*Original Research*

# The Impact of Catastrophic Flooding on Zooplankton

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**Abstract**

Technical regulations for the lower Vistula River made in the 19th century created a number of shallow reservoirs. The reservoirs are diverse: they can be permanently connected to or disconnected from the main channel of the river. Medium and low water levels of the Vistula cause the reservoirs to not have even a temporary connection to the river. In May 2010 the flood that occurred on the Vistula flooded all the investigated reservoirs. The aim of our study was to learn about the influence of catastrophic flooding on the zooplankton community in the studied floodplain lakes. The study compared the results of zooplankton investigations before the flood (July and August 2009) with results after the flood (July and August 2010). The flood destroyed submerged plants and brought suspension, which changed abiotic conditions of life in the floodplain lakes. The flood waters caused a decrease in the number of species and rebuilt the structure of zooplankton species in the reservoirs. The increase of rotifer species at the expense of crustaceans was observed at different sites. There was also a several-fold increase in the abundance of zooplankton. The largest changes of zooplankton after the flood were recorded in the floodplain lakes that were rich in submerged vegetation (before the flood).

**Keywords:** floodplain lake, flood, the Vistula River, Rotifera, Crustacea

## Introduction

One of the most significant elements of landscapes with big lowland rivers is floodplain lakes. They are usually shallow, dominated by macrophytes, astatic, and with variable habitat factors. A great value of all floodplain lakes is their diversity and biological richness [1-3].

Life in the river valley lakes at floodplain areas depends on the water level in the river and is associated with cyclic flooding as described by Junk et al. [4] in Flood Pulse Concept.

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Usually two successive phases can be observed in a floodplain lake: a potamophase, when the water from the river washes out the reservoir, and a limnophase, when the water returns to the river bed and conditions in the lake stabilize. During the isolation period floodplain lakes have relatively stable conditions which enable the development of macrophytes and several groups of algae and invertebrates.

The isolation period and relatively stable conditions promote the specific individualization of each reservoir. The abundance of crustaceans increases and they start to dominate the rotifers [5, 6].

Periods of stability are interrupted by periods of cyclic flooding. Water from the river washes out the floodplain lake, increases the water level, washes out organisms inhabiting the lake, and even washes out sediments accumulated during the limnophase [7].

The river's water carries a significant amount of suspension, therefore transparency decreases. Plants rooted at the bottom of floodplain lakes die from lack of light. The small organisms brought by the waters of the river start to dominate [8, 9].

The influence of floodplains on their zooplankton community depends on the abiotic (water age, physical, and chemical parameters) and biotic characteristics (food availability, competition and predation) of each tributary [10, 11]. According to the flood pulse concept [4], most of these parameters are defined by the water regime of the main arm, which of course varies over time [12].

Flood events cause major changes in physical and environmental conditions [13]. But a catastrophic flood can permanently change all the conditions, which were observed in May 2010 in the Vistula River Valley.

Technical regulations for the lower Vistula River made in the 19th century created a number of shallow reservoirs (old river beds, side arms, backwaters) [14]. The reservoirs are diverse: they can be permanently connected with or disconnected from the main channel of the river. Medium and low water levels of the Vistula cause the reservoirs to lose even a temporary connection to the river.

The lower Vistula Valley has very irregular flooding. There have been years of very low water, when even the connected floodplain lakes could not be washed out by the waters of the river. In May 2010, the catastrophic flood that occurred on the Vistula River flooded all the investigated reservoirs and changed all biotic and abiotic conditions.

Our knowledge about these astatic mesohabitats is still much less as compared to our knowledge on plankton of big lakes or rivers.

The aim of the study was to learn about the influence of catastrophic flooding on zooplankton of the studied floodplain lakes. Before the flood the studied water reservoirs were connected with the Vistula River to a different extent: from the total isolation sites W1, W2, and MW; to a limited connection site-PD. The catastrophic flood that occurred on the Vistula River flooded all the investigated reservoirs.

