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Decomposition of *Ruppia cirrhosa* (Petagna) Grande in the sediment of a coastal lagoon*

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SUMMARY: The decomposition process of *Ruppia cirrhosa* was studied in a Mediterranean coastal lagoon in the Delta of the River Ebro (NE Spain). Leaves and shoots of *Ruppia* were enclosed in 1 mm-mesh and 100 μm-mesh litter bags to ascertain the effect of detritivores, macroinvertebrates, and bacteria and fungi, respectively. Changes in biomass and carbon, and, nitrogen and phosphorus concentrations in the detritus were studied at the sediment-water interface and in the sediment. Significant differences in biomass decay were observed between the two bag types. Significant differences in decomposition were observed between the two experimental conditions studied using 100 μm-mesh bags. These differences were not significant when using the 1 mm-mesh bags. The carbon content in the detritus remained constant during the decomposition process. The percentage of nitrogen increased progressively from an initial 2.4 % to 3 %. The percentage of phosphorus decreased rapidly during the first two days of decomposition from an initial 0.26 % to 0.17 %. This loss is greater in the sediment than in the water column or at the sediment-water interface. From these results we deduce that the activity of microorganisms seems to be more important in the sediment than in the water-sediment interface, and that grazing by macroinvertebrates has less importance in the sediment than in the water column.

Key words: Decomposition rates, carbon, nitrogen, phosphorus, *Ruppia cirrhosa*, Ebro river delta, NE Spain.

RESUMEN: DESCOMPOSICIÓN DE *Ruppia cirrhosa* (Petagna) GRANDE EN EL SEDIMENTO DE UNA LAGUNA COSTERA. — Se estudió el proceso de descomposición de *Ruppia cirrhosa* en una laguna de la costa mediterránea en el delta del río Ebro (NE de España). Se colocaron hojas y tallos en bolsas de mallas de 1 mm y de 100 μm para comprobar el efecto de los detritívoros macroinvertebrados y las bacterias y de los hongos respectivamente. Se estudiaron los cambios de la biomasa y de las concentraciones de carbono, nitrógeno y fósforo de los detritos en la interfase agua-sedimento y en el interior del sedimento. Se hallaron diferencias significativas en la disminución de la biomasa entre los dos tipos de bolsas y también entre los dos tipos de condiciones usando bolsas de 100 μm de malla. Estas diferencias no fueron significativas cuando se usaron bolsas con mallas de 1 mnm. El contenido en carbono de los detritos permaneció constante durante el proceso de descomposición. El porcentaje de nitrógeno se incrementó progresivamente desde el 2,4 % inicial al 3 %. El tanto por cien de fósforo disminuyó rápidamente durante los dos primeros días de descomposición desde 0,26 % al principio hasta 0,17 %. Está pérdida es mayor en el sedimento que en la columna de agua o en la interfase agua-sedimento. A partir de estos resultados, se deduce que la actividad de los microorganismos parece ser más importante en el sedimento que en la interfase agua-sedimento y la presencia de macroinvertebrados tiene menos importancia en los sedimentos que en la columna de agua.

Palabras clave: Tasas de descomposición, carbono, nitrógeno, fósforo, *Ruppia cirrhosa*, delta del río Ebro, NE de España.

INTRODUCTION

Higher plants play an important role in aquatic ecosystems. Primary production due to macrophytes represents a high fraction of total primary production in shallow water environments (NIXON, 1982) where light reaches the water-sediment interface. They provide food and oxygen for other organisms, as well as

