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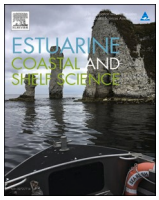

Impacts of anthropogenic resuspension on sediment organic matter: An experimental approach

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ABSTRACT

Globally coastal sediments are frequently disturbed by a wide range of physical anthropogenic processes (e.g. bottom trawling) which causes resuspension of sediment organic matter (OM) into the overlaying water column. In this study we present experimental results showing that anthropogenic sediment resuspension decreases the organic carbon (14x) and nitrogen (3x) content in the sediment material resuspended to the water column, while no measurable response was found for organic phosphorus. Our findings furthermore show that the OM bioavailability decreased and the Carbon:Nitrogen:Phosphorus stoichiometry was changed suggesting that anthropogenic resuspension changes the chemical composition, and/or production and degradation pathways of the OM pool. The detected changes in OM biogeochemistry could affect nutrient release, fuel oxygen consumption and at the same time increase CO_2 production in coastal waters.

1. Introduction

Marine sediments represent the largest reservoirs of organic matter (OM) on the planet, containing approximately three times as much carbon as found as carbon dioxide (CO_2) in the atmosphere, and they are, therefore, crucial for long-term carbon storage and climate change mitigation efforts (Atwood et al., 2020). A key assumption in these long-term storage efforts is that OM in undisturbed sediments are stable for thousands of years (Estes et al., 2019; Mcleod et al., 2011). However, the human physical reworking of sediments by e.g. trawling and dredging activities has been suggested to resuspend the stored OM, which is then returned to active cycling resulting in CO_2 production and release of nutrients. This degradation of otherwise stored material is thought to occur when OM kept in anoxic conditions is exposed to oxic conditions allowing a faster degradation (days to weeks) (Pusceddu et al., 2005). Furthermore, human reworking could enhance the release of mineral absorbed labile organic molecules and thereby promote their degradation (Keil et al., 1994; Mayer, 1994). In addition, when sediment OM is resuspended, it is often exposed to elevated light levels and higher temperatures, further promoting OM degradation (Lønborg et al., 2016, 2018b). The overall consequence is that physical reworking of sediments could potentially enhance OM degradation which results in increased oxygen consumption, CO_2 production and release of nutrients to the water column. Episodic natural events, such as storms, can also promote coastal sediment resuspension and nutrient release (Tiano et al., 2024; Wu et al., 2020). Although storms are expected to increase in intensity due to climate change (Knutson et al., 2010), they are episodic compared to direct human sediment disturbances that reoccur periodically (Martín et al., 2014).

Fishing gear such as trawls and dredging used to remove or excavate sediments are among the most commonly used ways humans disturb and damage the seabed. Trawls are cone-shaped open nets towed along the seabed. Bottom trawling fishing trawls around 4.9 million km^2 of the ocean seafloor yearly and can penetrate the seafloor down to a depth of around 35 cm (Amoroso et al., 2018; Eigaard et al., 2016). The depth of penetration can vary depending on the gear used and the sediment type (Eigaard et al., 2016). Dredging can be the removal or excavation of sediment, which can have various aims such as for construction purposes, but its biggest impact is due to fishing (particularly shellfish), with annual global estimates suggesting billions tons of sediment being

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dredged worldwide (Bianchini et al., 2019). Due to the large-scale impacts of these anthropogenic disturbances, it could be hypothesized that human activities can induce sediment OM release and degradation due to sediment resuspension. One study (Sala et al., 2021) used satellite images to infer the activity of industrial trawlers, and suggested 1.47 Pg of CO_2 would be emitted due to the degradation of released sediment OM over the first year. This suggestion, however, was challenged by Hiddink et al. (2023) that argued a much smaller release of CO_2 because not all released OM is readily available. However, whether this is indeed the case remains to be investigated.

Globally bottom trawl fisheries and dredging impact substantial areas of the ocean seafloor every year with most of this activity taking place in coastal waters (Amoroso et al., 2018). While numerous studies have demonstrated how such reoccurring physical disturbance can alter the diversity and abundance of sediment flora and fauna (Newell et al., 1998; Trimmer et al., 2005), there are only a few studies investigating the impacts on the biogeochemistry (Breimann et al., 2022; Ferguson et al., 2020; van de Velde et al., 2018). In the present study we used a controlled experimental approach to investigate how reoccurring resuspension, mimicking human anthropogenic resuspension of sediment, impacts the OM pool and the bioavailability of the material resuspended into the overlaying water column. We hypothesise that reoccurring sediment disturbance increases the release and stimulates degradation of the OM pool.

2. Methods

2.1. Field sampling

Samples were collected on September 19, 2022 at Løgten Strand, Denmark (Latitude 56.289368, Longitude: 10.383778) which is a shallow (<1 m water depth) location with organic rich sediments. The study site is seasonally (period from 2013 to 2021) exposed to salinities varying from 12 to 27 (Average: 22) and water temperatures from −0.4°C in winter to 23°C in summer (Average: 12°C). Overall nutrient inputs in the study area are dominated by land sources.

In total 300 L of seawater were collected in 30–40 L acid-washed and aged polyethylene containers and stored in the dark until used in the laboratory. Undisturbed sediment cores (in total 130 cores) were retrieved by hand-coring, kept at *in-situ* temperature and transported back to the laboratory in undisturbed condition in cooler boxes. Setup of the experiments and sample processing commenced within 6 h of collection.

Field water salinity and temperature were measured using a conductivity-temperature-depth (CTD) sensor (YSI Professional Plus). In the laboratory water for chlorophyll *a* (Chl *a*) determination were filtered (300 mL) through GF/F filters (nominal pore size of about 0.7 μm), and frozen (−20°C) until analysis. The Chl *a* concentrations were measured by extracting the GF/F filters in ethanol (96 %) for 12 h and analysis on a spectrophotometer (Strickland and Parsons, 1972). Field samples were also collected for the analysis of total and dissolved organic carbon (TOC and DOC), nitrogen (TN, TDN) and phosphorus (TP and TDP) and dissolved inorganic nitrogen (DIN: sum of NH_4, NO_2^- and NO_3^-) and phosphorus (DIP: HPO_4^{-2}). Unfiltered water was collected for TOC, TN and TP determination. Water samples for the dissolved phase were collected under low-vacuum by filtration through prewashed (500 mL Milli-Q water) 0.2 μm filters (Pall, Supor membrane Disc Filter). Water samples for DIN, DIP, TP and TDP were collected in 50 mL HDPE plastic containers and kept frozen (−20°C) until analysis. Samples (30 mL) for TOC, DOC, TN and TDN analysis were collected in pre-combusted (450°C, 12 h) glass vials, preserved by adding 50 μL 25% H_3PO_4 and capped with lids containing an acid washed polytetrafluoroethylene (PTFE) lined silicone septa. The collected sediment was characterized by measuring bulk density, dry matter/water content, TOC, TN and TP in 3 replicate sediment cores. The cores were sectioned in two layers, and variables were determined for each layer separately: 0–5 cm, 5–10 cm. For all sample collection and analysis in the field and in the below described experiments, glassware, sediment cores and incubation chambers used were acid washed (10% HCl for 24 h) and rinsed with Milli-Q water prior to use.

