Seasonal patterns of biomass variation of *Ruppia cirrhosa* (Petagna) Grande and *Potamogeton pectinatus* L. in a coastal lagoon

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SUMMARY: Coastal lagoons where salinity varies within a wide range during the year are colonized by euryhaline macrophytes which can develop extensive beds. Seasonal changes in biomass of *Ruppia cirrhosa* and *Potamogeton pectinatus* were studied in Tancada Lagoon (Ebro Delta, NE Spain) in order to reveal the environmental factors controlling their population development. *Ruppia cirrhosa* occupy a larger area of the lagoon than *Potamogeton pectinatus*. Their maximum above ground biomasses are also different (495 g m^{-2} and 351 g m^{-2} ash free dry weight, respectively). Below ground biomass of *Ruppia cirrhosa* is between 9 and 53 % of the above ground biomass, while it is 3-40 % for *Potamogeton pectinatus*. Chlorophyll *a* contents show fluctuations similar to biomass. Low salinity and high turbidity caused by freshwater inflows favour *Potamogeton* expansion, while *Ruppia* development is favoured by high salinity and transparent water.

Key words: seasonality, biomass, *Ruppia cirrhosa*, *Potamogeton pectinatus*, coastal lagoons, Ebro delta.

INTRODUCTION

Submerged macrophytes are very important contributors to the primary production in shallow lakes (WETZEL, 1964). In coastal lagoons a small number of angiosperm species can form extensive beds. Light and temperature are key factors regulating their photosynthetic efficiency (EVANS *et al.*, 1986). However, coexistence or exclusion may be the result of strategies adopted by the plants in response to many related factors (VERHOEVEN *et al.*, 1982).

Ruppia cirrhosa (Petagna) Grande and *Potamogeton pectinatus* L. can be found together in brackish temperate coastal waters in the range 5-12 ‰ Cl. The former dominates in the upper salinity range and the latter in the lower one (VERHOEVEN *et al.*, 1982).

However, coastal lagoons are very dynamic ecosystems where key factors controlling the growth of both species can fluctuate over a very wide range. Coastal lagoons in the Ebro River delta provide the opportunity for a large scale "experiment" as their hydrology is artificially controlled by freshwater irrigation inputs (COMÍN, 1982). In one of the lagoons, Tancada, bot species develop every year covering almost all the lagoon bottom, while salinity changes from high values in winter to low values in summer, in contrast to most Mediterranean coastal lagoons where salinity varies in the opposite sense (NISBET *et al.*, 1958; COLOMBO, 1972).

Seasonal changes in biomass of both species were studied in Tancada lagoon for a year in relation to some environmental factors, in order to contribute to the knowledge of their life strategies.

MATERIAL AND METHODS

Monthly samples were collected in Tancada lagoon. Above and below-ground biomasses were determined from five samples in each of the two basins of the lagoon (Fig. 1). Samples were collected with a cylindrical sampler (16 cm and 35 cm of diameter for *Ruppia* and *Potamogeton* respectively). The core saken extended driven 25 cm into the sediment in dense and monospecific stands of both species.
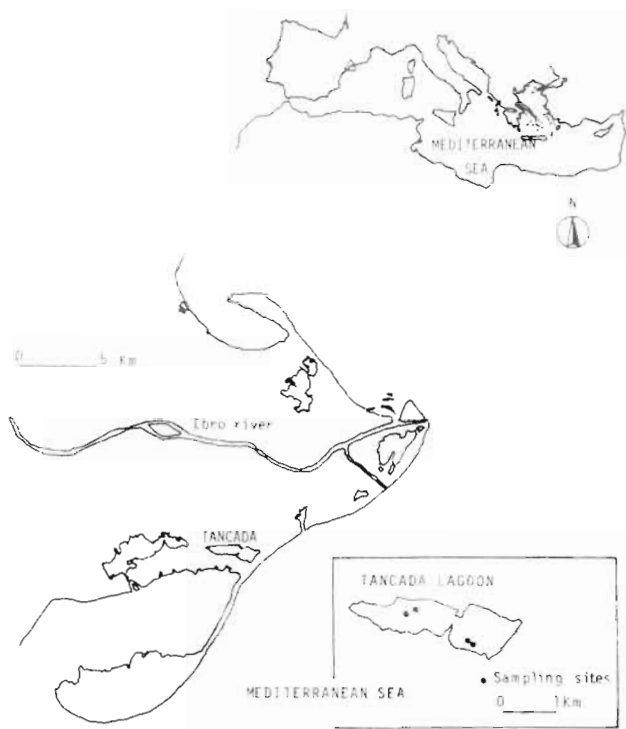
boratory. They were dried at 105 °C until constant weight (about 24 hours). Aliquots were burned at 550 °C for 3 h to measure ash content. All protocols were carried out following recommendations by VERHOEVEN (1980).

