A STUDY OF INVERTEBRATE DRIFT IN SMITH VALLEY CREEK, WISCONSIN

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ABSTRACT

The invertebrate drift and benthic invertebrate fauna in Smith Valley Creek (LaCrosse County, Wisconsin) were studied fron October 14, 1976 to May 14, 1977 and the influences of physical and chemical variables were examined.

Pairs of sample nets were set for 24 hours at 2-week intervals at 3 stations. Twelve sets of 2-hour samples were collected during two sampling periods in an effort to determine whether diurnal peroidicities in drift occurred. Benthic samples were collected five times during the sampling period. Dissolved inorganic nutrient concentrations and physical characteristics were determined for each sampling period.

The benthic invertebrate fauna appeared to be negatively impacted by human activity. Poor water quality due to additions of silt and soluble inorganic nutrients and the occurrence of potentially catastrophic events appeared to be the cause of low benthic populations. Nutrient concentrations fluctuated with highest concentrations coinciding with periods of greatest discharge. Significant differences in nutrient concentrations occurred between two of the stations.

The most abundant benthic taxon was Hydropsyche sp. (48% of the total benthic organisms). The highest drift rates were those of Gammarus limnaeus ($\bar{X} = 4.35/1000\ m^3$ of total discharge). There were no significant differences in total drift rates between stations 1 and 2. No major relationship was observed between soluble inorganic nutrient concentrations and drift rates. Seasonal variations in drift rates of Hydropsyche sp. and Gammarus limnaeus appeared to be inversely related to day length and (or) water temperature. Members of the Dytiscidae, Hydropsyche sp. and Gammarus limnaeus exhibited a negative phototaxis (bigeminous pattern) with respect to diurnal drift. Euparyphus sp. (Diptera) and Stratiomys sp. drifted predominantly during daylight hours.

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INTRODUCTION

The drifting of invertebrates is a normal feature of lotic systems. This phenomonon is referred to in various ways, e.g., as organic drift (Muller 1954), downstream drift of the invertebrate fauna (Bishop and Hynes 1969) stream drift (Muller 1974), invertebrate drift (Elliott 1969), drift of stream benthos (Diamond 1967), and simply as drift (Hildebrand 1974). The term drift fauna, as distinguished from bottom fauna, is incorrect since drifting is a temporary event in the life of many benthic invertebrate species (Waters 1972).

Berner (1951) described drift as a heterogeneous, macroscopic group of living and dead organisms carried by the current on or below the surface of the water. He included terrestrial and aquatic invertebrates and fishes. Waters (1962) defined drift as the quantity of organisms drifting downstream per unit time per unit stream width. Muller (1954) described drift as traveling benthos; furthermore, he provided impetus for studies of invertebrate drift with his observations of qualitative relationships among drift, bottom fauna, and drifting invertebrates as a source of fish food. Most detailed research concerning drift has been done in the last ten years. Consequently, the full ecological impact of drift phenomona have not been conclusively determined (Waters 1972).

Many fish which use drifting invertebrates as a food source in turn serve as a source of food and recreation for man. Because of this relationship, factors affecting drift rates are of importance in resource management.

The present study, therefore, was conducted to obtain data on the drift of benthic invertebrates and factors affecting drift rates. The primary objectives of this study were to:

(1) determine the taxanomic composition and quantity of invertebrate drift in Smith Valley Creek,

(2) determine whether diurnal periodicity exists in drift rates,

(3) determine the effect of soluble nurtients on drift rates,

(4) compare the composition of drifting organisms to the benthic fauna and compare seasonal changes in each,

(5) determine the effects of several physical variables (photoperiod, air and water temperature, and discharge) on drift rates.

LITERATURE REVIEW

Three types of drift have been described: constant, catastrophic, and behavioral. Waters (1965) described constant drift as the drift of occasional individuals of all species present that, for some reason, lose their attachment to the bottom and drift in low numbers without regard to diurnal periodicity. Constant drift has been observed by a number of investigators (Anderson and Lehmkuhl 1968, Anderson 1966, Elliott 1965). Constant drift, however, can be masked by catastrophic and behavioral drift, because the latter generally involves the movement of more organisms. Constant drift probably has no significant effect on invertebrate populations because of the small number of organisms involved (Waters 1972).

Physical-chemical disturbances (high discharge, drought, high temperature, ice scouring, pollution, and insecticides) are among the causes of catastrophic drift. The mechanical effects of flood water such as increases in width, depth, and velocity of water can result in exceptionally high drift rates as compared to those of normal water levels (Muller 1954, Waters 1961, Reisen 1972). Anderson and Lehmkuhl (1968) described a five-fold increase of Chironomidae and Simuliidae (Diptera) larvae in drift samples during a short period of high discharge, as well as a general tendency for larger individuals to be collected during these times. Minshall and Winger (1968) observed an increase in invertebrate drift after a sudden, artificially induced reduction in stream flow. Insects that normally drift at night could, by a sudden reduction in discharge, be induced to drift at midday. The discharge reduction acted more as a stimulus for increased invertebrate activity than as a mechanism for physical dislodgement from the sediment (Minshall and Winger 1968).

Waters (1972) defined behavioral drift as the result of a behavior pattern characteristic of certain species. Increased nocturnal activity brings organisms out from their places of daytime concealment, and increases their chances of being carried off by the current. Foraging in the relative concealment of darkness is a primary factor in periodic behavior of invertebrates (Waters 1967, Elliott 1967). Other factors include crowding during periods of rapid growth (Elliott 1967) and pre-pupation and preemergence activities (Reisen 1972).

The three types of drift (constant, catastrophic, and behavioral) can occur simultaneously. Anderson and Lehmkuhl (1968) found that members of the orders Ephemeroptera and Plecoptera retained their characteristic diurnal drift periodicity during periods of high discharge. At times there is apparently no clear distinction between the three causes of drift (Waters 1972).

Diurnal drift periodicities are well documented in the literature (Tanaka 1960, Muller 1963, Waters 1962, 1968, 1969, Elliott 1969). Whereas most investigators report a marked increase of drift at night, Anderson (1967) and Waters (1968) observed both day-drifting organisms and those with no diurnal drift pattern (Waters 1962, 1969).

Diurnal periodicities of drift rates commonly have 2 principal peaks per day. The bigeminus pattern, by far the most common, has a peak approximately one hour after sunset, and a smaller peak just before sunrise. The alternans pattern has a minor peak in drift rates approximately one hour after sunset, and a major peak within 2 hours of sunrise. Using concurrent 30-minute sampling periods, Elliott (1969) distinguished several minor drift rate peaks which could not be distinguished with longer sampling periods.

A member of the Amphipoda, Gammarus sp., had commonly shown marked diurnal drift patterns and high drift rates (Peterka 1969, Waters 1962, Iverson and Jessen 1977). Anderson (1966), Anderson and Lehmkuhl (1969), and Bishop and Hynes (1969) did not observe diurnal periodicity in drift rates of the Chironomidae (Diptera), however, both Steine (1972) and Reisen and Prins (1972) found members of the Chironomidae drifting with a diurnal pattern.

Apparently, light intensity is usually the stimulus for diurnal drift rate periodicity (Holt 1967, Elliott 1965, Harker 1964). Holt and Waters (1967) observed that, under decreasing light conditions the threshold of light intensity initiating high drift rates was 1 lux (approximating the light level one hour after sunset)(Holt and Waters 1967). Laboratory studies showed that the threshold can be as low as 0.001 lux (Bishop 1969). Holt and Waters (1967) and Elliott (1967) reported that with reversal of the light-dark periods, some drifting organisms adjust their drift patterns. Responses and light thresholds appear to be species specific.

Waters (1969) states that the secondary drift peak of some Baetis sp. mayflies appeared to be of endogenous origin. This was hypothesized by earlier investigators who suggested that any circadian drift rhythm is labile and easily modified (Holt and Waters 1967).

High invertebrate drift rates, due to behavioral drift, could seemingly denude upstream areas of benthic fauna. This, however, has not been observed (Muller 1954). Waters (1966) suggested that drift is production in excess of carrying capacity; therefore, no upstream recolonization is required. Drift acts as a regulatory mechanism by keeping the population level near the carrying capacity of the stream. Muller (1954) proposed that a colonization cycle exists in which aerial adults of aquatic insects compensate for downstream drift of the larvae by active upstream flight for oviposition. Colonization of denuded benthic areas occurs by four methods: drift, upstream migration within the water, migration from within the substrate, and aerial sources, e.g., oviposition (Williams and Hynes 1976). Of these methods, drift appears to be the most important mechanism (Williams and Hynes 1967).

Dendy (1944) postulated that pools tend to act as catch basins which allow drifting organisms to halt their downstream drift and begin an upstream movement. Because _Gammarus_ sp. (Amphipoda) lacks a flying stage, it is confined to swimming as a means of upstream transport. Minchley (1964) observed significant upstream movements of _Gammarus bousfieldi_ after displacement by floods. In laboratory studies involving the absence of food, upstream movements of _Gammarus pulex_ always exceeded drift rates. Lehmann (1967) found that the same number of _Gammarus pulex fossarum_ migrated upstream as drifted downstream, and that the size of a radioactive-marked population remained constant at the release point for a considerable time. It has been suggested by Waters (1972) that upstream movements of organisms do not completely compensate for their downstream movements due to drift. Upstream migration of adults is well documented, however, migrations with no discernible orientation have also been observed (Waters 1972). Muller (1974) reported that the upstream flights of adults occur with some members of the orders Ephemeroptera, Trichoptera, and Diptera.

Waters (1966) observed that drift can be greater below than above a riffle. If the relationship between drift and production in excess of carrying capacity is linear, production rates may be estimated by examining drift rates (Waters 1961). Life cycle and behavioral characteristics of the species must be examined to obtain accurate estimates of production rates (Hall et al. 1980). When examining drift phenomena, it becomes apparent that estimating production rates by using drift data is complex.

Waters (1972) reported that there is no direct relationship between invertebrate standing crops and drift rates. Any density dependent relationship between the two is not linear (Waters 1972). Drift is not a local phenomenon. Because drifting organisms travel, a drift-net sample is not necessarily a representation of the standing crop in the vicinity of the net.

Marked seasonal fluctuations in drift rates are documented. These drift changes may be closely related to periods of maximum growth and density independant variables such as prepupation and preemergence activities (Waters 1969, Reissen and Prins 1972, Stoneburner and Smock 1979). Stoneburner and Smock (1979) found a close correlation between exuviae collected and increased larval drift density. This observation indicates a relationship between periods of rapid growth and high drift rates. Lehmann (1967) reported that drift rates of Gammarus sp. males increased during the breeding season.

The effect of water temperature on drift appears to be varied. Both positive and negative correlations with drift rates have been observed (Reisen and Prins 1972). Water temperature appears to be the stimulus for the day drift of Oligophlebodes sigma (Waters 1968).

Net downstream movements of organisms can be significant to benthic populations. The distance through which organisms drift varies with species, current velocity, and substrate; however, it does not vary diurnally or monthly (Elliott 1971). In a blocking experiment, Waters (1965) estimated mean drift distances to be 50 to 60 m per night. For Baetis sp. and Gammarus sp., two genera frequently and abundantly caught in drift, mean drift distances of 1 to 5 m were observed. Both McLay (1970) and Elliott (1971) found an exponential relation in the return of released organisms to the benthos.

DESCRIPTION OF STUDY AREA

Smith Valley is a rural, agricultural area which has a 16 ha campground at the upper end. Smith Valley Creek is a small second order stream located in R6W and T15N in LaCrosse County, Wisconsin, with a mean discharge during this study of approximately 0.25 m^3/sec. (Fig. 1). The stream is approximately 6.6 km in length and empties into the LaCrosse River. It ranges from 0.5 to 2.0 m in width and from a few cm to approximately 0.4 m in depth. Three sample stations were established along the study reach (Fig. 2).

Station 1 was located near the headwaters of Smith Valley Creek 50 m downstream from a small spring and 100 m downstream from a campground. A small strip of hardwood trees enclose the stream at this point. Riffles, generally 2 to 5 m in length, and smaller pools with a rock and gravel bottom composed the stream in this area.

