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Characteristics of the quantitative composition of bottom fauna of the Upper Vistula (southern Poland) against the background of the chemical composition of its water

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Abstract – The present work gives the characteristics of the bottom macrofauna against the background of the changing chemical composition and pollution of the water of the Vistula in a section of about 45 km of its upper course. A fairly rich and differentiated bottom macrofauna was found. The variability in bottom macrofauna throughout the area was the result of changes in the environmental conditions, while the increase in water fertility and pollution corresponded to the rising numbers of Chironomidae and the appearance and increasing numbers of Oligochaeta.

Key words: rivers, ionic composition, nutrients, Chironomidae, Oligochaeta, Trichoptera, Ephemeroptera, Plecoptera.

Charakterystyka składu ilościowego fauny dennej górnej Wisły (południowa Polska) na tle składu chemicznego wody. Praca zawiera charakterystykę makrofauny dennej na tle zmieniającego się chemizmu i zanieczyszczenia wody rzeki Wisły w jej górnym biegu na odcinku około 45 km. Stwierdzono dosyć bogatą i zróżnicowaną faunę denną. Przestrzenne zróżnicowanie makrofauny dennej było konsekwencją zmian warunków środowiskowych, a wzrost żyzności i zanieczyszczenia wody pokrywał się ze wzrastającą liczebnością Chironomidae oraz pojawieniem się i wzrostem liczebności Oligochaeta.

1. Introduction

The bottom macrofauna of the Vistula in the section from its springs to the Goczałkowice Reservoir was described in the papers by Krzyżanek (1986), Dumnicka et al. (1988), and Kasza and Krzyżanek (1993). The above-mentioned authors, however studied only small sections of the river above and below the reservoirs Wisła Czarne and Goczałkowice.

The aim of the present work was the quantitative characterization of the bottom macrofauna against the background of the changing chemical composition and pollution of the water of the Vistula in the section from the confluence of the Biała and Czarna Wisełka streams to the backwaters of the Goczałkowice Reservoir.

2. Study area

The Vistula starts from the confluence of two source streams — the Biała Wisełka and the Czarna Wisełka. The Biała Wisełka originates from numerous small springs situated at an altitude of about 1000 m and collects water from the north - western and western slopes of Mt Barania Góra (alt. 1214 m). These slopes are overgrown by a fir-beech forest with additional spruce. The average gradient of the stream is 82‰, it is 6.7 km long. At an altitude of 560 m the stream flows into the Wisła Czarne Reservoir. The Czarna Wisełka flows out of a number of bogs on the south - western slopes of Mt Barania Góra, at about alt. 1100 m. It than passes through a deep valley, overgrown with spruce forest and flows into the Wisła Czarne Reservoir. An average gradient is 65‰, the stream is 9.3 km long. The Vistula proper flows from the Wisła Czarne Reservoir at an altitude of 530 m and then through the forest for the first 2 km. From the confluence with the Malinka stream it continues through a densely built up area. Sometimes the buildings reach the river banks, but they are usually separated from the river by a vegetation zone (osiers, meadows) and dykes. The river is regulated in the Wisła-Drogomyśl section. It flows into the reservoir Goczałkowice at an altitude of 250.5–255.5 m (the altitude depending on the water level of the reservoir) after covering 41.9 km. The average gradient of this section is 6.7‰.

The Vistula catchment up to the Reservoir Goczałkowice has an area of 532 km^2. The main sources of pollution of the river are the resorts Wisła (5 km), Ustroń Jaszowiec (12 km), Ustroń (20 km), and the little town of Skoczów (27 km), with its car and textile factories and fruit and vegetable processing plants.

The investigations were carried out at 8 sampling stations located along the Vistula course (fig. 1). The stations were selected in such a way as to be representative of a few kilometre sections of the river.

Station 1 — the Biała Wisełka stream, 500 m above the Wisła Czarne Reservoir, alt. about 580 m, width of the stream 5–6 m, the depth 10–60 cm, the bottom covered with cobbles, small areas with stagnant water with a gravelly bottom at the sides, banks with small areas covered with stones, overgrown with spruce-beech forest.

Station 2 — the Czarna Wisełka stream, 800 m above the Wisła Czarne Reservoir, alt. 580 m, width of the stream 3 m, depth 10–60 cm, the bottom covered with stones and boulders, cascades in some places, near the banks areas of stagnant water with a sandy-muddy bottom, steep banks overgrown with spruce forest.

Station 3 — the Vistula, 300 m below the Wisła Czarne Reservoirs, alt. 500 m, width of the river bed 10 m, depth and volume of discharge very variable, depending on the amount of water released from the reservoir, bottom covered with stones overgrown with a thick layer of algae, banks overgrown with alder.

