

Early decomposition of *Ruppia cirrhosa* (Petagna) Grande and *Potamogeton pectinatus* L. leaves

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SUMMARY

The decomposition of *Ruppia cirrhosa* and *Potamogeton pectinatus* was studied in laboratory in order to determine the release of nitrogen and phosphorus to water. We compare differences in short-term decomposition rates between *R. cirrhosa* and *P. pectinatus*, and we discuss the possible effect of the decomposition on the physical and chemical characteristics of the water. Senescent leaves of the two macrophyte species were put into plastic vessels with filtered water from La Tancada lagoon (Ebro River Delta, NE Spain). We analyzed biomass, C, N and ash content in the macrophytes samples and pH, conductivity, temperature and alkalinity and oxygen, N and P concentration in the water. We observed a decrease in oxygen concentration and pH, and an increase in alkalinity during the first 12 hours of incubation. Phosphorus and nitrogen as ammonium increases were higher in water with macrophytes than in water without macrophytes (control). Oxydized nitrogen decrease and SRP and ammonium increase were observed coinciding with dissolved oxygen depletion. Pattern of variation in N content was different in both macrophytes related to the chemical nature of the detritus and to inorganic nutrient concentration in the water. A quick nitrogen release in inorganic form during the four days of incubation was observed. Increase of SRP concentration may be related to leaching and to P solubility increase under anaerobic conditions.

KEYWORDS: *Ruppia cirrhosa*, *Potamogeton pectinatus*, decomposition

RESUMEN

Descomposición temprana de las hojas de *Ruppia cirrhosa* (Petagna) Grande y *Potamogeton pectinatus* L. Se estudió en el laboratorio la descomposición de las hojas de *Ruppia cirrhosa* y *Potamogeton pectinatus* con el fin de determinar la liberación de nitrógeno y fósforo al agua. Se comparan las diferencias en las tasas de descomposición a corto plazo entre *Ruppia cirrhosa* y *Potamogeton pectinatus* y se comenta el posible efecto de la descomposición en las características físicas y químicas del agua. Se colocaron hojas senescentes de las dos especies de macrófitos en contenedores de plástico con agua filtrada de la laguna de la Tancada (Delta del Ebro, NE España). Se analizó la biomasa y el contenido de C, N y cenizas en las muestras de macrófitos y pH, conductividad, temperatura, alcalinidad y concentración de oxígeno, N y P en el agua. Se observó una reducción en la concentración de oxígeno y el pH, y un aumento en la alcalinidad durante las primeras 12 horas de incubación. Los aumentos de fósforo y nitrógeno en forma de amonio fueron mayores en el agua con macrófitos que en el agua sin macrófitos (control). Se observó una disminución del nitrógeno oxidado y un aumento del SRP y del amonio en coincidencia con la depleción de oxígeno disuelto. La pauta de variación en el contenido en N fue distinta en las dos especies de macrófitos, en relación con la naturaleza química de los detritos y con la concentración de nutrientes inorgánicos en el agua. Se observó una rápida liberación de nitrógeno en forma inorgánica durante los cuatro días de la incubación. El aumento en la concentración de SRP puede estar relacionada con la lixiviación y con el aumento de la solubilidad del P en condiciones anaerobias.

PALABRAS CLAVE: *Ruppia cirrhosa*, *Potamogeton pectinatus*, descomposición.

INTRODUCTION

In shallow lakes macrophytes assume a greater part in the metabolism of the entire lake ecosystem (Wetzel & Allen, 1972; Mason & Bryant, 1975). Decomposition of these plants plays an important role in the metabolism of these lakes (Godshalk & Wetzel, 1978) mainly because they are temporal species which disappear once a year releasing its nutrient contents to the water and sediment. General models for the decay and remineralization of aquatic and terrestrial vascular plants have been proposed by Godshalk & Wetzel (1978), Rice (1982) and Melillo *et al.* (1984). The processes that affect the rates of loss of nonliving organic matter include leaching of soluble compounds, microbial degradation, and consumption by other heterotrophs (Mann, 1975; Harrison, 1977; Pellikaan, 1982). Three phases of decay of organic matter have been described:

- An initial phase of quick loss during which leaching rapidly removes materials that are either soluble or autolyzed after cell death (Valiela, 1984). The dissolved material is readily available to microbial heterotrophs for uptake and mineralization to CO₂ and inorganic nutrients (Godshalk & Wetzel, 1978,

Pellikaan & Nienhuis, 1988). Leaching is not a decomposition mechanism but a way in which soluble material is released and in most cases it is very hard to separate from microbial degradation and thus they have been studied together.

- A second stage, the decomposition phase, with lower rates of loss, when microbial activity is the prime process that degrades organic matter.

- A third phase, the refractory phase, where the remaining detritus are degraded slowly because of the high cellulose contents.

La Tancada is a small (1.8 Km²) shallow (37 cm mean depth) coastal lagoon, located in the Ebro Delta River (NE Spain). Conductivity changes from freshwater during spring-summer, coinciding with rice cultivation, to saltwater in autumn-winter. The lagoon shows extensive and dense rooted macrophytes beds mostly of *Ruppia cirrhosa*, which develops high biomasses from April to September (51-546.7 gAFDW m⁻², 350 g C m⁻² year⁻¹). A small part of the lagoon is covered with *Potamogeton pectinatus* (48.4-482 gAFDW m⁻², 242 g C m⁻² year⁻¹; Menéndez, 1989; Menéndez & Comín, 1989). At the end of summer, *R. cirrhosa* starts to degenerate, fall down (493 g AFDW m⁻² year⁻¹,

TABLE I. Comparison of *Ruppia cirrhosa* decomposition rates for dry weight, nitrogen and phosphorus in sediment, water-sediment interphase and water column (Menéndez *et al.*, 1989, 1993). *Comparación de las tasas de descomposición de Ruppia cirrhosa para peso seco, nitrógeno y fósforo en sedimento, interfase agua-sedimento y agua* (Menéndez *et al.*, 1989, 1993).

