusta Creek in southern Michigan. They reported some differences in allochthonous leaf litter processing from experiments in a heavily wooded head-water area and a less heavily wooded mid-drainage section that is open to solar radiation, warmer, and more autotrophic.

The heterogeneous physical nature of a small stream is easily observed in its characteristic riffle and pool arrangement. Hynes (1970) discusses the relationship between stream current velocity and sediment types. The scouring effect of fast flowing water in riffles leaves only the large particle-sized sediments, while the slow moving water of the pools allows the fine particles to settle out, forming sand and silt beds. The fauna of stony riffles is richer than the fauna of silty pools (O'Connell and Campbell 1953; Mackay and Kalff 1969; Cummins and Lauff 1969; Hynes 1970; Mackay 1972). Since the benthic community of riffles is different than that of pools then processes like allochthonous organic matter breakdown should also differ. Reice (1974) showed that allochthonous leaf litter was broken down less in silt than in other sediments.

The purposes of this study are to test the following hypotheses in a second-order stream of the eastern Kansas Flint Hills:

1. A natural stream in this region is a heterotrophic system, i.e., the photosynthesis/respiration ratio is less than one.
2. A channelized portion of the stream will exhibit autotrophic properties, i.e., the photosynthesis/respiration ratio is greater than one.
3. Leaf litter from different species of trees exhibits different leaching and degradation rates in this stream.
4. Allochthonous organic matter entering the channelized portion of the stream ecosystem will be processed differently than that which enters the natural portion.
5. Allochthonous leaf litter is broken down faster in

riffles than in pools.

DESCRIPTION OF THE STUDY AREA

A series of experiments designed to test these hypotheses was conducted in Lost Creek (Figure 1), located north and east of Belvue in Pottawatomie County at approximately 39°14' north latitude and 96°10' longitude. It is a second-order stream tributary of the Kansas River in the eastern Kansas Flint Hills. First-order stream channels are defined from the streams point of origin to its junction with another first-order channel, resulting in a channel which is defined as being of the second-order. Lost Creek flows about 16 km and drains an area of about 5200 hectares. Discharge averages 0.17 cubic meters per second at the mouth. The physical characteristics are listed in Table 1.

Table 1. Physical characteristics of Lost Creek

	Metric	English
Length	16 km	10 miles
Average flow at mouth	0.17 m^3/sec	6 cfs
Drainage area	52 km^2	20 $mi.^2$
Average slope of stream bed	0.4 %	0.4 %
Average stream width	5.0 m	16 ft
Average stream depth	0.2 m	8 in
Annual precipitation	80 cm	32 in
Water temperature (seasonal variation)	0-33 °C	32-91 °F

Lost Creek arises from springs in upland grasslands and flows through forest and cultivated farmland. Above the Kansas River terraces the stream cuts through limestone layers and exposes glacial till in some of its banks. In this portion it is associated with a riparian forest, but on the terraces it has

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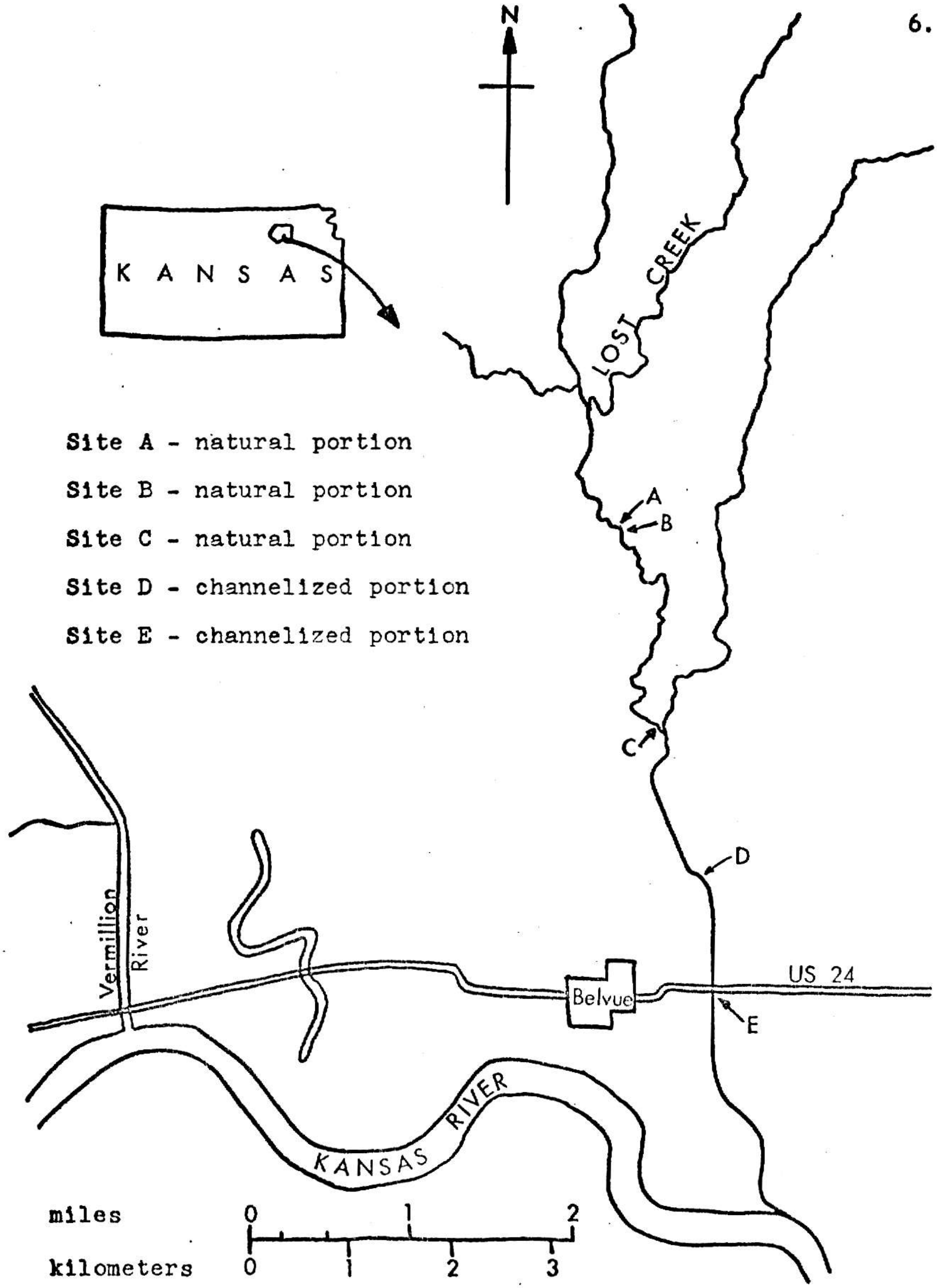

