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Production and decomposition in floating soils of the Iberá wetlands (Argentina)

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ABSTRACT

Floating soils grow due to the deposition of dead material onto their surface as well as the increment in belowground biomass. The imbalance between biomass production and decomposition is the source of organic matter accumulation. The Esteros del Iberá wetland (Argentina) features extensive areas of floating soils, locally known as "embalsados". The annual aboveground biomass production, decomposition rate, and changes in nitrogen content in *Thalia multiflora*, a common species of Iberá, were determined in order to assess the organic matter addition and the nitrogen dynamics in the floating soils dominated by this species. The aboveground net primary production was estimated by measuring the standing crop at the peak registered during the sampling period. The decomposition rates of leaves and stems were determined by the litterbag method. The litterbags were collected periodically during a year. The annual organic matter addition was estimated from the relation between aboveground production and the amount of mass lost in a year. The maximum aboveground biomass was 1368 g/m^2 (± 271 SD), 71 % stems and 29 % leaves. The loss of weight in the sampling period (399 days) corresponds to 78 % of the initial mass: the total biomass exponential decay coefficient was significantly (ANCOVA; $p<0.001$) lower in stems ($k = 0.0036$) than in leaves ($k = 0.0040$). Both the decomposition rate value as well as the P/D ratio = 1.37, indicate that in *T. multiflora* stands the organic matter incorporated to the floating soil's surface is small when compared to other peatlands. Initial nitrogen concentration in leaves and stems was 1.07 % and 0.32 %, respectively, this value increased to 1.76 % and 1.25 % in both substrates. Immobilization was observed in intermediate stages; by day 399, when leaves and stems lost nearly 2/3 of their initial weight, N values were similar to the initials, in agreement with the low nutrient availability that is characteristic of peatlands.

Keywords: wetlands; decomposition; production; macrophytes; floating soils; nitrogen.

RESUMEN

Los suelos flotantes crecen tanto debido al deposito de materia orgánica muerta en su superficie como al incremento en la biomasa subterránea. La acumulación de materia orgánica es el resultado de la diferencia entre la producción de biomasa aérea y su descomposición. Esteros del Iberá es un humedal que posee grandes extensiones de suelos flotantes, localmente llamados "embalsados". En este trabajo se determinaron la producción de biomasa aérea, la tasa de descomposición y los cambios en el contenido de nitrógeno de Thalia multiflora*, una especie abundante en Iberá, con el propósito de estimar el agregado anual de materia orgánica y la dinámica del nitrógeno en los embalsados dominados por esta especie. La producción de biomasa aérea anual fue estimada como la biomasa máxima registrada durante el período. Las tasas de descomposición de hojas y tallos fueron determinadas mediante la recolección de bolsas con material muerto de la especie, periódicamente a lo largo de un año. El agregado anual de materia orgánica al embalsado se estimó como la relación entre la producción de biomasa aérea y el peso perdido en un año. La biomasa máxima fue de 1368 g/m*^{2} *(± 271 DE), 71 % de tallos y 29 % de hojas. En el período de muestreo se perdió el 78 % del peso inicial, la tasa de descomposición fue significativamente (*$p<0.001$*) más lenta para tallos (*$k = 0.0036$*) que para hojas (*$k = 0.0040$*). Tanto la tasa de descomposición como la razón P/D = 1.37 indican que* T. multiflora *incorpora en forma superficial a los embalsados una pequeña cantidad de materia orgánica si se compara con otros humedales. La concentración inicial de nitrógeno en hojas y tallos fue de 1.07 % y 0.32 % respectivamente, aumentando hasta 1.76 % y 1.25 %. Se observó inmovilización en etapas intermedias del período de estudio, pero al final de 399 días cuando las hojas y tallos habían perdido cerca de 2/3 de su peso inicial, los valores de nitrógeno eran próximos a los iniciales, lo que concuerda con la baja disponibilidad de nutrientes señalada para humedales con características de turbera.*

Palabras clave*: humedales; descomposición; producción; macrófitas; suelos flotantes; nitrógeno.*

INTRODUCTION

Floating soils comprise large areas in wetlands of different latitudes. They originate from the interlacing of aquatic plant roots and rhizomes, and the accumulation of organic matter from the decay of vascular plants. The mats grow both due to the increments in belowground biomass and to the deposition of dead material on their surface (Denny, 1987; Hoog & Wein, 1987). As is the case with other wetlands, floating mats are detritus-based ecosystems (Wetzel, 1995) in which decomposition is the most important process driving the mineral cycling, and nutrient availability is low (Sasser & Gosselink, 1984; Verhoeven, 1986; Aerts *et al.*, 1999; Qualls & Richardson, 2000); the imbalance between biomass production and decomposition is the source of organic matter accumulation.

