A STUDY OF DRIFT IN THE KAKANUI RIVER, NEW ZEALAND

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Summary

The bottom fauna and drift in the Kakanui River, New Zealand, were studied for a period of one year. The fauna was dominated by Ephemeroptera and Chironomidae. A diurnal drift rate was found with maximum rates just after sunset. A mechanism is postulated to account for the observed correlation of decrease in light intensity at sunset and increase in drift rate. There was a quantative change in the drift at night with the occurrence of comparatively large numbers of mayfly nymphs and Rhyacophilidae larvae. Lowest drift rates were recorded during the winter. There is a close interrelationship between drift and bottom fauna: proportional occurrence in the bottom fauna is similar to that in drift but is modified by differences in behaviour of the animals, and the occurrence of pieces of algae, containing animals.

During the study a flood occurred which halved the density of the bottom fauna but within three weeks the density returned to near its pre-flood value. Some species had higher densities after the flood than before it. Recolonization of the substrate by the animals could be followed by interdependent changes in bottom fauna and drift samples. A large increase in drift rate was recorded at sunset immediately after the flood had occurred.

I. Introduction

This paper is a report on the results of a study of the drift and bottom fauna of the Kakanui River, conducted mainly during the summer of 1964–65. The Kakanui River is located on the east side of the South Island of New Zealand. From its headwaters in the mountains it flows in an eastward direction down into a shallow valley and through farmland to the sea. In the valley the river flows over a bed of coarse gravel. The width of the river varies from a metre or so in the source area to a maximum of 15 m near its mouth. The depth varies from a few centimetres to 60–70 cm in riffles, and up to 3 m in pools.

The fauna of the river was studied at two points, one on the main stream and the other on a tributary, Island Stream. The main stream site (Station 1) was located 1 mile upstream from the settlement of Five Forks, and the Island Stream site (Station 2) was located beside the homestead of the Kuriheka sheep station (see Figs. 1 and 2).

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At both stations drift and bottom fauna samples were taken to determine which of the members of the bottom fauna occurred in the drift and with what frequency. During the study a flood occurred and drift samples were taken before and after the flood. To date no report of the effect of a flood on the drift of a river has appeared in the literature.

II. Methods

The drift sampler used was constructed from a design published by Cushing (1964). The water is taken in through a narrow opening of a metal box to which the net is attached. The sampler is designed to prevent any back-pressure from the filtering surface. A sampling time of 30 min was used since it was found that longer time intervals tended to obscure significant changes in the rate and composition of the drift.

Bottom fauna samples were taken in the classic manner with a Surber sampler (Surber 1937) which sampled an area of $\frac{1}{16}$ m^2 (625 cm^2). These were taken just after the drift samples and in the area adjacent to the drift sampler. The mesh size of the net was the same as the drift net, ensuring comparable results.

III. Results

(*a*) *Bottom Fauna*

The following is a taxonomic list of the species recorded in the bottom fauna of the Kakanui River and its tributary Island Stream:

Oligochaetes
Planarians
Ephemeroptera
- *Deleatidium* sp.
- *Coloburiscus humeralis*
- *Nesameletus ornatus*
- *Atalophlebia* sp.

Plecoptera
- *Stenoperla prasina*
- *Zelandoperla maculata*

Neuroptera
- *Archichauloides diversus*

Trichoptera
- *Olinga feredayi*
- *Hudsonema hudsoni*
- *Triplectides* sp.
- *Pycnocentrodes* sp. (probably incl. *Oecetis, Pycnocentria*)
- *Helicopsyche iltona*
- *Oxyethira albiceps* (probably incl. *Paroxyethira*)
- *Hydropsyche colonica*
- *Hydrobiosis parumbripennis*
- *H. clavigera*
- *H. harpidiosa*
- *Psilochorema bidens*
- *P. leptoharpax*
- *Neurochorema confusum*
- *Neurochorema*(?) sp.
- *Polyplectropus puerilus*

Diptera
- *Austrosimulium* sp.

Tipulidae
Chironomidae
Coleoptera
- Parnidae
- Hydrophilidae

Mollusca
- *Potamapyrgus antipodum*
- *Physastra variabilis*
- *Planorbis corunna*
- *Psidium* sp.

