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Influence of hydrological situations on benthic organisms in a small river in Saxony (Germany)

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Abstract: This research was focused on the relationship between river discharge and organism drift. It was carried out for three years in a small heavily modified river in Saxony (Germany). The amount and species composition of drifting invertebrates were observed, depending on discharge and flow velocity. A station was installed where the flow velocity was continually measured and drifting organisms were caught with nets. An inventory of the aquatic community (benthic invertebrates) was taken to determine the species living in the river at the research station.

The highest drift density measured was 578 organisms per m^3 at a flow velocity of 0.90 m s^{-1}, the mainly drifting organisms were Chironomidae. Different organisms groups started drifting at different flow velocities. Heavy impacts, such as dredging the river and flood waves, affected the aquatic ecosystems and severely changed the aquatic community regarding the number and the diversity. Some of the aquatic invertebrates such as the Anthothecata completely disappeared after dredging.

It was found that many different terrestrial organisms were part of the drift. The typical family of soil biota Collembola represented the largest share.

Keywords: Macrozoobenthos; Drift; Discharge; Flow velocity.

INTRODUCTION

One of the most important indexes to characterize the ecological water quality of a river is, according to the WFD (2000), the species combination and the number of benthic invertebrates. The relocation of organisms in running waters is therefore a major environmental problem with positive (e.g. resettlement and gene exchange) and negative (e.g. loss of biodiversity) effects on the ecosystem. In rivers there exist organisms who dwell their whole life there, and some who spend only parts of their life cycle as larvae there. Both are drifting with the water, but also entirely terrestrial living organisms entering the water by chance in various ways, are included in this process. The structure of the river and the hydrological status of the area (e.g. rainfall intensity, soil moisture, runoff) play a big role in this process. It is extremely difficult to establish a link between the hydrological situation (low flow/high flow), particle transport and the drift processes in the river. The life of the organisms is subjected to day and night rhythms (Brittain and Eikeland, 1988) and to a temporal rhythm in the course of one year. The seasonal drift intensity was reported to be quite different. Hieberet al. (2003) found nearly no seasonal rhythm in alpine rivers, while e.g. Brittain and Eikeland (1988) described that seasonal patterns are usually more pronounced in low-altitude temperate streams, with minimum densities occurring in winter. Robinson et al. (2004) observed low drift densities during early summer, with an increase in late summer and autumn.

So far, only few systematic studies with special purposes as fish feeding or hydropeaking caused by waterpower plants were performed about the behaviour of organisms in stressful situations (e.g. Bruno et al., 2010; Hay et al., 2008; Meile et al., 2005; Svendson et al., 2004), which were mainly done in forested areas. Much research was undertaken regarding the behaviour of individual species (e.g. Gresens et al., 2007; Sagnes et al. 2008) and hydraulic stress situations depending on the properties of the riverbed (e.g. Gibbins et al., 2007a,b; Litvan et al., 2008). We focused thereupon how many and which species were transported with running water during different discharge or flow velocity.

Stressful situations frequently also occur in rivers which react quickly to rain events and show remarkable changes in water levels and discharge (Jackson et al., 2007; Wilcox et al., 2008). Such a river is the investigated Landwasser. Its catchment is dominated by agriculture, mainly arable land. Most of the river's floodplain has been urbanized.

The drift itself can be divided into three categories (a) behavioural – due to insect behaviour patterns; (b) constant – due to accidental dislodgement; (c) catastrophic – due to severe disturbances (Waters, 1972). Behavioural and constant drift together are considered to be background drift. Behavioural drift is an important part of the life of benthic invertebrates, whereas catastrophic drift can disturb the aquatic ecosystem severely. Catastrophic drift can cause severe mortality rates of the animals (Death, 2008). Fischer (1998) analysed many studies and identified three main hydraulic factors that influence the aquatic community.

- hydraulic stress because of changing stream velocity,
- bed load transport and reduction of substrate stability due to increasing shear stress,
- ”sandblast-effects“ due to inorganic suspended particles.

Entirely terrestrial living organisms were found to be more or less part of the drift in all hydrological situations.

To learn more about the relationships between the entire hydrologic and hydraulic situation and the drift processes in the river, detailed hydrological measurements (discharge, flow velocity, precipitation, turbidity) were done for 3 years in a small river in eastern Saxony. Within this period five surveys of the aquatic invertebrates were performed. Drifting organisms were sampled at different water levels, counted and determined as far as possible.

MATERIAL AND METHODS

The catchment of the Landwasser River (26.7 km^2, Kändler and Seidler, 2009) is situated in the south-east of Saxony (Germany) and is mainly used agriculturally (48% of the area). The most frequent crops are winter wheat (*Triticum aestivum*), maize (*Zea mays*), and oil seed (*Brassica napus*). Approximately 10% of the area is covered with small forests and 18% is settlement area. These are results from "mapping of biotope types and landuse" (LfULG, 2010) in Saxony (Germany) and the statistics of crop rotation database.

