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STRUCTURE AND FUNCTIONING OF ZOOPERIPHYTON AND BENTHOS COMMUNITIES OF THE CHANNELS OF HEATED LAKES OF KONIŃSKIE DISTRICT[1]

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A B S T R A C T. Zooperiphyton and benthos were studied in the supply and discharge channels connecting two coal power plants with five lakes. Eighty taxa of animals were recorded. The most interesting were two species of Chinese molluscs *Anodonta spp*. introduced into the lakes with the phytophagous fish from Hungary. *Anodonta woodiana* lives in the littoral, and the other species - more numerous and non-identified, in the warm discharge channels. The channels and their organisms play an important role in the self-purification process of Konińskie lakes. The degree of assimilation of organic matter by zooperiphyton and benthos of the channels was similar to that in the lake littoral.

Key words: LAKE, HEATED WATER, CHANNELS, ZOOPERIPHYTON, BOTTOM FAUNA, *Dreissena polymorpha* (Pall.), *Unionidae*, *Bryozoa*, BIOMASS, PRODUCTION, DESTRUCTION.

INTRODUCTION

The system of Konińskie lakes consists of five lakes connected with the channels. The lakes are used from 1958 as cooling reservoirs of „Konin" and „Pątnów" power plants. The lake ecosystems were already thoroughly studied with respect to the dynamics of environmental factors, plankton and fish (Zdanowski 1994). Dynamics of the bottom fauna in 1965-1974 was examined by Leszczyński (1976 a, b, c) and by the team of professor A. Wróblewski (1977) from The Adam Mickiewicz University of Poznań. Studies on adult and juvenile *Dreissena polymorpha* (Pall.) were carried out by Stańczykowska (1976) and Stańczykowska *et al*. (1988). These studies, except the works of Leszczyński (1976 a, b, c) on the terminal section of the Licheński Channel, never concerned fauna of the network of the supplying and discharge channels for cooling water.

Preliminary results published by Protasov et al. (1994) revealed that zoobenthos and periphyton of the channels differed from that of the lakes themselves. Three

1 The study was finnanced by the Committee for Scientific Research and PAK Power Plants in Konin

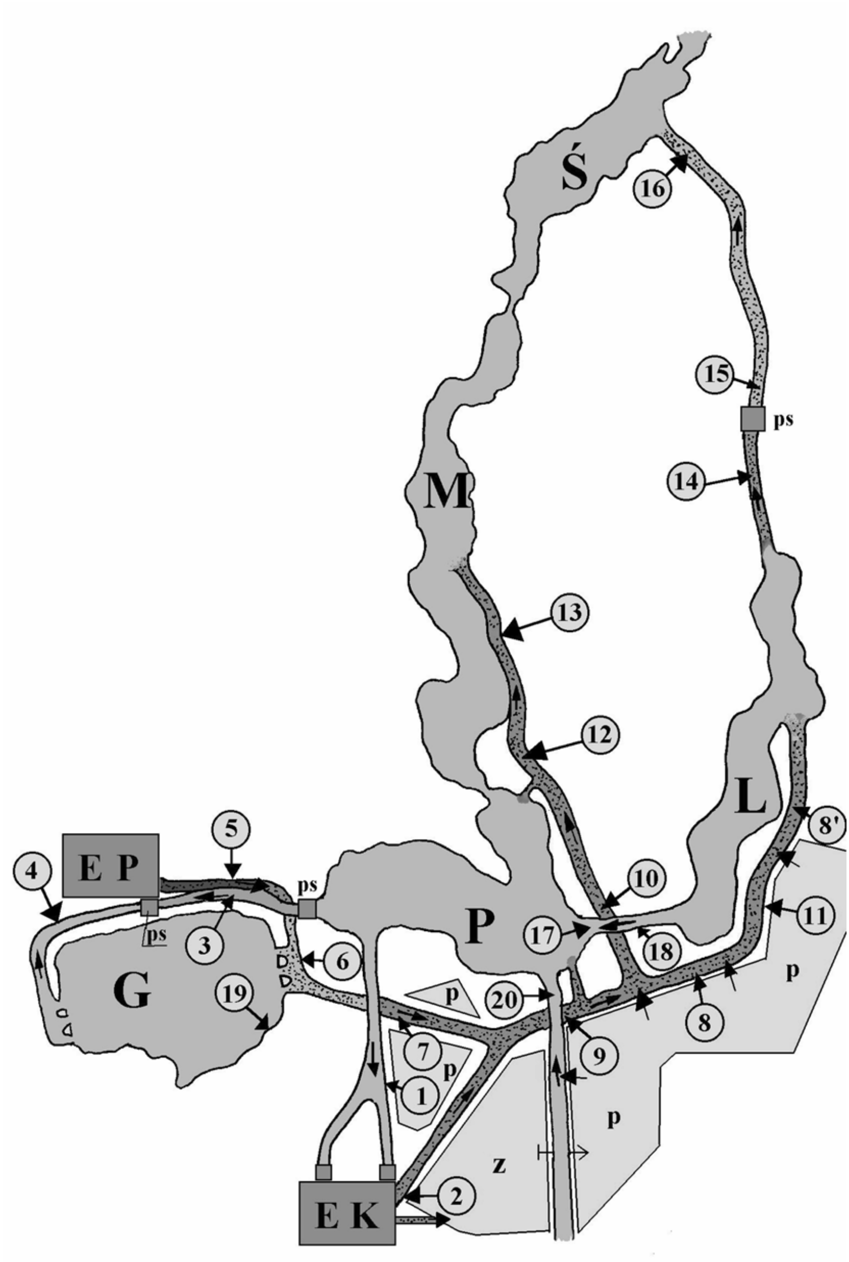

Fig. 1. System of Konińskie lakes and channels. Study sites: (1-20). lakes: (G)osławskie, (L)icheńskie, ()lesińskie, (M)ikorzyńskie, and (P)ątnowskie. EP - „Pątnów" power plant. EK - „Konin" power plant. Z - cooling reservoir, ps - pumping stations, p - carp ponds.

channels under study contained highly diversified fauna with stenotopic species adapted to high temperatures and high flow. High densities of *Dreissena polymorpha* (Pall.), and of large-sized *Anodonta spp.* were found, dominating in the trophic structure of the zooperiphyton and benthos of the channels. These filtrators played an important role in the self-purification of water in Konińskie lakes (Protasov *et al.* 1993). The present study describes zooperiphyton and benthos communities of the channel network of Konińskie power plants.

MATERIAL AND METHODS

Studies of zooperiphyton and benthos of the channels were carried out in August 1994 at 21 sites (fig. 1, Tab. I) of 3 supplying channels of total length about 6 km and a network of heated water discharge channels of total length about 26 km. The channels were approximately 10-15 m or 30-35 m wide (sites 9, 14, 15, 16). Maximum depth ranged from 2 to 3.5 m. The lowest water flow ranged from 3.0-7.0 m^3/s (sites 3, 12, 13, 17, 18), and the highest was 15 m^3/s (sites 2, 5, 7, 8, 9, 15). Water temperature during the study season ranged from 27°C (sites 1, 3, 4) to 34°C (sites 2, 5). Average water detention time in the channels did not exceed 9 hours.

Underwater study methods were applied (Protasov, Starodub, Afanasjev 1982). Observations and counting of easily visible animals revealed that temperature, flow and turbulence, as well as the type of substrate determined benthic communities of the channels (fig. 2). Sand, silt, stones and concrete constructions were the main types of the substrate used by the animals (Tab. 1).

