From a green perspective: management pressures on forest ecosystems from Danube Delta Biosphere Reserve linked with soil mesofauna dynamics and foliar gas - exchange parameters

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Abstract The investigation carried out in one of the most important wetland zone with an international value - Danube Delta Biosphere Reserve aims to assess ecological status of forest ecosystems under different management and climatic conditions. Ecophysiological analysis of plant communities to evaluate their adaptation status together with qualitative and quantitative aspects of soil mesofauna for understanding the indirect and direct effects of forest management practices were approached. Four sites located in northern part of Danube Delta were studied - two natural forests, one of them being a strictly protected area of national interest corresponding to IUCN category I and the other one a forest with native species as *Populus alba* and *Salix alba*. For comparison two forest plantations (*Populus x canadensis* and respectively *S. alba*) were also analyzed. Significant differences were found in gas-exchange parameters (photosynthesis, respiration, stomatal conductance), water use efficiency and relative water content in species from plantations versus natural forests, especially in drought period. The results highlighted the major influence of climatic conditions that occurred during the study period on edaphic mesofauna. Under the influence of drought and high temperatures were found significant changes in terms of global abundance, weight of systematic / trophic groups and spatial distribution of mesofauna.

Keywords: Danube Delta Biosphere Reserve, forest ecosystem, edaphic mesofauna, gas - exchange parameters

1. Introduction

Protected areas are essential to the conservation of natural heritage because their capital includes the most representative and significant areas in terms of biodiversity. Danube Delta was designated as a reserve by the Romanian Government in 1990, decision confirmed through law 82/1993 by the Romanian Parliament. Its universal value was recognised in 1990 by the Man and Biosphere Programme of UNESCO through its inclusion in the international network of biosphere reserves. The Management measures in these areas were developed and implemented as to maintain or to restore - where it is appropriate, the natural ecosystems and populations of wildlife at the same time maintaining or looking for the appropriate solutions for sustainable use of natural resources. Biosphere reserves are those protected areas with the precise scope of preservation of natural habitat areas and specific biological diversity. Forestry management actions were made in Danube Delta after 1960 and included embankments, grubbing and instead planting of some willow species and Canada poplar, followed by ash, white poplar, black poplar, grey poplar. These interventions were made for economical reasons, ignoring ecological aspects, e.g., that flora diversity provide habitats for deltaic fauna. In this study two natural forests and two plantations were compared from below ground and above ground perspective. Both soil mesofauna and ecophysiological parameters of plant communities were evaluated to obtain indication on ecosystem status. The influence of climatic factors is also discussed . In a previous study a comparison was made between soil mesofauna from these natural and anthropogenic forests which constituted the starting point for the present work (Călugăr & Ivan 2016).

2. Materials and methods

2.1 Study sites

The study was carried out in four different forest ecosystems (two natural forests and two forest plantations) located on the D.D.B.R. territory:

1- Letea - Hășmacul Mare (45°36′71.16″N 29°54′65.07″E), a fully protected area of national interest corresponding to IUCN category I. In Letea area 132 species of vascular plants included in the Red List are cited, and grouped into the following categories of danger: Ex. (extinct) - 20 species (possibly retrievable); E (endangered) - 7 species; V (vulnerable) - 8 species; R (rare) - 20 species; I (indeterminate) + K (insufficiently known) - 64 species; I? (possibly erroneously determined) - 13 species. Woody vegetation is represented by phytocenosis with *Quercus robur* + *Q. pedunculiflora* and *Fraxinus pallisae* + *F. angustifolia* + *Q. robur* phytocenosis. The presence of *Vitis sylvestris* and *Periploca graeca* lianas lends luxuriant aspect of Letea forest (Oțel 2000).

2 - Plauru I (45°17′42″N 28°53′42″E) a natural forest with *Populus alba*, *Salix alba* and with small areas of *P. x canadensis* along waterways;

3 - Plauru II (45°16′31.4″N 29°39′21.8″E) - plantation of *P. x canadensis*;

4 - Plauru II (45°16′31.4″N 29°39′21.8″E) - plantation of *S. alba*.