According to the official measurements of the German Weather Service (DWD) from different stations within the research area, the long-term annual amount of precipitation (1961–1990) varies between 785 mm in north-west and 674 mm in south-east of the catchment. The highest precipitation sums occur during the summer season. The mean air temperature is 7.7°C. In the years 2009–2011, the seasonal courses of the temperature were almost identical (Fig. 1). The winter months were cold (e.g. Jan 09: –4.0°C, Jan 10: –6.2°C, Dec 10: –6.4°C), the highest monthly mean temperature occurred in July 2010 (19.6°C). Precipitation was unusually high in August 2010 (244 mm), causing a big flood, and very low in April 2009 (6.2 mm), October 2010 (6.7 mm), and November 2011 (0 mm).

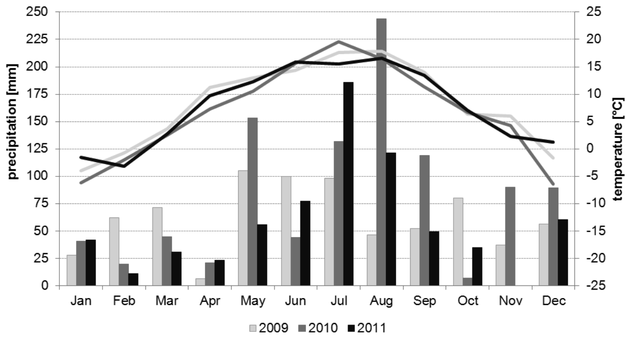

Fig. 1. Courses of monthly air temperature (lines) and precipitation (columns) in the Landwasser catchment (Saxony, Germany) for the years 2009–2011.

The altitude of the catchment varies between 583 m and 300 m a.s.l. The slopes of one quarter of the arable land are steeper than 4.5°. Together with the silty soils (Fluvisols), it often leads to surface runoff and erosion problems. The rain water from most of the adjacent settlement areas (e.g. streets, roofs) is directly released into the river. The river is classified as 'heavily modified' according to the water framework directive. It is straightened for long distances and bounded by concrete walls in many line sections. All these conditions cause a very dynamic discharge regime (Fig. 2) and high concentrations of suspended particles within the river especially during periods with only partly covered soils. The annual mean discharge (1987–2010) was 0.275 m^3 s^{-1}, the highest measured discharge within this period was 45.5 m^3 s^{-1} (7th August 2010) (LfULG 2012).

In spring 2009 a measuring station was installed at a non-walled but straightened section of the river (a detailed description can be found in Kändler, 2012). The banks were covered with grass (Fig. 3). Flow velocity and water level were measured at the sampling site using a wedge ultrasound sensor (Nivus), which was placed in the middle of the river width on the ground. The sensor measures a value of the mean flow velocity in the whole vertical profile every 5 minutes.

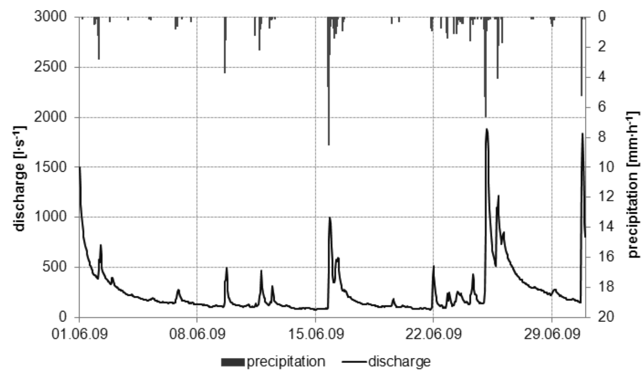

Fig. 2. Course of discharge and precipitation for the June 2009 (discharge: hourly means, precipitation: hourly sums), Landwasser River (Saxony, Germany).

During the investigation period five inventory samplings (Table 1) were performed to obtain information about the composition of the aquatic community and to know, which organisms could be expected during drift events. Within the same period drifting organisms were caught at different water levels, to investigate the share of organisms, which were shifted with the running water. To compare the results of inventory sam-

