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UTILISATION OF MAYFLIES (INSECTA, EPHEMEROPTERA) FOR DIVISING SOME ROMANIAN RUNNING WATERS INTO ZONES

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La répartition des ephemeroptères dans les sous-systèmes lotiques est corrélée avec la dominance des phénomènes d'érosion, de transport ou d'accumulation.

Les conditions trophiques déterminent la microdistribution des espèces dans les mosaiques de biotopes.

La zonation permet l'etablissement d'un programme de monitorisation et de prognose de la qualitée des eaux.

Any pattern of division can be a response to the necessity of understanding any present state (the ballance of the lotic system) as a basis for prognosing the changes induced by human activity.

Only an integralistic way of thinking can correctly solve this problem. A strictly biological or a strictly geological point of view cannot offer a complete solution, considering that they do not take into account the numerous relations between the elements of the lotic system.

The utilisation of a certain group of organisms for characterizing various areas within the lotic system must be approached in several ways, taking into account criteria defined by means of interrelations. These interrelations reffer to the connections established between different categories of organisms, between organsims and the elements of the geological and hydrological sub-system during the evolution of the system. Some of these criteria could be:

— the distribution in the compartiments of the system;

— the dependence upon certain types of substratum;

— a minimum time (historically speaking) of occurence in the aquatic basin;

— the capacity of responding to the requests is represented, from the geomorphological point of view, by the "Hurst phenomenon" (Ichim et col., 1986; 1989). This phenomenon points out the sharp deviations of the lotic system from a calculated average state;

— the utilisation of trophic resources originating in the system itself.

MATERIAL AND METHOD

By sampling different categories of drainage-systems, my purpose was not only the qualitative and quantitative collecting of benthic groups (especially Ephemeroptera) but also of realising an objective immage of the present communities and of correctly appreciating the trophic state of the aquatic basin and the quality of the water.

The benthos was completely sampled; all samples were (completely) sorted; a card was drawn for each station. By repeatedly sampling the same stations, I attempted to define the mosaic of biotopes.

The samples were collected with a simple dredge, with the sampling net or directly with the pincers from the substratum. In fast waters, I handled the dredge on the substratum, washing it directly in the dredge.

The samples were preserved in 29% formalyne.

Benefitting by the collaboration between the "Grigore Antipa" Natural History Museum and the Institute for Geology and Geophysics in Bucharest, I had the opportunity, when studying the Danube, the Danube Delta and the littoral lakes, to utilise the large bottom sampler and the box-corer fixed on the ship "Stuful".

The sampling was done on several types of biotopes:

— stones and gravels with lithorheophilic fauna;

— sandy, clayey or silt bottoms;

— the vegetation of the banks, washed-up by the water-flow;

— aquatic macrophytes;

— accumulation of coarse debris (wood, leaves);

— accumulations of fine debris (especially in the slow portions of the running waters).

The samples preserved in formalyne were washed through fine sieves and sorted in glass tubs containing 70° alcohol.

The collecting stations (Fig. 1):

a) montane and sub-montane areas

Rodna Mountains — Rodna massif — brooks in the drainage area of the Someşul Mare and Bistriţa Aurie (stations 1—9); Tarcău Mountains — the drainge-areas of the Bistriţa and the Olt (stations 10—15); Buzău Mountains — the drainage-area of the Buzău (stations 16—18); Piatra Mare-Postăvarul massif — brooks Timiş and Sipoaia (stations 19—22); Piatra Craiului massif — drainage-area of the Bîrsa Mare (stations 23—25); Leaota Mountains — the drainage-areas of the Dîmboviţa and the Ialomiţa (stations 26—30); Făgăraş Mountains — the drainage-areas of the Argeş and the Olt (stations 31—52); Bucegi Mountains (station 53); Cozia massif — the drainage-area of the Olt (stations 54—55); Retezat Mountains — Rîul Mare (station 56); Timiş—Cerna passage — the drainage-area of the Timiş (stations 57—68 and 75—85); the sub-montane area of Oltenia —Gilort, Cerna, Blahniţa, Olteţ (stations 69—74); Apuseni Mountains — the drainage-area of the Crişul Pietros (stations 86—89); Oaş—Gutîi Mountains — the drainage-area of the Tur (stations 90—98); Bihor — the Holod River area (stations 99—102) (Figs 2—4).

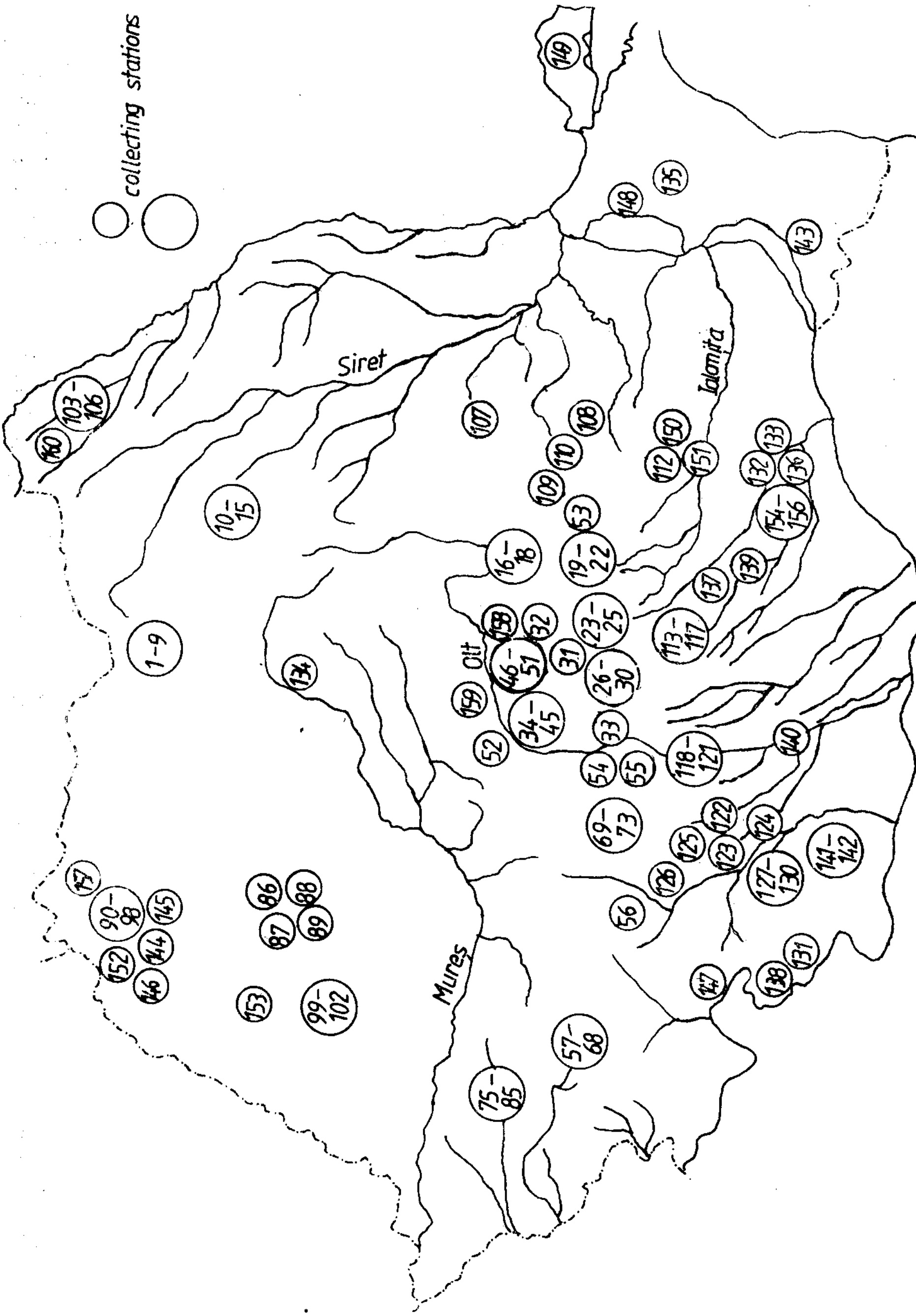


Fig. 1—Map. indicating the the collecting statione.

b) hilly and lowland areas

Jijia—Başeu drainage-area (stations 103—106); the drainage-area of the Siret (stations 107—112); the drainage-area of the Argeş (stations 113—117); the Olt drainage-area (stations 118—121); the Jiu drainage-area (stations 122—131); the Mureş drainage-area (station 134); the „derele“ (rivulets) of Dobrogea (station 135); limnocrene and helocrene springs (stations 136—145); the Danube and the Danube Delta (stations 147—149). The stations do not correspond to a simple collecting place, but to an area with several close places (especially in the case of the Danube and the Danube Delta) (Figs 5—9)

General considerations

It is considered that a fluvial system consists of 3 areas: the 1st area — or the drainage-area — the one where the sediments are produced (the fenomena of erosion prevail); the 2nd area, or the river bed, characterized by the transference the alluvial depozits (phenomena of transportation prevail); the 3rd area — characterized by accumulation, in plains, fans, deltas (the fenomena of depozit prevail) (S c h u m m, 1977).

The physical component (the geological sub-system) is in interconditioning relations with the biological component (the biotic sub-system), both contributing to the building of an „equilibrium profile" of the river. The variations of the physical component depend on the basic level, the tendency of this variations being to realise a dynamic equilibrium between the erosion and the deposit (accumulations) processes. The variations of the biotic component depend on two large categories of agents: external ones (consisting mainly of the physical component) and internal ones (genetic ones: the ones which identifie the limits of tolerance to external agents).

An attempt of demonstrating the way in which organisms influence the non-biotic environment is usefull (with the absolutely necessary mention that this influence is more difficult to observe, considering the complexity of the trophic web and especially the interference of the ecological niches).

This influences is mainly a qualitative one, considering the quantitative domination of the physical agents and it reffers in the first place to the way in which the benthic organisms utilise the energetical resources of the ecosystem. The occurence of the "shredders" (Gammaridae, Trichoptera, Isopoda), determine a gradual "consumption" of the exogenic vegetal matter, preventing a massive establishment of the decayer microflora and providing a considerable amount of fine organic debris (FPOM) which becomes suspensioned (C u m m i n s , 1973). The "digger" organisms (Ephemeroptera species which dig galleries or gamarid amphipods which dig open shelters — fig. 6) or species which build tubs out of sand, small stones or vegetal fragments are the only ones which have a direct mechanical action upon the non-biotic environment.

The evolution of a fluvial system is controled by the relief; the geomorphology is characterized by a "duality of time": short time (or reversible time, during which mechanical phenomena take place) and long time (or ireversible time, during which thermodynamical phenomena take place.)

The question arrises, whether the biological component could be characterized by such a duality. It is known that between the biotope and the biocenosis a feed-back connection is realized. The biotope (as a physical-chemical subsystem) will evolve towards the growth of the entropy and the reducing of the order. The biocenosis (as a biological system, provided with selection mechanisms which generate order) will evolue towards the reducing of entropy, the increasing of information (S t u g r e n, 1982). During "the short time", the biological component responds properly to the solicitations of the physical component (in respect of the present genetic possibilities); during the "long time" selection phenomena take place (or, we better say, the effects of the selection phenomena) by which ecological successions are finally reached.

Anyhow, the interaction of the subsystems must be seen as a necessary relation within the riverine system whose tendancy is the creation of a equilibrium.

An extremely important problem is that of the identification of the benthic communities which are characteristic to the erosion, transportation and accumulation areas: in other words, to distinguish the organisms which can resist to disorganizable mechanisms (erosion, transportation or accumulation ones). In the area where erosion prevails, the organisms created ecological niches especially on the lower side of the rocks and boulders, spaces protected from the impact of the coarse material carried by the water. Here, real microhabitats could be identified in which the main source of food is represented by bioderma. The ripal offers a great variety of conditions, especially to the accumulation of the exogenic vegetal matter (leaves) utilised by shredding organisms (G ă l d e a n, 1989).

