Transitional Waters Bulletin
TWB, Transit. Waters Bull. 3(2007), 51-55
ISSN 1825-229X, DOI 10.1285/i1825229Xv1n3p51
http://siba2.unile.it/ese/twb

RESEARCH ARTICLE

Ecosystem processes: litter breakdown patterns in Mediterranean and Black Sea transitional waters

F. Sangiorgio[1], A. Basset[1], M. Pinna[1], L. Sabetta[1], M. Abbiati[2], M. Ponti[2], M. Minocci[3], S. Orfanidis[4], A. Nicolaidou[5], S. Moncheva[6], A. Trayanova[6], L. Georgescu[7], S. Dragan[7], S. Beqiraj[8], D. Koutsoubas[9], A. Evagelopoulos[9], S. Reizopoulou[10]

[1]Di.S.Te.B.A., Univ. of Salento, SP Lecce Monteroni, 73100 Lecce, Italy
[2]Inter. Centre of Res. for Environ. Scie., Univ. of Bologna, Italy
[3]Dep. of Biol., Univ. Trieste, Italy
[4]National Agricultural Research Foundation, Kavala, Greece
[5]Dep.of Zoology and Marine Biology, University of Athens, Greece
[6]Institute of Oceanology, BAS, Varna, Bulgaria
[7]Eur. Excell. Centre for Environ., Univ. Dunarea De Jos, Galati, Romania
[8]Faculty of Sciences, University of Tirana, Albania
[9]Dep. of Marine Sciences, University of the Aegean, Mytilini, Greece
[10]Inst. of Ocean., Hellenic Centre for Marine Research, Anavyssos, Greece

Abstract

1 - Leaf litter decomposition rates, in aquatic ecosystems, are known to be related to many different abiotic and biotic factors.

2 - Here, we focus on the influence of abiotic factors, searching for patterns of reed litter decay rates on gradient of physiographic, hydrological and physico-chemical components of transitional water ecosystems.

3 - Field experiments were carried out in 16 water ecosystems in the Eastern Mediterranean and Black Sea in spring 2005.

4 - Significant differences of leaf litter decomposition were observed among ecosystems along univariate gradient of tidal range, index of sinuosity, water temperature and salinity. At least 71% of variance in the litter breakdown rate was explained by the considered abiotic factors.

5 - It is concluded that, at the macro-ecological scale of study, some key abiotic factors, such as tidal range and salinity, are suggested to play a major role as drivers of plant detritus decomposition processes.

6 - The relevance of the described abiotic drivers as descriptor of the most commonly used classification schemes for transitional water ecosystems (i.e., Confinement and Venice System classifications), is a further support to their role as environmental forcing factors.

Introduction

In transitional aquatic ecosystems, only a small part of aquatic macrophyte production is directly consumed by herbivores, and a large part of the macrophyte biomass has a major function in the detritic pathway (Webster and Benfield, 1986). Inputs of litter from littoral-emerged macrophytes are made available through decomposition processes and have been cited as a major source of energy for these ecosystems (Valiela, 1984), which are ecotones functionally connecting the land and its rivers on one side and the sea on the other. Litter decomposition rates, in aquatic ecosystems, are known to be related to many different abiotic and biotic factors (see Webster and Benfield, 1986) and have been widely studied in streams (Pinna *et al.*, 2003) and lakes (Gupta *et al.*, 1996); while studies on litter decomposition in transitional waters are less common (Bayo *et al.*, 2005). In this type of ecosystems, plant litter decomposition can be highly variable from site to site in relation to many different factors (Sangiorgio *et al.*, 2004); for example, *P. australis* decomposition has been found to vary with water nutrients in Mediterranean coastal lagoons (Menéndez *et al.*, 2004), and water salinity in coastal wetlands (Mendelssohn *et al.*, 1999).

Here, we propose a study of decomposition processes of plant detritus in transitional waters with a macro-ecological approach in the Eastern Mediterranean and Black Sea region. *Phragmites australis* ([Cav] Trin ex Steud.) decay rates were studied, searching for abiotic indirect drivers of plant detritus decomposition in transitional waters, even though biotic factors are known to be the direct agents of decomposition. The aims were: 1. to identify spatial patterns of *P. australis* leaf decomposition among ecosystems; 2. to analyse the relationships between reed decomposition and potential driving abiotic factors; 3. to evaluate the relevance of these abiotic factors as potential indirect drivers of decomposition processes in transitional waters.

