Stream Drift as an Indication of Water Quality

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ABSTRACT

Stream drift and benthos were collected from five stream locations having different levels of domestic and industrial pollution. The drift organisms from 100 m^3 of water during the diel period of peak drifting was compared with the benthos from 1 m^2 of stream bottom. Numbers and weights of both drift and benthos followed similar quantitative relations with water quality, generally increasing with water degradation. The relative abundance of benthos greatly exceeded that of the drift at the most polluted station where tubificids, which infrequently drift, were abundant. A greater variety of organisms occurred in the drift than in the benthos. Drifting organisms came from a wider spectrum of habitats and were collected with less effort than benthic organisms but did not always include certain benthic forms that seldom leave the stream bottom.

Aquatic invertebrates are sensitive to even subtle changes in water quality and consequently have been extensively examined as indicators of pollution. The objectives of this investigation were to relate the composition of stream drift to different levels of water quality and then to compare the efficiency of the drift net with that of benthic samplers in studying aquatic communities in small streams. The first of these objectives has been considered previously by Besch (1966), the second by Berner (1951) and Waters (1961, 1966).

The intensity of collecting drift and benthos in this study was similar to what might be practical in a general survey of stream habitats, water quality, or fish food supplies. The data were not examined statistically: final conclusions were based on gross differences among collections.

MATERIALS AND METHODS

Five stations variously affected by domestic and industrial pollution were established in the Salt Fork Basin, Champaign County, Illinois. Samples of stream drift were taken from each station in March, May, July, and October 1966. The collecting procedure consisted of setting a net in the stream flow just below the water's surface. The net was set for 30 or 60 min during the second hour after sunset, the period of maximum drift as determined in an adjoining central Illinois stream (Larimore 1972).

The net consisted of a bag of Nitex cloth (Tobler, Ernest & Traber, Inc.) with 471-μm pore size attached to a 0.09-m^2 (1 ft^2) brass frame held in the stream on a pair of steel rods (Waters 1961). The bag was approximately 80 cm long and had a total straining surface of approximately 0.8 m^2. The volume of water passing through the net during any one collecting period was determined by measuring the water velocity in the mouth of the net with a Gurley pigmy current meter (Model 625) and associating this velocity with the total time that the net was set. Samples were preserved in 95% ethanol to be sorted, identified, counted, and weighed. Weights of the damp organisms were recorded to the nearest 0.1 mg. Five benthic samples were taken from each station in July with a Surber stream sampler or a grab on handles described by Larimore (1970). The organisms were processed in the same way as drift. Fish, crayfish, mollusks, and terrestrial insects were not included in the tabulations because they occurred incidentally in the drift and/or benthos.

DESCRIPTION OF BASIN

The Salt Fork Basin was glaciated by the Kansan, Illinoian, and Wisconsinan glaciers. It is presently covered by Wisconsinan till with an overlay of 1 to 10 m of loess. There are no rock outcrops, the only stone in the streams is glacial sands, gravels, and small boulders. Until approximately 100 years ago the basin consisted of marshes and poorly drained, flat to rolling lands covered with heavy prairie vegetation. The forests of the basin were limited to the banks of permanent streams.

TABLE 1.—*Location of sampling stations and the approximate number of people living in drainage basin above each station in 1966*

Station	Location[a]	Approximate population	Drainage area in km^2
A	200′ W of NW corner of SW 1/4 of Sec. 25, T20N, R10E	500	122
B	700′ W of the NE corner of Sec. 29, T20N, R9E	800	120
C	100′ above confluence of Boneyard Creek, NE corner of SE 1/4 Sec. 8, T19N, R9E	2,000[b]	154
D	NE corner of the NW 1/4 of SW 1/4 Sec. 26, T20N, R10E	28,000	201
E	600′ S of the NE corner of Sec. 11, T19N, R9E	102,000	197

[a] Location described from U. S. Geological Survey Urbana Quadrangle Map, 15-min series, 1957 ed.
[b] Four industrial sources of pollution not included in count.

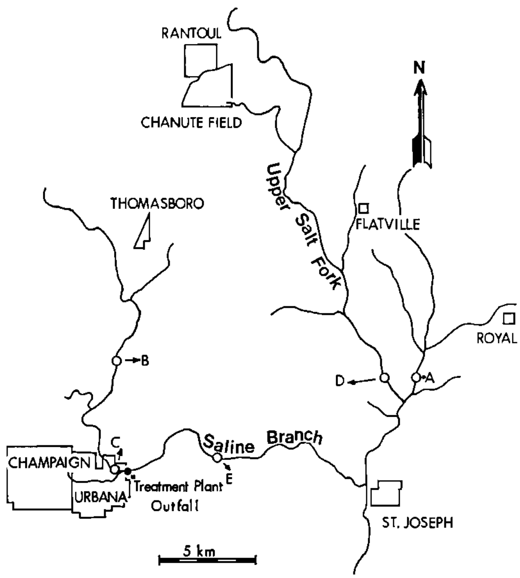

FIGURE 1.—Map of upper Salt Fork and Saline Branch showing locations of five collecting sites.