In the areas where the transportation prevails, the organisms cannot make niches in the medial part. Here we can speak only of biocenoses of the ripal.

In the areas where accumulation is prevalent the siltic sediments and hydraulic dunes permited the building of the niches of peleophagous and detritivorous organisms.

Benthic communities of the ,,erosion", ,,transportation" or "accumulation" type can be found not only in the rivers originating in hilly areas. The fundamental idea of this approach is that organisms creat ecological niches depending on the way physical-chemical agents reciprocally complete; the delimitation of many areas and subregions is useful but only after they have been inserted in a wider range which considers the interrelation of the entire physical subsystem with the entire biological one.

The subsystem of 1st area (prevalence of the erosion phenomena).

It may be asserted that the organisms adapted to this area had first to solve the problem of the direct physical impact with the material resulting from the erosion (the shelter places are represented by the habitats which can provide protection). The modifications of the body's shape (in a hydrodynamic direction) can be considered as being ulteriour, arising from the conditions imposed by the shelter habitat. Moreover, these adaptations are questionable as long as they are approached in a "classicall" manner.

The dynamics of the benthos of the 1st area is closely related to the rate of erosion. This rate depends on the interactions of the general rainfalls, seasonal or not, the average annual temperature, the difference of altitude, the type of soil and rocks of the hydrographic basin.

The adaptation to the rythm of the erosion is one of the main characteristics of the subsystem's biocenoses. During high water, the main sheltering habitat is represented by the ripal vegetation (as resulting from the qualitative differences between the spring and summer samples).

The talveg of the 1st area displays the highest variety of species in the whole fluvial system.

The correlation between fauna and the substratum (i.e., the strong link between these 2 components) is a function depending on the very system of the adaptation to the rhythm of erosion. Wagner (1984) asserts that the replacing of a heterogenous substratum by an exclusivly sandy one, drastically reduces the numbers of Plecoptera, Ephemeroptera, Coleoptera, Trichoptera and Diptera populations (with one or two exceptions, explainable by the ecological possibilities of the respective species).

Samples collected along the Vida River (Holod) Bihor District, 1986, demonstrated the faunistical poverty of the regulated streams; the existence of stony "rapids" allowed the establishment of a rich fauna (especially larvae of aquatic insects). Considering the low altitude, the water temperature of 18°C and its strong turbidity, a high variety of species would not be expected. The physical substratum seems to be the first characteristic of the ecological niche for rheophilic organisms.

From a strictly biological point of view, the 1st area contains the majority of the rheophilic forms (Table 1) and corresponds to the rithron of Illies and Botoşăneanu (1963).

The subsystem of 2nd area (prevailence of the transportation phenomena).

The increase of liquid and solid flow, the water speed and the prevailing sandy sediments determin a marked faunistical poverty in the middle area. The portions which have also clay sediments on which organic debris can accumulate, are the only ones containing benthic fauna. In the hilly strech of the Tur River (Fig. 5 C) (N—W of Romania) the dredging demonstrated the almost total absence of fauna from the sandy portions and the presence of several species (including the ephemeropters *Ephemerella notata* and *E. mesoleuca)* on the clay boulders. The same can be also noticed on the lower stretch of the Danube (Măcin Arm — Fig. 6).

The 2nd area subsystem interferes with the 3rd one.

The subsystem of the 3rd area is more obvious in the case of the Danube Delta, of the flood plains and of certain tributaries of large rivers in the hilly area.

These tributaries (this is the case of the left tributaries of the Olt River, originating in the Făgăraş Mountains) produce deposits at their confluence, because of the barrier represented by the high speed of the Olt (Figs 5 B; 12). For these tributaries, the erosion area is continued by the accumulation one. However, a transportation area is also present on small sandy portions (sandflats) which display the so-called ripple-mark formations, miniature instable dunes which tend to displace downstream.

The area in which accumulation phenomena prevail must also be considered under other circumstances which can explain its biotic features. The accumulation of sediments (most of which are fine ones) is accompanied by an accumulation of pollutants and of vegetal matter which is decomposed by bacteria, thus reducing the specific diversity.

This aspect is obvious especially in the Danube Delta, which is frequently subject to such "minor" accumulations.

Hence, fauna diminished drastically, especially the phytophylic one, which was extremely rich 10—15 years ago.

In the same time, the reduction and the disappearance of the flood plain caused the drastic reduction in the numbers of benthic populations which trophicaly depend on this compartment.

RESULTS AND DISCUSSIONS

Arguments in favour of the utilization of mayflies as characterizing biological zones of running waters.

The analysis of the above-mentioned criteria justiffies the following considerations:

a) the occurence of Ephemeroptera larvae along the hole stretch of running waters determin their utilization as division-characterizing elements. They are more important than the plecopters (restricted especially to the montaine regions) and even than the trichopters (frequently building agglomerations in different parts of the rivers).

b) Ephemeroptera display a dependence on the substratum, conditioned by the main type of food, among other criteria. Cummins and Lauff (1969), reffering to the macrodistribution of the macrobenthos in running waters, reveal the secondary importance of the substratum for a species of *Caenis* and one of *Ephemera* (of North-America waters). The above-mentioned exemple sustained by the data I obtained on the Vida River (Holod) determined me to consider that for many species of Ephemeroptera, the substratum is at least as important as the trophic resources provided by the ecosystem. This example is completed by another aspect, observed in the same river: the upper reach is delimited by a dense decidous forrest (beech being prevalent) whose branches almost cover the water's surface (at least on certain areas downstream the gorges). On these areas the benthos is totally dominated by Trichoptera (especially rhyachophillids); Ephemeroptera are rather rare but they are getting more numerous within the areas where the forest belt is more distant from the river's banks. I explain this phenomenon as follows: the vegetal matter fallen into the water in great quantities is a suitable food for "shredders" (i.e. caddis larvae) which transform it in a fine organic debris. The accumulation of a great quantity of fine organic debris offers favorable trophic conditions for Ephemeroptera (at least for Caenidae and Baetidae) but the nature of the sediment (coarse gravel and cobble) is a strongly limitating agent (Figs 7; 8).

c) As regards the food, mayflies are considered to be collectors and scrapers (Cummins and Klug, 1979). However, the pattern these authors propose is too general, all examples they give reffering to families.

For example, within Heptageniidae, the larvae of *Epeorus* and *Rhithrogena* are more rheophylic than those of *Ecdyonurus* and *Heptagenia*; they are scrapers, utilizing the food on the hard rocky substratum (the periphyton). *Heptagenia* larvae and some species of *Ecdyonurus* depend on the agglomerations of organic debris which gather by sweeping.

The role of the trophic agent in the evolution of Ephemeroptera deserves consideration; since the adaptation to well-oxygenated waters (hence, also to oligotrophic ones) is initial (Omodeo, Minelli and Baccetti, 1980), it can be asserted that the adaptation to feeding by scraping algae and bacteria on the surface of the stones evolved from it.

The same remark stands for some species of *Ecdyonurus*: the *dispar* group consists of both scrappers and collectors. This statement relies on the fact that the distal end of the terminal article of the maxillary palp bears a field of rigid bristles (in scrapers) or of soft bristles (in collectors) (Găldean, 1989).

In the time-history of the group, the trophic agents acted slowlyer than the physical ones (solved oxygen, temperature, water velocity): against the background of the stabilization of the physical agents (in the periods between two "rapids" of the lotic system) the trophic agent became the main one and directed the evolution of the group towards the exploitation of organic debris. The Ephemeroptera larvae evolved from the primary condition of scrapers feeding on algae and bacteria on the surface of stones to the secondary condition of collecting organic debris accumulated on the surface of soft sediments.

I. *THE DIVISION INTO ZONES OF THE "RÎUL MARE" OF AVRIG*

Rîul Mare of Avrig originates in the glacial lake Avrig, situated on the Eastern side of the Făgăraş Mountains, 2000 m high. As far as its confluence with the Olt, in front of Avrig village, its stretch is characteristic for the rithron (by the classification of Illies and Botoşăneanu, 1963).

On the basis of faunistical analysis I made between 1986 and 1987, I established several areas and subareas:

a) the area situated next to the lake (downstreams) (Fig. 2; 10); river bed with steady rocks partially covered with moss; water velocyty big, temperature of the water: 3–4°C. Fauna poor: Heptageniidae larvulae, especially in the moss, and Plecoptera larvulae. This area can be considered the crenon one.

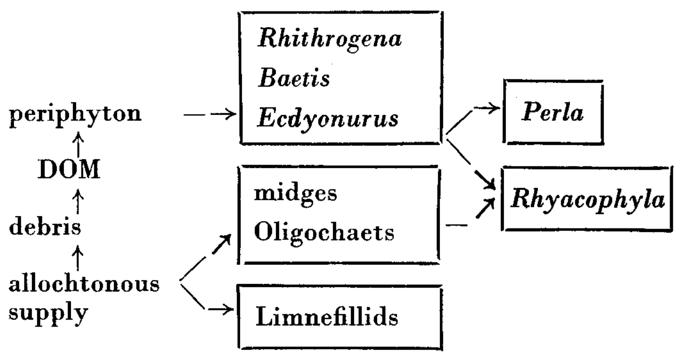
b) about 100 m downstreams, at 1800 m high, the area of the rhitron begins; the slope of the river bed permits the accumulation among stones of small quantities of vegetal organic debris; water temperature: 5–6°C

The faunistical community is dominated by Rhyacophylidae and Lymnephilidae, Trichoptera and by Turbelaria; Ephemeroptera are represented by *Baetis alpinus*, *Rhithrogena semicolorata* and *Ecdyonurus* larvulae (Fig. 2).

c) in the following area (1600 m high) the faunistical diversity increases. All these portions (A, B, C) are situated in the alpine meadows area; the supply of organic debris is almost absent in the area A_1, increases in B and is surprisingly large in C, on the one hand because of the rich herbacean vegetation of the banks and on the other hand because of the sheepfolds situted around.

"C" is the last portion of the stretch situated out of the forest. From the quantitative point of view, I noticed the prevalence of Trichoptera (g. *Rhyacophyla* and *Chaetopteryx)* but also the numerical increase of Ephemeroptera. *Ecdyonurus venosus*, *Rhithrogena semicolorata* (a numerous populations), *Ecdyonurus dispar* and *Baetis alpinus* (a numerous population, too). The controll factors for *B. alpinus* and *R. semicolorata* populations consists of 65% plecopters and 20% trichopters.

Analyses of the intestinal content of *Perla* and *Rhyacophyla* specimens revealed numerous fragments of Ephemeroptera larvae (identified especially by the branchial lamellae and the buccal pieces).