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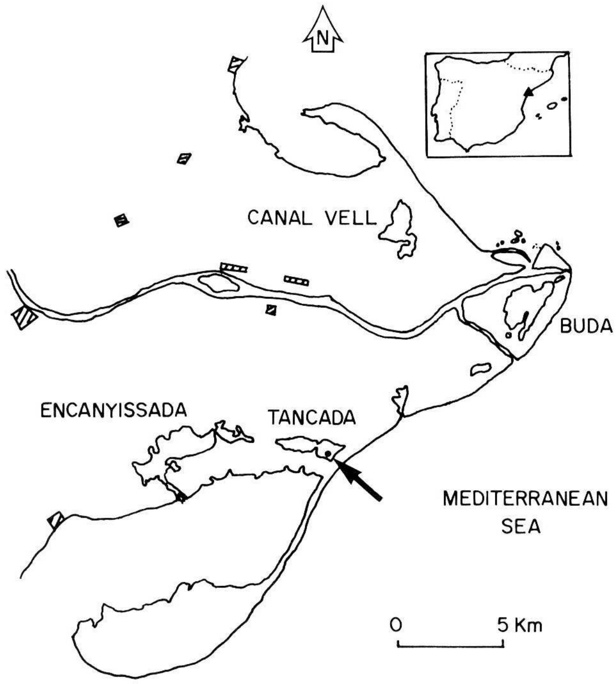

FIG. 1. — Map of the Ebro River delta showing the location of Tancada Lagoon and sampling site.

providing sites for attachment and shelter, and spawning areas for some fish. Numerous studies performed on submersed macrophytes indicate that only a small part of the biomass is used as food by herbivores (ODUM and DE LA CRUZ, 1967; MANN, 1972, 1976; REICE, 1977; NIENHUIS and VAN IERLAND, 1978, MENÉNDEZ and COMÍN, 1990a). The largest fraction is used by bacteria and fungi (THAYER *et al.*, 1977) at the end of the vegetative life, when macrophytes produce large amounts of organic detritus (POLUNIN, 1981), which at first are suspended in the water, and then fall to the water-sediment interface. Detritus can finally be buried by sediment resuspended by wind in these shallow aquatic ecosystems.

Decomposition of different species in shallow waters is generally studied by putting litter bags in the water column or in the sediment, but there are no published studies comparing the different positions occupied by the detritus during the decomposition process.

Tancada lagoon is a coastal lagoon in the Ebro River Delta (NE Spain), 1.8 Km^2 of surface and 37 cm deep on average. It is mostly occupied by a dense *Ruppia cirrhosa* (Petagna) Grande meadow, with a smaller part covered with *Potamogeton pectinatus* L. (MENÉNDEZ and COMÍN, 1990b). At the end of September *R. cirrhosa* starts to degenerate and it is deposited in dense packs on the banks of the lagoon and on the top of the sediment.

The aim of this paper is to compare the decay rates and changes in carbon, nitrogen and phosphorus contents of *R. cirrhosa* during its decomposition in two locations: sediment and water sediment interface. We also try to obtain an estimate of the contribution to plant decomposition by the different species of organisms present, using different mesh size litter bags. The results are compared with data obtained by MENÉNDEZ *et al.* (1989) on decomposition of *R. cirrhosa* placed in the water column.

MATERIAL AND METHODS

Green *R. cirrhosa* leaves, collected from the packs deposited on the banks of Tancada lagoon at the end of it vegetative cycle, were weighted (fresh weight) and placed in litter bags made of nylon net, of 100 μm and 1 mm mesh size. Some bags were placed at the sediment-water interface, and others buried a few cm below the surface (Fig. 1). It was noticed in preliminary studies that macroinvertebrates, such as amphipods and isopods, could enter the 1 mm mesh size bags, but not the bags with 100 μm mesh size (MENÉNDEZ *et al.*, 1989). Fresh material was used because pre-drying of plant material affects weight loss and nutrient release (BROCK *et al.*, 1982, 1985; LARSEN, 1982; ROGERS and BREEN, 1982). Although litter bags will allow fragmented particulate detritus to escape and this method may underestimate decomposition, it is assumed that the results of litter bag studies will reflect trends characteristic of unconfined decomposing litter, and as such allow for comparisons among species, sites and experimental manipulations (WIEDER and LANG, 1982).

In order to prevent resuspension and hydrodynamic effects, a weight was introduced into each bag. Two bags of each mesh size were removed after 1, 2, 15, 30, 90 and 142 days. A couple of bags were also removed immediately after their placement to estimate losses due to manipulation.

Samples were frozen immediately after they were collected and transported to the laboratory at the end of their incubation period. They were carefully washed (500 μm) with tap water in order to extract organisms and sediment.

