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LAND-COVER AND COARSE PARTICULATE ORGANIC

INFLUXES TO A SMALL STREAM

presented by

David Craig Mahan

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LAND-COVER AND COARSE PARTICULATE ORGANIC INFLUXES TO A SMALL STREAM

By

David Craig Mahan

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ABSTRACT

LAND-COVER AND COARSE PARTICULATE ORGANIC INFLUXES

TO A SMALL STREAM

By

David Craig Mahan

Effects of variation in streamside vegetation on allochthonous coarse particulate organic (CPOM) influx were determined for Augusta Creek, a third-order stream in a multiple-land-use catchment in southwestern Michigan. Three sampling sections were in common woody riparian associations; another had undergone selective vegetation removal. CPOM contributions were estimated with direct infall and lateral transport samplers for two years.

Significant differences in allochthonous CPOM were found, with litter totals correlated with vegetation and channel width changes. Litterfall was greatest to a first-order reach in dense forest (647 g/m^2) and lowest in the selectively cut section (108 g/m^2). As channel width increased, exogenous CPOM declined on an areal basis, due to decreased bank to channel area ratio and reduced canopy. Since most North American watersheds are multiple-land-use, these results suggest that CPOM influx variations should characterize most headwater streams.

Because of differences in channel width and vegetation, allochthonous CPOM was unevenly distributed among stream-orders. First- and second-orders made up 49% of the stream's surface, yet accounted for over 62% of the litter entering Augusta Creek. These totals underscore the role of small tributaries in CPOM collection and indicate that food resources for coarse particle detritivores may be

inversely correlated with stream-order in response to increased channel width.

Variations in patterns of CPOM influxes may also have a critical influence on in-stream detritus levels. In both years, CPOM totals and types were similar within each location. Leaves (70%) and wood (18%) were the dominant litter types, with more rapidly degraded fruits and herbs found in small amounts. Most litter entered the stream in autumn (70%), however, the remainder was quite evenly distributed among the other seasons, affording a low, but constant influx at these times. Several features of the CPOM influx pattern, its annual similarity, seasonal continuity and predominance of leaves and wood, should lend stability to the detrital resource base in Augusta Creek.

The mode and distance of CPOM transport to the stream are also important, since they determine the area of undisturbed vegetation required for normal litterfall. Most CPOM was transported by direct infall (78%), with low relief affording little lateral movement. Concurrent vegetation analyses indicated that most allochthonous CPOM originated within 10 m of the channel. Nearstream shrubs were particularly important litter sources, as suggested by correlations of shrub basal area and stand density with CPOM influxes. Thus, a 20-m corridor of natural vegetation should maintain typical litterfall levels to this stream.

While the catchment is multiple-land-use, the riparian zone is generally undisturbed. This natural "greenbelt" has probably been a leading factor in the maintenance of normal headwater stream structure and function in Augusta Creek.

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Headwater streams are the primary interface between aquatic and terrestrial environments (Sedell, et al., 1973). Their importance is underlined by the estimate that they account for over 85% of the total length of North American running waters. (Leopold, et al., 1964). Small streams are detritus-based ecosystems (Cummins, 1974; Minshall, 1978), and often depend on particulate organic material (POM; >0.5μm) from the terrestrial environment for a sizable portion of their annual energy budget (Hynes, 1963; Minshall, 1967; Cummins, 1974). In forested catchments, POM, most of which is greater than 1 mm in diameter (CPOM), may account for as much as 50 to 60% of the allochthonous organic influx to these lotic systems (Fisher and Likens, 1973; Sedel, et al., 1974).

Allochthonous CPOM usually takes the form of leaves, wood, fruit and herbaceous matter in forested areas (Gosz, et al., 1972). Autumnal-shed leaves are the dominant litter type in the deciduous forest biome (Kaushilk, 1969; Liston, 1972; Bell and Sipp, 1975), since over 90% of the foliage biomass is typically in the tree layer (Ovington, 1965; Whittaker, 1966; Monk, et al., 1970). While these losses are relatively insignificant to the terrestrial ecosystem (Fisher and Likens, 1973), they represent a tremendous resource to the aquatic system.

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Detrital use by shredders (coarse particle feeders), collectors (fine particle feeders), and the microflora (Suberkropp and Klug, 1976) is the dominant community activity in small, forested streams (Anderson and Cummins, 1979). Shredder life cycles appear to be timed to coincide with normal allochthonous CPOM inputs. Their growth is greatest from late fall to early spring, which corresponds with the maximum availability of deciduous leaf litter (Mackay and Kalff, 1973; Cummins and Klug, 1979). In turn, fine particulate organic material (FPOM) generated by shredders, and microbial and physical processes, may be utilized by collectors (Cummins, 1973). Shredders and collectors may serve as food for community members who function as predators.

The rate of detrital degradation by the biotic community is correlated with several characteristics of the detritus, including nutrient levels (particularly nitrogen - Hynes, 1975), structural components, rate of microbial colonization, and water temperature (Kaushik and Hynes, 1971; Barlocher and Kendrick, 1973; Anderson and Sedell, 1979). Due to seasonal, local and stream-order differences in detrital inputs, production and storage, detritivores in running waters are subject to spatially and temporally variable food resources (Cummins and Klug, 1979). These variations cause important changes in food quality (King, 1978; Ward and Cummins, 1978), which may affect growth rates, duration of life cycles, fecundity and survivorship (Anderson and Cummins, 1979).

The biota of small streams is well suited to make use of external organic influxes which contain a high percentage of CPOM (Cummins, 1974). In fact, up to 80% of this CPOM may be retained long enough to be used by aquatic macro- and microorganisms (Anderson and Sedell, 1979). Because the organisms of headwaters are adapted to these resource conditions (Ross, 1963), allochthonous CPOM differences due to nearstream vegetation changes should be reflected by variations in the species complex of the aquatic community (Vannote and Sweeney, 1980).

The area of the drainage basin which most influences running waters is the riparian zone (Meehan, et al., 1977). The riparian forest maintains normal structure and function of the stream ecosystem, especially due to shading and organic inputs which it provides (Fisher and Likens, 1973). Large wood debris physically stabilizes the channel and, by its retention of POM, increases POM availability to detritivores (Swanson, et al., 1976; Marzolf, 1978). Habitat and cover for aquatic organisms is another function of wood debris (Hynes, 1970; Marzolf, 1978). Riparian vegetation also reduces sediment and nutrient transport to streams (Mannering and Johnson, 1974; Sommers, et al., 1975; Ohlander, 1976) and is important in temperature control (Swiff and Messer, 1971).

When disruption of this streamside vegetation occurs, significant physical, chemical and biological changes in the aquatic environment may result (Karr and Schlosser, 1978). Clearcutting can greatly increase nutrient and temperature ranges in the water (Brown, 1970; Sedell, et al., 1973; Likens, et al., 1977). Serious silt buildup on stream beds, with concommitant reductions in fish and invertebrate populations, has also resulted from poor logging practices (Tebo, 1955; Chapman, 1962). In heavily agriculturalized areas, running water communities have experienced pronounced faunal changes (Thompson and Hunt, 1930; Trautman, 1939; Larimore and Smith, 1963). Urbanization has also affected many drainage basins, and the hydrologic problems which followed have been summarized by Coughlin and Hammer (1973).

Of particular interest to this study are the effects which changes in land-cover within a catchment, especially in the riparian zone, can have on allochthonous CPOM influxes to streams. Differences in detritus within small watercourses have resulted from changes in nearstream woody species and/or their abundance (Minshall, 1968; Liston, 1972). When deciduous woodlands were converted to conifers, differences in food quality of external CPOM occurred (Woodall and Wallace, 1972; Webster and Patten, 1979). More subtle changes in allochthonous influxes may result from natural vegetation variations along a stream due to altitudinal or other environmental differences (Meehan, et al., 1977). Introduction of plant diseases or alien species may also cause changes in organic influx patterns. For example, all the effects of the introduction and management of saltcedar (Tamarix) on the watercourses of the American Southwest will probably never be known (Robinson, 1965; Graf, 1978).

Previous measurements of CPOM influxes to running waters were in single-land-use drainage basins (Fisher and Likens, 1973; Sedell, et al., 1974; McDowell and Fisher, 1976; Webster and Patten, 1979), or at selected locations of one type of riparian vegetation (Otto, 1975; Dawson, 1976; Winterbourn, 1976). However, a majority of contemporary North American catchments encompass a number of land-use and vegetation types. Therefore, these results are of limited use in identifying exogenous CPOM contributions to multiple-land-use drainage basins.

This study was an attempt to more completely describe CPOM influxes. The objectives were: 1) to quantify distributional variation in woody streamside vegetation and its influence on the influx of allochthonous CPOM to a stream; 2) to identify the area of maximal CPOM contribution within the riparian zone; 3) to evaluate CPOM influxes in relation to other ecological measurements (detrital standing crop, P/R ratio, invertebrate standing crop, leaf processing rates). Because Augusta

Creek is a multiple-land-use drainage basin, these results should more accurately identify allochthonous CPOM contributions which are characteristic of most stream systems.

DESCRIPTION OF STUDY AREA

Drainage Basin

Augusta Creek is a small stream located in Barry and Kalamazoo Counties, Michigan (Figure 1). The total length of the watercourse, including its tributaries, is 63.3 Km, encompassed by a catchment of 72.3 Km^2. At its mouth, it is a third-order (Strahler, 1957) stream with an average discharge of 1.20 m^3/s (42.2 cfs) (U.S.G.S., 1978). The stream arises at an elevation of approximately 286.7 m and falls to 241.0 m at its terminus, with an average gradient of 2.0 m/Km (0.2%).

Most of the drainage basin is glacial outwash, with some moraines occurring near Augusta and in the Gilkey Lakes - Fair Lake area of Barry County (Schmalz, 1978). The land is moderate to slightly rolling with slopes usually less than 12%, except in morainic areas. Upland soils are generally well drained, with moderately permeable upper layers overlying permeable sand and gravel to loamy sand subsoils. Areas of organic soils (Adrian and Houghton muck) occupy some extinct glacial lake beds and lowlands along the stream (Konwinski, 1978).

Chemically, one of the most characteristic features of the stream is the high total hardness, averaging nearly 280 mg/l. This is a result of the calcareous sand and gravel which underlies the upper soils. With exception of the rather high levels of inorganic nitrate nitrogen (2-5 mg/l), which enters via the groundwater, other chemicals are present in amounts indicative of few disturbances along the stream (e.g. P as PO_4 of 10-40 μg/l). In a random survey of 10 similar sized tributaries of the Kalamazoo River, Augusta Creek was rated second

Figure 1. Augusta Creek Drainage Basin (cf. Figures 2 and 3 for sampling locations and scale).

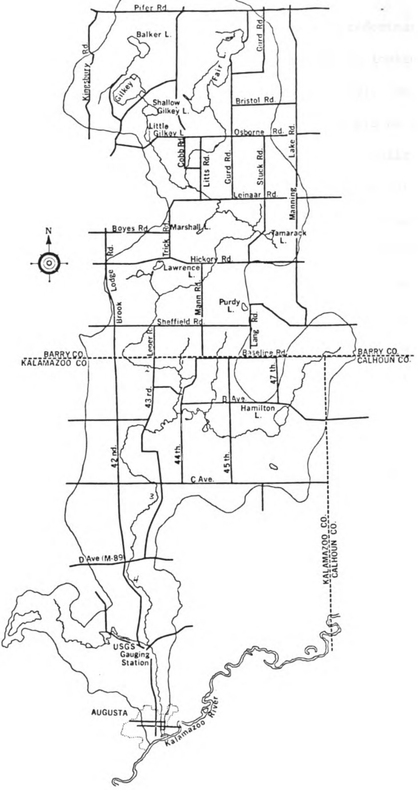
Pifer Rd.
Balker L.
Kingsbury Rd.
Gilkey
Shallow Gilkey L.
Little Gilkey L.
Fair L.
Gurd Rd.
Bristol Rd.
Osborne Rd.
Lake Rd.
Cobb Rd.
Litts Rd.
Gurd Rd.
Stuck Rd.
Leinaar Rd.
Manning
Boyes Rd.
Trick Rd.
Marshall L.
Tamarack L.
N
Hickory Rd.
Lawrence L.
Brook Lodge Rd.
Mann Rd.
Purdy L.
Sheffield Rd.
Lang Rd.
BARRY CO.
KALAMAZOO CO.
Baseline Rd.
BARRY CO.
CALHOUN CO.
47 th.
43 rd.
D Ave.
Hamilton L.
42 nd.
44th.
45 th.
C Ave.
D Ave (M-89)
KALAMAZOO CO.
CALHOUN CO.
USGS Gauging Station
AUGUSTA
Kalamazoo River

Figure 1

in terms of overall water quality (U.S.D.A., 1977).

Prior to 1840 most of the basin was in forest, predominantly the oak-hickory association. Along the stream the southern lowland forest as described by Curtis (1959) was common (Kenoyer, 1930). Most of the uplands were cleared for agricultural purposes in the mid to late 1800's and have remained under this use. The lowland forests, while also cut for lumber in the same period, have regrown in many areas into some resemblance of the stands which once existed (Thompson, 1972). One notable difference in the floodplain forests is the lack of large elms (Ulmus spp.), which were eliminated in the 1950's and 60's by the Dutch elm disease (Thompson, 1972). A characteristic feature along most of the stream's length is a dense layer of streamside shrubs. The woody riparian communities are important in maintaining the relatively natural condition of the stream.

Today the catchment is a multiple-land-use area, about half covered with lakes and natural vegetation such as forests, shrub-lands and marshes, with most of the remaining land in agriculture. Much of the more natural landscape lies adjacent to the stream, serving to buffer the creek from human activities.

The climate of southwestern lower Michigan is primarily continental, although it is somewhat modified by the proximity of Lake Michigan. Since the area is latitudinally at 42° North, strong seasonal temperature contrasts prevail (Eichenlaub 1978). The mean annual temperature of the study area, based on data from 1940-1969, is 9.1°C with a frost free growing season of 151 days. The coldest month of the year is January with a mean of -4.7°C whereas July, the warmest month, averages 22.2°C (Strommen, 1971). Mean annual precipitation is 87.1 cm and is rather evenly distributed throughout the year. June is the wettest month, with 10.5 cm of rain, while February, with a 3.8 cm average, is the driest month. Winds prevail from the southwest and average 16.1 kpm (Strommen, 1971). Because of frequent low pressure systems during the late winter and early spring, this period is often marked by storm activity, much cloudiness and occasional strong winds (Eichenlaub, 1978).

Methods

Stream temperature was monitored weekly at the four sites for two years with Bristol continuous temperature recording instruments (Model 636, Bristol Corporation, Waterburry, CN.). From the recording charts, mean daily, maximum and minimum weekly temperatures were determined. Seasonal degree days were estimated from weekly averages.

Discharge was monitored every Wednesday at the sites for the same time period. Mean velocities were estimated with a Beauvert Midget Current Meter (Nerpic Corporation, Grenoble, France), and cross-sectional areas were determined. Discharge calculations followed the method described by Hynes (1970) and were summarized as seasonal means and extremes.

Sampling Sites

Four locations were chosen along Augusta Creek which represented typical woody riparian plant communities (Figure 2). Each sampling area was named after the landowner (Smith, Nagel) or a nearby landmark (43rd Street, Kellogg Forest). Complete vegetative descriptions will follow in a later section.

The Smith site is typical of most first-order tributaries in the

Figure 2. Augusta Creek sampling sites: 1 = Smith; 2 = 43rd Street; 3 = Nagel; 4 = Kellogg Forest.

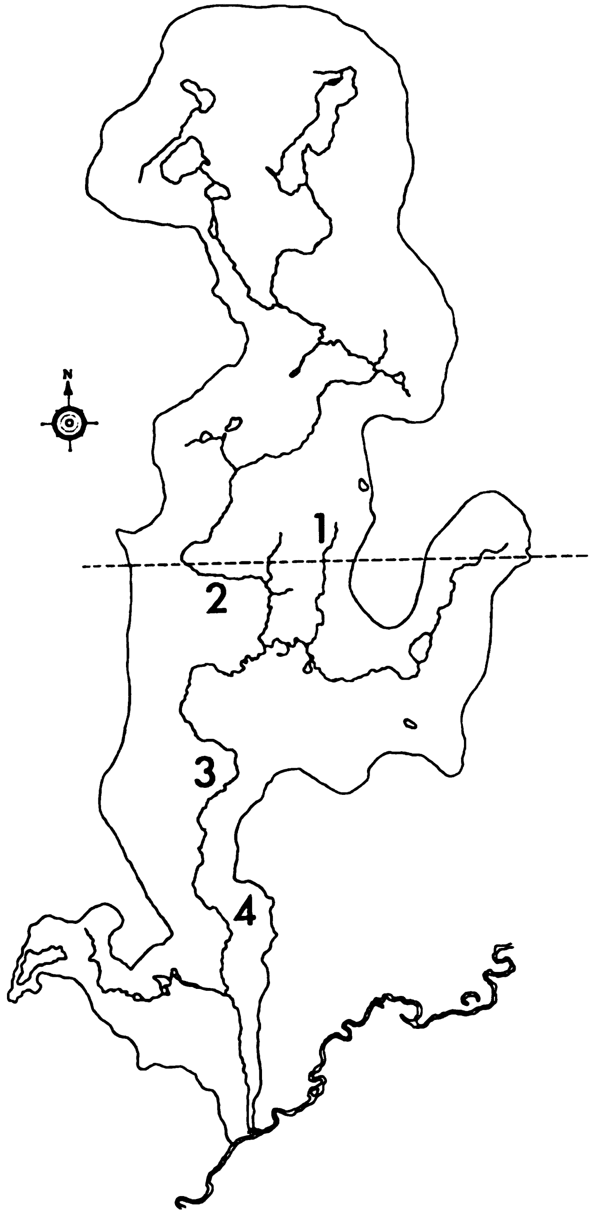

Figure 2

drainage basin. Streamside vegetation is dense, lowland forest, which provides a continuous canopy over the 1.0-2.0 m wide stream. This shade, plus relatively large groundwater contributions, serve to keep the water cooler than the other sites in warm periods and relatively warmer in the winter (Table 1). Although discharge is quite stable, variability was high because its small volume ($\bar{x}$ = .014 m^3/s, .494 cfs) was readily changed by rainstorms and snow melt (Table 2). The upper banks slope at 6% from a narrow floodplain of 4-20 m in width. The floodplain soil is Adrian muck, which is replaced by Kalamazoo sandy loam on the adjacent uplands.

At 43rd Street, a representative shrub-carr vegetation association is found. Highest summer water temperatures were found at this location (Table 1), probably due to its proximity to several lake outflows, and a reduced vegetative canopy upstream from the site. The average elevational gradient was 7%, with one bank being moderately steep (10%). The 15-50 m wide floodplain is Adrian muck, with uplands of Sunfield sandy loam. Augusta Creek is a second-order stream at this location, averaging about 7 m in width and 0.668 m^3/s (23.60 cfs) in discharge (Table 2).

Vegetation at the Nagel site is predominantly shrub-carr, with some lowland forest. It was selected as an example of a disturbed location, since on one side of the channel, only a 5-10-m corridor of natural vegetation has been retained. A lawn, with scattered trees, lies beyond this point. Annual degree days are higher here than the downstream Kellogg Forest site, probably due to a reduction in the canopy (Table 1). Upper bank slope is 2.3%, with a relatively wide (35-170 m) area of Adrian muck along the stream. The creek is

Table 1. Summary of temperature values from Augusta Creek sites, 1976-1977.

Site	Season	Degree Days	$\bar{x}$ Daily Temp. °C	$\bar{x}$ Weekly Temp. °C	S.D.[a]	C.V.[b]	Max. Temp. °C	Min. Temp. °C
	Win	380.3	3.40	23.77	20.5540	86.5	14.0	0.0
	Spr	676.1	8.05	56.34	25.5327	45.3	21.4	0.2
Smith	Sum	1296.2	15.43	108.02	10.8926	100.1	22.0	6.8
1976	Fal	1007.0	11.99	83.92	22.5259	26.8	19.3	1.4
	Annual	3359.6	9.23	64.61	38.3447	59.4	22.0	0.0
	Win	227.8	2.03	14.24	10.7439	75.4	8.7	0.0
	Spr	634.7	7.55	52.89	29.6128	56.0	21.8	0.2
Smith	Sum	1410.2	16.79	117.52	12.4190	105.7	25.6	7.5
1977	Fal	1128.2	13.43	94.02	23.6398	25.1	22.3	6.0
	Annual	3400.9	9.34	65.40	45.4609	69.5	25.6	0.0
	Win	345.5	3.08	21.59	22.5731	104.6	14.4	0.0
	Spr	711.0	8.46	59.25	30.4839	51.4	19.0	0.2
43rd	Sum	1610.7	19.17	134.22	14.7195	109.7	26.2	9.8
1976	Fal	1227.5	14.61	102.29	30.6382	30.0	24.6	3.0
	Annual	3894.7	10.70	74.90	50.5296	67.5	26.2	0.0
	Win	217.9	1.94	13.62	10.5599	77.5	8.3	0.0
	Spr	708.3	8.43	59.02	35.6615	60.4	22.5	0.4
43rd	Sum	1651.7	19.66	137.64	14.5413	105.6	29.6	10.0
1977	Fal	1301.6	15.50	108.47	30.1704	27.8	26.0	7.0
	Annual	3879.5	10.66	74.60	54.5688	73.1	29.6	0.0

[a]S.D. = Standard Deviation.
[b]C.V. = Coefficient of Variation.

Table 1. (cont'd.)

Site	Season	Degree Days	$\bar{x}$ Daily Temp. °C	$\bar{x}$ Weekly Temp. °C	S.D.	C.V.	Max. Temp. °C	Min. Temp °C
	Win	356.0	3.18	22.25	22.8982	102.9	14.4	0.0
	Spr	720.6	8.58	60.05	31.5250	52.5	20.4	0.2
Nagel	Sum	1606.2	19.12	133.85	14.1482	10.6	25.8	12.0
1976	Fal	1233.5	14.68	102.79	28.4030	27.6	23.0	3.2
	Annual	3916.3	10.76	75.31	50.0782	66.5	25.8	0.0
	Win	223.6	2.00	13.98	11.7229	83.8	7.7	0.0
	Spr	697.1	8.30	58.09	35.1629	60.5	20.2	0.2
Nagel	Sum	1618.2	19.26	134.85	18.4910	13.7	28.4	11.4
1977	Fal	1295.9	15.43	107.99	27.5840	25.5	23.9	6.0
	Annual	3834.8	10.54	73.75	53.6460	72.7	28.4	0.0
	Win	390.9	3.49	24.43	23.2869	95.3	14.4	0.0
	Spr	721.8	8.59	60.15	32.0000	53.2	20.2	0.8
Kel. For.	Sum	1579.2	18.80	131.60	13.9800	106.2	25.2	12.0
1976	Fal	1180.6	14.05	98.38	25.7527	26.2	21.8	4.4
	Annual	3872.5	10.64	74.47	47.9776	64.4	25.2	0.0
	Win	240.3	2.14	15.02	12.6348	84.1	8.0	0.0
	Spr.	691.6	8.23	57.63	34.5971	60.0	20.1	0.4
Kel. For.	Sum	1531.1	18.22	127.59	16.5793	129.9	27.2	11.0
1977	Fal	1272.7	15.15	106.06	26.9260	25.4	23.5	6.0
	Annual	3735.7	10.26	71.84	50.8728	70.8	27.2	0.0

Table 2. Summary of discharge values from Augusta Creek sites, 1976-1977.

Site	Season	$\bar{x}$ Daily Discharge m^3/sec	S.D.[a]	C.V.[b]	Max. Dis. m^3/sec	Min. Dis. m^3/sec
	Win	0.012	.0071	59.5	0.038	0.007
	Spr	0.021	.0073	34.5	0.042	0.016
Smith	Sum	0.040	.0720	180.0	0.257	0.009
1976	Fal	0.009	.0047	52.6	0.023	0.006
	Annual	0.020	.0359	181.7	0.257	0.006
	Win	0.006	.0008	13.1	0.008	0.006
	Spr	0.012	.0072	59.9	0.028	0.006
Smith	Sum	0.005	.0008	15.9	0.006	0.004
1977	Fal	0.006	.0016	26.9	0.009	0.004
	Annual	0.007	.0052	73.3	0.028	0.004
	Win	0.842	.2365	28.1	1.640	0.670
	Spr	1.073	.3562	33.2	2.100	0.690
43rd	Sum	0.754	.4197	55.7	1.970	0.440
1976	Fal	0.466	.2249	48.3	1.140	0.340
	Annual	0.789	.3707	47.0	2.100	0.340
	Win	0.5354	.0901	16.8	0.720	0.440
	Spr	0.7950	.2439	30.7	1.140	0.430
43rd	Sum	0.3720	.0531	14.3	0.430	0.290
1977	Fal	0.4910	.1165	23.7	0.700	0.350
	Annual	0.5470	.2030	37.1	1.140	0.290

[a]S.D. = Standard Deviation.
[b]C.V. = Coefficient of Variation.

Table 2. (cont'd.)