The plant cover of the lagoon bottom was estimated from visual observations from a boat sailing following transects covering the lagoon in May 1986. Transects were 10 m a part. This distance allowed visual observation of the surrounding submersed vegetation. Location of macrophyte beds was corroborated by means of aerial photographs made from an helicopter.

Ruppia and *Potamogeton* were collected in the East basin monthly for pigment analysis. Extraction of pigments was done according to SESTAK (1971) using 90 % acetone for triplicate samples from each plant. Determinations were based on the MACKINNEY (1942) equations.

In situ surface measurements of temperature and conductivity were done with a calibrated portable conductometer. Salinity was calculated from a regression equation, based on former simultaneous data on conductivity and salinity expressed in ‰ Cl (COMÍN, 1984).

Ruppia plants were sorted from the core after it was taken out of the water. *Potamogeton* plants were sorted by hand from the core. The sediment was sieved through a 1 mm mesh size net to collect the roots. Shoots and leaves were washed with 0.03 % HCl to remove $CaCO_3$ precipitates. Samples were fixed with 4 % formalin and transported to the la-

RESULTS

A clear spatial heterogeneity was observed in the distribution of *Ruppia* and *Potamogeton* in Tancada lagoon during 1986 and 1987 (Fig. 2). *Ruppia cirrhosa* formed very dense almost monospecific stands in the southern part of the lagoon. Mixed stands of both
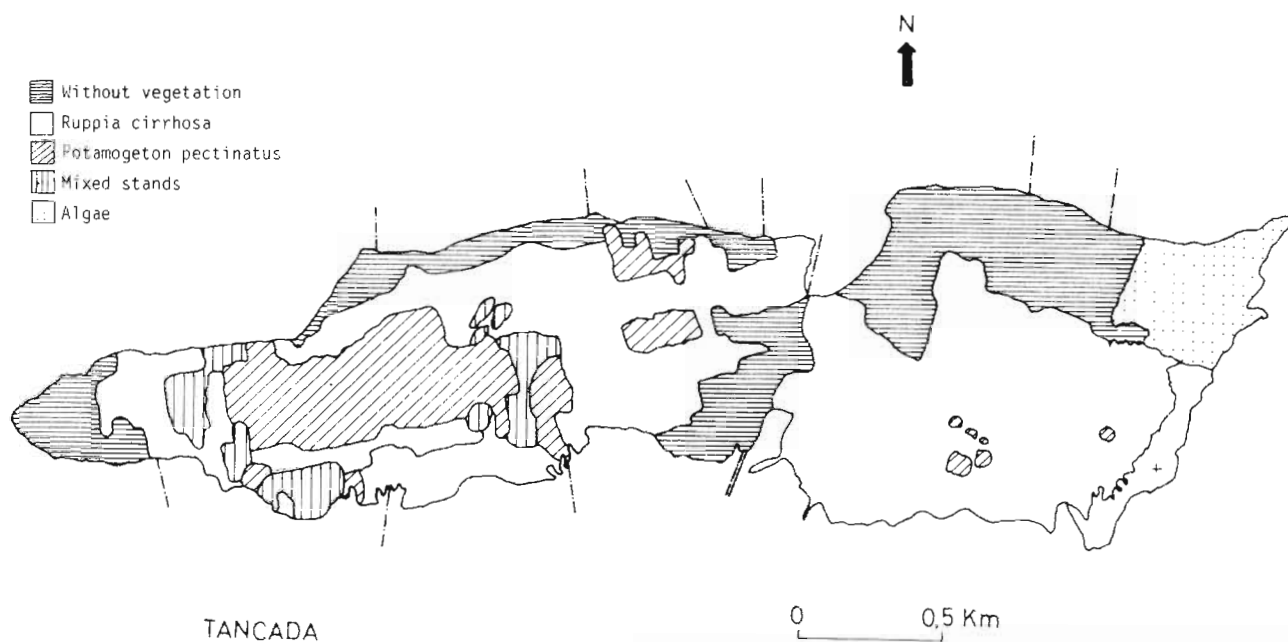