Time interval	mesh size	WATER COLUMN		
		DW, k day ⁻¹	N, k, day ⁻¹	P, k day ⁻¹
0-3 days	100 µm	0.163	0.141	0.174
0-3 days	1 mm	0.213	0.233	0.312
SEDIMENT-WATER INTERPHASE				
Time interval	mesh size	DW, k day ⁻¹	N, k, day ⁻¹	P, k day ⁻¹
0-3 days	100 µm	0.146	0.157	0.336
0-3 days	1 mm	0.160	0.142	0.351
SEDIMENT				
Time interval	mesh size	DW, k day ⁻¹	N, k, day ⁻¹	P, k day ⁻¹
0-3 days	100 µm	0.118	0.109	0.354
0-3 days	1 mm	0.187	0.218	0.426

Menéndez, 1989) and is deposited in dense packs on the shore of the lagoon where it decomposes (Menéndez *et al.*, 1989, 1993). Initial decomposition changes from aerobic to anaerobic conditions as detritus accumulate in the anaerobic sediment-water interface.

Ruppia cirrhosa decomposition was studied in situ in la Tancada lagoon using the litter bag method. From the obtained results comparing decomposition through 1 mm and 100 μm mesh size, and in different places (water column, sediment-water interface and buried in the sediment), an important role of macroinvertebrates in the decomposition process was concluded. Also significant differences between sediment-water interface and buried bags, where oxygen concentration was different, were found (Menéndez, 1989; Menéndez *et al.*, 1993; Table I). The main nitrogen and phosphorus contents decrease was described during the three first days of decomposition in water column. A 61-87 % decrease of total nitrogen content and a 66-75 % decrease of phosphorus content were observed using 100 μm and 1 mm mesh size bags.

The aim of this paper was to use an experimental design to understand the quick initial loss of biomass and nutrient contents observed in our previous study, and if this decrease involves nutrient release to the water column. Decomposition of *Potamogeton pectinatus* was included in the study, because it is the second species in importance found in La Tancada lagoon, and because this species shows a different nitrogen content than *Ruppia cirrhosa* (2.9 and 1.72 as a percentage of dry weight for *P. pectinatus* and *R. cirrhosa* respectively, Table II). Chemical composition of the organic matter is important in determining the loss of biomass and nutrients from leaching and microbial decay. Bacteria and fungi take up mineral elements, mainly nitrogen, but also phosphorus (Valiela, 1984). Differences between species, and between in situ and laboratory results are discussed.

TABLE II. Initial conditions in laboratory experiments with *Ruppia cirrhosa* and *Potamogeton pectinatus*. Condiciones iniciales en los experimentos de laboratorio con *Ruppia cirrhosa* y *Potamogeton pectinatus*.

	<i>R. cirrhosa</i>	<i>P. pectinatus</i>
Dry matter/culture	1.58	1.96
AFDW % DW	81.46	72.3
C % DW	38.09	35.22
N % DW	2.9	1.72
pH	7.93	8.08
O ₂ , ppm	8.2	7.4
Cond, mS cm ⁻¹	22.6	25.5
Alk, meq l ⁻¹	3.67	4.05
Cl ⁻ , mmol l ⁻¹	308	328
SO ₄ ⁼ , mmol l ⁻¹	12	14.2
Ca ⁺⁺ , mmol l ⁻¹	7.71	5.61
Mg ⁺⁺ , mmol l ⁻¹	31.4	21.88
K ⁺ , mmol l ⁻¹	5.39	3.12
NH ₄ ⁺ , mmol l ⁻¹	35.56	24.59
SRP, $\mu\text{mol l}^{-1}$	0.36	0.42
NO ₃ ⁻ +NO ₂ ⁻ , $\mu\text{mol l}^{-1}$	19.3	37.83

MATERIAL & METHODS

Experimental

Two separated and consecutive experiments, one of them with *R. cirrhosa* and the other with *P. pectinatus*, were performed in laboratory conditions. Senescent leaves (approximately 10 cm long) gathered from plants in La Tancada lagoon were collected at the end of its vegetative cycle in October. Plants were kept at 10° C and transported to the laboratory. Experiments started no longer than 10 h after the recollection. Leaves were gently blotted with paper for about 1 min. Leaves weighing about 10 g (± 0.001 g) of fresh weight were placed in plastic vessels (1 l capacity, 78 cm² section) with 500 ml of filtered water from La Tancada lagoon. The fresh:dry weight ratio of the initial plant material was computed from 6 replicates. The experiment was carried out in darkness to prevent phytoplankton growth. Both experiments included control vessels containing filtered water without macrophytes. Initial experimental conditions are shown in table II.

At various intervals (1, 5, 10, 15, 30 minutes and 1, 3, 4, 12, 24, 36, 96 hours) two vessels representing treatments and controls, in duplicate, were sacrificed for analysis. In each extraction triplicate samples of water for chemical analysis were taken in each vessel. Biomass was analyzed as dry weight, total C and N and ash contents of the macrophyte samples. Dry weight was determined at 60 °C for 48 h to constant weight. Total C and N were analyzed in a Carlo Erba elemental analyzer. A weighed fraction was ground and burnt at 500 °C for 3 hours for total ash determination.

Water with and without macrophytes was stirred before sampling. pH (Orion pHmeter), conductivity (Instran 10 conductivimeter), dissolved oxygen (Syland oxymeter) and water temperature (mercury thermometer) were measured. Nitrate, nitrite and ammonium nitrogen and soluble reactive phosphorus concentrations ($\mu\text{mol l}^{-1}$) were measured in filtered samples (Whatman, GF/C, 500 °C ashed filters) following Grasshoff *et al.* (1983) in a Technicon Autoanalyzer. Alkalinity (meq l^{-1}) was measured by potentiometric end-point titration (Metrohm 655 Dosimat).

In order to quantify differences between vessels with plants and controls, time of incubation and plants in physico-chemical parameters, a three-way ANOVA was performed on the data set. Factors considered were presence/absence of plant detritus, time and species of plant. Interactions between these factors were also considered. Tests for significant differences in nitrogen content between *R. cirrhosa* and *P. pectinatus* were conducted. Statistical tests were performed using the subprogram ANOVA/MANOVA CSS statistical.

RESULTS

Macrophytes

A decrease in dry weight was observed in the two macrophytes studied during the first

10 minutes of decomposition (Figs. 1 and 2). This decrease continues in *R. cirrhosa* during the rest of the incubation period (a 15.15% of the initial dry weight was lost until the 96 hours of decay; ANOVA, $p < 0.0004$).

