Effects of the summer flood 1997 on the collembolan and gamasid fauna in a Lower Oder Valley floodplain

ALFRED GRIEGEL

Abstract
A study from 1994 to 1996 showed that the populations of Collembola and gamasid mites in the Lower Oder Valley are well adapted to inundation that occur regularly during winter and spring. In 1997 an extreme summer flood occurred. After this rare event, further sampling took place at three sites until 2000. The data before and after the summer flood indicate a quick recovery of the general population densities, but long-term effects on the number of species for both groups. Some of the most frequent species reacted with normal or even higher densities, such as Folsomia quadrioculata (Collembola) or Hypoaspis nolli (Gamasida). Species of the collembolan genera Mesaphorura and Protaphorura and the gamasid Hypoaspis similisetae needed longer recovery times.

Keywords: Soil animals, long-term study, population densities, inundation resistance, vertical distribution

1. Introduction
The community structures and population developments of Collembola and Gamasida were studied from 1993 – 1996 at sites with different inundation intensities in the floodplains of the Lower Oder Valley, situated in north-east Germany (Griegel 1999, 2001). The polders in the valley, which are limited by the Oder on the east side and a canal on the west side, are normally flooded during winter and spring until the middle of April. Summer floods as in 1997 are very rare. This event led to further sampling at three sites from 1997 until 2000 to show the effects on the soil fauna.

Normally, long-term flooding occurs regularly in winter and early spring. The sluices in the dikes are open from November to April, then the sluices are closed and the water is pumped out within a few days. The flooding regime showed two exceptional events. In 1996 – after a very cold winter – the sluices had to be opened again from May to June for 16 days. This so-called »summer flood« was a late spring flood. In 1997 a catastrophic high-water period occurred and the sluices had to be opened on July 15th. The dike near the study sites broke. The flooding lasted until the end of August.

The abundance and number of species of Collembola and Gamasida before and after the summer flood of 1997 were the focus of this study. The main question was whether the main species have a short or long recovery period.

2. Materials and methods
All three sites are situated near Schwedt in the »Criewener Polder«. Site A (N1.G1 in Griegel 1999, 2001) is a small softwood floodplain forest (Salicetum albae, wet form) with
sandy soil along the »Alte Oder«, an old arm of the river. Site B (N1.Wi1) is a meadow (Alopecuretum pratensis) close to the lake »Großer Eichsee« with a loamy clay soil. Both sites are generally under water during the flooding season, corresponding to the water level of the Oder. The third site C (N1.Wi2) is a meadow (Alopecuretum pratensis with Agropyron repens) on a 1.5 m-high sandy elevation. It is only flooded at high water levels and dries quickly.

Per sampling date five soil cores were taken from each site for a total area of 125 cm². From 1993 to 1996 sampling occurred at 0 – 4 and 4 – 8 cm depths. This study presents only the data of 0 – 4 cm depth, because from 1997 to 2000 only this soil layer was generally researched. Deeper soil layers were only sampled at the meadow C on the elevation at the last date in 2000. The fauna was extracted by means of a modified Macfadyen extractor with a dynamic temperature programme for ten days. For determination under the microscope at 400 x magnification, individuals were transferred to a cavity slide containing a drop of lactic acid and heated briefly to 50 °C. The following determination literature was used:


3. Results

The first irregular inundation of 1996 led to low abundances of Collembola at the forest site A in June and October (Fig. 1). At the meadow B by the lake this effect was only visible in June, in October the population nearly reached the same level as the year before. The meadow C on the elevation exhibited high abundances. Exceptional and remarkable was the maximum of nearly 400 000 ind. m⁻² in October 1996. After the summer flood of 1997, the density of Collembola was very reduced at all three sites. However, in October 1998 and the following years, values reached those as before the summer flood.

The high presence of the species Sminthurinus aureus Lubbock, 1862 was remarkable in 1997. S. aureus was the most frequent species at the first two dates in the forest A. On September 25th the species achieved more than 5000 ind. m⁻², representing 90 % of all

![Fig. 1 Abundance and number of species of Collembola at the forest site A, the meadow B by the lake and the meadow C on the elevation.](image-url)
Effects of the summer flood 1997 on collembolan and gamasid fauna

Collembola. At the meadow B near the lake it reached high densities with more than 8000 ind. m\(^{-2}\) on the first (70 % dominance) and third sampling date (50 % dominance).

