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Spatial resilience of a soil microarthropod community on disturbed areas

Diana María Castillo Sañudo

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Dissertação apresentada à Universidade de Coimbra para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Ecologia, realizada sob a orientação científica do Professor Doutor José Paulo Sousa Professor Auxiliar do Departamento de Ciências da Vida da Faculdade de Ciências e Tecnologia da Universidade de Coimbra.

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Abstract

Disturbances in soil ecosystems are generally associated with natural or anthropogenic factors (or both), and may affect the abundance and diversity of soil microarthropod communities. Nevertheless, such changes help to maintain the dynamic of the ecosystems, and play an important role in its conservation and future reorganization. After disturbances in soil, the recovery of soil fauna communities stimulates the recolonisation of those areas and, consequently, the establishment and growth of the different populations. A successful recolonisation depends not only on the existence of suitable habitat conditions in those disturbed areas, but also on the dispersal ability of the organisms and the spatial configuration of disturbed and non-disturbed (donor) patches. In principle, an interspersion of disturbed and donor patches will increase the spatial resilience of these communities, i.e., recolonisation will be faster. Moreover, when minimum habitat conditions are found, community will recover faster on a spatial basis.

The study was developed at the Botanical Garden of the University of Coimbra, Portugal. Collembola were used as bioindicators to analyse the abundance and number of taxa after disturbances. Collembola are one of the most numerous species found in soils. Furthermore, Collembola help keep basic ecological services of the soils. Their traits allow an analysis of the ability of dispersal and recolonisation of each species according to morphotypes. This study aims to investigate the spatial resilience of Collembola on disturbed areas focusing on the influence of number of donor patches (non-disturbed habitat) within disturbed treatments. The experiments consisted of four treatments comprising

different numbers of donor patches (0, 1, 2 and 4 patches) inside a disturbed matrix, but maintaining the total donor area. Each treatment was replicated 3 times following a block design. A disturbance was applied in order to decrease the number of Collembola in the treatments, trying to minimize the impact on habitat structure. Both soil and litter layers were defauned: leaf litter was removed and dried at 70°C and placed again in the field; at leaf replacement, soil was showered with water at 80ºC. Soil corers were collected immediately after the disturbance and six weeks later. Soil microarthropods were extracted from these soil corers using the Tullgren funnel method. Extracted Collembola were classified according to morphtypes, following Vanderwalle's scoring traits (mainly related to the dispersal ability of the organisms).

Apart from a few rare exceptions, community composition was similar in undisturbed areas inside and outside treatments. Also, but contrary to what was expected, there was no clear trend in the decrease of dissimilarity values in community composition with the increase of the number of donor patches inside the disturbed areas. (with the exception of pitfall data on block 2). Since weather conditions and habitat structure play an important role in Collembola distribution, taking these variables into consideration when defining the disturbance to be applied may help further studies find better trends and differences in community composition and, ultimately, help to unveil a bit more on the process of recolonisation after disturbance.

Chapter 1 Introduction

1. Introduction

1.1. *The importance of disturbance on soil ecosystems*

A disturbance on a soil ecosystem may be caused by natural factors (e.g. fire and drought), or anthropogenic influences (e.g. human activities of tillage and soil environmental management varying the soil microarthropod communities (Alvarez et al., 2000; Bengtsson et al., 2005; Lindberg & Bengtsson., 2005; Ribeiro et al, 2009)). Other kinds of disturbance, such as pollution and land use changes, may also affect soil organisms (Bengtsson et al., 2002). These types of disturbances can be analysed over space and time according to their frequency, duration and size (Bengtsson et al., 2002). A natural disturbance is not a disaster; it may be looked on conservation ecological context (Bengtsson et al., 2000).

Changes in soil ecosystems tend to decrease the abundance and diversity of soil communities (Cassagne et al., 2006). Nevertheless, such changes help to maintain the dynamic of the ecosystems, and play an important role in its conservation and future reorganization. Soil organisms may be adapted to disturbed areas or contribute to recolonisation from non-disturbed areas (Bengtsson et al, 2002). Perhaps, these disturbances on soil communities are crucial to conserve the soil biodiversity (Ribeiro et al., 2009).

1.2. *Spatial resilience through recolonisation*

The soil organisms have dispersal ability and can recolonise disturbed areas from donor areas, maintaining the soil dynamic ecosystem (Bengtsson et al, 2002). Disturbed areas may be regenerated or recolonised by soil organisms taking into account the spatial configuration of habitats (Fig.1A), distances between donor patches (Fig.1B) and disturbance level (Bengtsson et al, 2002). In addition, the presence of source populations from donor areas helps the recovery of soil fauna communities (Alvarez et al., 2000) and keep the abundance and diversity of soil microarthropods (Rantalainen et al., 2005).

