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ABOVE AND BELOWGROUND PRODUCTION OF *PHRAGMITES AUSTRALIS IN* THE PO DELTA, ITALY(*)

Summary. From March through October 1995 above- and belowground production for *Phragmites australis* were studied in a tidally affected reedbed close to the mouth of the Po delle Toile distributary in the Po Delta. This site is subject to periodic influx of sea water as well as prolonged freshwater conditions during high river flow. Growth took place mostly between May and August. Aboveground production was 876 g d.w./m^2, with a peak live biomass of 780 g/m^2; belowground production was 2263 g/m^2 with a peak live biomass of 4087 g/m^2. The net efficiency, with regard to PAR, was 1.1 %. These production values are comparable with others observed at Mediterranean coastal sites, but regular submersion by salt water probably leads to lower aboveground biomass and higher belowground biomass at the Po Delta site.

Riassunto. *Produzione epigea ed ipogea di* Phragmites australis *nel Delta del Po, Italia.*
Da marzo ad ottobre 1995 è stato studiato l'accrescimento e la produzione di biomassa, sia epigea che ipogea, di *Phragmites australis* in un canneto alla foce del Po di Toile, nel settore meridionale del delta del Po. Lo sviluppo della componente epigea è stato maggiore nel periodo maggio-agosto, con valori di biomassa massima pari a 780 g p.s./m^2 La produzione epigea nel periodo marzo-agosto è risultata di 876 g./m^2, mentre quella ipogea nell'intero periodo di studio è stata di 2263 g/m^2, con valori di biomassa viva massima pari a 4087 g/m^2. L'efficienza netta di conversione dell'energia solare, considerando la sola componente PAR, è stata dell' l.1 %. 1 valori di biomassa e produttività sono confrontabili con quelli rilevati in altri siti costieri europei; l'influsso delle acque salmastre e l'alternanza di periodi di sommersione ed emersione, probabilmente determinano però un maggior sviluppo della componente ipogea nel canneto studiato.

Key words: biomass, production, *P.australis,* Po Delta

INTRODUCTION

Along the northern Adriatic coast of Italy there are a number of shallow coastal lagoons and deltas; the largest Italian lagoon, the Lagoon of Venice (55, 000 ha), and the largest delta, the Po Delta (61,0000 ha) are in this area. Coastal marshes make up a significant portion of the area of these coastal ecosystems. Despite the ecological and economic importance of these wetland habitats, no data are available about primary production of salt or freshmarshes plants occurring in these wetlands. There are many phytosociological studies in this area (GEHU et al., 1984; GERDOL et al., 1984; FERRARI et al., 1985; BUFFA et al., 1995), but growth dynamics have rarely been investigated for the Adriatic saltmarshes (CANIGLIA et al., 1976 and 1978; SCARTON et al., 1998 and 1999).

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Biomass and production of coastal wetlands are good indicator of vegetation health and of their importance to the functioning of the overall ecosystem (DAY et al., 1989). Factors such as competition, salinity, degree of waterlog ging, and nutrient status play important roles in regulating production (PENNINGS & CALLAWAY, 1992; MAHALL & PARK, 1976a and 1976b). Previous literature concerning primary production of wetland vegetation is very extensive (e.g., MASON and BRYANT, 1975; HOPKINSON et al., 1978; GROENENDJJK,1984; LINTHURST & REIMOLD, 1978; HACKNEY and DE LA CRUZ, 1980; GROENENDIJK and VINK-LIEVAART, 1987; LEE, 1990; LEFEUVRE and DAME, 1994; de LEEUW et al., 1996); however, very little of this literature refers to Mediterranean wetlands.

The data presented here were gathered in the framework of a larger European Community project, the MEDDELT Project, on the impact of cli mate change on three Mediterranean deltas; the Po in Italy, the Rhone in France and the Ebro in Spain. This larger effort involved measurements of vegetation ecology, accretionary dynamics in the deltaic plain, geomorphological change of beach and dune systems along the fringes of the deltas and the physical oceanography of the near shorezone. As part of the overall project, we measured the growth, production, and decomposition of two wetland species; *A. fruticosum*, which covers an extensive area in southern Venice lagoon saltmarshes (SCARTON et al., 1996 and 1998), and P. *australis*, for which we report here data about production and growth.

