

SEASONAL VARIATION IN PLANT BIOMASS IN A SALT MARSH COMMUNITY IN NORTHERN TURKEY

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Abstract

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Seasonal pattern in above- and belowground live and dead biomass in a salt marsh community was investigated. Multiple peaks were observed in terms of all biomass types. Maximum aboveground live and dead biomass was observed from the middle of spring to the end of autumn. Belowground dead biomass values were as usually lower than the other biomass types and usually peaked in autumn and winter months. There were significant differences between species and localities for all biomass types, while significant differences were only found for localities with respect to root/shoot ratio by multivariate repeated-measures analysis of variance. Mostly significant correlations were found between different biomass types and ion concentrations and EC. The highest annual production (gm^{-2}) in aboveground vegetation was found for *Salicornia prostrata* in the first locality. However, the highest turnover rate (yr^{-1}) in aboveground vegetation was found for *Spergularia marina* in the first locality. The highest annual production (gm^{-2}) and the highest turnover rate (yr^{-1}) in aboveground vegetation were found for *Artemisia santonicum* in the second locality.

Key words: aboveground living biomass, aboveground dead biomass, belowground living biomass, belowground dead biomass, halophytes

Introduction

Salt marshes around the world exhibit steep gradients of salinity and they usually develop under stable geomorphological conditions in estuaries, islands or protected bays, and they are usually periodically flooded (Barbour et al., 1987; Krüger, Peinemann, 1996). Until recently, major salt marsh areas have been reclaimed for agriculture or development in all parts of the world (Onaindia, Amezcaga, 1999). The success of salt marsh plants is affected

by several factors, the most common of which are edaphic factors and flooding, and these factors often are considered to the establishment and formation of zonal patterns of species in salt marshes. For example, biomass of salt marsh plants is strongly influenced by salinity, flooding, and nutrient limitation (Pennings, Callaway, 1992; Ungar, 1998). Biotic factors, such as interspecific competition, symbiont activity, and pressure by herbivores and parasites, may play additional important roles in shaping salt-marsh vegetation (Ungar, 1998).

Salt marsh communities are ideal for examining the forces that structure natural communities. They are simple native plant communities dominated by a handful of plant species usually found in distinct zonation patterns. Sharp physical gradients in these communities allow for close examination of the effects of physicochemical factors on species interactions (Bertness, Hacker, 1994).

Soil salinity reduces biomass of natural terrestrial ecosystems. Several studies are present on the biomass of salt marsh species (Hopkinson et al., 1978; Morris, Haskin, 1990; Benito, Onaindia, 1991; García et al., 1993; Dilustro, Day, 1997). However, they are usually related to only aboveground biomass and most of them are carried out in the salt marshes along the Atlantic Coast and Iberian Peninsula. The number of studies dealing with above- and belowground living and dead biomass in salt marshes are very scarce comparatively (Leendertse et al., 1997). This study addresses two main objectives: (a) to show the changes in above- and belowground living and dead biomass during a year in halophytic plants occurring in a salt marsh community, in the northern part of Turkey and, (b) to assess the factors affecting various biomass patterns in different salt marsh species.

Material and methods

Study area

The study area is one of the main routes for bird migration, so that it has a particular ecological interest and it was declared a protected area mainly for preparing a management plan to secure proper conservation (Yarar, Magnin, 1997). The area is situated in the central Black sea region, on the north of Turkey. Two different localities are present in the study area.

The first locality is situated on the north of Doganca village and is located 15 km from Bafra town and 2 km west of Cernek lake. The second locality is situated at Koşu village and is located 20 km from Bafra town and it is located 1 km east from the mouth of the Kızılırmak river. A channel lies from the edge of the area (Fig. 1). The first locality is characterized by *Spergularia marina* (L.) Gris. and *Salicornia prostrata* subsp. *prostrata* Pall. The second locality is characterized by *S. prostrata*, *Spergularia marina*, *Artemisia santonicum* L. and *Aster tripolium* L. The first and second localities are classified as upper and lower marsh, respectively. *Spergularia marina* and *Salicornia prostrata* were found in both localities. Taxonomic nomenclature followed that of Brummitt, Powell (2001).

Mean annual temperature and the mean rainfall during the study period in the study area is 13.7°C and 806.4 mm, respectively. Maximum temperature for the hottest month (July) is 33.8°C and minimum temperature for the coldest month (February) is -2.6°C during the study period. Pluviometric quotient (Q) is 76.7. Mean annual relative humidity is 79.8 % (Turkish Ministry of Agriculture, 2002). The study area may be characterised as having a semi-humid Mediterranean climate (Daget, 1977).

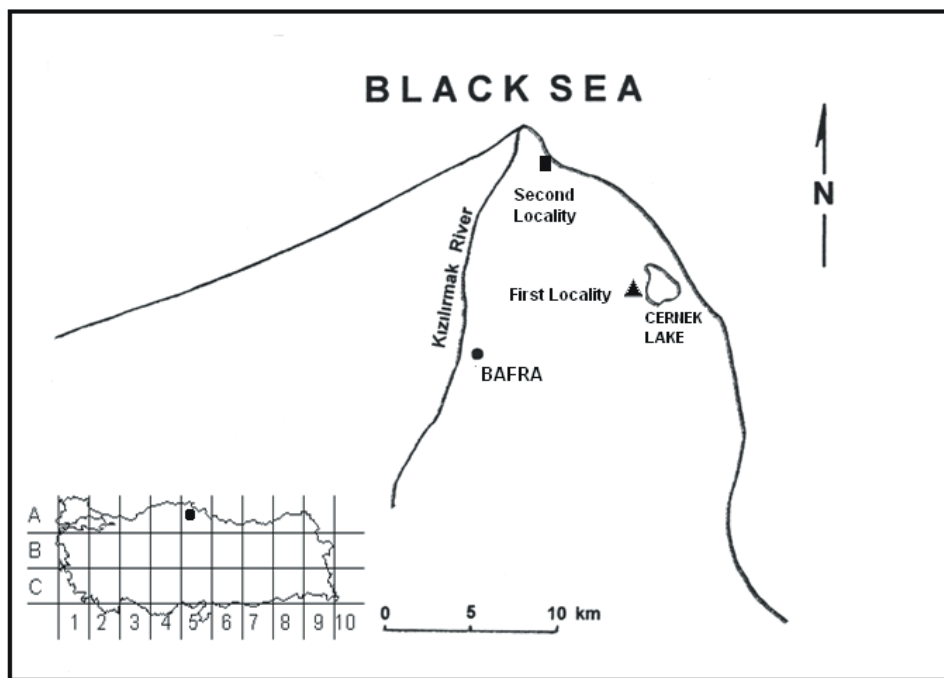


Fig. 1. Map of the study area.

