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REVIEW PAPER

Changes in zooplankton abundance and community structure in the cooling channel system of the Konin and Pątnów power plants

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Abstract. The aim of the research was to analyze changes in crustacean and rotifer plankton communities in channel systems cooling system for the Konin and Pątnów power plants (central Poland). Only small amounts of zooplankton (Rotifera and Crustacea biomass) were detected in the channel systems investigated in this study. In intake channels, the total zooplankton population ranged from 100 to 200 indiv. dm^{-3} and biomass normally did not exceed 1 mg dm^{-3}. The zooplankton population did not exhibit unambiguous changes immediately after moving across the stream condensers zone (thermal shock) or immediately after the turbines of the pumping station on one of the channels (mechanical and pressure stress). Decreases in the amount of biomass, as much as 96%, were detected several kilometers beyond the heated water release sites. Greater zooplankton mortality rates were recorded in the summer when the temperature of released water exceeded 30°C along with a larger rise in temperature (5-6°C). The loss of plankton in the Konin power plant (KPP) system of cooling channels was greater than that in the Pątnów power plant (PPP) system of cooling channels. The large decrease in the amount of zooplankton biomass in the channel beyond the pumping station suggests that mechanical and pressure stress in the turbines, which the Rotifera and Crustacea were subjected to, was the principal reason for the high rate of zooplankton mortality.

Keywords: heated lakes, zooplankton loss, Rotifera, Cladocera, Copepoda

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Introduction

The system of cooling channels at the Konin and Pątnów power plants is unique in Poland and features a variety of anthropogenic factors that have a powerful impact on aqueous biocenoses. The abundance and community structure of plankton as well as its mortality rate can be affected by changes in the thermal regime of a body of water caused by the release of heated water from power plants (Patalas 1970, Hillbricht-Ilkowska et al. 1976, Ejsmont-Karabin and Węgleńska 1988a, 1988b, Hillbricht-Illkowska and Zdanowski 1988a, 1988b, Tunowski 1988) or by mechanical stress (Evans et al. 1986).

Changes in species composition, trophic profile, and zooplankton productivity are more intensive in bodies of water where heating takes place in conjunction with changes in hydrological conditions and an accumulation of pollutants (Hillbricht-Ilkowska and Zdanowski 1988 a, 1988b, Zdanowski 1994a, 1994b). The heated Konin area lakes fit this category of lakes and are characterized by an altered thermal and hydrological regime. In the Konin system of five lakes, connected by a network of channels, thermal zones of different zooplankton species and their seasonal cycles have become disturbed (Hillbricht-Ilkowska and Zdanowski 1988b, Zdanowski 1994a). The lakes are now dominated by small rotifers and certain copepods (Hillbricht-Ilkowska et al. 1988, Tunowski 1994).

The temperature of the water released from Konin area power plants into their networks of cooling channels normally exceeds 30°C in the summer (Zdanowski 1994a). It can reach as high as 35°C during warmer periods of time, with discharge rates reaching 25 $m^3 s^{-1}$ (Tunowski 1988). The magnitude of the increase in temperature and the increase in discharge in the cooling channels limit the development of many species of plankton. The heated environment in the channels and lake release zones creates favorable conditions for species that prefer warm and highly turbulent water. In addition to thermal shock and hydraulic shock, other factors that determine the nature and abundance of zooplankton in channels are mechanical stress and pressure stress, which the organisms experience once they pass through the cooling system of a power plant. Cladocera was shown to experience the highest rates of mortality. This particular group of organisms is unique in terms of its size and delicate swimming and filtration trunk limbs (Tunowski 1988, 1994).

The aim of the paper is to show changes in crustacean and rotifers communities found in systems of intake and discharge channels at two Konin area power plants with respect to elevated water temperature and turbulence. A large number of sampling sites made it possible to not only evaluate changes in plankton communities after they leave a lake (lentic) system and enter a channel (lotic) system but also to estimate zooplankton losses once the organisms have moved through the stream condensers of the power plant or turbines at a channel pumping station. The impact that each power plant has on the trophic profile of zooplankton can also be assessed.