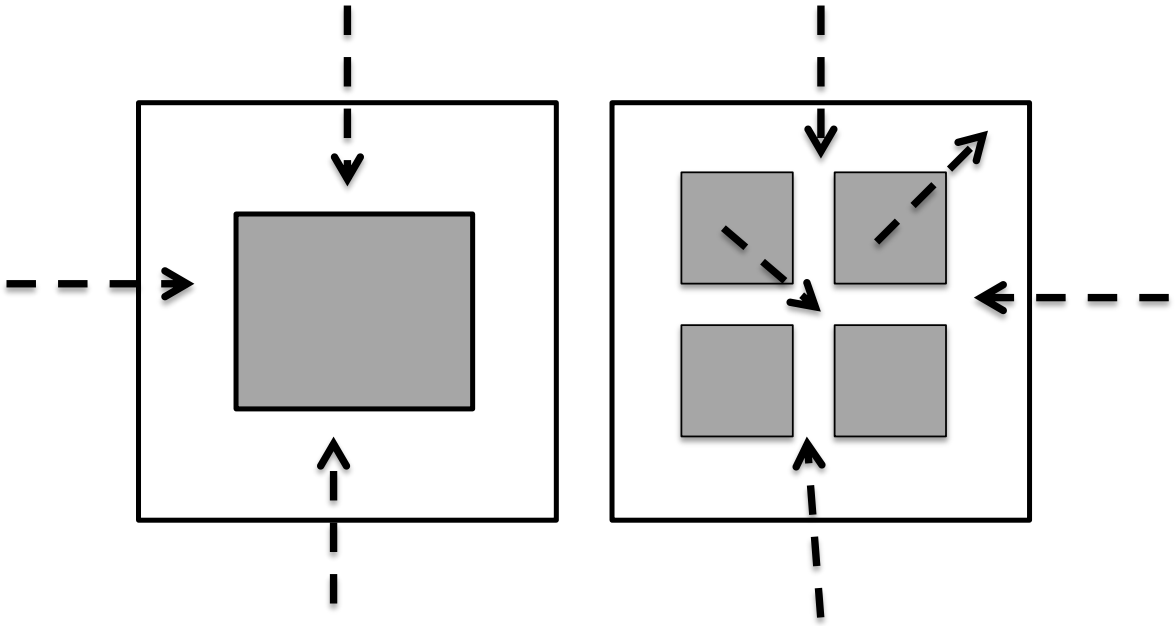

Figure 1. *The spatial configuration as a factor for resilience*
Adapted from Bengtsson et al., 2002

The dynamic of a soil ecosystem (Fig. 2) is influenced by spatial resilience in soil microarthropod communities and depends on four phases (exploitation, conservation, release or disturbance and reorganization) described by the Holling theory (Bengtsson et al., 2002). On the other hand, spatial resilience encompasses two important concepts: engineering resilience and ecological resilience. Bengtsson describes engineering resilience as the speed by which the system returns to the equilibrium and ecological resilience as the capacity to absorb disturbance and reorganize without losing its function, structure, identity and feedbacks (Bengtsson et al., 2000).

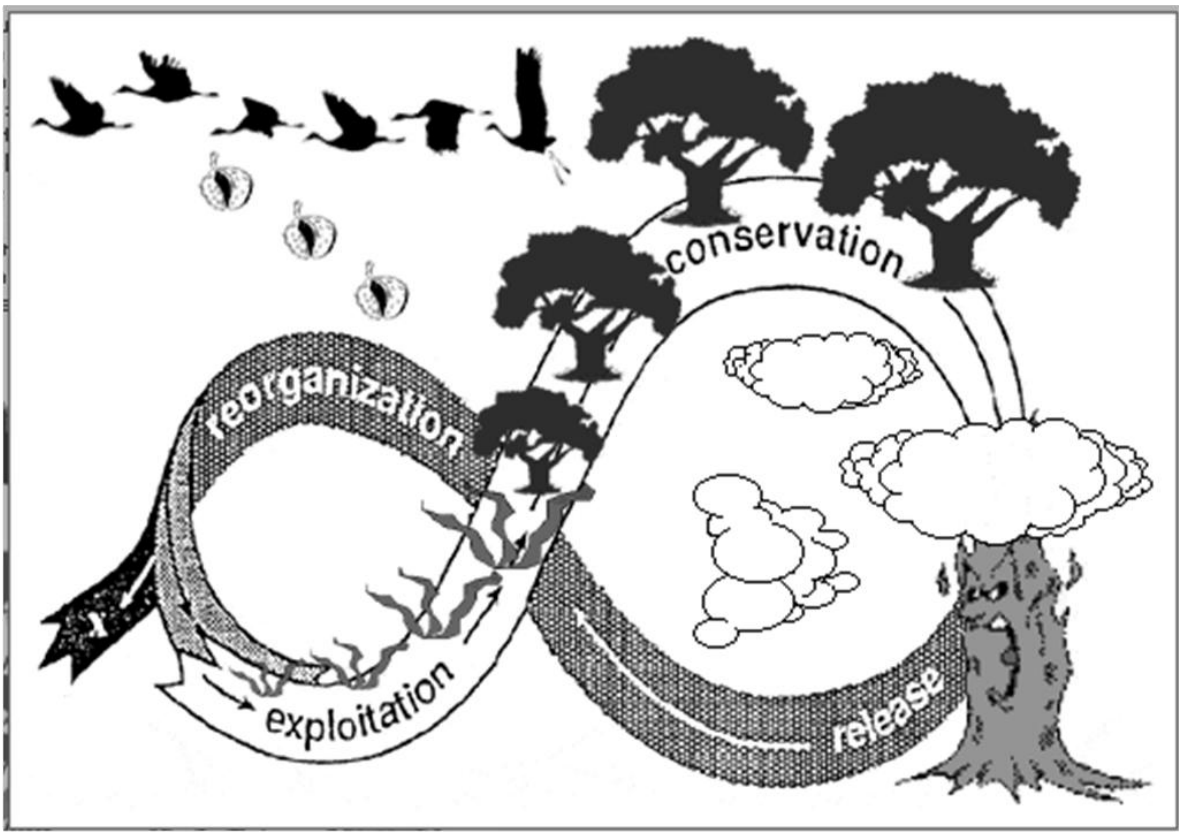

Figure 2*. Phases of dynamic ecosystem adapted from http://albaeco.com/english/htm/webbart/ecosystem.htm*