Five 0.5x0.5 m (0.25 m²) quadrats were selected taking into account to include principal plant species in each month from two localities. Regular sampling (once a month) was followed from August 1997 to July 1998. A 20x20 cm soil block was removed from the centre of each quadrat together with the aboveground material. The blocks were cut with metal blades to a depth of 30 cm because 95% of root material was concentrated in the top 30 cm soil layer and the blocks were sliced into two layers as above- ground and belowground material (Singh, Yadava, 1974; Rodríguez et al., 1996). In order to separate the soil particles from the biological components the samples were sieved through a 250 m mesh. The remaining particles were separated by flotation in water followed by a second sieving. Dead plant parts were separated by using the 2, 3, 5-triphenyl chloride (TTC) reduction techniques. Bright-colored and soft-textured fractions were assessed as live fractions (McNaughton et al., 1998; Milner, Hughes, 2000; Delitti et al., 2001). Both live and dead fractions were dried at 60 °C for three days and dry mass was recorded. Annual production was estimated by summing the positive changes in the above- and belowground biomass on successive sampling dates. The positive increases in biomass for only those sampling intervals during which a positive difference also occurred in above- and belowground biomass were summed. This method is used for the species exhibits more than one peak during its growth cycle (Singh et al., 1975). In the present study, multiple peaks were observed for all species. Turnover rates (yr⁻¹) were calculated by using the Dahlman Kucera's formula (Gill, Jackson, 2000).

After removing above- and belowground materials soil samples were air-dried, crushed and sieved using a 2 mm mesh. About 150 g of soil sample was dried in an oven at 80° until constant weight. Electrical conductivity (EC; dS/m) was determined in soil: water extracts at 1:1 (w:v) using a Jenway analyser. Water soluble Na⁺, Ca²⁺ and Mg²⁺ (meq/l) were determined using a Perkin Elmer atomic absorption spectrophotometer. Cl⁻ (meq/l) was determined gravimetrically (Black, 1965; Marr, Cresser, 1983; Allen et al., 1986; Abbas et al., 1991).

Table 1. Mean Ca²⁺, Mg²⁺, Na⁺, Cl⁻ (meq/l) and EC (dS/m) values ± 1 S.E. in the first and second localities.

Parameter	Locality	
	First	Second
Ca ²⁺	26.97 ± 4.49	12.66 ± 4.22
Mg ²⁺	79.95 ± 13.00	24.91 ± 7.14
Na ⁺	258.00 ± 28.67	185.44 ± 28.36
Cl ⁻	331.82 ± 42.35	210.09 ± 34.11
EC	20.25 ± 0.13	10.08 ± 0.98

Statistical analyses were performed using SPSS version 10.0 (1999). The differences in biomass during the growing season were assessed with repeated-measures analysis of variance (RMANOVA). RMANOVA was performed in multivariate mode since the data violated the sphericity assumption. Season and locality-species interaction were considered as between subjects and within-subjects factors, respectively. Tukey's honestly significant difference (HSD) test was used to compare different biomass types and root/shoot ratio over the growing season and Pearson correlation coefficients were also calculated to find the interactions between different biomass types and soil parameters by using SPSS version 10.0 (1999).

Results

Mean Ca²⁺, Mg²⁺, Na⁺ and Cl⁻ (meq/l) concentrations and EC (dS/m) of the soil were higher in the first locality as compared to the second locality (Table 1).

Biomass values in the first locality were higher as compared to the second locality for almost all species. The highest aboveground living biomass was recorded for *Spergularia marina* in August and May in the first and second localities, respectively. Aboveground living biomass of *Salicornia prostrata* peaked in September and August in the first and second localities, respectively. The highest aboveground living biomass values were recorded for *Artemisia santonicum* in September. Aboveground living biomass of *Aster tripolium* peaked in November (Figs 2–7).

The changes in belowground living biomass usually showed a similar pattern to aboveground living biomass. Aboveground dead biomass in *Spergularia marina* peaked in September in both localities (Figs 2–7).

Aboveground dead biomass of *Artemisia santonicum* peaked two times in February and May, respectively. Two peaks were observed for *Salicornia prostrata* and *Aster tripolium* in November and January, respectively in terms of aboveground dead biomass. Belowground dead biomass values are usually lower than the other biomass types and it usually peaked in autumn and winter months except for *Spergularia marina* (June in the first locality), *Salicornia prostrata* (April and May in the first and second localities, respectively) and *Artemisia santonicum* (February and May) (Figs 2–7).

According to Tukey's HSD test, autumn and winter months and spring and summer months were different from each other in terms of aboveground living and dead biomass

