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Macroinvertebrate drift in the middle course of the River Dunajec (Southern Poland)

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Abstract — The diel activity of macroinvertebrate drift in the middle course of the River Dunajec in certain months in 1980 and 1981 was investigated. A predominance of nocturnal activity in the investigated taxonomic groups (*Ephemeroptera, Plecoptera, Trichoptera*, and *Simuliidae*) was established. A similarity in specific composition of drift and benthos (P = 78%), differences in the temporal and spatial distribution of drift in the cross-section of the riverbed, a lack of correlation between drift and benthos density and of any significant influence of moonlight on the drifting of *Baetus fuscatus* (L.) were found.

Key words: rivers, macroinvertebrate drift, diel activity, drift-benthos density relationship.

1. Introduction

The pioneer researcher of the 24 hours changes in drift composition and intensity was Müller (1954). He investigated streams in northern Sweden and distinguished in their drifting macrofauna the so-called organic drift consisting mainly of insect larvae. Later on other detailed investigations on this subject were carried out by Waters (1962), Dimond (1967), Elliott (1967), Ulfstrand (1968), Bournard and Thibault (1973), Zelinka (1976), and others. Currently, many authors are investigating the phenomenon of macroinvertebrate drift in the broad aspect of hydrographic, hydrochemical, and biocenotic conditions (e.g. Hemsworth, Brooker 1981) and also from the point of view of the behaviour and biology of aquatic animal species (Corkum 1978).

In Poland drift (drifting fauna) was investigated in the River Vistula by Tarwid, Fabiszewska and Szczepańska (1954), in the River Krutynia in the Mazurian district by Szczepański (1958), and in the River Bajerka in Cieszyn Silesia by Sowa (1959). These investigations included a quantitative and qualitative evaluation and also the seasonal variability of drift. There have been no detailed investigations so far in Poland concerning the day and night rhytmics of the drifting of aquatic invertebrates. Furthermore, mountain rivers have not been taken into account.

The main purpose of the present work was to investigate the composition and density changes of macroinvertebrate drift in time and space in a mountain river. The investigation was carried out in the middle course of the River Dunajec.

2. Study area

The springs of the Dunajec river are in the West Tatra mountains at an altitude of 1650 m. The river flows through several physiographically different areas: the Tatra mountains, the Nowy Targ valley, the Pieniny mountains, the Sącz Beskids, and the Nowy Sącz valley. The length of the River Dunajec is 251 km, the catchment area 6798 km^2, the total gradient being 1450 m and the mean unitary gradient 5.8‰. July is the warmest month and January the coldest in the basin area, the average annual water temperature is low, i.e. 5—6°C. River pollution is relatively low and the quantity of nutrients increases only below the larger towns and settlement areas such as Nowy Sącz and Nowy Targ (Bombówna 1975).

One station in the Sącz Beskids near Kadcza was chosen for the drift investigation; it lies at the 128th km of the river course at about 340 m alt. in the section with a unitary gradient of 1.6‰. The river banks are not forested here and the riverbed is unregulated. The station is well exposed to the sun throughout the whole year. The river bottom is formed of large-grain gravel and large stones 5—35 cm in diameter. The riverbed at the station is 25 m wide, 0—2 m deep, while the velocity of flow measured near the bank is 0.5 m s^{-1} and in the current about 1.1 m s^{-1}.

3. Methods

The drift was caught by means of a 30 μm mesh net fixed on a square frame with sides of 14 cm, the shape of the net suggesting a cone 94 cm high. The frame with the net was placed on two metal bars with a scale. The frame could be moved along the bars until the proper depth in the river was gained. 3 layers of water were investigated in the river cross-section:

a) near the bank — the water layer from the bottom to the surface 114 cm high, 3 m distant from land

b) in the current — the water layer 28—42 cm from the water surface 10—15 m distant from land

c) in the current — the surface water layer 0—14 cm, 10—15 m distant from land.

The time of exposing the net in the water depended on the amount of suspension carried by the river and ranged from 3 to 5 minutes. Samples were taken at intervals of 1 or 2 hours throughout the 24 hours or only from dusk to dawn. The material caught was preserved in 4% formalin solution. Animal samples were selected and determined in the laboratory using a loupe and a microscope.

