Effects of a Pool on Stream Invertebrate Drift

WILLIAM P. KOVALAK[1]

School of Natural Resources, University of Michigan, Ann Arbor 48109

ABSTRACT: Invertebrate drift entering and leaving a pool in Club Stream, Otsego Co., Michigan, was studied between June and September 1971. Drift rates out of the pool were greater than drift rates into the pool for most taxa on all dates. Increase in drift rate between the upstream and downstream ends of the pool (expressed as percent of number entering the pool) averaged 86.4% (range 3.3 - 707.7%) and decreases in drift rate averaged 24.4% (range 1.2 - 72.1%). The source of drifting organisms was a rheophilic fauna living on logs and twigs along the margin of the pool. Patterns of drift periodicity of most taxa were similar at the two sampling sites, but nocturnal peaks of drift rate of Ephemeroptera and *Gammarus* occurred earlier in the evening at the downstream site. Estimates of deposition rate suggested that the total number of organisms deposited in the pool per day was greater than the numbers drifting into or out of the pool. Fish predation on drift probably was negligible, because the number of trout in the pool was small and the fish present were large.

INTRODUCTION

High invertebrate drift rates reported for many rivers (reviewed by Waters, 1972) have raised questions regarding the ability of benthos to withstand sustained high rates of attrition (Waters, 1965) and the effect of drift on benthos dynamics (Ulfstrand, 1968). Interpretation of the impact of drift on benthos dynamics depends on knowledge of the fate of drift (Ulfstrand, 1968). Although pools have been suggested as major sites of drift consumption (Waters, 1962), little is known about the fate of drift in pools. Waters (1962) reported large decreases in drift rate in pools and attributed these losses to fish predation and to deposition with subsequent mortality and decomposition. Elliott (1967), however, reported large numbers of organisms drifting through pools, and his attempts to collect depositing organisms on trays were unsuccessful.

The objectives of this study were to: (1) determine if pools act as sites of drift consumption; (2) estimate deposition rates in pools, and (3) assess fish predation on drift. This study was carried out between June and September 1971.

DESCRIPTION OF STUDY AREA

Club Stream originates ca. 1 km SE of Vanderbilt, Otsego Co., Mich., and flows NE approximately 17 km to its confluence with the Sturgeon River. The pool studied (Fig. 1) was 6 km upstream from the mouth of Club Stream and was located in a sharp bend which is characteristic of pools in this stream. The pool was bounded upstream and downstream by riffles with modal water depths at base flow of 26

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[1] Present address: Department of Biology, Allegheny College, Meadville, Pennsylvania 16335.

and 32 cm, respectively. Pool surface area was 136.5 m^2, maximum depth was 122 cm and modal depth was 68 cm. Pool substrates were primarily fine gravel, sand and silt. Distribution and abundance of substrate types were variable between dates owing to discharge instability. Discharge rates and maximum-minimum water temperatures on each sampling date are given in Table 1.

METHODS

Drift was sampled upstream and downstream from the pool at points where changes in bottom slope marked the transition between riffle and pool (Points A and D, Fig. 1). Drift nets (471 μ mesh) 30 cm sq at the opening and 1.2 m long were constructed with straight sides and a boxed end. This design allowed debris to collect at the back of the net, thereby permitting sampling for periods up to 10 hr before clogging and backwashing occurred. In the stream, drift nets were attached to iron rods driven into the bottom. Since water depth at the upstream sampling site was always less than 30 cm, the drift net rested on bottom; at the downstream sampling site where minimum water depth was 35 cm, the net was kept 2 cm below the water surface and never rested on bottom. In the first two drift collections, nets

