A COMPARISON OF INVERTEBRATE DRIFT IN THREE MICHIGAN STREAMS

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
L. Dean Eyman
1969

ABSTRACT

A COMPARISON OF INVERTEBRATE DRIFT IN THREE MICHIGAN STREAMS

By

L. Dean Eyman

The purpose of this study was to measure the rate of drift in three contrasting streams and determine what relationship exists between drift rate and degree of enrichment. Additionally an attempt was made to determine how drift is related to current velocity.

The three streams chosen for this study were the Jordan River in Antrim County, AuSable River in Crawford County, and Red Cedar River in Ingham County.

Two 24-hour series of drift samples were collected in each stream. Samples of benthic invertebrates were collected following each 24-hour drift collecting period. To investigate the relationship of current velocity to drift rate, five series of samples were collected along a transect across the stream at three points where the velocity was different.

Although standing crop estimates did not reflect the degree of enrichment in the streams, total drift measurements showed a relationship to enrichment.

L. Dean Eyman

The relationship between total drift and current velocity was linear, as expected. However, the drift rate of *Baetis* sp. and *Simulium* sp. appeared to be influenced by behavioral as well as physical factors and was therefore non-linear.

Methods for sampling drift are discussed with suggestions for standardization of technique.

A COMPARISON OF INVERTEBRATE DRIFT

IN THREE MICHIGAN STREAMS

By

L. Dean Eyman

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1969

G 55364
10/22/69

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to Dr. Niles R. Kevern for his counsel throughout the period of the study.

My thanks are extended to Drs. Robert C. Ball and T. Wayne Porter for time given in reviewing this manuscript, and to Dr. Kenneth W. Cummins for his aid in taxonomic problems.

I also wish to extend my thanks to fellow graduate students for aiding in field work as well as their discussions and suggestions pertaining to the study.

To my wife, Ginny, my thanks are given for her constant encouragement and hours spent in typing manuscript.

Finally I wish to thank the Federal Water Pollution Control Administration for financial support through training grant 5T1-WP-109 administered by Dr. Eugene W. Roelofs.

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INTRODUCTION

The phenomenon of benthic invertebrate drift as a continuous process in streams was first described by Dendy (1944). Since then several investigators have attempted to quantify drift and to determine what relationships exist between drift and various environmental parameters (Müller, 1954; Waters, 1961; Holt and Waters, 1967; Elliot, 1967; Pearson and Franklin, 1968).

Attempts to compare results of various studies were difficult due to differences in methods used for collection of samples and expression of results. Methods used for studying streams in which total discharge can be sampled are not applicable when working with large streams. Thus, it is important to determine if samples collected in a large stream are representative of the drift in that stream. This points up a need for standardization of procedures for sampling drift and expressing results if invertebrate drift is to be used in assessing stream conditions such as pollution or as an indication of available food for stream fishes.

The objectives of this study were to measure rate of drift in three contrasting streams and to determine the relationship between drift rate and degree of enrichment in those streams. A third objective was to determine if drift rate is related to current velocity.

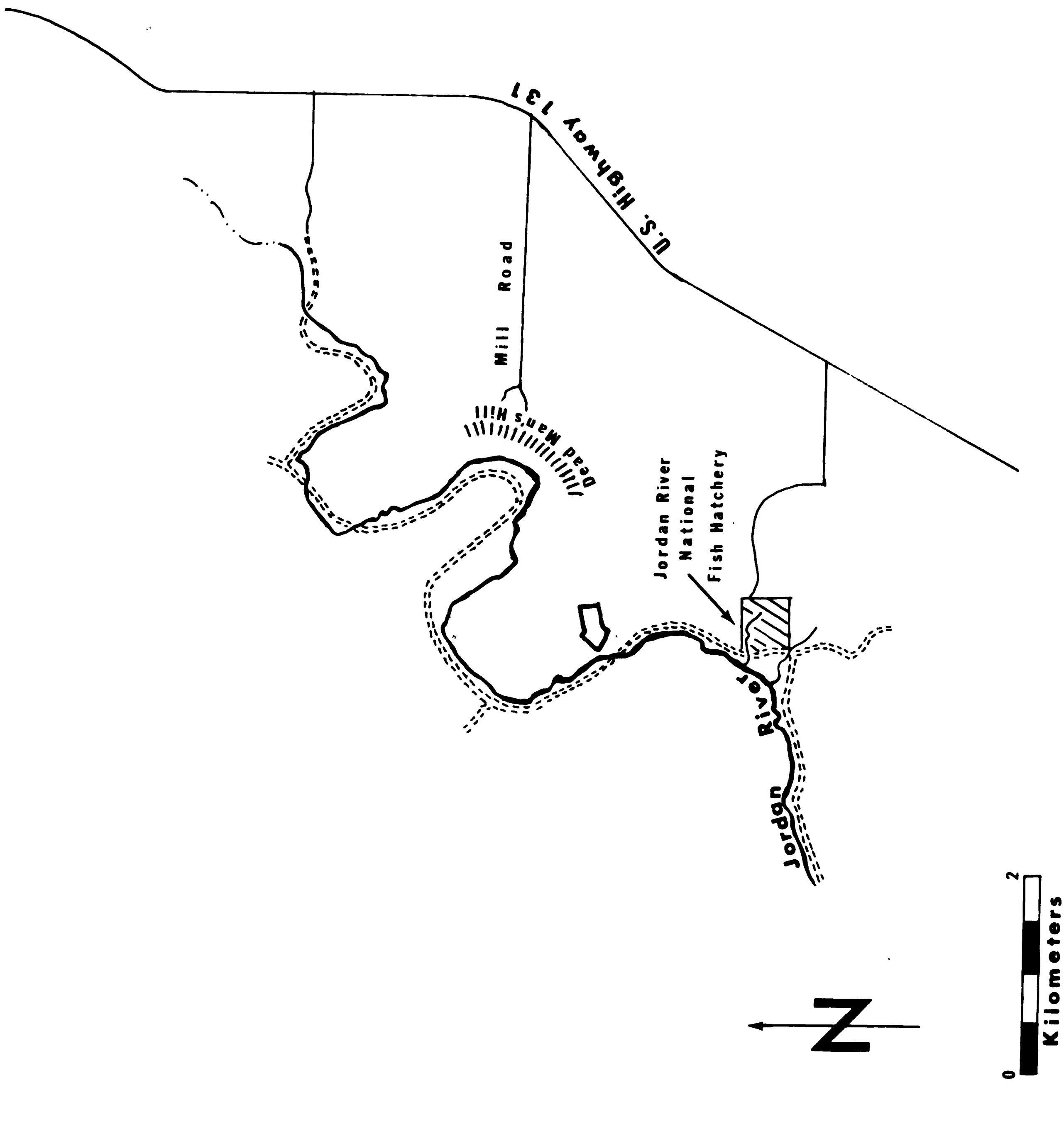
STUDY AREAS

Jordan River

Originating from several springs in Antrim County, this river empties into the south arm of Lake Charlevoix at the city of East Jordan, flowing a distance of approximately 53 km. The headwaters, located in the Jordan Valley Wilderness Area, are state owned.