Station 2 was located 2.8 km downstream from station 1, approximately 100 m downstream from Kiel Coulee Road. The stream flows through a small feedlot approximately 150 m above the sampling station. Pastureland dominates the area and grazing animals had access to the stream. The stream varies between 0.8 and 1.3 m in width at this point, and has a gravel bottom. In general, this portion of the stream consists of long riffles connected by small pools.

Station 3 was located 1.4 km downstream from station 2. Pastureland dominates the immediate area with animals having access to the stream. The stream is 1.0 to 1.3 m wide at this point. In contrast to stations 1 and 2, this portion of the stream is, in general, slightly deeper, has more pools than riffles, and has a gravel and silt bottom.

Figure 1. Map of LaCrosse County, Wisconsin, showing location of Smith Valley Creek.

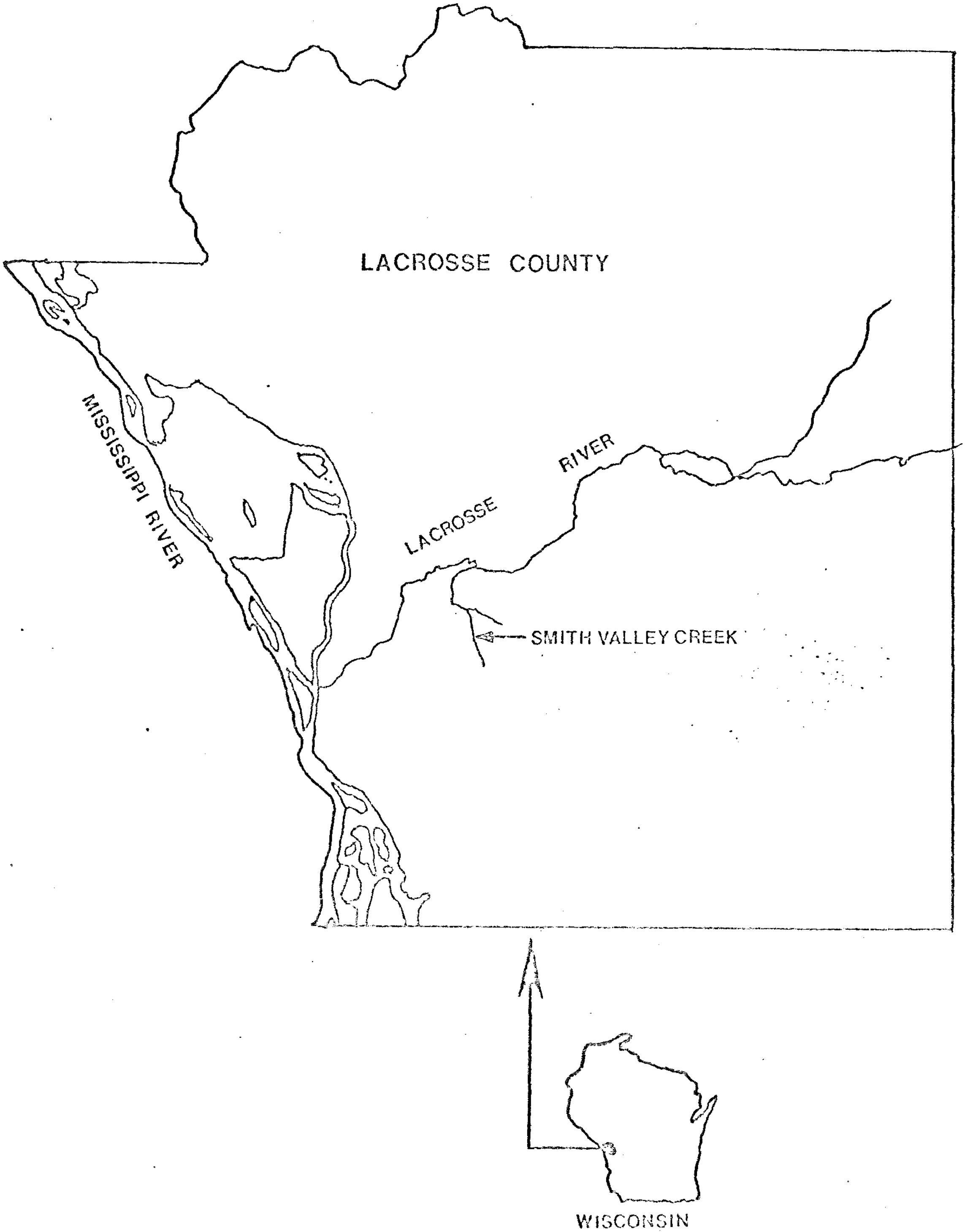
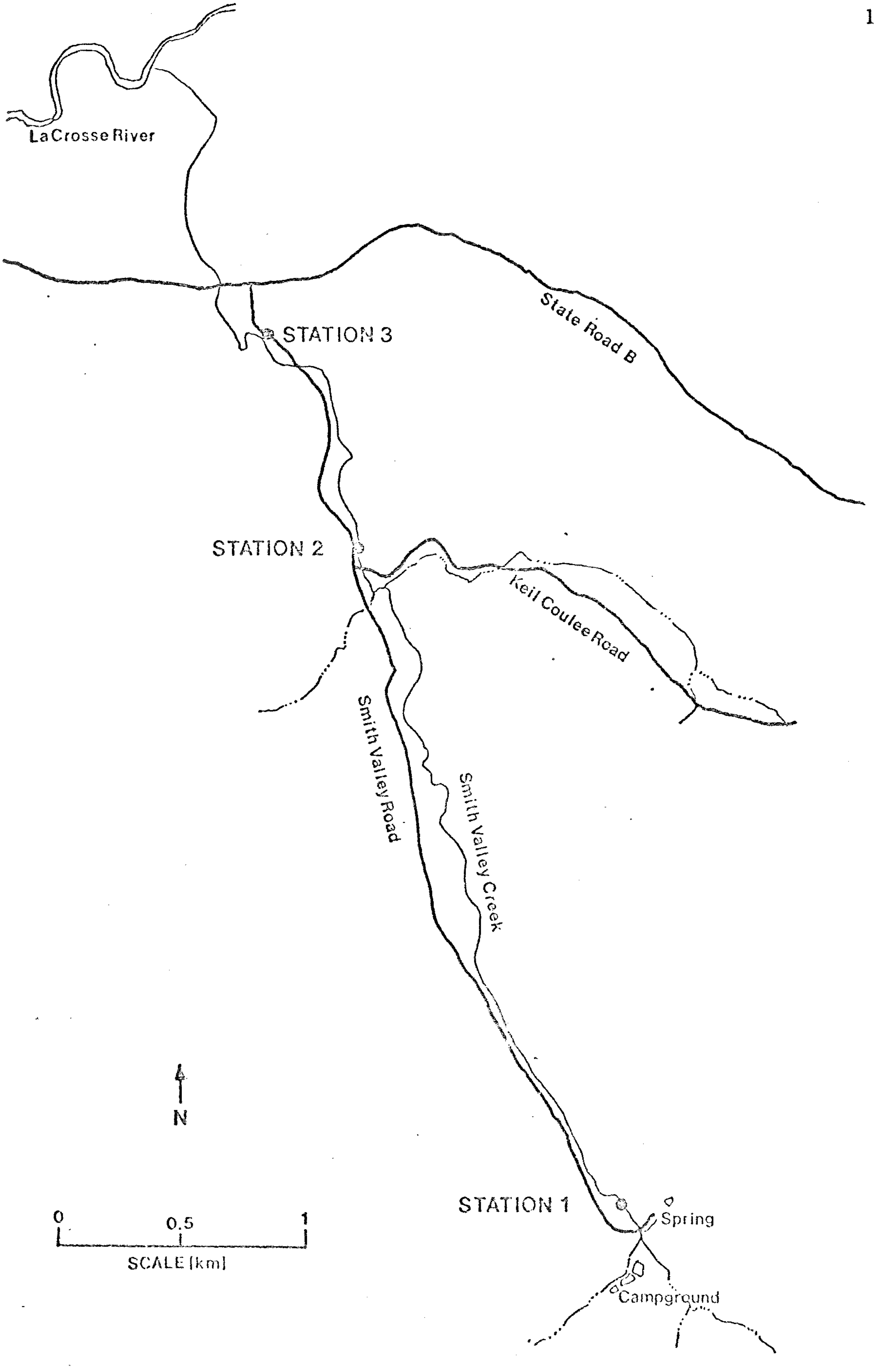

LACROSSE COUNTY
MISSISSIPPI RIVER
LACROSSE RIVER
SMITH VALLEY CREEK
WISCONSIN

Figure 2. Map of Smith Valley Creek, LaCrosse County, Wisconsin.


La Crosse River
State Road B
STATION 3
STATION 2
Keil Coulee Road
Smith Valley Road
Smith Valley Creek
N
STATION 1
Spring
Campground
0
0.5
1
SCALE (km)

METHODS AND MATERIALS

Field Methods

Drifting invertebrates were collected using nets with rectangular openings measuring 25 X 40 cm, allowing a maximum sampling area of 0.1 m^2. The net frames were fitted with Nitex^R netting (475μ mesh) and a detachable sample cup.

Sample nets at station 1 were placed at the downstream end of a small riffle. Benthic samples were taken a few meters downstream from the nets in a riffle area. Nets at station 2 were placed at the downstream end of a 15-m riffle. Benthic samples were taken immediately upstream from the drift sample site. Sample nets were set in the riffle portion of the stream at station 3. Bottom samples were taken a few meters upstream of the nets in areas with the least amount of silt.

The benthic community was sampled using a Surber type sampler with a sample area of 35 X 35 cm.

Air and water temperatures were measured with a glass thermometer and recorded during each sample period at each station.

Stream depths were measured for each sampling station at the beginning and end of each sampling period with a meter stick calibrated in 1-cm intervals. Measurements were taken at 10-cm intervals across the stream. The depth of water entering the sample nets was also measured in the center of the net frame at the beginning and end of each sampling period. Average depths were utilized to calculate total flow through the nets.

Current velocities were measured for each station at the beginning and end of each sampling period with a current meter (Price ^{R} Model AA). Measurements were taken at 20-cm intervals across the stream. Current velocities were measured at the center of each net frame at the beginning and end of the sampling period. Average current velocities were utilized to calculate total discharge.

Water samples for nutrient analysis were collected in acid-washed 1-L Nalgene^R bottles during each sampling period and were immediately returned to the laboratory for analysis.

Sampling Regime

Smith Valley Creek was sampled from 10-14-76 to 4-25-77. Pairs of sample nets were set for 24 hours at each station once each week for the first 3 weeks, and at two week intervals thereafter. Twelve sets of 2-hour samples were taken during 2 sampling periods (11-14-76 and 5-14-77) to determine the diurnal periodicity of drifting invertebrates. Duplicate benthic samples were taken at each sample station at six-week intervals.

Organisms and debris collected from both drift nets and benthic samples were placed in plastic containers and were taken to the laboratory.

Laboratory Procedures

Sample Preparation

All samples were fixed and preserved in 70% ethanol (containing rose Bengal) until the organisms could be picked from the debris. The samples were placed in white enameled pans and the organisms were picked from the debris with forceps. The organisms were then placed in vials conaining new 70% ethanol until they could by identified and counted. The organisms were keyed to the lowest identifiable taxon using Hilsenhoff (1975), Pennak (1953), and Mason (1973).

Weights

An analytical balance (Mettler, type H) was used to determine wet weights. The organisms were removed from the vials, blotted dry and weighed. Wet weights were determined for each taxon for each sampling period. Due to the small number and size of many taxa, average weights were determined by weighing a number of individuals from the same or adjoining sampling periods together. When practical, organisms were weighed separately.

Water Chemistry

Water was analyzed for the following nutrients: Ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, soluble inorganic phosphate-phosphorus, pH, hardness and alkalinity. Nitrogen as ammonia (NH_3-N) was determined by the phenate method (APHA 1976). Nitrite-nitrogen (NO_2-N) was analyzed using the diazontization method (APHA 1976), and the phenoldisulfonic acid method (APHA 1971) was used to analyze for nitrate-nitrogen (NO_3-N). Nitrogen species are expressed as mg NH_3-N/L, mg NO_2-N/L or NO_3-N/L. Soluble inorganic phosphate-phosphorus (PO_4-P) was analyzed using the EPA (1974) single reagent method and is expressed as PO_4-P/L. Hydrogen ion activity, as pH, was determined electrometrically with a pH meter (Coleman^R Model 12) and a combination electrode. Hardness was determined by the EDTA titrimetric method (APHA 1975) and is expressed as mg/L $CaCO_3$. Alkalinity was estimated by potentiometric titration (APHA 1976) and is expressed as mg/L $CaCO_3$.