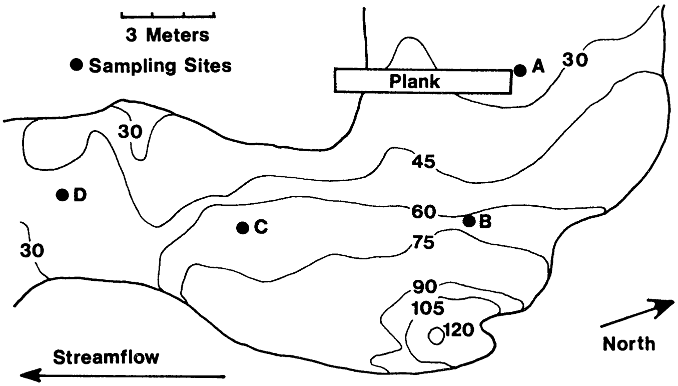

Fig. 1.—Contour map of the pool showing location of sampling sites. Numbers indicate depth in cm

TABLE 1.—Discharge and water temperature in Club Stream on the six sampling dates

Date	Discharge x10^3 m^3/day	Maximum-minimum water temperature (C)
June 17-18	71.2	14-17
July 7-8	71.1	19-21
July 19-20	71.6	20-23
July 30-31	69.7	20-22
August 7-8	65.9	16-20
August 23-24	67.0	12-15

were emptied at 2-hr intervals, thereafter at 8-hr intervals. A plank was suspended between the banks and iron pipes driven into the bottom at midstream so that it was possible to service the upstream drift net without disturbing the stream bottom (Fig. 1).

The volume of water filtered by drift nets differed between sampling sites and among dates. Drift catches were converted to drift densities (Waters, 1969a), and the product of drift density and total daily discharge was used to estimate total daily drift entering and leaving the pool. Drift densities as numbers/5000 m^3 of water were used to compare periodicity of drift entering and leaving the pool.

Deposited organisms were collected in metal trays (15 x 15 x 8 cm), filled to a depth of 3 cm with 1-2 cm diam gravel collected from the stream and rinsed with boiling water to kill the macrofauna. Ten trays were placed on the pool bottom for 24 hr on sampling dates. Five trays were equipped with covers made of ⅜ inch (0.95 cm) hardware cloth to prevent predation by fish or large invertebrates. A sponge-lined metal lid was pressed and held over trays to minimize loss of organisms during recovery.

Settling of drifting organisms between the upstream and downstream ends of the pool was studied by suspending nets from the top and bottom of iron rods driven into the bottom at Points B and C, Figure 1. Conical drift nets (471 μ mesh), 17 cm diam at the opening and 1 m long, were used. Top nets were positioned 5 cm below the surface; bottom nets were positioned 5 cm above the bottom. Samples were collected between 2100-2400 hr EST.

Fish populations were sampled biweekly between 15 June and 1 September using a portable electro-fishing unit. Three passes were made through the pool and the species and standard lengths recorded.

RESULTS

Drift rates out of the pool were greater than drift rates into the pool for most taxa on all dates (Table 2). Only *Ephemerella* and *Simulium* exhibited higher drift rates downstream on all dates. Other taxa exhibited decreased drift rates downstream on at least one date. On a taxon-by-taxon, date-by-date basis, increases in drift rate between the upstream and downstream ends of the pool averaged 85.4% (range 3.3-707.7%) and decreases in drift rate averaged 24.4% (range 1.2-72.1%). There was no relationship between the magnitude of change in drift rate and discharge or water temperature. Decreases in drift rate of three taxa and total fauna on 7-8 August, however, were coincident with the lowest discharge recorded during the study.

Qualitative observations indicated a substantial fauna of rheophilic insects, predominantly *Baetis, Ephemerella, Hydropsyche* and *Simulium,* present on logs and twigs along the pool margin. Insect abundance on these substrates increased between May and mid-June, decreased in July and increased again in September and October. Unfortunately, quantitative analysis of the pool fauna was not attempted.

The diel periodicity of drift entering and leaving the pool was compared using data collected 17-18 June and 7-8 July. For most taxa, the periodicity of drift entering and leaving the pool was similar. For *Gammarus* and taxa of Ephemeroptera, however, nocturnal peaks of drift density occurred earlier in the evening at the downstream site (Fig. 2).