Ash increase was observed during the first 5 min in *R. cirrhosa* (from 18.04% to 22.12 %) whereas in *P. pectinatus* ash decrease was observed (from 27.7 to 20.9 %). During the rest of the incubation the ash percentage remained fairly constant (around 21 % and 27 % respectively).

The initial N percentage of detritus DW was higher in *R. cirrhosa* (2.9 %) than in *P. pectinatus* (1.7 %; ANOVA, $p < 0.03$). Total N content of *R. cirrhosa* detritus remained fairly constant during the experiment, around 2.5 % DW, after an initial decrease (from 2.9 to 2.6 % N). A slight increase was observed between 3 and 12 hours of incubation (from 2.6 to 3 %). N content of *P. pectinatus* was also rather constant at 1.7-1.8 % of DW level, but increased slightly in the initial phase of the experiments (from 1.7 to 2 %) and decreased between 10 minutes and 12 hours of incubation (from 2.1 to 1.5 %).

C content remained fairly constant during the decomposition in both species of macrophytes (around 35-38 %; Figs. 1 and 2).

The instantaneous rate of decomposition (k) calculated according to the exponential model $W_t = W_0 e^{-kt}$ (Olson, 1963) was 0.033 day^{-1} ($r = 0.82$, $n = 13$, $p < 0.001$) for *R. cirrhosa*. Using a linear model, $W_t = -kt + W_0$ this rate was 0.047 day^{-1} ($r = 0.81$, $n = 13$, $p < 0.001$) (W_t : final biomass as DW, W_0 : initial biomass, t : time expressed as days).

Water

Statistical analysis revealed that differences between vessels with plants and controls in oxygen, alkalinity, pH, inorganic nitrogen and SRP concentrations were significant for *R. cirrhosa* and *P. pectinatus* (Table III). Differences between incubations with *R. cirrhosa* and *P. pectinatus* were also

significant. We observed significative interactions between all factors considered except for treatments (plant/control) and origin of detritus (*Ruppia* or *Potamogeton*) in alkalinity and ammonia.

The total depletion of oxygen content after 12 hours for both *R. cirrhosa* and *P. pectinatus* can be seen in figures 3 and 4. pH decreased from 7.93 to 6.97 in water with *R. cirrhosa* (Fig. 3). In water with *P. pectinatus*, pH

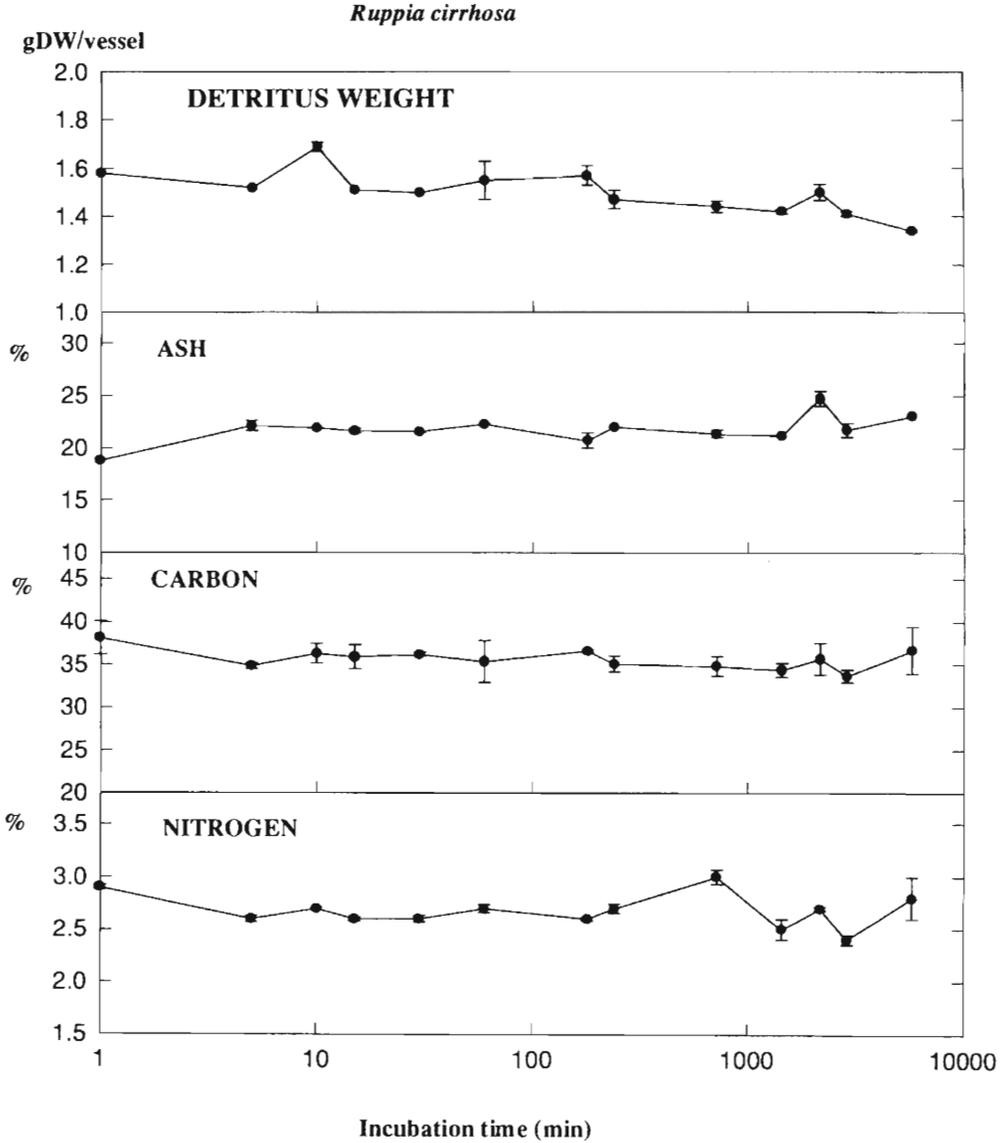


FIGURE 1. Variation of *Ruppia cirrhosa* detritus weight, % ash, % of dry weight of carbon and nitrogen during the decomposition process in laboratory. Variación del peso de detritos, porcentaje de cenizas, porcentaje de peso seco de carbono y nitrógeno durante el proceso de descomposición en el laboratorio.

decreased during the first 12 hours, remaining constant at about 7.2 and increasing at the end of the experiment. Oxygen content was correlated with pH during the first 12 hours, until oxygen disappeared ($r=0.92$, $n=8$ $p<0.001$; Fig. 4).