2.2. Resuspension experiments

Once back in the laboratory the sediment cores were adjusted so each core contained 20 cm of sediment and a shallow water column (around 100 mL) directly above the sediment surface. The cores were hereafter gently transferred to chambers (35 L), filled with seawater collected at the sampling site during sediment retrieval. The overlaying water (depth around 35 cm above sediment cores) was continually bubbled with atmospheric air which had been filtered through three 0.2 μm filters and transferred through three water traps to minimize the risk of contamination with microbes and volatile organic compounds. In our experimental setup we also included a seawater only (no sediment) control chamber which only contained the original seawater and was bubbled with the same air as the other treatments. This control was used to test for contamination effects, with no signs of contamination being detected (data not shown). The water column directly above the sediment cores allowed free passage of aerated air and prevented build-up of chemical gradients in the sediment without causing resuspension of the sediment surface. The experiments were conducted in the dark at the average annual temperature (12°C) measured at the sampling site. After transfer to the chambers the sediment cores were left over night to stabilize before initiation of the resuspension experiment the following day.

Mechanical sediment resuspension was applied to a set of cores so that over an 18-week period (T_0 initial; T_1: 6 weeks; T_2: 12 weeks; T_3: 18 weeks) they were exposed to one, two, three or four sediment resuspension events (Fig. S1). At the different time points water samples were collected before ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, and $R_{4\text{-}W}$) and after sediment resuspension (R_1, R_2, R_3, R_4; Fig. 1) from the relevant cores to follow changes in both the inorganic and organic pools. In this study we present results for 1) water samples collected before resuspension of the sediment ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$; Fig. 1), which we term 'water without resuspended sediment', and after resuspension which we term 'water plus resuspended sediment' (R_1, R_2, R_3, R_4; Fig. 1). Each of the resuspension events was followed by a resting period of 6 weeks, which is the suggested timeframe needed to allow the sediment biogeochemistry to recover after a disturbance event (van de Velde et al., 2018). Therefore, some sediment cores experienced reoccurring resuspension over time, while others did not and therefore acted as controls. The mechanical resuspension was applied with the aim of determining how reoccurring resuspension of the same sediment top layer (5 cm) into the overlaying water column affected the inorganic nutrients and organic matter pools. The resuspension penetration depth of 5 cm was chosen as bottom otter trawls, which globally dominates many fishing fleets, can penetrate the sediment down to a depth of 35 cm and therefore we used 5 cm as a conservative approach (Eigaard et al., 2016). Before the resuspension event, a custom build 30 cm water column extension, was fitted on top of the 20 cm sediment cores. The sediment cores were thereafter exposed to mechanical resuspension applied by inserting a custom-build propeller 5 cm deep into the sediment and resuspending the material for 5 s (Fig. S1). At each time point samples were collected from three replicate sediment cores which were disposed after sample collection. The remaining sediment cores exposed to resuspension, which had a shallow water column (10 cm), were allowed to settle for 1 h prior to being transferred back to treatment (R_1, R_2, R_3, R_4) specific chambers containing seawater (Fig. 1). This approach, with treatment specific chambers, was used in order to avoid potential impacts (e.g. changed diffusive fluxes) of different treatments on each other. Before and immediately after sediment resuspension samples of the overlying water were collected for the analysis of TOC, DOC, TN, TDN, TP, TDP, DIN and DIP. These samples were treated as described above and allowed us to determine changes in the inorganic nutrients and OM pool.

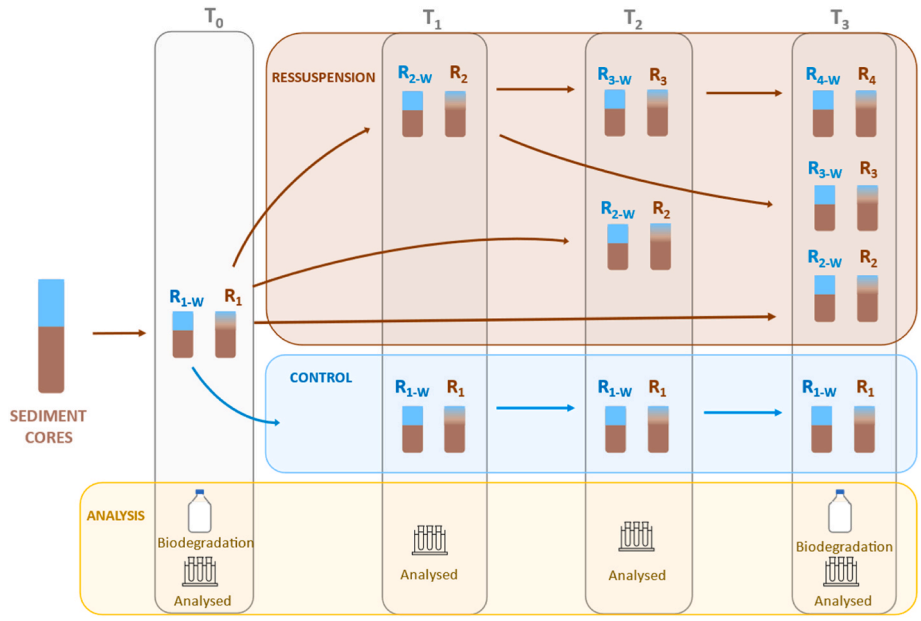

Fig. 1. Scheme of the experimental approach that exposed sediment to mechanical resuspension over time (T_0: Initial; T_1: 6 weeks after T_0; T_2: 12 weeks after T_0; T_3: 18 weeks after T_0). Water samples were collected before ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, ($R_{4\text{-}W}$) and after one (R_1), two (R_2), three (R_3) or four (R_4) sediment resuspension events. During the experiments samples for chemical analysis (all time points) and biodegradation (T_0 and T_3 only) were collected.

2.3. Biodegradation experiments

Samples from both seawater ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and seawater plus resuspended sediment (R_1, R_2, R_3, R_4) were used to determine differences (initial and final) in the bioavailability of the total organic matter (TOM) pool applying a previously described approach (Lønborg et al., 2018a). Initially (T_0; Fig. 1) two OM degradation experiments ($R_{1\text{-}W}$ - seawater without resuspended sediment; R_1 – water plus resuspended sediment) experiments were performed. At the final time point (T_3; Fig. 1) six OM degradation experiments were performed with samples collected before ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$; Fig. 1) and after sediment resuspension (R_1, R_2, R_3, R_4; Fig. 1) to follow changes in both the inorganic and organic pools. For the water samples collected after resuspension the material was kept homogeneous in suspension during distribution into the incubation containers by a magnetic stirrer. The water for each experiment was distributed into duplicate glass bottles (1 L) and incubated in the dark at a constant temperature of 12°C with the same bottles being analysed for sub-sampling at day 0 and 52. During the incubation period weekly mixing of the samples was applied. Unfiltered water from the experiments were used to follow changes in TOC, TN and TP. Samples for the analysis of the dissolved phase were collected as described above to follow changes in DIN, DIP, DOC, TDN and TDP. All collected samples were processed as described above. In this study we define the bioavailable OM as the difference between the initial and the remaining pool after 52 days of incubation (in μmol L^{-1}).

2.4. Sample measurements

Inorganic nutrients (NH_4^+, NO_3^-/NO_2^- and HPO_4^{2-}) were determined by segmented flow analysis (Hansen and Koroleff, 1999). The precisions were ±0.01 μmol L^{-1} for NH_4^+, ±0.1 μmol L^{-1} for $NO_3^- + NO_2^-$ and ±0.02 μmol L^{-1} for HPO_4^{2-}.

