DECOMPOSITION DYNAMICS OF *PHRAGMITES AUSTRALIS* LEAVES, STALKS AND RHIZOMES IN THE AREA OF LAKE BALATON AND KIS-BALATON WETLAND

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Abstract

The decomposition of plant litter is an important mechanism in regard to energy and nutrient dynamics of ecosystems. The decomposition dynamics of three plant parts of *Phragmites australis* (leaves, stalks and rhizomes) and the changes of total nitrogen and phosphorous concentrations were examined in Lake Balaton and Kis-Balaton Wetland for 230 days. The commonly applied litter bag technique was used, with two mesh sizes (litter bag mesh sizes ø = 3 mm; and plankton net bag mesh sizes ø = 900 μm). Leaf litter mass loss generally did not differ between the two mesh sizes and the study sites. The highest decomposition rates were observed at rhizomes (k=0.0051) and the slowest at stalks (k=0.0004). At the end of the investigation period, the remaining nutrient concentration was different in the three plant parts of *P. australis*. Nitrogen and phosphorous at the stalks in Lake Balaton was higher compared to the initial concentration. In the case of the leaves and rhizomes a decrease was observed.

Key Words: *Phragmites australis,* Lake Balaton, Kis-Balaton Wetland, leaf litter decomposition

Összefoglalás

A növényi anyag bomlása fontos mechanizmusa az ökoszisztémák energia- és tápanyagdinamikájának. 230 napos kísérletben vizsgáltuk a közönséges nád (*Phragmites australis*) három növényi részének (levél, szár és rizóma) lebontási ütemét és a visszamaradt teljes nitrogén és foszfor mennyiségét a Balaton (tó) és a Kis-Balaton (wetland) területén. A kísérlet során avarzsákos módszert alkalmaztunk, két lyukbőséggel (avarzsák lyukátmérő ø = 3 mm és planktonháló zsák lyukátmérő ø = 900 μm). A nád növényi részeinek tömegvesztése általában nem különbözött a két lyukbőségű zsák és a kísérleti területek között. A bomlási sebesség a leggyorsabb a rizóma esetében volt (k = 0,0051), míg a szárnál figyeltük meg a legalacsonyabb értékeket (k = 0,0004). A vizsgálati időszak végén a nád három növényrészében mért visszamaradt tápanyag-koncentráció eltérő volt. A balatoni nád szár esetében a nitrogén és a foszfor magasabb volt, mint a kezdeti koncentráció. A levél és a rizóma esetében csökkenés volt megfigyelhető.

Kulcsszavak: *Phragmites australis,* Balaton, Kis-Balaton, avarlebontás

Introduction

Common reed (*Phragmites australis* Cav. (Trin.) is one of the most abundant wetland plants world-wide (Schaller et al, 2016). *P. australis* substantially improves the total nitrogen and total phosphorous removal efficiency in wetland ecosystems, due to its high growth rate and great capacity for nutrient accumulation in stalks, roots, and rhizomes (Vymazal, 2005). Litter decomposition rates and nutrient dynamics also depend on a large extent on chemical properties (e.g., C, N and P concentrations) of the plant detritus material (Enríquez et al., 1993; Lee and Bukaveckas, 2002) and physical-chemical conditions of the water (Faye et al., 2006, Pozo, 1993). To better protect and manage lake and wetland ecosystems, it is important to understand the interacting forces that supports their functioning (Raposeiro et al, 2017).

In this study, the decomposition rate and the remaining nutrient concentrations were investigated in the Keszthely Bay of Lake Balaton and Fenéki Pond of Kis-Balaton Wetland using three plant parts of *P. australis* litter (leaves, rhizomes and stalks) in a 230 days long experiment.

Materials and Methods

Study Sites

The study was conducted the Lake Balaton and Kis-Balaton Wetland, Hungary. Lake Balaton is the largest shallow lake in Central Europe (Crossetti et al., 2013), connected to the Kis-Balaton Wetland, which serves as a filter for the lake (Anda et al., 2017). Lake Balaton lies in the western part of Hungary at an altitude of 104 m; its area is 589 km^2 and its average depth is 3 m (Dill, 1990). The westernmost of the four bays of Lake Balaton is Keszthely Bay, where an experiment was set up (17° 14' 46.3" E and 46° 43' 32.1" N, Fig. 1.). In order to protect the water quality of Lake Balaton, a wetland reconstruction of Kis-Balaton (Hídvégi and Fenéki Pond) was completed in 2015. Second part in our experiment was conducted in the Ingói Bay of Fenéki Pond (17° 11' 46.4" E and 46° 38' 37.4" N, Fig. 1.). Unlike Keszthely Bay, this area is typically a wetland.

