Making surfgrasses great again: photosynthetic net carbon fluxes support their key role as Blue Carbon systems

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INTRODUCTION

Seagrasses are very productive ecosystems that store large quantities of Carbon. *Phyllospadix torreyi* and *Phyllospadix scouleri* (also known as surfgrasses) are widely distributed along the west coast of North America, from Alaska to the Baja California peninsula in Mexico. These species form highly productive patchy but continuous shallow meadows along the rocky-exposed shores (down to ~ 5 m depth). Although its below-ground biomass is much smaller than other seagrasses, their very long leaves, high growing rates and perennial stability of the meadows might sustain an important role for *Phyllospadix* as Blue Carbon sinks/stocks. However, available knowledge about the functionality of surfgrasses as Blue Carbon systems is surprisingly scarce compared to other seagrass species. Also, descriptors typically analyzed are limited to Carbon content in the plant biomass and adjacent sediments, ignoring key carbon fluxes due to the plant photobiological activity.

Here we quantified the net-fixation capacity of dissolved inorganic carbon by an unaltered *Phyllospadix* meadow according to the photobiology and respiration of shoots and local light conditions for two contrasting seasons (winter and summer). We also estimated the total Carbon stored in its epigeal and hypogeal biomass to shed light into the amount of Carbon stored by these ecosystems.

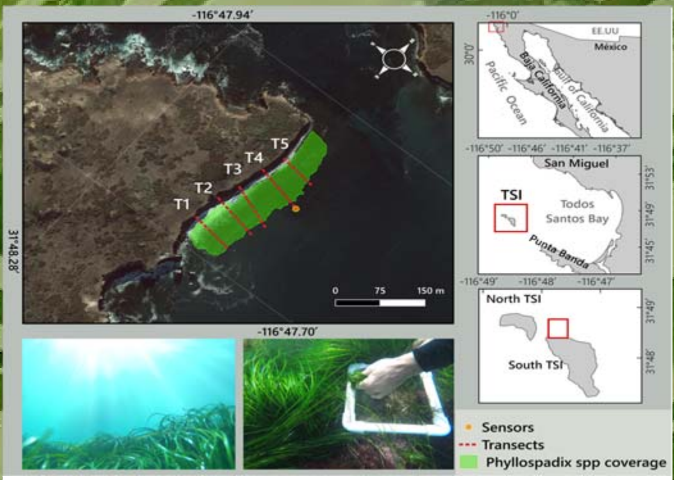

Figure 1. *Phyllospadix* meadow in Isla Todos Santos (Baja California, Mexico). The green polygon shows the seagrass meadow. The red dotted lines indicate the fixed transects (T1 - T5) on which the coverage sampling and biomass collection were carried out. The orange dot indicates the location of the light and temperature sensors.

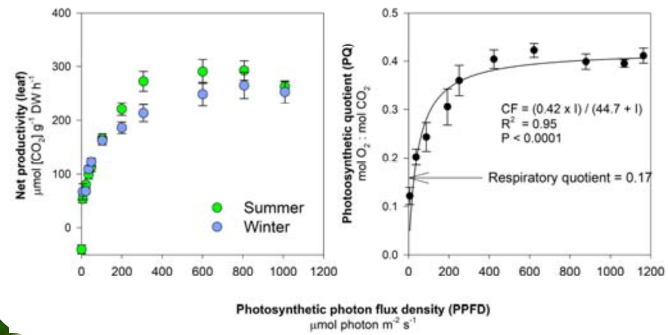

Figure 2. Net productivity rates (left panel) measured in the laboratory by P-E curves. Initial values of oxygen evolution were transformed to carbon according to the photosynthetic quotients at each irradiance and the respiratory quotient (right panel).

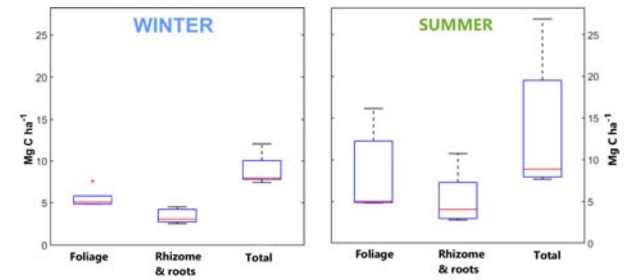

Figure 3. Carbon storage (Mg C ha^{-1}) by different plant tissues of *Phyllospadix spp.* calculated for winter (left) and summer (right). The red line shows the median of the 5 transects (see Fig. 1). The blue box represents the 25th and 75th percentiles, and the black lines the total range of the data. The red sign is an outlier.

MATERIAL AND METHODS

The study was carried out in an unaltered meadow located in Isla Todos Santos (Ensenada, Baja California, Mexico), within the Pacific Islands Biosphere Reserve Pacific (Fig. 1). This meadow is composed by *P. scouleri* and *P. torreyi*. All the biological descriptors were examined in two contrasting seasons, Winter 2019 and Summer 2020.