STUDY AREA

The Po is one of the most important rivers discharging to the Mediterranean; it is the fourth longest (650 km) and has a mean discharge of about 15⁽ⁱ0 m^3/s. The Po delta covers about 61,000 ha (Fig. 1). The delta was created over the past several thousand years as the river successively occupied a number of different river channels (SESTINI 1992). Formerly, most of the deltaic plain was covered by extensive freshwater wetlands. Most of these, however, were reclaimed over the past century for agriculture. Much of the deltaic plain now lies 1-4 meters below sea level due to subsidence caused primarily by extraction of shallow deposits of natural gas with a high water content (SESTINI 1992). The fringes of the delta are characterized by beaches and dunes, shallow lagoons and salt marshes. There are extensive reed swamps dominated by *P. australis* bordering the lower ends of the main river channels.

The study area is located in the southern Po Delta near the mouth of Po delle Tolle distributary, on the backside of a barrier island, at approximately 44°50'N, 12°28'E (fig. 1). The site consists of an almost pure stand of P *australis*, with sparse occurrence of *Scirpus* sp. in less frequently inundated locations. The site, which has a mean elevation of 0.28 m m.s.l., is located in a reedbed 50-80 m wide and which stretches about two km along the river. The river is about 50 m wide and 5-6 m deep; mean flood discharge is approximately 200 m^3/s. The marshes are flooded for extended periods during high river discharge and by about 20 cm during high tides when river discharge is low. Groundwater salinity at the site ranged between 6 and 25 ppt with a mean of 12 ppt.

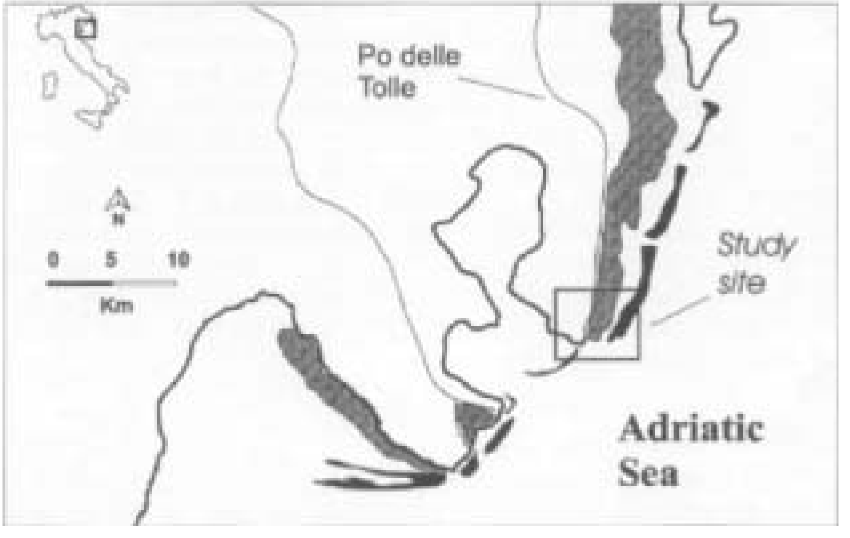


Fig. 1. Study area location; barrier islands are in black and reedbeds in grey.

MATERIALS AND METHODS

Measurements were carried out of above and belowground biomass and productivity. In September and October 1994, preliminary measurements were carried out to determine the number of biomass samples needed and the vertical distribution of root biomass.

Estimates of aboveground primary production were calculated from periodic harvest of aboveground biomass. At each sampling period, sampling locations within the plot were randomly selected. Seven 0.25 m^2 aboveground biomass samples were collected in March, May, June, August, and October 1995. Each component of the biomass samples was separated into live and dead material; the plant material was taken to the laboratory and dried at 80°C for 48 hours and weighed to a precision of 0.1 g. Aboveground production was estimated for both species using the Smalley method (see LINTHURST & REIMOLD, 1978a and GROENENDIJK 1984 for more details). The ash content of the material collected was determined by ignition for two hours at 550° C. In August, 35 stems of different height were measured and weighed, after being dried at 80°C for 48 h.