1.3. *Collembola as bioindicator of health soil*

Collembola (Fig. 3) are one of the most studied organisms in soil ecology (Römbke et al., 2006), and one of the most widespread and abundant terrestrial arthropods, found in litter, humus and in deep soil layers (Ribeiro et al., 2009). These organisms play important roles in soil biological processes, such as decomposition of organic matter, mainly acting as catalysts of microbial activity in soil and promoting the succession of microbial species during the process (Römbke et al., 2006). These species are small hexapod arthropods (Janssens & Dethier 2005; Ribeiro et al., 2009), measuring less than 6mm long. They have a pair of antennae, three pairs of true legs and may have a furcula used to jump. These traits dictate not only the place (soil depth) they leave in soil, but they also play an important role in the recolonisation by Collembola of disturbed areas from the surrounding and from isolated habitat patches.

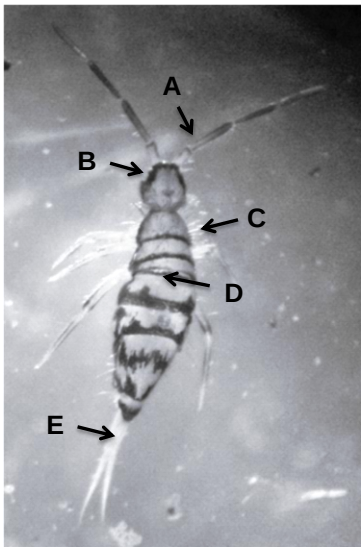

Figure 3. *Collembola (Springtails). A) Antenna length, B) Ocelli, C) Hairs/scales, D) Pigmentation and E) Furcula*

Soil organisms such as earthworms, mites, springtails and enchytraeids (Römbke et al., 2006) are applied in ecology as bioindicators to assess soil health, to monitor the environmental changes (Vanderwalle et al., 2010) and to perform ecotoxicological laboratory tests (Römbke et al., 2006). Collembola are used as bioindicators to assess the ecosystem health and soil environmental quality, as well as to detect environmental changes in an early stage due to land use practices and pollution (Van Straalen, 1998; Römbke et al., 2006; Ribeiro et al., 2009). Moreover, they can be useful for conservation and environmental monitoring in response to ecosystem change (Van Straalen et al., 2008; Ribeiro et al., 2009), since, they are sensitive to land use and pollution (Bispo et al., 2009). For this reason, some studies have used Collembola as bioindicators, to analyse the difference in species richness and species composition taking into account, the land use (Cassagne et al., 2006), climate change (Lindberg & Bengtsson, 2005) and the type of soil (Salmon et al., 2002).

Recent studies have been analysing functional traits of species and communities. However, there are still few studies that have been assessing functional traits of Collembola (Lindberg & Bengtsson 2005).

1.4. *The importance of working with functional traits*

The abundance of species and composition of communities (Vandewalle et al., 2010) have been used to compute biodiversity indexes, such as Margalef's richness index, Pielou's evenness index and Shannon diversity index (Laliberté & Legendre., 2010). Also, the functional diversity of Collembola communities (De

Bello et al., 2010; Vandewalle et al., 2010) can be useful to analyse the dynamic of community under ecosystem processes (Moretti et al., 2009). Furthermore, the abundance and diversity helps to define the functional traits of communities (De Bello et al., 2010).

A trait based analysis may be done calculating the mean trait value (mT) of community defined as the dominant traits in a community (Vandewalle et al., 2010). The mean value is calculated with relative abundance of each morphotype multiplied by the ecological morphological index (EMI) value of each morphotype. Likewise, the functional diversity (FD) can also be used to analyse environmental changes on dynamic species, ecosystem processes and ecosystem services (Laliberté & Legendre., 2010). Furthermore, the main principle to calculate FD is to understand the dynamic of the community under environmental changes (Lavorel et al., 2008 apud Vandewalle et al., 2010), analysing the dissimilarity of traits within species on community assembly, habitat and ecosystem or among regions with different biogeography (De Bello et al., 2009; Vandewalle et al., 2010).

To be resilient, a microarthropod community must have some functional traits, such as size, dispersal ability in a short distance, ecological features, life history traits, a diversity of species (local and alien species), life expectancy, reproductive strategies and “tolerance” (Lindberg & Bengtsson., 2005). In addition, the functional traits of soil organisms depend on the soil layer, habitat and environmental conditions. For this reason, functional traits as a bioindicator may support the assessment of the spatial resilience in soil microarthropod communities (Rantalainen et al., 2006). Even more, these traits may help in monitoring changes on soil ecosystem (Vanderwalle et al., 2010).

On the other hand, the majority of studies have focused more on abundance, diversity and function of Collembola on soil than their functional group (Rantalainen et al., 2006; Vandewalle et al., 2010). Over the last decade, some studies have begun to use traits of microarthropod communities to determine the dispersal ability and recolonisation of the microarthropod communities on soil disturbed areas (Lindberg & Bengtsson 2005; Vandewalle et al., 2010). However, there is still limited knowledge due to a lack of data for many species (Lindberg & Bengtsson 2005; Van Straalen et al., 2008; Vandewalle et al., 2010).