The TOC, DOC, TN and TDN concentrations were measured by high temperature combustion (720°C) using a Shimadzu TOC-L carbon analyser. Prior to analysis, CO_2 remaining in the acidified sample water was removed by sparging with O_2 carrier gas. Concentrations were determined by subtracting a Milli-Q blank and dividing by the slope of a daily 4 points standard curve. We compared peak areas of the blanks and standard solutions to ensure stability between runs with no major deviations found. The TN,TP, TDN and TDP concentrations were measured in triplicates by oxidation to soluble reactive nitrogen and phosphorous in alkaline conditions by persulphate digestion (Valderrama, 1981), which were then analysed for inorganic nutrients. The dissolved organic nitrogen (DON) and phosphorus (DOP) concentrations are calculated as the differences between TDN/TDP and DIN/-DIP with the errors calculated as the sum of measurement errors. As our experiments had very high inorganic nutrient concentrations with associated errors it resulted in large uncertainty in the estimates of DON and DOP concentrations. Therefore, we chose to instead follow only changes in the TOC, TON and TOP concentrations. The TON concentrations were calculated by subtracting DIN from TN (TON = TN – DIN), with the standard deviation (SD) for TON estimated as $SD^2_{TON} = SD^2_{TN} + SD^2_{DIN}$. In the same way TOP was determined as the difference between TP and DIP (TOP = TP – DIP) with the SD for TOP calculated as: $SD^2_{TOP} = SD^2_{TP} + SD^2_{DIP}$.

Sediment water content was determined as the weight difference after drying samples at 105°C for 24 h. The bulk density of the sediments was determined as the mass of the total sediment sample divided by the sample volume. The sediment TOC and TN content was measured using an Elemental analyser (Thermo Analytical Flash EA, 2000 Elemental Analyzer) after the sediments had been homogenized, acidified in order to remove inorganic carbon, and dried. The sediment TP content was determined using an initial high temperature combustion step (550°C for 24 h) followed by a chemical digestion step (Strickland and Parsons, 1972). Following this, the sediment TP content was analysed as orthophosphate with the ammoniummolybdate method using a spectrophotometer.

2.5. Statistical analysis

Differences between the treatments and organic and inorganic parameters (TOC, DOC, TN, TDN, DIN, TP, TDP, and DIP) were assessed through 1-way analysis of variance (ANOVA) for the variables where real replicates and not only average values can be reported. If a significant result was obtained the post hoc Tukey HSD was performed. Homogeneity of variances was assessed by Levene's test and normality of the residuals through the Shapiro test. For the analysis of the TP and TDP the nonparametric Kruskal–Wallis and the post hoc Dunn's test (with a

Bonferroni adjustment) were applied since assumptions on the homogeneity of variances and normality of the residuals were violated. All statistical and data analyses were performed with R-4.3.2.

3. Results

3.1. Field conditions

During sample collection, seawater salinity (20.3), temperature (13.0°C), chlorophyll *a* (2.6 μg L^{-1}), inorganic nutrient ((average ± SD); DIN: 2.4 ± 0.3 μmol N L^{-1}; DIP: 0.30 ± 0.03 μmol P L^{-1}), TOC (294 ± 2 μmol C L^{-1}), DOC (267 ± 1 μmol C L^{-1}), TN (23.1 ± 1.8 μmol N L^{-1}), TDN (20.8 ± 0.1 μmol N L^{-1}), as well as TP (1.45 ± 0.02 μmol P L^{-1}) and TDP (0.68 ± 0.06 μmol P L^{-1}) concentrations were comparable to general autumn conditions found in Danish Coastal waters (Lønborg et al., 2023). The sediment water content in the top 5 cm was 73 ± 2% increasing to 79 ± 2% in the 5–10 cm depth range. The bulk density (0–5 cm: 2.1 ± 0.2 g cm^{-3}; 5–10 cm: 2.0 ± 0.2 g cm^{-3}) and TP (0–5 cm: 0.40 ± 0.01 mg g^{-1}; 5–10 cm: 0.37 ± 0.01 mg g^{-1}) were similar in the two depth ranges while both the TOC (0–5 cm: 12 ± 1 mg g^{-1}; 5–10 cm: 4 ± 1 mg g^{-1}) and TN (0–5 cm: 1.3 ± 0.9 mg g^{-1}; 5–10 cm: 0.4 ± 0.1 mg g^{-1}) concentrations were higher in the surface 5 cm of the sediment.

3.2. Experimental results

In this study we present results for 1) water samples collected before resuspension of sediment ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and 2) samples collected after sediment was resuspended into the water (R_1, R_2, R_3, R_4). Detailed statistical analysis of all variables is provided in the supplementary material (Table S3).

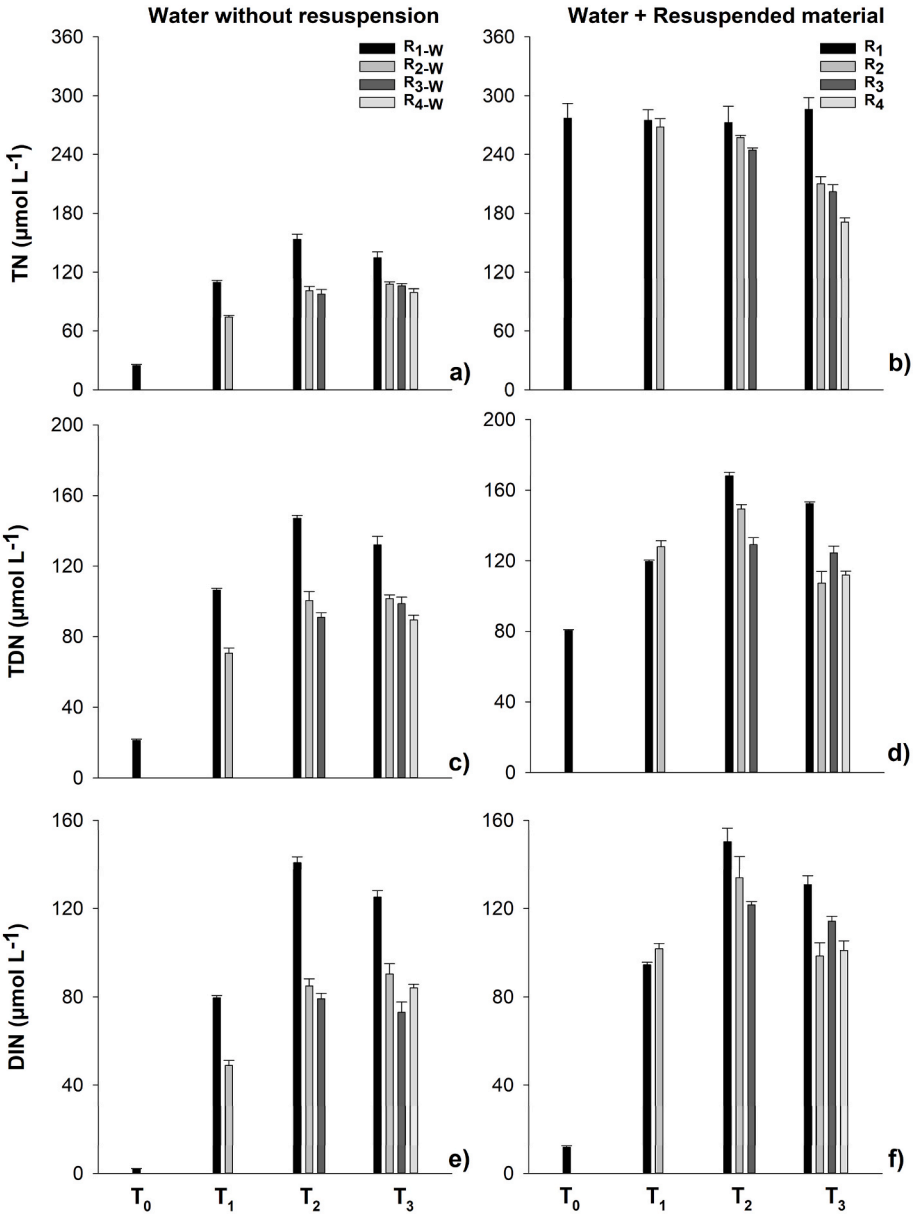

Fig. 2. Changes in total nitrogen (TN; **a**,**b**), total dissolved nitrogen (TDN; **c**,**d**) and dissolved inorganic nitrogen (DIN; **e**,**f**) concentrations in the water phase over time (T_0: Initial; T_1: 6 weeks after T_0; T_2: 12 weeks after T_0; T_3: 18 weeks after T_0) before resuspension (**a**, **c**, **e**; $R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and after (**b**, **d**, **f**) one (R_1), two (R_2), three (R_3) or four (R_4) sediment resuspension events. Please note that different y-axis ranges are used in the figures due to large difference in concentrations. Values are averages ± standard deviation.