Belowground biomass was sampled in March and October 1995. Seven randomly chosen locations were sampled with a PVC core 9.4 cm in diameter; cores were taken to a depth of 50 cm. The depth was chosen based on root distributions measured in the October 1994 preliminary sampling. In the laboratory, the material was sieved through a mesh of 0.1 cm, sorted into dead and live small and large roots/rhizomes and then dried and weighted in the same manner as the aboveground material. Invasion cores were prepared at each site in March 1996 by filling with sand the seven holes made when belowground biomass was sampled. The core locations were carefully marked and they were collected at the end of the growing season in October. New root material in the invasion cores was sieved, dried and weighted in the same manner as the total belowground biomass. Belowground production was estimated using Smalley's biomass method and the invasion core methods. Meteorological data refer to a station located about ten km north west of the study site. Calorific value for the *Phragmites* plant was taken as 19.5 KJ/g ash-free dry weight (Ho, 1979).

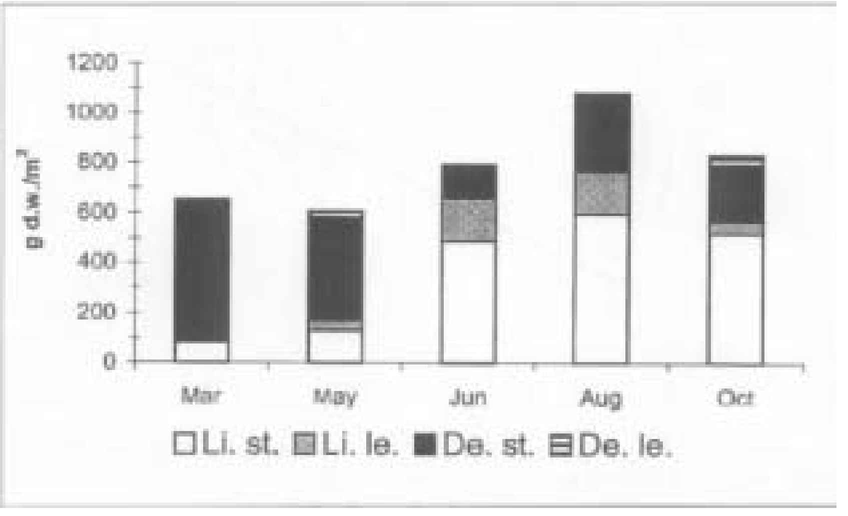
RESULTS

Mean monthly air temperature in 1995 ranged from 3.1-24.5 °C, with a annual mean of 13.0°C; the annual precipitation was 896 mm and the total radiance was 152.7 MJ/m^2

In fig. 2 the observed values for above- and belowground biomass are displayed. Maximum biomass occurred in the late summer or early fall for both above and belowground biomass; the aboveground biomass increased steadily from March to August, then decreased. Maximum aboveground biomass occurred in August (1095 g/m^2) while maximum belowground biomass was in October (5600 g/m^2). In August, live stems made up about 55%, live leaves 15% and dead standing material 30% of the total aboveground biomass. Surface litter (not included in the above reported values) was always abundant, ranging from 300 to 600 g/m^2. In August, during the period of maximum growth, the reedbed was less than 2.5 in height, with a stem density ranging between 160 and 200 stems/m^2. The regression line for biomass and height, measured in August, is shown in fig. 3.

Roots and rhizomes biomass was 5600 g/m^2 in October with live roots representing 18%, live rhizomes 55% and dead material 27%. Since there was no significant occurrence of other species, these values can be assumed to be representative of *P. australis* only. The ratio of above to belowground live biomass in October was 0.14.

The aboveground production was 876 g/m^2, based on the Smalley method.



