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Modeling the long-term decomposition of marine dissolved organic carbon through a network of compounds and bacteria

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Dissolved organic carbon (DOC) forms the main energy source for marine bacteria, but a small fraction resists degradation and accumulates in the ocean. The reason behind this recalcitrance is unknown. Here, we test whether the long-term stability of DOC requires the existence of structurally recalcitrant molecules. We established a mechanistic model of bacteria-substrate interactions, considering the high diversity of dissolved organic substrates and degrading bacteria. Uptake kinetics are identical for all substrate molecules, i.e. all molecules are considered equally degradable. We show that three central observations can be explained by basic principles of microbiology: (i) long-term resistance of DOC, (ii) microbial utilization of concentrated deep-sea DOC, and (iii) mixed radiocarbon ages. In virtual incubations, >15 % of an initial pulse of intrinsically labile DOC resisted degradation. In agreement with experimental data, modeled deep-sea DOC was utilized by bacteria if concentrated. Consistent with field observations, the modeled DOC compounds showed mixed ages from less than hundred to several thousand years in dynamic steady-state.