3.3. Total and dissolved nutrient dynamics

The concentrations of N and P species in the seawater ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and in the seawater plus resuspended sediment (R_1, R_2, R_3, R_4) are shown in Figs. 2 and 3. Initial N and P concentrations in the chambers with seawater and sediment cores were the same as those measured during sample collection (Table S1; Figs. 2 and 3). At T_0 the concentrations of both total and dissolved nutrient species in the seawater plus resuspended sediment (R_1) were clearly higher than in the seawater alone ($R_{1\text{-}W}$) with similar proportional increases in both N and P (Figs. 2 and 3). Overall TN was significantly different before and after resuspension (ANOVA, $p < 2.6 \times 10^{-16}$; Table S2), whereas TP was different, but not significantly (Table S3). The TN and TP concentrations at T_0 were around 10 times higher compared with the seawater before resuspension ($R_{1\text{-}W}$ vs. R_1; average ± SD; TN: 24.6 ± 1.4 vs. 276.9 ± 15.4 μmol N L^{-1}; TP: 1.27 ± 0.06 vs. 14.00 ± 0.11 μmol P L^{-1}; Table S1; Figs. 2 and 3). In the sediment resuspended at T_0 (R_1) the increase in dissolved N and P concentrations were much lower than for the TN and TP pools, showing that most of the initially released nutrients were in the particulate phase (Figs. 2 and 3). Over time the difference in the total and dissolved N and P pools before ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and after resuspension (R_1, R_2, R_3, R_4; Fig. 1) decreased, which for the dissolved phase was due to a continued diffusive flux over the sediment-water interphase. Over time, except in R_1, the TN concentration in the water plus resuspended sediment (R_2, R_3, R_4) decreased (Fig. 2). On the other hand, sediment resuspension led to comparably lower decreases in TP, which is likely due to reoxidation of the sediment which increases P adsorption to iron oxides and therefore retains P within the sediment (e.g. (Krom and Berner, 1980).

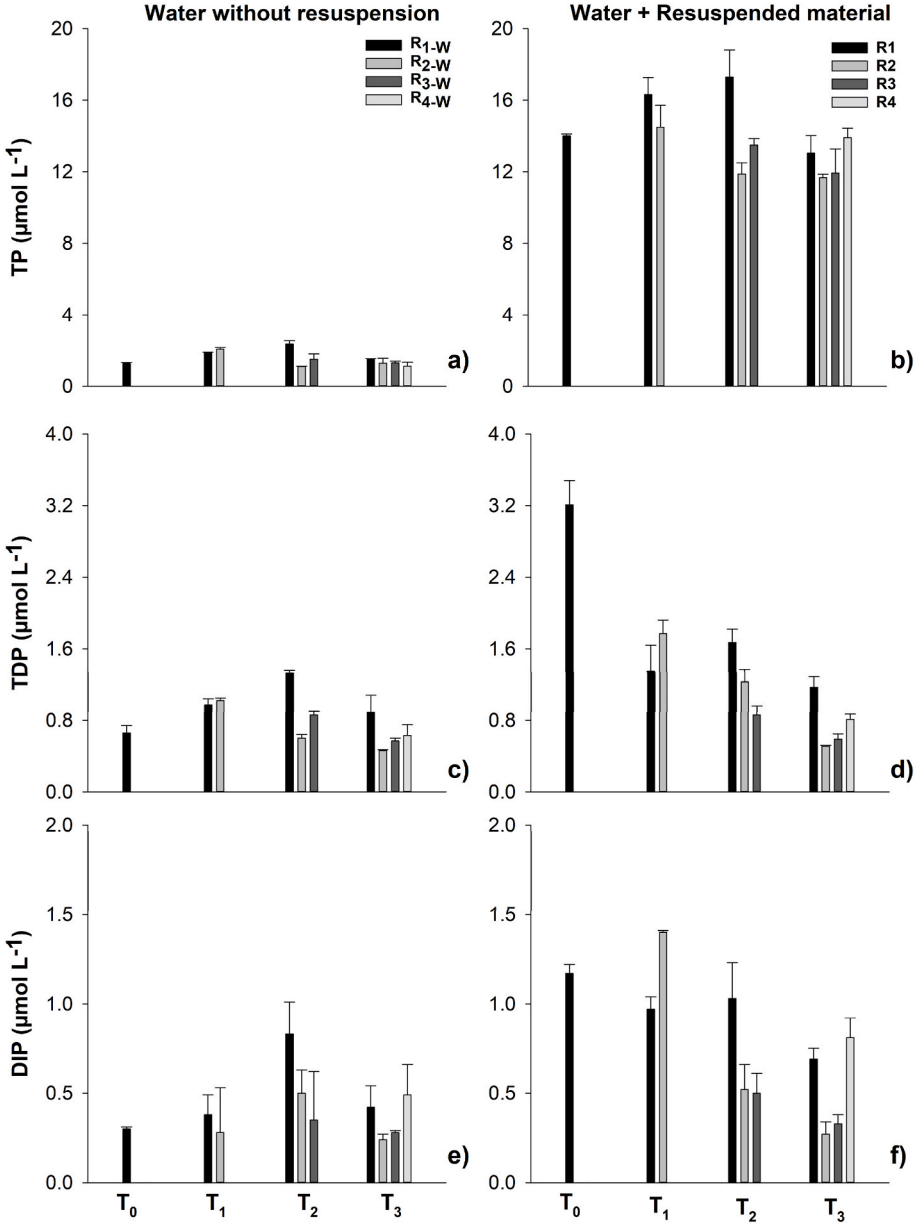

Fig. 3. Changes in total phosphorus (TP; **a**,**b**), total dissolved phosphorus (TDP; **c**,**d**) and dissolved inorganic phosphorus (DIP; **e**,**f**) concentrations over time (T_0: Initial; T_1: 6 weeks after T_0; T_2: 12 weeks after T_0; T_3: 18 weeks after T_0) before resuspension (**a**, **c**, **e**; $R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and after (**b**, **d**, **f**) one (R_1), two (R_2), three (R_3) or four (R_4) sediment resuspension events. Please note that different y-axis ranges are used in the figures due to large difference in concentrations. Values are averages ± standard deviation.

3.4. Organic matter dynamics

The average TOC concentration in the seawater before resuspension ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) decreased from initially (T_0) about 294 ± 1 μmol C L^{-1} to 269 ± 7 μmol C L^{-1} by the end of the experiment (T_3; Table 1; Fig. 4). The TOC concentrations in the seawater plus resuspended sediment in the R_1 treatment decreased from T_0 to T_3 from an initial concentration of 1553 ± 167 μmol C L^{-1}, to around 1249 ± 8 μmol C L^{-1}, while in those experiencing repeated mechanical resuspension, the concentrations were significantly lower (3–4 times; ANOVA, $p < 2.6 \times 10^{-16}$; Table S2; Table 1; Fig. 4). Generally, the DOC concentrations remained fairly constant over time and between resuspension treatments (Fig. S2). Initially in the seawater DOC constituted the major part (around 90%) of the TOC pool, while in the seawater plus resuspended sediment (R_1, R_2, R_3, R_4) it only contributed around 18% (data not shown). Overall, increasing the number of sediment resuspensions decreased the overall TOC pool size in the resuspended material but increased the % contribution of DOC to the TOC pool (data not shown). The TON concentrations in $R_{1\text{-}W}$ were different decreasing from initial levels of 22.5 ± 1.4 μmol N L^{-1} to 9.4 ± 9.0 μmol N L^{-1} by the end of the experiment, while the TOP concentrations varied but overall were fairly constant (Table 1; Figs. 2 and 3). Generally, increasing numbers of resuspension decreased at T_3 the concentrations of TOC (up to 4 times) and TON (up to 2 times) in the R_2, R_3, R_4 treatments compared to the R_1 treatment, while no measurable impact was found for TOP (Table 1; Fig. 4). When calculating the net effect on the resuspended sediment (difference in concentrations before ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and after (R_1, R_2, R_3, R_4) resuspension) the TOC concentrations decreased at T_3 with up to 14 times while TON decreased 4 times (Table S3).