Data Analysis

Total discharge at each station and discharge through the sample nets were determined. The instantaneous rate of discharge through the nets was calculated using the equation:

$$V = \frac{Q(0)}{K}(1-e^{-24K})$$

where V = the instantaneous rate of discharge through the nets, Q(0) = discharge at time zero,

Q(24) = discharge 24 hours after time zero

$$K = \frac{\ln \frac{Q(24)}{Q(0)}}{-24} \; .$$

These data were used in conjunction with the drift data to estimate the total drift at each sampling station. For comparative purposes, total drift at each sampling station is expressed as drift/1000 m^3 of total discharge.

Correlations, standard deviations and means were determined using standard statistical procedures (Roberts 1974).

RESULTS

Water Chemistry

Ammonia concentrations fluctuated throughout the sampling period. The greatest concentration (0.63 mg NH_3-N/L) was recorded on March 5, 1977 at station 3 (Table 1). High ammonia concentrations on March 5, 1977 coincided with high discharges (Fig. 5). The lowest concentration (0.025 mg NH_3-N/L) was recorded during four sample periods (October 28, 1976; November 18, 1976; December 9, 1976; and February 2, 1977). Usually, ammonia levels were highest at station 3 and lowest at station 1.

Nitrite concentrations were consistently lowest at station 1. The maximum concentration (0.014 mg NO_2-N/L) was recorded on February 24, 1977 and March 5, 1977; this coincides with periods of high discharge (Table 1, Fig. 5). Seasonal variations in nitrite concentrations were not observed.

The maximum nitrate concentration (1.720 mg NO_3-N/L) occurred on January 6, 1977 (Table 1). Nitrate concentrations fluctuated considerably, however, they were lowest at station 1. Concentrations at station 3 were similar to those at station 2. In general, nitrate concentrations were highest during winter (late November through February) and lowest during spring (late March through April).

With the exception of February 24 and March 5, 1977, phosphate concentrations were below 2.9 mg PO_4-P/L (Table 1). High phosphate concentrations on February 24 and March 5, 1977 coincided with high discharges (Fig. 5). Phosphate concentrations were lowest at station 1. Seasonal variations in phosphate levels were not observed.

The pH fluctuated throughout the sampling period. The mean pH value was 8.28 (Table 1). Station 1 consistently had the highest

Table 1. Means and ranges of dissolved inorganic nutrient concentrations in Smith Valley Creek, Wisconsin, 1967-1977.

Nutrient	Station 1	Station 2	Station 3
NH_3-N	0.090a*	0.162ab	0.218b
(mg/L)	0.025-0.375	0.025-0.500	0.025-0.625
NO_2-N	0.004	0.007a	0.008a
(mg/L)	0.002-0.014	0.004-0.013	0.006-0.014
NO_3-N	0.345	0.935a	1.045a
(mg/L)	0.100-0.730	0.370-1.700	0.320-1.720
PO_4-P	0.166a	0.270a	0.289a
(mg/L)	0.025-1.000	0.125-1.200	0.025-1.150
pH	8.45	8.18a	8.21a
	7.95-8.80	7.82-8.52	7.87-8.55
Hardness	253.4	282.0a	278.5a
(mg/L)	228.2-270.0	250.6-294.5	240.0-294.2
Alkalinity	248.4	278.1a	278.5a
(mg/L)	218.0-262.0	244.1-301.0	239.1-292.2

* Any values in the same horizontal row followed by the same letter are not significantly different from each other when treated by the t-test.

pH values ranging from 7.95 to 8.80. The pH's at station 2 were similar to those at station 3.

Hardness and alkalinity were stable ($\bar{X}$ of 271 and 268, respectively) except for the low observed on February 25, 1977 ($\bar{X}$ of 239 and 233, respectively) (Table 1). Station 1 consistently had the highest hardness and alkalinity values. Values of both variables were declining at the end of the study period.

Concentrations of soluble inorganic nutrients at station 1 were significantly different ($P < 0.05$) than those at stations 2 and 3 except for NH_3-N and PO_4-P at station 2 and PO_4-P at station 3 (Table 1). Nutrient concentrations at stations 2 and 3 were not significantly different ($P > 0.05$).

Drift

Frequency of Occurrence

Drift samples showed considerable variation. Two taxa, *Hydropsyche* sp. and *Gammarus limnaeus*, were collected with regularity (Table 2). The most frequently encountered taxon, *Gammarus limnaeus*, appeared in 92% of the samples, and members of the Dytiscidae and *Hydropsyche* sp. were collected in 64% and 85% of the samples, respectively. Table 2 indicates that representatives of remaining taxa were present in less than 40% of the samples (Table 2).

Four of the nine most abundant taxa were collected most frequently at station 2. *Gammarus limnaeus* was encountered more frequently at station 2 (93%) than at stations 1 (14%) and 3 (78%) (Table 2). The most frequently encountered organism at station 1 was *Hydropsyche* sp. (78%). Members of the Chironomidae were collected only at station 1 (Table 2). The frequencies of occurrence at stations 2 and 3 were significantly

Table 2. Frequency of occurrence (%) of the major invertebrate taxa collected in drift samples at Smith Valley Creek, Wisconsin, 1976-1977. All percentages based on 14 sample periods.

Taxon	Station 1	Station 2	Station 3	Stream Totals
Baetis sp.	-*	14.3	14.3	14.3
Hemiptera	21.4	7.1	14.3	28.6
Hydropsyche sp.	78.6	50.0	21.4	85.7
Dytiscidae	14.3	42.8	28.5	64.3
Gyrinidae	14.3	-	7.1	14.3
Hydrophilidae	14.3	21.4	7.1	35.7
Chironomidae	28.6	-	-	28.6
Atherix sp.	7.1	14.3	7.1	14.3
Gammarus limnaeus	14.3	92.8	78.6	92.8

* a hyphen (-) denotes the taxon was not collected

correlated ($r = 0.93$, $P < 0.01$) (App. 1).

Composition of Drift

A total of 50 taxa were collected in drift samples (Table 3). The relative densities and relative biomasses of the drift organisms in Smith Valley Creek are presented in Table 4. The drift was comprised of five orders of the Insecta and one member of the Amphipoda (Gammarus limnaeus). The Trichoptera, consisting mostly of Hydropsyche sp., were the most abundant members of the Insecta, accounting for 23% of The total number of drift organisms and 13% of the total biomass if one large Belostoma sp. (Hemiptera) is deleted.

Of the most frequently collected organisms, members of the Diptera represented 8% of the total number of drift organisms and 12% of the biomass. Members of the Chironomidae were the most abundant dipterans. The eight genera of the Chironomidae collected were combined for statistical treatment. Representatives of three families of the Coleoptera were collected. Members of the Dytiscidae were the most abundant and represented 5% of the total organisms. The most abundant taxon (50% of total number of drift organisms and 40% of the total biomass) was Gammarus limnaeus.

Drift Rates

The dominant taxa in drift samples were Gammarus limnaeus and Hydropsyche sp. No other taxon approached these rates of drift (Table 5).

With the exception of the December 27, 1976 sampling period, the highest drift rates occurred during December 1976 and January 1977 (Fig. 3). The lowest drift rates occurred during the October 14, 1976; October 21, 1976; February 24, 1977; and March 8, 1977 sampling periods.

Drift rate data for all stations are noted in Table 5. On a numerical basis, the highest and lowest rates occurred at stations 2

Table 3. Taxa collected in drift and benthic samples at Smith Valley Creek, Wisconsin, 1976-1977.

Taxon	Drift	Benthos
Class Amphipoda		
Gammarus *limnaeus*	X	X
Class Insecta		
Order Odonata		
Family Corduliidae		
Samatocholora sp.	X	X
Order Hemiptera		
Family Gerridae		
Gerris sp.	X	
Family Corixidae		
Ramphocorixa sp.	X	
Family Belostomatidae		
Belostoma sp.	X	X
Family Notonectidae		
Notonecta sp.	X	
Order Megaloptera		
Family Sialidae		
Sialis sp.	X	X
Order Trichoptera		
Family Hydropsychidae		
Hydropsyche sp.	X	X
Cheumatopsyche sp.		X
Family Phryganeidae		
Ptilostomis sp.	X	
Family Leptoceridae		
Oecetus sp.	X	X
Leptocerus sp.	X	X
Family Brachycentridae		
Brachycentrus sp.	X	
Order Coleoptera		
Family Dytiscidae		
Agabus sp.	X	
Hygrotus sp.	X	
Copelatus sp.	X	
Laccophilus sp.	X	
Ilybius sp.	X	
Family Gyrinidae		
Gyrinus sp.	X	
Dineutus sp.	X	

Table 3 Cont.

Taxon	Drift	Benthos
Order Coleoptera cont.		
Family Hydrophilidae		
Helophorus sp.	X	
Hydrochara sp.	X	
Helocombus sp.	X	
Tropisternus sp.	X	
Laccobius sp.	X	
Hydrobius sp.	X	
Enochrus sp.	X	
Hydrochus sp.	X	
Family Halpidae		
Peltodytes sp.	X	
Family Dryopidae		
Helichus sp.	X	
Family Elmidae		
Optioservus sp.		X
Family Chrysomelidae		
Donacia sp.	X	
Order Diptera		
Family Tipulidae		
Tipula sp.		X
Antocha sp.	X	X
Family Simuliidae	X	X
Family Muscidae	X	X
Family Chironomidae		
Procladius sp.	X	X
Heterotrissocladius sp.	X	X
Cardiocladius sp.	X	X
Metrionemus sp.	X	X
Diamesa sp.		X
Cricotopus sp.	X	X
Prodiamesa sp.		X
Brilla sp.		X
Family Stratiomyidae		
Stratiomys sp.	X	X
Euparyphus sp.	X	
Family Tabanidae		
Tabanus sp.	X	X
Family Rhagionidae		
Atherix sp.	X	X
Variegata sp.		X

Table 4. Relative density (% of total density) and relative biomass (% of total biomass) of taxa collected in drift samples at Smith Valley Creek, Wisconsin, 1976-1977.

Taxon	Relative Density				Relative Biomass			
	Station 1	Station 2	Station 3	Stream Totals	Station 1	Station 2	Station 3	Stream Totals
Ephemeroptera								
Baetis sp.	-*	5.1	6.3	3.7	-	7.2	1.6	4.1
Hemiptera	1.0	0.4	2.4	0.9	0.9	0.1	20.3	6.1
Trichoptera								
Hydropsyche sp.	54.3	9.7	5.4	32.1	56.5	6.3	7.8	20.2
Coleoptera								
Dytiscidae	1.5	6.4	5.6	5.6	1.3	7.2	1.5	4.3
Gyrinidae	1.2	-	1.5	0.2	2.4	-	0.4	1.4
Hydrophilidae	2.7	1.4	1.1	1.7	17.7	1.8	0.3	4.8
Diptera								
Chironomidae	26.5	-	-	7.8	6.8	-	-	1.5
Atherix sp.	0.2	0.3	3.1	0.7	0.3	0.3	0.6	0.3
Amphipoda								
Gammarus limnaeus	10.1	73.4	70.4	50.4	11.4	69.4	64.1	56.1

* a hyphen (-) indicates the taxon was not collected

Figure 3. Total invertebrate drift rates, density and biomass, at Smith Valley Creek, Wisconsin, 1976-1977.