Without vegetation
Ruppia cirrhosa
Potamogeton pectinatus
Mixed stands
Algae

TANCADA

0   0,5 Km
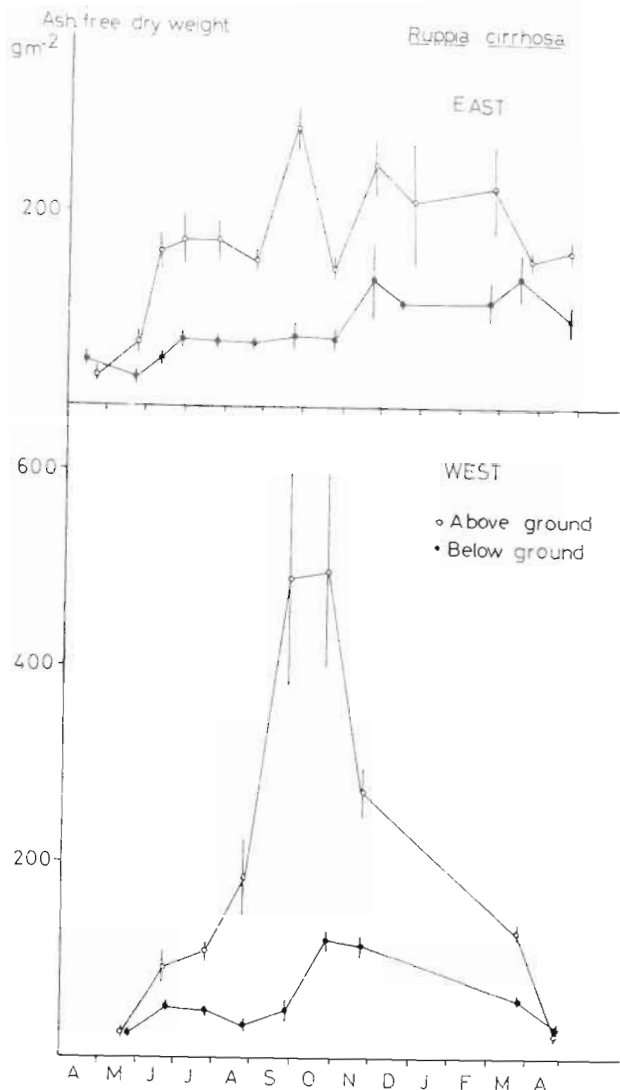
FIG. 3. — Seasonal changes of biomass of *Ruppia cirrhosa*. Bars indicate standard error.

Western basin, the maximum above ground biomass was reached in November, 346.76 g afdw m⁻² (15 °C, 1.0 ‰ Cl). In the Eastern basin it increased from 35.53 g afdw m⁻² in April 1986 up to 182.28 g afdw m⁻² in August (27 °C, 6.5 ‰ Cl). After reading these values, biomass decreased in the Western basin and persisted in the Eastern one for *Ruppia* for several months.

Below ground biomass is for both species 13-41 % of total plant biomass. *Ruppia* below ground biomass was slightly higher than *Potamogeton* in relation to their respective above ground biomasses. The below/above ground ratio was lower than 0.5 for both species most of the time except during the winter-early spring period (Fig. 6).

Ruppia and *Potamogeton* flowering took place from June to August. *Ruppia* fruits were formed in the East basin in June and in the West basin in August. *Potamogeton* fruits were observed in October and November.