Materials and methods

The Konin lakes are located in central Poland in the Wielkopolsko-Kujawskie Lakeland (52°18'N, 18°18'E). They are an aqueous system located in the drainage basin of the Ślesiński Channel, which connects the Warta River with Lake Gopło (Zdanowski 1994a). The name is used to describe five natural bodies of water: Lake Gosławskie, Lake Pątnowskie, Lake Licheńskie, Lake Wąsosko-Mikorzyńskie, and Lake Ślesińskie. The lakes are connected by a network of channels about 32 kilometers long (Table 1). There are two water circulation systems in the Konin lakes; from September to May, when temperatures are lower, the short water circulation cycle is in operation. In the summer months, the long cycle is put into operation and Lake Ślesińskie and the northern deep water section of Lake Mikorzyńskie are included in it (Fig. 1).

Table 1

Hydrological characteristics and average (min-max) water temperature in the channels analyzed (according to Kraszewski and Zdanowski 2001)

Channel	Length (km)	Width (m)	Discharge ($m^{-3}s^{-1}$)	Water temperature (°C)
Konin power plant intake channel	2.3	20-50	25	14.2 (1.5-27.8)
Konin power plant discharge channel	1.8	25-40	25	21.3 (10.6-34)
Pątnów power plant discharge channel	4.3	20-40	30	23.2 (12.5-34.8)
Licheński Channel	4.4	20-50	29	21.1 (9.4-33.8)
Piotrkowicki Channel	1.5	25-45	23	16.0 (4.0-30.3)

Zooplankton research in the cooling systems of the KPP and PPP was conducted at thirteen sampling sites (1-13) in July and September of 1999 and at eight sampling sites (1-8) in May of 1999 (Fig. 1). A total of 34 samples was collected for analysis. Samples were obtained from the entire water column using a five liter semi-automatic Toń sampler. Water (30 dm^3) was filtered from each sampling site and filtered using plankton filter no. 25. Each sample was fixed with Lugol's solution and preserved using formalin (2-3% solution). Sub-samples were placed in a Sedgwick-Rafter cell and analyzed under a microscope. The number and length of individuals of different species were noted (20-30 per species). The amount of Rotifera and Crustacea biomass was estimated using formulas relating length and individual mass (Hillbricht-Ilkowska and Patalas 1967, Bottrell

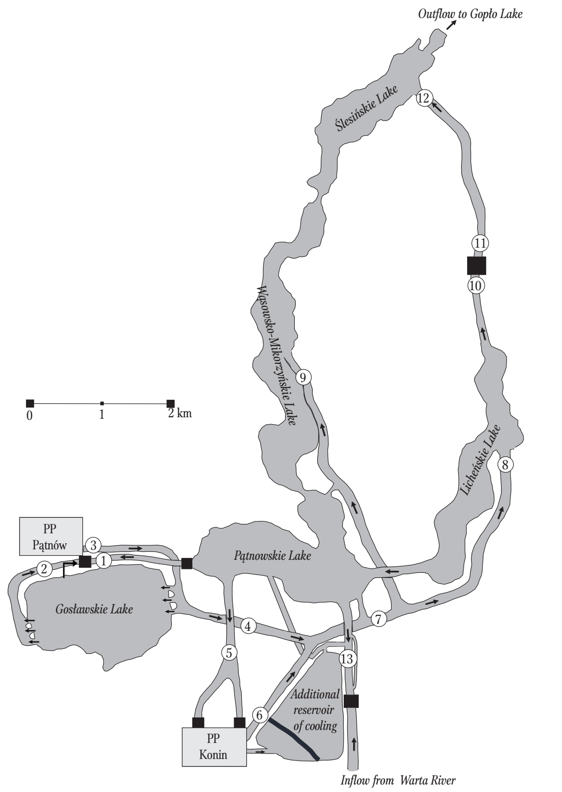

Figure 1. Map of the Konin lake system. Zooplankton sampling sites (white circles – site numbers, black squares – water pumping stations).

et al. 1976, Ruttner-Kolisko 1977). In order to determine the taxonomic diversity of the zooplankton obtained at the various sampling sites, the Shannon-Weaver diversity index modified by Margalef was used (Margalef 1958). The index was used with respect to the abundance and zooplankton biomass. Pearson's coefficient of linear correlation was used to analyze the impact of altered habitat conditions on the abundance and amount of animal plankton biomass.

The temperature of the water in the cooling system varies from season to season and from the major cooling cycle to the minor cooling cycle. Table 2 shows temperatures at selected sampling sites during plankton sampling and the distance of each channel sampling site from a power plant. A detailed description of the lakes and the channel system is available in other publications (Zdanowski 1994a, Kraszewski and Zdanowski 2001).