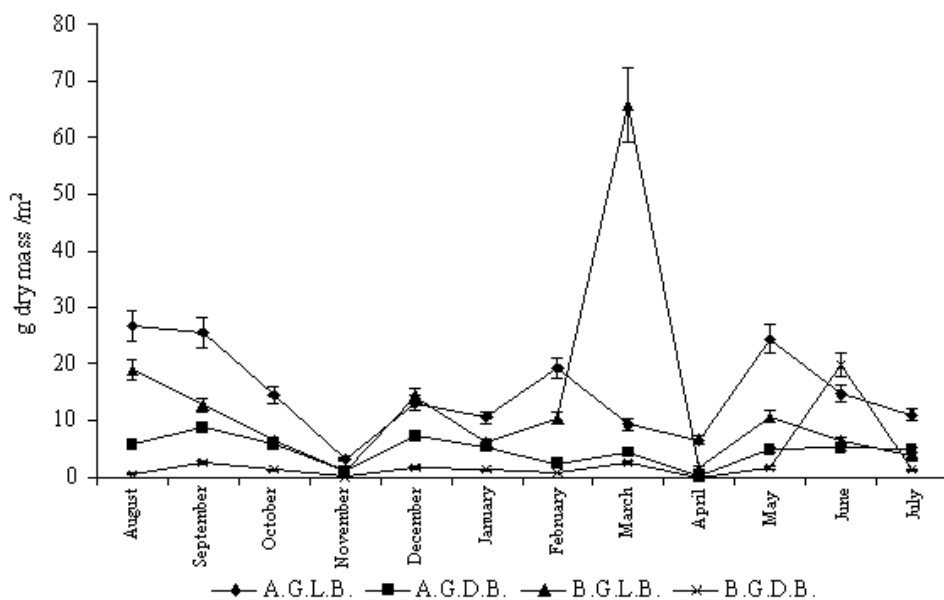


Fig. 2. Annual changes in biomass of *Spergularia marina* in the first locality. AGLB – aboveground living biomass, AGDB – aboveground dead biomass, BGLB – belowground living biomass, BGDB – belowground dead biomass.

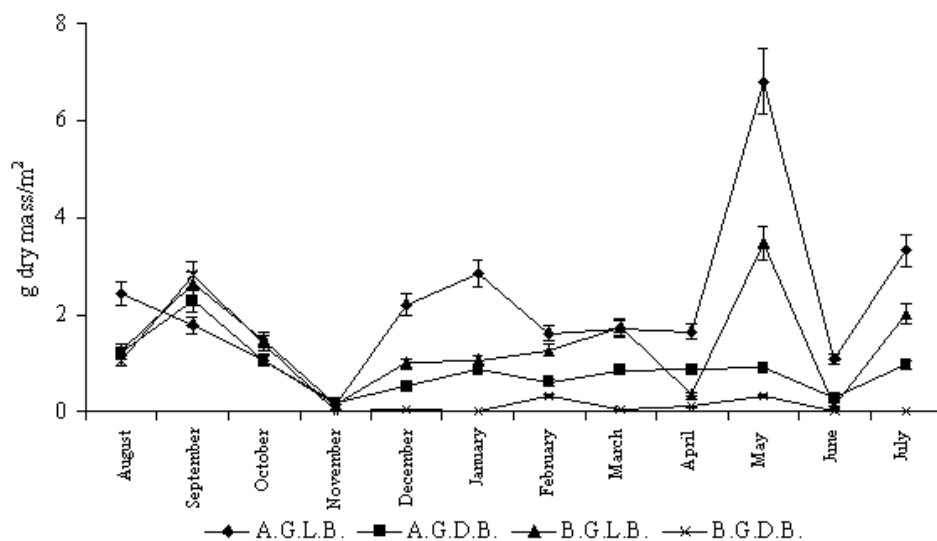


Fig. 3. Annual changes in biomass of *Spergularia marina* in the second locality. Abbreviations see Fig. 2.

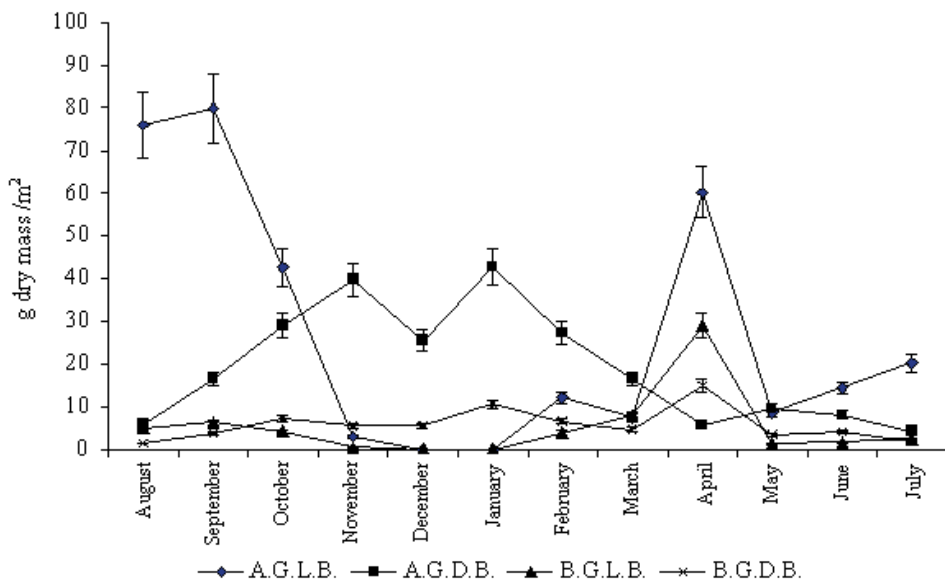


Fig. 4. Annual changes in biomass of *Salicornia prostrata* in the first locality. Abbreviations see Fig. 2.

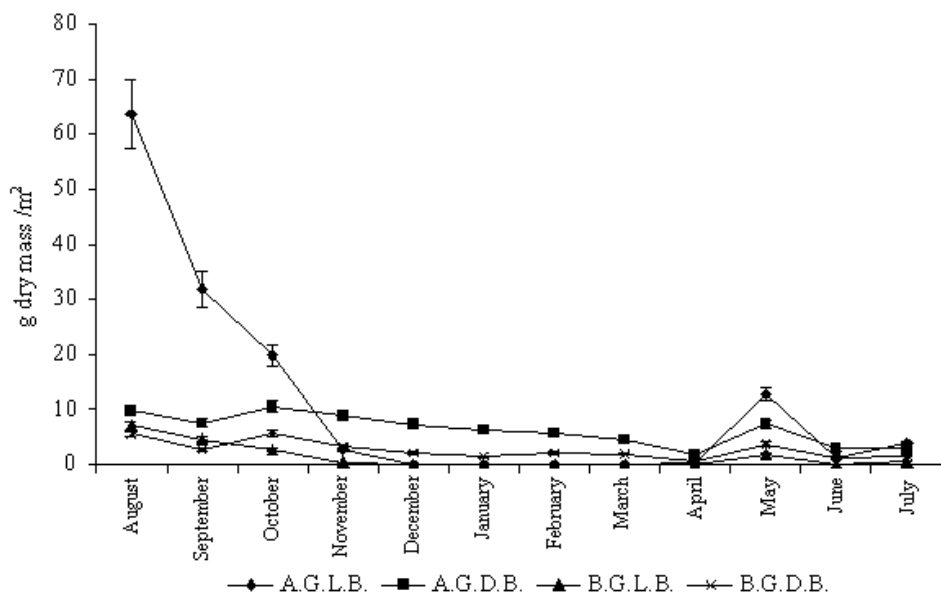


Fig. 5. Annual changes in biomass of *Salicornia prostrata* in the second locality. Abbreviations see Fig. 2.