Initial fresh weight was converted to dry weight using a fresh weight/dry weight ratio of 5.47 ± 0.05 calculated from six samples of the same plant material used to fill the bags. The final dry weight was determined at each sampling period by drying the plant material to constant weight at 60 °C (48 h). The difference between both values expresses the loss of biomass (dry weight). Subsamples were combusted at 550 °C for 3 hours to determine total ash content. Total carbon and nitrogen content of the detritus were analyzed in a Carlo Erba elemental analyzer. Total phosphorus was measured by colorimetry after wet oxidation (JACKSON, 1970), using two aliquots of each sample. Statistical tests were performed using Subprogram ANOVA/MANOVA CSS statistics. F-Tests for significant differences between mesh-sizes for sediment and sediment-water interface, and between sediment and sediment-water interface for each mesh-size were conducted.

RESULTS

Significant differences were observed between the biomasses estimated in different mesh bags in the sediment-water interface (ANOVA, $p<0.01$), but this difference was not observed in the sediment (Table 1). During the first 90 days, losses of 86.1 % and 78.9 % of the initial biomass in the 100 µm-mesh bags and losses of 75.1 % and 73 % of the initial biomass in the 1 mm-mesh bags were observed in the sediment-water interface and in the sediment respectively (Fig. 2). An increase of biomass was observed after 142 days of decay, although these data were not used. An increase was observed in the ash content of the detritus from an initial 16 % up to 18 % and 24 % in 100 µm and 1 mm-mesh bags respectively.

Significant differences between decomposition at the sediment-water interface and in the sediment were observed from 100 µm and 1 mm-mesh bags (ANOVA, $p<0.00001$) (Table 1).

With respect to the nutrient content of the detritus expressed as a percentage of the dry weight, the total carbon content remained fairly constant throughout the experiment (Fig. 3), with values of nearly 40 % of the dry weight and a slightly higher mean concentration in the 100 µm-mesh bags. The percentage of nitrogen increased progressively from an initial 2.4 % to values near 3 % (Fig. 4). No significant differences were found in detritus from the two positions studied. The phosphorus content decreased during the two first days from 0.26 % to 0.18 % and 0.16 % at the sediment-water interface and in the sediment respectively. At the sedimet water interface, the P content then increased to 0.29 % in the 100 µm-mesh size bags and 0.23 % in the 1 mm-mesh size bags. This increase in P content was not observed in the bags buried in sediment, where the values remained near 0.15 % (Fig. 5).

TABLE 1. — Two-way ANOVA results from analysis of data in Fig. 2 (% Biomass).

SEDIMENT-WATER INTERFACE				
SOURCE	d.f.	SS	F	p
Mesh size	1	0.066	15.04	0.01
Time	6	0.5845	132.91	10^{-6}
Error	14	0.044		
SEDIMENT				
SOURCE	d.f.	SS	F	p
Mesh size	1	0.0015	0.76	n.s.
Time	6	0.8645	425.58	10^{-6}
Error	14	0.020		
100 µm				
SOURCE	d.f.	SS	F	p
Inc. site	1	0.2677	78.78	10^{-6}
Time	6	0.6526	192.02	10^{-6}
Error	14	0.0033		
1 mm				
SOURCE	d.f.	SS	F	p
Inc. site	1	0.089	29.62	10^{-5}
Time	6	0.7799	257.29	10^{-6}
Error	14	0.030		

Using a simple exponential decay model ($W_t = W_0 e^{-kt}$, OLSON, 1963) in which the percentage of weight remaining is regressed on time (Fig. 2), decay rates of 0.00107 day^{-1} ($r=0.94$, $p<0.001$) and 0.0209 day^{-1} ($r=0.98$, $p<0.001$) were obtained with the results of the 100 µm and 1 mm-mesh bags respectively in the sediment water interface. Using the same model with samples buried in sediment, decay rates of 0.014 day^{-1} ($r=0.99$, $p<0.001$) and 0.016 day^{-1} ($r=0.98$, $p<0.001$) were obtained in 100 µm and 1 mm-mesh bags respectively.