Figure 1: LOST CREEK, POTTAWATOMIE COUNTY, KANSAS
showing location of sampling sites

been channelized for drainage purposes to facilitate agricultural practices and little riparian vegetation is present. In the fall of 1973 and the spring of 1974 several severe rainstorms caused the waters in the creek to rise, resulting in minor flooding. As a result of these floods, which are characteristic of the type of flooding which occurs in the streams of this region, the natural portion of the stream is characterized by a deep bed with banks of various degrees of slope. The channelized downstream portion has an even deeper bed with banks of a fairly uniform 60° slope, which are more stable because the flood waters are channeled swiftly downstream and do not cause extensive erosion of the banks.

Prior to 1846 the Kanza Indians inhabited this region. On June 5th of that year they ceded their claims to this country to the Federal Government who, in turn moved the Pottawatomie tribe to a 900 square mile reservation which included the Lost Creek drainage. The Pottawatomie tribe was removed from this reservation prior to the coming of the Union Pacific Railroad (Kansas Division) in 1866. A railroad station was established at Belvue and the town was laid out by 1871. The pre-channelization condition of Lost Creek on the terraces was one of a shallow stream channel that did not satisfactorily drain the land, which resulted in a marsh-like habitat along its lower reaches. Maps of the region show that this lower reach of Lost Creek has been significantly altered by two major drainage projects, one in the 1890's and another in the 1920's. By 1940 the channelization of the lower portion of the stream was complete, with the last dredging of the channel having occured in the mid-1950's.

MATERIALS AND METHODS

Diurnal Oxygen Curve Analysis

Diurnal oxygen and temperature measurements were made to test the hypothesis that the channelized portion of the stream would exhibit autotrophic conditions and would therefore identify sites for the leaf litter degradation experiment. Hourly estimates of the oxygen concentration of the stream water, using a Yellow Springs Instrument Model 54 Oxygen Meter, were made at four selected sites for a 24-hour period beginning on July 24, 1974 (sites A,B,C, & D in Figure 1). The single station diurnal oxygen curve method of analysis proposed by Odum (1956) was applied. This method is a simplification of the upstream-downstream method discussed at length by Odum (1956) and Owens (1969).

With this method, the diurnal changes in oxygen concentration at a single point in the stream are used to estimate photosynthesis, respiration, and diffusion. The change in the concentration of dissolved oxygen in the stream water per square meter of surface area at the station can be expressed as:

$$Q = P - R + D$$

where Q is the rate of gain or loss of oxygen per square meter of stream surface area, P is the rate of production of oxygen (photosynthesis), R is the rate of oxygen use (respiration), and D is the rate of oxygen gain by diffusion. All of these rates are expressed as g $O_2/m^2/hr$.

The change in the concentration of dissolved oxygen can be measured as:

$$Q = ((C_2 - C_1)/(T_2 - T_1)) \times (\text{depth})$$

where C_1 is the dissolved oxygen concentration (mg/l) at time T_1 and C_2 is the dissolved oxygen concentration at time T_2 and depth is the mean channel depth at the site in meters (Owens 1965).

The oxygen saturation value of the water, given the temperature (C) and the barometric pressure (mm Hg) is:

$$C_{s1} = (468/31.6 + \text{temperature})/(760/\text{pressure})$$

where C_{s1} is the oxygen saturation concentration at time T_1 (Montgomery et al. 1964).

Diffusion is calculated as:

$$D = (f) \times (C_{s1} - C_{s2}).$$

The exchange coefficient (f) is a measure of the rate at which oxygen transfers through a unit surface area, in unit time, when there is a unit deficit of oxygen in the water. It can be calculated using a slope method which plots Q , the change in the concentration of dissolved oxygen, versus $(C_{s1} - C_{s2})$, the saturation deficit, for all the nighttime hours. A least squares method is employed to determine the best linear relationship between the points. Since during the night $Q = D - R$, which can also be written:

$$Q = (f) \times (C_{s1} - C_{s2}) - R$$

the slope of the regression line is the exchange coefficient (f) in m/hr and the y-intercept represents the average nighttime respiration value (Brock 1975).

Respiration was assumed either (1) constant throughout the

24 hour period, or (2) to respond with a temperature coefficient (Q_{10}) of 2.0. The hourly respiration values are then used to calculate photosynthesis during the daylight hours:

$$P = Q + R - D.$$

The P/R ratio (photosynthesis/respiration ratio) was calculated from the diurnal values to determine whether autotrophic or heterotrophic processes were dominant at each site.

