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Stream ecosystems in mountain grassland (West Carpathians)*

12. General conclusion

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Abstract — In its present form the pastoral economy does not drastically affect the quality of the water in the investigated streams. However, the first signs of impairment of self-regulation mechanisms in these ecosystems have been observed. Differences in the number of individual groups of organisms and in the structure of biocenoses, and disturbances in the seasonal fluctuations of numbers and structures of the communities were found. The changes in natural stream biocenoses were caused not only by increasing amount of nutrients washed out from the meadows but also by such physical factors as differences in water discharge, insolation, and temperature.

Key words: stream ecosystems, influence of pastoral economy, the West Carpathians.

1. Introduction

An attempt was made to determine the effect on stream ecosystems of pastoral economy in mountainous areas and to find signs of any transformation of the biocenosis under the influence of this economy. Hydrological investigations (Kurek, Pawlik-Dobrowolski 1982), hydrochemical (Bombówna 1982 — macroelements, Reczyńska-Dutka 1982 — microelements), bacteriological (Starzecka, Trela 1982), algological (Kawecka 1982), and faunistic (Gra-

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b a c k a 1982 — communities of *Infusoria*, D u m n i c k a 1982 — *Oligochaeta*, N i e s i o ł o w s k i 1982 — *Simuliidae, Empididae (Diptera)*, K o w n a c k i 1982b — the remaining groups of invertebrates, S t a r m a c h 1982 — fishes) were carried out in order to elucidate the problem. On the basis of the available literature, the investigations were complemented by geological and pedological descriptions the catchment basin and the characteristics of the agricultural utilization of the Grajcarek stream upper basin (K o w n a c k i 1982a).

In summing up, only the results of the hydrochemical and hydrobiological investigations from the years 1977—1978 are presented. The investigations were carried out at three stations: BW1, the control, not affected by pasturing, established in the upper sector of the Biała Woda stream at altitude 690 m, at the outskirts of a large forest complex; BW2 in the Biała Woda stream at 640 m, in the area of traditional pastures, and K2 in the Kamionka stream at 690 m, in the area of experimental pastures of the Institute for Land Reclamation and Grassland Farming. The aim was to find stations lying at a similar altitude, that is in the same ecological zone, where the only modifying factor would be the character of land use of the catchment area. Unfortunately, some differences in the chemical composition of the water owing to the geological structure of the basin were inevitable.

2. General characterization of the investigated stream ecosystems

2.1. Characteristics of the catchment area

The head waters of the Grajcarek stream (Biała Woda, Czarna Woda, Skalski, and Kamionka streams) drain two morphological units of the West Carpathian Mountains: to the north the Radziejowa range (the Beskid Sądecki Mts), built of Carpathian flysch, and to the south the Małe Pieniny range, built of Jura and lower Cretaceous limestones and of sandstones, shales and marls of the Upper Cretaceous age. The investigated area is mostly covered by acid soils (acid brown and podsolic soils) and, in a small percentage, by neutral or basic soils (rendzinas).

The climate is that of the Carpathian climatic region with a mean annual temperature of 6.1°C and mean precipitation of 923.8 mm. In the period of investigation the mean discharge unit reached 17.4 dm^3/sec.

Forests and sheep pastures prevail in the basin of the upper Grajcarek stream with arable land covering a small percentage of the area.

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2.2. Hydrochemistry

The investigated streams were characterized by low water temperatures (0.2°C in winter and 12.1—13.8°C in summer). Oxygen saturation was always high and usually exceeded 90%. The ion equivalent composition of the water was chiefly determined by calcium and magnesium carbonates whose content was particularly high in the Kamionka stream. The content of chlorides, sulphates, potassum, sodium, and iron was always low in relation to the total sum of ions. Apart from differences