No differences were observed in decay rates of biomass (AFDW), carbon and nitrogen for each of the time periods between two consecutive sample extractions (Table 2). Only the phosphorus decay rate was higher than biomass, carbon and nitrogen decay rates during the first days of the process (ANOVA, $p<0.01$).

Water temperature during the experimental period varied between 9 and 21 °C.

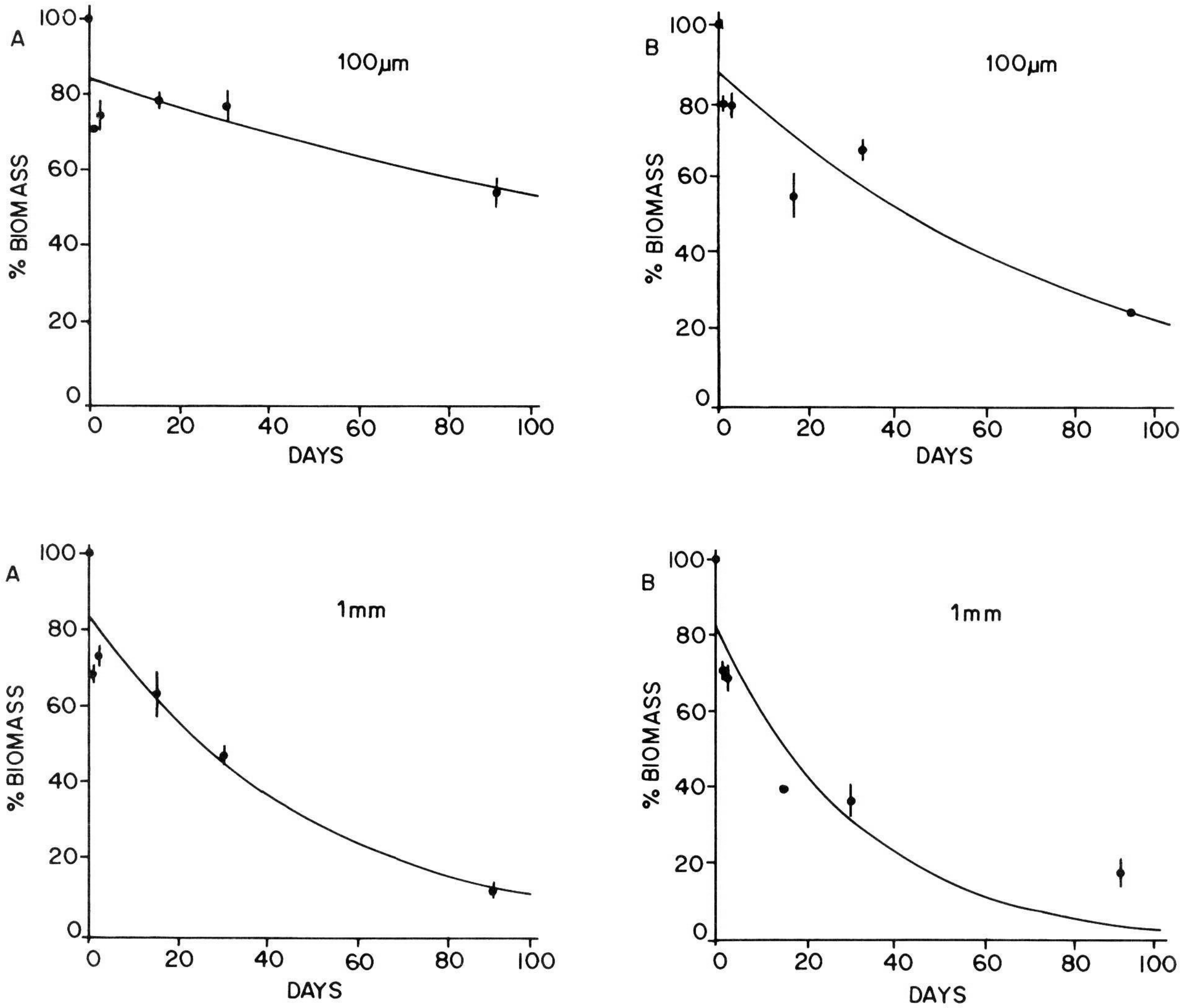

Fig. 2. — Percentage of the initial dry weight lost during decomposition of *Ruppia cirrhosa* **A.** In the sediment-water interface, ***B.*** In the sediment. Vertical bars indicate standard deviations.