Leaf Litter Degradation Analysis

The diurnal oxygen curve experiment identified the establishment of four sampling stations on Lost Creek for this leaf litter degradation experiment. Two stations were located upstream, above the Kansas River terraces, in the natural portion where the riparian forest exists (site C in Figure 1). The other two stations were located downstream, where the stream has been channelized and the vegetation along it has been reduced due to agricultural practices (site E in Figure 1). Both sites consisted of a pool station with a riffle station immediately downstream. The experiment was designed to coincide with the autumnal leaf fall and started at the time when the largest input of allochthonous organic matter occurs (Minshall 1967).

Leaves of hackberry, *Celtis occidentalis* L., and chinquapin oak, *Quercus muehlenbergii* Engelm., were collected just prior to or just after abscission during late September and early October 1974 from trees growing together on the campus of Kansas State University, Manhattan, Kansas. The leaves were randomly arranged so that they did not all face the same direction in packs of 30 leaves for hackberry and 20 leaves for oak, then fastened loosely together with long shank buttoneers. Use of larger leaf packs would have resulted in them being unnaturally cohesive. The packs were air-dried for one week, weighed, and subsamples were oven dried at 50°C for 48 hours to determine the oven-dry initial weight. Samples were then ashed at 550°C for 3 hours to determine the ash-free initial dry weight. The packs, equivalent to oven-dry weight approximately 5 to 6 grams each, were individually lashed loosely to numbered holed bricks with ten pound test monofilament nylon line. The leaf packs were left exposed, instead of enclosed in nylon mesh bags, thus not limiting the natural access to macroscopic benthic fauna or constraining the physical flow of the water (Cummins 1973).

Hackberry leaf packs were placed in the stream on October 8, 1974 and the chinquapin oak leaf packs on October 22, 1974. This closely followed the actual time of entry of these leaves into the stream from the riparian trees located near the sites. The bricks were set in the stream with the leaf packs facing upstream. Random sampling of three replicates at each site was at 24 hours, 1 week, 8 weeks, and 16 weeks. These four sampling times provide for a resonable analysis of leaf pack degradation during the four months following natural leaf entry into the stream (Cummins 1973). Any differences in the leaves as a result of differences between trees from which they were collected or between leaf collection time relative to leaf abscission are equalized during the 24 hour leaching interval (Cummins 1973). The sampled leaf packs were removed from the bricks, sealed in plastic bags and returned to the laboratory and frozen until they were analyzed.

In the laboratory, each leaf pack was rinsed and hand sorted to remove animals and debris. The leaves were dried at 50°C for 48 hours to determine their respective oven-dry final weight. The leaf packs were then ground in a Wiley mill and a sample of ground leaf material from each pack was ashed at 550°C for 3 hours to determine the ash-free final dry weight. The ash-free dry weight measures only the organic portion of the leaf packs and corrects for fine mineral sediments that were not removed during rinsing.

The leaf pack degradation experiment is a completely randomized four factor experiment. The assumptions of randomization are met by the random assignment of leaves to packs and packs to treatments. The total number of treatment combinations was 32 (2 species, 2 stream sites, 2 stations at each site, and 4 sampling times). The total number of samples was 96 (3 replicates of the treatments).

Since there are seven degrees of freedom available for analysis of variance comparison of treatments, seven (1 df) degradation rate comparisons may be made. The selected comparisons of leaf pack weight loss which provide the most information about the differences in leaf pack degradation in the context of this experiment were:

1. Hackberry vs. oak
2. Natural sites vs. channelized sites
3. Riffle stations vs. pool stations
4. Natural riffles vs. channelized riffles
5. Natural pools vs. channelized pools

6. Hackberry in natural sites vs. hackberry in channelized sites.

7. Oak in natural sites vs. oak in channelized sites.

A priori the 0.05 level was chosen for statistical significance.

RESULTS

Diurnal Oxygen Curve Analysis

Table 2 provides a description of the physical parameters of sites A, B, C, and D during the diurnal period July 24, 1974.

Table 2. Physical description of sites A, B, C, & D. 7-24-1974

STATIONS	A	B	C	D
Depth, avg.	.07 m	.04 m	.06 m	.05 m
Depth, max.	.12 m	.05 m	.09 m	.07 m
Width	4.2 m	3.2 m	1.5 m	3.0 m
Velocity	.14 m/sec	.33 m/sec	.46 m/sec	.46 m/sec
Flow	148 m^3/hr	152 m^3/hr	149 m^3/hr	248 m^3/hr
Distance from mouth	8.2 km	8.0 km	5.5 km	3.5 km
Substrate	small pebble and silt	small and medium rock	small and medium rock	small pebble and clay
Shading	semi-shaded	semi-shaded	semi-shaded	not shaded
Dissolved oxygen range	5.5-10.6 mg/l	6.0-11.2 mg/l	6.5-9.8 mg/l	5.6-17.7 mg/l
Water temp. range	21.0-26.3 °C	20.8-26.8 °C	20.9-27.0 °C	20.8-31.2 °C

Site D, the only sampling site in the channelized portion of Lost Creek during this mid-summer experiment, is characterized as being completely open to insolation, having a different substrate, and a greater flow than the three sites in the natural portion.