Deposition rates of the most abundant taxa are given in Table 3, as is a comparison of numbers deposited in covered and uncovered trays on 7-8 July. There were no significant differences between numbers in covered and uncovered trays (t-test), suggesting that predation on deposited organisms by either fish or invertebrates was not important. Deposition rates did not appear to be related to absolute drift rate, discharge or water temperature. Deposition rates were

TABLE 2.—Total daily drift rates of the most common taxa and total fauna into and out of the pool. Net change in drift rate expressed as percentage of the number entering the pool given in parentheses

Taxon	June 17-18		July 7-8		July 19-20	
	In	Out	In	Out	In	Out
Baetis	3745	4471	2661	2503	2334	2305
	(19.4)		(10.7)		(−1.2)	
Tricorythodes	....	....	1024	2090	1675	2406
			(104.1)		(43.6)	
Ephemerella	2036	2905	853	1223	544	1031
	(42.7)		(43.4)		(89.5)	
Lepidostoma	1809	3218	2133	2233	2076	3251
	(77.9)		(4.7)		(56.6)	
Hydropsyche	1225	983	498	484	358	687
	(−19.8)		(−2.8)		(91.9)	
Simulium	1282	1324	4835	6172	3136	13074
	(3.3)		(27.7)		(316.9)	
Gammarus	1139	1040	995	1294	1446	1332
	(−8.7)		(30.1)		(−7.9)	
Total Fauna	18938	23439	14519	23818	13805	26349
	(23.8)		(64.1)		(90.9)	

TABLE 2.—(continued)

Taxon	July 30-31		August 7-8		August 23-24	
	In	Out	In	Out	In	Out
Baetis	990	2133	870	461	17098	19698
	(115.5)		(−47.0)		(15.2)	
Tricorythodes	6859	11988	1476	1107	2358	3243
	(74.8)		(−25.0)		(37.5)	
Ephemerella	265	558	132	264	121	214
	(110.6)		(100.0)		(76.9)	
Lepidostoma	404	237	13	105	1152	938
	(−41.3)		(707.7)		(−18.6)	
Hydropsyche	4210	5353	896	1213	2278	3094
	(27.1)		(35.4)		(35.8)	
Simulium	1129	2286	1186	1358	509	844
	(102.5)		(14.5)		(65.8)	
Gammarus	1478	3053	659	184	831	1581
	(106.6)		(−72.1)		(90.3)	
Total Fauna	17313	29427	6827	5786	26063	32173
	(70.0)		(−15.2)		(23.4)	

highest when there were large (percent) increases in drift rate downstream. The number deposited per unit area was small; but if the area of the pool bottom is assumed to be the same as the area of the pool surface (136.5 m^2), the number deposited per day was substantial. In all cases these estimates of total deposition rate greatly exceeded the numbers entering or leaving the pool.

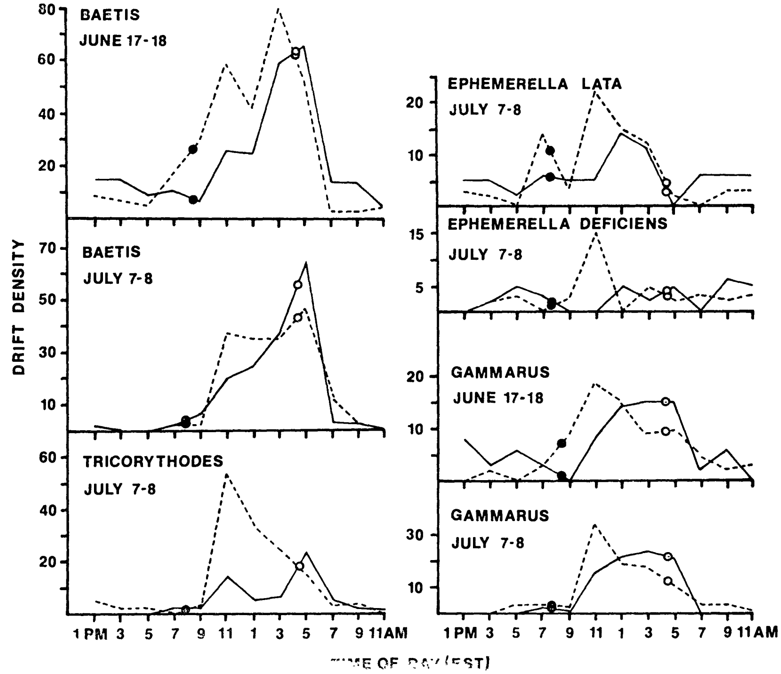

Fig. 2.—Comparison of the diel periodicity of drift of Ephemeroptera and *Gammarus* entering (———) and leaving (.........) the pool (● denotes sunset, o denotes sunrise)

