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# Diversity of benthic macroinvertebrates as a monitoring method for polluted rivers*

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**Abstract** – On the basis of publications concerning several Polish rivers, the effect of sewage on benthic invertebrate diversity was estimated. This effect was observed above and below the sewage input, and also with time. Increased pollution causes significant impoverishment of benthic invertebrate diversity, or even the disappearance of whole systematic groups. The best indicators are Ephemeroptera, Plecoptera, and Trichoptera. The worst is the Chironomidae family, because the differences in numbers of these organisms between clean and polluted rivers are not significant. The diversity of Mollusca changes slightly or not at all. Diversity and abundance of Oligochaeta may increase in more polluted waters. Hence, that of biodiversity can be an effective method of river monitoring.

**Key words:** biodiversity, benthic macroinvertebrate, river, pollution, biomonitoring.

## 1. Introduction

Although, the idea of biodiversity has been known for a long time, it has become very popular in recent years, both also as a scientific term and in social and political discussions on environmental protection (Gliwicz 1992, Głowaciński 1994, Hawksworth 1996, Hilbricht-Ilkowska 1998). Biodiversity in the broad sense, means variety and variation of all the life forms on Earth. The problem of biodiversity can be analysed at several levels:

1. Genetic level – diversity within species: this includes different populations of the same species with genetic variations within the population.

2. Species level – may be considered on the basis of:

a) species richness – number of species in a certain area(s);

b) dominance – the degree of species differentiation within the community refers to the fact that not all species are equally important in determining the nature of the community;

c) diversity index – in the general sense, it is S/N or in modified version S/logN ratio where S is the number of species/taxa and N their abundance.

3. Ecosystem level – the distribution of ecological units (communities, ecosystems) in a given area.

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The aim of the present work was to prove that biodiversity can be a good method of monitoring water quality in rivers. In the present work species diversity was used. The effect of pollution was considered as changes in space observed above and below the sewage discharge, as well as changes in time under increased pollution in a particular reach of a river. In the present work, the results of other publications were used, both those describing the effect of sewage on the benthic community in some Polish rivers, and also long-term studies on pollution in chosen reaches of the Rivers Vistula and Dunajec.

## 2. Data and conclusions

### 2.1. Changes above and below the sewage discharge

The results of works dealing with changes in benthic fauna in the following six Polish rivers and streams of different type observed above and below the sewage input were used:

1. Rybi Potok stream – a high-mountain stream in the Tatra National Park, with stony bottom, rapid, turbulent flow, water well oxygenated, where in the 1970s there was an inflow of raw sewage from the tourist shelter "Morskie Oko" (Kownacki 1977). Below the sewage inflow, the numbers of Trichoptera, Plecoptera, and Ephemeroptera decreased considerably (Fig. 1). Chironomidae taxa at polluted sites were also lower, although this difference was less significant. The richness of Oligochaeta species was higher below the sewage inflow source.

2. Kryniczanka stream – a mountain stream, with stony bottom, rapid turbulent flow, water well oxygenated, partly regulated, with sewage inflow from the Krynica health resort (Szczęsny 1974). In the Kryniczanka stream the numbers of taxa of all benthic fauna were considerably lower in polluted parts of the stream; Amphipoda and Plecoptera species were not found at all, while only one Trichoptera species from 20 known was detected (Fig. 1). Only Oligochaeta and Mollusca had the same species richness above and below the sewage inflow.

3. River Dunajec – a big mountain river with stony bottom, rapid turbulent flow, water well oxygenated (Szczęsny 1995). The differences between the polluted reach of the river below the town Nowy Targ (municipal and industrial sewage) and that situated 30 km below (the Pieniny National Park) were not so significant, although the numbers of taxa were lower below the pollution point source, with the exception of Mollusca (Fig. 1).

4. Prądnik stream – a highland stream, flowing through the Ojców National Park with rapid flow, well-oxygenated water, and bottom covered with small stones, sand, and mud. In the 1970s there was a sewage inflow from a dairy (Dratnal 1976). In this stream the number of taxa was always smaller below the sewage inflow (Fig. 2). The only difference was in Amphipoda (*Gammarus* sp.), which occurred in this stream below and above the pollution source. This group is characteristic of the fauna of calciferous running waters.