The data on which the single station diurnal oxygen curve analyses are based is given graphically in Figure 2. The dramatic difference in diurnal changes in oxygen concentration and temperature associated with channelization of Lost Creek is revealed by comparison of the curves from Site D with those from Sites A, B, and C. The oxygen content of the water during the daylight hours is higher at Site D, the maximum value being 17.7 mg/liter as compared to a range of 9.8 to 11.2 mg/liter at the natural sites. The maximum water temperature for Site D is also higher (31.2 °C compared to a range of 26.3 to 27.0 °C at Sites A, B, and C).

Table 3 shows the photosynthetic rate (P), the respiration rate (R), and the P/R ratio for each site.

Table 3. Results of the diurnal oxygen-curve analysis

A. When respiration is assumed constant:

Site	Photosynthesis ($g\ O_2/m^2/day$)	Respiration ($g\ O_2/m^2/day$)	P/R ratio
A	0.83	1.02	0.81
B	0.51	0.54	0.95
C	1.21	1.88	0.64
D	4.16	2.11	1.97

B. When respiration is assumed to have a temperature coefficient (Q_{10}) of 2.0:

Site	Photosynthesis ($g\ O_2/m^2/day$)	Respiration ($g\ O_2/m^2/day$)	P/R ratio
A	0.94	1.13	0.83
B	0.56	0.59	0.96
C	1.42	2.09	0.67
D	4.60	2.55	1.81

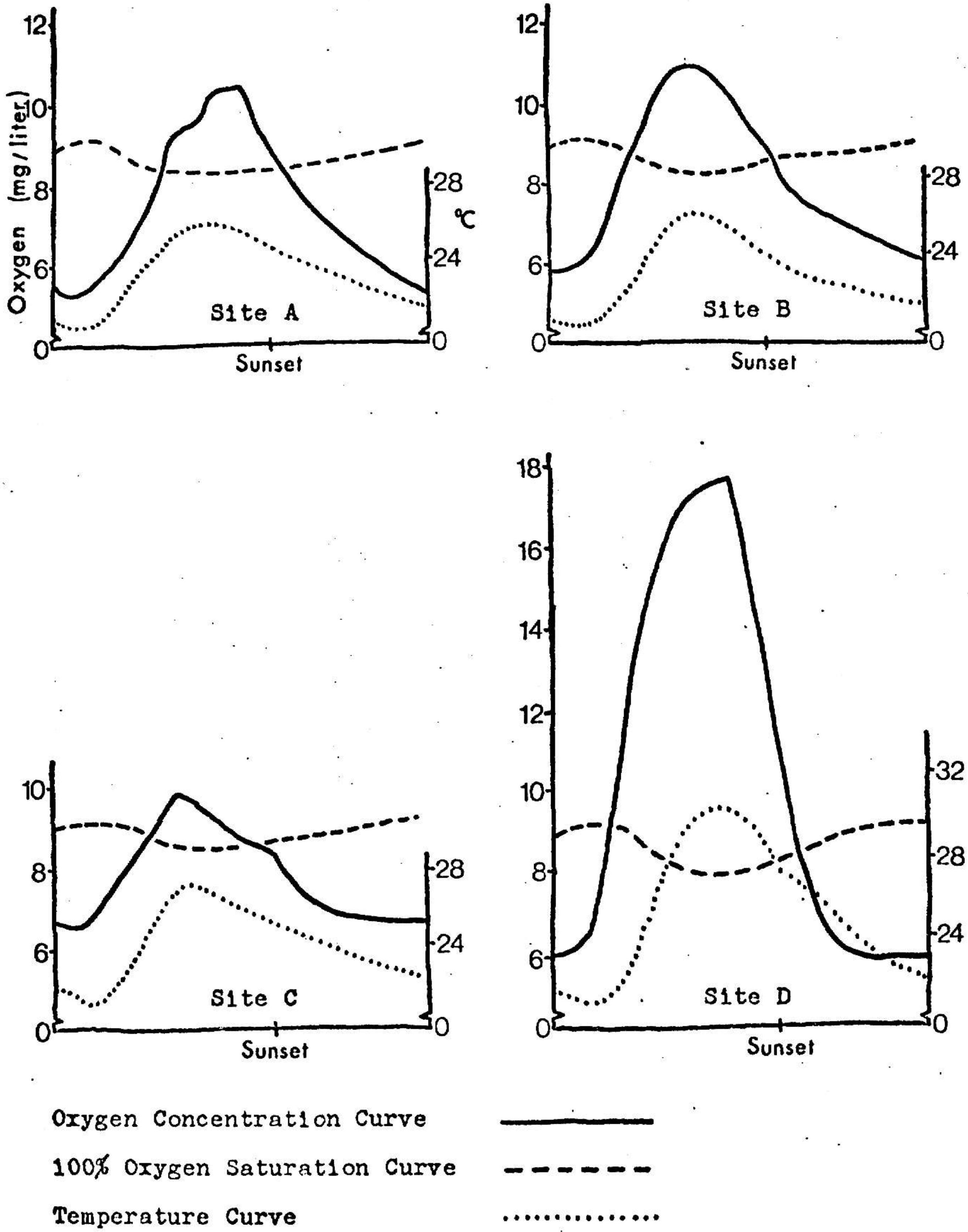

Figure 2: Diurnal curves of dissolved oxygen, oxygen saturation, and temperature values
LOST CREEK July 24-25, 1974

Site D, in the channelized portion of Lost Creek, is autotrophic (P/R ratio >1), whereas all three stations in the natural section have lower primary production estimates than respiration estimates (P/R ratio <1) and are therefore predominantly heterotrophic.

These differences between Site D in the channelized portion and the three sites in the natural portion led to the prediction that leaf litter processing may also differ in the two portions of the stream.