3.5. Organic matter bioavailability

Sediment OM bioavailability is challenging to measure directly in the field. In our incubations with resuspended sediment OM matter, we are unable to account for all processes involved in the natural degradation process and the approach is therefore crude. In these experiments, we closed the system for new production and therefore forced the microbial community to use the OM already present. Under these conditions, we defined the recalcitrant OM pool as the concentration in the samples taken after 52 days of incubation and the difference between initial and final concentration as the bioavailable fraction. In the initial degradation experiments (T_0) the TOC concentrations at day 0 were 294 ± 2 in $R_{1\text{-}W}$ and 1644 ± 49 μmol C L^{-1} in the R_1, for TON were 25.0 ± 2.0 ($R_{1\text{-}W}$) and 235.9 ± 4.9 (R_1) μmol N L^{-1}, and for TOP were 1.20 ± 0.11 ($R_{1\text{-}W}$) and 14.02 ± 0.48 μmol P L^{-1} (R_1), respectively (Table 2). The bioavailable TOC (BTOC) was 50 ± 4 and 652 ± 78 μmol C L^{-1} in the $R_{1\text{-}W}$, and R_1 respectively which corresponded to 17% and 40% of the initial TOC pool (Table 2). The DOC pool in all degradation experiments showed fairly constant concentrations over time with no distinct pattern (data not shown). The bioavailable TON (BTON) was 6 ± 4 ($R_{1\text{-}W}$) and 98.1 ± 20.4 (R_1) μmol N L^{-1} representing 24% and 42% of the TON pool, while the bioavailable TOP (BTOP) was 0.34 ± 0.20 ($R_{1\text{-}W}$) and 6.49 ± 2.47 (R_1) μmol P L^{-1} corresponding to 28% and 46% of the TOP pool (Table 2). Our incubation experiments showed different bioavailable TOM (BTOM) concentrations at the final timepoint (T_3) between treatments (Table 2). For the incubations with seawater collected before resuspension ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) the initial TOM concentrations were quite similar in-between treatments for TOC which varied between 254 ± 2 and 271 ± 1 μmol C L^{-1}, while TON and TOP varied from 12.7 ± 2.2 to 19.9 ± 0.4 μmol N L^{-1}, and 1.02 ± 0.09 to 1.47 ± 0.11 μmol P L^{-1} (Table 2). In addition, the bioavailable (BTOC, BTON, BTOP) and recalcitrant (TOC_{52}, TON_{52}, TOP_{52}) TOM concentrations at T_3 were comparable in all incubations with seawater collected before resuspension ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$; Table 2). As a result, the BTOC varied between 4 ± 9 and 20 ± 3 μmol C L^{-1}, the BTON varied between 3.2 ± 5.3 and 6.2 ± 2.1 μmol N L^{-1}, while the BTOP varied between 0.01 ± 0.01 and 0.74 ± 0.46 μmol P L^{-1} (Table 2). In the incubations with seawater plus resuspended sediment (R_1, R_2, R_3, R_4) the BTOC, BTON and BTOP concentrations as well as % bioavailability decreased compared with the control (R_1) with increasing number of resuspensions (Table 2). The BTOC decreased from 364 ± 4 μmol C L^{-1} (29% of pool) in R_1 to 22 ± 9 μmol C L^{-1} (7%) in the R_4, BTON decreased from 77.8 ± 12.1 μmol N L^{-1} (34%) in R_1 to 3.5 ± 24.7 μmol N L^{-1} (6%) in R_4, while BTOP decreased from 7.05 ± 1.23 μmol P L^{-1} (56%) in R_1 to 0.74 ± 1.78 μmol P L^{-1} (5%) in the R_4 treatment (Table 2). As in the initial degradation experiment the DOC concentrations at T_3 showed no clear general pattern (data not shown). On the whole, reoccurring sediment resuspension increased the degradation and decreased the bioavailability of TOM compared to the R_1 treatment with increasing number of resuspensions (Table 2).

3.6. Organic matter stoichiometry

The average initial TOM C:N:P stoichiometry for the seawater before resuspension was 245:21:1, while the initial stoichiometry for the resuspended sediment had a lower ratio of 105:16:1 (Table 3). Over time the TOM C:N:P stoichiometry in the seawater before resuspension ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and the R_1 remained fairly constant within treatments

Table 1
Concentrations of total organic carbon (TOC), nitrogen (TON) and phosphorus (TOP) over time (T_0: Initial; T_1: 6 weeks after T_0; T_2: 12 weeks after T_0; T_3: 18 weeks after T_0) in the seawater **a**) before resuspension ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and **b**) after one (R_1), two (R_2), three (R_3) or four (R_4) sediment resuspension events. Values are averages ± standard deviation.

a)	$R_{1\text{-}W}$				$R_{2\text{-}W}$				$R_{3\text{-}W}$				$R_{4\text{-}W}$			
Measurement	T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3	T_0	T_1	T_2	T_3
TOC (μmol C L^{-1})	294 ± 1	287 ± 6	282 ± 3	269 ± 7	–	286 ± 10	255 ± 9	255 ± 3	–	–	266 ± 4	249 ± 3	–	–	–	253 ± 3
TON (μmol N L^{-1})	22.5 ± 1.4	30.5 ± 3.0	12.4 ± 7.9	9.4 ± 9.0	–	25.3 ± 3.9	16.2 ± 7.7	17.6 ± 6.8	–	–	18.7 ± 7.2	33.1 ± 7.2	–	–	–	15.4 ± 5.3
TOP (μmol P L^{-1})	0.97 ± 0.08	1.50 ± 0.13	1.53 ± 0.37	1.08 ± 0.18	–	1.80 ± 0.34	0.59 ± 0.16	1.05 ± 0.31	–	–	1.17 ± 0.56	1.03 ± 0.10	–	–	–	0.63 ± 0.39
b)	**R_1**				**R_2**				**R_3**				**R_4**			
Measurement	**T_0**	**T_1**	**T_2**	**T_3**	**T_0**	**T_1**	**T_2**	**T_3**	**T_0**	**T_1**	**T_2**	**T_3**	**T_0**	**T_1**	**T_2**	**T_3**
TOC (μmol C L^{-1})	1553 ± 167	1219 ± 47	1323 ± 59	1249 ± 8	–	618 ± 30	661 ± 18	436 ± 5	–	–	500 ± 30	352 ± 1	–	–	–	321 ± 4
TON (μmol N L^{-1})	265.2 ± 16.1	180.2 ± 12.0	122.2 ± 19.6	155.3 ± 16.2	–	166.1 ± 11.0	123.3 ± 12.2	111.5 ± 13.4	–	–	122.9 ± 3.9	87.6 ± 9.58	–	–	–	69.9 ± 8.4
TOP (μmol P L^{-1})	12.83 ± 0.16	15.34 ± 1.02	16.27 ± 1.71	12.35 ± 1.04	–	13.09 ± 1.24	11.37 ± 0.76	11.41 ± 0.27	–	–	13.00 ± 0.47	11.60 ± 1.40	–	–	–	13.10 ± 0.63