Even so, Collembola have an enormous potential for being used in biodiversity monitoring schemes (Van Straalen et al., 2008; Vandewalle et al., 2010). They may be classified according to different morphological characteristics such as: presence or absence of ocelli and hairs or scales, the size of antenna, the size of furcula and pigmentation features.

1.5. *Objectives and hypotheses*

The aim of the present study was to evaluate the influence of the spatial configuration of disturbance, according to the number of patches (disturbed areas versus non-disturbed patches), on the spatial resilience of a soil microarthropod (Collembola) community. Our working hypothesis were: (i) a higher number of patches will enhance recolonisation and spatial resilience on soil microarthropod (Collembola) communities in disturbed areas; (ii) the ability of species to recolonise disturbed areas will be influenced by morphological characteristics (in particular dispersal traits).

Chapter 2 Material and methods

2. Material and methods

2.1. *Study area*

The study was performed at the Botanical Garden of the University of Coimbra (40°12'19.22"N 8°25'29.23"W), from January to March 2012. Weather conditions during the study period (Table I) were obtained from the agro-meteorology information system of ESAC (Agricultural School of Coimbra).

Table I. Mean temperature (T), relative humidity (RH) and total precipitation (PPT) at the Coimbra Municipality between January and March 2012

Month	T(°C)	RH (%)	PPT (mm)
January	8,3	82,9	19,8
February	7,9	67	4,6
March	13,4	67,9	15

2.2. *Sampling design area*

The experimental design consisted in 3 blocks (replicates). In each block, 4 treatment areas were set, in which a disturbance was applied; these treatments had an area of $6m^2$ (3m x 2m) each and were 2m apart from each other. Each treatment had undisturbed isolated patches ("donor areas") in different numbers (0, 1, 2 and 4 patches, defined as MD, M1, M2 and M4 respectively); outside the treatments, the area was left undisturbed (ND) (Fig. 4). The sum of the total area of the patches was $1,44m^2$.

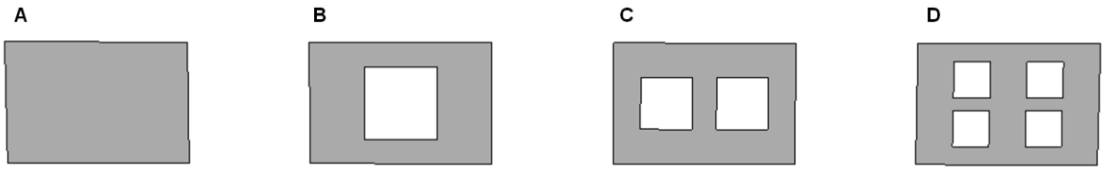

Figure 4. Experimental design; only one block is shown - disturbed area is presented in grey. A) Treatment with all area disturbed (MD). B) Treatment with 1 undisturbed patch (M1). C) Treatment with 2 undisturbed patches (M2). D) Treatment with 4 undisturbed patches (M4).

2.3. *Methodology used for disturbance*

Leaf litter was removed a week prior to disturbance from the area to be disturbed in each treatment and oven dried at 70°C for 2 hours (Fig. 5A). At the day of disturbance, about 6 litres/m^2 of water at 80°C (Fig. 5B) was applied onto soil (after which dried leaves were replaced to respective areas).

Figure 5. *A) Oven for drying leaves B) Camping stove for boiling water*

2.4. *Fieldwork and sampling*

Sampling took place over two periods: at the time of disturbance (10 minutes after disturbance, in order to verify its defaunation effect) and six weeks after disturbance (in order to survey the recolonisation of Collembola community).

At each sampling time, litter and soil samples (5cm depth, 5cm Ø) were collected using a soil core sampler. At the second sampling time, a set of pitfall traps (20ml cups filled with 80% ethanol, left in field for one week) were also set (the pitfall trap points were the same as the soil sampling point). A total of 48 soil samples/sampling time and 48 pitfall samples were taken in each block (Fig. 6): 25 samples on disturbed areas, 11 samples on the outer undisturbed area and 12 in donor patches.

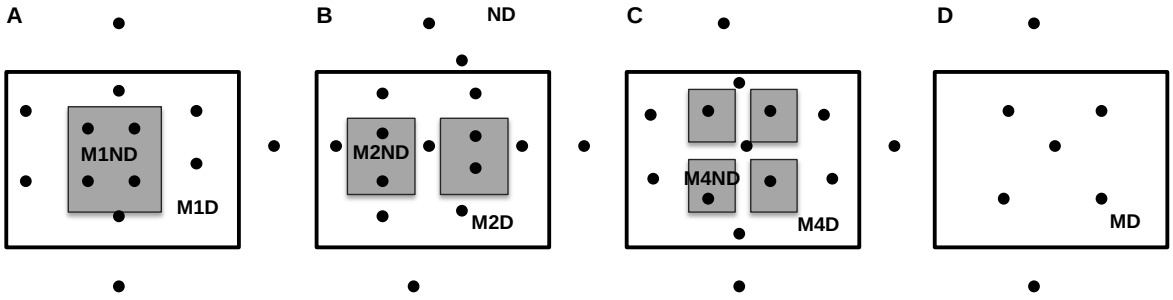

Figure 6. Sample points of soil and pitfall trap. Undisturbed treatment (ND), Disturbed treatment 1 (M1D), Undisturbed treatment 1 (M1ND), Disturbed treatment 2 (M2D), Undisturbed treatment 2 (M2ND), Disturbed treatment 4 (M4D), Undisturbed treatment 4 (M4ND), Disturbed treatment (MD)

2.5. *Soil fauna extraction*

Fauna from soil and litter samples was extracted using the Berlese Tullgren method (Fig. 7), submitting the samples to 45°C for ten days and collecting specimens in 80% ethanol.