Leaf Litter Degradation Analysis

Leaf packs were located in Lost Creek at natural and channelized sites, (sites C and E respectively in Figure 1), with a station in a pool and another in a riffle immediately downstream at each site. Figure 3 shows the results of this four month leaf pack degradation experiment.

Weight reduction in leaf packs involves two identifiable processes. The first is a rapid 24 hour loss due to leaching. Associated with this, secondly, is a long period of gradual loss due to leaf pack degradation (Nykvist 1959, 1961; Cummins 1973; Petersen and Cummins 1974; Reice 1974).

Table 4 presents the 24 hour leaching loss rate from monospecific leaf packs of *Celtis occidentalis* and *Quercus muehlenbergii* at each station in this experiment.

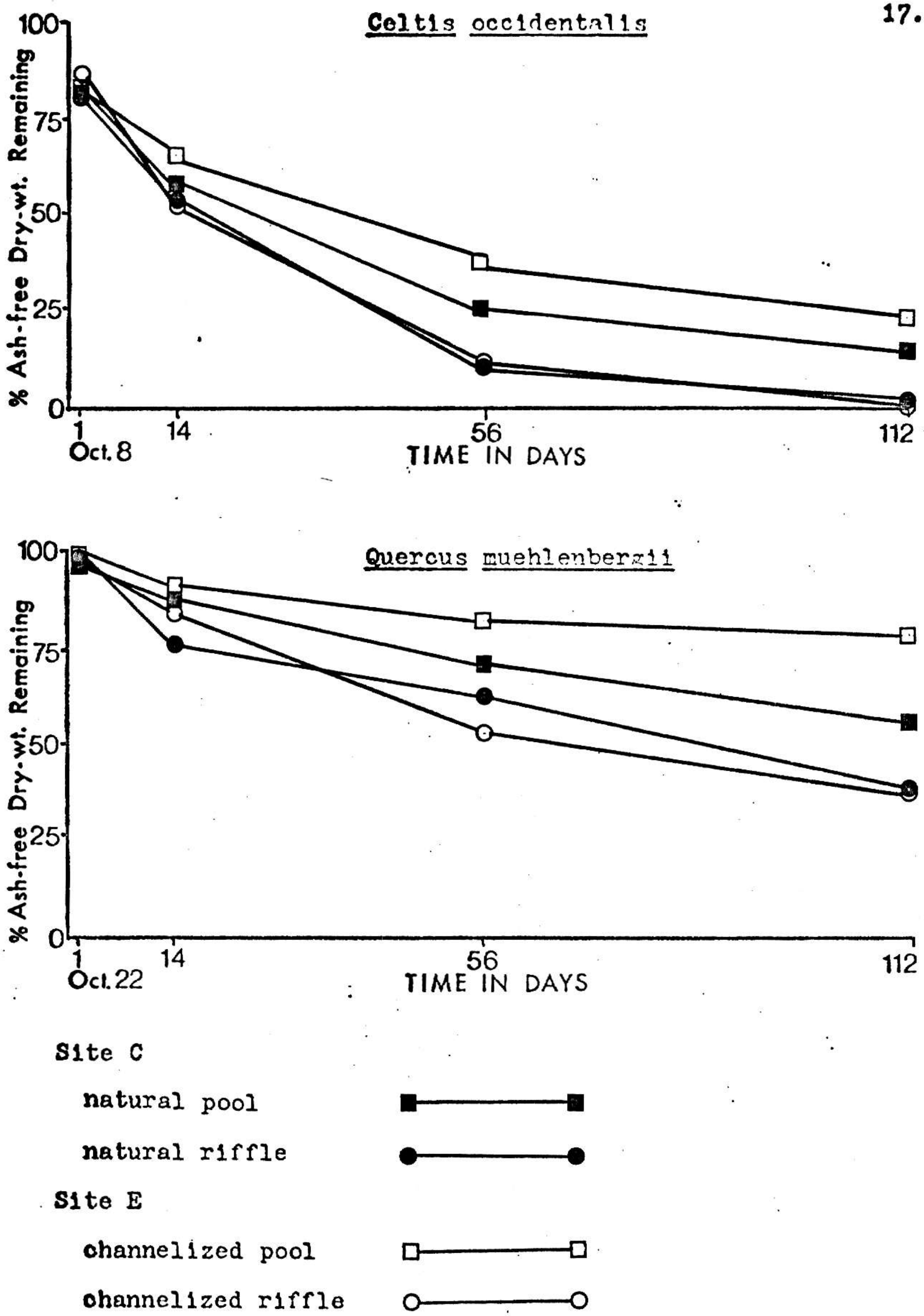

Figure 3: Average Rates of Leaf Litter Degradation
LOST CREEK Fall-Winter 1974-1975

Table 4. Mean 24-hour leaching loss from 3 leaf pack samples per stream station*

Species	Stream Station	Mean Percent Leaching Loss	Standard Error
Celtis occidentalis	Natural Pool	18.56 %	2.50
	Natural Riffle	19.13 %	2.20
	Channelized Pool	15.79 %	0.51
	Channelized Riffle	13.38 %	0.94
Quercus muehlenbergii	Natural Pool	3.05 %	0.58
	Natural Riffle	1.86 %	0.39
	Channelized Pool	1.37 %	0.69
	Channelized Riffle	2.37 %	0.73

* expressed as percent ash-free dry weight loss

Table 5 presents the analysis of variance comparisons of these leaching losses.

