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Floating Islands: A method to detect aquatic dispersal and colonisation potential of soil microarthropods

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Abstract

In floodplains and river marshes, aquatic dispersal is a potential way of migration for soil microarthropods. However, this migration pathway and particularly the colonisation potential after aquatic dispersal in freshwater systems has never been studied before, probably because suitable methods were missing. We therefore developed a method based on artificial floating islands that are filled with defaunated soil as colonisation medium. The islands can be installed in freshwater streams to investigate colonisation potential of soil microarthropods after aquatic dispersal. In combination with small fishing nets and sticky covers they allow disentangling just drifting species from actually colonising ones as well as the detection of individuals introduced to the stream by wind. First testing showed that the islands are a valuable, low-priced and easy-to-handle tool that already allowed recording colonisation of Oribatida, Gamasina, Collembola and Myriapoda after aquatic dispersal.

Keywords Oribatida | Collembola | water transport | dispersal | river marshes

1. Introduction

Dispersal is defined as any movement of individuals (or propagules) with potential consequences for gene flow across space (Ronce 2007). Getting from one habitat patch to another influences both, species distribution and population dynamics on one hand as well as ecosystem evolution on the other hand (Bowler & Benton 2005). Hence, the observation of dispersal pathways is crucial for the understanding of many basic ecological processes, for instance in succession (Ojala & Huhta 2001, Wanner & Dunger 2002, Zaitsev et al. 2006, Lehmitz et al. 2012, Perdomo et al. 2012). In soil microarthropods, the observation of dispersal is particularly critical because of their small size and hidden way of life.

Oribatid mites and Collembola, two of the biggest groups in soil microarthropods, inhabit all kinds of environments from soil to leaf litter, moss and also aquatic habitats (Schuster 1979, Behan-Pelletier 1999, Russell 2008). They are important organisms e. g. for nutrient cycling feeding mainly on dead organic matter and fungi (Klironomos & Kendrick 1996, Schneider et al. 2004 & 2005, Weigmann 2006a). In wetlands, Oribatida and Collembola are the most abundant soil microarthropods, but individual and species numbers largely depend on the environmental conditions (Silvan et al. 2000, Tronstad et al. 2005, Yin et al. 2015, Seniczak et al. 2016). In Finnish and Polish *Sphagnum* bogs with acidic and nutrient-poor conditions, 140,000 to 165,000 oribatid individuals per m² and up to 36 species were found (Markkula 1986, Seniczak 2011). Dierssen & Dierssen (2001) reported about 200,000 Acari and 76,000 Collembola per m² from oligotrophic peatlands in central Europe and Behan-Pelletier & Bissett (1994) listed 71 oribatid species for Canadian peatlands. In wetlands with less strict conditions or a broader range of habitat types, species numbers can be quite high. Lehmitz (2014) found 87 oribatid species in a German wetland and Fischer & Schatz (2010) altogether found 150 oribatid species in different wetlands of South Tyrol. Also in floodplains,

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Collembola can achieve up to 60,000 individuals per m^2 and 35 species (Russell et al. 2004), although increasing flood stress generally reduces species numbers and abundances of terrestrial arthropods (Weigmann & Wolgemuth-von Reiche 1999).

Diverse methods have been invented to detect dispersal of microarthropods, e. g. radioactive tagging for mobility in general (Berthet 1964), pitfall traps for active above-ground movement (Ojala & Huhta 2001, Lehmitz et al. 2012), minicontainer traps for active below ground movement (Eisenbeis et al. 1999, Lehmitz et al. 2012), window traps (Karasawa et al. 2005), windsocks (Vanschoenwinkel et al. 2007) and sticky traps (Lehmitz et al. 2011) for wind dispersal and extraction from birds feathers as well as from skin of mammals (Krivolutsky & Lebedeva 2004a, b) for phoresis.