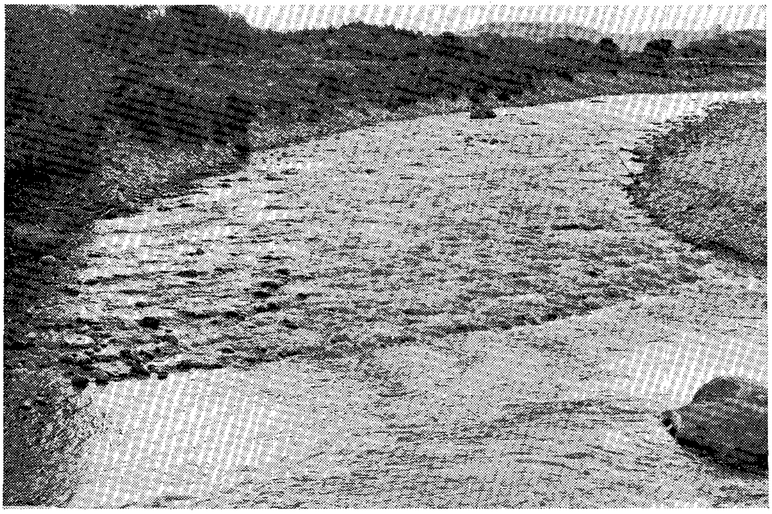


Fig. 1.—The riffle at station 1, Kakanui River. Dimensions: 80 m long by approximately 16 m wide; depth of water varied from 20 to 70 cm. Samples were taken at the right-hand edge of the river just above the lower end of the riffle and adjacent pool (May 1965).

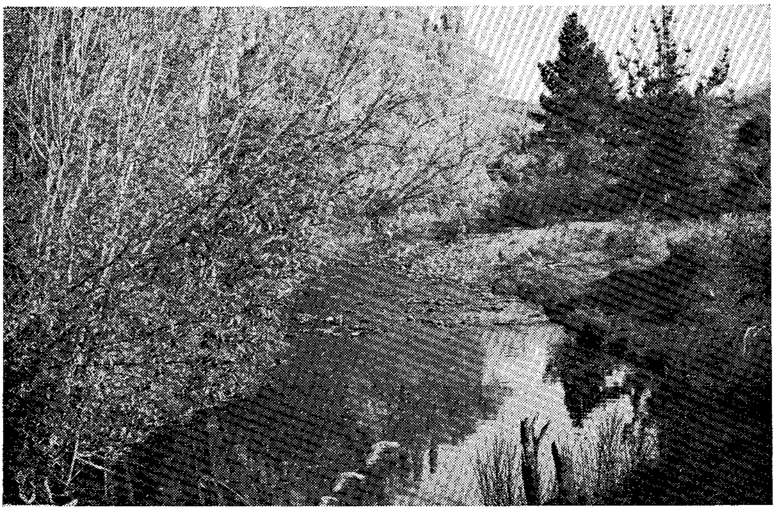


Fig. 2.—The river at station 2, Island Stream, with the pool in the foreground and the riffle separating it from the pool beyond the figure in mid-field. Dimensions: 51 m long by approximately 9 m wide; depth of water varied from 10 to 30 cm (May 1965).

The composition of the bottom fauna in riffles and pools at both stations is shown in Figures 3(*a*)–(*d*). The densities are expressed as numbers/m² and each is the