Table 2

Water temperature in the channels analyzed and distance of sampling sites from power plant in 1999

Sampling site	Water temperature (°C)			Distance from release site (km)
	May	July	September	
1	18.0	25.1	21.4	-
2	19.0	23.8	23.0	-
3	23.4	30.4	27.4	0.1
4	22.3	30.3	27.0	3.7
5	18.2	25.6	20.8	-
6	22.6	31.8	25.9	0.2
7	23.0	31.1	27.1	3.6
8	23.5	31.4	26.5	6.2
9	-	31.0	25.1	10.6
10	-	28.5	23.3	7.2
11	-	28.5	23.1	8.0
12	-	28.4	22.3	10.5
13	-	28.4	23.4	-

Results

Zooplankton abundance

Thirty seven taxons of plankton organisms were identified in the intake channels and discharge channels of the two Konin area power plants. Fourteen species of cladocerans, three species of copepods, and twenty species of rotifers were identified (Table 3). Rotifera were the most common of the species in the channel systems. Each sample tested contained organisms from the species *Synchaeta stylata* Wierzejski as well as *Synchaeta kitina* Rousselet. Other commonly found species were: *Polyarthra vulgaris* Carlin, *Polyarthra remata* Skorikov, and *Brachionus angularis* Gosse. Among crustaceans, *Diaphanosoma brachyurum* (Lievin) and *Mesocyclops leuckarti* (Claus) were the species most commonly found (Table 3). The greatest species richness was noted in September at site 9 in the Wąsoski Channel. The smallest number of species were found in May at site 7, and in July, at site 2 (in the intake channel of the PPP) (Fig. 2).

Table 3
List of zooplankton species found in the cooling system channels of two Konin power plants in 1999

Taxa	May	July	September
Cladocera			
Acroperus harpae (Baird)	+		
Alona affinis (Leydig)	+		
Bosmina coregoni ssp.coregoni Baird		+	+
Bosmina longirostris (O.F. Müller)	+	+	+
Ceriodaphnia pulchella G.O. Sars		+	
Ceriodaphnia reticulata (Jurine)		+	
Chydorus sphaericus (O.F. Müller)	+	+	+
Daphnia cristata cristata G.O. Sars	+		+
Daphnia cucullata G.O. Sars	+	+	+
Daphnia hyalina (Leydig)	+		
Daphnia longispina (O.F. Müller)			+
Diaphanosoma brachyurum (Lievin)	+	+	+
Rynchotalona rostrata (Koch)		+	
Leptodora kindtii (Focke)		+	+
Copepoda			
Eudiaptomus gracilis (G.O. Sars)			+
Mesocyclops leuckarti (Claus)	+	+	+
Thermocyclops crassus (Fischer)		+	+
Rotifera			
*Anureopsis fissa (*Gosse)		+	
Bdelloidae n. det.	+	+	+
Brachionus angularis Gosse		+	+
Brachionus calicyflorus Pallas		+	+
Brachionus diversicornis (Daday)		+	+
Brachionus leydigi Cohn		+	
Brachionus quadridentatus Herman		+	
Cephalodella sp.		+	+
Filinia longiseta (Ehrenberg)		+	+
Keratella cochlearis v. tecta (Gosse)	+	+	+
Keratella cochlearis v. typica (Gosse)	+	+	+
Keratella quadrata (O.F. Müller)	+	+	+
Lecane luna O.F. Müller	+		
Polyarthra remata Skorikov	+	+	+
Polyarthra vulgaris Carlin	+	+	+
Synchaeta kitina Rousselet	+	+	+
Synchaeta oblonga Ehrenberg	+		+
Synchaeta pectinata Ehrenberg	+	+	
Synchaeta stylata Wierzejski	+	+	+
Trichocerca pusilla (Lauternborn)	+	+	+