Material and methods

The study took place in the Central, Adriatic, Danubian and South-Eastern European Space (see www.twreferencenet.com) including 16 ecosystems: Leahova and Sinoe in Romania; Grado Marano, Grado fish farm, Grado Cavanata, Pialassa Baiona, Margherita of Savoia, Torre Guaceto, Cesine and Alimini in Italy; Varna in Bulgaria; Patok, Karavasta and Narta in Albania; Agiasma and Kalloni in Greece.

Ecosystems' physiographic, hydrological features (*i.e.*, area, depth, index of sinuosity, outlet length, outlet width and tidal range), water parameters (*i.e.*, dissolved oxygen, pH, water salinity and temperature) and nutrient (*i.e.*, ammonium, nitrite, nitrate and phosphate) were recorded in each lagoon. Detritus processing was studied on leaves of *Phragmites australis* using the litter bag technique (Shanks and Olson, 1961) in spring. Litter bags were filled with 3.000$\pm$0.005g of oven-dried leaves (60°C, 72h), placed at each sampling site (5 replicates) and retrieved after 30 days. In laboratory, leaves were washed, dried (60 °C, 72 h), weighed and combusted (500°C, 6h) to obtain the ash content. An estimate of the initial ash free dry mass was determined on sub-samples.

Dry mass loss per day was used as estimate of litter breakdown and was calculated assuming an exponential decay model (Petersen and Cummins, 1974). One-way ANOVA was used on abiotic and decay rate data to test significant differences among ecosystems. Multi-Dimensional Scaling (MDS) analysis was performed on abiotic data, and Ordinary Least Square (OLS) regressions were calculated between leaf mass loss per day and abiotic variables. Potential sources of litter decomposition variation were evaluated by Stepwise multiple regression analysis.

Results

Ecosystems differed for physiographic, hydrological features (one-way ANOVA, $F_{5, 90} = 5.56$, $P < 0.001$) and water physico-chemical parameters (one-way ANOVA, $F_{7, 120} = 19.32$, $P < 0.001$).

Considering all characteristics, three groups of lagoons were derived from MDS analysis (ANOSIM, R = 0.97, P<0.01). Grado Marano and Sinoe with the highest surface area (average = 135.8 kmsq) separated from the other lagoons in a first group; Leahova, Torre Guaceto and Cesine, that together with Sinoe were the four ecosystems with the lowest water salinity (average = 2.93‰), constituted a second group, and the remaining ecosystems separated in a third group (Figure 1).

Overall, leaf mass loss per day was on average of 1.93 + 0.28%, and varied significantly among ecosystems (one-way ANOVA, F15, 56 = 7.1; P < 0.001) (Table 1).

On univariate scale, P. australis leaf mass loss per day increased with tidal range (P < 0.01), index of sinuosity (P < 0.05) and water temperature (P < 0.01), and decreased with water salinity (P < 0.05) (regression analysis, OLS). Taking account of the subset of sampling sites in which nutrients were analysed, reed mass loss per day co-varied positively with ammonium (P < 0.01) and nitrite (P < 0.05).

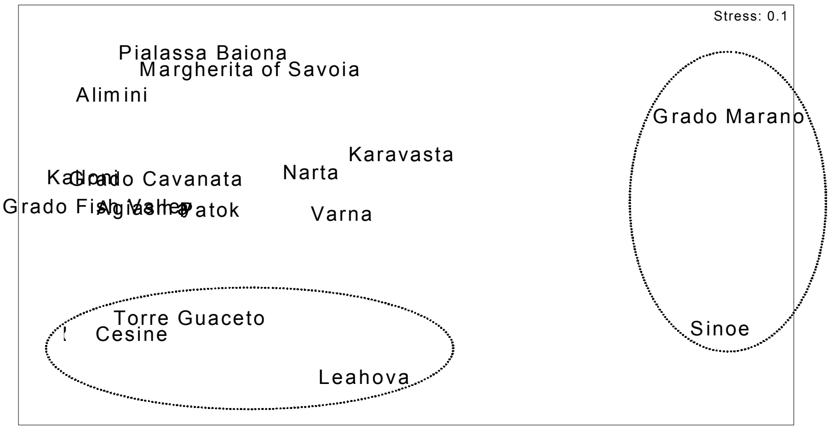

Figure 1 – MDS ordination of the sixteen ecosystems based on Euclidean distances of physiographic, hydrological and physico-chemical characteristics.

