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P. RENOM, M. PÉREZ, T. ALCOVERRO, M. MANZANERA, J. ROMERO

Department of Ecology, University of Barcelona, Av. Diagonal 645, 08028 Barcelona, Spain.

ASSESSING TEMPORAL VARIABILITY IN THE CARBON BALANCE OF THE SEAGRASS *POSIDONIA OCEANICA* (L.) DELILE

Abstract

We estimated the carbon gains and carbon losses of the Mediterranean seagrass Posidonia oceanica *to obtain a plant carbon budget at different time scales. The model was based on the knowledge of P-I relationships for different age classes, and respiration demands of different plant parts, and it was fed with data of incoming solar irradiance and water turbidity recorded at the study site since 1990. The estimation of the model, over the last decade, was within the rage 0.125-0.665 g C shoot^{-1} year^{-1}. Interannual variability of the net carbon gain was high (coeficient of variation 34%). Interannual changes were mostly driven by changes in the incoming solar irradiance.*

Key-words: *sea surface irradiance, water turbidity, timescale, depth.*

Introduction

Carbon balance models have became important research tools widely used in terrestrial plant ecology and ecophysiology (e.g. Gutiérrez *et al.*, 1985; Abdel-Razik, 1989; Janecek *et al.*, 1989, among many others). Application of similar models to marine plants (and, specifically, to seagrasses) is less common (e.g. Pérez and Romero 1992; Zimmerman *et al.*, 1994; Dunton, 1994; Lee and Dunton, 1996; Herzka and Dunton, 1998; Alcoverro *et al.*, submitted), and they have been mostly aimed at assessing plant-light relationships within a single growth cycle. However, little is known about carbon budget variability at other temporal scales (both larger and shorter). For example, to what extent can the carbon budget (in which plant growth or other outputs, such as reproductive effort, relies) fluctuate from one year to another remains an unanswered, although critical, question. Of course, the scarcity of long-term data series on underwater irradiance is a major difficulty in assessing such long-term variability.

Here we benefit from the existence of long-term records of water transparency and aerial irradiance, and we use this data in combination with a simple carbon balance model, to, first, examine the temporal variability in the carbon budget of *Posidonia oceanica*, at time scales ranging from one week to ten years and second, to assess the statistical dependence of such a budget on the two components determining the amount of irradiance reaching the plant canopy, *i.e.* water transparency and irradiance reaching the sea surface.

Materials and methods

The carbon budget was based mostly on Alcoverro *et al.* (submitted), and experimental data was obtained in the seagrass meadow off the Medes Islands (NE Spain), at two depths: 5 m and 14 m.

An estimate of the daily carbon budget of the plant was obtained as follows: daily-integrated respiration of non-photosynthetic parts was subtracted from daily-integrated net carbon gains by leaves, which were computed based on photosynthesis-irradiance curves obtained bi-monthly (for each one of four different leaf-age classes: data in Alcoverro *et al.*, 1998); integration was done on an hourly basis.

Underwater irradiance was estimated using values of sea surface irradiance (SSI), recorded since 1990 at a meteorological station close to the study site, that were transformed into underwater PAR quantum irradiance using empirical factors and formulae in Kirk (1983) to account for reflection at the sea-air interface; irradiance reaching the plant canopy was calculated applying the Beer-Lambert law of light attenuation ($I_z=I_0e^{-kz}$), and the coefficient of light extinction k was estimated from weekly observations of water transparency (Secchi disc).

We had hence an estimate of the daily carbon budget of the plant from January 1990 to December 1999, at both 5 and 14 m; we obtained, by integration, estimates of the carbon budget over longer time scales (weeks, months, years). We analyzed the periodicity within each data series using Fourier analysis, and the dependence of carbon budget estimates on SSI and water turbidity using multiple regression analysis, the carbon budget being the dependent variable and SSI and k the independent ones.

Results and discussion

SSI (Fig. 1a) was the variable showing the clearest annual periodicity, but interannual variations were also very evident. Changes in water transparency, although exhibiting a significant yearly periodicity, were more irregular, and peaks of water turbidity were at times recorded, mostly in winter (Fig. 1b). Carbon balance had also a main period of one year (Fig. 1c), but varied greatly from one year to the next, with annual carbon budgets ranging from 0.13 to 0.67 g C $shoot^{-1}$ $year^{-1}$ (see Fig. 1d).

The contribution of each independent variable to explain the variability in the dependent variable (as expressed by β, the standardized regression coefficient), depends on the depth and on the time-scale considered. At 5 m and over weekly and monthly timescales, both independent variables (k and SSI) contribute significantly to predicting the variability in the carbon budget, SSI being the most prominent of the two (Tab. 1). This situation changes at 14 m, with k being the variable explaining the most variability on a monthly timescale. This is due to the increasing importance of light extinction as the water column thickness increases. However, interannual variability (as indicated by yearly averaged carbon budget) seemed only to be explained by interannual variability in SSI at both 5 and 14 m. This is probably due to the fact that the highest values of k (water turbidity) were found during winter storms, when SSI is at its minimum and the plant budget is already negative, independently of light extinction. This finding, although preliminary, seems to highlight the role of meteorology, rather than hydrography in determining light availability for seagrasses, under the specific conditions of the generally clear Mediterranean waters.

The consequences of interannual variability on the seagrass meadow are still to be elucidated. Apparently, the differences in the carbon budget did not change annual leaf growth, since the values obtained in 1991, 1992 and 1997 (Alcoverro, 1995; Alcoverro *et al.*. submitted; Invers *et al.*. 2000) were quite similar; however, the number of leaves produced from 1990 to 1992 (Mateo *et al.*, submitted) decreased, as did the carbon budget.