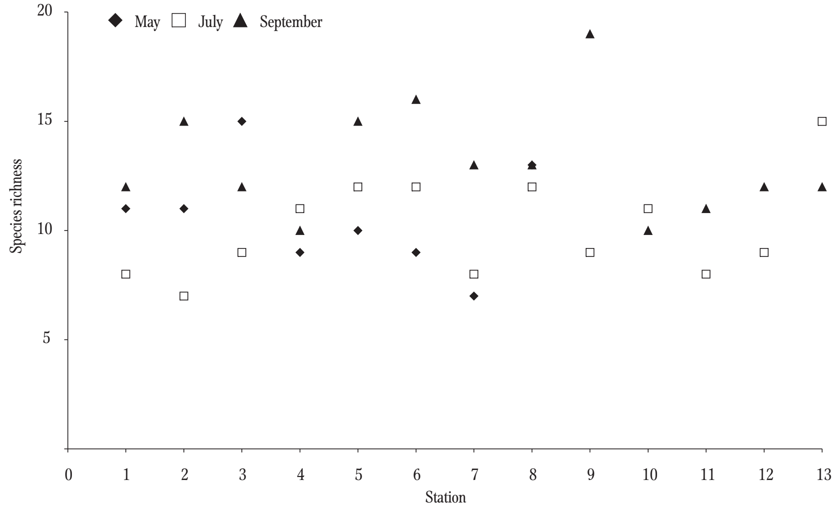

Figure 2. Zooplankton species richness found in the cooling system channels of Konin power plants.

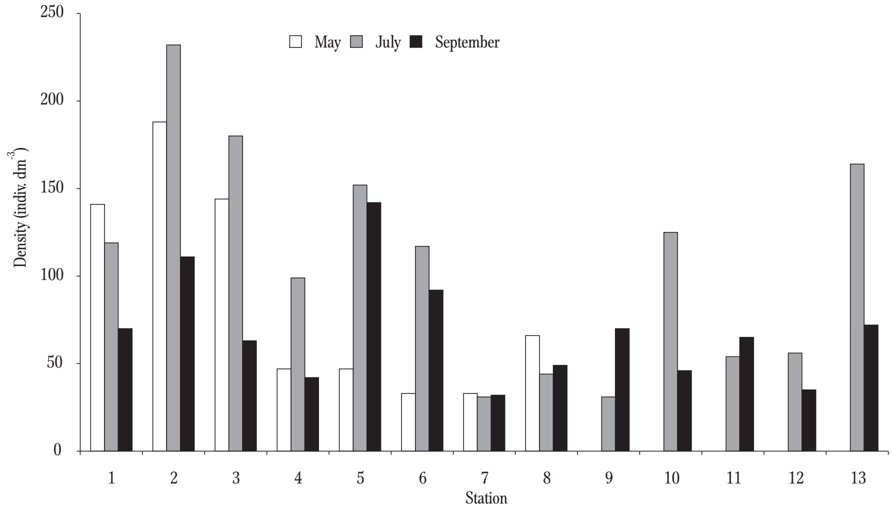

Figure 3. Zooplankton density (indiv. dm^{-3}) at sampling sites on cooling system channels of Konin power plants.

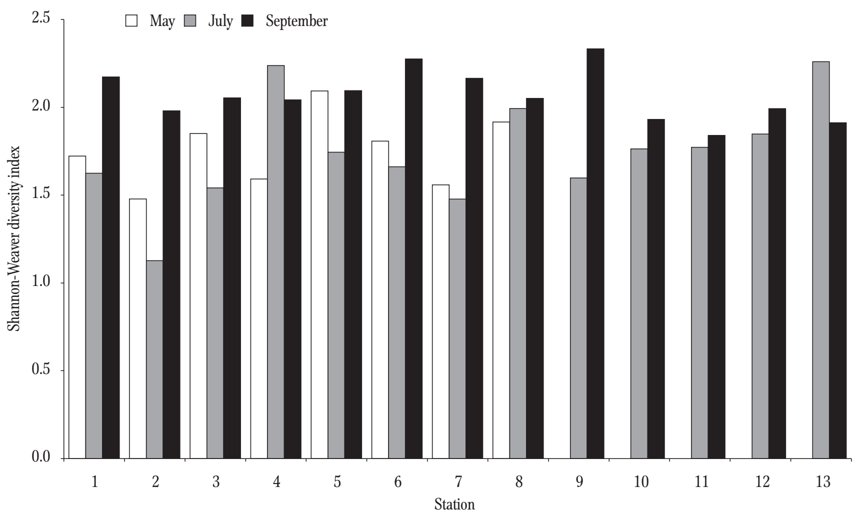

Figure 4. Shannon-Weaver zooplankton diversity index values for the analyzed channels.

The entire system was characterized by small quantities of zooplankton (Fig. 3). Rotifera were the most commonly found species, while Cladocera were the least common. Copepoda constituted a rather high percentage of the total population, ranging from several percent in May to eighty percent in July, when the number of young stages was very high (nauplii and copepodites). They constituted between 77.4 and 100% of the copepods. Benthic life forms were not found in large numbers - less than 1% of the total zooplankton population over the entire course of the research period.

