Quantifying the carbon benefits of ending bottom trawling

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Bottom trawling disrupts natural carbon flows in seabed ecosystems due to sediment mixing, resuspension and changes in the biological community. Sala, et al. [1] suggest that seafloor disturbance by industrial trawlers and dredgers results in 0.58 to 1.47 Pg of aqueous CO_2 release annually (equivalent to 0.16 to 0.4 Pg C per year), owing to increased organic carbon (OC) mineralisation that occurs after trawling. We are concerned, however, that Sala et al. seriously overestimate trawl-induced CO_2 release because their model uses a reactivity value (*k*, the first order decay rate) estimated for highly reactive OC delivered recently to the sediment surface, and apply it to bulk sediment (typically composed of labile, recalcitrant and refractory C) which is known to have a much lower reactivity[2]. These issues result in an upward bias in the estimated CO_2 release by several orders of magnitude, severely overestimating the impact of trawling on global organic carbon mineralisation rates.

The parameter values in Sala et al. ignore the important role of composition in driving OC mineralisation in marine sediments. Organic carbon that reaches the sediment represents a mixture of different compounds that range from very reactive to very unreactive molecules[4]. Typically, around 70% (represented by the fraction of reactive material *p* of 0.70 for muddy sediment in the model of Sala et al.) is very reactive and mineralised by micro-organisms within the first few centimetres of sediment, which translates into a high *k*-value (reactivity of the OC pool, 1-10 y^{-1}). The remaining, less reactive, fractions are mineralised much slower, with typical *k*-values of < 0.1 y^{-1} ([5]). Because of the preferential mineralisation of the more reactive fractions, the *k*-value of the bulk OC decreases exponentially with sediment depth, generally from 1-10 y^{-1} at the sediment-water interface to <0.01 y^{-1} below 5 cm depth[5,6] (Figure 1). The standing stock of OC in the sediment thus typically exhibits a *k*-value of 0.01 - 0.1 y^{-1}. Consequently, the approach Sala et al. [1] have taken - using a *k*-value of 0.3-17 y^{-1} and applying this to the bulk of the OC stock – and may result in an overestimation of CO_2 release of historically-buried OC by two to three orders of magnitude. We argue that incorporating the role of composition would require lowering the *k* value to around 0.01 y^{-1}, which is representative for sub-surface sediment[6], and applying it to the bulk of the sediment (fraction of reactive material *p* = 1), or alternatively using the original high *k* values (k = 0.3-17 y^{-1}) and applying them to the fraction of reactive material *p* present in historically buried OC (*p* = 0.001-0.01). More importantly, the calculations in Sala, et al. [1] would only have given an estimate of OC remineralisation independent of trawling – since these *k*- and *p*-values are representative of OC mineralisation in marine sediments (Fig. 1 shows typical *k*-values relative to sediment depth for a range of North Sea sediments).

Furthermore, the OC model presented by Sala, et al. [1] does not differentiate between OC mineralisation in undisturbed sediment, and OC mineralisation induced by sediment disturbance. Instead, Sala et al. implicitly assume that the OC mineralisation rate calculated using their model results from trawling disturbance alone. As a result, their model assumptions imply that OC in an area protected from trawling is unreactive and will not be mineralised. The 'carbon model validation' in the Methods section clearly illustrates this issue. Sala et al. compare the modelled CO_2 emissions that derive only from the trawl disturbance of historically-buried OC with empirical estimates of CO_2 emissions from natural-plus-trawling mineralisation of all sedimentary OC, and without comparisons to untrawled control sites. These fundamentally incomparable measures are unsuitable for the model validation. The fact that these measures are of the same order of magnitude illustrates that CO_2 emissions by trawling are likely to be small compared to emissions from natural mineralisation [3] and much smaller than modelled by Sala, et al. [1].

The ultimate question is whether the reactivity of the OC stock is increased by trawling disturbance and resuspension, and thus if the *k*-value is higher after trawling. Unfortunately, this question is not addressed by Sala et al.[1]. To date, our knowledge of the effects of trawling-induced disturbance and resuspension on the reactivity of OC, and how this compares to those by natural resuspension events (e.g., storms, waves) is extremely limited. A recent review of 49 studies investigating OC stocks after trawling-induced disturbances demonstrated highly mixed results, with 61% of studies reporting no significant effect, 29% reporting lower OC stocks, and 10% reporting higher stocks[3]. To robustly estimate the global impact of bottom trawling on OC mineralisation, new experiments are needed that quantify the reactivity of disturbed OC in the sediment and in resuspension.

In conclusion, we currently do not know enough about the impact of trawling on seabed carbon to make robust global projections. Reliable estimates of sediment carbon loss should be based on models that use parameter estimates for the change in OC reactivity and that are tested against empirical measurements. Sala, et al. [1] suggest that reducing CO_2 release through reducing trawling effort could generate carbon credits and provide an opportunity for financing Marine Protected Areas. While this is certainly an idea worth considering, we argue that the Sala et al.'s CO_2 release estimates create unrealistic expectations about the quantity of carbon credits that can be generated. Even initial plans for the management of bottom trawling for carbon benefits require estimates that are of the correct order of magnitude, and we argue that Sala et al. does not supply them.

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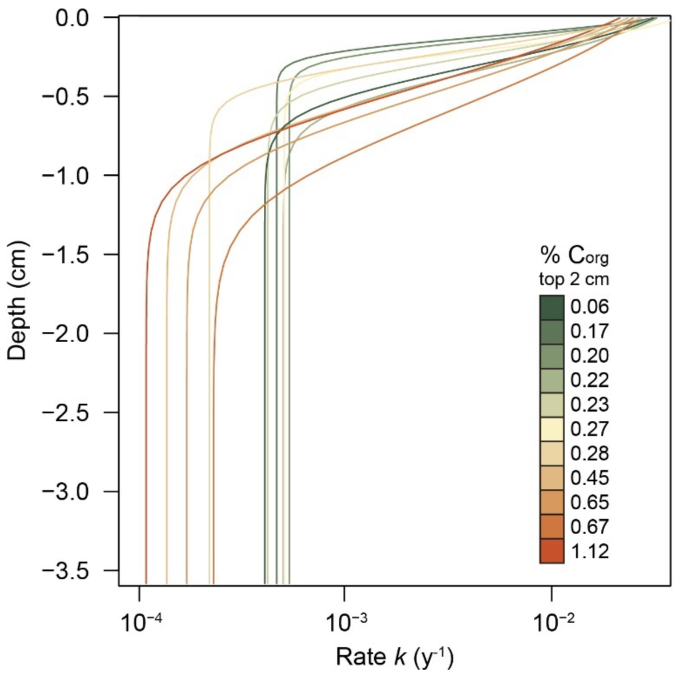

Figure 1. Decrease in modelled OC degradation rate constants (k, y^{-1}) with sediment depth, for 11 sites in the North Sea, with varying organic carbon contents at the sediment surface (C_{org}, %). Average rates stem from the degradation of OC consisting of a reactive and a less-reactive OC fraction, where both fractions have a different degradation rate k. Data and modelling results from [7].