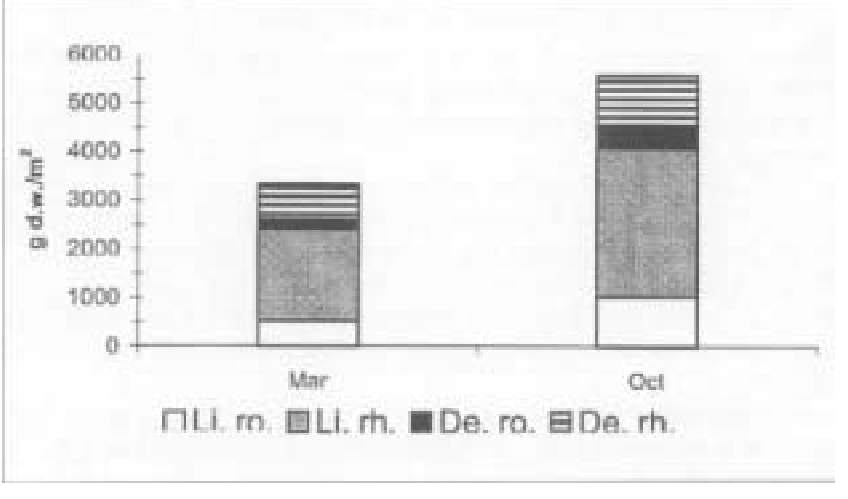


Fig. 2. Above and belowground biomass (note the different scales in the graphs) of *P. australis*. De=dead, le=leaves, Li=live, ro=roots, rh=rhizomes, st=stems.

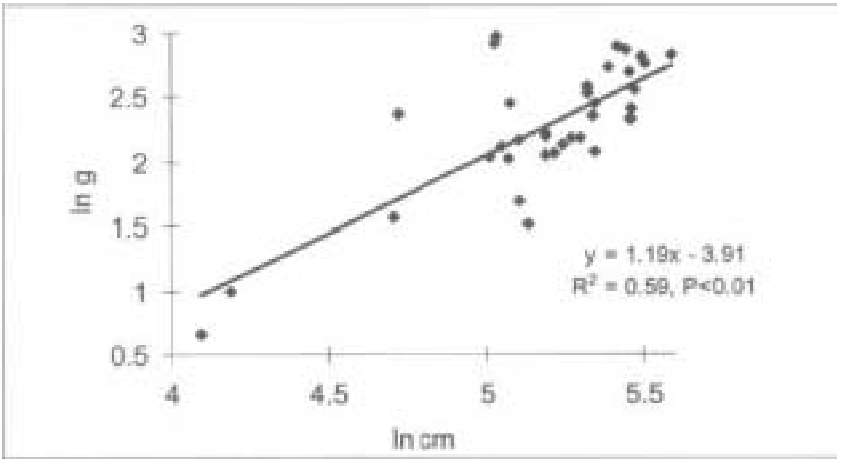


Fig. 3. Weight of *P. australis* plants in relation to the length.

The turnover rate (production/mean live biomass) was 1.9; daily production rate (considering only the period for which production was observed, i.e. March-August) was 4.8 g/m^2. In this period three phases can be identified: low production, 1.4 g/m^2 (between March and May), high production (8.9 g/m^2, between May and June) and intermediate production (4.7 g/m^2, from June to August).

With the observed values of 3.9% (on dry weight) ash content for stems and 9.7% for leaves, the aboveground production expressed as organic matter is 831 g/m^2 (669 g stems and 162 g leaves), which is equivalent to 16205.6 KJ/m^2. Total incident global radiation in the period March - August was 3306 MJ/m^2, of which 1488 MJ/m^2 as PAR (Photosynthetically Active Radiation); the efficiency values are equal to 0.49% of total radiation and 1.1% of PAR radiation.

Belowground production estimates were 2263 g/m^2 (Smalley's) and 1986 g/m^2 (invasion cores), with a daily rate of 9.7 g/m^2 (Smalley's) or 8.5 g/m^2 (invasion cores).