Site	Season	$\bar{x}$ Daily Discharge m^3/sec.	S.D.	C.V.	Max. Dis. m^3/sec.	Min. Dis. m^3/sec.
	Win	1.072	.4350	40.3	2.110	0.730
	Spr	1.495	.6734	45.0	3.300	0.970
Nagel	Sum	0.801	.2345	29.3	1.410	0.610
1976	Fal	0.602	.1718	28.5	0.990	0.450
	Annual	0.999	.5269	52.8	3.300	0.450
	Win	0.678	.0838	12.4	0.860	0.580
	Spr	1.092	.3940	36.1	1.720	0.590
Nagel	Sum	0.517	.0943	18.2	0.630	0.400
1977	Fal	0.724	.1220	16.8	0.950	0.550
	Annual	0.747	.2878	38.5	1.720	0.400
	Win	1.349	.5282	39.2	2.610	0.870
	Spr	1.807	.6965	38.6	3.470	1.160
Kel. For.	Sum	0.914	.2657	29.1	1.510	0.640
1976	Fal	0.667	.1946	29.2	1.130	0.500
	Annual	1.197	.6244	52.2	3.470	0.500
	Win	0.743	.1045	14.1	0.869	0.623
	Spr	1.204	.4323	35.9	1.883	0.680
Kel. For.	Sum	0.568	.1091	19.2	0.739	0.430
1977	Fal	0.797	.1327	16.6	1.032	0.649
	Annual	0.822	.3187	38.8	1.883	0.430

third-order at this location, and averages 7 m in width and 0.873 m^3/s (30.83 cfs) in discharge (Table 2).

The Kellogg Forest area illustrates a mature, lowland forest. Because of increased canopy and greater groundwater contributions from nearby porous soils (U.S.D.A., 1979), water temperature is cooler in the summer and warmer in the winter than the upstream Nagel site (Table 1). Bank slope is low (1-2%), with the stream flowing through a 90-115 m wide floodplain of Adrian muck. This third-order channel is 6-10 m wide and has a mean discharge of 1.010 m^3/s (35.65 cfs) (Table 2).

Continuous discharge records have been collected just below the Kellogg Forest since 1964 by the U. S. Geological Survey. Recurrence intervals for maximum and minimum discharge during the study period were estimated from these data. Highest discharge occurred in 1976 with a five-year flood, while 1977 was a time of drought with a 14-year low.

METHODS AND MATERIALS

Land-Cover

Information on land-cover (use) patterns within the Augusta Creek drainage basin was obtained from three sources: aerial photographs; U.S.G.S. 7.5 Minute (1:15,000) Series Topographic Maps; direct observation on the land surface (ground truthing). In order to get a thorough knowledge of the riparian environment I walked along most of the mainstream and the accessible tributaries.

The aerial photography and general information on land-cover was supplied by the Remote Sensing Project of Michigan State University.

This group was contracted to delineate land-cover in the Kalamazoo River Basin (e.g. Richason and Enslin, 1973) as part of a land and water resource planning project by the Soil Conservation Service (U.S.D.A., 1977). Color infrared imagery was obtained for the Augusta Creek basin and predominant land-cover was identified within all six acre sections by using a grid overlay. Coverage types followed the classification scheme used by the Remote Sensing Project.

In addition to the land-use analysis, land-cover was more closely identified within a 100 m wide zone along the stream. The categories were chosen to be compatible with vegetation and organic input analyses which followed.

Vegetation Analyses

Riparian woody vegetation was inventoried by the transect method discussed by Cain and Castro (1959). At each end of the 30-m section of channel where terrestrial particulate organic influxes were monitored, two 10 x 30-m belt transects running perpendicular to the watercourse were established on the two opposing slopes. Gradient of these slopes was determined with a Brunton pocket transit. Within each 300-m^2 transect, three 100-m^2 quadrats were outlined with stakes, representing 0-10-m, 10-20-m and 20-30-m distances from the channel. Therefore, at each sampling location twelve 100-m^2 areas were censused, with four of these quadrats combined for each 10-m distance from the stream. The 100-m^2 samples represent plot sizes normally selected for woody vegetation analyses (Oosting, 1956; Cain and Castro, 1959).

Within the quadrats all woody vegetation greater than 2 cm in diameter at breast height (DBH) was identified, measured to the nearest

0.5 cm and enumerated. With these data, relative density, relative dominance and relative frequency for each species were calculated, and the results combined to determine importance values, following the method described by Cox (1967). Taxonomic nomenclature followed Gleason and Cronquist (1963), with plants classified as tree or shrub based on the criteria of Harlow (1957) and Braun (1961).

CPOM Influx Estimates

The movement of organic material greater than 1 mm in diameter (CPOM) into the stream was estimated at the four sampling locations, within 30-m sections of creek channel. The channel area in m^2 at the sites was: Smith - 53.7; 43rd Street - 213.3; Nagel - 209.1; Kellogg Forest - 250.2. In the designated 30-m section, the sampling apparatus was randomly placed within two distinct zones, depending on sampler type. Two kinds of samplers were used in order to measure CPOM falling directly into the stream and material transported laterally down the bank (Figure 3). The direct litterfall (infall) traps consisted of 1.0 m^2 wooden frames mounted on steel rods and lined with 1 mm mesh nylon bags. They were 0.4 m deep and suspended just above the water level at bankfull discharge. The infall traps were positioned at the stream edge and projected out over the water surface. The lateral transport (lateral) samplers were 0.25 m wide and 0.2 m high. They were three-sided boxes, with corregated steel bottoms, and had wooden covers to eliminate direct fall-in. They were each located on the bank adjacent to an infall trap, just above the bankfull discharge level, with their open ends positioned upslope. Such trap placement assured the collection of CPOM destined to enter the stream along its margin.

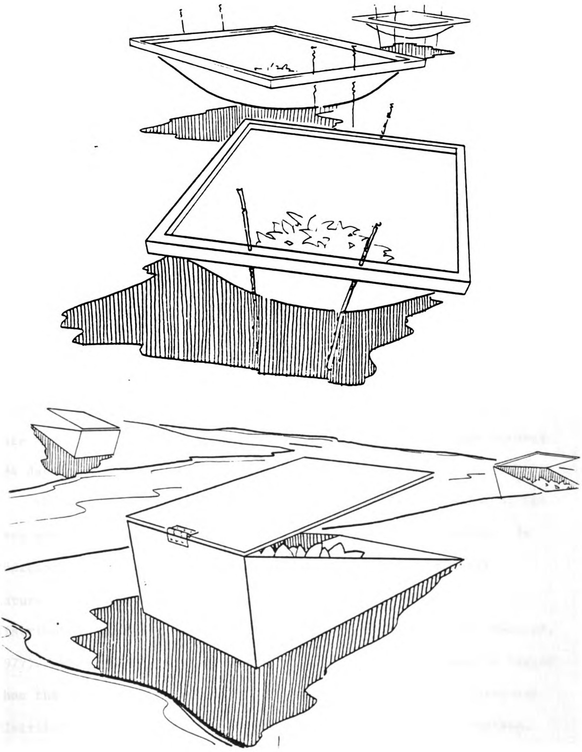

Figure 3. Representation of litterfall samplers, with direct infall traps shown at the top and lateral transport traps shown at the bottom of the figure.

Six sampling units of each type were placed at each site (in 1977 at Smith, n=12), which allowed for six independent litterfall estimates per meter of bank.

Litter collections were made every 28 days, from November 5, 1975 through November 1, 1977. Samples were oven-dried at 50° C, sorted and then weighed to the nearest 0.01 g on a top-loading balance (Mettler P163). Particles were sorted into four categories: leaves; wood (branches and twigs); fruits; herbs (herbaceous plant parts). Leaves and fruits were identified to species (or genera), in order to facilitate comparisons with the vegetation transects. After inspection of the data, the 28-day amounts were combined into four seasonal totals in a manner similar to that of Grigal and Grizzard (1975). Based on input trends, the periods chosen were: winter - November through February (112 days); spring - March to late May (84 days); summer - late May to mid August (84 days); autumn - mid August through October (84 days).

The small number of replications confounded determination of the frequency distribution and statistical analysis of the samples. In addition, variability was inherently large due to the seasonal nature of the litter movement, and the uneven pattern of distribution of the vegetation (Gosz, et al., 1972; Post and delaCruz, 1977). When the raw data were examined, variances were usually larger than the mean and proportional to it, indicating a negative binomial distribution (Elliot, 1971). Following logarithmic transformation, however, variances were still often not homogeneous. Therefore, appropriate nonparametric statistics, as described by Gibbons (1976), were used. These tests are particularly suitable for small sample sizes with contagious distributions, and may be almost as efficient as their parametric equivalents (Sokal and Rohlf, 1969). Initially, the Kruskal - Wallis test, a nonparametric alternative to the one way analysis of variance (Gibbons, 1976), was used. If significant differences in the ranking of totals were detected, the multiple comparison test of Dunn (1964) was utilized in order to detect sample differences. Where correlation analysis between variables was desired, Kendall's coefficient of rank correlation was determined (Sokal and Rohlf, 1969).

RESULTS AND DISCUSSION

Land-Cover

The general pattern of land-cover in the catchment is summarized in Table 3 and shown in Figure 4. Almost half of the area is in a more natural state, being covered with lakes, wetlands or native terrestrial plant communities. Wetlands are predominantly of the type classified as shrub-swamp (Jeglum, et al., 1974) or shrub-carr (Curtis, 1959), with some herbaceous areas (true marsh - Jeglum, et al., 1974). The major associations in the forested areas were previously noted, except for conifer plantings which are found in scattered upland areas. The native stands are all second or third growth, with no virgin remnants.

Most of the remaining land is under agricultural use, underscoring the rural nature of the area. Because of porous soils and moderate slope, there is little prime agricultural land, and pasturing is common (U.S.D.A., 1977). Nevertheless, overgrazing, streambank erosion and

Table 3. Land use patterns in the Augusta Creek Drainage Basin.

Use Categories	Acres	Hectare (Ha)	%	
Water (Lakes and Streams)	504.7	204.2	2.8	
Agriculture			44.7	
Cultivated cropland (row crops, grains)	3495.6	1414.6		19.6
"Permanent" pasture, hay, crop rotation fields (inactive agriculture)	4317.0	1747.0		24.2
Fruits	108.3	43.8		
Tree	39.4	15.9		0.2
Bush and vineyards	68.9	27.9		0.4
Feed lots	49.2	19.9		0.3
Residential	314.9	127.4	1.8	
Transportation, Communication, Utilities	297.0	120.2	1.6	
Commercial (services and institutional)	78.7	31.8	0.4	
Other urban-outdoor recreation, cemetery	131.2	53.1	0.7	
Industrial	19.7	8.0	0.1	
Extractive (gravel pits)	19.7	8.0	0.1	
Woodland			29.3	
Broadleaf forest	2219.2	898.1		12.4
Coniferous	816.7	330.5		4.6
Mixed	464.2	188.0		2.6
Swamp forest (forested wetlands)	1730.8	711.0		9.7
Brush (less than 25% trees)	1053.0	426.1	5.9	
Nonforested Wetlands[a]			12.6	
emergent vegetation	297.1	120.2		1.7
vegetated open water	191.6	77.5		1.1
shrub-carr	1756.8	711.0		9.8
Totals	17,865.4 ($27.9 mi^2$)	7,229.9 ($72.2 km^2$)	100	

[a]In Figure 4, nonforested wetlands are called marshlands.

Figure 4. Land-use in the Augusta Creek Drainage Basin.

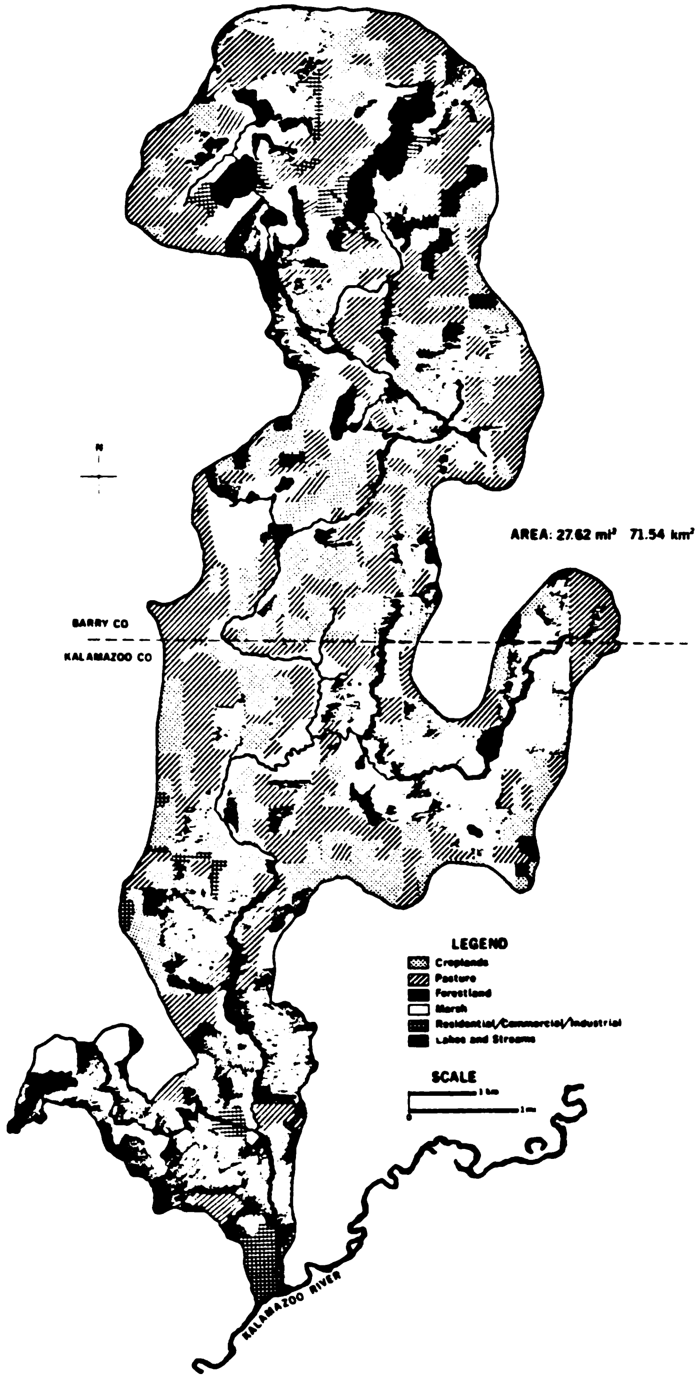
N
AREA: 27.62 mi² 71.54 km²
BARRY CO
KALAMAZOO CO
LEGEND
Croplands
Pasture
Forestland
Marsh
Residential/Commercial/Industrial
Lakes and Streams
SCALE
KALAMAZOO RIVER

Figure 4

livestock wastes do not presently create significant water quality problems along the creek. Areas classified as brush are principally inactive agricultural lands which are being invaded by woody vegetation.

Residential, commercial and industrial uses occupy only an estimated 2.5% of the total land area. However, within a 48 Km radius of the town of Augusta, there are over 250,000 people in the Kalamazoo-Battle Creek metropolitan area (Heller, 1978). If current trends continue (Ross Twp. Planning Com., 1974; Heller, 1978), the impact of these people on the drainage basin in terms of housing, recreation and other uses will increase.

The pattern of land-cover (uses) in the basin is significant (Figure 4). Nearly all of the non-forested wetlands (marshlands in Figure 4), the lowland forests, and roughly one-third of the upland forest stands lie adjacent to the stream. Almost two-thirds of the more natural landscape is closely associated with the creek, which should be a critical factor in maintaining high water quality.

In respect to land-cover, the Augusta Creek basin appears to be fairly typical of most rural basins of similar size in southwestern Michigan (U.S.D.A., 1977). However, profound changes in land use are taking place in many areas of this region (U.S.D.A., 1977; Heller, 1978) and Augusta Creek may one day be affected.

As noted earlier, riparian cover within a 100-m corridor along the stream was determined (Table 4). The general categories are descriptive of vegetation types, exclusive of lakes and human impacted areas, along the watercourse. A 100-m zone was chosen, because it usually included the entire floodplain and some adjoining uplands. By the criteria of Trimble and Sartz (1957), this width was more than

Table 4. Summary of riparian cover along Augusta Creek.

Cover Type	Channel Length (Km)	% of Total
Marsh	3.1	4.9
Shrub-Carr[a c]	15.1	23.9
Shrub-Carr[b c]	6.4	10.1
Lowland Forest[a]	22.5	35.6
Lowland Forest[b]	6.9	10.9
Lake	8.1	12.8
Human Impacted	1.1	1.8
Totals[d]	63.2	100.0

[a]First- and second-order channels.

[b]Third-order channels.

[c]Includes some wet-meadow where shrub cover is less than 25%.

[d]Almost 77% of the length of the stream was first- and second-order.

double the vegetative corridor required for effective treatment of surface runoff when upper bank slopes do not exceed 12%.

The most common streamside plant community was lowland forest (Table 4). This ash-basswood-elm (Fraxinus - Tilia - Ulmus) dominated forest resembles the southern lowland forest described by Curtis (1959). A distinction was made between lowland forest (and shrub-carr) along first- and second-order channels and third-order reaches, in order to estimate their relative abundance in conjunction with allochthonous CPOM measurements. Due to their width, the vegetative canopy was closed over first- and second-order tributaries. Along third-order sections, occasional gaps in vegetative cover were found. Considering that first- and second-order tributaries account for about 77% of the total length of stream (Table 4), the distribution of lowland forest along these smaller channels was almost the same (46%) as that along third-order reaches (47%).

While lowland forests were widespread on river and stream valleys and old glacial lake plains (Stearns and Kobriger, 1975), the extent of their present coverage (47%, Table 4) as compared to presettlement times is not known. The lack of remaining uncut (i.e. virgin) stands probably indicates a reduced contemporary coverage of this vegetation type. Relatively large areas (70%) of the original acreage is still occupied by these forests in Wisconsin, because of frequent flooding and poor drainage (Curtis, 1959).

Shrub-carr was the next most abundant nearstream plant association (Table 4). This type of cover consists of a moderate, to thick growth of one to four meter tall shrubs (Curtis, 1959). The stems of these shrubs are usually clumped, so that a vigorous growth of sedges, grasses, forbs, and low shrubs covers the ground (Stearns and Kobriger, 1975). In some areas, shrub cover may have been sparse enough (<25%) so that a wet-meadow association (Curtis, 1959) existed. The shrub-carr is a common vegetation type along streams of this geographical region (White, 1965), and may be more commonplace today than at time of settlement (Stearns and Kobriger, 1975).

Marshes are not very common plant communities along Augusta Creek. Distinctive marsh flora such as cattails (*Typha* spp.) and arrowheads (*Sagittaria* spp.) are frequent in a narrow zone at the channel margin, but extensive stands of marsh species are not widespread. Most of the estimated riparian marsh occurs in the extensive wetlands between 43rd and 45th Streets which is an extinct glacial lake bed (Figures 1 and 4).

The Augusta Creek catchment contains one of the largest concentrations of lakes in the Kalamazoo River Basin (U.S.D.A., 1977) (Figure 1). Lakes are a prominent feature in the upper part of the drainage basin, where they serve as the primary source of the two first-order tributaries which form the main branch of the stream. Several low-head dams along the creek have created small flooded areas. They are not so deep as to be considered lakes, but rather fall under the vegetative types mentioned above.

The final riparian cover recognized was that land which showed obvious signs of human alteration. This includes bridges and culverts, livestock crossings, channelized sections and residentially influenced areas. Although the entire basin was previously affected by cultural activities, most of it now shows a more natural aspect and was not included in this class (Table 4).

While the Augusta Creek catchment encompassed a number of different land-cover types, a natural assemblage of nearstream vegetation was characteristic along the stream. Especially common were plant communities dominated by lowland species of trees and shrubs. This undisturbed riparian cover should aid in maintaining and protecting the associated aquatic environment (Karr and Schlosser, 1978).

Vegetation Analyses

Woody vegetation was described in order to assist in the analysis of CPOM influxes. Approximately 50 species of trees and shrubs were observed at the sites along Augusta Creek (Table A1). Those types found in the vegetation transects are shown in Tables 5-8, with species listed in descending order of dominance (basal area). Importance values are useful for the descriptive analysis of plant communities (Curtis and McIntosh, 1957; Curtis, 1959), however, in situations where some species differ significantly in size from others, trends in importance value may diverge from density and basal area (Reiners, 1972). In addition, basal area is a fundamental measure of forest structure, roughly paralleling biomass and production (Reiners, 1972) and showing a higher degree of correlation with litterfall (Crosby, 1961; Bray and Gorham, 1964). The transects were oriented perpendicular to the stream channel in order to parallel the major axis of environmental gradients (cf. Bell, 1974; Killingbeck and Wali, 1978). This placement should have given a more complete analysis of stand composition (Bormann, 1953) and, in combination with litterfall measurements, allowed some rough estimate of overland transport of allochthonous particulate organics.

Except for the shrub corridor and black walnut (Juglans nigra) and American elm (Ulmus americana) at the stream margin, the vegetation is largely upland in nature at the Smith site (Table 5). The dominant trees are mesic forest species such as sugar maple (Acer saccharum), black cherry (Prunus serotina) and shagbark hickory (Carya ovata) (Braun, 1961) (Table 9). As indicated by basal coverage and importance values, the leading species from 10-30 m is sugar maple. Stand basal area increased along the topographic gradient back from the stream, while density declined due to the presence of fewer, but larger, individual stems. Based on overstory coverage and composition (Curtis, 1959; Bell and Del Moral, 1977), soil type, and the extent of flooding during extreme discharges, the forest community beyond 10 m from the channel is a young, mesic upland association.

Of the 22 woody species at Smith, 15 were shrubs and seven were trees (Tables 5 and A1). Shrubs formed an important component in all samples, but were greatest in coverage near the stream. Gray dogwood (Cornus racemosa) was the leading woody species in all descriptive categories in the first 10 m, creating an almost inpenetrable thicket. A comparable predominance of dogwoods was noted by Liston (1972) along a small Kentucky stream. Some other dominant shrubs at the Smith site were musclewood (Carpinus caroliniana) on the floodplain, and staghorn sumac (Rhus typhina) on well-drained soils.

At 43rd Street, shrubs accounted for almost 30% of the total basal area, and when all vegetation discriptors are included (i.e. importance value), they were found to be the leading woody components at the site (Table 6). Hawthorn (Crataegus spp.), black willow (Salix nigra) and red-osier dogwood (C. stolonifera), all common along southern Michigan

Table 5. Summary of vegetation transects at the Smith site.

Species	Den. #/10^3m^2	Rel. Den.	Dom. $cm^2/10^3m^2$	Rel. Dom.	Freq.	Rel. Freq.	Imp. Value
0-10m							
Cornus racemosa	820.0	66.9	4088.55	26.7	4	10.5	104.1
Prunus serotina	17.5	1.4	3284.42	21.4	2	5.3	28.1
Juglans nigra	15.0	1.2	2172.60	14.2	3	7.9	23.3
Carpinus caroliniana	60.0	4.9	2050.00	13.4	2	5.3	23.6
Ulmus americana	52.5	4.3	1789.50	11.7	4	10.5	26.5
Populus tremuloides	5.0	0.4	465.82	3.0	2	5.3	8.7
Corylus americana	65.0	5.3	319.15	2.1	2	5.3	12.7
Salix nigra	57.5	4.7	282.32	1.8	2	5.3	11.8
Sambucus canadensis	37.5	3.1	184.12	1.2	3	7.9	12.2
Viburnum lentago	15.0	1.2	143.75	1.0	2	5.3	7.5
Crataegus spp.	15.0	1.2	121.25	0.8	2	5.3	7.3
Acer saccharum	7.5	0.6	96.48	0.6	3	7.9	9.1
Rosa palustris	17.5	1.4	85.92	0.6	2	5.3	7.3
Rhus typhina	17.5	1.4	85.92	0.6	1	2.6	4.6
Lonicera xylosteum	7.5	0.6	73.15	0.5	1	2.6	3.7
Ribes americanum	10.0	0.8	49.10	0.3	2	5.3	6.4
Vitis aestivalis	5.0	0.4	24.55	0.2	1	2.6	3.2
TOTALS	1225.0	99.8	15,316.60	100.1	38	100.2	300.1
10-20m							
Acer saccharum	160.0	21.7	5498.08	27.8	4	14.3	63.8
Prunus serotina	22.5	3.1	5478.65	27.7	3	10.7	41.5
Carya ovata	7.5	1.0	2374.38	12.0	1	3.6	16.6
Rhus typhina	72.5	9.8	1427.53	7.2	1	3.6	20.6
Carpinus caroliniana	32.5	4.4	1416.90	7.2	1	3.6	15.2
Cornus racemosa	227.5	30.8	1292.75	6.5	4	14.3	51.6
Ulmus americana	37.5	5.1	1164.68	5.9	4	14.3	25.3
Ilex verticillata	50.0	6.8	245.50	1.2	1	3.6	11.6
Sambucus canadensis	37.5	5.1	184.13	0.9	1	3.6	9.6
Corylus americana	35.0	4.7	171.85	0.9	2	7.1	12.7
Populus tremuloides	15.0	2.0	133.30	0.7	1	3.6	6.3
Quercus borealis	12.5	1.7	126.43	0.6	1	3.6	5.9
Vitis aestivalis	5.0	0.7	107.00	0.5	1	3.6	4.8
Pyrus malus	10.0	1.4	85.90	0.4	1	3.6	5.4
Salix nigra	7.5	1.0	36.83	0.2	1	3.6	4.8
Crataegus spp.	5.0	0.7	24.55	0.1	1	3.6	4.4
TOTALS	737.5	100.0	19,768.46	99.8	28	100.3	300.1
20-30m							
Acer saccharum	160.0	49.2	9098.98	54.7	4	21.1	125.0
Carya ovata	2.5	0.8	3141.60	18.9	1	5.3	25.0
Prunus serotina	7.5	2.3	1455.93	8.7	2	10.5	21.5
Ulmus americana	32.5	10.0	1198.20	7.2	3	15.8	33.0
Quercus borealis	35.0	10.8	659.75	4.0	2	10.5	25.3
Moras rubra	2.5	0.8	601.33	3.6	1	5.3	9.7
Rhus typhina	57.5	17.7	332.38	2.0	2	10.5	30.2
Cornus racemosa	12.5	3.8	61.38	0.4	1	5.3	9.5
Crataegus spp.	7.5	2.3	36.82	0.2	1	5.3	7.8
Populus tremuloides	2.5	0.8	31.42	0.2	1	5.3	6.3
Corylus americana	5.0	1.5	24.55	0.1	1	5.3	6.9
TOTALS	325.0	100.0	16,642.32	100.0	19	100.2	300.2

Table 6. Summary of vegetation transects at the 43rd Street site.

