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ECOLOGICAL CONDITION OF SMALL WATER RESERVOIRS OF WDZYDZE LANDSCAPE PARK (NORTHERN POLAND) BASED ON MEIOBENTHOS ASSEMBLAGES ANALYZES

Barbara Wojtasik

HydroBiolLab – firma naukowo-badawcza i laboratorium hydrobiologiczne
hydrobiollab@wp.pl

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Summary. The assessment of the ecological status of small water reservoirs of different types, located in the area of Wdzydze Ladnscape Park (northern Poland) was based on major meiobenthic taxa analysis. The study on the state of the bottom sediments and possible to assess the stage of development of the reservoir: the development of trophy, the maximum eutrophication, degradation. The conducted research method uses a new algorithm for the balance of organisms in an assemblages identified as B_W. The research found that a small area we can conclude reservoirs of low, medium and good ecological status. This assessment does not reflect water quality analysis. The study of pH and C waters for the same positions indicate different results obtained by the analysis of physical and chemical parameters and meiobenthos. Ecological status assessment relates to the quality of sediments, not the quality/class of water purity. The applied method for assessing the ecological status allows for quick screening study data. This is extremely helpful in focusing research on reservoirs that require special attention and performance analysis of the ecological status in a wider range.

Key words: freshwater reservoirs, meiobenthos, 3D analysis, ecological status, monitoring

INTRODUCTION

Analysis of the ecological status of fresh water reservoirs, particularly sediments, is a difficult and complex problem. There is as yet standardized method that would allow for the assessment of the ecological status of water bodies, both small and large lakes. In the case of small water reservoirs of small capacity makes them more vulnerable to human pressure, changes in weather conditions than the big lake. Because of the random research and very extensive literature on the subject it is difficult to present the results obtained to the situation prior to the period of intensification of agriculture (pesticides, herbicides, insecticides), commercial fish farming and, as well as effects related to the general tourism, automotive and fashion new/invasive organisms to a variety of garden ponds leak into the environment. Biomarkers used based on the analysis of macrobenthos [Kownacki 2000a, b, Kownacki *et al*. 2003, Czerniawska-Kusza 2005, Czerniawska-Kusza and Szoszkiewicz 2007, Klimarczyk and Trawiński 2007], but are impossible to use as an universal bioindex. This is due to the properties of macrobenthos, namely the majority of the group of organisms used in the assessment of environmental constitute insect larvae that occur seasonally, which limits the duration of the study. In addition, the organisms are relatively large, often occur in assemblages and are actively on the move. Therefore, they do not show differences of sites located within a short distance. In the case of small reservoirs, the situation is even more complicated because a number of macrobenthos taxa/individuals in this type of reservoirs occurs in a small number or occasionally, or not at all.

In order to assess the ecological status of small fresh water reservoirs near lake Wdzydze used meiobenthos [Wojtasik 2010, 2013a, b], an assemblage of organisms commonly found in all types of waters. Meiobenthos assemblages is composed of small aquatic invertebrates of different systematic assignment. Most accepted criterion is given as the limits of dimensions 0.042–1 mm [Pfannkuche and Thiel 1988]. The following are the freshwater meiobenthos various ranks of the regular invertebrates: Turbellaria, Rotifera, Nematoda, Oligochaeta, Conchostraca, Cladocera, Copepoda, Ostracoda, Collembola, including among other things Insecta larvae Diptera, Trichoptera, Ephemeroptera, Arachnida, Tardigrada, Gastropoda and Bivalvia.

Part of major meiobenthic taxa is constant (present by virtue of size and bind with an aqueous medium throughout the ontogeny), while a part of meiobenthos operating (changing the size of the body, and also by the lack of binding with an aqueous medium for the entire duration of development). Meiobenthos organisms are a separate functional group and a functional group are a sensitive indicator of change in the aquatic environment [Warwick 1990, Särkkä 1992]. Many species belonging to the group of animals were used as bioindicators [Mezquita *et al*. 1999, Walker *et al*. 2002, Martins *et al*. 2007]. The meiobenthos belong pioneering taxa resistant to changing or extreme physical and chemical conditions [Wiśniewska-Wojtasik and Walczak 2005, Wojtasik and Cieszyńska 2008], many of which appear in very different aquatic environments [Wojtasik 2007, Wojtasik *et al*. 2009] as eutrophic or polluted water bodies [Joiners and Wojtasik 2008, Wojtasik and Mioduchowska 2010]. In addition, meiobenthic taxa react to local changes in environmental conditions by creating specific, characteristic groupings for specific small area [Wojtasik *et al*. 2009, 2010, 2013a, b).