DISCUSSION

From the results obtained in this study and those reported in MENÉNDEZ *et al.* (1989) (Table 3) we conclude that fragmentation or grazing by detritivorous macroinvertebrates have less importance for the decomposition of *R. cirrhosa* in the sediment-water interface and in the sediment than in the water column in Tancada lagoon. Bag manipulation and hydrodynamics could contribute to the loss of small fragments formed during the decay process in the 1 mm mesh bags. This effect was more important in the sediment-water interface than in the sediment. However the weight introduced into each of the litter bags placed in the sediment-water interface hinder movements due to hydrodynamics.

The lack of mesofauna in Tancada lagoon sediment during the period studied (GONZÁLEZ, pers. comm.) may explain the similar decay rates obtained using 1 mm and 100 µm mesh-bags buried in the sediment. Differences observed between the two mesh-size bags in sediment-water interface can be explained by the distribution of macroinvertebrates observed over the plant detritus in the water column (MENÉNDEZ *et al.*, 1989).

Activity of microorganisms seems to be most important in the sediment according to the significant differences observed in the 100 µm-mesh bags between the different sites studied. In the field, it is assumed that detritus buried in the sediment decays anaerobically (KENWORTHY and THAYER, 1984). Anaerobic cellullolytic bacteria have been reported from sediment associated with rhizomes and roots of eelgrass (ROTH and HAYASAKA, 1984); this could be

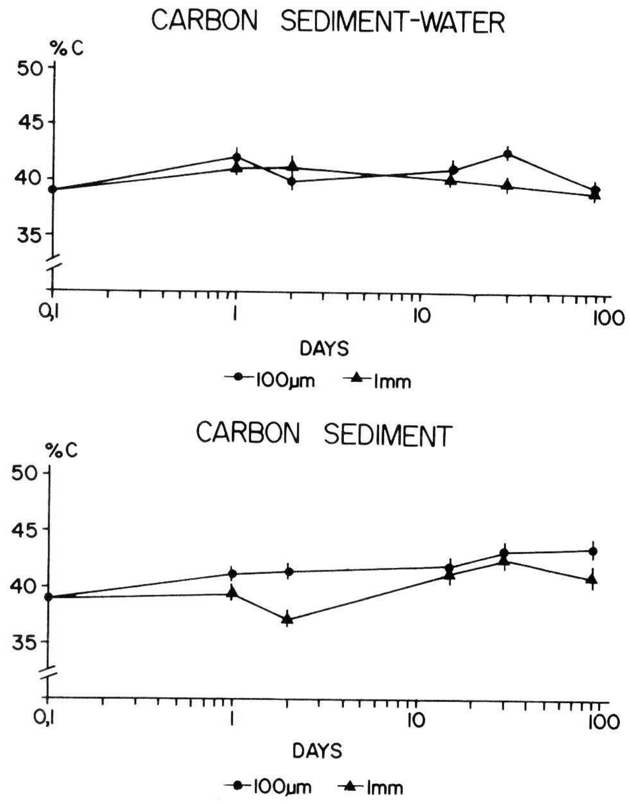

FIG. 3. — Percentage of Carbon in dry weight of *Ruppia cirrhosa* during decomposition. . Vertical bars indicate standard deviations.

