Go with the Flow; Spatial Distribution in the Occurrence of Amphipods and its Relation to Flow Intermittency in a Headwater Catchment of the Reppisch

GEO 511 Master's Thesis

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«Klein und unscheinbar, ihre Bewegung dennoch schnell,
gehen sie ihrem Werke nach in Bach und Quell.
Geschützt von harter Schale, mit unzähligen Beinen,
zumeist versteckt, harren sie unter Laub oder Steinen.
Sie zerkleinern Pflanzen, fressen das verrottende Blatt,
alsbald nur noch dessen Gerippe steht, ein jeder ist nun satt.
Dem Flussbarsch auf seiner beschwerlichen Reise,
sind sie eine stets willkommene Speise.
Handelt es sich um Würmer, Fliegen, Käfer gar?
Nein, diese fleissigen Tierchen stellen Flohkrebse dar!»
R. Alther, 2017

Wenn es warm wird im Sommer, kein Regen mehr fällt
Und das Bachbett austrocknet, das Wasser nicht hält.
Ziehen sie sich zurück in die kühl-nassen Erden
Und hoffen es bleibt feucht, sonst müssen sie sterben.
Sie warten aufs Wasser, im Herbst kommt die Flut
Da kriechen sie nach draussen in frisch-frohem Mut
Wenn der Bach wieder plätschert, alle Tümpel verbunden
Da wissen die Krebschen, die schwere Zeit ist überwunden
Sie wandern im Wasser, wie es ihnen gefällt
Und breiten sich aus, da sie gar nichts mehr hält.
A. Jenny, 2019

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Abstract

Temporary waterways are among the most common freshwater ecosystems worldwide. Their discharge regime, that causes a shift between a terrestrial and an aquatic state at least once a year, strongly influences the biota that inhabit the channels. The amphipod species *Gammarus fossarum* KOCH, 1835 is one of the animals that inhabit temporary streams during the presence of flow. Its strategy to survive a dry spell is to retract to perennial reaches or pools and persevere until the flow resumes. The surviving population can subsequently recolonize the stream from there. This thesis aimed to investigate patterns of flow in a temporary stream in a headwater catchment of the Reppisch, Switzerland, over time and to link these patterns to the presence and abundance of *Gammarus fossarum*. The resilience strategy of the amphipods, including the recolonization of flowing reaches after the dry period was investigated as well.

The flow in the channels was mapped every other week for half a year, and amphipods were sampled at distinct points along the channels, on average around 30 m apart. The water level at the furthest downstream measurement point and the precipitation were recorded in hourly intervals to link the flow patterns to the precipitation.

The measurement period included a very dry summer and fall. 89 % of the examined channel length was dry on the most extreme measurement day. Both downward contraction and disintegration of the flowing stream network were observed during the desiccation period. When flow increased in late November, headward expansion and coalescence were witnessed, but no downstream expansion.

Amphipods were present in sixteen locations at the time of their maximum expansion, but their distribution decreased rapidly with the flow. Only in three locations was the population able to survive the dry period, all of which contained surface water throughout the whole measurement period. Individuals were also observed at sites with a wet streambed on ten occasions, which demonstrates that they can survive in moist sediment. In one location, they were present in a wet streambed on three successive measuring days, resulting in a maximum survival time of 56 days. The location dried out on the subsequent measuring day. At another location, they could no longer be verified after two succeeding measurements despite the continuous presence of saturated soil.

Amphipod movement could be verified on 14 occasions. The average travel speed was 5m/day with upstream travel being slightly faster. There was a tendency towards a higher speed at higher flows but with a sample size of 14 the results regarding migration need to be treated with caution. Further research in this area is needed, to verify the results found in this study.

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Introduction

1.1. Temporary Waterways

Temporary streams are among the most abundant freshwater ecosystems worldwide (Boulton et al., 2017; Datry et al., 2014). These streams do not have continuous flow over their entire course throughout the whole year. Flow in temporary streams may be present in some reaches of a tributary and be completely absent in others at the same time (Mcdonough et al., 2011). Their specific flow patterns strongly influence the biota inhabiting temporary streams, as well as all physical, biological and chemical processes (Datry et al., 2014; Mcdonough et al., 2011). It is estimated that globally more than 50 % of the stream network goes dry for at least a short period of time (Datry et al., 2017; Raymond et al., 2013). This is not only the case for rivers in arid regions, although larger temporary rivers are more common there. In temperate regions, temporary streams are most common in headwater catchments. In the regions below 60° latitude, they comprise about 69 % of all the first order streams (the uppermost reaches of a dendritic stream network) (Acuña et al., 2017; Raymond et al., 2013). Their abundance and increasingly recognized importance (Datry et al., 2011), entails many recent studies, such as this thesis, which focus on diverse aspects of temporary streams (Erine Leigh et al., 2016).

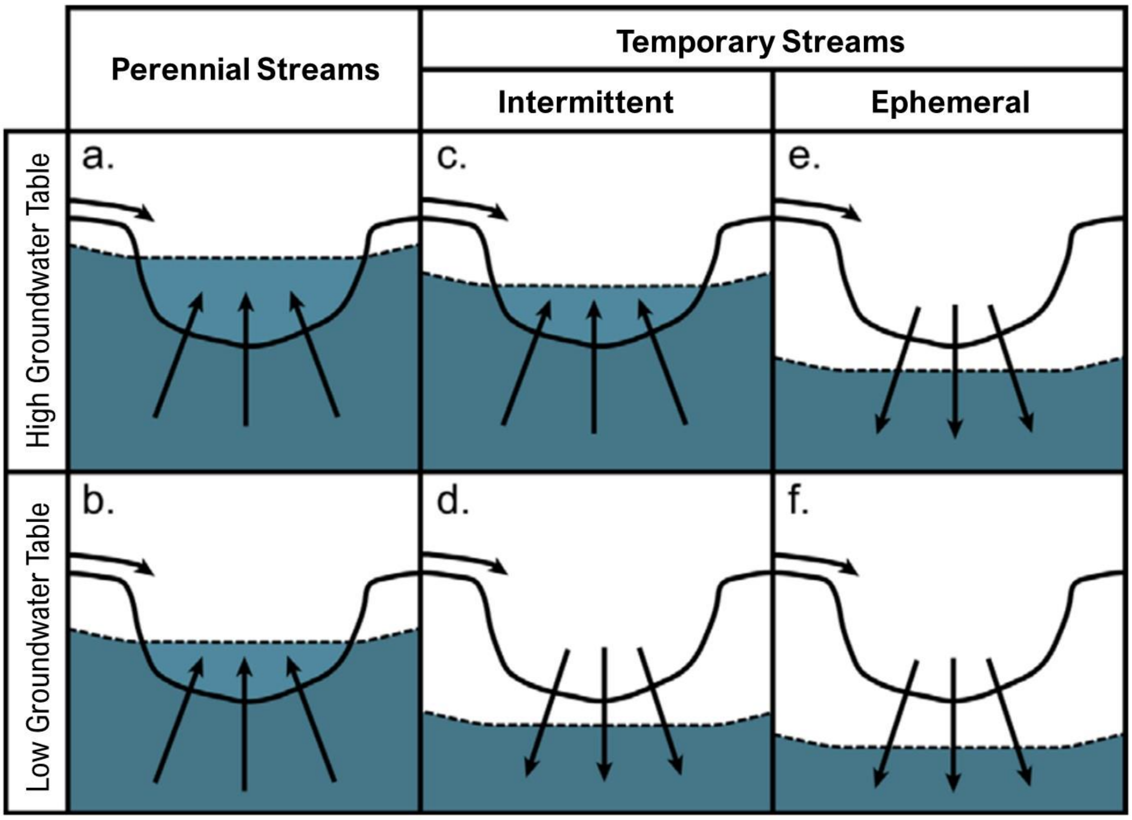


Figure 1: Interaction of streamflow and groundwater in temporary and perennial waterways (Mcdonough et al., 2011)

Depending on the mechanism that controls the drying and rewetting pattern, temporary streams can be classified as either ephemeral or intermittent (Fritz et al., 2013). An ephemeral stream flows only in direct response to a precipitation event. The groundwater table is lower than the streambed throughout the entire year, so it always loses water to the groundwater (Figure 1, right side) (Mcdonough et al., 2011). Therefore, the flow is as unpredictable as the weather and the duration of the dry period is usually a lot longer than the wet period (Olden et al., 2015).

The main water source of an intermittent stream is groundwater. It dries out when the groundwater table falls below the riverbed. When the groundwater table rises above the riverbed, it discharges and provides a baseflow supply (Figure 1, middle). The flow in intermittent streams is thus linked to long term changes in catchment wetness conditions. It is often seasonal, with dry summer periods, rewetting during autumn and flow during the winter. The flow pattern in these streams is predictable over a large scale (Mcdonough et al., 2011).

In many cases the distinction between an ephemeral and an intermittent regime is not clear. Thus, some researchers prefer to use the term temporary stream (Buttle et al., 2012).

The connection and disconnection dynamics of stream network expansion and contraction can provide important insights as to how the hyporheic zone is structured spatially. From this knowledge it's possible to deduce processes and patterns for runoff generation (Godsey and Kirchner, 2014; Goulsbra et al., 2014). When the groundwater table declines during a dry period, the flowing section in intermittent streams begins to contract.

There are two main patterns of flow contraction (Figure 2, left side). Downward contraction occurs when the drying of the stream network starts in the channel heads and continuous down to the perennial reaches with the lowering of the groundwater table (Goulsbra et al., 2014). When the flow decreases along the whole stream, topographic high points, such as crests or boulders emerge, and flowing reaches become disconnected. With further lateral and longitudinal contraction of the flowing stream segments, a series of disconnected pools form. This process is described as disintegration (Bhamjee and Lindsay, 2011). The absence of surface flow between flowing stream sections, however, does not necessarily mean that there is no hydrologic connectivity, as they may be connected via subsurface flow, or hyporheic flow. This water re-emerges downstream in water-upwelling zones (Mcdonough et al., 2011). However, the temperature and biogeochemistry of the water in pools can abruptly change when they become isolated (Larned et al., 2010).

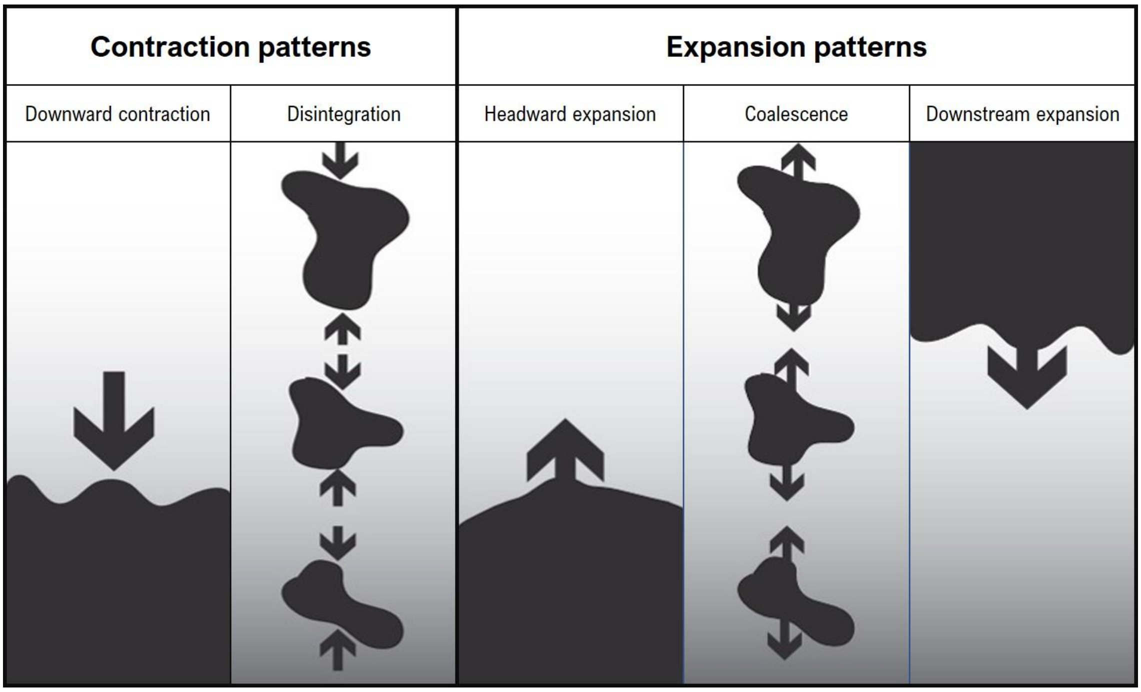


Figure 2: Patterns of streamflow expansion and contraction (Bhamijee and Lindsay, 2011)

For the expansion of the flowing stream network, three different patterns can be observed (Figure 2, right side) (Goulsbra et al., 2014). The inverse mechanism to disintegration is coalescence. When local low points within the streambed are saturated and filled, they expand outward with a rising water table until they connect, and flow can resume. The case of headward expansion similarly results from soil saturation due to a rising groundwater table. In this case, the flowing channel segment expands from a downstream location towards the channel head (Bhamjee and Lindsay, 2011). The rewetting of the channels can also occur as top-down expansion of the flow. This is a result of drainage from surrounding slopes into the upper channels. The flow then continues downstream (Goulsbra et al., 2014). This expansion is common for locations with low infiltration capacity or during intense precipitation events (Peirce and Lindsay, 2015).

The isolated aquatic areas in temporary streams vary in space and time and range from the size of small pools to extensive reaches in which the flow permanence is high. Similarly, terrestrial habitats in the stream network can consist of a single boulder, or an entire dry reach. The frequency with which stream segments shift between inundated and dry can range from less than a day to over a year (Larned et al., 2010).

1.2. Management of Temporary Streams

Despite their hydrological, ecological and biogeochemical importance (Datry et al., 2014; Godsey and Kirchner, 2014) and their global abundance, temporary streams have been neglected by hydrologists and ecologists for a long time (Larned et al., 2010) and are traditionally not gauged (Acuña et al., 2014; Datry et al., 2014). In addition, due to the small size of many intermittent streams, especially in headwater catchments, they are rarely shown on maps, so that the total stream length within a watershed is often severely underestimated (Benstead and Leigh, 2012; Mcdonough et al., 2011). Especially by non-ecologists the dry phases are interpreted as a useless stage, so that intermittent rivers and ephemeral streams are considered less valuable than perennial waters (Acuña et al., 2017; Erine Leigh et al., 2016; Leigh et al., 2019). Indeed, species richness and density decrease from perennial to intermittent reaches. These shifts however, result mainly from the loss of species that are not adapted to drying events, and benefit the ones that are (Datry, 2012; Datry et al., 2007).

Due to climate change, the dry periods in temporary streams are predicted to become longer and more frequent (Acuña et al., 2017; Datry et al., 2016; Sabo, 2014). In many areas, this trend is exacerbated by an increase in water abstraction for agriculture, industry and municipal use (Larned et al., 2010). The combination of climatic and the anthropogenic factors may lead to a lowering of the regional groundwater table, which in turn leads to less streamflow (Dodds et al., 2004). By 2050 the global average annual flows are predicted to decrease in 25–45 % of all river catchments, and some perennial rivers will become temporary (Larned et al., 2010). Some large-scale rivers, such as the Nile, have already ceased to flow continuously over their whole course (Datry et al., 2014; Gleick, 2003).

In comparison to perennial streams, temporary waterways have (so far) been understudied (Datry et al., 2017; Mcdonough et al., 2011). This has significant consequences regarding the management of temporary rivers and streams (Acuña et al., 2014; Datry et al., 2017). In many countries, temporary streams are not protected by the laws that protect perennial rivers. Thus, they are prone to anthropogenic degradation. As their value is not yet widely recognized, they are buried or degraded as a result of channel modification or used as waste water drains or corridors for live-stock and vehicles (Acuña et al., 2014; Steward et al., 2012). Such a behavior could be observed during this study. The westernmost stream that was not part of the study streams was filled during unauthorized construction work within the catchment (Figure 3).

Figure 3: Westernmost reach of the Diebisbach, Switzerland, under construction (photo by M. Steinmann, 2018)

However, the importance of temporary streams is starting to be recognized more and more (Datry et al., 2014; Leigh et al., 2019). In many countries the definitions of 'stream' and 'river' are being reviewed (Godsey and Kirchner, 2014), and the number of studies on temporary streams is growing (Datry et al., 2016; Erine Leigh et al., 2016). Due to the important information on ecosystem responses to environmental changes they can provide (Datry et al., 2011), the relevance of such studies, especially in the light of the ongoing climate change, is increasing (Sabo, 2014). Furthermore, there are novel attempts to correctly map all waterways (Acuña et al., 2014). Such attempts include citizen science initiatives, where volunteers (usually residents) assist in the monitoring and/or mapping of the stream channels. This approach allows observations of the timing, amount and spatial pattern of flow over a long period (Stubbington et al., 2018). It is an especially important approach for headwater streams, as these are hard to map with traditional techniques (Benstead and Leigh, 2012). Aquatic organisms such as macroinvertebrate communities can also serve as indicators for intermittence, but so far, they have only helped to differentiate between broad states of flow, such as flowing and disconnected pools (Stubbington et al., 2018).

1.3. Temporary Stream Ecology

Temporary streams are connected to their watersheds and the perennial reaches further downstream (Mcdonough et al., 2011; Nadeau and Rains, 2007). This connection is essential for the riparian ecosystems at the edge of the stream, as the changes in the flow results in transport of organisms and nutrients between the channel and the riparian floodplain. The channels serve as regions of nutrient and carbon processing and as transportation corridors (Acuña et al., 2014).

The connectivity of the flowing stream network itself, also directly influences the biota in the channels. When it is low, it creates places of refuge in disconnected pools during dry phases, and it enables dispersal and geneflow between the metapopulation (the collectivity of all distinct populations of the same species in the catchment), when connectivity is high (Meyer et al., 2007).

Figure 4: Measurement Point MP50 in the Diebisbach catchment in a terrestrial state on the 22.08.18 (left), and in an aquatic state on the 09.12.2018 (right)

The ecological state within the reaches of a temporary stream shifts between terrestrial and aquatic, depending on the presence or absence of flow (Figure 4) (Mcdonough et al., 2011). Temporary streams contain areas that can be classified as terrestrial, aquatic or transitional based on the biogeochemical pathways and the presence of certain species. The borders that separate adjacent areas function as ecotones through which organisms and materials can flow (Larned et al., 2010). Ecotones provide ecosystem functions and services from both terrestrial and aquatic environments as they are situated at the boundary between the two (Mcdonough et al., 2011; Meyer et al., 2007). After a flood or a drying event, aquatic and terrestrial species and pathways briefly co-exist in transitional areas that also serve as temporal ecotones (Larned et al., 2010).

The complete transformation of an aquatic ecosystem to a fully terrestrial one and back, however, takes a lot longer than a simple flooding and drying event. To finalize this process, the respective populations dynamics, biogeochemical cycles and food-webs need to re-develop after the event (Larned et al., 2010).

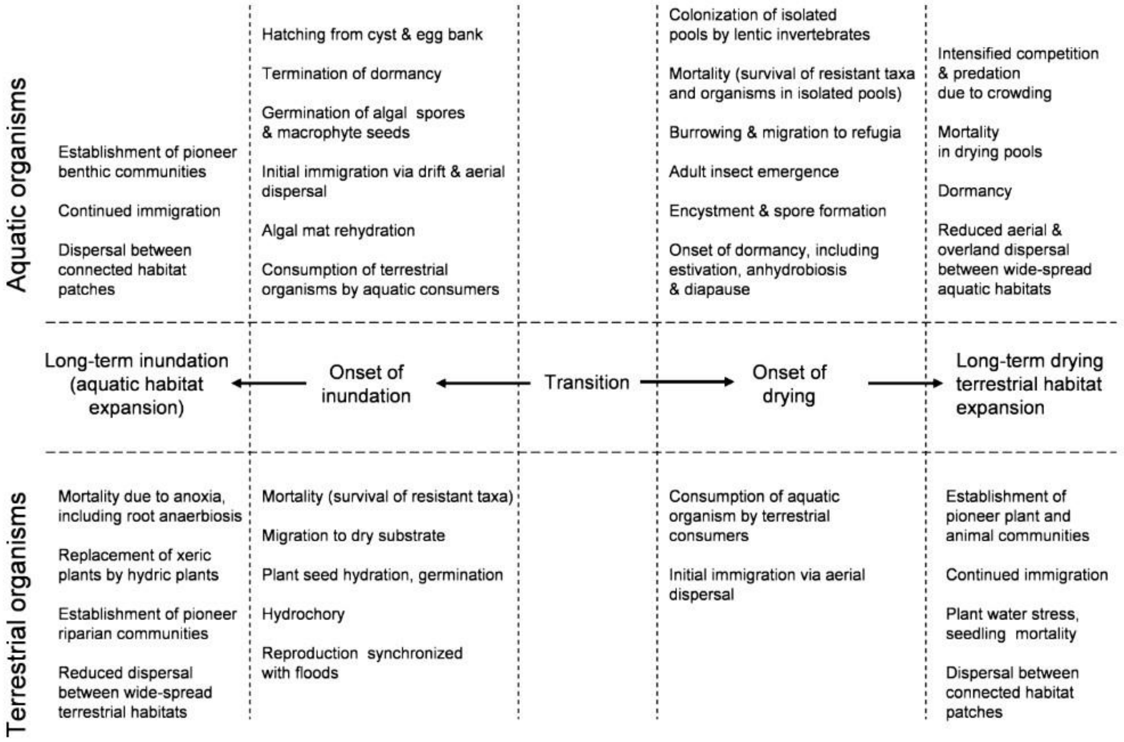


Figure 5: Cycle of transition between an aquatic and a terrestrial ecosystem and its influence on the respective organisms (Larned et al., 2010)

Species that are able to survive in both aquatic and terrestrial environments, or are particularly adapted to cope with extreme environmental conditions, can profit from these transitions (Altermatt et al., 2009; Strachan et al., 2015). Competitive species without any such adaptions or tolerance for the extreme conditions in temporary streams risk local extinction with every ecosystem change (Datry, 2012; Zickovich and Bohonak, 2007).

There are different factors, which influence the competitive advantage of different species. For the biota in isolated pools the duration and the severity of the dry period is important (Bogan et al., 2015); species with a high tolerance to oxygen shortages or very high temperatures become dominant in the long term (Larned et al., 2010). After a flooding event, one of the main factors that influences community composition, is the distance between the disconnected reaches, and the ability of the different species within the temporary pond networks to disperse (Larned et al., 2010). The importance of the distance factor can be observed, as the proximity to perennial retreats, affects the distribution patterns of species in intermittent streams (Datry et al., 2007).

Many species found in intermittent streams have developed strategies or life histories to survive the harsh environmental conditions (Mcdonough et al., 2011). These strategies can be categorized into resistance strategies and resilience strategies.

Resistance refers to the strategies that aim to maintain a population during a dry period (Datry et al., 2016). They include physiological adaptions, such as eggs resistant to desiccation (Strachan et al., 2015), or resistant juvenile or adult stages (Vadher et al., 2018).

Resilience describes strategies that allow a species to re-establish its population after a dry period (Datry et al., 2016). This includes several behavioral responses like movement into wet subsurface sediments (Vadher et al., 2018), or flying away from a dry habitat to find more permanent water. From there, the habitats where the population has gone locally extinct can be recolonized when surface flow reoccurs. Many species possess more than one strategy to survive a lack of surface water and use them in different stages of their life history (Strachan et al., 2015). Thus, in addition to the duration and severity of the dry period, its timing is an essential factor for population persistence, as some organisms need to be in the right stage of their development to respond to the lack of surface water in time (Sánchez-Montoya et al., 2018).

1.4. Amphipods

Amphipods are one of the many organism groups adapted to life in intermittent streams. They belong to the class of higher crustaceans, which includes, amongst others, crabs and shrimp. There are around 10,000 different species of amphipods. Although most species live in marine or brackish environments, around 20 % of the amphipod species inhabit, lakes and perennial rivers, and temporary stream reaches. In temperate regions, they are the most abundant freshwater macroinvertebrates. They can reach population densities of thousands of individuals per square meter. (Van den Brink et al., 1991). Few amphipod species prefer a terrestrial environment (Väinölä et al., 2008). Amphipods are some of the most common macroinvertebrates that inhabit freshwater ecosystems in the northern hemisphere (Altermatt et al., 2014; Alther and Altermatt, 2018; Väinölä et al., 2008). The most abundant and widespread species in Switzerland is the *Gammarus fossarum* KOCH, 1835 (Figure 6) (Altermatt et al., 2014), which is the species that was investigated in this study.

Figure 6: Individual of the species Gammarus fossarum, *the amphipod species investigated in this study (photo by R. Alther)*

Amphipods contribute significantly to the biodiversity and the functioning of the ecosystem. The ecological and economic importance of amphipods is (besides their abundance) mainly connected to their position in the food-web. Most above-ground living amphipod species, including the *Gammarus fossarum,* are detritivores. As detritivores, they play an important role in the decomposition of organic matter. They eat dead leaf litter (detritus) and by doing so make this material more accessible to microbes. Like most detritivorous amphipod species, *Gammarus fossarum* also feed on dead animal material and in the case of high population densities cannibalism can occur (Eisenring et al., 2016; Kelly et al., 2002). They also live as herbivores and as predators and are themselves an important food source for many fish species (Alther, 2018; Nery and Schmera, 2016). Because amphipods provide these ecosystem functions and link different trophic levels, they are a keystone species in aquatic food-webs (Alther and Altermatt, 2018; Little and Altermatt, 2018).