Conducting research based on meiobenthic assemblages enables a fast sort reservoirs tested for their similarity and ecological status. The method allows to determine the degree of purity/degradation of closely spaced groups of reservoirs and/or a similar hydrological types. Method for assessing the ecological status based on the analysis of major meiobenthic taxa previously tested for various freshwater reservoirs, including Czorsztyński and Sromowiecki dam reservoirs [Wojtasik 2010, 2013b], lakes of Zaborski Landscape Park [Wojtasik 2010].

MATERIAL AND METHODS

The study included 11 small fresh water reservoirs with different characteristics: the reservoir of the buildings in the village Wdzydze Tucholskie, reservoirs surrounded by a forest, in the village Borsk: a small source pond, meadow draining channel now almost completely dried up, pond in the meadow, bend dammed a small, slow current river, small and shallow lakes: Chądzie, Głuchówko, Kotel. The approximate location of the positions shown in Figure 1.

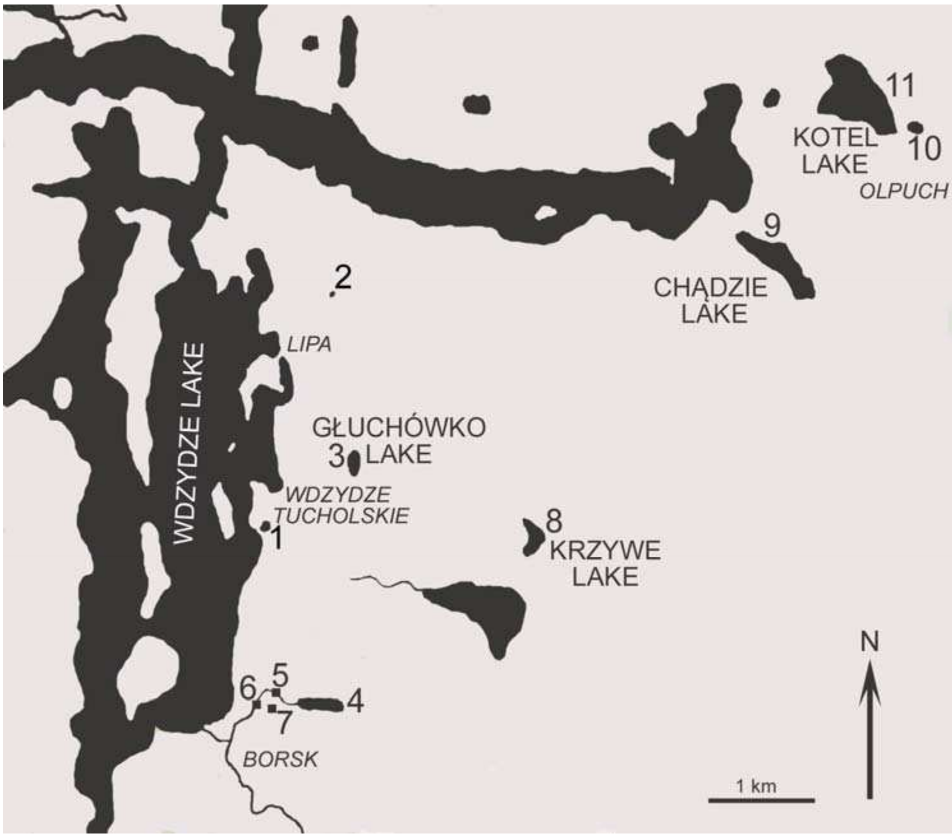

Fig. 1. Sampling station

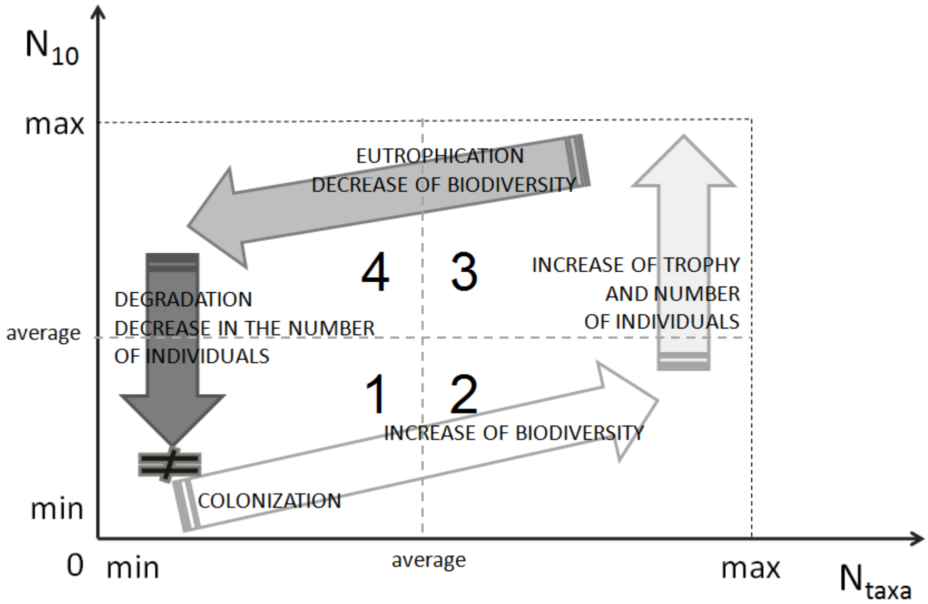

Fig. 2. Course of changes in abundance and taxonomic diversity occurring with the development of the fresh water reservoir until it is degraded diagram shows four areas: 1 – low density of settlement and low biodiversity (the area in initial stage of development or degraded), 2 – low density settlement, high biodiversity (area relatively stable, mostly low-trophic, at steady state), 3 – high density settlement