Each quantity of the carried animals was converted into a water volume unit taking into consideration the velocity of drift flow (density $n\ m^{-3}$).

For comparison, macrobenthos was taken from the bottom 50 m above the place where the drift was caught. Samples from the river bottom were taken by a quantitative method using a standard sampler from a projective surface of about 7 dm^2. Application of this method was difficult because of the considerable structural diversity of the bed. Benthos was collected from the banks and the river current in 3—5 samples. The bottom macrofauna was preserved and investigated similarly as the drift. Benthos density was converted into 1 m^2 surface (benthos density = $n\ m^2$). Drift and benthos samples were collected in September 1980 and in March (without benthos), April, June, and July 1981. The time of sampling depended on the water level in the river. Besides, water temperature and low velocity were measured at the banks and in the current (colour method).

To illustrate the relation between the drift number and benthos number D_B coefficient was accepted, this being calculated on the basis of the equation:

$$D_B = d\ b^{-1}$$

d standing for drift density ($n\ 100^{-1}\ m^{-3}$), and b for benthos density ($n\ m^{-2}$). Drift density (d) is the average value for 24 hours measured once in each month of investigation. Similarity in qualitative composition of drift and benthos was calculated from the percentage coefficient according to Jaccard:

$$P = 100c\ (a + b + c)^{-1}$$

in which a stands for the sum of species occurring in the drift, b for the sum of species occurring in the benthos, and c for the sum of species common to drift and benthos.

4. Results

4.1. Drift composition

Most numerous in the drift were *Diptera*, *Ephemeroptera*, *Plecoptera*, and *Trichoptera*. Representatives of *Hirudinea*, *Oligochaeta*, *Amphipoda*, and *Coleoptera* constituted an insignificant percentage of the drifting fauna and were not taken into account.

In September 1980 and in spring 1981 *Chironomidae* larvae dominated. In summer the number of *Chironomidae* decreased in favour of *Ephemeroptera*, while the remaining groups of macrofauna constituted a small percentage of the drift (fig. 1). The dominating mayflies were *Baetis rhodani* (60% — September, 41% — March), *B. fuscatus* (88.4% — June, 94% — July), *B. lutheri* (26.5% — April), and *Rhithrogena semicolorata* (26.5% — April, 70% — May). Among stoneflies most numerous in the months in investigation were *Leuctra* sp. (September, June, July) and *Protonemura* sp. (March, May). Caddisflies were not so numerous, the dominating species being *Hydropsyche pellucidula* (90% — March) and

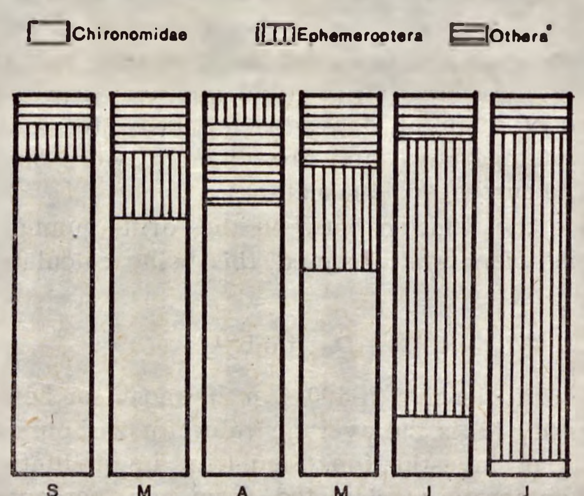

Fig. 1. Percentage share in drift of more important taxonomic groups. * *Hydrozoa*; *Plecoptera*; *Trichoptera*; *Simuliidae*

Table I. Percentage share in the drift of species within the three main groups of aquatic insects