Amphipods are very sensitive to pollution and environmental change in general. If no amphipods are present in otherwise suitable waters in Switzerland, this is often due to pollution of the waterbody by pesticides from agriculture. Consequently, some amphipod species including *Gammarus fossarum* are bioindicators for water quality (Hodkinson and Jackson, 2005) and are used in ecotoxicological tests (Bundschuh et al., 2011; Gerhardt, 2011). For *Gammarus fossarum*, the sensitive reactions to organic pollution not only consist of mortality, but also in behavioral changes, especially a reduction of feeding activity (Bundschuh and Schulz, 2011).

There are 44 known amphipod species in Switzerland (Alther, 2018). Almost all freshwater amphipods in Switzerland inhabit the benthic zone, which consists of the sediment, the streambed and the riparian zone of waterbodies. In streams, they can be found between and under rocks and stones, leaflitter, branches or roots and macrophytes (Alther, 2018). In this master thesis, I study the species *Gammarus fossarum* KOCH 1835 (Figure 6), which is the most abundant and widespread species in Switzerland (Altermatt et al., 2014).

Gammarus fossarum consists of a species complex of multiple morphologically identical species. The only way to separate the three *Gammarus fossarum* species in Switzerland is through genetic analysis (Alther, 2018; Müller, 2000). In middle to low elevations (250–1300 m a.s.l.) they populate almost all surface waters. In waters with high organic or chemical pollution the species is not present (Eisenring et al., 2016; Feckler et al., 2012). *Gammarus fossarum* can tolerate strong currents and low temperatures, which gives it an advantage over other amphipod species such as the second most abundant species in Switzerland, the *Gammarus pulex* (Karaman and Pinkster, 1977).

Above-ground living amphipod species such as the *Gammarus fossarum* live 8–9 months up to a few years. They can hibernate in different stages of their development. Sexual maturity is reached within about 3–4 months, so populations are typically intergenerational (Alther, 2018; Ginet, 1960). *The Gammarus fossarum* species is reproductive all year round, except when the water temperatures are too high during summer. In this case the reproduction will only take place during the winter months (Karaman and Pinkster, 1977). The *Gammarus fossarum* prefers alkaline, nutrient poor waters with good oxygen conditions and a fast flow (Poznańska et al., 2013). As benthic macroinvertebrates, they populate the sediment, the streambed and the riparian zone of waterbodies, and are visible by eye (Alther, 2018). They cannot survive out of the water for a long time but have been observed to migrate horizontally, following a retreating waterline during a drying experiment (Poznańska et al., 2013). This reaction to desiccation can be classified as a resilience strategy, as they aim to survive in disconnected reaches and pools. From there they recolonize the streams when flow resumes.

The movement of amphipods is laterally recumbent (Väinölä et al., 2008). They move upstream in the shelter of obstacles that divert the flow locally. Downstream migration is a result of individuals caught in drift and carried downstream by the current (Statzner and Bittner, 1983). Many amphipod species can cover large distances in a relatively short time span (Bollache et al., 2004); Apart from the small scale active movement of the animals over a few kilometers (Altermatt et al., 2016), they can also be displaced over large distances by ships, as stowaways (Bollache et al., 2004). This leads to an increasing competition by invasive amphipod species which can be disadvantageous for native amphipod species (Seymour and Altermatt, 2014; Van den Brink et al., 1991).

1.5. This MSc Thesis

1.5.1. Thesis Objective and Research Questions

This master thesis links hydrological and ecological questions regarding amphipod abundance and flow in temporary streams. I mapped the spatial and temporal patterns of drying and rewetting in the temporary streams of the Diebisbach, in a headwater catchment near Zürich, Switzerland, and investigated the connection between these patterns and the distribution and dispersal of the amphipod species *Gammarus fossarum*. Before starting the research, it was hypothesized that the amphipods would die out in the locations that go dry, and that local populations of amphipods would survive in disconnected pools and perennial reaches and recolonize the streams from there. The novelty of this study is the very high spatial and temporal resolution of the data to answer the following research questions.

1. *During what conditions do temporary stream sections of a headwater stream dry out and rewet and how does this transition occur?*

The focus of this question is on the hydrology of the temporary streams and what determines whether different stream reaches contain water or dry out. The flow data is linked to the precipitation data to examine the extent to which the precipitation changes the flow. The patterns of flow over time are then investigated to determine mechanisms of flow contraction and expansion.

2. *How is the presence and abundance of amphipods linked to the presence of flow?*

Gammarus fossarum is known to survive in wet reaches of temporary streams. They follow the contracting water line but die when the streambed dries out completely, before they reach a wet or flowing refuge (Vadher et al., 2018). The individuals, that manage to survive in a pool or perennial reach, can recolonize the reaches upstream and downstream when water is present again. Based on the recurrent mapping of the streamflow and amphipod presence over time, I aimed to locate survival hotspots of the *Gammarus fossarum* to determine the conditions under which a local population could be sustained.

3. *What are the hydrological prerequisites for the recolonization by amphipods after a drying and rewetting event in a temporary stream?*

Amphipods are present in almost all rivers and streams in Switzerland. They are also present in the wet phases of reaches that dry out periodically. It is aimed to determine the conditions necessary for amphipods to recolonize previously dry reaches, and the speed with which this recolonization takes place. Both upstream and downstream velocities are quantified and a possible correlation to the amount of streamflow is examined.

1.5.2. Importance of the Research Topic

To manage temporary streams and to implement suitable conservation measures, it is crucial to understand the dynamics and drivers of drying and wetting of such streams and the consequent changes in community structures (Alther, 2018; Vadher et al., 2018). Changes in amphipod presence and abundance may reflect the flow dynamics but may also be the results of the high sensitivity of the amphipods to pollution and environmental change. In addition, invasive amphipod species are colonizing new habitats in Switzerland and the rest of Europe, leading to increased competition for native species (Altermatt et al., 2016; Little and Altermatt, 2018). The community structures of amphipods can thus reflect the biogeographic past of a region and is an important factor when analyzing relationships between biodiversity and ecosystem functioning in aquatic systems (Altermatt et al., 2014). It is crucial to have baseline data on what to expect in unaltered streams and the relation between the presence and abundance of amphipods and certain stressors, to draw the right conclusions, and take correct management decisions (Dudgeon et al., 2006).

The shifting habitat mosaics due to changes in flow conditions are a key feature of temporary streams (Larned et al., 2010). Flow is an important variable in the studies focusing on the dispersal of organisms. In fact, patterns of flow are considered the most important factor influencing biological communities in temporary streams. They influence the presence and absence of a habitat for plants and animals (Mcdonough et al., 2011; Poole et al., 2006), and are thus directly linked to the survival and extinction of organisms (Sánchez-Montoya et al., 2018). In addition, hydrology is the central driver of physical, biological and chemical processes in streams (Mcdonough et al., 2011; Poff, 1996). As the dry periods in intermittent streams are predicted to increase in duration and intensity, it is crucial to improve our knowledge about the influences, such changes have on benthic invertebrates (Vadher et al., 2018). Furthermore, the mapping of the changing stream network over time and the location of transition points between surface and subsurface flow, provides knowledge on subsurface hydrology. This in turn can help with the deduction of processes and patterns for runoff generation (Godsey and Kirchner, 2014).

1.5.3. Scientific Context

Other studies have addressed this subject matter, linking behavioral traits of amphipods to the hydrology of their habitat. Some investigated the reaction of the animals to stressors related to hydrology. Vadher et al. (2018) for example focused on the survival of *Gammarus pulex* in relation to the duration of a lack of surface water. They found a linear relationship between the length of a dry stream phase and the survival of the amphipods. *Gammarus pulex*, were able to survive a lack of surface water in subsurface sediments for up to 21 days (Vadher et al., 2018). As members of the Gammaridae family, they are related to the *Gammarus fossarum* complex, which leads to the assumption that they too can survive in moist streambeds for a similar amount of time (Poznańska et al., 2013). Poznańska et al. (2013) examined the behavioral defenses of four amphipod species including *Gammarus fossarum* to substratum drying. *Gammarus fossarum* migrated laterally following the retreating waterline. This is especially interesting for this thesis, as their findings on the behavioral responses of *Gammarus fossarum* to stream drying are used as a basis for the interpretation of the discoveries in this study.

There are other studies that, similar to this thesis, investigated dispersal characteristics in relation to streamflow. Elliott (2002) considered the connection between mean water velocity and the mean time spent in drift, as well as the mean distance travelled by *Gammarus pulex*. The relationship was determined experimentally, and a distance-water velocity model was developed and validated with field data. There was a significant positive relationship between drift rate and water velocity, which indicates a link between amphipod dispersal and flow. However, the setup was experimental, and drift only results in downstream dispersal, whereas here upstream dispersal is considered as well.

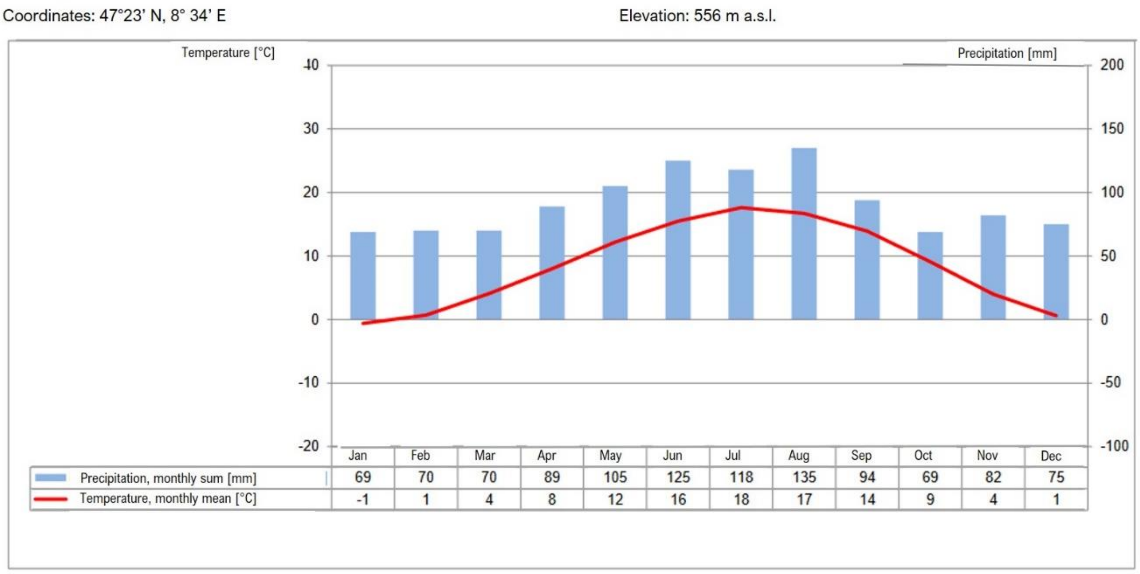
To my knowledge this master thesis is the first one to link repeated mapping of flow with the monitoring of amphipod presence and abundance in intermittent streams over a several month period. The data has a very high spatial and temporal resolution with the measurement points being roughly 30 m apart and measurements taken every second week. The detailed mapping of the drying and rewetting of the Diebisbach in combination with the monitoring of the presence of a species of aquatic organisms illustrates the influence of intermittency on the biota in different reaches. The knowledge of the colonization speed of the *Gammarus fossarum* and the flow necessary for the recolonization to take place, can help to avoid misinterpretations of their absence in relation to ecotoxicology.

2. Methods

2.1.Fieldwork

2.1.1.Study Catchment

The study was conducted in the Diebisbach catchment in the canton of Zürich, Switzerland. It is a small headwater catchment located on the southside of the Üetliberg (Figure 8, inset map). It has an area of 0.47 km^2 and a total channel length of 5.45 km. The elevation ranges from 513 m a.s.l. to 835 m a.s.l. and the dominant aspect is south-west. The catchment is located in the temperature climate zone, with four clearly separate seasons and an increase in temperature and precipitation in the summer (Figure 7).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation, monthly sum [mm]	69	70	70	89	105	125	118	135	94	69	82	75
Temperature, monthly mean [°C]	-1	1	4	8	12	16	18	17	14	9	4	1

Figure 7: Climate chart from the station Zürich Fluntern (see Figure 10 for its location) (dwd.de)[1]

The geology Üetliberg consists of Upper Freshwater Molasse (Pavoni, 1957). In the upper part, older surface ballast from the last glacial maximum in the Pleistocene can be found (Hantke, 1987). The soil consists of calcareous brown earth in the western part and waterlogging gley in the lower eastern part (maps.zh.ch[2]). The discharge process map shows a delayed surface overland flow in the eastern parts of the catchment, due to a small water storage capacity of the soil (mid-streams and lower part of east-stream, Figure 9). The predominant discharge process in the western part of the catchment (west-stream, Figure 9) is subsurface flow and the soil storage capacity is classified as medium (maps.zh.ch)[3].

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[1] https://www.dwd.de/DWD/klima/beratung/ak/ak_066600_di.pdf - accessed 28.04.2019
[2] https://maps.zh.ch/s/obaovmsp – accessed 25.04.2019
[3] https://maps.zh.ch/s/jir4n3sm - accessed 27.04.2019

In the upper part of the catchment, the main landcover type is forest, with beech-mix forest in the eastern part and alder-ash forest in the western part (maps.zh.ch)[4]. In the medium elevations, where the main channels converge the land cover consists mainly of meadows and in the lowest part, below the small village of Diebis, down to where the Diebisbach discharges into the Reppisch, the stream flows through agricultural fields (Figure 8). The Electric Conductivity (EC) ranges from roughly 400 µS/cm to around 700 µS/cm, with a few outliers.

2.1.2.Sensor-Derived Data

The data collection period started in June 2018 and lasted until December 2018. Hourly precipitation data was derived from three measurement stations (Figure 10): 1) the private weather station of Prof. Dr. Jan Seibert in Wettswil (590 m a.s.l.), 1.4 km from the lowest measurement point, MP50, (Wettswil), 2) the Meteoblue measurement station in the Üetlibergtower (879 m a.s.l.) 0.9 km from MP50 (Üetliberg) and 3) the Meteoschweiz measurement station in Zürich Fluntern (556 m a.s.l.), 7.2 km from MP50 (Fluntern). A tipping bucket rain gauge (0.2 mm per tip) was

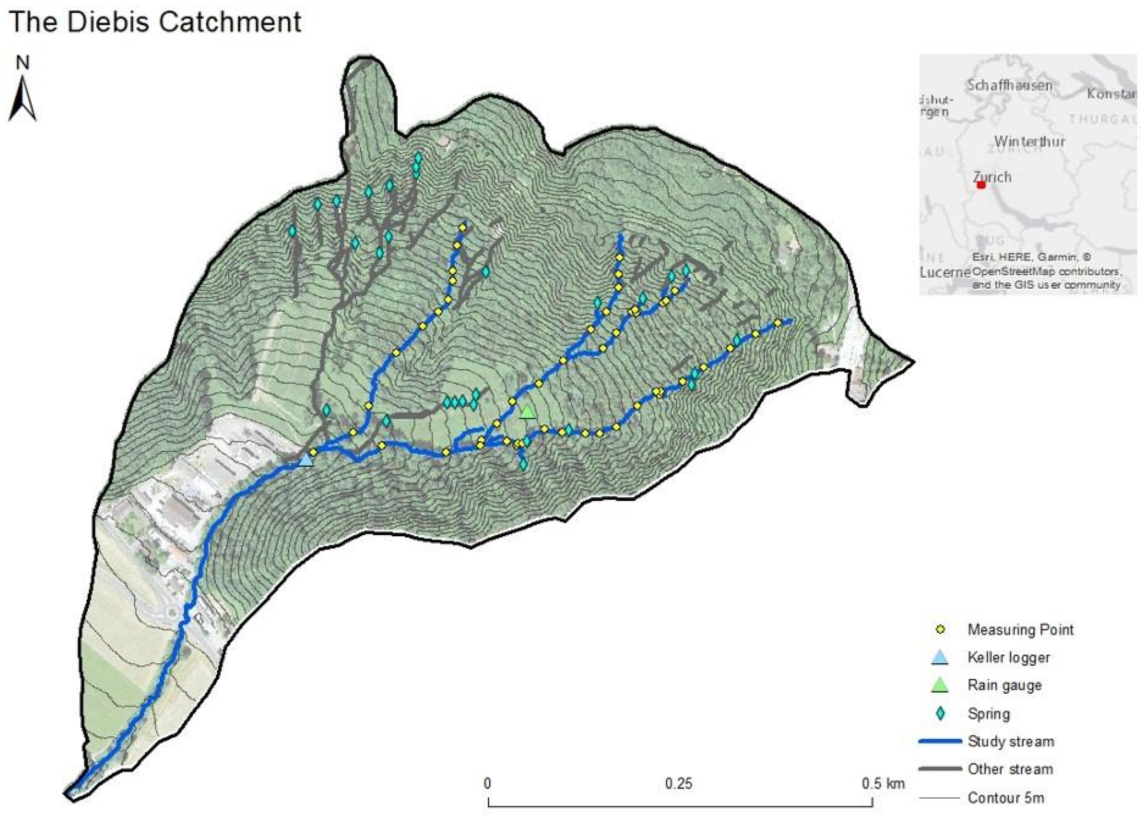

Figure 8: Overview map of the Diebis catchment

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[4] https://maps.zh.ch/s/tntms7nb - accessed 25.04.2019

installed in the catchment (Figure 10: Diebis). To monitor the water level a Keller pressure transducer was installed at the lowest confluence of the channels within the catchment, around 5 m below MP50 (Figure 8). A similar pressure transducer measured the air pressure inside a bird house above MP50.

2.1.3. Manually Derived Data

Fieldwork was conducted every second week with the first measurement taken on the 15th of June 2018 and the last one on the 19th of December 2019. In the last weeks, three measurements were taken (on the 3rd, the 9th and the 19th of December) due to high precipitation.

The focus of the fieldwork was on the eastern streams of the catchment (marked blue in Figure 9). The far west stream was omitted for accessibility and time reasons (the grey streams in Figure 9). An additional reason was the branching of its channels in the upper part. Data interpretations in terms of amphipod origin would be difficult due to the many possibilities. This decision was not regretted, as the far west stream was filled over the course of an unauthorized construction project

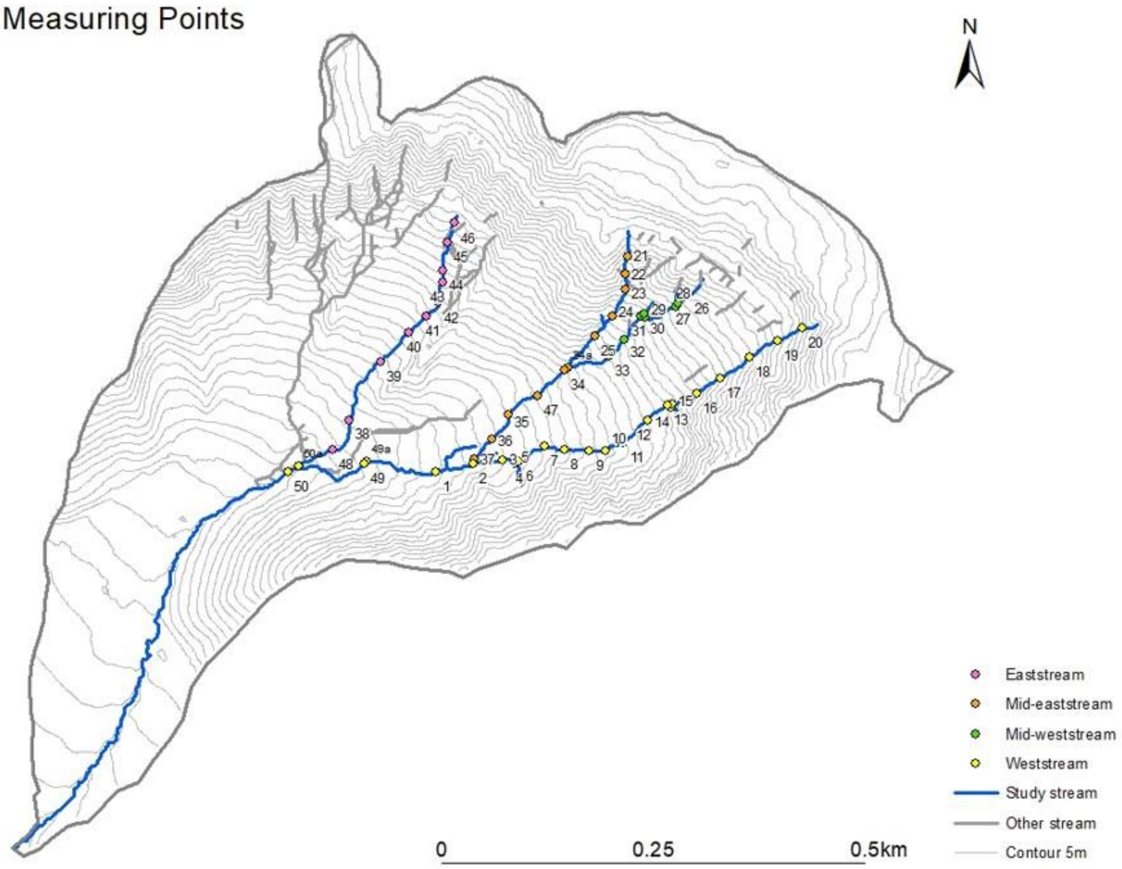

Figure 9: Measurement points along the study streams, colored according to the reach they represent in the heatmaps (description of the measurement points in Appendix A)

towards the end of the study period (Figure 3). The combined channel length of the observed streams was 2518 m and thus contained a little less than half of the total channel length in the catchment. These streams will henceforth be referred to as study streams. The different stream segments are referred to as the east stream, the mid-east stream, the mid-west stream and the west stream (measuring points marked accordingly in Figure 9).

Fifty measurement points (MP1–MP50) were distributed along the study streams, with a mean distance of 33 m between points (Figure 9). The maximum distance was 107 m and the minimum distance 4 m. The larger distances were due to inaccessibility of the channel. On the other hand, interesting aspects in the channel bed or in the dendritic network, such as high steps (e.g. MP5–MP6) or channel forks (e.g. MP29–MP30–MP31) were considered specifically. With the aim to observe difficulties or preferences in amphipod dispersal, measurement points were placed close before and after locations of interest, resulting in shorter distances between these points. Measurement points that pertained to more than one stream were assigned to the one with which the connectivity was estimated to be highest based on personal observation (colored accordingly in Figure 9).

The flow in the study streams was mapped along the whole course, using ordinal flow categories (Table 1). The flow was estimated (not measured) and assigned a flow category. If surface flow was present (FC ≥ S) the width and depth of the stream was measured, as well as the temperature and the electric conductivity of the water (detailed measurements in Appendix C).

Table 1: Flow categories and approximate corresponding discharge and rank

Flow Category	Abbreviation	Rank	Description
Dry	D	1	Dry streambed
Wet streambed	WSB	2	Saturated soil, no standing water
Standing	S	3	Standing water, no flow
Weakly trickling	WT	4	Flow < 1 l/min
Trickling	T	5	Flow 1-2 l/min
Weakly flowing	WF	6	Flow 2-5 l/min
Flowing	F	7	Flow >5 l/min

If the streambed was at least saturated (FC ≥ WSB), the stream was surveyed for amphipod presence. Following the procedure recommended by Alther (2018), these measurements were conducted using a square net of 15x20 cm and a mesh size of 2 mm. The net was placed on the channel bed and the substrate was churned by hand. Amphipods present in the benthic zone would consequently be swept into the net, which was emptied into a flat white dish, so that the individuals could be counted. Their number was assigned into one of four groups: 0, 1-10, 11-100, >100.

Measurements were taken at each measurement point at least three times within one meter from each other, to account for small scale variability in amphipod presence (Sánchez-Montoya et al. 2018). The three measurements aimed to include the different substrate compositions at the measurement points (e.g. leaf litter, gravel, mud). For the data analyses only the highest class per location was used.