The discharge zone of heated water from „Konin" power plant (33-34°C) was dominated by a *Bryozoa* species *Plumatella emarginata* Allm., living mainly on solid substrates (site 2) and sand at the overflow zone (site 6), as well as behind the siphon (site 9). This species of *Bryozoa* was noted also in lower temperature (29.5°C), on a concrete substrate of the Western Channel (site 4).

High densities of large *Anodonta sp.* were observed in zones of turbulent water under the cages and behind the siphons and bridges (sites 7, 9, 10, 11, 12). In the outflow channels from Licheńskie Lake (sites 14, 17, 18) they were accompanied by dense colonies of *Dreissena polymorpha*. Aggregations of *Unionidae* on the bottom of long section of Licheński Channel were less abundant (site 8). Dense colonies of *Dreissena polymorpha* (Pall.) were observed in the channel behind the pumping station in Piotrko-

TABLE 1

Characteristics of the sampling sites of zooperiphyton and zoobenthos in Konińskie channels

Sites (see Fig. 1)	Temperature (°C)	Depth(m)	Substrate of periphyton	Substrate of benthos
1. Supplying channel EC Konin	27	1.3-2.5	stone	sand
2. Discharge channel EC Konin	33.0	1.0-2.5	stone	sand
3. East water intake channel EC Pątnów	29.5	0.4	concrete	
4. West water intake channel EC Pątnów	30.0	0.3-3.0		sand
5. Begining the discharge channel EC Pątnów	34.5	0-0.1	concrete	
6. Discharge channel EC Pątnów	34.0	0.5-3.0		sand, silt
7. Discharge channel EC Pątnów	33.7-34	0.2-3.0	metal	silt, sand
8. Licheński Channel	33	2.5-3.0		sand, silt
9. Licheński Channel near siphon	34	0.5-3.0		sand, silt
10. Wąsowski Channel near siphon	34	2.5		silt
11. Licheński Channel (cages)	33.0	3.0		sand, silt
12. Wąsowski Channel (cages)	33	2.5		sand, silt
13. Wąsowski Channel	32	1.0-2.5	concrete	sand
14. Piotrkowicki Channel (600 m above pump station)	32	2.5		sand
15. Piotrkowicki Channel (100 m below pump station	32	2.5-2.7	stone	clay
16. Piotrkowicki Channel	31.5	0.2	concrete	
17. Licheńsko - Pątnowski Channel (outlet)	31	2.0		sand
18. Licheńsko - Pątnowski Channel	30	2.0		sand, silt
19. Lake Gosławskie	30.0	0-1.2		stone
20. Morzysławski Channel	29.0	0.5 - 3.0	stone	sand, silt

wice (site 15), and in the Eastern Channel supplying water to the „Pątnów" plant (site 4). Single individuals and small colonies of *D. polymorpha* were noted in the supply channel of „Konin" plant (site 1).

Benthos and periphyton were sampled from the transects in each channel. Animals from solid substrates were collected with a scraper of 5.5 cm width, and from soft substrates - with a box sampler of the surface 10 x 10 cm. Counting and collecting of large molluscs was done using a 50 x 50 cm frame. The samples were rinsed and separated using a binocular. The organisms, except *Nematoda*, were identified in preserved samples, under laboratory conditions, using an Amplival microscope. Total number of 49 benthos samples and 15 periphyton samples were analysed. Statistical analyses were performed using Water Community software of the Hydrobiological Institute of the UAS in Kiev.

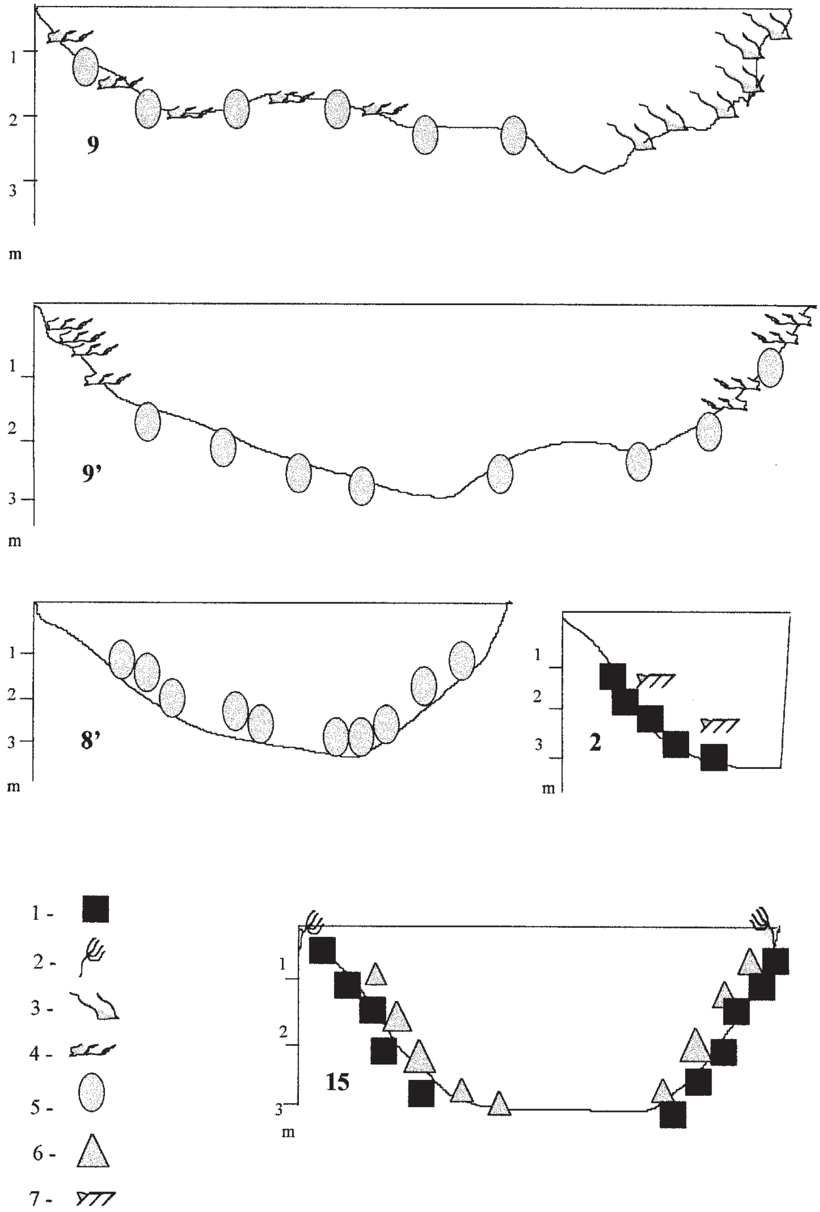

Fig. 2. Selected characteristics of macroorganisms in the channels: 9 (Pątnowski below the siphon), 9′ (Pątnowski 20 m below the siphon), 8′ (Licheński), 2 (discharge channel of „Konin" plant), and 15 (Piotrkowicki).
Legend: 1 - stone, concrete, 2 - *Chara sp.*, 3 - filamentous algae, 4 - settled blue-green algae, 5 - *Anodonta spp.*, 6 - *D. polymorpha*, 7 - *P. emarginata*.

Similarity of species composition of the fauna in the channels was calculated as the averages and for particular samples using Serensen qualitative coefficient and Czekanowski - Serensen quantitative coefficient (for the biomass) (Pesenko 1982). Biomass of the organisms was estimated either by direct weighing of the animals or from the size-length relationship.