Although most oribatid mites are terrestrial, many of them can survive in aquatic systems for long time periods, for example in case of flooding (Schatz & Behan-Pelletier 2008). Consequently, water dispersal is another potential pathway for soil microarthropods. Mites in littoral zones and marsh land survived several months submerged in water (Schuster 1979, Weigmann & Wolgemuth-von Reiche 1999) and also springtails are able to adjust to harsh environments in flooding areas (Weigmann 2006a, Russell 2008). Laboratory experiments with intertidal oribatid mites proved that they can survive up to 40 and 143 days submerged in fresh and salt water, respectively (Pfingstl 2013). In a comparable experiment, five high Arctic Collembolan species with hydrophobic cuticles survived approximately two weeks on seawater surface and the oribatid mite *Camisia anomia* was still active after 14 days of submersion in seawater (Coulson et al. 2002). The authors conclude that mites and springtails could survive a transport over a distance of 700 km (Coulson et al. 2002) or even 3,000 km (Pfingstl 2013) in seawater.

We are not aware of any study on aquatic dispersal and colonisation potential of soil microarthropods in streams, probably due to the lack of an appropriate detection method. To catch arthropods from the water surface, methods from sieving the ocean water with plankton nets (Peck 1994) to using floating pitfall traps (Parys & Johnson 2011, Chen et al. 2012) or emerging traps (Cadmus et al. 2016) have been used. Their main purpose, however, was catching aquatic insects in water without further investigations on their colonisation potential. Therefore, we herein present for the first time a simple method set up to substantiate colonisation potential of soil microarthropods after water dispersal.

2. Material and methods

2.1 Floating island construction

To investigate if soil microarthropods are able to survive water dispersal and may colonise new habitats afterwards, we developed artificial floating islands. The islands were constructed with commercially available Polystyrene containers (Coveris Rigid, Zell (Mosel), 550 ml) in cylindrical shape with an opening of 10.8 cm in diameter and 9.2 cm height (Fig. 1). First, the bottom was filled with a 3 cm layer of small pieces of Polystyrene and covered with another round, flat layer of Polystyrene (Video 1, Supplementary Material: www.soil-organisms.org). This layer was sealed with hot glue at its line of contact with the container. Approximately 3 cm beneath the top margin, three small holes were drilled into the container in equal distance to each other, to enable the fixation of a wall fan cover on top of the container with elastic bands later on. Afterwards, the containers

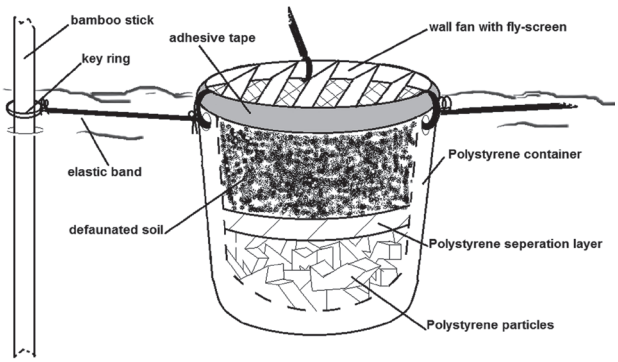

Figure 1. Line drawing explaining configuration of the floating island.

Figure 2. Floating island in situ with petri dish cover.

were filled to the top with 400 ml defaunated soil. The soil had previously been taken from one of the study sites, it was then heated up to 90°C for 10 minutes in the microwave and after cooling down, frozen at -20°C for at least 7 days. The whole container was then closed with a wall fan cover (Rotheigner, Bornheim/Pfalz, 10 cm diameter of the inner margin), with an already attached fly net inside (2 mm mesh size), in order to prevent bigger organisms from entering the island. Hot glue was applied to the margin of the wall fan cover and smoothly spread while still flexible to decrease the wall fans' inclination and therefore facilitate the entrance for floating microarthropods. On top, adhesive tape with a rough surface was applied throughout the whole margin. Half of the 30 floating islands sustained a plastic petri dish (14 cm in diameter) as cover to prevent passive immigration of microarthropods by wind, laid on top of three small wooden sticks hot glued to the inner border of the wall fan cover. The islands were transported to the sampling sites in closed boxes to prevent any organisms from entering before set up in the field.