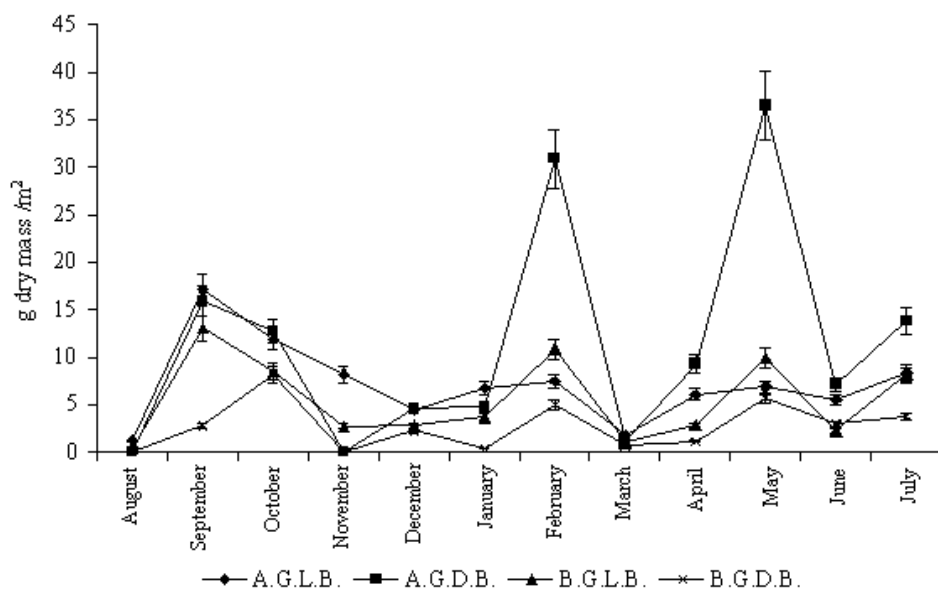


Fig. 6. Annual changes in biomass of *Artemisia santonicum* in the second locality. Abbreviations see Fig. 2.

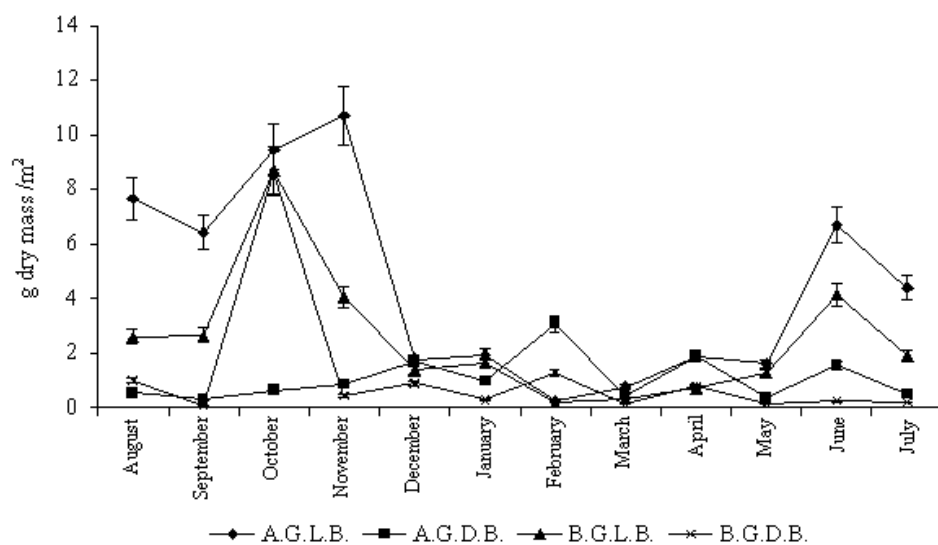


Fig. 7. Annual changes in biomass of *Aster tripolium* in the second locality. Abbreviations see Fig. 2.

and root/shoot ratio in *Spergularia marina* in the first locality. Seasonal differences were also found in terms of aboveground biomass in *S. marina* and *Aster tripolium* in the second locality, respectively (Table 2).

Table 2. Seasonal mean aboveground living, dead biomass and root/shoot ratio of *Spergularia marina* and *Salicornia prostrata* in two localities. Means followed by the same letter are not significantly different at the 0.05 level using Tukey's HSD test.

Species	Locality	Season	AGLB g.m ⁻²	AGDB g.m ⁻²	BGLB g.m ⁻²	BGDB g.m ⁻²	R/S Ratio
<i>S. prostrata</i>	1	winter	14.34a	4.98a	10.27a	1.29a	.60a
		spring	13.45a	3.11a	5.96a	1.44a	.39a
		summer	17.49a	5.24a	9.77a	7.28a	.68a
		autumn	14.45a	5.14a	6.68a	1.34a	.27a
<i>S. marina</i>	1	winter	4.02b	31.89a	1.32a	7.58a	.25ab
		spring	10.24ab	10.59b	12.73a	7.74a	.91a
		summer	36.87ab	6.05b	3.04a	2.47a	.20ab
		autumn	41.81a	28.41a	3.67a	5.53a	.12b
<i>S. prostrata</i>	2	winter	2.22a	0.66a	1.11a	0.12a	.26ab
		spring	3.39a	0.87a	1.86a	0.15a	.22b
		summer	2.29a	0.81a	1.13a	0.36a	.16b
		autumn	0.99a	1.17a	1.41a	1.41a	.66a
<i>S. marina</i>	2	winter	1.10 ⁻⁵ b	4.48a	1.10 ⁻⁵ a	1.88a	8,5.10 ⁻² a
		spring	4.33ab	4.51a	1.10 ⁻⁵ a	2.06a	.26a
		summer	22.88a	5.16a	2.57a	2.71a	.19a
		autumn	18.14ab	8.97a	2.54a	3.94a	.18a
<i>A. santonicum</i>	2	winter	6.28a	13.42a	5.77a	2.56a	.64a
		spring	4.91a	15.72a	4.57a	2.49a	.15a
		summer	5.04a	6.98a	3.62a	2.26a	.19a
		autumn	12.42a	9.55a	8.13a	3.65a	.33a
<i>A. tripolium</i>	2	winter	1.32b	1.89a	1.07a	.82a	.24a
		spring	1.41ab	.90a	.77a	.35a	.30a
		summer	6.25ab	.86a	2.88a	.47a	.32a
		autumn	8.85a	-.60a	3.47a	.17a	.26a