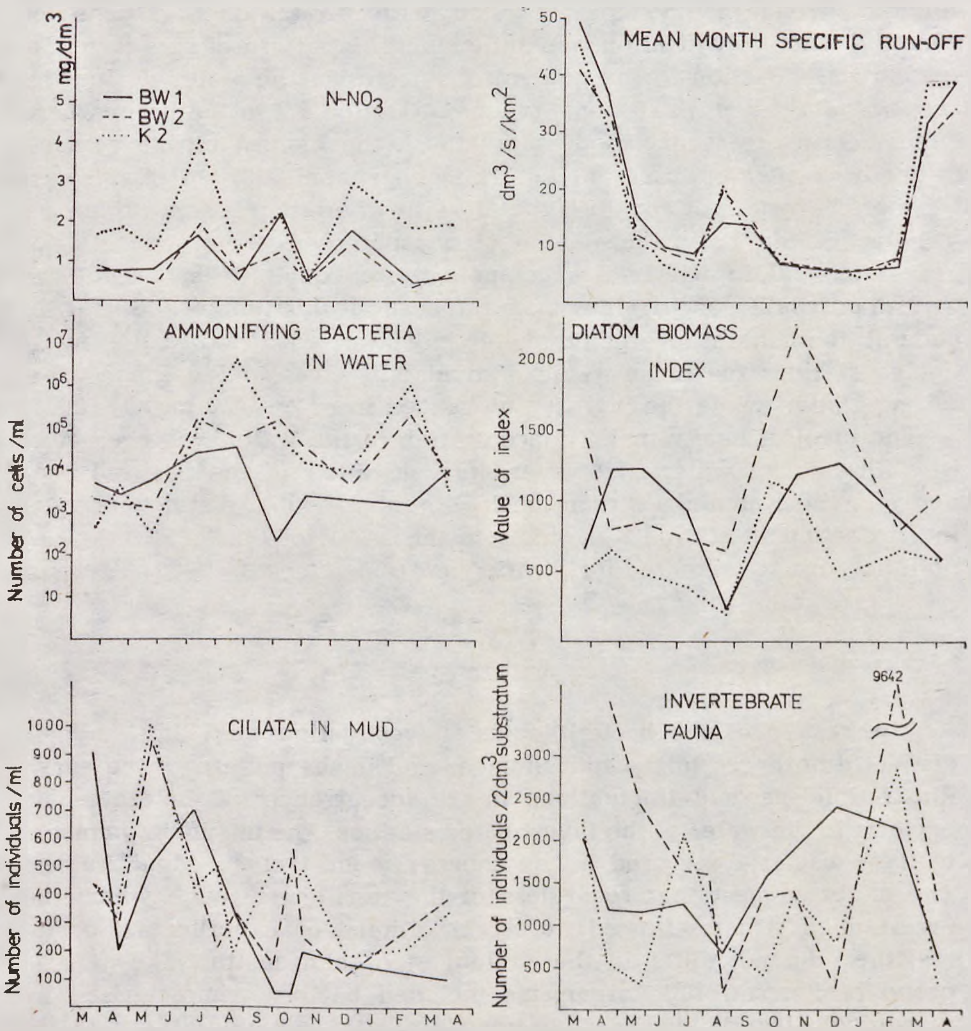

Fig. 1. Seasonal fluctuations of selected elements of stream ecosystems in catchment basin having different intensification of pastoral land use

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in the concentration of electrolytes at the different stations, marked changes in their concentration occurred throughout the year. The highest concentration of electrolytes was found in winter and the lowest one in spring, in March. This differentiation in the chemical composition of the water is associated both with the geological structure of the substratum and with the interpendences between the amount of precipitation, the discharge and underground feeding, and the resulting magnitude of the ground runoff in the total runoff.

The content of mineral nutrients chiefly depends on the agricultural land use of the basin and the surface runoff. In the investigated streams mineral nitrogen compounds prevailed, with nitrates decisively predominating when oxygenation was sufficient. The pattern of curves representing the variation in the content of nitrates in the water during the year was similar at all stations, though at station K2 in the basin where intensive pastoral economy was practised, the highest nitrate concentration was always observed (fig. 1). The ammonium from of nitrogen was not characteristic for this type of basin where there were no human settlements. Similarly, the amount of phosphates in the water was not very high and in winter this component was depleted because there was no possibility of its inflow from the basin at this time of the year. In general, the content of organic matter indicators was low. At the investigated stations the mean value of oxidability was in the range 2.9—3.5 mg O_2/dm^3 while the BOD_5 value ranged from 2.5—5.0 mg O_2/dm^3.