Considering all ecosystems, at least 71% of reed breakdown variance was explained by five abiotic characteristics (Stepwise multiple regression analysis, $r^2 = 0.71$, $P < 0.01$; n = 16): tidal range (beta = 0.40), index of sinuosity (beta = 0.55), depth (beta = - 0.30), temperature (beta = 0.29) and salinity (beta = - 0.27). As regards the ecosystems selected on the basis of MDS analysis (see Fig. 1), at least 65% of reed breakdown variance was explained by the same ecosystems' characteristics with exclusion of salinity (Stepwise multiple regression analysis, adjusted $r^2 = 0.65$, $P < 0.05$; n = 11).

Discussions and conclusions

Comparative studies of organic matter decomposition rates have been conducted for many years, mainly in terrestrial ecosystems (Aerts, 1997) and rivers (Covich, 1988). In the present study, even though all ecosystems were included in the fast category of litter breakdown rates (see Petersen and Cummins, 1974), significant patterns of variation in litter decomposition were seen on the macro-ecological scale. Here, spatial patterns described for *P. australis* leaf breakdown were unlikely to be due to methodological biases arising from the experimental treatment of the leaf material (Newell, 1996); we collected all leaves at the same time and from the same area at the beginning of autumn, we cut off the basal and apical parts of all leaves, and we used only the central leaf section for leaf packs.

Variations of plant detritus decay rates in relation to abiotic factors, as observed in this work, have been considered (see Webster and Benfield, 1986) and the relevance of microorganisms and benthic invertebrates as real agents of decomposition is well established (Saunders, 1980).

However, the distribution and activity of these two groups of organisms are affected by various abiotic variables, which in turn can be considered indirect but crucial agents of decomposition. In the studied transitional waters, reed litter breakdown rates varied with water temperature, although variations in reed breakdown rates along a latitudinal gradient were not observed. Results obtained in this work were consistent with comparative observations of decomposition processes in various streams in Costa Rica, Michigan and Alaska. Irons *et al.* (1994) showed no significant changes in litter decay rates of different tree species with increasing latitude and decreasing temperature.

Table 1 – Mass loss per day (%), coefficient of variation (%) and half-life (days) are reported for each transitional water. All ecosystem are ordered according to decreasing mass loss per day.

Ecosystem	Mass loss per day (%)	C.V. (%)	t_{50} (days)
Pialassa Baiona	2.81	18.8	24
Grado Marano	2.52	1.1	27
Cesine	2.36	14.2	29
Leahova	2.13	9.8	33
Agiasma	2.03	19.3	34
Kalloni	2.03	16.2	34
Patok	1.98	20.7	35
Sinoe	1.98	11.6	35
Grado fish farm	1.77	11.0	39
Torre Guaceto	1.77	15.0	39
Alimini	1.71	22.1	41
Karavasta	1.64	15.7	42
Grado Cavanata	1.63	8.3	42
Margherita di Savoia	1.60	11.9	43
Varna	1.52	36.5	45
Narta	1.39	3.3	49

Here, water temperature did not show latitudinal variation, probably due to the highly dynamic nature of the transitional waters in which the experiments were carried out; for example the limited sampling times may not reflect the variation in temperatures resulting from the exchange of fresh and marine waters in these environments. Moreover, the link between transitional waters and terrestrial and marine ecosystems, and the spatial or temporal variations of their boundaries, may indirectly affect litter breakdown, through an influence on water parameters, especially salinity. Here, water salinity negatively affected leaf litter breakdown on the eco-regional scale and this pattern is consistent with previous results obtained for aquatic ecosystems (Reice and Herbst, 1982). Similarly, the effects of hydrological characteristics on litter decomposition in the studied ecosystems were consistent with those of other Mediterranean aquatic ecosystems (Menéndez *et al.*, 2004). These abiotic factors act as an environmental niche, producing indirect effects on the decomposition process and direct effects on the individual physiological traits or structural community characteristics of the biotic agents of decomposition (Pascoal *et al.*, 2003). After all, the present work emphasizes the importance of abiotic ecosystem characteristics in litter decomposition, highlighting their role as indirect drivers of reed litter breakdown in transitional waters. Moreover, two of the driving factors of reed decomposition in the studied ecosystems, *i.e.*, water salinity and tidal range, are also key structural factors in two major proposed typological classifications of transitional waters (*i.e.*, Venice System and Confinement) (see Basset *et al.*, 2006). This aspect probably is the main result of the present study because the selection of abiotic ecosystem characteristics as forcing factors of litter decomposition on the macro-ecological scale and their inclusion among the key factors in the most commonly used typological schemes of transitional waters may constitute an important aspect in the monitoring and conservation of these ecosystems.