Notes: AGLB – aboveground living biomass, AGDB – aboveground dead biomass, BGLB – belowground living biomass, BGDB – belowground dead biomass, R/S – root/shoot ratio

The violation of sphericity (Huynh-Feldt) was severe (> 0.7) for all biomass types except for belowground living biomass (Table 3). There were significant differences between species and localities for all biomass types and root/shoot ratio. However, species x locality interaction was only significant for aboveground dead biomass like season x locality interaction which is also significant for aboveground dead biomass. Thus, for the significant season

Table 3. Mauchly's test of sphericity.

Epsilon								
Source	Withinsub- jects effects	Mauch- ly's W	Approx. chisquare	df	S	Greenhouse- Geisser	HuynhFeldt	Lower-bound
AGLB	season	0.361	112.815	5	0.000	0.667	0.722	0.333
AGDB	season	0.546	67.068	5	0.000	0.698	0.756	0.333
BGLB	season	0.103	251.632	5	0.000	0.445	0.476	0.333
BGDB	season	0.365	111.543	5	0.000	0.707	0.766	0.333

Notes: Approx. – approximately, df – degrees of freedom, S – significance

Table 4. Multivariate repeated-measures analysis of variance for aboveground living and dead biomass for season repeated measures.

Source	Aboveground living biomass				Belowground dead biomass			
	Df	MS	F	P > F	df	MS	F	P > F
Species	3	1607.87	3.46	.020	3	276.71	2.63	.05
Locality	1	9086.45	19.55	.000	1	166.,77	15.85	.000
Species x locality	1	9.85	.02	n.s.	1	138.51	1.31	n.s.
Season	3	3185.06	9.26	.000	3	28.36	.30	n.s.
Linear	1	8634.79	31.34	.000	1	12.68	.25	n.s.
Quadratic	1	4.24	.01	n.s.	1	15.81	.19	n.s.
Season x species	9	1160.45	3.37	.001	9	69.78	.74	n.s.
Season x locality	3	405.09	1.17	n.s.	3	63.90	.68	n.s.
Season x locality x species	3	232.36	.676	n.s.	3	215.21	2.29	n.s.
Error	252	343.65			252	93.86		

Source	Belowground living biomass				Belowground dead biomass			
	Df	MS	F	P > F	df	MS	F	P > F
Species	3	3145.70	12.39	.000	3	184.01	3.85	.012
Locality	1	4432.30	17.45	.000	1	455.26	9.54	.003
Species x locality	1	1416.79	5.58	.020	1	10.97	.23	n.s.
Season	3	815.36	4.65	.003	3	.73	.01	n.s.
Linear	1	148.83	.76	n.s.	1	3.64.10 ⁻⁶	.00	n.s.
Quadratic	1	2185.29	13.39	.000	1	.78	.01	n.s.
Season x species	9	298.42	1.70	n.s.	9	36.20	.84	n.s.
Season x locality	3	586.95	3.35	.020	3	26.54	.61	n.s.
Season x locality x species	3	527.57	3.01	.031	3	113.82	2.64	.05
Error	252	175.10			252	43.075		

Notes: df – degrees of freedom, MS – mean square, F – F-value, P – probability, n.s. – not significant

effect quadratic contrast was significant for aboveground dead biomass and these indicating a complex season covariance relationship for aboveground dead biomass types. Similarly, season x species interaction was only significant for aboveground living biomass. Season x locality x species interaction was significant for all biomass types except for aboveground living biomass. There were significant differences between species, localities and seasons in

terms of above- and belowground living biomass. However, no significant differences were observed in terms of seasons with respect to belowground dead biomass although species and localities were significantly different. Significant differences were only found between localities with respect to root/shoot ratio. (Table 4).

Table 5. Multivariate repeated-measures analysis of variance for root/shoot ratio for season repeated measures.

Source	df	MS	F	P > F
Root/Shoot ratio				
Species	3	.42	1.19	n.s.
Locality	1	1.84	5.21	.025
Species x locality	1	1.44.10 ⁻²	.041	n.s.
Season	3	.30	1.09	n.s.
Linear	1	.72	2.45	n.s.
Quadratic	1	.10	.44	n.s.
Season x species	9	.69	2.49	.010
Season x locality	3	1.13	4.07	.008
Season x locality x species	3	.77	2.78	.041
Error	252	.27		

Notes: df – degrees of freedom, MS – mean square, F – F-value, P – probability, n.s.– not significant

In contrast to biomass types season x species, season x locality and season x locality x species interactions were significant despite species x locality interaction was not statistically significant in terms of root/ shoot ratio (Table 5).

Mostly significant correlations were found between different biomass types and ion concentrations and EC (Tables 6–8).

The highest annual production (gm⁻²) in aboveground parts was found for *Salicornia prostrata* in the first locality. However, the highest turnover rate (yr⁻¹) in aboveground parts was found for *Spergularia marina* in the first locality. The highest annual production (g m⁻²) and the highest turnover rate (yr⁻¹) in aboveground parts was found for *Artemisia santonicum* in the second locality. The highest annual production (gm⁻²) and the highest turnover rate (yr⁻¹) in belowground parts were obtained for *Spergularia marina* and *Artemisia santonicum* in the first and second localities, respectively (Table 9).