5. River Warta – a big lowland river with sandy bottom and laminar flow, with the inflow of municipal and industrial sewage from the city of Poznań (Biesiadka and Kasprzak 1977). In the River Warta below Poznań the number of taxa of most of the systematic groups decreased, while that of Oligochaeta and Odonata increased (Fig. 2). It should be pointed out here that only in this river did the number of Chironomidae below the pollution inflow increase significantly.

6. River Łyna – a lowland river with muddy bottom, laminar water flow, sometimes with oxygen deficiency, with the inflow of sewage from the city Olsztyn

(Wielgosz 1979). Below Olsztyn the number of taxa of all groups was smaller than above the city, and some groups were absent. The number of Chironomidae taxa was similar at the two sites (Fig. 2).

In each described river or stream, without regard to their character (a high mountain stream or a lowland river), the number of taxa at the site situated below the sewage discharge was decreased (Table I). The smallest changes were noted in the River Dunajec (15.5% decrease), while the greatest were observed in the Kryniczanka stream and the River Łyna (64.1 and 54.7%, respectively). On the other hand, fauna abundance was greater at the polluted stations. In the Łyna it was increased 12 times, in the Kryniczanka – twice. When the diversity index is calculated it is clearly seen that it is smaller at sites with polluted waters.

Table I. Effect of pollution on invertebrate species diversity in chosen Polish rivers and streams.

| Rivers and streams | Species Richness (S; number of species) | | | Density (N; ind. $m^{-2}$) | | Diversity Index (D = S/log N) | |
|---|---|---|---|---|---|---|---|
| | Clean | Polluted | Decrease (%) | Clean | Polluted | Clean | Polluted |
| Rybi Potok[a] | 79 | 50 | 36.7 | 25875 | 118125 | 17.90 | 9.85 |
| Kryniczanka[b] | 167 | 60 | 64.1 | 59175 | 126175 | 34.99 | 11.76 |
| Dunajec[c] | 116 | 98 | 15.5 | 15500 | 93149 | 27.68 | 19.72 |
| Prądnik[d] | 120 | 68 | 43.3 | | | | |
| Warta[e] | 83 | 52 | 37.3 | | | | |
| Łyna[f] | 95 | 43 | 54.7 | 2860 | 35410 | 27.48 | 9.45 |

[a] Kownacki 1977; [b] Szczęsny 1974; [c] Szczęsny 1995; [d] Dratnal 1976; [e] Biesiadka and Kasprzak 1977; [f] Wielgosz 1979.

## 2.2. Changes in time

The river pollution process may change in time. In the Vistula above Cracow it is possible to observe the changes in water chemistry which took place within the last 100 years (Kownacki 1997) and in the fauna composition within the last 50 years (Starmach1948, Zięba and Zaćwilichowska 1966, Dumnicka and Kownacki 1988). It was possible to make a similar comparison in the River Dunajec (Dratnal and Szczęsny 1965, Dratnal et al. 1979, Szczęsny 1995).

In the Vistula above Cracow at the end of the 19th century, the water was clean. The inflow of sewage from the Upper Silesian region led to this reach of the Vistula being now the most polluted part of Polish rivers. There were also substantial changes in the composition of benthic invertebrate fauna (Table II). The numbers of fauna rose because there was an increase in the contribution of Oligochaeta and a decrease in other groups. Animals belonging to Porifera, Ephemeroptera, Plecoptera, Odonata, and Trichoptera disappeared from the mentioned part of the river and 24 taxa are from that reach extinct (Table III).