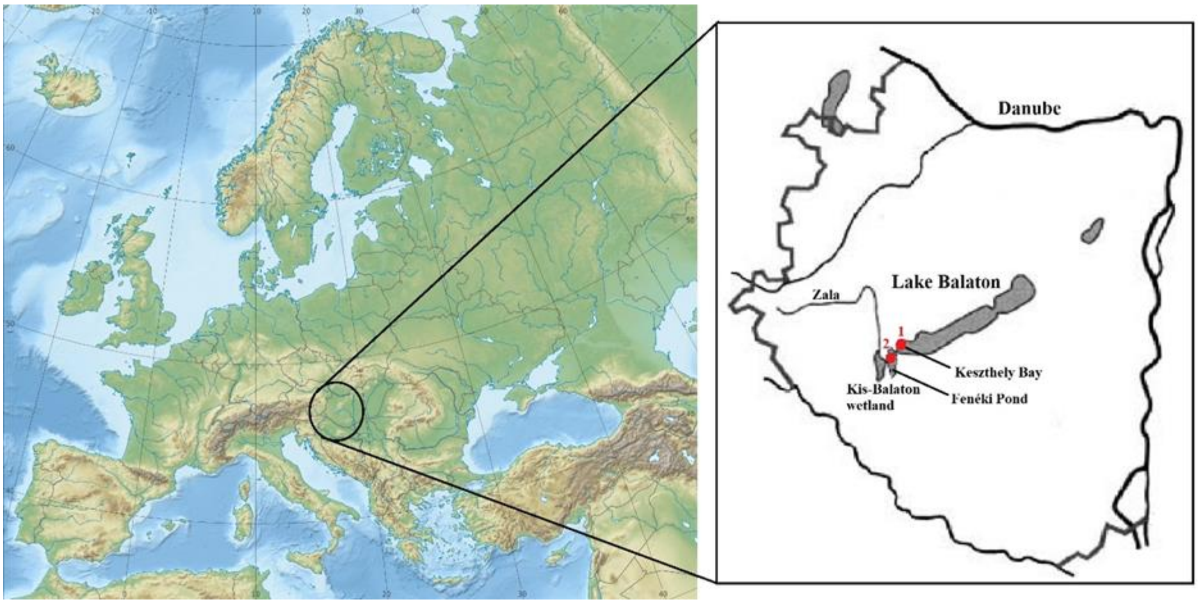

Figure 1. The sampling sites of Lake Balaton (1) and Kis-Balaton Wetland (b) (hu.wikipedia.org)

Plant Litter Decomposition

The decomposition of the dominant emergent macrophyte, *Phragmites australis* was analysed with the litter bag technique (Bärlocher et al., 2005). Standing dead leaves, stems and rhizomes were collected in October 2017 from the area of Lake Balaton and Kis-Balaton Wetland. Samples were air dried at room temperature to a constant weight. Whole parts of *P. australis* were fragmented to produce a coarse litter containing natural proportions. 10-10 g sample of plant material was transferred into polyethylene bags with two mesh sizes (litter bag mesh size ø = 3 mm; and plankton net bag mesh size ø = 900 µm). A total of 360 litter bags were positioned on 16 November 2017 at the water–sediment interface of the experimental area. Three replicates of the sample bags were collected 14, 32, 48, 60, 74, 123, 144, 158, 197 and 230 days after the start of the experiment. On each sampling occasion water samples were taken, from which pH, conductivity, PO_4^-, NH_4^+, NO_3^-, SO_4^{2-}, Cl^- were determined in the laboratory. Plant material was transported to the laboratory and washed with water. Samples were air dried for approximately 10 days to a constant weight. The dried litter was weighed to determine weight loss. The concentrations of phosphorous and nitrogen of the litters were determined using a spectrophotometer method at the end of experiment.