Species	Years (months)					
	1980	1981				
	Sept.	March	April	May	June	July
Ephemeroptera						
Baetis fuscatus (L.)	-	-	-	-	88.4	94.0
- lutheri Müll.-Lieb.	-	20.0	26.5	5.4	6.6	2.5
- muticus (L.)	-	4.0	5.9	1.0	0.1	0.05
- rhodani (Pict.)	60.0	41.0	11.7	22.6	1.5	0.4
- vardarensis Ikon.	-	4.0	-	1.0	0.9	0.1
Baetis sp. juv.	-	1.0	17.7	-	0.5	1.1
Rhithrogena semicolorata (Curt.)	40.0	30.0	26.5	70.0	0.7	0.65
Ecdyonurus dispar (Curt.)	-	-	-	-	0.5	1.0
Oligoneuriella rhenana (Imh.)	-	-	11.7	-	-	-
Ephemerella ignita (Poda)	-	-	-	-	0.8	0.2
- krieghoffi Ulm.	-	-	-	1.0	-	-
Plecoptera						
Protonemura sp.	-	40.0	28.5	48.5	4.5	11.0
Amphinemura sulcicollis (Steph.)	-	8.0	-	6.1	-	-
Nemoura sp.	-	16.0	-	6.1	-	-
Leuctra sp.	100	16.0	71.5	36.3	95.5	89.0
Isoperla grammatica (Poda)	-	20.0	-	3.0	-	-
Trichoptera						
Rhyacophila nubila (Zett.)	-	-	50.0	-	70.0	9.0
Psychomyia pusilla (Fabr.)	33.3	10.0	-	-	-	-
Hydropsyche pellucidula (Curt.)	66.7	90.0	50.0	100	30.0	91.0

Rhycophila nubila (70% — June). Other macrofauna species appeared irregularly in the drift (Table I).

4.2. Spatial distribution of the drift

It was established that the drift density decreased 2—4 times in the direction from the bank towards the middle of the river current but the differences were small within 1 water column taken from the current (between the surface and full water layers). This gradient of drift density in the river cross-section was the same for all invertebrate groups except *Chironomidae* (September 1980, April 1981) and *Plecoptera* larvae (September 1981), which were more numerous in the current (Table II).

4.3. Seasonal and diel changes in drift density

With regard to seasonal numerical changes in the drifting animals it was found that the total drift density increased gradually during successive months from $1.6 \cdot 10^3$ in Sepember to $68.1 \cdot 10^3$ n 100^{-1} m^{-3} in July 1981.

Considerable variations in drift density were also observed during the 24 hours. Two types of drift behaviour were established (on the basis of changes in numbers and drifting period of organisms) i.e. aperiodic

Table II. Percentage share of the more important taxonomic groups in the drift in the river cross-profile (estimated on the basis of average diel drift density ($n \cdot 100^{-1} m^{-3}$). The highest density from three investigated layers was accepted in the given group as 100 %. WS – the layer of water strained near the bank; DR – water layer from the current 28–24 cm deep; SR – surface water layer from the current

Months		Major taxonomic groups	Environment		
			WS	DR	SR
1980	September	Ephemeroptera	100	64	13
		Plecoptera	0	100	0
		Trichoptera	100	0	0
		Chironomidae	67	77	100
		Simuliidae	100	55	42
1981	March	Ephemeroptera	100	50	57
		Plecoptera	100	18	16
		Trichoptera	100	36	24
		Chironomidae	100	48	53
		Simuliidae	100	51	65
	April	Ephemeroptera	100	30	30
		Plecoptera	100	45	45
		Trichoptera	100	21	21
		Chironomidae	94	100	90
		Simuliidae	100	63	99
	May	Ephemeroptera	100	28	-
		Plecoptera	100	94	-
		Trichoptera	100	55	-
		Chironomidae	100	37	-
		Simuliidae	100	44	-

and periodic. *Chironomidae* drifted aperiodically since in September 1980 there occurred several numerical maxima of various distribution in the 24 hours. In March 1981 the main maximum occurred in the afternoon but in the following months at night. The remaining taxonomic groups drifted periodically, that is, in all months mainly at night (fig. 2). In *Simuliidae* the main numerical maxima occurred at various times of the night in particular months. *Ephemeroptera* gradually increased their share in the drift after dusk, the density maximum shifting in the given month according to the duration of darkness. *Plecoptera,* similarly as mayflies, drifted mainly at night but their drifting maxima were shifted to the second part of the night. *Trichoptera* occurred in the drift at various times of the night but were less numerous than the other groups. *Hydrozoa* (*Hydra* sp.) were caught only in June and July. A distinct night drifting maximum was observed in this group in June.