and high biodiversity (reservoir reaches the maximum level of eutrophication, the balance may be upset and will further increase eutrophication – degradation), 4 – high settlement density, low biodiversity (progressive degradation of sediment)

Samples were collected on 7–14 September 2013 tests for quantitative and qualitative analyzes were collected tube with a diameter of 2.5 cm from the surface sediment layer (0–10 cm), for each position of 3 repetitions. Samples were preserved in 70% ethanol and stained with rose bengal (Rose Bengal sodium salt, Sigma No. R3877-5G). The prepared material after washing on a sieve with a mesh of 0.042 mm was subjected to detailed analysis in terms of which the major meiobenthic invertebrates. The analyzed material was flushed out of the frame using a mesh of 1.0 mm to separate meiobenthos of macrobenthos. The samples were analyzed using a stereomicroscope. To assess the size of the animals were used including Petri dish with grids of 1 and 2 mm. Invertebrates that periodically occur in meiobenthic assemblages (Turbellaria, Oligochaeta, larvae of Insecta, Mollusca) and their dimensions theoretically allowed to pass through the mesh with a mesh of 1 mm were included into meiobenthos. All representatives of the permanent meiobenthic invertebrates (Rotifera, Ostracoda, Copepoda, Cladocera) counted irrespective of the dimensions to meiobenthic assemblages. To complement the research meiobenthic analysis measured two basic physical and chemical parameters: pH and electrolytic conductivity C.