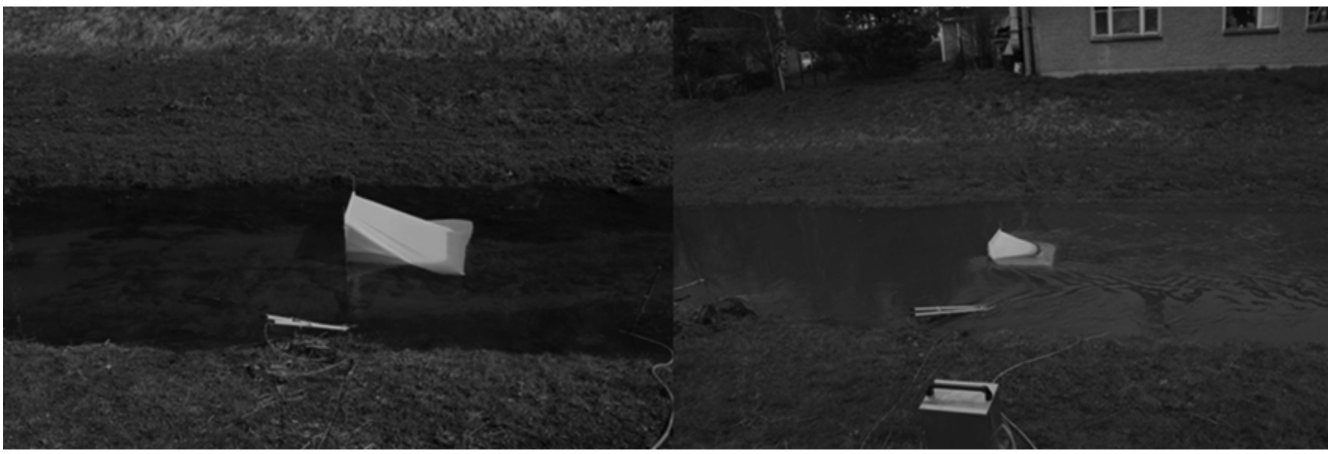

Fig. 3. Measuring site in the Landwasser River (Saxony, Germany) with the drift net (80 x 60 cm^2, 140 cm long, mesh size 500 µm) left: mean water level, right: high water level.

plings and drift catches, all organisms of a species were summed up for each method separately, and related to the total sum of inventories and drift catches, respectively. The autumn catches were not considered because similar periods should be compared (April until August) and they were done only once after an extreme flood event.

Drift catches

There are different methods used to catch drifting organisms (e.g. Svendson et al., 2004). In our case the organisms were caught with a net with an opening of 80 x 60 cm^2 (width x height) and a length of 140 cm (Fig. 3). The mesh size was 500 µm. The net was installed in the middle of the river (Fig. 3) for time intervals of 10 min to 15 h. The time intervals were chosen depending on hydrological situations. The time interval was longer during low water levels to reach a comparable filtered water volume and a certain number of organisms. At the beginning of the investigation the organisms were caught in day- and night cycles to identify possible differences. It was also intended to catch organisms at different water levels (rising/falling hydrograph limbs). However, this was not possible due to the quick rise of the water level (Fig. 2). Therefore, we often missed the beginning increase and also the short peak itself. Neither was it possible to install the net during the peak water levels in many cases. Finally, in total 53 ($42 \le 120$ min) measurements of organism drift were made from spring 2009 until summer 2011. After the catching was finished, the net was taken out of the river and treated with 99% Ethanol. All organisms were transferred into plastic bottles. Depending on the volume of the sample, from one quarter up to the total sample was analysed and the organisms were determined and counted. Sometimes, a lot of different plant material accumulated in the drift net, making it difficult to sort all animals out. The organisms were divided between stage of development (larva or imago) and their life-forms (aquatic or terrestrial). If less than the whole sample was investigated, the result from the subsample was extrapolated to the total.

Measurements of water level and flow velocity made it possible to calculate the drift density (organism per volume of water), which is a widely used index (Svendsen et al., 2004). The total water volume V passing the net during the measuring periods was calculated by

$$V = \sum_{i=1}^{n} \left(h(t_i) \cdot u(t_i) \cdot b \cdot \Delta t \right) \quad (\mathrm{m}^3),$$

where i is number of 5 minute intervals,

$$h(t_i) = \begin{cases} \text{measured water level } H \text{ if } H \le 0.6 \text{ m} \\ 0.6 \text{ m if } H > 0.6 \text{ m} \end{cases}$$

$u(t_i)$ is flow velocity (m s^{-1}), b is width of the net (0.8 m), Δt is duration between 2 measurements of the sensor (300 s).

Inventories

They were performed along a section up to 50 m upstream of the measurement site following the instructions of the „Methodological handbook assessment of running waters“ (Meier et al., 2006) using the required surber sampler. The inventory samples were taken from the different habitats, regarding their share in the chosen river section (Table 2). Thus, all 20 subsamples were merged and divided into 30 parts subsequently. Thereof, a minimum of one fifth had to be analysed (which means six portions of 30). Additional portions had to be completely analysed until at least 300 individuals in total were counted. On the basis of the analysed subsamples, the total number of organisms in the whole sample was extrapolated (Meier et al., 2006). Normally, inventories are done in spring to early summer. Because of the extreme flood waves in August and September 2010, the inventory was repeated in autumn 2010 (16. 9. and 6. 10.) and again in spring 2011 (03. 04.).

Table 2. Types of riverbed substrates (according to Meier et al., 2006), their portion in the selected river section and the number of samples which were gathered for each habitat in the Landwasser River (Saxony, Germany).

Riverbed substrate	Coverage (%)	Number of samples
Makrolithal (big stones, 20–40 cm)	5	1
Mesolithal (small stones, 6–20 cm)	10	2
Mikrolithal (coarse gravel, 2–6 cm)	15	3
Akal (fine gravel, 0.2–2 cm)	35	7
Psammal/Psammopelai (sand, 6 µm–2 mm)	25	5
Emerse Makrophytes	10	2

The meteorological and hydrological conditions during the respective sampling are shown in Table 1. In October 2010 unfortunately no measurements of discharge and flow velocity were available at the sampling site. The discharge was estimated using the values from a gauging station downstream, while flow velocity was estimated using the values that had been measured at the same discharge in the past. The low amounts of organisms in autumn 2010 (marked in Table 1) are related to the above mentioned extreme flood waves.