Species	Den. (per 1000m^2)	Rel. Den.	Dom. (cm^2/1000m^2)	Rel. Dom.	Freq.	Rel. Freq.	Imp. Value
0-10m							
Salix alba	5.0	0.7	5,987	42.2	1	3.7	46.6
Salix nigra	265.0	35.2	1,892	13.4	4	14.8	63.4
Prunus serotina	17.5	2.3	1,680	11.8	2	7.4	21.5
Robinia psuedoacacia	62.5	8.3	1,371	9.7	1	3.7	21.7
Crataegus spp.	45.0	6.0	997	7.0	3	11.1	24.1
Cornus stolonifera	155.0	20.6	784	5.5	3	11.1	37.2
Physocarpus opulifolius	75.0	10.0	385	2.7	2	7.4	20.1
Zanthoxylum americanum	55.0	7.3	299	2.1	2	7.4	16.8
Viburnum lentago	32.5	4.3	267	1.9	2	7.4	13.6
Juglans nigra	7.5	1.0	255	1.8	2	7.4	10.2
Ulmus americana	10.0	1.3	150	1.1	2	7.4	9.8
Rosa palustris	22.5	3.0	110	0.8	3	11.1	14.9
TOTALS	752.5	100.0	14,177	100.0	27	99.9	299.9
10-20m							
Prunus serotina	22.5	3.6	11,385	59.5	3	14.3	77.4
Crataegus spp.	60.0	9.6	2,618	13.7	3	14.3	37.6
Robinia psuedoacacia	185.0	29.7	2,290	12.0	1	4.8	46.5
Cornus stolonifera[a]	125.0	20.0	686	3.6	3	14.3	27.9
Physocarpus opulifolius	90.0	14.4	442	2.3	2	9.5	26.2
Viburnum lentago	47.5	7.6	381	2.0	2	9.5	19.1
Ulmus americana	5.0	0.8	374	2.0	1	4.8	7.6
Juglans nigra	10.0	1.6	364	1.9	2	9.5	13.0
Salix nigra	52.5	8.4	317	1.7	1	4.8	14.9
Malus coronaria	2.5	0.4	142	0.7	1	4.8	5.9
Zanthoxylum americanum	12.5	2.0	61	0.3	1	4.8	7.1
Sambucus canadensis	10.0	1.6	60	0.3	1	4.8	6.7
TOTALS	622.5	99.7	19,120	100.0	21	100.2	299.9
20-30m							
Robinia pseudoacacia	35.0	19.4	1,036	56.7	1	16.7	92.8
Viburnum lentago	50.0	27.8	319	17.5	1	16.7	62.0
Cornus stolonifera[a]	52.5	29.2	263	14.4	2	33.3	76.9
Physocarpus opulifolius	32.5	18.0	160	8.7	1	16.7	43.4
Sambucus canadensis	10.0	5.6	49	2.7	1	16.7	25.0
TOTALS	180.0	100.0	1,827	100.0	6	100.0	300.1

[a]Most Cornus was C. stolonifera, with some scattered C. amomum and C. racemosa also present.

stream borders (Otis, 1950), were the dominant shrubs, and accounted for 82% of the shrub basal area. Vegetation varied in respect to composition and coverage between the sample quadrats, reflecting the properties of the sample location. One transect fell along a moderately steep bank and accounted for most of the black cherry and black locust (Robinia pseudoacacia) found at this site. In comparison to the other locations (Table 10), this site was low in woody species (16), with three of these confined to one transect (steep bank). The other transects were more representative of the shrub-carr vegetation type found along Augusta Creek. Stem density declined markedly back away from the stream, not only due to a decline in shrubs, but also due to the general lack of woody vegetation.

Disturbance at the Nagel site is indicated by its vegetative description (Table 7). Of the 19 species found at Nagel, 11 were trees and nine were shrubs. Most of the woody plants here are characteristic of swamp forests of the region (Otis, 1950; Braun, 1961). Red maple (A. rubrum) and musclewood dominate the trees and shrubs, respectively, together comprising almost 60% of the basal area of the stand (Table 9). Interpretation of the transects was difficult at this location because of disturbance. Basal area was very low, at least in part, because of vegetation removal. For example, only scattered red maples were present in most disturbed area due to selective cutting by the landowner. Shrub cover has been reduced in comparison to the other sites, as shown by the low density and basal coverage, particularly at the creek margin (Table 9).

In the Kellogg Forest, Augusta Creek transverses a well developed (50-60-year-old, Walt Lemmien, pers. com.) bottomland forest. Three

Table 7. Summary of vegetation transects at the Nagel site.

Species	Den. (per 1000m^2)	Rel. Den.	Dom. (cm^2/1000m^2)	Rel. Dom.	Freq.	Rel. Freq.	Imp. Value
0-10m							
Prunus serotina	22.5	15.8	783	40.6	3	17.6	74.0
Salix nigra	42.5	29.8	601	31.1	4	23.5	84.4
Physocarpus opulifolius	25.0	17.5	123	6.4	3	17.6	41.5
Carpinus ccaroliniana	12.5	8.8	122	6.3	1	5.9	21.0
Salix discolor	15.0	10.5	102	5.3	2	11.8	27.6
Cornus racemosa	12.5	8.8	97	5.0	1	5.9	19.7
Fraxinus nigra	2.5	1.8	49	2.5	1	5.9	10.2
Viburnum lentago	5.0	3.5	30	1.6	1	5.9	11.0
Cornus stolonifera[a]	5.0	3.5	25	1.3	1	5.9	10.7
TOTALS	142.5	100.0	1,932	100.1	17	100.0	300.1
10-20m							
Betula lutea	12.5	7.9	1,857	36.3	2	18.2	62.4
Carpinus caroliniana	57.5	36.5	1,724	33.7	1	9.1	79.3
Prunus serotina	2.5	1.6	567	11.1	1	9.1	21.8
Acer rubrum	5.0	3.2	300	5.9	2	18.2	27.3
Moras rubra	27.5	17.5	212	4.1	1	9.1	30.7
Populus tremuloides	35.0	22.2	204	4.0	1	9.1	35.3
Robinia psuedoacacia	2.5	1.6	158	3.1	1	9.1	13.8
Acer saccharum	7.5	4.8	53	1.0	1	9.1	14.9
Physocarpus opulifolius	7.5	4.8	37	0.7	1	9.1	14.6
TOTALS	157.5	100.1	5,112	99.9	11	100.1	300.1
20-30m							
Acer rubrum	17.5	12.5	8,644	70.3	3	25.0	107.8
Tilia americana	2.5	1.8	1,431	11.6	1	8.3	21.7
Carpinus caroliniana	15.0	10.7	554	4.5	1	8.3	23.5
Cornus racemosa	67.5	48.2	492	4.0	2	16.7	68.9
Ulmus americana	5.0	3.6	403	3.3	1	8.3	15.2
Moras rubra	22.5	16.1	269	2.2	1	8.3	26.6
Betula lutea	2.5	1.8	238	1.9	1	8.3	12.0
Prunus avium	2.5	1.8	216	1.8	1	8.3	11.9
Populus tremuloides	5.0	3.0	42	0.3	1	8.3	12.2
TOTALS	140.0	100.1	12,289	99.9	12	99.8	299.8

[a]Includes some C. amomum.

canopy species, basswood (Tilia americana), red ash (Fraxinus pennsylvanica) and black ash (F. nigra), account for almost 90% of the basal area (Tables 8 and 9). The two ashes predominated in the first 20 m while basswood was the leading species in the following 10 m. Total basal area was highest in the 0-10-m plots where red ash attained greatest size. This species is very tolerant to high (>3%) flooding frequencies (Bell, 1974), and was apparently best suited to the environment conditions at streamside. Basswood, which requires more well-drained soils (Otis, 1950), increased as the terrace was approached. The canopy association at the Kellogg Forest site is much like the type dominating the most strongly developed seral stages on the floodplain of Hickory Creek, Illinois (Bell and Del Moral, 1977).

Shrub cover, which constituted less than 10% of total basal coverage, was dominated at this site by musclewood and gray dogwood. Similar reduced shrub cover was noted by Johnson, et al., (1976) under mature, dense-canopied ash-elm floodplain forests along the Missouri River. Species richness among shrubs was high, since they accounted for 15 of the 22 woody species at the site. As with the trees, shrubs were predominantly those types associated with lowland habitats.

When comparing the different locations in this study and other riparian associations, it is important to consider controlling environmental factors. Variations in the structure of stands of streamside vegetation have been associated with various physical gradients, such as relative flooding severity (Bell, 1974; Franz and Bazzaz, 1977), slope aspect and slope angle (Wikum and Wali, 1974; Killingbeck and Wali, 1978). Due to microtopographic changes, floodplains exhibit a flood frequency gradient. Along this gradient

Table 8. Summary of vegetation transects at the Kellogg Forest site.

Species	Den. (per 1000m^2)	Rel. Den.	Dom. (cm^2/1000m^2)	Rel. Dom.	Freq.	Rel. Freq.	Imp. Value
0-10m							
Fraxinus pennsylvanica	37.5	7.2	23,130	63.1	4	11.8	82.1
Tilia americana	10.0	24.0	8,108	22.1	3	8.8	32.8
Fraxinus nigra	25.0	4.8	1,660	4.5	4	11.8	21.1
Populus tremuloides	10.0	1.9	747	2.0	1	2.9	6.8
Cornus racemosa	125.0	24.0	619	1.7	3	8.8	34.5
Viburnum lentago	65.0	12.5	459	1.3	3	8.8	22.6
Rhamnus cathartica	5.0	1.0	454	1.2	1	2.9	5.1
Physocarpus opulifolius	67.5	13.0	342	0.9	2	5.9	19.8
Carpinus caroliniana	27.5	5.3	276	0.8	3	8.8	14.9
Corylus americana	40.0	7.7	208	0.6	3	8.8	17.1
Crataegus spp.	32.5	6.3	160	0.4	1	2.9	9.6
Viburnum opulus	22.5	4.3	149	0.4	1	2.9	7.6
Cornus amomum	25.0	4.8	123	0.3	2	5.9	11.0
Rosa palustris	20.0	3.8	98	0.3	1	2.9	7.0
Ulmus americana	2.5	0.5	110	0.3	1	2.9	3.7
Vitis aestivalis	5.0	1.0	25	0.1	1	2.9	4.0
TOTALS	495.0	100.0	36,668	100.0	34	99.7	299.7
10-20m							
Tilia americana	35.0	8.6	8,807	40.6	3	9.4	58.6
Fraxinus pennsylvanica	42.5	10.4	8,054	37.1	4	12.5	60.0
Fraxinus nigra	40.0	9.8	2,464	11.4	4	12.5	33.7
Carpinus caroliniana	62.5	15.2	572	2.6	3	9.4	27.2
Crataegus spp.	22.5	5.5	546	2.5	1	3.1	11.1
Cornus racemosa	92.5	22.6	466	2.1	4	12.5	37.2
Populus tremuloides	5.0	1.2	190	0.9	2	6.3	8.4
Corylus americana	37.5	9.1	182	0.8	4	12.5	22.3
Viburnum lentago	25.0	6.1	123	0.6	1	3.1	9.8
Ulmus americana	7.5	1.8	94	0.4	1	3.1	5.3
Cornus amomum	15.0	3.7	74	0.3	1	3.1	7.1
Rhamnus catharticus	12.5	3.0	61	0.3	2	6.3	9.6
Prunus virginiana	10.0	2.4	49	0.2	1	3.1	5.7
Sambucus canadensis	2.5	0.6	8	0.0	1	3.1	3.7
TOTALS	410.0	100.0	21,690	99.8	32	100.0	299.8
20-30m							
Tilia americana	65.0	16.6	21,879	67.8	3	10.7	95.1
Pinus strobus	2.5	0.6	2,474	7.7	1	3.6	11.9
Fraxinus nigra	30.0	7.6	2,128	6.6	2	7.1	21.3
Fraxinus pennsylvanica	25.0	6.4	1,717	5.3	4	14.3	26.0
Acer rubrum	10.0	2.5	1,156	3.6	1	3.6	9.7
Populus tremuloides	2.5	0.6	950	2.9	1	3.6	7.1
Carpinus caroliniana	77.5	19.7	896	2.8	4	14.3	36.8
Cornus racemosa	62.5	15.9	310	1.0	3	10.7	27.6
Viburnum lentago	27.5	7.0	192	0.6	1	3.6	11.2
Physocarpus opulifolius	32.5	8.3	160	0.5	1	3.6	12.4
Corylus americana	27.5	7.0	154	0.5	2	7.1	14.6
Crataegus spp.	2.5	0.6	96	0.3	1	3.6	4.5
Prunus serotina	10.0	2.5	49	0.2	1	3.6	6.3
Sambucus canadensis	7.5	1.9	34	0.1	1	3.6	5.6
Cornus amomum	5.0	1.3	25	0.1	1	3.6	5.0
Rhamnus cathartica	5.0	1.3	25	0.1	1	3.6	5.0
TOTALS	395.2	99.8	32,245	100.0	28	100.2	300.1

the best predictor of the field distribution of a species is its relative level of flood tolerance (Gill, 1970; Franz and Bazzaz, 1977). Another consideration important to stand composition is its successional development (Hosner and Minckler, 1963; Bell and Del Moral, 1977). Generally, old, compositionally stable floodplain forests characteristically have the highest basal area and a reduced density (Curtis, 1959; Johnson, et al., 1976).

The coverage of woody vegetation, particularly the tree species, varied considerably between the four Augusta Creek locations. Total tree basal area was highest in the Kellogg Forest by a factor of two, three and five as compared to the Smith, 43rd and Nagel sites, respectively (Table 9; Figure 5). Furthermore, there was little species overlap between the stands. Black cherry was among the leading species at Smith, 43rd and Nagel, while Kellogg Forest and Nagel shared basswood. Even at a location, there were often considerable changes in canopy species along the transect, probably reflecting the topographic gradient back from the channel. Within transect differences were particularly evident at Smith, where the floodplain was most narrow and an upland association prevailed. The other three sampling areas were predominantly lowland communities and reflected their differences in wetness, succession and disturbance.

The most striking vegetational differences were observed at the Nagel and Kellogg Forest sites (Figure 5). Nagel has undergone the most alteration, and all stand descriptors have been greatly reduced (Table 7). The canopy species which remained were representative of the wet-mesic southern lowland forest (Curtis, 1959; Catana, 1967), and indicated lower soil moisture than that at the Kellogg Forest. The

Table 9. Dominant trees and shrubs and quadrat summaries at the sites.

Species	Site	Basal[a] Area	% of Type	% of Stand	Quadrat Totals m²/ha	
Tree Total	Smith	12.9	-	75.0	Trees	
Acer saccharum		4.9	37.9		0-10m	7.8
Prunus serotina		3.4	26.4		10-20m	14.8
Carya ovata		1.8	14.2		20-30m	16.2
Ulmus americana		1.4	10.7			
Tree Total	43rd	8.3	-	71.0		
Prunus serotina		4.4	52.5		0-10m	9.4
Salix alba		2.0	24.0		10-20m	14.4
Robinia pseudoacacia		1.6	18.9		20-30m	1.0
Juglans nigra		0.2	2.5			
Tree Total	Nagel	5.0	-	77.0		
Acer rubrum		3.0	59.8		0-10m	0.8
Betula lutea		0.7	14.0		10-20m	3.1
Tilia americana		0.5	9.6		20-30m	11.0
Prunus serotina		0.4	9.0			
Tree Total	Kel. For.	27.9	-	92.0		
Tilia americana		12.9	46.3		0-10m	33.8
Fraxinus pennsylvanica		11.2	40.2		10-20m	19.6
Fraxinus nigra		2.1	7.5		20-30m	30.4
Pinus strobus		0.8	3.0			
Shrub Total	Smith	4.3	-	25.0	Shrubs	
Cornus racemosa		1.8	42.0		0-10m	7.5
Carpinus caroliniana		1.2	26.8		10-20m	5.0
Rhus typhina		0.6	14.2		20-30m	5.0
Corylus americana		0.2	4.0			
Shrub Total	43rd	3.4	-	29.0		
Crataegus spp.		1.2	35.3		0-10m	4.7
Salix nigra		0.7	21.6		10-20m	4.7
Cornus stolonifera		0.6	16.9		20-30m	0.8
Physocarpus opulifolius		0.3	9.6			
Shrub Total	Nagel	1.5	-	23.0		
Carpinus caroliniana		0.8	54.7		0-10m	1.1
Salix nigra		0.2	13.7		10-20m	2.0
Cornus racemosa		0.2	13.4		20-30m	1.3
Moras rubra		0.2	11.0			
Shrub Total	Kel. For.	2.3	-	8.0		
Carpinus caroliniana		0.6	25.3		0-10m	2.9
Cornus racemosa		0.5	20.2		10-20m	2.1
Viburnum lentago		0.2	11.2		20-30m	1.9
Corylus americana		0.2	7.9			

[a]Mean m^2/ha based on the quadrat totals.

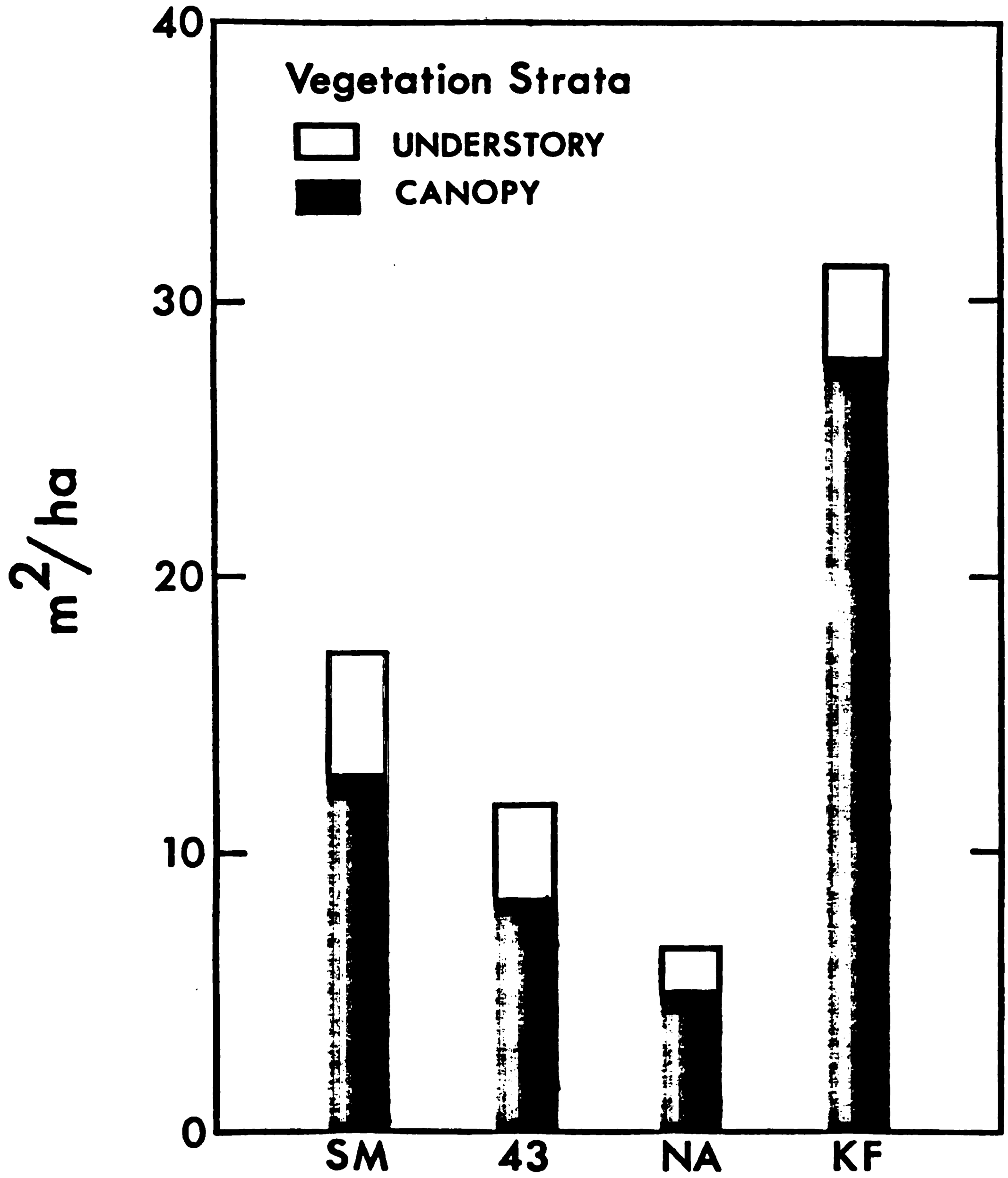

Figure 5. Average basal area of the woody vegetation (>2.0 cm DBH) at the sites.

community in Kellogg Forest experienced more complete inundation (i.e. across the entire transect), and resembles the wet, southern lowland forest type (Curtis, 1959). Because of the most uniform environment along the transects, the Kellogg Forest stand showed the greatest homogeneity in vegetative cover among the sites (Table 8). The increased basal area, reduced density and greater coverage of trees (90%, Table 9) all suggested that this was also the oldest stand surveyed in this study (cf. Johnson, et al., 1976).

Relative to the trees, shrub basal area was much more uniform between locations, and between quadrats within a location (Table 9; Figure 5). Greatest coverage was found at the Smith site, with its young forest association. The lowest total was at Nagel, reflecting its disturbance. Dominant shrub species were similar at the sites, with musclewood and gray dogwood shared among three locations and black willow between two of them. Except for hawthorn at 43rd Street, the shrub layer was largely made up of dogwoods, musclewood and black willow. From other regional studies (White, 1965; Liston, 1972; Sytsema and Pippen, 1980), these are common riparian species.

Shrubs appeared to be well adapted to the edaphic and moisture conditions next to the stream, since they reached their greatest density and basal coverage there (Table 9). Ice damage, erosion, flooding and siltation, which are most prevalent at the channel margin (Sigafoos, 1961; Lindsay, et al., 1961), are normal effects of the hydrologic regime of north-temperate running waters (Cooke and Doornkamp, 1971). These environmental attributes may serve to maintain an earlier successional stand dominated by a few small species (i.e. shrubs - Nicholson and Monk, 1975). Once established, many streambank shrubs form dense colonies from underground, horizontal rootstalks, which tend to persist in a relatively stable condition for a long period of time (White, 1965). Ware and Penfound (1949) noted that shrubs were of primary importance in stabilizing the sides of the channel of an Oklahoma river and, in flood prone areas, these species tended to remain dominant.

Published results from other deciduous, riparian woodlands are quite variable, in part because of the different locations and stand histories, but also due to dissimilar methods of analysis (Table 10). Most investigations of woody vegetation along watercourses have been carried out in areas of relatively undisturbed or mature second growth forests. In addition, as is evident by the paucity of data on basal coverage of understory woody vegetation, these surveys concentrated on canopy species. Such differences make comparisons with the Augusta Creek sites more difficult.

Among riparian forests in the Midwest, the Augusta Creek stands appear to be younger than most which have been studied, but comparable in species numbers (Table 10). Density was very high at the sites in this study, while basal area ranged from moderate (Kellogg Forest) to low (other sites) levels. Because of the relationship between biomass and litterfall (Bray and Gorham, 1964), the age of the stands is important to the level of CPOM influx to the aquatic system. With normal seral development, forests along Augusta Creek should accumulate biomass and decrease in density (Bormann, et al., 1970).

Table 10. A comparison of selected stands of woody riparian vegetation from the Midwestern U.S.A.

Source	Canopy Den.[a]	Canopy B.A.[b]	Understory Den.	Understory B.A.	Total Den.	Total B.A.	Woody Species Trees	Woody Species Shrubs	Woody Species Total	Vegetation Type
Systema & Pippen, 1980	-	-	-	-	6640	35.8	3	8	11	Young, wet, northern forest[c]-MI
Robertson, et al., 1978	416	36.8	548	-	-	-	-	-	62	Old-growth, floodplain forest-IL
Robertson, et al., 1978	603	31.2	836	-	-	-	-	-	59	Secondary floodplain forest-IL
Killingbeck & Wali, 1978	1099	36.3	-	-	-	-	-	-	17	50-70 yr. old floodplain forest-ND
Johnson, et al., 1976	534	28.8	-	-	-	-	6	3	9	Avg. of 34 Missouri R. floodplain stands-NE
Reiners, 1972	3348	25.1	-	-	-	-	14	7	21	Wet, northern forest[c]-MN
Liston, 1972	-	-	-	-	2889	31.1	25	13	38	Avg. of 4 stands along Doe Run-KY
Root, et al., 1971	2071	21.8	-	-	-	-	9	3	12	Secondary floodplain forest-IL
Crites & Ebinger, 1969	614	37.0	-	-	-	-	12	8	20	Avg. of 6 mature floodplain stands-IL
Catana, 1967	377	20.8	-	-	-	-	13	7	20	Wet, northern forest[c]-MI
Lindsey, et al., 1961	250-736	19.1-71.5	-	-	-	-	55+	-	-	Mature stands along Wabash & Tippecanoe Rivers-IN
Cain & Slater, 1948	1470-1870	27.0-34.6	-	-	-	-	10	19	29	Several wet, northern forests[c]-MI
Cain & Penfound, 1936	-	20.9-49.0	-	-	-	-	8	13	21	Red maple dominated stands-NY
Smith	1981	12.9	5636	4.3	7617	17.2	7	15	22	
43rd Street	1203	8.3	3979	3.4	5182	11.7	5	11	16	
Nagel	416	5.0	1049	1.5	1467	6.5	11	8	19	
Kellogg Forest	1190	27.9	3139	2.3	4329	30.2	7	15	22	

[a]Density in #/ha.