During the past century the entire area has been drained with ditches and field tiles and converted from prairie marsh to some of the best grain land in the world. The use of great amounts of commercial fertilizers, especially nitrogen during the past decade, has affected the chemical composition of surface waters. Cattle feed lots, although a threat of pollution in many areas of the Midwest, do not noticeably affect streams of the upper Salt Fork Basin.

The cities of Champaign, Urbana, and Rantoul, the University of Illinois, and Chanute Air Force Base, with a combined population of 130,000 to 135,000 persons, are all in the upper Salt Fork Basin and have a tremendous impact on the quality of surface waters. Domestic waste from this population is the main influence on water quality, although the activities at the Air Force Base and of the several small industries around Champaign-Urbana contribute industrial wastes.

DESCRIPTION OF STATIONS

The five stream stations studied were all in dredged channels and all drained rich agricultural lands. The main differences in them were imposed by the population centers in the basin above them (Table 1). The objectives of the study required that the stations be arranged in order of water quality; consequently stations were designated "A" for the station least affected by pollution and progressing in order of descending water quality to Station "E" which was severely polluted (Fig. 1).

Chemical parameters usually associated with pollution support this arrangement of stations (Table 2). From Station A to Station E, the water contained increasing amounts of ammonium, organic nitrogen, phosphate, and alkyl benzene sulfonate, the main component of detergents at that time. Nitrates were lower at Station E due to the large amounts of reduced nitrogenous materials and dilution water being contributed by the Urbana-Champaign Treatment Plant. The ranges of five parameters measured at each station during each collecting period revealed increasing extremes of water composition progressing from Station A to E (Fig. 2). The wide range of conditions found at Station D reflects the inadequacy of upstream treatment plants and the unsteady quality of their effluents. Although hardness and dissolved solids fluctuated greatly at Station E, the dominating influence of the Urbana-Champaign Treatment Plant stabilized alkalinity, pH, and chlorides

TABLE 2.—*Five pollution-related parameters of water collected from the stream stations when study was initiated 7:30–8:30 PM, 2 March 1966. Measurements in mg/liter*

Station	Ammonium (NH_4)	Organic nitrogen (N)	Nitrate (NO_3)	Phosphate (PO_4)	Alkyl benzene sulfonate
A	0.1	1.1	25.4	0.1	0.1
B	0.1	1.3	29.2	0.1	0.1
C	0.2	1.1	27.0	0.2	0.2
D	1.0	1.6	25.2	1.0	0.3
E	6.7	2.8	16.5	5.2	0.4

at this station (Fig. 2). The high dissolved solids at Station A are not due to pollution but come from seepages found along the stream that carry high concentrations of dissolved solids and from water pumped from upstream gravel pits. Seasonal differences in chemical parameters of the water at the five stations were largely associated with seasonal changes in the volume of stream flow.

Station A was in a drainage ditch with steep banks covered by grasses and other low herbaceous vegetation. The stream channel proper had a mean width of 4 m and, at normal water level, had a maximum depth of 40 cm. Every 30 to 60 m, shallow riffles of coarse sand and fine gravel separated shallow pools that accumulated silt and fine sand. No rooted aquatic macrophytes were present. The drainage basin consisted of rich farmland and supported only one small village that did not have a sewer system and consequently no point source of stream pollution. There were no indications of water pollution (Table 2). Roeske (1969) found relatively low total nitrogen and orthophosphate at this station in 1967–68.

Station B was similar in dimensions and physical characteristics to Station A but there was a greater development of mud bars and slight meanders in the channel, indicating that this portion of the stream had not been dredged in recent years. There were no rooted macrophytes in the water nor woody plants along the bank. The drainage basin supported one village of less than 1,000 people that did not have a sewer system at the time of this study. No pollution modified the water. The flow almost ceased during dry seasons and prevented drift sampling in October 1966.