Data analysis

Litter decomposition rates were calculated of the simple first-order model, which assumes that litter decomposes at a constant rate over time (Jenny et al., 1949; Olson, 1963):

$$W_t = W_0 e^{-kt}$$

where t is the time (d), W_t the litter dry matter remaining at time t relative (g), W_0 the initial litter dry matter at time 0 (g), e the base of natural logarithm and k is the decomposition rate coefficient (d^{-1}). Differences in dry mass remaining, litter nutrient concentrations among plant parts and the two study sites were examined by least-significant difference approach of t-test using the Microsoft Office Excel 2016.

Results and Discussion

Water quality

Regarding the physical and chemical variables of the water samples from the two study sites (Table 1), there was a significant difference between the pH values of the two sites ($p<0.001$). The pH was higher in Lake Balaton, than in Kis-Balaton Wetland, which can be explained by the presence of organic acids in water (Gaudet and Muthuri, 1981). There was no significant difference ($p=0.3695$) in conductivity between the two sampling points, but Kis-Balaton Wetland has a higher conductivity in average (758.2±164.16 μS cm^{-1}). Dahrouga et al. (2016) made the statement, that denser bacterial biomass causes higher conductivity . Esteves (1988) concluded, that conductivity values also related to the trophic level of water.

Table 1 Changes in the main physical and chemical parameters of water during the decomposition period in Lake Balaton and Kis-Balaton Wetland

	Lake Balaton	**Kis-Balaton Wetland**
pH	8.3 ± 0.29	7.5 ± 0.32
Conductivity (μS cm^{-1})	677.8 ± 134.0	758.2 ± 164.16
$\mathbf{NO_3^-}$ (mg l^{-1})	u.r.	u.r.
$\mathbf{NH_4^+}$ (mg l^{-1})	0.77 ± 0.35	1.08 ± 1.17
$\mathbf{SO_4^{2-}}$ (mg l^{-1})	187.0 ± 92.80	172.5 ± 112.55
$\mathbf{PO_4^{3-}}$ (mg l^{-1})	0.31 ± 0.20	0.61 ± 0.35
$\mathbf{Cl^-}$ (mg l^{-1})	43.2 ± 16.45	43.0 ± 21.76

The presence of microorganisms and ammonia-volatility (Reddy and Sacco, 1981) caused low concentration of NO_3^-.. Between the two habitats, there were no significant differences regarding SO_4^{2-} ($p=0.6247$) and Cl^- ($p=0.7242$) concentrations. . Kis-Balaton

Wetland had higher NH_4^+ concentrations (1.08±1.17 mg l^{-1}), than Lake Balaton (0.77±0.35 mg l^{-1}), the difference is not significant (p=0.1705). The PO_4^{3-} concentrations of the two study sites were different on a large-scale (p=0.0307), twice as high in Kis-Balaton Wetland, than in Lake Balaton. Excessive concentrations of N and P are the most common causes of eutrophication in freshwater lakes and reservoirs (Correll, 1998). Eutrophication - the excessive enrichment of mineral nutrients in receiving waters - results an excessive production of autotrophs, especially algae and cyanobacteria, which could be observed in the study sites.

Emergent plant decomposition

Respect of *P. australis* leaves, 54% - 59% of the initial dry mass remained in the litter bags after 230 days of incubation in Lake Balaton and Kis-Balaton Wetland (Figure 2a and b). The rate was higher in the litterbags, than plankton net bags. There was no significant correlation between leaf litter mass losses in the large and small mesh size bags in Lake Balaton (p=0.5231) and Kis-Balaton Wetland (p=0.2814). The amount of the remaining *P. australis* stalks (Figure 2c and d) were 76% in the litter bags (Lake Balaton), whereas 80 % retained in the plankton net bags (Kis-Balaton Wetland) of the original weight. The reduction in the dry weight of *P. australis* rhizomes (Figure 2e and f) in two water bodies was 50 - 53%. No significant difference was found between the litter bags and the plankton net bags either in Lake Balaton (stalks p=0.1247; rhizomes p=0.0945) or in Kis-Balaton Wetland (stalks p=0.7256; rhizomes p=0.1036).