[b]Basal area in m^2/ha.

[c]Classification after Curtis (1959).

CPOM Influxes at the Sampling Sites

The total amount of allochthonous CPOM entering the stream per meter of bank at the Smith location was an estimated 714 g/m in 1976 and 547 g/m in 1977 (Table 11). Of these totals, almost 80% was direct litterfall, with the rest downslope movement (Figure 13). Generally, leaves and woody material were the most common components, comprising 80% or more of the litter (Table 12; Figure 6). Fruit totals were especially large in 1977, with this being a good mast year for black walnut (Table A10). The high amount of wood in 1976 (45% of total) resulted from several severe storms in the winter and early spring (Figure 6; Table A2).

Autumn was the season of largest particulate influx and accounted for 52% of the annual total in 1976 and 76% in 1977 (Table 13; Figure 6). Inputs were quite similar in the fall between the two years and were mostly leaves. Consistently lower totals were recorded for the other three seasons, with variability at these times due to influxes of woody material as a result of inclement weather patterns. Except for these wood pulses, winter appears to be the time of lowest litter input to the aquatic system (Table 13).

Leaf inputs were quite constant during the two years, totalling 366 g/m and 348 g/m in 1976 and 1977, respectively (Table 14). An estimated 65% of the incoming leaves were from species characteristic of the medium processing (decomposition rate) range, predominantly black walnut and American elm (Table 20). Species which break down rather rapidly in streams ("fast") averaged 20% of the total and were mostly gray dogwood. "Slow" leaves made up 15% of the leaf litter and were mostly quaking aspen (*Populus tremuloides*).

Table 11. Seasonal and total CPOM influxes at the Augusta Creek sites by sampler types.[a]

		Smith		43rd Street		Nagel		Kellogg Forest	
	Season	Mean[b]	S.E.[c]	Mean	S.E.	Mean	S.E.	Mean	S.E.
	Winter	96.993	66.2104	10.273	2.5901	11.456	2.3397	12.108	2.5647
	Spring	155.642	50.7126	26.651	7.6207	6.656	2.0081	24.746	3.6350
I[d]	Summer	27.028	5.3014	30.778	8.6716	4.161	1.9842	23.880	3.9225
	Fall	275.135	27.8306	146.473	35.3619	52.766	35.0826	203.650	17.9393
	TOTAL	554.798		214.175		75.039		264.384	
1976	Winter	22.575	4.6782	15.302	3.8025	15.773	1.2118	5.694	0.8054
	Spring	26.913	4.4231	20.698	4.1708	12.330	3.3022	3.594	0.7743
L	Summer	10.431	2.7705	18.102	4.0128	13.130	5.7194	6.620	3.4198
	Fall	99.470	11.1544	101.911	25.8806	75.192	44.2272	46.010	2.4276
	TOTAL	159.389		156.013		116.425		61.917	
	GRAND TOTAL	714.187		370.188		191.464		326.301	
	Winter	8.609	1.0031	12.131	4.2450	3.713	0.4011	7.660	1.1736
	Spring	34.750	4.1122	16.690	5.9327	5.606	1.9527	11.046	1.6532
I	Summer	31.060	3.5100	41.323	13.9359	10.601	7.3423	29.356	6.0133
	Fall	350.721	76.4404	211.928	43.7020	54.573	34.0606	280.275	22.4128
	TOTAL	425.140		282.072		74.492		328.337	
1977	Winter	12.336	2.2000	17.720	4.8736	10.273	1.5985	9.186	1.4289
	Spring	36.300	5.4952	40.873	5.8745	36.140	10.0308	8.613	1.3454
L	Summer	7.740	1.7600	32.106	7.5709	8.086	2.2503	3.640	0.2710
	Fall	65.743	9.6057	114.587	35.8021	61.086	34.9621	55.386	7.6991
	TOTAL	122.119		205.286		115.585		76.825	
	GRAND TOTAL	547.259		487.538		190.077		405.162	

[a]The slight discrepancies between the totals in this table and those in Tables 12-17 and A2-A6 are due to rounding errors.

[b]n = 6 for all seasons and sites except for Smith 1977 when n = 12.

[c]S.E. = Standard Error.

[d]I = direct infall in g/m^2; L = lateral transport in g/m.; Total = g/m of bank.

Table 12. Categories of CPOM and total CPOM influxes at the Augusta Creek sites.

	1976				1977			
Category	I[a] (g/m^2)	L (g/m)	Total (g/m of bank)	% of Total	I (g/m^2)	L g/m)	Total (g/m of bank)	% of Total
Smith								
Leaves	269.08	97.33	366.41	51.3	271.65	76.32	347.97	63.6
Woody Matter	272.52	47.75	320.27	44.8	56.96	27.08	84.04	15.4
Fruit	6.40	0.12	6.52	0.9	93.23	1.08	94.31	17.2
Herbaceous Matter	6.80	14.16	20.96	2.9	3.30	17.56	20.86	3.8
Total	554.80	159.36	714.16	99.0	425.14	122.04	547.18	100.0
43rd Street								
Leaves	164.78	94.08	258.86	69.9	229.94	124.68	354.62	72.8
Woody Matter	38.54	36.41	74.95	20.2	38.93	52.00	90.93	18.7
Fruit	4.83	11.14	15.97	4.3	9.65	9.20	18.85	3.9
Herbaceous Matter	6.03	14.38	20.41	5.5	3.54	19.48	23.02	4.7
Total	214.18	156.01	370.19	99.9	282.06	205.36	487.42	100.0
Nagel								
Leaves	50.98	68.53	119.51	62.4	60.71	67.60	128.31	76.5
Woody Matter	5.43	11.77	17.20	9.0	5.87	4.48	10.35	5.4
Fruit	4.32	2.16	6.48	3.4	0.65	-	0.65	0.3
Herbaceous Matter	14.31	33.94	48.25	25.2	7.26	43.48	50.74	26.7
Total	75.04	116.40	191.44	100.0	74.49	115.56	190.05	99.9
Kellogg Forest								
Leaves	212.74	44.91	257.65	79.0	267.42	64.72	332.14	82.0
Woody Matter	44.18	13.43	57.61	17.7	57.59	5.68	63.27	15.6
Fruit	6.42	1.26	7.68	2.4	3.10	0.08	3.18	0.8
Herbaceous Matter	1.05	2.35	3.40	1.0	0.22	6.28	6.50	1.6
Total	264.39	61.95	326.34	100.1	328.33	76.76	405.09	100.0

[a] I = direct infall trap; L = lateral transport trap.

Table 13. Combined seasonal CPOM totals and rates at the Augusta Creek sites.

Site	Season	1976 g/m[a]	1976 %	1976 g/m/day	1977 g/m	1977 %	1977 g/m/day
Smith	Winter	119.55	16.7	1.08	20.93	3.8	0.19
	Spring	182.58	25.6	2.17	71.02	13.0	0.84
	Summer	37.46	5.2	0.45	38.79	7.1	0.46
	Fall	374.58	52.4	4.46	416.44	76.1	4.96
	Total	714.17	99.9	1.96	547.18	100.0	1.50
43rd Street	Winter	25.58	6.9	0.23	29.89	6.1	0.27
	Spring	47.34	12.8	0.56	57.57	11.8	0.68
	Summer	48.89	13.2	0.58	73.43	15.1	0.87
	Fall	248.38	67.1	2.96	326.53	67.0	3.89
	Total	370.19	100.0	1.02	487.42	100.0	1.34
Nagel	Winter	27.23	14.2	0.24	13.99	7.4	0.12
	Spring	18.99	9.9	0.23	41.73	22.0	0.50
	Summer	17.27	9.0	0.20	18.68	9.8	0.22
	Fall	127.95	66.8	1.52	115.65	60.8	1.38
	Total	191.44	99.9	0.52	190.05	100.0	0.52
Kellogg Forest	Winter	17.80	5.4	0.16	16.82	4.2	0.15
	Spring	28.36	8.7	0.34	19.65	4.8	0.23
	Summer	30.52	9.4	0.36	32.99	8.1	0.39
	Fall	249.66	76.5	2.97	335.63	82.8	4.00
	Total	326.34	100.0	0.90	405.09	99.9	1.11

[a]Combination of direct infall and lateral transport results in g/m of bank.

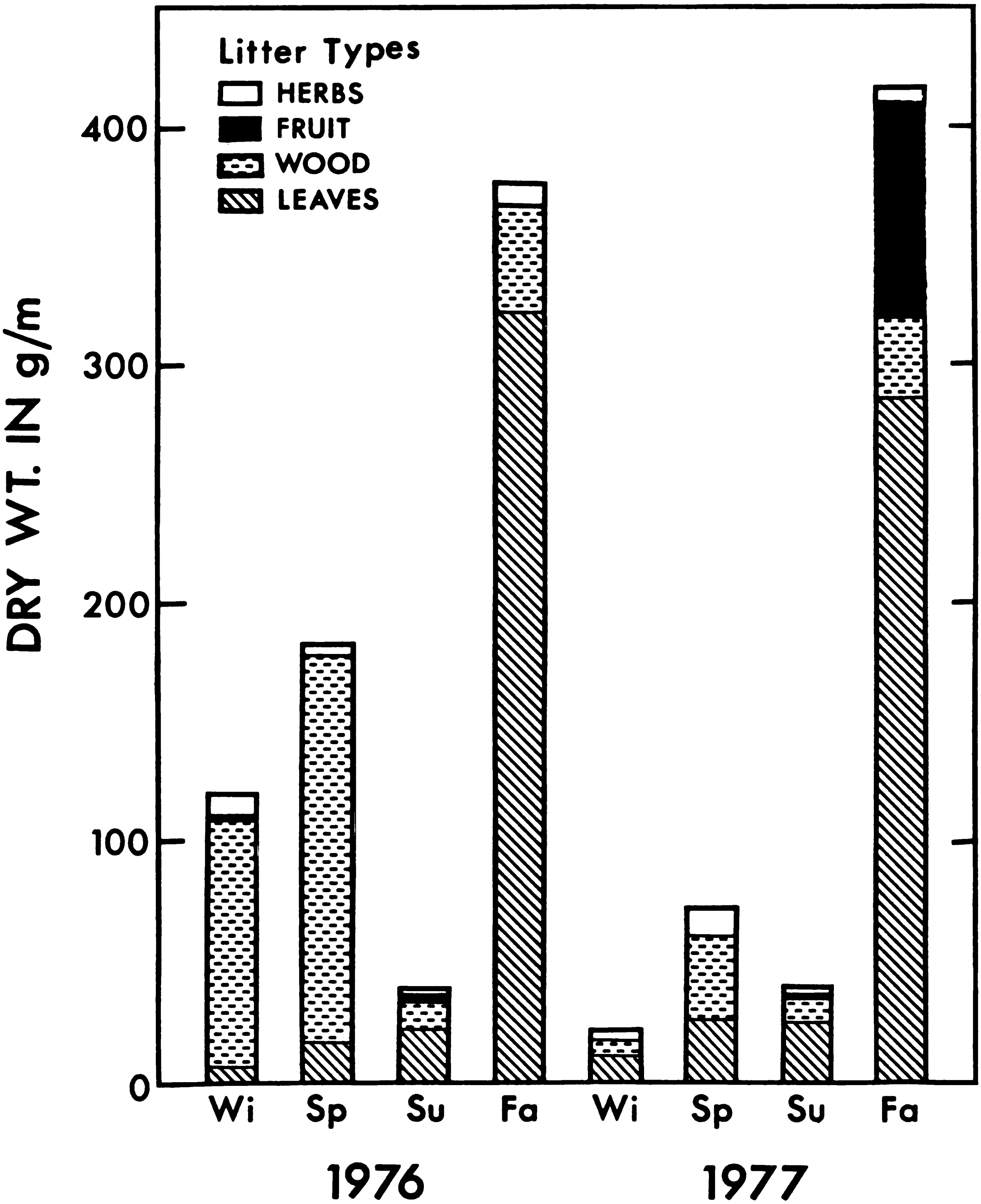

Figure 6. Seasonal CPOM influx in g/m of streambank at the Smith site.

Table 14. Leaf influx at the Smith site.

Species	Yearly total in g/m of stream bank 1976	1977	$\bar{x}$	Cumulative total	Cum. % of total
Juglans nigra	87.82	97.92	92.52	92.52	25.9
Ulmus americana	68.58	60.29	64.44	156.96	43.9
Cornus spp.	67.77	57.46	62.62	219.58	61.5
Populus tremuloides	47.53	47.70	47.62	267.20	74.8
Viburnum lentago	26.81	13.66	20.24	287.44	80.5
Prunus serotina	22.21	17.64	19.92	307.36	86.0
Spring fragments[a]	17.86	16.29	17.08	324.44	90.8
Acer saccharum	11.10	6.02	8.56	333.00	93.2
Quercus borealis	1.66	10.12	5.89	338.89	94.9
Salix nigra	5.10	5.89	5.50	344.39	96.4
Miscellaneous leaves	1.43	9.07	5.25	349.64	97.9
Corylus americana	5.89	3.82	4.86	354.50	99.2
Crataegus spp.	0.80	0.80	0.80		
Populus grandidentata	0.61	0.76	0.68		
Carpinus caroliniana	0.85	0.12	0.48		
Carya ovata	-	0.62	0.31		
Quercus alba	0.14	0.36	0.25		
Rosa palustris	-	0.16	0.08		
Acer saccharinum	0.14	-	0.07		
Fraxinus nigra	0.14	-	0.07		
Totals	366.44	348.00	357.24		

[a]Includes leaf particles, bud scales and reproductive parts which were captured during the spring and early summer.

A comparison of leaf influx (Table 14) with the vegetation transects (Table 5) at this location indicated that relatively small amounts of leaf litter (as CPOM) which entered the stream originated more than 10 m from the channel. The five dominant species (Table 14), which contributed more than 80% by weight to the total, reached their greatest basal area in the 0-10-m vegetational quadrats. Of the upland species at this site, only black cherry was well represented in the leaf input totals. However, it was also of importance in the 0-10-m portion of the riparian zone (Table 5).

CPOM influx to the 43rd Street site was 370 g/m in 1976 and 488 g/m in 1977, a 32% increase in the second year (Table 11). Of these totals, 58% was collected in the infall traps giving a relatively high lateral transport of 42% (Table 12). The four basic litter components were remarkably consistent between the two years in respect to their percentage of total inputs (Table 12). Therefore, the estimated differences in CPOM inputs between 1976 and 1977 involved all litter types, in contrast to the situation previously noted at the Smith site. Leaves (71%) and twigs (19%) were the dominant categories of litter (Figure 7).

Among the seasons, winter, spring and summer CPOM contributions were consistently low and accounted for one-third of the total in both years (Table 13). Inputs were lowest in the winter, averaging only 6.5%, while spring and summer averaged 12% and 14% respectively, of the annual total. Fall influxes were mostly leaves (83%) and twigs (9%), with herbaceous materials and fruits of minor importance (Figure 7). Over the rest of the year, leaves made up 50% of the litter, with twigs and herbs comprising most of the remainder (Table A3). Direct infall was

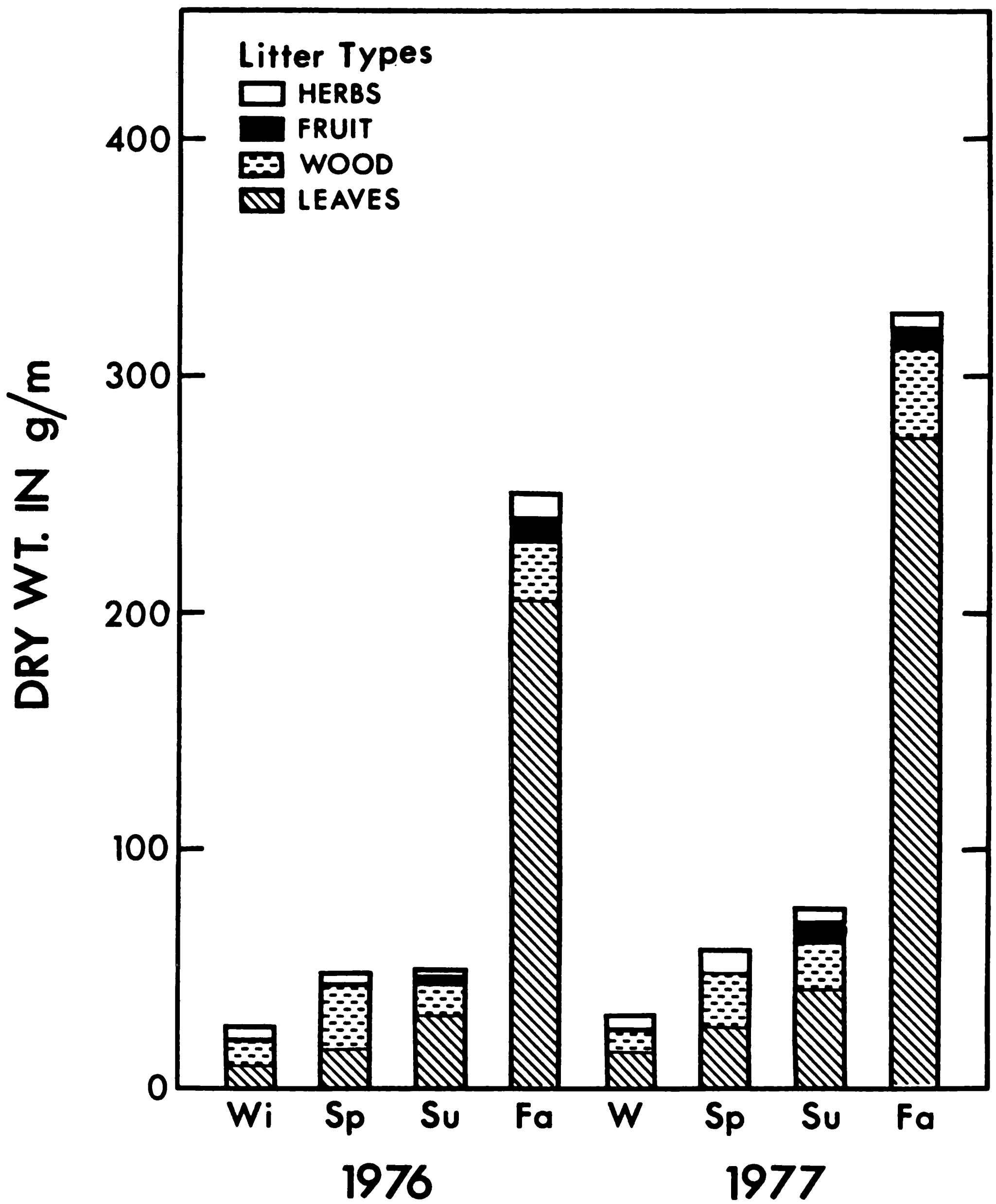

Figure 7. Seasonal CPOM influx in g/m of streambank at the 43rd Street site.

the preponderant input in summer and fall, while lateral transport was higher in the other seasons. Increased lateral transport was especially evident in the early spring following snowmelt and thawing of the ground (Table A6; 24 Mar 76, 23 Mar 77).

Although the total influx of leaves was almost 40% higher in 1977, the percentages by processing types were quite similar in each year (Tables 15 and 20). Leaves were commonly of the medium processing rate, particularly black willow, black cherry and nannyberry (*Viburnum lentago*). "Fast" leaves were mostly dogwoods, prickly ash (*Zanthoxylum americana*) and black locust, while the most abundant "slow" leaves were hawthorns.

Most CPOM reaching the stream probably originated within 20 m of the channel, since only 5% of the basal area of woody plants was found beyond that point (Table 6). The major leaf input was black willow (Table 15), the dominant shrub at the channel margin. Of the other abundant leaf inputs, several reached their greatest basal coverage in the 10-20-m quadrats (Table 6 - black cherry, hawthorn). While the 0-10-m portion of the vegetation corridor was probably the major litter contributor, this cannot be stated conclusively due to the overlap in riparian species in the 0-10-m and 10-20-m quadrats.

The annual estimate of allochthonous CPOM at the Nagel site was almost identical over the two years (Table 11). The amounts within the different categories of litter were quite similar, with most of the total made up of leaves (65%) and herbaceous material (26%) (Table 12). A distinctive characteristic of this location was the high level of lateral transport, accounting for over 60% of the annual sum.

Autumn was the time of greatest particulate organic movement into

Table 15. Leaf influx at the 43rd Street site.

Species	Yearly total in g/m of stream bank 1976	1977	$\bar{x}$	Cumulative total	Cum. % of total
Salix nigra	53.67	61.69	57.68	57.68	18.8
Prunus serotina	47.15	51.82	49.48	107.16	34.9
Crataegus spp.	38.83	52.86	45.84	153.00	49.9
Cornus spp.	20.61	46.76	33.68	186.68	60.7
Viburnum lentago	28.79	22.55	25.67	212.35	69.2
Spring fragments[a]	24.65	20.51	22.58	234.93	76.6
Zanthoxylum americanum	10.98	17.96	14.47	249.40	81.3
Robinia psuedoacacia	8.76	19.42	14.09	263.49	85.9
Juglans nigra	10.28	16.71	13.50	276.99	90.9
Rosa palustris	5.83	10.56	8.20	285.19	93.0
Ulmus americana	3.20	11.72	7.46	292.65	95.4
Miscellaneous leaves	3.16	6.22	4.69	297.34	96.9
Physocarpus opulifolius	1.53	7.48	4.50	301.84	98.4
Malus coronaria	0.06	3.06	1.56		
Fraxinus spp.	0.57	2.27	1.42		
Quercus borealis	0.72	1.68	1.20		
Corylus americana	-	0.86	0.43		
Hammamelis virginiana	0.04	0.48	0.26		
Totals	258.83	354.61	306.72		

[a]Includes leaf particles, bud scales and reproductive parts which were captured during the spring and early summer.

the stream, averaging 64% of the whole. Mean inputs for the other seasons ranged from 9 to 16% of annual totals, with summer the lowest, winter intermediate and spring highest (Table 13; Figure 8). Though leaves were almost 80% of the autumn litter, they accounted for only 27 to 45% during the rest of the year (Tables 12 and A4). Herbaceous material averaged 40% of all CPOM inputs over the non-fall seasons. Generally, lateral transport was higher than direct infall, even in the autumn when litterfall was maximal.

Rapidly processed leaves were the most abundant type at the Nagel location, averaging 60% of total leaf litter (Tables 16 and 20). These were mostly basswood, with some dogwood and swamp rose (Rosa palustris). "Medium" leaves, mainly black willow and nannyberry, averaged 28% of the leaf sum. There were only two species contributing measureable "slow" leaves, red oak (Quercus borealis) and quaking aspen (Populus tremuloides).

Due to the vegetational pattern at this site, the transects (Table 7) do not readily identify the riparian area which contributed CPOM. Leaf litter inputs were relatively meager at Nagel as a result of reduced woody vegetation. Because of this, one clump of basswood located next to trap number 4 contributed almost 50% of the leaf total. Since these trees were located in the middle of the 30-m sampling section they were not included in the vegetation transects. Except for basswood, the dominant woody species in the 10-20-m and 20-30-m quadrats (Table 7) are poorly represented in the litter data (Tables 16 and 20). Thus, it was likely that most leaf influxes came from the 0-10-m zone.

In the Kellogg Forest, the annual litter input was 326 g/m in 1976

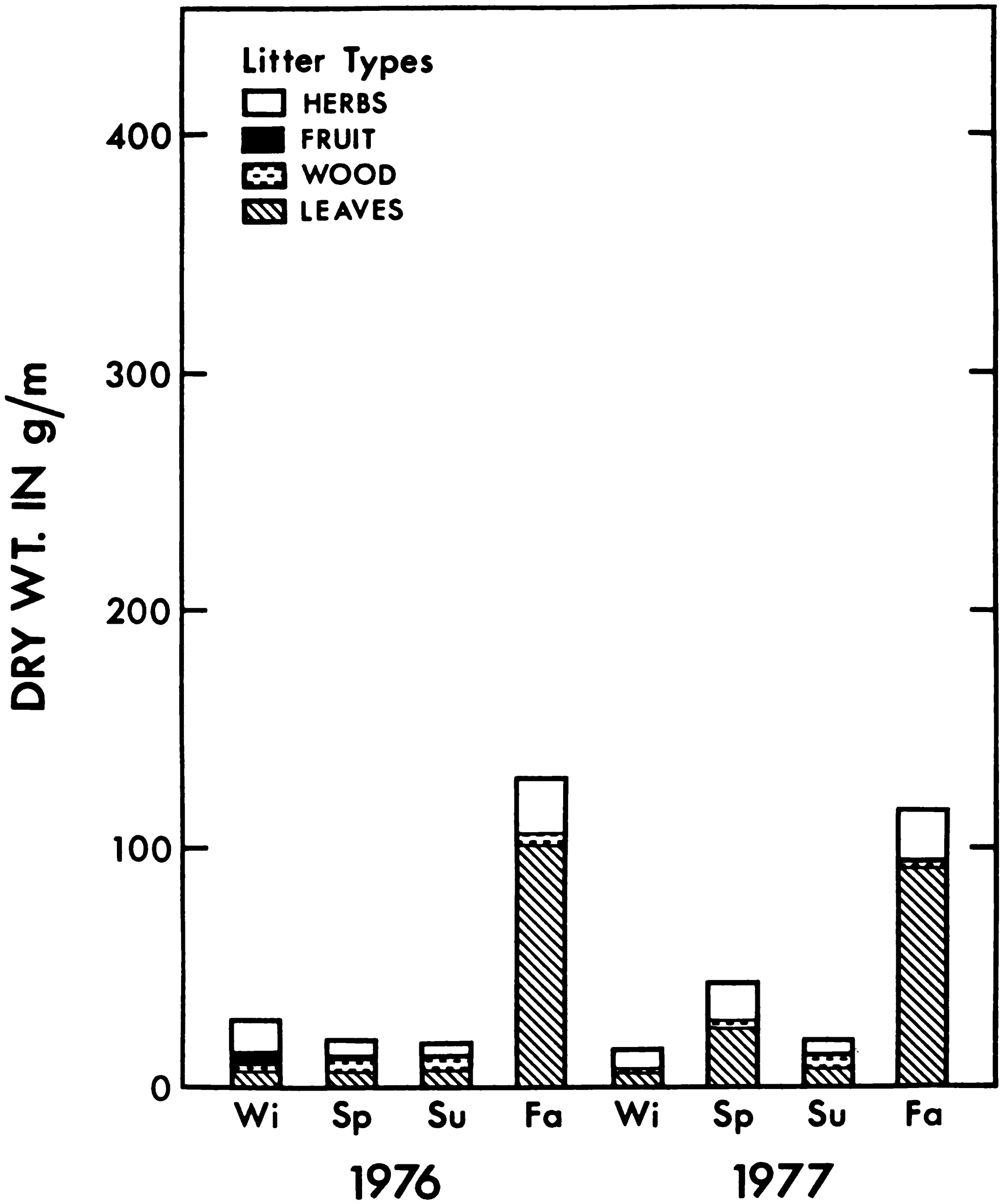

Figure 8. Seasonal CPOM influx in g/m of streambank at the Nagel site.