Most chlorophyll concentrations were between 0.5 and 1.5 mg Chlorophyll a g^{-1} fresh weight (Fig. 7). However the two species differed in the seasonal
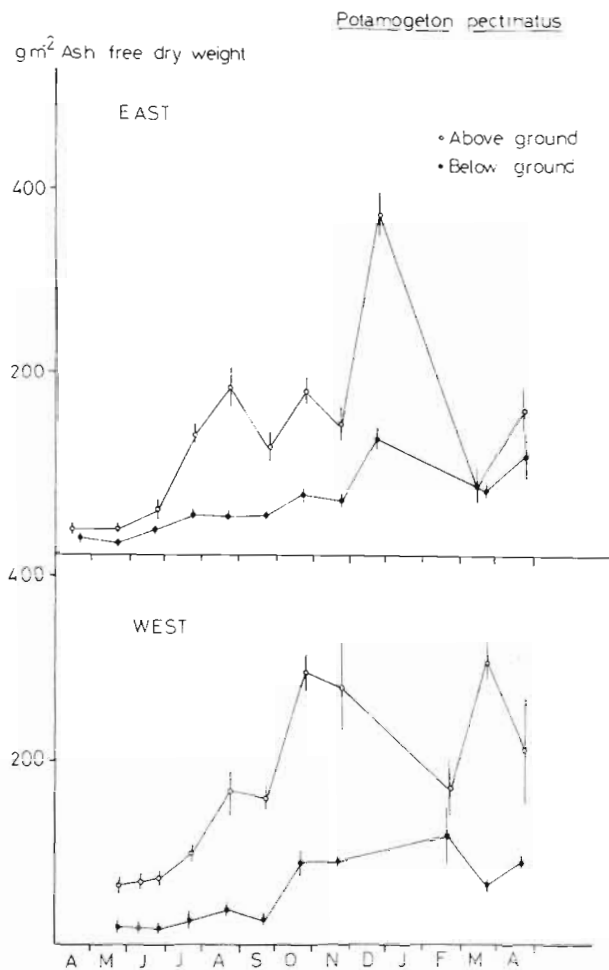

FIG. 4. — Seasonal changes of biomass of *Potamogeton pectinatus*. Bars indicate standard error.

species were found in the central area of the lagoon and monospecific stands of *Potamogeton* in the Northern part of the West basin. There was no vegetation in the North part of the East basin.

For both species, significant differences were observed between the seasonal biomass changes in the two basins (Fig. 3). *Ruppia cirrhosa* above ground biomass increased in the Western basin exponentially starting in early spring up to 495.67 g m⁻² ash free dry weight (afdw) in September. In the Eastern basin the biomass increase stopped in June and remained constant until autumn. Meanwhile, temperature varied, reaching a maximum of 29 °C in August (Fig. 5), while salinity decreased from 25 ‰ Cl to 1 ‰ Cl. Salinity values were always slightly lower in the Western than in the Eastern basin (Fig. 5).

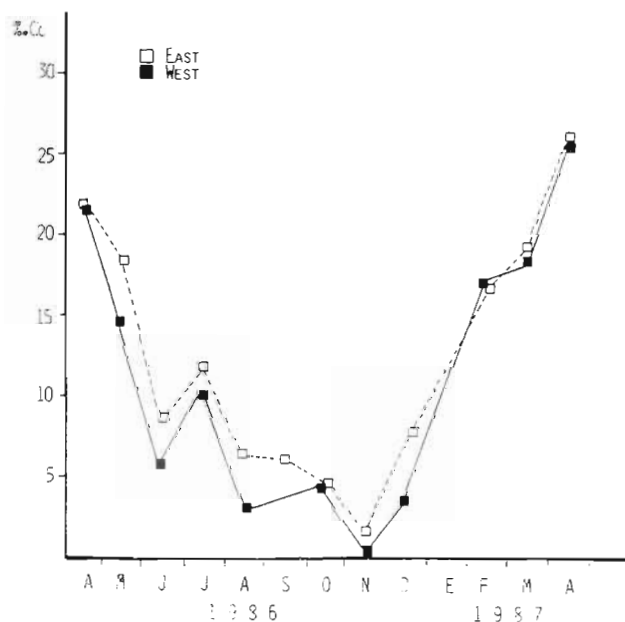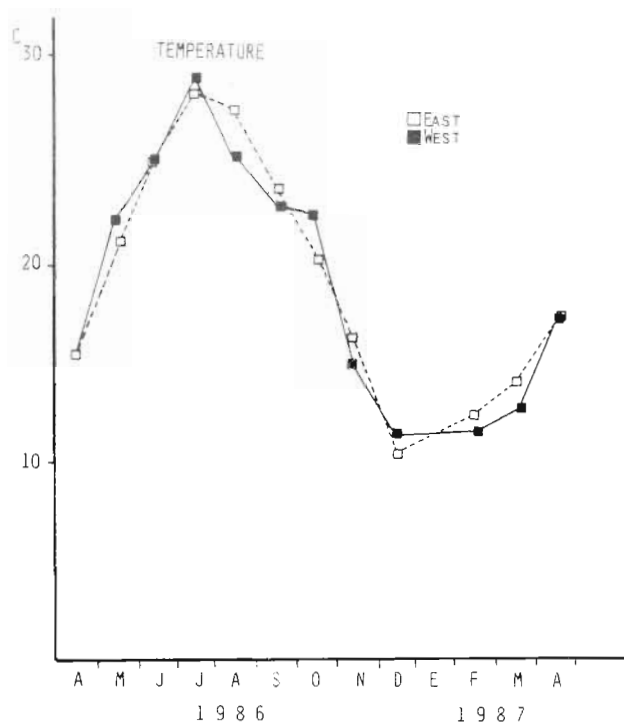*Potamogeton pectinatus* biomass varied in a similar way to *Ruppia* in both basins (Fig. 4). In the