2.2 Sampling and extraction

Gas-exchange parameters were measured by a photosynthesis portable system in the study sites (LCi ADC Bioscientific, UK). Leaf relative water content (RWC) or turgidity method was investigated, according to Smart and Bingham (1974).

For investigation of edaphic microarthropods two series of samples were collected in July 2015 and May 2016. Series of samples of 100 cm^2 each were taken at two different levels – Olf (litter and fermentation layer) and Ah (humification layer), with one exception, that of Plauru I. This forest was flooded in May 2016, so the sampling was done on one level. The extraction of the edaphic mesofauna was made by Tullgren – Berlese method, than it was sorted on groups.

2.3 Data analysis

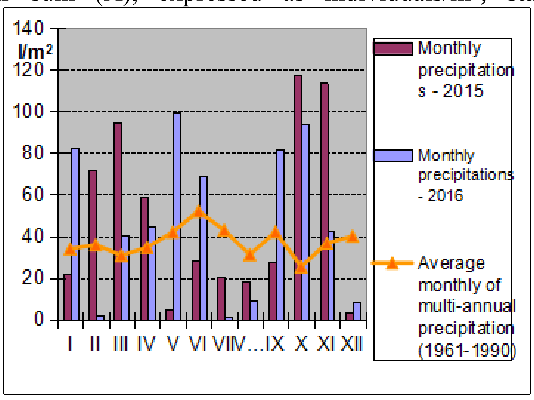
The student's *t-Test* and the one-way analysis of variance (ANOVA) were used to evidence any significant difference among investigated sites in terms of gas-exchange parameters ($\alpha = 0.05$ level of significance).

The analysis of the edaphic mesofauna was done on the base of the following parameters: average abundance ($\bar{a}$) of every identified group in each soil layer (Olf and Ah) and their sum ($\bar{A}$), expressed as individuals/m^2; standard deviation (σ) and Pearson's coefficient of variation (cv%) of $\bar{A}$.

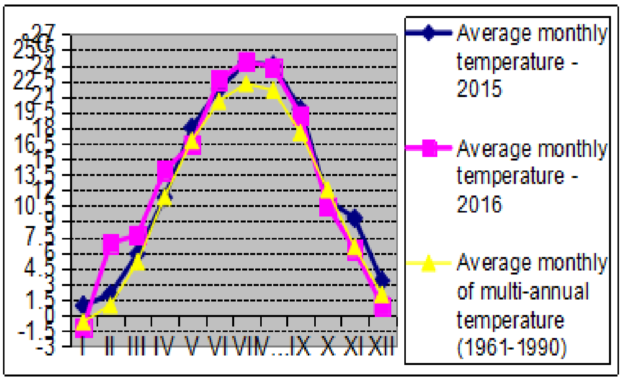
2.4 Climatic data

The main climatic factors (temperature and precipitation) for 2015 and 2016 were provided by National Administration of Meteorology; the average monthly multi-annual precipitation and temperature are obtained from the web address: http://meteoplus.antena3/statistics.ro. The dynamics of these factors is represented in Fig. 1, with sampling period indicated by frame.

Total precipitations recorded especially in May, respectively June of the two years differ substantially, being deficient in 2015 and excessive in 2016, compared to the multi-annual average (Fig. 1a). Thus, in May and June 2016 total rainfall was over 10 times higher, respectively 2 times higher than in the same months of 2015; in April precipitation amount exceeded the multi-annual average in both years, while in July the deficit was recorded also in both years. In terms of average monthly temperature, we observed that the values are very close in these two years but higher than the multi-annual average during the summer months (Fig. 1b). Therefore, is noticed starkly different climate conditions in the periods when field investigations and sampling were conducted (July 2015 and May 2016). The current study attempts to highlight even responses and traits of certain components of forest ecosystems in such conditions, depending on the management measures.



1.a.