There were significant correlations in the litter bags between leaves and stalks (Lake Balaton p<0.001; Kis-Balaton Wetland p<0.001), leaves and rhizomes (Lake Balaton and Kis-Balaton Wetland p<0.001) and stalks and rhizomes (Lake Balaton and Kis-Balaton Wetland

$p<0.001$). There were no significant correlations between Lake Balaton and Kis-Balaton Wetland regarding leaves ($p=0.1122$), stalks ($p=0.3158$) and rhizomes ($p=0.1274$) in the mass loss. A similar tendency was observed for plankton net bags.

Duke et al. (2015) described 49% weight loss was in *Phragmites* litter in Lake Erie. (144 days). At the same place, Rothman and Bouchard (2007) detected 86% weight loss during the 208 days of the investigation period. Findlay et al. (2002) examined the decomposition dynamics of *P. australis* in the Tivoli North Bay of the Hudson River and found that during the 3 years study period 28.5% of the original weight remained. The conflicting results among other studies comparing decomposition of *Phragmites* litter can be explained by the importance of environmental conditions.

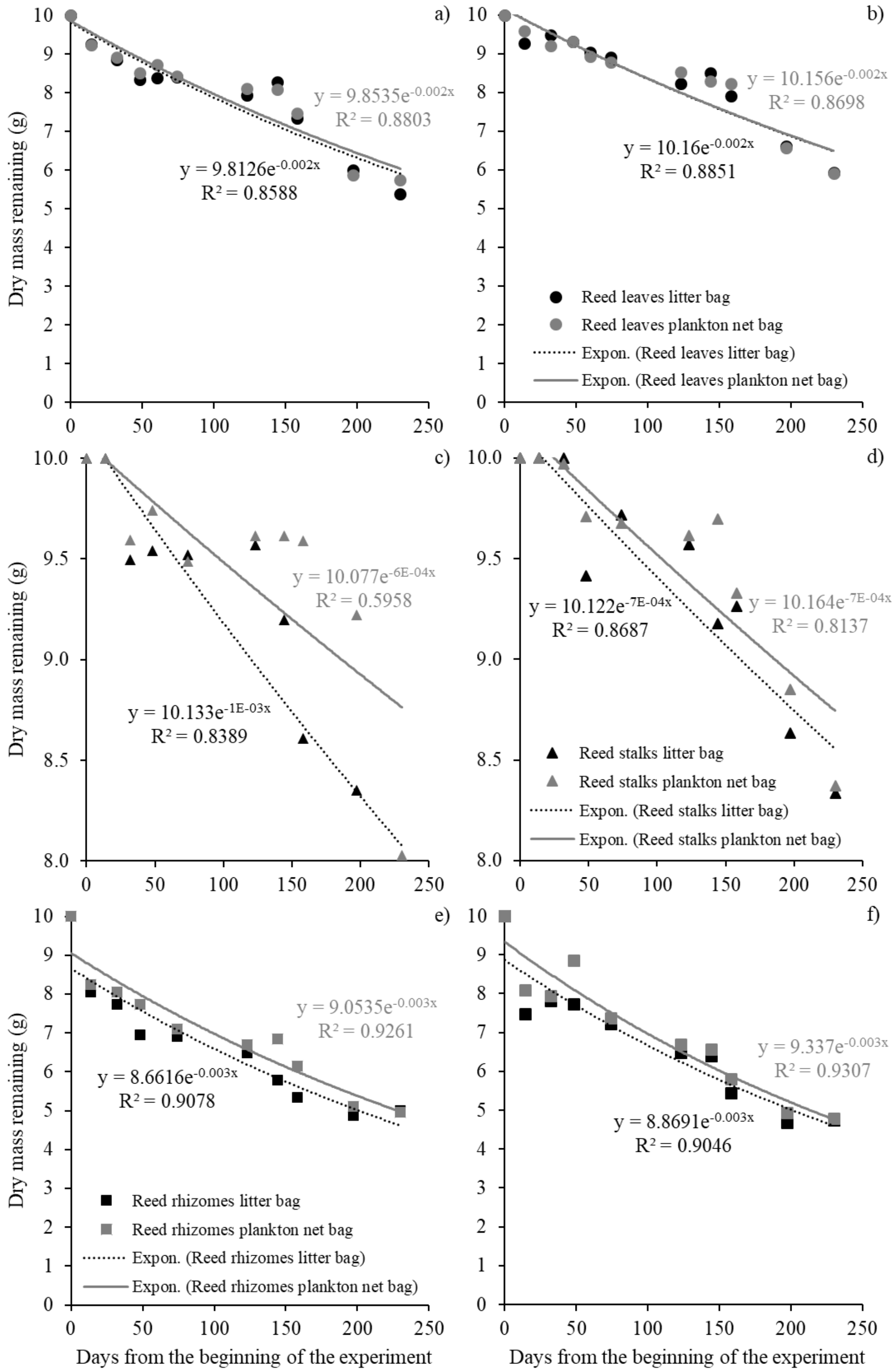

Figure 2. The remaining dry mass for P. australis leaves (a and b), stalks (c and d) and rhizomes (e and f) during the 230 days long experiment in the area of Lake Balaton (a, c and e) and Kis-Balaton Wetland (b, d and f)