Table 1. Meteorological and hydrological conditions and number of sampled organisms during the inventories of the aquatic community in the Landwasser River.

		03. 06. 2009	24. 03. 2010	16. 09. 2010	06. 10. 2010	03. 04. 2011
Air temperature (daily mean)	(°C)	10.5	9.7	12.6	12.2	14.4
Global radiation (daily mean)	(W m^{-2})	261	179	147	60	214
Discharge (actual value)	(l s^{-1})	265	505	240	210	250
Flow velocity (actual value)	(m s^{-1})	0.32	0.72	0.65	0.60	0.53
Number of organisms (total sample)	(–)	1332	1441	**638**	**109**	878

RESULTS

Comparison of inventories and drift

Within the free water, aquatic and terrestrial organisms were found. In total for the inventories 4.398 organisms were counted, for the drift catches 55.345 organisms (larvae and imagines). The relationships between the organisms caught in drift and during the surveys for considerable invertebrate groups are shown in Fig. 4. Altogether, organisms out of 27 different orders were caught in the flowing water, out of 19 orders during the inventories (Tab. 3).

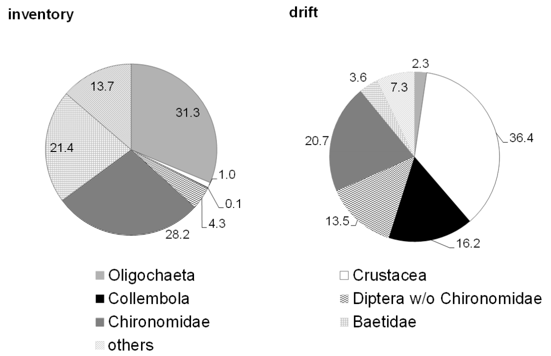

Fig. 4. Comparison of the sampled organisms groups during the inventories and the drift catches between May 2009 and July 2011 (mean values of all samples in %) in the Landwasser River (Saxony, Germany).

The most frequent orders detected in the inventories were Oligochaeta (31.3 %) and Diptera (32.5 %) including the family Chironomidae with 28.2 %. Within the order Ephemeroptera the family Baetidae (21.4 %) dominated.

Drifting organisms belong particularly to the orders of Diptera (34.2 % including Chironomidae), Crustacea (36.4 %) and Collembola (16.2 %). The latter are terrestrial organisms. Other terrestrial imagines of the orders Hymenoptera, Thysanoptera, Homoptera, Coleoptera, Araneae und Nematocera were also caught in the drift.

The most frequent family in drift was Chironomidae, which were found in each sample ranging between 3 and 88 %, with an average of 20.7 % (Kändler, 2012). Thornton (2007) found Chironomidae to be one of the families, which were known for drift. In contrast, organisms of the order Oligochaeta were rarely caught (2.3 %) because of their habitat. The same can be said for the family Baetidae (3.6 %).

The result of the severe impacts such as dredging (August 2009) and flood waves (August 2010, September 2010) on the number and composition of the organisms can be seen in Fig. 5 (compare also Table 1). In autumn 2010 the number of organisms was small which was, beside the influence of the ontogenetic cycle, a result of the extreme flood waves (7th and 16th August 2010 and 27th Sept. 2010). The biocenosis already damaged by the first flood wave, was nearly destroyed by the next ones. Thus, in the inventory only 109 organisms were counted in the whole sample. In spring 2011 the biocenosis had slightly recovered, but did not reach the numbers of individuals from springs 2009 and 2010. The composition of the aquatic community had changed. After the flood waves the portion of Oligochaeta was decreased but more Ephemeroptera were collected. After the second flood wave neither Hirudinea nor Pisidum were found in drift and inventory anymore. Instead, organisms of the orders Amphipoda, Cyclopoida and Coleoptera occurred.

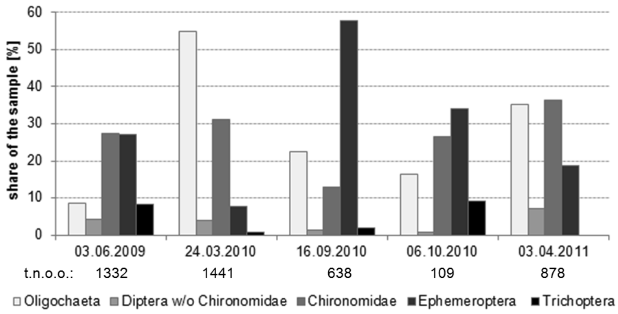

Fig. 5. Substantial groups of organisms (t.n.o.o. – total number of organisms) during the surveys at different dates in the Landwasser River (Saxony, Germany).