2.2. Data Analyses

2.2.1. Precipitation Data

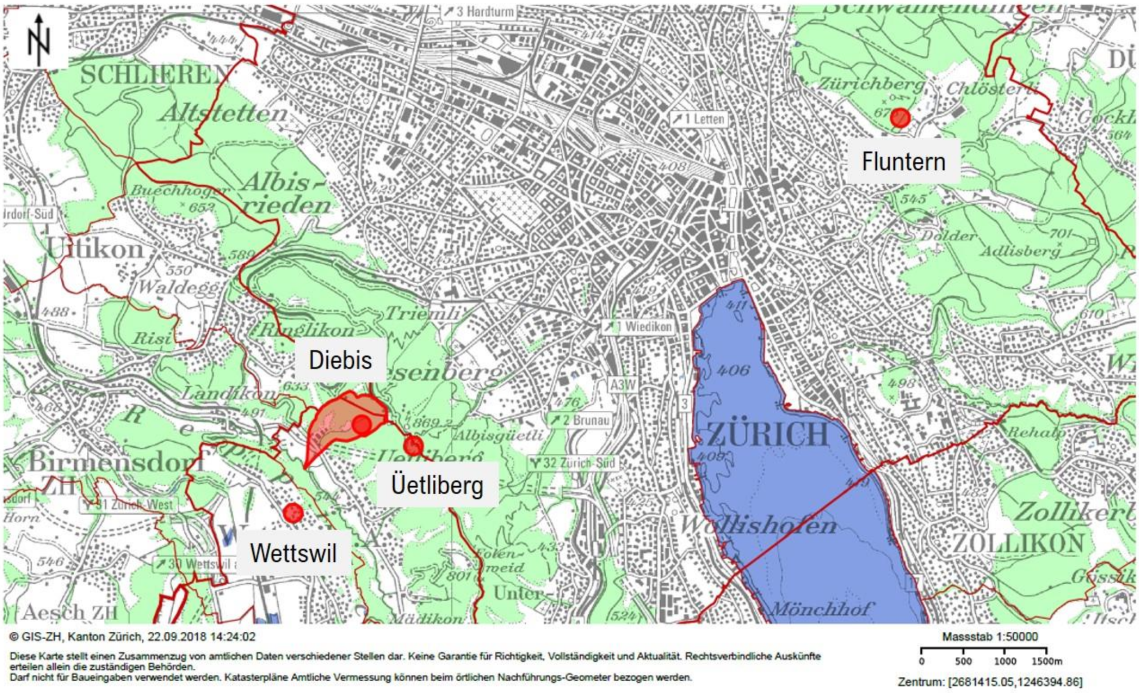

Figure 10: Sites of the precipitation measurement stations (red circles) and the location of the catchment (red outline) (based on map.geo.admin.ch)[5]

The three weather stations around the catchment (Fluntern, Üetliberg, Wettswil; Figure 10) measured precipitation at hourly intervals and a tipping bucket rain gauge (Diebis; Figure 10) registered every 2mm of precipitation. The four datasets provided data for different time periods. For Fluntern data was available for the entire study period. The Wettswil dataset started on 19.06.2018. The Üetliberg station data was available from 14.08.2018 onwards but has a two-week gap in December. The rain gauge within the catchment, near Diebis, was installed on 26.07.2018 and didn't record data after 07.12.2018.

As none of the data sets are normally distributed, I used Spearman's Rho to determine whether the Wettswil dataset was representative for the area. The results are presented in Table 2.

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[5] https://s.geo.admin.ch/8193575e9f - accessed, 28.04.2019

Table 2: Correlations between the hourly and the daily precipitation measurements of the different weather stations around the Diebis catchment. The p-value was 2.2e-16 for all of them

Stations	r_s hour	r_s day	Slope day
Diebis-Fluntern		0.865	1.181
Diebis-Wettswil		0.827	0.958
Fluntern-Wettswil	0.603	0.836	0.901
Uetliberg-Wettswil	0.421	0.793	0.484
Uetliberg-Fluntern	0.394	0.773	0.433
Uetliberg-Diebis		0.714	0.335

The daily precipitation at Wettswil was strongly correlated to the precipitation data at all the other stations (Table 2) For the hourly values, the correlations to the Üetliberg station were only medium to strong. The slopes of the linear correlations between the stations Diebis, Fluntern and Wettswil were always close to one, so none of them significantly over- or underestimate the rainfall. The slope for the relation with Üetliberg station was around 0.5, meaning that it constantly measured less rainfall. This may be due to its higher elevation. Overall the precipitation data of the Wettswil station is deemed representative and was used exclusively for further analysis as it is complete and closer to the catchment than the Fluntern dataset.

As a measure of the catchment wetness, the antecedent precipitation was calculated using the formula suggested by Ali et al., (2010):

$$\sum_{t=-1}^{-i} P_t k^{-t}$$

Where *i* is the number of antecedent days, ***P*** the rainfall during day *t* and *k* a decay constant. The k-value is dependent on evaporation, air temperature, vapor pressure deficiency and dewpoint. It usually varies with the seasonality of the weather (Kohler and Linsley, 1951). Kohler & Linsley (1951) found that for the eastern and central parts of the USA the k-value ranged from 0.85 to 0.9. Ali et al. (2010) proposed a value between 0.8 to 0.98. It was decided to use a k-value of 0.85, as the Diebis catchment is in the moderate climate zone, like the eastern USA and the value lies within both proposed ranges for k. The lower value was chosen, because during a large portion of my measurement period the catchment was very dry.

2.2.2. Water Level Data

The Keller-logger measured the water pressure around 5 m downstream from the lowest measurement point (MP50) at 5 min intervals (with a weeklong gap in November). To obtain the correct water level, the air pressure measurements was subtracted from the water pressure. The pressure during a measurement from when the stream was dry was determined and the difference from the measured value to 0 was subtracted from all other measurements. I calculated the hourly mean of the resulting pressure values and used the following equation derived from the Keller-logger manual, to determine the water level: $h = \frac{p}{\rho * g}$ where p = hydrostatic pressure, g = gravitational acceleration (9.80665 m/s^2), and ρ = water density (998.207 kg/m^3) (Keller AG, 2015).

The Keller-logger was installed on the 20.08.2018. I used the water level that was manually measured at MP50 on each field-day for the period before the logger was installed and for the gap in November. To account for systematic divergence of the two measures due to small scale variability of the streambed and the distance between the Keller-logger and MP 50 (ca. 5 m), I calculated the mean deviation between the Keller-logger's daily mean and the water level measured on the field-days after the 20.08.2018. This deviation was then added to the manual measurements. A possible discrepancy, due to the measurement time of the manual values (which was usually between 9 am and 11 am) and the daily mean calculated from the Keller-logger, was also avoided with this adjustment.

2.2.3. Visualization of the Field Data

The stream network data was mapped by Rick Assendelft. Because hydrological data on temporary waterways is still scarce, several alternative strategies to correctly record and map intermittent and ephemeral streams are being implemented, including flow modelling, remote sensing and citizen science (Stubbington et al., 2018). Using a digital elevation model (DEM), the geomorphology of a catchment can be mapped, and the streambed channels can be deduced (Rodriguez-Iturbe et al., 2009). Rick Assendelft used a DEM to create a map of the topographic wetness index for the Diebis catchment. This index is used to determine the topographic influence on hydrological processes and to identify hydrological flow paths (Beven and Kirkby, 1979). The catchment was then surveyed based on the resulting map to determine the location of all streams. The measurement locations for amphipod sampling were marked in the field and their positions were recorded by GPS. Later, the points were imported into ArcMap as a separate layer. Small scale displacements of the measurement point file in relation to the channel network were edited by hand.

A map, displaying the state of the catchment on that day, was created in ArcMap for every field day (Appendix B). Each channel segment was assigned a numeric value corresponding to the flow category listed on the corresponding measuring date (1 = D to 7 = F).

For the amphipod surveys, classes were assigned to each measurement point. Their numeric values used for the maps were follows:

0 = no amphipods and FC = D
1 = no amphipods and FC ≥ WSB
2 = 1–10 individuals
3 = 11–100 individuals

The class >100 amphipods never occurred, so it was omitted from the maps.

Additionally, an overview map of the overall stream state of the catchment was created based on the most frequent flow category for each stream segment.

To summarize the amphipod movement over space and time, the measurement points were assigned to the categories: “absence”, “presence”, “fluctuation” and “disappearance”. The class “disappearance” consists of the points that hosted amphipods in the beginning of the study period and then experienced an extinction of the entire amphipod population with no subsequent recolonization. The class “fluctuations” includes all measurement points that experienced one or more recolonization events. This was visualized on an additional map.

The data displayed in the maps for each day, was additionally summarized into heatmaps for amphipod distribution and flow categories to provide an overview of the stream state and amphipod abundance over time. For the amphipod distribution, four heatmaps were created (one for each stream that contained amphipods on at least one measurement day). The west stream was omitted from the amphipod-heatmaps, as amphipods were not observed at any of the locations throughout the whole data collection period. All streams are included in the heatmaps regarding the flow categories. From the resulting maps and the two sets of heatmaps, information about the presence and abundance of amphipods over time in relation to streamflow could be deduced.

2.2.4.Recolonization Speed

Each time amphipods were observed on a location and they had not been documented during the previous field day, it was noted as a migration event with arrival time (t_1). As departure time (t_0) the date of arrival at the neighboring measurement location was listed. The distance between the measurement locations (d) was determined in ArcMap. The minimal speed (in m/day) for each new colonization was then calculated using $\frac{t_1 - t_0}{d}$. A distinction was made between upstream-travel speed (USS) and downstream-travel speed (DSS) in the further analysis. In cases, where the location of origin might have been upstream or downstream, both possibilities were considered in the calculations. For locations 50a, 49a and 34a which were established mid-way through the field season and supported amphipods during their first measurement (on the 03.10.18 (50a), the

28.11.18 (49a) and the 31.10.18 (34a)), the first wet period after the last known dry period at each location (on the 22.08.18 (50a), the 17.10.18 (49a), and the 22.08.18 (34a)) respectively) was used as t_0. For locations 49 and 32 the first measurement day counted as t_0 as there was no way to establish for how long the amphipods had been absent before that day.

To find out which flow categories were limiting the amphipod dispersal, I used the lowest flow category (FC) per segment between a point of origin and the recolonized MP, derived on the wetter field day (either t_0 or t_1).

2.2.5.Statistical Analysis

Presence of Amphipods and flow category

To relate amphipod abundance and surface water, the number of measurement locations with flow and the number of locations without flow were added for each date and compared with the number of locations with amphipods. The correlation was determined using Spearman's rank correlation. To determine if the flow category WSB influences the presence of the amphipods negatively, the correlation test was done twice: once adding WSB to "no flow" and once by including it as a "flow" category.

Recolonization speed and limiting flow category

To determine the average speed of the amphipods all calculated recolonization speeds were merged into classes of 5 m/day and the frequency per speed-class was counted.

To investigate a relationship between the speed of the amphipod dispersal and the limiting flow categories the two variables were plotted against each other. Each flow category was assigned a rank from 1 = D to 7 = F. As the data was not normally distributed, the correlation was tested using Spearman's rank correlation. The correlation between speed and the limiting flow category was tested for both the upstream and downstream travel speed separately, and independently from the direction of travel. To investigate the influence of the first recolonization at MP5, which might have been an error (the reasons will be discussed later), the correlation was also visualized excluding this measurement. In the further calculations it was included, as it cannot be conclusively verified as an error. The difference between the two slopes of the upstream and the downstream correlation, was further investigated using Fisher's z-transformation. This test is intended for Pearson correlation coefficients but can also be used for Spearman's rank correlation. The result is more robust, if Spearman's rank correlation is treated as a Pearson correlation coefficient, than if it is converted to Pearson equivalents prior to transformation (Myers and Sirois, 2006).

Changes in Flow Categories

To visualize the changes in FC over time, each FC was assigned a rank from D = 1 to F = 7. For each location and measuring day the change in FC was marked as the difference to the rank of the last measurement. This was plotted as a boxplot. Locations that were dry throughout the entire data collection period were not considered in the plot, as they are not of interest to the reaction of the changes in FC. The heatmaps served to visualize the spatial development of the flow over time.

3. Results

3.1.Precipitation and Flow Data

The average precipitation remained relatively low and consistent throughout the whole period, with an increase of around 2 mm/d towards the end of the study period. However, the dry phases became shorter later in the study period. The water level at MP50 followed the precipitation until the 27th of October, when the stream no longer dried out between events (the cumulative precipitation was 190 mm between the 19.06.18 and the 26.10.18). After that, the water level still responded to the precipitation, but no longer dropped to zero (Figure 11, top).

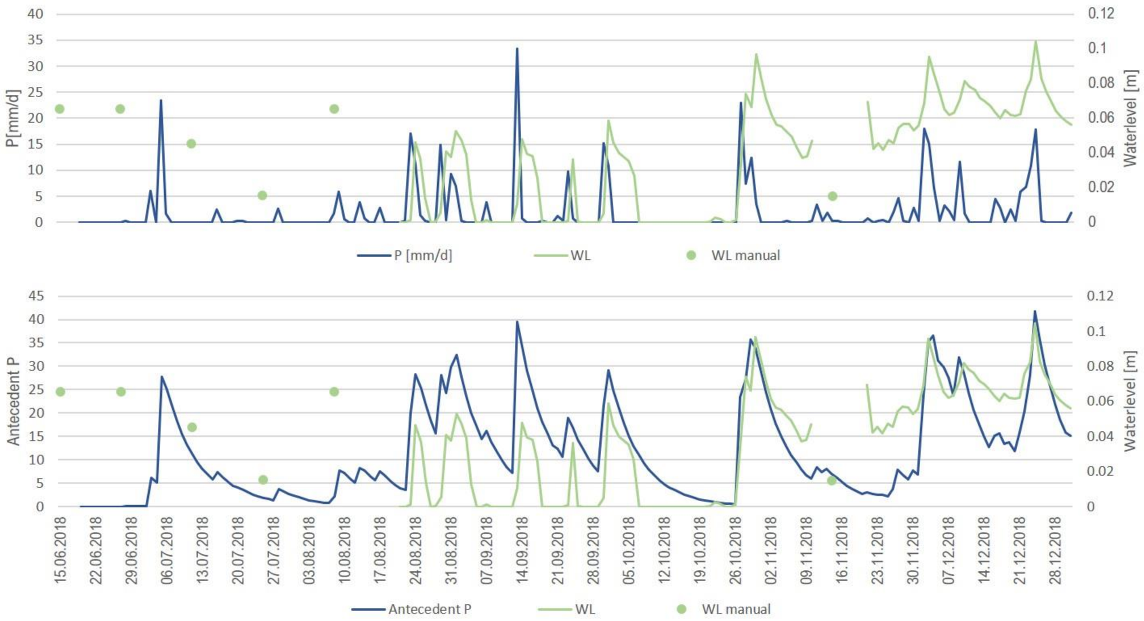

Figure 11: Top: daily precipitation and water level at measurement point MP50, bottom: antecedent precipitation (k = 0.85) and water level at the measurement point MP50

During the summer months, the antecedent precipitation overestimated the catchment wetness compared to the stream level, while in late fall it underestimated the water level (Figure 11, bottom). This suggests that the stream did not only respond to the recent precipitation but also to long term changes in evapotranspiration and precipitation and associated changes in groundwater levels. In order to use the antecedent precipitation as a proxy of water level, the k-value would need to be adjusted over time. This was not attempted, because the measured water level at MP50 provided a good estimate of the catchment's wetness.

After a strong decrease in flow between the first and the second measurement, the catchment remained dry until the late fall, with the flow category changing only for a few measurement points.

Often, there was an increase in flow in one location and a similar decrease in another, reflecting some uncertainties in the assignment of the flow category (single points in both increase and decrease direction in Figure 12). For times with extreme conditions however, such as the drying out between the first two measurements or the large precipitation event on the 03.12.2018, clear changes can be discerned. Although the boxplot is quite stretched, showing that the amount of increase per measurement point diverged largely, not one point experienced a decrease in flow (Figure 12).

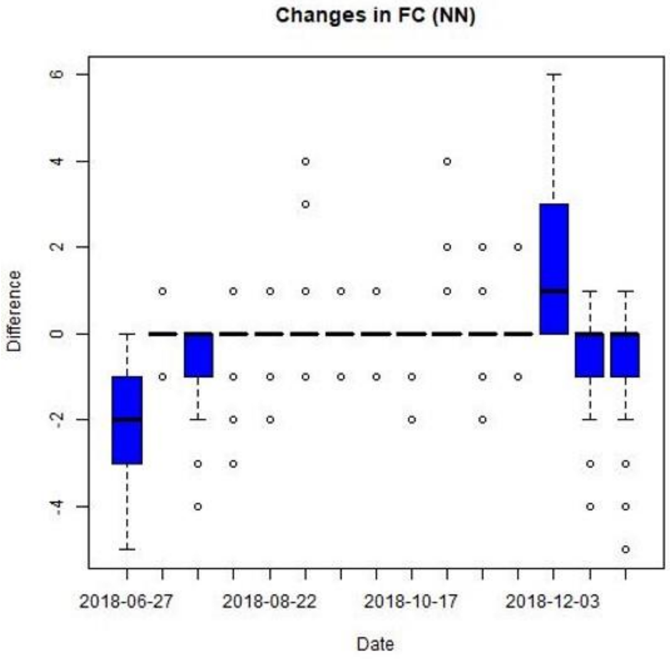

Figure 12: Box plots of the change in flow category compared to the flow category on the previous measurement. The plots represent how many of the 50 measuring points experienced an increase or a decrease in the flow category.

The temporal variation of flow follows the expected pattern of a decrease in summer and an increase in fall (Figure 13). At the time of the first measurement, on the 15th of June 75 % of the study-stream length contained surface water (FC ≥ WSB). This percentage declined rapidly to the minimum of only 10.7 % on the 8th of August. After a slight rewetting, the percentage of moist or flowing stream length varied between 20 % to around 40 % until the end of November, when a longer and more extensive rewetting period started. The maximum for the fall period was reached on the 3rd of December when 68 % of the stream channel was wet (Figure 13). The measurement period continued until the 19th of December where after another slight decrease in flow to exactly 50 %.

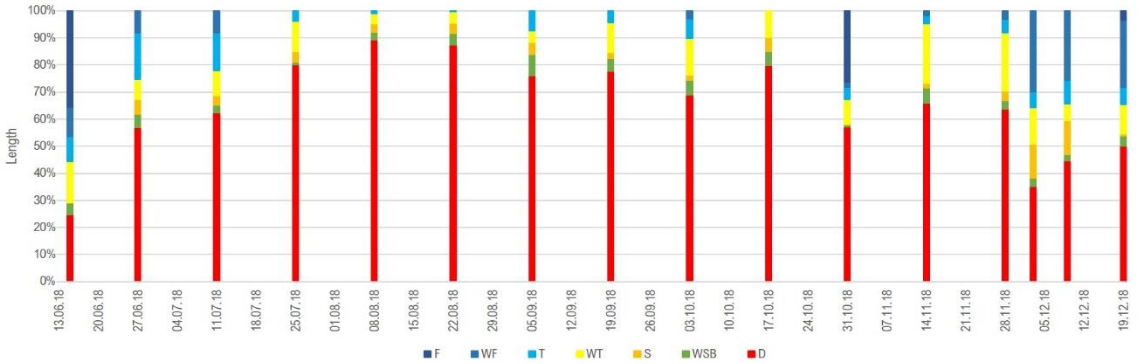

Figure 13: Percentage of the total study-stream length per flow category

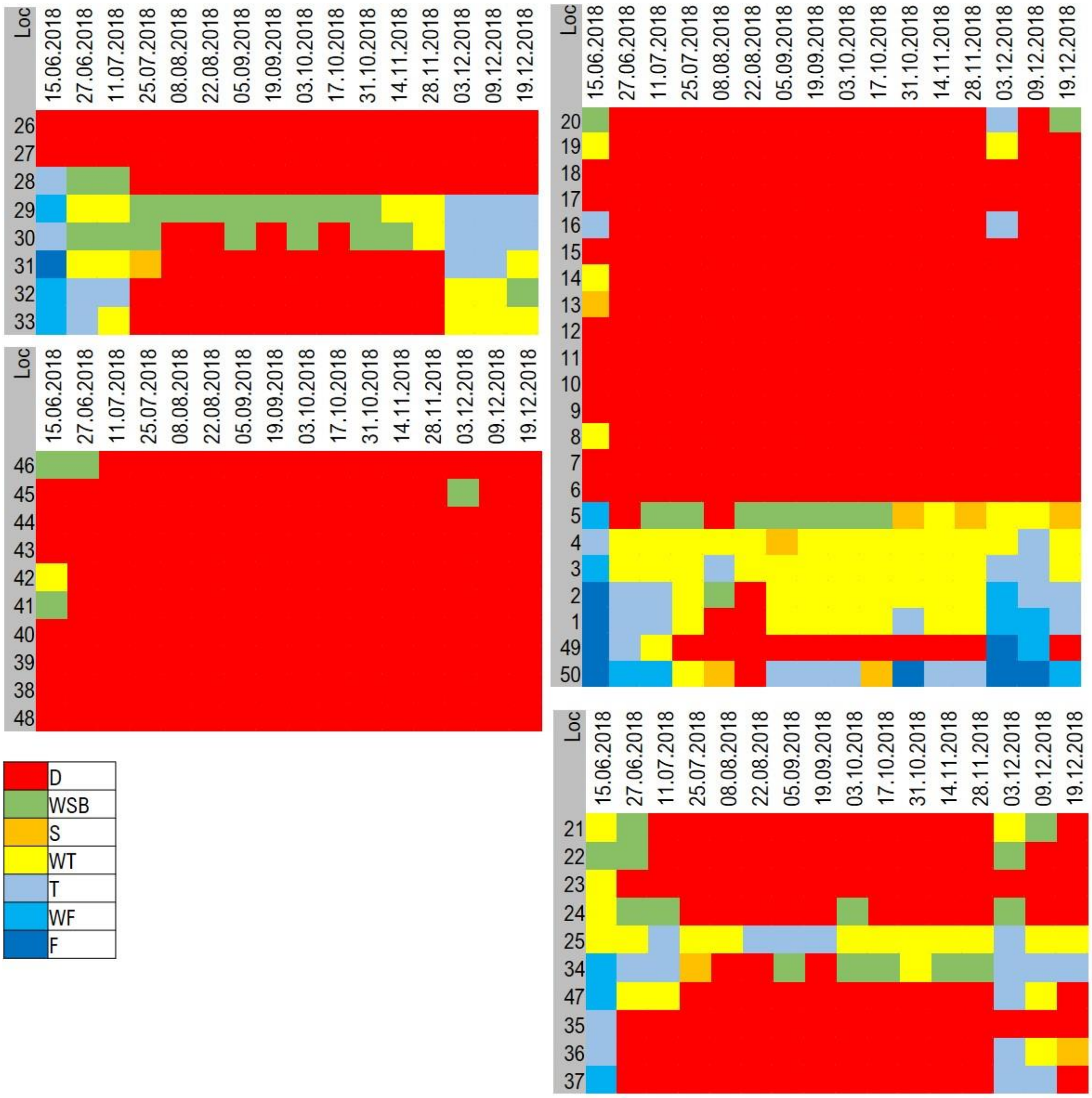

Figure 14: Heatmaps of the spatial and temporal variation of the flow categories at all measurement points. Top-left: mid-east stream, top-right: east stream, bottom-left: west stream, bottom right: mid-west stream

To investigate the spatial patterns of the flow conditions, the maps for each measurement day (Appendix B) and the heatmaps that display the variation of flow categories over time (Figure 14) need to be consulted. They reveal that especially in the upper parts of the catchment, most measurement points were dry throughout the entire study period. Only four points never experienced a dry phase. It is also evident, that the catchment first dried out in the upper region, while the flow declined later in the lower regions (MP50–MP4). Thereafter, flow started to increase from there. Exceptions are MP25 and MP29 that are located in the higher regions of the catchment below local springs or seeps, from where flow could expand downstream in fall.

3.2. Amphipod Occurrence and Flow Data

The number of points with Amphipod was strongly correlated with the number of measurement points with surface water (Figure 15). The correlation was higher when the flow category WSB is counted to the surface water categories ($r_s = 0.83$, p-value = 7.6e-05) than when it is counted as dry ($r_s = 0.783$, p-value = 0.0003).

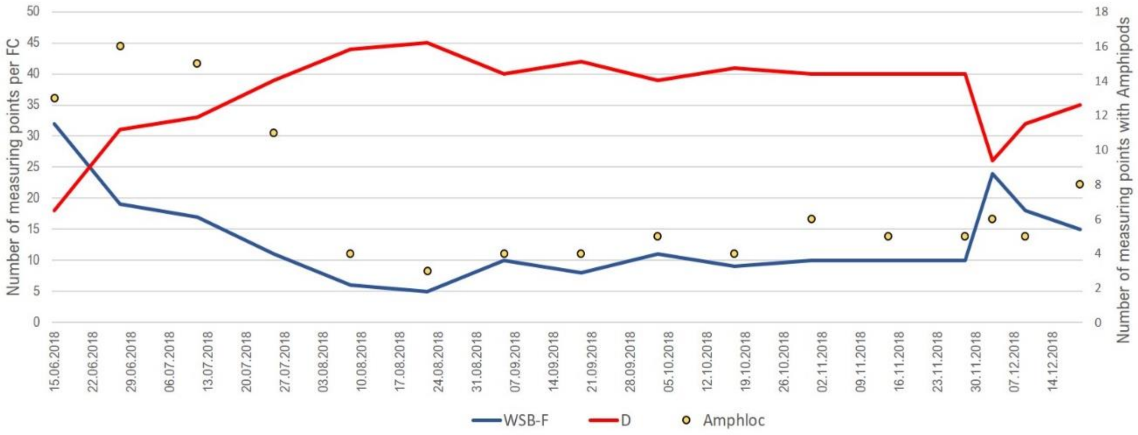

Figure 15: Time series of the number of measurement points with flow (FC ≥ WSB) and no flow (FC = D) (linearly interpolated between surveys), and the number of measurement points with amphipods (dots)

Amphipods were found in five locations with a wet streambed (at a total of ten measurements). The longest possible period for which they remained at a wet streambed location was 56 days (i.e., for three consecutive measurements at MP30). In all cases, except for MP29, the stream subsequently fell dry resulting in an extinction of the local amphipod population. In MP29, the population died out after two consecutive measurements, despite the continuous presence of saturated soil (derived from the comparison of Figure 14 and Figure 16).