Station C, on the edge of the city of Urbana, was above the influences of the highly polluted Boneyard Creek and the outfall of the Urbana-Champaign Sanitary Treatment Plant (Fig. 1). Although the waters here were not noticeably affected by domestic wastes (Table 2), several industries upstream occasionally released materials, such as oils and detergents, that were toxic to aquatic organisms. The bottom materials in this area consisted of sand

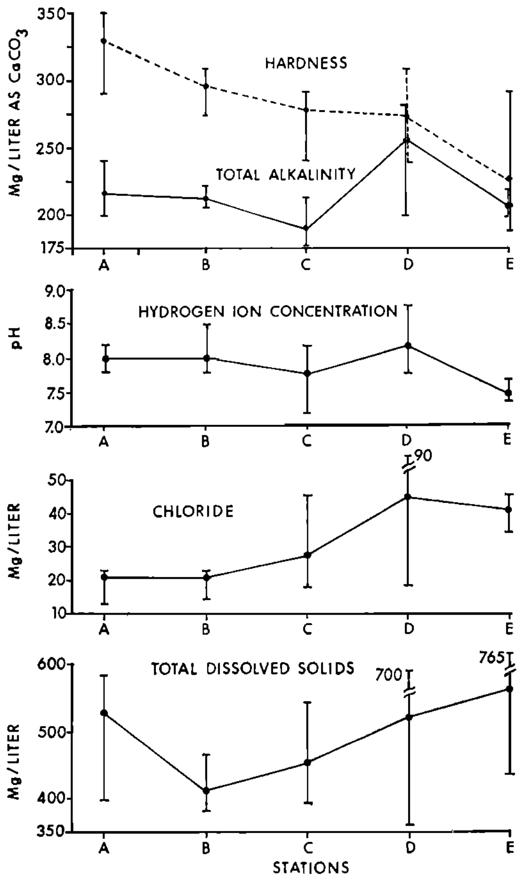

FIGURE 2.—Means and ranges of several chemical parameters measured each collecting period at each station.

TABLE 3.—*Number and weight (mg) of various drift organisms taken from 100 m³ of water at each station, 2 March 1966*

	Station							
	A		B		D[a]		E	
Taxon	no.	wt.	no.	wt.	no.	wt.	no.	wt.
Tubificidae	712	42	1,181	20	65	27	6	8
Amphipoda	+	2	1	2	+	+		
Isopoda					+	1		
Cladocera			10	1				
Copepoda	48	2			2	+		
Siphlonuridae (n)	1	+						
Pseudocloeon (n)					11	4		
Potamanthus (n)	+	2						
Hexagenia limbata (n)	2	1						
Stenonema (n)	3	4	1	6				
Caenis (n)	57	27			1	1		
Coenagrionidae (n)	1	3	+	3				
Isoperla minuta (n)	+	1						
Corixidae (a)					+	4		
Megaloptera (l)			2	3				
Dubiraphia quadrinotata (l)	+	+			+	+		
Rhyacophila (l)	+	1	2	4				
Chironomidae (l)	184	408	398	673	31	22	17	55
Chironomidae (p)			10	14	3	3	3	4
Chironomidae (a)					3	+	+	+
Simuliidae (l)	3	6	46	56				
Ceratopogonidae (l)			2	2				
Psychodidae (l)							30	8
Psychodidae (p)			3	5	+	+		
Psychodidae (a)			+	1	1	1	52	31
Empididae			+	1				
Totals	1,014	500	1,656	790	120	62	109	108

(l) = larvae, (n) = nymphs, (p) = pupae, (a) = adults, + = less than 1 after adjustment to 100 m³.
[a] = no collection for Station C.

and gravel overlain by trash and rubble contributed by the surrounding community which accumulated to form occasional rifflelike areas and shallow pools. The channel was generally 5 to 8 m wide. Small trees and shrubs lined the banks. Larimore and Smith (1963) collected nine species of fishes at this station in 1959; anomalies, apparently due to pollution, were common.

Station D was in a channel that had been formerly dredged and whose banks were kept free of woody plants. The occasional riffle in this area was formed of coarse sand and small gravel. No aquatic macrophytes were present. The actual stream channel in this area varied from 12 to 20 m wide. Occasional pools were 1 m or more deep at normal stream flow. This station was 13 km (8 mi) below the severe domestic pollution from Rantoul and Chanute Air Force Base, so that the stream had assimilated much of the domestic wastes before reaching this sampling site. Chlorides were frequently high and there were occasional pulses of petroleum and heavy detergents from upstream. Roeske (1969) attributed the high concentrations of ammonia, nitrate, and orthophosphate at this station in 1967–68 to effluents from upstream wastewater treatment plants. Austin and Sollo (1969) analyzed water 5.3 km (3.3 mi) below this station in March, June, and July 1968. Their data indicated that chlorides were somewhat high, but other parameters associated with pollution (COD, BOD, fecal coliform) were normal and showed that the upstream pollution had been mostly assimilated by the stream. Larimore and Smith (1963) collected 21 species of fishes from Station D in 1959 and thought that the upstream pollution enriched the stream in this area.