Analyses were performed based on the developed methodologies for assessing the ecological status by meiobenthos assemblages [Wojtasik 2010, 2013a, b), which for a two-dimensional analysis of the abbreviated form shown in Figure 2. Analyses are conducted for the relative scale taking into account the minimum, maximum on the parameters in the obtained results: N_{10} – the number of individuals per 10 cm^2, N_{taxa} – number of identified major meiobenthic taxa. Arithmetic means calculated for maximum and minimum values of both parameters, the boundaries of the intervals (Fig. 2). Also included is a new algorithm developed B_W [Wojtasik 2013b] to calculate the balance of taxa present in the assemblage. The algorithm used is different from that previously used such as the Shannon-Wiener index, Pielou, Margalef, Simpson. These indicators mathematical impose restrictions not allowing for placement in the analysis of a single taxon/individual (because of the use of logarithms, or the possibility of a 0 in the denominator, as a result of the calculating). The proposed algorithm does not impose any restrictions on mathematical calculations. The maximum value is 1, while the minimum is 0 for one taxa in assemblage or greater than 0, the value B_W ratio is in the range [0, 1]. Letter B outlining the index is derived from the word balance. The index W is derived from the initial name of the author, due to the use of names previously indicators related to the author's name. B_W factor is described by the following formula:

$$B_w = 1 - \sum_{\substack{i, j \in (N) \\ nj \geq ni \\ 0 \leq \ldots \leq ni \leq nj \leq \ldots \leq nM \leq N \\ k = 1; 2; \ldots; M-1}}^{N} \frac{(n_j - n_i)}{kN}$$

where:
N – number of all individuals in the sample,
n_i, n_j – number of individuals of the *i*-th and *j*-th taxon,
$0 < \ldots \leq n_i \leq n_j \leq \ldots \leq n_M \leq N$, where M – number of taxa in one sample.

Taxa are ranked in the order of increasing number of individuals in the following groups in order to distinguish from N – number of individuals, in this case (N) denotes a natural number.
k – depend of number of taxa group
k = 1 for $(n_M - n_{M-1})$
k = 2 for $(n_{M-1} - n_{M-2})$
………………
k = M-1 for $(n_2 - n_1)$.

B_W indicator assumes a maximum value equal to 1 when all the taxa present are represented by the same number of individuals. The lower the ratio, the stronger is the dominance of one of the taxa. The value of the maximum and minimum B_W is the extent of our audit. The arithmetic average of the maximum and minimum values of the border ranges between equilibrium and its absence in the meiobentic assemblages.

RESULTS AND DISCUSSION

The collected material has been identified in 11 major meiobenthic taxa (Tab. 1). The maximum number of taxa found at one station was 7 (station No. 1 in the village Wdzydze Tucholskie), and the minimum 2 (bog located in a forest near the village Lipa). Maximum density (number of individuals/10 cm^2) was 200 (station No. 1), and the minimum 7.5 (station No. 5, meadow draining channel near the village of Borsk). The maximum value of the equilibrium ratio is 0.91 (station No. 5), and a minimum 0.19 (station No. 9, Chądzie Lake). Details of all the positions shown in Table 2.

Table 1. Number of individuals and major meiobenthic taxa, parameters: pH and C for each stations

Taxa	Station/number of individuals										
	1	2	3	4	5	6	7	8	9	10	11
Turbellaria	75		21	6			7			22	10
Nematoda	36		102	8	3	7			2	7	15
Oligochaeta	164		13	20	2	9	9	6	58	2	5
Rotifera							9			5	
Cladocera		6			3				9		6
Copepoda	9	9		3	3	3		37			
Ostracoda						2	32			2	
Tardigrada	2										
Diptera larvae	4					5					
Gastropoda	4										
Bivalvia						14					
pH	7.83	5.91	6.48	8.08	7.12	7.50	7.05	7.20	6.80	6.80	7.10
C, μS/cm	332	24.2	24.6	146	436	363	446	65.4	334	227	187

The analyzes 2D take into account only two-dimensional indicators N_{taxa} and N_{10} (Fig. 3) show considerable variation surveyed stations. However, taking into account only the analysis of 3D with B_W factor allows for a more accurate assessment of ecological status. Imbalance between major meiobenthic taxa inhibiting a strong domination of one meiobenthic taxon often indicates a progressive degradation of the reservoir.