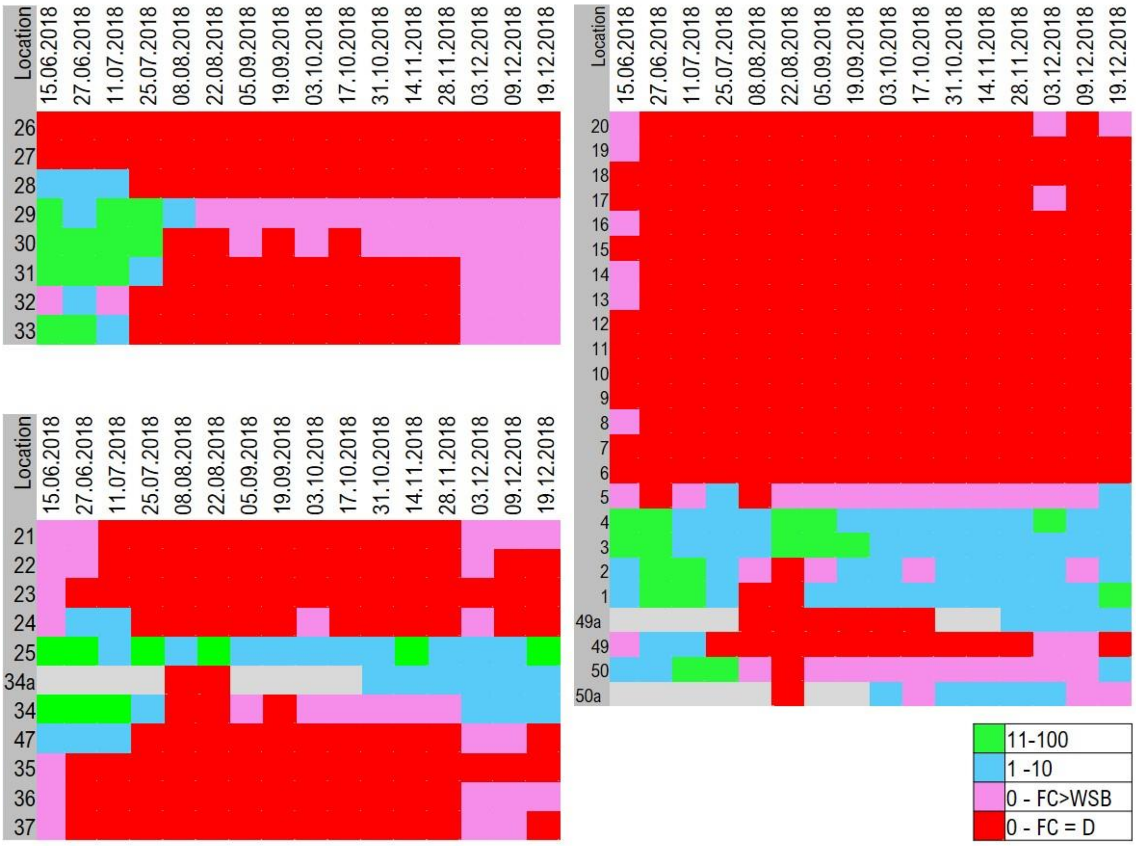

Figure 16: Heatmaps of the spatial and temporal variation in the occurrence of amphipods at al measurement points. Top-left: mid-east stream, right: east stream, bottom-left: mid-west stream

The correlation between flow and amphipod presence is also visible on the maps that were created during the fieldwork (Appendix B), and the summary maps of flow (Figure 17) and amphipod movement (Figure 18). The first displays the most frequent flow category per stream segment, and the second displays the movement of the amphipods. In all locations, except the ones marked "presence" (marked in green in Figure 18) the amphipods disappeared at some point during the study period. These locations represent the refuge spots in which local populations were able to outlast the summer drought. It is clear, that a large part of the study-streams was dry during most measurement days (marked red in Figure 17), which emphasizes the importance of such refuges.

The three locations with weakly trickling WT as the most frequent flow category (MP3, MP4, MP25) (yellow in Figure 17) are located beneath three springs or seeps (Figure 8). Amphipods were found at these measurement points throughout the entire study period. They thus functioned as refuges from where the recolonization began in late fall. A fourth location of origin was situated in the lower part of the westernmost stream that was not part of the study streams. It is most likely, that MP50a and sequentially MP50 were recolonized from there.

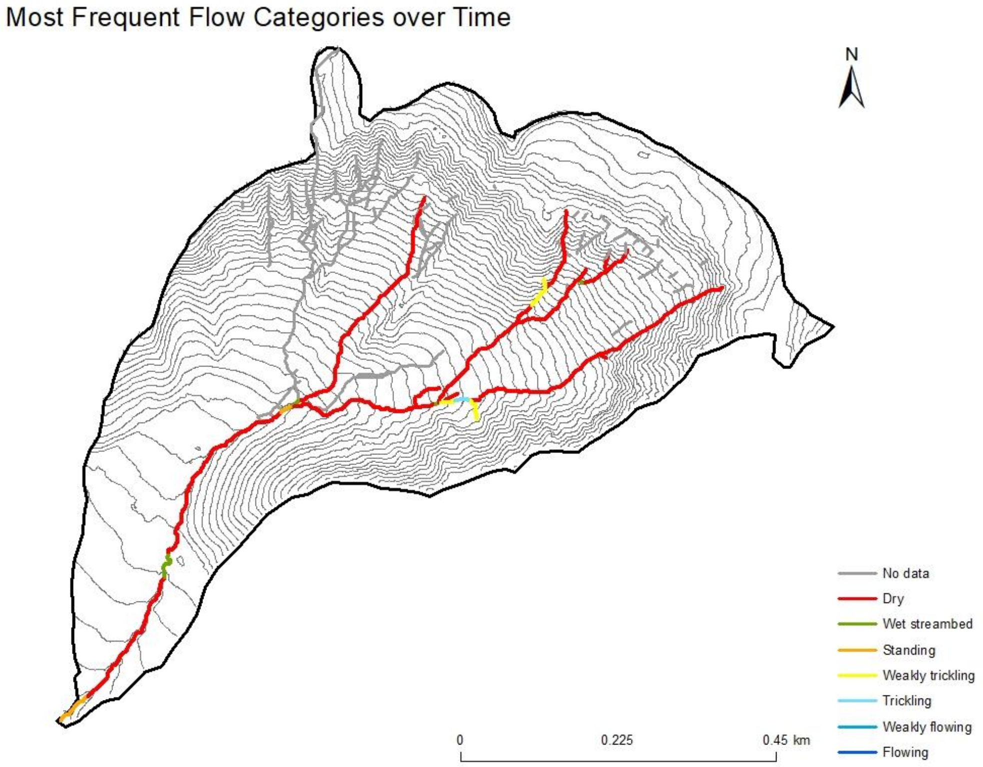

Figure 17: Map of the Diebis catchment displaying the most frequently measured flow category per stream segment

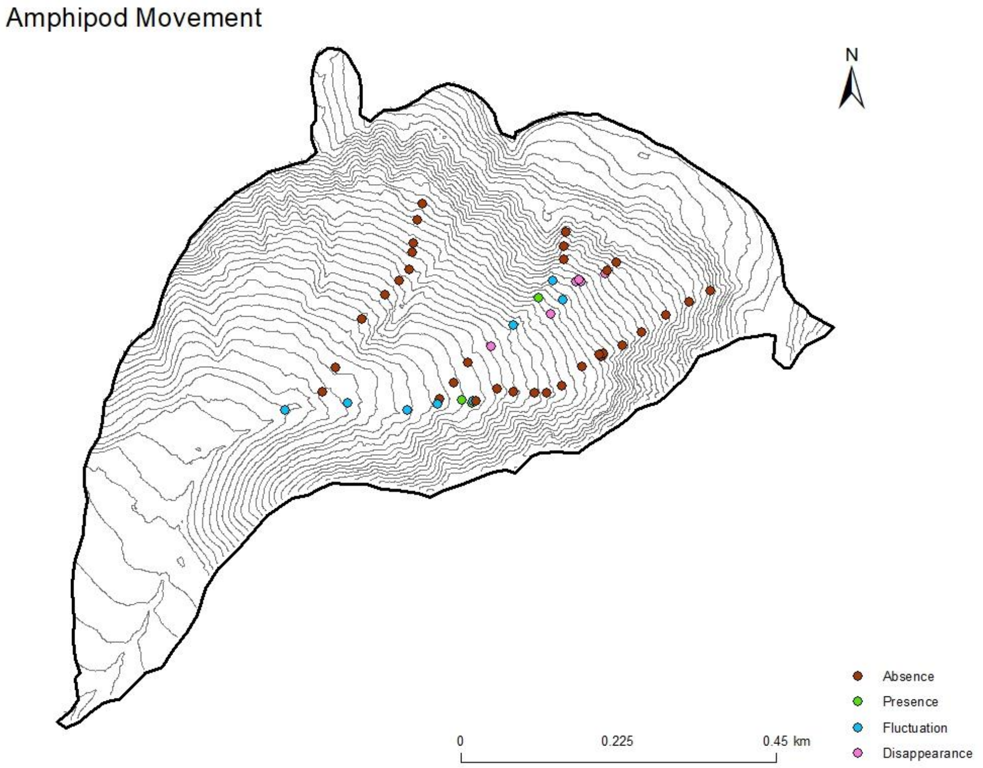

Figure 18: Map of the Diebis catchment displaying the class of amphipod occurrence per measurement point

Except for MP29, all other locations were dry for at least one measurement (Figure 14). In MP29, the amphipods died out despite the continued presence of surface water. This location was situated below a large step in the channel where subsurface water re-emerged. The most frequent flow category there was wet streambed “WSB”. On the third consecutive measurement of this flow category amphipods were no longer present. They thus survived in the wet streambed for at least 14 days and were no longer present after 28 days of verified WSB. Considering the two-week gap between the last measurement of WT and the first of WSB, the maximum time they might have survived at MP29 in a wet streambed is 42 days. Amphipods survived in a wet streambed in four other locations; In MP30, they were verified on three consecutive measuring dates, resulting in a maximum survival time of 56 days and a minimum survival time of 28 days, and in MP24 and MP28 they were present in a wet streambed on two consecutive measurements and in MP5 on one, after which all three of these locations dried out completely.

3.3. Amphipod Speed and its Relation to Flow

The travel or recolonization-speed of the amphipods ranged from 0.4–14.0 m/d for downstream-travel and from 0.2–15.3 m/d for upstream-travel. The speed data is not normally distributed (p-value of 0.023 for the Shapiro test). The most common speed category for downstream-travel was 1–5 m/day and for upstream-travel 5–10 m/day (Figure 19). The overall average speed was 5.1 m/day (6.2 m/d for upstream-travel and 4.4 m/day for downstream-travel).

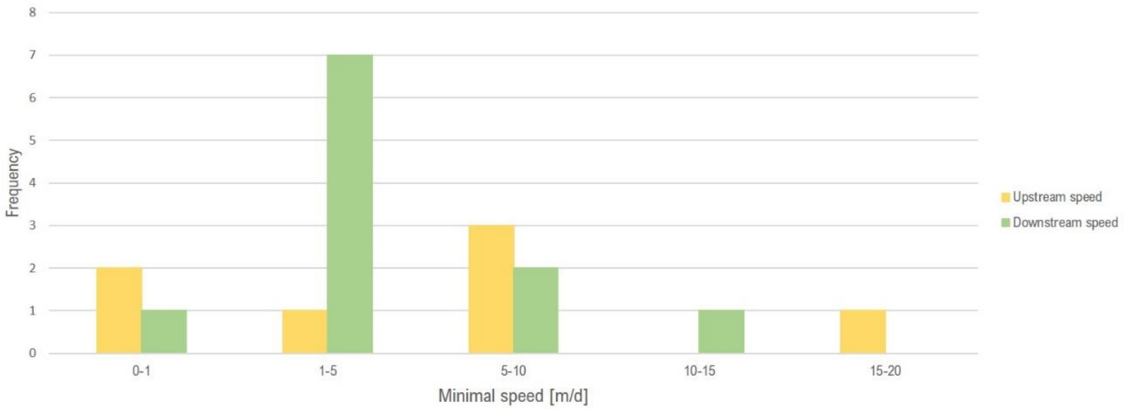

Figure 19: Number of times a recolonization occurred per speed category. Recolonizations for which the location of origin might have been upstream or downstream are considered in both categories

To find a possible link between the amphipods travel velocity and the flow category, the two variables were plotted against each other (Figure 20).

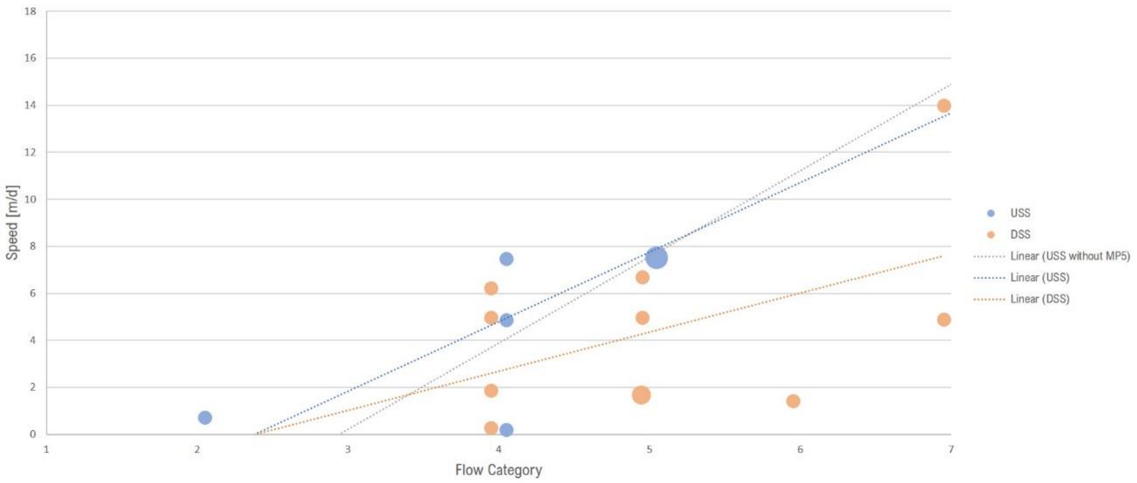

Figure 20: Velocity of each recolonization event in relation to the limiting flow category (1 = D, 7 = F) that had to be traversed. Recolonizations for which the location of origin might have been upstream or downstream are considered in both categories. The bigger points represent 2 (orange) or 3 (blue) events under the same conditions. The grey line displays the correlation without the consideration of the MP5 migration (blue point in class 2), as it might have been an error.

The lowest limiting flow category measured during a recolonization event was WSB. It was only measured once, and the stream segment with FC = WSB was only about 1 m long before rising to WT. The correlation is therefore also displayed without the consideration of this event (grey line in Figure 20). It is included in the general analysis, as it cannot be conclusively verified as an error and because the correlation is significant in both cases ($r_s = 0.82$, p-value = 0.045 without MP5).

The Spearman rank correlation between flow category and colonization speed was $r_s = 0.45$ (p-value = 0.062). When considering only the upstream-travel speed, the correlation is stronger ($r_s = 0.82$) and the significance higher (p-value = 0.025). In contrast, the correlation for downstream-travel time is poor and not significant ($r_s = 0.15$; p-value = 0.653). The slope of the correlations between speed and flow category did not differ significantly for upstream and downstream travel, regarding Fisher's z (p = 0.106, confidence interval 0.05).

4. Discussion

4.1. Flow Patterns and Precipitation

How did the flow vary spatially and temporally?

Two processes of catchment drying could be observed. Both disintegration and downstream contraction, as described by Bhamjee & Lindsay (2011), occurred during the first half of the study period. Disintegration was most visible in the two mid-streams, where in both channels the dry patches expanded and merged from above and from below. Downstream contraction could be observed in the east-stream, as the whole upper area went dry on the second measurement date. The aquatic reaches in the west-stream were already severely disintegrated during the first measurement, with surface water remaining at only three locations, and the remainder of the stream drying out rapidly in the following weeks (Figure 14).

The maximum effect of the drought on the flowing stream network was reached on the 8th of August, with 89 % of the channel length of the study streams being dry. Afterwards, the dry periods between the precipitation events became shorter over time. The average temperature decreased from around 25° C in June to around 5° C in December (measurements at the weather station in Wettswil). This presumably resulted in a higher vapor pressure, which in turn led to lower evapotranspiration rates. A lasting rewetting of the catchment did not start until December. Before December, short-term increases in surface water extent could be observed on three measurement dates, but they were followed by renewed drying (Figure 21, middle). This pattern corresponds to an ephemeral flow regime, where flow may occur as a direct reaction to a precipitation event, but is constantly lost to the groundwater and ceases, after the precipitation ends (Mcdonough et al., 2011).

Only four measurement points had surface water throughout the entire study period. MP3, MP4, MP25 and MP29. All these measurement points were located below these local source areas (Figure 14 and Figure 8). These flowing stretches expanded, as the precipitation increased, and coalescence of wet and flowing stream segments could be observed. It is the result of saturation of small-scale low points in the channel bed that expand upstream and downstream with the rising water table (Bhamjee and Lindsay, 2011). This expansion could be observed best in the mid-east-stream, from MP29 and MP30 to MP31 and to the lower areas, as well as from MP25 downstream. In the eastern stream, flowing areas coalesced from MP3. For MP49 it is not clear if the flow was a result of coalescence from upstream or the saturation of the soil expanding from downstream (Figure 14).

No long-term downstream expansion could be observed. For this expansion pattern to be the norm, low infiltration capacities of the soil or heavy precipitation events are required (Peirce and Lindsay, 2015). As roots in general enhance the infiltration capacity of soil (Lange et al., 2009), and the main landcover type in the upper region of the Diebis catchment was forest, a low infiltration capacity is unlikely. Also, downstream expansion mainly occurs during precipitation events and most measurements were taken between events. During the precipitation event on the 3rd of December, a short-term downward expansion was observed at MP20 and MP21 (Figure 14). It had no lasting effect, as flow didn't expand further than one measurement point and these points fell dry in the following weeks. These patterns also advocate an ephemeral flow regime.

How was the variation in flow linked to the precipitation?

This observation coincides with the precipitation data and the data of the water level logger at MP50, that showed an increase and decrease in water level in response to precipitation events. The water level declined to zero (no water left in the stream) after each increase during summer, but surface water remained in the stream from the 27th of October onwards. The water level still responded to precipitation events, but the streambed no longer dried out (Figure 21, top and bottom). This turning point is assumed to represent the time that the groundwater table rose above the streambed at MP50.

The antecedent precipitation overestimates the wetness in summer and underestimates it in fall, as the k-value remains constant over time (Figure 21, left and right). Thus, it doesn’t consider the changing atmospheric conditions.

Another explanation for the discrepancy between the antecedent precipitation graph and the water level is that the Keller-logger was installed at the lowest measurement point, whereas the antecedent precipitation considers the whole catchment. The rewetting in fall was clearer for the lower part of the catchment, whereas the upper regions of the catchment remained dry for much longer (Figure 14). In some cases, they remained dry until the end of the study period. This indicates a rewetting pattern of headward expansion, where, with the water level rising, the lower parts of the catchment are saturated first and the flow expands upwards (Bhamjee and Lindsay, 2011). On the whole, the flow in the lower parts of the catchment can be considered to mainly be controlled by an intermittent flow regime, whereas in the upper regions an ephemeral regime was predominant throughout the study period.

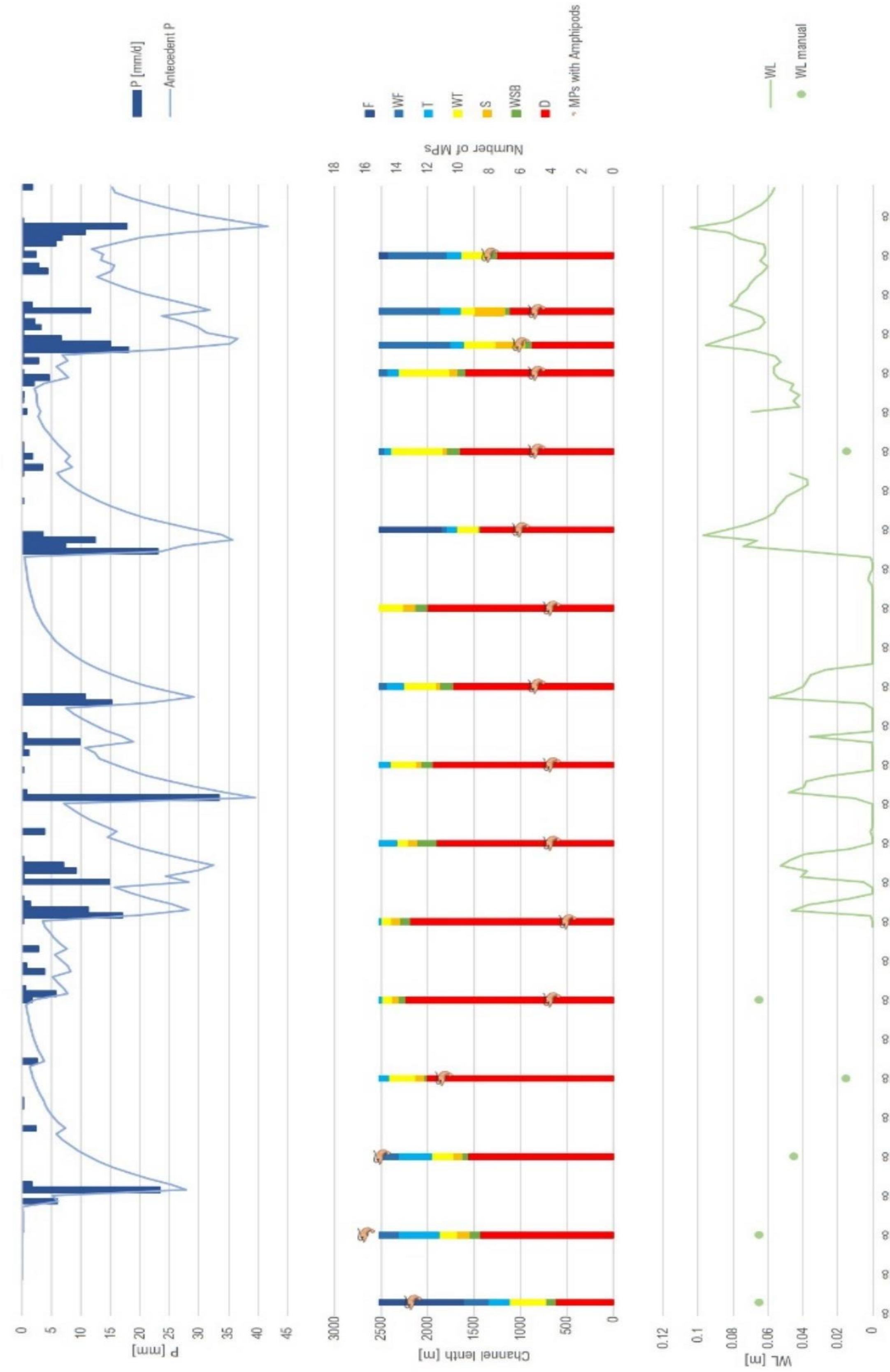

Figure 21: Left: daily precipitation and antecedent precipitation, middle: km of study-stream length per flow category and number of locations with amphipods, right: water level at measurement point MP50

4.2. Abundance of Amphipods and Flow

What was the relation between flow and the occurrence of amphipods?

Only four measurement points contained surface water throughout the entire study period. In three of these locations (MP3, MP4 and MP25) amphipods were able to survive the dry period (Figure 16). There was a very strong correlation between the presence of surface water and the presence and abundance of amphipods (Figure 21, middle and Figure 15), with a Spearman's rank correlation coefficient r_s of 0.83 (p-value = 7.598e-05 when the flow category wet streambed (WSB) was counted as flow as well (if it was counted as dry r_s = 0.78, p-value = 0.0003). This result indicates that in the absence of standing water, amphipods can survive in a wet streambed. *Gammarus fossarum* found refuge in the moist substratum at five locations (MP5, MP24, MP28, MP29 and MP30). In MP5, they were only sampled on one measuring day (this measurement must be treated with caution, as discussed later on). At the other locations they could be observed in a wet streambed on two consecutive dates. However, all these locations (except for MP29) dried out entirely in the following weeks, resulting in the extinction of the local populations (Figure 14 and Figure 16). In MP29, the local population died out despite the presence of at least a wet streambed throughout the entire study period. For this reason, MP29 is particularly interesting, with regards to the maximum time of survival of *Gammarus fossarum* in a wet streambed. It is conceivable that the individuals resorted to the strategy of immersing themselves into the moist soil, because all measurement points around MP29 were dry (Figure 14). Thus, they had no possibility of following a retracting waterline. The most frequent flow category recorded at MP29 was wet streambed. This category was recorded on eight consecutive measurement dates, which adds up to ~ 98 days of wet streambed (Figure 14) (short term changes could not be considered due to the measurement frequency of two weeks). The presence of *Gammarus fossarum* could be verified during the first two measurements where the flow category was wet streambed (Figure 16). Individuals were able to survive for a minimum of 14 days and a maximum of 42 days in the moist sediment. In MP30, the maximum time of survival was 56 days, and the population persevered for at least 28 days in the moist soil.