Station E received nearly the full impact of pollution from the Urbana-Champaign Sanitary District, with its outfall 6.4 km (4 mi) upstream, and from Boneyard Creek. This creek, highly polluted by a great variety of domestic and chemical wastes as it drains Champaign-Urbana and the University of Illinois campus, entered the Saline Ditch 7.2 km (4.5 mi) above this station. The stream in this area had not recently been dredged, and small trees and shrubs grew along the steep banks. There were patches of *Elodea canadensis* and

TABLE 4.—*Number and weight (mg) of various drift organisms taken from 100 m³ of water at each station, 2 and 3 May 1966*

	Station									
	A		B		C		D		E	
Taxon	no.	wt.	no.	wt.	no.	wt.	no.	wt.	no.	wt.
Nematoda							74	2	1	+
Tubificidae	3	3	335	8	302	7	56	169	159	66
Isopoda			11	18			5	18		
Amphipoda			2	5			6	22		
Copepoda					36	3			1	+
Pseudocloeon (n)	30	16	169	20	43	37	2	2		
Hexagenia limbata (n)	3	463	14	173						
Caenis (n)	53	48	12	19	2	1	13	4		
Stenonema (n)			3	1	2	1				
Coenagrionidae (n)							1	6	1	10
Perlidae (n)			3	6						
Isoperla minuta (n)	4	7	17	13						
Corixidae (n)			1	1	2	9				
Corixidae (a)			3	6						
Haliplidae (l)			2	7						
Dytiscidae (l)							1	1		
Rhyacophilidae (l)			2	7						
Cheumatopsyche (l)			2	2						
Simuliidae (l)			9	70						
Chironomidae (l)	26	59	134	70	138	66	20	8	154	146
Chironomidae (p)	29	21	6	4	5	2	11	4	100	58
Chironomidae (a)	6	1			21	3	48	19	50	21
Psychodidae (l)							6	2	151	25
Psychodidae (p)							1	1	16	22
Psychodidae (a)									209	129
Empididae (l)									3	3
Hydracarina							2	+	18	2
Totals	153	614	728	432	555	130	246	259	876	488

(l) = larvae, (n) = nymphs, (p) = pupae, (a) = adults, + = less than 1 mg.

attached and floating strands of *Cladophora* and *Spirogyra*. Although some sand and rubble could be found where the current was greatest, most of the bottom was composed of silt, and sludge beds were well developed in several areas near the station. The actual stream channel was 10 to 12 m wide. Ammonium and organic nitrogen, chlorides, and phosphates were abnormally high at this station (Table 2). Three times during August 1968, Austin and Sollo (1969) measured diel chemical changes in the stream 1.6 km (1 mi) below Station E. They found the carbonaceous BOD generally varied from 6 to 12 mg/liter during a 24-hr period, with maxima reaching 16 mg/liter. Ammonia was often 8 to 12 mg/liter as N with one 4-hr period of levels between 24 to 30. Organic nitrogen, chlorides, and phosphorus were frequently high, while dissolved oxygen fell below 2 mg/liter for several hours each night. They recorded bacteria counts of 2×10^5 fecal and 4.2×10^8 total coliforms per ml at Station E in July 1968. The stream at this point occasionally carried great amounts of fibrous material, apparently from the Sanitary District's treatment plant, and occasionally experienced pulses of chemical wastes from Champaign-Urbana and the University of Illinois.

Larimore and Smith (1963) found only two species of fishes in this area. These species formed a total population of less than one fish per 80 m² (100 yd²) which was extremely low compared to 10 species comprising 675 fish per 80 m² taken 1.6 km (1 mi) above the sources of pollution.

COMPOSITION OF DRIFT

Only those taxa that were abundant and frequently represented in the drift (Tables 3–6), or those that suggested a pertinent relationship to water quality will be considered.

Nematoda.—A few nematodes large enough to be retained in the drift net were collected in May at the most polluted stations, D and E. The actual abundance of nematodes in these waters was demonstrated by Chaudhuri, Siddiqi, and Engelbrecht (1964), who collected nematodes on 5-μ membrane filters. The average numbers of nematodes per 3.8 liters (1 gal) of water found by these workers were: 3, 2 km above Station B; 10, 2 km below B; 70, at C, and 2,139, at E. These data show that nematode concentrations reflect the extent

TABLE 5.—*Number and weight (mg) of various drift organisms taken from 100 m³ of water at each station, 4–6 July 1966*