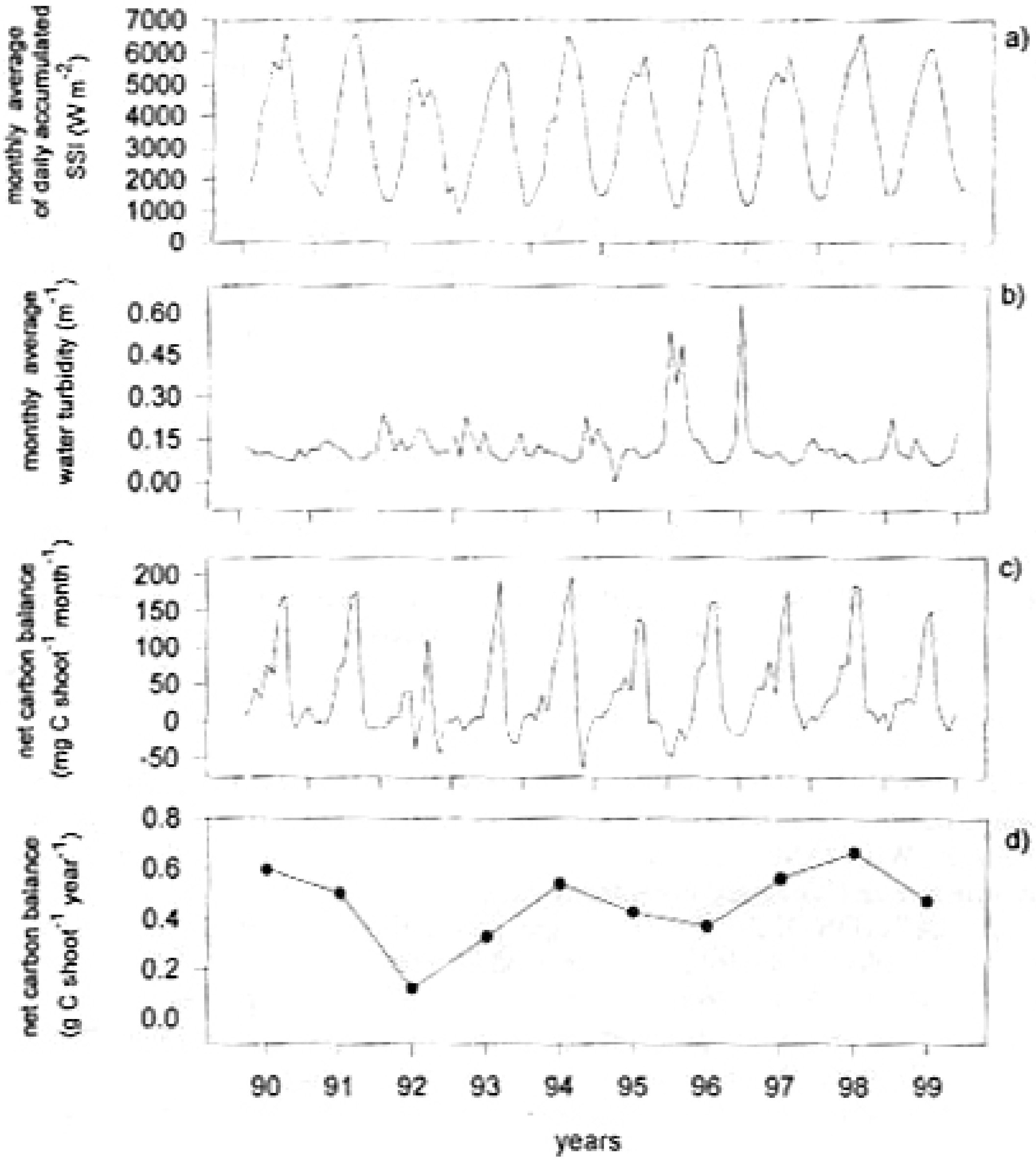

Fig. 1. a) SSI recorded at the meteorological station, b) water turbidity (Secchi disc), c) monthly estimate of net carbon balance of *Posidonia oceanica* at Medes Islands at 5 meter depth, d) annual averages.

Tab. 1. Effect of the independent environmental variables, SSI (sea surface irradiance) and k (coef. of light extinction) on the carbon balance variability at different temporal scales. β standardized regression coef., P, probability of error when rejecting the null hypothesis β=0, r^2 determination coef.

	5 meters			14 meters		
	P	β		P	β	
Weekly	SSI: <0.001	0.751	r^2: 0.666	SSI: <0.001	0.431	r^2: 0.360
	k: <0.001	-0.16	n: 3650	k: <0.001	-0.30	n: 3650
	P	β		P	β	
Monthly	SSI: <0.001	0.663	r^2: 0.625	SSI: 0.061	0.159	r^2: 0.351
	k: <0.001	-0.23	n: 120	k: <0.001	-0.51	n: 120
	P	β		P	β	
Annual	SSI: <0.001	0.822	r^2: 0.858	SSI: 0.061	0.839	r^2: 0.891
	k: 0.244	-0.20	n: 10	k: 0.190	-0.20	n: 10

Moreover, at this site, a massive flowering event occurred in 1994, and sparse flowering was detected in 1990, 1997 and 1998 (personal observation), in all cases years with a highly positive carbon budget. It is also possible that interannual changes in the carbon budget would influence some features of the seagrass meadow (density, cover); this possibility, however, remains untreated due to the difficulty in obtaining reliable long-term data series.

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