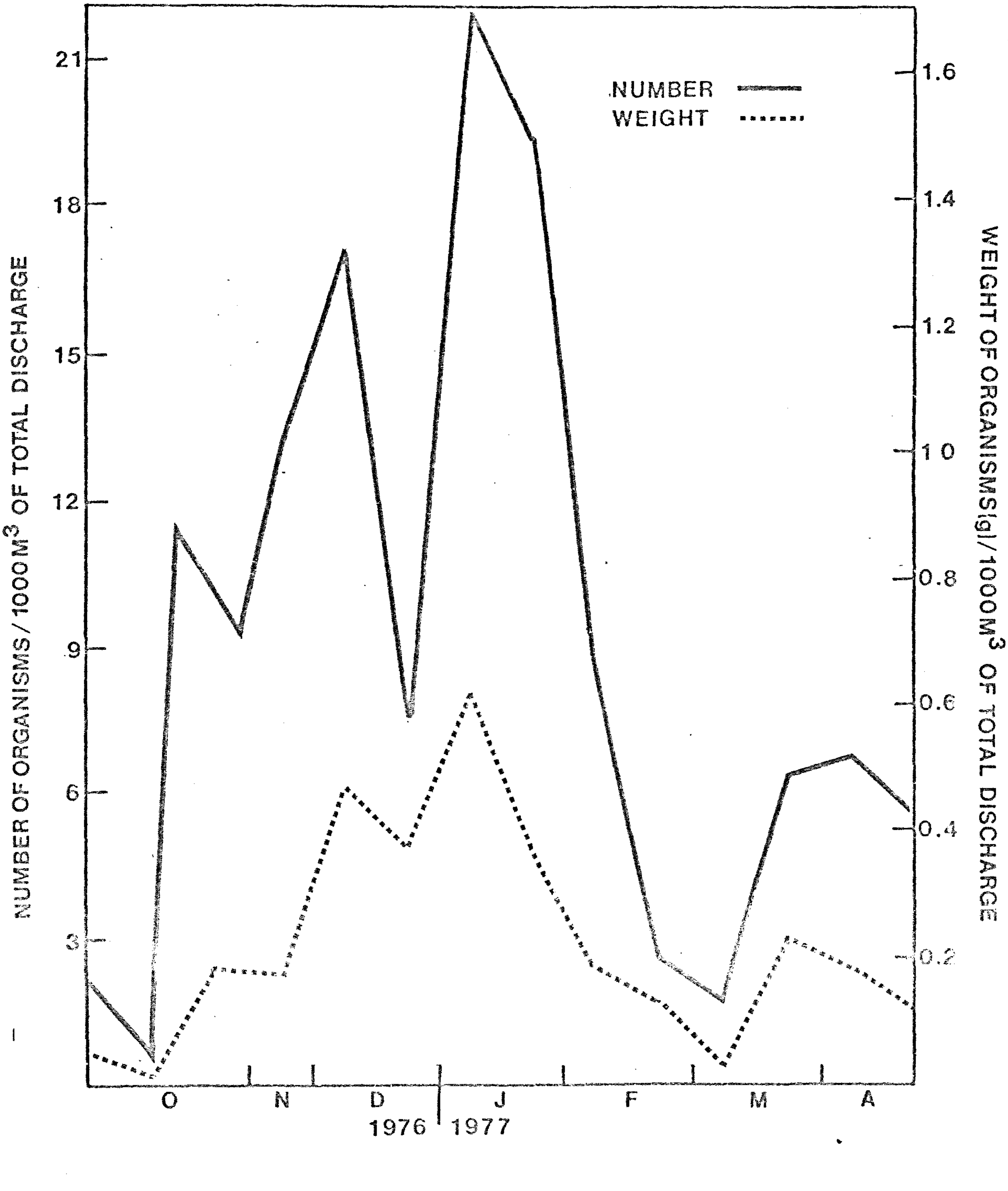

NUMBER
WEIGHT
NUMBER OF ORGANISMS / 1000 M^3 OF TOTAL DISCHARGE
WEIGHT OF ORGANISMS(g)/1000M^3 OF TOTAL DISCHARGE
21
18
15
12
9
6
3
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
O
N
D
J
F
M
A
1976
1977

Table 5. Density (organisms/1000 m^3 of total discharge) and biomass (grams/1000 m^3 of total discharge) (means and standard deviations) of the most commonly collected drifting invertebrates at stations 1, 2, and 3, in Smith Valley Creek, Wisconsin, 1976-1977.

Location	*Baetis* sp.		*Hydropsyche* sp.		Coleoptera Dytiscidae		Coleoptera Hydrophilidae		Chironomidae		Diptera *Atherix* sp.		*Gammarus limnaeus*		Totals	
	$\overline{X}$[a]	s[b]	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
Density																
Totals	0.32	0.90	2.00	1.91	0.49	0.75	0.15	0.31	0.68	0.17	0.06	0.19	4.35	3.58	8.63	6.64
Station 1	-[c]	-	1.39	1.49	0.04	0.13	0.07	0.25	0.68	1.67	0.01	0.02	0.26	0.68	2.55	2.30
Station 2	0.23	0.62	0.43	0.67	0.28	0.54	0.06	0.14	-	-	0.01	0.03	3.24	2.78	4.41	3.98
Station 3	0.09	0.28	0.08	0.19	0.08	0.16	0.02	0.06	-	-	0.04	0.16	1.01	0.97	1.44	1.14
Biomass																
Totals	.009	.031	.040	.038	.009	.024	.011	.032	.003	.011	.001	.002	.120	.110	.293	.305
Station 1	-	-	.021	.023	.001	.002	.008	.028	.003	.011	.000	.000	.005	.013	.049	.081
Station 2	.008	.028	.007	.011	.008	.022	.002	.005	-	-	.000	.000	.007	.081	.111	.123
Station 3	.001	.003	.005	.018	.001	.022	.000	.000	-	-	.000	.000	.041	.004	.064	.055

[a] $\overline{X}$ = mean
[b] s = standard deviation
[c] = indicates the taxon was not collected

and 3, respectively. The most abundant drift organism at stations 2 and 3 was Gammarus limnaeus (Table 5). At station 1, the highest drift rates were those of Hydropsyche sp. On the basis of biomass, the highest drift rates in this study occurred at station 2. At stations 2 and 3, the highest drift rates (biomass) were those of Gammarus limnaeus and at station 1 the highest drift rates were those of Hydropsyche sp.

Total drift rates at station 1 were not significantly different ($P > 0.05$) than those at stations 2 and 3 (App. II). At station 2, the drift rates on a numerical basis were significantly different ($P < 0.05$) than those at station 3. On the basis of biomass, the drift rates at station 2 were not significantly different ($P > 0.05$) than those at station 3.

Seasonal Effects

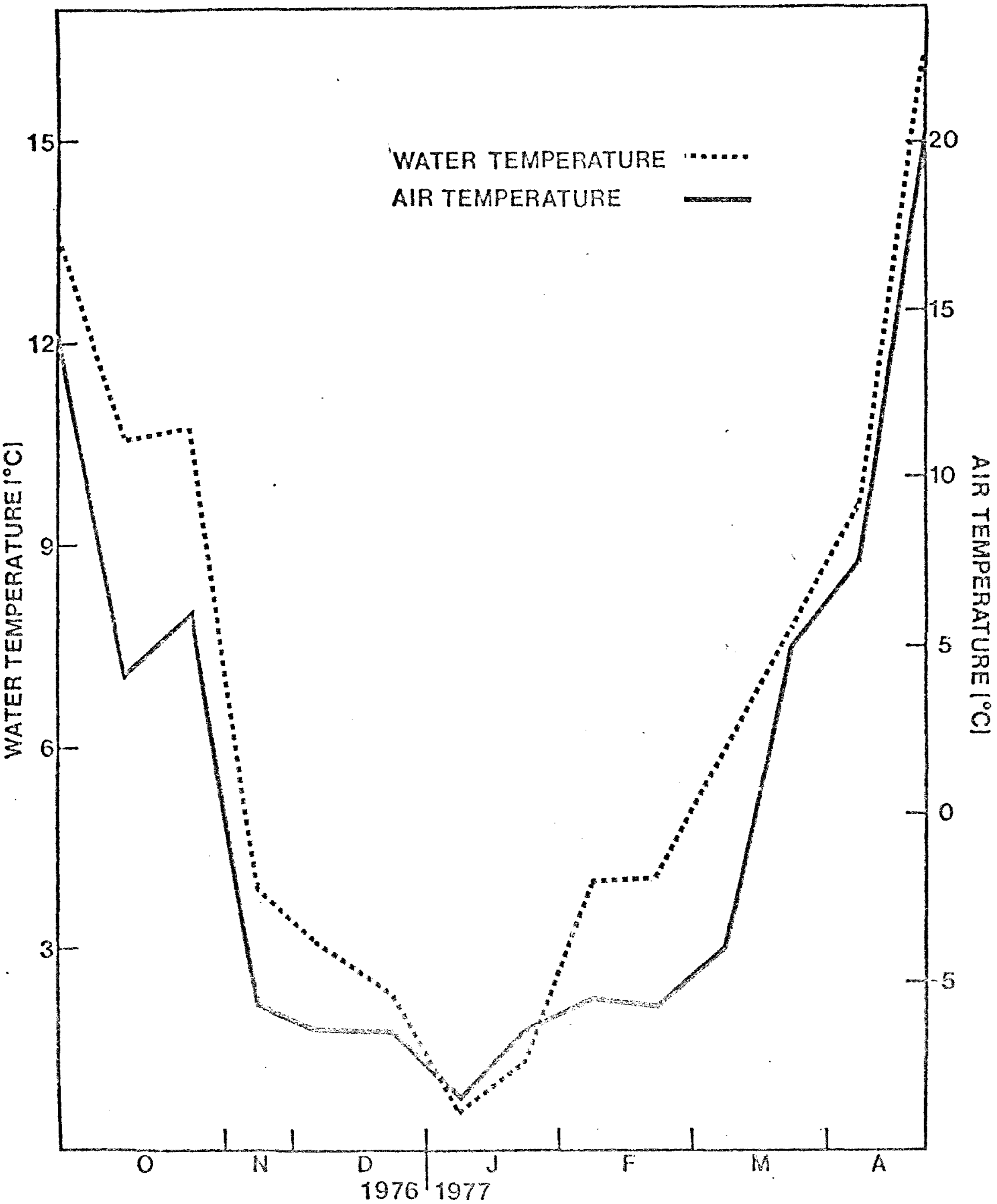
Light

Drift rates of Hydropsyche sp. and total drift rates were correlated with length of darkness ($r = 0.80$, $P < 0.01$ and $r = 0.57$, $P < 0.05$), respectively). Other taxa (Gammarus limnaeus, Chironomidae, Dytiscidae, Hydrophilidae, Hemiptera) were not significantly correlated with day length.

Temperature

Late afternoon air temperatures during this study ranged from -9 C on January 6, 1977 to 22 C on April 25, 1977 (Fig. 4). Drift rates of Hydropsyche sp. and total drift rates were negatively correlated with air temperature ($r = -9.64$, $P < 0.01$ and $r = -0.69$, $P < 0.01$, respectively) and water temperature ($r = -0.59$, $P < 0.05$

Figure 4. Mean air and water temperatures recorded at sampling stations 1, 2, and 3, at Smith Valley Creek, Wisconsin, 1976-1977.


WATER TEMPERATURE
AIR TEMPERATURE
WATER TEMPERATURE (°C)
AIR TEMPERATURE (°C)
15
12
9
6
3
20
15
10
5
0
-5
O
N
D
J
F
M
A
1976
1977

and r = -0.56, $P < 0.05$, respectively) at station 1. At station 2, drift rates of Gammarus limnaeus and total drift rates were correlated negatively with air temperature (r = -0.58, $P < 0.05$ and r= -0.54, $P < 0.05$, respectively).

Discharge

Total discharges fluctuated between 0.15 m/sec. and 0.64 m/sec. (Fig. 5). The increased discharge on March 5, 1977 was primarily due to snow melt and was less pronounced at station 1 than at stations 2 and 3. Drift rates of Hydropsyche sp. and the total drift rates at station 1 were correlated negatively with the discharge at station 1 (r = -0.66, $P < 0.01$ and r = -0.71, $P < 0.01$, respectively). No other significant correlations concerning discharge and drift rates were found.