The level of heavy metal concentration in the water was characteristic for natural waters. However, intensification of the pastoral economy in the Kamionka stream basin brought about a distinct increase in Zn content at station K2. This was the result of the local inflow of pollution due to increased fertilization and sheep faeces.

2.3. Stream biocenoses

The results of the bacteriological investigations did not suggest distinct differences in the total number and in the pattern of the curve illustrating seasonal fluctuations in the occurrence of heterotrophic bacteria in the water of the investigated stations. The maximum numbers of these bacteria occurred in the summer months of July and August. The might suggest that regardless of the territory through which the investigated streams flowed (forest, traditional or experimental pastures) they did not differ in the content of organic matter. The general group of heterotrophic organisms included bacteria characterised by physiological variability and the ability to utilize various types of nutritive substrate. The differentiation of the water at the investigated stations was illustrated by the analysis of bacteria utilizing nitric sub-

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stances in organic or mineral form. The smaller numbers of proteolytic bacteria in the water at station K2 than at stations BW1, and BW2 may have been associated with a greater proteolytic and ammonifying activity of soils in the intensively grazed areas. In this connection greater amounts of protein substances entered the stream waters. The substances were partly mineralized, as was shown by the pattern of changes in the numbers of ammonifying bacteria (fig. 1). Thus, in the Biała Woda stream at station BW1 the numbers of ammonifiers rose in the summer in accordance with natural seasonal changes while at stations BW2 and K2, which receive runoff from the pastures, large numbers of amminifiers occurred not only in summer but also in winter. Similarly, the nitrate-reducing bacteria chiefly occurred at station K2 in the autumn-winter period. This could also have been connected with the runoff of mineral forms of nitrogen brought in with the fertilizers used on the pastures.

In interpreting the obtained results, the flow rate in the stream and the temperature of the water must be taken into consideration. This is particularly important in the elaboration of bacteria collected from the water. At low temperatures the generation time of these organisms is markedly prolonged as compared with the optimum and, owing to the rapid flow of water, the development of the next generation occurs at a considerable distance from the sampling station. This leads to the conclusion that the increased number of bacteria in the pasture area did not arise only from the higher degree of water eutrophication, due to the inflow of nutrients from the neighbouring area; the soil bacteria also penetrated into the streams with the surface runoff, this being reflected by an increase in the numbers of these organisms. The number of bacteria, increasing in the course of the stream, resulted from the accumulation of surface runoff.

Seasonal variation in the numbers of bacteria, especially of the heterotrophic and ammonifying ones, were correlated with changes in the number of *Ciliata*. The numbers usually rose in the spring, summer, and autumn period. It is true that the bacteriological samples were collected from the water while the samples of protozoa were taken from stones in the lotic habitat and from muddy sediments in the marginal part of the stream. However, it may be conjectured that a corresponding increase in the numbers of bacteria occurred in the sediments, though here their numbers should be 10—100 times greater than those of bacteria in the water.

Despite the similarity in the pattern of the seasonal curves, the number of *Ciliata* was usually higher at stations BW2 and K2 in the area of pastures than at the control station BW1 (fig. 1). Apart from those feeding on bacteria, in some periods, especially in the spring and autumn, *Ciliata* consuming only algae, particularly diatoms and blue-green algae, appeared in the Biała Woda stream. This was usually correlated

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with the development of algae in the substratum. However, it should be stressed that in the winter, in spite of large amounts of easily accessible food in the form of masses of diatoms, no ciliates were found in the stream. This absence could have resulted from their sensitivity to low temperatures.