Alkalinity increased during the incubation period. No differences were observed between water with *R. cirrhosa* and controls during the first 12 hours. After this period, alkalinity increased at the same time as oxygen depletion and pH decrease, reaching a maximum of 5.86

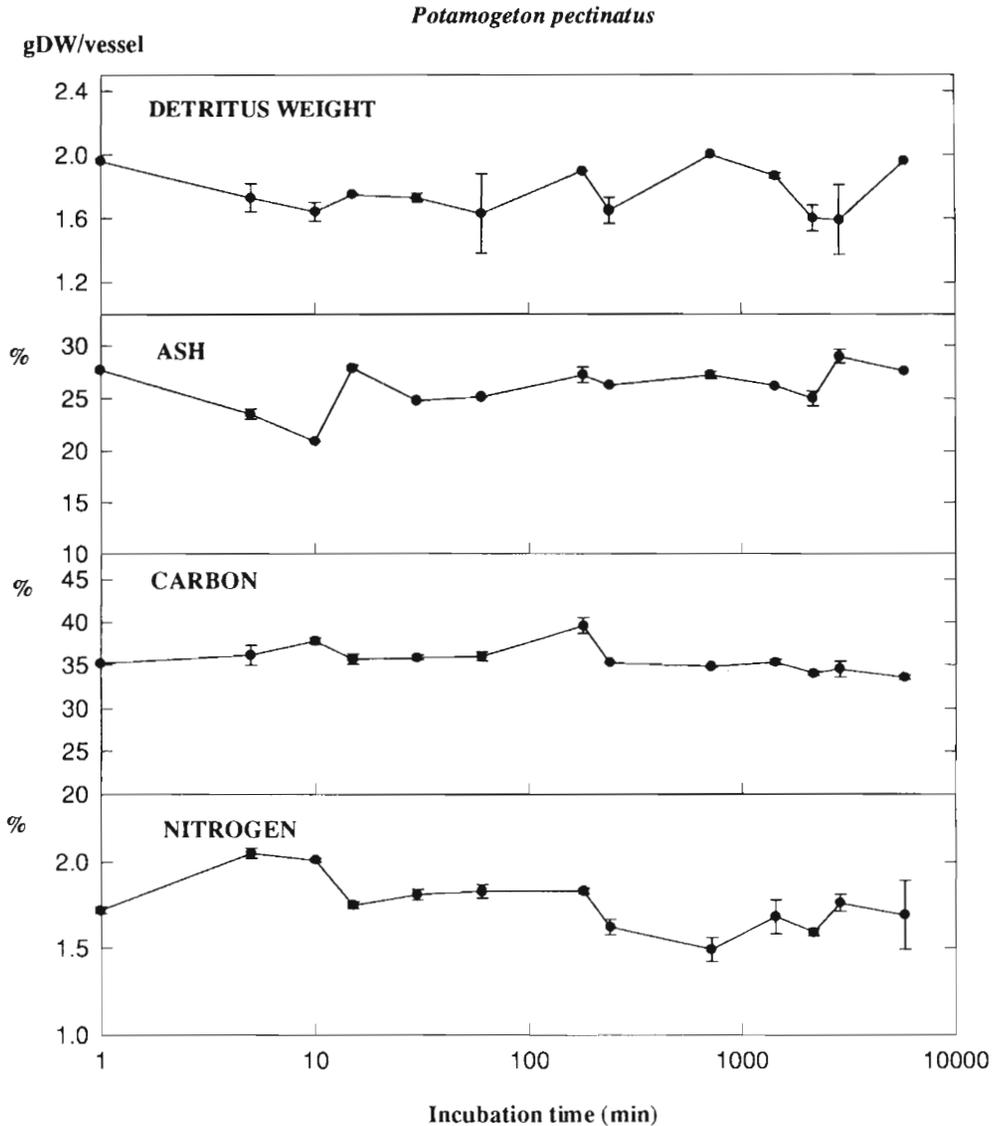


FIGURE 2. Variation of *Potamogeton pectinatus* detritus weight, % ash, % of dry weight of carbon and nitrogen during the decomposition process in laboratory. *Variación del peso de detritos, porcentaje de cenizas, porcentaje de peso seco de carbono y nitrógeno de Potamogeton pectinatus durante el proceso de descomposición en el laboratorio.*

TABLE III. Three-way ANOVA results from analysis of data on pH, oxygen, alkalinity, dissolved inorganic nitrogen and SRP concentrations. *Resultados de un ANOVA de tres vías del análisis de los datos sobre pH, oxígeno, alcalinidad y concentraciones de nitrógeno inorgánico disuelto y SRP.*