Diurnal Drift

Samples were collected on November 14, 1976 and May 14, 1977 at two-hour intervals to determine whether diel periodicity occurred with drift patterns. Data for station 1 were excluded from these analyses due to the low number of organisms sampled and the subsequent absence of diurnal drift patterns. The total drift and the drift of Gammarus limnaeus dramatically increased during the evening crepuscular period at station 2 on November 14, 1976 (Fig. 6). A smaller, but distinct increase occurred at 0200 hours. The drift of members of the Dytiscidae and Hydropsyche sp. increased during crepuscular periods at station 2 on November 14, 1976 (Fig. 7). The total drift and the drift of Gammarus limnaeus were highest during daylight hours at station 2 on May 14, 1977 (Fig. 6). The dipterans Euparyphus sp.

Figure 5. Total discharges (m^3/sec) at stations 1, 2, and 3, in Smith Valley Creek, Wisconsin, 1976-1977.

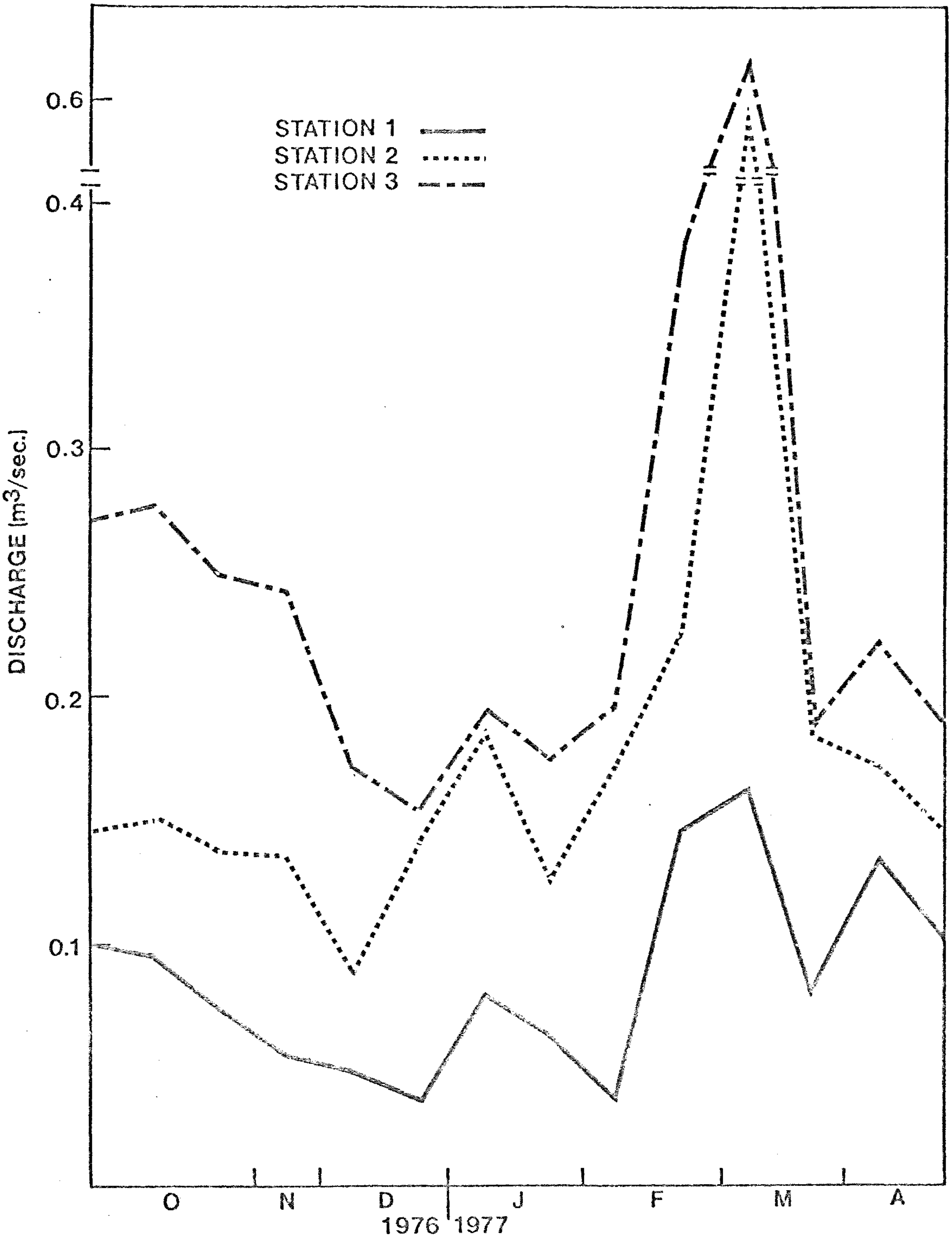

STATION 1
STATION 2
STATION 3
DISCHARGE (m3/sec.)
0.6
0.4
0.3
0.2
0.1
O
N
D
J
F
M
A
1976
1977

Figure 6. Total drift and the drift of <u>Gammarus limnaeus</u> on May 14, 1977 and November 14, 1976 at station 2 in Smith Valley Creek, Wisconsin.

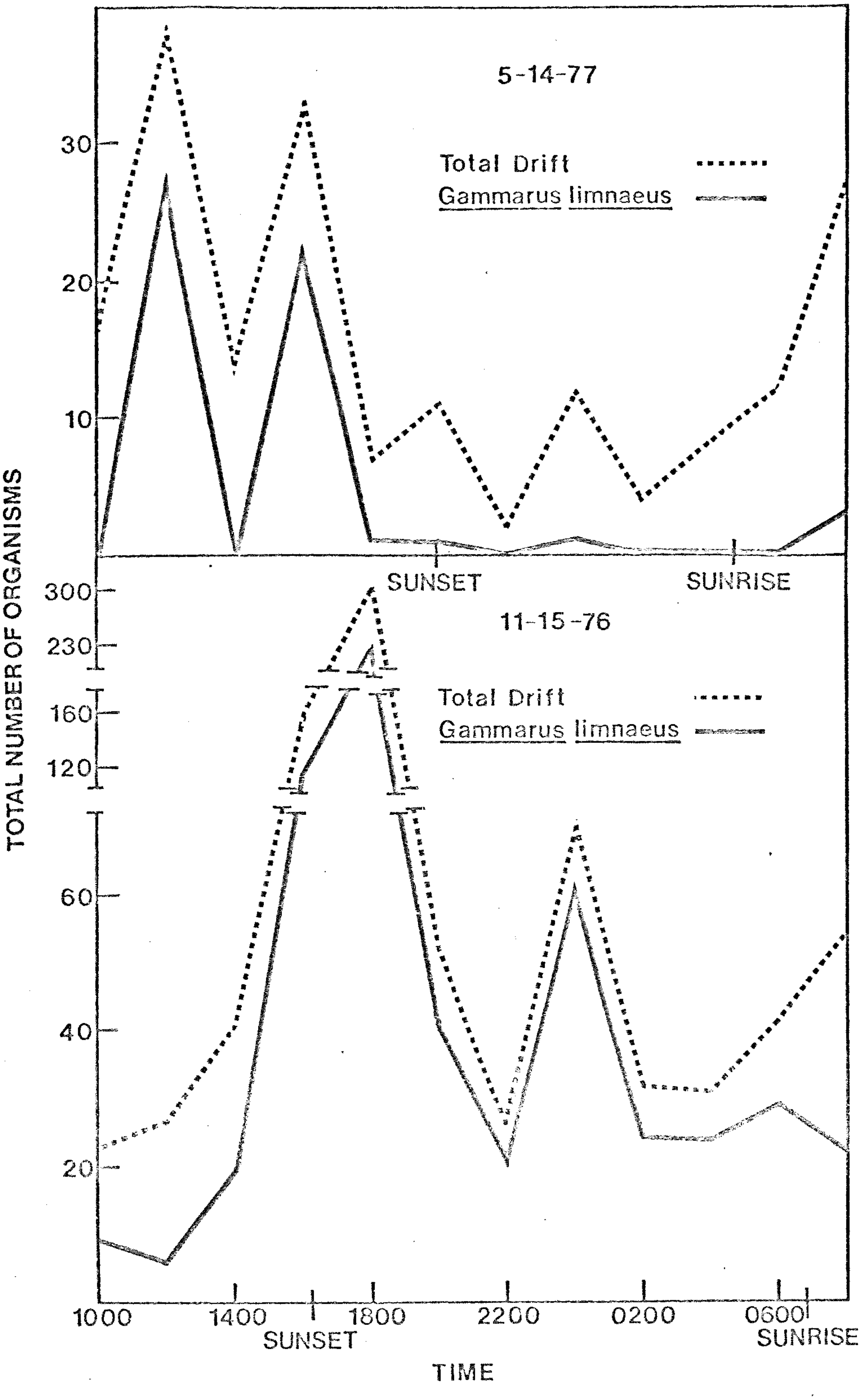
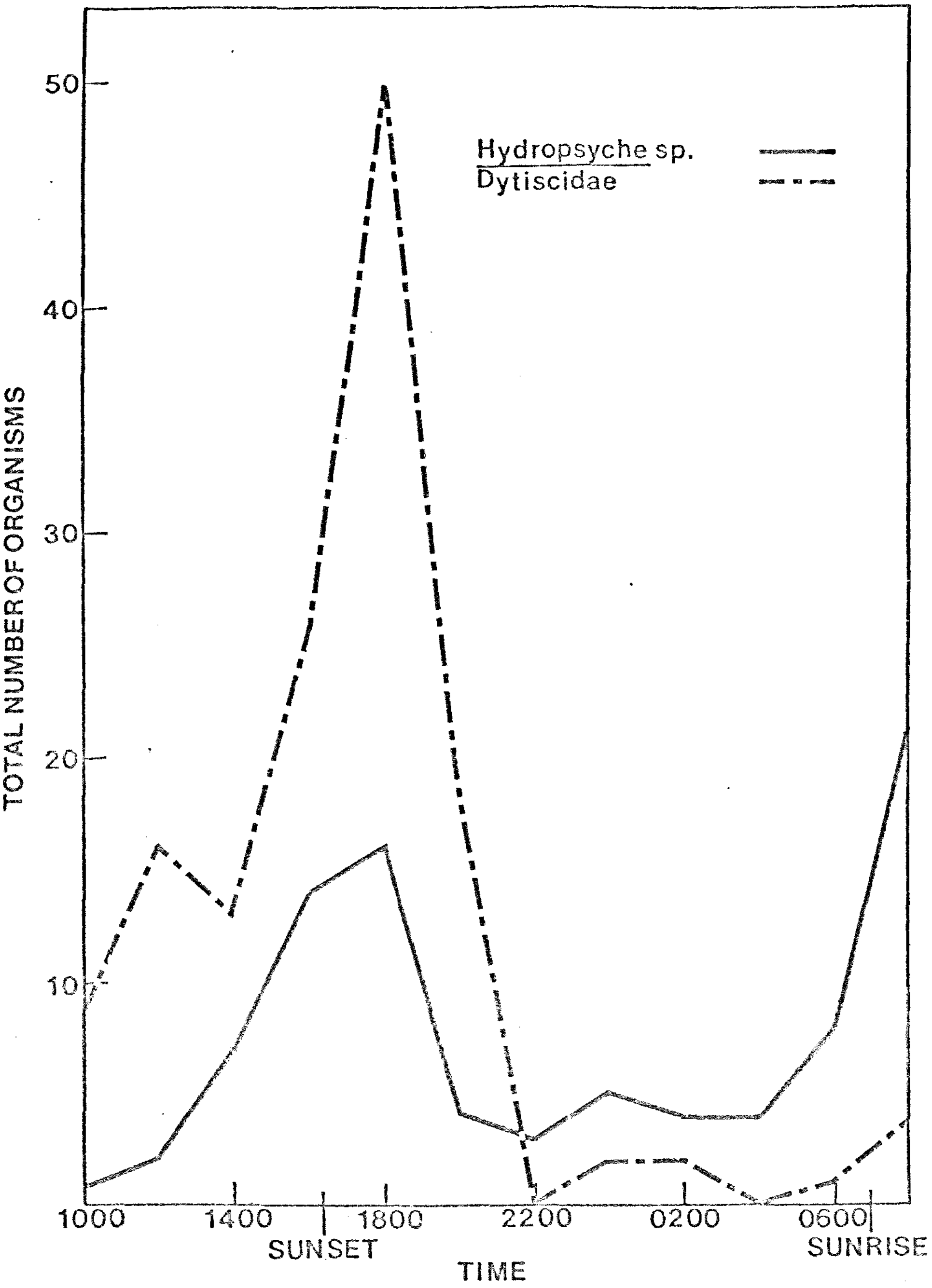

5-14-77
Total Drift
Gammarus limnaeus
30
20
10
SUNSET
SUNRISE
300
230
160
120
60
40
20
11-15-76
Total Drift
Gammarus limnaeus
TOTAL NUMBER OF ORGANISMS
1000
1400
1800
2200
0200
0600
SUNSET
SUNRISE
TIME

Figure 7. The total drift of Hydropsyche sp. and members of the Dytiscidae at station 2 on May 14, 1977, in Smith Valley Creek, Wisconsin.