Acknowledgments

This paper was funded by an INTERREG IIIB CADSES grant to the project TWReferenceNET.

References

Aerts R. 1997. Climate, leaf chemistry and leaf litter decomposition in terrestrial ecosystems: a triangular relationship. *Oikos* **79**: 439-449.

Basset A, Sabetta L, Fonnesu A, Mouillot D, Do Chi T, Viaroli P, Giordani G, Reizopoulou S, Abbiati M, Carrada GC. 2006. Typology in Mediterranean transitional waters: new challenges and perspectives. *Aquatic Conservation: Marine and Freshwater Ecosystems* **16**: 441-455.

Bayo MM, Casas JJ, Cruz-Pizarro L. 2005. Decomposition of submerged Phragmites australis leaf litter in two highly eutrophic Mediterranean coastal lagoons: relative contribution of microbial respiration and macroinvertebrate feeding. *Archiv für Hydrobiologie* **163**: 349-367.

Covich AP. 1988. Geographical and historical comparisons of neotropical streams: biotic diversity and detrital processing in highly variable habitats. *Journal of North American Benthological Society* **7(4):** 361-386.

Gupta MK, Shrivastava P, Singhal PK. 1996. Decomposition of young water hyacinth leaves in lake water. *Hydrobiologia* **335**: 33-41.

Irons IG, Oswood MW, Stout RJ, Pringle CM. 1994. Latitudinal patterns in leaf litter breakdown: is temperature really important*? Freshwater Biology* **32**: 401-411

Mendelssohn IA, Sorrell BK, Brix H, Schierup H, Lorenzen B, Maltby E. 1999. Controls on soil cellulose decomposition along a salinity gradient in a Phragmites australis wetland in Denmark. *Aquatic Botany* **64**: 381-398.

Menéndez M, Hernández O, Sanmartí N, Comín FA. 2004. Variability of organic matter processing in a Mediterranean coastal lagoon. *International Review of Hydrobiology* **89**: 476-483.

Newell SY. 1996. Established and potential impacts of eukaryotic mycelial decomposers in marine terrestrial ecotones. *Journal of Experimental Marine Biology and Ecology* **200**: 187-206.

Pascoal C, Pinho M, Cassio F, Gomes P. 2003. Assessing structural and functional ecosystem condition using leaf breakdown: studies on a polluted river. Freshwater Biology 48: 2033-2044.

Petersen RC, Cummins KW. 1974. Leaf processing in a woodland stream. *Freshwater Biology* **4**: 343-368.

Pinna M, Sangiorgio, F, Fonnesu A, Basset A. 2003. Spatial analysis of plant detritus processing in a Mediterranean River type: the case of the River Tirso Basin, Sardinia, Italy. *Journal of Environmental Sciences* **15**: 227-240.

Reice SR, Herbst G. 1982. The role of salinity in decomposition of leaves of Phragmites australis in desert streams. *Journal of Arid Environments* **5**: 361-368.

Sangiorgio F, Pinna M, Basset A. 2004. Inter- and intra-habitat variability of plant detritus decomposition in a transitional environment (Lake Alimini, Adriatic Sea). *Chemistry and Ecology* **20**: 353-366.

Saunders GW. 1980. Organic matter and decomposers. In Le Cren ED, Lowe-McConnell (Eds), The functioning of freshwater ecosystems. Cambridge University Press: Cambridge.

Shanks RE, Olson JS. 1961. First year breakdown of leaf litter in Southern Appalachian forest. *Ecology* **134**:194-195.

Valiela I. 1984. Marine Ecological Processes. Springer-Verlag: New York.

Webster JR, Benfield EF. 1986. Vascular plant breakdown in freshwater ecosystems. *Annual Review of Ecology and Systematics* **17**: 567-594.