Station 4 — the Vistula below Wisła, 8 km below the dam of the Wisła Czarne Reservoir, alt. 480 m, width of the river bed about 12 m, depth and volume of discharge variable, stony-sandy bottom, steep grass-covered banks.

Station 5 — the Vistula below Ustroń, 18 km below the dam of the Wisła Czarne Reservoir, alt. 368 m, width of the river bed 15 m, depth and volume of discharge variable, stony-sandy bottom, numerous weirs, regulated river banks, overgrown with willow.

Station 6 — the Vistula 1 km below Skoczów and the outlet of sewage from a biological treatment plant, 30 km below the dam of the Wisła Czarne Reservoir, alt. 284 m, width of the river bed 24 m, depth and volume of discharge variable,

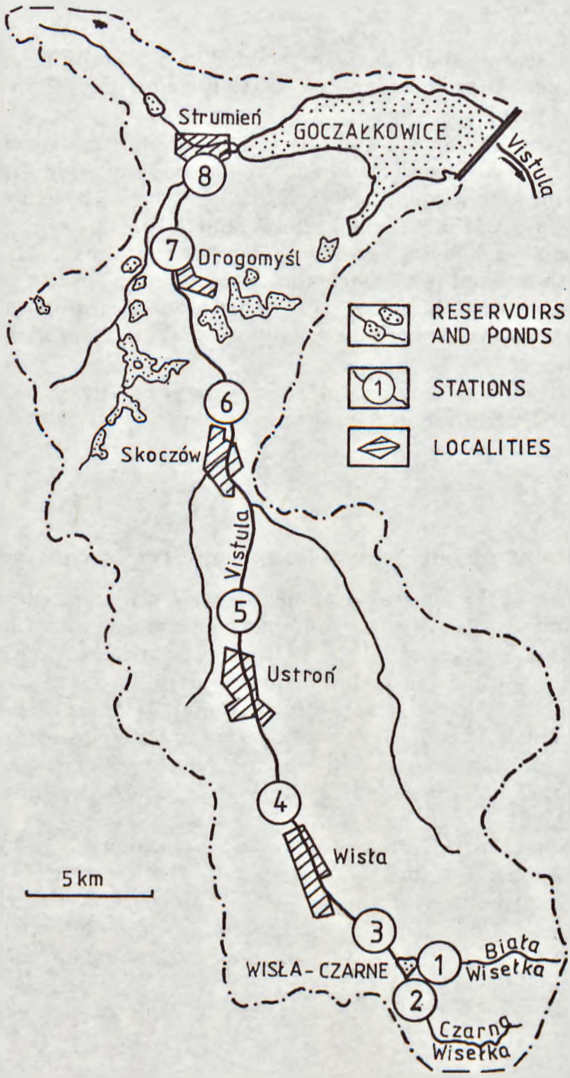

Fig. 1. Location of sampling stations.

stony-sandy bottom, regulated river banks, overgrown with rushes vegetation and willows.

Station 7 — the Vistula at Drogomyśl, 37 km below the dam of the Wisła Czarne Reservoir, alt. 260 m, width of the river bed 25 m, depth and volume of discharge variable, gravely bottom, steep banks, overgrown with willow and alder.

Station 8 — the Vistula at Strumień, 41 km from the dam of the Wisła Czarne Reservoir, alt. 255 m, width of the river bed 28 m, muddy bottom, the depth variable, about 2–3 m, dyked banks, overgrown with willow, very slow current, inflow of backwaters of the Goczałkowice Reservoir.

3. Material and methods

Physico-chemical water analyses were carried out according to the methods suggested by Just and Hermanowicz (1964), Golterman and Clymo (1969), and Hermanowicz et al. (1976).

The material for the bottom macrofauna investigation was collected from stony and sandy bottoms from an area of 500 cm^2 using a 20 cm wide dredge and from a muddy bottom using an Eckman type grab (5 samples with an area of 100 cm^2 each) on four dates in 1991: 5.03, 15.05, 29.07, and 1.10.

The samples were washed in a net with an 0.5 mm mesh. The selected live invertebrates were than fixed in 4% formalin. The obtained results were calculated per 1 m^2. The number and biomass were estimated according to the methods applied in the investigation of bottom macrofauna of the Goczałkowice Reservoir (Krzyżanek 1991).

A statistical analysis was carried out on the basis of The Statistical Graphics System "STATGRAPHICS" computer program.