	Station									
	A		B		C		D		E	
Taxon	no.	wt.	no.	wt.	no.	wt.	no.	wt.	no.	wt.
Tubificidae (c)			21	7						
Tubificidae (a)							1,412	60	445	566
Cladocera					17	6				
Copepoda	6	3			25	1	42	2		
Pseudocloeon (n)	145	30	50	13	8	16	900	352		
Pseudocloeon (a)	133	66								
Stenonema (n)	6	8	4	40						
Caenis (n)	182	45	67	26						
Caenis (a)			8,083	2,110						
Coenagrionidae (n)	6	7			25	10				
Corixidae (n and a)			42	119	17	5	12	68	10	24
Gerridae (n)			4	2						
Sisyridae (l)					8	+				
Stenelmis vittipenis (l)									5	14
Dubiraphia quadrinotata (l)	72	35	4	3					25	10
D. quadrinotata (a)			17	10			4	2		
Hydrophilidae (a)									25	852
Dytiscidae (a)			4	3	8	14			5	36
Haliplidae (l)			4	1						
Haliplidae (a)			4	11						
Cheumatopsyche (l)			4	20						
Trichoptera (a)	272	62	8	30	33	90	33	8	25	13
Leptoceridae (a)			188	30						
Leptoceridae (l)			4	13						
Chironomidae (l)	67	28	158	9	67	28	10,516	3,486	750	3,784
Chironomidae (p)	739	133	188	34	275	1,013	2,154	847	22,550	5,550
Chironomidae (a)	745	112	17	3	383	52	1,600	860	20,790	7,258
Ceratopogonidae (l)							8	9		
Psychodidae (l)									5	10
Psychodidae (p)					8	13	4	7	1,100	1,101
Psychodidae (a)									30	4
Totals	2,424	545	8,871	2,473	892	1,281	16,700	5,750	45,865	19,468

(c) = cocoons, (l) = larvae, (n) = nymphs, (p) = pupae, (a) = adults, + = less than 1 mg.

of pollution and are abundant in waste treatment plant effluents. Nematodes are important components of stream drift but usually are not adequately sampled with netting ordinarily used for collecting drift organisms.

Tubificidae.—Worms of the genera *Tubifex* and *Limnodrilus* were taken in the drift at each station. Although the highest average numbers occurred at Stations D and E, large collections were taken in March at A (Table 3). A few cocoons were collected at Station B in July in association with an abundance of drifting filamentous algae and detritus. The worms may have been associated with floating detritus temporarily lifted from the bottom, for *Tubifex* and *Limnodrilus* are not considered active swimmers. Brigham (In Austin and Sollo 1969: 116–7) took relatively few tubificids in the drift near Station E. The differences between his numbers and mine may have been associated with diel activities of the worms, for Brigham collected during the day, whereas I collected at night.

Microcrustacea.—Several undetermined genera of Copepoda and Cladocera occurred sporadically. A net of smaller mesh undoubtedly would have taken greater numbers. In general, more were taken in the less polluted waters than in the heavily polluted waters.

Ephemeroptera.—The mayflies, most commonly and consistently represented by *Pseudocloeon*, *Caenis*, *Stenonema*, and *Hexagenia*, strongly reflected the succession of water quality in these collections. They were abundant in the less polluted areas and absent or rare in the polluted areas, with the exception of one very large collection of *Pseudocloeon* nymphs at Station D in July (Table 5). None was taken at Station E. *Stenonema* and *Hexagenia* were virtually restricted to the three least polluted stations. The numbers of nymphs collected increased from early spring through the summer and into the fall. Only in July were large numbers of adults taken (see *Pseudocloeon* and *Caenis* in Table 5).

Coleoptera.—Although aquatic beetles were taken in each of the four series of collections, they occurred most frequently in July (Table

TABLE 6.—*Number and weight (mg) of various drift organisms taken from 100 m³ of water at each station, 4 and 10 October 1966*

	Station							
	A		[a] C		D		E	
Taxon	no.	wt.	no.	wt.	no.	wt.	no.	wt.
Tubificidae	10	15			40	1	35	186
Copepoda	200	5	20	+				
Potamanthus (n)			20	130				
Leptophlebiidae (n)			20	16				
Pseudocloeon (n)	40	3	120	40				
Caenis (n)	490	49	260	156				
Hexagenia limbata (n)			260	88				
Stenonema (n)			220	118	7	7		
Coenagrionidae (n)	20	19	20	58	20	299		
Isoperla (n)			20	26				
Corixidae (n)	10	5	20	214			7	47
Peltodytes (a)					280	1,457		
Dubiraphia quadrinotata (l)	10	3						
D. quadrinotata (a)	20	9						
Chironomidae (l)	120	16	60	54	587	247	926	4,501
Chironomidae (p)	760	69	280	390	587	658	547	2,792
Chironomidae (a)	40	5			1,053	361	28	67
Ceratopogonidae (p)							35	98
Ceratopogonidae (a)					27	44		
Psychodidae (l)							12	11
Syrphidae (l)							20	12
Culex (l)					80	31	20	10
Culex (a)							63	86
Chaoborus (l)							7	4
Totals	1,720	198	1,340	1,334	3,200	3,301	1,693	7,864

(l) = larvae, (n) = nymphs, (p) = pupae, (a) = adults, + = less than 1 mg.
[a] = insufficient flow, no collection taken at Station B.