These findings are consistent with the literature. *Gammarus fossarum* are known to migrate horizontally, following the retracting water line, but have also been observed to immerse themselves in the moist substratum as a survival strategy (Poznańska et al., 2013). The time-span of survival in saturated subsurface soil, that was measured in this study, is in agreement with the 21-day survival period determined for *Gammarus Pulex* (Vadher et al., 2018), though the maximum time of survival that was observed for *Gammarus fossarum,* is longer. The *Gammarus pulex* are morphologically and ecologically similar to *Gammarus fossarum* (Jażdżewski, 1977), and may coexist in the same locations. Therefore a similar behavior may be expected for both species

(Poznańska et al., 2013). However, in the experiment conducted by Vadher et al. (2018), 21 days was the maximum period that their individuals were exposed to a lack of streamflow. If the assumption made by Poznańska et al. (2013), that the persistence of the *Gammarus fossarum* is similar to *Gammarus pulex,* is correct, it may be assumed that *Gammarus pulex* can last for a longer period of a lack of standing water than tested by Vadher et al. (2018). Further research needs to be conducted to determine conclusively for how long the two species can last in saturated soil during a dry spell.

In MP1, the substratum was completely dry on two consecutive measurement dates. On the third date, 28 days later, amphipods were found despite their absence from adjacent measurement points, both upstream and downstream (Figure 16). From then on, until the end of the study period, they could always be verified at MP1. This suggests subsurface survival despite the complete desiccation of the streambed surface. With the available data however, it is not possible to say if they really did survive the dry period in subsurface sediments, as their presence in the dry soil was not verified. The depth to which amphipods may migrate horizontally depends largely on the sediment grain size (Vadher et al., 2015). This decreases with depth, making it more difficult for individuals, especially of a larger size, to reach the saturated soil with a lowering groundwater table (Clifford, 1965). The bed material at MP1 site consisted of dense mud. In the region of this measurement point, the soil is registered as gley (maps.zh.ch)[6], which is a very fine grained soil (USDA and NRCS, 2010). The depth of the saturated zone and the exact soil properties were not determined in the field. It is possible, that the individuals were able to immerge themselves to hyporheic sediments to survive the dry spell. Because Gleysol is a soil that tends to get waterlogged due to its small grain sizes (maps.zh.ch), this property might have resulted in the inclusion of water below the surface during the dry period in the case of MP1. However, it is also possible that they migrated downstream from MP3. They might have been overlooked at MP2 or not been present at the exact measurement point due to the small-scale habitat variability of benthic macroinvertebrates (Sánchez-Montoya et al., 2018).

In MP50 the population vanished even though the flow category, that was recorded on the firs day without amphipods, was standing water (Figure 14 and Figure 16). The flow category standing water describes a series of disconnected pools. It is possible, that the individuals followed the retreating waterline during the disintegration of the flow, and retreated to another pool further upstream, rather than the one directly at MP50 (Poznańska et al., 2013). This theory is supported by the fact, that individuals were indeed found in a rock pool further upstream (MP50a), when it was sampled

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[6] https://maps.zh.ch/s/6dk6wyu1 - accessed 25.04.19

two months later. It is also possible that the amphipods vanished from the standing water because the water chemistry in disconnected pools can change severely (Larned et al., 2010). *Gammarus fossarum* prefer alkaline, nutrient poor waters with good oxygen conditions and a fast flow (Poznańska et al., 2013). It is conceivable, that these conditions were no longer present at MP50 once the location was disconnected from the flow, especially considering the relatively high temperature of 17.7 °C, which was determined on the first measurement without amphipods at MP50. The high temperature alone might have caused their disappearance, as *Gammarus fossarum* is affected negatively by too much warmth (Pinkster et al., 1992).

4.3. Amphipod Dispersal

The main survival strategy of *Gammarus fossarum* to survive the drying of the stream network during dry periods, is to migrate along the streambed with the retracting waterline, so that it can survive a in small pools or reaches with perennial water (Poznańska et al., 2013). They can also survive in a wet streambed for a limited time. From these refuges the organisms can recolonize the stream when flow resumes. This resilience strategy could be observed in my measurements. At three measurement points, the recorded flow categories were standing water or higher, throughout the entire study period. In all these locations amphipods were able to survive (Figure 18). To establish whether they followed the retracting waterline to their survival spots or consisted of the population that was already there in the beginning, we would need to analyze the populations over time. The recolonization from the refuges, unlike the retreat of the amphipods, could be observed. Especially the downstream recolonization from MP25 after the resumption of flow was clearly visible (Figure 16). From MP3 they were observed to migrate upstream.

To examine the dispersal behavior of the *Gammarus fossarum* more closely, the recolonization events were quantified. Each time amphipods were noted in a location where they were not present the previous week, this was listed as a recolonization event. In total, fourteen of these events could be counted. In case both upstream and downstream were realistic for the point of origin, both directions were considered, resulting in a sample size of eighteen. Despite the small sample size, the measurements were studied for different aspects.

What was the limiting flow category for amphipod migration?

The lowest flow category that the amphipods were able to traverse was wet streambed. However, this happened in only one case; from MP3 to MP5 (Figure 20). The two locations were very close to each other and only two different flow categories were observed for this stretch: WSB directly at MP5 and WT from around 1 m below MP5 and downward. The amphipods in this case didn't have to traverse the category WSB but enter it, to be counted in the measurement (a short-term flood between the previous measurement can be excluded, as only a total of 2.8 mm of precipitation were recorded in the 14 days between the measurements). This behavior is contradictory to what was found by Poznańska et al. (2013), as the amphipods in the Diebisbach did not only neglect to follow the waterline, but moved away from it. It thus needs to be considered, that the amphipods found at MP5 on the 25.07.2018 might have been due to an error in the measurement (e.g. amphipods still caught in the net from the last location). For all other recolonizations the lowest flow category that was traversed was weakly trickling.

What was the speed of the amphipods dispersal and how was it linked to the flow?

The average speed of the amphipod movement determined in this study was around 5 m/day (Figure 19), with the upstream travel being slightly faster than downstream travel. Downstream travel is usually the result of amphipods caught in drift and being swept down. Upstream travel is also considered a transient event but results from an active upstream movement of the amphipods. When the flow is too strong and amphipods need to leave sheltered areas during upstream migration, it may happen that they are caught in the drift and are carried downward (Statzner and Bittner, 1983).

There was a slight positive correlation between speed and the flow category (Figure 20) (statistically significant at a confidence interval of 10 %). When distinguishing between upstream travel and downstream travel, there was a strong correlation between the flow category and speed for upstream travel and no correlation for downstream travel. Yet, based on Fisher's z-transformation the difference between the two slopes was not statistically significant. It makes sense to look at the two directions separately as the mechanisms for the dispersal of *Gammarus fossarum* are different. Upstream travel is an active migration, with individuals moving in sheltered pathways of low flow. The downstream dispersal occurs when amphipods are detached from the substratum as a result of high flow in unsheltered locations and are swept downwards (Statzner and Bittner, 1983). Accordingly, the correlation between speed and flow category was initially expected to be higher for downstream travel, as a higher flow category results in stronger currents. This assumption was also supported by Elliott (2002), who found a positive correlation between water velocity and drift. An explanation for the lack of such a correlation in my data could be that the category flowing started at 5 l/min and includes all higher flows as well (Table 1). *Gammarus fossarum* are adapted to live in waters with fast flow (Poznańska et al., 2013). It is thus possible that the individuals can withstand a lot more flow before the current influences their dispersal, than what was experienced during the measurements. There is no data available on the absolute maximum discharge along the channels in the catchment as flow data was exclusively collected in the ordinal categories described in Table 1. However, the very dry conditions and lack of very high flows, suggests that velocities were likely low throughout the entire study period.

Another explanation for this inconsistency is the small size of the sample. With eighteen data points it is audacious to make a general statement about the relation between speed and the limiting flow condition. However, a trend towards a positive correlation for both directions is visible in Figure 20. To verify it, further research with more recolonization events will need to be conducted.

In this study measurements were taken every second week. As starting time for each migration event, the arrival of the amphipods at a neighboring location was registered. The velocity calculated from this data implies a permanent and steady migration of all individuals over the study period. The resulting speed thus only reflects the minimum possible time for the recolonization. If the colonization occurs in waves, as suggested by Statzner and Bittner (1983), the speed with which each colonization event occurs might be much faster. On the other hand, the method with which the velocity was determined in this thesis also takes the amount of time amphipods spend in one location into account (although this amount of time was not quantified separately). To determine how long it will take for individuals to arrive at a certain location upstream, the speed of their actual movement would lead to an underestimation of the time required for recolonization, as the pauses between migration waves need to be considered. For water management purposes, such as the use of amphipods for ecotoxicological investigations, the overall time required for amphipods to reach a location is more important that the actual speed of their movement. This justifies the definition of velocity that was used in this study.

For further field studies, it would be advisable to additionally consider water quality, as this might be a reason why amphipods don’t migrate to a certain location (Eisenring et al., 2016; Feckler et al., 2012). In the case of MP5 for example, the second recolonization took 77 days, starting from the day the location had rewetted, despite the short distance to MP3 (Figure 9). The mean EC of 683 µS/cm was above the average of all measurement points (544 µS/cm). However, it was not the highest measurement throughout the catchment. This was measured at MP4 (989 µS/cm), a location that served as a shelter for amphipods throughout the entire measuring period. MP5 still was considered to have an inferior water quality than the rest of the catchment due to a slight smell of compost (personal observation). If these assessments were true, the late recolonization of the amphipods might be due to the improved water quality as a result of higher flow. This suspicion cannot be verified as the EC was the only measure regarding water chemistry that was taken in this study.

Another location to be observed more closely is MP50. The amphipods vanished when the flow category was still standing water, and despite flow resuming in the beginning of September, the first amphipods only arrived on the last measuring day (19th of December) (Figure 14 and Figure 16). Amphipods were found at a location ~15 m upstream (MP50a) on the 3rd of October. Due to the abundance of amphipods at MP50 in the beginning of the study period, and the high flow category in fall, the aspect of poor water quality as a factor for the late recolonization, is considered to be improbable. Downstream migration by *Gammarus fossarum* is usually a result of amphipods caught in drift due to high flow in unsheltered locations (Statzner and Bittner, 1983). It is thus possible, that the individuals found upstream were in a location that was sheltered, so no individuals were swept away. This coincides with my observations of MP50a, which was as rather deep rock pool filled with leaf litter.

4.4. Discussion of Possible Errors

As mentioned in the discussion of the migration of amphipods from MP3 to MP5, some errors might have occurred during the fieldwork. Amphipods are small and inconspicuous. Especially when they are not moving, they can be easily overlooked. The equipment was checked between each measurement point for stray amphipods that might had gotten caught in the net and had not been set free after counting them. Yet, it might still be possible, that this caused the "first recolonization" at MP5 on the 25.07.18. In case of doubt, additional measurements were taken at the same location to verify the presence of the amphipods. In MP5 the wetted stretch was very short (~30 cm), and the width of the wetted channel only 20 cm. The only possibility to verify the measurement, was to sample three times at exactly the same location. The presence of amphipods could not be verified after the first measurement, which strengthens the suspicion that there might have been an error.

For the analysis of the amphipod migration, the small number of migration events strongly limits the inferences. The influence of a single point in such a small sample is very strong. For a sample size smaller than 30, it is ventured to make a general statement about the recolonization behavior of *Gammarus fossarum* (Ellis, 2010). We were able to observe trends, and calculate possible correlations, but they will need to be verified by further research.

For this study the biggest challenge was the extremely dry fall. The summer drought was welcome, as it enabled the observation of the drying patterns in temporary streams. In addition, the resilience strategy of the *Gammarus fossarum* to outlive drying of the streams could be verified, and the time that individuals can survive in a wet streambed could be quantified. At the end of the study period, however only 50 % of the stream length had rewetted (Figure 21, middle). All streams still contained isolated stretches of flow, none of them had surface water along the entire stream (Figure 14). The study period had to be terminated due to the limited time-span of the study and the arrival of snowfall in December. Considering that all but one migration event required a minimum flow category of weakly trickling WT, no further recolonizations would have been possible without an increase in the flow. At the end of the study period in December, *Gammarus fossarum* had recolonized all measurement points with a flow category of at least WT that were linked to one of their survival locations.

5. Conclusions

In this thesis the drying and rewetting patterns of an intermittent stream in Switzerland were analyzed and linked to the presence and abundance of the amphipod species *Gammarus fossarum.* The research focused on three research questions.

1. *During what conditions do temporary stream sections of a headwater stream dry out and rewet and how does this transition occur?*

The source of an intermittent stream is groundwater. Thus, it dries out when the groundwater table is lowered below the streambed, and rewets permanently when it rises again (Mcdonough et al., 2011). In this study two patterns of drying were observed: the disintegration of local points with flow and downstream contraction of the flow. The reversed pattern was observed during the rewetting of the catchment: both headwater expansion and coalescence occurred. During the dry period the streams maintained an ephemeral regime, with surface flow lasting only for a short period after a precipitation event. The more permanent rewetting likely began as the groundwater table rose to the surface in the lower part of the catchment at the end of November. The upper region maintained an ephemeral flow regime throughout the study period. The calculation of the antecedent precipitation shows, that the time-span between precipitation events is a significant factor for the rewetting of intermittent streams. If it is too long much of the groundwater-storage evaporates before the next rainfall.

2. *How is the presence and abundance of amphipods related to the presence of flow?*

The amphipod species *Gammarus fossarum* survives dry periods by taking refuge in perennial stream sections. This behavior was observed in this study. Amphipods survived in all three locations that had a flow category of at least "standing" water throughout the entire period. The correlation between the presence of surface water and the abundance of amphipods was very high and even higher if the flow category "wet streambed" was counted as surface water and not as dry.

Amphipods were able to survive for up to three consecutive measurements in the wet streambed at five locations. They could survive there for a maximum of 56 days. This is longer than the 21 days that the amphipod species *Gammarus pulex* are known to survive for in saturated sediments (Vadher et al., 2018). However, 21 days was the maximum duration *Gammarus pulex* were exposed to draught in the experiments of Vadher et al. (2018). The similarity of the two species suggests that the *Gammarus pulex* may also survive longer in moist sediment.

3. *What are the hydrological prerequisites for the recolonization by amphipods after a drying and rewetting event in a temporary?*

Migration of the amphipods was observed on 14 occasions. For all but one of these events the limiting flow category was at least "weakly trickling". For one case individuals migrated across a location with a wet streambed. As their typical behavior is to follow the retreating waterline (Vadher et al., 2018), rather than migrating away from it, this measurement must be considered a possible error.

In addition to the hydrological prerequisites for recolonization, the speed of the amphipod recolonization and its correlation to the limiting flow category was quantified. The mean speed was 5.1 m/day. There was a positive correlation between speed and the flow category but with a sample size of 18 (on some occasions upstream and downstream migration was considered), including one likely error, it is ventured to make a general statement about amphipod speed of dispersal. The trend visible in the data collected in this study needs to be verified by further research.

If the speed of the amphipods and its correlation to the amount of flow in a stream can be determined, it will enable accurate predictions of the time and place amphipod presence can be expected. This will in turn simplify examinations of ecotoxicology in intermittent streams and prevent false conclusion owing to the absence of amphipods.

Because amphipods contribute significantly to the biodiversity and the functioning of the ecosystem, their presence in a stream is desirable. This study will help to predict how fast amphipods may recolonize a temporary stream after a dry period.

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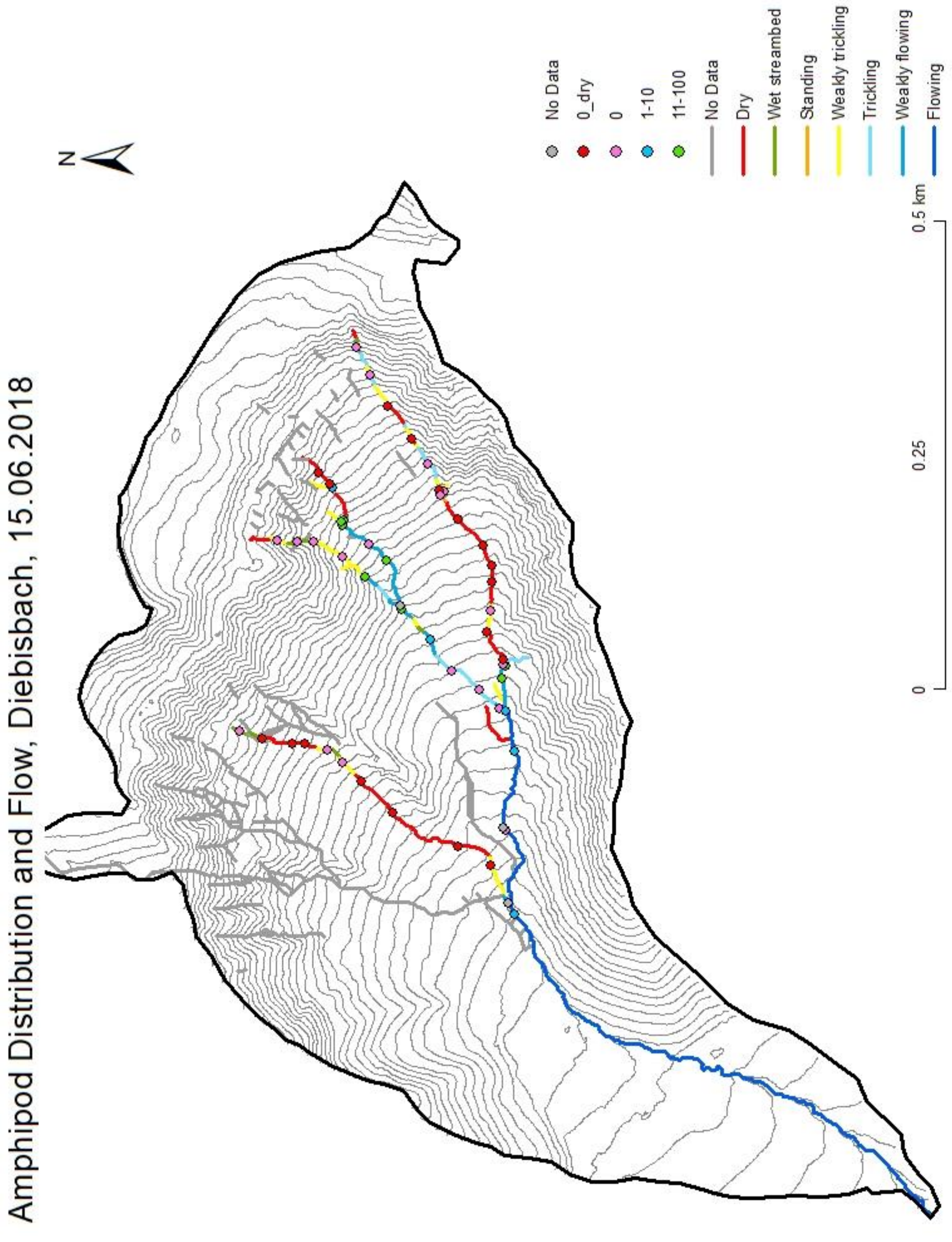
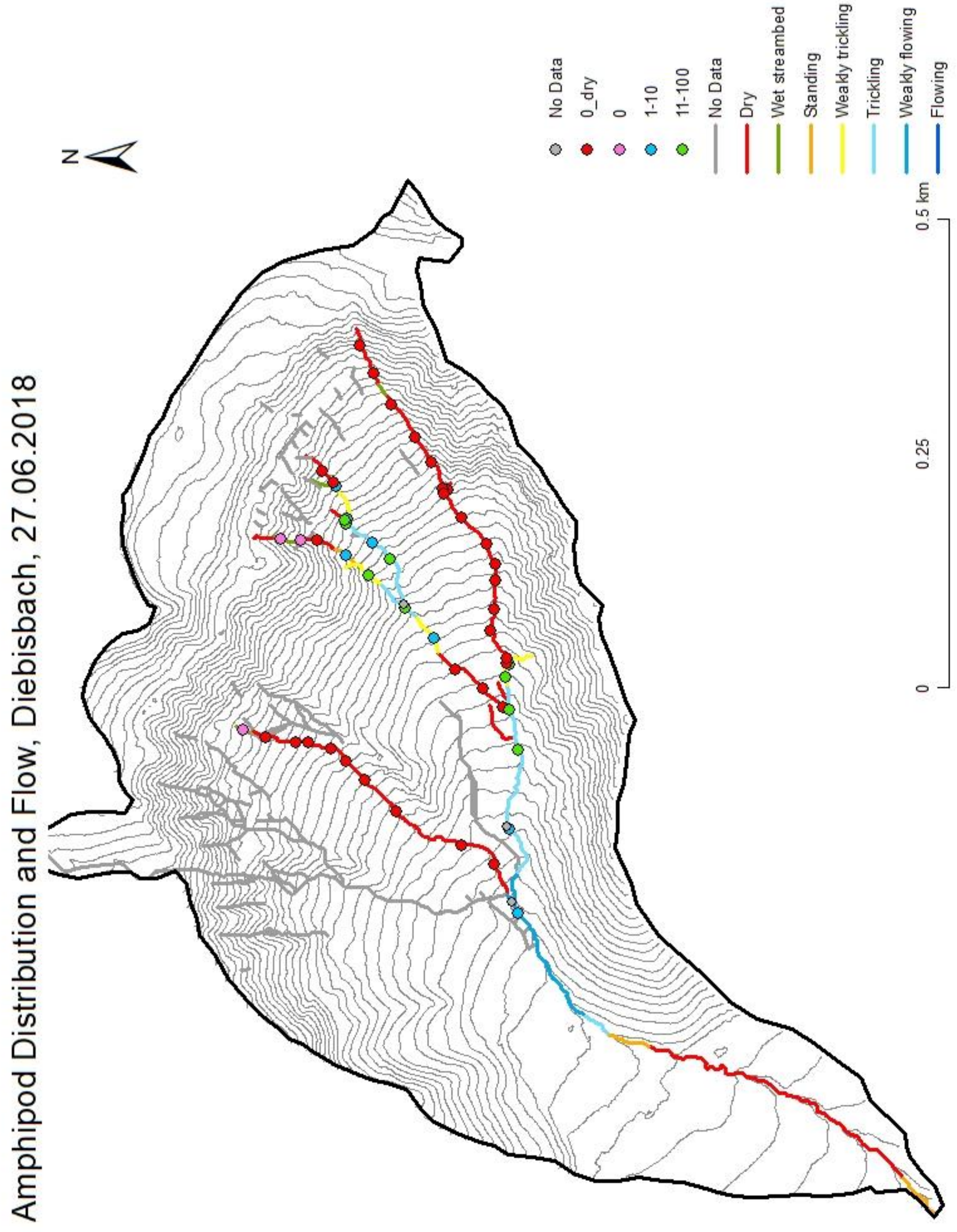
Appendix