In intake channels, the total zooplankton density generally ranged from 100 to 200 indiv. dm^{-3}. The largest number, 232 indiv. dm^{-3}, was observed in July in the western intake channel of the PPP (site 2). Values under 100 indiv. dm^{-3} were recorded in May in the intake channel of the KPP (site 5), and in September, in the eastern intake channel of the PPP (site 1). In discharge channels, the total density normally did not exceed 100 indiv. dm^{-3}. The lowest numbers were recorded in July at sites 7 and 9, where the total density was at 31 indiv. dm^{-3} (Fig. 3).

Values of the Shannon-Weaver diversity index of species diversity were calculated based on the abundance of particular species in the samples tested and ranged from 1.13 to 2.28 (Fig. 4). The smallest value was recorded in July at site 2, a location dominated by *S. stylata* (62% of total zooplankton abundance). In addition to young copepods, single individuals of other species were also found: *D. brachyurum*, *B. angularis*, *S. stylata* and *Trichocerca pusilla* (Lauternborn). The greatest diversity of zooplankton was observed in September at site 6 in the discharge channel of the KPP. No single species was dominant at this location. Small groups of rotifers, cladocerans, and copepods were found in roughly equal numbers.

The relationship between zooplankton abundance, water temperature, and distance from a power plant was statistically significant only in July and September. In July, total zooplankton abundance ($r = -0.75$, $P < 0.05$) and copepod abundance ($r = -0.74$, $P < 0.05$) decreased with increasing distance from a heated water release site. In September, the number of cladocerans ($r = -0.58$, $P < 0.05$) and copepods ($r = -0.59$, $P < 0.05$) decreased with increasing distance from a heated water release site with respect to the distance of the site from the power plant. The influence of temperature alone on the abundance of animal plankton was statistically significant only in July with respect to rotifers ($r = -0.57$, $P < 0.05$) and total zooplankton abundance ($r = -0.58$, $P < 0.05$).

Zooplankton biomass

The amount of crustacean and rotifer biomass in the channel system was small and normally did not exceed 1 mg dm^{-3}, ranging from 0.005 mg dm^{-3} in May at sampling site no. 7 to over 2.03 mg dm^{-3} in July at site 5. Rotifera possessed the smallest share of the total amount of zooplankton biomass. The shares of Clacodera and Copepoda changed during the research period. The largest amount of Copepoda biomass was recorded in July. A particularly clear increase in the amount of Copepoda biomass was recorded at site 5 in the discharge channel of the KPP, where it reached over 1.3 mg dm^{-3}. The amount of Clacodera biomass fluctuated from 0 to 0.95 mg dm^{-3} (Fig. 5).

In May, the main constituents of total zooplankton biomass were Clacodera, mainly *Daphnia cucullata* Sars, *Daphnia hyalina* (Leydig), and *Bosmina longirostris* (O.F. Müller). The percentage of cladocerans in the total zooplankton biomass ranged from 53% to 91% at selected sampling sites. The only exception was site no. 7, where none were found. Rotifera (8.3%) and Copepoda (8.2%) populations were quite similar as a percentage of total zooplankton biomass. Rotifera numbers ranged from 0.3% to 93% at some sampling sites. Copepoda never exceeded 35% of total zooplankton biomass at any sampling site.

In July, much like in May, the largest amount of biomass was detected at sampling site no. 5 in the discharge channel of the Konin power plant, with over 2 mg dm^{-3}. Most of the biomass consisted of *M. leuckarti* and *D. brachyurum*. There was a larger presence of Copepoda, which made up between 12%