The rate of organic matter destruction (R) by the zoobenthos was calculated from the equations on the relation of oxygen consumption to body mass, reported in the references (see Protasov *et al*. 1991, 1994). Advantage was taken of the data on the metabolism of *Dreissena polymorpha* and *Plumatella emarginata* (Sinicyna 1989). Calculations of the energetic value of benthic biomass were based on the published data (see Protasov 1991, 1994), and on the results concerning calorific values of *Bryozoa*, *Dreissena* and molluscs (Sinicyna 1990).

Value of K2 of 0.2 was assumed for the daily zoobenthic production (Alimov 1987). Energy flow (the rate of organic matter assimilation) was calculated as a sum of daily production and an amount of energy used for the destruction of organic matter (Winberg 1986, Alimov 1089). Filtration rate of water by the molluscs (F) was calculated from the filtration coefficient Q (ml/mgO_2) and oxygen consumption R ($mg\ O_2/m^2/h$), expressed as Q=F/R, for *Unionidae* and *Dreissenidae* equal to 910.0 and for *Sphaerium* to 136.0 (Alimov 1981).

RESULTS

TAXONOMIC COMPOSITION

Eighty taxa of periphyton and benthos were found in the channels. *Hydra*, *Ostracoda*, *Odonata* and *Nematoda* were not identified to species. The most diversified were: *Oligochaeta* (20 species), *Chironomidae* larvae (20 species and forms), crustaceans (8 species and groups), and molluscs (11 genera). Other animals were also found: *Planaria*, two species of *Bryozoa*, *Kamptozoa*, *Tubificidae* and insect larvae.

The most interesting from a faunistic point of view were two species of molluscs described in an earlier paper as *Anodonta sp*. (Protasov *et al*. 1994). They are of Chinese or Middle Asian origin and have been brought to the lakes from Hungary in the mid-eighties, together with the phytophagous fishes. A less numerous species has been identified as *Anodonta woodiana* Lea 1834, and the other - more numerous - is still u-

TABLE 2

Benthic and periphyton taxa found in Konińskie channels (Aug. 1994).

L.p.	Taksons	St. 4	St. 3	St. 1	St. 2, 5, 6, 7	St. 8, 9, 10, 11, 12, 13	St. 17, 18	St. 14	St. 15, 16
1	*Spongilla lacustris* L.								
2	*Hydra sp.*								
3	*Cordilophora caspia* (Pallas)								
4	*Planaria torva* (O.F.Müller)								
5	*Nematoda sp.*								
6	*Aeolosoma hemprichi* Ehr.								
7	*Chaetogaster diastrophus* (Gruit.)								
8	*Chaetogaster sp.*								
9	*Pristina aequiseta* Bourne								
10	*Pristina longiseta* Ehr.								
11	*Pristina sp.*								
12	*Dero obtusa* d'Udek								
13	*Stylaria lacustris* L.								
14	*Nais barbata* O.F.Müller								
15	*Nais elinguis* O.F.Müller								
16	*Nais pardalis* Pig.								
17	*Nais communis* Pig.								
18	*Nais sp.*								
19	*Limnodrillus helveticus* Pig.								
20	*Limnodrillus hoffmeisteri* Claparede								
21	*Limnodrillus sp.*								
22	*Tubificidae sp.* juv.								
23	*Enchytreidae sp.*								
24	*Branchiura sowerbii* Beddard.								
25	*Potamotrix sp.*								
26	*Potamotrix heusheri*								
27	*Erpobdella octoculata* (L.)								
28	*Glossiphonia complanata* (L.)								
29	*Cladocera sp.*								
30	*Sida crystallina* (O.F.M· ller)								
31	*Cyclopoida sp.*								
32	*Harpaacticoida gen. sp.*								
33	*Ostracoda gen. sp.*								
34	*Chaetogammarus ishnuus* (Stebbing)								
35	*Corophium curvispinum* G.O.Sars								
36	*Corophium robustrum* G.O.Sars								
37	*Odonata sp.*								
38	*Ordela maxima*								
39	*Caenis macrura* Steph.								

L.p.	Taksons	St. 4	St. 3	St. 1	St. 2, 5, 6, 7	St. 8, 9, 10, 11, 12, 13	St. 17, 18	St. 14	St. 15, 16
40	*Caenis horaria* L.								
41	*Ephemeroptera sp.*								
42	*Ecnomus tenellus* Ramb.								
43	*Neureclipsis bimaculata* L.								
44	*Trichoptera sp.*								
45	*Simuliidae*								
46	*Cladotanytarsus mancus* Walk.)								
47	*Rheotanytarsus ex g. exiguus* Johan.								
48	*Cricotopus sylvestris* (Fabr.)								
49	*Cricotopus ex g. algarum* (K.)								
50	*Criptochironomus defectus* (K.)								
51	*Criptochironomus vulneratus* (Zett.)								
52	*Criptochironomus viridulis* (Fabr.)								
53	*Parachironomus pararostratus* Lenz								
54	*Gliptotendipes glaucus* Kieffer								
55	*Endochironomus tendens* Fabr.								
56	*Endochironomus albipensis* Meigen								
57	*Chironomus plumosus* L.								
58	*Chironomus semireductus* Lenz								
59	*Chironomus bathophilus* Kieffer								
60	*Limnochironomus nervosus* (Staeg.)								
61	*Polypedilum convictum* (Walk)								
62	*Microcricotopus bicolor* (Zett.)								
63	*Procladius ferrugineus* (Kiefer)								
64	*Trissocladius sp.*								
65	*Micropsectra praecox* Meig.								
66	*Chironomidae* juv.								
67	*Chironomidae sp. puppae*								
68	*Dreissena polymorpha* (Pallas)								
69	*Pisidium sp.*								
70	*Bivalvia* juv.								
71	*Unio tumidus* Philipsson								
72	*Anodonta sp.*								
73	*Limnaea sp.*								
74	*Valvata sp.*								
75	*Viviparus viviparus* L.								
76	*Anisus albus* O.F.Müller								
77	*Gastropoda sp.*								
78	*Bithynia tentaculata* (L.)								
79	*Urnatella gracilis* Leidy								
80	*Plumatella emarginata* Allm.								
81	*Plumatella fungosa* (Pall.)								

nidentified. At present, detailed taxonomic and genetic studies are being carried out in order to identify this mollusc. Thus, in the present study both forms are still analysed together as *Anodonta sp.*

Particular channels were inhabited by various numbers of taxa, and species composition of periphyton and benthic communities was also diversified (Tab. 2). In the channels of „Pątnów" and „Konin" power plants, in the section between the discharge and the siphon zone under Morzysławski Channel, 40 species were found. In the remaining sections of the channels, to the outflow to Mikorzyńskie and Licheńskie Lakes - only 12 species. Five species occurred in the Western Channel supplying water to „Pątnów" plant, and in the Eastern Channel - 19 species. The supplying channel of „Konin" plant was inhabited by 15 species of the periphyton and benthos.

Serensen's analysis of taxonomic similarity revealed close relation (0.45-0.70) among the invertebrate communities of the following channels: discharge channel of „Pątnów" plant (up to the siphon), the channel between Licheńskie and Pątnowskie Lakes, and the outflow channel from Licheńskie Lake to Piotrkowice Pumping Station (fig. 3a). Similarity of the communities was also established among the supplying channels of „Pątnów" plant. Species composition of the Western Channel was similar to that of the channel connecting Licheńskie and Pątnowskie lakes, and the species composition of the community of the Eastern Channel was similar to that of Piotrkowicki Channel below the pumping station, and to the community of the supplying channel of „Konin" power plant.