TABLE 3.—Estimated numbers of organisms deposited on the pool bottom per 24 hr. A comparison of numbers deposited in covered and uncovered trays (*see* text) on 7-8 July is also given

Taxon	Density (No./m^2)					
	July 7-8			July 19-20	July 30-31	August 7-8
	Covered	Uncovered	Mean			
Baetis	53	62	58	44	75	31
Tricorythodes	53	44	49	22	120	31
Ephemerella	18	9	14	62	18	9
Lepidostoma	36	27	32	71	4	9
Simulium	62	116	89	142	13	13
Gammarus	44	98	71	13	173	67
Total Fauna	338	418	378	408	506	204

Attempts to study the settling of drifting organisms in the pool were unsuccessful because of the small numbers of naturally drifting organisms collected. In general, there were no large changes in the vertical distribution of drifting organisms between the sampling sites. In a few cases drift density at the surface increased between the sampling sites, and in only one case (*Simulium,* 9 August) did drift density at the bottom increase between the sampling sites.

A maximum of two brown trout (*Salmo trutta* L.) were collected in the pool on any date between 15 June and 1 September. Catch of fish did not increase when the pool was blocked upstream and downstream with wire mesh prior to sampling. Mean standard length of all trout collected was 41.2 cm (range 37.7-47.4). Small sample sizes precluded gut analysis. A very small number of sculpins (*Cottus* sp.) and dace (*Rhinichthys* sp.) were also collected.

DISCUSSION

The pool studied did not act as a site of drift consumption, but rather it served as a source of drifting organisms. It is usually assumed that few rheophilic organisms inhabit pools (Hynes, 1970). Although rheophilic insects may not inhabit fine sediments on pool bottoms, a substantial fauna was present on logs and twigs along pool margins. Current velocities along the outside margin of the pool often exceeded 50 cm/sec, making this habitat comparable to riffle habitat. Little is known about stream faunas living on woody substrates (*see* Marlier, 1954; Nilson and Larimore, 1973).

Percent increases in drift rate between the upstream and downstream ends of the pool were greater than corresponding changes in drift rate between the ends of riffles and runs. Increases in drift rate between the ends of riffles reported by Waters (1962) averaged 28.8% (range 11.4-53.8%), and the increase in drift rate between the ends of a run reported by Elliott (1967) was 15.3%.

One of the most important problems for rheophilic insects inhabiting pools is obtaining an adequate oxygen supply. Most aquatic insects depend on passive diffusion of oxygen through gills or the body surface to satisfy oxygen requirements (Hynes, 1970). Oxygen supply depends both on the oxygen content of the water and on the rate of water renewal at respiratory surfaces. The rate of renewal is a function of current velocity and/or turbulence. At low water temperatures when oxygen consumption rates of ectothermic insects are low and oxygen solubility is high, the slow currents in pools may be adequate to meet oxygen demands. As water temperature increases, oxygen consumption rates increase but oxygen solubility decreases. At this time the slow currents in pools may not provide an adequate renewal of oxygen supply resulting in respiratory stress.

It is hypothesized that respiratory stress accounts for changes in faunal abundance in the pool. The increase in faunal abundance on logs and twigs in June may have been due to their movements from the pool bottom to compensate for decreasing oxygen concentration and increasing oxygen demand with increasing water temperature. Current velocities at the bottom of the pool rarely exceeded 20 cm/sec., whereas current velocities along the pool margin often exceeded 50 cm/sec. Williams and Hynes (1973) reported *Chimarra aterrima* migrated from the streambed in riffles to roots along the stream margin as water temperatures approached 28 C.