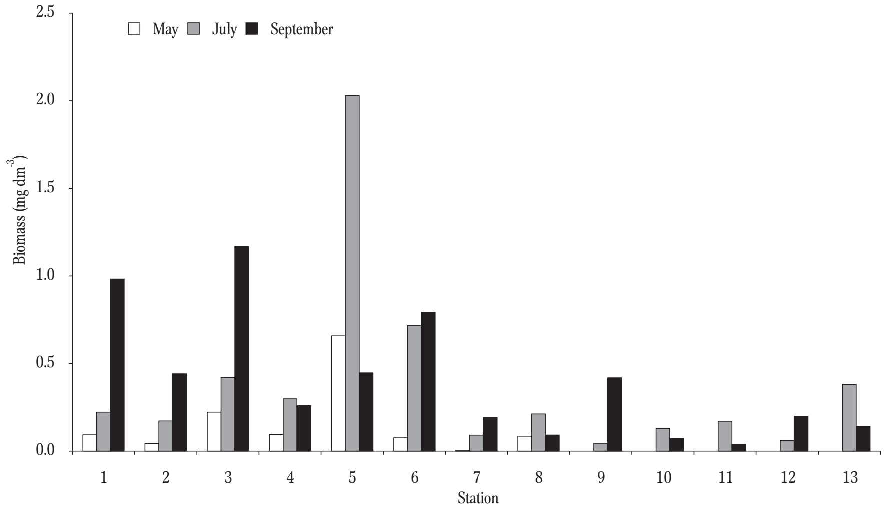

Figure 5. Zooplankton biomass (mg dm^{-3}) at sampling sites on cooling system channels of Konin area power plants.

and 93% of the biomass. The smallest amount of biomass was detected at site 9, with no clacoderans present. In general, with the exception of sites 3 and 11, the share of Clacodera had decreased. The amount of Rotifera biomass was small at under 14%.

In September, the share of Cladocera increased again, fluctuating between 24% at site 11 and 80% at site 3 in the discharge channel of the PPP. Copepoda constituted a maximum of 52% of total zooplankton biomass. Rotifera biomass, with the exception of site 11, did not exceed 20%. The largest amount of biomass (> 1 mg dm^{-3}), mainly *D. cucullata*, was recorded at site 3 in the discharge channel of the PPP.

The Shannon-Weaver diversity index, which reflects the amount of species biomass, fluctuated between 0.6 and 1.9 (Fig. 6). The highest value of the zooplankton diversity index was recorded in May at site 2 in the eastern intake channel of the PPP (Fig. 6). The *D. cucullata* species was the principal constituent of the biomass, being the only constituent to

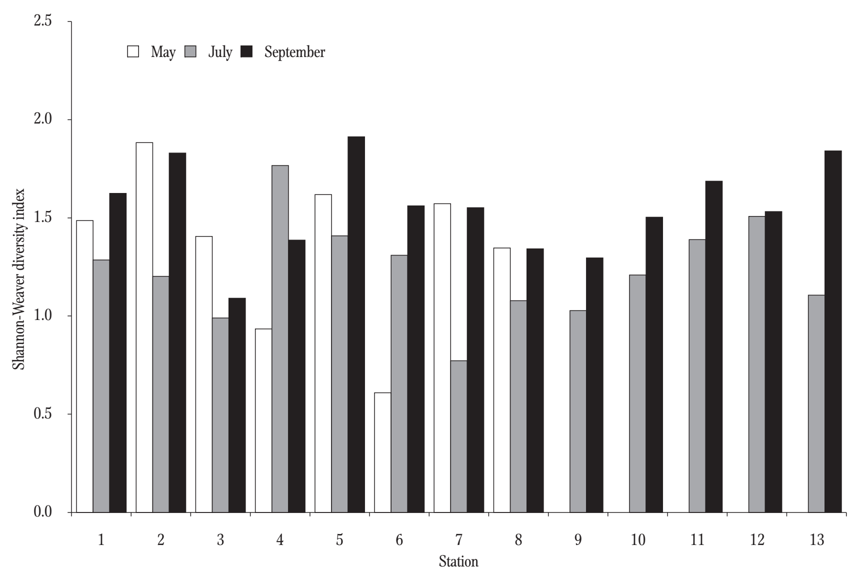

Figure 6. Shannon-Weaver diversity index for zooplankton biomass in the analyzed channels.

exceed 0.01 mg dm^{-3} at this sampling site. The lowest degree of diversity was also recorded in May at site 6 in the discharge channel of the KPP

The relationship between the amount of zooplankton biomass and distance from a power plant was statistically significant only in the month of September. It has been shown that the total amount of biomass decreases with distance from heated water release sites ($r = -0.57$, $P < 0.05$). The same holds true of cladoceran biomass ($r = -0.78$, $P < 0.05$) and copepod biomass ($r = -0.56$, $P < 0.05$).