Benthic fauna of the River Dunajec between Nowy Targ and the Pieniny Mountains is among the best investigated in Poland. Detailed studies have been carried out from the beginning of the 1960s until now. In this period the water quality decreased. In the 1960s the Dunajec had waters of I class of purity, while now it belongs to II class or periodically to the III class (Kownacki and Starmach 1989). Also the diversity of benthic fauna changed in this river (Table IV). In the

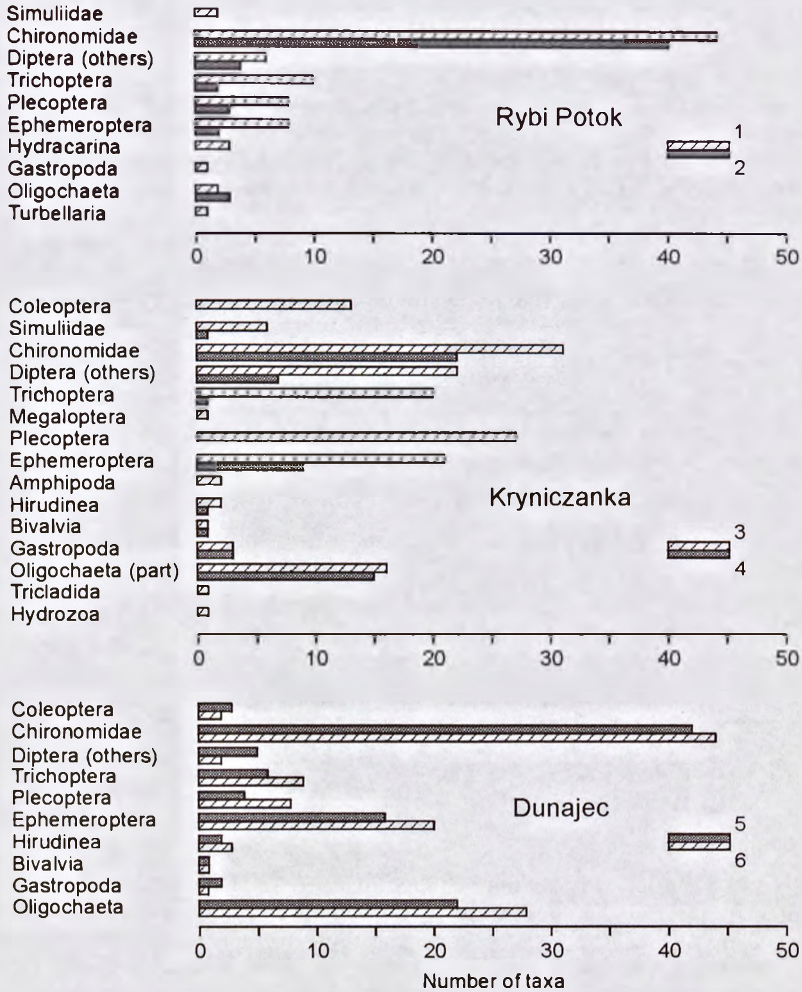


Fig. 1. Composition of macrofauna in the Rybi Potok stream (the Tatra National Park) at the sewage discharge (1) and 3 km below it (2) (after Kownacki 1977), in the Kryniczanka stream above (3) and below (4) the sewage discharge from Krynica health resort (after Szczęsny 1974), and in the River Dunajec at the sewage discharge from Nowy Targ (5) and 30 km below in the Pieniny National Park (6) (after Szczęsny 1995).

1960s the number of Ephemeroptera, Plecoptera, Trichoptera species and even Oligochaeta was higher when compared with the 1990s. Only in the number of taxa of Chironomidae was no significant change.