2.2 Field procedure

At the sampling site, the islands were kept shut with two hands and then submerged individually and saturated with water (Video 1, Supplementary Material: www.soil-organisms.org). If the margin of the island was not in line with the water surface afterwards, the wall fan cover was removed and one to three small stones were put into the island to increase weight by dwelling them beneath the soil. As soon as the swimming characteristics were sufficient the wall fan cover was fixated with three elastic bands by pulling and knotting them through the small holes in the container (Fig. 1). A 20 mm diameter key ring was attached to the opposite end of the elastic band. The islands where then placed into the water and fixated in their position by three bamboo sticks passed through the key rings, preventing horizontal drift but allowing vertical movement with changes in water level (Fig. 2). The opening of the wall fan cover thereby needs to be turned against the flow direction so that the water flows into the island. Finally, insect glue (Aurum Insekten

Figure 3. Top view of the creek Altes Fließ.

Figure 4. Floating islands at sample site 2.

Figure 5. Fishing nets in situ.

Figure 6. Floating islands and fishing nets at sample site 3.

Leim, Neudorff, Emmerthal) was applied to the petri dishes covering half of the floating islands (sticky covers) to detect microarthropods transported to the water surface by wind.

The floating islands were tested at three sampling sites in the biosphere reserve 'Oberlausitzer Heide- und Teichlandschaft', Saxony in Germany in a small creek called 'Altes Fließ' (Fig. 3). The creek has a total length of about five kilometres and is on average 3 m wide. Water level fluctuates in the middle of the stream approximately between 22 and 42 cm at the sample sites. We placed 10 floating islands at each of the three sample sites, with a distance of 20 to 40 cm to each other (Fig. 4 & 6). Distances between the outer islands and the bank ranged from 1.0 to 2.3 m.

All floating islands were installed on the 10th of August 2016 and maximally stayed in the creek for 16 weeks. Sticky covers where exchanged every week for a five week period. Afterwards, sticky covers where replaced by petri dishes without insect glue. Two islands (one with, one without sticky cover) where taken out from each sampling site after 4 weeks. Unfortunately, all islands of sample site one had to be removed after 8 weeks, because they were submerged and turned upside down by a heavy flooding after emptying of a fish pond. Further two islands per remaining sample site were taken out after 12 weeks. All remaining islands were removed on the 30th of November 2016 when the first ice covered the islands.

To get an idea of how many and which soil microarthropods are drifting on the water surface and oppose them to the species actually colonising the floating islands, we additionally installed five fishing nets with a frame size of 20 cm (JBL, Neuhofen) per sampling site for a five week period from the start of the experiment (Fig. 5 & 6). Fishing nets were emptied once a week and the contents scanned for soil microarthropods under a stereo microscope.

2.3 Specimen extraction and processing procedure

As soon as the floating islands were taken out from the water, they were transferred into a 3 l plastic bag and sealed in order to catch also the water which was in the island. Soil microarthropods were extracted for ten days on a MacFadyen high-gradient apparatus. The extraction started one to two hours after collecting the islands. Therefore, islands were opened, still partly surrounded by the plastic bag, by cutting the elastic bands and lifting the wall fan cover. If water was still in the islands it was emptied into the plastic bag. The soil was then poured into the MacFadyen container, upside down. All islands were extracted for soil microarthropods, even if they had been overturned in the creek or frozen. The water from the plastic bag was examined for soil microarthropods under a stereo microscope on the same day or the day after the extraction was started, pouring the water into a petri dish. All adult Collembola and Oribatida in the islands were determined to species level (Bretfeld 1999, Potapov 2001, Weigmann 2006b, Fjellberg 2007). A single juvenile myriapod could only be determined to family level.