The sampling site was located in section 31, T31N, R5W of Antrim County approximately 0.8 km upstream from the Jordan River National Fish Hatchery (Figure 1). At the sampling station the stream was 14.6 m wide with a maximum depth of 61 cm. Discharge was approximately 40 cubic feet per second (cfs). Daily water temperatures varied from 8.3 C to 15.6 C on sampling dates. The Jordan is a high quality, undisturbed trout stream throughout its upper reaches. The stream bottom was composed of sand and marly gravel with large marl concretions. The stream bed was heavily log strewn. The logs were covered with mats of *Fontinalis* sp. growing from crevices and from marl concretions on the surface. Dense growths of *Chara* sp., *Potamogeton* sp. and *Nasturtium* sp. were observed in patches along the stream

Figure 1. Map of Jordan River showing sampling location in vicinity of Jordan River National Fish Hatchery.


U.S. Highway 131
Mill Road
Dead Mans Hill
Jordan River National Fish Hatchery
Jordan River
N
0
2
Kilometers

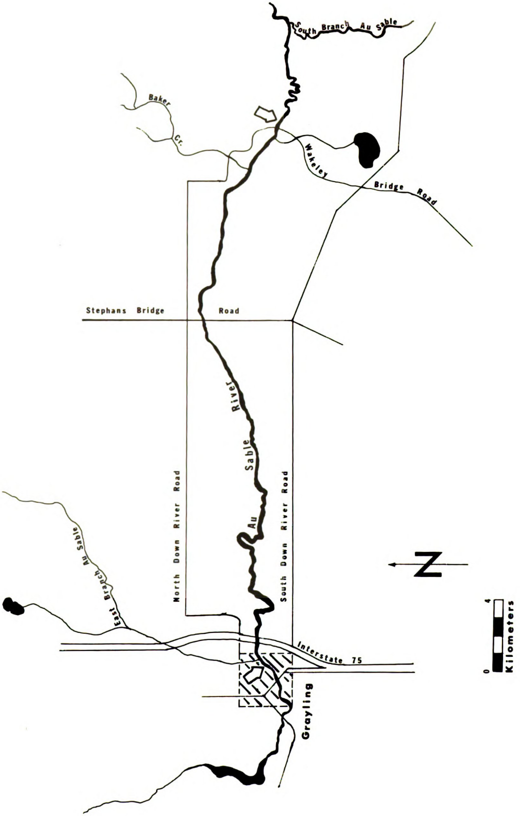
margins. Samples were collected in the Jordan River on July 12-13 and August 13-14, 1968.

Au Sable River

The Au Sable is formed at the confluence of Kolka Creek and Bradford Creek in Crawford County approximately 3 km north of the city of Frederic. It empties into Lake Huron near the city of Oscoda in Iosco County. Total river length is about 322 km.

Two sampling sites were selected. One site was located in section 12, T26N, R2W of Crawford County approximately 183 m downstream from Wakeley Bridge. The second site was located in section 7, T26N, R3W approximately 91 m upstream from the Grayling Municipal Waste Water Treatment Plant outfall (Figure 2). The sampling site near Wakeley Bridge was 18.6 m wide with a maximum depth of 68 cm. Discharge was 178 cfs. Water temperature ranged from 13.9 C to 19.4 C during the sampling period. The stream bottom was composed of gravel and rubble in midstream and grading to sand along the margins. Few aquatic plants were observed in the area of the sampling transect. This was an area of relatively uniform velocity in excess of 0.76 m/sec. Samples were collected here on July 10-11, 1968. The stream at the site near the waste water treatment plant was 15.2 m wide with a maximum depth of 43 cm. Discharge was 79 cfs. Water temperature varied between 18.9 C and 21.7 C during

Figure 2. Map of Au Sable River showing sampling locations in Grayling and in the vicinity of Wakeley Bridge.


South Branch Au Sable
Baker Cr.
Wakeley Bridge Road
Stephans Bridge Road
Au Sable River
North Down River Road
South Down River Road
East Branch Au Sable
Interstate 75
Grayling
N
0
4
Kilometers

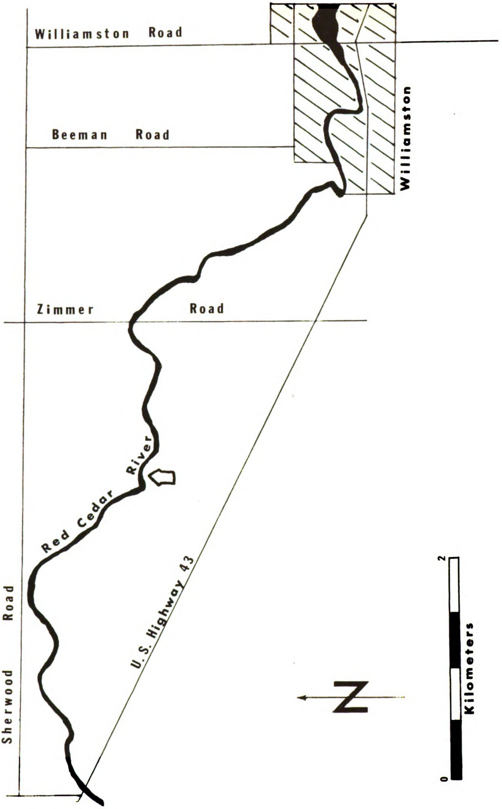
the sampling period. The stream bed had identical features as described at Wakeley Bridge. Potamogeton sp. was common with localized areas of dense growth in midstream. Nasturtium sp. was present in isolated spots along the stream margin. Samples were obtained in the Au Sable River on August 20-21, 1968.

The Au Sable is one of the most important recreational streams in Michigan. Hendrickson (1966) estimated an average of 200 canoes per day leave the city of Grayling during the summer months and 50% of these traveled as far as Wakeley Bridge. On one occasion he observed 60 canoes within 40 minutes passing a point 14.5 km downstream from Grayling. Long recognized by fishermen as an excellent trout stream, the river is becoming marginal trout habitat in some stretches (Anon., 1966).