Discussion

Maximum aboveground live and dead biomass values were observed usually from the middle of spring to the end of autumn for almost all species and multiple peaks were observed for all biomass types in almost all species. Others have found similar results (White et al., 1978; Ellison et al., 1986; Cranford et al., 1989; Morris, Haskin, 1990; Dilustro, Day, 1997).

Table 6. Pearson correlation coefficients between different biomass types and Na⁺ and Cl⁻ in the first locality.

First locality				
Species	Biomass type	Ion	r	Significance
<i>S. marina</i>	AGLB	Na ⁺	-0.864	**
<i>S. marina</i>	AGDB	Na ⁺	-0.873	**
<i>S. marina</i>	BGLB	Na ⁺	-0.863	**
<i>S. marina</i>	BGDB	Na ⁺	-0.874	**
<i>S. marina</i>	AGLB	Cl ⁻	-0.820	**
<i>S. marina</i>	AGDB	Cl ⁻	-0.831	**
<i>S. marina</i>	BGLB	Cl ⁻	-0.842	**
<i>S. marina</i>	BGDB	Cl ⁻	-0.842	**
<i>S. prostrata</i>	AGLB	Na ⁺	-0.844	**
<i>S. prostrata</i>	AGDB	Na ⁺	-0.859	**
<i>S. prostrata</i>	BGLB	Na ⁺	-0.872	**
<i>S. prostrata</i>	BGDB	Na ⁺	-0.872	**
<i>S. prostrata</i>	AGLB	Cl ⁻	-0.820	**
<i>S. prostrata</i>	AGDB	Cl ⁻	-0.831	**
<i>S. prostrata</i>	BGLB	Cl ⁻	-0.842	**
<i>S. prostrata</i>	BGDB	Cl ⁻	-0.842	**
Second locality				
<i>S. marina</i>	AGLB	Na ⁺	-0.795	**
<i>S. marina</i>	AGDB	Na ⁺	-0.797	**
<i>S. marina</i>	BGLB	Na ⁺	-0.796	**
<i>S. marina</i>	BGDB	Na ⁺	-0.798	**
<i>S. marina</i>	AGLB	Cl ⁻	-0.777	**
<i>S. marina</i>	AGDB	Cl ⁻	-0.779	**
<i>S. marina</i>	BGLB	Cl ⁻	-0.779	**
<i>S. marina</i>	BGDB	Cl ⁻	-0.780	**
<i>S. prostrata</i>	AGLB	Na ⁺	-0.774	**
<i>S. prostrata</i>	AGDB	Na ⁺	-0.788	**
<i>S. prostrata</i>	BGLB	Na ⁺	-0.796	**
<i>S. prostrata</i>	BGDB	Na ⁺	-0.794	**
<i>S. prostrata</i>	AGLB	Cl ⁻	-0.760	**
<i>S. prostrata</i>	AGDB	Cl ⁻	-0.771	**
<i>S. prostrata</i>	BGLB	Cl ⁻	-0.779	**
<i>S. prostrata</i>	BGDB	Cl ⁻	-0.777	**
<i>A. santonicum</i>	AGLB	Na ⁺	-0.787	**
<i>A. santonicum</i>	AGDB	Na ⁺	-0.778	**
<i>A. santonicum</i>	BGLB	Na ⁺	-0.789	**
<i>A. santonicum</i>	BGDB	Na ⁺	-0.794	**
<i>A. santonicum</i>	AGLB	Cl ⁻	-0.770	**
<i>A. santonicum</i>	AGDB	Cl ⁻	-0.762	**
<i>A. santonicum</i>	BGLB	Cl ⁻	-0.772	**
<i>A. santonicum</i>	BGDB	Cl ⁻	-0.777	**
<i>A. tripolium</i>	AGLB	Na	-0.791	**
<i>A. tripolium</i>	AGDB	Na	-0.797	**
<i>A. tripolium</i>	BGLB	Na	-0.795	**
<i>A. tripolium</i>	BGDB	Na	-0.798	**
<i>A. tripolium</i>	AGLB	Cl ⁻	-0.774	**
<i>A. tripolium</i>	AGDB	Cl ⁻	-0.779	**
<i>A. tripolium</i>	BGLB	Cl ⁻	-0.778	**
<i>A. tripolium</i>	BGDB	Cl ⁻	-0.780	**

Notes: ** P< 0.01. Abbreviations see in Table 2.

Table 7. Pearson correlation coefficients between different biomass types and Ca and Mg in the first locality.