Table 5. Leaching loss analysis of variance with seven non-orthogonal comparisons

Sources of Variation	df	S.S.	M.S.	F	Prob.
Treatments	7	1339.2	191.3	37.09	<0.0001
(1) Hackberry vs. Oak	(1)	1270.8	1270.8	246.34	<0.0001
(2) Natural site vs. Channelized site	(1)	35.3	35.3	6.85	0.0187
(3) Riffle stations vs. Pool stations	(1)	1.5	1.5	0.30	0.5923
(4) Natural Pool vs. Channelized Pool	(1)	14.9	14.9	2.88	0.1089
(5) Natural Riffle vs. Channelized Riffle	(1)	20.7	20.7	4.01	0.0624
(6) Hackberry Natural vs. Hackberry Channelized	(1)	54.6	54.6	10.59	0.0050
(7) Oak Natural vs. Oak Channelized	(1)	1.0	1.0	0.20	0.6606
Error	16	82.5	5.2		
Total	23	1421.8			

The average leaching loss from hackberry leaf packs was 16.72 % and from oak leaf packs was 2.16 %. This is a significant difference ($P < .0001$). This measure of leaching loss was significantly higher from leaf packs in the natural site ($P = .0187$) than in the channelized site. Hackberry leaves leached faster in the natural site ($P = .0050$), but oak leaves did not significantly leach faster in the natural site ($P = .6606$). This *in situ* measurement of 24 hour weight loss from the leaf packs is a measurement primarily of leaching loss, but it may also include some measure of leaf pack degradation if larval insect invasion is rapid. Early degradation of *Celtis occidentalis* leaf packs in the natural site may be a source of error in this leaching loss interpretation. Inspection of the data on the number of insect larvae removed from the leaf pack samples showed that invasion was higher in the natural sites after 24 hours.

From the analysis of variance comparisons for the measurements of leaf pack degradation (Table 6) it can be seen that the major cause of weight loss is exposure time ($P < .0001$). This is expected, because more breakdown will occur the longer the leaf packs are left in the stream. Leaf packs made from leaves of the two tree species disappear at different rates ($P < .0001$), with hackberry leaf packs losing weight faster than chinquapin oak leaf packs. After 16 weeks in the stream hackberry leaves had lost 75-100 % of their original weight and oak leaves only 20-65 %. Leaf packs of both species disappear faster in riffles than in pools ($P < .0001$). Hackberry lost 98 % in riffles and 81 % in pools, but oak leaf packs lost only 63 % in riffles and 35 % in the pools after 16 weeks. Leaf packs disappeared more rapidly in the natural stream portion than in

Table 6. Four factor leaf pack degradation analysis of variance with seven non-orthogonal comparisons

Source of Variation	df	S.S.	M.S.	F	Prob
Treatments	31	89883.3	2899.5	95.75	<0.0001
Sampling Units	(7)	30746.3	4392.3	145.05	<0.0001
(1) Hackberry vs. Oak	(1)	25539.1	25539.1	843.37	<0.0001
(2) Natural site vs. Channelized site	(1)	431.8	431.8	14.26	0.0004
(3) Riffle stations vs. Pool stations	(1)	4257.7	4257.7	140.60	<0.0001
(4) Natural Pool vs. Channelized Pool	(1)	884.3	884.3	29.20	<0.0001
(5) Natural Riffle vs. Channelized Riffle	(1)	0.1	0.1	0.004	0.9492
(6) Hackberry Natural vs. Hackberry Channelized	(1)	212.0	212.0	7.00	0.0102
(7) Oak Natural vs. Oak Channelized	(1)	219.8	219.8	7.26	0.0090
Sampling Times	(3)	52545.4	17515.1	41.03	<0.0001
Units x Times Interaction	(21)	6591.6	313.9	10.36	0.0018
Error	64	1938.1	30.3		
Total	95	91821.4			

the channelized portion of the stream (P =.0004). Both hackberry leaf packs (P =.0102) and oak leaf packs (P =.0090) degraded faster in the natural site than in the channelized site. Since there was no significant difference in leaf pack degradation between the natural and the channelized riffles (P =.9492), the main difference between the natural and the channelized portions of the stream is the processing in pools, where the natural stream pool processes the leaf packs faster (P < .0001). Processing in the natural pools was 85 % loss of hackberry and 46 % loss of oak leaf packs, compared to 79 % and only 24 % respectively in the channelized pool after 16 weeks. During the same period of time processing in the natural riffle was

97 % loss of hackberry and 63 % loss of oak, the comparable values in the channelized riffle was 100 % and 64 % for hackberry and oak respectively. Degradation of leaves was invariably faster in riffles than in pools, both in the natural and the channelized portions of the stream.

DISCUSSION

The observation of the dramatic difference in diurnal changes in oxygen concentration and temperature associated with the channelization of Lost Creek is consistent with the hypothesis that removal of the canopy will result in higher temperatures and higher photosynthetic oxygen production.

There are two methods to estimate primary production in flowing waters from the analysis of diurnal fluctuations of dissolved oxygen. They are the upstream-downstream (two station) method and the single station method. The upstream-downstream method measures the rate of change of dissolved-oxygen between two stations. The resulting estimate of primary production is for the stretch of stream between the two stations. The single station method assumes that 'the incoming water has had the same diurnal history as the water just preceding', i.e. 'a second station would reveal a curve identical with that of the first station' (Odum 1956).

A major source of error in the upstream-downstream method is that imposed by irregularities caused by longitudinal mixing. This method assumes that measurements of changes in oxygen concentration and temperature are made in the same water mass.

Longitudinal mixing, however, implies that the further apart the stations the longer it takes water to pass between stations and the lower the probability that the measurements are being made on the same mass of water. Corrections for longitudinal mixing have not been successful (Owens, Edwards and Gibbs 1964).