Table 2. Calculated values

Factor	Station										
	1	2	3	4	5	6	7	8	9	10	11
N	294	15	136	37	11	40	57	43	69	38	36
N_{10}	200.0	10.2	92.5	25.2	7.5	27.2	38.8	29.3	46.9	25.9	24.5
N_{taxa}	7	2	3	4	4	6	4	2	3	5	4
B_W	0.59	0.80	0.38	0.62	0.97	0.82	0.58	0.28	0.24	0.55	0.79

N – number of all individuals for the station, N_{10} – number of individuals/10 cm^2, N_{taxa} – number of major meiobenthic taxa, B_W – an indicator of balance in meiobenthic assemblages

The results indicate different ecological status of respondents stations. According to the accepted interpretation of the following data on the investigated stations:

Station No. 1. Water reservoir surrounded by houses in the village Wdzydze Tucholskie – has reached the maximum level of eutrophication and is in the initial stage of degradation of bottom sediments .

Station No. 2. Water reservoir located in a forest near the village of Lipa – in initial stage of increasing of bottom sediments.

Station No. 3. Głuchówko Lake surrounded by forest on one side and on the other buildings in the village Wdzydze Tucholskie – stage of degradation of bottom sediments.

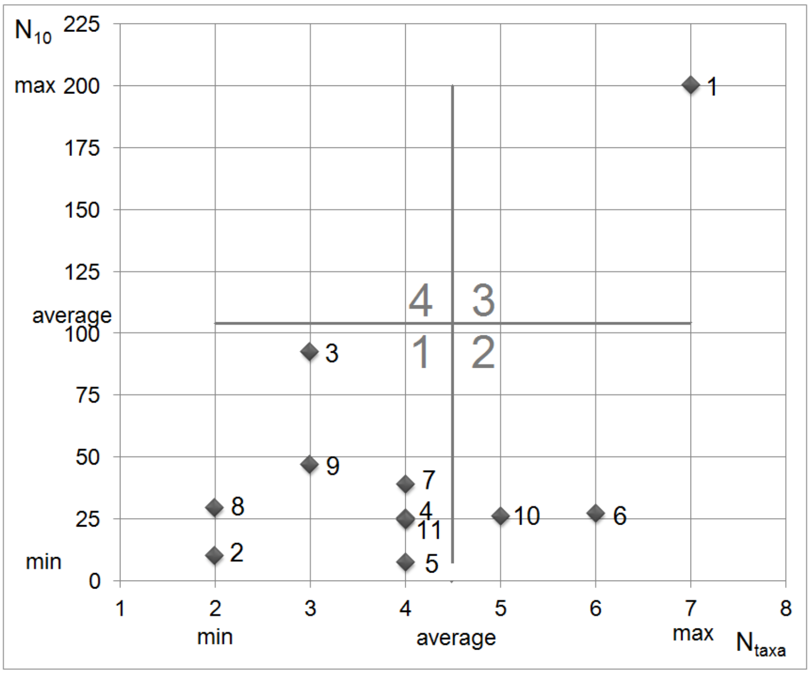

Fig. 3. 2D scatter plot of N_{10}, N_{taxa} for the tested stations

Station No. 4. „Horse Mud" pond located in meadows surrounded by forest, near the village of Borsk – in development stage, near the border of equilibrium.

Station No. 5. meadow draining channel, largely dried up, village Borsk – in initial stage of development.

Station No. 6. Bend dammed a small, slow current river, village Borsk – increasing trophy.

Station No. 7. The small source pond surrounded by trees, village Borsk – increasing trophy, initial phase of development, but under the border of equilibrium.

Station No. 8. Krzywe Lake – surrounded by forest and the adjacent part by summer houses – the degradation phase of sediments.

Station No. 9. Chądzie Lake – surrounded by forest – at the stage of degradation of bottom sediments .

Station No. 10. The peat excavation, near the village of Olpuch – increasing trophy, but under the border of equilibrium.

Station No. 11. Kotel Lake, near the village Olpuch – increasing trophy, initial littoral increasing phase.