Table 16. Leaf influx at the Nagel site.

Species	Yearly total in g/m of stream bank 1976	1977	$\bar{x}$	Cumulative total	Cum. % of total
Tilia americana	73.28	44.99	59.14	59.14	47.7
Viburnum lentago	4.40	23.22	13.81	72.95	58.9
Salix nigra	14.65	10.95	12.80	85.75	69.2
Quercus borealis	5.38	16.51	10.94	96.69	78.0
Cornus spp.	7.27	11.63	9.45	106.14	85.6
Rosa palustris	4.41	8.08	6.24	112.38	90.7
Spring fragments[a]	2.37	3.32	2.84	115.22	93.0
Populus tremuloides	1.96	2.39	2.17	117.39	94.7
Miscellaneous leaves	1.57	1.24	1.40	118.79	95.8
Acer rubrum	1.16	3.44	2.30	121.09	97.7
Physocarpus opulifolius	1.55	0.83	1.19	122.28	98.7
Fraxinus nigra	0.15	0.93	.54		
Acer saccharum	0.54	0.12	.33		
Ulmus americana	0.15	0.47	.31		
Carpinus caroliniana	0.57	0.03	.30		
Prunus serotina	0.19	0.15	.17		
Totals	119.60	128.30	123.93		

[a]Includes leaf particles, bud scales and reproductive parts which were captured during the spring and early summer.

and increased 24% to 405 g/m in 1977 (Table 11). Of these totals the majority (81%) was direct infall. The yearly sums were mostly leaves and woody material which averaged 82% and 17% of the whole (Table 12, Figure 9).

Of the annual CPOM contributions, 80% entered in the fall. The remainder of the year received fairly constant, but low amounts, which were most reduced (4%) in the winter (Table 13). Lateral transport exceeded direct infall in all seasons except autumn, especially in the winter. Leaves were the dominant litter type in the fall period in 1976, and in 1977, throughout the entire year (Table A5; Figure 8). Woody materials were the leading litter component in winter and spring of 1976, probably as a consequence of severe weather conditions. Fruits were especially abundant in the 1976 winter samples (Figure 7) and were mostly ash samaras (Table A10).

Leaf litter collections in the Kellogg Forest were usually "fast" types like ash and dogwood, which together accounted for 70% of the total (Table 17). "Slow" leaves were almost nonexistent (30%), while "medium" species, dominated by nannyberry, were moderately represented (19%) (Table 20).

The vegetation analysis (Table 8) rather clearly indicates the origin of the leaf litter. Green and black ash accounted for over 50% of the leaf input sum and made up almost 70% of the basal area in the 0-10-m quadrats. The basal coverage of these two species decreased by 60% the next 10 m and by over 90% beyond 20 m from the stream. Basswood showed an opposite trend in ground cover and averaged only 5% of the leaf total. Dogwoods, nannyberry and swamp rose reached their greatest basal area at streamside and were important leaf contributors

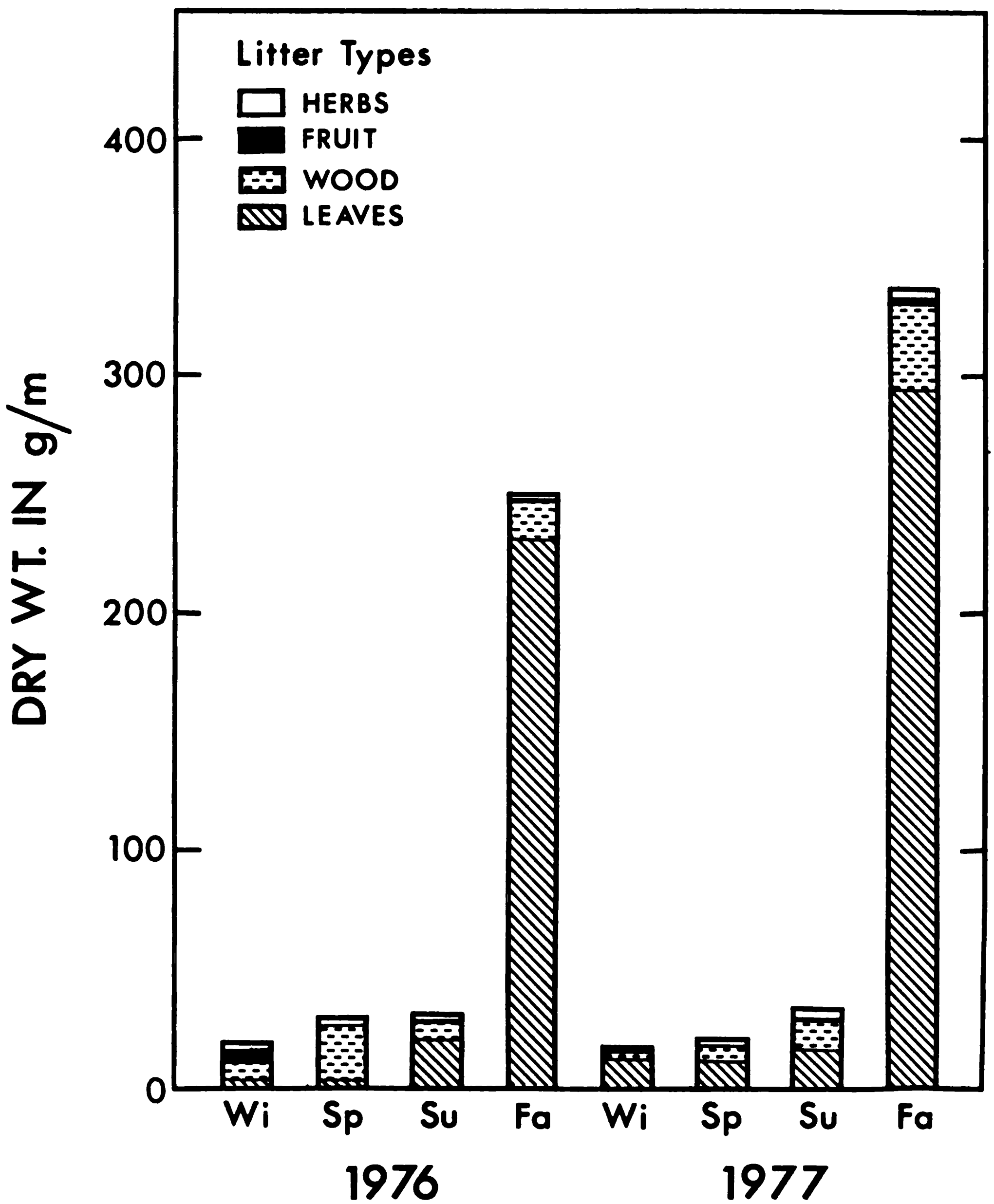

Figure 9. Seasonal CPOM influx in g/m of streambank at the Kellogg Forest site.

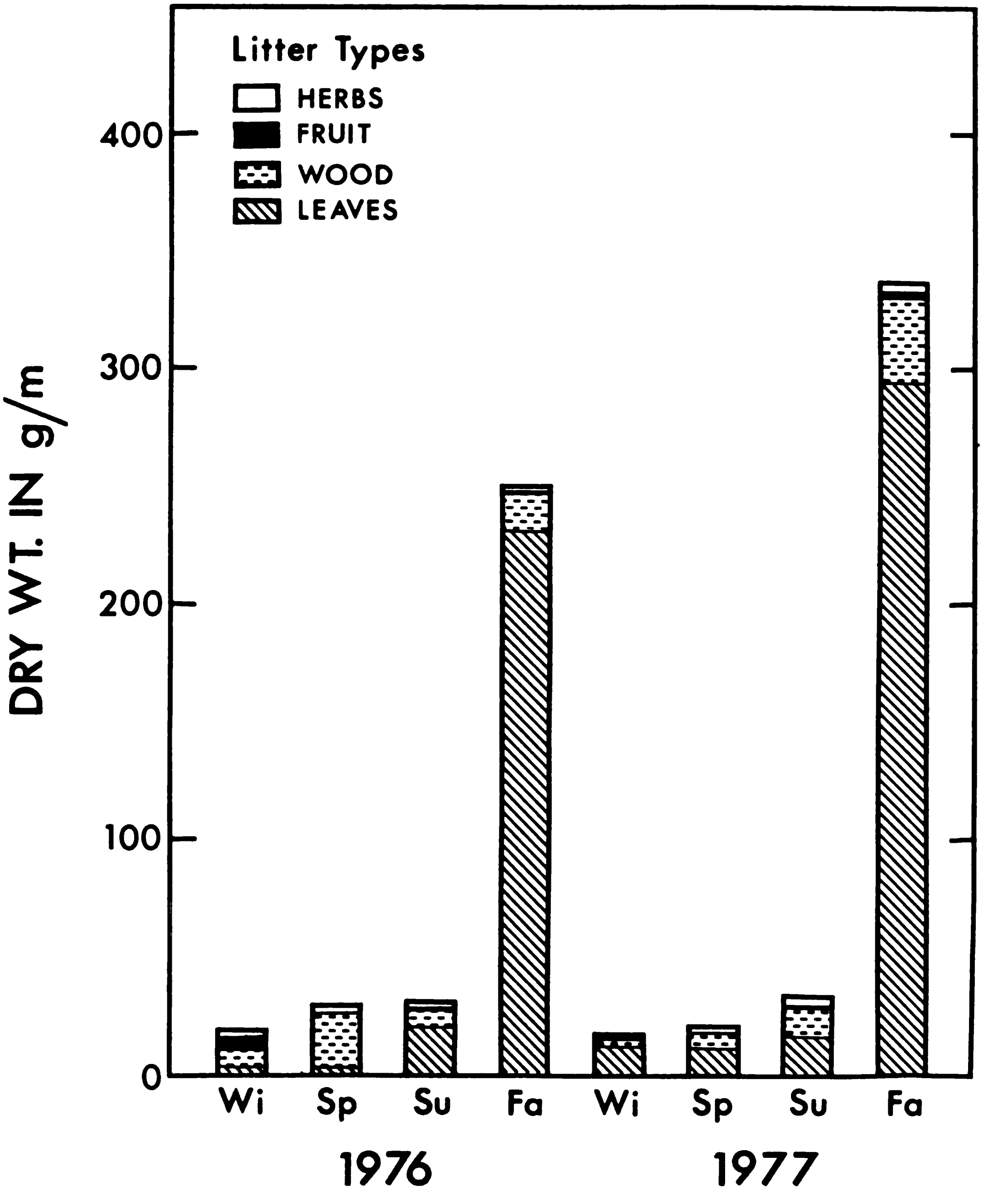

Figure 9. Seasonal CPOM influx in g/m of streambank at the Kellogg Forest site.

Table 17. Leaf influx of the Kellogg Forest site.

Species	Yearly total in g/m of stream bank 1976	1977	$\bar{x}$	Cumulative total	Cum. % of total
Fraxinus spp.	133.78	162.63	148.20	148.20	50.2
Cornus spp.	50.32	65.92	58.12	206.32	70.0
Viburnum lentago	15.41	21.80	18.60	224.92	76.3
Tilia americana	13.22	15.72	14.47	239.39	81.2
Rosa palustris	7.05	15.54	11.30	250.69	85.0
Corylus americana	7.47	14.92	11.20	261.89	88.8
Spring fragments[a]	7.69	9.74	8.72	270.61	91.8
Carpinus caroliniana	7.99	7.58	7.78	278.39	94.4
Rhamnus catharticus	3.41	8.71	6.06	284.85	96.4
Ulmus americana	7.26	3.77	5.52	289.97	98.3
Miscellaneous leaves	1.13	2.36	1.74		
Populus tremuloides	1.10	0.92	1.01		
Quercus bicolor	0.36	1.71	1.03		
Quercus borealis	0.93	0.67	0.80		
Pinus strobus	0.36	0.08	0.22		
Prunus serotina	0.20	-	0.10		
Physocarpus opulifolius	-	0.11	0.06		
Totals	257.68	332.18	294.93		

[a]Includes leaf particles, bud scales and reproductive parts which were captured during the spring and early summer.

(30% - Table 17). Species such as white pine (Pinus strobus) and red maple, which were prominent beyond 20 m from the channel, were collected in negligible amounts. In addition, the woody stem cover in the Kellogg Forest was much higher in the 10-20-m and 20-30-m quadrats than at the other locations (Table 9). If appreciable movement of leaves from areas further than 10 m from the creek had taken place, measured totals should have been higher than at the other sites. Therefore, it appeared that most leaf litter contributed to the stream in the Kellogg Forest came from the 0-10-m portion of the vegetative corridor.

CPOM Influxes Among the Sampling Sites

Over the two years of study, CPOM influxes were significantly different ($p<.05$) among the locations (Table 18). Changes in riparian vegetation appeared to play an important role in litterfall, since CPOM totals (g/m or g/m^2) were correlated ($p<.05$) with stand density and shrub basal area (Table A9). Allochthonous litter was especially reduced at the disturbed Nagel site (Figure 10), with significantly lower ($p<.05$) amounts found at this location than a pooled value for the others (Table 18). Between sites, CPOM collections were significantly lower at Nagel than Smith ($p<.05$) in 1976 and 43rd Street and Smith ($p<.05$) in 1977 (Table 18). Among the locations with no disturbance, only one difference was significant; Kellogg Forest was lower than Smith ($p<.10$) in 1976.

Removal of woody vegetation also affected the types of litterfall at the Nagel site (Table 12; Figure 11). Herbaceous material accounted for over 25% of CPOM influxes at the disturbed site, but only 6% at the others. Wood influxes were much lower in total and relative

Table 18. Results of Kruskal-Wallis and Dunn's multiple comparison tests for the combined trap totals.[a]

1976

Group	ni	Ri	Ri^2/ni	$\overline{Ri}$	Pooled $\overline{Ri}$[b]
Smith	6	122	2480.67	20.3	
43rd Street	6	78	1014.00	13.0	14.6
Kellogg Forest	6	63	661.50	10.5	
Nagel	6	37	228.17	6.2	6.2
	24	300	4384.34		

$x^2_{.01}$ (v=4-1=3) = 11.34 K=12.69** (P<.01)

Group i	$\overline{Ri}$	Group j	Smith $\lvert\overline{Ri}-20.3\rvert$	43rd $\lvert\overline{Ri}-13.0\rvert$	Kel. For. $\lvert\overline{Ri}-10.5\rvert$	Nagel $\lvert\overline{Ri}-6.2\rvert$	Pooled[b] $\lvert\overline{Ri}-14.6\rvert$
Smith	20.3		0				
43rd	13.0		7.3	0			
Kel. For.	10.5		9.8*	2.5	0		
Nagel	6.2		14.1*	6.8	4.3	0	8.4*

when ni=6, nj=6 ∝=.05=10.77 ∝=.10=9.77 when ni=18, nj=6 ∝=.05=6.53
Nagel<Smith (p<.05) Kel. For.< Smith (p<.10) Nagel<Pooled (p<.05)

1977

Group	ni	Ri	Ri^2/ni	$\overline{Ri}$	Pooled $\overline{Ri}$[b]
Smith	12	244	4181.33	18.7	
43rd Street	6	116	2242.67	19.3	17.4
Kellogg Forest	6	85	1204.17	14.2	
Nagel	6	40	266.67	6.7	6.7
	30	465	7894.83		

$X^2_{.05}$ (v=4-1-3) = 7.81 K=8.87* (p<.05)

Group i	$\overline{Ri}$	Group j	Smith $\lvert\overline{Ri}-18.7\rvert$	43rd $\lvert\overline{Ri}-19.3\rvert$	Kel. For. $\lvert\overline{Ri}-14.2\rvert$	Nagel $\lvert\overline{Ri}-6.7\rvert$	Pooled[b] $\lvert\overline{Ri}-17.4\rvert$
Smith	18.7		0				
43rd	19.3		0.6	0			
Kel. For.	14.2		4.5	5.1	0		
Nagel	6.7		12.0*	12.6*	7.5	0	10.7*

when ni=12, nj=6 ∝=.05=11.61 when ni=24, nj=6 ∝=.05=7.88
Nagel<Smith and 43rd Street (p<.05) Nagel<Pooled (p<.05)

[a]Values upon which rankings are based are in Table A8.

[b]Pooled values represent combination of the Smith, 43rd Street and Kellogg Forest sites.

*Significant at 5% level; **significant at 1% level.

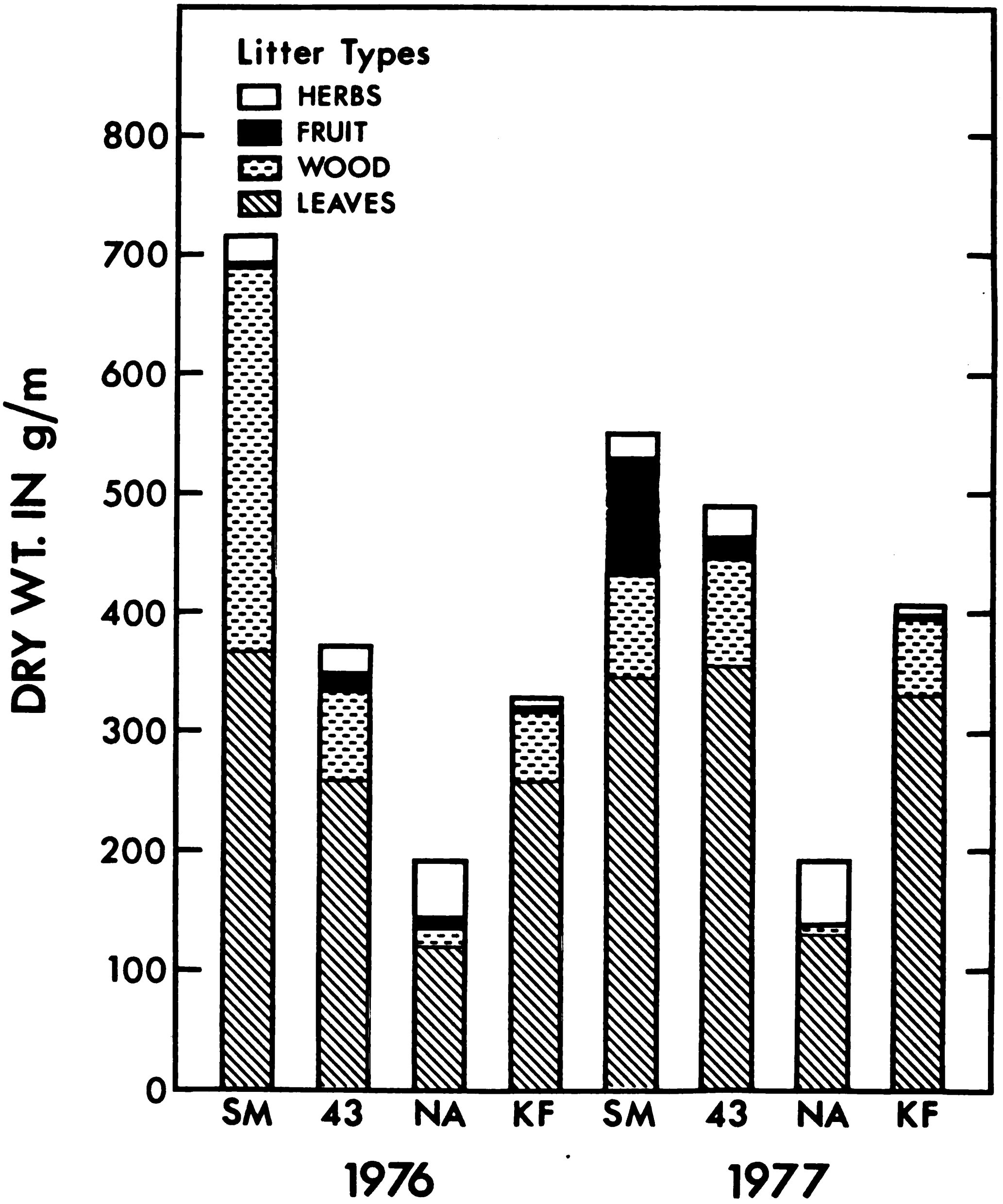

Figure 10. Annual CPOM totals by litter types at the sites.

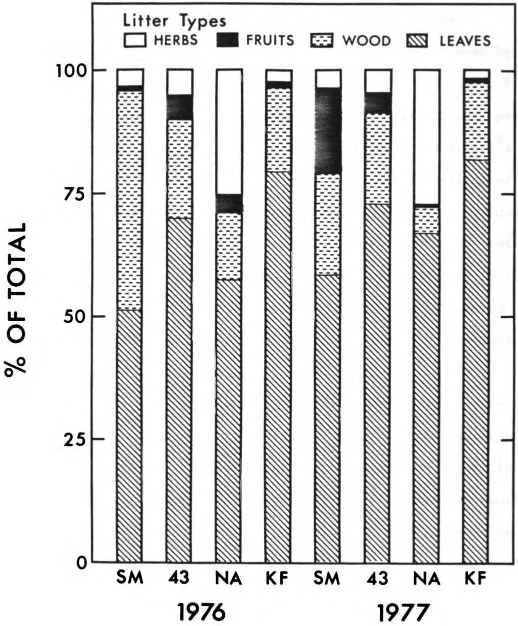

Figure 11. Annual CPOM influx, with CPOM types expressed as a percentage of the total.

amounts (6%) at Nagel. Leaf litter totals at Nagel were significantly lower than Smith ($p<.05$) in 1976 and all other sites ($p<.20$) in 1977 (Table 19). In both years, leaf collections at Nagel were significantly below ($p<.05$) the pooled estimate for the other locations.

Most allochthonous CPOM was transported to Augusta Creek by direct infall, particularly at the undisturbed sites (72% - Table 11; Figure 12). While lateral transport exceeded direct infall at Nagel per meter of stream bank (Table 11), total inputs on an areal basis (g/m^2) were dominated by direct infall (Table A11). By either expression of the data, however, lateral transport accounted for a higher percentage of the CPOM total at the Nagel site than at the others. In contrast to CPOM influxes from direct infall, lateral transport amounts were similar among all sites (Tables 19 and A11). These differences suggested that the greatest impact from vegetational disturbance at Nagel was a reduction in direct infall.

Autumn was the time of most (70%) litter influx to the stream (Table 13; Figure 13), with this season's totals predominantly leaves (range = 70-90%, Tables A2-A5). Due to leaf importance, the timing of autumnal litterfall reflected the composition of riparian communities. For example, CPOM influx at Nagel and Kellogg Forest was greatest in September because the dominant ash and basswood leaves fell in that month. In contrast, leaf-fall from nearstream woody species at the other sites was more evenly divided between September and October.