Red Cedar River

The Red Cedar originates as an outflow of Cedar Lake in Livingston County and flows 79 km to its confluence with the Grand River in the city of Lansing. The sampling station location was in section 28, T4N, R1E, of Ingham County about 1.6 km downstream from Zimmer Road Bridge (Figure 3). The sampling transect was 32.9 m wide with a maximum depth of 36 cm. Discharge was 100 cfs. Water temperatures ranged from 19.9 C to 26.7 C on sampling dates. The Red Cedar is a typical southern Michigan warm-water

Figure 3. Map of Red Cedar River showing sampling location in vicinity of Williamston.


Williamston Road
Beeman Road
Williamston
Zimmer Road
Red Cedar River
U.S. Highway 43
Sherwood Road
Kilometers
0
2

stream. Certain local stretches of the stream show signs of gross pollution due to industrial and domestic waste effluents (Brehmer, 1956; King, 1962; Garton, 1968). One of these areas is below the Williamston Waste Water Treatment Plant outfall. Polluted and recovery areas extend about 5.6 km downstream to the area between Zimmer Road Bridge and the sampling location (King, 1962). Samples were collected in the Red Cedar River on July 31-August 1 and August 23-24, 1968.

METHODS AND MATERIALS

A 24-hour series of drift samples was collected on each date. Each series consisted of sampling at two-hour intervals during daylight (0800-2000 hrs) and at one-hour intervals during darkness (2100-0700 hrs). Drift nets were 1 m long, mounted on a frame 30.5 cm by 45.7 cm. Net material was Nitex nylon, 11.8 mesh per cm. Nets were held in place by iron rods 0.5 mm in diameter driven into the stream bed.

Stream discharge was measured with a Gurley current meter prior to the collection of each drift series. The information on velocity and depth obtained by measuring discharge was used in placement of the nets. Drift nets were placed so the opening extended from the stream bed to above the water surface; thus the total water column was filtered.

Sampling periods varied from 15 minutes at the Red Cedar to 30 minutes at the Jordan. This was based on observations of the time required for the nets to become coated with drift materials and debris. Current velocity was measured at the mouth of each net with a Gurley Pygmy current meter. Water and air temperatures were recorded during each sampling period.

Samples, including organisms and debris, were washed into enamel pans, concentrated with a sieve (11.8 mesh/cm) and preserved in jars with formalin. In the laboratory the organisms were separated from the debris by hand under a dissecting scope and preserved in 70% ethyl alcohol solution.

Organisms were classified to genus and counted. Weights were determined for those forms which exhibited a definite diel periodicity in numbers drifting. Weight determinations were made using methods described by King and Ball (1964) as giving a close approximation of live weight. Organisms were removed from vials containing 70% alcohol and placed in tap water for 30 minutes. They were next placed on small screens (11.8 mesh/cm) and spun at 1800 RPM for 30 seconds in a clinical centrifuge. Following centrifugation the organisms were weighed on a four-place analytical balance.

Samples were collected for estimates of benthic standing crop after completion of drift sampling on each date. Bottom samples were collected upstream from the location of the drift nets using a Surber square-foot sampler.

To investigate the relationship of current velocity to drift rate, samples were collected from three points along a transect where the current velocities were 0.27, 0.45, and 0.85 meters per second. Five samples, each of 10 minute duration, were collected at 20 minute intervals at each point. These samples were collected from 2200 hrs to

2320 hrs on August 23, 1968, in the Red Cedar River. Depth of water passing through the nets ranged from 25 to 31 cm. These samples as well as Surber samples were handled in the same manner as described for drift samples except weights were not determined.

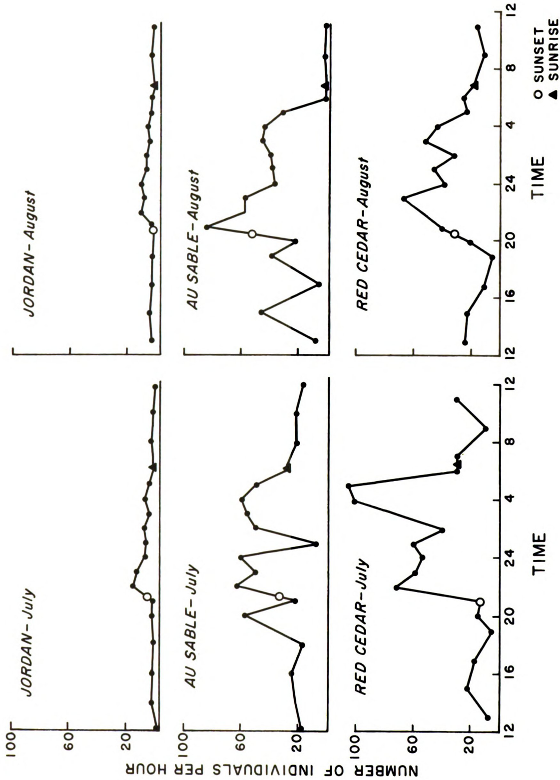
RESULTS

Periodicity of Drift

A circadian rhythm in the drift of stream invertebrates has been described by Waters (1962). The rhythm, in most cases, involves greater nocturnal drift rates as a result of greater night-time activity by the organisms involved. Waters (1968) also reported day-active limnephilid larvae in a mountain stream in Utah. However, this is the only record of an organism showing a day-active pattern of drift.

Total drift--An increase in rate of total drift during hours of darkness was found in all three rivers on all collecting dates. Increases in nocturnal drift (number per hour per net) were very evident in the Red Cedar and Au Sable. Samples from the Jordan showed increased rates at night also although day-night differences were subtle (Figure 4). The peak which appeared prior to sunset (2000 hrs) in July samples from the Au Sable was caused by a canoe capsizing about 10 m upstream from the nets resulting in a considerable disturbance to the stream bed. Increases in total drift at 1500 hrs and 1900 hrs in August samples from the Au Sable coincide with periods of heavy canoe traffic

Figure 4. Total numbers of organisms drifting per hour per net showing circadian rhythm of stream invertebrates in July and August samples from Jordan River, Au Sable River, and Red Cedar River.