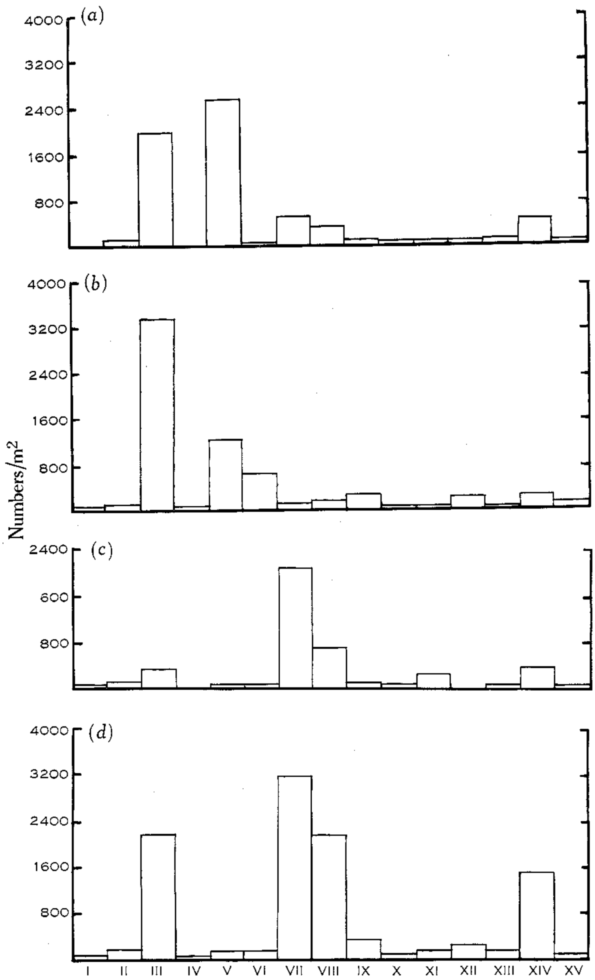


Fig. 3.—Summary of the composition of the bottom fauna at both stations on dates mentioned and also mean population density $\bar{X}$. (*a*) Station 1, pool, 8.iii.65, $\bar{X} = 6210$; (*b*) station 1, riffle, 28.ii.65, $\bar{X} = 6627$; (*c*) station 2, pool, 8.iii.65, $\bar{X} = 4686$; (*d*) station 2, riffle, 8.iii.65, $\bar{X} = 11327$. I, Planarians; II, oligochaetes; III, *Deleatidium* sp.; IV, *Coloburiscus humeralis*; V, Parnidae; VI, *Astrosimulium* sp.; VII, Chironomidae; VIII, *Pycnocentrodes* sp.; IX, *Olinga feredayi*; X, *Hudsonema hudsoni*; XI, *Oxyethira albiceps*; XII, *Hydropsyche colonica*; XIII, Rhyacophilidae; XIV, *Potomapyrgus antipodum*; XV, others.

mean of four samples. The fauna of the river was dominated by *Deleatidium* sp., Chironomidae larvae, Parnidae larvae, *Pycnocentrodes* sp., and *Potamapyrgus antipodum*. Some species showed consistently higher densities in riffles than in pools. These were:

Deleatidium sp.	*Olinga feredayi*
Coloburiscus humeralis	*Hydropsyche colonica*
Austrosimulium sp.	Rhyacophilidae spp.
Pycnocentrodes sp.	

There were five species of Rhyacophilidae on the riffles and only one in the pools. The only species showing consistently higher densities in the pools were the Parnidae.

Only at station 2 (Figs. 3(*c*)–(*d*)) was there a substantial difference between riffles and pools, in the total density: 11327 per m^2 compared to 4686 per m^2.

(*b*) *Drift*

Only animals which occur in the bottom fauna have been used in calculating the drift rates: animals such as *Microvelia* sp., Daphniidae, Culicidae, terrestrial adults, and flying adult stages were excluded.

(i) *Diurnal Variation in Drift Rates.*—Three studies were made of the variation of the drift rate over a period of 24 hr: Station 2 on December 28, 1964, Station 1 on January 3, 1965, and again on December 2, 1965. Drift nets were placed at lower end of riffles and samples taken regularly every hour except during the early morning.