We assumed that the flood could significantly change the structure of zooplankton, but it seemed that two months after the flood we should see at least a partial restoration of the former community of zooplankton (rotifers, cladocerans, and copepods) [15, 16].

Table 1. Location and morphometric data of floodplain lakes.

| Site | W1 | W2 | MW | PD |
|---|---|---|---|---|
| Location | N 53º01'<br>E 18º40' | N 53º01'<br>E 18º39' | N 53º00'<br>E 18º34' | N 53º01'<br>E 18º30' |
| Area [ha] | 2.5 | 1.5 | 2.8 | 71 |
| Max. depth [m] | 2.5 | 1.8 | 2.5 | 1.5 |
| Length [m] | 220 | 140 | 640 | 1800 |
| Width [m] | 40 | 67 | 61 | 390 |

## Material and Methods

The studied floodplain lakes are situated in the valley of the Lower Vistula River, within the city of Toruń, between 736 and 738 km of the river's course. A catastrophic flood on the Vistula River in Toruń was observed from 24 to 26 May 2010, the water flow rate (Q) reached 5,800 $m^3 \cdot s^{-1}$, while the long-term average amounted to 970 $m^3 \cdot s^{-1}$ [17].

The studies were conducted in the Vistula River and in four old river beds in July and August 2009 (before the flood) and July and August 2010 (after the flood). Samples were taken when the floodwaters returned to the river.

Samples were taken at the following sites: W – Vistula River at the 736th km of its reaches, three old river beds disconnected from the main channel of the river: W1 – Winnica 1 (N53º01', E18º40'), a floodplain with submerged macrophyte and rich littoral zone, W2 – Winnica 2 (N53º01', E18º39'), nearly all the surface of the floodplain was covered by floating plants, and MW – Martwa Wisła (N53º00', E18º34'), a floodplain with submerged macrophyte and rich littoral zone; and one floodplain permanently connected with the main channel of the Vistula: PD – Port Drzewny (N53º01', E18º30'), a floodplain with poor littoral zone. The morphometric data are presented in Table 1.

Water samples were collected with a 1 $dm^3$ Patalas' bucket at the depth of ca. 0.5 m. The water was filtered through a plankton net with mesh diameter of ca. 25 µm. In order to obtain one sample of zooplankton, 10 $dm^3$ of water was filtered. All samples were preserved with Lugol's solution [18, 19]. Altogether, 20 both qualitative and quantitative samples were collected. Identification and measurement of zooplankton was performed with the use of a light microscope Nikon Alphaphot YS2, as well as a Panasonic camera and MultiScan – a software for image analysis. The sample volume (10 $dm^3$) was adjusted to 10 ml, a 1 ml aliquot of well-mixed concentrate pipetted into a Segdwick-Rafter chamber. The zooplankton was counted under a microscope in a Segdwick-Rafter chamber by the sub-sample method [20]. The abundance of zooplankton was calculated per volume of 1 $dm^3$ of water. For the identification of zooplankton the commonly available studies and keys were used [18, 21-24].

Table 2. The physico-chemical parameters.

| | W | | W1 | | W2 | | MW | | PD | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| SD | n | n | 1.25 | 0.55 | 1.65 | 0.63 | 2 | 0.43 | 0.95 | 1.4 | 1.46 | 0.75 |
| pH | 8.1 | 8.35 | 7.8 | 8 | 7.75 | 7.9 | 8.25 | 8.65 | 8.15 | 8.2 | 8.01 | 8.22 |
| Cond. | 554 | 469 | 780 | 652 | 813 | 698 | 942 | 471 | 735 | 617 | 764 | 581 |
| T | 21.3 | 22.3 | 18 | 20.5 | 17.7 | 20.6 | 21.4 | 22.2 | 22.2 | 21.6 | 20.1 | 21.4 |
| $O_2$ | 5.47 | 7.76 | 0.49 | 3.84 | 1.06 | 5.25 | 5.65 | 9.05 | 6.32 | 7.55 | 3.8 | 6.69 |

SD – transparency (m), pH, Cond. – conductivity (μS), T – temperature (ºC), $O_2$ concentration (mg·dm$^{-3}$).
W – site at Vistula River; W1, W2, MW, PD sites at floodplain lakes.

