SUPPLEMENTARY MATERIALS

SM1 Implementation of the clonal growth rules

Local interactions among shoots are considered using a density dependent branching rate of the form:

$$\nu(\rho) = \nu_0 + \alpha\hat{\rho}\left(1 - \hat{\rho}\right), \tag{1}$$

where ν_0 is the intrinsic branching rate that depends on external factors such as temperature or irradiance, $\hat{\rho} = \rho/\rho_{max}$ is the normalized local density, and α is a coefficient that controls the strength of the interaction. Given the parabolic shape of the interaction, the growth of over- and under-populated areas is penalized, whereas regions around an optimal density $\rho = \rho_{max}/2$ is favoured. Equation (1) can be easily extended to consider the interaction among N species as follows. We define a normalized local density for the species $i = 1, \ldots, N$ as:

$$\hat{\rho}_i = \frac{1}{\rho_{max,i}}\left(\rho_i + \sum_{j \neq i}\gamma_{ij}\rho_j\right), \tag{2}$$

where $\rho_{max,i}$ is the saturation density for the $i-$species. γ_{ij} is the coupling coefficient between species i and j. The normalized density $\hat{\rho}_i$ is used in Equation (1) to evaluate the branching rate for the $i-$species, $\nu_i(\rho_i)$. The simulation starts placing a random distribution of seeds (a shoot carrying an apical meristem) of the competing species and assigning to it a unitary vector $\hat{u}$, randomly oriented, setting the direction of growth of the rhizome. At each iteration, the following steps are repeated:

1. Since species have different characteristic growing times: $\tau_i = \delta_i/v_i$, at each iteration, one of the species is selected with probability $p_i = \tau_i/\left(\sum_i \tau_i\right)$.

2. The rhizome that originates in the nth-apex of the i-species, randomly selected, is proposed to extend over a distance $\delta_i\hat{u}_i^{(n)}$.

3. The apex will be relocated to its new position and a new shoot will develop only if the normalized local density in the corresponding cell, given by the Equation (2), fullfils: $\hat{\rho}_i < 1$.

4. Time is increased by $\Delta t = \delta_i/(v_i N_a^T(t))$, where $N_a^T(t)$ is the total number of apices from all species at time t

5. A new branch with a growing apex will develop according to the branching rate $\nu_i(\rho_i) = \nu_{0i} + \alpha_i\hat{\rho}_i(1 - \hat{\rho}_i)$ with probability: $p_{\nu,i}(t) = \nu_i(\rho_i)\Delta t N_{a,i}(t)$, with $N_{a,i}(t)$ the number apices of the $i-$species.

6. During this time step, a number of shoots of the $i-$species are removed with probability $p_{\mu,i}(t) = \mu_i\Delta t/N_{s,i}(t)$, with $N_{s,i}(t)$ the number shoots of the $i-$species.

SM2 Differential equations for regressive meadows

Seagrass shoots are modeled by the following differential equation describing the evolution of a decaying population:

$$\frac{dN(t)}{dt} = -\omega N(t),\tag{3}$$

where $N(t)$ is the number of shoots at time t, and ω is the net mortality rate. For time-dependent $\omega = \omega(t)$, the generic solution to equation (3) is:

$$N(t) = N_0 e^{-\int_t dt' \omega(t')}.\tag{4}$$

For constant ω, equation (4) boils down to the exponential $N(t) = N_0 e^{-\omega t}$. The net mortality rate of a meadow is often represented as the difference $\omega = \mu - \nu_0$, where μ is shoot mortality rate, and ν_0 is the recruitment rate or branching rate. Performing the integral at the exponent (4), for a time mortality rate $\mu(t) = \alpha t + \mu_0$, and neglecting local interactions (ν_0 is constant):