A. Description of the Measurement Points

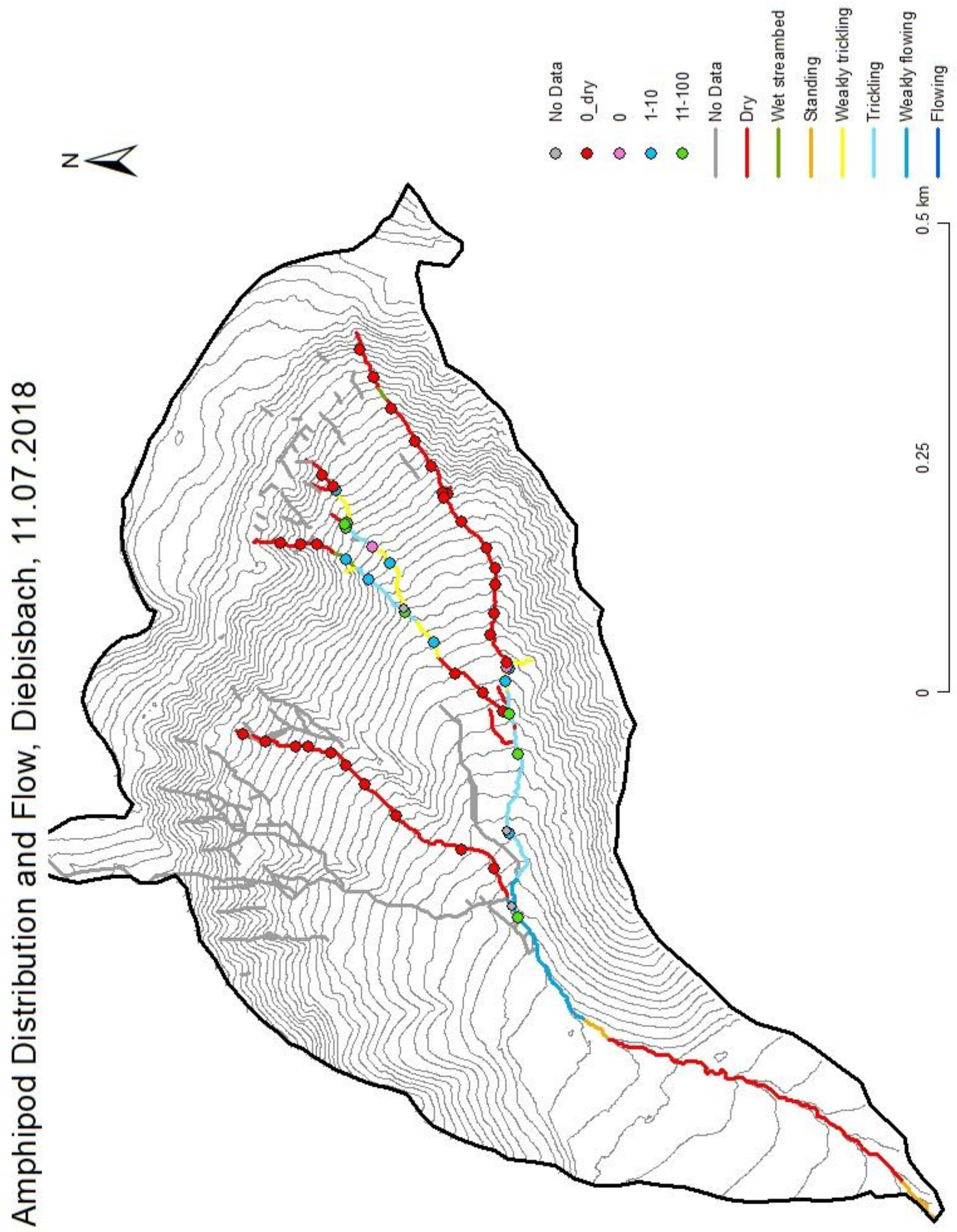
MP	Latitude	Longitude	Elevation [m a.s.l.]	Substrate
1	N47.35114	E008.48054	602.009	Kies, Schlamm, Blätter
2	N47.35115	E008.48115	611.567	Kies, Schlamm, Blätter
3	N47.35116	E008.48178	619.098	Schlamm, Blätter
4	N47.35162	E008.48176	621.451	Blätter, Schlamm, Kies
5	N47.35135	E008.48183	621.011	Kies, Blätter
6	N47.35120	E008.48191	622.586	Kies, Blätter
7	N47.35131	E008.48229	630.26	Kies, Blätter
8	N47.35132	E008.48266	636.172	Kies, Blätter
9	N47.35131	E008.48298	643.528	Blätter, Schlamm
10	N47.35137	E008.48327	652.523	Blätter, Schlamm
11	N47.35140	E008.48363	659.724	Kies, Holz, Blätter
12	N47.35172	E008.48394	672.828	Blätter, Schlamm, Steine
13	N47.35173	E008.48432	680.681	Blätter, Schlamm
14	N47.35173	E008.48450	682.101	Blätter, Steine
15	N47.35178	E008.48443	683.039	Blätter, Schlamm, Steine
16	N47.35193	E008.48459	695.748	Blätter, Schlamm, Kies
17	N47.35200	E008.48504	710.617	Blätter, Holz
18	N47.35223	E008.48557	729.84	Blätter, Steine
19	N47.35234	E008.48604	598.354	Holz, Betonkanal
20	N47.35249	E008.48624	747.631	Blätter, Schlamm
21	N47.35317	E008.48352	754.958	Blätter, Schlamm
22	N47.35295	E008.48361	728.249	Blätter, Kies
23	N47.35296	E008.48353	715.13	Blätter, Schlamm
24	N47.35256	E008.48316	707.011	Blätter, Schlamm
25	N47.35240	E008.48289	688.461	Blätter, Kies, Schlamm
26	N47.35279	E008.48419	672.393	Blätter, Schlamm
27	N47.35262	E008.48406	717.06	Blätter, Steine
28	N47.35269	E008.48380	707.885	Blätter, Kies
29	N47.35272	E008.48372	705.346	Blätter, Kies
30	N47.35268	E008.48364	696.597	Blätter, Kies
31	N4735255	E008.48362	696.84	Steine, Kies, Schlamm
32	N47.35237	E008.48330	695.344	Kies, Schlamm, Blätter
33	N47.35221	E008.48299	681.403	Kies, Schlamm, Blätter
34	N47.35215	E008.48251	671.78	Kies, Schlamm, Blätter
35	N47.35166	E008.48172	655.158	Schlamm, Kies
36	N47.35145	E008.48152	631.386	Schlamm (lehmig)
37	N47.35116	E008.48114	624.89	Schlamm, Blätter
38	N47.35161	E008.47928	611.537	Überwuchert
39	N47.35220	E008.47950	646.351	Steine, Blätter
40	N47.35251	E008.47997	612.959	Blätter, Steine
41	N47.35271	E008.48023	629.486	Blätter, Schlamm
42	N47.35275	E008.48047	641.319	Steine Schlamm
43	N47.35287	E008.48061	649.723	Blätter
44	N47.35299	E008.48061	656.763	Blätter, Steine
45	N47.35339	E008.48072	660.513	Blätter
46	N47.35361	E008.48084	673.334	Schlamm, Blätter, Holz
47	N47.35199	E008.48225	684.792	Kies, Blätter, Schlamm
48	N47.35196	E008.47929	607.217	Blätter, Schlamm
49	N47.35120	E008.47943	586.848	Kies, Blätter
50	N47.35131	E008.47848	567.2	Kies, Blätter

B. Field Maps


Amphipod Distribution and Flow, Diebisbach, 15.06.2018
N
0
0.25
0.5 km
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing



Amphipod Distribution and Flow, Diebisbach, 27.06.2018


Amphipod Distribution and Flow, Diebisbach, 11.07.2018
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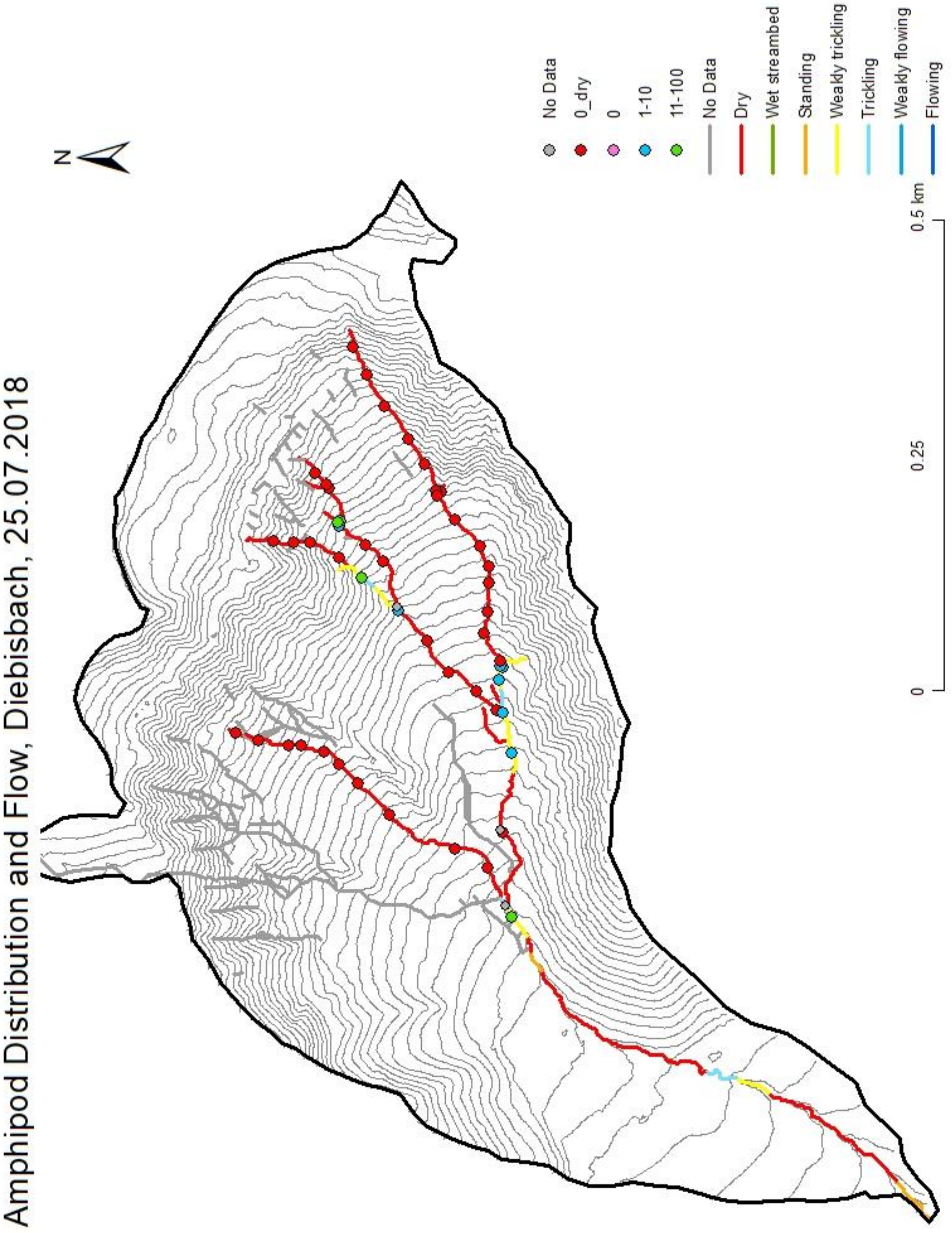
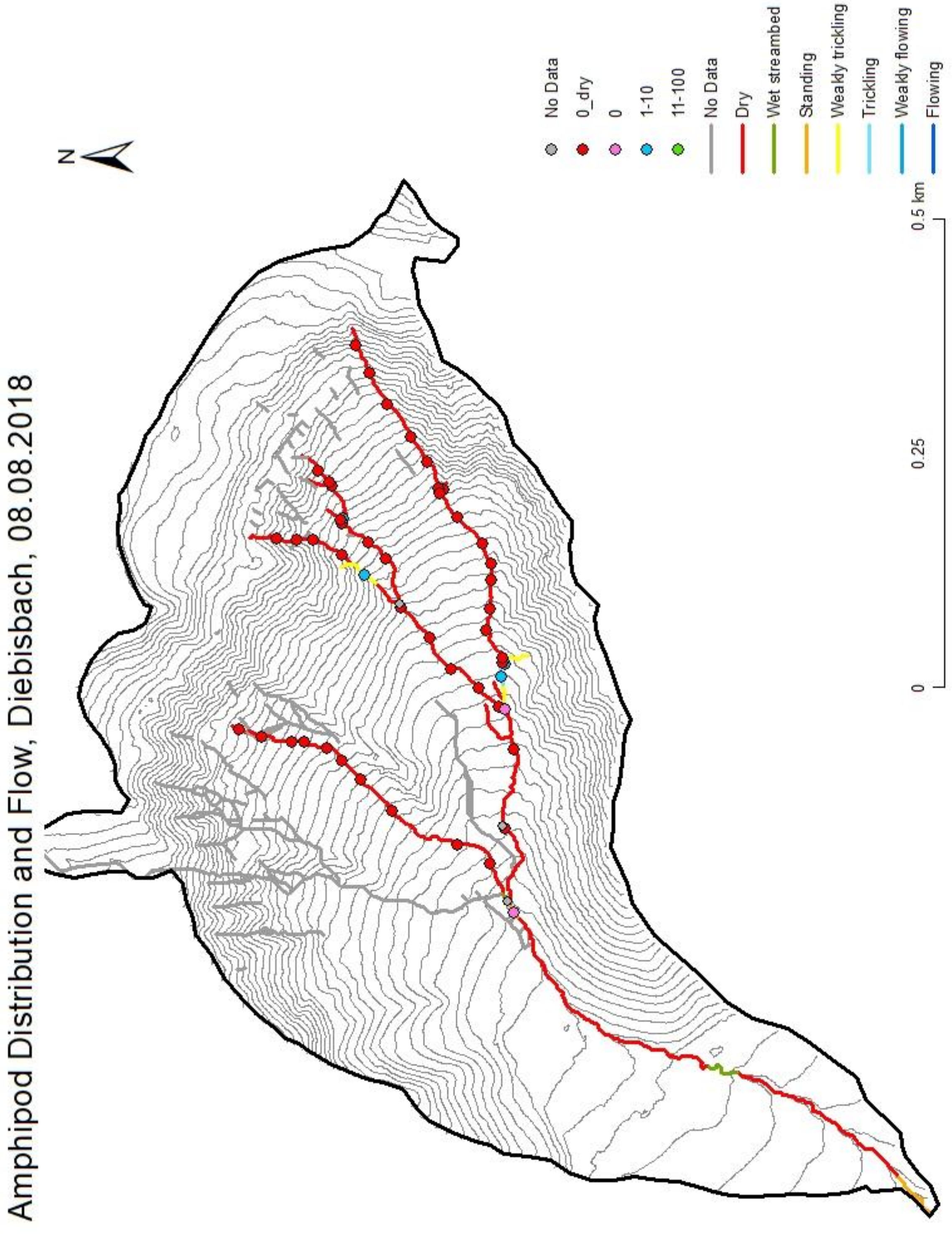
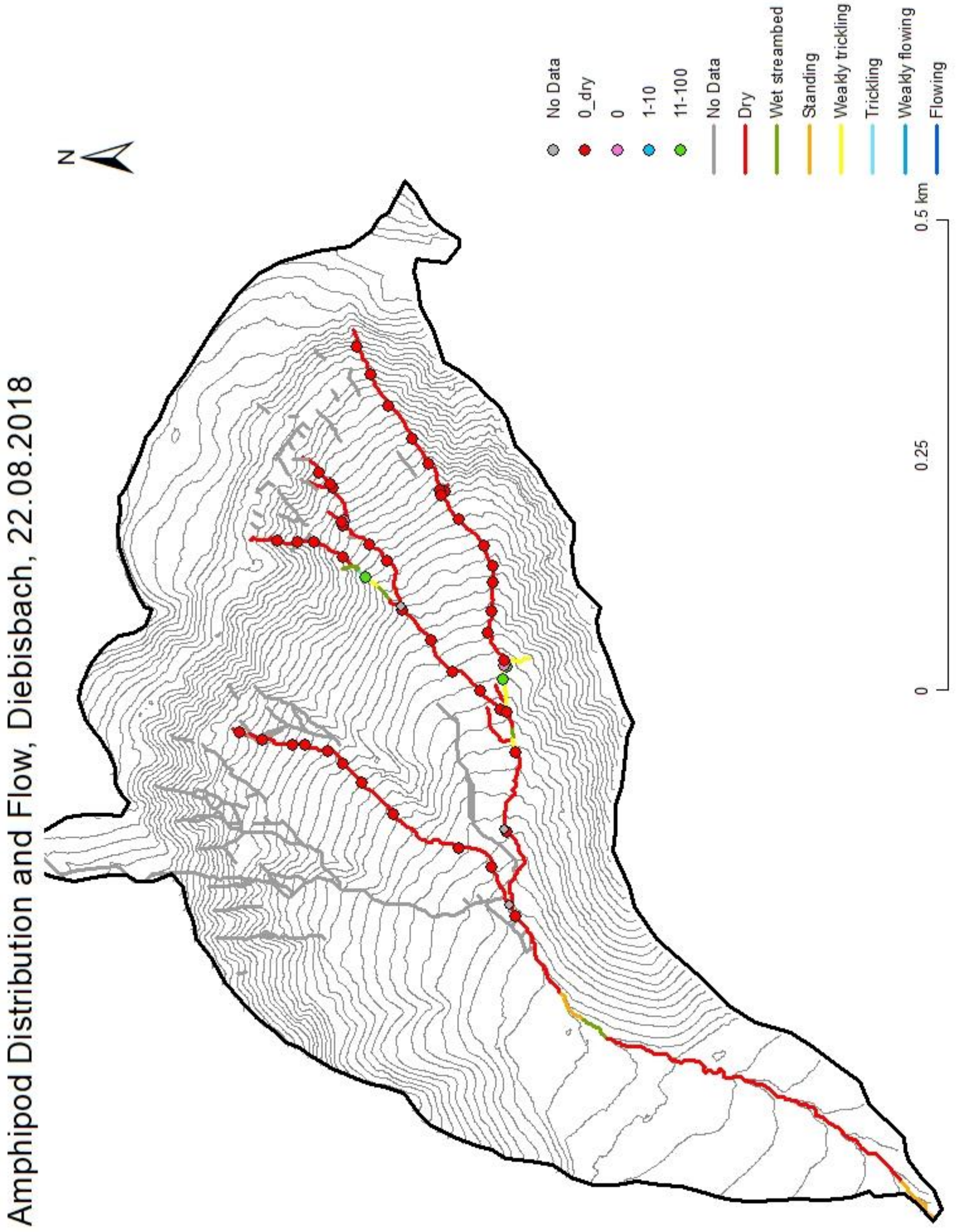
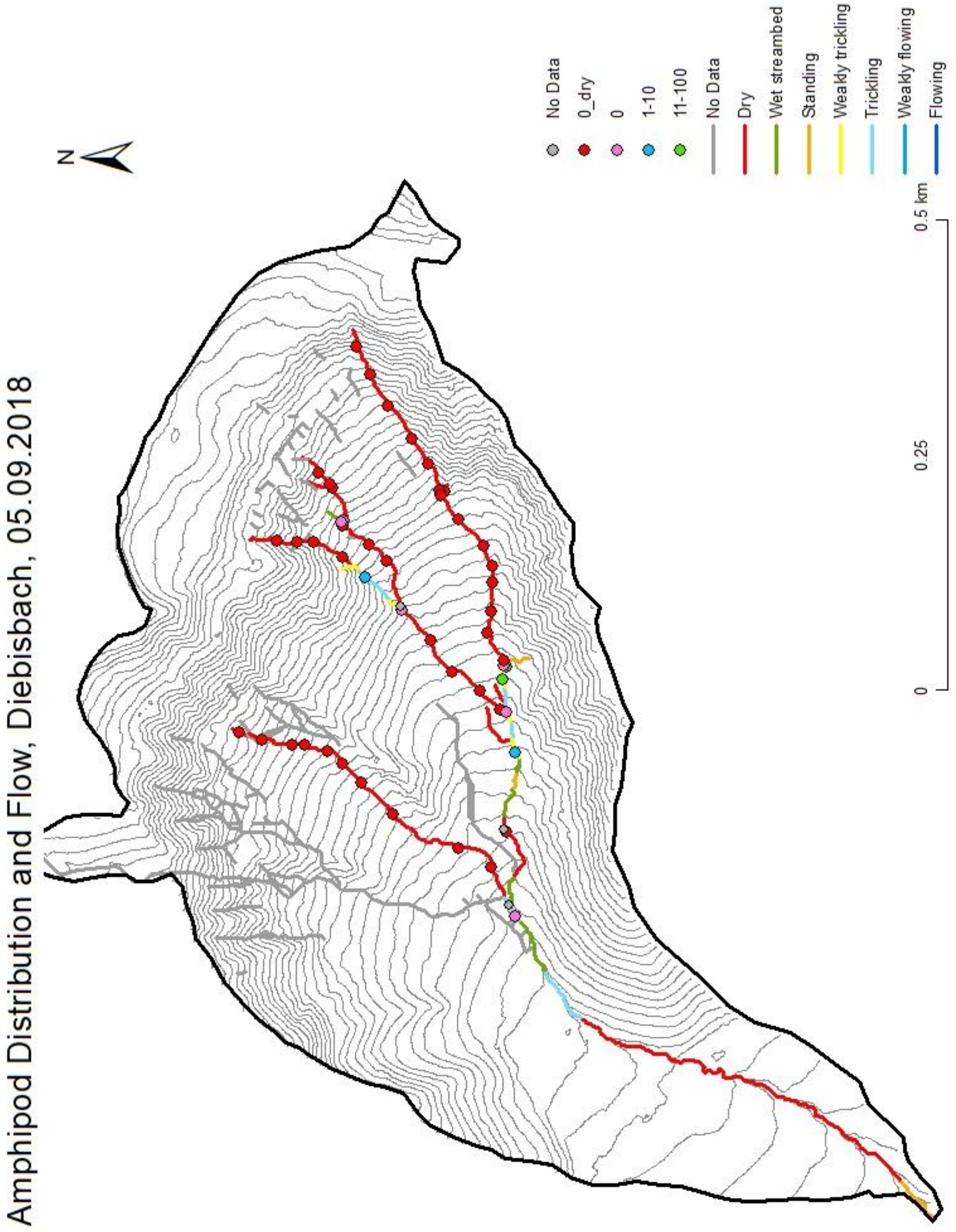
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km

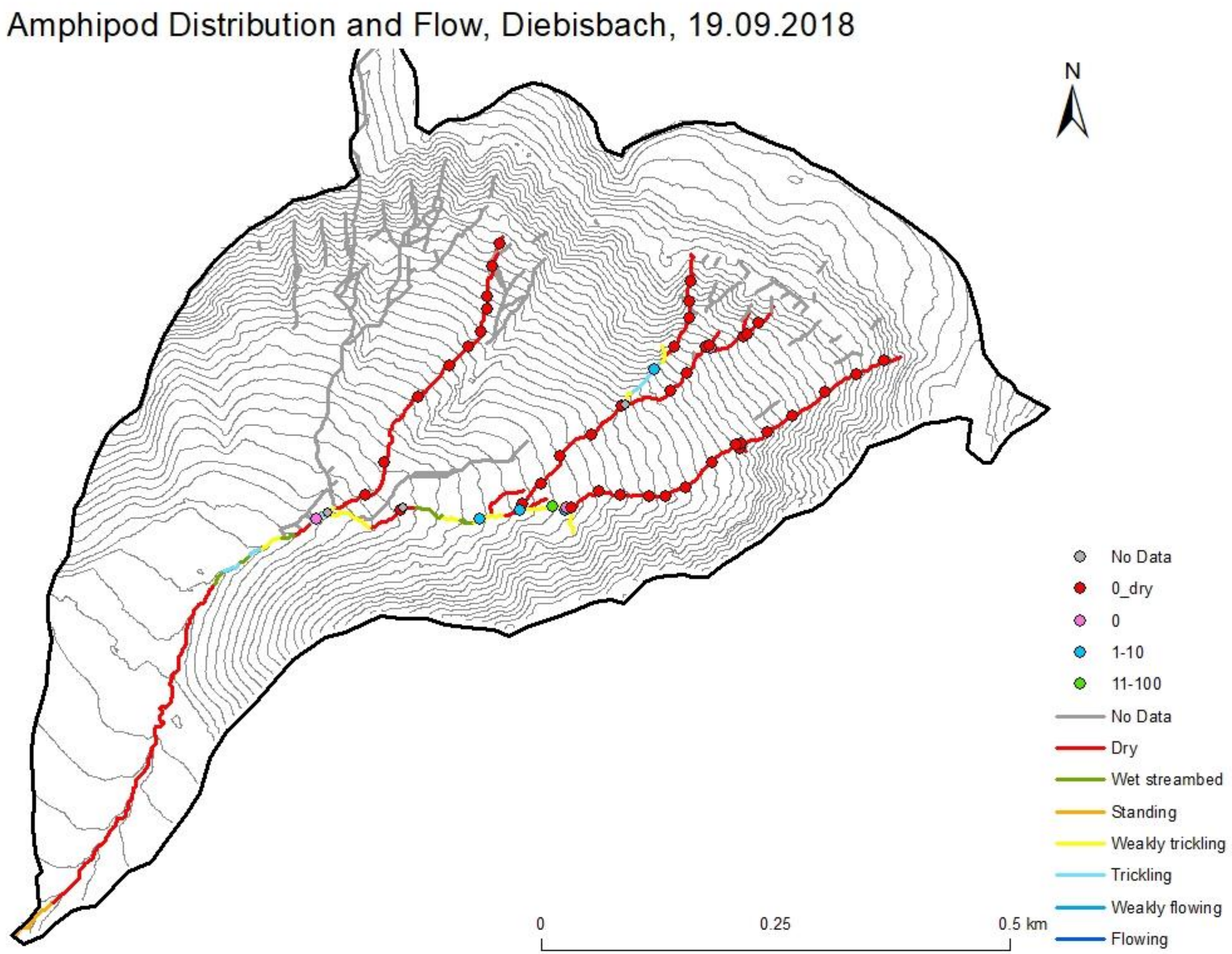


Amphipod Distribution and Flow, Diebisbach, 25.07.2018


Amphipod Distribution and Flow, Diebisbach, 08.08.2018
N
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km


Amphipod Distribution and Flow, Diebisbach, 22.08.2018


Amphipod Distribution and Flow, Diebisbach, 05.09.2018
N
● No Data
● 0_dry
● 0
● 1-10
● 11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km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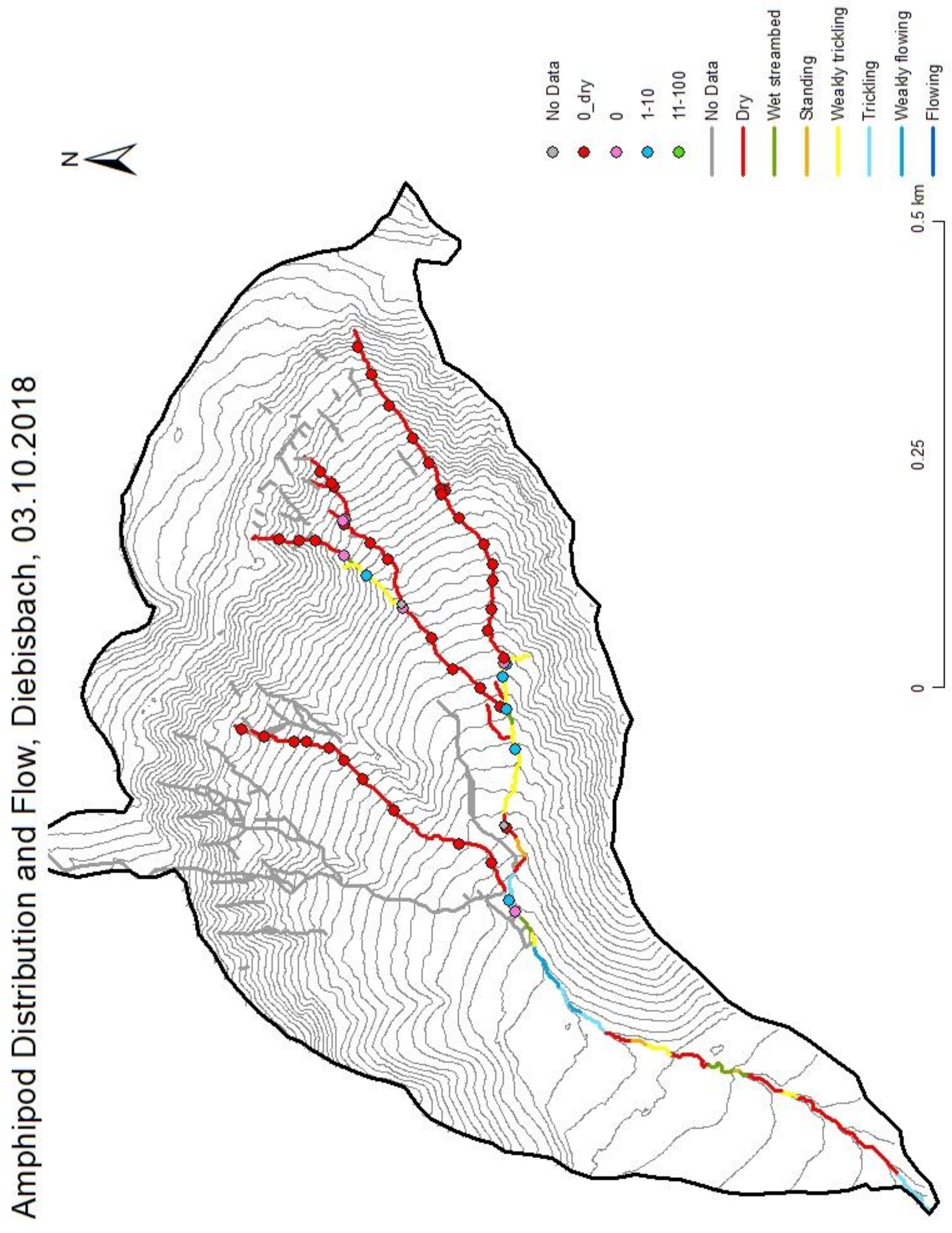
N
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km


