Variability in the net ecosystem productivity (NEP) of seaweed farms†

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The critical role of vegetated ecosystems in carbon sequestration has attracted substantial interest across various disciplines. With growing evidence of the potential of macroalgae ecosystems to capture carbon, there is burgeoning interest in applying newfound knowledge of carbon capture rates to better understand this potential for carbon sequestration. Seaweed farms are expected to play a significant role in carbon capture; advocates for expanding seaweed farms are increasing in many countries.

In general, seaweed farms are expected to be highly productive, although whether they are autotrophic or heterotrophic ecosystems and hence their potential as exporters of carbon is under debate. All in all, we present our investigation on three seaweed farms, two *Undaria pinnatifida* (Wakame) farms in northern Japan (Matsushima Bay and Hirota Bay) and one *Cladosiphon okamuranus* (Mozuku) farm in southern Japan (Bise Point). In addition, data were collected from two natural seaweed ecosystems (Arikawa Bay and Omura Bay) and one degraded seaweed ecosystem (Tainoura Bay) in Nagasaki Prefecture. We examined the frequency of autotrophic days and compared potential carbon capture rates from these six geographic locations across Japan.

We estimated potential carbon capture rates by calculating the net ecosystem productivity (NEP) from continuous recordings of dissolved oxygen concentrations under natural environmental conditions. Water temperature and dissolved oxygen concentrations were recorded with dataloggers at a rate of one sample every ten minutes. In the natural and degraded ecosystems, one datalogger was placed directly above the sediment, another 50 cm above the sediment, and a third 50 cm below the water surface (*i.e.*, a total of three instruments and a mean depth of 3 m for Omura Bay, 5 m for Arikawa Bay, and 8 m for Tainoura Bay). The dataloggers at the seaweed aquaculture farms were placed on the cultivation ropes and 1 m (Bise Point) and 2 m (Hirota Bay and Matsushima Bay) below the cultivation ropes (*i.e.*, a total of two instruments). The instruments were placed so that the majority of the biomass of the seaweed was between the data loggers. Recordings were carried out for four to twenty days before the instruments were retrieved for maintenance and data offloading. Calculations of productivity were based on the ensemble mean of the dissolved oxygen time series recorded by the dataloggers to account for vertical heterogeneity. The gross ecosystem production (GEP) rates and ecosystem respiration (ER) rates were estimated from the diurnal fluctuations of the dissolved oxygen concentration with the open-water method (*e.g.*, Hinode *et al.*, 2020). Briefly, the NEP rate can be defined as NEP = GEP + ER.

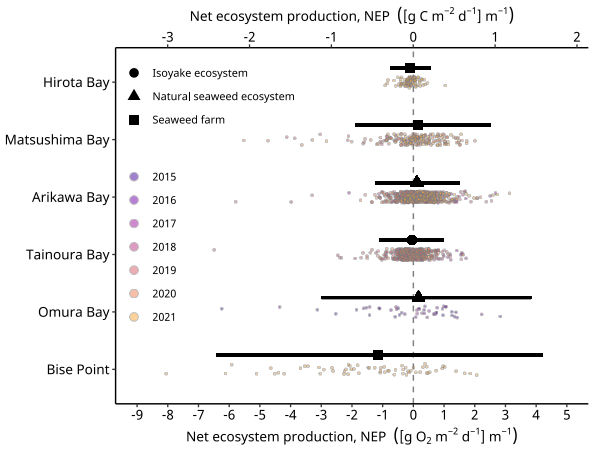

Fig. 1. Observed (colored points) and conditional mean of the net ecosystem production (black symbols) rates of the study sites. The black horizontal lines indicate the 95% highest density credible interval of the predicted values. Hirota Bay and Matsushima Bay are Wakame farms, Bise Point is Mozuku farm, Arikawa Bay and Omura Bay are sites of the natural Sargassum spp. ecosystem, and Tainoura Bay is a site where a seaweed ecosystem has degraded. The net ecosystem production in O_2 and C are calculated assuming a 1 to 1 molar ratio.

The NEP rates for the natural ecosystems in Arikawa Bay and Omura Bay were equivalent to 0.043 and 0.054 [g C m^{-2} d^{-1}] m^{-1}, respectively (Fig. 1). Consering for the degraded ecosystem in Tainoura Bay, it was -0.01 [g C m^{-2} d^{-1}] m^{-1}. We noticed that the Wakame farm in Matsushima Bay experiences autotrophy more often than natural ecosystems, although autotrophy of the Wakame farm in Hirota Bay and Mozuku farm at Bise Point was less frequently observed. Nevertheless, up to 14.1 g C m^{-2} (0.110 g C m^{-2} d^{-1}) was captured by the production of Wakame and 3.6 g C m^{-2} (0.034 g C m^{-2} d^{-1}) was captured by Mozuku, and the total yield of carbon captured during 2021 production season for these farms was 43,385 kg C. Seaweed farms are still highly valuable for their contribution to the livelihood of coastal communities and have lesser detrimental impact on the environment than other forms of aquaculture (*e.g.*, Visch *et al.*, 2020). We believe that the potential for carbon capture will not be homogenous across species and location, and that more studies on carbon flux at organismal and ecosystem scales remain to be conducted.

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References

1) K. Hinode *et al.*, Phycol. Res. **68**, 298 (2020).
2) W. Visch *et al.*, J. Appl. Phycol. **32**, 3199 (2020).