Table 3. Number of species of different zooplankton groups at the following sites.

| | W | | W1 | | W2 | | MW | | PD | | Total* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Rotifera | 12 | 16 | 19 | 23 | 16 | 22 | 22 | 20 | 10 | 20 | 36 | 35 |
| Cladocera | 1 | 0 | 7 | 2 | 4 | 3 | 6 | 1 | 2 | 0 | 10 | 4 |
| Copepoda | 1 | 0 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 |
| SUM | 14 | 16 | 28 | 26 | 22 | 27 | 30 | 23 | 14 | 21 | 48 | 41 |
| Total** | 19 | | 36 | | 35 | | 39 | | 26 | | 62 | |

*The total number of species in floodplain lakes before and after the flood.
**The total number identified species of zooplankton at the sites.
W – site at Vistula River; W1, W2, MW, PD sites at floodplain lakes.

Along with the collection of samples, the physical and chemical parameters of water were studied, such as: transparency (SD) (except the river), temperature, $O_2$ concentration and saturation, conductivity, and pH. Measurements of physical and chemical parameters were performed by instruments from the WTW company (Multi 3430 SET F).

To characterize the abundance-dominance relationship the Shannon-Weaver diversity index (H') was used. In order to compare zooplankton communities before and after the flood Jaccard index, Sörensen index (presence-absence type) and Bray-Curtis similarity index (meristic type) were applied [19, 25]. The euclides distance of STATISTICA for comparison of samples also was used.

## Results

Based on the results of physico-chemical studies conducted before and after the flood it was found that: the average transparency (SD) after the flood dropped from 1.5 to 0.75 m, the average conductivity also dropped from 767 μS to 581 μS, the average oxygen concentration in the water increased from 3.8 mg·dm$^{-3}$ to 6.69 mg·dm$^{-3}$, the average temperature of the floodplain lake water rose slightly from 20.1ºC to 21.4ºC (probably as a result of the increased air temperature), and pH rose slightly from 8.01 to 8.22 (Table 2).

The largest decrease of water transparency after the flood was recorded at sites W1, W2, and MW (Table 2). At all the studied sites the increase of oxygen concentration was reported after the flood, but the largest increase was noticed at W1 and W2 sites.

The research on zooplankton of floodplain lakes revealed the presence of 62 species altogether, including: 50 species of Rotifera, which constitute 81% of all determined species, 10 species of Cladocera (i.e. 16% of the total number of species), and 2 species of Copepoda (i.e. 3% contribution to the species structure of the community Table 3).

Most of the species (39) were recorded at the MW site. The fewest species were recorded at the PD site – 26. (Table 3)

There were considerably fewer species in the main arm of the Vistula River – 19 (Fig. 1).

Before the flood in 2009, a total of 48 species of zooplankton were determined: 36 species of Rotifera (75%), 10 species of Cladocera (21%), and 2 species of Copepoda (4%). After the flood, a total of 41 species were identified: 35 species of Rotifera (85%), 4 species of Cladocera (10%) and 2 species of Copepoda (5%) (Table 3).

After the flood the number of rotifer species was almost the same while the number of crustacean species decreased (Table 3). There was a decrease in the number of zooplankton species at sites W1 and MW. At the same time, the number of species increased at MW and PD sites (Fig. 1). At all the sites (except MW site), the number of rotifer species increased. Whereas at all the studied sites the number of Cladocera species decreased (Table 3).