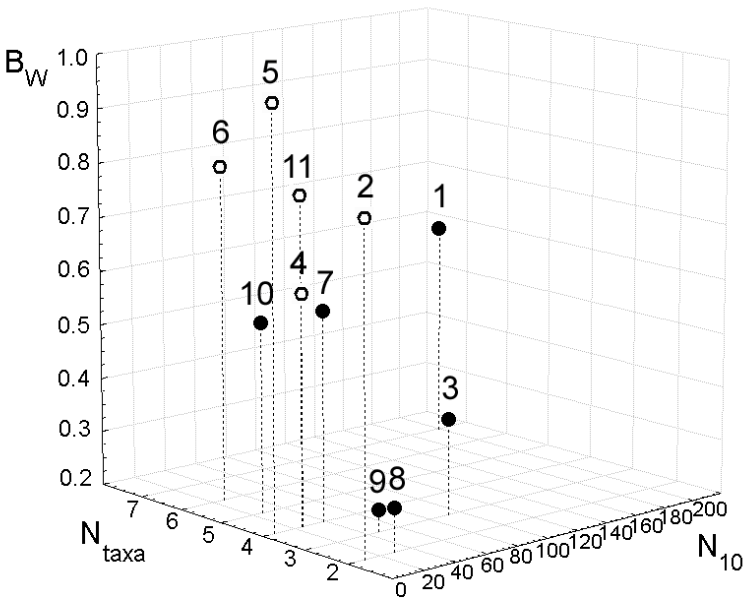

Fig. 4. 3D scatter plot of N_{10}, N_{taxa}, B_W for the tested stations. Black dots mark the stations of $B_W < 0.605$ (taxonomic imbalance in a meiobenthic assemblage), black circles the stations of $B_W \geq 0.605$ (taxonomic balance in a meiobenthic assemblage), $B_W = 0.605$ – average value

The results are indicative. However, in order to verify a case for increasing the number of stations, particularly in the case of reservoirs for which the results were evidence of progressive degradation of bottom sediments. Taking into account the basic measured physical and chemical parameters (pH and C), the interpretation is based on the analysis of the ecological status of a major meiobenthic taxa differ significantly from the results that could be obtained by relying solely on physical and chemical parameters. For example, for stations No. 9 and No.10 obtained is identical to the pH value 6.80. However, the interpretation of the results shows a completely different ecological status of sediment. Although the reservoir (No. 10), on the site of a former peat (anthropogenic factor) deposit is in good ecological status of increasing trophy. However, Chądzie Lake indicates the progressive degradation of bottom sediments. Like the Głuchówko Lake, which, unlike the Chądzie Lake has a low electrolytic conductivity, but also has progressive degradation of the bottom sediment.

CONCLUSIONS

The conclusions that arise from the research meiobenthic assemblages are (used three-step approach assessment of the ecological status of sediments: low, medium or good):

1. Small lakes: Głuchówko (No. 3), Krzywe (No. 8), Chądzie (No. 9) despite the impression there is no pollution and good location surrounded by partial or complete forest, have a low ecological status of bottom sediments.
2. The reservoir in the village Wdzydze Tucholskie (No. 1) has already reached the maximum level of eutrophication and further supply of nutrients will cause progressive degradation of bottom sediments, ecological status – medium.
3. The reservoir mid-forest near the village of Lipa (No. 2) remains in initial stage of evolution. The ecological status should be called good for this stage of bottom sediments.
4. The meadow draining channel (No. 5), the bend dammed a small, slow current river (No. 6) has not yet reached the maximum eutrophication and are in good ecological status.
5. The small source pond surrounded by trees (No. 7) are in the increase phase of sediments trophy and are in good ecological status but with the ability to transition into a state of degradation.
6. „Horse Mud" – pond located in meadows surrounded by forest (No. 4) despite initial development phase sediments, near the border of equilibrium, ecological condition can be described as good.
7. Extensive recess formed in place of peat excavation (No. 10) is an example of a humane activity, as a result of which was a reservoir. Increasing trophy, but under the border of equilibrium. The ecological status should be defined as medium. Although the environment and appearance of the reservoir did not indicate this.
8. Lake Kotel (No. 11), the littoral is in initial stage of increase has a good ecological condition.

