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1 Quantifying the carbon benefits of ending bottom trawling

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25 Bottom trawling disrupts natural carbon flows in seabed ecosystems due to sediment mixing,
26 resuspension and changes in the biological community. Sala, et al. ¹ suggest that seafloor disturbance
27 by industrial trawlers and dredgers results in 0.58 to 1.47 Pg of aqueous CO₂ release annually
28 (equivalent to 0.16 to 0.4 Pg C per year), owing to increased organic carbon (OC) mineralisation that
29 occurs after trawling. We are concerned, however, that Sala et al. seriously overestimate trawl-
30 induced CO₂ release because their model uses a reactivity value (*k*, the first order decay rate)
31 estimated for highly reactive OC delivered recently to the sediment surface, and apply it to bulk
32 sediment (typically composed of labile, recalcitrant and refractory C) which is known to have a much
33 lower reactivity². These issues result in an upward bias in the estimated CO₂ release by several orders
34 of magnitude, severely overestimating the impact of trawling on global organic carbon mineralisation
35 rates.

36

37 The parameter values in Sala et al. ignore the important role of
38 composition in driving OC mineralisation in marine sediments. Organic carbon that reaches the
39 sediment represents a mixture of different compounds that range from very reactive to very
40 unreactive molecules⁴. Typically, around 70% (represented by the fraction of reactive material *p* of
41 0.70 for muddy sediment in the model of Sala et al.) is very reactive and mineralised by micro-
42 organisms within the first few centimetres of sediment, which translates into a high *k*-value (reactivity
43 of the OC pool, 1-10 y⁻¹). The remaining, less reactive, fractions are mineralised much slower, with
44 typical *k*-values of < 0.1 y⁻¹ (⁵). Because of the preferential mineralisation of the more reactive
45 fractions, the *k*-value of the bulk OC decreases exponentially with sediment depth, generally from 1-
46 10 y⁻¹ at the sediment-water interface to <0.01 y⁻¹ below 5 cm depth^{5,6} (Figure 1). The standing stock
47 of OC in the sediment thus typically exhibits a *k*-value of 0.01 - 0.1 y⁻¹. Consequently, the approach
48 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 -
49 and may result in an overestimation of CO₂ release of historically-buried OC by two to three orders of
50 magnitude. We argue that incorporating the role of composition would require lowering the *k* value
51 to around 0.01 y⁻¹, which is representative for sub-surface sediment⁶, and applying it to the bulk of the

52 sediment (fraction of reactive material $p = 1$), or alternatively using the original high k values ($k = 0.3-$
53 17 y^{-1}) and applying them to the fraction of reactive material p present in historically buried OC ($p =$
54 $0.001-0.01$). More importantly, the calculations in Sala, et al. ¹ would only have given an estimate of
55 OC remineralisation independent of trawling – since these k - and p -values are representative of OC
56 mineralisation in marine sediments (Fig. 1 shows typical k -values relative to sediment depth for a
57 range of North Sea sediments).

58 Furthermore, the OC model presented by Sala, et al. ¹ does not differentiate between OC
59 mineralisation in undisturbed sediment, and OC mineralisation induced by sediment disturbance.
60 Instead, Sala et al. implicitly assume that the OC mineralisation rate calculated using their model
61 results from trawling disturbance alone. As a result, their model assumptions imply that OC in an area
62 protected from trawling is unreactive and will not be mineralised. The ‘carbon model validation’ in the
63 Methods section clearly illustrates this issue. Sala et al. compare the modelled CO₂ emissions that
64 derive only from the trawl disturbance of historically-buried OC with empirical estimates of CO₂
65 emissions from natural-plus-trawling mineralisation of all sedimentary OC, and without comparisons
66 to untrawled control sites. These fundamentally incomparable measures are unsuitable for the model
67 validation. The fact that these measures are of the same order of magnitude illustrates that CO₂
68 emissions by trawling are likely to be small compared to emissions from natural mineralisation ³ and
69 much smaller than modelled by Sala, et al. ¹.

70 The ultimate question is whether the reactivity of the OC stock is increased by trawling disturbance
71 and resuspension, and thus if the k -value is higher after trawling. Unfortunately, this question is not
72 addressed by Sala et al.¹. To date, our knowledge of the effects of trawling-induced disturbance and
73 resuspension on the reactivity of OC, and how this compares to those by natural resuspension events
74 (e.g., storms, waves) is extremely limited. A recent review of 49 studies investigating OC stocks after
75 trawling-induced disturbances demonstrated highly mixed results, with 61% of studies reporting no
76 significant effect, 29% reporting lower OC stocks, and 10% reporting higher stocks³. To robustly
77 estimate the global impact of bottom trawling on OC mineralisation, new experiments are needed
78 that quantify the reactivity of disturbed OC in the sediment and in resuspension.

79 In conclusion, we currently do not know enough about the impact of trawling on seabed carbon to
80 make robust global projections. Reliable estimates of sediment carbon loss should be based on models
81 that use parameter estimates for the change in OC reactivity and that are tested against empirical
82 measurements. Sala, et al. ¹ suggest that reducing CO₂ release through reducing trawling effort could
83 generate carbon credits and provide an opportunity for financing Marine Protected Areas. While this
84 is certainly an idea worth considering, we argue that the Sala et al.’s CO₂ release estimates create
85 unrealistic expectations about the quantity of carbon credits that can be generated. Even initial plans
86 for the management of bottom trawling for carbon benefits require estimates that are of the correct
87 order of magnitude, and we argue that Sala et al. does not supply them.

88
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102

103 **Data availability statement:** Data sharing not applicable

104 **Code availability:** Code availability not applicable

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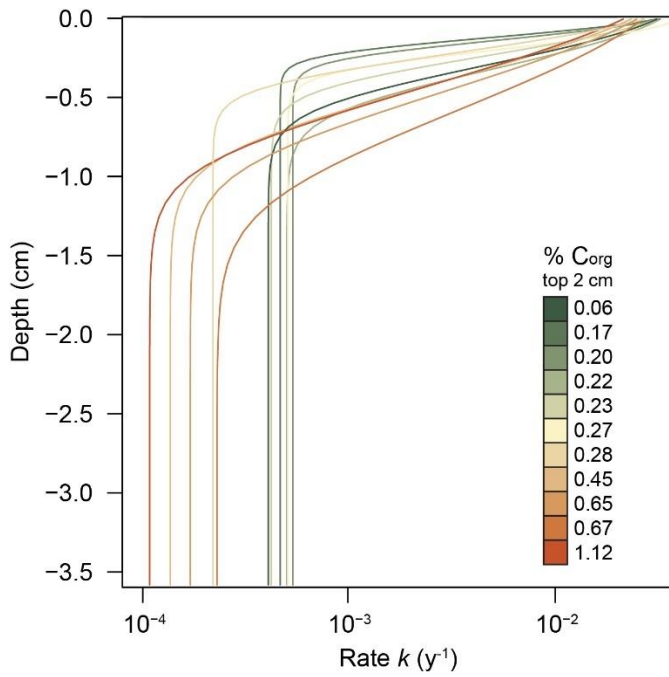
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127 Figure 1. Decrease in modelled OC degradation rate constants (k, y^{-1}) with sediment depth, for 11
128 sites in the North Sea, with varying organic carbon contents at the sediment surface (C_{org} , %).
129 Average rates stem from the degradation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

131