Faunistic diversity of the channels was also confirmed by the analysis of similarity for the zooperiphyton communities: Serensen's coefficient of qualitative (fig. 3b), and Czekanowski-Serensen coefficient for quantitative similarity (fig. 3c). Zooperiphyton in the supplying channel of „Konin" plant (site 1) was similar to the communities of Piotrkowicki Channel below the pumping station (site 15), and of Gosławskie Lake. Zooperiphyton of the discharge channels was similar to the communities of the Eastern Channel supplying „Pątnów" plant. Terminal sections of Wąsoski and Piotrkowicki Channels (sites 13 and 16) were inhabited by completely different organisms comparing to the remaining sites.

STRUCTURE, DENSITY AND BIOMASS OF THE ZOOPERIPHYTON

Several communities were distinguished, dominated by the *Bryozoa* (sites 2, 3 and 7), by *Dreissena polymorpha* (sites 1, 15 and 19), or with no distinct dominants (site 4).

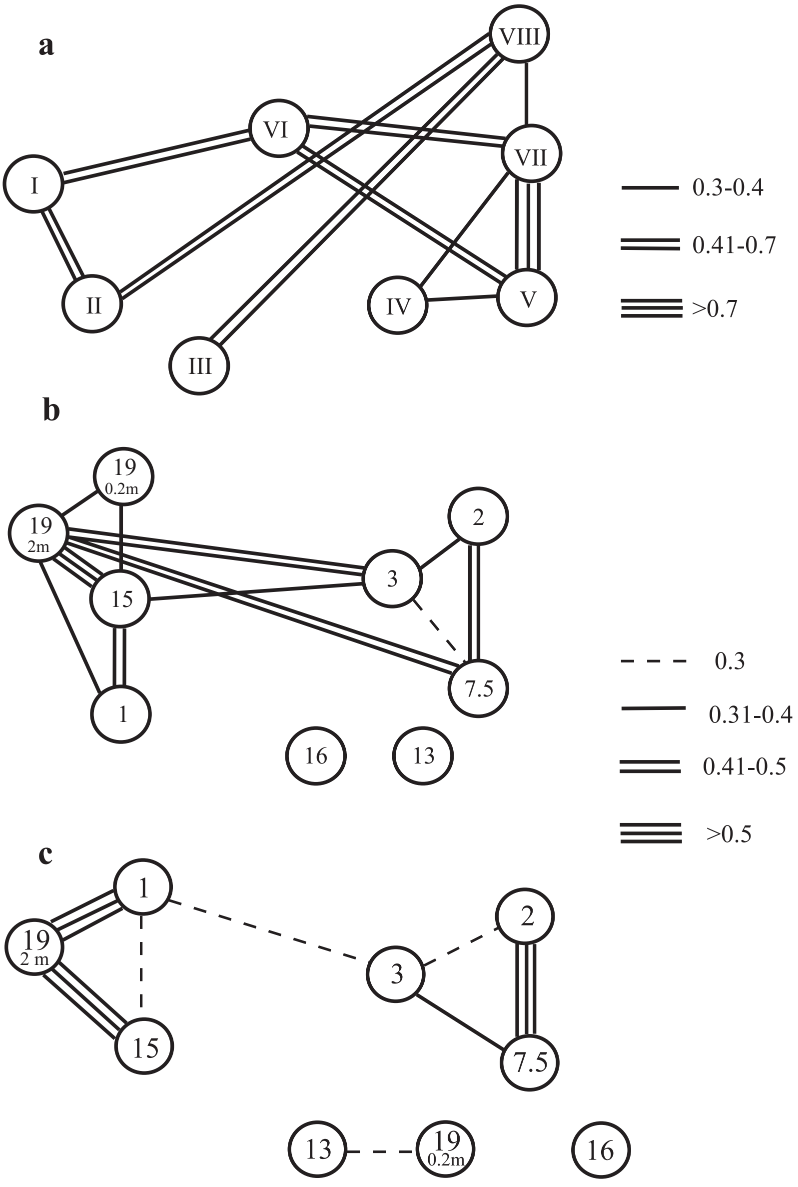

Fig. 3. Similarity of zoobenthos and zooperiphyton at various sites of Konińskie channels.
a) zoobenthos + zooperiphyton, according to Serensen: I - Western Channel of EP, II - Eastern Channel of EP, III - supplying channel of EK, IV - discharge channel of EP and EK, V - Licheński Channel (discharge), VI - channel connecting Licheńskie and Pątnowskie lakes, VII - Piotrkowicki Channel before the pumping station, VIII - Piotrkowicki below the pumping station.
b) zooperiphyton, according to Serensen - sites (1-19) - see fig. 1.
c) zooperiphyton according to Czekanowski - Serensen - sites (1-19) - see fig. 1.

The highest density and biomass of zooperiphyton, up to 272000 ind./m^2 and to 14.5 kg/m^2 was noted at site 15 (Piotrkowicki Channel, below the pumping station). The lowest densities were observed at site 13 of Wąsoski Channel (up to 800 ind./m^2), and the lowest values of biomass at site 5 of the discharge channel of „Pątnów" plant and at site 13 of Wąsoski Channel (0.9-1.1 g/m^2). Relatively high biomass of periphyton was noted at site 19, along the concrete banks of Gosławskie Lake (10.2 kg/m^2).

Zooperiphyton densities in the discharge zone from „Konin" plant were low and fluctuated between 6800 to 47690 ind./m^2. The communities were dominated by *Ostracoda* and *Nematoda*. Single colonies of *Urnatella gracilis (Kamptozoa)* observed in 1993, in 1994 were considerably more abundant - up to 90000 col./m^2, to 26 g/m^2 of the biomass, and 2.5-3.0 m in height. In the bryozoan communities *Plumatella emarginata* predominated, and its biomass was three times as high as in 1993 (938.8 g/m^2 at 1 m depth, and 1152.0 g/m^2 at 2 m).

Bryozoa predomination (*P. emarginata*) was noted also on the floats of the fish cages situated in the discharge channel of „Pątnów" plant (site 7). This zone was inhabited only by 8 species of invertebrates of low density (31300 ind./m^2) and biomass (609 g/m^2). The biomass of *P. emarginata* represented 93.6% and of *U. gracilis* 6.1% of the total zooperiphyton biomass. The discharge zone of „Pątnów" plant (site 5) was free from periphyton. Bottom fauna was predominated by *Nematoda* (94.9% of total benthic density, 600 ind./m^2). The biomass of benthos was low - 1.1 g/m^2, and the community was dominated by *Chironomidae* and *Corophiidae* larvae.

In the supplying channel of „Pątnów" plant (site 3), at high water temperature (29.5°C) in summer 1994, 18 species typical for strongly heated water (*Pristina aequiseta*, *Plumatella emarginata*), and slightly heated water (*Dreissena polymorpha*, *Corophium robustum*) were found. However, total density of the animals was rather low - 29000 ind./m^2. Similar share of *D. polymorpha* (36.2%), *Corophiidae* (28.7%), *Oligochaeta* (14.9%) and *Chironomidae* (10.3%) in total density resulted in low quantitative diversity of the community (0.64). The biomass (673.8 g/m^2) was dominated by *Bryozoa* (76.6%), with the most numerous species *Plumatella emarginata* (43.5%) and *P. fungosa* (33.1%). The biomass of *D. polymorpha* was 5 fold lower comparing to the biomass of *Bryozoa* (108.8 g/m2). In the supplying channel of „Konin" power plant (site 1) total density and biomass of the periphyton and biomass of *D. polymorpha* were similar to the values recorded in the previous season and equal to 69250 ind./m^2, 2416.1 g/m^2, and 2379.3 g/m^2 respectively. *Corophiidae* represented 66.7% of the total periphyton density.