4.4. Night drifting of *Ephemeroptera* and the phases of the moon on the example of *Baetis fuscatus* (L.)

The effect of moonlight on the night drifting of *Baetis fuscatus* was investigated in June and July. In June the moon was in the third quarter

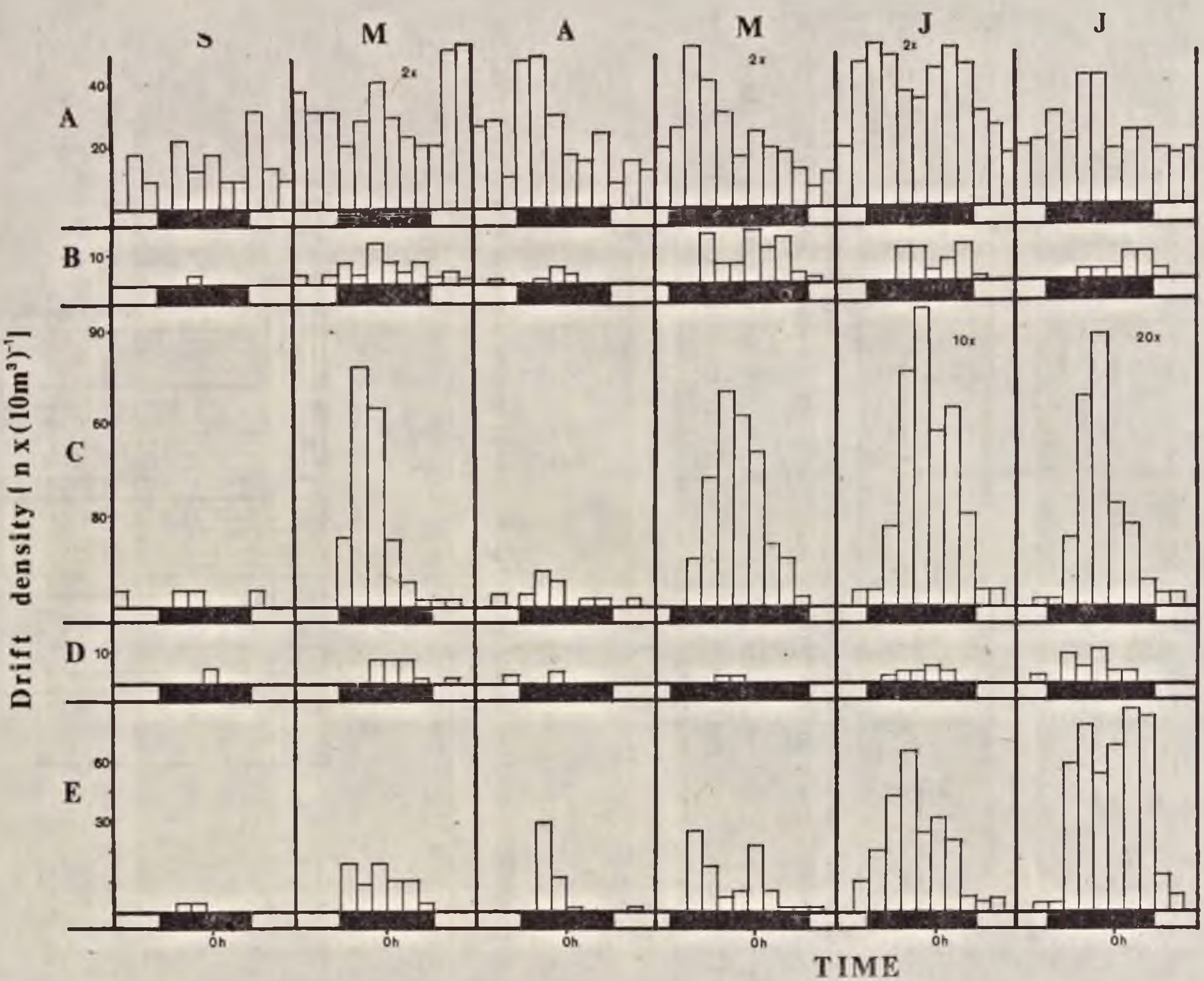

Fig. 2. Diel drift density changes from some macroinvertebrate groups: A — *Chironomidae*; B — *Plecoptera*; C — *Ephemeroptera*; D — *Trichoptera*; E — *Simuliidae*. Values of drift density should be appropriately multiplied x times. All results, except for *Plecoptera* in September 1980, come from the water layer near the bank