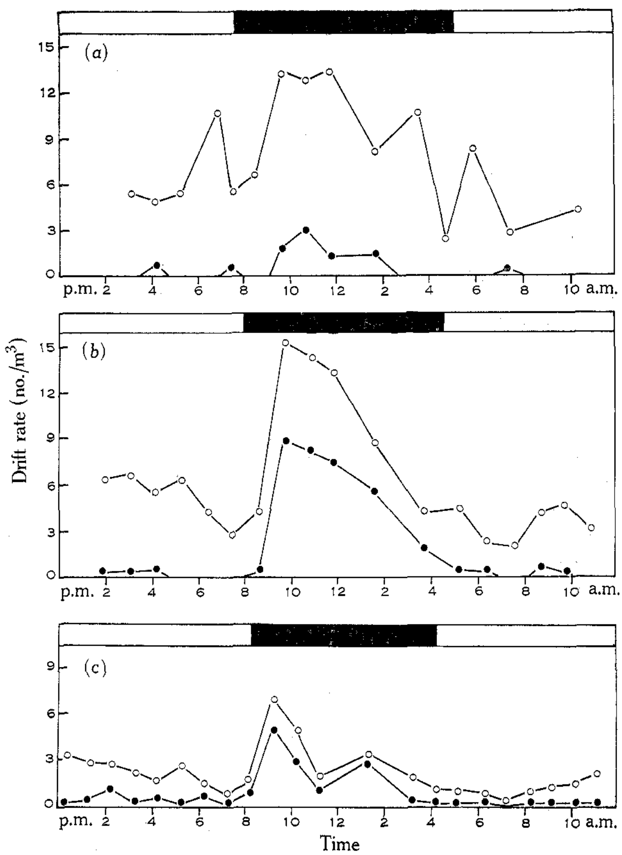


Fig. 4.—Change in drift rate over a period of 24 hr at each station on the dates shown. The dark region of the bar at the top of each graph represents the period of darkness. ○—○ Total drift rate. ●—● Drift rate of Ephemeroptera and Rhyacophilidae. (*a*) Station 2, 28.xii.64; (*b*) station 1, 3.i.65; (*c*) station 1, 2.xii.65.

The results of these studies are expressed graphically in Figure 4. During the first two studies only one sampler was used, and during the last, two samplers.

During the daylight hours the drift rate fluctuated irregularly at a low level. The drift was composed largely of Chironomidae larvae, oligochaetes, Parnidae larvae and adults, and the occasional cased Trichoptera larva. At sunset the composition changed quite suddenly. Large numbers of mayfly nymphs and Rhyacophilid larvae (plotted separately in Fig. 4) appeared in the samples and their occurrence was restricted mainly to samples taken at night. This was not true of the series of samples taken at station 1 on December 2, 1965. In this series nymphs of the mayfly *Deleatidium* sp. occurred largely at night but continued to appear throughout the day. The reason for this difference is unknown.

The appearance of the mayfly nymphs and Rhyacophilidae larvae was closely correlated with the time of sunset. Sunset was taken as the time at which the sun disappeared behind the adjacent hills, and it became difficult to distinguish the features of the landscape. In all series of samples there was a time lapse of ½–1 hr between the time of sunset, and the occurrence of the peak in drift rate. After the initial increase in drift rate there is a steady decrease throughout the night, reaching normal daytime rates by sunrise.

TABLE 1

SEASONAL VARIATION IN DRIFT RATE AT STATION 2

	3.i.65	19.i.65	2.ii.65*	11.ii.65	6.iii.65	5.vi.65†	2.xii.65
Oligochaetes	0·32	0·07	0·49	—	—	0·02	0·07
Deleatidium sp.	3·61	2·77	26·47	2·34	5·20	1·17	2·08
Coloburiscus humeralis	0·25	—	0·49	—	—	—	—
Nesameletus ornatus	—	—	—	—	—	—	0·04
Pycnocentrodes sp.	0·06	0·14	0·98	0·28	0·20	0·01	—
Olinga feredayi	0·32	0·14	0·98	0·21	—	0·07	—
Hydropsyche colonica	0·12	0·21	5·15	0·35	—	0·02	0·04
Polyplectropus puerilis	0·06	—	0·12	—	—	0·01	0·04
Rhyacophilidae	0·92	0·14	2·57	0·70	0·01	0·02	0·20
Adults	0·76	0·07	1·23	0·21	—	—	—
Parnidae							
Larvae	0·18	0·35	2·70	0·57	0·40	—	—
Chironomidae	2·34	2·84	3·68	0·49	0·90	0·06	0·85
Simulidae	0·57	0·21	—	0·14	0·20	0·01	—
Ostracoda	—	0·07	0·24	—	—	—	—
Potamapyrgus antipodum	—	—	0·12	0·35	0·10	0·02	—
Others	0·12	—	1·08	0·14	—	—	—
Total numbers (N)	148	99	376	82	72	120	86
Total vol. of water filtered (V)	15·80	14·10	8·16	14·11	10·10	83·50	26·00
Drift rate no./m³ (N/V)	9·33	7·01	46·30	5·78	7·10	1·41	3·36

* Samples taken after the flood.

† Two samples.