4. Results

4.1. Characteristics of physico-chemical parameters of the Vistula (fig. 2)

The Vistula in its upper course (Stations 1, 2, 3) was characterized by a low degree of water mineralization, small content of organic matter (oxidability), and low degree of pollution, expressed by the BOD_5 indicator, and a comparatively low concentration of nitrogen and phosphorus compounds.

The Vistula collects waters from a recreational - touristic and moderately industrialized area below Station 3. A gradual rise in the concentration of mineral salts and nutrients was observed in this section of the river (Stations 4 and 5). Water richest in nutrients was found in the Vistula below the industrial town of Skoczów (Station 6).

Before its inflow to the Goczałkowice Reservoir (Stations 7 and 8) the Vistula flows over arable areas, not densely inhabited. The quantities of electrolytes defining the ionic composition of the water in this part of the river increased slightly in relation to Station 6. The concentration of organic matter (oxidability) and the value of BOD_5 also increased. However, the amount of nitrogen and phosphorous compounds decreased.

Oxygenation of the water at all the stations was high, oxygen saturation being within the range 70–110%.

4.2. Faunal characteristics

The greatest density of bottom macrofauna was found in May, when it amounted to 20700 ind. m^{-2} at Station 6 with a biomass of over 30 g m^{-2}. The lowest density of bottom macrofauna was in March at Station 6 when the numbers amounted to 900 ind. m^{-2}, and the biomass to 5 g m^{-2}. Throughout the period of investigation Chironomidae larvae formed the dominant group, especially at Station 6. Ephemeroptera (Stations 1, 4, and 7) and Trichoptera (Stations 1, 4, and 5) also occurred fairly numerously.

The differentiation of bottom macrofauna in the area is presented in fig. 3. At Station 1 Trichoptera, Plecoptera, and Chironomidae dominated, and periodically also Ephemeroptera and Gastropoda (*Ancylus fluviatilis* Müll.). Station 2

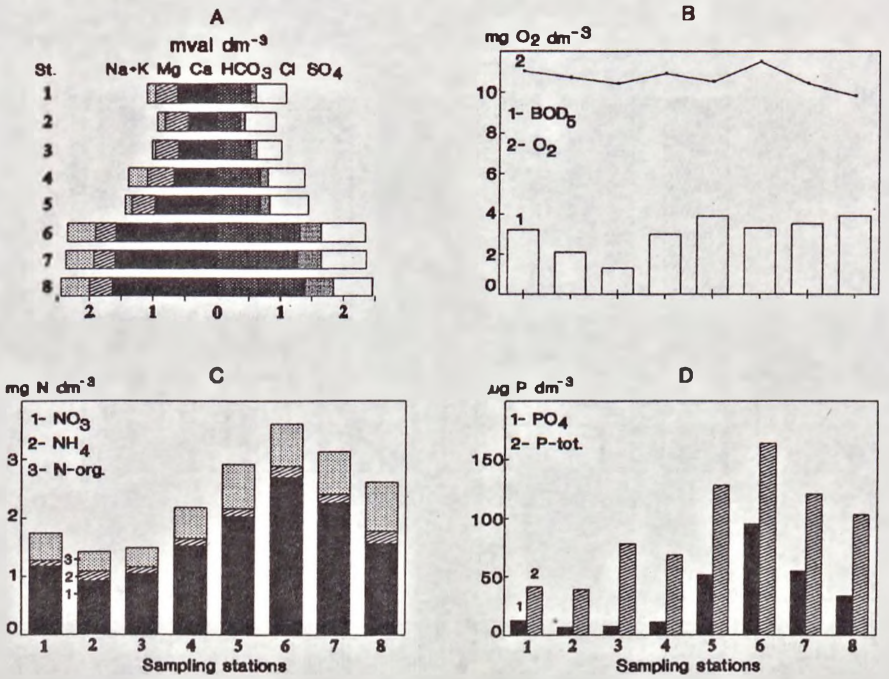

Fig. 2. Mean values of ionic composition of the water of the Vistula (A), values of BOD_5 (B;1), and oxygen concentrations (B;2), concentrations of the forms of nitrogen (C) and phosphorus (D).