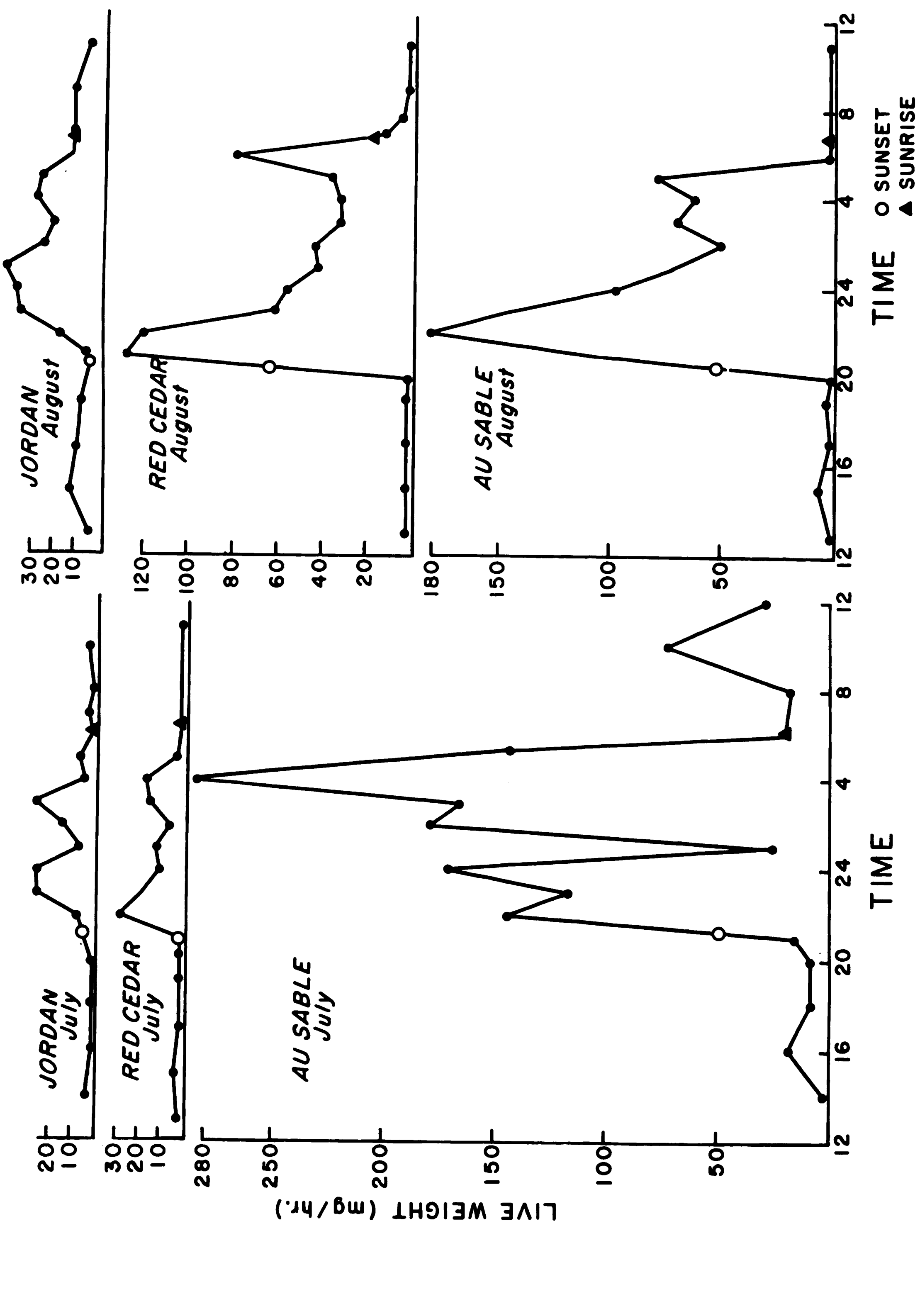
JORDAN- July
JORDAN- August
AU SABLE-July
AU SABLE-August
RED CEDAR-July
RED CEDAR-August
NUMBER OF INDIVIDUALS PER HOUR
100
60
20
TIME
12
16
20
24
4
8
12
O SUNSET
▲ SUNRISE

passing the sampling point. Many canoeists allow current to carry them downstream, periodically pushing a canoe paddle into the stream bed to steer the canoe. The resulting disturbance to the stream bottom could account for the increase in drift during those periods.

Baetis sp.--This mayfly was collected in quantities sufficient for weight determinations on all sampling dates. A pronounced increase in drift after sunset followed by a decline with a second peak just prior to sunrise was evident on all collecting dates (Figure 5). Aschoff (1966) describes this double peaked pattern for many forms including mammals, birds, reptiles and fishes. Müller (1963) found a similar pattern in the drift rate of *Gammarus pulex*. The magnitude of increase in nocturnal drift rate over daylight drift rate varied considerably with a 20 to 30 fold increase in the Au Sable and Red Cedar while day-night differences in the Jordan were much less (3 to 10 fold).

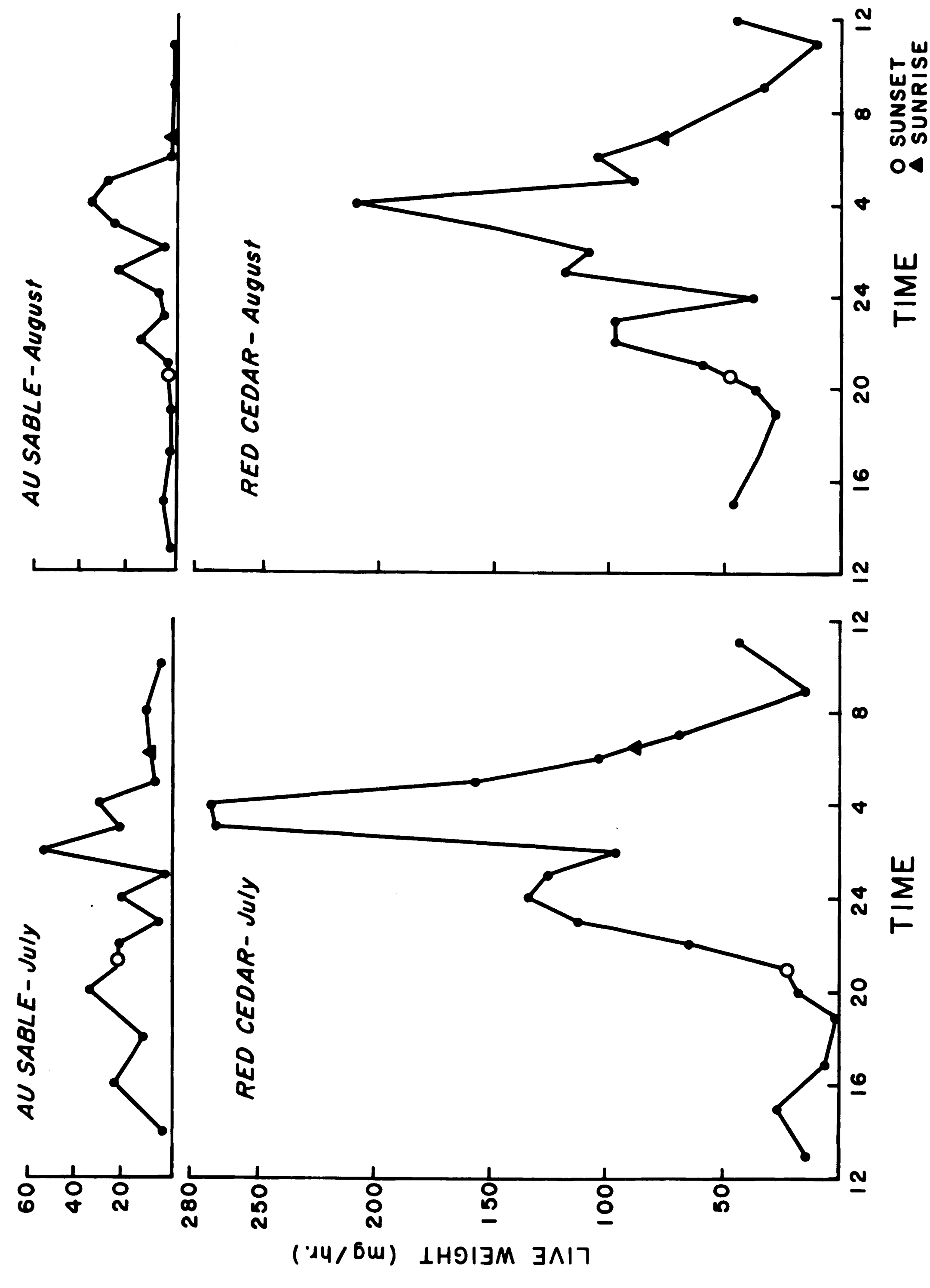
Simulium sp.--Weight analyses of black-flies were performed on those samples from the Au Sable and Red Cedar. Numbers were insufficient for weight determinations on samples from the Jordan. In the Au Sable and Red Cedar, increased nocturnal drift occurred with a pre-dawn peak greater than the post-dusk peak (Figure 6). Aschoff (1957, as cited in Aschoff, 1966) has termed this sequence an "alternans" pattern as opposed to a "bigeminus" pattern in which the