This very concise pattern of the trophic web demonstrate the link represented by Ephemeroptera, which take over energy from the periphyton and transfer it to the secondary consumers.

d) The next portion (between 1400 and 800 m high) is the longest one, the river running through spruce forests than through decidous ones. I delimited 2 sub-areas of this portion (Fig. 11):

d_1) The stretch of the water, running through the spruce forest, is characterized by the presence of the boulders (the slope is rather steep) but the agglomerations of logs of wood, sticks and branches occure frequently permiting the establishment of very rich biocenoses. The communities of these biocenoses include plecopters (more hologhnate, detritivorous ones than sisteloghnate, carnivorous ones), limnephilids (Trichoptera) and mayflies *(Ecdyonurus insignis*, *Heptagenia lateralis* (not many specimens), *Bae-*

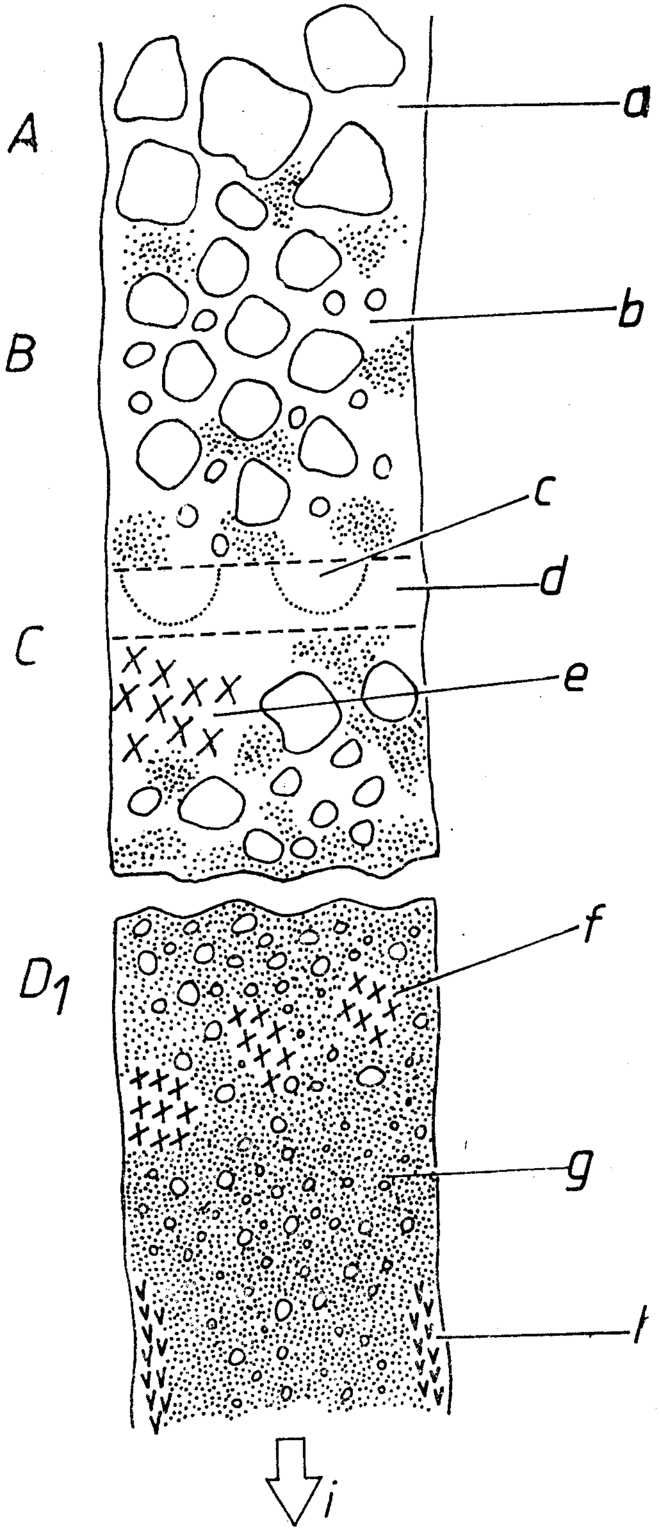


Fig. 10 — The diagram of the mosaic of biotopes from the superior area of the Avrig River, A, B, C, D_1 — main areas: a, the area with *Rhithrogena* and *Ecdyonurus* : b, course boulders and gravel with *Baetis alpinus* and *Rhithrogena semicolorata;* c, the moss area; d, a water fall; e, course vegetal debris with *Ecdyonurus venosus* ; f, leaves accumulations with *Heptagenia lateralis* and *Habroleptoides modesta* ; g, medium-sized gravel and sand with *Ephemerella;* h, vegetation washed-up by the water.

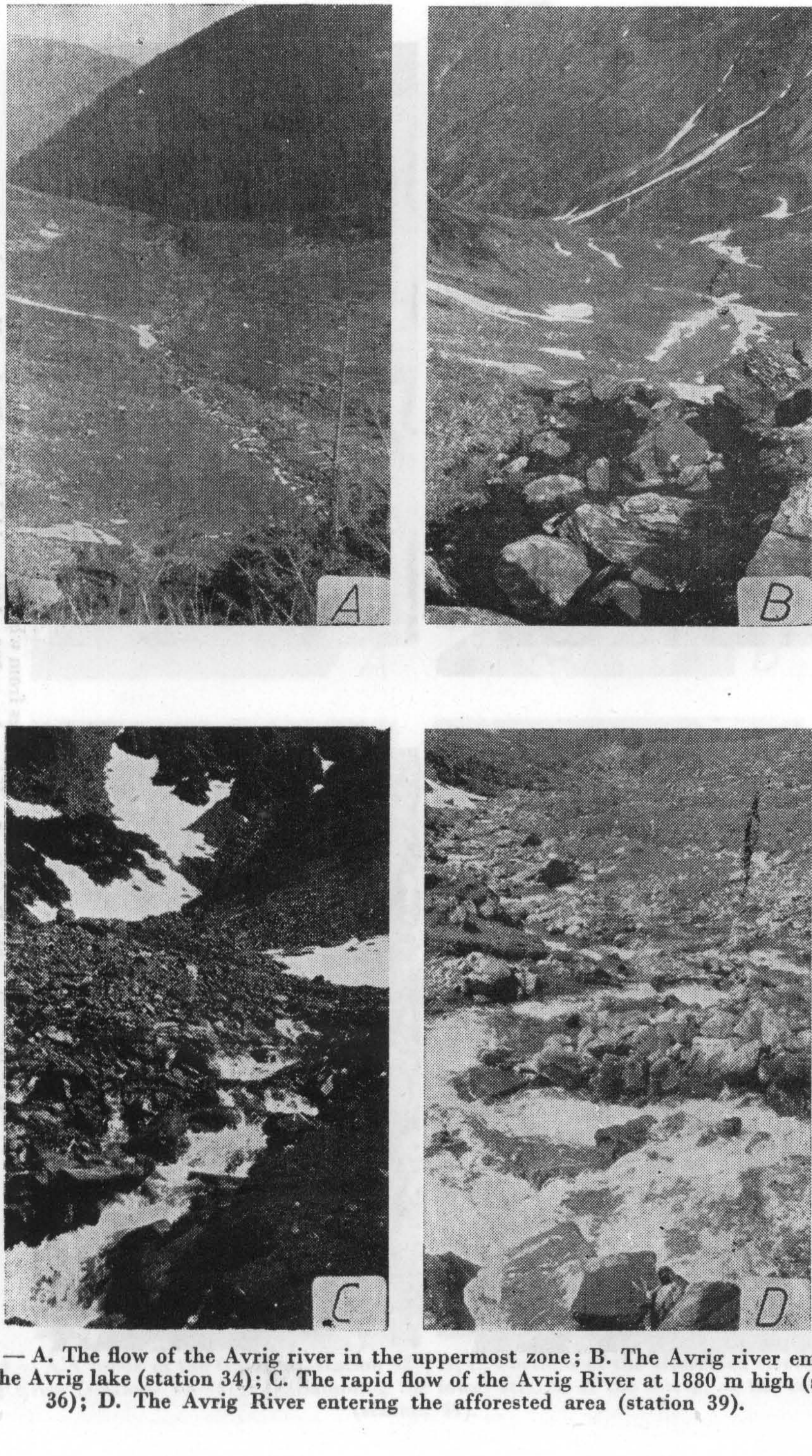


Fig. 2 — A. The flow of the Avrig river in the uppermost zone; B. The Avrig river emerging from the Avrig lake (station 34); C. The rapid flow of the Avrig River at 1880 m high (station 36); D. The Avrig River entering the afforested area (station 39).

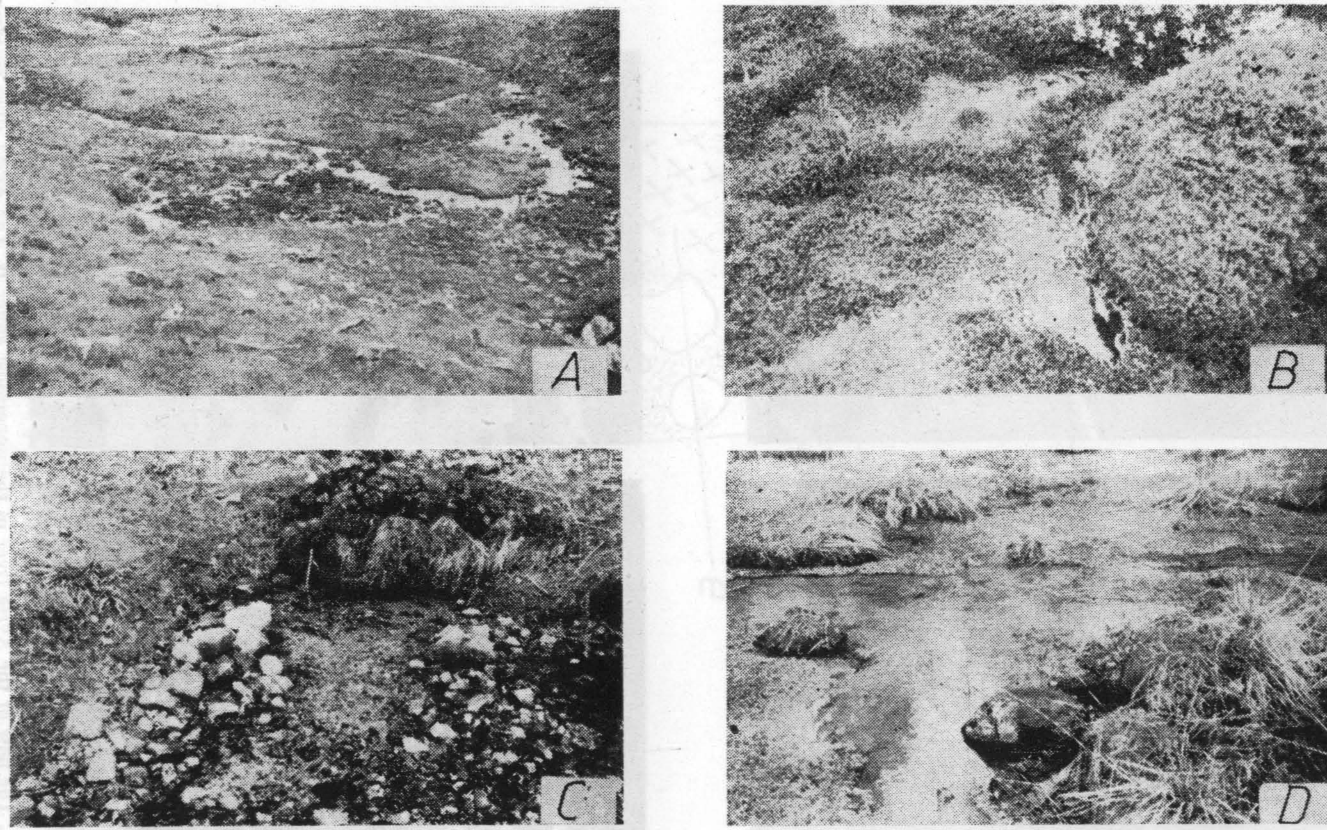


Fig. 3 — A. The complexe of helocrene springs from which the Repedea brook originates (Rodna Massif - station 8); B. C. D. Small brooks at 800—1000 m high in the Făgăraș Mountains.