Figure 7. Extraction of soil microarthropods using Berlese Tullgren method

2.6. *Collembola identification/classification*

Collembola were separated from other soil microarthropods and, afterwards, identified and classified into morphotypes according to Vanderwalle's scoring traits (Vandewalle et al., 2010) (Table II). The sum of the scores for each morphotype constitutes the ecomorphological index (EMI) of that morphotype. High, medium and low EMI values, were used to represent eu-edaphic (slow dispersers), hemi-edaphic (medium dispersers) and epigeic (fast dispersers) organisms, respectively.

Table II. Collembola traits and its score according to Vanderwalle (Vanderwalle et al., 2010)

Trait	Score	
Ocelli	2	Absent
	0	Present
Antenna length	4	Antenna is shorter than body length
	2	Antenna is half of body length
	0	Antenna is bigger than body length
Furca	4	Absent
	2	Reduced/short
	0	Fully developed
Hairs/Scales	2	Absent
	0	Present
Pigmentation	4	Absent colour (White)
	2	Coloured but not patterns
	0	Coloured and with patterns

In addition, morphotypes were characterised to differentiate adaptation levels of Collembola. High EMI values (MF13 – MF21), medium EMI values (MF8 – MF12) and low EMI values (MF1 – MF7) were used to represent eu-edaphic (Fig. 8A), hemi-edaphic (Fig. 8B) and endogeic (Fig. 8C) organisms, respectively.

Figure 8*. Examples of morphotypes found in A) Eu-edaphic Collembola (EMI:14) B) Hemi-edaphic Collembola (EMI:8) and C) Epigeic Collembola (EMI:2)*

2.7. *Statistical Analysis*

Collembola abundance and number of taxa at each treatment, block and type of sample (soil core/pitfall) were compared by a block ANOVA, followed by a

Newman-Keuls test when differences were found. Data was log transformed prior to analysis whenever normality or homoscedasticity criteria were not met (Zar, 1996).

The average mean, standard deviation and variance were also calculated using R software.

In order to observe the dominant community trait (epigeic, hemiedaphic or euedaphic) from disturbed and non-disturbed areas at each treatment, the mean trait (mT) and functional diversity (FD) was calculated for each treatment.

The diversity per treatment, type and block was computed in accordance to Margalef's, Pielou´s, Shannon and Simpson's indexes using PRIMER software (Clarke, 1993). Significant differences on community composition between disturbed and undisturbed patches at each treatment were assessed via an ANOSIM using the Bray-Curtis Similarity index. The contribution of morphotypes in the recolonisation (explaining dissimilarities observed) was analysed with SIMPER. These analyses were done both considering soil and pitfall data separately, with permutation-based hypothesis testing (ANOSIM) using one way factor treatment and two ways factors (treatment and block).

Finally, Principal Component Analysis (PCA) were performed on CANOCO 4.5 software (Ter Braak & Smilauer, 2002) using Collembola morphotype data from .soil and pitfall samples per treatment and block.

Chapter 3 Results

3. Results

3.1. *Abundance*

A total of 1164 Collembola individuals was found on soil samples from block 1 (24,25±18,64), 594 individuals (12,38±11,39) for block 2 and 357 individuals (6,69±8,02) for block 3. Regarding pitfall data, a total of 1267 Collembola individuals (26,40±18,69) was found in block 1, 642 individuals (13,38±8,87) in block 2 and 406 individuals (8,46±6,12).

The ANOVA revealed significant differences in the abundance of Collembola at different blocks and treatments. Regarding soil samples, differences between treatments were borderline (p=0,04), therefore the post-hoc test was not able to detect them. Regarding pitfall data differences were found between ND and M1D and M1ND, with the non-disturbed area outside (ND) having a higher abundance (Fig. 9).

3.2. *Morphotypes and biodiversity descriptors*

Regarding morphotypes of Collembola, a total of 21 were observed in the samples (Table III): 19 were found in soil and 16 in pitfall samples. In general, the number of morphotypes in pitfall samples was higher than in soil samples (Table IV). Block ANOVA did not reveal any differences between the numbers of morphortypes among treatments neither in soil nor pitfall samples. Only differences between blocks were found.