Since there is a correlation between the change in light intensity and appearance of these animals it is possible that there is some critical light intensity which "releases" the increase in activity. If this is true then local weather conditions such as the amount of cloud near the horizon would modify the light intensity and mask the relationship between changes in drift and light intensity.

(ii) *Seasonal Variation in Drift.*—A series of drift samples were taken at irregular intervals between January 3, 1965 and December 2, 1965. A number of samples were taken during the sunset period on each date. All the samples on each date have been combined and drift rates for each species calculated. The results are given in Table 1.

The most numerous animal was *Deleatidium* sp., which appeared in relatively large numbers throughout the period. Two days prior to the samples of February 2, 1965 a flood had occurred in the river. Samples on this date showed a substantial increase in drift rate for most species. Chironomids which were abundant prior to the flood were much less common in later samples. Generally, lowest drift rates for each species were recorded during the winter, and many were absent from samples at this time.

(iii) *Composition of Drift in Relation to the Bottom Fauna.*—In Table 2 a comparison is made between drift samples taken over a period of 24 hr and bottom

TABLE 2

RELATIONSHIP BETWEEN DRIFT AND BOTTOM FAUNA

	Station 1 3.i.65		Station 2 29.xii.64	
	% Bottom Fauna	% Drift	% Bottom Fauna	% Drift
Oligochaetes	0·8	3·2	8·0	11·1
Deleatidium sp.	25·1	27·3	20·8	4·6
Coloburiscus humeralis	0·9	1·8	0·9	0·9
Pycnocentrodes sp.	5·9	2·4	8·4	2·8
Oxyethira albiceps	0·1	0·6	0·3	20·3
Olinga feredayi	5·2	2·2	4·1	—
Hydropsyche colonica	5·9	1·0	0·1	1·4
Rhyacophilidae	2·1	6·0	0·6	3·2
Helicopsyche iltona	—	—	1·5	—
Adults	1·6	9·4	—	0·4
Parnidae				
Larvae	24·0	4·4	0·9	1·4
Chironomidae	22·2	33·7	28·3	38·2
Austrosimulium sp.	0·4	6·4	0·9	9·7
Ostracoda	—	—	—	0·9
Potamapyrgus antipodum	4·7	0·2	20·8	2·8
Planorbis corunna	—	—	—	1·8
Others	1·1	1·4	4·0	1·5
Totals	100·0	100·0	100·0	100·0

fauna samples taken at the same time. Most animals listed in Table 2 occur in the drift in proportion to their occurrence in the bottom fauna, but there are some notable exceptions. It seems that occurrence in the drift is initially determined by the numbers of each species present, and that exceptions to this can be accounted for by considering the behavioural differences which are most important, and also mechanical influences such as the occurrence of lumps of algae detached from the substrate and which contain variable numbers of animals.

The consistently higher proportional occurrence in the drift than in the bottom fauna of the rhyacophilid larvae is the result of their leaving the gravel during the hours of darkness. The free-swimming Parnidae adults were also more frequent in the drift but their larvae which are normally found well below the surface layer of gravel occurred less frequently in the drift. The frequent occurrence of *Austrosimulium* sp. is probably attributable to the particular behaviour which it shows. Zahar (1951) has described how Simulidae larvae move around on the stones using the suckers at the anterior and posterior end, and also how they can be carried downstream while attached to a thread of silk which has been anchored onto a stone. As a result of this behaviour more frequent occurrence in the drift than in the bottom fauna would be expected.

Lumps of algae detached from the substrate contain mainly Chironomidae larvae and small oligochaetes embedded within the mass. Since the algae were the major source of these animals their more frequent occurrence in the drift may be attributed to the effects of the current.