During the rest of the year, CPOM influxes were low and quite uniform (Table 13; Figure 13), although occassional severe storms increased the variability. Intense low pressure fronts occur in this region in winter and early spring (Eichenlaub, 1978), and associated

Table 19. Results of Kruskal-Wallis and Dunn's multiple comparison text for the combined trap totals (leaves only).[a]

1976

Group	ni	Ri	Ri^2/ni	$\overline{Ri}$	Pooled $\overline{Ri}$[b]
Smith	6	114	2166.00	19.0	
43rd Street	6	77	988.17	12.8	14.5
Kellogg Forest	6	70	816.67	11.7	
Nagel	6	39	253.50	6.5	6.5
	24	300	4224.33		

$X^2_{.05}(v=4-1=3) = 7.81$ K=9.49* (p<.05)

Group i	$\overline{Ri}$ Group j	Smith $\lvert\overline{Ri}-19.0\rvert$	43rd $\lvert\overline{Ri}-12.8\rvert$	Kel. For. $\lvert\overline{Ri}-11.7\rvert$	Nagel $\lvert\overline{Ri}-6.5\rvert$	Pooled[b] $\lvert\overline{Ri}-14.5\rvert$
Smith	19.0	0				
43rd	12.8	6.2	0			
Kel. For.	11.7	7.3	1.1	0		
Nagel	6.5	12.5	6.2	5.2	0	8.0*

when ni=6, nj=6 α=.05=10.77 when ni=18, nj=6 α=.05=6.53

Nagel<Smith (p<.05) Nagel < Pooled (p<.05)

1977

Group	ni	Ri	Ri^2ni	$\overline{Ri}$	Pooled $\overline{Ri}$[b]
Smith	12	210	3675.00	17.5	
43rd Street	6	111	2053.50	18.5	17.6
Kellogg Forest	6	101	1700.17	16.8	
Nagel	6	43	308.17	7.2	7.2
	30	465	7736.83		

$X^2_{.10}(v=4-1=3)=6.25$ K=6.83 (p<.10)

Group i	$\overline{Ri}$ Group j	Smith $\lvert\overline{Ri}-17.5\rvert$	43rd $\lvert\overline{Ri}-18.5\rvert$	Kel. For. $\lvert\overline{Ri}-16.8\rvert$	Nagel $\lvert\overline{Ri}-7.2\rvert$	Pooled[b] $\lvert\overline{Ri}-17.6\rvert$
Smith	17.5	0				
43rd	18.5	1.0	0			
Kel. For.	16.8	0.7	1.7	0		
Nagel	7.2	10.3*	11.3*	9.6*	0	10.4*

when ni=12, nj=6 α=.10=10.54 α=.15=9.64 α.20=9.37

when ni=24, nj=6 α=.05=7.88

Nagel<43rd Street (p<.10) Nagel<Smith (p<.15)

Nagel<Kellogg Forest (p<.20) Nagel<Pooled (p<.05)

[a]Values upon which rankings are based are in Table A8.

[b]Pooled values represent combination of the Smith, 43rd Street and Kellogg Forest sites.

*Significant at 5% level.

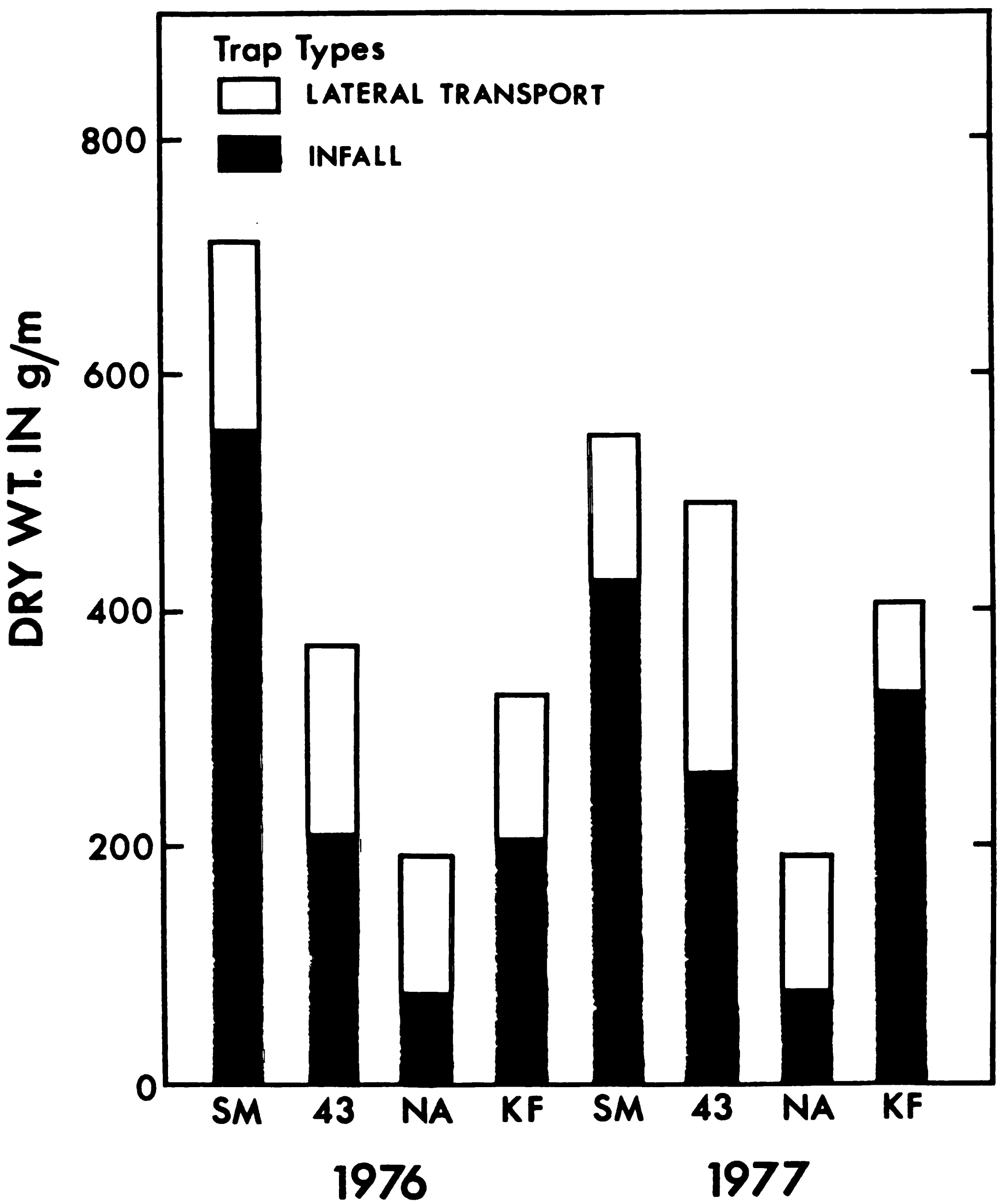

Figure 12. Annual CPOM totals by sampler type at the sites.

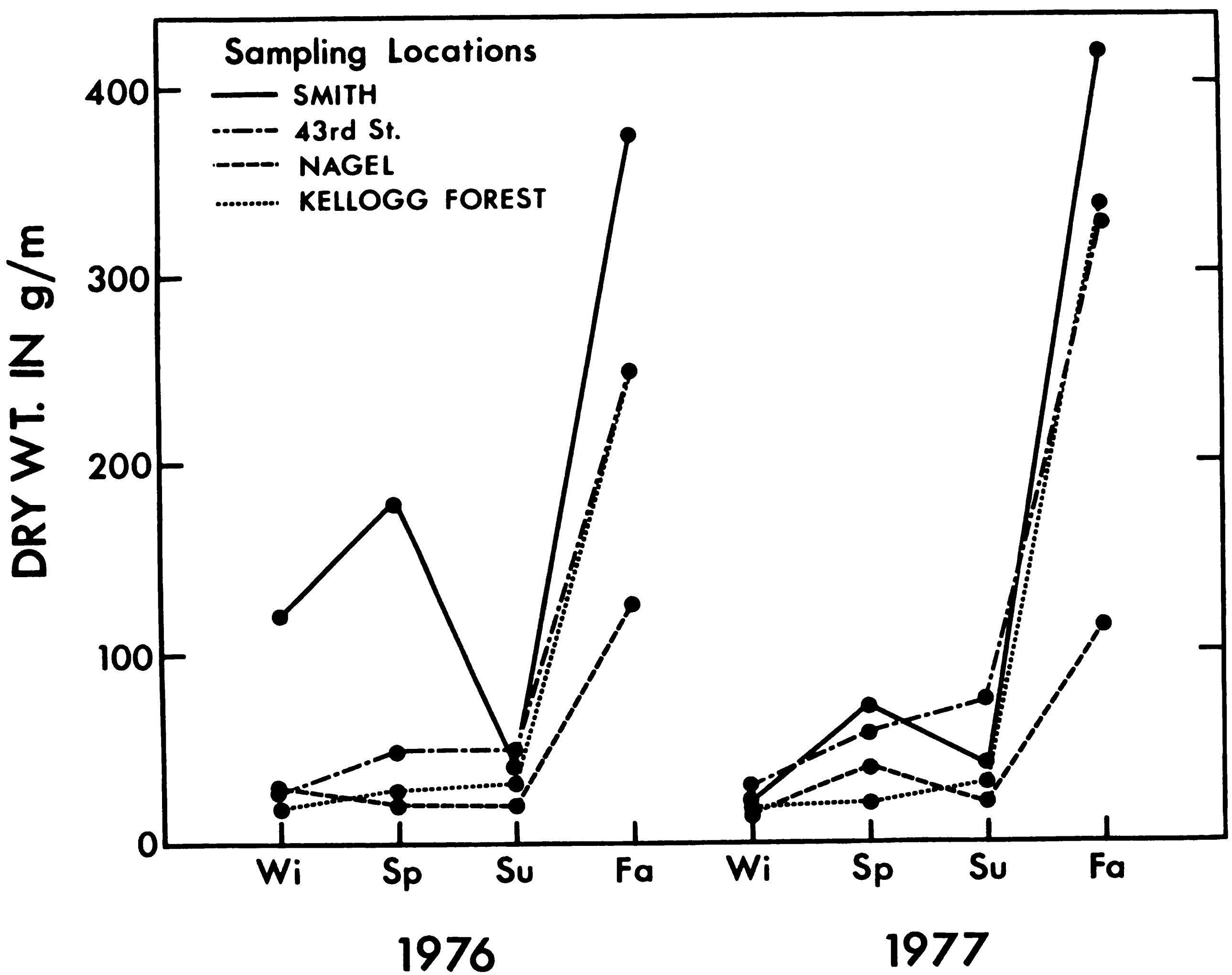

Figure 13. Seasonal CPOM totals at the sites.

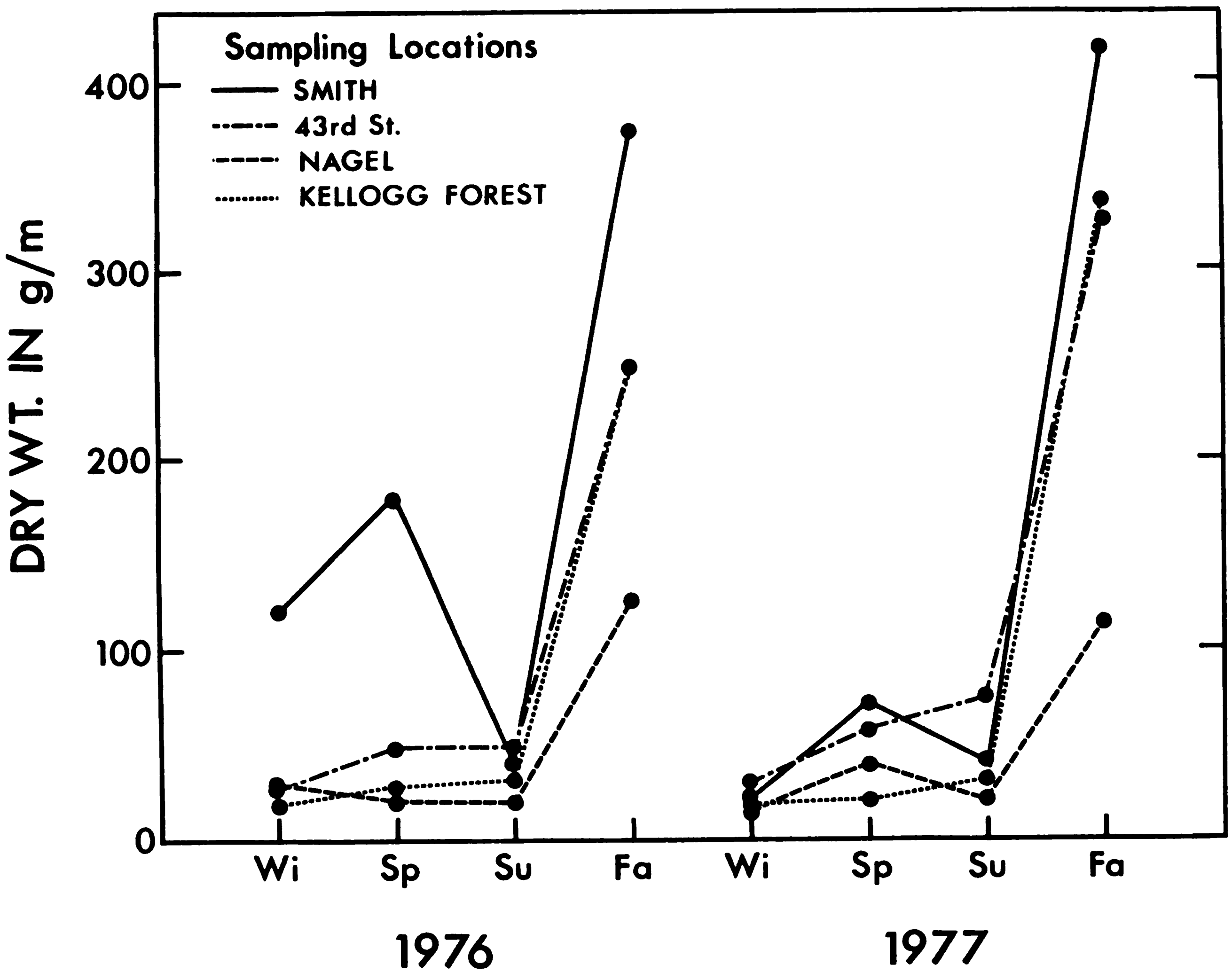

Figure 13. Seasonal CPOM totals at the sites.

high winds, particularly with freezing rain, can cause high amounts of litter to fall. Unusually large influxes of woody material occurred at the Smith and Kellogg Forest sites after severe winds on November 10, 1975 and an ice storm on March 2, 1976 (Table A6). While the sampling apparatus effectively retained much of this material, occassional trees and large limbs which fell were not adequately sampled (cf. Christensen, 1975). Although litter movement to the stream was lowest in the winter, due to the dormant state of the vegetation and snow cover, storm activity served to increase allochthonous CPOM supply to the system.

Because of differences in nearstream plant associations, leaf inputs were dissimilar. Most leaves of Smith and 43rd Street were of the medium processing rate, while the "fast" leaves, ash, basswood and dogwood, were dominant at Nagel and Kellogg Forest. (Tables 20 and A7; Figure 14). Dogwoods were common at all four sites, particularly in the 0-10-m portion of the riparian zone (Table 5-8). Ash and basswood were most abundant along third-order reaches due to a wider floodplain (Tables 7 and 8). The dominant "medium" leaf species were black cherry, black willow, nannyberry, American elm and black walnut. Except for black cherry, these are all floodplain species which had their greatest coverage within 10 m of the channel (Tables 5-8). Slow leaves made up a small portion of the leaf litter and were mostly upland species, red oak, hawthorn and quaking aspen.

Table 20. Summary of leaf collections expressed on the basis of processing rates.

Site	Processing Rate	I[a] (g/m^2)	L[a] (g/m)	1976 Total[b]	%	I (g/m^2)	L (g/m)	1977 Total	%
Smith	Fast	53.88	25.14	79.02	21.6	48.51	15.12	63.63	18.3
	Medium	183.16	53.52	236.68	64.6	181.46	43.14	224.57	64.5
	Slow	32.04	18.67	50.71	13.8	41.66	18.09	59.75	17.2
	Total	269.08	97.33	366.41		271.63	76.35	347.98	
43rd	Fast	34.36	12.40	46.76	18.1	82.66	14.29	96.95	27.3
	Medium	122.11	50.37	172.48	66.6	136.52	63.54	200.06	56.4
	Slow	8.32	31.30	39.62	15.3	10.76	46.87	57.63	16.2
	Total	164.79	94.07	258.86		229.94	124.70	354.64	
Nagel	Fast	36.35	49.27	85.62	71.6	29.16	36.61	65.77	51.3
	Medium	12.66	13.95	26.61	22.3	29.45	14.18	43.63	34.0
	Slow	1.97	5.31	7.28	6.1	2.1	16.80	18.90	14.7
	Total	50.98	68.53	119.51		60.71	67.59	128.30	
Kellogg Forest	Fast	170.50	33.85	204.35	79.3	213.64	46.20	259.84	78.2
	Medium	36.80	10.34	47.14	18.3	43.60	16.67	60.27	18.1
	Slow	5.43	0.72	6.15	2.4	10.17	1.89	12.06	3.6
	Total	212.73	44.91	257.64		267.41	64.76	332.17	

[a] I = direct infall trap; L = lateral transport trap.

[b] Total = g/m of bank.

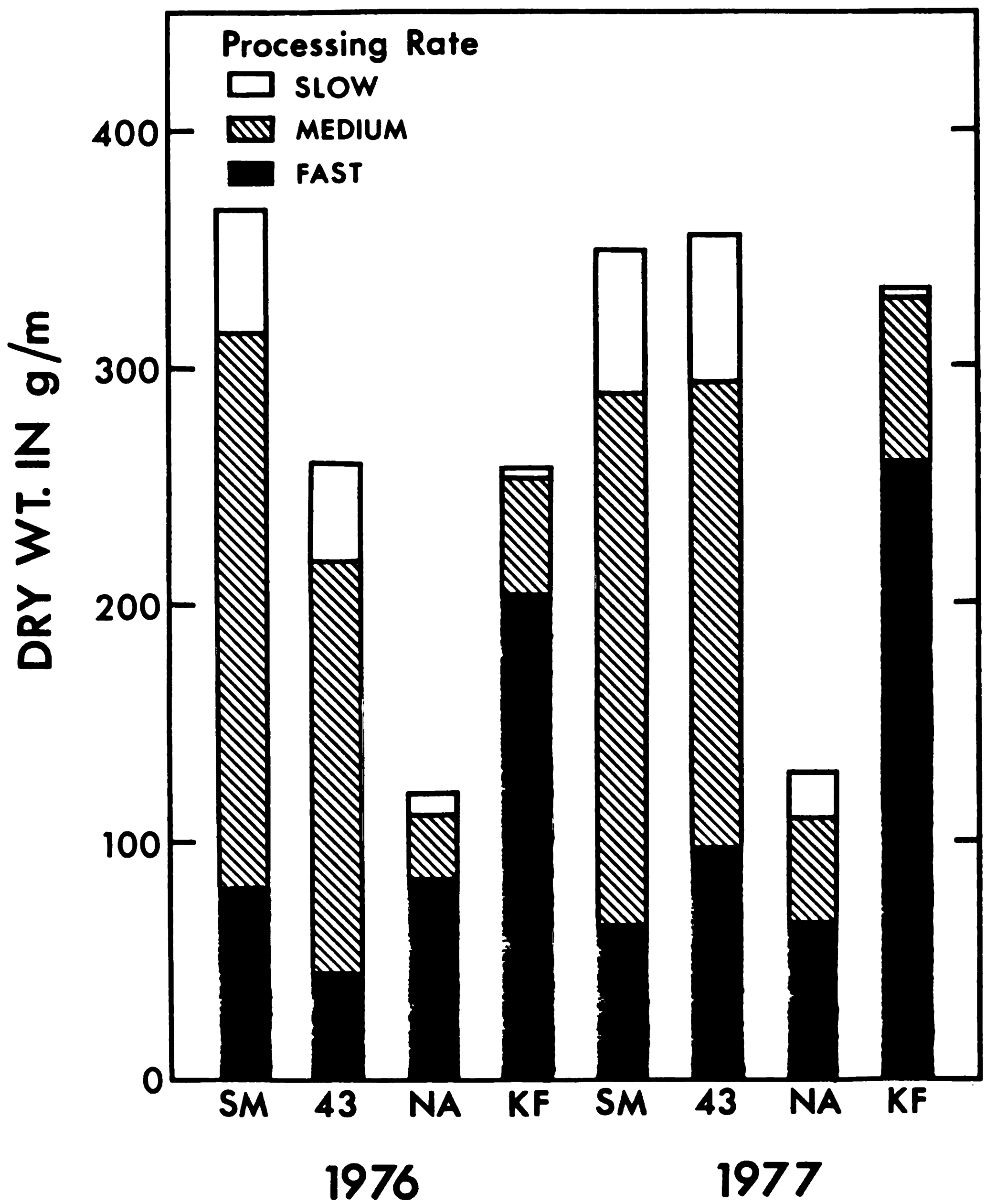

Figure 14. Annual leaf influx by processing category at the sites.

Literature Comparisons of Litterfall Estimates

Results from this study were expressed in g/m^2 of channel surface (Table 21 - Column 4), like most other investigations of particulate organic influxes to running waters. With a continuous canopy, litterfall levels over the stream and in the adjacent forest are similar (Fisher and Likens, 1973; Dawson, 1976). Among Augusta Creek sites, only Nagel lacked a complete canopy over the entire 30-m sampling section. Therefore, the results from the direct infall samplers were extended over the entire channel surface. CPOM inputs were a combination of direct infall (Column 1) and lateral transport (Column 2) totals.

These particulate organic influxes are affected by channel width, and generally decline as the channel widens (Cummins, 1975; Hynes, 1975). This decrease in CPOM is a result of reduced canopy and lowered bank length to stream bottom ratio (Meehan, et al., 1977). Highest litter influxes (>500 g/m^2) have been reported from small, first- or second-order forested streams (Table 21). Results from the Smith site seem representative of such systems. Among watercourses with 5-15 m widths (Liston, 1972; Dawson, 1976; Post and DeLaCruz, 1977), CPOM inputs are reduced, with 43rd Street and Kellogg Forest totals at the low end of this range (Table 21). When available data (Table 21) on allochthonous CPOM and mean channel width were ranked, a significant ($p<.05$) negative correlation was found (Table A9).

While the importance of riparian vegetation to allochthonous CPOM is generally recognized (Cummins, 1974), few investigations of litter inputs to streams have included concurrent measurements of nearstream woody cover. Dawson (1976) and McDowell and Fisher (1976) reported that litter composition reflected the abundance of riparian species, but

Table 21. Comparison of annual CPOM inputs to streams with different riparian vegetation.

Forest type and location	LT[a] (g/m)	DI (g/m^2)	TI (g/m)	T2 (g/m^2)	$\bar{x}$ channel width (m)	Reference
Willow - England	-	-	1588	23	60.0	Matthews and Kowalczewski, 1969
Alder - England	-	-	-	466	9.0	Dawson, 1976
Southern beech - New Zealand	132	458	590	567	2.4	Winterbourn, 1976
Mixed hardwood- Alabama	-	-	-	386	-	Post and DeLaCruz, 1977
Douglas fir - Oregon	274	365	639	912	0.6	Sedell, et al., 1974
Mixed hardwood - Kentucky	-	-	-	354[b]	13.6	Liston, 1972
Alder - Sweden	-	-	-	780	0.7	Otto, 1975
Mixed hardwood - New Hampshire	161	555	716	648	3.4	Fisher and Likens, 1973
This study[c]						
Smith	140	490	530	647	1.8	
43rd St.	180	248	428	299	7.1	
Nagel	116	74	190	108	7.0	
Kel. For.	70	296	366	313	8.3	

[a]The heading abbreviations represent: LT - lateral transport; DI - direct infall; Tl - total/m of stream bank; T2 - total/m^2 of channel surface.

[b]Leaf litter only. Wood should add an estimated 94 g/m^2 according to the data of Bray and Gorham (1964).

[c]Averages for the two year sampling period.

provided no numerical support for their observations. Liston (1972) quantified the first 10 m of streamside vegetation and noted an apparent correlation of leaf litter influx and basal area of woody species. Along Augusta Creek, CPOM inputs showed a significant ($p<.05$) positive correlation with stand density and mean shrub basal area (Table A9). In addition, vegetation transects (Tables 5-8) indicated that the first 10 m of riparian cover contributed most CPOM to the aquatic system.

The significance of shrubs to stream CPOM inputs was denoted by the afore mentioned correlations (shrubs made up most of the stand density, Tables 5-8), and by the disproportionate share of leaf contributions from shrubs (Tables 14-17) in respect to their basal area in the stand (Table 9). In contrast to their role in providing bank stabilization, shading and cover to small streams (Ware and Penfound, 1949; White and Brynildson, 1967; Karr and Schlosser, 1977), the importance of shrubs to CPOM inputs has not been noted before.

Except where slope is severe, direct infall is usually the leading source of allochthonous CPOM to headwater streams (McDowell and Fisher, 1976; Winterbourn, 1976). This method of litter transport was dominant at the Augusta Creek locations (Tables 21 and A11). In most instances, CPOM movement across the ground surface increases with greater slope (Malmquist, et al., 1978). This observation was supported in this study, since lateral transport totals were significantly correlated ($p<.05$) with bank slope (Table A9). However, because slope was moderate (<12%, U.S.D.A., 1979), less than one-fourth of CPOM influxes resulted from downslope movement (Table A11). Only Sedell, et al. (1974) have found higher litter contributions from lateral transport, which seems to have resulted from extreme (>40%) bank slope (McDowell and Fisher, 1976).

Another aspect of allochthonous inputs involves seasonal changes. Litterfall in temperate, deciduous forests is concentrated in the autumn (Bray and Gorham, 1964; Gosz, et al., 1972; Grigal and Gizzard, 1975). An average of 70% of annual CPOM inputs to Augusta Creek were in this season (Table 13), which is similar to levels reported for other streams in deciduous forests (Liston, 1972; Fisher and Likens, 1973; Otto, 1975; Post and DeLaCruz, 1977). As generally noted by these earlier studies, litter inputs were low, but rather evenly distributed throughout the rest of the year (Table 13). The rate of CPOM influx was lowest in the winter, which is characteristic of north-temperate latitudes with pronounced snow cover (Gosz, et al., 1972).