The exponential decay coefficients of *P. australis* leaves, stalks and rhizomes are presented in Figure 3. The k-values of rhizomes were high in Lake Balaton in the litterbags (k=0.0051), while k of stalks were low in Kis-Balaton Wetland in the plankton net bag (k=0.0004). The exponential decay coefficients were high in Lake Balaton in case of leaves and stalks and, in Kis-Balaton Wetland (both types of bags) in case of rhizomes. The rhizomes in the litterbags in Lake Balaton and Kis-Balaton Wetland were classified to the medium, all other samples to the slow category. Zhang et al. (2014) investigated the decomposition of *P. australis* leaves and stalks in area of the Shanyutan wetland in 2010 (90 and 210 days experimental period). They observed the k values of 0.0018-0.0053 for the leaves and 0.00096-0.00275 for the stalk. Their experimental results were close to ours.

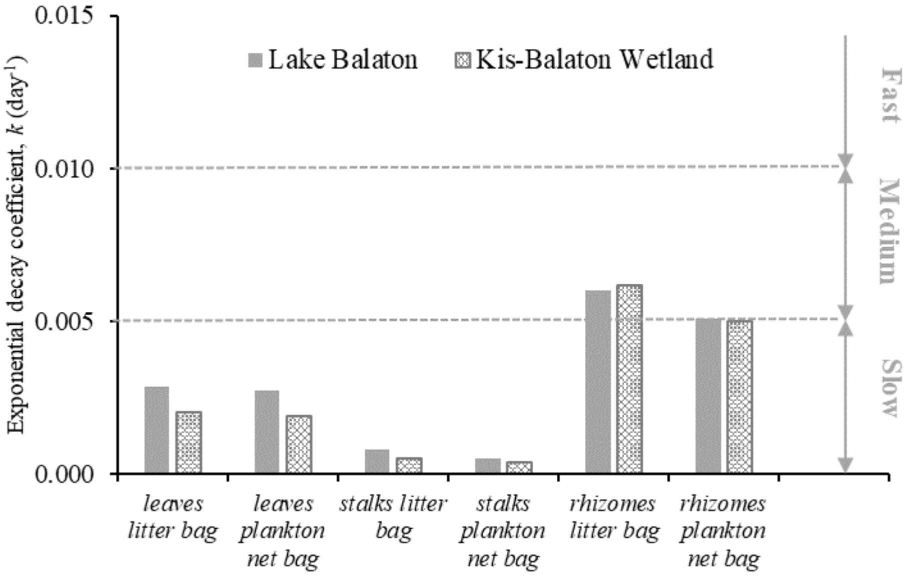

Figure 3. Decomposition coefficients (k) of P. australis leaves, stalks and rhizomes in Lake Balaton and Kis-Balaton Wetland

The remaining N and P concentrations in the decaying litter

Changes in the total nitrogen and total phosphorus contents in *P. australis* leaves, stalks and rhizomes at the beginning and end of the investigation period are presented in Figure 4. The initial phosphorous concentration was high in the rhizomes in Lake Balaton (0.104%) and Kis-Balaton Wetland (0.106%), while low in the stalks in Lake Balaton (0.012%) and Kis-Balaton Wetland (0.014%). At the end of the investigation period phosphorous concentration was reduced to near zero in the leaves and rhizomes, but in the stalks its amount increased.