The Esteros del Iberá wetlands feature extensive areas of these floating soils, locally known as "*embalsados"*. They sustain a high vegetation biomass, and high species diversity whose decomposition rate could determine the nutrient availability to the vegetation. Since there is no information on litter dynamics, overall decomposition and relation between production and decomposition in Iberá floating mats, we determined the annual aboveground biomass production and decomposition rate of a common species of the embalsados, *Thalia multiflora* Horkel (Fam. Marantaceae). Our goal was to assess the annual organic matter addition and nitrogen dynamics of dominant *T. multiflora* stands.

STUDY AREA

The Esteros del Iberá wetland, is located in the Corrientes Province (NE of Argentina) and has an area of 13 000 km^2. Iberá is a complex ecosystem developed in an inland depression, and comprises lagoons, streams, marshes, floating soils (*embalsados*) and rice fields, all interconnected by shallow streams of slow-flowing water (Bonetto & Hurtado, 1998). The annual mean air temperatures vary between 19.8 y 21.4°C, annual PPT between 1200 and 1700 mm (Ferrati *et al.*, 2003)

This wetland has been characterized as a tropical peatland because of the organic matter accumulation and the dominance of macrophyte vegetation (Neiff, 1999). Iberá has high diversity, as well as several animal species of conservation interest. For that reason the area is protected since 1985. Human activities are mainly constrained to rice fields, extensive livestock raising, forestry exploitations, and tourism.

Sampling was carried out in the "embalsados" around the littoral of the Iberá Lagoon. This water body is located in the southeastern part of the Esteros del Iberá (57°11'W - 57°04'W; 28°27'S - 34°24'S) (Fig. 1). Some characteristics of the interstitial water of the "embalsados" during the study were (mean ± SD): temperature: 18.8°C ± 4.8°C; pH: 5.76 ± 1.1 and dissolved oxygen 1.46 mg /l ± 1.40. The organic matter content in the embalsados' sediment was 77 % ± 5 % and moisture was 90 % ± 2 %

The dominant species in this area were *Cyperus giganteus*; *Rhyncospora* spp.; *Thalia multiflora*, and *Schoenoplectus californicus*

Figure 1. Location of the Iberá lagoon in the Corrientes province (Argentina) and location of sampling sites (a and b). *Ubicación de la laguna Iberá en la provincia de Corrientes (Argentina) y de los sitios de muestreo (a y b).*

(Gantes *et al.*, 2003). *T. multiflora* is a common species in the Esteros del Iberá (Neiff, 1981). It is a latifoliated perennial plant with rhizomes, that looses all the aboveground biomass in winter.

MATERIALS AND METHODS

Aboveground net primary production was estimated using the peak of the standing crop registered during the sampling period (Westlake, 1965; Boyd & Vickers, 1971; Ibañez *et al.*, 1999; Venterink *et al.*, 2002). *T. multiflora* aboveground biomass was measured in *T. multiflora* dominant stands, at six times during the year. Each time, the total vegetation present in 3 quadrates (2500 cm^2) was clipped, sorted between leaves and stems, and oven-dried at 80°C to constant weight; ash content was determined by combusting sub-samples at 500°C. It was considered that the annual litter production could be estimated from the aboveground net primary production. This is possible because, *T. multiflora* turns over nearly all the aboveground biomass annually; but on the other hand, and because an unknown portion of this production is translocated to underground parts, it was estimated that the annual litter production is at most, equivalent to the aerial production.