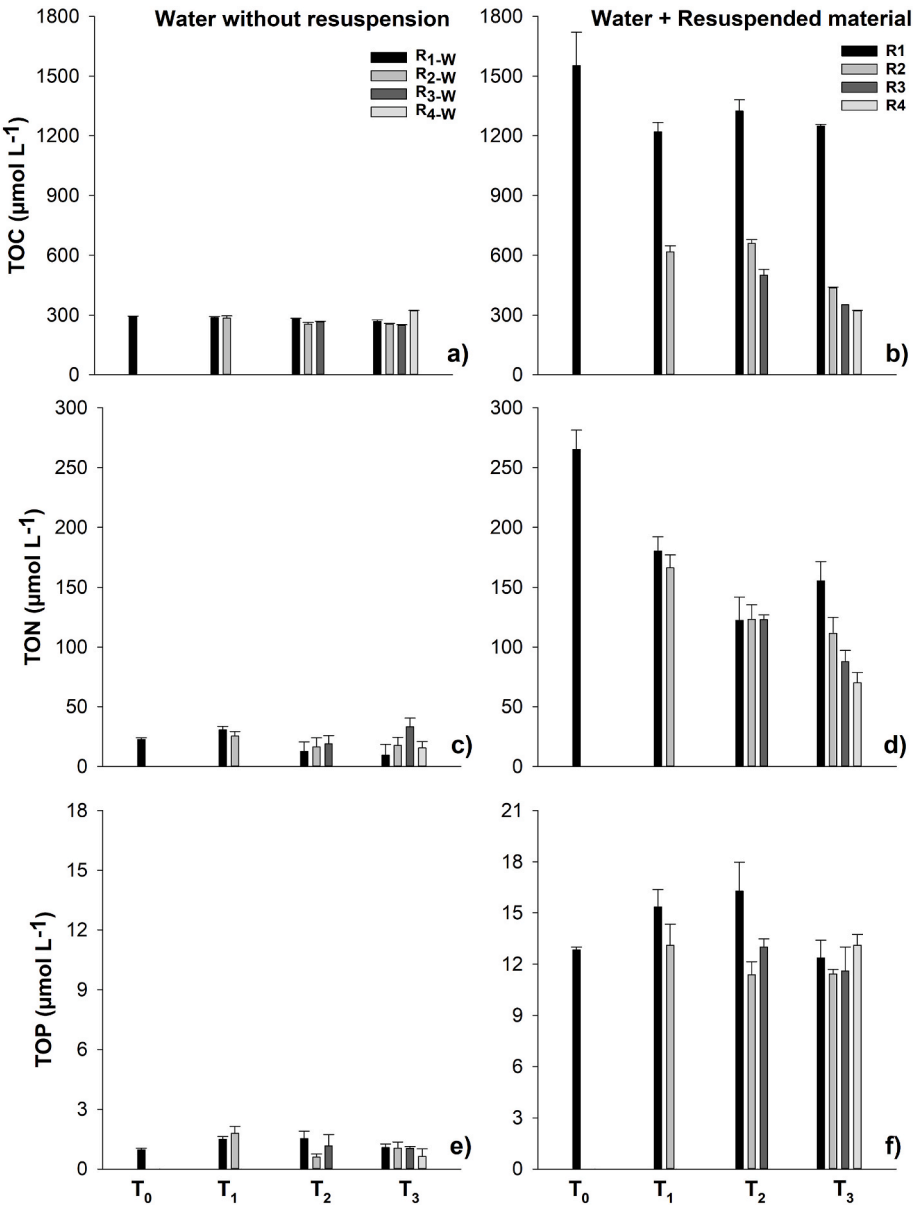

Fig. 4. Changes in total organic carbon (TOC; **a**) nitrogen (TON; **b**), and phosphorus (TOP; **b**) concentrations over time (T_0: Initial; T_1: 6 weeks after T_0; T_2: 12 weeks after T_0; T_3: 18 weeks after T_0) in the water phase before resuspension (**a**, **c**, **e**; $R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and after (**b**, **d**, **f**) one (R_1), two (R_2), three (R_3) or four (R_4) sediment resuspension events. Please note that different y-axis ranges are used in the figures due to large difference in concentrations. Values are averages ± standard deviation.

(Table 3). On the other hand, by the end of the experiments in the treatments receiving reoccurring sediment resuspension (R_2, R_3, R_4), the C:N:P ratios were low, varying between 5:4:1 and 20:10:1, compared to R_1 (80:12:1) (Table 3). In the degradation experiment at T_0 the C:N:P stoichiometry of the bioavailable TOM pool was 149:18:1 ($R_{1\text{-}W}$) and 103:15:1 (R_1), showing no differences between them, and they were N- and P- enriched compared with the total pool (Table 3). In the degradation experiments at T_3 the C:N:P generally increased over time in the before resuspension samples ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$), whereas the stoichiometry remained fairly constant in the resuspended sediment (R_1, R_2, R_3, R_4) (Table 2).

4. Discussion

Globally, shallow coastal sediments are frequently impacted by anthropogenic sediment resuspension caused by activities such as trawling and dredging. Sediments in Danish waters are no exception with about 80% of Danish waters being impacted by bottom trawling, although these numbers are uncertain (Miljø- og Fødevareministeriet, 2019). Furthermore, for example, in the Danish part of the Baltic Sea, approximately 3.3. million m^3 of sediment are dumped at sea every year, mainly from dredging activities (HELCOM, 2021). Our results demonstrate how such anthropogenic sediment resuspension can increase organic matter and nutrient release to the water column and decrease the organic matter pool size.

4.1. Nutrient release due to sediment resuspension

Coastal marine sediments often contain higher per volume concentrations of TN and TP than found in the overlying water column (Lønborg and Markager, 2021). Therefore, resuspension of sediments due to e.g. trawling could reintroduce nutrients into the overlaying water column from both porewater and sedimentary bound material (Breimann et al., 2022). Such resuspension events could also change the

Table 2
Biodegradation experiment results from the initial (T_0) and final (T_3) timepoint for seawater before resuspension ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and after one (R_1), two (R_2), three (R_3) or four (R_4) sediment resuspension events. Initial concentrations of total organic carbon (TOC_0), nitrogen (TON_0) and phosphorus (TOP_0) as well as at the concentration after 52 days of incubation (TOC_{52}, TON_{52}, TOP_{52}) together with the bioavailable fraction concentration (BTOC, BTON, BTOP) and percentage (%) are shown. Values are averages of the two replicate bottles ± standard deviation.