FIG. 5. — Seasonal variation of water temperature (top) and of salinity (expressed as a chloride concentration, below) in Tancada lagoon.
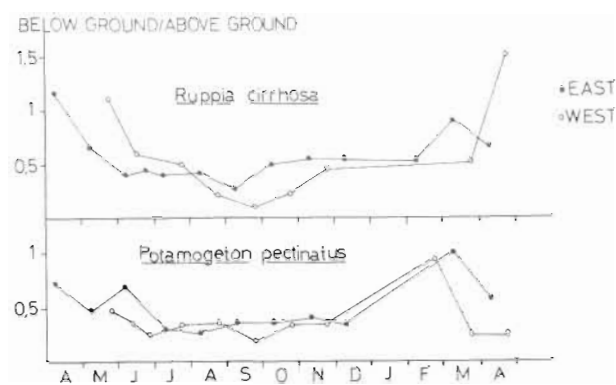

FIG. 6. Below ground / Above ground biomasses ratio.

a:chlorophyll *b* ratios were very similar for both species, between 1.5 and 2.5, but in the early growth stages in March when the ratio for *Ruppia* was exceptionally high (Fig. 8).

Ash percentage of total biomass was 10-27 % for *Potamogeton* and 10-47 % for *Ruppia*. Maximum ash contents occurred in spring and minima in summer. Fresh to dry weight ratio is 7.3 for *Ruppia* and 5.5 for *Potamogeton*.
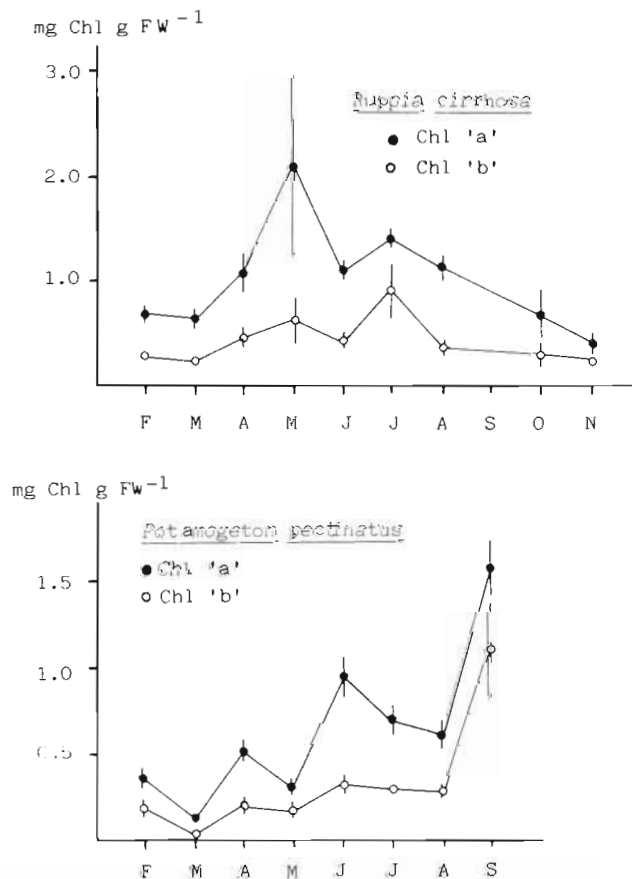
FIG. 7. — Seasonal changes of chlorophyll *a* and *b* in leaves of *R. cirrhosa* and *P. pectinatus*. Bars mean standard deviation.