Standing dead material was harvested from randomly chosen "embalsados" at several different locations in the Iberá lagoon. The litter was rinsed, cut into 10 cm fragments and oven dried at 40°C. Sixty litterbags (20 x 20 cm, 1 mm mesh) filled with 10 g of this material (5 +/- 0.5 g leaves and 5 +/- 0.5 g petioles and stems) were placed lying horizontally on the "embalsado". The litterbag technique is probably not the ideal method to study decomposition of emergent plants (Newell, 1993). However it is still widely used and it was applied for comparative purposes. The litterbags were collected after 39, 85, 123, 206, 275, 333 and 399 days. They were carefully rinsed and sediment was removed from the litter by hand. Dry weight and ash free dry weight of litter were determined here as in the aboveground biomass samples. Leaves and stems were separated and the data analyzed separately. The total nitrogen Kjeldhal (AOAC, 1984) was determined for three sub-samples each date, except for the second and last collections.

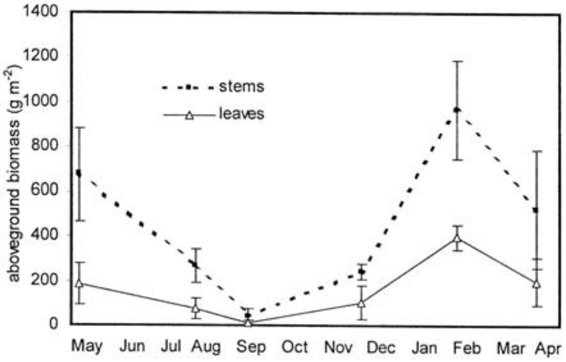

Figure 2. Changes in aboveground biomass (g dry weight/m^2) of *Thalia multiflora* (mean ± SD). *Cambios en la biomasa aérea (g peso seco /m^2) de* Thalia multiflora *(media ± un desvío estándar).*

The decomposition data were evaluated with a single exponential decay model (Olson, 1963). The data were ln transformed and ANCOVA was employed to compare the leaves and stems weights' remaining in the bags, using the elapsed time as a co-variable. The annual dead material addition was then estimated from the relation between aboveground production and the amount of mass lost in a year (Thormann *et al*, 1999). Differences in the percentages of initial nitrogen during the sampling period were determined by ANOVA and followed by Tukey's test.

RESULTS

The maximum aboveground biomass reached 1368 g dry weight/m^2 (± 271 SD), 71 % of which corresponded to stems and 29 % to leaves; the minimum aboveground biomass was 53 g/m^2 (± 46 SD) (Fig. 2). Maximum biomass was achieved in February, whereas the minimum value was observed in September.

Stems of *T. multiflora* lost 74 % of their initial mass in 399 days, whereas leaves lost 81 % of their initial mass that corresponds to decay coef-

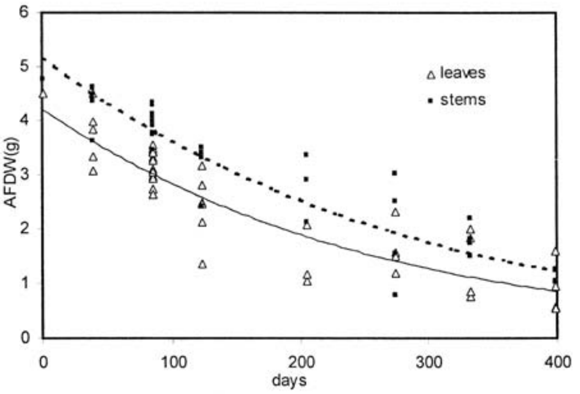

Figure 3. Mass remaining (g AFDW) of *T. multiflora* in the litterbags. Exponential equations of mass remaining are: $y = 4.200 \exp(-0.004\, t)$, $r^2 = 0.75$ for leaves and $y = 5.172 \exp(-0.0036\, t)$, $r^2 = 0.82$ for stems. *Peso (g peso seco libre de cenizas) de* T. multiflora *persistente en las bolsas de descomposición. Las ecuaciones exponenciales correspondientes son:* $y = 4.200 \exp(-0.004\, t)$, $r^2 = 0.75$ *para las hojas e* $y = 5.172 \exp(-0.0036\, t)$, $r^2 = 0.82$ *para los tallos.*