Experiment	T_0		T_3							
	$R_{1\text{-}W}$	R_1	$R_{1\text{-}W}$	R_1	$R_{2\text{-}W}$	R_2	$R_{3\text{-}W}$	R_3	$R_{4\text{-}W}$	R_4
TOC_0 (μmol C L^{-1})	294 ± 2	1644 ± 49	271 ± 1	1241 ± 1	258 ± 7	444 ± 3	255 ± 6	344 ± 6	254 ± 2	322 ± 5
TOC_{52} (μmol C L^{-1})	245 ± 2	992 ± 13	256 ± 1	883 ± 6	254 ± 2	381 ± 18	247 ± 2	340 ± 21	233 ± 1	300 ± 4
BTOC (μmol C L^{-1})	50 ± 4	652 ± 78	14 ± 2	364 ± 4	4 ± 9	63 ± 22	3.7 ± 8	19 ± 6	20 ± 3	22 ± 9
BTOC (%)	17	40	5	29	1	14	1	6	8	7
TON_0 (μmol C L^{-1})	25.0 ± 2.0	235.9 ± 4.9	18.9 ± 1.4	228.1 ± 4.1	19.9 ± 0.4	117.8 ± 11.5	19.6 ± 1.7	83.4 ± 3.1	12.7 ± 2.2	63.3 ± 3.2
TON_{52} (μmol C L^{-1})	19.0 ± 2.0	137.8 ± 9.7	15.2 ± 2.0	150.4 ± 2.3	13.7 ± 1.7	112.0 ± 10.3	14.7 ± 2.0	76.3 ± 12.6	9.5 ± 3.1	59.8 ± 6.1
BTON (μmol C L^{-1})	6.0 ± 4.0	98.1 ± 20.4	3.7 ± 3.4	77.8 ± 12.1	6.2 ± 2.1	25.8 ± 21.8	4.8 ± 3.7	4.0 ± 12.1	3.2 ± 5.3	3.5 ± 24.7
BTON (%)	24	42	20	34	31	22	25	5	25	6
TOP_0 (μmol C L^{-1})	1.20 ± 0.11	14.02 ± 0.48	1.02 ± 0.09	13.27 ± 0.39	1.44 ± 0.16	10.94 ± 0.65	1.11 ± 0.40	11.41 ± 0.31	1.47 ± 0.11	13.70 ± 0.06
TOP_{52} (μmol C L^{-1})	0.87 ± 0.09	7.54 ± 2.84	0.85 ± 0.24	6.22 ± 0.29	0.70 ± 0.30	8.94 ± 2.97	0.77 ± 0.10	9.76 ± 1.40	1.47 ± 0.11	12.95 ± 3.05
BTOP (μmol C L^{-1})	0.34 ± 0.20	6.49 ± 2.47	0.17 ± 0.35	7.05 ± 1.23	0.74 ± 0.46	2.00 ± 1.40	0.34 ± 0.50	1.65 ± 0.50	0.01 ± 0.01	0.74 ± 1.78
BTOP (%)	28	46	17	56	51	18	31	14	1	5

Table 3
The total organic carbon (TOC), nitrogen (TON) and phosphorus (TOP) stoichiometry at the initial timepoint (T_0) (TOC_0:TON_0:TOP_0) together with the bioavailable fraction (BTOC:BTON:BTOP) in the biodegradation experiments. The bioavailable fraction is determined as the difference between concentrations at day 0 and the remaining pool after 52 days of incubation. Results are shown for **a)** seawater before resuspension ($R_{1\text{-}W}$, $R_{2\text{-}W}$, $R_{3\text{-}W}$, $R_{4\text{-}W}$) and b) after one (R_1), two (R_2), three (R_3) or four (R_4) sediment resuspension events.

a)	$R_{1\text{-}W}$		$R_{2\text{-}W}$	$R_{3\text{-}W}$	$R_{4\text{-}W}$
Stoichiometry	T_0	T_3	T_3	T_3	T_3
TOC_0: TON_0: TOP_0	245:21:1	266:18:1	179:14:1	303:23:1	303:23:1
BTOC: BTON: BTOP	149:18:1	85:22:1	5:4:1	10:14:1	4015:650:1

b)	**R_1**		**R_2**	**R_3**	**R_4**
Stoichiometry	**T_0**	**T_3**	**T_3**	**T_3**	**T_3**
TOC_0: TON_0: TOP_0	106:16:1	80:17:1	20:10:1	8:6:1	5:4:1
BTOC: BTON: BTOP	103:15:1	52:11:1	37:11:1	1:5:1	3:1:1

sediment redox conditions, increase microbial activity and oxygen consumption affecting oxygen levels and longer-term nutrient release from the sediment to the water column (De Borger et al., 2021). On the other hand, concentrations of dissolved nutrients in the water column can also decrease during sediment resuspension events due to absorption to sediment particles (Tengberg et al., 2003; Tiano et al., 2019). Another factor that is important to consider is how the sediment particle size distribution can be altered ("particle sorting") due to the combined impact of resuspension and physical transport (e.g. currents) of particles away from the impacted area to other downstream areas where the material can again reach the sediment, which possibly can impact both inorganic particle composition and the absorption of nutrients (Breimann et al., 2022).

In the present study we found that sediment resuspension resulted in large increases of TN and TP concentrations in the water column. In all cases, the water column concentration of DIN increased with resuspension, while the DIP concentrations showed no clear response. The increased water column DIN concentrations suggest that physical resuspension of the sediment could increase the release and act as a internal nutrient loading mechanism. In combination with our results, it has been suggested that sediment disturbance by trawling can reduce sediment denitrification by up to 50% (Ferguson et al., 2020), suggesting that anthropogenic sediment resuspension could increase bioavailable N levels and further boost nutrient availability and eutrophication in coastal waters. These mechanisms therefore need to be considered when attempting to understand and manage eutrophication in coastal waters. However, it is important to remember that DIP showed only minor or no response to sediment resuspension. Previous studies have obtained similar results and suggested that P compounds can both absorb and desorb from particles and iron oxides, with the formation of iron oxide rich particles being promoted by sediment resuspension (Rios-Yunes et al., 2023; Tengberg et al., 2003). In conclusion, despite that we use highly controlled laboratory experiments, our results suggests that anthropogenic resuspension of sediments strongly enhances the transport of N from the sediment to the water column.

4.2. Changes in sediment organic matter bioavailability

Sediments play a key role in the global OM cycle mainly through the exchange and storage of organic carbon (Burdige, 2007). Coastal sediments are furthermore important as they are responsible for 68% of the global aerobic sediment OM degradation (Jørgensen et al., 2022). The sediment OM pool contains diverse chemical forms and molecular sizes spanning from simple organic molecules to highly complex natural compounds and man-made organic pollutants (Hedges et al., 2000; Zhao et al., 2024; Zhou et al., 2022). Multiple studies have demonstrated that a part of the OM pool in sediments is preferentially degraded and have short turn over times (e.g. (Cowie and Hedges, 1994), while other parts remain in the sediment for months to years (e.g. (Burdige, 2007; Wellsbury et al., 1997). The factors controlling OM storage and degradation in sediments are highly complex and are influenced by multiple factors such as fauna, flora and microbial activity; seabed lithology and granulometry; as well as the chemistry, hydrology and biology of the surrounding water column (e.g. (Burdige, 2007; Keil, 2017). Due to this complexity, OM degradation and preservation can be highly variable even over small scales (e.g. (Blair and Aller, 2012) and consequently disentangling the interplay between controlling factors is challenging.

Sediment OM bioavailability has traditionally been linked with its biochemical composition, access to oxygen and absorption to minerals (Hedges et al., 2000; Mayer, 1994; Middelburg, 2019). However other factors such as temperature and nutrient regimes, varying terrestrial inputs, sun-light, changing bacterial community and the effect of priming as well as the presence of heavy metals can also influence the OM bioavailability (e.g. (Keil and Mayer, 2014; Kieber et al., 2006;

Lønborg et al., 2020; Wang et al., 2024). In our study we found that resuspension decreased the standing stocks in the sediments and increased the degradation of sediment OM resulting in a less bioavailable pool by the end of the experiment. These changes could be linked with resuspension induced mixing which increases sediment oxygen availability but also it could have released mineral absorbed organic matter, which together could increase OM degradation (Canfield et al., 2005; Mayer, 1994). In addition sediment resuspension and mixing could have induced priming effects, as it has been observed that addition of labile OM can modify or trigger degradation of previously recalcitrant OM (Blagodatskaya and Kuzyakov, 2008). All these processes were most likely at play in our experiment, but unfortunately, we are not able to determine which process(es) was the most important for decreasing the standing stocks and increasing OM degradation. Studies in natural systems with a wider range of environmental conditions (e.g. changed sediment conditions) are therefore needed to determine which process (es) are most important in explaining these results.