The communities of algae which developed in the investigated streams were fairly similar as regards their floristic composition, though the greatest number of taxa appeared at station BW2 and the smallest at station K2. At all stations diatoms of the genus *Achnanthes* prevailed; among blue-green algae abundant communities of *Schizothrix fasciculata* were observed and among green algae unidentified species of the family *Chlorosarcinaceae* were found. *Hydrurus foetidus* occurred in its greatest numbers at station BW2 whereas at K2 no macroscopic aggregations of this species were observed. Differences in the quantitative development of the species were also noted. In the Kamionka stream (K2), flowing across an area of intensively fertilized pastures, algal coats were much poorer than in the Biała Woda stream at the control station BW1 and in the area of traditional sheep grazing (BW2). The biomass index of diatoms was also much lower at station K2 than at stations BW2 and BW1. Contrary to bacteria, whose greatest development occurred in the summer, the smallest numbers of algae were noted then, their most abundant development occurring in the autumn, winter, and spring (fig. 1).

In the communities of invertebrate animals no significant taxonomic variation was noted at the different stations, nor were forms which could be regarded as characteristic for polluted waters identified there. On the other hand, fairly distinct differences among the stations occurred in the total numbers of fauna and in the structure of communities. In the lotic habitat the greatest numbers were noted at station BW2 and the smallest at K2. This was in accordance with the variation in the number of algae but did not correlate with the content of nutrients in the water, especially of nitrates, whose greatest amounts were always noted at station K2. The increase in the nutrient content observed at station K2 was so pronounced that it should rather have induced an increase and not a reduction in the number of algae and, indirectly, of fauna. At this station (K2) the content of microelements, specially of Zn whose concentration increased 2—5 times as compared with station BW1, was not so high as to inhibit the development of algae and animals, especially as the high concentration of calcium in the water (the highest one at station K2) limited considerably the noxious influence of these metals. It is difficult not to explain this phenomenon. A marked increase in the number of *Chironomidae* with a simultaneous decrease in the percentage of the other groups of fauna, especially of mayflies and caddis flies in the lotic habitat at stations BW2 and K2, as compared with the control

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station BW1, suggested that a gradual eutrophication of the stream associated with the pastoral economy, was taking place there.

Characteristic changes in the seasonal cycles of the fauna were also observed at the different stations. At the control station BW1 these changes were regular in character. The total numbers of fauna increased in the winter months. They then decreased, reaching a minimum in the summer period. The pattern of this variation is associated with the seasonal succession of the different communities and with the life cycles of the dominant species. However, already at station BW2, despite a similarity in the changes of numbers of animals (though these numbers were much higher than those at the control station), the domination structure was greatly disturbed. In some periods, species of which single specimens were usually noted there, appeared in masses. At station K2 the changes were still more irregular. During the course of the year several maxima followed by rapid decreases in the total numbers of the fauna were observed (fig. 1).

The rapid decline in the total numbers of animals at station 2 in August must be separately discussed. It was brought about by a flood wave which reduced to $^1/_3$ the number of taxa and to $^1/_8$ the total number of fauna. The structure of the community also changed. As a consequence of the flood the percentage of mayflies rose while that of the remaining bottom groups, among them also of *Chironomidae*, fall. Thus, among the reasons for disturbances in the natural development of zoocenoses may be included frequent floods in the summer period. They are much more violent in open pastures than in forest areas.

The ichthyofauna of the head waters of the Grajcarek stream is represented by two species: *Salmo trutta* m. *fario* L. and *Cottus poecilopus* Heckel. This species composition is typical for the upper course of Carpathian streams. However, as compared with other streams, the number of specimens of the two species was exceptionally high in the upper Grajcarek basin. The fish were characterized by a relatively great body weight but their increases were much lower, especially in the trout, in the Biała Woda and Kamionka than in other streams of the River Dunajec catchment basin.

3. The influence of pastoral land use on stream ecosystems

In examining the effect of pastoral land use in mountain areas on the stream ecosystems, two factors have to be taken into consideration.

One of them is the intensification of the pastoral system, leading to the runoff of greater amounts of nutrients, especially of nitrates, from the pastures than from the forest covered basin. Increased concentrations of these compounds bring about an increase in bacteria and, indirectly,

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in the *Ciliata* feeding on them. On the other hand, the effect of the nutrient runoff on the communities of algae and animals in the streams was less significant. In the investigated waters no plant or animal organisms which could be regarded as indicatory for polluted environments were found. Some differences observed in structure and numbers, especially of the invertebrate fauna communities, could be associated with the increased fertility of the stream.