Hydropsyche sp.
Dytiscidae
TOTAL NUMBER OF ORGANISMS
50
40
30
20
10
1000
1400
1800
2200
0200
0600
SUNSET
SUNRISE
TIME

and Stratiomys sp. seemed to drift more during daylight hours (Fig. 8); however, the sample size was small. Drift of Gammarus limnaeus and the total drift at station 3 on November 14, 1976 exhibited a large evening crepuscular increase and a smaller morning crepuscular increase (Fig. 9). Air and water temperatures were not significantly correlated with drift patterns on November 14, 1976 or May 14, 1977 (App. V).

Benthic Fauna

Frequency of Occurrence

Each benthic sample contained Hydropsyche sp. (Table 6). All samples at stations 2 and 3 and 40% of the samples at station 1 contained Gammarus limnaeus. Members of the Chironomidae were collected at each sampling station but not during each sampling period (Table 6).

Composition of Benthic Fauna

Five orders of the Class Insecta and one member of the Amphipoda (Gammarus limnaeus) comprised the 16 most commonly collected taxa (Table 7). The most abundant taxa were Hydropsyche sp. and Gammarus limnaeus, which represented 80% and 63% of the total biomass. No other taxon comprised more than 6% of the total standing crop (density or biomass). The invertebrate density at station 1 was significantly different ($P < 0.05$) than densities at stations 2 and 3, and the biomass at station 1 was not significantly different ($P > 0.05$) than those at stations 2 and 3. The standing crop (density and biomass) at station 2 was not significantly different than at station 3. The standing crop (density and biomass) of Gammarus limnaeus was not significantly different ($P > 0.05$) between stations 1, 2, and 3.

Relationship between Benthic Fauna and Drift

The invertebrate drift and benthic fauna had five taxa in common.

Figure 8. The drift of *Euparyphus* sp. and *Stratiomys* sp. at station 2 on May 14, 1977, in Smith Valley Creek, Wisconsin.

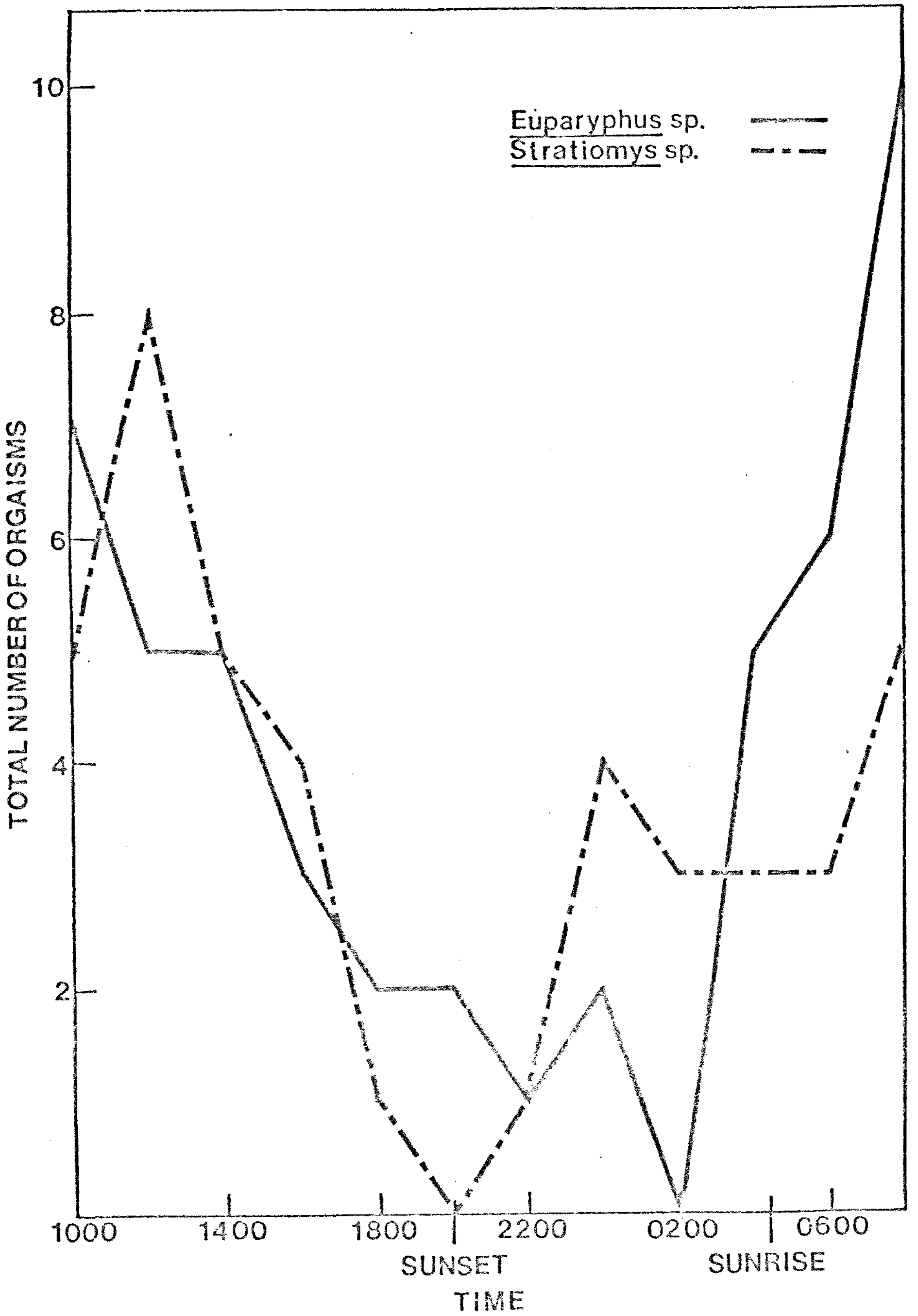

Euparyphus sp.
Stratiomys sp.
TOTAL NUMBER OF ORGAISMS
10
8
6
4
2
1000
1400
1800
2200
0200
0600
SUNSET
SUNRISE
TIME

Figure 9. Total drift at station 3 on May 14, 1977, and total drift and drift of _Gammarus limnaeus_ at station 3 on October 14, 1976 at Smith Valley Creek, Wisconsin.

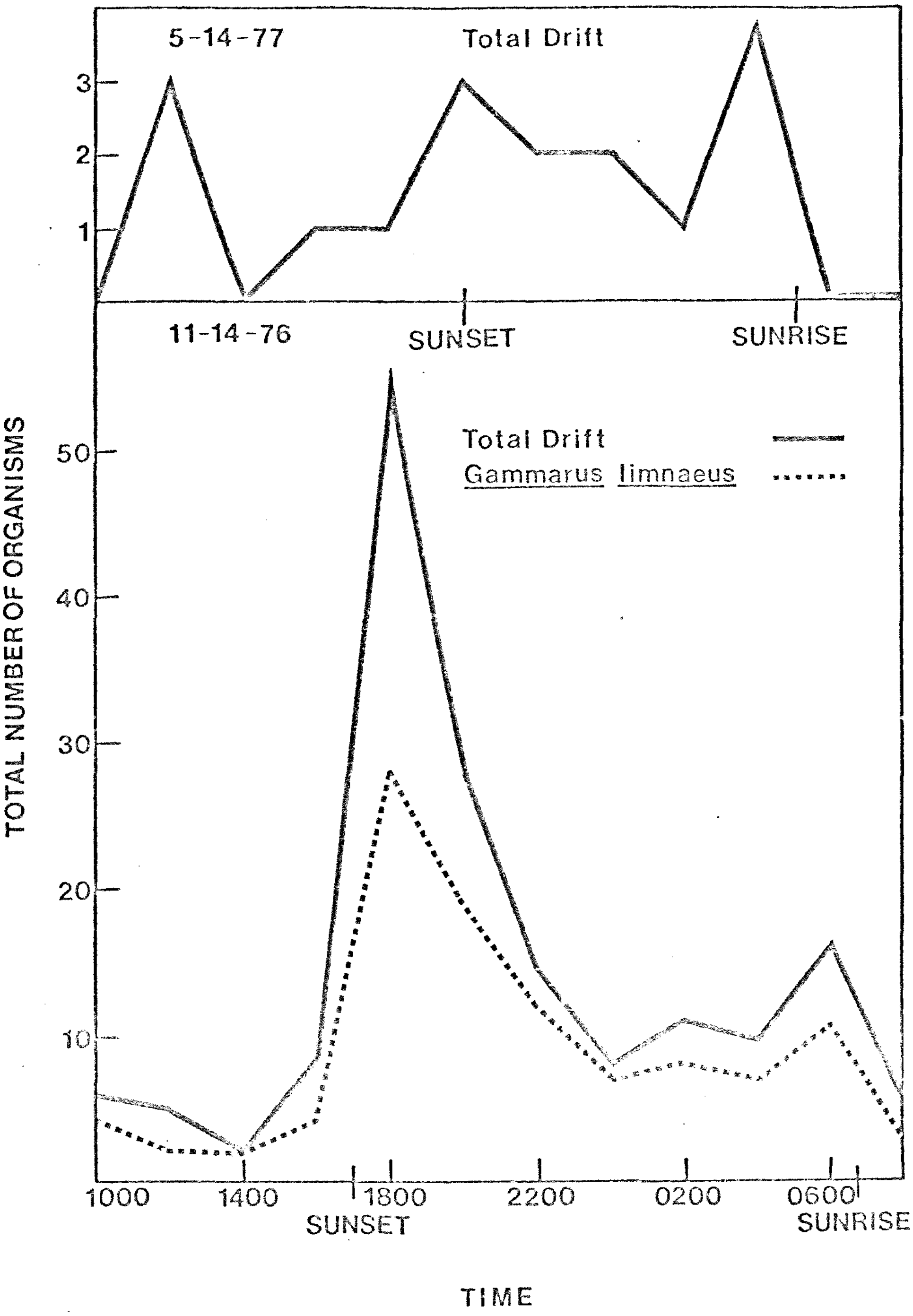

5-14-77
Total Drift
3
2
1
SUNSET
SUNRISE
11-14-76
TOTAL NUMBER OF ORGANISMS
50
40
30
20
10
Total Drift
Gammarus limnaeus
1000
1400
1800
2200
0200
0600
SUNSET
SUNRISE
TIME

Table 6. Frequencies of occurrence (%) of the invertebrate taxa collected in benthic samples at Smith Valley Creek, Wisconsin, 1976-1977. All percentages based on 5 sampling periods.

Taxon	Station 1	Station 2	Station 3	Stream Totals
Baetis sp.	20	20	40	40
Hemiptera *Belostoma* sp.	20	-*	-	20
Trichoptera *Hydropsyche* sp.	100	100	100	100
Trichoptera *Leptocerus* sp.	-	20	60	60
Trichoptera *Oecetis* sp.	-	20	20	20
Trichoptera *Cheumatapsyche* sp.	20	-	-	20
Coleoptera *Optioservus* sp.	-	20	40	40
Diptera *Antocha* sp.	-	20	80	100
Diptera Simuliidae	20	20	-	40
Chironomidae	40	20	60	80
Stratiomys sp.	-	20	-	20
Tabanus sp.	60	20	40	80
Atherix sp.	-	40	60	60
Muscidae	-	40	60	60
Amphipoda *Gammarus limnaeus*	40	100	100	100

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* a hyphen (-) denotes the taxon was not collected

Table 7. Standing crop (density and biomass) of the invertebrate taxa collected in benthic samples at Smith Valley Creek, Wisconsin, 1976-1977.