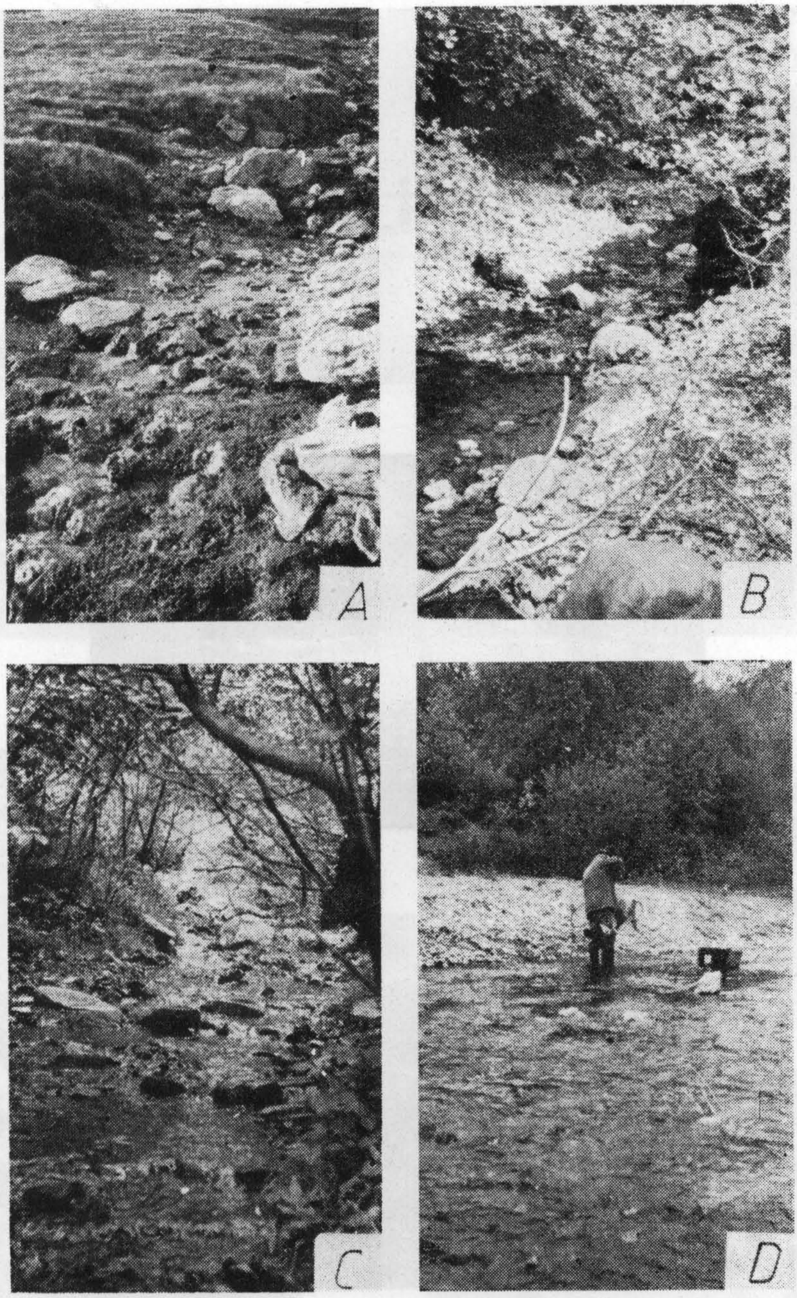


Fig. 4 — A.A brook of the Oaş area (station 92); B, C. Portions of the afforested stretch of the Avrig River (stations 40—41); D. Sampling the lower stretch of the Avrig, at the confluence (station 49).

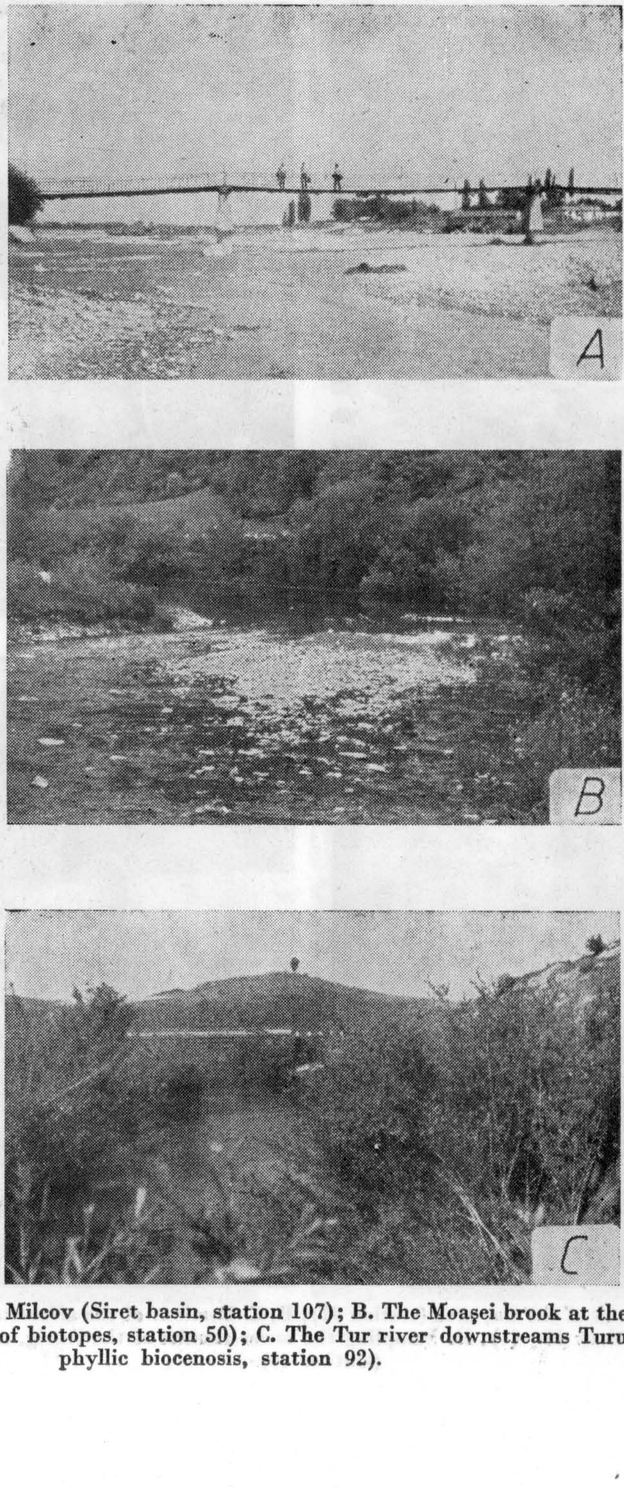


Fig. 5 — A. The Milcov (Siret basin, station 107); B. The Moaşei brook at the confluence with the Olt (mosaic of biotopes, station 50); C. The Tur river downstreams Turulung (argilloreophyllic biocenosis, station 92).

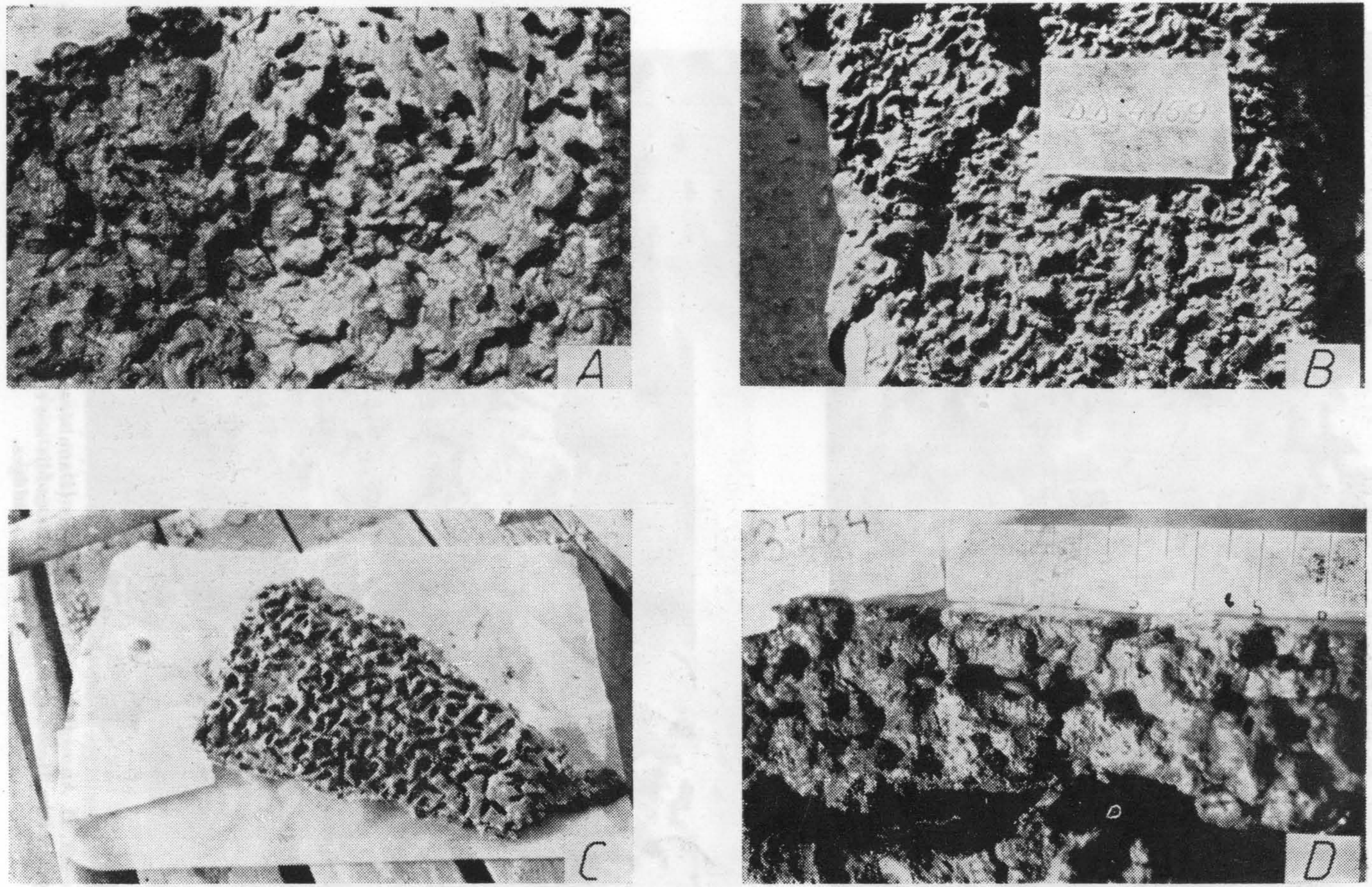


Fig. 6 — A, B, C, D. The influence of the organisms upon the substratum: ovular shelters which gammaridae digg in the argillaceous portions of the Măcin Arm (station 148).

Fig. 7 — A, B. An agglomeration of animals (Danube, upstreams „Cazane") resembling the one at Copăceni (the Holod river, station 102); caddis are replaced by polychaets, oligochaets and midges.