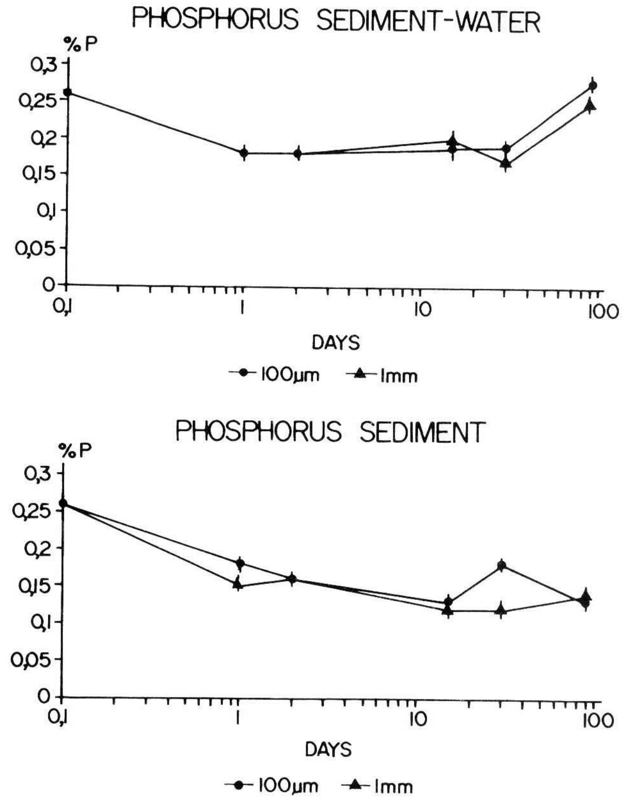

FIG. 5. Percentage of Phosphorus in dry weight of *Ruppia cirrhosa* during decomposition. Vertical bars indicate standard deviations.

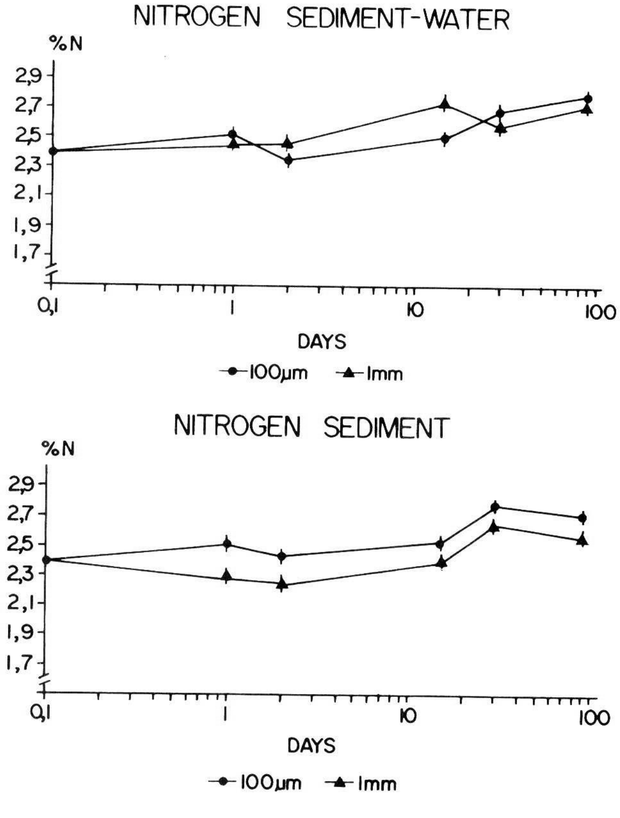

Fig. 4. — Percentage of Nitrogen in dry weight of *Ruppia cirrhosa* during decomposition. . Vertical bars indicate standard deviations.

the reason for a higher rate of decay observed in the sediment.

The increase in the concentration of nitrogen in the detritus is in agreement with the results obtained by numerous authors (KAUSHIK and HYNES, 1971; VALIELA *et al.*, 1985; TWILLEY *et al.*, 1986), explained in terms of the formation of phenolic compounds originating from decomposition of proteins, also capable of inhibiting the enzymatic activity of the microorganisms (SUBBERKROPP *et al.*, 1976). Other authors attributed this N increase to contamination with sediment material and dead parts of invertebrates (with fresh green leaves of *Nymphoides peltata* and roots of *Nuphar lutea* in situ litterbags) (BROCK, 1984; BROCK *et al.*, 1985), a high nutrient concentration in the microbial biomass (FENCHEL, 1970) and/or extracellular excretions of micro-organisms associated with the detritus (HOBBIE and LEE, 1980; ROBINSON *et al.*, 1982). However, ZIEMAN *et al* (1984) reported a decrease of the percent nitrogen utilizing fresh, green leaves of *Thalassia testudinum* held in situ litterbags. The difference between these results may be related to the chemical nature of the detritus sources (HARRISON, 1989).