First locality				
Species	Biomass type	Ion	r	Significance
<i>S. marina</i>	AGLB	Ca ²⁺	-0.442	*
<i>S. marina</i>	AGDB	Ca ²⁺	-0.707	**
<i>S. marina</i>	BGLB	Ca ²⁺	-0.393	n.s.
<i>S. marina</i>	BGDB	Ca ²⁺	-0.719	**
<i>S. marina</i>	AGLB	Mg ²⁺	-0.708	**
<i>S. marina</i>	AGDB	Mg ²⁺	-0.761	**
<i>S. marina</i>	BGLB	Mg ²⁺	-0.699	**
<i>S. marina</i>	BGDB	Mg ²⁺	-0.767	**
<i>S. prostrata</i>	AGLB	Ca ²⁺	-0.367	n.s.
<i>S. prostrata</i>	AGDB	Ca ²⁺	-0.260	n.s.
<i>S. prostrata</i>	BGLB	Ca ²⁺	-0.663	**
<i>S. prostrata</i>	BGDB	Ca ²⁺	-0.681	**
<i>S. prostrata</i>	AGLB	Mg ²⁺	-0.573	**
<i>S. prostrata</i>	AGDB	Mg ²⁺	-0.674	**
<i>S. prostrata</i>	BGLB	Mg ²⁺	-0.755	**
<i>S. prostrata</i>	BGDB	Mg ²⁺	-0.755	**
Second locality				
<i>S. marina</i>	AGLB	Ca ²⁺	-0.446	*
<i>S. marina</i>	AGDB	Ca ²⁺	-0.492	*
<i>S. marina</i>	BGLB	Ca ²⁺	-0.476	*
<i>S. marina</i>	BGDB	Ca ²⁺	-0.503	*
<i>S. marina</i>	AGLB	Mg ²⁺	-0.662	**
<i>S. marina</i>	AGDB	Mg ²⁺	-0.676	**
<i>S. marina</i>	BGLB	Mg ²⁺	-0.671	**
<i>S. marina</i>	BGDB	Mg ²⁺	-0.680	**
<i>S. prostrata</i>	AGLB	Ca ²⁺	-0.040	n.s.
<i>S. prostrata</i>	AGDB	Ca ²⁺	-0.290	n.s.
<i>S. prostrata</i>	BGLB	Ca ²⁺	-0.471	*
<i>S. prostrata</i>	BGDB	Ca ²⁺	-0.431	*
<i>S. prostrata</i>	AGLB	Mg ²⁺	-0.478	*
<i>S. prostrata</i>	AGDB	Mg ²⁺	-0.614	**
<i>S. prostrata</i>	BGLB	Mg ²⁺	-0.669	**
<i>S. prostrata</i>	BGDB	Mg ²⁺	-0.657	**
<i>A. santonicum</i>	AGLB	Ca ²⁺	-0.274	n.s.
<i>A. santonicum</i>	AGDB	Ca ²⁺	-0.047	n.s.
<i>A. santonicum</i>	BGLB	Ca ²⁺	-0.308	n.s.
<i>A. santonicum</i>	BGDB	Ca ²⁺	-0.425	*
<i>A. santonicum</i>	AGLB	Mg ²⁺	-0.600	**
<i>A. santonicum</i>	AGDB	Mg ²⁺	-0.517	**
<i>A. santonicum</i>	BGLB	Mg ²⁺	-0.620	**
<i>A. santonicum</i>	BGDB	Mg ²⁺	-0.655	**
<i>A. tripolium</i>	AGLB	Ca ²⁺	-0.358	n.s.
<i>A. tripolium</i>	AGDB	Ca ²⁺	-0.486	*
<i>A. tripolium</i>	BGLB	Ca ²⁺	-0.453	*
<i>A. tripolium</i>	BGDB	Ca ²⁺	-0.506	*
<i>A. tripolium</i>	AGLB	Mg ²⁺	-0.635	**
<i>A. tripolium</i>	AGDB	Mg ²⁺	-0.674	**
<i>A. tripolium</i>	BGLB	Mg ²⁺	-0.664	**
<i>A. tripolium</i>	BGDB	Mg ²⁺	-0.680	**

Notes: * P < 0.05, ** P < 0.01. Abbreviations see in Table 2.

Table 8. Pearson correlation coefficients between different biomass types and EC in the first locality.

First locality			
Species	Biomass type	r	Significance
<i>S. marina</i>	AGLB	0.328	n.s.
<i>S. marina</i>	AGDB	0.328	n.s.
<i>S. marina</i>	BGLB	0.172	n.s.
<i>S. marina</i>	BGDB	0.779	n.s.
<i>S. prostrata</i>	AGLB	-0.126	n.s.
<i>S. prostrata</i>	AGDB	0.094	n.s.
<i>S. prostrata</i>	BGLB	0.738	**
<i>S. prostrata</i>	BGDB	0.845	**
Second locality			
<i>S. marina</i>	AGLB	0.789	**
<i>S. marina</i>	AGDB	0.855	**
<i>S. marina</i>	BGLB	0.510	*
<i>S. marina</i>	BGDB	0.867	**
<i>S. prostrata</i>	AGLB	-0.018	n.s.
<i>S. prostrata</i>	AGDB	0.094	n.s.
<i>S. prostrata</i>	BGLB	0.696	**
<i>S. prostrata</i>	BGDB	0.666	**
<i>A. santonicum</i>	AGLB	-0.217	n.s.
<i>A. santonicum</i>	AGDB	-0.315	n.s.
<i>A. santonicum</i>	BGLB	-0.063	n.s.
<i>A. santonicum</i>	BGDB	0.394	n.s.
<i>A. tripolium</i>	AGLB	0.474	*
<i>A. tripolium</i>	AGDB	0.694	*
<i>A. tripolium</i>	BGLB	0.661	**
<i>A. tripolium</i>	BGDB	0.723	**

Notes: ** P < 0.01. Abbreviations see in Table 2.

Table 9. Annual production and turnover rates in above- and belowground parts.

Locality	Plant part	Species	Live/dead ratio	Peak live biomass (g/m ²)	Production (g/m ² / yr ⁻¹)	Turnover rate (yr ⁻¹)
First	aboveground	<i>S. marina</i>	3.32	117.77	55.48	0.47
First	aboveground	<i>S. prostrata</i>	1.40	286.84	71.96	0.25
Second	aboveground	<i>S. marina</i>	1.60	19.80	4.28	0.21
Second	aboveground	<i>S. prostrata</i>	1.81	140.28	87.9	0.62
Second	aboveground	<i>A. santonicum</i>	0.62	136.84	110.5	0.80
Second	aboveground	<i>A. tripolium</i>	4.20	27.01	16.97	0.62
First	belowground	<i>S. marina</i>	4.64	125.95	80.80	0.64
First	belowground	<i>S. prostrata</i>	0.89	72.50	36.29	0.50
Second	belowground	<i>S. marina</i>	1.81	13.20	7.19	0.54
Second	belowground	<i>S. prostrata</i>	0.54	28.47	16.35	0.56
Second	belowground	<i>A. santonicum</i>	2.01	60.19	50.06	0.83
Second	belowground	<i>A. tripolium</i>	4.55	12.36	6.33	0.51

Benito, Onaindia (1991) who studied in a Mediterranean salt marsh similar to the current study stated the species inhabits salt marshes followed a defined seasonal cycle similar to the present study. Maximum dead above- and belowground biomass was reached usually in September and October except for *Aster tripolium* and *Salicornia prostrata* in the first locality which reached to the maximum dead biomass in February and January, respectively.