Variables	Source of Variation	Degrees of freedom	MS	F-ratio	p-level
pH	Time inc.	12	0.14	100.7	10 ⁻⁶
	plant/CT	1	5.21	3673.	10 ⁻⁶
	Pot/Rup	1	0.53	379.4	10 ⁻⁶
	Error	52	0.01		
	1,2	12	0.33	235.9	10 ⁻⁶
	1,3	12	0.02	20.5	10 ⁻⁶
	2,3	1	0.08	58.2	10 ⁻⁶
	1,2,3	12	0.02	15.1	10 ⁻⁶
O ₂	Time inc.	1	12.8	512	10 ⁻⁶
	plant/CT		651.9	2593	10 ⁻⁶
	Pot/Rup		1.44	57	10 ⁻⁶
	Error	5	0.02		
	1,2	1	13.1	521	10 ⁻⁶
	1,3	1	1.1	44	10 ⁻⁶
	2,3		25.8	1027	10 ⁻⁶
	1,2,3	1	0.92	37	10 ⁻⁶
Alkalinity	Time inc.	1	0.69	162	10 ⁻⁶
	plant/CT		1.86	433	10 ⁻⁶
	Pot/Rup		5.38	1251	10 ⁻⁶
	Error	5	0.00		
	1,2	1	0.56	130	10 ⁻⁶
	1,3	1	0.02	6.7	10 ⁻⁶
	2,3		0.06	1.5	0.2 N
	1,2,3	1	0.03	7.2	10 ⁻⁶
NO ₂ +NO ₃	Time inc.	1	0.67	121	10 ⁻⁶
	plant/CT		5.22	938	10 ⁻⁶
	Pot/Rup		1.91	343	10 ⁻⁶
	Error	5	0.05		
	1,2	1	0.86	155	10 ⁻⁶
	1,3	1	0.04	7.2	10 ⁻⁶
	2,3		0.72	12.9	0.000
	1,2,3	1	0.08	1.6	0.122
NH ₄	Time inc.	1	0.27	15.05	10 ⁻⁶
	plant/CT		1.26	70.36	10 ⁻⁶
	Pot/Rup		1.04	58	10 ⁻⁶
	Error	5	0.01		
	1,2	1	0.20	11.2	10 ⁻⁶
	1,3	1	0.05	3.14	0.00
	2,3		0.07	3.990.05	N
	1,2,3	1	0.07	4.02	0.000
SRP	Time inc.	1	0.66	63	10 ⁻⁶
	plant/CT		64.24	4185	10 ⁻⁶
	Pot/Rup		0.73	47	10 ⁻⁶
	Error	5	0.01		
	1,2	1	0.92	60	10 ⁻⁶
	1,3	1	0.48	31	10 ⁻⁶
	2,3		0.14	9.4	0.00
	1,2,3	1	0.37	24	10 ⁻⁶

meq l⁻¹ (Fig. 3; Table III). In water with *P. pectinatus* (Fig. 4) there was an increase after 24 hours of incubation, up to a value of 5.81 meq l⁻¹.

No significant changes in conductivity were observed for either *R. cirrhosa* or *P. pectinatus*. The observed final increase was caused by evaporation, as we can see from the control values. Temperature ranged from 18 to 22 °C. These variations were caused by fluctuations in ambient temperatures in incubation room and were similar to environmental water temperatures observed in La Tancada lagoon at the time of collection (20-22 °C).

Nitrogen as ammonium and SRP concentrations were higher in water with macrophytes than in controls (Figs. 5 and 6). In *R. cirrhosa* SRP concentration varies between 20 and 40 µmol l⁻¹ during the first 48 hours of incubation, increasing at the end of the experiment to 109 µmol l⁻¹. In *P. pectinatus* SRP concentration was around 20 µmol l⁻¹ up to 12 hours of incubation, when a tendency to a fluctuating increase was observed, reaching the maximum at the end of the experiment (96 hours) with 84 µmol l⁻¹. During the first 4 hours of incubation, ammonium concentrations fluctuated between 25 and 40 µmol l⁻¹ and between 35 and 70 µmol l⁻¹ in water with *R. cirrhosa* and *P. pectinatus* respectively. After this time, coinciding with oxygen decrease, an increase of 123 and 163 µmol l⁻¹ was observed for *R. cirrhosa* and *P. pectinatus*, decreasing afterwards and increasing again to a maximum value at the end of the incubation period (386 and 347 µmol l⁻¹ for *R. cirrhosa* and *P. pectinatus* respectively). A significant correlation was observed between ammonium and SRP concentrations for both *R. cirrhosa* (r=0.85) and *P. pectinatus* (r=0.78; n=13, p<0.001).

Water initial concentration of oxydized nitrogen in experiments with *P. pectinatus* (37.9 µmol l⁻¹) was almost double the concentration in experiments with *R. cirrhosa*