Increase of N was not observed when detritus was placed in the water column (MENÉNDEZ *et al.*, 1989).

TABLE 2. — Relative decomposition rates and relative nutrient loss rates (k) calculated from the exponential equation $W_t = W_0 e^{-kt}$ for each period between samplings during the decomposition process.

SEDIMENT-WATER INTERPHASE				
k, 100 µm	D.W.	C	N	P
0-2 days	0.1462	0.1360	0.1566	0.3361
2-15 days	—	—	—	—
15-30 days	—	—	—	—
30-90 days	0.0050	0.0053	0.0021	—
90-142 days	0.0065	0.0067	0.0035	0.0068
k, 1 mm				
0-2 days	0.1602	0.1333	0.1423	0.3515
2-15 days	0.0105	0.0159	0.0167	0.0065
15-30 days	0.0200	0.0026	—	0.0018
30-90 days	0.0241	0.0272	0.0119	0.0221
90-142 days	—	—	—	—
SEDIMENT				
k, 100 µm	D.W.	C	N	P
0-2 days	0.1179	0.0880	0.1095	0.3540
2-15 days	0.0279	0.0271	0.0249	0.0417
15-30 days	—	—	—	—
30-90 days	0.0125	0.0119	0.0114	0.0132
90-142 days	—	—	—	—
k, 1 mm				
0-2 days	0.1867	0.2098	0.2179	0.4258
2-15 days	0.0112	0.0040	0.0057	0.0320
15-30 days	0.0327	0.0329	0.0219	0.0314
30-90 days	0.0113	0.0122	0.0132	0.0096
90-142 days	—	—	—	—

TABLE 3. — Comparison of *Ruppia cirrhosa* decomposition rates in sediment, sediment-water interface and water column (MENÉNDEZ *et al.*, 1989).

k, day^{-1}						
WATER COLUMN						
DAYS	0-3	3-15	15-30	30-60	60-120	120-180
100 µm	0.163	0.003	0.003	0.001	0.010	0.004
1 mm	0.213	0.011	—	0.004	0.001	—
SEDIMENT-WATER						
DAYS	0-2	2-15	15-30	30-90	90-142	
100 µm	0.146	—	—	0.005	0.006	
1 mm	0.160	0.010	0.020	0.024	—	
SEDIMENT						
DAYS	0-2	2-15	15-30	30-90	90-142	
100 µm	0.118	0.028	—	0.012	—	
1 mm	0.187	0.011	0.033	0.011	—	

However, the initial P content was greater in the detritus placed in the sediment (0.26 %) than in the detritus placed in the water column (0.15 %) (MENÉNDEZ, *et al.*, 1989). This difference could be the reason for a large development of microorganisms in the sediment and therefore the reason for the increment in the N content of the detritus (ELWOOD *et al.*, 1981).

Phosphorus was lost quickly during the first stages of the decomposition process from detritus, in agreement with the observations made by HOWARD-WILLIAMS and DAVIES (1979), BIRCH *et al.* (1983) and PELLIKAAN (1984). Phosphorus loss from the detritus was higher in the sediment than in the sediment-water interface and in the water column ($K_{0\text{-}3\ \text{days}}$ were 0.1037 and 0.2037 day^{-1} MENÉNDEZ *et al.*, 1989). BRINSON (1977) estimated an initial C:P ratio are of 200:1 as the maximum value that the microorganism can support to ensure complete decomposition. If the detritus C:P ratios is higher than this value (382:1 and 748:1 in detritus deposited in sediment-water interface and water column respectively) microorganisms need phosphorus from the environment. The high decay rates observed in the sediment using the same plant material can be explained by phosphorus limitation in water environments according to low phosphorus concentration observed in the water column during the period studied (COMÍN, 1984; COMÍN *et al.*, 1987, 1990). Differing phosphorus availability in sediment and water can explain the different decay rates in both environments. Further research on relationships between decomposition rates and nutrient availability are needed to support our hypothesis.

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