1.b

Figure 1. Dynamics of precipitation level (a) and temperatures (b) in the study area

Table 1 Summary of ANOVA results comparing physiological leaf parameters among the investigated sites at *Populus alba*

	Ecophysiological parameter	Natural forest		Plantation		Plantation X natural forest	
		F	p-value	F	p-value	F	p-value
Spring floods period-May	A	0.06	0.93	7.9	0.01	15.48	<0.0001
	E	310	<0.0001	471	<0.0001	596	<0.0001

	R	25.7	<0.0001	874	<0.0001	59	<0.0001
	gs	498	<0.0001	532	<0.0001	0.06	0.795
	WUE	97.36	<0.0001	9.13	0.008	49.7	<0.0001
	RWC	2.81	0.110	0.178	0.677	2.30	0.146
Drought period - July	A	14.8	0.001	266	<0.0001	5.15	0.03
	E	38.03	<0.0001	471	<0.0001	596	<0.0001
	R	847	<0.0001	13.09	0.001	309	<0.0001
	gs	43.47	<0.0001	121	<0.0001	91.95	<0.0001
	WUE	0.83	0.371	23.9	0.0001	7.89	0.01
	RWC	2.06	0.167	8.01	0.01	5.9	0.02

Legend: A - rate of photosynthesis, E - rate of transpiration, R - rate of respiration, gs - stomatal conductance, RWC - relative water content, WUE - water - use efficiency, F crit = 4.41, α= 0.05.

Table 2 Summary of ANOVA results comparing physiological leaf parameters between natural forest and plantation in *Populus x canadensis* and *Salix alba*

Spring floods period - May	**Ecophysiological parameter**	***P. x canadensis***		***S. alba***	
		F	**p-value**	**F**	**p-value**
	A	2.06	0.168	43	<0.0001
	E	297	<0.0001	36.87	<0.0001
	R	7.161	0.01	74	<0.0001
	gs	5.87	0.02	6.9	0.01
	RWC	17.97	0.0006	1.26	0.27
	WUE	34.19	<0.0001	2.16	0.160
Drought period - July	A	29.29	<0.0001	61.96	<0.0001
	E	125	<0.0001	54	0.0006
	R	93.29	<0.0001	47	<0.0001
	gs	1.012	0.327	14.61	0.001
	WUE	0.04	0.83	26.29	<0.0001
	RWC	2.138	0.160	44.59	<0.0001

Legend: A - rate of photosynthesis, E - rate of transpiration, R - rate of respiration, RWC - relative water content, WUE - water - use efficiency, gs - stomatal conductance, F crit = 4.41, α= 0.05

3. Results and discussion

Statistical analysis of almost all studied ecophysiological parameters among natural forest with nature reserve groups revealed the significant differences ($0.0001 \geq P \leq 0.001$) in *P. alba*, with some exceptions such as: A and RWC (May) and respectively, RWC and WUE (July) (Table 1). Plantations were showed statistically significant differences with natural forest and as well as nature reserve. High significant differences ($P \leq 0.05$) were observed for A, E, R, WUE (both studied period) at interaction groups (plantation with natural forest) (Table 1). At *Populus x canadensis*, statistical analysis showed a strong difference for E and R between natural forest and plantation in both studied periods (Table 2). In May, differences between natural forest (Plauru I) and plantation (Plauru II) groups in *Salix alba* were statistically significant for A, E, R and gs and not significant differences were observed for RWC and WUE. In spring floods, at *Salix alba* were observed statistically not significant differences in relative water content and water-use efficiency but in drought period (July) the differences were highest in all studied parameters between plantation with natural forest groups (Table 2).

The investigations concerning edaphic mesofauna consisted in analysing four groups of mites (Mesostigmata, Trombidiformes, Oribatida, Astigmatina), one order of Entognatha (Collembola), insects and some other groups (Table 3). Among these, Acari and Collembola were the dominant groups both in natural forests and plantations. The insects held low densities in all investigated stands, for both studied years. Overall densities of the soil mesofauna suffered a significant decrease in 2016 comparatively with 2015 (6.9 times lower) only in the flooded forest from Plauru I, fact which shows that excessive humidity constitutes a limiting factor.

The vertical distribution of the mesofauna exhibited variation in relation with different climate conditions in the sampling periods. In the year 2015, with low precipitations amount, a mesofauna migration in the depth, was observed in all investigated stands. (in Ah layer 67-97% of the individuals were found). In the next year, with high precipitation amount a higher population of the litter and fermentation layer, with one exception, that of Plauru II - *Populus x canadensis* where it was observed a reverse situation, with 58% of the effectives in the deeper layer. Here the Oribatida and Collembola which dominated the communities of edaphic mesofauna were the main contributors to the overall abundance curve (Table 3, Fig. 3).