$$N(t) = N_0 \exp\left[-\frac{\alpha}{2}t^2 + (\nu_0 - \mu_0)t\right].\tag{5}$$

The previous expression shows a quadratic exponential decay in seagrass populations when the mortality rate is linearly increasing in time.
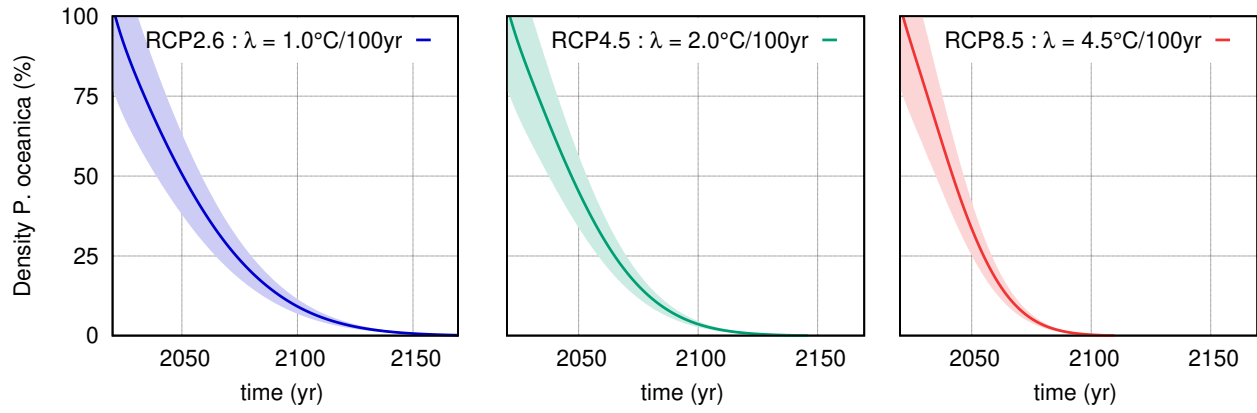
Figure S 1: Population decay (in %) of *P. oceanica* meadows subjected to different sea warming rates $\lambda = 1.0, 2.0, 4.5\,^{\circ}\text{C}/100\,yr$, corresponding respectively to RCP2.6, RCP4.5, RCP8.5, following the results by (Darmaraki et al. 2019). The errors in the warming rates are considered in the range of $20 - 25\%$, leading to the uncertainties plotted in the shadowed areas.

Symbol	Spacer length	Rhizome elongation	Branching rate	Branching angle	Mortality	Optimal Density	Coupling coeff.
	δ	v	ν_0	ϕ	μ_0	$\rho_{max}/2$	γ_{ij}
Units	cm	cm yr^{-1} apex^{-1}	branches yr^{-1} apex^{-1}	degree	yr^{-1}	m^{-2}	adim.
P. oceanica (1)	2.81 ± 0.64	2.35 ± 0.20	0.050 ± 0.004	41 ± 10	0.03 - 0.07	900	$\gamma_{12} = 0.1$
Source	Marbà & Duarte (1997)	Marbà et al. (1996)	Meinesz et al. (1991)	Marbà & Duarte (1998)	Jordà et al. (2012)	Marbà et al. (1996)	This work
Site	15 Spanish sites	29 Spanish sites	Corsica & Golf-Juan	16 Spanish sites	-	29 Spanish sites	Ses Olles de Son Saura
Season	Summer	Summer	annual averages	annual averages	-	Summer	Autumn
C. nodosa (2)	3.7 ± 0.1	160 ± 5	2.3 ± 0.05	46 ± 15	0.92 ± 0.08	1200	$\gamma_{21} = 6.5$
Source	Terrados et al. (1997)	Duarte & Sand-Jensen (1990)	Duarte et al. (unpubl.)	Marbà & Duarte (1998)	Duarte & Sand-Jensen (1990)	Vaquer-Sunyer & Barrientos (2021)	This work
Site	Alfacs Bay	Alfacs Bay	16 Spanish sites	16 Spanish sites	Alfacs Bay	13 sites in Menorca	Ses Olles de Son Saura
Season	Summer	Summer	Summer	Summer	Summer	Summer	Autumn

Table S 1: Summary of the values chosen for the model parameters. Left to the vertical line, we collect the clonal growth parameters distinctive of *Posidonia oceanica* and *Cymodocea nodosa*. These parameters have been measured by direct field observations and characterized by their averaged value and standard deviation. We also display their original references, locations, and seasons of the field observations. For a review that collects these and other seagrass growth parameters, see (Marbà & Duarte 1998). The values of the *P. oceanica* constant mortality rate (μ_0) are fixed to two different values: 1) $\mu_0 = 0.03yr^{-1}$, to reproduce stable density meadows, and 2) $\mu_0 = 0.07yr^{-1}$, to consider local disturbances that cause the deterioration and death of the meadows (Jordà et al. 2012). To the right of the vertical line, we show the parameters that are estimated indirectly from the outcomes of the simulations, comparing them to field observations. The optimal densities for each species are to reproduce healthy and realistic meadows with densities similar to those measured in the Balearic Sea (Marbà et al. 1996, Vaquer-Sunyer & Barrientos 2021), and the coupling coefficients are chosen such that we reproduce the behavior of the front between mono-specific meadows of *Posidonia oceanica* and *Cymodocea nodosa*, as explained in this work in Sec. 3.1.2.

4

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