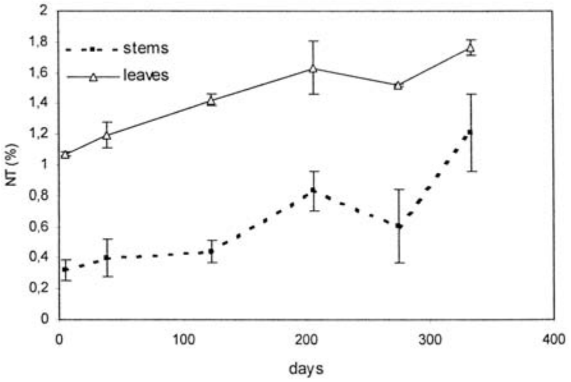

Figure 4. Nitrogen concentration (% dry weight) in leaves and stems remaining in litterbags (mean ± SD). *Concentración de nitrógeno (% del peso seco) en hojas y tallos persistentes en las bolsas (media ± un desvío estándar).*

ficients of k = 0.0036 and 0.0040 for stems and leaves respectively, being the difference significant at $p < 0.001$ (ANCOVA, Fig. 3).

Annually *T. multiflora* stands contribute a maximum of 1208 g ash free dry weight (AFDW)/m^2 to the “embalsados”. In agreement with the decay coefficients calculated, in the same period, breakdown of the material was 73 %, and therefore a maximum of 326 g (AFDW)/m^2 of dead material is accumulated annually on the “embalsado” surface. As a result, the estimated relation between litter production and decomposition was 1.37 (Table 1).

Nitrogen concentration increased from 1.07 % (± 0.07 SD) in leaves as well as from 0.32 % (± 0.01 SD) to 1.76 % (± 0.25 SD) in stems and 1.25 % (± 0.05 SD) respectively at the end of the study period (Fig. 4). Percentage of initial nitrogen in litterbags exceeded 100 % (immobilization) in intermediate stages in stems ($p<0.008$) (Fig. 5); in leaves, the difference was significant only between the intermediate period and the last record ($p<0.03$) (Fig. 6). Therefore, at the end of approximately one year, the amount of nitrogen in the material remaining in the bags was not significantly different from the initial content.

DISCUSSION

Decomposition rates of leaves have been related to intrinsic factors such as leaf chemistry and to environmental conditions such as temperature

Table 1. Aboveground production (mean ± SD), decomposition rate (standard error), dead persistent material (mean ± SD), non-persistent material (mean ± SD), and Production/non-persistent material ratio of *Thalia multiflora* over a year period in Iberá. *Producción de biomasa aérea (media ± DE), tasa de descomposición (error típico), material muerto persistente (media ± DE), material no persistente (media ± DE), y relación entre producción y material no persistente al cabo de un año para* Thalia multiflora *en Iberá.*

	Annual production (g AFDW m^{-2} yr^{-1})	**Exponential decay coefficient k (1/day)**	**Mass remaining (g AFDW m^{-2} yr^{-1})**	**Mass lost (g AFDW m^{-2} yr^{-1})**	**Production / Mass lost**
Stems	855 (± 195)	0.0036 (± 0.0003)	249 (± 57)	605 (±139)	1.41
Leaves	353 (± 51)	0.0040 (± 0.0004)	77 (± 11)	277 (±40)	1.28
Total	1208 (± 239)	0.0038 (±0.0002)	326 (± 66)	882 (±173)	1.37

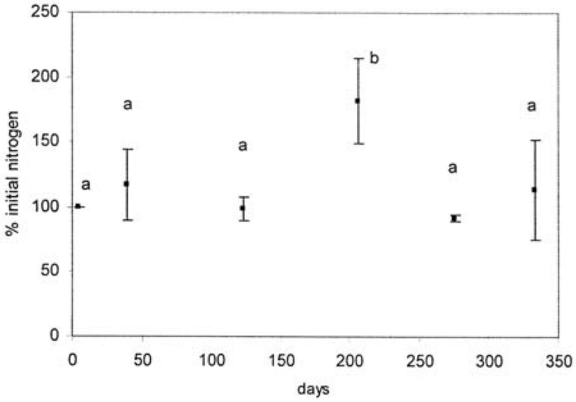

Figure 5. Percentage of initial nitrogen in stems remaining in litterbags (mean ± SD). Data points with the same letter are not significantly different (Tukey, p<0.008). *Porcentaje de nitrógeno inicial en los tallos persistentes en las bolsas (media ± un desvío estándar). Letras iguales no son significativamente diferentes (Tukey, p<0.008).*