5). The largest single collection, on the other hand, was of 280 adult *Peltodytes* in October at Station D (Table 6). This unusual collection of *Peltodytes* was composed of 140 *P. duodecimunctatus* (Say), 126 *P. edentulus* (LeConte), and 14 *P. litoralis* Matheson. The few samples of Coleoptera did not reveal any definite relationship between beetle occurrence and water quality.

Trichoptera.—Only a few caddisflies (larvae) were taken in March and May and none in October. In July, however, larvae were collected at Station B and adults at each station (Table 5). Their abundance decreased with a decline in water quality.

Diptera.—Of the several families of dipterans taken, Chironomidae and Psychodidae occurred in abundance, occasionally in numbers as high at 10,000 and 22,000 individuals per 100 m³ of water (Table 5). Chironomids were taken in every collection. Their distribution was not directly associated with water quality even though the badly polluted stations, D and E, produced the largest collections (Table 5). The extreme variation of mean weights of larvae from different collections was due not only to seasonal growth patterns but also to the occurrence in abundance of species of different sizes. Chironomids were the most abundant organisms in the drift collected by Brigham (In Austin and Sollo 1969) just above Station E.

The numbers of psychodids (*Psychoda alternata* with an occasional specimen of *P. cinerea*) increased with a decline in water quality. They were not taken at Station A but were taken once at B and C, three of four times at D, and every time at E. They occurred in large numbers only at E below a waste treatment plant outfall. Brigham (In Austin and Sollo 1969) found psychodids abundant in the drift above Station E but scarce downstream. Their association with organic wastes and their occurrence each month in drift collections made psychodids useful indicators of pollution. *Culex* were found only at Stations D and E.

Hydracarina.—Water mites were collected only in May (Table 4) and only at Stations D and E. The species collected, *Fuscuropoda agitans* (Banks), is often associated with humus and organic debris which might explain its occurrence at the two most polluted stations.

The total numbers and weights of organisms

TABLE 7.—*Number of taxa (families or higher) of aquatic invertebrates in drift taken in each collection, and the mean number of taxa, number organisms, and weight (g) per 100 m³ at each station.*

Month	Station A	B	C	D	E
March	14	12	[a]	10	3
May	6	15	7	11	7
July	8	12	10	11	9
October	8	[b]	11	7	8
Mean no. taxa	9	13	9	10	7
Mean no. organisms	1,328	3,752	929	5,066	12,136
Mean wt. per collection	0.46	1.2	0.92	2.34	6.98

[a] Collection lost.
[b] Stream flow too low to yield drift collection.

in each collection (bottom of Tables 3 to 6) show considerable variation, both between stations at the same time and at the same station at different times. Such quantitative differences must be expected in warmwater streams which are affected by many changing conditions and sudden disturbances, as will be discussed later in evaluation of drift collections as measures of water quality.

In spite of quantitative variations, the total numbers and weights of organisms generally increased with degradation of water quality, i.e., for Stations A to E. The quantitative means for all collections at each station show this trend (Table 7). The order is disturbed by the data from Station C which are consistently low. Since the benthic collections at this station were also sparse (Table 8), it seems probable that the intermittent industrial wastes (mostly oil) known to occasionally pass down this reach, reduced the invertebrate community without stimulating those organisms that often became abundant in moderate organic pollution. The high mean numbers and weights at Stations D and E were largely due to the very large collections procured at the polluted station in summer and fall (Tables 5 and 6).

Diversity within an aquatic community, whether measured by the actual number of taxa present or the number of taxa in relation to the number of individuals in the community, generally declines with degradation of the water. The numbers of taxa (families or higher) of aquatic invertebrates in the drift (Table 7), excluding the mollusks and crayfishes as explained elsewhere, do not show any definite change in diversity between stations with different amounts of pollution. Consideration of more specific identifications of organisms, available for many but not all groups, might have revealed more genera or species in the unpolluted waters than the polluted. A major influence on diversity found in the drift collections was the efficiency of the drift net in collecting organisms from a wide spectrum of microhabitats at a station. Thus, even in a severely polluted reach, minor habitats that might support less tolerant organisms would be contributing their species to the drift, even though in small numbers.