Among allochthonous CPOM types, leaf litter from riparian forest species is usually the most abundant form. At the Augusta Creek sampling areas, leaves averaged 70% of annual inputs (Table 12). This patterns is consistent with the results of Fisher and Likens (1973), Sedell, et al. (1974), Otto (1975) and Winterbourn (1976), whose values ranged from 50 to 90% of the yearly sum. Woody material, which averaged 18% (Table 12), was the second largest category of CPOM. Inputs of wood to forested headwaters have been shown to account for about one-fifth (Fisher and Likens, 1973; Sedell, et al., 1974; Otto, 1975; Winterbourn, 1976) of yearly litter totals, although values up to 70% have been reported (Anderson and Sedell, 1979). Other forms of exogenous CPOM are usually of minor importance (Fisher and Likens, 1973), as was found in this study (Table 12).

Variations in leaf types entering headwaters, in response to changes in riparian vegetation, have not received much prior attention. Meehan, et al. (1977) noted that along Oregon streams, "fast" leaves tended to increase in proportion to "slow" leaves in a downstream direction. A similar trend took place along Augusta Creek (Table 20). Among the sampling locations, "slow" leaf totals and floodplain width were negatively correlated ($p<.05$, Table A9). The general distribution of forest types in this region supports this observation; uplands are dominated by oak and hickory and floodplains by faster processed ash, basswood and dogwood (Stearns and Kobriger, 1975). As floodplains widen, a normal consequence is a great reduction in litter movement from adjoining uplands to the stream (Table 20; Bell and Sipp, 1975). Thus, leaf types may differ as a consequence of environmental change.

Allochthonous CPOM influxes to Augusta Creek were lower than most comparable literature values (Table 21), possibly due to differences in riparian vegetation. Forest stands along Augusta Creek had a high presence of shrubs and low to moderate basal area (Table 10) while, as judged by site descriptions, woody communities at the other locations (Table 21) were more mature. Due to normal seral development (Bormann, et al., 1970), CPOM inputs to Augusta Creek should increase as the stands accrue biomass.

The effect of woody vegetation removal upon CPOM inputs is demonstrated by the Nagel site results (Table 21), since litter totals are much lower than all other locations. While such an impact from alteration of nearstream vegetation has been suggested (Hynes, 1975), it has not previously been quantified. Furthermore, the Nagel site has experienced only selective cutting (Table 6). Extensive disturbances like clearcutting (cf. Likens, et al., 1977) should have a much more severe effect on allochthonous CPOM.

Synthesis

Allochthonous CPOM Resources

Variations in allochthonous CPOM along headwater stream ecosystems are important because of the significance of this material to the detrital resource base. Just as lakes were once viewed as microcosms, lotic studies, including most descriptions of allochthonous CPOM (Table 21), have often focused on isolated reaches of running waters. Where CPOM influxes from an entire catchment have been estimated, (Fisher and Likens, 1973), it was assumed that CPOM was added at a constant rate along the channel. Results from this study have demonstrated that litterfall will vary significantly ($p<.05$) along a watercourse as a function of woody riparian cover (Table A9), particularly in areas of vegetative disturbance (Table 21). CPOM influxes also varied due to changes in channel width, narrower channels had a more complete canopy and a larger bank-to-surface area ratio and consequently, greater influx per channel area (Table 21).

Because of changes in channel width and vegetation, CPOM influxes within the Augusta Creek catchment were unevenly distributed along the stream (Table 22). If nearstream vegetation had been uniform, litter influxes per unit of channel length would have been constant (Fisher and Likens, 1973), and inversely proportional to channel width. While the riparian zone was predominantly forested, two native associations were present, shrub-carr and lowland forest, which differed in amount of litter input (Table 22). Lowland forest along first- and second-order sections made up 30% of the channel surface, yet accounted for one-half of the CPOM total (Table 22).[a] Including the shrub-carr community, first- and

[a]This result was not an artifact of forest distribution, since lowland forest was as frequent along third-order reaches as along smaller channels (50% of length, Table 4).

Table 22. Annual CPOM influxes to Augusta Creek based on litterfall and land cover estimates.[a]

Land Cover	Channel Length (Km)	%	$\bar{x}$ Channel Width (m)[b]	Channel Area ($m^2 \times 10^3$)	%	CPOM Input (g/m^2)	CPOM Total ($Kg \times 10^3$)	%
Marsh	3.1	4.9	-	-	-	-	-	-
Lake	8.1	12.8	-	-	-	-	-	-
Shrub-Carr	21.5	34.0	7.1	152.6	53.5	299	45.6	42.2
Lowland Forest (third-order)	6.9	10.9	8.3	57.3	20.1	313	17.9	16.6
Lowland Forest (first- and second-order)	22.5	35.6	3.0	67.5	23.7	647	43.7	40.4
Human Impacted	1.1	1.8	7.0	7.7	2.7	108	0.8	0.7
Totals	63.2	100.0		285.1	100.0		108.0	100.0

[a]CPOM contributions from Marsh and Lake riparian zones are unknown but probably rather small based on the data of Wetzel and Otsuki (1974), plus the relatively small amount of Marsh occurrence.

[b]Average width at the representative sampling locations, except for 3.0 m which is an average for all first- and second-order channels.

second-order channels received 62% of the litterfall, while totalling 49% of the channel area.

Seasonal and annual allochthonous CPOM variations should also have a critical influence on detrital levels within the stream system. In both years of study, CPOM totals and types at a location were similar (Tables 12 and 13). Even though most allochthonous CPOM entered the stream in the autumn (70%), the remainder was quite evenly distributed among the other seasons, affording a low, but continuous litter influx at these times (Tables 13 and A11). Such a litterfall pattern should lend stability to the detritus base in Augusta Creek.

The major kinds of allochthonous CPOM play an important role in detrital availability, since they range from rapidly degraded herbs and fruits, to leaves of intermediate degradation rate, to refractory woody material (Anderson and Cummins, 1979). Leaves and wood promote continuity in the detrital resources of Augusta Creek, because they are the dominant forms of external CPOM (70% and 23%, Table 23), and, because they remain within the system for the longest time (Petersen and Cummins, 1974). Wood inputs were greatest along first- and second-order tributaries, especially in sections of lowland forest, since 40% of the catchment total came from these reaches (Table 23). In systems where it is very abundant, wood may serve as an important source of dissolved (DOM) and fine particulate organic material (FPOM) (Anderson and Sedell, 1979). However, the greatest significance of wood along Augusta Creek may lie in its influence on the physical structure of the channel (Likens, et al., 1978), and in its retention of particulate organic matter (POM), so that more complete biotic utilization of POM may occur (Marzolf, 1978). The other litter forms, fruits and herbs, do

Table 23. Annual CPOM influxes by categories to Augusta Creek.

Land Cover	CPOM[a] Total (Kg x 10^3)	CPOM Categories (Kg x 10^3)				Leaf Types (Kg x 10^3)		
		Leaves	Wood	Herbs	Fruit	Fast	Medium	Slow
Shrub-Carr	45.6	34.9	7.8	1.4	1.5	7.9	21.5	5.5
Lowland Forest (third-order)	17.9	14.5	3.0	0.1	0.3	11.5	2.6	0.4
Lowland Forest (first- and second-order)	43.7	24.9	13.9	1.5	3.4	5.0	16.1	3.8
Human Impacted	0.8	0.6	0.0	0.2	0.0	0.4	0.2	0.0
Totals	108.0	74.9	24.7	3.2	5.2	24.8	40.4	9.7

[a] cf. Table 20.

not enter the stream in large amounts (Table 12). They are high quality food resources (Meehan, et al., 1977), however, and may be important nutritional sources for some detritivores.

Because of their differences in food quality (Hynes, 1975; Ward and Cummins, 1979), changes in leaf influxes to Augusta Creek are noteworthy. Variations in woody species occurrence (Tables 5-9) and life history resulted in leaf litter differences. Diversity of leaf inputs was greatest along first- and second-order tributaries, with species that have medium rates of degradation accounting for 60% of the total and "fast" and "slow" leaves 20% each (Table 23). In contrast, third-order reaches received leaves of mostly "fast" (65%) and medium (26%) species. Additionally, the autumn leaf-fall ended a month earlier in third-order lowland forests. Since leaves are the most prevalent kind of allochthonous CPOM, the variation in inputs to the stream should have caused differences in food value of CPOM for detritivores.

The method and distance of CPOM transport to the stream are critical in determining the area of undisturbed vegetation ("greenbelt") which will insure normal litterfall to the aquatic system. The mode of transport is of interest because it affects the condition of CPOM entering the stream, since significant degradation can occur on the floodplain if litter has a long residence time there (Merritt and Lawson, 1978). Direct infall was dominant at all sites throughout the year ($\bar{x}$ = 78%, Table A11), which indicated that CPOM entering the stream had undergone little degredation in the floodplain. In conjunction with litterfall estimates, streamside vegetation analyses showed that almost all CPOM came from within 10 m of the channel. CPOM totals, types and timing all reflected the composition of the woody riparian community.

Therefore, the quantity and quality of CPOM entering small running waters is under control of the nearby terrestrial environment. These two areas are functionally inseparable, and should be viewed and managed as a single unit.

Other Estimates of Detrital Resources

One estimate of the elaboration of organic matter within the stream is the P/R ratio, which involves an assessment of gross primary production and community respiration (Odum, 1969). P/R values are from King (1980),[a] and disclose a great difference between the first-order section (Smith) and the other sites (Table A12). In general, P/R increased with stream order. Since CPOM influxes were reduced on an areal basis as the channel widened and P/R increased, the community should show an increased use of autochthonous production and a decreased dependence on allochthonous sources with larger stream-order.

Another measure of detrital resources in Augusta Creek is the POM standing crop. Average standing crop is similar between locations within a habitat (pool or riffle) and does not change markedly over the year (Table A14). These totals suggest an overall balance in storage, processing, and import-export processes, which has been noted in other headwater systems (Naiman and Sedell, 1979). A rather constant level of benthic POM may act to buffer the community from the effects of seasonal and annual differences in detrital inputs.

Seasonal and longitudinal changes in allochthonous CPOM may produce changes in benthic POM size classes. CPOM standing crop was highest in the winter and spring and lowest in the summer and fall (Table A14),

[a]Interpretation is difficult because the canopy was more open in the area where P/R was estimated than in the litterfall sampling section at 43rd Street and Kellogg Forest.

which corresponds with litterfall patterns. FPOM totals at the first-order site are most reduced in the summer and fall, but show no seasonal trend at the other sites. This difference could be a result of low autochthonous production and FPOM export in the smallest tributaries. A combination of pool and riffle totals shows an upstream increase in benthic CPOM and a decrease in FPOM. Such a trend has been predicted in headwater systems as a result of normal fluvial processes (Vannote, et al., 1980).

Biotic Responses to Changes in Allochthonous CPOM

Since allochthonous CPOM forms the base of the food web in forested, headwater streams (Cummins, 1974; Meehan, et al., 1977), differences in inputs should produce changes in detritivore populations and community structure. Within communities, species tend to separate out along three major niche dimensions, space, time and food (Pianka, 1974). As riparian vegetation and channel width differ along Augusta Creek, so will exogenous food resources available to the biota.

As judged by CPOM inputs (Table A11) and benthic CPOM (Table A14), food resources for coarse particle feeders (shredders) appear to be inversely correlated with stream width. Increased CPOM should result in a greater density of shredders. While numbers of the dominant species should increase, higher diversity may also occur, since each species should use less of the total range of food (Ricklefs, 1979). More diversity (specialization) could increase the efficiency of resource utilization (Pianka, 1974), so the most efficient biotic processing of CPOM may occur in the smallest tributaries. Shredder numbers are highest at the Smith site (Table A13; Cummins, unpub. data), with a rich array of functionally obligate forms like the cranefly, *Tipula*, and the caddisfly, *Lepidostoma*. The seasonal aspect of CPOM influxes should also be an important factor in shredder density differences along the creek. Much higher litterfall occurred along first-order sections in winter and spring (Table A11). An extended period of CPOM availability may encourage greater shredder diversity in these reaches by allowing more separation of life cycles over time.

The greatest effect of CPOM (food supply) changes on shredder populations should be found in areas where natural inputs have been altered. The Nagel site not only had the lowest litter inputs (Table 21), it also had fewer log jams or other debris-retaining structures. This last condition apparently resulted from riparian tree removal, since the channel has not been disturbed. Debris dams are a major site of shredder activity (Anderson and Sedell, 1979), so a paucity of these structures should lower shredder populations. Less food will cause emigration (drift-Walton, 1978), reduced growth and/or survivorship. At the four locations, shredder numbers (spring and fall) and leaf processing rates were lowest at the Nagel site (Cummins, unpub. data). Reduced rates of leaf degredation, as a consequence of small shredder numbers, have been reported in several other studies (Anderson and Sedell, 1979).

Reduced CPOM at the Nagel site should particularly affect specialist (obligate shredder) species, since faculative representatives would utilize available CPOM, but switch to other foods when necessary (Cummins and Klug, 1979). An increase in a generalist species in response to reduced food (CPOM) levels has been noted in two streams with severe vegetative disturbance in their catchments (Webster and Patten, 1979). As Ricklefs (1979) has pointed out, one of the most consistent effects of disturbances on community structure is to increase the dominance of a few species.

The frequency of vegetationally altered sections and their distribution will influence CPOM inputs and community structure. The processing efficiency of shredders in such sections should decline, because generalists sacrifice efficiency in the conversion of food to growth for the ability to use a greater variety of resources (Pianka, 1974; Cummins and Klug, 1979). POM is sequentially reduced in size as it passes downstream (Vannote, et al., 1980), however, the Nagel section could be a break in this processing chain. In addition, reduced CPOM inputs to these reaches lowers the supply of POM (mostly as FPOM) to downstream communities. While increased autochthonous production in disturbed areas may replace some of the lost allochthonous resources (Gelroth and Marzolf, 1978), endogenous production supports different functional groups (Cummins, 1974).

Shredder populations should reflect food quality differences (dissimilar leaf influxes) which occurred along Augusta Creek. Food quality may directly affect shredder growth rates, which should influence life cycle length, size at maturity and fecundity (Anderson and Cummins, 1979). Due to early-dropped, mostly "fast" leaves (Tables 20 and A2-A5), shredder growth in third-order sections should begin earlier, but be compressed into a shorter time period. In contrast, the leaf input pattern to first- and second-order channels should extend the period of similar shredder diets (well-conditioned leaves). This should allow increased temporal segregation, which is a common means of coexistence among closely related stream invertebrates (Vannote and Sweeney, 1980). The greater variety of leaf inputs to the smaller tributaries may also increase species diversity, because it permits smaller niche breadth, i.e., more specialization (Pianka, 1974). As mentioned earlier, shredders are more numerous and exhibit greater species richness in first- and second-order sections of the system.

One other influence on contemporary leaf influxes, particularly to third-order channels, is Dutch elm disease. Before this fungal introduction, American elm was a leading component of local lowland forests, especially along streams with extensive floodplains (Curtis, 1959). In the Augusta Creek catchment, the species was most common where the channel (and floodplain) were widest. Ash and basswood, previous co-dominants, have replaced elms in the community (Thompson, 1972). Consequently, the diversity of allochthonous leaf litter has declined with respect to stream detritivores, since a "medium" species has been replaced by "fast" leaves. More extreme changes in food quality, resulting from the conversion of deciduous forests to conifers, have reduced detritivore diversity (Huet, cited in Hynes, 1970:231; Wallace, et al., 1970). Because the range of food resources is important to temporal separation of invertebrates within a functional group (Vannote and Sweeney, 1980), shredder diversity in downstream areas may have declined since the loss of elms.

CPOM influxes to Augusta Creek are reduced to FPOM by physical abrasion and microbial and invertebrate processing. Fine particle feeders (collectors) in small, woodland streams are dependent on such processes for much of their food supply (Cummins, 1974). Because CPOM inputs were reduced as the stream widened (Table 21), FPOM generation and export from the smallest tributaries should be very important to collectors in larger orders.

Some of the highest quality food resources available to collectors are well-conditioned leaf fragments and invertebrate feces (Cummins and Klug, 1979). Such high quality types of food may increase collector growth rate (King, 1978), which could shorten the life cycle period (Ward and Cummins, 1979). A number of the common species of collectors in Augusta Creek have two generations per year, autumnal and vernal (Cummins, 1974). While it is possible that increased levels of leaf fragments and shredder feces (high inputs and shredder numbers) may cause better growth in vernal generations in first- and second-order sections, downstream transport of FPOM and greater autochthonous FPOM may have a compensatory effect for third-order reaches.

The use of smaller-sized POM by filtering collectors as streams get larger (Wallace, et al., 1977) may be related to allochthonous input patterns and in-stream CPOM degradation. CPOM influxes and benthic CPOM totals declined as Augusta Creek widened, while the benthic FPOM sum increased and became smaller in size (Tables A11 and A14). POM transport data from the stream indicates a downstream decrease in mean particle size (Sedell, et al., 1979). Wallace, et al. (1977) and Alstad (1980) have demonstrated mesh size increases in an upstream direction in the most common family of net-spinning caddisflies, Hydropsychidae. While they contend this is largely due to effects of the current, changes in food particle size would offer an additional hypothesis.

Predators are another important functional group in headwaters. Animals provide the highest quality food in streams (Anderson and Cummins, 1979), with production among lower trophic levels usually reflected in predator production (Warren, et al., 1964; Hynes, 1970). Levels of non-predaceous invertebrates (Table A13) indicate that animal food resources are greatest in the smallest orders. The higher number of predators in an upstream direction may be a response to these conditions.

Since food availability is important to ecological relationships among aquatic invertebrates (Cummins, 1973), variations in allochthonous CPOM should influence community structure and function. CPOM influxes (Table 21) and P/R values (King, 1980) from Augusta Creek suggest that allochthonous detrital resources should decline and autochthonous resources increase with larger stream-order due to increased channel width. Results from this study also demonstrated that CPOM influxes change within stream-order (Tables 22 and 23). From my observations on other streams, such heterogeneous allochthonous influxes should occur along most small streams, since riparian communities normally are quite variable. Some of the implications of these resources changes to the biota, especially shredders, have been discussed.

In order for the factors which control community relationships to be better understood, some quantitative measurements within streams seem necessary. First of all, the array and level of food resources should be carefully estimated. While microbial conditioning rates and nutrient levels have been determined for general types of detritus, these values have not been closely related to detrital totals in the aquatic system. Secondly, our understanding of how species use food resources is poor. The functional groups concept (Cummins, 1973) has been useful in identifying general roles of the biota in organic matter degredation, however, many species are not confined to a single functional group (Anderson and Sedell, 1979). Even within a functional group, our information on resource partioning among species is limited to a few organisms (e.g. Hydropsychidae - Wallace, et al., 1977; Alstad, 1980; Limnephildae - Cummins, 1964; Mackay and Kalff, 1973). Until the resource needs of species (or even genera - Wiggins and MacKay, 1978) are identified, throughout their life cycles, our understanding of how environmental factors affect the community species complex will be severely limited. Headwater streams typically exhibit rich and diverse invertebrate communities (Patrick, 1975). The natural variation in allochthonous CPOM influxes may be an important agent in maintaining this richness, both within and among stream-orders.

Allochthonous CPOM and the Riparian Zone

The stability of headwater stream ecosystems, which has been defined as their "ability to withstand and recover from perturbation" (Webster and Patten, 1979), is controlled by the terrestrial environment. Although small streams do not have a high standing crop of living biomass, they do have a large detritus standing crop which maintains organizational integrity (Odum, 1969). Since endogenous primary production is low and exogenous CPOM is high in forested streams, CPOM from nearstream vegetation accounts for much of the detrital base (Vannote, et al., 1980). Results from the Nagel site demonstrated that alteration of riparian vegetation can significantly reduce CPOM inputs. Where large-scale vegetation removal has occurred, in-stream detritus reservoirs have greatly decreased (Webster and Patten, 1979). Recovery of such systems depends on re-establishment of nearstream vegetation (Likens, et al., 1977; Gurtz, et al., 1980). Thus, the presence of natural riparian vegetation is critical if small streams are to exhibit the attributes of stability, as defined above.

Nearstream disturbances are infrequent along Augusta Creek, so their effect on allochthonous CPOM, available light and nutrient levels is small. Consequently, biological features typical of forested headwaters, such as low levels of primary producers and abundant CPOM-feeding invertebrates (Cummins, 1974), are found along most of the stream's length.

Results from this study suggest that small watercourses in multiple-land-use catchments should exhibit characteristic attributes of woodland stream structure and function if natural riparian vegetation is maintained. Since most drainage basins are under multiple-uses, the management implications of this conclusion are important. While "the valley rules the stream" (Hynes, 1975), the most significant portion of the valley is the area next to the channel. Although a 20-m corridor along Augusta Creek was critical for CPOM influxes, this is not the entire region required for protection of the aquatic environment. Because of hydrologic (Maddock, 1978) and biotic interactions (Merrit and Lawson, 1978), the entire floodplain should not be disturbed in order to insure system integrity. Where relief is higher than in this basin, further consideration must be given to the amount of slope (Trimble and Sartz, 1958; Karr and Schlosser, 1977). Within these constraints, a "stream corridor" concept provides a prudent and effective way to maintain and enhance our running water resources.

SUMMARY AND CONCLUSIONS

Significant differences in allochthonous CPOM influxes were found along Augusta Creek. Litterfall variations in this study were correlated with changes in nearstream woody vegetation and channel width. Influxes were greatest to a first-order reach in dense forest (647 g/m^2) and lowest in a section with selectively cut riparian vegetation (108 g/m^2). As channel width increased, litterfall declined on a surface area basis, due to decreased bank to channel area ratio and reduced vegetative canopy. While CPOM influx variations in multiple-land-use catchments have received little previous attention, results from Augusta Creek indicate that such differences characterize inputs to most small lotic systems.

In respect to the drainage basin, CPOM influxes were unevenly distributed among stream-orders. While first- and second-order sections made up 49% of the stream's surface, they accounted for over 62% of the litter entering Augusta Creek. This result suggests that the greatest interface between aquatic and terrestrial ecosystems occurs in smallest channels, with food resources for coarse particle feeders inversely correlated with stream width.

Most CPOM was transported to the stream by direct infall (78%). Low relief afforded relatively little lateral litter movement, however, bank slope and lateral transport were correlated. The transport data indicated that CPOM entering the aquatic system had undergone little degredation in the riparian zone.

At each site, CPOM influxes were similar in totals and types in both years of study. While autumn was the season of greatest litter influx (70%), a low, but constant amount of litter entered the creek during the rest of the year. Leaves were the dominant type of litterfall (70%), with wood accounting for most of the remainder. This combination of constant annual influxes, continual litterfall throughout the year, and a variety of leaf types, should lend stability to the detrital resource base of the ecosystem.

Vegetational changes along the stream resulted in influxes of leaf litter with differential decomposition rates. In first- and second-order tributaries, leaf inputs were mostly of species with medium processing rates (60%), while "fast" leaves were dominant (65%) along third-order channels. Although never abundant (<20%), "slow" leaves decreased with greater stream size and were inversely correlated with floodplain width. Furthermore, leaf-fall to the creek was finished almost a month earlier along third-order sections. These data suggest that allochthonous CPOM resources are more diverse, and may have an extended period of availability to detritivores in smaller tributaries.

A comparison of vegetative transects and leaf influxes demonstrated that almost all of the allochthonous CPOM originated from a 20-m corridor of vegetation along the channel. Within this zone, nearstream shrubs were particularly important litter sources, as indicated by the significant correlations ($p<.05$) of shrub basal area and stand density (mostly shrubs) to CPOM inputs. Protection of this corridor appears critical if normal levels of allochthonous CPOM are to be maintained.

Even though the basin has been subjected to many different land uses, especially agricultural, most of the riparian zone (>90%) appears undisturbed. This natural "greenbelt" probably is one of the most important factors in the maintenance of typical headwater stream structure and function in Augusta Creek.

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APPENDIX

Table A1. Woody vegetation along Augusta Creek.[a]

Acer rubrum L. - red maple - T[b]
Acer saccharinum L. - silver maple - T
Acer saccharum Marsh - sugar maple - T
Betula lutea Michx. f. - yellow birch - T
Carpinus caroliniana Walt - musclewood - S
Carya ovata (Mill.) K. Koch. - shagbark hickory - T
Cornus amomum Mill. - silky dogwood - S
Cornus racemosa Lam. - gray dogwood - S
Cornus stolonifera Michx. - red osier dogwood - S
Corylus americana Walt. - hazel - S
Crataegus spp. - hawthorn - S
Fraxinus nigra Marsh. - black ash - T
Fraxinus pennsylvanica Marsh. - red ash - T
Hammamelis virginiana L. - witch hazel - S
Ilex verticillata (L.) Gray. - black alder - S
Juglans nigra L. - black walnut - T
Larix laricina (Du Roi) K. Koch. - tamarack - T
Lonicera xylosteum L. - European fly honeysuckle - S
Morus rubra L. - red mulberry - S
Ostrya virginiana (Mill.) K. Koch. - ironwood - T
Physocarpus opulifolius (L.) Maxim. - ninebark - S
Pinus strobus L. - white pine - T
Populus grandidentata Michx. - large-toothed aspen - T
Populus tremuloides Michx. - quaking aspen - T
Prunus avium L. - sweet cherry - T
Prunus serotina Ehrh. - black cherry - T
Prunus virginiana L. - choke-cherry - S
Pyrus coronaria L. - wild crab-apple - S
Pyrus malus L. - apple - S
Quercus alba L. - white oak - T
Quercus bicolor Wild - swamp white oak - T
Quercus borealis Michx. f. - northern red oak - T
Quercus velutina Lam. - black oak - T
Rhamnus catharticus L. - buckthorn - S
Rhus typhina L. - staghorn-sumac - S
Rhus vernix L. - poison-sumac - S
Ribes americanum Mill. - wild black currant - S
Robinia psuedoacacia L. - black locust - T
Rosa palustris Marsh. - swamp-rose - S
Salix alba L. - white willow - T
Salix discolor Muhl. - pussy willow - S
Salix nigra L. - black willow - S
Sambucus canadensis L. - common elder - S
Tilia americana L. - basswood - T
Ulmus americana L. - American Elm - T
Ulmus rubra Muhl. - slippery elm - T
Viburnum lentago L. - nannyberry - S
Viburnum opulus L. - high-bush cranberry - S
Vitis aestivalis Michx. - summer grape - S
Zanthoxylum americanum Mill. - prickly ash - S

[a]All species observed in the transects and/or the input traps - scientific nomenclature of Gleason and Cronquist (1963).