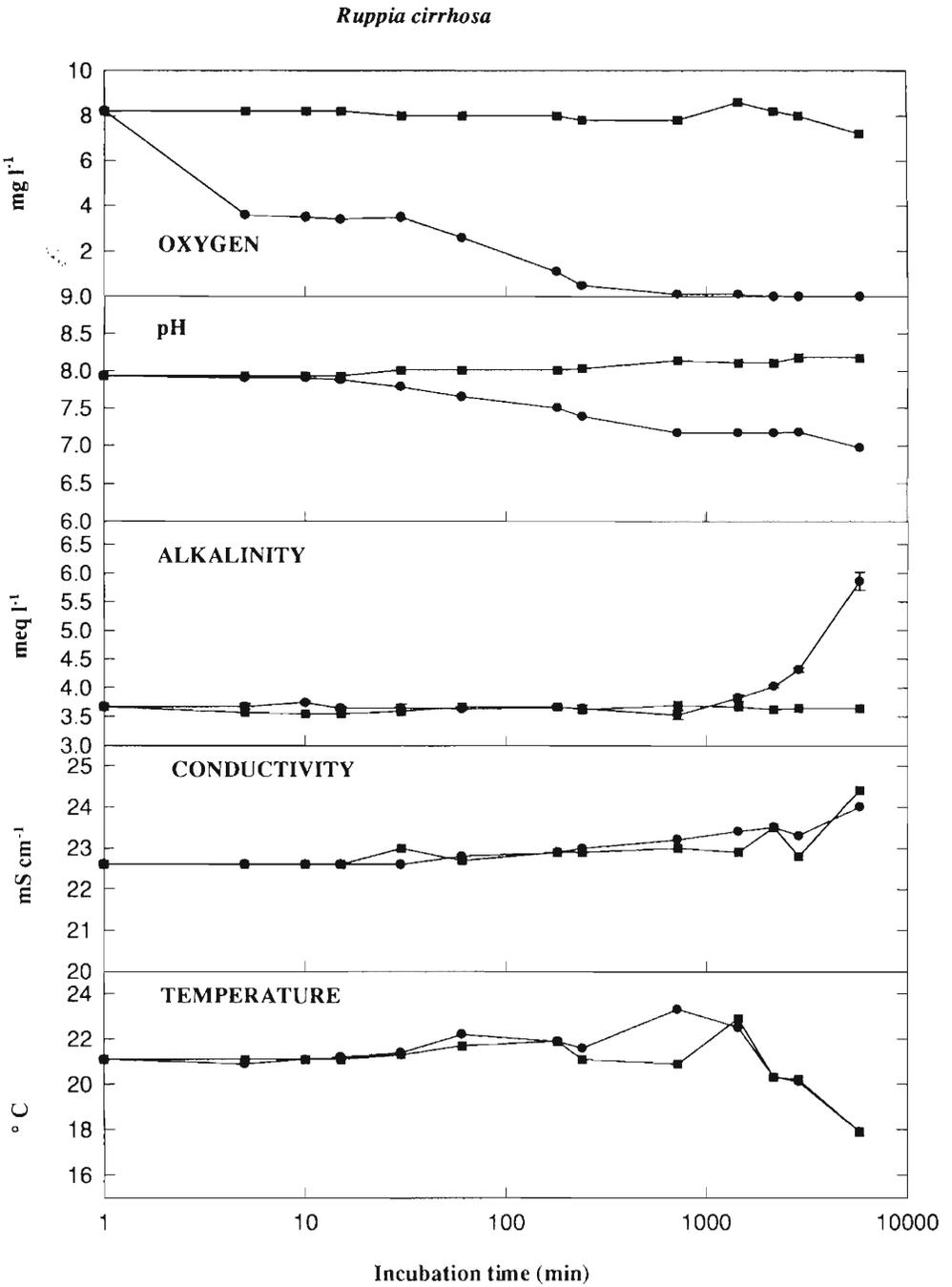


FIGURE 3. Changes in dissolved oxygen concentration, pH, total alkalinity, conductivity, temperature during *R. cirrhosa* experiments. Full squares, control; full dots, water with macrophytes. *Cambios en la concentración de oxígeno disuelto, pH, alcalinidad total, conductividad, temperatura durante los experimentos con R. cirrhosa. Cuadrados llenos, control; círculos llenos, agua con macrófitos.*

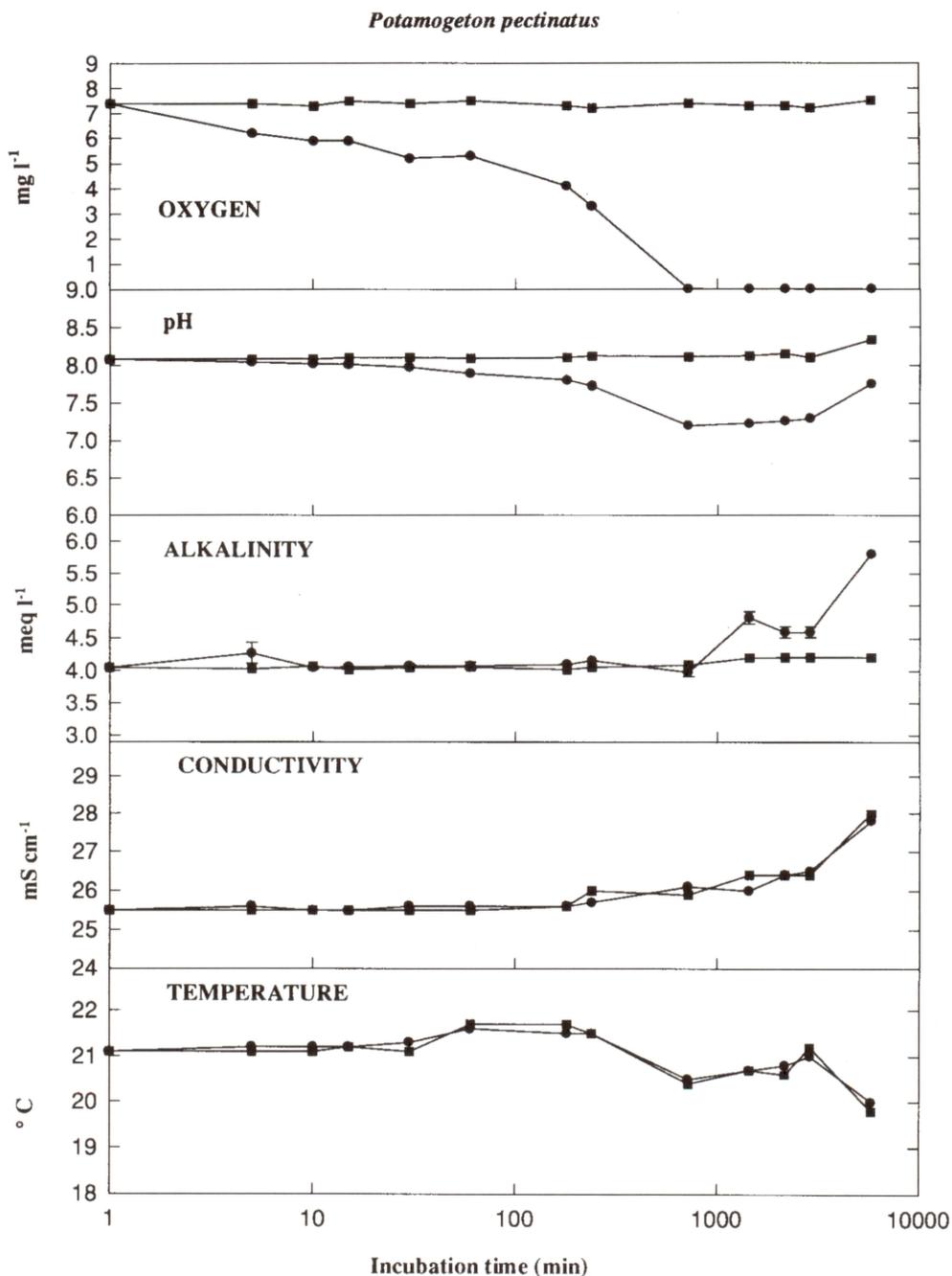


FIGURE 4. Changes in dissolved oxygen concentration, pH, total alkalinity, conductivity, temperature during *P. pectinatus* experiments. Full squares, control; full dots, water with macrophytes. *Cambios en la concentración de oxígeno disuelto, pH, alcalinidad total, conductividad, temperatura durante los experimentos con P. pectinatus. Cuadrados llenos, control; círculos llenos, agua con macrófitos.*

(19.3 $\mu\text{mol l}^{-1}$). Oxydized nitrogen concentrations in water with *R. cirrhosa* fluctuated around 15-20 $\mu\text{mol l}^{-1}$ whereas in water with *P. pectinatus* this concentrations were rather constant during the first 4 hours of incubation. After this time, oxydized nitrogen dissapeared completely in both experiments, coinciding with dissolved oxygen depletion (Figs. 5 and 6).