Figure 5. Drift rate of Baetis sp., mg per hour per net in July and August samples from the Jordan River, Au Sable River, and Red Cedar River.



JORDAN July
RED CEDAR July
AU SABLE July
JORDAN August
RED CEDAR August
AU SABLE August
LIVE WEIGHT (mg/hr.)
TIME
O SUNSET
▲ SUNRISE

Figure 6. Drift rate of *Simulium* sp., mg per hour per net in July and August from the Au Sable River and Red Cedar River.


AU SABLE - July
AU SABLE - August
RED CEDAR - July
RED CEDAR - August
LIVE WEIGHT (mg/hr.)
60
40
20
280
250
200
150
100
50
12
16
20
24
4
8
12
TIME
O SUNSET
▲ SUNRISE

first peak exceeds the second. Upstream disturbance to the stream bed is reflected in the July samples from the Au Sable (Figure 6).

Hyalella azteca--The Red Cedar was the only stream of the three studied where *H. azteca* was present in sufficient numbers for weight determinations. A marked increase in rate of drift occurred after sunset on both dates followed by a gradual tapering off with a small peak prior to sunrise (Figure 7).

Bottom Samples

The number of families ranged from 32 in the Jordan to 22 in both the Au Sable at Wakeley Bridge and in the Red Cedar (Table 1). The most important group at all sampling locations (except the Au Sable at Grayling) was the Tendipedidae. At Grayling and in the Red Cedar, Simulidae was also an important group. Rhyacohpilidae was second in importance in the Au Sable at Wakeley Bridge. This sampling location was described earlier as an area of high current velocity which is favorable habitat for rhyacophilid larvae (Pennak, 1953). All families found in bottom samples occurred in the drift except Sphaeridae (fingernail clams) and Ancylidae (limpets). The average density of all organisms ranged from 2,587 per m^2 at the Jordan to 33,785 per m^2 at the Red Cedar (Table 2).

Figure 7. Drift rate of Hyalella azteca, mg per hour per net in July and August samples from the Red Cedar River.