represented the poorest section of the river, for only Plecoptera and Chironomidae periodically occurred in slightly greater numbers, but rarely exceeding 200 ind. m^{-2}. Amphipoda (*Gammarus fossarum* Koch.) and Chironomidae were of decicive importance at Station 3. Station 4 had a much richer bottom macrofauna than the preceding two stations consisting mainly of Chironomidae. At Station 5 the macrofauna was slightly less numerous, but its biomass was the greatest among all the stations. Snails (Gastropoda — *Ancylus fluviatilis*) and other faunal groups, e.g. Simuliidae, not included in the list, constituted the great biomass. With regard to the number of individuals, Station 6 had the richest bottom macrofauna, in which Chironomidae larvae decidadly dominated. Oligochaeta were also more numerous, especially on 5 March, when they constituted over 50% of the whole bottom macrofauna. Periodically, Trichoptera and representatives of such groups as Hirudinea, Simuliidae, Megaloptera (Sialidae — not included in the list) were noted in greater numbers. The numbers of bottom macrofauna at Station 7 were much poorer. Apart from Chironomidae, Ephemeroptera and Trichptera occurred more numerously. The bottom macrofauna at Station 8 consisted almost entirely of Chironomidae larvae, typical of stagnant waters, mainly *Chironomus* sp. (? *Chironomus plumosus* L.) and Oligochaeta. Only in July did Ephemeroptera and Gastropoda (*Lymnea peregra* Müll.) also occurr at this station.

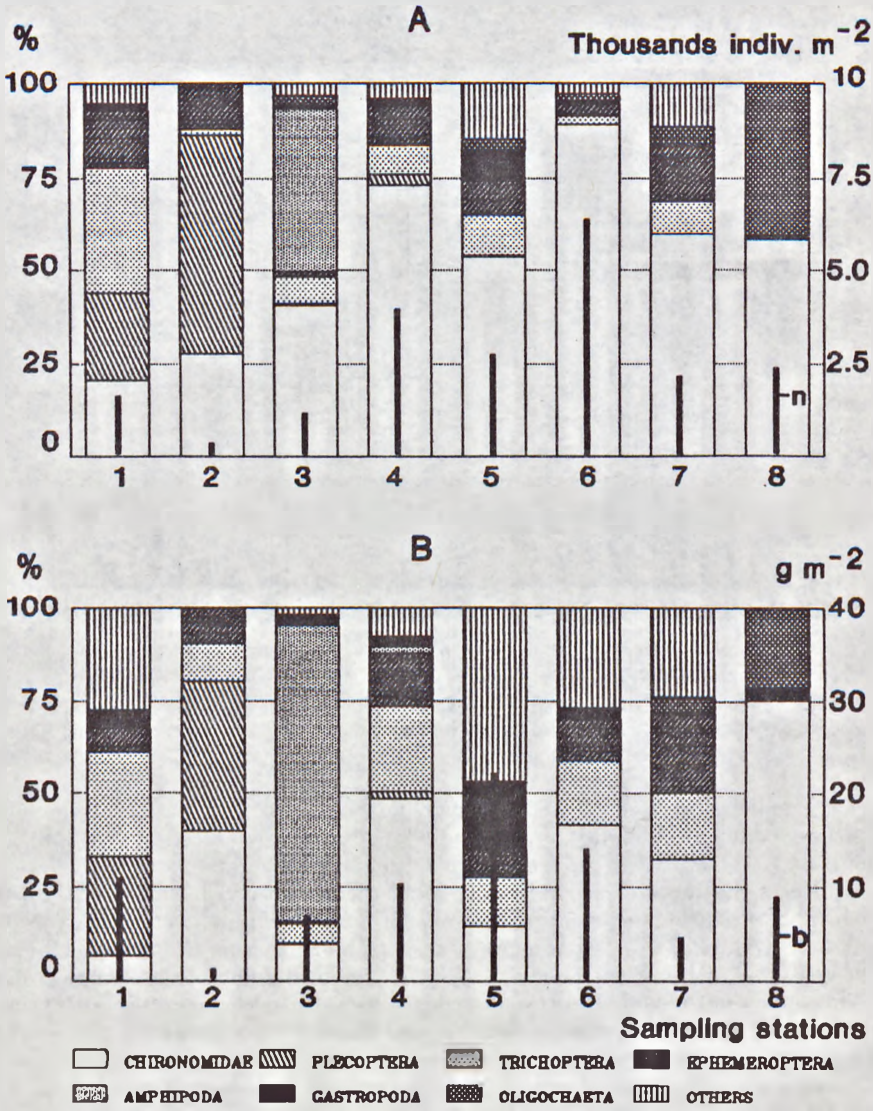

Fig. 3. Percentage share of the particular groups in numbers (A), biomass (B), density (A;n) and biomass (B;b) of bottom macrofauna.

4.3. Interdependences between the bottom macrofauna and chemical composition of the Vistula

The described differences and the increased numbers of Chironomidae larvae at particular stations coincided with an increase in the concentrations of nitrates and phosphorus forms and showed a correlation at $p = 0.05$ (fig. 4 A–C). A similar

interdependence (at the same significance level) was observed for the mutual relations between the abundance of oligochaetes and the resources of organic compounds in the water. It was found that the higher the value of oxidability, the greater the numbers of Oligochaeta (fig. 4 D).