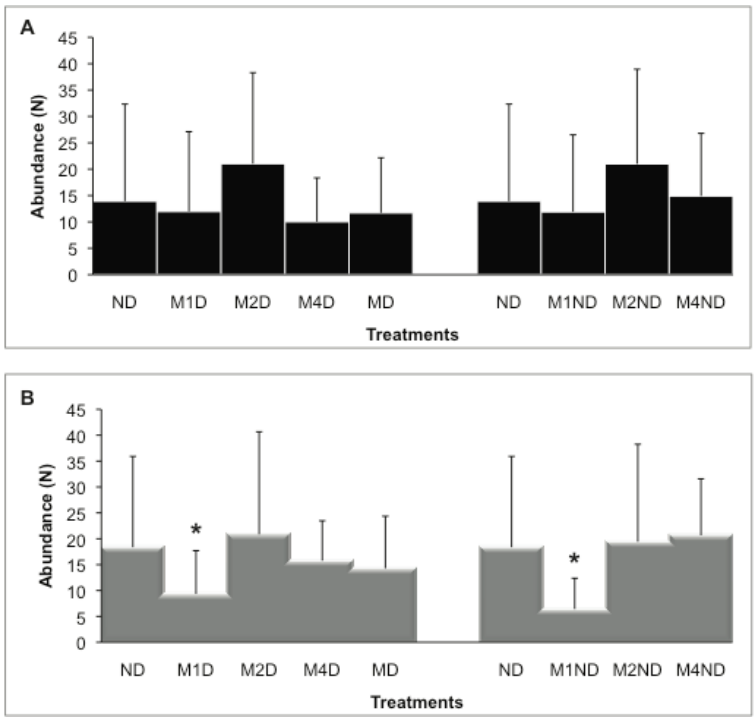

Figure 9. The abundance of Collembola per treatment A) in soil samples and B) in pitfall samples per treatment and block; asterisks indicate significant differences.

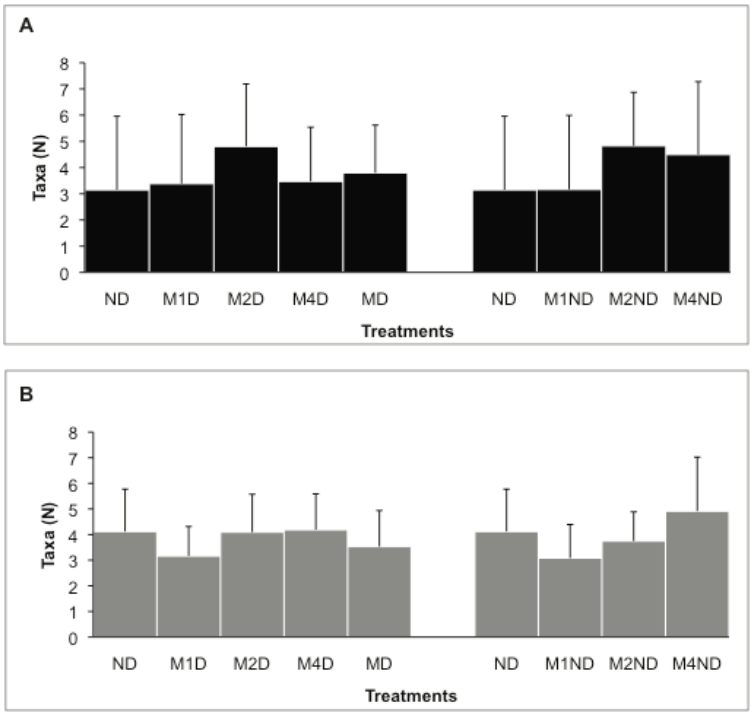

Figure 10. The number of morphotypes of Collembola per treatment A) in soil samples and B) in pitfall samples per treatment and block; asterisks indicate significant differences.

Table III. Morphotypes of Collembola collected and their eco-morphlogical index (EMI) score

Morphotype	Species	EMI
MF1	00002	2
MF2	02000	2
MF3	02020	4
MF4	04000	4
MF5	00420	6
MF6	02004	6
MF7	02022	6
MF8	02400	6
MF9	04002	6
MF10	04020	6
MF11	04200	6
MF12	02024	8
MF13	02402	8
MF14	04022	8
MF15	04202	8
MF16	04220	8
MF17	04400	8
MF18	04024	10
MF19	04222	10
MF20	24004	10
MF21	24404	14

Considering biodiversity descriptors (Table IV), no major differences were found neither between blocks nor treatments. No clear trends were found when comparing soil and pitfall data, neither when comparing the non-disturbed with the disturbed matrices among the different treatments.

Table IV. Biodiversity descriptors in each block per treatment and type of sample

Block	Type	Index	ND	M1D	M1ND	M2D	M2ND	M4D	M4ND	MD
Block 1	Soil	S	13	10	12	12	8	12	10	8
		N	303	154	109	243	131	73	69	82
		D(Margalef)	2,10	1,79	2,34	2,00	1,44	2,56	2,13	1,59
		J (Pielou)	0,72	0,75	0,61	0,67	0,73	0,75	0,76	0,81
		H (Shannon)	1,85	1,74	1,51	1,66	1,52	1,86	1,76	1,69
	Pitfall trap	S	11	8	7	10	8	10	12	9
		N	341	93	47	278	170	133	94	111
		D(Margalef)	1,71	1,54	1,56	1,60	1,36	1,84	2,42	1,70
		J (Pielou)	0,58	0,57	0,80	0,50	0,40	0,69	0,74	0,72
		H (Shannon)	1,38	1,19	1,56	1,16	0,84	1,58	1,83	1,58
Block 2	Soil	S	11	8	3	11	8	8	9	9
		N	119	43	11	144	52	104	74	47
		D(Margalef)	2,09	1,86	0,83	2,01	1,77	1,51	1,86	2,08
		J (Pielou)	0,63	0,76	0,78	0,64	0,64	0,62	0,75	0,84
		H (Shannon)	1,50	1,58	0,86	1,55	1,33	1,29	1,64	1,85
	Pitfall trap	S	8	5	5	7	6	6	6	5
		N	166	37	11	120	34	112	90	72
		D(Margalef)	1,37	1,11	1,67	1,25	1,42	1,06	1,11	0,94
		J (Pielou)	0,70	0,79	0,94	0,81	0,83	0,72	0,84	0,62
		H (Shannon)	1,46	1,28	1,52	1,57	1,48	1,28	1,50	1,00
Block 3	Soil	S	8	9	7	11	10	9	9	7
		N	38	19	23	55	69	34	36	47
		D(Margalef)	1,92	2,72	1,91	2,50	2,13	2,27	2,23	1,56
		J (Pielou)	0,94	0,91	0,79	0,87	0,82	0,91	0,97	0,87
		H (Shannon)	1,96	2,00	1,54	2,08	1,89	2,01	2,14	1,70
	Pitfall trap	S	9	6	7	6	5	8	5	6
		N	99	38	19	40	29	86	64	31
		D(Margalef)	1,74	1,37	2,04	1,36	1,19	1,57	0,96	1,46
		J (Pielou)	0,75	0,86	0,79	0,87	0,77	0,70	0,74	0,86
		H (Shannon)	1,66	1,54	1,54	1,56	1,23	1,45	1,20	1,54