(iv) *The Effects of a Flood on the Fauna of the River*.—On January 31, 1965 heavy rain caused the river level to rise substantially, the volume of flow being increased by at least 5–6 times its previous value. The velocity of the water in mid-stream at Station 1 was approximately 4–6 m/sec, and the water was highly discoloured. The river did

TABLE 3

THE EFFECT OF THE FLOOD ON THE BOTTOM FAUNA AT STATION 1

Numbers per m^2

	Pre-Flood 19.i.65	Post-Flood 11.ii.65*	Post-Flood 28.ii.65†
Oligochaetes	80	16	79
Deleatidium sp.	1808	2152	3340
Coloburiscus humeralis	136	—	12
Parnidae	792	336	1252
Austrosimulium sp.	48	690	624
Chironomidae	3088	121	152
Pycnocentrodes sp.	288	121	184
Olinga feredayi	648	296	284
Hudsonema hudsoni	46	40	36
Oxyethira albiceps	8	—	4
Hydropsyche colonica	860	392	240
Rhyacophilidae	216	24	32
Potamapyrgus antipodum	136	280	272
Others	40	56	116
Total	8194	4724	6627

* Mean of two Surber samples.

† Mean of four Surber samples.

not exceed its banks at any point. Large trunks of dead willow trees were carried away and overhanging banks were eroded.

The effects on the bottom fauna may be estimated from the figures given in Table 3. Most species showed a reduction in numbers but some, *Deleatidium* sp., *Austrosimulium* sp., and *P. antipodum* showed an increase. On January 19, 1965 (prior to the flood), the mean density was 8194 per m^2, on February 11 (11 days after the flood) it was 4724 per m^2, and 18 days later it was 6627 m^2. From the initial halving of the density the bottom fauna had built up to approximately three-quarters of the original density in 18 days. Whereas the chironomids had initially been the most abundant animals, *Deleatidium* sp. became by far the most abundant by the last sampling date.

Drift samples were taken before and after the flood. On each sample date four half-hour samples were taken during the sunset period 7.30–11.00 p.m. Changes in the amount of drift during this period are shown in Figure 5. All the

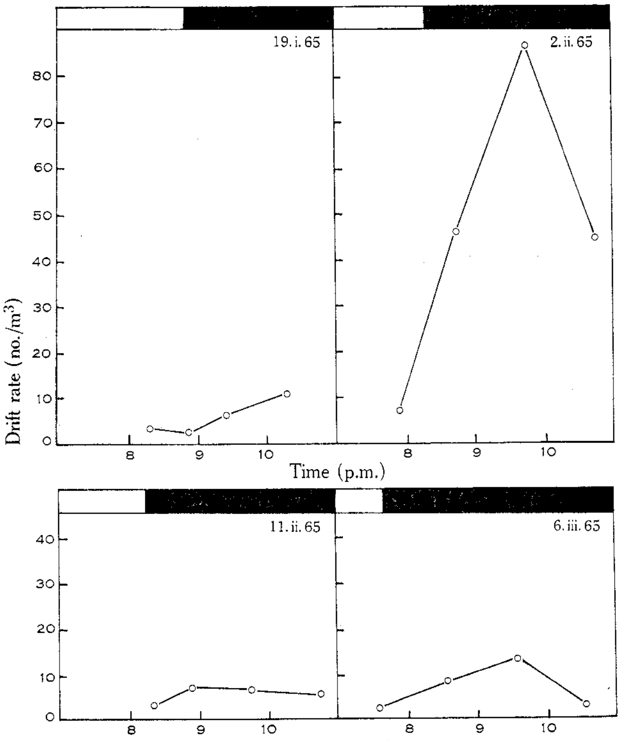


Fig. 5.—The effect of the flood on change in drift rates during the sunset period before and after the flood. Light region of the bar at the top of each graph, daylight; dark region, darkness.

animals in each set of four samples have been added together and the drift rate for each species calculated. These results are presented in Table 1. After the flood most species showed an increased drift rate which is in keeping with the assumption that most of them were not lost from the system. This large increase may represent recolonization after disturbance by the flood. Large increases in post-flood drift rate were recorded for *Deleatidium* sp., *H. colonica*, and Parnidae larvae. While the latter pair showed a decrease in the bottom fauna, *Deleatidium* sp. showed an increase on pre-flood values (Table 3). Two other species showed an increase in bottom fauna density: *Austrosimulium* sp. and *P. antipodum*. The increase of the snail (*P. antipodum*) is inexplicable since, as the flood had disturbed the substrate, it would have been expected that this species would show a reduction. Since both these species adhere to the stones with a sucker-like action, it may be that they managed to adhere to stones below the surface during the flood.