pattern of pigment concentration. *Ruppia* chlorophyll concentration increased during spring with average maximum of 2 mg g^{-1} fw in May. A second peak was observed in July. Then it decreased to the winter values, 0.5 mg g^{-1} fw. *Potamogeton* increased the amount of chlorophyll from winter, 0.1 mg g^{-1} fw. to September 1.6 mg g^{-1} fw. Two other peaks were observed in April and June. Chlorophyll

Fig. 8. — Seasonal changes of chlorophyll *a* / chlorophyll *b* ratio in *Ruppia cirrhosa* and *Potamogeton pectinatus*.

DISCUSSION

Ruppia cirrhosa and *Potamogeton pectinatus* are able to coexist in temperate coastal lagoons because they have overlapping ranges of tolerance to salinity (VERHOEVEN, 1980). They both develop in extensive beds in Tancada lagoon every year. The maximum *Ruppia* b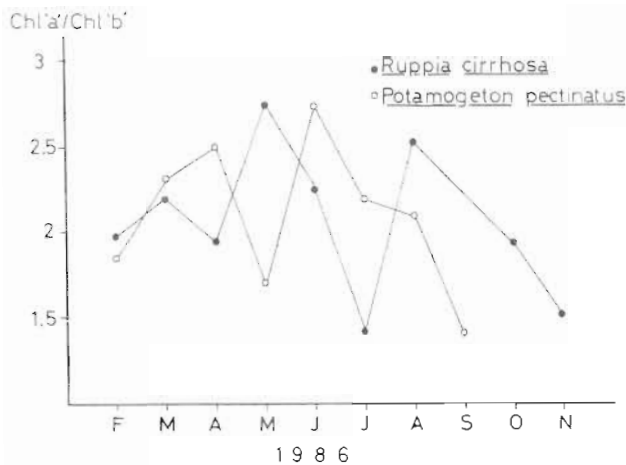iomass density observed was amongst the highest reported, indicating that this lagoon provides very good conditions for its growth. This is not the case for *Potamogeton* whose maximum biomass density is among the lowest reported (Table I).

Several environmental factors may be responsible for the differences observed between the seasonal changes in biomass of *Potamogeton* and *Ruppia* in the Western and Eastern basins of Tancada lagoon. Monospecific stands of *Potamogeton* develop only in the deepest zone of the Western Tancada basin while in the Eastern basin mixed stands of *Potamogeton* and *Ruppia* develop, the latter being dominant. One critical factor is the fact that freshwater from ricefields discharges overwhelmingly into the West basin. *Potamogeton pectinatus* is well adapted to eutrophic and low salinity waters. It develops perfectly in coastal waters with annual mean salinity below 9 ‰ Cl and annual maximum below 15 ‰ Cl (VERHOEVEN, 1980; VAN WIJK, 1988).

Turbidity may be another important factor controlling macrophyte growth. *Potamogeton* is less light dependent than *Ruppia*. The former quickly grows vertically with a surface canopy (VAN WIJK, 1988) where terminal meristems often lie at the tips of the erect stems (STEVENSON, 1988), while *Ruppia* develops first as dense meadows of linear leaves (VERHOEVEN, 1980) with basal meristems.