DISCUSSION AND CONCLUSIONS

There are many studies of the growth and production of *P australis (e.g.,* MASON & BRYANT, 1975; HOPKINSON et al., 1978; LINTHURST & REIMOLD, 1978a; HO, 1979; LEE, 1990) but, as far as we know, there are only a few studies for Mediterranean coastal sites with brackish waters (SCARTON et al., 1999 for the Lagoon of Venice, CURCÒ et al., 1996 for the Ebro delta and IBAÑEZ et al., 1999 for the Rhone delta). In table 1 we present some biomass and production parameters for these sites.

Tab 1. Biomass and production values for *P.australis* found at several brackish sites around the Mediterranean. Smalley method used throughout for estimating aboveground and belowground production; at Po Delta invasion cores method was also adopted (values between brackets).

	Mean live biomass g. d.w./m^2	Peak live biomass g. d.w./m^2	Production g. d.w./m2	Turnover rate (P/Mlb)	Source
Aboveground biomass					
Po Delta	455	780	876	1.9	This study
Lagoon of Venice	338	712	699	2.1	Scarton et al., 1999
Rhone Delta	305	680	824	2.7	Ibanez et al., 1998
Ebro Delta	435	649	1271	2.9	Cured et al., 1996
Belowground biomass					
Po Delta	3251	4087	2263 (1986)	0.69 (0.61)	This study
Lagoon of Venice	3196	3700	1008	0.31	Scarton et al., unpub.
Ebro Delta	1083	1406	2474	2.3	Curcò et al., 1996

In the Po Delta, most of the growth takes place between May and August; before and after this period the growth is very low or zero. This is in close agreement with our data for the Venice Lagoon (SCARTON et al., 1999), whereas in the Camargue growth is very rapid from March to May and then it slows down until August; in the Ebro the peak is attended in June. Lower temperatures of the Po Delta site (the mean values in March and April were 12.3 ° C and 16.3 °C) probably account for these differences.

The mean aboveground live biomass (455 g/m^2) is close to the values reported for the Ebro delta (467 g/m^2) and larger than that for the Rhone delta (305 g/m^2). Aboveground production values from the two Italian sites are smaller than those for the Ebro delta and comparable with the Rhone delta {824 g/m^2).

Overall, the values for the three Mediterranean deltas are in the lower range of production data generally reported for this species (1000-2000 g/m^2, LEE 1990). Most of these other studies were carried out in fresh water systems with no salinity. Nevertheless, low productivity values have been reported at higher latitude location; 550 g/m^2/yr in England (MASON & BRYANT, 1975) and 650 g/m^2/yr in Scotland (Ho 1979). Low production and a high belowground/aboveground ratio are both indicators of stressful environmental conditIons (SCHUBAUER and HOPKINSON, 1984), which lead to a larger investment in belowground tissues by plants. Indeed, the ratio of below to aboveground biomass (7.14) and production (2.58) we observed were both greater than one.

At our site, the reedbed periodically experiences high water salinity, which is likely to lower productivity (CHAMBERS, 1997); moreover, the combined effects of high litter biomass and fluctuating water tables have been proved to cause growth reduction in a freshwater reedbed (CLEVERING, 1998).

The invasion core method we used produced values that were close, 87%, of the Smalley method. This good approximation may be due to the fact that sand was used to refill the holes; since the soils at *the P. australis* site were primarily sandy, this closely duplicated the existing condition.

The conversion of solar energy via photosynthesis into *Phragmites australis* biomass available to heterotrophs is an important aspect in the dynamics of the reed bed system. The value we found (1.1 %), was remarkably similar to that observed in the Venice Lagoon (1.2%). Since the efficiency values reported for *P.australis* are usually higher (1.3% to 8.3% of PAR; Ho, 1979 and MITSCH & GOSSELINK, 1986), this would indicate a lower efficiency of reedbeds growing in brackish waters. More researches are needed to confirm this finding.

In the Po Delta almost 2000 ha of reedbed have been recently measured with the aid of aerial photos (L. Furlanetto, pers. comm.). Many of these reedbeds are located at sites with environmental conditions close to ours, whereas others are in more freshwater dominated areas, with presumably higher production values. Research about detritus production and utilisation is lacking in the Po Delta, and it is not known how much of this material is exported to the delta ecosystem, but without doubt it makes a significant contribution to the carbon budget of the system.

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