The upstream-downstream method is advantageous in streams that have long reaches of relative uniformity in which longitudinal mixing is minimized. In small streams with the riffle-pool arrangement the reaches of relative uniformity are short and the use of the single station method is favored. The shorter the reach, the greater the probability that it is experiencing a simultaneous fluctuation in dissolved oxygen concentration. The single station analysis gives estimates of the rates of photosynthesis and respiration that are not necessarily precise or accurate descriptions of the processes in the entire stream. The interpretation is limited to small reaches of the stream, because the diurnal rhythms are measured at a single point. The purpose of this study was to compare the photosynthesis/respiration ratios between natural and channelized sites and not to establish definitive estimates of these processes.

The results of the diurnal oxygen curve analyses support the hypothesis that a natural second-order Kansas Flint Hills stream is a heterotrophic system in mid-summer and that channelization to improve drainage by the stream and removal of the associated forest canopy is accompanied by a shift to an autotrophic condition.

The leaf packs used in this study were analogous to natural autumnal leaf accumulations in streams and allows near natural processing (Petersen and Cummins 1974). The measurement of leaf pack weight loss determined only the removal of leaf material from the pack and not the total degradation of leaf material. Transport of fine particles downstream was not directly measured and no distinction between export and consumption by bacteria and fungi, and/or consumer fauna was possible.

The leaf litter degradation data show that two distinct processes are involved, a rapid early loss of leachable material followed by a gradual loss due to degradation. The measurement of leaching loss is the rate that the leaf pack is losing weight rather than the loss rate of the total leachable component (Petersen and Cummins 1974). Kaushik and Hynes (1971) stated that detrital feeding invertebrates may select leaves due to differential rates of microbial colonization. The measurement of leaching loss in this experiment is compatible with these findings.

Petersen and Cummins (1974) hypothesize that leaves of different tree species may form a continuum of processing rates with new sources of food becoming functionally available to the stream system as slower leaf species degrade. Using their rate classification system Celtis occidentalis would be classified as a 'fast' degrading species, rapidly available as food for the system, while Quercus muehlenbergii is a 'medium' or 'slow' species, which is slower in becoming functionally available as food.

Reice (1974) concluded that stream velocity per se is secondary in leaf litter decomposition to the direct activities of the different communities found in riffle and pool areas. Species diversity was reported by Mackay and Kalff (1969) as being proportional to the relative heterogeneity and stability of the sediments. The greater relative heterogeneity and stability of the sediments may help explain higher leaf litter degradation in riffle areas.

It is significant that naturally occuring leaf packs are absent from the channelized portions of Lost Creek, making it doubtful that degradation normally occurs at those sites.

CONCLUSIONS

These experiments were designed to provide evidence with which questions posed in the introduction could be answered. An interpretation of these analyses as related to those hypotheses is:

Hypothesis	Result	Remarks
A natural stream in the Kansas Flint Hills is a heterotrophic system, ($P/R < 1$).	Accept as true	On July 24, 1974 at the three natural stations tested, this hypothesis was true.
A channelized portion of the stream will exhibit autotrophic properties, ($P/R > 1$).	Accept as true	On July 24, 1974 at the one channelized station tested, this hypothesis was true.

Leaf litter from different species of trees exhibit different leaching and degradation rates in this stream.	Accept as true	Leaching rates are not fully interpretable. The percent loss from <u>Celtis occidentalis</u> leaves in the first 24 hours was greater than that from <u>Quercus muehlenbergii</u>.
Allochthonous organic matter entering the channelized portion of the stream ecosystem will be processed differently than that which enters the natural portion.	Accept as true	Leaf litter degradation is different in natural and channelized pools, but may not be different in riffles. Leaf litter is not naturally present in the channelized portion of the stream.
Allochthonous leaf litter is broken down faster in riffles than in pools.	Accept as true	This hypothesis is true in both channelized and natural portions of the stream.

LITERATURE CITED

Brock, J.T. 1975. Procedure for the estimation of stream etabolism by the two station diel oxygen technique. Unpublished mimeograph.

Congdon, J.C. 1971. Fish populations of channelized and unchannelized sections of the Chariton River, Missouri. In Stream Channelization, A Symposium by North Central Division American Fisheries Society, Special publication #2, December 1971: 52-62.

Cummins, K.W. 1972. Predicting variations in energy flow through a semi-controlled lotic ecosystem. Mich. State Univ. Inst. Water Res. Tech. Rep. 19:1-21.

Cummins, K.W. 1973. A simple bioassay for detrital consumer activity in streams. Unpublished manuscript.

Cummins, K.W., J.J. Klug, R.G. Wetzel, R.C. Petersen, K.F. Suberkropp, B.A. Manny, J.C. Wuycheck, and F.O. Howard. 1972. Organic enrichment with leaf leachate in experimental lotic ecosystems. Bioscience 22:719-722.

Cummins, K.W. and G.H. Lauff. 1969. The influence of substrate particle size on the microdistribution of stream macrobenthos. Hydrobiologia 34:145-181.

Cummins, K.W., R.C. Petersen, F.O. Howard, J.C. Wuycheck, and V.I. Holt. 1973. The utilization of leaf litter by stream detritivores. Ecology 54:336-345.

Egglishaw, H.J. 1964. The distributional relationship between bottom fauna and plant detritus in streams. J. Animal Ecology 33:463-476.

Fisher, S.G. 1971. Annual energy budget of a small forest stream ecosystem, Bear Brook, West Thornton, New Hampshire, Unpublished Ph.D. Dissertation, Dartmouth College, 97 p.