Photosynthesis vs. Irradiance curves (P-E curves) were performed in the lab by using respirometers (Fig. 2). Initial values of oxygen evolution were transformed to carbon according to the photosynthetic quotients (PQ) at each irradiance, and the respiratory quotient (RQ). PQ and RQ (mol O_2: mol CO_2) were obtained by simultaneous incubations, in which the dissolved oxygen was measured with optodes, while the inorganic carbon species were derived (CID and CO_2; CO2SYS) from a pH time series (± 0.01 units) and discrete samples of total alkalinity (± 3 µmol kg^{-1}).

Total Biomass (Leaves and rhizomes) was measured from plants collected within 20x20 cm quadrats. Tissue was separated and dried in the laboratory. The total Carbon fraction of the plant biomass was calculated assuming a C content of 30% of the dry weight (Fig. 3). Light and temperature were continuously recorded in the field by submersible sensors.

The daily net fixation rates of dissolved inorganic carbon at meadow level (Fig. 4) were calculated from the difference between the net photosynthesis rates calculated for each light condition *in situ*, and respiration rates at night. The estimation of productivity at meadow level, considered the averaged biomass and coverage obtained from *in situ* sampling.

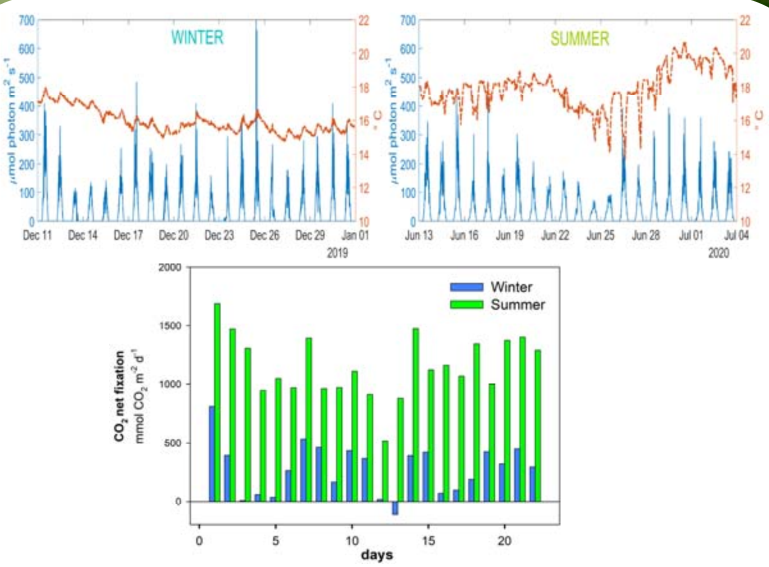

Figure 4. Seasonal PAR irradiance and temperatures recorded by at 5m below surface, i.e. subtidal meadow limit (top panels). Net inorganic carbon fixation calculated at meadow scale according to natural PAR light availability (panel below).

RESULTS

- Photosynthetic capacities of *Phyllospadix* measured by P-E curves in laboratory were similar between seasons (Fig. 1).
- The net inorganic carbon fixation was ~279 mmol CO_2 m^{-2} day^{-1} during winter, and 2 to 3 times greater ~1156 mmol CO_2 m^{-2} day^{-1} during summer (Fig. 4). These rates were similar (or even higher) to that quantified for other seagrasses that play an important role as blue carbon stocks in Mexico, such as *Zostera marina* and *Thalassia testudinum* (300-800 mmol C m^{-2} day^{-1}; Herrera-Silveira et al., 2019).
- In terms of C content in foliar biomass for winter, average values of 5.52 Mg C ha^{-1} were obtained, while for summer we found 8.36 Mg C ha^{-1} (Fig. 3), well above the 0.001 – 5.548 Mg C ha^{-1} range reported for seagrasses globally by Fourqurean et al., (2012).
- Contrastingly, for below-ground biomass (rhizome and roots; Fig. 3) we estimated an average of 3.44 Mg C ha^{-1} in winter, and 5.33 Mg C ha^{-1} in summer. Tipping towards the lower end of the 0.001 – 17.835 Mg C ha^{-1} range reported for seagrasses (Fourqurean et al., 2012).

CONCLUSIONS

- The seagrass beds of *Phyllospadix* show high rates of net fixation of DIC by photosynthetic productivity.
- The C stored in the foliar biomass is much higher than the seagrass meadows of Baja California and other regions worldwide.
- Instead of physiological photosynthetic capacities, the photosynthetic net C fixation of *Phyllospadix* meadows largely depend on their foliar biomasses and their seasonal changes.
- The perennial nature of the foliar biomass of *Phyllospadix* and the annual stability of the area / coverage of the populations are factors that can support the role of these meadows as efficient sinks of blue-C.

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