Collembola showed a longer lasting flood effect on the number of species recorded at every date. The values recovered slowly after the summer flood and even were still lower in 2000 than before this event. Only in May 1999 could a value equal to the period before 1997 be observed both at the forest site A and the meadow C on the elevation.

The results for the abundance and number of species of Gamasida were very similar to Collembola (Fig. 2). The populations recovered quickly with high densities in 1998 and 1999. Species richness, which was very reduced in 1997, increased slowly both at the forest sites A and the meadow B by the lake. However, the number of species at the meadow C was only reduced in 1997, the year of the summer flood. In 1998 and 1999 high values were again recorded, also concerning the abundances.

Effects of the summer flood on the main species or species groups of Collembola and Gamasida were examined in more detail at the three sites. Within the Collembola the most abundant and dominant species at all three sites were *Folsomia quadrioculata* Tullberg, 1871 and species of the genera *Mesaphorura* and *Protaphorura*.

The abundance of *Folsomia quadrioculata* in 1996 followed the pattern of Collembola in general (Fig. 3). In June only one or a few individuals appeared in the samples of both the
forest A and the meadow B by the lake. In October the value for A was still low, but for B again normal. At the meadow C the population reached very high abundances in October 1996. After the summer flood of 1997, the populations decreased at the three sites, but again reached normal values already later in the same year. The density of *F. quadrioculata* in the following years, specially in May 1999, was very high. This species appears to have profited from the summer inundation.

Species of the genus *Mesaphorura* showed a long recovery period after the summer flood of 1997 (Fig. 4). In the samples of 1997 (A and C) or even of 1998 (B), only single or a few individuals were recorded. In 1999, two years after the summer flood, normal values of the population densities appeared again. The main species at all three sites was *Mesaphorura krausbaueri* Börner, 1901. At the meadow C *Mesaphorura critica* Ellis, 1976 was also frequent. After the summer flood, this species was no longer detected until the end of the study.

The irregular inundation of 1996 already led to a decrease of *Protaphorura* spp. at A and B (Fig. 5). After the summer flood of 1997, these species nearly vanished from the forest and the meadow by the lake. In 1999 the populations increased again. At the meadow C, which showed a very high colonisation before the summer flood, only a few individuals appeared in the samples of 1997 and 1998. Values as before the summer flood did not appear again during the study period.

A shift in the dominance of the *Protaphorura*-species after the summer flood 1997 was observed. At the sites with higher and longer inundation (A and B), *Protaphorura islandica* Bödvarsson, 1959 was the dominant species. At the meadow C, with lower and shorter flooding, *Protaphorura campata* Gisin, 1952 was the main species. After the summer flood 1997 with decreasing population densities of all species, the populations became more equal in numbers and *Protaphorura subuliginata* Gisin, 1956 became dominant.

*Hypoaspis nolli* Karg, 1962 was an abundant and dominant species of the Gamasina at all three sites (Fig. 6). Only a few individuals appeared in the samples of sites A and B after the irregular inundation in 1996. The values remained low in October 1996. Surprisingly, the population density increased again at the meadow B directly after the summer flood in 1997. From 1998 to 1999, a large and stable population was found. At the meadow C a positive effect on the population was visible with densities higher than before the summer flood. Only in the forest A did the species vanish until 1999. This site is situated along the »Alte Oder« near one of the sluices. If a flood occurs suddenly, as in 1996 when the sluices were opened

---

**Fig. 4** Abundance of the collembolan *Mesaphorura* spp. at the forest site A, the meadow B by the lake and the meadow C on the elevation (logarithmic scale). Scale as in Fig. 3.
Effects of the summer flood 1997 on collembolan and gamasid fauna at a very high Oder level, the water rushes vehemently through this wood. The flood water probably washed out parts of soil animals living in the upper soil layer.