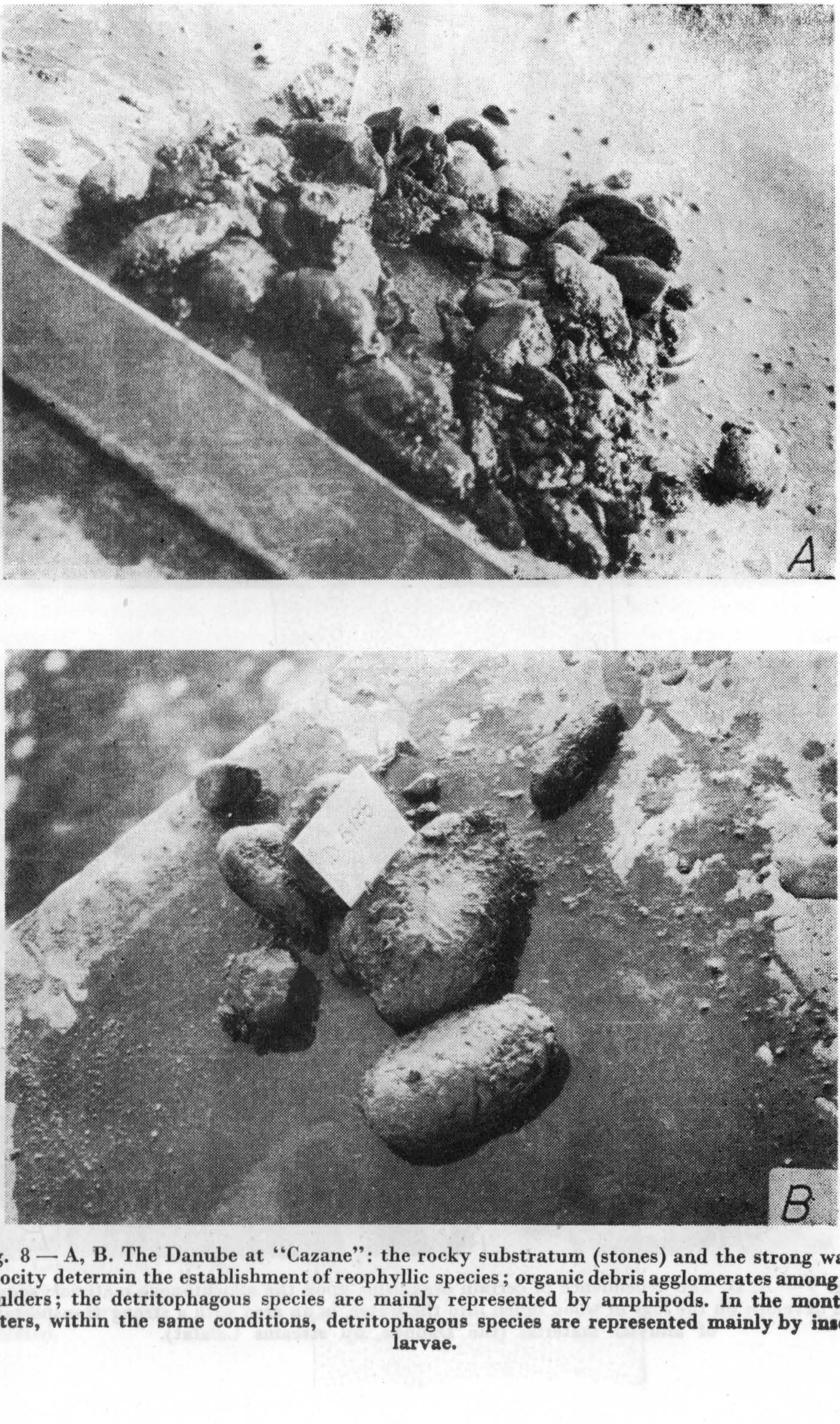


Fig. 8 — A, B. The Danube at "Cazane": the rocky substratum (stones) and the strong water velocity determin the establishment of reophyllic species; organic debris agglomerates among the boulders; the detritophagous species are mainly represented by amphipods. In the montane waters, within the same conditions, detritophagous species are represented mainly by insects larvae.

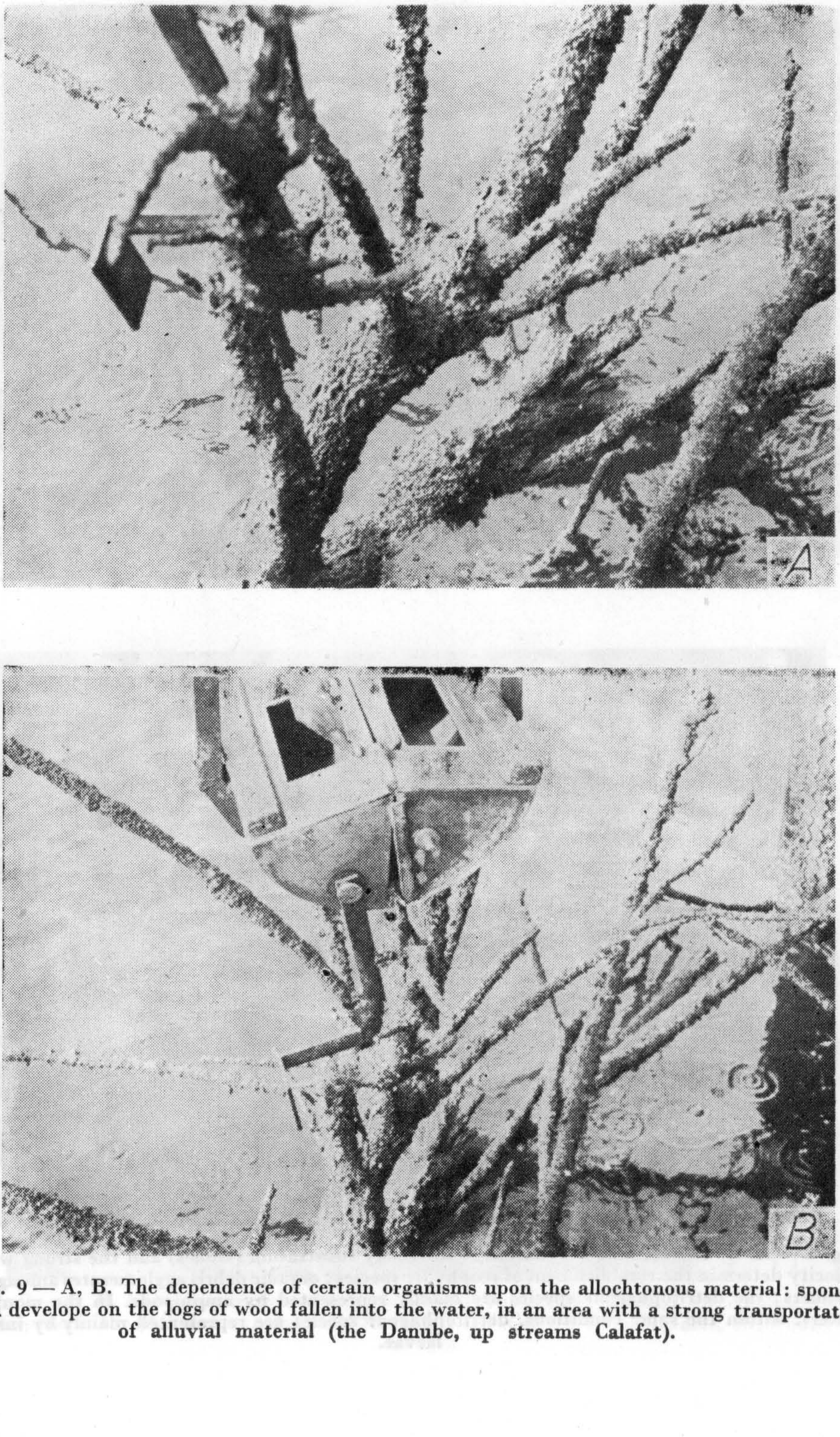


Fig. 9 — A, B. The dependence of certain organisms upon the allochtonous material: sponges can develope on the logs of wood fallen into the water, in an area with a strong transportation of alluvial material (the Danube, up streams Calafat).

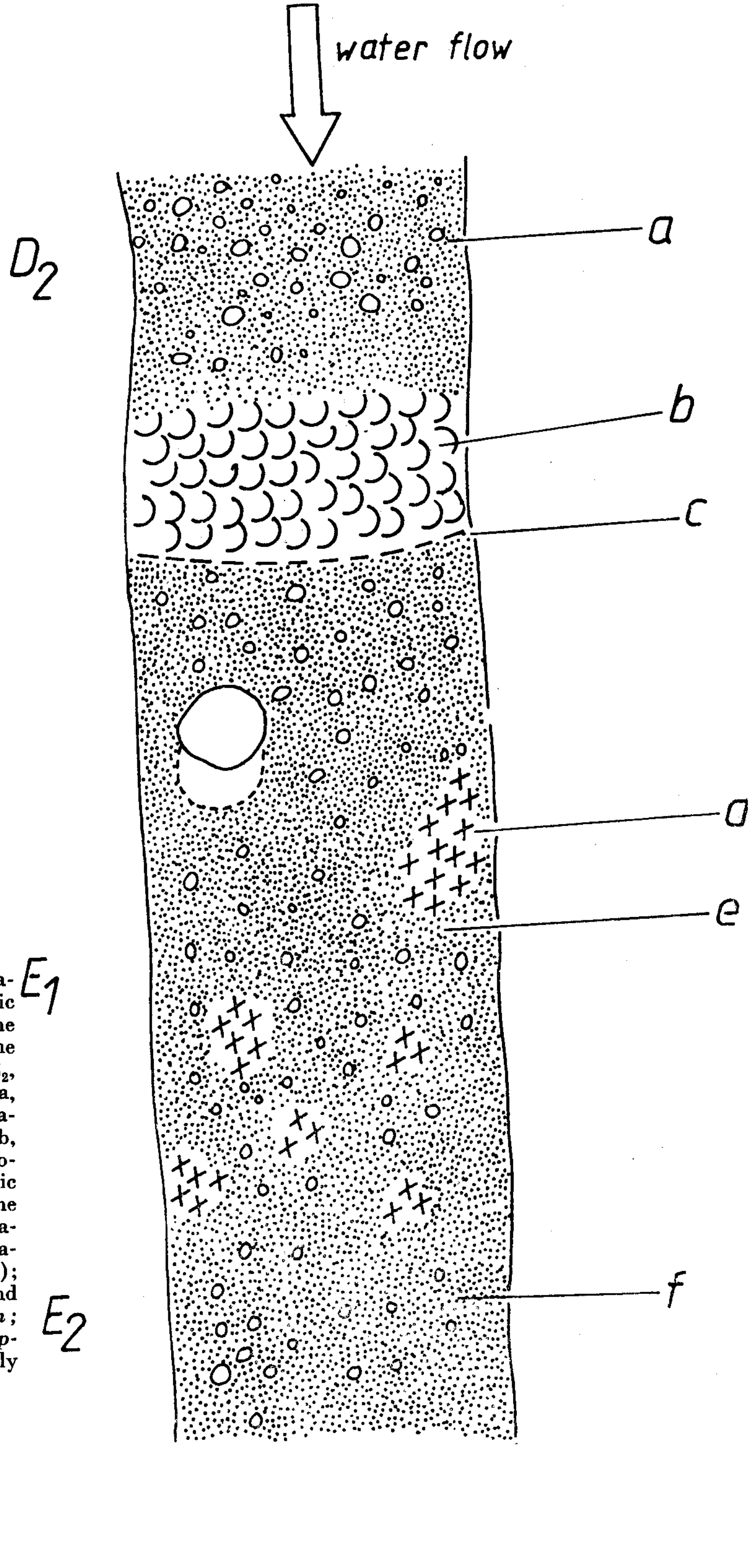


Fig. 11 — The diagram of the mosaic of biotopes from the inferior area of the Avrig River. D_2, E_2, E_2 — main areas; a, medium-sized gravels and sand; b, sandflat with agglomerations of organic debris; c, oxygene rapid; d, agglomerations of course organic debris (leaves); e, gravel and sand with *Centroptilum*; f, portion with *Ephemerella*, strongly insolated.

tis rhodani, *Caenis macrura*. In the agglomerations of coarse organic debris amphipod Gammaridae occure, too.

The community formed on coarse gravel includes: *Rhithrogena semicolorata*, *R. germanica*, *Ecdyonurus venosus*, *E. dispar*, *E. torrentium*, perlid stoneflies, *Ryacophyla* (Trichoptera) and midges.