DISCUSSION

The initial nitrogen content is often considered as the controlling factor in plant

decomposition processes (Howarth & Fisher, 1976; Godshalk & Wetzel, 1978a, 1978b; Melillo *et al.*, 1984). Leaves high in nitrogen decay more rapidly than nitrogen-poor leaf species (Kaushik & Hynes, 1971, Twilley *et al.*, 1986).

Changes in the N-content and the C:N ratio are difficult to interpret because leaching of soluble components, nutrient enrichment of the particulate detritus by microbial colonization and formation of structural protein-like compounds can occur simultaneously (Pellikaan, 1984). Pattern of variation in N content was different in both macrophytes. These differences may be

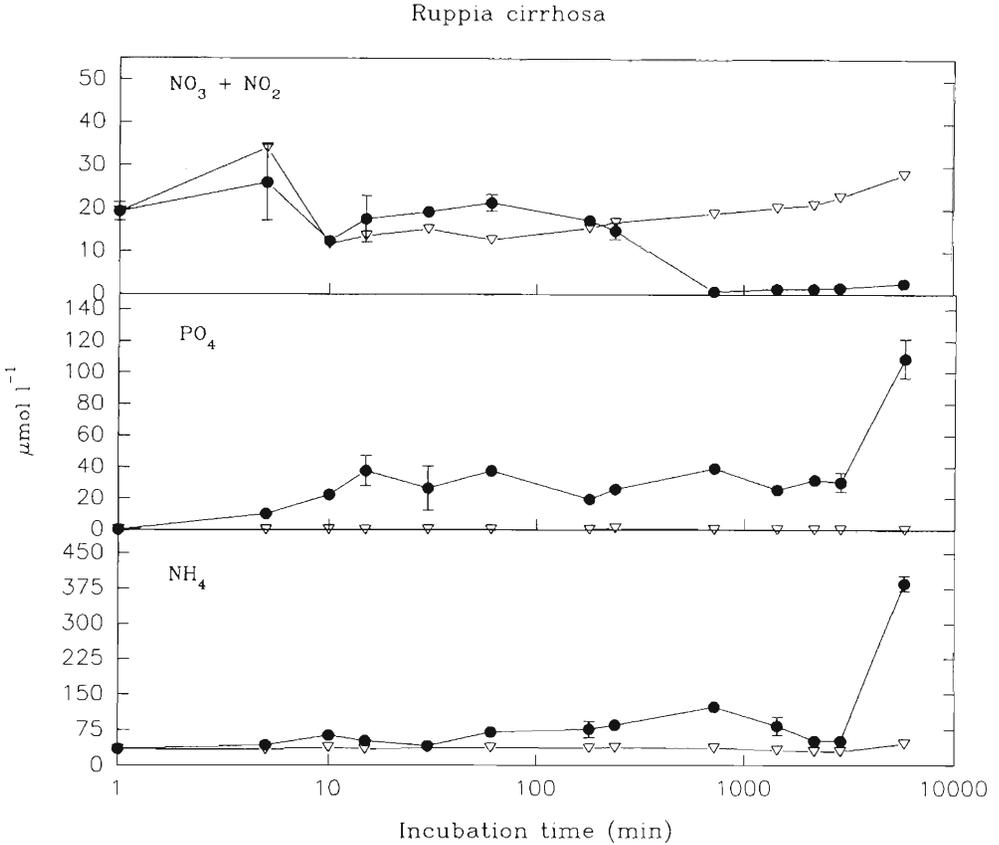


FIGURE 5. Changes in inorganic oxydized nitrogen (NO_3 and NO_2), ammonium (NH_4^+) and soluble reactive phosphorus (PO_4^{3-}) during *R. cirrhosa* decomposition. Inverted triangles, control; full dots, water with macrophytes. *Cambios en nitrógeno inorgánico oxidado (NO_3 and NO_2), amonio (NH_4^+) y fósforo reactivo soluble (PO_4^{3-}) durante la descomposición de *R. cirrhosa*. Triángulos invertidos, control; círculos llenos, agua con macrófitos.*