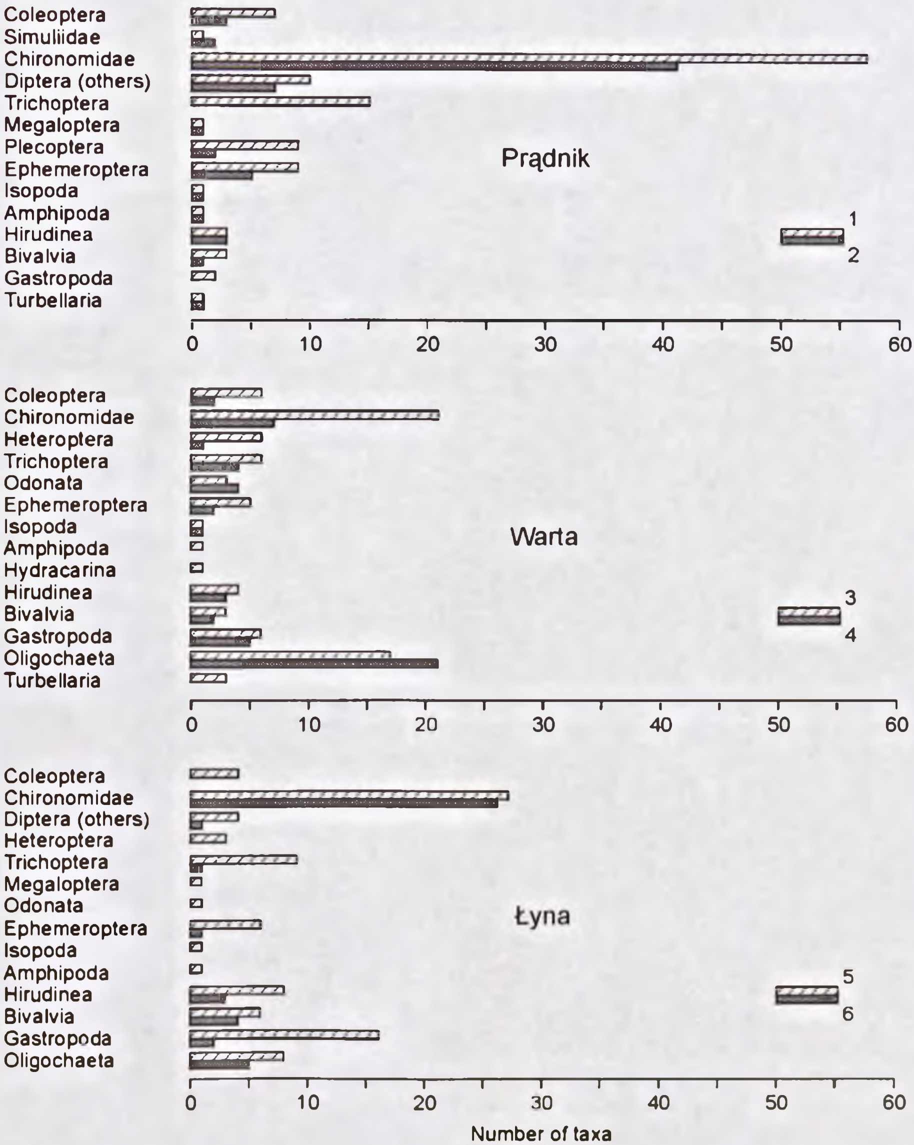


Fig. 2. Composition of macrofauna in the Prądnik stream (the Ojców National Park) above (1) and below (2) the sewage discharge from the dairy (after Dratnal 1976), in the River Warta above (3) and below (4) the discharge of sewage from Poznań (after Biesiadka and Kasprzak 1977), and in the River Łyna above (5) and below (6) the discharge of sewage from Olsztyn (after Wielgosz 1979).

Table II. Changes during 40 years in abundance and composition of benthic macrofauna in the Vistula above Cracow.