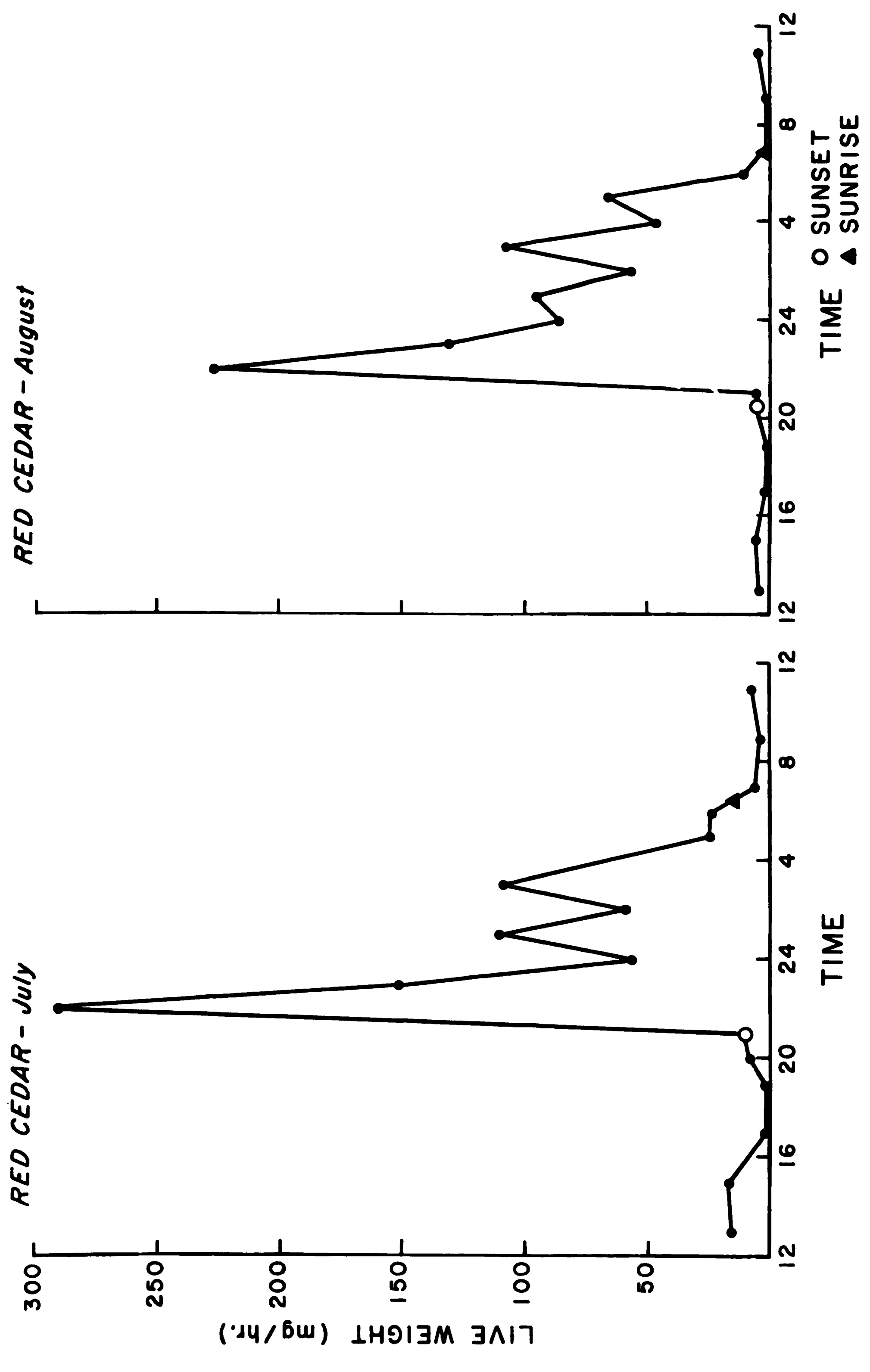

RED CEDAR - July
RED CEDAR - August
LIVE WEIGHT (mg/hr.)
300
250
200
150
100
50
12
16
20
24
4
8
12
TIME
O SUNSET
▲ SUNRISE

Table 1. Average percent composition by numbers of aquatic invertebrates occurring in bottom samples at the four sampling locations.

Organism	Location: Jordan River	Grayling	Wakeley Bridge	Red Cedar River
Baetidae	10.0	4.7	1.0	7.8
Baetiscidae	.3	.1		
Caenidae	.3	.1		.3
Ephemerellidae	.2		2.5	.1
Ephemeridae	.3	.5		
Heptageniidae	.1	1.5		1.2
Leptophlebeidae	.0-		.6	.0-
Siphlonouridae	.0-		.3	2.7
Tricorythidae	.7	.3	.3	4.3
Ceratopogonidae	2.8		.0-	.1
Rhagionidae	.1		.1	
Simulidae	2.2	17.2	1.8	22.4
Tabanidae	.2			
Tendipedidae	55.3	17.2	63.4	34.3
Tipulidae	9.5	.5	.5	.2
Brachycentridae	.6	1.3	5.0	
Helicopsychidae		.4		
Hydropsychidae	1.4	8.0	.3	12.0
Hydroptilidae	.0-	2.4	.8	.4
Lepoceridae			.0-	
Limnephilidae	1.0	3.0	.6	4.2
Philopotamidae		.7		
Phryganeidae	.3		.7	
Psychomyiidae		.4		.1
Rhyacophilidae	.0-	.8	19.0	
Gammaridae	2.4	7.5	.3	
Talitridae				4.0
Elmidae	2.1	12.3	1.8	.4
Psephenidae	.0-			
Perlodidae	.0-			
Perlidae	.0-			
Sialidae	.0-			
Lepidoptera				.0-
Agrionidae	.0-			
Oligochaeta	2.4	.9	.6	3.4
Hydracarina	.1	2.5	.2	.2
Ancylidae		.4		
Asellidae		3.9		
Tricladida	.0-	1.4		.1
Sphaeridae	4.2	11.0	.1	1.0
No. of families present	32	25	22	22

Total Drift vs. Standing Crop

Total drift per day per net in both the Au Sable and Red Cedar was approximately 10 times as great as in the Jordan in July samples and 7 times as great in August samples (Table 3). Total drift per day appears to be inconsistent with standing crop in the respective rivers (Tables 2, 3) if one assumes a relationship exists between them. Waters (1966) concluded "Drift, then, rather than being a linear function of either production rate or population density, may be a function of production rate at or above the point at which the carrying capacity is reached, or in other words, a function of the degree to which the carrying capacity tends to be exceeded."

Drift vs. Current Velocity

A relationship between drift rate and current velocity has been reported (Müller, 1954; Waters, 1966); however, no attempt has been made to determine the exact nature of this relationship or to quantify it.

In the present study total drift (exclusive of *H. azteca* sp., *Baetis* sp., and *Simulium* sp.) exhibited a linear relationship to current velocity as did the drift rate of *H. azteca* (Figure 8). Drift rates of both *Baetis* sp. and *Simulium* sp.; however, showed an unexpected curvi-linear relationship to current velocity. Drift rates of these

Table 2. Average number of organisms per m^2.

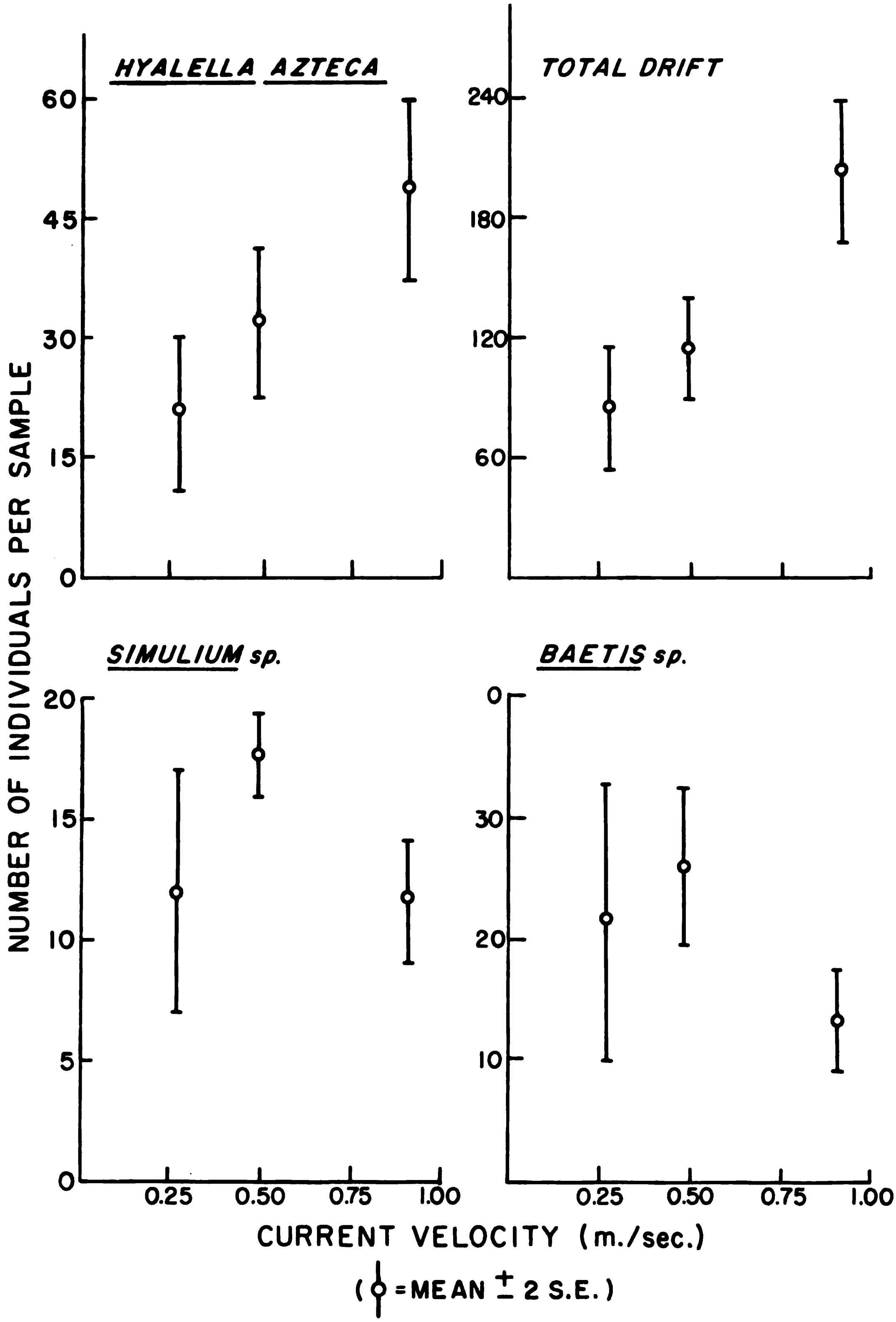
	July	August
JORDAN	3,302	2,563
AU SABLE	3,333	4,397
RED CEDAR	33,785*	2,068