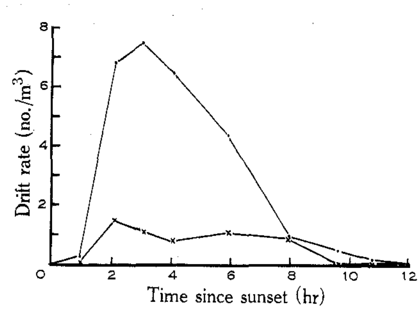
In addition, one sample was taken during the flood at the river's edge, and the drift rates for the recorded species were: oligochaetes 11·4, *H. hudsoni* 0·3, *O. albiceps* 0·3, Chironomidae larvae 5·2, and Parnidae larvae 0·7 with a total of 17·9 organisms per m^3. Notable for their absence are *Deleatidium* sp., Rhyacophilidae, and most of the cased caddisfly larvae. Their absence suggests that they may have taken evasive action, sheltering lower in the substrate, or have been concentrated in less turbulent parts of the river. The oligochaetes and Chironomidae larvae (which made up 92% of the during-flood drift sample) could not have taken such action. Further evidence of this is the marked reduction in bottom fauna density shown by these two species.

IV. Discussion

The appearance in the drift of Ephemeroptera nymphs and Rhyacophilidae larvae mainly during the hours of darkness suggests that it is a consequence of a diurnal rhythm in their activity. No other species showed such a pattern of occurrence. It is probably not safe to assume that the latter do not have a diurnal activity pattern since such a pattern could exist without it being reflected in the drift.

A possible function of the greater activity at night is obtaining food. The animals seem to move out onto the surface of the substrate, where for herbivores there is a greater concentration of algae growing. If obtaining algal food is a result of this activity, then samples of herbivore stomachs taken at night should contain larger quantities of algal material than those taken during the day. Chapman and Demory

Fig. 6.—Co-occurrence in the drift after sunset of *Deleatidium* sp. (upper) and Rhyacophilidae larvae (four species) (lower) at station 1 on 2.i.65. Time of sunset 1945 hr.



(1963) found that stomachs from a sample of *Paraleptophlebia* taken at night contained far more algae than those taken during the day. Stomachs taken from nymphs caught during the daytime contained mainly detritus. Samples of other members of the fauna taken at midday and midnight did not appear to show a similar relationship. As a result of the herbivorous nymphs moving out onto the surface they would be more accessible to predators. Carnivorous Rhyacophilidae larvae were observed to feed on nymphs of the mayfly *Deleatidium* sp., and they showed a very similar pattern of activity as recorded in the drift samples (Fig. 6).

It seems necessary to postulate a possible mechanism by which the change in light intensity at sunset, which produces greater activity, could operate to produce higher drift rates at night. The following mechanism is postulated for the free-swimming mayfly species and Rhyacophilidae. If large numbers of herbivores were moving over the surface of the substrate, then physical contact between individuals may result in some swimming up into the water. The response envisaged may be the same as that observed with animals kept in the laboratory. When nymphs are irritated by touching them with a seeker, or when physical contact between individuals occurs, they often swim upwards from the bottom and then settle down in a different area of the dish. Similar observations apply to Rhyacophilid larvae, and there is also the possibility of interaction with *Deleatidium* sp. nymphs which can form their prey. These movements would result in the appearance of at least some of the animals in the drift. This implies that density may have an indirect effect on the composition of the drift since physical interference would be proportional to numbers of animals present. This type of interaction would be included in the second meaning of competition, of Birch (1957), i.e. interference when there is no shortage of a resource. It was observed that after the flood extremely high drift rates for *Deleatidium* sp. occurred during the sunset period. While this occurrence can be attributed to interaction in response to change in light intensity, it seems that the disturbance of the substrate provided an additional stimulus which resulted in far more animals appearing in the drift.

Unfortunately little idea of the effect of the flood on the distribution of the bottom fauna could be obtained, since this had not been adequately mapped prior to the flood. It would be expected that the flood would result in destruction of longtitudinal distribution of most species. There seem to be very few reports in the literature on the effect of floods on the distribution of different species.

V. Acknowledgments

I wish to acknowledge the help of Dr D. Scott with all aspects of this work and his continued interest in its progress. I also wish to thank Mr A. G. McFarlane for identifying the Trichoptera larvae and Mr J. McLean for checking the identifications of the Ephemeroptera larvae.

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