Taxon	Relative Density (%)				Relative Biomass (%)			
	Station 1	Station 2	Station 3	Stream Totals	Station 1	Station 2	Station 3	Stream Totals
Baetis sp.	0.7	0.4	6.7	2.7	0.0	0.0	0.1	0.0
Hemiptera *Belostoma* sp.	0.7	-	-	0.1	2.7	-	-	0.1
Trichoptera *Hydropsyche* sp.	55.8	50.9	45.0	48.4	12.7	50.8	55.5	39.5
Leptocerus sp.	-	0.5	7.2	2.9	-	7.4	9.2	5.9
Oecetis sp.	-	0.4	0.9	0.5	-	0.7	8.3	2.4
Cheumatapsyche sp.	0.7	-	-	0.1	0.0	-	-	0.0
Coleoptera *Optioservus* sp.	-	0.4	1.2	0.6	-	0.0	0.0	0.0
Diptera *Tipula* sp.	0.7	0.5	-	0.4	3.1	2.0	-	1.3
Diptera *Antocha* sp.	-	0.2	10.8	4.1	-	0.0	0.3	0.7
Simuliidae	0.7	1.1	-	0.6	0.0	0.0	-	0.0
Chironomidae	10.8	1.1	9.8	5.4	0.0	0.0	0.0	0.0
Stratiomys sp.	-	0.2	-	0.1	-	0.1	-	0.0
Tabanus sp.	3.5	0.4	0.5	0.8	60.7	10.2	6.3	22.6
Atherix sp.	-	1.2	1.4	1.1	-	2.8	2.0	1.7
Muscidae	-	0.3	0.7	0.4	-	0.2	0.4	0.2
Amphipoda *Gammarus limnaeus*	26.4	42.4	16.1	31.9	18.6	28.6	17.5	23.0

* a hyphen (-) denotes that the taxon was not collected

Several significant correlations were found by comparing the frequencies of occurrence of these five taxa. The drift at stations 1 and 2 correlated with the benthic fauna at stations 1 and 2 ($r = 0.94$, $P < 0.01$; $r = 0.90$, $P < 0.05$, respectively), and total drift correlates with total benthic fauna ($r = 0.88$, $P < 0.05$) (App. IV).

Moreover, with the exception of three families of the Coleoptera (Dytiscidae, Gyrinidae, and Hydrophilidae), all taxa found in drift samples were also found in benthic samples (Table 3).

DISCUSSION

Roback (1974) characterizes an undamaged stream as one which: supports a diverse fauna and flora; has all trophic levels proportionally represented; and has no obvious population imbalance. This definition alludes to the effects of human activity on streams. Potentially damaging factors to the biota of streams are frequently cumulative and can occur without being noticed. Agricultural sources of this type include the use of biocides, clearing of stream banks, substitution of native vegetation for agricultural crops, sheet erotion, return of irrigation water, use of fertilizers, and feedlot and pasture runoff. In a comparison of 13 undamaged stations to 10 damaged stations, Roback (1974) found that insects and fish were affected more severely than Protozoa and other invertebrates. Members of the Insecta represented a lower percentage of the total fauna in damaged streams than in undamaged streams. Also, the species composition and relative abundances of taxa within the Insecta were altered.

The benthic invertebrate fauna in Smith Valley Creek appears to be negatively impacted by human activity. Low benthic populations could be the result of such factors as increased siltation (Sprules 1941, Hynes 1970), increased dissolved inorganic nutrients (Roback 1974), physical distrurbances of the sediment, pesticide runoff (Diamond 1967), and the flushing of a chlorinated swimming pool.

Several conditions in Smith Valley have apparently resulted in the addition of silt to Smith Valley Creek. These conditions include cleared slopes for row-crop agriculture, cleared and heavily grazed bottomland adjacent to the stream, destruction of stream banks, and disturbance of the stream bottom by cattle. Current velocities at stations 1 and 2 were sufficient in riffle areas to keep silt from settling on the gravel substrate. The interstitial spaces of the substrate appeared to contain significant amounts of silt. In the lower stream reach (station 3), two to five cm of fine silt covered the gravel substrate. The presence of silt on stony substrates has been shown to change the fauna (Hynes 1970). When spaces between rocks are filled, suffocation of invertebrates can result. Sprules (1941) found that deposition of sandy silt reduced the total number of insects especially members of the Plecoptera, Ephemeroptera and Trichoptera.

According to criteria established by Hem (1970), Smith Valley Creek has very hard, well-buffered water. Runoff from agricultural fields, septic sewage systems, grazing cattle, and a small feedlot probably add to the dissolved inorganic nutrient levels of Smith Valley Creek. In general, inorganic nutrient concentrations increased between stations 2 and 3 (Table 1). Between stations 1 and 2 Smith Valley Creek drains agricultural cropland, a small feedlot, and areas containing private residences with septic sewage systems. The stream reach between stations 2 and 3 drains mostly pasture land. Nutrient loading has been shown to occur under similar conditions (Edwards et al. 1972, Loehr 1974, Wanialista et al. 1977). During the period of highest discharge, concentrations of NH_3-N, NO_2-N, NO_3-N, and PO_4-P increased and hardness and alkalinity values decreased. These data are in agreement with that of several investigators (Wanielista et al. 1977, Muir et al. 1973). The highest nitrate concentrations coincided with periods of lowest water temperature (11-26-76 through 3-5-77). Low temperatures could have limited primary production and thus reduced the uptake of nitrate. Similarly, Hynes (1970) reported that nitrate concentrations can increase during the winter when primary production is reduced.

Roback (1974) gives ranges of chemical parameters of waters from which species of aquatic insects were collected. Values for pH, alkalinity, NO_3-N, and PO_4-P in Smith Valley Creek approached or exceeded the upper limits of these ranges for many species of the Plecoptera, Hemiptera, and Ephemeroptera. Hilsenhoff (1975) stated that low levels of pollution from pasturing cattle are probably responsible for an absence of members of the Plecoptera from most streams in Wisconsin agricultural areas.

Several events potentially catastrophic to aquatic organisms occurred in the Smith Valley Creek drainage basin. On May 14, 1977, the contents of the campground swimming pool were emptied into Smith Valley Creek. The volume was sufficient to turn the upper portion of the stream milky white. In addition, small amounts of chlorine may enter the stream during the summer in the swimming pool effluent. Catastrophic events such as these can limit the distribution of less tolerant species.

The highest drift rates in Smith Valley Creek were those of Gammarus limnaeus at stations 2 and 3. Each benthic sample at stations 2 and 3, and 40% of the benthic samples at station 1 contained Gammarus limnaeus (Table 7). The Amphipoda, particularly Gammarus sp., were common benthic invertebrates and were found frequently in drift samples (Waters 1969, Embody 1911, Iverson and Jesson 1977, Hughes 1970, Muller 1963).

In benthic samples, Hydropsyche sp. was the most abundant and the most frequently encountered taxon (Table 6, Table 7). Drift samples frequently contained Hydropsyche sp. at station 1 (79% of the samples) and station 2 (50% of the samples) (Table 7.). Conversely, many investigators cite members of the Trichoptera as a minor or intermediate component of drift (Anderson 1967). Peterka (1969) and Waters (1961) commonly found *Hydropsyche* sp. in benthic samples; however, Waters (1961) reported *Hydropsyche* sp. to be strongly sedentary and found few of them in drift samples. Peterka (1969) apparently did not find *Hydropsyche* sp. in drift samples.

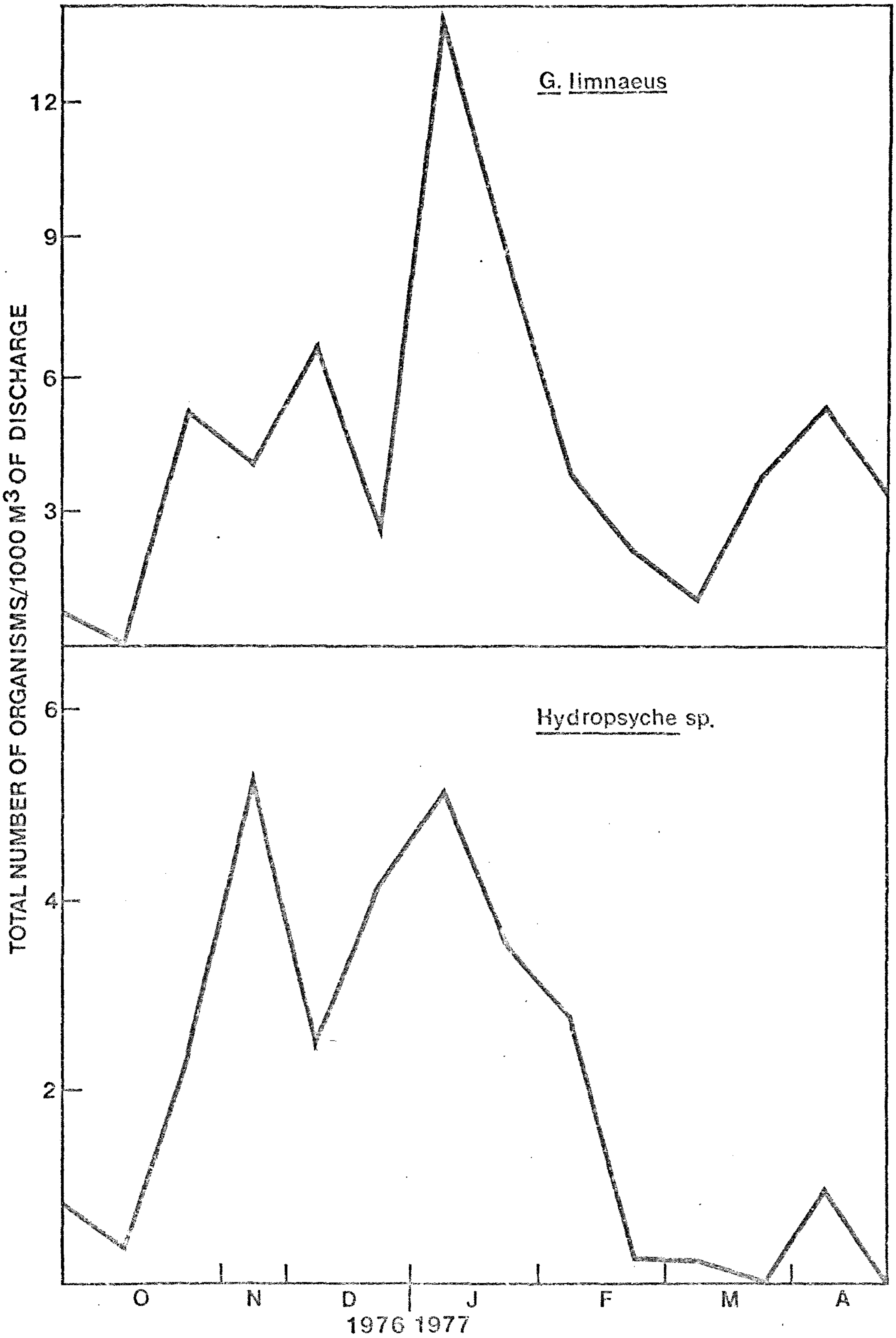
Although present at each station in benthic samples, members of the Chironomidae were found in drift samples only at station 1. No explanation for this occurrence has been found.

The three most common families of the Coleoptera in drift samples (Dytiscidae, Gyrinidae, Hydrophilidae) were not collected in benthic samples. Pennak (1953) states that these 3 families are inhabitants of quiet water. Because all benthic samples were taken from riffle areas, members of these families would not be expected to be encountered

Concentrations of soluble inorganic nutrients at station 1 were significantly different than those at stations 2 and 3 except for NH_3-N and PO_4-P at station 2 and PO_4-P at station 3. Drift rates at station 1 were not significantly different than drift rates at stations 2 and 3. No major relationships were observed between soluble inorganic nutrient concentrations and drift rates. Minor relationships, if they exist, were masked by effects of other factors.