COMPARISON OF DRIFT WITH BENTHOS

The most striking difference between the drift and benthic collections was the frequent abundance and variety of terrestrial insects taken in the drift. Because the terrestrial organisms occurred more or less accidentally in the drift after having fallen or having been blown or washed into the water, they were not reported. This is not to suggest they are without great importance to the stream community; they are substantial food resources for fishes and other predators. Terrestrial Coleoptera, Hemiptera, Hymenoptera, and Homoptera, usually adults, were the insects most frequent in drift collections.

Mollusca (both clams and snails) were frequently abundant in the benthos but not included in this comparison because they were taken only incidentally in drift nets. Young fish and crayfish were not tabulated for similar reasons.

Tubificidae.—Numbers of tubificids at each station generally increased with increased water pollution. The large numbers taken at Station E were associated with sludge beds and poor water conditions (Table 2) below the city's waste treatment plant. Tubificids comprised 86% of the weight of benthos collected by Brigham (In Austin and Sollo 1969) near Station E. Drift collections of these worms also reflected the water quality although the largest collections was taken at Station D and not at Station E. A few cocoons were

TABLE 8.—*Numbers of the most abundant organisms in drift and benthos taken in July at each station and the mean number and weight of all organisms collected*

Taxon	Drift (numbers/100 m^3) at specified stations					Benthos (numbers/m^2) at specified stations				
	A	B	C	D	E	A	B	C	D	E
Tubificidae (c)		21								41,108
Tubificidae (a)				1,412	445	1,679	316	2,818	2,763	36,893
Copepoda			25	42						
Pseudocloeon (n)	145	50		900			186		47	
Pseudocloeon (a)	133									
Caenis (n)	182	67				106	667			
Caenis (a)		8,083								
Coenagrionidae (n)			25							
Corixidae (n)			17					16		
Corixidae (a)		42								
Trichoptera (a)	272	188	33	33						
Chironomidae (l)	67	158	67	10,516	750	856	19,964	70	2,473	464
Chironomidae (p)	739	188	275	2,154	22,550	22	2,617	5	261	43
Chironomidae (a)	745		383	1,600	20,790				4	5
Psychodidae (p)					1,100					68
Total number	2,424	8,871	892	16,700	45,865	2,756	25,870	2,910	5,591	78,630
Total weight (g)	0.54	2.47	1.28	5.75	19.47	1.94	5.77	1.04	4.92	58.30

c = cocoons, n = nymphs, l = larvae, p = pupae, a = adults.

taken in the drift while enormous numbers were included in the benthos at Station E. Tubificids in the drift, whether as cocoons or worms, might not consistently represent the actual populations because their abundance depends on the amounts of floating algae and detritus at the time of collection and the chance that a mass of floating material enters or misses the drift net.

Ephemeroptera.—Caenis and *Pseudocloeon* were the common mayflies in the July collections of both benthos and drift. *Caenis* was taken only at Stations A and B, whereas *Pseudocloeon* occurred at these stations as well as at Station D. As would be expected, only nymphs were taken in the benthos. *Caenis* nymphs were especially abundant in the benthos at Station B. *Pseudocloeon* was not taken in the benthos at Station A even though many occurred in the drift at this station in July. The occurrence of *Pseudocloeon* nymphs in the benthos and drift at Station D in July (Table 8) suggests that this species may tolerate rather highly enriched stream waters.

Trichoptera.—Too few caddisflies occurred in the benthic collection to be listed in Table 8. Although few larvae were taken in the drift collections, adult caddisflies were common and their numbers generally declined directly with the decline in water quality (Table 5).

Diptera.—Chironomid larvae and pupae were generally abundant in the benthos but varied tremendously with no obvious relationship to water quality. Benthic collections had more larvae than drift collections, somewhat fewer pupae, and practically an absence of adults compared to the occasional abundance of adults in the drift.

Psychodids were taken in large numbers only at Station E, and their abundance was associated with the outfall from the sewage treatment plant above the station. Only pupae occurred in moderate numbers in the benthos and in large numbers in the drift (Table 8) although small numbers of larvae and adults had been collected in the drift at this time (Table 5).

Drift and benthos followed similar quantitative relationships with water quality in the series of stations. Weight of drift organisms per 100 m^3 of water passing through the net

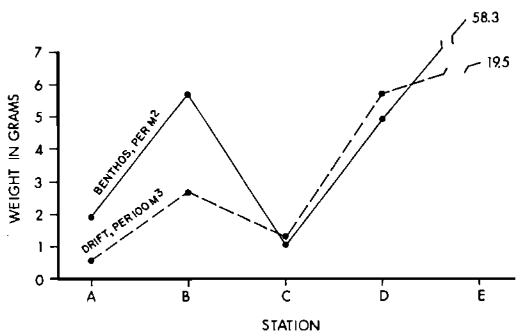

FIGURE 3.—Weights of benthos and stream drift taken from each station during July 1966.