3.3. *Trait based analysis*

The FD of each treatment (Table V) was higher in the communities found in soil samples (about 0.42 compared to the communities found in pitfall samples about 0.26). This trend was common to all treatments.

Table V. Functional Diversity (FD) of each treatment per type between blocks

	Block 1		Block 2		Block 3	
Treatment	Soil	Pitfall trap	Soil	Pitfall trap	Soil	Pitfall trap
ND	0,46	0,30	0,45	0,22	0,38	0,26
M1D	0,45	0,28	0,44	0,24	0,44	0,25
M1ND	0,46	0,37	0,32	0,34	0,33	0,25
M2D	0,44	0,26	0,43	0,23	0,44	0,27
M2ND	0,40	0,17	0,39	0,24	0,38	0,20
M4D	0,45	0,37	0,42	0,17	0,45	0,25
M4ND	0,41	0,34	0,46	0,23	0,42	0,24
MD	0,44	0,37	0,49	0,13	0,36	0,28

The mT values obtained at each treatment and at each block are shown in Table VI. A block ANOVA did not reveal any differences between treatments among soil samples. However, between pitfall samples significant differences were obtained. The outside non-disturbed matrix (ND) presented the highest mT value of all treatments, with significant differences found in all of them except on M2D and M4ND. The lower values obtained, especially on disturbed treatments, indicate that the community was dominated by species with higher epigeic characteristics (Fig. 11).

Table VI. Mean trait (mT) value at each treatment and at each block

Block	Treatment	Soil	Pitfall
Block 1	ND	33,97	21,42
	M1D	21,04	5,36
	M1ND	12,77	5,87
	M2D	23,34	19,48
	M2ND	9,81	7,57
	M4D	14,68	12,96
	M4ND	8,16	25,69
	MD	6,22	9,64
Block 2	ND	17,36	29,38
	M1D	13,14	2,79
	M1ND	0,82	1,26
	M2D	22,01	14,25
	M2ND	8,70	2,98
	M4D	11,34	5,39
	M4ND	20,05	5,43
	MD	16,58	4,52
Block 3	ND	8,20	13,79
	M1D	5,04	4,26
	M1ND	4,28	3,75
	M2D	24,89	5,20
	M2ND	19,06	3,15
	M4D	11,28	9,36
	M4ND	9,88	7,02
	MD	11,37	5,47

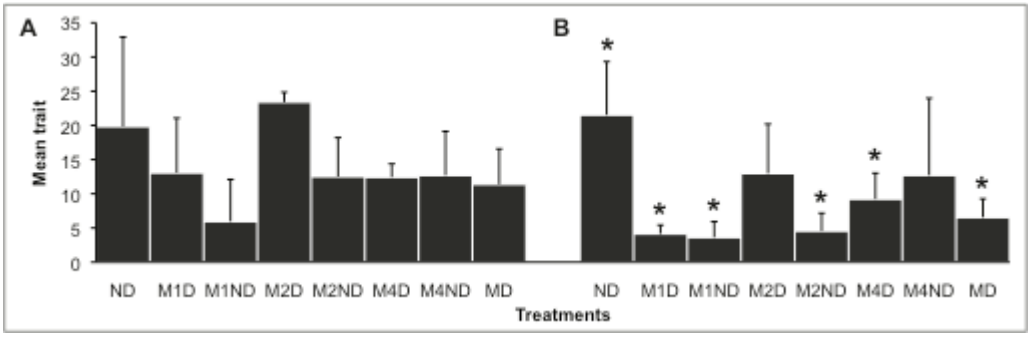

Figure 11. Mean trait (mT) value A) in soil samples and B) in pitfall samples at each treatment and at each block; asterisks indicate significant differences.

3.4. *Similarity between community composition*

Considering data obtained in soil samples, ANOSIM revealed no significant differences in community composition between non disturbed matrices outside (ND) and inside the disturbed areas (MxND). Regarding pitfall trap data, the only differences were found between ND and M1ND (Table VII).