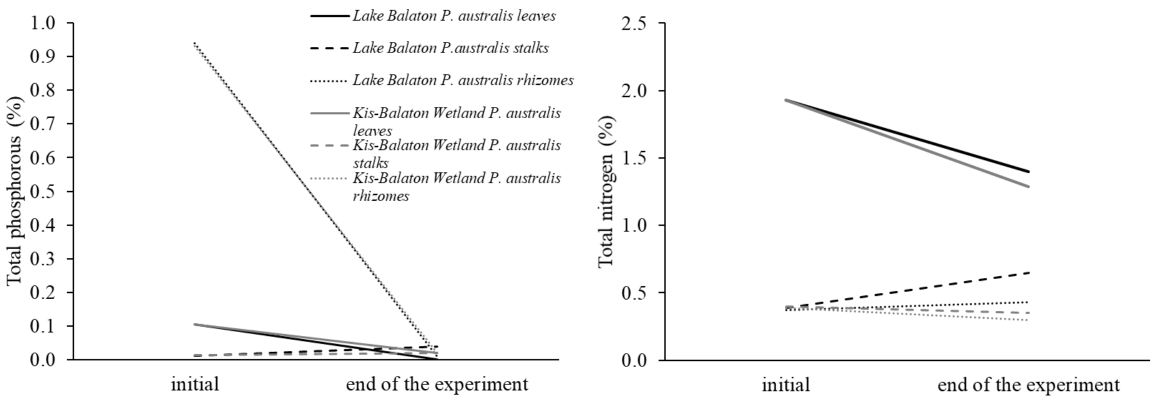

Figure 4. The remaining total nitrogen and total phosphorus contents in the P. australis leaves, stalks and rhizomes in the area of Lake Balaton and Kis-Balaton Wetland

The initial nitrogen concentration was high in the leaves (Lake Balaton 1.931%, Kis-Balaton Wetland 1.933%) and low nitrogen contents were detected in rhizomes (0.390% and 0.399%) and stalks (0.371% and 0.389%). The amount of phosphorus increased in the stalks in Lake Balaton, in all other samples the nitrogen content did not change (in Lake Balaton in rhizomes). The reason for the increase of nutrients was likely a biofilm formation, which could not be removed completely during the washing of the samples.

Zhang et al. (2014) observed, that by the end of their experiment, the litter nitrogen concentration in the leaves, stalks and flowers increased by 12% and 99% of the initial value of the sediment-surface phase for *P. australis*. The high phosphorus leaching from macrophytes may be related to the large inorganic fraction of phosphorus in tissues (Twilley et al., 1986). The increased P concentration during decomposition is usually caused by decomposer microbes associated with the plant tissue immobilizing P nutrient for their own growth (Pagioro and Thomaz, 1999; Ozalp et al., 2007). Köchy and Wilson (1997) suggested that nutrient loss depended on both litter quality (C, N, P) and nutrient availability in the surrounding environments.

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References

Anda, A., Soós, G., Teixeira da Silva, J.A. 2017: Leaf area index for common reed (*Phragmites australis*) with different water supplies in the Kis-Balaton wetland, Hungary, during two consecutive seasons (2014 and 2015). *Időjárás*. **121** (3). 265–284.

Bärlocher, F. 2005: Leaf Mass Loss Estimated by Litter Bag Technique. In: Graça, M.A.S., Bärlocher, F. and Gessner, M.O., Eds., Methods to Study Litter Decomposition, a Practical Guide, Springer, Dordrecht, 37-42.

Correll, D. L. 1998: The Role of Phosphorus in the Eutrophication of Receiving Waters: A Review. J. Environ. Qual. **27**. 261-266.

Crossetti, L.O., Stenger-Kovács, C., Padisák, J. 2013. Coherence of phytoplankton and attached diatom-based ecological status assessment in Lake Balaton. *Hydrobiologia*. **716**. 87–101.

Dahrouga, Z., Santana, N.F., Pagioro, T.A. 2016: *Eichhornia azurea* decomposition and the bacterial dynamic: an experimental research. *Brazilian Journal of Microbiology*. **47**. 279-286.