Ecological status assessment by meiobenthic assemblages (major meiobenthic taxa) refers to the quality of sediments, not the quality/class of water purity. The applied method for assessing the ecological status allows for quick screening study data. This is extremely helpful in focusing research on the containers and/or jobs that require special attention and undertake research into the ecological.

REFERENCES

Czerniawska-Kusza I., 2005. Comparing modifield biological monitoring working party score system and several biological indices based on macroinvertebrates for water quality assessment. Limnologica 35, 169–176.

Czerniawska-Kusza I., Szoszkiewicz K., 2007. Biological and hydromorphological assessment of running waters: an example of the Mała Panew River (in Polish). Uniwersytet Opolski, Opole, 68 pp.

Klimarczyk P., Trawiński A., 2007. Ocena stanu rzek na podstawie makrobezkręgowców bentosowych. Indeks BMWP-PL. Zakład Ochrony Wód UAM. http://www.staff.amu.edu.pl/zow/pobieranie/BMWP-PL.pdf.

Kownacki A., 2000a. The use of benthic macroinvertebrates in the biomonitoring of river water quality – how do we interpret faunistic data? Acta Hydrobiol. 42, 187–206.

Kownacki A., 2000b. Diversity of benthic macroinvertebrates as a monitoring method for polluted river. Acta Hydrobiol. 42, 207–214.

Kownacki A., Soszka H., Fleituch T., Kudelska D., 2003. The Ecological assessment of River quality in Poland on the basis of the communities of benthic invertebrates, in: River biomonitoring and benthic invertebrate communities, A. Kownacki, H. Soszka, T. Fleituch, D. Kudelska (eds). W. Szafer Institute of Botany, Polish Academy of Science, Warszawa–Kraków, p. 71–88.

Martins J., Soares M.L., Saker M.L., Oliva Teles L., Vasconcelos V.M., 2007. Phototactic behavior in *Daphnia magna* Straus as an indicator of toxicants in the aquatic environment. Ecotoxicol. Environ. Saf., 67, 417–422.

Mezquita F., Hernández R., Rueda J., 1999. Ecology and distribution of ostracods in a polluted Mediterranean river. Palaeogeography, Palaeoclimatology, Palaeoecology, 148, 87–103.

Pfannkuche O., Thiel H., 1988. Sample Processing, in: Introduction to the Study of Meiofauna, (eds) R.P. Higgins, H. Thiel. Smithsonian Institution Press Washington D.C. London, p. 134–145.

Rowan J.S. Lake Habitat Survey in the United Kingdom. Filed Survey Guidance Manual. Version 4. December 2008. SNIFFER, www.snifer.org.uk.

Rowan J.S., Soutar I., Bragg O.M., Carwardine J., Cutler M.E.J. Lake Habitat Survey in the United Kingdom. Filed Survey Guidance Manual. Version 3.1. May 2006. SNIFFER, www.snifer.org.uk.

Särkkä J., 1992. Lacustrine profundal meiobenthos as an environmental indicator. Hydrobiologia, 243/244, 333–340.

Stolarska M., Wojtasik B., 2008. The impact of the phosphogips heap on meiobenthos assemblages (Pomerania, Poland) (in Polish). Annales UMCS, sec. C Biologia, 64, 1,109–114.

Szoszkiewicz K., Zbierska J., Jusik S., Zgoła T., 2010. Makrofitowa metody oceny rzek. Podręcznik metodyczny do oceny klasyfikacji stanu ekologicznego wód płynących w oparciu o rośliny wodne. Bogucki Wydawnictwo Naukowe, 81 ss.

Walker C.H., Hopkin S.p., Silby R.M., Peakall D.B., 2002. Podstawy ekotoksykologii. PWN, Warszawa, 374 ss.

Warwick R., 1990. Analisys of macrobenthic and meiobenthic community structure in relation to pollution and disturbance in Hamilton Harbour, Bermuda. J. Exp. Mar. Biol. Ecol., 138, 119–142.

Wiśniewska-Wojtasik B., Walczak A., 2005. Meio- and macrofauna of the selected reservoirs of Werenskiold glacier foreland (in Polish). Polish Polar Stud., XXXI Symp. Polarne, Kielce, p. 181–197.