Fig. 5 Abundance of the collembolan *Protaphorura* spp. at the forest site A, the meadow B by the lake and the meadow C on the elevation (I) and the dominance of *Protaphorura*-species (II). Scale in A as in Fig. 3.

Fig. 6 Abundance of the gamasin species *Hypoaspis nolli* at the forest site A, the meadow B by the lake and the meadow C on the elevation (logarithmic scale).
The gamasin species *Hypoaspis similisetae* Karg, 1965 was a frequent species at the sites with intense inundation (A and B) and only rare in C. The irregular flood in 1996 had no visible effect on the populations of both sites A and B (Fig. 7). After the summer flood of 1997, the species disappeared at the forest site A until 2000. At the meadow B the species was not detectable in 1997. It seems that the species returned in 1998, but the densities decreased again at the following sampling dates.

*Arctoseius cetratus* Sellnick, 1940 is a gamasin species which occurred only occasionally in low quantities at the three sites (Fig. 8). The species profited from the summer flood 1997. In 1998 the populations reached peak abundances at all three sites.

At the meadow C the small gamasin species *Rhodacarellus silesiacus* Willmann, 1935 was very frequent (Fig. 9). This species was apparently severely impaired by the summer flood. In 1999 the species returned in small numbers.
Effects of the summer flood 1997 on collembolan and gamasid fauna

The population density of the parthenogenetic *Rhodacarellus silesiacus* was generally high in spring and small in autumn (Fig. 9). In the previous study (1993 to 1996), most of the specimens of *R. silesiacus* were found in the deeper soil layer of 4 – 8 cm in autumn. Adults appeared in high densities in the upper layer in spring. The females probably moved already in September to deeper soil for passing the winter season. In 2000 samples were taken also from deeper soil layers (Fig. 10). Most of the specimens of *R. silesiacus* were indeed found at a depth below 8 cm (more than 70 %). In accordance with the depth of 20 cm, the species showed a very high abundance with 11 300 ind. m⁻². *Rhodacarellus kreuzi* Karg, 1965 and *Rhodacarus coronatus* Berlese, 1921 also prefer deeper soil layers, but at much lower densities. Other Gamasida species remained in the upper soil layer.

Small collembolan species such as *Mesaphorura* spp. and *Neotullbergia crassicuspis* Gisin, 1943 were also distributed in deeper layers of the sandy soil (Fig. 10). Although the upper layer showed the highest density for *Mesaphorura* spp., more than 50 % of the individuals appeared below 8 cm. The species of this genus have a different vertical distribution pattern. *Mesaphorura krausbaueri* (the main species with a total of 176 individuals) appeared in all layers with a preference for the upper layer. *Mesaphorura sylvatica* Rusek, 1971 (only 11 individuals) was limited to the depth of 8 – 12 cm and *Mesaphorura delamarei* Weiner, 1991 (48 individuals) is only found below 12 cm.

Within the Uropodina, only the species *Dinychus inermis* C. L. Koch, 1841 and *Nenteria breviunguiculata* Willmann, 1949 were important for the areas with inundation. After the summer flood of 1997, specimens of *D. inermis* were found in the samples of all three sites, *N. breviunguiculata* disappeared during the remaining study period.

4. Discussion

Floods lead to extreme conditions for soil organisms. In the Lower Oder Valley, it was shown that Collembola react to rising inundation intensity with lower population densities (Griegel 1999, 2001). Summer floods have a strong impact on the populations of Collembola and Gamasida, which are well adapted to the regular floods in winter and spring. The populations recovered quickly after the summer flood of 1997, but the main species react differently.

A survival in the egg state is postulated for many Collembola. *Folsomia quadrioculata* showed a short recovering period. It achieved high densities as a result of the summer flood. The species is well known from flooded meadows (Rusek 1984) and wet habitats (Ponge
1993). At the first date after the summer flood 1997, only juveniles were found at the meadow B by the lake and in the forest A. At the meadow C on the elevation, where floodwaters withdraw much faster, adults already appeared at the first date in 1997. _Sminthurinus aureus_ – the most abundant species at A and B in 1997 – already appeared with adults at the first sampling period after the summer flood. This species, which survives inundation (Tamm 1984) and the summer season (Volz 1989) in the egg state, might have a faster development time than _Folsomia quadrioculata_.