Amphipod Distribution and Flow, Diebisbach, 03.10.2018
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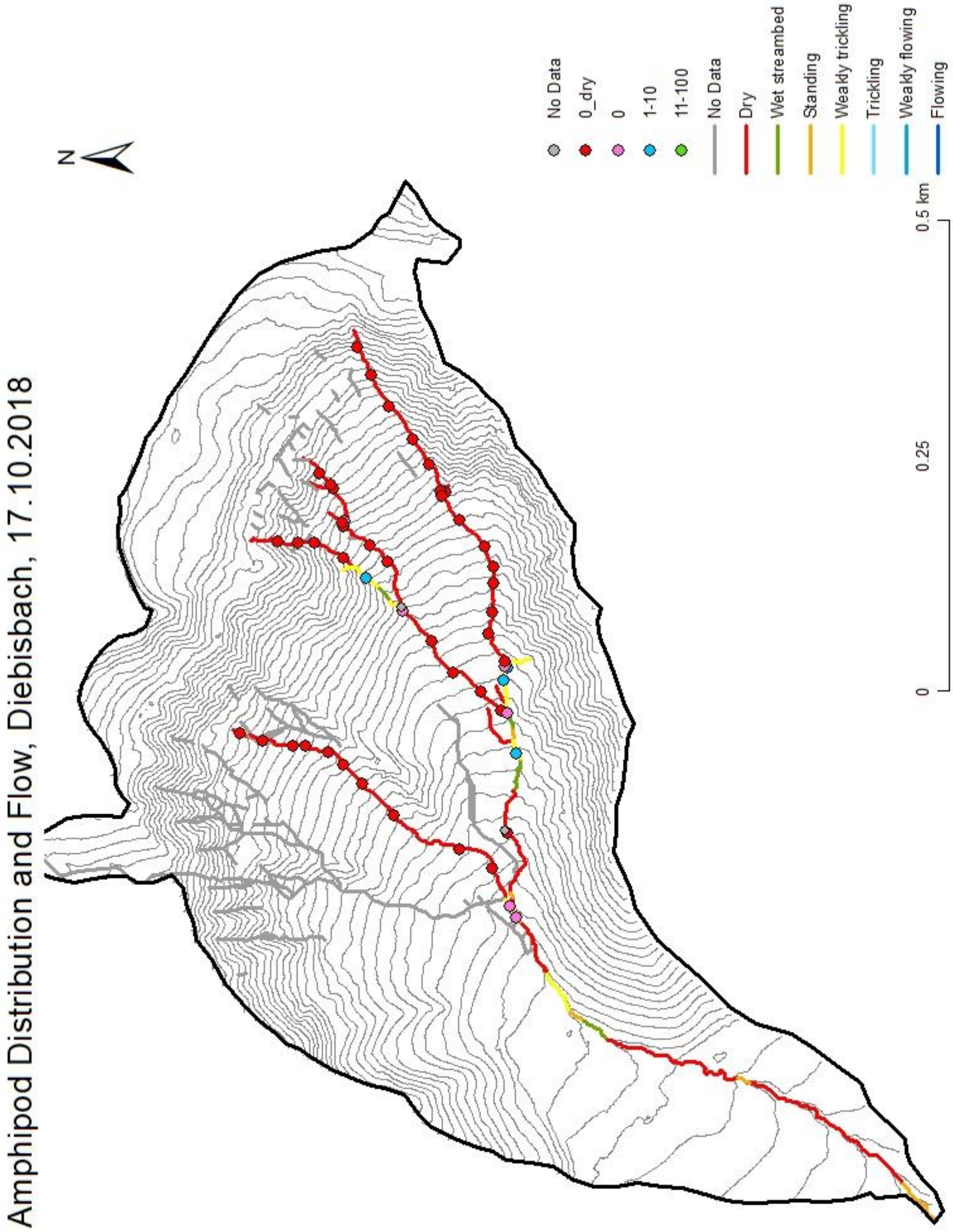
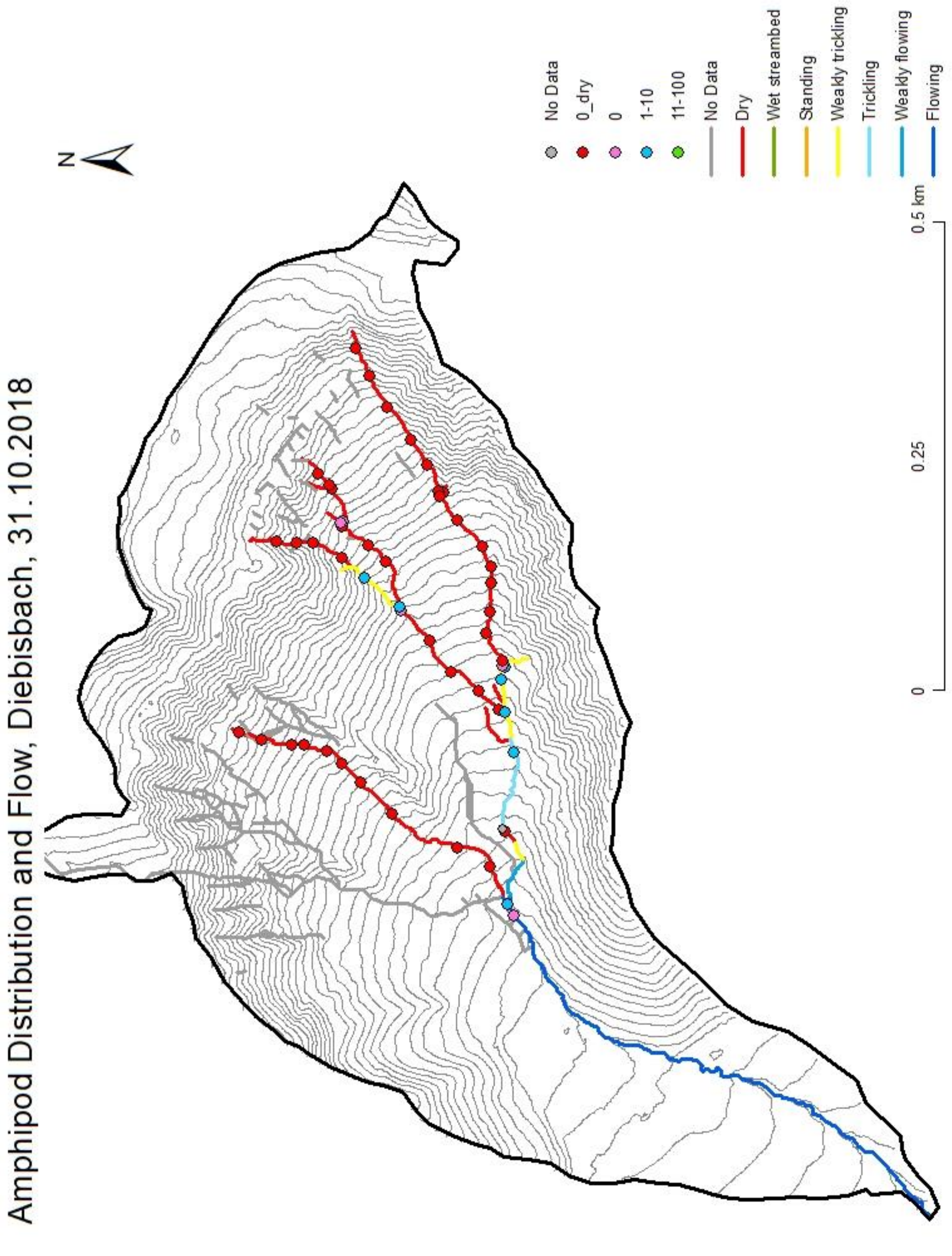
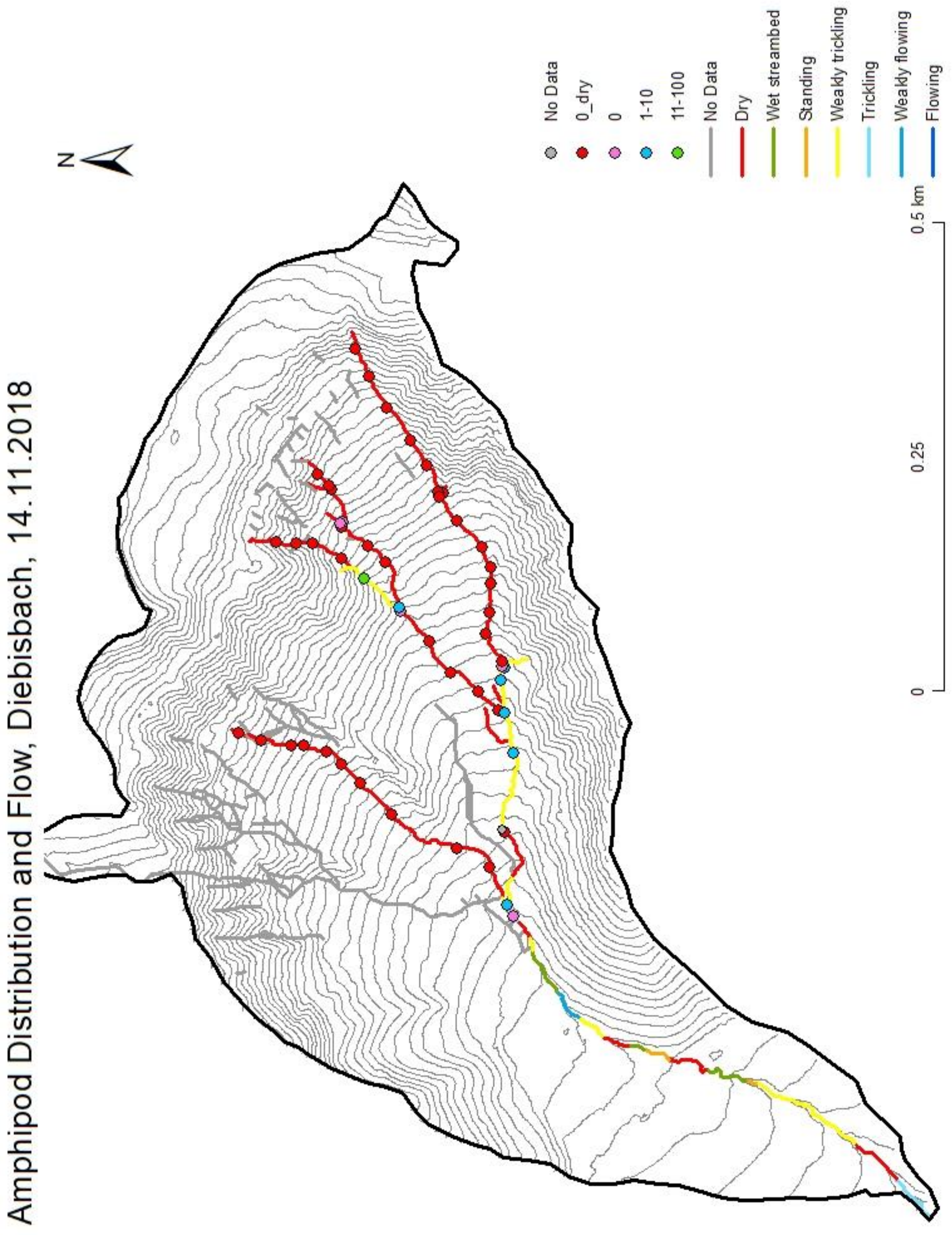
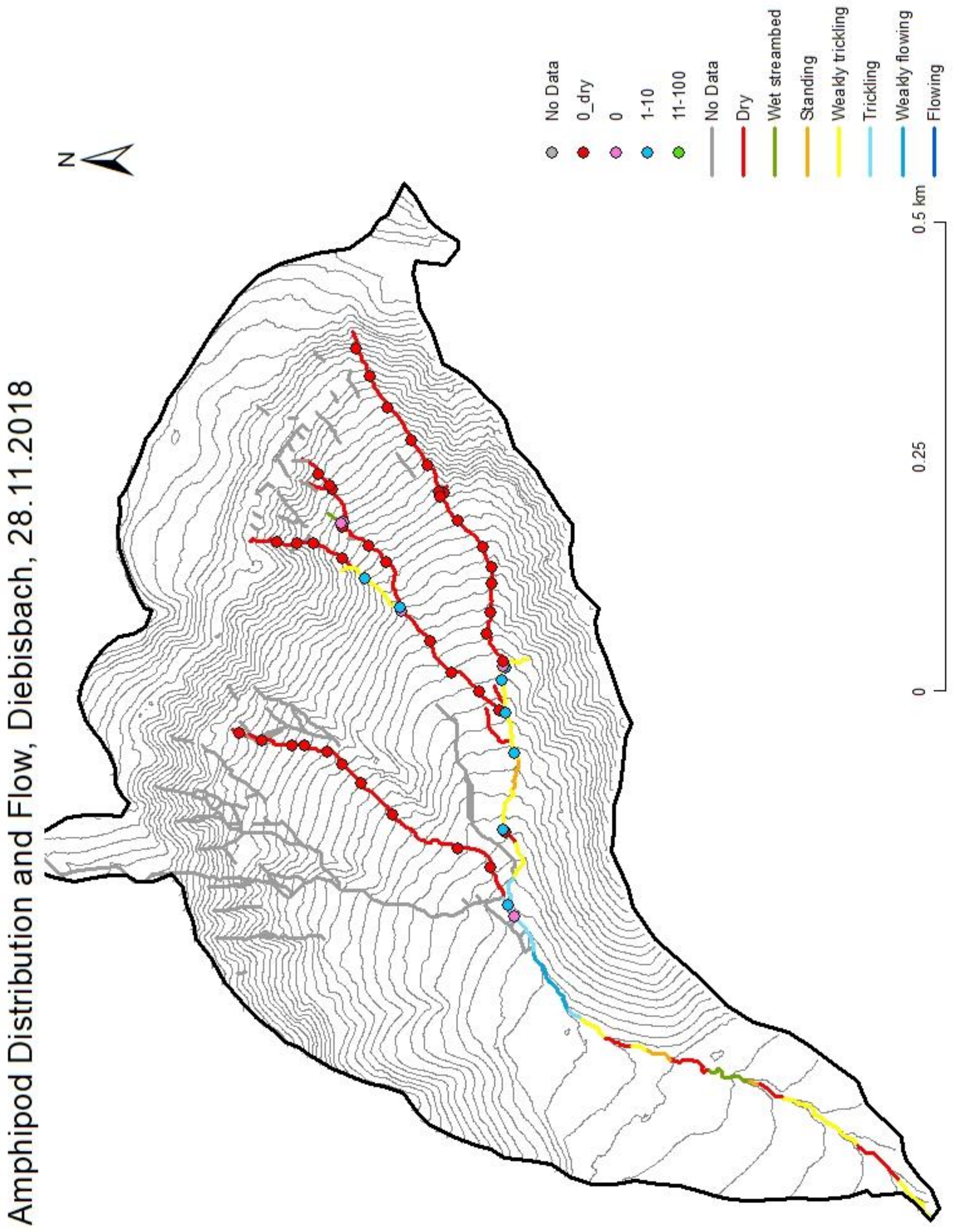
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km

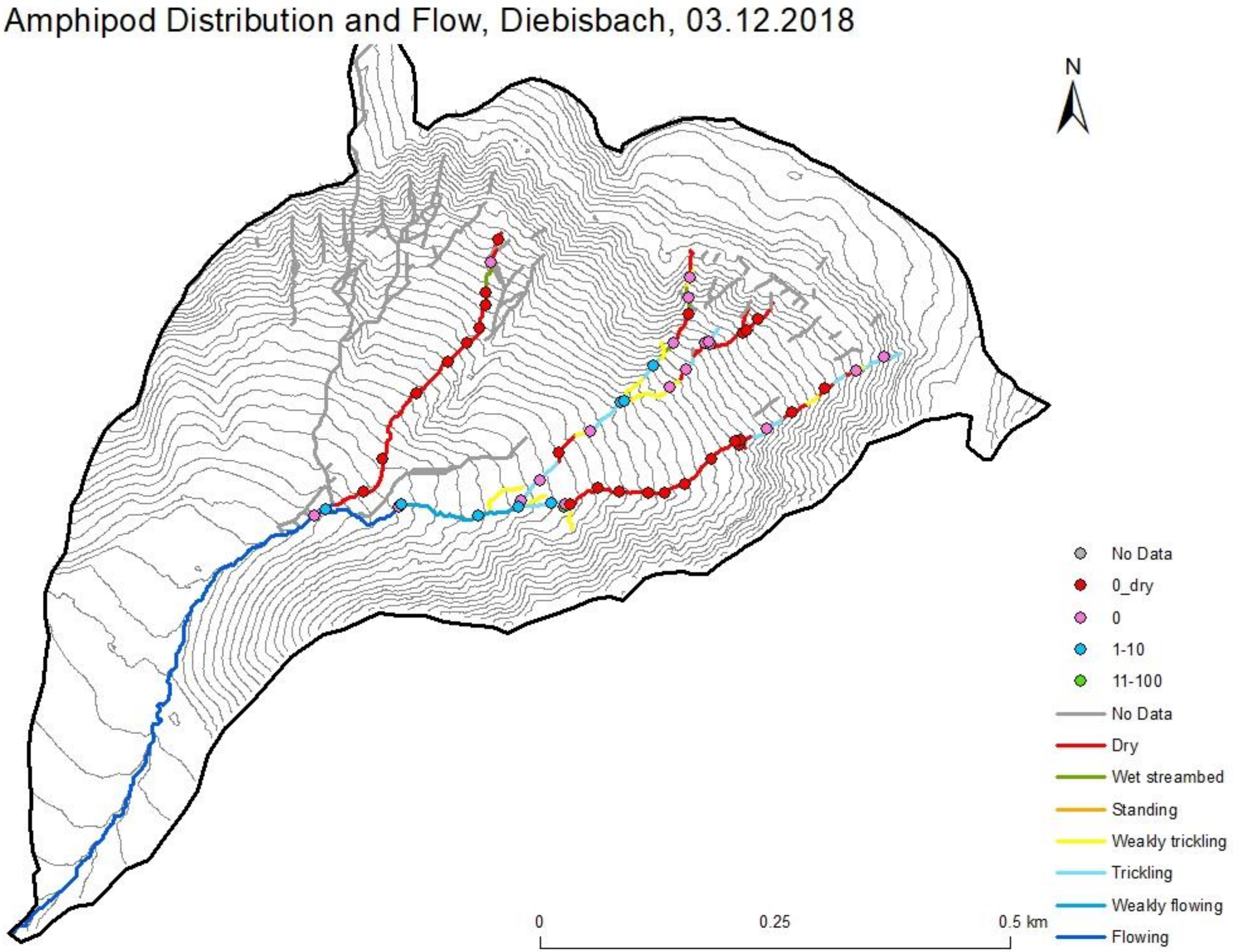

Amphipod Distribution and Flow, Diebisbach, 17.10.2018
N
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km



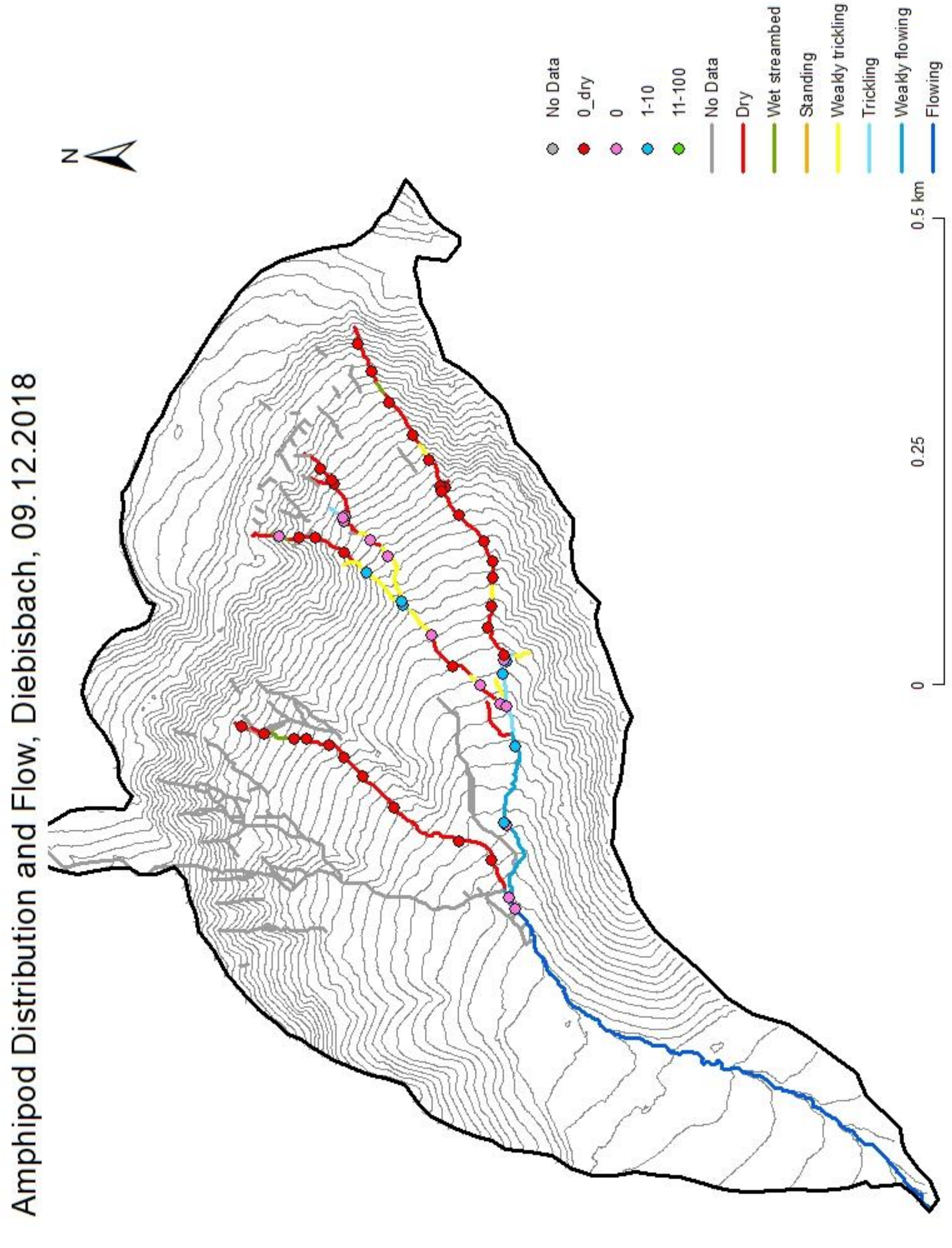
Amphipod Distribution and Flow, Diebisbach, 31.10.2018