Table VII. Similarity between ND and MxND in community composition

	Matrix	Soil	p-value	Pitfall Trap	p-value
Block 1	ND-MD	49,46	ns	43,35	Ns
	ND-M1D	52,48	ns	49,27	Ns
	ND-M2D	45,69	ns	44,58	Ns
	ND-M4D	56,80	ns	43,85	Ns
Block 2	ND-MD	69,00	ns	52,30	p<0,05
	ND-M1D	67,36	ns	55,58	p<0,05
	ND-M2D	61,39	ns	49,00	p<0,05
	ND-M4D	55,19	ns	37,13	Ns
Block 3	ND-MD	69,63	ns	62,14	Ns
	ND-M1D	78,02	ns	48,67	Ns
	ND-M2D	72,58	ns	55,07	Ns
	ND-M4D	86,86	ns	52,84	Ns

Comparing the community composition on soil samples between non-disturbed areas outside (ND) and disturbed areas (MxD) for each treatment at each block, also no significant differences were obtained. Regarding pitfall trap data, significant differences with ND were denoted only at MD, M1D and M2D (Table VII). Contrary what was expected, there was no clear trend in the decrease of dissimilarity values with the increase of the number of donor patches inside the disturbed areas. The only block where that occurred was in block 2.

Table VIII. Similarity between ND and MxD in community composition

	Matrix	Soil	p-value	Pitfall Trap	p-value
Block 1	ND-M1ND	50,35	ns	54,89	ns
	ND-M2ND	48,19	ns	40,75	ns
	ND-M4ND	54,07	ns	41,82	ns
Block 2	ND-M1ND	65,83	ns	73,60	p<0,001
	ND-M2ND	58,59	ns	54,47	ns
	ND-M4ND	61,81	ns	33,05	ns
Block 3	ND-M1ND	73,49	ns	51,98	ns
	ND-M2ND	79,60	ns	46,82	ns
	ND-M4ND	70,67	ns	49,09	ns

Chapter 4 Discussion and conclusion

4. Discussion and conclusion

Analysing the results obtained in this study, in spite of the significant differences obtained for Collembola abundance at different blocks and treatments, these were not translated in terms of morphtype diversity (at least for treatments) nor on major biodiversity descriptors. The lack of a clear trend amongst treatments suggests the disturbance didn't cause the significant effect expected. A possible explanation for the lack of effectiveness in disturbance may have to do with Collembola life-cycle. The reproduction of Collembola is rapidly and takes just around 3 to 5 weeks from hatching to adult stage. These organisms have moult period all their life (Zeppelini & Carvalcante, 2004). The feeding and moulting of Collembola is influenced by temperature (Worland & Convey, 2008).

On the other hand, Collembola are known to be sensitive to environmental conditions. Changes in variables such as soil cover or soil structure can have an effect on Collembola distribution.

Collembola are sensitive organisms to environmental changes which decrease the abundance and composition of Collembola such as fire (Malmström, 2012) and drought (Lindberg & Bengtsson 2006). The anthropogenic activities as tillage operation (Larsen et al., 2004) have also influence in the low rate of Collembola when has been changed the soil structure. Further, contamination also decreases the number of individuals of Collembola (Chauvat & Ponge, 2002)

Some studies have demonstrated that the disturbance levels influences the abundance and composition of Collembola community. In the study of Cassagne the richness and abundance of Collembola decreased in response to the human

disturbance (Cassagne et al., 2006). Lindberg and Bengtsson, when analysing the response of Collembola populations after drought, found that the most sensitive species to drought were living deeper in the soil.

The effect of soil structure on Collembola was addressed by Larsen (Larsen et al., 2004), who found a negative relation between soil compaction and the abundance of Collembola. Likewise, other disturbance as a tillage operation influence in the soil compaction (Dittmer & Schrader, 2000).

Regarding community composition, functional diversity differences between soil and pitfall samples may reflect the morphotypes caught by each sampling method. Pitfall traps “target” epigeic organisms (Querner & Bruckner, 2010), who, in general, have lower EMI values; on the contrary, soil cores can extract the deeper burrowing organisms (eu-edpahic), which generally have traits with higher EMI scores (Vandewalle et al., 2010). Dispersion and recolonisation rates may be influenced by species responses, which depend on life history characteristics and traits related to mobility and habitat requirements. (Lindberg & Bengtsson, 2006); Collembola communitis of deeper soil layers are considered poor dispersers (Rantalainen et al., 2006), opposite to fast dispersers which are generally epigeic. In this study, fast dispersers were expected to be found on disturbed areas samples but, with the exception of block 2 where treatments with lower number of patches were significantly different in community composition from the undisturbed area, the selected disturbance (draught) didn’t seem to cause a strong disruption on these soil communities.

Conclusion

Although there were no clear trends found in this study, disturbance in soil communities, namely draught, should be further investigated,. The extension (both in time and space) of the disturbance can play a key role in defining the recolonisation process after draught. Disturbances enrolling soil structure variables (such as compaction) may induce even further disruptions and should be considered in possible future research scenarios.

Habitat fragmentation or the number of donor patches in a disturbed area can be a possible factor promoting a faster recolonisation, increasing the spatial resilience of Collembola communities. Even though that wasn't visible in terms of representation of the deeper soil communities, the epigeic communities surveyed in this study gave good indications of how this process seems to be facilitated when the donor patches' area is more evenly distributed along the disturbed area.

Nevertheless, others factors appear to influence the recolonisation process, namely vegetation cover (which can act as a shelter provider, but also as by adding leaf litter to the system providing a food source for detritivore Collembola). Collembola life history traits and their relation with their environment should, therefore, be taken into consideration when studying their behaviour and response to environmental stress or disturbance.

Chapter 5 References

5. References

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