Fisher, S.G. and G.E. Likens. 1972. Stream ecosystem: organic energy budget. Bioscience 22:33-35.

Fisher, S.G. and G.E. Likens. 1973. Energy flow in Bear Brook, New Hampshire: an integrative approach to stream ecosystem metabolism. Ecol. Monogr. 43:421-439.

Hall, C.A.S. 1971. Migration and metabolism in a stream ecosystem. Rpt. Water Resources Res. Inst., Univ. N. Carolina 49:1-243.

Hall, C.A.S. 1972. Migration and metabolism in a temperate stream ecosystem. Ecology 53:585-604.

Hynes, H.B.N. 1963. Imported organic matter and secondary production in streams. Proc. Int. Cong. Zoo. 16:324-329.

Hynes, H.B.N. 1970. The ecology of stream insects. Ann. Rev. Ent. 15:25-42.

Jewell, M.E. 1927. Aquatic biology of the prairie. Ecology 8:289-298.

Kaushik, N.K. and H.B.N. Hynes. 1971. The fate of the dead leaves that fall into streams. Arch. Hydrobiol. 68:465-515.

Mackay, R.J. 1972. The life history and ecology of Pychnopsyche gentilis (McLachlan), P. luculenta (Betten) and P. scabripennis (Rambur), (Trichoptera: Limnephilidae) in West Creek, Mt. St. Hilarie, Quebec. Ph.D. Dissertation, McGill University, Montreal, 103 p.

Mackay, R.J. and J. Kalff. 1969. Seasonal variation in standing crop and species diversity of insect communities in a small Quebec stream. Ecology 50:101-109.

Minshall, G.W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology 48:139-149.

Minshall, G.W. 1968. Community dynamics of the benthic fauna in a woodland springbrook. Hydrobiologia 32:305-339.

Montgomery, H.A.C., N.S. Thom and A. Cockburn. 1964. Determination of dissolved oxygen by the Winkler Method and the solubility of oxygen in pure water and sea water. J. Applied Chem. 14:280-296.

Nelson, D.J. and D.C. Scott. 1962. Role of detritus in the productivity of a rock outcrop community in a Piedmont stream. Limnol Oceanogr. 7:396-413.

Nykvist, N. 1959. Leaching and decomposition of litter. I. Experiments on leaf litter of Fraxinus excelsior. Oikos 10:190-211.

Nykvist, N. 1961. Leaching and decomposition of litter. III. Experiements of leaf litter of Betula verrucosa. Oikos 12:249-263.

O'Connell, T.R. and R.S. Campbell. 1953. The benthos of the Black River and Clearwater Lake, Mo. Univ. Mo. Studies 26:25-41.

Odum, H.T. 1956. Primary production of flowing water. Limnol. Oceanogr. 1:102-117.

Owens, M. 1965. Some factors involved in the use of dissolved-oxygen distributions in streams to determine productivity. Mem. Ist. Ital. Idrobiol. 18 Suppl.:209-224.

Owens, M. 1969. Methods for measuring production: rates in running waters, p. 92-97. In: R.A. Vollenweider (ed.). A manual on methods for measuring primary productivity in aquatic environments. IBP Handbook No. 12, 244 p.

Owens, M., R.W. Edwards, and J.W. Gibbs. 1964. Some reaeration studies in streams. Int. J. Air Water Pollut. 8:469-486.

Petersen, R.C. and K.W. Cummins. 1974. Leaf processing in a woodland stream. Freshwater Biol. 4:343-368.

Reice, S.R. 1974. Environmental patchiness and the breakdown of leaf litter in a woodland stream. Ecology 55:1271-1282.

Tarplee, W.H., Jr., D.E. Louder, and A.J. Weber. 1971. Evaluation of the effects of channelization on fish populations in North Carolina's coastal plain streams. N. Carolina Wildlife Resources Comm., Raleigh, N.C.

Triska, F.J. 1970. Seasonal distribution of aquatic hyphomycetes in relation to the disappearance of leaf litter from a woodland stream. Ph.D. Thesis, Univ. Pittsburgh. 189 p.

Vannote, R.L. 1970. Detrital consumers in natural systmes. In: K.W. Cummins (ed.). The stream ecosystem. AAAS Symp. Tech. Rep. Mich State Univ. Inst. Water Res. 7:20-23.

Wolf, J., J.McMahon and Sister M. Diggins. 1972. Comparison of benthic organisms in semi-natural and channelized portions of the Missouri River. Proc. South Dakota Acad. Science 51: 160-167.

COMPARISONS OF PRIMARY PRODUCTION AND LEAF LITTER DECOMPOSITION IN NATURAL AND CHANNELIZED PORTIONS OF A KANSAS STREAM

by

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Second-order streams that are associated with a riparian forest are generally characterized as heterotrophic systems, dependent upon allochthonous sources of organic matter. It is predicted that the system would shift to an autotrophic condition when channelization results in decreased allochthonous organic matter input and increased solar energy input.

Primary production and leaf pack degradation processes were studied in natural and channelized portions of a second-order Kansas Flint Hills stream. Diurnal oxygen curve analysiis and leaf pack degradation analysis provided the experimental tests.

The channelized portion of the stream had higher photosynthetic rates in mid-summer and lower leaf pack degradation rates during the winter than the more natural portion of the stream. Photosynthesis/respiration ratios were less than one in the natural portion of the stream and greater than one in the channelized portion. *Celtis occidentalis* leaf packs degraded faster than *Quercus muehlenbergii* leaf packs, losing an average of 90% and 50% respectively after 16 weeks in the stream. Degradation was faster in the natural portion than in the channelized portion of the stream.