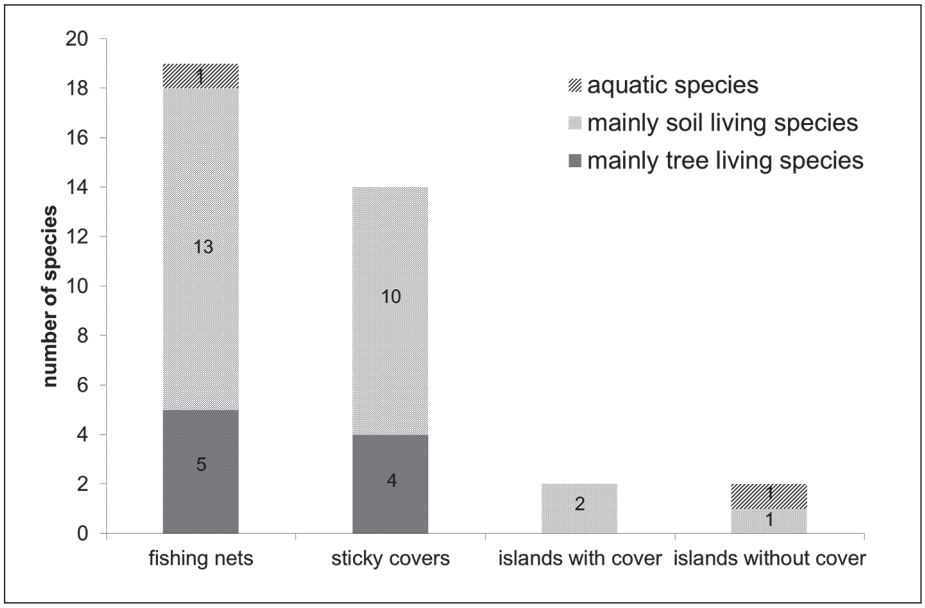

Figure 7: Number of oribatid species in fishing nets, on sticky covers and in covered and uncovered floating islands; hatching indicates which main ecological niche the species usually settle (Weigmann 2006b).

Specimens from the sticky covers were also sorted the same day by picking up the soil microarthropods, still covered with the insect glue, with a forceps and placing it on a labelled piece of paper. This paper was then transferred into a sampling tube with Ethanol, 70 % denatured. After two weeks the glue became completely bond so that oribatid mites could be relieved by breaking the hardened glue cover with a small tip of the forceps, releasing a perfect intact individual. Collembolans were just counted and not stored, because they would be destroyed when removed from the sticky cover. Only adult Oribatida individuals caught with sticky covers and fishing nets were determined to species level Weigmann (2006b).

3. Results

From the soil of the islands with cover we retrieved in total four specimens of Oribatida, six Collembola, one Myriapoda, three Gamasina and two Coleoptera. Additionally, from the uncovered island two oribatid mite specimens, four springtails and one Coleoptera were extracted. Individuals were found at every sampling date (after 4, 8, 12 and 16 weeks). For species numbers see Table 1.

With the sticky covers, 43 individuals of oribatid mites and five Collembola were detected; with the fishing nets we caught 31 individuals of Oribatida and seven Collembola. Thirteen oribatid mite species were caught by sticky covers and 16 species by fishing nets, most of them presumably originating from soil (Fig. 7, Tab. 1, Weigmann 2006b). Fishing nets and sticky covers moreover contained tree-living species, which were absent from the floating islands.

4. Discussion

Floating islands are a valuable tool to record colonisation potential of soil microarthropods after aquatic dispersal, because all flightless individuals extracted from the floating islands with covers must have achieved the island by passing a certain distance over water. Since the animals had to leave the soil actively during extraction on the MacFadyen apparatus, all extracted individuals obviously survived the water transport and were able to colonise the new 'habitat'. The new method therefore enabled us proving aquatic dispersal of Oribatida, Collembola and Myriapoda in a stream.