Potamogeton is also favored over *Ruppia* because high nutrient concentrations are associated with the

freshwater discharges which promote a higher eutrophic level in the Western than in the Eastern basin, as has been shown by comparing phytoplankton populations from both places (COMÍN, 1982). So differences between the seasonal biomass changes of *Potamogeton* and *Ruppia* in the Western basin can be attributed to the effects of salinity and turbidity caused by freshwater inputs. This is corroborated by the fact that *Ruppia* biomass decreases but that of *Potamogeton* does not in the Western basin after October, when freshwater discharges are higher because of intensive drainage of ricefields at the end of the cultivation period. Seasonal biomass changes showed marked contrasts between the two locations in Tancada lagoon. Both species have a longer exponential growth period in the Western basin. Biomass increase stopped in the East basin in June for *Ruppia* and in August for *Potamogeton*. It appears that both species follow different patterns of biomass change in each of the two basins. The pattern in the Western basin is similar to the seasonal changes in *Ruppia* observed by VERHOEVEN (1980) in Texel (Netherlands) and by HOWARD-WILLIAMS (1978) for

Table I. — Biomass data in the literature from other coastal water masses.

Species	Range of biomass Density	Site	Reference
R. cirrhosa	9-11 g m^{-2} afdw	Askö, Baltic Sweden	ANKAR & ELMEGREEN[*] (1977)
R. cirrhosa	4-15 g m^{-2} afdw	Askö, Baltic Sweden	JERLING & LINDE[*] (1977)
R. cirrhosa	49.7-157.1 g m^{-2} afdw	Carmargue France	VERHOEVEN (1980)
R. cirrhosa	56.9-188.4 g m^{-2} afdw	Coastal ponds Netherlands	VERHOEVEN (1980)
R. cirrhosa	92.2-146.9 g m^{-2} afdw	Twärminne Finland	VERHOEVEN (1980)
R. cirrhosa	125-275 g m^{-2} afdw	Bahía del Fangar Ebro Delta Spain	PÉREZ & CAMP (1986)
R. cirrhosa	51-546.7 g m^{-2} afdw	Tancada lagoon Ebro Delta Spain	This study
R. cirrhosa	10-111 g m^{-2} dw	Mar Menor Murcia Spain	BALLESTER (1985)
Ruppia sp.	375 g m^{-2} afdw	Blackwood estuary Australia	CONGDOM & McCOMB[*] (1979)
Potamogeton pectinatus	1770 g m^{-2} afdw	Brackish lake S. Africa	HOWARD-WILLIAMS (1978)
Potamogeton pectinatus	575 g m^{-2} dw	Lake Nainital India	PUROHIT et al. (1986)
Potamogeton pectinatus	48.4-482.0 g m^{-2} afdw	Tancada lagoon Ebro Delta Spain	This study

[*] In VERHOEVEN, 1980

(Netherlands) and by HOWARD-WILLIAMS (1978) for *Potamogeton* in South Africa, although with lower biomasses in *Ruppia* than in Tancada. In the Eastern basin both species have a shorter exponential growth period before their maximum biomass, which persists for a longer period than in the Western basin. The loss of plant material after several months of exponential growth due to decay of the bases of the vertical stems has been held responsible for the latter pattern (VERHOEVEN, 1979).

Chlorophyll concentrations change as plants grow. The maximum chlorophyll content of *Ruppia* is observed in the early growth stages, and decreases in Autumn because of seasonal leaf senescence stimulated by low salinity. The chlorophyll *a*:chlorophyll *b* ratio increase in March for *Ruppia* can be related to a normal initial growth stage, although SPENCER (1986) also mentioned temperature decrease as having the same effect.

The seasonal patterns of biomass change of *Ruppia* and *Potamogeton* show some differences between the two basins. In both basins *Ruppia* biomass increases faster than *Potamogeton* biomass. It is quite evident that at the relatively high salinities of the early growing season, March-May *Ruppia* growth is favoured over *Potamogeton*. Both species maintain a high biomass throughout the growing period in different basins: *Ruppia* in the Eastern basin, favoured by relatively high salinities, and *Potamogeton* in the Western basin, estimulated by freshwater inputs. But in the Western basin, *Ruppia* biomass decreases quickly after October, when salinity is lowest. In the Eastern basin, *Potamogeton* biomass reached the maximum in December, just after the lowest salinity value, and then quickly decreased. Of course, plant decomposition is also important in autumn and winter.

ACKNOWLEDGEMENTS

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