Significant differences were observed between autumn and winter months and spring and summer months with respect to aboveground living and dead biomass and root/shoot ratio in *Spergularia marina* in the first locality. In the second locality, there were significant differences in *S. marina* and *Aster tripolium* in terms of aboveground living biomass. Seasonal differences were found in *Salicornia prostrata* in the second locality in respect to root/shoot ratio. The highest aboveground living biomass values were found during summer in *Spergularia marina* in the first locality, while aboveground dead biomass was lower during summer. Low belowground living biomass values were observed during summer and these values were increased during autumn in *S. marina* in the first locality although seasonal differences were not statistically significant in respect to belowground living biomass. *S. marina* showed evidence of the translocation of belowground biomass to aboveground biomass during summer, when aboveground growth is at the highest level (Connor, Chmura, 2000). The study area may be characterised as having a semi-humid Mediterranean climate (Daget, 1977). In Mediterranean-type climate peak live biomass was usually observed during summer, while peak dead biomass was found during autumn and winter, respectively, mainly due to translocation of belowground biomass to aboveground biomass although interspecific differences were also occurred in this respect (Curcó et al., 2002).

In general, biomass values in the first locality were higher than that of the second locality. Flooding is more widespread in the second locality as compared to the first locality because the second locality is located near the sea shore, whereas salinity is higher in the first locality (Kutbay, Demir, 2001). Baldwin et al. (1996) found that changes that occur in community structure in salt marshes mainly depend on inundation regime and salinity. Sánchez et al. (1996) stated that Na^+ and Cl^- concentrations decline with increasing distance from the sea, in clear accordance with the principal pattern of vegetation zonation and this indicates the existence of a gradient perpendicular to the coastline.

The differences between the species in terms of biomass types would be related to different tolerance to soil salinity and inundation (Curcó et al., 2002). In the first (high marsh) and second (low marsh) localities stress produced by salinity and inundation, respectively. For example, *S. marina* is tolerant to high salinity in the first locality, whereas *Artemisia santonicum* is tolerant to inundation in the second locality (Kutbay, Demir, 2001). In the first locality (high marsh) salinity acts as an ecological filter that reduces species biomass. In the second locality (low marsh) flooding acts as the other ecological filter.

There were significant negative correlation coefficients obtained between different biomass types and Na^+ , Cl^- , Ca^{2+} and Mg^{2+} concentrations of soil and Na^+ and Cl^- were the most prevalent cation and anion in soils of the study area (Kutbay, Demir, 2001). Salinity and sodium toxicity act as ecological filters that reduce species biomass in salt marshes as previously indicated (García et al., 1993; El Demerdash, 1996).

Spergularia marina and *Artemisia santonicum* show the highest recycling of live material due to their high turnover rates in the first and second localities, respectively. These two species also have the highest production rates in their above- and belowground parts although the production in aboveground parts of *Salicornia prostrata* in the first locality was the highest as compared to *Spergularia marina*.

Turnover rates in belowground parts in the present study were within the ranges reported for the tidal marsh communities which extended from 0.11–1.80 (Gill, Jackson, 2000). However, aboveground turnover rates were low as compared to the other studies (Hopkinson et al., 1978; Benito, Onaindia, 1991). The turnover of the above- and belowground live and dead biomass was lower than 1.00 in the present study and similar to Curcó et al.'s (2002) study who studied in Mediterranean type salt marshes. Low live/dead biomass ratios were obtained in other studies and it was explained on the basis of a reflection of the high litter turnover rates in aboveground parts (Hopkinson et al., 1978; Benito, Onaindia, 1991). However, high live/dead biomass ratios were observed in the present study as compared to the other studies and this may be a result of low turnover rates in aboveground parts.

The highest mean aboveground living and dead biomass values were observed for *Salicornia prostrata* occurred in the first locality except for belowground living biomass. The highest mean belowground living biomass was observed for *Spergularia marina* occurred in the first locality. Ungar et al. (1979) reported *Salicornia* species were highly competitive in highly saline soils, because they made optimal growth at salinity levels that would be limiting to other species. Yeo (1983) stated plants which are able to cope with harsh conditions, benefit from a high availability of water, light and nutrients, compensate for the “extra cost for tolerance” and produce a large amount of biomass. *Salicornia* L. species was also classified as high phenotypic plasticity species (Wilkoń-Michalska, 1985). Callaway et al. (1990) also found *Spergularia marina* a high phenotypic plasticity and a plastic response to different saline conditions.

Onaindia, Amezaga (1999) suggested the distribution of halophytic species has already been recognised to follow environmental gradients. Waide et al. (1999) stated soil properties such as pH, Ca, Mg and anoxia may correlate with biomass. Significant correlations were observed between different biomass types and soil parameters. Most of the correlation coefficients were negative due to the harsh conditions in the studied salt marsh. Soil salinity has been affected by above- and belowground live and dead biomass negatively. It can be concluded that soil parameters may be the predictors of the community biomass.

Conclusion

Biomass values in the first locality were higher as compared to the second locality for almost all species. The highest aboveground living biomass was recorded for *Spergularia marina* in August and May in the first and second localities, respectively. Aboveground living biomass of *Salicornia prostrata* peaked in September and August in the first and second localities, respectively. The highest aboveground living biomass values were recorded for

Artemisia santonicum in September. Aboveground living biomass of *Aster tripolium* peaked in November. The changes in belowground living biomass usually showed a similar pattern to aboveground living biomass. Aboveground dead biomass in *Spergularia marina* peaked in September in both localities.

There were significant differences between species and localities for all biomass types and root/shoot ratio. However, species x locality interaction was only significant for aboveground dead biomass like season x locality interaction which is also significant for aboveground dead biomass. In contrast to biomass types season x species, season x locality and season x locality x species interactions were significant despite species x locality interaction was not statistically significant in terms of root/ shoot ratio.

The highest annual production (gm^{-2}) in aboveground parts was found for *Salicornia prostrata* in the first locality. However, the highest turnover rate (yr^{-1}) in aboveground parts was found for *Spergularia marina* in the first locality. The highest annual production (g m^{-2}) and the highest turnover rate (yr^{-1}) in aboveground parts was found for *Artemisia santonicum* in the second locality. The highest annual production (g m^{-2}) and the highest turnover rate (yr^{-1}) in belowground parts were obtained for *Spergularia marina* and *Artemisia santonicum* in the first and second localities, respectively.

Most of the correlation coefficients were negative due to the harsh conditions in the studied salt marsh. Soil salinity has been affected by above- and belowground live and dead biomass negatively. It can be concluded that soil parameters may be the predictors of the community biomass.

Translated by the authors

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