Dill, W.A. 1990: Inland fisheries of Europe. EIFAC Technical Paper. No. 52. Rome, FAO

Duke, S.T., Francoeur, S.N., Judd, K.E. 2015: Effects of *Phragmites australis* Invasion on Carbon Dynamics in a Freshwater Marsh. *Wetlands*. **35**. 311–321.

Enríquez, S., Duarte, C.M., Sand-Jensen, K. 1993: Patterns in decomposition rates among photosynthetic organisms: the importance of detritus C:N:P content .*Oecologia*. **94**. 457–471.

Esteves, F.A. 1988: Fundamentos da Limnologia. Rio de Janeiro:Interciência/FINEP, Rio de Janeiro.

Faye, L.M., Beth, R.L., Ormerod, S.J. 2006: The effects of low pH and palliative liming on beech litter decomposition in acid-sensitive streams. *Hydrobiologia*. **571**. 373-381.

Findlay, S.E.G., Dye, S., Kuehn, K.A. 2002: Microbial growth and nitrogen retention in litter of *Phragmites australis* compared to *Typha angustifolia*. *Wetlands*. **22**. 616–625.

Gaudet, J.J., Muthuri F.M. 1981: Nutrient relationships in shallow water in an African lake, Lake Naivasha. *Oecologia*. **49**. 109-118.

Jenny, H., Gessel, S.P., Bingham, F.T., 1949. Comparative study of decomposition rates in temperate and tropical regions. *Soil Sci*. **68**. 419–432.

Köchy, M., Wilson, S.D. 1997: Litter decomposition and nitrogen dynamics in Aspen forest and mixed-grass prairie. *Ecology*. **78**. 732–739.

Lee, A.A., Bukaveckas, P.A. 2002: Surface water nutrient concentrations and litter decomposition rates in wetlands impacted by agriculture and mining activities. *Aquat. Bot.* **74**. 273–285.

Olson, J.S., 1963. Energy storage and the balance of producers and decomposers in ecological systems. *Ecology*. **44**. 322–331.

Ozalp, M., Conner, W.H., Lockaby, B.G. 2007: Above-ground productivity and litter decomposition in a tidal freshwater forested wetland on Bull Island, SC, USA. *Forest Ecol. Manage*. **245**. 31–43.

Pagioro, T.A., Thomaz, S.M. 1999: Decomposition of *Eichhornia azurea* from limnologically different environments of the Paraná River River floodplain. *Hydrobiologia*. **411**. 45–51.

Pozo, J. 1993: Leaf litter processing of alder and eucalyptus in the Agüera stream system (North Spain). I. Chemical changes. *Archiv für Hydrobiologie*. **127**. 299-317.

Raposeiro, P.M, Ferreira, V., Guri, R., Goncalves, V., Martins, G.M. 2017: Leaf litter decomposition on insular lentic systems: effects of macroinvertebrate presence, leaf species, and environmental conditions. *Hydrobiologia*. **784**. 65–79.

Reddy, K.R., Sacco P.D. 1981: Decomposition of water hyacinth in agricultural drainage water. *Journal of Environmental Quality*. **10**. 228-234.

Rothman, E., Bouchard, V. 2007: Regulation of carbon processes by macrophyte species in a Great Lakes coastal wetland. *Wetlands*. **27.** 1134–1143.

Schaller, J., Böttger, R., Dudel, G., Ruess, L. 2016: Reed litter Si content affects microbial community structure and the lipid composition of an invertebrate shredder during aquatic decomposition. *Limnologica*. **57**. 14–22.

Twilley, R.R., Lugo, A.E., Patterson-Zucca, C. 1986: Litter production and turnover in basin mangrove forests in southwest Florida. *Ecology*. **67**. 670–683.

Vymazal, J. 2005: Horizontal sub-surface flow and hybrid constructed wetlands systems for wastewater treatment. *Ecological Engineering*. **25** (5). 478–490.

Zhang, L.H. , Tong, C., Marrs, R., Wang, T.E., Zhang, W.J. , Zeng C.S. 2014: Comparing litter dynamics of *Phragmites australis* and *Spartinaa alterniflora* in a sub-tropical Chinese estuary: Contrasts in early and late decomposition. *Aquatic Botany*. **117**. 1–11.