Generally, sediment OM has been shown to be readily degraded, with only around 1% of the OM input being preserved in coastal sediments (Middelburg, 2019). In addition, it has been shown that up to 45% of aged OM (up to 500 years) once desorbed from inorganic sediment particles can be degraded within days (Keil et al., 1994). In line with this we find that initially around 45% of the sediment OM pool was bioavailable over the 52 days incubation period. Our measurements show that the initial resuspended sediment OM had a higher bioavailability (Carbon: 40%; Nitrogen: 42%; Phosphorus 47%) than found for coastal pelagic waters worldwide (Carbon: 22 ± 12%; Nitrogen: 35 ± 13%; Phosphorus: 70 ± 18%) (Lønborg and Álvarez-Salgado, 2012), while the final OM bioavailability was lower than those average values. However, it should be noted that our estimates are only for the top 5 cm, which generally contains the most biodegradable OM so it is not possible to extrapolate our results to deeper sediment layers. The bioavailability at the final timepoint, suggests a more recalcitrant nature of the remaining OM pool compared with the initial. Therefore overall, our experiments show that anthropogenic resuspension decreases the sediment OM standing stock and bioavailability.

4.3. Sediment organic matter stoichiometry

Sediment OM C:N:P stoichiometry is the result of a complex interplay between the sources, prevailing degradation pathways but also the location (erosion vs. accretion of sediments) of the study area. In general the C:N:P ratios of marine OM in the ocean water column are fairly well understood with a mean value of 106:16:1, i.e. the Redfield ratio (Anderson, 1995; Redfield et al., 1963); on the other hand, the elemental ratios of sediment OM are less well constrained. In our study the initial C:N:P stoichiometry for the water column OM pool was 245:21:1, while the initial resuspended pool had a lower ratio of 106:16:1. This could suggest a larger contribution of continental material (e.g. rivers) or a more refractory nature of the seawater OM pool, while the resuspended sediment pool had ratios similar to the Redfield ratio indicating a more labile nature and larger influence of plankton sourced OM. The OM C:N:P stoichiometry in the treatments with reoccurring sediment resuspension were lower, between 21:5:1 and 40:10:1, than in the control experiment (80:17:1). In both the controls and the initial OM degradation experiments the C:N:P in the seawater ($R_{1\text{-}W}$) and resuspended material (R_1) increased, showing that the bioavailable compounds were N- and P- enriched compared with the total pool. At the final timepoint the OM C:N:P ratios generally increased over time in the seawater while in the sediment resuspension treatments the stoichiometry remained constant over time. Therefore, initially the seawater and the sediment resuspended incubations followed the common pattern of increasing C:P and N:P ratios during marine OM degradation. This suggest that C, N and P containing compounds in these circumstances are more bioavailable than the C and N containing compoundswhich in turn are more bioavailable than C containing compounds (Lønborg and Álvarez-Salgado, 2012). On the other hand, in the treatments with reoccurring sediment resuspension the C:P and N:P were very low, which is likely partly connected with the very low concentrations of the bioavailable pool leading to large uncertainties in the calculated C:N:P stoichiometry. The P rich nature of the remaining OM pool in the resuspended sediment could also potentially, as described above, be explained by the strong binding of P rich compounds to iron-oxides (Jensen et al., 1995). However previous studies have also shown that polyphosphates, which is likely not included in the DIP pool determined here, can make a large contribution to the total sediment TP pool (Watson et al., 2018). Such inorganic compounds might therefore partly have been included in our TOP estimates, but from this study we are unable to quantify this contribution. Overall, the measured difference in C:N:P ratios demonstrate that anthropogenic sediment resuspension changes the chemical composition, and/or production and degradation pathways of the OM pool towards a more P rich nature of the remaining OM pool.

4.4. Environmental relevance

Previous studies have demonstrated how resuspension by towed fishing trawls can produce sediment plumes containing high concentrations of suspended dissolved and particulate matter (Dounas et al., 2007; Nilsson and Rosenberg, 2000; Bradshaw et al., 2021; Pilskaln et al., 1998). This displacement can have strong impacts on the benthic productivity by changing the sediment type, and the biological community within it (Hale et al., 2017). This has resulted in a model study proposing that trawling could decrease OM degradation rates due to a reduction in bioturbation rates (De Borger et al., 2021). Our study demonstrates that disturbance of coastal sediments by anthropogenic resuspension promotes the degradation and reduces the OM standing stocks. Therefore, if these findings are applicable under *in-situ* conditions, anthropogenic sediment resuspension will deplete the OM stocks and result in the release of nutrients and CO_2 to the water column. As sediments globally are impacted by a wide range of physical disturbances which can resuspend sediment material into the water column our findings could have wider ranging implications. These effects include increased nutrient release and increased OM degradation which potentially could fuel oxygen consumption and leave a climate footprint (i.e. CO_2 release).

Sediment biogeochemistry is controlled by a complex interplay of physical-chemical variables and the activities of bottom-dwelling organisms (Malcolm and Sivyer, 1997; Reise, 2002). Our manipulation experiments therefore have clear limitations as some of the processes and interactions that occur in natural sediments cannot be included in our experimental setup. One important factor we did not include was the impact on sediment bioturbation and “recovery” after induced sediment resuspension. Bioturbating organisms are known to increase sediment oxygen uptake and permeability as well as reduce the organic content and accumulation of reduced products in the sediment pore water (Kristensen et al., 2012; Volkenborn et al., 2007). Our study does also not consider the impact of variable sediment composition, as well as differences due to temporal (seasons) and spatial (locations) factors. However, our simplistic manipulation approach is valuable for investigating cause and effect relationships in response to the specific manipulation.

Clearly there is a high degree of uncertainty associated with scaling our study to global levels but given the potentially large impact of our results on global OM standing stocks and degradation pathways there is a clear need for investigating these processes in more natural setups and at larger scales. Such studies should attempt to address the complex interactions between benthic fauna, OM and recovery after anthropogenic sediment resuspension. Experiments, such as these which are reminiscent of a more natural system, will deliver valuable data which can be used to asses overall ecosystem impacts of human activities.

5. Conclusion

Our study supports the hypothesis that repeated sediment anthropogenic resuspension: 1) promotes the nutrient and OM release to the water column, 2) decreases the organic carbon (14 times) and nitrogen (3 times) content, while no measurable impact was found for organic phosphorus stocks; 3) decreases the bioavailability of the remaining organic carbon (5 times), nitrogen (7 times) and phosphorus (10 times) pools, 4) changes the chemical composition, and/or production and degradation pathways of OM, and 5) increases OM degradation and loadings of nutrients which are expected to fuel oxygen consumption and increase the climate footprint (i.e. CO_2).

CRediT authorship contribution statement

Christian Lønborg: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Stiig Markager:** Writing – review & editing, Conceptualization. **Simon David Herzog:** Writing – review & editing, Resources, Methodology. **Catia Carreira:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Signe Høgslund:** Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Significance statement

Humans disturb coastal sediments by a wide range of physical anthropogenic processes such as bottom trawling and dredging which cause resuspension of sediment organic matter into the overlaying water column. Yet, the potential impacts of this disturbance on the standing stocks and degradation pathways of sediment organic matter remains to be determined. In this study we investigated this impact and show that repeated sediment resuspension decreased the content and bioavailability of the organic matter pool. Our findings also suggest that anthropogenic resuspension changes the chemical composition, and/or production and degradation pathways of the organic matter pool. Our results are not only of large importance for understanding coastal water biogeochemistry but also for guiding possible conservation efforts aiming at reducing human impacts on coastal waters.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecss.2024.108981.

Data availability

Data will be made available on request.

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