Table 4. The abundance of different zooplankton groups (ind dm-3) before (2009) and after (2010) flooding.

| | W | | W1 | | W2 | | MW | | PD | | Mean* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Rotifera | 186 | 290 | 552 | 5,209 | 408 | 8,291 | 1,185 | 13,768 | 43 | 6,352 | 547 | 8,405 |
| Cladocera | 2 | 0 | 498 | 4 | 347 | 30 | 26 | 12 | 6 | 0 | 219 | 12 |
| Copepoda | 20 | 0 | 610 | 78 | 783 | 278 | 781 | 850 | 86 | 576 | 565 | 446 |
| SUM | 208 | 290 | 1,659 | 5,291 | 1,538 | 8,599 | 1,992 | 14,630 | 135 | 6,928 | 1331 | 8,862 |

*Mean value of different zooplankton groups (ind·dm$^{-3}$) in floodplain lakes.
W – site at Vistula River; W1, W2, MW, PD sites at floodplain lakes.

Table 5. Species and abundance of zooplankton (ind·dm$^{-3}$) before (2009) and after (2010) flooding.

| | W | | W1 | | W2 | | MW | | PD | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Species | 14 | 17 | 27 | 26 | 21 | 26 | 29 | 22 | 13 | 21 |
| Abundance | 208 | 290 | 1,659 | 5,291 | 1,538 | 8,599 | 1,992 | 14,630 | 135 | 6,928 |
| H' | 1.89 | 2.06 | 1.61 | 1.47 | 1.56 | 1.925 | 1.575 | 1.395 | 1.32 | 1.84 |
| B-C | 49 | | 6 | | 20 | | 22 | | 4 | |
| S | 73 | | 39 | | 51 | | 51 | | 53 | |
| J | 58 | | 23 | | 34 | | 34 | | 36 | |

Shannon-Weaver diversity index (H') before and after flooding. Bray-Curtis similarity index (B-C), Sörensen index (S), Jaccard index (J) expressed in percent of similarity.
W – site at Vistula River; W1, W2, MW, PD sites at floodplain lakes.

Thus it seems that the flood (inundation) rebuilt the structure of zooplankton species. In extreme cases, as much as 20 species disappeared and 16 other species came in, e.g. site W1 (Table 4). Most frequently the number of crustacean species decreased and the number of rotifers increased.

The flood changed slightly the structure of zooplankton in the main bed of the Vistula River as shown by Sorensen and Jacckard indexes (73% and 58%). The zooplankton of the floodplain lakes changed the most, e.g. at site W1 (38% and 23% species similarity coefficient) (Table 5). After the flood the following species appeared in the floodplain lakes: *Anuareopsis fissa*, *Brachionus budapestinensis*, *Filinia longiseta*, *Keratella tecta*, *Trichocerca pusilla*. The other species such as *Acropercus harpae*, *Bosmina longirostris*, *Ceriodaphnia quadrangularis*, *Daphnia cucullata*, *Lecane luna*, and *Lepadella ovalis* have disappeared. It is shaped differently at different sites (Table 4).

The average abundance of zooplankton in the floodplain lakes before the flood during the entire research period was 1331 ind·dm$^{-3}$ (from 135 ind·dm$^{-3}$ – site PD, to 1992 ind·dm$^{-3}$ – site MW) (Table 6). Copepoda (mainly larval forms) and Rotifera were the dominant groups with the contribution of 42% and 41%. Cladocera constituted 17%.

The average abundance of zooplankton in the Vistula River before the flood was 208 ind·dm$^{-3}$. Rotifera were the dominant group with a contribution of 89%. Copepoda constituted 9% and Cladocera only 2% (Table 6).

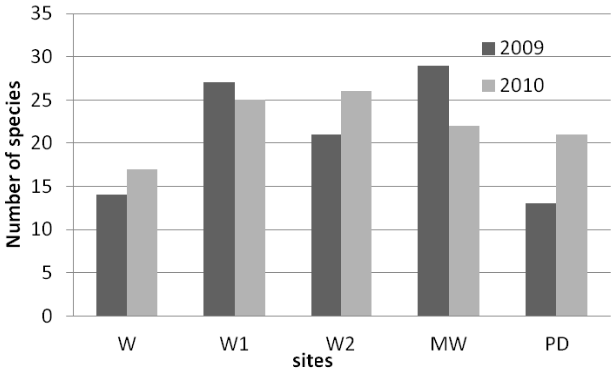


Fig. 1. Number of species before and after flooding at the sites.