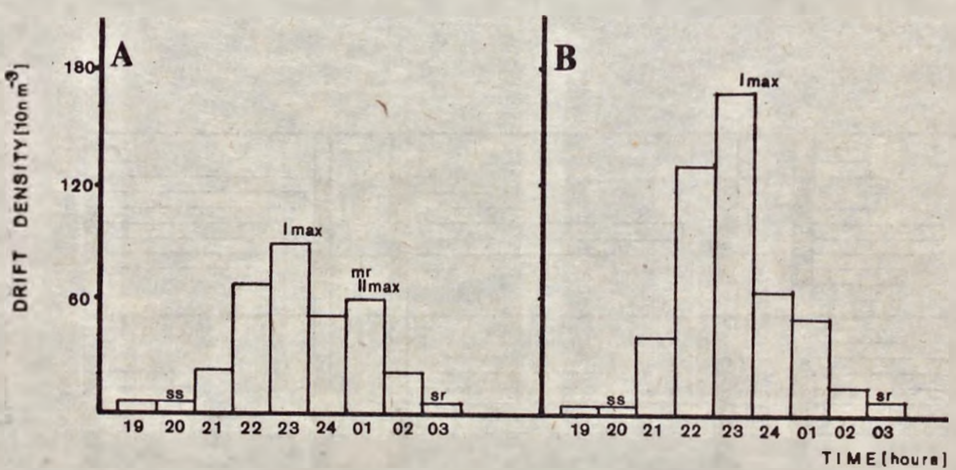

Fig. 3. Comparison of *Baetis fuscatus* (L.) night drifting: A — in June; B — in July; max — maximum density; ss — sunset; sr — sunrise; mr — moonrise

(moonrise at 1.00), while in July there was complete darkness because of the moon. This maximum drifting of mayflies occurred at the same time in the two months, though after moonrise in June, besides the main maximum, there was an additional less significant numerical maximum (fig. 3).

4.5. Benthos composition and number

Proportionally the most numerous group in the benthos were *Chironomidae* (September 1980 and April, May, June 1981). *Ephemeroptera* dominated in July 1981. No *Plecoptera* were noted in September 1980,

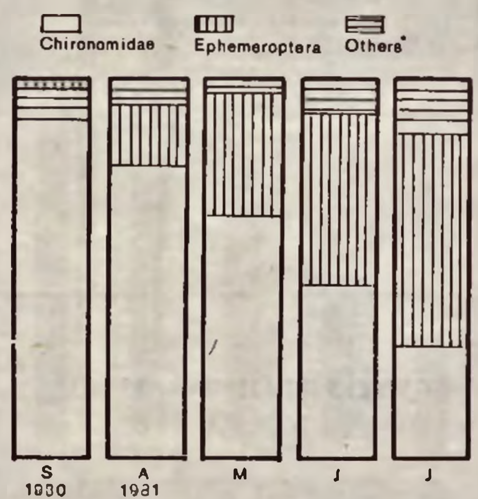

Fig. 4. Percentage share in benthos of the more important taxonomic groups. * *Hydrozoa; Plecoptera; Trichoptera; Simuliidae*

Table III. Percentage composition of benthos species of three selected insect orders