In this sub-area, periphyton and fine organic debris are the trophic resources of Ephemeroptera.

d_2) The sub-area of the decious forest has the richest fauna. The leaves fallen in the water are transformed by phytophagous Gammaridae and Trichoptera which produce great quantities of fine organic debris. On this portion, Ephemeroptera become the prevailing group in the whole benthic fauna, but with differences depending on the biotope. In this sub-area occure the following species: *Baetis alpinus*, *B. lutheri*, *B. rhodani*, *B. muticus*, *Epeorus sylvicola* (not many specimens), *Rhithrogena semicolorata*, *R. germanica*, *Ecdyonurus dyspar*, *E. helveticus*, *E. venosus*, *E. forcipula*, *E. insignis*, *Heptagenia lateralis*, *H. sulphurea*, *Ephemerella ignita* (sporadically), *Caenis macrura*, *Paraleptophlebia submarginata)*.

The biocenosis with the richest Ephemeroptera fauna is the one formed on medium-sized gravels, with sand and agglomerations of organic debris.

Another biocenosis is that of the sandflats (oxygene rapids) which are characterized by large deposits of organic debris; the organic debris substratum lyes on sand. This great quantity of organic debris is a limitating agent for Plecoptera and even for Ephemeroptera (represented by a few specimens of *Baetis vernus*, *Ephemerella ignita*, *Heptagenia sulphurea* and *Paraleptophlebia submarginata)*; the biocenosis is dominated by Trichoptera, Chironomidae, and other larvae of Diptera. This 20—30 m long sandflat practically interrupts the gravel biocenosis which occure again downstreams; containing as rich a fauna as I mentioned above.

The mosaic of biotopes also includes:

— small accumulations of still water under the boulders with deposits of sand and organic debris, inhabited by a fauna which resembles the lenitophyllic one: Isopoda *(Asellus aquaticus)* and bivalves *(Pisidium)* are prevalent, followed by Nematoda, Hirudinea, Oligocheta, Plecoptera, Ephemeroptera *(Baetis vernus)*, limnephylid Trichoptera, Chironomidae and other Diptera larvae;

— agglomerations of leaves, especially at the bends of the banks, with large populations of gammaridae which practically eliminate any other group.

e) After leaving the decidous forest, at about 600 m high, the river runs through an area of meadows and shrubs.

e_1) The portion with flood-plain is partially shaded; the sediments are formed by medium-sized and fine gravels and by sand; agglomerations of branches and leaves.

The fauna is dominated by Ephemeroptera: *Baetis rhodani*, *B. vernus*, *B. fuscatus*, *B. muticus*, *Centroptilum luteolum*, *Rhithrogena semicolorata*, *Ecdyonurus dispar*, *E. insignis*, *Heptagenia sulphurea*, *Ephemerella ignita*, *Caenis macrura*, *Ephemera danica*. The presence of *C. luteolum* (a more thermophyllic species) differentiates this area from the previous one. The faunistical communities also include: oligochaets, gammarids (rather few), Trichoptera, Plecoptera, (but not carnivorous ones), Odonata (near the banks; they are the only secondary consumers), many chironomids. The biocenosis is dominated by primary consumers: organic debris and periphyton are abbundent.

e_2) The stretch completely exposed to insolation, barren banks, without vegetation, the flow rather strong, providing a good oxygezing of the water. The gravel is covered by bioderma. Chironomids in sandy tubes prevail; also occur: rhyacophyllid, hidropsichyd and limnephyllid Trichoptera, Ephemeroptera: *Baetis vernus*, *Rhithrogena semicolorata*, *Ecdyonurus insignis*, *Heptagenia lineata*, *Ephemerella ignita*, *Paraleptophlebia submarginata*. It is worth mentioning the absence of Plecoptera.

f) The area of the confluence with the Olt exhibits a very interesting mosaic of biotopes (Fig. 12, 13).

Upstreams, next to the confluence, the sediment consists of gravel and sand, with a very rich fauna, dominated by the Ephemeroptera species *Baetis tenax* and *B. vernus* (the most numerous populations), *Rhithrogena semicolorata*, *Ecdyonurus insignis*, *Epeorus sylvicola*, *Heptagenia lateralis*, *H. sulphurea*, *Ephemerella ignita*, *E. krieghoffi*, *Caenis macrura*, *Ephemera danica*, *E. vulgata*; numerous Trichoptera of genus *Hydropsyche*. The characteristics of this association is given by the pair *B. tenax—B. vernus* which forms very large populations, as well as *Epeorus sylvicola*.

As the confluence with the Olt is getting nearer, the diversity of the fauna obviously diminishes because of the influence of the pollution of this river. The confluence displays characteristics of the sediment accumulation area.

The Avrig may be considered a river with a montane character; the erosion area, in which transportation phenomena take place, prevails; a tipical transportation area does not occur.

On the contrary, a small final portion displaying an accumulation aspect can be delimited.

As a conclusion, I list ephemeropters associations which are characteristic to this river (for the above mentioned areas).

a) Heptageniidae larvulae;

b) *Baetis alpinus*, *Rhithrogena semicolorata*;

c) *Baetis alpinus*, *Rhithrogena semicolorata*, *Ecdyonurus venosus*; the occurence of the *Ecdyonurus* species, whose populations display a tendency to increase, is to be noticed;

d_1) *Baetis alpinus*, *Rhithrogena semicolorata*, *Ecdyonurus insignis*, *Caenis macurura*;

d_2) *Baetis alpinus* (which tends to be replaced by *B. lutheri*), *Epeorus sylvicola*, *Rhithrogena semicolorata*, *Heptagenia* species, *Caenis macrura*, *Ephemerella ignita*;

e_1) *Centroptilum luteolum*, *Rhithrogena semicolorata*;

e_2) *Rhithrogena semicolorata*, *Ephemerella ignita*;

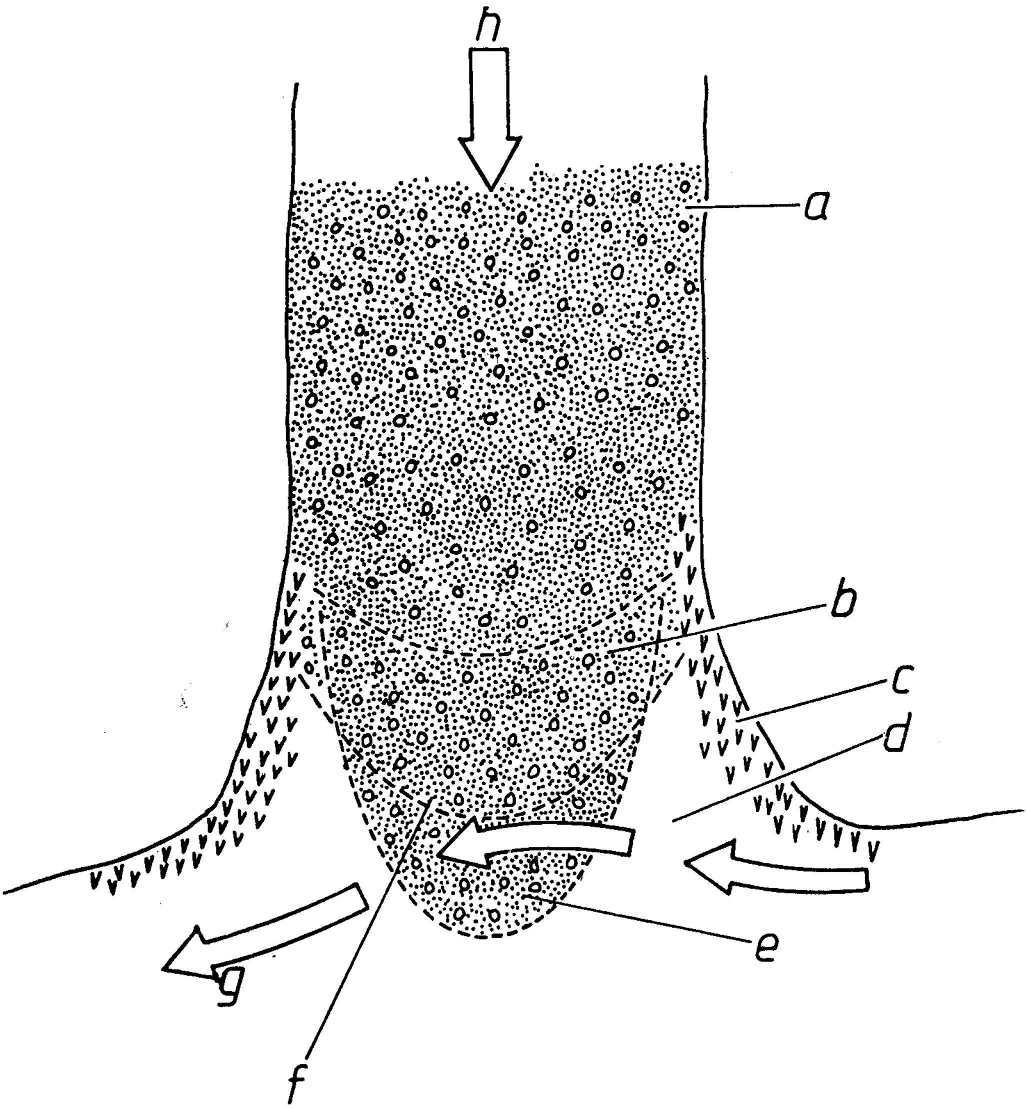


Fig. 12 — The diagram of the mosaic of biotopes at the confluences of some rivers (Avrig, Porumbacu, Arpaş) with the Olt. a, fine gravel and medium-sized sand with *Epeorus sylvicola* and other heptageniids; b, the transition area (fine gravel and medium-sized sand with *Caenis macrura* ans *Baetis tenax)*; c, the riparian vegetation washed-up by the water; d, silt without fauna; e, gravel and sand with a high organic load, with oligochaets; f, the limit of mayflies; g, the flow of the Olt; h, the flowing direction of the tributary.