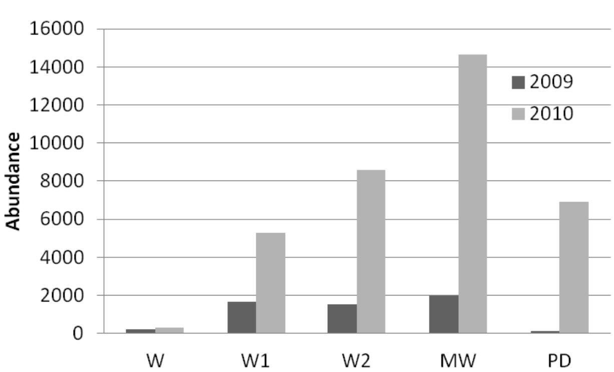


Fig. 2. The abundance of zooplankton (ind·dm$^{-3}$) before and after flooding at the sites.

Table 6. The number of zooplankton species and the most abundant species that appeared and disappeared after flooding.

| | Appeared after flooding | Disappeared after flooding | Appeared after flooding | Disappeared after flooding |
|---|---|---|---|---|
| W | 5 | 4 | *Anuaeropsis fissa, Brachionus calyciflorus* | *Lecane luna, Copepoda* – nauplii |
| W1 | 16 | 20 | *Anuareopsis fissa, Brachionus budapestinensis, Filinia longiseta* | *Ceriodaphnia quadrangularis, Chydorus sphaericus, Acropercus harpae* |
| W2 | 10 | 8 | *Brachionus budapestinensis, Trichocerca pussila, Keratella tecta* | *Ceriodaphnia quadrangularis* |
| MW | 9 | 16 | *Anuareopsis fissa, Trichocerca pussila* | *Bosmina longirostris, Lepadella ovalis, Lecane luna* |
| PD | 12 | 4 | *Brachionus angularis, Polyarthra remata* | *Daphnia cucullata* |

W – site at Vistula River; W1, W2, MW, PD sites at floodplain lakes.

Table 7. The dominant species (eudominants) before and after flooding at the sites. W – site at Vistula River; W1, W2, MW, PD sites at floodplain lakes.

| Sites | Eudominant before flooding | Eudominant after flooding |
|---|---|---|
| W1 | *Keratella cochlearis, Ceriodaphnia quadrangularis*, nauplii | *Keratella tecta* |
| W2 | *Keratella cochlearis, Bosmina longirostris,* nauplii | *Keratella tecta, Keratella cochlearis* |
| MW | *Keratella cochlearis, Polyarthra longiremis*, nauplii | *Keratella tecta* |
| PD | nauplii | *Keratella cochlearis, Keratella quadrata* |
| W | *Keratella tecta, Keratella cochlearis* | *Brachionus angularis, Keratella tecta* |

The average abundance of zooplankton in the floodplain lakes after the flood increased and amounted to 8,862 ind·dm$^{-3}$ (from 5,291 ind·dm$^{-3}$ – site W1 to 14,630 ind·dm$^{-3}$ – site MW) (Table 6, Fig. 2). Rotifers were the most abundant group with 94% contribution. Copepoda constituted 5% and Cladocera 1%. After the flood the average abundance in the Vistula River was 290 ind·dm$^{-3}$ and Rotifera constituted 100% of total zooplankton abundance.

The flooding caused a significant increase of rotifer abundance and a decrease of crustacean abundance (especially cladocerans). However, the abundance of Copepoda (mainly nauplii and copepodites) changed only slightly (Table 6).