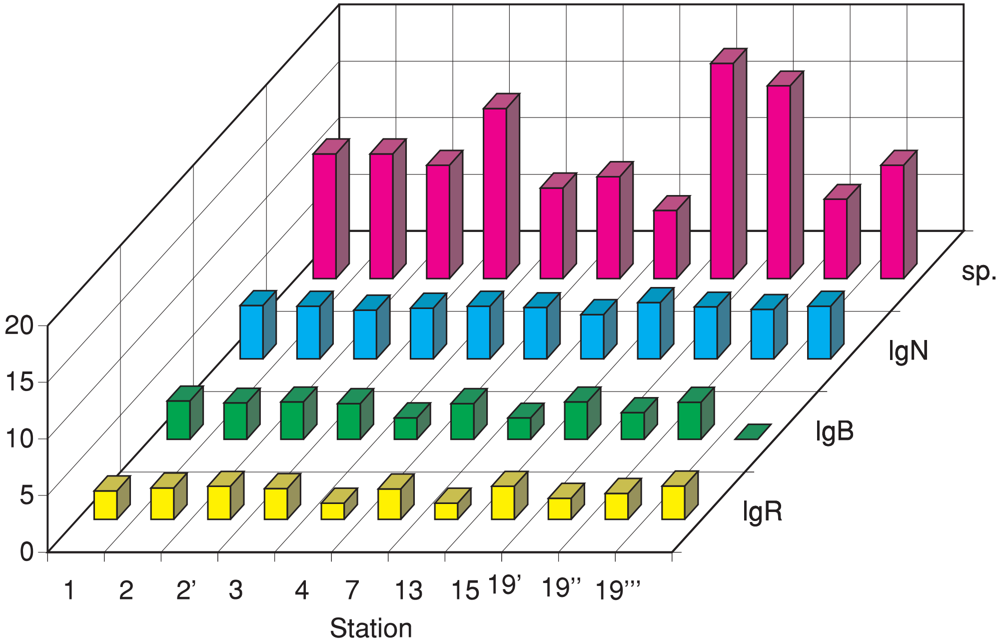

Fig. 4. Number of species (sp.), density (lgN, ind./m^2), biomass (lgB, g/m2), and respiration rate (lgR, mg $O_2/m^2/h$) of zooperiphyton in Konińskie channels (sites - see fig. 1).

Much higher densities of *D. polymorpha* were observed in Piotrkowicki Channel below the pumping station (fig.4.). At the depth of 2 m, stones were covered in 100% by *D. polymorpha*, and the bottom - up to 50%. The colonies of *D. polymorpha* developed at the beginning of May, in the initial phase of channel filling, when water level was 1.5-2.0 m lower than in summer. As in the Western Channel supplying cooling water to „Pątnów" power plant, also here the population of *D. polymorpha* consisted mainly of the youngest age group, up to 6.5 mm (fig. 5.). Larger individuals were fairly numerous only in the channel connecting Licheńskie and Pątnowskie lakes (site 18), in Morzysławski Channel, and in Gosławskie Lake, where two age groups were distinguished (fig. 5.).

D. polymorpha colony in Piotrkowicki Channel enriched the community of 23 species and forms of other invertebrates. Four taxa of *Oligochaeta* were found, 6 forms of larval *Chironomidae*, and 7 species of crustaceans. Total density of the invertebrates was 272000 ind./m^2, *D. polymorpha* representing 68.2%, *Turbellaria* and *Ostracoda* - 13.7% and 10.8%, respectively. *D. polymorpha* predominated in the biomass: 99.4% of

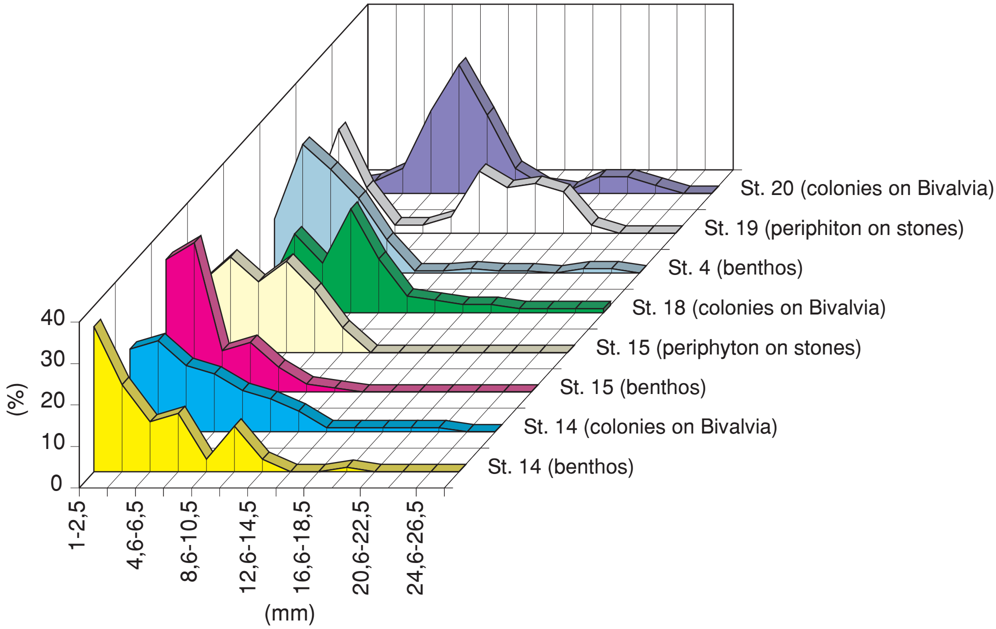

Fig. 5. Size classes (mm) of *Dreissena polymorpha* (Pall.) and their share in total number (%) in Konińskie channels in August 1994 (sites - see fig. 1).

the total community biomass (14400.9 g/m^2). Biomass of a bryozoan *P. fungosa* was low - 40. 0 g/m^2. In the terminal section of that channel (site 16) and of Wąsoski Channel no animals attached to the substrate were found. Among the filamentous algae (*Cladophora sp.*, *Lyngbya fontana*) covering the concrete Piotrkowicki Channel, and amounting to 52 g/m^2 of the biomass, 11 species of animals occasionally attached to the substrate were found. In poorly developed periphyton of Wąsoski Channel only 3 species were observed. Densities of the periphyton were low - only 3611 and 800 ind./m^2, and the biomass - 13.4 and 0.9 g/m^2. In Gosławskie Lake, in the discharge zone of heated water (sites 6 and 19), where the biomass of the filamentous algae (*Cladophora sp.*) reached 100 g/m^2, only active animals were found, temporarily attached to the substrate. Density of 20 species and forms, among which *Oligochaeta* represented 30%, *Copepoda* - 15%, and larval *Chironomidae* - 18%, was 45000 ind./m^2, and the biomass was 6.9 g/m^2.