Species	Years				
	1980	1981			
	Sept.	April	May	June	July
Ephemeroptera					
Baetis fuscatus (L.)	69.6	-	-	80.9	85.2
- lutheri Müll.-Lieb.	-	1.8	0.8	1.1	3.2
- muticus (L.)	-	4.7	2.5	-	-
- rhodani (Pict.)	-	11.6	9.2	0.06	0.4
- vardarensis Ikon.	-	-	-	0.12	-
Rhithrogena semicolorata (Curt.)	-	66.4	85.0	0.25	-
Ecdyonurus dispar (Curt.)	7.6	9.6	2.5	8.3	4.8
Heptagenia sulphurea Müll.	7.6	0.4	-	0.06	-
Oligoneuriella rhenana (Imh.)	7.6	2.5	-	1.0	0.6
Ephemerella ignita (Poda)	7.6	-	-	7.8	4.4
- krieghoffi Ulm.	-	3.0	-	-	-
Caenis macrura Steph.	-	-	-	0.15	1.4
Habroleptodes modesta Hag.	-	-	-	0.06	-
Plecoptera					
Protonemura sp.	-	7.0	6.6	-	-
Amphinemura sulcicollis (Steph.)	-	2.8	-	-	-
Nemoura sp.	-	1.4	-	-	-
Leuctra sp.	-	80.4	60.0	100	100
Isoperla grammatica (Poda)	-	8.4	33.4	-	-
Trichoptera					
Rhyacophila nubila (Zett.)	2.4	13.2	19.1	6.9	4.0
Psychomyia pusilla (Fabr.)	-	-	-	2.4	-
Hydropsyche pellucidula (Curt.)	58.6	86.8	80.1	76.8	96.0
Oligoplectrum maculatum Fourc.	2.4	-	-	2.3	-
Brachycentrus subnubilus Curt.	36.6	-	-	11.6	-

their maximum density being reached in April 1981. *Trichoptera* were most numerous in the benthos in September. Besides, *Simuliidae* and *Hydrozoa* (fig. 4) were sporadically present in the bottom fauna. The list of benthos species is given in Table III.

The average density of bottom macrofauna taken near the banks ranged from $3.5 \cdot 10^3$ in September 1980 to $12.4 \cdot 10^3$ n m^{-2} in June 1981.

4.6. Comparison of drift and benthos density

The presence of aquatic macroinvertebrates in the drift results from their passive or active detachment from the riverbed. The decision was therefore made to investigate whether there is a dependence between drift and benthos density. To demonstrate this dependence the D_B coefficient was accepted (section 3). In the successive months of investigation as increase in density of the drifting macrofauna in relation to that at the bottom was observed, the value of coefficient D_B rising in this time (for the sum of all taxonomic groups). However, for the particular aquatic invertebrate groups this coefficient varied in value. The highest values of coefficient D_B were found in *Chironomidae* and *Plecoptera* in May, In *Simuliidae* in April, in *Ephemeroptera* and *Trichoptera* in July, and in *Hydrozoa* in June (Table IV).

Table IV. Values of D_B coefficients for the selected taxonomic groups and for the total number of organisms

Months	Hydrozoa	Ephemeroptera	Plecoptera	Trichoptera	Chironomidae	Simuliidae	Total number
September 1980	-	0.16	-	0.01	0.04	-	0.05
April 1981	-	0.04	0.05	0.11	0.06	3.32	0.07
May 1981	-	0.16	0.77	0.10	0.16	-	0.19
June 1981	1.03	0.73	0.23	0.16	0.15	0.68	0.45
July 1981	0.05	1.36	0.15	0.22	0.12	2.14	0.90

Non-significant correlations ($P > 0.05$) were found between drift and benthos density for the more important taxonomic groups, i.e. *Ephemeroptera* ($r = 0.87$), *Chironomidae* ($r = 0.83$), *Simuliidae* ($r = 0.73$), *Trichoptera* ($r = 0.39$), and *Plecoptera* ($r = 0.27$).

The Jaccard percentage coefficient suggests a great similarity between drift and benthos, but only regarding the specific composition of these two ecological formations ($P = 78\%$).