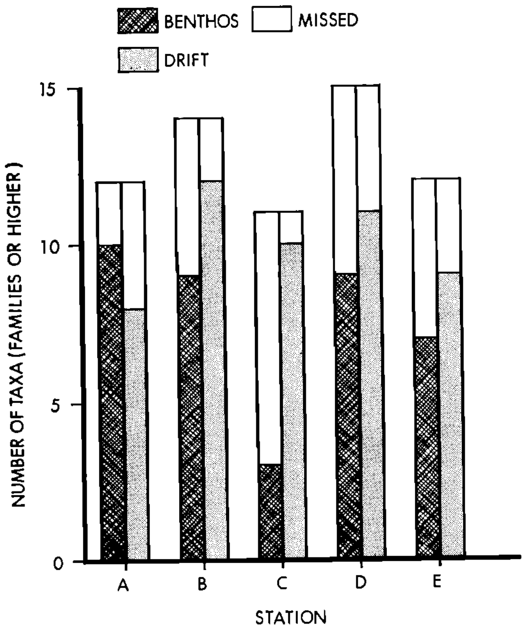

FIGURE 4.—Number of taxa (families or higher) taken in the drift and in the benthos and the number of taxa not taken in one but taken in the other at each station during July 1966.

during the period of maximum drift was comparable to the weight of benthos taken from one square meter of stream bottom (Fig. 3). The benthos vastly exceeded the drift only at Station E where the benthic community was predominantly tubificids that only occasionally entered the drift.

Weights of drift and benthos were much higher at the most polluted station, E, than at any other station. The weight would have increased with increased pollution except that Station C was unusually low, probably because of sporadic industrial pollution, as explained earlier.

The number of kinds of aquatic organisms did not change significantly, nor follow any consistent relationship with water quality through the series of stations (Fig. 4). Except at Station A, more taxa were taken in the drift than in the benthos. Furthermore, there was less difference in the number of taxa taken in the drift at each station than in the benthos. These two points can be related to the broader spectrum of stream habitats represented in the drift collections than in the benthic collections.

ADVANTAGES OF COLLECTING DRIFT INSTEAD OF BENTHOS

1. The drift collection usually represents a wide spectrum of the habitats found in a stream; a benthic sample shows only what was existing in the particular area (1 square foot, fraction of a meter, etc.) that was collected. The great variation in benthic samples, even in a limited area, illustrates the necessity of several samples and the influence of selecting the collecting sites. One drift sample might be adequate, whereas a large number of benthic samples would be needed to cover the variety of bottom habitats even in an unusually uniform reach of stream.
2. A single piece of bottom-sampling gear does not function with the same efficiency on different types of stream substrates, at different depths, and different water velocities. Seldom is benthic sampling extended to include stream banks, organic substrates (logs, etc.), and areas of dense vegetation. The drift net collects organisms from all these areas.
3. The drift collection requires much less work than a series of benthic samples. The net is light-weight, easy to set up in the stream, and yields a light-weight collection. Benthic sampling usually requires the use of a relatively heavy grab or dredge and procures samples heavy with inorganic materials. Drift samples are neat collections of organic materials that do not require the laborious, time-consuming job of washing out silts and clays and picking through much sand and gravel.
4. A drift net is inexpensive to construct, whereas bottom samplers are often costly and more than one kind may be required, as pointed out above. (If an adequate current meter is not available, the cost of one to use in drift collecting would offset the saving of the inexpensive net.)
5. The drift collection usually reveals interesting aspects of the organisms' life histories, e.g., period of transformation.
6. The drift collection includes terrestrial organisms that have fallen into the stream and which contribute to the food supplies of fish.

DISADVANTAGES OF COLLECTING DRIFT INSTEAD OF BENTHOS

1. Certain aquatic organisms only sporadically enter the drift and might be missed even though common in the benthos.
2. At least a slight current is necessary if a drift collection is to be taken.
3. Most organisms drift more abundantly at night, so that the best collection is usually taken in the dark. There is a waiting period while the drifting organisms accumulate in the net.
4. Tree leaves in the autumn, floating and anchor ice in the winter, and heavy debris (logs) during floods may interfere with drift collecting.
5. The abundance and composition of drift changes seasonally and might prevent direct comparison of collections taken at different times. At times certain life stages of an organism might not be fairly represented in the drift.
6. Drift collections give little precise habitat information for individual organisms, since the exact source of the individual is not known.
7. Collections of drift, with the organisms originating an indefinite distance above the collecting site, may not show local or temporary deleterious effects imposed on an aquatic community, whereas bottom samples might reveal the destruction or reduction on benthos in only a small area.

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