Another factor, also associated with the pastoral land use, was a change in the physical parameters in the stream, the differences in water discharges, insolution, and temperature being brought about by the felling of forests. After torrential rains, which frequently occur in the summer, the rainwaters flows rapidly down the bare slopes, giving rise to a flood wave which destroys plant and animal communities. This could explain a decline in the total number of plant and invertebrate fauna in the summer, and disturbances in the seasonal fluctuations of number and structure of biocenoses in streams flowing across pastures. The floods eliminate species, particularly of animals having a longer life cycle, from the biocenoses. However, the species which develop several generations during a year or are characterized by a prolonged development of the mature form, can regenerate a destroyed habitat in a much shorter time. During periods of drought, the reduction of water discharge appeared much earlier in streams draining pasture areas than in those from the forests. This created more favourable conditions for the development of species associated with lenitic habitats.

The action of these two factors causes a poorer stabilization of biocenoses in streams flowing in pasture areas than of biocenoses in forest streams.

4. Aspects of nature protection

The current pastoral land use has not so far drastically affected the quality of the water, though, the first signs of a poorer condition of self-regulation mechanisms in the stream ecosystems can be observed. With a further intensification of the pastoral economy — and this, it seems in inevitable — by the increased application of mineral fertilizers and larger flocks of sheep, a considerable detoriation of the quality of the water in such streams may be expected.

Therefore, the question arises of how this process could be checked. In the first place, in the mountain areas the fertilizers should be divided into small doses and applied several times during the year. This would prevent them from being washed down to the streams with to rainwater. Secondly, the banks of streams having a gradient of more than 10° should be protected by forest belts. Finally, the establishing of sheep

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folds or pens near streams should be avoided in order to prevent pointwise pollution.

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5. Polish summary

Ekosystemy potokowe na terenach pastwisk górskich (Karpaty Zachodnie)

12. Ogólne podsumowanie

W latach 1976—1978 zespół pracowników Zakładu Biologii Wód PAN prowadził kompleksowe badania hydrobiologiczne, mające na celu określenie wpływu wypasu owiec na biocenozy potoków górskich w zlewni górnego Grajcarka (dorzecze Dunajca). Badania prowadzono na trzech stanowiskach: BW1 — w Białej Wodzie, usytuowane tuż poniżej dużego kompleksu leśnego, BW2 — na terenie pastwisk, gdzie wypasy prowadzono systemem tradycyjnym, K2 — w potoku Kamionka, na obszarze pastwisk doświadczalnych IMUZ, gdzie od wielu lat prowadzi się intensywną gospodarkę pasterską, wysiewając na łąki znaczne ilości nawozów sztucznych.

Stwierdzono, że najbardziej korzystny wpływ na czystość potoków górskich ma zlewnia leśna. Spływy z pastwisk zwiększają zawartość związków biogennych w wodzie, co znajduje odzwierciedlenie w zmianach pewnych komponentów biocenozy. Co prawda, na podstawie uzyskanych wyników biologicznych stwierdzono, że w badanych potokach brak organizmów roślinnych i zwierzęcych, które by można uznać za wskaźnikowe dla środowisk zanieczyszczonych, niemniej istniały znaczne różnice w liczebności poszczególnych grup organizmów, w strukturze zespołów tworzących biocenozę, jak również zaobserwowano zaburzenia w sezonowych zmianach liczebności. Przedstawione powyżej zmiany naturalnych biocenoz są spowodowane nie tylko przez wzrost biogenów w wodzie, ale również przez wiążące się z gospodarką pasterską zmiany fizycznych parametrów, takich jak różnice w przepływie wody, oświetleniu i temperatury spowodowane wycięciem lasu.

Pomimo że gospodarka pasterska nie wpływa drastycznie na pogorszenie się jakości wód, to jednak obserwuje się pierwsze sygnały świadczące o osłabieniu mechanizmów samoregulacji w ekosystemie. Dalszy wzrost intensyfikacji gospodarki pasterskiej może doprowadzić do znacznego pogorszenia się jakości wody w tego typu potokach.

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