Other main species of Collembola have a long recovery period. Species of the genus _Mesaphorura_ showed losses in the first two or three years after the summer flood of 1997. A massive diminishment of _Mesaphorura_-species was also observed on salt meadows after continuous wetness (Weigmann 1973). Shortage of oxygen in the soil could be a cause of the decreases.

Species of the genus _Protaphorura_ showed an even longer recovery period. Adults can survive on the water surface for long periods (Griegel 1999, 2001). They can colonise other habitats by drifting with floating debris during inundation. This explains the mixed distribution of _Protaphorura_-species after the summer flood. _Protaphorura subuliginata_ became more important after this event. This species seems to be even more tolerant of intense inundation than _Protaphorura islandica_ (Griegel 2001). The massive impact on _Protaphorura_ is probably an effect on population development. Three generations are produced with a maximum always in autumn (Griegel 2001). The summer flood must have a disastrous effect on the summer generation, which probably consists mainly of juveniles.

Survival in the egg state has not been observed for the Gamasida. The predatory mites (Gamasina) _Hypoaspis nolli_ and _Hypoaspis similisetae_ are known from wet grasslands (Moermann 1994). In the Lower Oder Valley, _H. nolli_ is wide spread at sites with less flooding as well as in areas with permanent inundation, and is often the dominant species. _H. similisetae_ is more restricted to sites with intense flooding, but not at sites with permanent inundation (Griegel 1999, 2001). The loss of _H. nolli_ after the summer floods of 1996 at the meadow B by the lake and in the forest A indicates that this species is more sensitive to irregular inundation than _H. similisetae_. However, the results after the summer flood of 1997 showed less negative effects on _H. nolli_ compared to _H. similisetae_, which suffered severely from the summer flood.

_Arctoseius cetratus_ was normally a rare species at the three sites. After the summer flood the populations increased, probably as a reaction to the competition-free conditions. As a pioneer-species, _A. cetratus_ has a high reproduction rate (Siepel & van de Bund 1988) and can colonise new areas through phoresis (Binnis 1976).

The Uropodina generally have a long postembryonic development (Karg 1989) and mostly only one generation per year (Maibohm 1993, Griegel 2001). If populations suffer from heavy losses, the recovery time will be long. For this reason the absence of the eurytopic species _Nenteria brevinguiculata_ after the summer flood is not surprising. On the other hand, _Dinychus inermis_ is specialised on very moist to swampy habitats (Karg 1989). In the Lower Oder Valley _D. inermis_ was also present at sites with permanent inundation (Griegel 1999, 2001).

This study confirmed that the euedaphic predatory mite _Rhodacarellus silesiacus_ moves into deeper soil to pass the winter season (Griegel 2001). High densities of overwintering females at depths of 5 – 15 cm have been reported earlier (Karg 1961). This overwintering
strategy protects the species against inundation during winter. Summer floods have a decreasing effect on the population, as the results from spring 1999 indicate.

After the summer flood, the number of species was reduced for both Collembola and Gamasida. The values returned slowly to the results before the summer flood. An exception is the meadow C on the elevation. At this site the number of recorded species of Gamasida increased after the summer flood. This effect was also visible in 1996 after the irregular inundation in May and June. After flooding, much debris was deposited along the edges of the elevation. An immigration of species thus drifting with the floodwater is possible (Griegel 1999, 2001).

5. Acknowledgements

I thank my colleagues at the »AG Bodenzoologie und Ökologie« of the Institute for Biology for their support. Special thanks to Prof. Gerd Weigmann, who organized the sampling in the years 1997 – 1999. For financial support during 1993 – 1996, I thank the »Stifterverband für die Deutsche Wissenschaft«.

6. References


Author’s address:

Alfred Griegel
Institute for Biology
Freie Universität Berlin
Königin-Luise-Str. 1-3
14195 Berlin
Germany
present address:
State Museum of Natural History
Postfach 300 145
02806 Görlitz
Germany
e-mail: alfred_griegel@web.de