Discussion

Studies of the impact the discharge of power plant post-cooling waters has on zooplankton taxonomic diversity, spatial distribution, abundance, biomass, and production have been conducted for many years (Patalas 1970, Hillbricht-Ilkowska and Zdanowski 1978, Tunowski and Siergiejeva 1998, Tunowski 2009). The impact of different degrees of heating and variable retention times on zooplankton development in the Konin area lakes have also been studied (Tunowski 2009). Other research delved into changes in thermal-oxygen relationships and changes in water composition as factors affecting the zooplankton metabolism (Zdanowski and Prusik 1994).

Research conducted in the summer of 1983 (Tunowski 1988) indicated that zooplankton levels were low in the cooling system of the KPP. The largest numbers of Cladocera, Copepoda, and Rotifera (518 indiv. dm^{-3}) were recorded in July in the power plant's intake channel. Rotifera were the largest group with the most numerous species being *Keratella cochlearis* (Gosse). The average of four sampling sessions at this particular site was 342 indiv. dm^{-3}, with rotifers at 77%, copepods at 20%, and cladocerans at 2.4%. Once the organisms had moved through the cooling system of the Konin power plant, their numbers diminished as following: rotifers (by 33%), copepods (by 63%), and cladocerans (by 58%). At site 8, the loss of large plankton organisms was significant, with the largest being: *Bosmina coregoni coregoni* (Baird), *D. cucullata, D. brachyurum,* young Diaptomidae and Cycylopoidae copepods, as well as adult copepods and rotifers of the genus *Polyartha*. Smaller plankton organisms were better able to survive than larger ones. The following species lost the fewest members: *Chydorus sphaericus* (O.F. Müller), *B. angularis, K. cochlearis*. In the course of the first three sample collection attempts, the number of individuals decreased between 44 and 60% when the water temperature was raised 7-8°C. In the course of a sample collection attempt in August, 1983, the zooplankton population decreased 32% when the water temperature was raised by 3.9°C. Losses within each particular group depended on the degree to which the water was heated in the power plant's cooling system and ranged from 0 to 50% in the case of Rotifera and from 65 to 100% in the case of Cladocera. The amount of zooplankton biomass was small and did not exceed 0.56 mg dm^{-3} in the intake channel of the KPP. The amount of biomass decreased, on average, by 68% after the plankton had moved through the power plant's cooling system. Cladocera and Copepoda suffered the greatest losses.

A high degree of water heating significantly limits the growth of zooplankton (Patalas 1956, 1970, Evans et al. 1986, Protasov et al. 1991). Post-embryonic development of zooplankton as well as the organisms' life span, size, and rate of growth all depend on water temperature (Praszkiewicz 1974). The heating of water can support increased zooplankton reproduction (Hillbricht-Ilkowska and Zdanowski 1978).

The abundance and the amount of zooplankton biomass were at low levels during the research period. The most numerous organisms were the Rotifera and the least numerous were the Cladocera. The flow of water also caused the appearance of organisms (in addition to pelagic plankton) typical of littoral and benthic waters e.i. Bdelloidea. Previously quite abundant organisms of the genus Pompholyx disappeared altogether. The abundance of rotifers of the genus *Keratella* decreased and the abundance of rotifers of the genus *Synchaeta* increased. The abundance of young stages of Copepoda remained the same. The largest reduction in the abundance of zooplankton was observed in the summer, when the temperature of released water exceeded 30°C, and the water was being heated more than previously (5-6°C). This response is consistent with experimental data obtained by Zargar and Ghosh (2007). They concluded that the survival rate of crustacean plankton becomes limited at temperatures above 33°C. The highest rate of zooplankton reproduction was noted at 26°C, while at higher temperatures (> 31°C), the reproduction rate clearly decreased. The decrease in zooplankton count was observed in the Licheńskie and Ślesińskie lakes at sampling sites directly affected by water being discharged after the cooling process (Tunowski 2009). The altered aqueous environment in the channels caused a decrease in the diversity of zooplankton species. Specifically, the conditions present in this system affected the species domination structure found at sampling sites characterized by different water temperatures. Small differences in the values of the species diversity index may mean a wide spectrum of trophic possibilities offered by this environment (Ejsmond-Karabin and Węgleńska 1988a, 1988b). A relative lack of species diversity indicates a transformation that differentiates these systems from natural streams featuring different temperature conditions. Most of the organisms found in the channels had probably drifted in from lakes, as the zooplankton reproduction period is longer than the time that zooplankton resides in the channel system. A hypothesis can be put forth that if the channels were longer, these organisms would be able to reproduce freely. On the other hand, elevated temperatures tend to shorten the diapause of dormant eggs, which affects diversity, species richness, and genetic variability (Hairston 1996). Increasing values of the Shannon-Weaver diversity indicate that the zooplankton community structure at sampling sites located far away from heated water release sites begins to regenerate itself. At the same time, the actual number of organisms remains lower and so does their biomass. This has been shown via high correlation coefficients for distance from heated water release sites and plankton abundance.