STRUCTURE, DENSITY, AND BIOMASS OF ZOOBENTHOS

Structure of zoobenthos communities in the channels reflected various thermal adaptive abilities of the species (fig. 6.). In the warmest heated water discharge zone of „Konin" power plant (site 2), at the depth of 2.5 m, *Nematoda* and *P. emarginata*

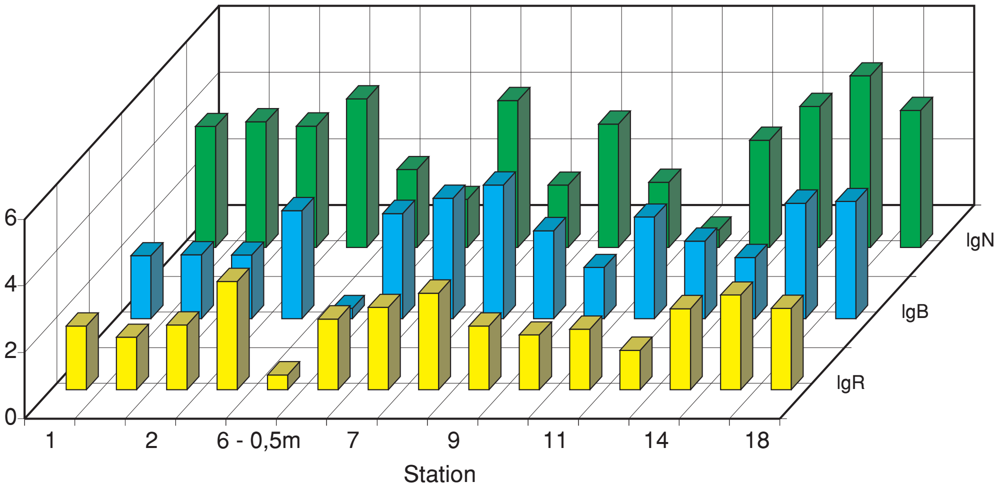

Fig. 6. Number of species (sp.), biomass (lgB, g/m^2), and respiration rate (lgR, $mgO_2/m^2/h$) of zoobenthos in Konińskie channels (sites - see fig. 1).

predominated - 81% of the total density (4800 ind./m^2), and 98% of the total biomass of benthos (132.9 g/m^2). *Bryozoa* predominated in the bottom zone, and *Tubificidae* in the discharge zone of heated water from „Pątnów" power plant (sites 5 and 6), where biomass of invertebrates was 1650.3 g/m^2. The most abundant zoobenthos was observed in the most distant sections of warm discharge channels (sites 7, 8, 9 and 10), where large Anodonta predominated, and in cooler supplying channels of both power plants (sites 1 and 4), in the channel connecting Licheńskie and Pątnowskie lakes (sites 17 and 18), and in Piotrkowicki Channel (sites 14 and 15), predominated by *D. polymorpha* (fig. 6.). Shallow parts of Wąsoski Channel (site 9) were inhabited mostly by young individuals of *Anodonta sp*, up to 55 mm. In deeper parts older individuals were usually found, of 120-170 mm (fig. 7.). Maximum biomass values of the largest *Anodonta sp.* aggregations near the cages and behind the siphons (up to 17.2 kg/m^2) were even higher than the maximum biomass of *D. polymorpha* (14.2 kg/m^2) that predominated in the zooperiphyton of Piotrkowicki Channel.

Total density of *Oligochaeta* which dominated in the benthos of the shallow parts of the channels (0.6-1.0 m) was 4870 ind./m^2. The density of *Anodonta*, a dominating community of the deeper parts (2.5-3.0 m), was 12000 ind./m^2 (total biomass 14953

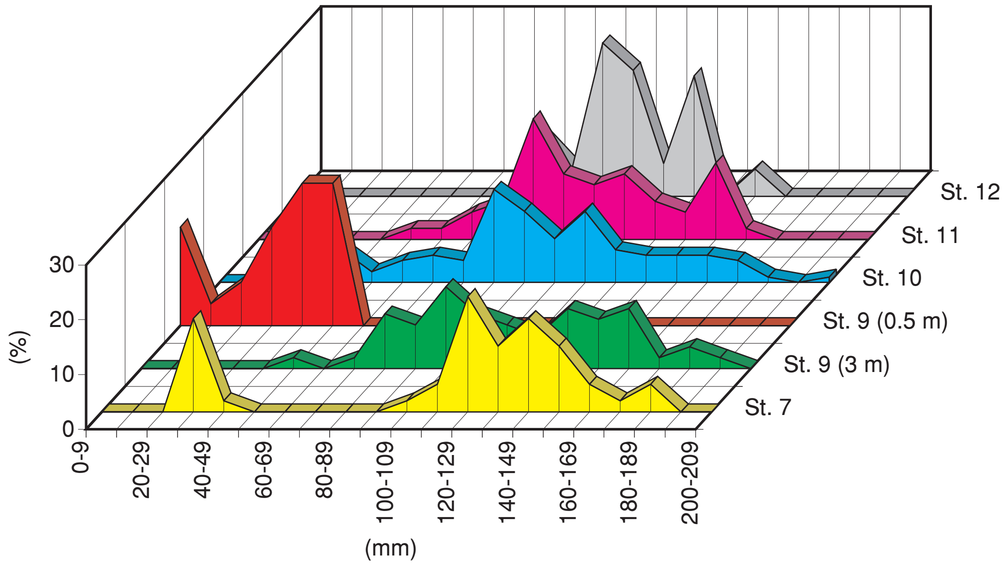

Fig. 7. Share (%) of size classes (mm) in total number of *Anodonta sp*. in Konińskie channels in August 1994 (sites - see fig. 1).

g/m^2). Density of the molluscs decreased to single individuals with the distance from siphon (site 9), towards Licheńskie and Mikorzyńskie lakes. In the terminal sections of the channels total biomass of the molluscs did not exceed 210 g/m^2. Similar decrease of the total benthos biomass, from 34.3 to 2.8 g/m^2, and a decrease of *Oligochaeta* density from 11964 to 1900 ind./m^2 were observed also in Wąsoski Channel (sites 10, 12 and 13).

Strong development of the benthos predominated by *D. polymorpha* was observed in the outflow channels carrying water from Licheńskie Lake (sites 14, 15, 17, 18). Total density of the bottom fauna fluctuated within the range 9770-148600 ind./m^2, and the biomass from 1048.3 to 3190.0 g/m^2 (fig. 6). In Piotrkowicki Channel *D. polymorpha* predominated (93-99%), and in the channel connecting Licheńskie with Pątnowskie Lake - *Anodonta sp* (75%), with a subdomination of *D. polymorpha* (25%). The lowest density (6480 ind./m^2) and biomass (79.7 g/m^2) of *D. polymorpha* and *Gastropoda*, a dominating benthos, was observed in the coolest channels carrying cooling water to the power plants (sites 1 and 4).