In Table 3, a more detailed view of organisms found in surveys and in drift catches is presented. Additional information is given by the verbal assessment of the frequency of the organisms in the samples according to Meier et al. (2006) for each group, and respectively, the period or date of special cases of occurrence. Examples are the mass occurrences of Cyclopoida (18. 07. 2009, 3. 4. 2010) due to their life cycle.

Flow velocity and drift

Although the studied river bed was artificial and strengthened, the relation between water level and flow velocity changed over the years (Fig. 6). In spring 2009, the bank vegetation grew more intensively and narrowed the river width. At the beginning of summer 2009, plants covered nearly the whole profile. In September 2009, the riverbed was dredged, resulting in an altered water level-flow velocity relation. The flow velocity was also faster with low water level. The mentioned flood waves lead to a severe transport of river sediment, the flow velocity decreased afterwards.

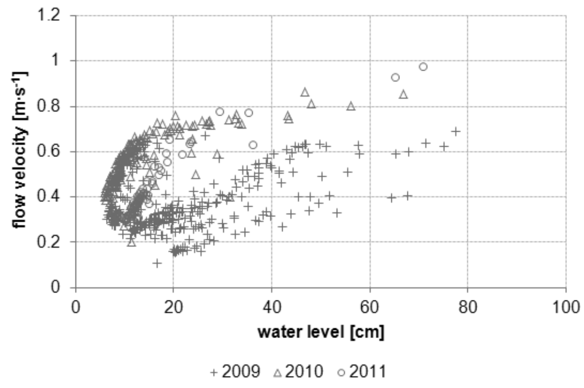

Fig. 6. Relation between water level and mean flow velocity at the measuring site in the Landwasser River (Saxony, Germany), 2009–2011.

The changes in the hydraulic conditions resulted also in changes in the drift (Fig. 7). In 2009, the flow velocity during the drift catches did not exceed 0.4 m s^{-1}. The drift density ranged between 0.1 and 1 organism per m^3. After the dredging, higher flow velocities occurred and the drift density increased by a factor of 100. In 2010 and 2011 the drift density ranged between 10 and 500 individuals per m^3.

Table 3. Portions (%) of organisms groups which were caught during inventories and during drift events related to the total sum of all analysed organisms within the whole period of investigation, where: single 1–2, few 3–10, few-mean 11–30, mean 31–100, mean-many 101–300, many 301–1000, mass occurrences > 1000 individuals, Landwasser River (Saxony, Germany).

Organism group	Inventory	Drift	Remarks for the drift (frequency of occurrence according to Meier et al., 2006)
Oligochaeta	31.3	2.4	many (02. 04. 2010), missing April 2011, mean-many (July 2011)
Hirudinea	0.6	0.1	few (2009, 2010), missing 2011
Aranea	some	0.1	few-mean (03. 04. 2010), else single
Acari	3.3	1.0	few-mean and mean (2009), few-mean (2010) few (2011)
Amphipoda	0.2	0.5	mean-many (30. 05. and 18. 07. 2009), few April 2010, afterwards missing
Calanoida	some	0.1	mean (September 2010 after extreme flood)
Cyclopoida	0.1	29.3	mass occurrences (18. 07. 2009, 3. 04. 2010), else mean-many
Diplostraca	0.8	4.8	many (July 2011)
Isopoda		1.6	mean-many (2009) afterwards few
Coleoptera	0.3	0.9	few (2009), mean (April/ May 2010 and 2011)
Collembola	0.1	16.1	mass occurrences, many (April 2010), else mean-many
Diplura	some	some	only 27. 09. 2010 after extreme flood
Diptera	32.5	34.2	many (April/May 2009, 2010, 2011)
Ephemeroptera	23.7	3.9	mean May/June 2009, 2010), few (2011)
Homoptera		0.6	few, few-mean (June/July, 2009, 2010, 2011)
Heteroptera	1.9	0.1	few (May/June 2009, 2010, 2011)
Hymenoptera	some	1.6	mean (April and June 2009, 2010, 2011)
Megaloptera	some	some	only 22. 07. 2011
Plecoptera	some	some	some (2009, 2010, 2011)
Psocoptera	some	some	some (2010 and 2011)
Lepidoptera	some	0.1	few (April 2010, July 2010 and 2011)
Thysanoptera	some	0.4	some (2009) few-mean (2010, 2011)
Trichoptera	3.3	0.5	few (2009) few-mean (2010, 2011 mostly April)
Pulmonata	0.7	0.9	few-mean, mean (2009) few (2010) after extreme flood missing, few (22. 07. 2011)
Veneroida	1.3	some	Few-mean (April 2010), else some
Nematomorpha		some	
Anthoathecata	some	0.8	mean (June 2009), afterwards missing

The composition of the species had altered and some species such as Anthoathecata had disappeared completely, because they prefer low flow velocities and they need plants to hide.

In August (7th, 16th) and September (27th) 2010, floods with unusual high discharges (45.5, 32.7 and 14.6 m^3 s^{-1}, respectively) took place in the Landwasser River. They changed the hydraulic conditions in the river and the aquatic ecosystem. Unfortunately, it was impossible to measure or sample organisms during the extraordinary floods themselves, but only afterwards.