In addition to elevated temperatures, organisms are subjected to two other types of pressure. All the organisms are mechanically halted on the rotating sieves that purify water of most larger impurities. Large varieties of crustaceans may become virtually eliminated at this stage (Tunowski 1988). This is true in the case of Cladocera, whose abundance in tested samples decreased to several individuals per one liter or none at all. An abrupt rise in temperature in the cooling system causes an increase in the rate of elimination of plankton organisms (Tunowski 1988). The thermal shock depends on the degree of heating of water and the size of the given organisms (Morduchaj-Boltovskoj 1975a, 1975b). Zooplankton is also subjected to pressure and mechanical stress when it moves through the mechanisms of pumping stations found along channels. Dubovskaia et al. (2004) were able to show that once zooplankton passes through the machinery of the hydroelectric power plant in Krasnoyarsk (upper Yenisei River), an average of 77% of it survives below the dam. Either damaged or dead organisms constituted only 3-6% of the total zooplankton population found immediately beyond the hydroelectric power plant. Another 10% did not survive the highly turbulent 32 km stretch of river downstream of the dam.

A similar situation was observed in the Konin area lake system. No statistically significant decreases in zooplankton abundance were recorded immediately beyond the stream condensers of the power plants (thermal and mechanical shock) or immediately beyond the turbines of the pumping station on the channel (mechanical and pressure stress). On the other hand, plankton tests conducted several kilometers beyond heated water release sites showed a large decrease (up to 96%) in biomass.

An analysis of changes in the abundance and amount of zooplankton biomass conducted in the Konin area lake system indicates that the main factors limiting the survival rate of plankton organisms are physical forces such as increased turbulence in channels and mechanical stress at pumping stations. Thermal stress is a significant factor only during the summer when the temperature in the channels exceeds 30°C.

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Streszczenie

Zmiany struktury i obfitości zooplanktonu w systemie kanałów chłodzących elektrowni Konin i Pątnów

Badano zmiany zespołów planktonu skorupiakowego i wrotkowego w systemach kanałów dolotowych i wylotowych dwóch elektrowni konińskich (tab. 1, rys. 1). Badania prowadzono w okresie małego (wiosna) i dużego obiegu chłodzącego (lato i jesień). Rozmieszczenie stanowisk pozwalało na określenie wpływu na zooplankton każdej z elektrowni, jak i ocenę skutków okresowych zmian środowiska planktonu z jeziornego na przepływowy (tab. 2). W całym okresie badań oznaczono 14 taksonów Caladocera, 3 Copepoda i 20 Rotifera (tab. 3, rys. 2). Cały układ charakteryzował się niską liczebnością i biomasą skorupiaków i wrotków, oraz dużą zmiennością różnorodności gatunkowej (rys. 3-6). W kanałach dolotowych liczebność całkowita wahała się w granicach 100-200 osobn. dm^{-3} a biomasa z reguły nie przekraczała 1 mg dm^{-3}. Natomiast plankton badany na stanowiskach położonych kilka kilometrów za tymi zrzutami charakteryzował się spadkiem biomasy nawet o 96%. Większą śmiertelność zooplanktonu notowano w okresie lata, kiedy to temperatura wody zrzutowej przekraczała 30°C i notowano wyższy stopień podgrzania wody (5-6°C). W grupach taksonomicznych najwyższą śmiertelność obserwowano wśród Cladocera, których liczebność w strefach przyujściowych kanałów spadała do kilku osobników w litrze wody. Największe straty zooplanktonu obserwowano w układzie kanałów systemu chłodzącego Elektrowni Konin. Redukcja planktonu zwierzęcego w kanałach wylotowych Elektrowni Pątnów była niższa, mimo wyższych temperatur wody. Duży spadek biomasy zooplanktonu w kanale za przepompownią wody wskazuje na to, że stres mechaniczny i ciśnieniowy, jakim w turbinach poddane są Rotifera i Crustacea, oraz wysoka turbulencja wody w kanałach, stanowią główne czynniki zwiększonej śmiertelności zooplanktonu.