Among soil mites Oribatida is distinguished as the most abundant group (65-96% of total mites) and also one of the best represented microarthropod groups (31-73% of total mesofauna), both in natural forests and in plantations (Table 3, Fig. 2). Average abundance ranges widely from one site to another, depending on specific bio-edaphic stand conditions. Thus, in the summer of 2015, in conditions of drought and high temperatures (Figs.1a, b), were recorded close density values of oribatid mites except poplar plantation, where abundance was lower. In all investigated sites, both plantations and natural forests, mainly populating of deep humic layer was noted, so only 2.16-45.14% of individuals were found in the surface layer of litter and fermentation; vertical migration of oribatids was more pronounced in forest plantations (Fig. 3). In the spring 2016 with surplus rainfall (Fig.1a) the oribatid abundance values were lower, except poplar plantation, where it increased by about 51%; especially in Plauru I forest, flooded in the sampling period, density reduction was severe - 5.6 times (Table 3). In the two plantations at Plauru II large differences of oribatid abundance were recorded, and also a different dynamics of it; given the close proximity of the two stands, the litter quality that determines proliferation of specific microflora could explain these differences. Regarding the vertical distribution it was observed its change from the previous year, 69-76% of individuals being identified in the surface layer, except the poplar plantation, where only 35% of individuals were found in the litter and fermentation layer (Table 3, Fig. 3).

Collembolans, the second most abundant group of edaphic microarthropods have densities that vary widely from one stand to another, representing between 14.4 and 58% of the total mesofauna. As in the oribatid mites, no differences between natural forests and plantations were observed in terms of quantitative parameters (Table 3, Fig. 2). Vertical distribution was as follows: 3.6-21.9% of individuals in the surface layer in July 2015 and 42.6-73.6% in May 2016; it is similar to that of most microarthropods and reflects the impact of climatic factors, particularly temperature and humidity (Fig. 3). Dynamics analysis of collembolans and oribatid abundance in the two-year study shows that in the sites where the oribatid density increases, a decrease of collembolans occurs and vice versa, except the Plauru I forest, where excessive humidity became a limiting factor, affecting nearly all groups of microarthropods (Table 3). This illustrates complementarity of the two groups within the trophic level of detrito-microphytophages. The ratio Oribatida / Collembola was predominantly supra-unit, but in some stands (Letea, Plauru II - poplar plantation) was found a reversal favouring one or the other group, as an indication of their different response to changing habitat conditions (Jeffrey *et al* 2000). Mesostigmata which is an important group of predator mites representing 1-23% of total mites depending on stand conditions. The drought and high temperatures recorded in summer 2015 strongly affected mesostigmata whose proportion within Acari was very low (Figs. 1, 3) In the next year in the stands where excessive humidity occurs (Plauru I especially), very low densities were found and also high values of Pearson's coefficient of variation which indicate an aggregate distribution of these mites (Table 3).

Conclusions

Ecophysiological behavior of poplar stands (*P. alba*, *P. x canadensis* clone) important for water management in riparian forest showed that some parameters values are close in natural forest and plantations or even in nature

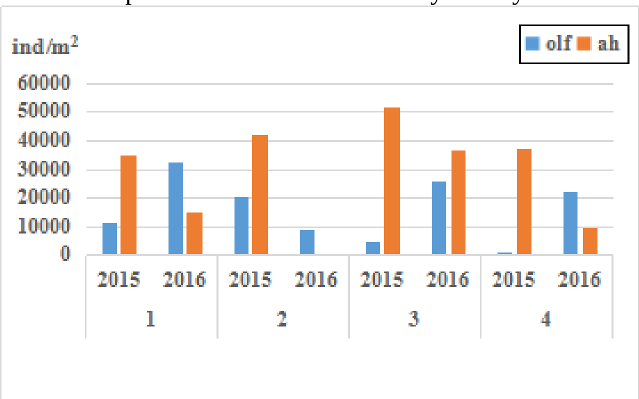


Figure 3. Evolution of the microarthropods densities by soil layers - Olf - litter and fermentation layer ; Ah - humiferous layer