*Including an average of 17,770 Simulium sp. larvae per m^2. In one sample the density exceeded 48,000 per m^2.

Table 3. Total numbers of drifting organisms collected per net in 24 hour sampling series.

	July	August
JORDAN	837	985
AU SABLE	8,489	6,694
RED CEDAR	8,243	6,649

Figure 8. Relationship of drift (number of individuals per 10-minute sample), to current velocity for total drift (exclusive of _Hyalella azteca_, _Baetis_ sp. and _Simulium_ sp.), _Baetis_ sp., _Hyalella azteca_, and _Simulium_ sp. in the Red Cedar River.


HYALELLA AZTECA
TOTAL DRIFT
SIMULIUM sp.
BAETIS sp.
NUMBER OF INDIVIDUALS PER SAMPLE
60
45
30
15
0
240
180
120
60
20
15
10
5
0
0
30
20
10
0.25
0.50
0.75
1.00
CURRENT VELOCITY (m./sec.)
(= MEAN ± 2 S.E.)

forms shows a direct relationship to current velocity below approximately 0.45 m per second and an inverse relationship in current velocities above that range. Minshall and Winger (1968) found an increase in drift when they decreased the discharge of a small stream; however, due to experimental design, whether increased drift was due to changes in velocity or changes in depth could not be determined. Their study was concerned with the effect of changes in discharge on drift whereas the present study was concerned with distribution of drift in relation to current velocity during a period of normal discharge. It is possible that sudden changes in discharge (whether increasing or decreasing) would elicit an increase in drift. Sudden changes in various factors governing the organisms behavior that would accompany abrupt changes in discharge could cause behavioral changes on the part of the organism resulting in increased drift. These "key" factors may include depth, velocity, turbidity, available oxygen, available food and physical effects (scouring of bottom).

Since the Red Cedar was at constant flow for a period of 3 weeks prior to the sampling date, changes in distribution of drift due to changes in discharge can be discounted. Distribution of drift in relation to velocity can be attributed to either behavioral response to current velocity as in the case of *Baetis* sp. and *Simulium* sp. or the effect of physical forces associated with water current as with *H. azteca* and total drift.

Estimates of Total Daily Drift

Two methods were used to calculate total drift per day for the six sampling dates. One method used the ratio: average discharge through net/ discharge of stream. The second method used the ratio: width of net/ width of stream. The second ratio could be used since the total water column was sampled thus eliminating the variable of depth. The results of these calculations (Table 4) show the estimate of total drift based on width was higher than the estimate based on discharge on all dates except the Au Sable in July. The Au Sable at Wakeley bridge is deeper than all other stations so that discharge per foot of stream width is greater. The total drift based on discharge would therefore be greater at this station than total drift based on width.

Table 4. Estimates of total drift per day in the Jordan River, Au Sable River and Red Cedar River based on discharge and on stream width.

River and Date	Based on discharge: Observed Drift (Average No. organisms per net per day)	Total Stream* discharge / discharge per net	Total Drift (No. organisms per stream per day)	Based on width: Observed Drift (Average No. organisms per ft stream width per day)	Stream width (ft)	Drift (No. organisms per stream per day)
Jordan 7/12/68	837	39.5	33,100	837	48.8	40,800
Jordan 8/13/68	985	32.6	32,100	985	47.0	46,300
Au Sable 7/9/68	8,489	143.2	1,215,600	8,489	60.0	509,340
Au Sable 8/20/68	6,694	47.2	316,000	6,694	49.2	329,300
Red Cedar 8/1/68	8,243	65.8	542,400	8,243	95.0	783,100
Red Cedar	6,648	69.5	462,000	6,648	94.0	624,900

*Measured in cfs.

DISCUSSION AND CONCLUSIONS

Periodicity of drift in streams is well documented by several investigators (Anderson and Lehmkuhl, 1968; Waters, 1962; Ulfstrand, 1968). Light has been demonstrated to be of primary importance for the circadian drift rhythm of night-active forms (Waters, 1962).

Although a major portion of drift is contributed by chironomid larvae, no circadian rhythm has been demonstrated in these forms. A bigeminus pattern of drift (Aschoff, 1957 as cited in Aschoff, 1966) has been established for several night-active forms (Müller, 1954; Waters, 1962) although an alternans pattern has not been demonstrated on previous studies for drifting invertebrates. The present study demonstrated the latter type of pattern for Simulium sp. Total drift per day per net of this form was much greater in the Red Cedar than in either of the other two rivers. This may be partially explained by the location of the sampling transect in the Red Cedar. Drift samples were collected downstream from areas of dense growths of Potamogeton sp. Surber samples collected in weed beds yielded 48,915 Simulium sp. larvae per m^2. Observations revealed larvae were attached to plants along with pupal cases. Larvae of the family Simulidae are generally recognized as fast water forms (Pennak, 1953); however, density of growth in the beds of _Potamogeton_ sp. would tend to decrease the speed of water flowing through them so the larvae were located in an area of medium or low current velocity. Photosynthetic activity of the plants would increase dissolved oxygen in the water flowing through them and would maintain available oxygen for the larvae comparable to oxygen levels in fast water. Perhaps the high drift rate of larvae during the period of darkness might be due to a combination of activity of the larvae and lack of sufficient dissolved oxygen due to oxygen uptake by plants. Physiological stress exerted on the organisms by lack of dissolved oxygen combined with increased activity of organisms at night may explain the pronounced alternans pattern in the Red Cedar since the combined effect of these two factors would be greatest just prior to sunrise.