TABLE 3

Share (%) of zooperiphyton and zoobenthos communities in total destruction of organic matter (R), assimilation rate (A), and water filtration (F), and the ratio of destruction to the biomass of the communities (R/B)

Organism groups	Sites	Share in destruction (R)	R	A	F	R/B
		(%)	(kJ/m^2/h	(kJ/m^2/24h)	(dm^3/m^2/24h)	(h^{-1})
PERIPHYTON						
1. *D. polymorpha*	1, 15	84-94	3.43-32.75	98.78-933.77	3133.7-33461.4	0.0046-0.007
2. *P. emarginata*	1, 3, 7	77-96	4.81-18.31	192.74-720.68		0.0071-0.0093
3. *Corophium* + *Chironomidae*	5	56+33	0.048	1.38		0.014
4. *Trichoptera* + *Chironomidae*	13	77+22	1.96	0.81		0.0092
5. *Odonata*	16	77	14.69	6.02		0.0042
BENTHOS						
1. *Anodonta sp.*	7, 8, 9, 11, 10, 12, 13, 17, 18	52-96	0.22-14.22	6.30-425.37	141.40-154-23.59	0.0002-0.0009
2. *D. polymorpha*	14, 15	64-97	2.23-8.87	64.23-255.46	2420.25-6-167.31	0.0059-0.0074
3. *P. emarginata*	2, 6	86-99	1.18-26.08	46.44-1026.51		0.009
4. *Gastropoda* + *D. polymorpha*	4	65+22	0.51	11.52	162.43	0.0100
5. *Cyclopoida sp.*	1	63	0.108	3.11		0.0087
6. *Oligochaeta*	6	99.9	0.038	1.09		0.0065

ZOOPERIPHYTON AND ZOOBENTHOS PRODUCTION, AND ORGANIC MATTER DESTRUCTION

Basing on oxygen consumption by the animals, expressed in energy units, five types of zooperiphyton and six types of zoobenthos communities were distinguished (Tab. 3). The highest rate of destruction (32.75 kJ/m^2/h) was observed in the periphyton composed of *D. polymorpha* community in Piotrkowicki Channel. Maximum levels of destruction in benthic communities of *P. emarginata* (18.31 - 26.08 kJ/m^2/h), and of *Anodonta sp*. (14.22 kJ/m^2/h) were equally high.

The ratio of energy used for metabolism to the energy stored in the biomass (R/B), showing the rate of energy flow through the communities, fluctuated within the range from 0.0002 in *Anodonta sp.* to 0.010 in *Gastropoda* + *D. polymorpha*, and to

0.0014 in *Corophiidae + Chironomidae* communities. The rate of energy flow in *D. polymorpha*, dominating communities in Konińskie lakes, was twice as high comparing to the other heated reservoirs, both in the periphyton and in benthos (Protasov 1994, Protasov *et al.* 1991, 1994). This indicates viability of the population, each year dominated by young individuals.

The highest amount of energy (up to 80%) was transformed by the organisms inhabiting warm discharge channels. Much less energy (14%) flew through the fauna of the channels connecting Licheńskie with Pątnowskie and Slesińskie lakes. The least energy flow (5%) was noted in the coolest supplying channels. Energy flow was the highest in channel sections below the siphons (sites 9 and 10), $7.05*10^5$ kJ/24 h, on the average, and decreased with increasing distance from the siphons. Towards Licheńskie and Mikorzyńskie lakes the values for benthos dropped initially over 10 fold - to $5.38*10^4$ kJ/24 h, and in the terminal sections of Licheński and Wąsoski Channels increased again to $2.73*10^5$ kJ/24 h but did not reach maximum values noted below the siphons, despite a less muddy bottom.

Energy transformation by the zooperiphyton and benthos calculated per total surface of the communities inhabiting the channels amounted to 65000 thousand kJ/24 h, and was 3 fold lower than that recorded in 1993 in the littoral zones of the lakes overgrown with macrophytes, macroalgae and *D. polymorpha* colonies (Protasov *et al.* 1994). About 90% of the energy was transformed by the zoobenthos, mainly by *D. polymorpha* and *Anodonta sp*.

The molluscs inhabiting the channels filtered daily about 587700 m^3 of water. The highest filtration rate (33.5 m^3/m^2/24 h) was observed in the community dominated by *D. polymorpha* in Piotrkowicki Channel, and two fold lower (15.4 m^3/m^2/24 h) in *Anodonta sp*. community below the siphon in Wąsoski Channel. Filtration rate of benthic *D. polymorpha* fluctuated within the range of 2.4 - 6.2 m^3/m^2/24 h. Share of *D. polymorpha* and large *Unionidae* in filtration by the entire community was similar and amounted to 54%, and 45%, respectively. An assumed concentration of suspended matter in the channels was 8.53 mg/l on the average, and calculation revealed that the molluscs filtered about 4.7 tons of total suspended matter per day, and 3.5 tons of C. 43% of the suspension was filtered by *Anodonta sp*. and 57% by *D. polymorpha*.

The mean daily assimilation rate of organic matter by *Bryozoa* was about $5.22*10^7$ kJ, which makes 1.33 tons of carbon. Assuming a coefficient of assimilation value equal to 0.6, calculation indicates that the rate of carbon sedimentation by these animals was up to 2.2 tons/day.

DISCUSSION

Detailed examination of the channels performed in summer 1994 considerably enlarged the list of invertebrate taxa found in Konińskie lakes. The most interesting finding were *Urnatella gracilis* Leidy, (*Kamptozoa*), a species characteristic for brackish, heated water, which lived in the water discharge zones. Other interesting animals found in the channels were two large species of *Anodonta* brought in the eighties from Hungary together with the stocking material of silver and bighead carps. At the same time also stone moroco (*Pseudorasbora parva*) was brought to carp ponds of Gosławice and became a component of the ichthyofauna in the Barycz River system (Witkowski 1991).

Large molluscs found in Konińskie lakes were temporarily identified by J. I. Starobogatov basing on the shell morphology as: *Sinanodonta gibba* (Benson) and *S. orbicularis* (Heude). Detailed studies carried out by A. Piechocki (unpubl.) did not confirm this. The presumed *S. gibba* turned out to be a species already well known in Europe: *Anodonta woodiana woodiana* (Lea 1834). This species originates from Amur and Jangtsy rivers. At present, the species is very abundant in Hungarian fish ponds (Kiss, Pekli 1988); its biology was described by Kiss (1990, 1995). The other species has been not identified as yet, but its origin seems to be similar. It found better conditions in heated lakes and channels than in Hungary and became predominant over *Anodonta woodiana* and other three native *Anodonta* species. At the end of June, at the same time as in the case of Kiss' observations (1995), mass occurrence of glochidia on carp fry was observed in Konińskie ponds.

Less numerous *Anodonta woodiana* was found only in the littoral of Lichenskie and Pątnowskie lakes. This species was very numerous in all discharge channels, Morzysławski Channel, the channel connecting Licheńskie and Pątnowskie Lakes, and a part of Piotrkowicki Channel. The highest densities (up to 50 kg/m^2) were found in 1993 at the depth of 3 m under carp cages situated in the channels (Protasov *et al*. 1993, 1994). In 1994 and in 1995 the greatest colonies (up to 17 kg/m^2) were observed in the most turbulent water (near the bridges and siphons). Old individuals (11 - 12 years) were 21 cm long, with body mass up to 1 kg.

The experiments revealed that the unidentified mollusc species was much more tolerant, comparing to *A. woodiana* and *D. polymorpha*, to a gradual controlled increase of water temperature (Afanasjev et al. 1997). Measurements of oxygen consumption performed *in situ* in Licheńskie Lake using respirometers placed at natural sites revealed that metabolic rates of the individuals were similar to those reported for other smaller molluscs (Sinicyna et al. 1997).