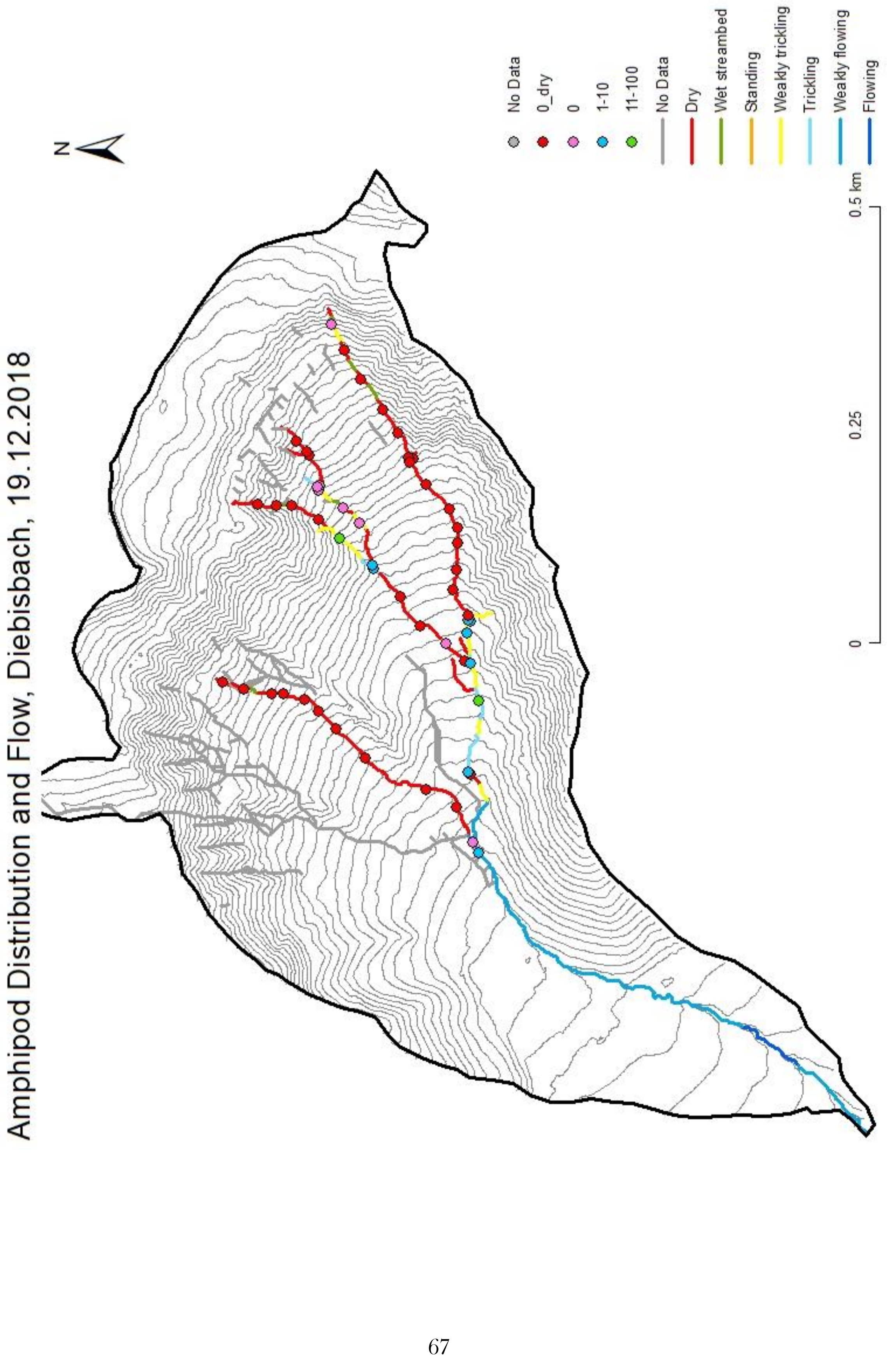

Amphipod Distribution and Flow, Diebisbach, 14.11.2018
N
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km


Amphipod Distribution and Flow, Diebisbach, 28.11.2018
N
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km



Amphipod Distribution and Flow, Diebisbach, 03.12.2018


Amphipod Distribution and Flow, Diebisbach, 09.12.2018
N
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km


Amphipod Distribution and Flow, Diebisbach, 19.12.2018
N
No Data
0_dry
0
1-10
11-100
No Data
Dry
Wet streambed
Standing
Weakly trickling
Trickling
Weakly flowing
Flowing
0
0.25
0.5 km

C. Measurement Protocol

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
15.06.2018	1	1	0	1	2	F	NA	NA	40	5
15.06.2018	2	1	0	0	2	F	NA	NA	40	10
15.06.2018	3	1	2	0	3	WF	NA	NA	10	5
15.06.2018	4	2	1	0	3	T	NA	NA	10	3
15.06.2018	5	0	0	0	1	WF	NA	NA	10	5
15.06.2018	6	0	0	0	0	D	NA	NA	0	0
15.06.2018	7	0	0	0	0	D	NA	NA	0	0
15.06.2018	8	0	0	0	1	WT	NA	NA	20	2
15.06.2018	9	0	0	0	0	D	NA	NA	0	0
15.06.2018	10	0	0	0	0	D	NA	NA	0	0
15.06.2018	11	0	0	0	0	D	NA	NA	0	0
15.06.2018	12	0	0	0	0	D	NA	NA	0	0
15.06.2018	13	0	0	0	1	S	NA	NA	20	2
15.06.2018	14	0	0	0	1	WT	NA	NA	20	1
15.06.2018	15	0	0	0	0	D	NA	NA	0	0
15.06.2018	16	0	0	0	1	T	NA	NA	20	1
15.06.2018	17	0	0	0	0	D	NA	NA	0	0
15.06.2018	18	0	0	0	0	D	NA	NA	0	0
15.06.2018	19	0	0	0	1	WT	NA	NA	10	0.5
15.06.2018	20	0	0	0	1	WSB	NA	NA	0	0
15.06.2018	21	0	0	0	1	WT	NA	NA	30	1
15.06.2018	22	0	0	0	1	WSB	NA	NA	0	0
15.06.2018	23	0	0	0	1	WT	NA	NA	20	1
15.06.2018	24	0	0	0	1	WT	NA	NA	25	2
15.06.2018	25	1	2	1	3	WT	NA	NA	80	2
15.06.2018	26	0	0	0	0	D	NA	NA	0	0
15.06.2018	27	0	0	0	0	D	NA	NA	0	0
15.06.2018	28	1	1	1	2	T	NA	NA	30	1
15.06.2018	29	2	1	2	3	WF	NA	NA	40	2
15.06.2018	30	2	1	1	3	T	NA	NA	30	1
15.06.2018	31	1	2	0	3	F	NA	NA	40	5
15.06.2018	32	0	0	0	1	WF	NA	NA	40	3
15.06.2018	33	1	2	1	3	WF	NA	NA	30	3
15.06.2018	34	2	0	0	3	WF	NA	NA	40	3
15.06.2018	35	0	0	0	1	T	NA	NA	20	3
15.06.2018	36	0	0	0	1	T	NA	NA	20	5
15.06.2018	37	0	0	0	1	WF	NA	NA	20	5
15.06.2018	38	0	0	0	0	D	NA	NA	0	0
15.06.2018	39	0	0	0	0	D	NA	NA	0	0
15.06.2018	40	0	0	0	0	D	NA	NA	0	0
15.06.2018	41	0	0	0	1	WSB	NA	NA	0	0
15.06.2018	42	0	0	0	1	WT	NA	NA	20	0.5
15.06.2018	43	0	0	0	0	D	NA	NA	0	0
15.06.2018	44	0	0	0	0	D	NA	NA	0	0
15.06.2018	45	0	0	0	0	D	NA	NA	0	0
15.06.2018	46	0	0	0	1	WSB	NA	NA	70	0
15.06.2018	47	1	1	0	2	WF	NA	NA	30	3
15.06.2018	48	0	0	0	0	D	NA	NA	0	0
15.06.2018	49	0	0	0	1	F	NA	NA	45	10
15.06.2018	50	1	0	1	2	F	NA	NA	50	10

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
11.07.2018	1	2	2	2	3	T	515	13.7	40	3
11.07.2018	2	2	2	1	3	T	516	14	20	3
11.07.2018	3	1	1	1	2	WT	561	12.9	20	2
11.07.2018	4	1	0	1	2	WT	566	12.8	10	2
11.07.2018	5	0	0	0	1	WSB	NA	NA	10	0
11.07.2018	6	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	7	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	8	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	9	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	10	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	11	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	12	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	13	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	14	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	15	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	16	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	17	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	18	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	19	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	20	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	21	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	22	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	23	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	24	1	0	0	2	WSB	NA	NA	40	0
11.07.2018	25	1	1	1	2	T	465	14.4	50	1
11.07.2018	26	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	27	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	28	1	1	0	2	WSB	435	14.9	40	0
11.07.2018	29	1	0	2	3	WT	454	14.6	30	1
11.07.2018	30	2	1	1	3	WSB	NA	NA	30	0
11.07.2018	31	2	1	2	3	WT	446	13.9	30	5
11.07.2018	32	0	0	0	1	T	402	14.4	40	5
11.07.2018	33	1	1	1	2	WT	468	14.5	30	1
11.07.2018	34	1	1	2	3	T	455	14.6	70	4
11.07.2018	35	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	36	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	37	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	38	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	39	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	40	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	41	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	42	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	43	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	44	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	45	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	46	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	47	0	1	1	2	WT	471	15.2	20	2
11.07.2018	48	0	0	0	0	D	NA	NA	NA	NA
11.07.2018	49	0	1	0	2	WT	478	14	50	3
11.07.2018	50	0	2	2	3	WF	473	14.2	50	8

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
25.07.2018	1	1	1	1	2	WT	529	17.9	30	1
25.07.2018	2	1	1	1	2	WT	501	16.7	30	3
25.07.2018	3	1	1	1	2	WT	560	15.9	15	1
25.07.2018	4	1	1	1	2	WT	570	16.3	30	2
25.07.2018	5	1	0	0	2	WSB	NA	NA	20	0
25.07.2018	6	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	7	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	8	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	9	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	10	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	11	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	12	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	13	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	14	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	15	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	16	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	17	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	18	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	19	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	20	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	21	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	22	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	23	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	24	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	25	1	1	2	3	WT	457	18.7	80	1
25.07.2018	26	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	27	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	28	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	29	2	2	2	3	WSB	NA	NA	30	0
25.07.2018	30	1	2	2	3	WSB	NA	NA	30	0
25.07.2018	31	1	1	1	2	S	398	18.1	30	5
25.07.2018	32	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	33	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	34	1	1	1	2	S	475	17.9	30	3
25.07.2018	35	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	36	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	37	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	38	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	39	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	40	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	41	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	42	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	43	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	44	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	45	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	46	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	47	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	48	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	49	0	0	0	0	D	NA	NA	NA	NA
25.07.2018	50	0	1	2	3	WT	498	17.4	40	5

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
08.08.2018	1	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	2	0	0	0	1	WSB	NA	NA	20	0
08.08.2018	3	1	1	0	2	T	554	15.4	15	5
08.08.2018	4	1	0	0	2	WT	572	15.3	20	1
08.08.2018	5	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	6	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	7	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	8	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	9	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	10	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	11	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	12	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	13	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	14	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	15	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	16	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	17	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	18	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	19	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	20	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	21	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	22	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	23	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	24	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	25	1	1	1	2	WT	NA	NA	70	0.5
08.08.2018	26	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	27	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	28	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	29	0	0	1	2	WSB	NA	NA	30	0
08.08.2018	30	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	31	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	32	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	33	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	34	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	35	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	36	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	37	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	38	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	39	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	40	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	41	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	42	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	43	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	44	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	45	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	46	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	47	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	48	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	49	0	0	0	0	D	NA	NA	NA	NA
08.08.2018	50	0	0	0	1	S	566	17.7	50	10

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
22.08.2018	1	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	2	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	3	2	1	1	3	WT	545	15.5	20	3
22.08.2018	4	1	2	1	3	WT	577	15.8	20	0.5
22.08.2018	5	0	0	0	1	WSB	NA	NA	15	0
22.08.2018	6	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	7	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	8	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	9	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	10	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	11	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	12	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	13	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	14	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	15	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	16	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	17	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	18	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	19	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	20	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	21	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	22	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	23	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	24	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	25	2	1	2	3	T	461	19.7	50	1
22.08.2018	26	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	27	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	28	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	29	0	0	0	1	WSB	NA	NA	40	0
22.08.2018	30	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	31	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	32	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	33	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	34	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	35	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	36	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	37	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	38	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	39	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	40	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	41	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	42	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	43	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	44	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	45	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	46	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	47	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	48	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	49	0	0	0	0	D	NA	NA	NA	NA
22.08.2018	50	0	0	0	0	D	NA	NA	NA	NA

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
05.09.2018	1	0	1	1	2	WT	574	14.8	40	1
05.09.2018	2	0	0	0	1	WT	533	14.3	20	1
05.09.2018	3	1	2	0	3	WT	581	13.9	20	1
05.09.2018	4	1	2	0	3	S	590	13.9	30	1
05.09.2018	5	0	0	NA	1	WSB	NA	NA	20	0
05.09.2018	6	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	7	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	8	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	9	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	10	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	11	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	12	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	13	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	14	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	15	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	16	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	17	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	18	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	19	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	20	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	21	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	22	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	23	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	24	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	25	1	1	1	2	T	469	15.8	50	1
05.09.2018	26	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	27	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	28	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	29	0	0	0	1	WSB	NA	NA	30	0
05.09.2018	30	0	0	0	1	WSB	NA	NA	30	0
05.09.2018	31	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	32	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	33	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	34	0	0	0	1	WSB	NA	NA	100	0
05.09.2018	35	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	36	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	37	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	38	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	39	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	40	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	41	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	42	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	43	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	44	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	45	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	46	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	47	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	48	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	49	0	0	0	0	D	NA	NA	NA	NA
05.09.2018	50	0	0	0	1	T	532	13.7	60	5

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
19.09.2018	1	1	1	1	2	WT	572	14.8	40	2
19.09.2018	2	0	0	1	0	WT	534	15.8	30	1
19.09.2018	3	1	2	2	3	WT	586	14.3	15	5
19.09.2018	4	1	1	0	2	WT	594	14.1	40	0.5
19.09.2018	5	0	NA	NA	1	WSB	NA	NA	15	0
19.09.2018	6	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	7	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	8	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	9	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	10	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	11	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	12	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	13	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	14	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	15	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	16	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	17	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	18	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	19	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	20	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	21	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	22	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	23	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	24	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	25	1	1	1	2	T	464	17	80	1
19.09.2018	26	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	27	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	28	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	29	0	1	0	1	WSB	NA	NA	40	0
19.09.2018	30	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	31	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	32	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	33	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	34	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	35	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	36	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	37	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	38	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	39	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	40	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	41	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	42	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	43	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	44	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	45	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	46	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	47	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	48	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	49	0	0	0	0	D	NA	NA	NA	NA
19.09.2018	50	0	0	0	1	T	575	14.9	80	10

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
03.10.2018	1	1	1	1	2	WT	607	10.7	40	2
03.10.2018	2	1	1	0	2	WT	563	10.3	30	1
03.10.2018	3	1	1	0	2	WT	587	11.6	15	2
03.10.2018	4	1	1	0	2	WT	598	12.4	40	0.5
03.10.2018	5	0	0	NA	1	WSB	NA	NA	20	0
03.10.2018	6	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	7	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	8	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	9	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	10	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	11	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	12	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	13	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	14	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	15	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	16	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	17	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	18	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	19	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	20	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	21	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	22	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	23	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	24	0	0	0	1	WSB	NA	NA	30	0
03.10.2018	25	0	0	1	2	WT	472	10.5	70	1
03.10.2018	26	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	27	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	28	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	29	0	0	0	1	WSB	NA	NA	40	0
03.10.2018	30	0	0	0	1	WSB	NA	NA	20	0
03.10.2018	31	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	32	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	33	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	34	0	0	0	1	WSB	NA	NA	50	0
03.10.2018	35	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	36	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	37	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	38	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	39	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	40	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	41	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	42	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	43	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	44	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	45	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	46	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	47	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	48	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	49	0	0	0	0	D	NA	NA	NA	NA
03.10.2018	50	0	0	0	1	T	618	10.9	50	5

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
17.10.2018	1	1	1	1	2	WT	555	10.9	50	1
17.10.2018	2	0	0	0	1	WT	530	10.9	20	2
17.10.2018	3	1	1	1	2	WT	596	11.7	20	5
17.10.2018	4	0	1	1	2	WT	989	12.1	50	1
17.10.2018	5	0	0	0	1	WSB	NA	NA	20	0
17.10.2018	6	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	7	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	8	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	9	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	10	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	11	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	12	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	13	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	14	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	15	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	16	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	17	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	18	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	19	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	20	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	21	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	22	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	23	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	24	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	25	1	1	1	2	WT	485	13.9	90	0.5
17.10.2018	26	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	27	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	28	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	29	0	0	0	1	WSB	NA	NA	30	0
17.10.2018	30	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	31	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	32	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	33	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	34	0	NA	NA	1	WSB	NA	NA	40	0
17.10.2018	35	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	36	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	37	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	38	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	39	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	40	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	41	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	42	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	43	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	44	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	45	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	46	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	47	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	48	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	49	0	0	0	0	D	NA	NA	NA	NA
17.10.2018	50	0	0	0	1	S	535	11.9	40	5

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
31.10.2018	1	1	1	1	2	T	611	7.8	40	3
31.10.2018	2	1	1	1	2	WT	618	6.8	30	2
31.10.2018	3	1	1	1	2	WT	620	9.2	20	3
31.10.2018	4	1	0	0	2	WT	606	10.5	30	3
31.10.2018	5	0	0	0	1	S	791	8.7	20	3
31.10.2018	6	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	7	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	8	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	9	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	10	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	11	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	12	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	13	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	14	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	15	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	16	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	17	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	18	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	19	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	20	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	21	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	22	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	23	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	24	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	25	1	1	1	2	WT	485	6.7	100	1
31.10.2018	26	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	27	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	28	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	29	0	0	0	1	WSB	546	9	40	0
31.10.2018	30	0	0	0	1	WSB	NA	NA	30	0
31.10.2018	31	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	32	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	33	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	34	0	1	1	2	WT	491	6.4	80	1
31.10.2018	35	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	36	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	37	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	38	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	39	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	40	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	41	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	42	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	43	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	44	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	45	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	46	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	47	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	48	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	49	0	0	0	0	D	NA	NA	NA	NA
31.10.2018	50	0	0	0	1	F	652	8.9	70	10

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
14.11.2018	1	1	1	1	2	WT	583	8.7	40	2
14.11.2018	2	1	1	0	2	WT	568	8.4	40	3
14.11.2018	3	1	1	1	2	WT	587	9.7	20	7
14.11.2018	4	1	1	0	2	WT	605	10.3	40	2
14.11.2018	5	0	0	0	1	WT	607	9.2	20	2
14.11.2018	6	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	7	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	8	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	9	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	10	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	11	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	12	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	13	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	14	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	15	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	16	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	17	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	18	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	19	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	20	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	21	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	22	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	23	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	24	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	25	1	2	2	3	WT	482	8.8	100	1
14.11.2018	26	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	27	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	28	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	29	0	0	0	1	WT	521	9.4	60	1
14.11.2018	30	0	0	0	1	WSB	NA	NA	30	0
14.11.2018	31	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	32	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	33	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	34	0	0	0	1	WSB	495	8.9	50	0
14.11.2018	35	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	36	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	37	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	38	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	39	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	40	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	41	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	42	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	43	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	44	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	45	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	46	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	47	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	48	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	49	0	0	0	0	D	NA	NA	NA	NA
14.11.2018	50	0	0	0	1	T	592	9.3	50	5

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
28.11.2018	1	1	1	1	2	WT	593	5.1	30	2
28.11.2018	2	1	0	1	2	WT	578	4.9	30	2
28.11.2018	3	1	1	1	2	WT	592	7.3	20	3
28.11.2018	4	1	1	0	2	WT	594	7.3	60	1
28.11.2018	5	0	0	0	1	S	602	6.3	20	2
28.11.2018	6	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	7	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	8	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	9	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	10	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	11	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	12	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	13	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	14	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	15	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	16	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	17	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	18	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	19	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	20	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	21	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	22	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	23	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	24	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	25	1	1	1	2	WT	482	4.8	80	1
28.11.2018	26	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	27	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	28	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	29	0	0	0	1	WT	528	6.1	40	1
28.11.2018	30	0	0	0	1	WT	504	6.9	30	0.5
28.11.2018	31	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	32	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	33	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	34	0	0	0	1	WSB	493	4.4	40	0
28.11.2018	35	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	36	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	37	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	38	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	39	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	40	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	41	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	42	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	43	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	44	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	45	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	46	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	47	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	48	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	49	0	0	0	0	D	NA	NA	NA	NA
28.11.2018	50	0	0	0	1	T	581	5.8	50	10

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
03.12.2018	1	1	1	1	2	WF	537	7.8	60	6
03.12.2018	2	1	1	1	2	WF	552	7.7	40	5
03.12.2018	3	1	1	1	2	T	629	8.4	25	5
03.12.2018	4	2	1	1	3	WT	562	8.9	40	1
03.12.2018	5	0	0	0	1	WT	692	8.4	20	5
03.12.2018	6	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	7	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	8	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	9	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	10	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	11	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	12	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	13	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	14	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	15	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	16	0	0	0	1	T	538	8.7	40	1
03.12.2018	17	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	18	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	19	0	0	0	1	WT	NA	NA	10	0.1
03.12.2018	20	0	0	0	1	T	617	8.1	10	1
03.12.2018	21	0	0	0	1	WT	451	8.5	30	0.5
03.12.2018	22	0	0	0	1	WSB	NA	NA	80	0
03.12.2018	23	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	24	0	0	0	1	WSB	NA	NA	40	0
03.12.2018	25	1	1	1	2	T	476	8.7	70	1
03.12.2018	26	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	27	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	28	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	29	0	0	0	1	T	511	9.2	40	1
03.12.2018	30	0	0	0	1	T	516	8.3	60	2
03.12.2018	31	0	0	0	1	T	510	8.9	60	1
03.12.2018	32	0	0	0	1	WT	508	8.3	50	1
03.12.2018	33	0	0	0	1	WT	634	9.4	50	1
03.12.2018	34	1	1	1	2	T	571	8.3	70	1
03.12.2018	35	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	36	0	0	0	1	T	433	7.4	10	4
03.12.2018	37	0	0	0	1	T	478	7.2	20	1
03.12.2018	38	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	39	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	40	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	41	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	42	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	43	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	44	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	45	0	0	0	1	WSB	NA	NA	50	0
03.12.2018	46	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	47	0	0	0	1	T	551	8.8	40	1
03.12.2018	48	0	0	0	0	D	NA	NA	NA	NA
03.12.2018	49	0	0	0	1	F	501	7.7	40	8
03.12.2018	50	0	0	0	1	F	541	8.5	80	12

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
09.12.2018	1	1	0	1	2	WF	597	7.4	40	7
09.12.2018	2	0	0	0	1	T	680	7.5	50	4
09.12.2018	3	1	1	1	2	T	651	8.6	20	7
09.12.2018	4	1	1	1	2	T	564	8.6	50	2
09.12.2018	5	0	0	0	1	WT	703	9.1	20	5
09.12.2018	6	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	7	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	8	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	9	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	10	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	11	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	12	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	13	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	14	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	15	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	16	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	17	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	18	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	19	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	20	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	21	0	0	0	1	WSB	NA	NA	40	0
09.12.2018	22	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	23	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	24	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	25	1	1	1	2	WT	461	5.6	80	1
09.12.2018	26	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	27	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	28	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	29	0	0	0	1	T	515	7.9	50	3
09.12.2018	30	0	0	0	1	T	331	8.9	40	1
09.12.2018	31	0	0	0	1	T	510	7.6	40	3
09.12.2018	32	0	0	0	1	WT	505	7.3	40	1
09.12.2018	33	0	0	0	1	WT	463	8.5	20	1
09.12.2018	34	1	1	1	2	T	524	6.7	70	2
09.12.2018	35	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	36	0	0	0	1	WT	637	7.4	20	4
09.12.2018	37	0	0	0	1	T	625	7.6	20	2
09.12.2018	38	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	39	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	40	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	41	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	42	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	43	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	44	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	45	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	46	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	47	0	0	0	1	WT	526	6.7	20	1
09.12.2018	48	0	0	0	0	D	NA	NA	NA	NA
09.12.2018	49	0	0	0	1	WF	574	7.1	40	4
09.12.2018	50	0	0	0	1	F	591	8.3	70	8

Date	MP	# a	# b	# c	#tot	FC	EC [µS/cm]	T [°C]	Width [cm]	Depth [cm]
19.12.2018	1	2	0	1	3	T	621	4.8	50	4
19.12.2018	2	1	1	1	2	T	622	4.9	40	5
19.12.2018	3	1	1	1	2	WT	644	7	30	3
19.12.2018	4	1	1	0	2	WT	578	7.5	50	2
19.12.2018	5	0	0	1	2	S	700	8.1	20	4
19.12.2018	6	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	7	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	8	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	9	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	10	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	11	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	12	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	13	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	14	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	15	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	16	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	17	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	18	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	19	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	20	0	0	0	1	WSB	NA	NA	40	0
19.12.2018	21	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	22	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	23	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	24	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	25	1	2	1	3	WT	483	3.6	70	1
19.12.2018	26	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	27	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	28	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	29	0	0	0	1	T	522	6.6	40	3
19.12.2018	30	0	0	0	1	T	524	6.9	30	1
19.12.2018	31	0	0	0	1	WT	520	5.7	30	2
19.12.2018	32	0	0	0	1	WSB	NA	NA	40	0
19.12.2018	33	0	0	0	1	WT	565	6.3	20	2
19.12.2018	34	0	0	1	2	T	502	4.5	40	3
19.12.2018	35	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	36	0	0	0	1	S	717	4.5	20	3
19.12.2018	37	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	38	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	39	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	40	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	41	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	42	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	43	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	44	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	45	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	46	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	47	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	48	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	49	0	0	0	0	D	NA	NA	NA	NA
19.12.2018	50	0	1	0	2	WF	622	5.9	60	7

Personal declaration: I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.