Thus, on 27th September 2010, only 52 organisms were collected per m^3 at a flow velocity of 0.97 m s^{-1}, whereas on 21st of July 2011 at a similar flow velocity of 0.90 m s^{-1} the highest drift density was measured with 578 organisms per m^3. That means the ecosystem recovered quite fast from the strong flood effects.

A more detailed analysis shows that different organism groups started to drift at different flow velocities. The group of Diptera (without Chironomidae and Simuliidae) started drifting at 0.4 m s^{-1} and stayed nearly constant with rising flow velocity, while Oligochaeta started drifting at velocities > 0.6 m s^{-1} (Fig. 8).

Depending on the hydrological situation, up to 90 % of the caught organisms were terrestrial ones. During low water levels and slow flow velocities with mainly behavioural and constant drift, 0.1 to 1 organism per m^3 drifted. In those situations, the portion of terrestrial organisms is often unexpectedly high (Fig. 9). With rising discharge, the share of aquatic organisms increased (Fig. 9), and catastrophic drift prevailed. However, with rising flow velocity the drift density increased for both, aquatic and terrestrial organisms, but the ratio changed.

Terrestrial organisms were mainly caught in spring time, when the fields are only partly covered by vegetation. The typical family of soil biota Collembola then represented the largest share of sampled terrestrial organisms.

Nematocera were often simultaneously caught as adult organisms which live terrestrially, and as larvae which are typical aquatic organisms.

DISCUSSION

The benthic drift is strongly influenced by the hydraulic conditions of the river. There is a positive correlation between drift density and flow velocity. Robinson et al. (2004) found, that drift density rapidly increased when flow increased, which was similar in the Landwasser.

It was impossible, to derive a clear pattern between rising and falling limb because too few measurements could be taken for both cases. The extremely quick rise of the discharge, impeded drift catches during this stage.

During periods with slow flow velocities between 0.20 and 0.25 m s^{-1}, drift densities among 0.3 and 0.5 organisms per m³ were observed. They were considered to be the background drift. The drift increased rapidly at flow velocities higher than 0.3 m s^{-1} (Fig. 7, Fig. 8). Long et al. (2011) found similar values for Plecoptera for the beginning of the drift. The reason for decreased numbers in drift density of some groups (e.g. Baetidae) at high flow velocities was that most of them are already washed off at the beginning of rising discharge, while organisms, living in the sediment of the river bed like Oligochaeta, were not displaced until the material was moved, and their habitats were at least partly destroyed (Cellot and Juget, 1998).

The portion of entirely terrestrial living organisms in the drift was unexpectedly high, particularly during the low flow situations. Many inhabitants of the riversides (ants, spiders, bugs) drop in the water by chance, or are washed from the riversides if the water level rises quickly. In periods with only partly covered arable land close to the river, the portion of drifting terrestrial organisms increased because of surface run-off and erosion, as well as a rising water level (Kändler, 2012). Particularly in April 2009, high amounts of Collembola were caught. On the sloped fields directly alongside the river winter wheat in a very early stage was growing, and the soil was covered only by approximately 10 %. The grass stripes between water and field were very small with about 30 cm.

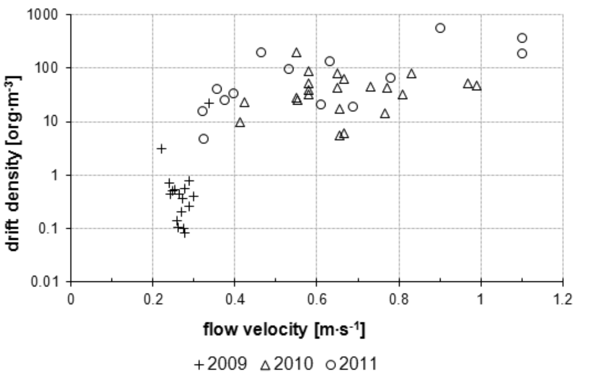

Fig. 7. Drift density of all organisms depending on flow velocity splitted by years, Landwasser River (Saxony, Germany).

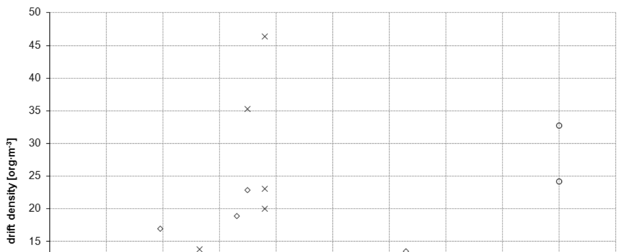

Fig. 8. Drift density of different groups of organisms depending on flow velocity, Landwasser River (Saxony, Germany).

During our investigations, the aquatic life was influenced by two drastic incidents causing heavy catastrophic drifts, one human and one natural. In 2009 the riverbed was dredged. As a consequence, the benthic community was modified because the hydraulic conditions had changed. It is necessary to take such knowledge into account when performing engineering activities at rivers.