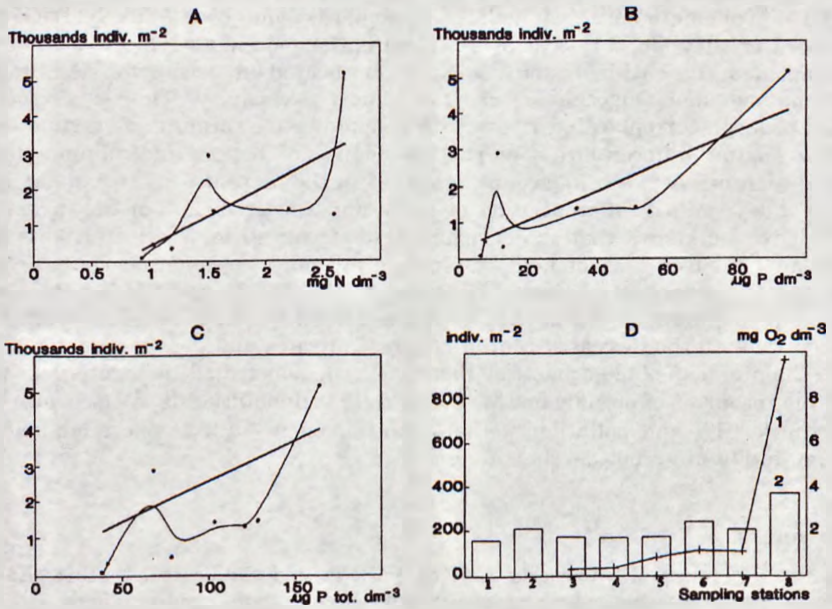

Fig. 4. Mean numbers of Chironomidae in the Vistula against the background of the mean concentration of nitrates (A), phosphates (B) and total phosphorus (C) (straight lines define the calculated trend), and mean density of Oligochaeta (D;1) against the background of the mean oxidability (D;2).

5. Discussion

The groups of bottom macrofauna of streams and rivers and their mutual proportions often reflect the trophic state of the water and their degree of pollution. In the flows of natural type (i.e. not yet undergoing strong anthropopressure) there live, apart from Diptera (among them especially Chironomidae), many stoneflies (Plecoptera, numerous especially in clean and cold montane streams), mayflies (Ephemeroptera, preferring clean but rather not cold waters and therefore occurring numerously in the lower course of streams and rivers), and caddisflies (Trichoptera, abundantly settling streams and rivers along their whole course). In the lower course of streams and rivers, especially in polluted sections, oligochaetes (Oligochaeta) develop in masses. The more fertile the rivers, or more polluted with organic compounds, the greater the numbers of oligochaetes (Szczęsny 1991). Thus, the differentiation in occurence of the bottom fauna throughout the area is usually the result of the differentiation of environmental conditions (Kajak 1988).

The invertebrate fauna in the source streams of the Vistula (Stations 1 and 2) was diverse and represented by four groups occurring in different proportions. The numbers and structure of zoocenosis at these stations were typical of clean streams.

The differences were mainly caused by a dissimilar geological structure and hence chemical composition of the water. At Station 3, situated below the Wisła Czarne Reservoir, amphipoda (Gammaridae) and Chironomidae dominated. This is a zoocenosis typical of rivers below dam reservoirs situated in montane streams. Chironomidae was the dominant group from Stations 4 to 7. The contribution of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddis flies (Trichoptera) decreased or they did not occur at all. Here is the zoocenosis typical of a markedly eutrophicated river with a stony substratum covered in periphyton. At Station 8 Chironomidae and Oligochaeta occurred almost exclusively. This is a zoocenosis typical of large eutrophicated rivers with a muddy substratum and stagnant water.

The spatial differentiation of the abundance of bottom macrofauna and the mutual relations between its groups described in the present work are in accordance with the determined differentiation of biotic and abiotic factors of the investigated river. It is also known that the enrichment of stream waters with nutrients brings about an increased development of microflora, and, consequently, changes in the structure of invertebrate animals (Szczęsny 1991). The increase in numbers of the Chironomidae larvae at the particular stations described in the present work was in accordance with the increased concentration of nitrates and phosphorus (fig. 4 A–C), while the numbers of oligochaetes (Oligochaeta) demonstrated their interdependence with the resources of organic matter in the river (oxidability) (fig. 4 D). It also shows that the fertilty and pollution of the Vistula explicitly affects the abundance and differentiation of its bottom macrofauna.

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