| Taxa | Bottom substrate | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Stones | | | | Sand | | | |
| | 1942/1943[a] | | 1982/1983[b] | | 1942/1943[a] | | 1982/1983[b] | |
| | ind. $m^{-2}$ | % | ind. $m^{-2}$ | % | ind. $m^{-2}$ | % | ind. $m^{-2}$ | % |
| Oligochaeta | 3000 | 56.68 | 30018 | 80.16 | 55600[c] | 90.35 | 275953 | 99.93 |
| Chironomidae | 1200 | 22.67 | 6745 | 18.01 | 2100[c] | 3.43 | 183 | 0.07 |
| Hirudinea | 240 | 4.53 | 440 | 1.17 | | 0 | | 0 |
| Gastropoda | 200 | 3.78 | 245 | 0.65 | | 0 | | 0 |
| Ephemeroptera | 500 | 9.45 | | 0 | | 0 | | 0 |
| Trichoptera | 60 | 1.13 | | 0 | | 0 | | 0 |
| Plecoptera | 5 | 0.09 | | 0 | | 0 | | 0 |
| Odonata | 8 | 0.15 | | 0 | | 0 | | 0 |
| *Asellus aquaticus* L. | 80 | 1.51 | | 0 | | 0 | | 0 |
| Ceratopogonidae | | 0 | | 0 | 3400[c] | 5.56 | | 0 |
| Others | | 0 | | 0 | 100[c] | 0.16 | | 0 |
| Total | 5293 | | 37448 | | 61200[c] | | 276136 | |

[a] after Starmach 1948; [b] after Dumnicka and Kownacki 1988; [c] recalculated values (in Starmach 1948 they were in ind. $L^{-1}$)

Table III. Species extinct in the Vistula between Oświęcim and Cracow during the last 100 years (after Kownacki 1999).

| | |
|---|---|
| PORIFERA | PLECOPTERA |
| *Spongilla lacustris* (L.) | *Nemura* sp |
| *Ephydatia fluviatilis* (L.) | *Perlodes* sp |
| *Eunapius fragilis* (Leidy) | *Perla* sp |
| | |
| OLIGOCHAETA | HETEROPTERA |
| *Propappus volki* Michaelsen | *Corixa* sp |
| | |
| EPHEMEROPTERA | TRICHOPTERA |
| *Baetis fuscatus* (L.) [= *B. bioculatus* L.] | Rhacophilidae |
| *Centroptilum luteolum* (O.F. Muller) | Hydropsychidae |
| *Cloeon dipterum* (L.) | Leptoceridae |
| *Ecdyonurus dispar* (Curtis) [= *E. fluminum* Pictet)] | |
| – *isignis* (Eaton) | MEGALOPTERA |
| – *venosus* (Fabricius) | *Sialis* sp. |
| *Heptagenia coerulans* Rostock | |
| – *flava* Roztock | |
| – *sulfurea* (O.F. Müller) | |
| *Ephemerella ignita* (Poda) | |
| *Caenis luctuosa* (Burmeister) [= *C. moesta* Bengtsson] | |
| *Paraleptophlebia submarginata* (Stephens) | |
| *Habroleptoides confusa* Sart. et Jacob | |

Table IV. Changes occurring in the species richness in the River Dunajec below Nowy Targ during the last 30 years (after Dratnal and Szczęsny 1965, Dratnal et al. 1979, Szczęsny 1995).

| Taxa | Years of investigations | |
|---|---|---|
| | 1963–1973 | 1993–1994 |
| Oligochaeta | 42 | 33 |
| Ephemeroptera | 46 | 22 |
| Plecoptera | 23 | 10[a] |
| Trichoptera | 19 | 11 |
| Chironomidae | 68[b] | 67[b] |

[a] in most cases only genera of Plecoptera were determined at this time
[b] it is not always possible to determine Chironomidae larvae to the species level

### 2.3. Conclusions

These examples showed that biodiversity can be an effective method of river monitoring. Increased pollution causes significant impoverishment of benthic invertebrate variety, and even the disappearance of whole taxonomic groups. The best indicators are: Ephemeroptera, Plecoptera, and Trichoptera, the worst being Chironomidae, the difference in their number between clean and polluted rivers not being significant. Diversity of Mollusca is changing slightly if at all, while variety and number of Oligochaeta increase in more polluted waters.

Using this method it should be remembered that a river is not a uniform ecosystem and its taxa number is not constant. The decrease in species richness may be the effect not only of pollution but may also depend on the type of a given ecosystem. In unpolluted high mountain streams the number of benthic macroinvertebrates ranges from a few to a dozen species. Similarly, the species diversity of headwater streams or unpolluted sandy lowland rivers is markedly smaller than in polluted stony, submontane rivers.

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