In our first test run the number of specimens and species in the floating islands was low in contrast to the sticky covers and the fishing nets. Hence, large numbers of terrestrial microarthropods were probably introduced to the creek by aerial transport (Lehmitz et al. 2011) or just fell from trees lining the water edge, but could not colonise new soils. This is also suggested by the amount of tree-living species on the sticky covers and in the fishing nets being completely absent from the islands soil. However, even the low number of microarthropods arriving in a new habitat may contribute to the genetic exchange between populations, because several mites and Collembola are parthenogenetic and therefore a single individual could contribute to the population (Coulson et al. 2002). Colloff (2010) suggested that even if the arthropod itself will not survive, eggs inside females might do. Tamm (1984) found out that Collembola eggs are very resistant towards flooding. Nevertheless, our results are only preliminary and investigations are still continued.

Floating islands are low in cost (less than 10 € for one island), suitable to endure one season in almost all weather conditions and even if partly destroyed easy to be repaired or replaced completely. The floating island can be used for sampling at multiple locations, as it can easily be assembled indoors and transported to and from the sampling site. It is light in weight and one person is able to set up the trap alone within approximately five minutes to assemble and even less to disassemble a floating island. Thunderstorms, heavy rain or drought may flood or uncover the islands, but they were never teared off or destroyed and were still in good condition after 16 weeks at the end of autumn. However, Polystyrene containers should be replaced after one season, because they might become brittle due to weather influences over time.

Difficulties were identified in form of flooding, turn over, freezing and uplifting of islands due to heavy water-level fluctuations and weather conditions. However, slight changes of the water level were easily settled by the elastic bands, but fluctuations of several decimetres after heavy rain drowned the islands. Narrow sampling dates (every two weeks) are therefore recommended, also to remove larger leaves and branches washed up to the islands. As an improvement we consider placing the defaunated soil not directly into the island, but rather placing a plastic bag with the soil into it. Thereby, handling the soil into the MacFadyen for extraction becomes easier. Alternatively, the bottom of the Polystyrene container may be cut and the remaining container with the soil then placed directly on the MacFadyen upside down.

To the best of our knowledge, the floating islands are the only way to detect potentially colonising soil arthropods achieving new habitats through water dispersal. Preliminary results suggest that water dispersal of soil microarthropods takes place and that a part of the drifting animals is able to colonise new habitats.

Table 1: Oribatid mite species from sticky covers, floating islands and fishing nets. Collembola and Myriapoda were only determined from floating islands.

taxa	sticky covers	floating islands		
		with cover	without cover	fishing nets
Oribatida				
Camisia horrida				1
Camisia segnis	1			
Carabodes rugosior				1
Ceratoppia bipilis	1			
Chamobates pusillus			1	
Cymbaeremaeus cymba	9			
Dometorina plantivaga	14			8
Galumna lanceata				1
Galumna obvia				1
Globozetes cf. *longipilus*				1
Hydrozetes lacustris			1	2
Liebstadia pannonica	1			
Liochthonius tuxeni				3
Micreremus brevipes	3			
Nanhermannia pectinata				1
Neoribates aurantiacus	1			
Oribatella quadricornuta	1			
Oribatula tibialis	1			
Pergalumna willmanni	1			
Poecilochthonius spiciger				1
Protoribates dentatus				1
Punctoribates hexagonus				1
Punctoribates punctum	1	1		
Scheloribates ascendens				1
Scheloribates latipes				1
Trichoribates cf. *novus*		1		
Trichoribates novus	6			2
Trichoribates trimaculatus				1
Zetomimus furcatus	1			
Oribatida juvenil	2	2		4
Collembola				
Isotomurus spec. juv.			1	
Lepidocyrtus lanuginosus			1	
Lepidocyrtus lanuginosus juv.		1		
Sminthurides malmgreni		7		
Sminthurides malmgreni juv.			2	
Sphaeridia pumilis juv.		1		
Myriapoda				
Julidae juv.		1		

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