[b]T-tree, S-shrub - by the criteria of Braun (1961), Gleason and Cronquist (1963) and Harlow (1957).

Table A2. Total CPOM input by category and season at the Smith site.

Season		1976 I	1976 L	1976 T[a]	1976 %	1977 I	1977 L	1977 T[a]	1977 %
	L[b]	269.08	97.33	366.41	51.3	271.65	76.32	347.97	63.6
Annual	W	272.53	47.75	320.28	44.8	56.96	27.08	84.04	15.4
Totals	F	6.40	0.12	6.52	0.9	93.23	1.08	94.31	17.2
	H	6.80	14.16	20.96	2.9	3.30	17.56	20.86	3.8
	Total	554.81	159.36	714.17	99.9	425.14	122.04	547.18	100.0
	L	0.63	4.62	5.25	4.4	4.14	6.44	10.58	50.5
Winter	W	89.15	14.18	103.33	86.4	2.74	2.40	5.14	24.6
	F	2.07	0.12	2.19	1.8	-	-	-	-
	H	5.14	3.64	8.78	7.3	1.73	3.48	5.21	24.9
	Total	96.99	22.56	119.55	99.9	8.61	12.32	20.93	100.0
	L	9.59	7.27	16.86	9.2	10.04	16.60	26.64	37.5
Spring	W	144.88	16.45	161.34	88.4	24.04	12.04	36.08	50.8
	F	-	-	-	-	-	-	-	-
	H	1.18	3.20	4.38	0.8	0.66	7.64	8.30	11.7
	Total	155.64	26.92	182.58	100.0	34.74	36.28	71.02	100.0
	L	18.39	3.49	21.88	58.4	22.46	1.60	24.06	62.0
Summer	W	4.91	5.59	10.50	28.0	6.28	3.40	9.68	25.0
	F	3.73	-	3.73	10.0	2.32	0.40	2.72	7.0
	H	-	1.35	1.35	3.6	0.01	2.32	2.33	6.0
	Total	27.03	10.43	37.46	100.0	31.07	7.72	38.79	100.0
	L	240.47	81.94	322.41	86.1	235.01	51.68	286.69	68.8
Fall	W	33.59	11.53	45.12	12.0	23.90	9.24	33.14	8.0
	F	0.60	-	0.60	0.2	90.91	0.68	91.59	22.0
	H	0.48	5.97	6.45	1.7	0.90	4.12	5.02	1.2
	Total	275.14	99.44	374.58	100.0	350.72	65.72	416.44	100.0

[a] I = direct infall in g/m^2; L = lateral transport in g/m; T = total in g/m of bank.

[b] L-Leaves, W-Wood, F-Fruit, H-Herbaceous Material.

Table A3. Total CPOM input by category and season at the 43rd Street site.

Season		1976 I	1976 L	1976 T[a]	1976 %	1977 I	1977 L	1977 T[a]	1977 %
Annual Totals	L[b]	164.78	94.08	258.86	69.9	229.94	124.68	354.62	72.8
	W	38.54	36.41	74.95	20.2	38.93	52.00	90.93	18.7
	F	4.83	11.14	15.97	4.3	9.65	9.20	18.85	3.9
	H	6.03	14.38	20.41	5.5	3.54	19.48	23.02	4.7
	Total	214.18	156.01	370.19	99.9	282.06	205.36	487.42	100.1
Winter	L	3.10	5.29	8.39	32.8	3.92	11.20	15.12	50.6
	W	3.41	6.71	10.12	39.6	6.74	1.56	8.30	27.8
	F	1.48	0.25	1.73	6.8	-	1.00	1.00	3.3
	H	2.28	3.06	5.34	20.9	1.47	4.00	5.47	18.3
	Total	10.27	15.31	25.58	100.1	12.13	17.76	28.89	100.0
Spring	L	10.34	5.56	15.90	33.6	7.29	17.84	25.13	43.7
	W	14.44	12.65	27.09	57.2	8.45	14.96	23.41	40.7
	F	0.51	0.26	0.77	1.6	-	-	-	-
	H	1.36	2.22	3.58	7.6	0.95	8.08	9.03	15.7
	Total	26.65	20.69	47.34	100.0	16.69	40.88	57.57	100.0
Summer	L	22.95	6.96	29.91	61.2	31.20	9.56	40.76	55.5
	W	5.86	7.71	13.57	27.8	5.26	15.56	20.82	28.4
	F	1.76	1.63	3.39	6.9	4.77	2.64	7.41	10.1
	H	0.22	1.80	2.02	4.1	0.08	4.36	4.44	6.0
	Total	30.79	18.10	48.89	100.0	41.31	32.12	73.43	100.0
Fall	L	128.39	76.27	204.66	82.4	187.53	86.08	273.61	83.8
	W	14.83	9.34	24.17	9.7	18.48	19.92	38.40	11.8
	F	1.08	9.00	10.08	4.1	4.88	5.56	10.44	3.2
	H	2.17	7.30	9.47	3.8	1.04	3.04	4.08	1.2
	Total	146.47	101.91	248.38	100.0	211.93	114.60	326.53	100.0

[a] I = direct infall in g/m^2; L = lateral transport in g/m; T = total in g/m of bank.

[b] L-Leaves, W-Wood, F-Fruits, H-Herbaceous Material.

Table A4. Total CPOM input by category and season at the Nagel site.

Season		1976 I	1976 L	1976 T[a]	1976 %	1977 I	1977 L	1977 T[a]	1977 %
	L[b]	50.98	68.53	119.51	62.4	60.71	67.60	128.31	67.5
Annual	W	5.43	11.77	17.20	9.0	5.87	4.48	10.35	5.4
Totals	F	4.32	2.16	6.48	3.4	0.65	-	0.65	0.3
	H	14.31	33.94	48.25	25.2	7.26	43.48	50.74	26.7
	Total	75.04	116.40	191.44	100.0	74.49	115.56	190.05	99.9
	L	2.21	3.53	5.74	21.1	1.60	3.08	4.68	33.5
Winter	W	1.32	0.89	2.21	8.1	0.29	0.96	1.25	8.9
	F	3.77	1.30	5.07	18.6	-	-	-	-
	H	4.16	10.05	14.21	52.2	1.82	6.24	8.06	57.6
	Total	11.46	15.77	27.23	100.0	3.71	10.28	13.99	100.0
	L	1.64	4.83	6.47	34.1	2.30	20.56	22.86	54.8
Spring	W	2.51	2.25	4.76	25.1	1.90	1.36	3.26	7.8
	F	0.06	0.86	0.92	4.8	-	-	-	-
	H	2.45	4.39	6.84	36.0	1.41	14.20	15.61	37.4
	Total	6.66	12.33	18.99	100.0	5.61	36.12	41.73	100.0
	L	2.43	3.56	5.99	34.7	6.78	1.36	8.14	43.6
Summer	W	0.60	5.31	5.91	34.2	2.98	1.96	4.94	26.4
	F	0.49	-	0.49	2.8	0.28	-	0.28	1.5
	H	0.64	4.24	4.88	28.3	0.56	4.76	5.32	28.5
	Total	4.16	13.11	17.27	100.0	10.60	8.08	18.68	100.0
	L	44.70	56.61	101.31	79.2	50.03	42.60	92.63	80.1
Fall	W	1.00	3.32	4.32	3.4	0.70	0.20	0.90	0.8
	F	-	-	-	-	0.37	-	0.37	0.3
	H	7.06	15.26	22.32	17.4	3.47	18.28	21.75	18.8
	Total	52.76	75.19	127.95	100.0	54.57	61.08	115.65	100.0

[a]I = direct infall in g/m^2; L = lateral transport in g/m; T = total in g/m of bank.

[b]L-Leaves, W-Wood, F-Fruits, H-Herbaceous Material.

Table A5. Total CPOM input by category and season at the Kellogg Forest site.

Season		1976 I	1976 L	1976 T[a]	1976 %	1977 I	1977 L	1977 T[a]	1977 %
Annual	L[b]	212.74	44.91	257.65	79.0	267.42	64.72	332.14	82.0
	W	44.18	13.43	57.61	17.7	57.59	5.68	63.27	15.6
	F	6.42	1.26	7.68	2.4	3.10	0.08	3.18	0.8
	H	1.05	2.35	3.40	1.0	0.22	6.28	6.50	1.6
	Total	264.39	61.95	326.34	100.1	328.33	76.76	405.09	100.0
Winter	L	1.85	1.76	3.61	20.3	5.62	7.00	12.62	75.0
	W	4.10	2.28	6.38	35.8	1.94	1.04	2.98	17.7
	F	5.77	1.26	7.03	39.5	-	-	-	-
	H	0.39	0.39	0.78	4.4	0.10	1.12	1.22	7.3
	Total	12.11	5.69	17.80	100.0	7.66	9.16	16.82	100.0
Spring	L	2.34	0.68	3.02	10.6	5.89	5.12	11.01	56.0
	W	22.24	2.79	25.03	88.3	5.06	2.16	7.22	36.7
	F	-	-	-	-	-	-	-	-
	H	0.17	0.14	0.31	1.1	0.10	1.32	1.42	7.2
	Total	24.75	3.61	28.36	100.0	11.05	8.60	19.65	99.9
Summer	L	19.09	0.75	19.84	65.0	13.84	1.28	15.12	45.8
	W	4.44	4.53	8.97	29.4	14.35	0.28	14.63	44.3
	F	0.36	-	0.36	1.2	1.14	0.08	1.22	3.7
	H	-	1.35	1.35	4.4	0.02	2.00	2.02	6.1
	Total	23.89	6.63	30.52	100.0	29.35	3.64	32.99	99.9
Fall	L	189.46	41.72	231.18	92.6	242.07	51.32	293.39	87.4
	W	13.40	3.83	17.23	6.9	36.24	2.20	38.44	11.5
	F	0.29	-	0.29	0.1	1.96	-	1.96	0.6
	H	0.49	0.47	0.96	0.4	-	1.84	1.84	0.5
	Total	203.64	46.02	249.66	100.0	280.27	55.36	335.63	100.0

[a]I = direct infall in g/m^2; L = lateral transport in g/m; T = total in g/m of bank.

[b]L-Leaves, W-Wood, F-Fruits, H-Herbaceous Material.

Table A6. Average CPOM inputs for the 28 day sampling periods.

Starting	Smith		43rd		Nagel		Kel. For.	
Date	I[a]	L	I	L	I	L	I	L
5 Nov 75	75.04	12.14	6.95	8.09	5.94	8.48	8.40	3.58
3 Dec 75	1.59	4.55	0.65	2.58	2.41	3.20	0.52	1.03
31 Dec 75	8.14	1.73	1.08	1.29	1.24	0.92	1.27	0.38
28 Jan 76	12.22	4.16	1.60	3.34	1.86	3.20	1.91	0.70
25 Feb 76	132.00	6.67	11.11	5.53	4.13	4.89	21.06	1.13
24 Mar 76	16.79	15.41	7.84	8.76	1.06	4.74	2.03	2.02
21 Apr 76	6.85	4.82	7.70	6.42	1.46	2.70	1.66	0.44
19 May 76	8.38	3.40	14.85	6.42	1.13	5.10	9.74	0.42
16 Jun 76	5.80	2.72	6.07	3.89	1.02	3.35	6.31	2.40
14 Jul 76	12.84	4.31	9.86	7.80	2.01	4.65	7.83	3.80
11 Aug 76	25.00	12.11	34.62	26.77	6.30	10.64	26.81	5.61
8 Sep 76	141.44	63.47	60.10	48.47	35.34	48.25	123.95	31.33
6 Oct 76	104.08	24.71	51.76	26.66	11.13	16.27	52.89	9.08
TOTAL	554.79	160.20	214.19	156.03	75.03	116.40	264.38	61.94
3 Nov 76	3.72	8.38	3.64	13.92	1.56	5.45	4.43	6.08
1 Dec 76	2.33	1.62	1.70	2.02	1.08	1.31	1.71	1.32
29 Dec 76	0.80	1.22	0.72	1.14	0.34	0.73	0.93	0.82
26 Jan 77	1.76	1.10	6.07	0.62	0.74	2.78	0.59	0.96
23 Feb 77	10.38	6.78	3.98	13.91	2.02	19.56	2.86	3.27
23 Mar 77	15.38	22.98	6.15	15.96	1.40	13.07	1.94	3.83
20 Apr 77	8.98	6.53	6.56	10.90	2.19	3.49	6.26	1.50
18 May 77	6.94	2.46	10.96	6.36	1.89	3.13	4.98	1.15
15 Jun 77	13.79	1.98	11.47	14.47	4.51	2.59	18.84	1.24
13 Jul 77	10.33	3.30	18.89	11.26	4.20	2.36	5.54	1.24
10 Aug 77	53.00	8.80	40.24	18.42	14.56	13.32	48.32	3.45
7 Sep 77	208.11	25.10	58.34	39.78	24.64	29.23	162.32	27.24
5 Oct 77	89.57	31.84	113.35	56.38	15.37	18.52	69.62	24.68
TOTAL	425.09	122.09	282.07	205.24	74.50	115.54	328.34	76.78

[a] I = direct infall in g/m^2; L = lateral transport in g/m.

Table A7. Leaf species collected in the litter traps arrayed by processing types.[a]

Fast

Acer saccharum - sugar maple - S,N[b]
Cornus spp. - dogwood - S,43,N,KF
Fraxinus spp. - ash - 43,N,KF
Robinia psuedoacacia - black locust - 43
Rosa palustris - swamp rose - 43,N,KF
Tilia americana - basswood - N,KF
Zanthoxylum americanum - 43

Medium

Acer rubrum - red maple - N
Acer saccharinum - silver maple
Carpinus caroliniana - musclewood - KF
Carya ovata - shagbark hickory
Hammamelis virginiana - witch hazel
Juglans nigra - black walnut - S,43
Prunus serotina - black cherry - S,43
Salix spp. - willow - S,43,N
Ulmus americana - American elm - S,43,KF
Viburnum lentago - nannyberry - S,43,N,KF
Miscellaneous Leaves - S,43,N,KF
Spring Fragments - S,43,N,KF
Physocarpus opulifolius - 43,N
Corylus americana - hazel - S,KF

Slow

Crataegus spp. - hawthorn - 43
Pinus strobus - white pine
Populus grandidentata - large-toothed aspen
Populus tremuloides - quaking aspen - S,N,KF
Quereus bicolor - swamp white oak - KF
Quereus borealis - northern red oak - S,43,N
Rhamnus catharticus - buckthorn - KF
Pyrus coronaria - wild crab-apple - 43

[a]Processing types after Petersen and Cummins (1974) or K.W. Cummins (pers. com.).

[b]Study sites where more than 1 g/m of this species was collected. S-Smith, 43-43rd Street, N-Nagel, KF-Kellogg Forest.

Table A8. Annual totals of combined direct infall and lateral transport samplers in g/m of bank.

Location		Smith		43rd Street		Nagel		Kel. For.	
	Trap #	Total	Leaves	Total	Leaves	Total	Leaves	Total	Leaves
	1	1164.96	332.66	443.34	351.13	96.77	25.36	274.06	202.45
	2	699.08	421.04	545.07	385.61	93.56	42.23	303.55	230.78
	3	583.12	373.54	113.71	80.94	112.55	24.63	366.48	303.47
1976	4	865.40	442.69	449.00	318.08	655.15	538.51	381.75	301.10
	5	540.95	393.96	312.20	209.84	76.81	26.40	273.16	230.96
	6	431.61	234.65	357.82	207.56	113.97	59.99	358.82	277.09
	1	432.96	225.78	568.97	410.91	96.87	18.36	346.71	288.00
	2	431.25	272.02	703.67	544.19	90.37	50.74	380.31	335.85
	3	622.70	330.55	176.01	131.06	85.55	24.78	466.22	417.33
	4	1115.85	453.23	593.16	433.88	589.31	521.68	401.77	340.98
	5	435.25	237.51	388.26	283.29	93.25	50.94	356.20	309.72
1977	6	357.85	214.40	494.09	324.45	185.13	103.27	479.68	301.02
	7	221.49	120.51						
	8	371.96	201.27						
	9	390.87	225.10						
	10	1158.95	404.34						
	11	615.04	334.68						
	12	412.96	240.41						

Table A9. Variables used in rank correlations and the correlation results.

Variables	Smith 1976	Smith 1977	43rd 1976	43rd 1977	Nagel 1976	Nagel 1977	Kel. For. 1976	Kel. For. 1977
Total inputs (g/m of bank)	714	547	370	487	191	190	326	405
Total inputs (g/m^2)	733	561	258	340	108	108	279	348
Lateral transport (g/m)	159	122	156	205	116	115	62	77
Total leaves (g/m of bank)	366	348	259	355	120	128	258	332
"Slow" leaves (%)	13.8	17.2	15.3	16.2	6.1	14.7	1.1	1.0
Bank slope (%)	6.0		7.0		2.5		1.5	
Mean channel width (m)	1.9		7.1		7.0		8.3	
Mean floodplain width (m)	12		25		75		100	
Mean basal area (m^2/ha)	17.2		11.7		6.5		30.2	
Mean stand density	7617		5182		1467		4329	
Mean shrub b. area (m^2/ha)	4.4		3.4		1.5		2.3	

Correlation Results[a]

Variables			n	N
Total inputs (g/m)	vs.	mean stand basal area	8	20
Total inputs g/m^2)	vs.	mean stand basal area	8	26
Total inputs (g/m)	vs.	mean shrub basal area	8	44**
Total inputs (g/m^2)	vs	mean shrub basal area	8	38*
Total inputs (g/m)	vs.	mean stand density	8	44**
Total inputs (g/m^2)	vs.	mean stand density	8	38*
Total leaves	vs.	mean stand basal area	8	16
Total leaves	vs.	mean shrub basal area	8	40*
Total leaves	vs.	mean stand density	8	36*
Lateral transport	vs.	bank slope	8	42*
"Slow" leaves	vs.	mean floodplain width	8	-36*
Total inputs (g/m^2) from Table 19[b]	vs.	mean channel width	10	-62**

Critical values of N	n	α=.05	α=.01
$N=4 \sum^{n} C_i - n(n-1)$	8	36	44
n=variable pairs	10	46	58

[a]Kendall's rank correlation test as described in Sokal and Rohlf (1969).

[b]The Nagel site was excluded due to vegetation disturbance. The results of Post and delaCruz (1977) were not included because mean channel width could not be determined.

*Significant at 5% level; **significant at 1% level.

Table A10. Total fruit collections at the sites by species and trap type.

Site	Species	1976 I	1976 L	1976 T[a]	1977 I	1977 L	1977 T[a]
Smith	*Cornus* spp.	3.28	-	3.28	1.49	-	1.49
	Viburnum lentago	1.04	-	1.04	0.18	-	0.18
	Rosa palustris	1.66	-	1.66	-	-	-
	Juglans nigra	0.38	-	0.38	91.42	1.08	1.08
	Miscellaneous	0.06	0.12	0.18	0.14	-	0.14
	Total	6.40	0.12	6.52	93.23	1.08	94.31
43rd	*Crataegus* spp.	0.88	10.52	11.40	-	7.30	7.30
	Viburnum lentago	-	-	-	1.28	-	1.28
	Cornus spp.	0.05	-	0.05	1.46	-	1.46
	Prunus serotina	1.96	0.20	2.16	4.91	1.90	6.81
	Rosa palustris	1.57	0.42	1.99	2.00	-	2.00
	Miscellaneous	0.37	-	0.37	-	-	-
	Total	4.83	11.14	15.97	9.65	9.20	18.85
Nagel	*Rosa palustris*	0.57	-	-	-	-	-
	Tilia americana	3.10	2.16	5.26	0.31	-	0.31
	Cornus spp.	0.65	-	-	-	-	-
	Viburnum lentago	-	-	-	0.34	-	0.34
	Total	4.32	2.16	6.48	0.65	-	0.65
K. For.	*Fraxinus* spp.	4.20	1.26	5.46	1.66	0.08	1.74
	Tilia americana	0.64	-	0.64	-	-	-
	Cornus spp.	0.38	-	0.38	0.53	-	0.53
	Viburnum lentago	1.20	-	1.20	0.91	-	0.91
	Total	6.42	1.26	7.68	3.10	0.08	3.18

[a] I = direct infall in g/m^2. L = lateral transport in g/m. T = total in g/m of bank.

Table A11. Seasonal and total CPOM inputs at the sampling locations by channel surface area.[a]

Location	Season	DI[b]	%[c]	LT	%	Total (g)	Total (g/m^2)	%
	Winter	95.0	73.1	34.8	26.9	129.8	72.1	11.1
	Spring	171.4	73.1	63.2	26.9	234.6	130.3	20.2
Smith	Summer	52.2	74.5	18.0	25.5	70.5	39.2	6.1
	Fall	563.2	77.3	165.2	22.7	728.4	404.7	62.6
	Annual	881.8	75.8	281.2	24.2	1163.3	646.3	100.0
	Winter	79.5	70.7	33.0	29.3	112.5	15.8	5.3
	Spring	153.4	71.4	61.6	28.6	215.0	30.3	10.1
43rd	Summer	255.8	83.6	50.2	16.4	306.0	43.1	14.4
	Fall	1272.3	85.5	216.4	14.5	1488.7	209.7	70.2
	Annual	1761.0	77.8	361.2	21.2	2122.2	298.9	100.0
	Winter	53.2	67.2	26.0	32.8	79.2	11.3	10.5
	Spring	42.7	46.9	48.4	53.1	91.1	13.0	12.0
Nagel	Summer	51.8	71.0	21.2	29.0	73.0	10.4	9.6
	Fall	375.9	73.4	136.3	26.6	512.2	73.2	67.8
	Annual	523.6	64.6	231.9	35.4	755.5	107.9	99.9
	Winter	82.2	84.7	14.8	15.3	97.0	11.7	3.7
	Spring	148.6	92.4	12.2	7.6	160.8	19.4	6.2
Kel. For.	Summer	220.8	95.6	10.2	4.4	231.0	27.8	8.9
	Fall	2008.2	95.2	101.4	4.8	2109.6	254.2	81.1
	Annual	2459.8	92.0	138.6	8.0	2598.4	313.1	99.9

[a]Channel surface area for a 1 m long section of stream: Smith - 1.8 m^2; 43rd - 7.1m^2; Nagel - 7.0m^2; Kellogg Forest - 8.3m^2.
[b]DI = CPOM input in g/channel surface area as estimated by direct infall samplers. LT = CPOM input in g/channel surface area as estimated by lateral transport samplers.
[c]Percent of total seasonal CPOM input.

Table A12. Seasonal production/respiration ratios (P/R) from selected riffle sections of Augusta Creek, 1974-1975 (King, 1980).

Season	Smith	43rd Street	Nagel	Kellogg Forest
Winter	0.23 ± .01[a]	0.97 ± .12	0.96[b]	1.62[b]
Spring	0.39 ± .35	1.76 ± .46	1.70 ± .46	2.29 ± .82
Summer	0.22 ± .05	1.23 ± .22	1.16 ± .19	1.25[b]
Fall	0.23 ± .09	1.04 ± .25	2.00 ± .32	2.02 ± .34

[a]Values are means of 3 replicates ± 1 standard deviation.

[b]Two replicates.

Table A13. Riffle invertebrate community functional group analysis at the Augusta Creek sites from the River Continuum Project, Summer, 1976 (Vannote, Cummins, Minshall, Sedell).

Functional Group	Smith	43rd Street	Kellogg Forest
# Shredders/m^2	1600	43	86
%	6.7	0.4	1.1
# Collectors/m^2	21306	9207	7740
%	88.7	95.1	96.0
# Scrapers/m^2	986	367	151
%	4.1	3.8	1.9
# Predators/m^2	132	65	86
%	0.6	0.7	1.1
# Detritivores/m^2	22906	9250	7826
%	95.4	95.6	97.1
Total	24024	9682	8063

Table A14. Particulate organic matter (POM) in Augusta Creek sediments from the River Continuum Project (Vannote, Cummins, Minshall, Sedell, 1976).[a]

	Fall			Winter			Spring			Summer			Annual $\bar{x}$		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
POOL[b]															
CPOM	255	177	87	695	233	119	1538	67	106	113	201	186	650	170	125
FPOM	706	1623	1152	850	1386	850	1170	772	1398	459	1583	1982	796	1341	1346
UPOM	274	771	431	210	572	315	296	275	366	206	692	759	246	578	468
Total[c]	961	1800	1239	1545	1619	969	2708	839	1504	572	1787	2168	1446	1511	1470
RIFFLE															
CPOM	25	23	14	44	51	30	52	75	21	36	45	23	39	48	22
FPOM	77	94	182	259	102	94	108	160	79	193	136	157	159	123	128
UPOM	68	91	300	222	204	203	82	205	143	161	109	152	133	152	200
Total	132	117	196	303	153	124	160	235	100	229	181	180	206	172	150

[a]All values are mean ash-free dry weight in g/m^2.

[b]CPOM = Coarse particulate organic matter (>1-mm dia.); FPOM = fine particulate organic matter (<1-mm); UPOM = very fine particulate organic matter (<53-mm >0.45-mm).

[c]Total=CPOM + FPOM; UPOM is included in FPOM total.