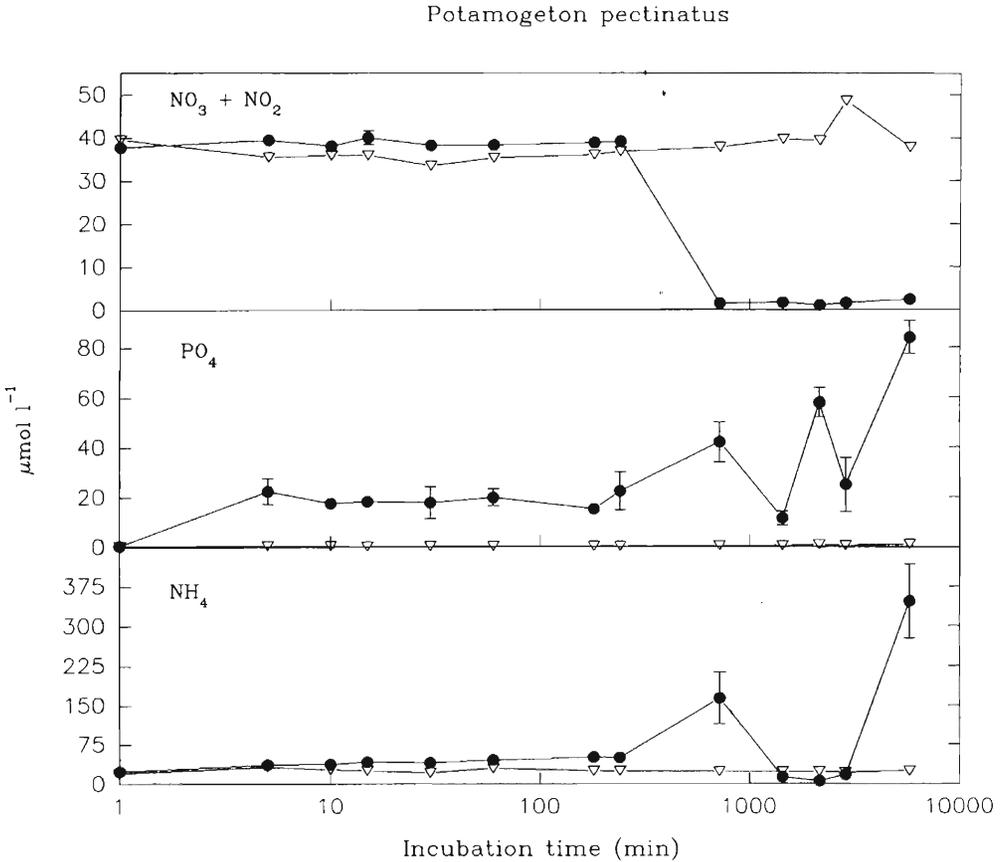


FIGURE. 6.- Changes in inorganic oxydized nitrogen (NO_3 and NO_2), ammonium (NH_4^+) and soluble reactive phosphorus (PO_4^{3-}) during *P. pectinatus* decomposition. Inverted triangles, control; full dots, water with macrophytes. Cambios en nitrógeno inorgánico oxidado (NO_3 and NO_2), amonio (NH_4^+) y fósforo reactivo soluble (PO_4^{3-}) durante la descomposición de *P. pectinatus*. Triángulos invertidos, control; círculos llenos, agua con macrófitos.

related to the chemical nature of the two detritus and to inorganic nutrient concentration in the water. It has been suggested that plant tissues with low initial C:N ratios tend to release N while tissues with C:N > 20 will conserve N as a result of microbial demand during decomposition. The initial increase in N content observed in *P. pectinatus* and the latter decrease when oxygen and oxydized forms of nitrogen disappear, may be related to the relative low initial N-content (C:N ratio of 20.5) in the detritus and to the high water

nitrate+nitrite concentrations observed (38 mol l^{-1}). This initial N enrichment in the detritus was probably the reason for the high initial decay and the percent ash decrease observed in *P. pectinatus* biomass during the first minutes of decomposition. However, in *R. cirrhosa* the initial N content decrease and C:N ratio increase may be related to the relative high initial N content in the detritus (C:N ratio of 12.5) and the low nitrate+nitrite water concentrations (19 mol l^{-1}). The increase of N-content in the detritus at the moment of the

oxygen depletion could be assimilated to an increase in ammonium concentrations (from 41 to 76 $\mu\text{mol l}^{-1}$) in the water.

The k value obtained (0.033 day^{-1}) for *R. cirrhosa* was lower than that obtained in litter bags experiments in La Tancada lagoon (0.1634 and 0.2174 using 100 μm and 1 mm mesh size litter bags; Menéndez *et al.*, 1989). Biological detrital processing includes microbial decay, remineralization, shredding and grinding by animals and digestion in animal guts (Odum, 1984). The differences observed could be explained by the activity of mesofauna and other variables (hydrodinamism, lost of particles from the bags, presence of sediment) in detritus accumulated in La Tancada water column. Mesofauna species (mainly *Gammarus aequicauda* and *Sphaeroma hookeri*) can speed up microbial decay by fragmenting large pieces of plant, thus increasing the surface available for attack by microbial enzymes. Direct assimilation of plant components in the litter by invertebrates may also contribute to the loss of biomass. In our laboratory experiments water was filtered through a Whatman GF/C filter; this allows nannoplankton and bacteria to pass but not the passage of individuals with a size between 1 and 100 μm (i. e., ciliates) which might play an important role in the in situ decomposition. Another possibility for the slow decomposition is a low bacterial growth and decomposing activity under anaerobic conditions (Godshalk & Wetzel, 1978b; Pellikaan & Nienhuis, 1988), particularly because lignin cannot be transformed by microorganisms as oxygen is required for cleavage of the ring structure (Fenchel & Blackburn, 1979). Increase of biomass observed in *P. pectinatus* after some incubation time could be explained by microbial conversion of DOC to the particulate fraction (Pellikaan, 1984).

The decomposition process began with a period of autolysis but was soon followed by active microbial degradation of organic matter.

Previous experiments made with different species (Bastardo, 1979; Novella, personal communication), demonstrates the importance of leaching of nutrients during the first days of decomposition. The increase of nitrogen as ammonium and phosphorus after three days of incubation is in agreement with the results obtained by these authors. Although leaching and microbial degradation were difficult to separate in the initial phase of decomposition, Kistritz (1978) found a drastic increase in suspended bacteria within the first five days of *Myriophyllum spicatum* incubation in in situ enclosed environments. In our study microbial breakdown probably began between the three and four days of incubation when a sudden increase in NH_4^+ concentration was observed (Figs. 5 and 6). Increase of SRP concentration may be related to leaching and to P solubility increase under anaerobic conditions.

Beginning from initial (1.58 g) and final (1.34 g) dry weight and nitrogen content in *R. cirrhosa* tissue (initial 2.9 %, final 2.6 %) we can calculate the expected value of N coming from plant decomposition in water as 784 $\mu\text{mol l}^{-1}$. As the observed concentration in water was 334 $\mu\text{mol l}^{-1}$ at the end of the studied period we can conclude that 42.6 % of the N released by *R. cirrhosa* during decomposition is in inorganic form after four days of incubation. This inorganic nitrogen could proceed from leaching and organic nitrogen remineralization. This result shows a quick nitrogen release during biomass decomposition. Jewell (1971) and Kistritz (1978) found a similar rapid release of nitrogen when aquatic plants were placed in complete darkness under laboratory conditions.

Although results derived from laboratory experiments were difficult to relate with processes occurring in natural environments, mainly the «enclosure effect» that contributes to anaerobic conditions, this situation is frequently encountered in eutrophic systems where aquatic plants are decomposing. In La Tancada lagoon local anaerobic environments near the shoreline where plant detritus

accumulates were observed. More research on the importance of initial leaching of nutrients in the recycling of N and P in coastal lagoons are needed in order to improve the knowledge of the availability of these nutrients to the primary producers in these shallow aquatic ecosystems.

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