The flooding also has changed the structure of domination in the zooplankton community (Table 7). Before the flooding the following species predominated in floodplain lakes isolated from the Vistula River (eudominants which constituted >10.0% a total number of individuals): *Keratella cochlearis*, *Ceriodaphnia quadrangularis* (W1), *Bosmina longirostris* (MW), and nauplii – larval forms of copepods (Table 7). After the flood one species *Keratella tecta* dominated definitely in the above floodplain lakes.

In the floodplain lake (site PD), which is connected to the Vistula River, the largest number of copepods larval stages was recorded before the flooding. After the flooding *Keratella cochlearis* and *Keratella quadrata* started to dominate.

For comparison, *Keratella tecta* predominated in the Vistula River before and after the flood. Furthermore, before and after the flood *Keratella cochlearis* and *Brachionus angularis* also were dominant (Table 7).

It was found that the average value of the Shannon-Weaver index before flooding amounted to 1.59 (from 1.39 site PD to 1.89 site W) and after flooding it was 1.74 (from 1.40 at site MW to 2.06 at site W) (Table 5).

Based on the results of the Jaccard similarity coefficient and the Sorensen-Dice coefficient (Table 5), it could be concluded that the flood primarily changed the structure of zooplankton species in floodplain lakes W1, W2, MW, and finally in PD. The zooplankton structure at the site in the Vistula River (W) was the least modified. Similar results were obtained using the Bray-Curtis (B-C) similarity index and Euclidean distance (Fig. 3). According to the B-C index the greatest changes in the structure and density of zooplankton after the flood at W1 and PD sites were noted. The lowest difference was observed at the W site (Vistula River) (Table 5).

## Discussion

In May 2010, the water of the Vistula River flooded huge areas of its valley. The water level at the water gauge in Toruń reached its highest level in history at 839 cm (about 513 cm above the average water level and about 189 cm above the alarm state) [26].

Water flooded the fields and meadows, as well as the floodplain lakes, which for decades had no direct contact with the river. The studies on zooplankton were conducted for many years in two different types of floodplain lakes: connected with the Vistula River by the inlet (site PD) and completely isolated from the river bed (sites W1, W2, MW).

According to the Flood Pulse Concept [4] the life in the floodplain is formed by cyclic flooding. Unfortunately, the water of the Vistula River (probably due to regulation) has very irregular swells and floods. It happened that for many years, even the floodplain lakes connected with the river were not washed out because of too low levels of water in the Vistula.

The floods that affected the valley of the Vistula River in 2010 allowed for detailed study of the impact of catastrophic high-water levels on the zooplankton community in floodplain lakes.

Average water transparency in the floodplain lakes after the flood decreased almost two times (Table 2). Floodwaters carried a considerable amount of small mineral and organic suspensions, which had an impact on transparency. Moreover, the floodwaters could carry nutrients that promote algae growth and could affect the decline in water transparency [27].

The conductivity of the floodplain lakes water declined after the flood, which could be related to the dilution of the concentration of chemical compounds by the waters of the river [28].

Noteworthy was the increase in the average oxygen concentration in the waters of the old river beds after the flood (Table 2). Probably well-oxygenated waters from the river caused the increase of oxygen concentration in the floodplain lakes. It was also possible that nutrients brought with floodwater promote the growth of algae responsible for the production of oxygen in the water [29]. Škute et al. [27] found a similar significant impact of floods on transparency, conductivity, and $O_2$ concentration, but also on the increase of nutrient concentration.

Our studies have shown that the Vistula is much poorer in zooplankton species as compared to the floodplain lakes (Table 3). Relatively stable hydrological conditions in the floodplain lakes are more favourable to the development of zooplankton as compared to the river [30, 31].

Rotifers dominated among the zooplankton species at all the studied stations both before and after the flood (Table 3). Rotifera are better adapted to adverse conditions of lotic and astatic habitats than the crustacean species [8, 32].