5. Discussion

Diptera and particularly *Chironomidae*, whose share in September 1980 was 83.7% (fig. 1), dominated in the drift of the middle course of the Dunajec. A slightly smaller percentage of *Diptera* in the macrofauna drifting in the mountain river Couze Pavin (Massif Central) was given by Neveu and Echaubard (1975). Hemsworth and Brooker (1981), at one of the stations of the upper basin of the River Wye also found a considerable share of this group in the drifting macrofauna (69.1%). Armitage (1977) noted the numerous occurrence of *Chironomidae* and *Naididae* in the drift and benthos in the upper basin of the regulated River Tees, and compared it with the unregulated small Maize Beck where *Plecoptera* and *Baetidae* dominated. Apart from *Chironomidae* the most numerous group in the River Dunajec were the mayflies *Baetidae* and *Rhithrogena semicolorata*. The number of drifting animals was much smaller (2—4 times) in the current than near the bank, this being connected with the difference in density of bottom microfauna (authors unpublished results). A similar density gradient was observed by Tuša (1967), while earlier Waters (1962) took the view that cross-profiles are significant in numerical estimation of total drift. Seasonal variations in drift density in the Dunajec (summer density of drifting macrofauna was higher than that in spring and autumn) are similar to those in upper basin of the Tees (Armitage 1977). Elliott (1967) showed that the rise in drift density in spring is caused by increased activity of macroinvertebrates. This consists in intensified transformation processes (e.g. indusium), intensified reproduction, feed competition etc. Since Tanaka (1960) described diel changes in drift composition and intensity there have been many works on this subject. They indicate that in most groups of river macrofauna, even in different climatic zones, there is intensified night activity (Bishop 1973, Ulfstrand 1968, Müller 1973, 1974). In the River Dunajec drift density also increased during the night, with the exception of *Chironomidae*, which drifted aperiodically. It might result in this group from the overlapping activity of different species, a view which may be supported by the work of Brooker and Morris (1980), who, forestalling Hemsworth and Brooker's (1981) drift investigation in the River Wye, found 48 *Chironomidae* taxa in the benthos of that river.

The intensified drifting of macrofauna in the River Dunajec in summer months was caused (as reported in Elliott 1969) by the shortened night. Sunshine inhibits the drifting of animals (negative phototaxis) but the effect of moonlight is controversial. Some authors found an inhibiting effect of moonlight on the detachment of organisms from the substratum, but this dependence was not established in the Dunajec (fig. 3). In Elliott and Minhall's opinion (1968) the moon does not affect drift intensity in any way.

The lack of any significant dependence between drift and benthos density established in the present work is in accordance with results obtained by other authors (Elliott 1967, Crisp, Gledhill 1970). However, Hemsworth and Brooker (1981) found significant correlations between drift and benthos, though only for some taxonomic groups, for most species this dependence being non-significant. Corkum's (1978) laboratory investigations showed that the numbers of two *Ephemeroptera* species detaching from the substratum were similar to their initial bottom density. For Dimond (1967) there is a proportional correlation between drift and benthos density, while the appearance of drifting fauna in a river is caused by overproduction of macrofauna and excessive density at the bottom. In the River Dunajec one can only observe a similarity in the quality composition of the two investigated ecological formations.

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6. Polish summary

Unoszenie makrobezkręgowców w środkowym biegu Dunajca (Polska Południowa)

Przedmiotem badań była aktywność dobowa fauny unoszonej (dryftu) w środkowym biegu rzeki Dunajec w niektórych miesiącach roku 1980 i 1981. Określono skład jakościowy i ilościowy dryftu (ryc. 1, tabela I). Stwierdzono przewagę nocnej aktywności u niektórych grup makrofauny (ryc. 2) oraz znaczne różnice w gęstości dryftu w poprzecznym przekroju koryta rzeki (tabela II). Porównano nocne dryfowanie *Baetis fuscatus* w czerwcu i lipcu. Nie wykazano istotnego wpływu światła księżyca na unoszenie tej jętki (ryc. 3).

W celach porównawczych, równolegle z dryftem, badano bentos. Określono jego skład ilościowy i jakościowy (ryc. 4, tabela III). Za pomocą współczynnika D_B (iloraz gęstości dryftu i bentosu) wykazano zwiększanie się unoszenia zwierząt (także ich aktywności) w odniesieniu do bentosu w kolejnych miesiącach (tabela IV). Obliczenie korelacji między gęstościami dryftu i bentosu wykazało brak istotnych zależności ($P > 0{,}05$). Stwierdzono jedynie, że istnieje podobieństwo w składzie jakościowym ($P = 78\%$) tych dwóch grup ekologicznych. Wyniki badań fauny unoszonej pokrywają się w zasadzie z obserwacjami z innych stref klimatycznych.

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