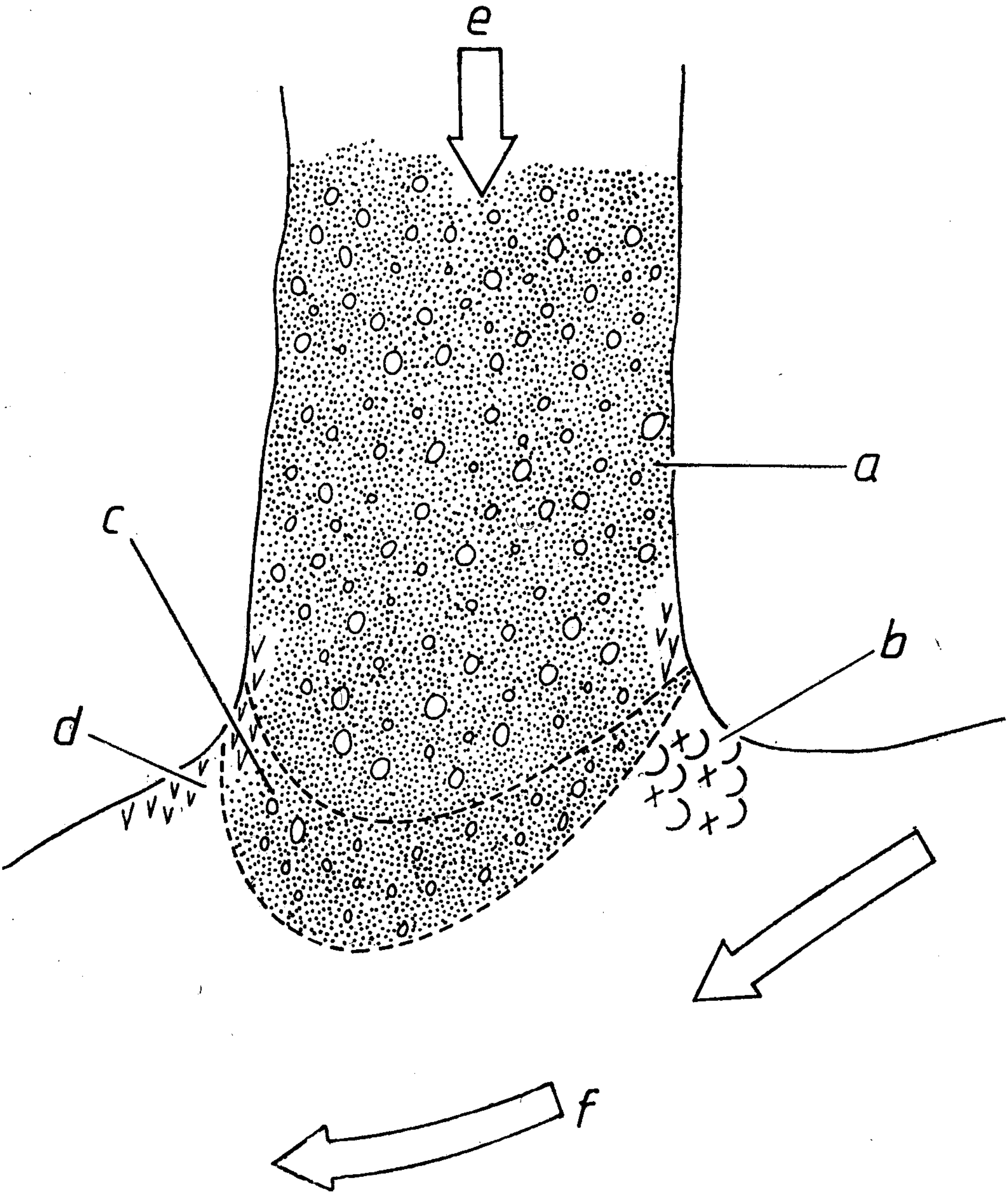


Fig. 13 — The diagram of the mosaic of biotopes at the confluence of the Aniniş brook with the Olteţ; a, gravel and sand with *Epeorus sylvicola*, *Rhithrogena semicolorata* and *Ecdyonurus insignis*; b,accumulatioo of silt and organic debris with *Potamanthus luteus*; c, the interpre-netration area (with *Ephemerella ignita* and *Oligoneuriella rhenana)*; d, vegetation washed-up by the water, with baetids; e, the flowing direction of the tributary; f, the flow of the Olteţ.

f) *Rhithrogena semicolorata*, *Baetis vernus*, *Baetis tenax*, *Rhithrogena semicolorata*, a species occuring all along the Avrig, which confers to this river a montane character (from the faunistical point of view).

II. *CONSIDERATIONS REGARDING THE CHARACTERISTIC SPECIES OF EPHEMEROPTERA IN MONTANE AREAS.*

Over 1800 m high, I generally found the same associations as the one described for the Avrig River. The fauna is dominated by Plecoptera and Trichoptera. Ephemeroptera are represented by *Baetis alpinus*, *Rhithrogena semicolorata* and one or two species of *Ecdyonurus*; most of the specimens of Ephemeroptera I collected in the area of the montane springs were larvae in the first or second stage. This can be explained by the incapacity of organisms to survive in the present conditions (especially by their incapacity to resist to the drift when the body dimensions exceed certain limits).

In some cases, the association is completed by *Baetis melanonyx* (in the Rodna Mountains) as well as by *B. rhodani*; the genus *Rhithrogena* is also represented by the species *hybrida* (in Oaş county) and by *germanica* (relatively frequent).

The biotope of the montane springs consists of moss-covered boulders, on a gravel and sandy bed; among boulders, small accumulations of very fine organic debris may occure (only if the slope permits it).

In the epirithron area, characterized by associations of *Baetis alpinus* —*Rhithrogena semicolorata*, the biotope consists of boulders and course gravel, logs of wood and branches, which creat shelters for the fauna.

The occurence of *Baetis lutheri* specimens marks the begining of the metarithron area. This area displays a faunistical variety which increases downstreams and which can be graded as follows:

— more Plecoptera and Trichoptera species;

— „the competition" between Baetidae and Heptageniidae;

— the prevalence of Ephemeroptera (especially in the portion with less ammounts of course debris).

This is valid for brooks situated at distinct altitudes but restricted to montane areas (brooks in the Rodna Massif, tributaries of the Buzău River, tributaries of the Ialomiţa, tributaries of the three Criş Rivers etc.). The metarithron is characterized by a mosaic of biotopes which also occure in the epirithron but with a less variety. I exemplify this situation with the description of the mosaic of biotopes identified for the Şipoaia (a brook within the Bîrsa system, in the Piatra Mare Massif):

— course gravel on sandy bed, with logs of wood and branches: *Baetis alpinus*, *Rhithrogena semicolorata*, *Ecdyonurus dispar*, *E. helveticus*, *E. aurantiacus*, *E. subalpinus* (the occurence of four species of *Ecdyonurus* is to be mentioned), *Heptagenia longicauda*, *Leptophlebia vespertina*, Plecoptera, Trichoptera:

— agglomeration of organic debris (leaves) on a sandy substratum (a portion with low water velocity): *Baetis vernus*, *Caenis macrura;* many gammarids, plecopters, chironomids;

— accumulation of fine organic debris: *Baetis vernus*, *Ecdyonurus dispar*, *Heptagenia sulphurea*, Oligochaeta (numerous), *Plecoptera* (especially *Perla)*, Trichoptera;

— a portion with sand and fine gravel: *Baetis lutheri* (a massive population), *Ephemerella ignita*, *Caenis macrura*;

— medium-sized gravel, with small agglomerations of organic debris (especially leaves): *Epeorus sylvicola*, *Ephemerella ignita*; many planarians and a few Plecoptera, Oligochaeta, Chironomida.

The biocenoses of the Timiş River (in the Banat) can be ascribed to the rithron areas; the Ephemeroptera associations illustrate the modification of the specific spectrum from upstream to downstream:

a) the association characterising the confluence with the Hideg: *Baetis lutheri*, *B. vernus*, *Oligoneuriella rhenana*; secondary species: *Epeorus sylvicola*, *Ecdyonurus dispar*, *E. aurantiacus*, *Caenis macrura*, *Ephemerella ignita*;

b) the association characterising the station situated slightly upstreams the confluence with the Rîul Alb: *Baetis lutheri*, *B. fuscatus*, *Ephemerella ignita*:. secondary species: *Rhithrogena semicolorata*, *Ecdyonurus venosus*, *E. aurantiacus*, *Caenis macrura*;

c) the association characterising the station Armeniş: *Ephemerella ignita*, *Caenis macrura*; secondary species: *Heptagenia coerulans*, *H. sulphurea*, *Ecdyonurus venosus*, *E. dispar*;

d) the association characterising the station upstreams Sebeş, at the confluence with the Cîrpa: *Oligoneuriella rhenana*, *Ephemerella ignita*, *Ecdyonurus venosus*; secondary species: *Baetis rhodani*, *Rhithrogena semicolorata*, *Ecdyonurus aurantiacus*, *Caenis macrura*, *C. moesta*, *Pothamanthus luteus*.

The Bega River, in its non-managed portion, displays a succesion of areas resembling those from the Avrig River (although the Bega originates at 700 m high); the degree of similitude is confered mainly by the componence of the substratum, which in the first part of the river mainly consists of course gravels and boulders.

In the last portion of the river, a slight accumulation of sediments occur, transportation phenomena prevailing.

The first portion of the rithron is dominated by *Baetis alpinus* and by *Rhithrogena semicolorata*. Also occur *Ecdyonurus insignis*, as well as *Baetis rhodani*; the presence of the last one is not surprising, considering the tendency of its range to extend, but the following problem arises: the area equally offers conditions to certain stenoik species but also to eurioik ones. The substratum type is clearly favourable to rheophyllic stenoterms, *Baetis alpinus* and *Rhithrogena semicolorata*, but the general climatic conditions also permitted the establishment of *B. rhodani* (in the case of the Avrig River, the montane conditions do not permit this — for the corresponding area). It can also be considered that the deterioration of the biotopes permits the expansion of the population of *B. rhodani* to the prejudice of the other species.

For the second rithron area of the Bega River, I noticed the prevalence of *Baetis rhodani*, *Rhithrogena semicolorata*, *Oligoneuriella rhenana* and *Ephemerella ignita*. *E. ignita* is more competitive than *O. rhenana* and tends to replace it as the biotope is changing.

The third area is characterized by the presence of *Heptagenia* and *Caenis* species. The fact that *R. semicolorata* does not occur indicates that the river gradually "looses" its montane character.

III. *CONSIDERATIONS ON THE SPECIES OF EPHEMEROPTERA WHICH CHARACTERISE THE HILLY AREAS*

I shall now reffer especially to some rivers from the south of Romania (Oltenia): Blahniţa, Desnăţui, Terpeziţa, Huşniţa, Argetoaia, Bîrlui, Teslui. These rivers are characterized by the prevalance of the transportation phenomena; the erosion upon the own river bed is weaker, compared to the same phenomenon in montane rivers (the slope being much more gentle) but it is facilitated by the geological characteristics of the much more erodable areas they are running through. A great part of the transported material is allochtonous (many vegetal fragments and dust which become suspensioned) (Fig. 14).

In these waters, a number of biocenoses can be delimited:

— the psamorheophyllic biocenosis (in the Desnăţui and the Huşniţa Rivers) comprising *Baetis tenax*, *Caenis moesta* and *C. macrura*; oligochets, trichopters *(Hydropsyche)*, midges;

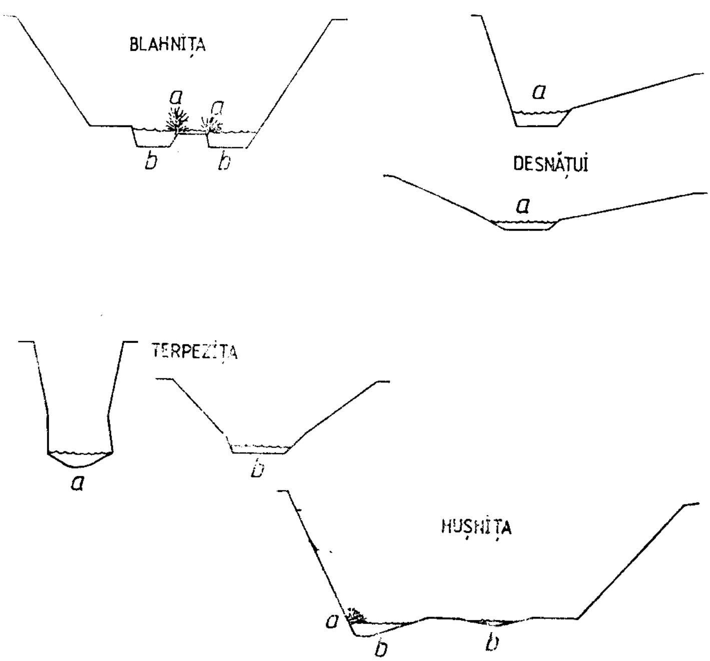


Fig. 14 — The profiles of some rivers from the hilly area of Oltenia: Blahniţa (a, the phytophyllic biocenosis; b, the argillorheophyllic biocenosis); Desnăţui (a, the psamorheophyllic biocenosis); Terpeziţa (a, the argillorheophyllic biocenosis; b, the psamorheophyllic biocenosis); Huşniţa (a, the phytophyllic biocenosis; b, the psamorheophyllic biocenosis).