In the following year, three big flood events within eight weeks affected the biotic community strongly. Due to these extreme situations some groups (e.g. Hirudinea) could not be found anymore in the ensuing period. Shortly after the events only low drift densities were observed. A few months later the drift intensity reached similar amounts of drift with equal flow velocities as before the events, but the composition of species differed. According to Hieber et al. (2003) the seasonal patterns of drift widely vary and seem to decrease with altitude and distance from the source. For we performed measurements in October only once, it is difficult to distinguish between the impact of seasonality and flood waves on the decrease of organisms in autumn and the increase in spring 2011. Solely seasonality can be excluded because the composition of the aquatic community had severely changed.

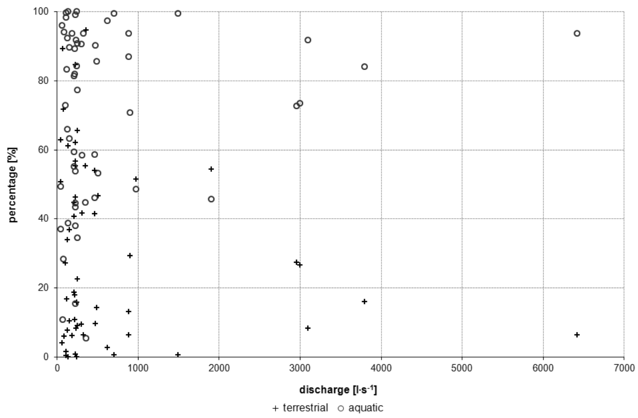

Fig. 9. Share of terrestrial and aquatic organisms in the samples depending on discharge, Landwasser River (Saxony, Germany).

The inventories of the benthic invertebrates, which were conducted 10 days and 6 months after the flood, showed, that the aquatic ecosystem recovered fast from such heavy impacts. It had adjusted to the altered hydraulic conditions, but the diversity was lowered and the organisms' composition changed. Orr et al. (2008) observed a decline in the density of macro invertebrates after a dam removal in a stream, followed by a change in the composition of the biotic community. They found that Trichoptera and Ephemeroptera were mostly affected, while Diptera showed only little effects. In the Landwasser, Trichoptera disappeared and the share of Diptera increased in the inventories after the flood.

One main problem in the investigation was that during events with high concentrations of suspended sediments, many organisms were destroyed and many animals could not be determined exactly, and also the amount of organisms was difficult to count. Death (2008) and Jones et al. (2011) faced similar problems, analysing many studies from different regions regarding the influence of suspended sediments on water organisms.

CONCLUSIONS

A high proportion of drifting organisms in the river are terrestrial ones, which were either swept off the river banks by the rising water level, or were transported by surface runoff especially from bare soils during rain events.

The drift intensity was found to be strongly dependent on the flow velocity and the discharge. For future investigations of the benthic drift, it will be important to take frequent samples within a flood wave with simultaneous measurements of flow velocity in order to detect changes in the drift density. Therefor the nets used in this study are not suitable. It should be considered whether a sampling for example by pumping water and subsequent filtration in short time intervals is possible.

Severe interventions in the structure of the river and its hydraulics, such as measures to river maintenance or extreme runoff events, affect the ecosystems of the river negatively. Habitats are destroyed and living conditions (such as flow rate, shading) changed. In the Landwasser River organisms such as the Anthothecata disappeared due to river maintenance, the Hirudinea and Veneroida disappeared after a disastrous flood.

The intensity of such maintenance measures must be reconsidered, in order to meet both a sustainable water management (i.e. flood protection) and the "good ecological potential" according to the water framework directive.

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REFERENCES

Bruno, M.C., Maiolini, B., Carolli, M., Silveri, L., 2010. Short time-scale impacts of hydropeaking on benthic invertebrates in an Alpine stream (Trentino, Italy). Limnologica, 40, 281–290.

Brittain, J.E., Eikeland, T.J., 1988. Invertebrate drift – A review. Hydrobiologia, 166 (1), 77–93.

Cellot, B., Juget, J., 1998. Oligochaete drift in a large river (French Upper Rhône): the effect of life cycle and discharge. Hydrobiologia, 389, 183–191.

Death, R.G., 2008. The effect of floods on aquatic invertebrate communities. In: Lancaster, J., Briers, R.A. (eds): Aquatic Insects – Challenges to Populations. Proceedings of the Royal Entomological Society's 24th Symposium. ISBN 978-184593-3968.

Fischer, J., 1998. Influence of combined sewer overflows on the mater balance and the ecosystem of small rivers in rural areas. Wasser Abwasser Umwelt Bd. 19, Diss. Univ. Kassel. (In German.)

Gibbins, C., Vericat, D., Batalla, R.J., 2007a. When is stream invertebrate drift catastrophic? The role of hydraulics and sediment transport in initiating drift during flood events. Freshwater Biology, 52, 2369–2384.