Drift rates of *Hydropsyche* sp. were correlated positively with length of darkness ($P < 0.05$) and negatively with air and water temperature ($P < 0.01$ and $P < 0.05$, respectively). Seasonal drift rates of *Hydropsyche* sp. appear to be inversely related to day length and (or) water temperature (Fig.3, Fig. 10). Similarly, Iverson and Jessen (1977) found the highest drift of *Gammarus pulex* in samples taken in October

Figure 10. Total drift rates of *Gammarus limnaeus* and *Hydropsyche* sp., at Smith Valley Creek, Wisconsin, 1976-1977.


G. limnaeus
Hydropsyche sp.
TOTAL NUMBER OF ORGANISMS/1000 M^3 OF DISCHARGE
12
9
6
3
6
4
2
O
N
D
J
F
M
A
1976 1977

1972 through February 1973, whereas drift rates in March through May 1973 were consistently lower.

Catastrophic drift was not observed in this study. High discharges (Fig. 5), one cause of catastrophic drift, coincided with very low drift rates (Fig. 3). Drift rates of Hydropsyche sp. and total drift rates at station 1 were correlated negatively with discharge at station 1 (App. VI). Members of the Chironomidae drifted most abundantly during periods of lower discharge. Conversely, Anderson and Lehmkuhl (1968) reported that drift rates increased within 24 hours of rainy periods. This increase was approximately proportional to the increase in discharge. They also observed that drift rates of members of the Chironomidae increased fivefold during short periods of high discharge.

Diurnal periodicities in the drift of benthic invertebrates are well documented (Tanaka 1960, Muller 1963, Waters 1962, 1968, 1969, Elliott 1969, Peterka 1969, Cloud and Stewart 1974). On November 14, 1976, Gammarus limnaeus exhibited large evening crepuscular period and smaller morning crepuscular period increases in drift at stations 2 and 3 (Fig. 6, Fig. 9). Drift of Gammarus limnaeus at station 2 had a significant second increase at 2400 hours. These approximated the bigeminus pattern of drift. In accordance, Waters (1962), Peterka (1969) and Muller (1963) reported that Gammarus sp. had high drift rates during the evening crepuscular period. Usually, a smaller increase in drift rates occurred shortly before and during the morning crepuscular period. Drift rates, in these studies, were lower during the day. Drift patterns for Gammarus limnaeus on May 14, 1977, were significantly different than those on November 14, 1976 (Fig. 6). Drift rates were highest at 1200 and 1600 hours; whereas, crepuscular and night drift rates were almost undetectable. A depression in drift rates due to moonlight was unlikely because May 14, 1977 was two days before a new moon. No explanation for this pattern of drift has been found.

The drift of Hydropsyche sp. at station 2 on October 14, 1976 displayed a definite phototaxis (Fig. 7). Drift increased significantly during the evening crepuscular period, was sharply reduced at dark, and remained low all night. Similarly, Cloud and Stewart (1974) reported that during June and August 1972, the highest drift rates for Hydropsyche simulans were an hour after sunset. During October 1976, Reisen and Prins (1972) found the diel drift peak for Hydropsyche sp. to be between 0930 and 1330. Members of the Dytiscidae at Smith Valley Creek showed a distinct phototaxis (Fig. 7). Drift increased during evening and morning crepuscular periods and was low during periods of full daylight and darkness.

The drift rates of Euparyphus sp. and Stratiomys sp. were highest during daylight hours (Fig. 8). The stimulus for reduced drift at night was not determined.

CONCLUSIONS

1. Differences in soluble inorganic nutrient concentrations among stations were probably a result of the addition of nutrients from human activity in the drainage basin.
2. The benthic invertebrate fauna at Smith Valley Creek appears to be negatively impacted by human activity.
3. The highest drift rates in Smith Valley Creek were those of *Gammarus limnaeus*.
4. The most abundant benthic taxon in Smith Valley Creek was *Hydropsyche* sp.
5. No major relationship was observed between soluble inorganic nutrient concentrations and drift rates.
6. Seasonal variations in drift rates of *Hydropsyche* sp. and *Gammarus limnaeus* appear to be inversely related to day length and (or) water temperature.
7. Catastrophic drift was not observed in Smith Valley Creek.
8. Members of the Dytiscidae, *Hydropsyche* sp., and *Gammarus limnaeus* exhibited a negative phototaxis with respect to drift.
9. A negative phototactic response in *Gammarus limnaeus* was not always observed.
10. The drift of *Euparyphus* sp. and *Stratiomys* sp. was predominantly during daylight hours.

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Appendix 1A. Nutrient concentrations at Station 1 on Smith Valley Creek, Wisconsin, 1976-1977.

Date	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	pH	Hardness (mg/L)	Alkalinity (mg/L)
10-14-76	0.050	0.004	0.130	0.075	7.95	250	251
10-21-76	0.050	0.002	0.210	0.130	8.38	256	258
10-28-76	0.075	0.002	0.400	0.100	8.26	252	254
11-18-76	0.050	0.002	0.300	0.125	8.15	260	255
11-26-76	0.150	0.002	0.275	0.060	8.35	260	245
12-9-76	0.025	0.008	0.420	0.075	8.42	260	254
12-27-76	0.050	0.004	0.300	0.075	8.78	270	262
1-6-77	0.375	0.004	0.730	0.100	8.20	264	255
1-22-77	0.050	0.005	0.420	0.075	8.55	250	252
2-2-77	0.025	0.005	0.650	0.160	8.75	256	257
2-24-77	0.075	0.014	0.580	1.000	8.50	228	218
3-5-77	0.175	0.006	0.360	0.250	8.12	256	241
3-24-77	0.075	0.004	0.160	0.125	8.77	262	255
4-6-77	0.075	0.004	0.100	0.025	8.80	244	237
4-6-77	0.050	0.003	0.100	0.075	8.50	240	238

Appendix 1B. Nutrient concentrations at Station 2 on Smith Valley Creek, Wisconsin, 1976-1977.

Date	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	pH	Hardness (mg/L)	Alkalinity (mg/L)
10-14-76	0.250	0.008	0.810	0.150	7.96	280	284
10-21-76	0.100	0.005	0.800	0.180	8.25	280	283
10-28-76	0.045	0.004	0.960	0.150	8.04	264	275
11-18-76	0.025	0.005	0.860	0.140	8.08	280	282
11-26-76	0.175	0.005	1.250	0.135	8.05	292	286
12-9-76	0.125	0.006	1.200	0.160	8.22	286	274
12-27-76	0.125	0.006	1.200	0.260	8.40	290	288
1-6-77	0.125	0.008	1.700	0.175	8.15	288	281
1-22-77	0.250	0.007	1.500	0.150	8.39	280	286
2-2-77	0.060	0.008	1.000	0.125	8.52	290	292
2-24-77	0.095	0.013	1.500	1.200	8.20	250	244
3-5-77	0.500	0.009	1.040	0.600	7.82	274	261
3-24-77	0.175	0.006	0.670	0.175	8.45	296	301
4-6-77	0.125	0.006	0.450	0.175	8.15	294	280
4-25-77	0.125	0.007	0.370	0.125	8.21	284	259

Appendix 1C. Nutrient concentrations at station 3 on Smith Valley Creek, Wisconsin, 1976-1977.

Date	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	pH	Hardness (mg/L)	Alkalinity (mg/L)
10-14-76	0.550	0.008	0.850	0.175	8.05	280	284
10-21-76	0.175	0.008	0.720	0.175	8.32	272	280
10-28-76	0.025	0.006	0.900	0.025	8.09	254	278
11-18-76	0.150	0.006	0.780	0.150	8.08	280	287
11-26-76	0.190	0.006	1.200	0.150	8.08	290	285
12-9-76	0.200	0.008	1.200	0.200	8.25	292	282
12-27-76	0.150	0.008	1.500	0.200	8.31	286	287
1-6-77	0.150	0.008	1.720	0.175	7.95	290	281
1-22-77	0.250	0.008	1.600	0.200	8.34	276	286
2-2-77	0.050	0.007	0.950	0.200	8.56	290	292
2-24-77	0.150	0.014	1.350	1.150	8.29	240	239
3-5-77	0.625	0.014	1.040	0.600	7.87	270	264
3-24-77	0.225	0.007	0.680	0.253	8.55	290	291
4-6-77	0.175	0.008	0.600	0.175	8.15	294	280
4-25-77	0.150	0.008	0.320	0.175	8.22	275	270

Appendix II. Correlation coefficients (r) of the frequency of occurrences of the nine most abundant taxa collected in drift samples at Smith Valley Creek, Wisconsin, 1976-1977.

Station 1 versus Station 2 $r = 0.22$

Station 2 versus Station 3 $r = 0.93^{**}$

Station 1 versus Station 3 $r = 0.01$

** indicates significance at 0.01 level.

Appendix III. Values of t-tests of the total drift rates in Smith Valley Creek, Wisconsin, 1976-1977.

Density	t-test Value
Station 1 versus Station 2	1.31*
Station 1 Versus Station 3	1.86*
Station 2 versus Station 3	2.69
Biomass	t-test Value
Station 1 versus Station 2	1.72*
Station 1 versus Station 3	0.50*
Station 2 versus Station 3	1.39*

* indicates $P < 0.05$

Appendix IV. Values of t-tests of the total benthic fauna and *Gammarus limnaeus* in Smith Valley Creek, Wisconsin, 1976-1977.

Total Benthic Fauna	
Density	t-test Value
Station 1 versus Station 2	3.15*
Station 1 versus Station 3	3.01*
Station 2 versus Station 3	1.05
Biomass	
Station 1 versus Station 2	1.05
Station 1 versus Station 3	0.13
Station 2 versus Station 3	1.44
Gammarus limnaeus	
Density	
Station 1 versus Station 2	1.67
Station 1 versus Station 3	1.43
Station 2 versus Station 3	0.76
Biomass	
Station 1 versus Station 2	1.05
Station 1 versus Station 3	0.13
Station 2 versus Station 3	1.44

* indicates $P < 0.05$

Appendix V. Correlation coefficients (r) of the frequencies of occurrence of the 5 taxa common to both the benthic and drift samples taken at Smith Valley Creek, Wisconsin, 1976-1977.

Drift at Station 1 versus Benthic samples at Station 1 r = 0.94**

Drift at Station 2 versus Benthic samples at Station 2 r = 0.90*

Drift at Station 3 versus Benthic samples at Station 3 r = 0.88*

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* indicates significance at 0.05 level.
** incicates significance at 0.01 level.

Appendix VI. Correlation coefficients (r) of the total drift and the drift rates of *Hydropsyche* sp. versus water temperature and total discharge at station 1 and the total drift and the drift rates of *Gammarus limnaeus* versus air temperature at station 2 in Smith Valley Creek, Wisconsin, 1976-1977.

Variable	Total Drift	*Hydropsyche* sp.	*Gammarus limnaeus*
Station 1			
Water temperature	-0.69**	-9.64**	
Total discharge	-0.71**	-0.66**	
Station 2			
Air temperature	-0.54**		-0.58*

* indicates significance at 0.05 level

** indicates significance at 0.01 level

Appendix VII. Air and water temperatures at station 1 (S-1), station 2 (S-2) and station 3 (S-3), on 11-14-76 and 5-14-77, at Smith Valley Creek, Wisconsin, 1976-1977.

	11-14-76						5-14-77					
Time	Water Temperature (C)			Air Temperature (C)			Water Temperature (C)			Air Temperature (C)		
of Day	S-1	S-2	S-3	S-1	S-2	S-3	S-1	S-2	S-3	S-1	S-2	S-3
10:00	2	4	3	3	3	3	17	18	17	24	29	25
12:00	3	6	4	2	2	4	17	21	21	28	28	28
14:00	3	6	5	3	3	2	17	22	23	30	29	31
16:00	3	4	4	-1	-3	-2	21	22	23	29	28	30
18:00	2	2	2	-8	-8	-9	21	21	22	22	27	29
20:00	1	1	1	-1	-1	-1	21	18	20	23	22	22
22:00	1	1	1	-7	-7	-7	19	15	16	19	19	19
24:00	1	1	0	-5	-5	-5	18	14	14	20	18	19
2:00	1	1	0	-10	-10	-10	17	14	14	21	20	20
4:00	0	0	0	-4	-4	-4	20	20	20	14	14	14
6:00	1	2	1	-2	-2	-2	16	13	13	19	19	17
8:00	1	3	2	3	3	3	16	14	14	21	21	21