— the lithophyllic biocenosis (the medium—fine gravels from Argetoaia); *Centroptilum luteolum*, *Ecdyonurus dispar*, *Ephemerella ignita*;

— the biocenosis with fluvial arenites (in the Blahniţa, upstreams the confluence with the Danube), dominated by trichopters larvae (especially *Hydropsyche pellucidula* and *Agraylea multipunctata*, *Baetis rhodani*, *B. vernus*, *B. muticus*, *B. buceratus*, *B. tricolor*, *Heptagenia lateralis*, *Caenis macrura*, *C. moesta*, *Potamanthus luteus)*. It is the richest biocenosis in all the hilly area and plain waters I studied; the bed is sandy-argillaceous and the agglomerations of trichopters larvae determin the accumulation of the retained organic debris;

— the argillophyllic biocenosis (in the Terpeziţa River) has the poorest Ephemeroptera fauna *(Baetis vernus* is the only species); the limnefilid trichopters prevail (a large population of *Limnephilus hirsutus)* accompanied by Odonata, corixid Heteroptera and chironomids;

— the biocenosis of the ripal vegetation (in all the rivers I mentioned above) is dominated by Ephemeroptera: *Baetis rhodani*, *B. tenax*, *Caenis moesta*; also occur: Gammaridae, Isopoda, Hirudinea, Odonata, Chironomidae.

This last biocenosis best characterizes the area where the transportation phenomena prevail. As regards the Neajlov River (the portion between the villages Călugăreni and Mihai Bravu) and the Tur River (at Turulung) (the Neajlov is situated in the S—E and the Tur in the N—W of Romania) I have noticed the same richness of the bank biocenosis, where Ephemeroptera are prevalent *(B. rhodani*, *B. vernus*, *B. scambus*, *B. niger)*.

In all the rivers I mentioned, I also identified areas where intense processes of silt accumulation take place, in which Baetidae *(B. vernus*, *B. scambus)* — but also Caenidae *(C. horaria)* — occur. In the accumulation area of the Danube and the Danube Delta, the caenids *(C. robusta* and *C. horaria* are elearly prevalent.

IV. *EPHEMEROPTERA WITHIN THE MOSAIC OF BIOTOPES OF THE PLAIN SPRINGS ECOSYSTEMS.*

The plain springs (helocrenic and limnocrenic ones) whose collecting brook flows into a river or into a pool and which represent biotopes with well-deffined characteristics, are formed by a mosaic of substrata, each substratum being inhabited by a specific faunistical community.

As regards the Romanian Plain, I studied three large groups of springs:

— the group from Comana and Mihai Bravu; ballanced and stable ecosystems (M a n o l e l i, G ă l d e a n, B a r d a n, 1979);

— the group on the Danube terrace (Mehedinţi); balanced and stable ecosystems (G ă l d e a n, M a n o l e l i, 1978);

—the group from the northern limit of the Oltenia Plain, of the Argetoaia, Bîrlui and Teslui system; ecosystems displayng an unballance tendency.

All these springs display similar mosaics of biotopes, both for the collecting basin and for the effluent brook. Ephemeroptera are respresented only by Baetidae and Caenidae. It seems that the mosaic of biotopes, occuring on a very small surface, is favourable to certain Baetidae (*B. rhodani*, *B. vernus)*, which "can not tolerate" an uniform substratum. These two species prevail.

Ephemeroptera are distributed as folows, in dependance of the substratum:

— vegetation: *Baetis rhodani*, *B. vernus*, *B. fuscatus*, *Cleon dipterum*, *C. simile*, *Caenis horaria*, ;

— clay: *B. tenax*;

— sand and gravel: *B. rhodani*;

— agglomerations of organic debris and leaves: Ephemeroptera are absent.

By the structure of the Ephemeroptera fauna, these springs do not resemble any of the running waters areas: they are independent biotopes, also distinct from still waters.

They form the area of the plain springs.

The problem of the drift.

It is known that many benthic organisms which live in running waters, including Ephemeroptera, must face the drift created by the strength of the flow. The drift apears during high water (the exceptional drift) but also currently, especially at night, when many organisms move in search of food (the common drift, Bournaud and Thibault, 1973).

However, the drift is limitted especially by the sediment conditions.

The data obtained by collectings in the field are demonstrating a present situation, reflecting — among other things — the response of the or-organisms to the drift. Certain mechanisms of compensation also occur — for instance, the adults fly upstreams for laying their eggs (Bogoescu, 1973.)

V. *THE GENERAL PATTERN OF THE DIVISION INTO ZONES OF THE ROMANIAN RUNNING WATERS BASED ON EPHEMEROPTERA (CONSIDERING EROSION, TRANSPORTATION AND SEDIMENTATION AREAS).*

1. The area characterised by the prevalence of erosion phenomena (Table 1).

1.1. Baetidae and Heptageniidae larvulae (the crenon)

1.2. *Baetis alpinus*, *B. melanonyx*, *Rhithrogena semicolorata*, *R. germanica*, *R. hybrida*, *Ecdyonurus venosus*, *E. torrentis*, *E. insignis*, *E. dispar* (epirithron).

1.3. *Baetis lutheri*, *B. sinaicus* (metarithron).

1.4. *Baetis rhodani*, *B. scambus*, *B. fuscatus*, *B. muticus*, *Rhythrogena semicolorata*, *Ecdyonurus dispar*, *E. insignis*,. *E. helveticus*, *Heptagenia lineata*, *Leptophlebia marginata*, *L. vespertina*, *Paraleptophlebia submarginata* *Oligoneuriella rhenana*, *Ephemerella ignita*, *Caenis macrura*, *Ephemera danica* (metarithron).

1.5. same species as in 1.4. (but Baetidae prevail as well as: *Centroptilum luteolum*, *Pseudocloeon* inexpectatum, *Ephoron virgo*, *Potamanthus luteus* (hiporithron; the last two species mark the transition to potamon).

2. The area characterized by the prevalence of transportation phenomena (Table 2).

2.1. *Baetis vernus*, *B. tenax*, *Caenis moesta*, *Ephoron virgo*, *Potamanthus luteus* (epipotamon).

3. The area characterized by the prevalence of accumulation phenomena. (Table 3).

3.1. *Baetis vernus*, *Caenis robusta*, *C. horaria* (metapotamon).

CONCLUSIONS

SIGNIFICANCE AND PRACTICAL VALUE OF THE DIVISION INTO ZONES OF RUNNING WATERS, BASED ON EPHEMEROPTERA AS CHARACTERISTIC ELEMENTS.

Ephemeroptera, as well as other benthic organisms, must be understood within the dynamic phenomena which are specific to running waters.

Table 1

Mayflies which characterize the area dominated by EROSION processes

The main sediment	Species	Remarks
boulders and coarse gravels (more stable area)	*Baetis alpinus* *B. melanonyx* *B. sinaicus* *Rhithrogena semicolorata* *Ecdyonurus venosus* *E. carpaticus*	the most frequent species
course gravel, logs of wood, branches	*Baetis alpinus* *B. sinaicus* *B. rhodani* *B. lutheri* *B. fuscatus* *Ecdyonurus venosus* *E. dispar* *Rhithrogena semicolorata*	no dominant species; diversity increases
medium-sized gravels (with rolled elements); accumulation of leaves	*Baetis lutheri* *Oligoneuriella rhenana*	large populations;
	Epeorus sylvicola	the most characteristic species
	Rhithrogena semicolorata *Ecdyonurus dispar* *E. insignis* *E. helveticus* *Heptagenia lateralis* *Ephemerella ignita*	
	Caenis macrura *Habroleptoides modesta*	dominant species
riparian vegetation washed-up by the water; fine organic debris	all baetids and heptageniids	the refuge biotope during high waters

The lotic environment exercises a permanent selective pressure on the populations, determining them to respond to different physical solicitations.

These solicitations arise from 2 types of phenomena:

— the water-flow itself and the transportation of the eroded matter;
— the depositation of the transported matter.

Table 2

Mayflies which characterize the area dominated by TRANSPORTATION processes

The main sediment	Species	Remarks
fine gravel and coarse to medium-sized sand	*Baetis rhodani* *B. fuscatus* *Centroptilum luteolum* *Ecdyonurus dispar* *E. insignis* *Heptagenia sp .* *Ephemerell ignita* *Caenis macrura*	
sand	*Baetis vernus* *Caenis macrura*	sporadic occurence
sand, clay and accumulations of organic debris	*Baetis muticus* *B. buceratus* *B. tricolor* *Caenis macrura* *C. moesta* *Habrophlebia fusca* *Potamanthus luteus*	species frequent in rivers from the hilly areas
riparian vegetation washed-up by the water	*Baetis rhodani* *B. vernus* *B. scambus* *B. niger*	large populations

Table 3

Mayflies which characterize the area dominated by ACCUMULATION processes

The main sediment	Species	Remarks
silt, massive accumulations of organic debris	*Caenis horaria* *C. robusta*	in the deltaic perimeter
	Baetis vernus *B. scambus* *B. niger* *Caenis horaria* *Habroleptoides modesta*	in slowly-running stretches (hilly and plain areas)

The characterization of a river's segments using organisms adapted to erosion, transportation or sedimentation (accumulation) reflects not only their zonal distribution but also the state of the ecosystem.

Ephemeroptera must find sure and sufficient trophic resources; the movements of the larvae are extremely limited and their food depends on the permanent state of the bacterial and algal populations (diatoms). The presence of these populations offers sure data regarding the trophic state of an area.

A division once established, it can be used as a standard for the periodical checking of the state of a lotic ecosystem, considering the action of natural or anthropic agents.

In this way, the faunistical analysis and the correct explanation of the distribution of Ephemeroptera along a river complete the physical and chemical analysis and ennable the realisation of a general, complete image of the studied ecosystem.

The observation, during a certain amount of time, of the distribution of Ephemeroptera in an aquatic system can provide prognosis ellements regarding the subsequent evolution of the system.

The divisions of a lotic system can be qualitatively modified because of the action of several agents:

— natural agents: river-piracy resulted from the modification of watersheds; the damming caused by the obstruction of the valleys or, as was the case in the past, by the activity of beavers (Naiman and coll., 1984); changes in the water velocity;

— anthropic agents: hydroenergetical damms, managements in respect of irigations, regularization and sewerage, clearings, operations of the ballast.

The indirect effects, the most numerous and difficult to identify ones, can be more easily analysed if qualitative parameters, based on the distribution of different animal groups (in this case, mayflies), are established for every natural running-water. The modifications of the biotopes are rapidly reflected in the structure of the benthic communities, before anything in the quality of the water is changed (physically or chemically).

Considering the present distribution of mayflies and the prospect of damming further on certain rivers, some prognosis elements can be given:

— the persistence of the componence of mayfly faunae in the montane areas;

— the disappearance, upstreams the dams, of the leptophlebiids and of some caenids; the massive development of the populations of oportunistic species *(Baetis rhodani, B. niger, Ephemerella ignita)*;

— the reduction of the populations of *Oligoneuriella rhenana* in respect of the increasing amounts of organic debris and of sediments depositing upstreams the damms;

— the decreasing tendency of the numerical level of diggers (especially *Ephoron virgo)*;

— the acceleration of erosion phenomena upstreams the ballast operations will mainly affect the lithorheophilic forms.

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UTILIZAREA EFEMEROPTERELOR (INSECTA, EPHEMEROPTERA) ÎN ZONAREA APELOR CURGĂTOARE DIN ROMÂNIA

REZUMAT

Problema zonării unor cursuri de apă din România este abordată sistemic, luînd în considerație valoarea informațională a grupului studiat. Repartiția efemeropterelor este discutată atît în raport cu fenomenele de eroziune, transport și acumulare cît și pe baza necesităților trofice, a tipului de substrat și a structurii biocenozelor.

Se argumentează utilizarea efemeropterelor ca specii indicatoare prin particularitățile lor evolutive.

Zonele descrise (montane, colinare și de cîmpie) sînt încadrate într-o schemă generală care poate servi drept etalon pentru verificarea periodică a stării ecosistemelor lotice.

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