Gibbins, C., Vericat, D., Batalla, R.J., Gomez, C.M., 2007b. Shaking and moving: low rates of sediment transport trigger mass drift of stream invertebrates. Canadian Journal of Fisheries and Aquatic Sciences, 64(1), 1–5.

Gresens, S.E., Kenneth, A.E., Belt, T., Jamie, A.E., Tang, A., Daniel, A.E, Gwinn, C., Patricia, A.E., Banks, A., 2007. Temporal and spatial responses of Chironomidae (Diptera) and other benthic invertebrates to urban stormwater runoff. Hydrobiologia, 575, 173–190.

Hay, C.H., Franti, T.G., Marx, D.B., Peters, E.J., Hesse, L.W., 2008. Macroinvertebrate drift density in relation to abiotic factors in the Missouri River. Hydrobiologia, 598(1), 175–189.

Hieber, M., Robinson, C.T., Uehlinger, U., 2003. Seasonal and diel patterns of invertebrate drift in different alpine stream types. Freshwater Biology, 48, 1078–1092.

Jackson, H.M., Gibbins, C.N., Soulsby, C., 2007. Role of discharge and temperature variation in determining invertebrate community structure in a regulated river. River Research and Applications, 23, 651–669.

Jones, J.I., Murphy, J.F., Collins, A.L., Sear, D.A., Naden, P.S., Armitage, P.D., 2011. The impact of fine sediment on Macro-Invertebrates. River Res. Applic., doi: 10.1002/rra

Kändler, M., Seidler C., 2009. Erosion processes alter water quality in a stream within a small catchment in the Upper Lusatia Region in Saxony. Biologia, 64, 546–549.

Kändler, M., 2012. Analysis of the erosion dynamic in the Landwasser catchment (Upper Lusatia) – Influence on water quality and macrozoobenthos drift. Diss. Internationales Hochschulinstitut Zittau. (In German.)

LfULG, 2010. Description of the mapping units for recasting the BTLNK (Biotope type and land use mapping). Saxon State Office for Environment, Agriculture and Geology. (In German.)

LfULG, 2012. Hydrological handbook part 3. Saxon State Office for Environment, Agriculture and Geology. (In German.)

Litvan, M.E., Stewart, T.W., Pierce, C.L., Larson, C.J., 2008. Effects of grade control structures on the macroinvertebrate assemblage of an agriculturally impacted stream river. Res. Applic., 24, 218–233.

Long, A., Ashe, W., Ravana, K., Simon, K.S., 2011. The effects of water velocity and sediment size on Acroneuriaabnormis (Plecoptera: Perlidae) entrainment. Aquatic Insects, 33(2), 105–112.

Meier, C., Haase, P., Rolauffs, P., Schindehütte, K., Schöll, F., Sundermann, A., Hering, D., 2006. Methodological handbook assessment of running waters, handbook for investigation and assessment of running waters on the basis of the markozoobenthos in the background of the EU-Water Framework direktive. http://www.fliessgewaesserbewertung.de/downloads/abschlussbericht_20060331_anhang_IX.pdf (30. 03. 2011) (In German).

Meile, T., Fette, M., Baumann, P., 2005. Synthese Schwall/Sunk. Publikation des Rhone-Thur Projektes. Eawag, WSL, LCH-EPFL, Limnex. 48 pp. (PDF-Document 12.5 MB) http://www.rivermanagement.ch/schwall-sunk/docs/synthese.pdf (Downloaded 26. 04. 2010.)

Orr, C.H., Kroiss, S.J., Rogers, K.L., Stanley, E.H., 2008. Downstream benthic responses to small dam removal in a coldwater stream. River Research and Applications, 24(6), 804–822.

Robinson, C.T., Aebischer, S., Uehlinger, U., 2004. Immediate and habitat-specific responses of macroinvertebrates to sequential, experimental floods. J. North Am. Benthol. Society, 23, 4, 853–867.

Sagnes, P., Merigoux, S., Peru, N., 2008. Hydraulic habitat use with respect to body size of aquatic insect larvae: Case of six species from a French Mediterranean type stream, Limnologica, 38(1), 23–33.

Svendsen, C.R., Quinn, T., Kolbe, D., 2004. Review of Macroinvertebrate Drift in Lotic Ecosystems. Final Report for Wildlife Research Program Environmental and Safety Division. Washington Department of Fish and Wildlife.

Thornton, D.P., 2007. Macroinvertebratestream drift – an Australian example. Applied Ecological and Environmental Research, 6(1), 49–55.

Waters, T.F., 1972. The drift of stream insects. Department of Entomology, Fisheries and Wildlife, University of Minnesota, St. Paul, Minnesota, Sc. Journal Series 1972, Reprinted from annual review of Entomology, 17, 253–272.

WFD, 2000. Directive 200/60/EC of the European parliament and of the Council of 23 October 2000. Official Journal of the European Communities. L 327.

Wilcox, A.C., Peckarsky, B.L., Taylor, B.W., Encalada, A.C., 2008. Hydraulic and geomorphic effects on mayfly drift in high-gradient streams at moderate discharges. Ecohydrology, 1, 176–186.

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