The flood had an impact on the decrease in the number of zooplankton species identified in floodplain lakes (from 48 to 41 species). The largest decrease was recorded in the number of Cladocera species (from 10 to 4) (Table 3).

During the studies we observed a decrease in the number of species recorded at stable floodplain lakes (site W1 and MW) – shallow macrophyte lakes (Fig. 1).

However, in the floodplain lakes (site W2 and PD), less stable, without evident littoral zone, resembling a turbid shallow lake, the increased number of zooplankton species was recorded after the flood (Fig. 1).

The results of our studies did not confirm that a zooplankton community that emerges from an inundated floodplain is often highly diverse and abundant [33]. Probably the change of diversity depends on the nature of the flood. Too rapid and high a flood destroys lentic habitats and leads to the decrease of diversity. Moreover, the kind of floodplain lake determines response of its biota to flooding, which was proven by our studies (Table 4).

Also, according to the Shannon-Weaver index results (Table 5), zooplankton diversity at W1 and MW sites decreased after the flood, whereas at the MW and PD sites the diversity increased. The studies showed that the flood destroyed macrophytes at the W1 and MW sites. It also destroyed the ecological niches necessary for life of certain species of zooplankton and this affects the decrease in diversity (Table 5). Havel et al. [34] argues that subsequent floods led to rapid changes in morphometry of floodplain lakes and this physical change limited the littoral vegetation.

The flood could rather enrich the diversity of zooplankton in reservoirs W2 and PD, bringing new species from the river.

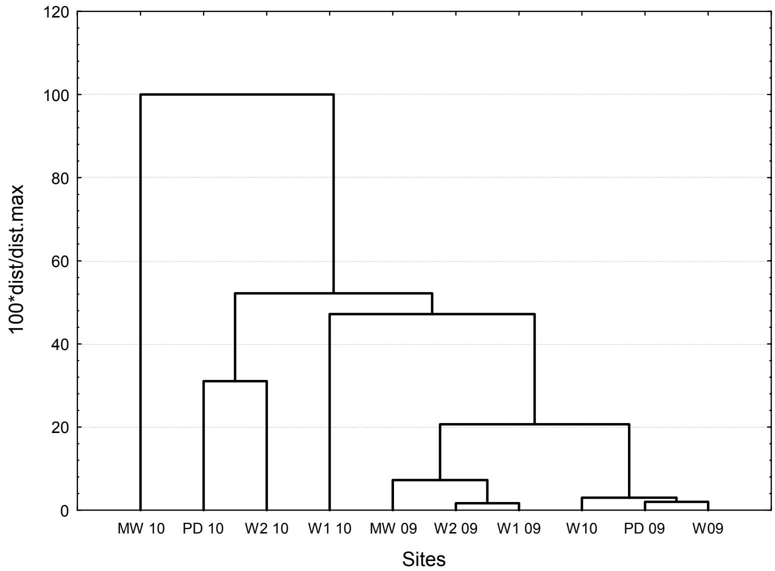


Fig. 3. Dendrogram. Single nodes. Euclidean distance between sites before (09) and after (10) flooding.

Even before the flood zooplankton of W1 and MW sites was slightly more diverse than that at the W2 and PD sites (Table 5).

It was surprising that before and after the flood the zooplankton of the W site at the Vistula River was the most diverse.

Not only the number of species but also the structure of zooplankton species had been changed by the flood (Table). According to indexes J, S, B-C (Table 5), and Euclidean distance (Fig. 3), the most considerable changes in the structure of zooplankton were observed at the W1 site but also at the other floodplain sites (W2, MW, and PD), where the differences between the structure of zooplankton before and after the flood were huge (Table 5).

However, the zooplankton community changed the least in the main river bed of the Vistula River – site W (Tables 4 and 5).

The similarity between the structure of zooplankton at different sites before and after the flood are presented in Table 5.

All used indicators showed that the zooplankton in the Vistula River (W) changed the least and that it altered the most in the macrophyte floodplain lake (W1).