Wojtasik B., 2007. Meiobenthic assemblages in the lakes of the Upper Radunia catchment (in Polish), in: D. Borowiak (red.) Jeziora Kaszubskiego Parku Krajobrazowego. Badania limnologiczne, 5, p. 131–144.

Wojtasik B., 2009a. Evaluation of the stage of development of the littoral of Czorsztyński and Sromowiecki reservoirs (Pieniny Mountains, Poland) on the basis of analyses of meiobenthos assemblages. Ecohydrol. Hydrobiol. 9, 2–4, 149–157.

Wojtasik B., 2009b. The influence of Water Power Station in Niedzica on littoral zone meiobenthos of Czorsztyński and Sromowiecki dam reservoirs. Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 6, 411–423.

Wojtasik B., 2010. Meiobenthos as an environmental changeability conditions indicator in freshwater reservoirs (in Polish), in: R. Wiśniewski (ed.) Ochrona i rekultywacja jezior. Salus Toruń, p. 185–203.

Wojtasik B., 2013a. Ocena-Diagnoza-Naprawa (ODN) – kompleksowa metoda ochrony zbiorników wodnych, in: R. Wiśniewski (red.), Ochrona i rekultywacja jezior. Toruń, s. 239–248.

Wojtasik B., 2013b. Zgrupowanie organizmów meiobentosowych do zastosowania w ujednoliconym systemie oceny stanu ekologicznego zbiorników wodnych i rzek, w szczególności osadów dennych oraz do tworzenia map stanu ekologicznego. Wniosek patentowy nr P.406458, Urząd Patentowy RP.

Wojtasik B., Cieszyńska J., 2008. Meiobenthic assemblages, particularly Copepoda-Cyclopoida in the Czorsztyński and Sromowiecki reservoirs (Pieniny, Poland) (in Polish). Annales UMCS, sec. C Biologia, 64, 1, 99–108.

Wojtasik B., Rodzik J., Stachyra P., Mioduchowska M., 2009. Variety of meiobenthic assemblages against the background of environment in selected freshwater reservoirs of Central Roztocze Region (SE Poland). Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 6, 424–431.

Wojtasik B., Mioduchowska M., 2010. Meiobenthic assemblages inhabiting small freshwater reservoirs (Pomerania, Poland) (in Polish). Ochr. Środ. Zasob. Natur. 45, 46–62.

OCENA STANU EKOLOGICZNEGO NIEWIELKICH ZBIORNIKÓW WODNYCH WDZYDZKIEGO PARKU KRAJOBRAZOWEGO (PÓŁNOCNA POLSKA) NA PODSTAWIE ANALIZ MEIOBENTOSU

Streszczenie. Ocenę stanu ekologicznego niewielkich zbiorników wodnych różnego typu położonych w okolicy jeziora Wdzydze (północna Polska) przeprowadzono na podstawie analizy zgrupowania meiobentosu. Badania dotyczą stanu osadów dennych i pozwalają na ocenę stadium rozwoju zbiornika: rozwój trofii, maksymalna eutrofizacja, degradacja. W metodzie badawczej zastosowano nowy algorytm dotyczący równowagi organizmów w zgrupowaniu, określony jako B_W. W wyniku badań stwierdzono, że na niewielkim obszarze występowały zbiorniki o niskim, średnim i dobrym stanie ekologicznym. Ocena ta nie jest odzwierciedleniem analizy jakości wód. Badania dotyczące wartości pH i C wód dla tych samych stanowisk wskazują na różne wyniki uzyskane za pomocą analiz parametrów fizyczno-chemicznych i meiobentosu. Ocena stanu ekologicznego odnosi się do jakości osadów, nie do jakości/klasy czystości wód. Zastosowana metoda oceny stanu ekologicznego pozwala na szybkie, przesiewowe opracowanie danych. Jest to niezwykle pomocne w przypadku badań na zbiornikach, które wymagają szczególnej uwagi i wykonania analiz stanu ekologicznego w szerszym zakresie.

Słowa kluczowe: zbiorniki słodkowodne, meiobentos, analiza 3D, stan ekologiczny, monitoring