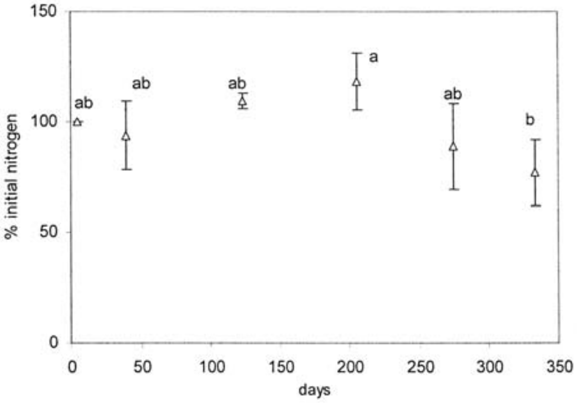

Figure 6. Percentage of initial nitrogen in leaves remaining in litterbags (mean ± SD). Data points with the same letter are not significantly different (Tukey, p< 0.03). *Porcentaje de nitrógeno inicial en las hojas persistentes en las bolsas (media ± un desvío estándar). Letras iguales no son significativamente diferentes (Tukey, p< 0.03).*

and availability of nutrients (Clymo, 1965; Brinson *et al*., 1981; Verhoeven, 1986). Moreover, the results are also likely to be affected by methodology (Boulton & Boon, 1991). Even though there are no records of *T. multiflora* decomposition rates, the results presented here are in good agreement with other decomposition studies performed with other emergent aquatic plants and under similar conditions: the decay coefficient (*k*) found in this study, overall k=0.0038 1/day, is similar to the decomposition rate found in floating soils for *Scirpus cubensis* in Sao Paulo, Brazil, (k=0.0035 1/day) (Nogueira & Esteves, 1993); and for *Typha latifolia* in other "embalsados" of the Paraná basin (k=0.0040 1/day) (Zozaya Bruquetas & Neiff, 1991). According to data on wetlands published by several authors, the decomposition rate presented here is not comparatively low: *Typha latifolia* (Brinson *et al*., 1981); *Phragmites australis, Scirpus lacustris glaucus, Typha x glauca* (van der Valk *et al*., 1991); *Nectandra falcifolia* (Leguizamón *et al*., 1992); *Typha angustifolia*, *T. latifolia*, *T. glauca* (Mitsch & Gosselink, 1993); *Typha spp*, *Lythrum salicaria* (Emery & Perry, 1996); *Juncus effusus* (Kuehn & Suberkropp, 1998); *Typha latifolia* (Thormann *et al*., 1999); *Cyperus giganteus*, *Schoenoplectus californicus* (Villar *et al*., 2001).

In this study, primary production was estimated from maximum aerial biomass measurements. This estimation does not take into account the substances translocated between aerial and belowground parts. Furthermore, herbivory and mortality before the biomass peak could then underestimate this maximum. However, *T. multiflora* is not part of the capybara and marsh deer diets (Becassesi, pers. comm.); moreover, we did not observed signs of herbivory in *T. multiflora* during samplings. Nevertheless, mortality previous to maximum biomass could not be discarded, and therefore biomass production, and then the litter production could have been underestimated.

The maximum litter accumulated in one year during our study was about 326 g AFDW/m^2. This value was calculated from dead material remaining in the bags. However, it does not take into account the loss of plant fragments passing through the 1 mm mesh size; therefore, the rate of organic matter accumulation was partially underestimated.

There is no available data to compare with, on the production /decomposition ratio (P/D) from similar places. At higher latitudes, Thormann *et al.* (1999) working in a gradient of wetlands in Canada, found values for this ratio ranging from 7.1 to 1.6, the highest in

Sphagnum dominant peatlands, with 4.5 m thickness. The Iberá ratio is close to the lowest value for Canada, and corresponds to a primary production three times higher in Iberá.

Hoog & Wein (1987) pointed out that floating-mats originated in vascular perennial plants, grow mainly from belowground organs. The results of our study indicate that there is annual organic matter accumulation on the "embalsados'" surface. Nevertheless, if the total floating mat weight is considered, the aboveground biomass contribution is small; the average dry weight of one m^2 of floating mat, 30 cm in thickness was 28.362 g (Gantes *et al*., in press). Thus, the annual organic matter accumulated from the aerial biomass represents approximately 1.15 % of the total "embalsado" mass.

The absence of nitrogen mineralization after nearly one year, indicates that nitrogen remains as organic matter, in agreement with low nutrient availability pointed out for peatlands (Aerts *et al*., 1999; Mitsch & Gosselink, 1993).

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