During the floods sediments are eroded and deposited, which is a process that can both create and destroy lentic habitats in the floodplain [34]. A sudden flood brought a lot of the suspension to the floodplain, which significantly changed transparency in the floodplain lakes. The decrease of transparency caused the disappearance of submerged plants. Many littoral plants were mechanically damaged by the flood waters. Lack of macrophytes in the floodplain lakes resulted in the disappearance of many species of zooplankton related to this type of environment [23, 24], e.g. rotifers: *Lecane luna*, *Lepadella ovalis* or crustaceans: *Ceriodaphnia quadrangula*, *Acropercus harpae* (Table 4).

The mineral suspension also did not favor the development of Cladocera, which could damage their filter apparatus and prevent cladocerans from feeding. Welker and Walz [35] emphasize the importance of the increased concentration of suspended mineral matter, which negatively affects the fertility and efficiency of filtration in Cladocera.

Small rotifer species appeared and began to dominate in the floodplain lakes under the influence of flood waters (Table 4). Most of them were species specific for the environment rich in detritus and bacteria, thermophilic, living in reservoirs of high trophy (frequently used as indicators of high trophic status) [36]. These include: *Anuareopsis fissa*, *Keratella tecta*, *Trichocerca pusilla*, *Brachionus angularis*, *Brachionus budapestinensis*, and *Polyarthra remata*.

The largest reconstruction of the zooplankton structure was observed in the "macrophyte" floodplain lakes – sites W1 and MW (Table 4). After the damage caused by the flood these reservoirs were open to colonization by plankton, their high nutrient content allowed for high primary production and subsequently high secondary production [34].

The average abundance of zooplankton in the floodplain lakes after the flood increased sevenfold (Table 6, Fig. 2). The flooding caused a 15-fold increase in the average number of rotifers and 18-fold decrease in the number of cladocerans. The average abundance of copepods, including larval forms, remained almost unchanged (Table 6).

The abundance of rotifers after the flood increased in all floodplain lakes even up to 147 times (site PD). According to several authors, rotifers reach the maximum density in waters with high trophic levels [23, 36, 37].

However, the abundance of cladocerans dropped 124 times (site W1).

Flood events as noticed by Baranyi et al. [16] reset the zooplankton community to an early successional phase.

Conditions caused by flooding are conducive to the development of rotifer plankton and the emergence of the absolute dominant in the abundance of zooplankton – *Keratella tecta* that could even constitute 65% of the total abundance of zooplankton at the W1 and MW sites (Table 7).

*Keratella tecta* dominates in reservoirs rich in bacteria and nannoplankton – the basic food for this group of rotifers [38]. Lack of predators such as *Asplanchna priodonta* also favors the rapid development of *Keratella tecta* [39].

Conditions created after the flood promote the development and domination of other small rotifers such as *Keratella cochlearis* and *Brachionus angularis*. Probably rotifers of the Brachionidae family that dominate among the zooplankton found a period with optimum temperature for their development [18].

Before the flood there were more species belonging to eudominants, such as the crustaceans among them (*Ceriodaphnia quadrangula*). After the flood the other crustacean almost disappeared except for copepods (Table 7).

The results cited above show that the time which had passed since the flood was too short to rebuild Cladocera population. Also, the conditions in the floodplain lakes after the flood could be unfavorable to the development of Cladocera [34].

## Conclusions

The flood destroyed submerged plants and brought suspension, which changed the abiotic conditions of life in the floodplain lakes.

The change of abiotic conditions caused changes in the structure of zooplankton species.

Instead of organisms related to submerged plants, species that prefer detritus and bacterial environments appeared and started to dominate.

The flood caused an increase in zooplankton abundance, especially rotifers. Abundance of cladocerans decreased.

The zooplankton structure was changed so much that the similarity measured by indices before and after the flood was low.

The largest changes of zooplankton after the flood were recorded in the floodplain lakes, which were rich in submerged vegetation.

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