Further increases in water temperature in July and early August presumably caused respiratory stress which resulted in drift and subsequent diminution of the fauna living on logs and twigs. Photonegative organisms like Ephemeroptera normally spend daylight hours in cryptic microhabitats (Waters, 1972) where renewal of oxygen supplies largely depend on current velocity in adjacent areas. Madsen (1968) reported that oxygen supply to cryptic microhabitats was about 6% of that to current-exposed microhabitats. Oxygen supplies in cryptic microhabitats, therefore, may be inadequate to meet the oxygen requirements of the insects. At night oxygen supplies may become limiting because of increased oxygen consumption rates controlled by endogenous physiological rhythms (Zoladek and Kapoor, 1971; Ulanoski and McDiffett, 1972; P. Klotman, pers. comm.). Inadequate oxygen supplies result in respiratory stress which could cause insects to move to current-exposed microhabitats where there is more oxygen but where the probability of erosion and drifting is also greater.

Considerable effort has been spent characterizing and classifying patterns of drift periodicity (*e.g.*, Müller, 1966; Elliott, 1969; Waters, 1969b). Most invertebrates exhibit diel periodicities of drift with a nocturnal maximum (Waters, 1972), but there are seasonal, geographic and specific differences in the number and timing of nocturnal peaks. Results of this study suggest that some of this variability may be related to the current velocity in the habitat where drifters originate.

It is hypothesized that differences in timing of peak drift rates also are related to respiratory stress. In pools, where oxygen supply to cryptic microhabitats is low, increases in oxygen consumption rate after sunset should cause insects to move immediately to current-exposed habitats resulting in a peak of drift just after sunset. In riffles where oxygen supply to cryptic microhabitats is greater, oxygen may not become limiting until late in the night after an extended period of high oxygen consumption rates by the insects and of microbial community respiration. The result would be a delay of peak drift until late in the night. Not all taxa exhibited differences in drift periodicity at the two sites and this may reflect differences in respiratory physiology between taxa (Dodds and Hisaw, 1924).

Although deposition occurred in the pool, it apparently had little relationship to changes in drift rate. Highest deposition rates were not associated with decreases in drift rate but with the largest (percent) increases in drift rate. Furthermore, the estimated numbers deposited per day in the pool greatly exceeded the numbers drifting into or out of the pool. This latter point may be misleading because trays used to measure deposition rates were not distributed randomly on the pool bottom but were concentrated near the deepest part. If deposition rates were greater in this area, then estimates of the total numbers deposited in the pool each day are overestimates. Further, sediments used in the deposition trays were coarser than sediments on the pool bottom. Consequently, there may have been a higher rate of accrual of organisms in the trays than on the pool bottom.

Deposition rates may be more a measure of the activity of the fauna living in the pool than a measure of numbers deposited from upstream areas. To account for the large numbers deposited in the pool each day, it is suggested there was daily redistribution of the pool fauna between logs and twigs along the pool margin and the pool bottom. Insects presumably drifted from the logs and twigs and were deposited on the bottom at night and then subsequently returned to the pool margin. Drift densities at the top and bottom of the water column were comparable suggesting that organisms were being added to the drift continuously. Analysis of water movement in the pool using fluorescein dye suggested mixing did not account for similarity of drift densities at the surface and bottom because mixing was important only near the downstream end of the pool.

Predation by brown trout probably had little effect on drift rates, because the numbers in the pool were small and the fish present were large. The low fish population density was probably due to territorial behavior (Kalleberg, 1958) which kept other fish, particularly smaller ones, out of the pool. Metzlaar (1929) reported that large brown trout (> 38 cm) feed little on insects and small invertebrates. T. F. Waters (pers. comm.) indicated small brook trout [*Salvelinus fontinalis* (Mitchell)] were abundant in pools where he observed marked decreases in drift rate. Clemens (1928) and Ricker (1930) reported that small brook trout (< 30 cm) feed predominantly on larvae and nymphs of aquatic insects and small crustaceans.

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