The magnitude of drift in the three streams studied appears to be related to the degree of enrichment of each stream. The pollutional status of the Red Cedar due to domestic and industrial wastes has been well established (Brehmer, 1956; Garton, 1968; King, 1962; Linton, 1967). The Au Sable receives no industrial wastes, however there are two sources of domestic wastes entering the stream in and above the area studied. The primary source is the city of Grayling. Grayling Municipal Waste Water Treatment Plant serves a population of 2,150. During summer months an influx of tourists increases the population to approximately 3,150 (Anon., 1966). The wastewater treatment plant provides primary treatment consisting of screening, primary sedimentation and separate sludge digestion. Sewage is chlorinated prior to sedimentation and again following sedimentation. The treatment plant contributes an effluent of 1.15×10^6 liters per day to the stream.

A second possible source of domestic wastes arises from the septic systems of summer cottages and permanent residences on both sides of the river downstream from Grayling. There are approximately 220 dwellings between Grayling and Wakeley Bridge. The contribution of nutrients to the river from septic systems associated with these dwellings is unknown (D. C. Brege, personal communication*).

Large growths of aquatic plants are present in the stream in localized areas between Grayling and Wakeley Bridge. These growths are esthetically unpleasant and interfere with fishing. In addition they cause an increase in the magnitude of diurnal dissolved oxygen fluctuation which, if great enough, can result in the dissolved oxygen being depressed below acceptable levels during the period of darkness. The Michigan Water Resources Commission report on the Au Sable River Basin (Anon., 1966) concluded that domestic waste effluents were the most significant sources of nutrient material in the Au Sable basin.

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*Fellow graduate student in Department of Fisheries and Wildlife.

The Jordan, in and upstream from the area studied, is a stream of excellent water quality. The watershed above the sampling point is state owned and there is no significant addition of wastes to the stream.

If drift is density dependent or more precisely represents production in excess of carrying capacity of a stream as suggested by Waters (1966), it would appear that production in the Au Sable and Red Cedar are significantly greater than in the Jordan. Dimond (1967) found in streams treated with DDT, recovery of bottom fauna to pre-treatment densities of standing crop occurred within 2-3 years. Drift however, did not occur until after the standing crop had reached pre-treatment levels. He concluded that drift was apparently the result of population surpluses. From this it may be concluded that the bottom density at which drift occurred represented the carrying capacity of streams he studied.

A comparison of standing crop densities in the three streams shows the Jordan and Au Sable to be very similar as opposed to the Red Cedar (Table 1). However, rates of total drift per day per net in these streams do not show this trend. As discussed previously, the Au Sable is regarded as an excellent trout stream. It does receive domestic wastes from municipal and private sources. Any changes taking place in the stream due to nutrient addition are not reflected in the bottom fauna as measured by standing crop estimates. Drift measurements, however, show a significant difference between the Au Sable and Jordan. Drift analysis of a stream such as the Au Sable could give indications of changes taking place in the stream at very early stages of enrichment.

Since the portion of the study concerned with the relationship of drift rate to current velocity was carried out during the period of maximum drift (2200-2320 hrs), it is assumed organisms were at their peak of activity and any selective effects due to light would be nonexistent.

A direct relationship between drift rate and current velocity was expected. Animals caught up in the current would be carried greater distances downstream in higher velocities. Drift samples collected in a higher velocity zone would represent drifting organisms originating from a larger portion of the stream bed than samples from a zone of low velocity.

The relationship found between drift rates of _Baetis_ sp. and _Simulium_ sp. and current velocity may have at least two plausible explanations. The first is related to an experiment conducted by Elliot (1967), using artificial streams. He found that in the presence of current all species tested showed a strong positive thigmotaxis, but if the flow of water ceased the taxis was reversed and nymphs became free swimming. In the present study it appears a positive thigmotactic response occurred at velocities above approximately

0.45 m per second (which may be a "threshold" velocity). At velocities below this threshold the thigmotactic response to current is reversed so that organisms become free-ranging. Since they are moving about freely, they would be more susceptible to downstream displacement and there would be a direct relationship between current velocity and their drift rate at velocities below the threshold value.

A second explanation may be that organisms tend to avoid zones of high or low velocity due to their inability to exist there. Pressure exerted by high current velocity may render *Baetis* sp. incapable of normal feeding behavior. Their absence in areas of low velocity may be due to an inadequate food supply or oxygen may be insufficient for survival of the organisms.

Distribution of the drift of *Simulium* sp. larvae with respect to current velocity may have been influenced by location of the sampling site. As mentioned earlier the major source of simuliid larvae in drift were weed beds upstream from the sampling sites. It would appear that distribution of drift of this form with respect to velocity is incidental to the effect of very high density of larvae in the weed bed above the sampling site.

Regardless of the causes of distribution of the drift of *Baetis* sp. with respect to velocity, the importance of a knowledge of velocity of water passing through the net is apparent.

Drift appears to be of potential value as a tool in evaluating effects of water quality on the ecology of a stream. In order to use drift as a diagnostic tool, several considerations are important if comparisons are to be made among streams:

1. In large streams where total discharge cannot be sampled it must be determined if samples being collected are representative of drift in the total stream.
2. Variations in current velocity should be determined by gauging the stream. This information should be used in placement of the collecting nets.
3. Whether or not organisms being studied exhibit a behavioral response to various current velocities should be determined.
4. Drift-collecting nets should extend from the stream bed to above the water line. This negates any differences in vertical distribution of organisms in the water column (Waters, 1965; Ulfstrand, 1968).
5. The length of time nets are left in the stream during each sampling period should be such that they are not blocked by debris, thus decreasing velocity through them.

Standing crop of stream benthos does not give a complete measure of available food supply for stream fishes. The contribution of drift or "traveling benthos" (Müller,

1954) to the food supply appears to be considerable. This contribution cannot be satisfactorily quantified until values for drift collected in nets can be expanded to give estimates of the total drift in a stream.

Expressing drift as weight, volume, or numbers drifting per standard foot of stream width per unit of time (Waters, 1961), appears to be satisfactory for quantifying drift in small, shallow streams of relatively uniform velocity in cross section. In large streams with irregular cross sections with respect to depth and velocity, the complex fluid dynamics of stream flow must be taken into consideration in expressing results.

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