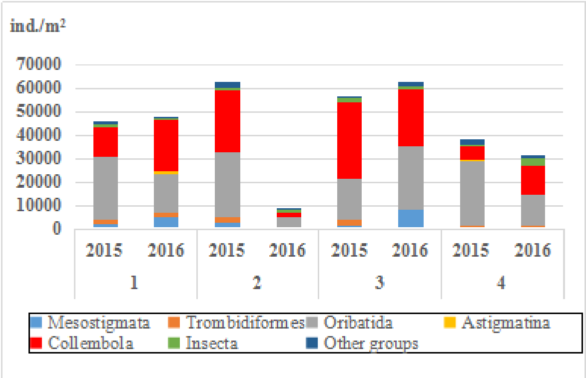


Figure 2. Average abundance of the main microarthropod groups

Table 3 Average density and vertical distribution of the most abundant microarthropod groups

Taxa	Year	Soil layer	1	2	3	4
Mesostigmata	2015	ā (Olf)	540	600	140	20
		ā (Ah)	1480	1720	1380	800
		Ā±cv	2020 ± 76.59	2320 ± 21.36	1520 ± 55.10	820 ± 84.98
	2016	ā (Olf)	4140	60± 133.33	4360	200
		ā (Ah)	900		3760	60
		Ā±cv	5040± 48.91		8120±40.61	260±107.69
Oribatida	2015	ā (Olf)	6160	12360	2100	600
		ā (Ah)	20720	15020	15460	27200
		Ā±cv	26880 ± 51.52	27380 ± 40.5	17560 ± 15.85	27800 ±35.58
	2016	ā (Olf)	12240	4860±96.33	9280	9160
		ā (Ah)	3820		17240	4100
		Ā±cv	16060± 83.55		26520±46.5	13260±34.55
Total Acari	2015	ā (Olf)	7900	14660	2720	680
		ā (Ah)	23160	17900	18460	28860
		Ā±cv	31060 ± 50.94	32560 ± 37.78	21180 ± 21.57	29540 ± 35.73
	2016	ā (Olf)	18960	5040±91.38	13900	9920
		ā (Ah)	5600		21200	4660
		Ā±cv	24560± 68.27		35100±40.94	14580±37.74
Collembola	2015	ā (Olf)	2780	4640	1740	200
		ā (Ah)	9920	22240	31240	5320
		Ā±cv	12700 ± 71.66	26880 ± 36.88	32980 ± 67.95	5520 ± 27.26
	2016	ā (Olf)	12860	1740±63.54	10600	9040
		ā (Ah)	9140		14240	3240
		Ā±cv	22000± 49.88		24840±30.32	12280±88.09
TOTAL	2015	ā (Olf)	11220	20580	5060	1080
		ā (Ah)	34820	42060	51720	37200
		Ā±cv	46040 ± 50.32	62640 ± 34.40	56780 ± 40.36	38280 ± 29.01
	2016	ā (Olf)	32520	9020±72.09	26060	22440
		ā (Ah)	15080		36880	9340
		Ā±cv	47600± 53.82		62940±33.97	31780±43.23

Legend: 1 - 4 - sampled stands (see § Material and method); ā - average abundance on each group (individuals/m^2)/soil layer; Ā - global average abundance (individuals/m^2); cv - Pearson's coefficient of variation (%), Olf - litter and fermentation layer and Ah - humiferous layer.

reserve (not statistically significant differences) such as: photosynthesis, water-use efficiency and relative water content. The significant differences were revealed in plantations with *S. alba* and *P. alba* at almost all investigated ecophysiological parameters, especially in drought period.

Dynamics of the numerical ratio between the main detritophagous groups indicate that in decomposition of organic matter, humification and mineralization processes are prevalent in certain periods, depending on the climatic factors.

Acknowledgements

This study was supported by the BIODIVERS research program, coordinated by NIRDBS Bucharest and funded by the National Authority for Scientific Research and Innovation. Special thanks are due to Dr. M.V. Bîrsan from National Administration of Meteorology for providing climate data for 2015 and 2016 recorded in the study area.

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