The study of periphyton and benthos communities settled on the substrate and hydrotechnic devices showed that besides the bacterial destruction processes, three groups of animals played an important role in water self-purification process: in the warmest zones of the discharge channels two species of *Bryozoa* (*P. emarginata* and *P. fungosa*), and in the transient zones large *Anodonta*, and *D. polymorpha* in the coolest regions. Maximum assimilation rates for *Bryozoa* were 1026.5 kJ/m^2/24 h, for *D. polymorpha* - 933.8 kJ/m^2/24 h, and for *Anodonta spp*. - 425.4 kJ/m^2/24 h. Comparing the areas inhabited by the animals it appeared that *D. polymorpha* and *Anodonta spp*. played a most important role in the filtration processes. Comparison of total values revealed that benthic communities of the channels assimilated only 3 fold less energy than the communities of the lake littoral and profundal, and only 1.3 fold less than the littoral communities alone. Thus, the channels play an important role in organic matter utilisation in Konińskie lakes system, especially when one takes into consideration that total length and volume of the channels is two fold lesser comparing to the littoral zones of all 5 lakes.

The results encourage enhancement of the species important for water self-purification in order to maintain good water quality . This includes conservation of the sites inhabited by large molluscs, and creation of artificial substrates (reefs) in the channels where fish cages are situated, at channel outlets, and in some zones of the lakes. Taking into consideration the importance of *D. polymorpha* in water biofiltration, resulting in a reduction of organic matter load which is eutrophicating Ślesińskie Lake, it would be advantageous to start the extended water circulation system in first decade of May, when *D. polymorpha* larvae settle down to develop and mature in summer.

The role of the three main benthic communities in self-purification processes still requires additional studies of their life strategies. Unlike the molluscs (*D. polymorpha, Anodonta spp*.), the colonies of *Bryozoa* participate in filtration only in warm season. In autumn their bodies die off resulting in an additional load of organic matter. Similar effect in Ślesińskie Lake is produced by *D. polymorpha* deaths that take place in Piotrkowicki Channel which is drained every autumn.

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STRESZCZENIE

STRUKTURA I FUNKCJONOWANIE ZESPOŁÓW ZOOPERYFITONU I BENTOSU W KANAŁACH SYSTEMU PODGRZANYCH JEZIOR KONIŃSKICH

Zbadano zooperyfiton i zoobentos zasiedlający kanały konińskie, którymi wody z pięciu jezior pobierane i zrzucane są przez dwie elektrownie (rys. 1). Charakterystykę jezior i systemu schładzania wody podano w pracy Zdanowskiego (1994). Badania fauny, wykorzystując metodykę badań podwodnych, wykonano latem 1994 roku (sierpień) na 21 stanowiskach - profilach. Objęto nimi trzy kanały poboru wody przez elektrownie o długości 6 km oraz sieć kanałów zrzutu wód podgrzanych o długości 26 km (tab. 1, rys. 2).

Poszczególne kanały charakteryzowały się odmienną liczbą znalezionych taksonów peryfitonowych i bentosowych (tab. 2). Najbardziej interesujące okazały się dwa gatunki dużych małży, które w pracy Protasova i in. (1994) opisano jako *Anodonta sp*. Pochodzą one z Chin i zostały zawleczone do badanych jezior w latach osiemdziesiątych z Węgier z rybami roślinożernymi. Mniej liczny, występujący tylko w jeziorach, to *Anodonta woodiana woodiana* (Lea, 1834), zaś drugi - masowo zasiedlający kanały nie został do tej pory zidentyfikowany. Analiza podobieństwa faunistycznego Serensena wykazała spójny związek (0,45 - 0,70) łączący w jedną grupę faunę bentosową kanałów: zrzutowego elektrowni „Pątnów (aż po syfon), łączącego Jez. Licheńskie z Pątnowskim oraz odcinka Kanału Piotrkowicki z Jez. Licheńskiego do stacji pomp (rys. 3a). Swoistość faunistyczną kanałów potwierdza analiza podobieństwa zooperifitonu określona za pomocą współczynników jakościowych Serensena (rys. 3b) i ilościowych Czekanowskiego-Serensena (rys. 3c).

Wydzielono kilka zgrupowań zooperyfitonu, w których przeważały mszywioły (stan. 2, 3 i 7) lub *D. polymorpha* (stan. 1, 15 i 19), a także miejsca bez wyraźnego dominanta (rys. 4). Najwyższą liczebność i biomasę zooperyfitonu do 272 000 egz./m^2 i do 14,5 kg/m^2 odnotowano poniżej stacji pomp na stanowisku 15 odcinka Kanału Piotrkowickiego, gdzie pokrycie kamieni przez *D. polymorpha* osiągało tu 100%, a dna przez gęste przerosty - do 50%. Kolonie *D. polymorpha* zdominowane zostały przez osobniki najmłodszej generacji o wymiarach do 6,5 mm (rys. 5).

Struktury zoobentosu w kanałach wskazują na zróżnicowaną adaptację gatunków do warunków termicznych (rys. 6). W strefie zrzutu wód podgrzanych z elektrowni „Konin" dominowały głównie *Nematoda* i *P. emarginata*, stanowiące 81% ogólnej liczebności (4 800 egz./m^2) i 98% ogólnej biomasy bentosu (132,9 g/m^2). Podobną dominację mszywiołów w strefie dennej i *Tubificidae* na odkosach kanału odnotowano również w strefie zrzutu wód podgrzanych z elektrowni „Pątnów". Biomasa bezkręgowców wynosiła tu 1650,3 g/m^2. Największy rozwój zoobentosu z dominacją dużych małży z rodzaju *Anodonta* odnotowano w dolnych odcinkach kanałów zrzutowych oraz z dominacją *D. polymorpha* w chłodniejszych kanałach poboru wody przez obie elektrownie, w kanale łączącym Jezioro Licheńskie z Pątnowskim i w Kanale Piotrkowickim (rys. 6). Płytsze partie zasiedlały młode osobniki *Anodonta sp*. o wymiarach do 55 mm, zaś głębsze partie - osobniki starsze o wymiarach 120 - 170 mm (rys. 7).

Wykazano znaczącą rolę organizmów zasiedlających kanały (mszywioły, *Anodonta sp.*, *D. polymorpha*) w samooczyszczaniu się wód w systemie jezior konińskich. Asymilacja materii organicznej przez zooperyfiton i bentos kanałów była porównywalna z litoralem jezior. Wydzielono 5 charakterystycznych zgrupowań zooperyfitonu i 6 zoobentosu (tab. 3). Największą destrukcję, (32,75 kJ/m^2/h) odnotowano w peryfitonie *D. polymorpha* w Kanale Piotrkowickim. Wysokie okazały się maksymalne wskaźniki destrukcji zespołu bentosowego i peryfitonowego *P. emerginata* (18,31-26,08 kJ/m^2/h), a także zespołu bentosowego *Anodonta sp.* (14.22 kJ/m^2/h). Największe tempo filtracji (33.5 m^3/m^2/24h) odnotowano w zespole zdominowanym przez *D. polymorpha* w Kanale Piotrkowickim i o połowę niższe (15,4 m^3/m^2/24h) przez zespół *Anodonta sp.* za syfonem w Kanale Wąsoskim. Obliczono, że małże odfiltrowują w ciągu doby około 4,7 ton zawiesiny ogólnej i 3,5 ton C, z czego na *Anodonta sp.* przypada 43%, a na *D. polymorpha* 57%. Średnie dobowe tempo asymilacji materii organicznej przez mszywioły zamieszkujące kanały wynosi $5{,}22 \cdot 10^7$ kJ, co w przeliczeniu na węgiel odpowiada 1,33 tonom tego pierwiastka. Przyjmując współczynnik przyswajalności równy 0.6 wyliczono, że mszywioły sedymentują 2,2 tony węgla w ciągu doby.

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