Interactive comment on "Warming and ocean acidification may decrease estuarine dissolved organic carbon export to the ocean" by Michelle N. Simone et al.

Anonymous Referee #1 Received and published: 23 November 2020

Review of bg-2020-335 Warming and ocean acidification may decrease estuarine dissolved organic carbon export to the ocean Michelle N. Simone, Kai G. Schulz, Joanne M. Oakes, and Bradley D. Eyre

"This contribution studies the effect of increased pCO_2 and temperature on the fate of DOC in photic sediments. There are two autochthonous sources for DOC in sediments: degradation of detrital POC and release from microphytobenthos. Diffusive fluxes between the overlying water and sediment pore water depend on the concentration gradient (excluding bioturbation in more permeable sediments). Increases in pCO_2 will be expected to enhance benthic primary production (and associated DOC production) while increases in temperatures will increase carbon mineralisation rates. The net effect of these combined is difficult to assess and hence the focus of this experimental study. The experiment is very well designed and carried out, and the results are clearly condensed and presented."

Comment: The results and discussion sections are, however, difficult reading, and I had to re-read many times to follow.

Reply: In addition to addressing the specific comments of both reviewers, the results and discussion section will be revised to improve clarity and readability.

Comment: I wonder if the carbon budget/fluxes can be summarised in a figure or table so it is easier for the reader to follow the net result of the treatments. I found myself doing this while reading the discussion, gathering numbers from different figures. This would great increase the impact of the paper.

Reply: Figures 2, 3 and 5 already provide a summary of flux data referred to in the main text. However, we appreciate that some readers may find it easier to refer to a table. We are happy to build a summary table of fluxes. To avoid duplication this will be included as an appendix to the manuscript.

Comment: I found it misleading to always refer to the high pCO_2 scenario as ocean acidification OA. It is the increased DIC availability that is fuelling higher primary production which seems to be the major driver, rather than acidification influencing a rate as such. I recommend that this is rectified.

Reply: We agree with the reviewer, the use of OA and high-pCO_2 will be simplified as a reference to high-pCO_2 only.

Comment: It is also unclear what the nutrient levels were during the experiment. The results and discussion are focused solely on carbon limitation and assume adequate nutrient supply. That said the system the sediment cores were sampled from appears to be low nutrient. It is worth addressing this at some point.

Reply: Nutrients did not appear to be limiting in any of the treatments as nutrient concentration increased during all incubations. This will be outlined in the text and the methods and data in the table below will be included in supplementary information.

Supplementary methods:

Dissolved inorganic nitrogen (DIN) samples were collected at the start and end of the the flux incubations and syringe-filtered (0.45 μm cellulose acetate) into duplicate 10 mL polyethylene vials with a headspace, and stored frozen. Samples were analysed colorimetrically using a Lachat^{TM} flow-injection system as described in Eyre and Pont (2003).

Table S#. DIN concentration (μM) at the start (minimum) and end of the full incubation cycle.

Treatment	Current-pCO_2		High-pCO_2	
	Start	End	Start	End
Δ-3	1.19	2.02	1.85	6.66
	(± 0.01)	(± 0.45)	(± 0.27)	(± 1.36)
Control	1.85	4.00	2.42	6.11
	(± 0.16)	(± 0.27)	(± 1.01)	(± 1.39)
Δ+3	1.88	4.47	1.97	9.61
	(± 0.42)	(± 2.10)	(± 0.31)	(± 1.36)
Δ+5	2.37	15.52	2.40	14.68
	(± 0.18)	(± 1.81)	(± 0.58)	(± 4.42)

Comment: What effect would N limitation have on the result. Competition between MPB and heterotrophs for available nutrients for example.

Reply: This comment from Reviewer 1 addresses an important possibility in the system. We have discussed the potential effect of nutrient limitation on DOC flux in LN 398-399: "This failure to intercept DOC may be compounded if nutrient supply is limited (Brailsford et al., 2019), as it is common for heterotrophic bacteria to rely on refractory DOC when labile sources are not readily available (Chróst, 1991), which can occur under conditions of nutrient limited biological productivity (Allen, 1978)." (with underlined sections adjusted for clarity)

Comment: Finally, I do not see the value in scaling the data up to global estimates of sediment estuarine DOC uptake (4.3.3). It is not necessary and is fraught with very large assumptions. Similar scale ups have been done in the cited literature (Duarte papers), arrive at questionable results and conflict with current understanding of the global ocean DOC budget. The findings of this present study are relevant, intriguing and warrant publication without this final section.

Reply: We thank the reviewer for their positive comments on the relevance and interest of this study. We do, however, acknowledge the limitations of the upscaling included in the manuscript. This exercise was intended to provide a more qualitative perspective on the potential impact a future high-pCO_2 climate could have on the DOC export from estuaries. We believe it is interesting to consider the role of unvegetated sediments in an ecosystem/global context as this system is often overlooked in carbon budgets, whereas our upscaling exercise highlights the potential importance of processes (and changes to those processes) in this environment. To address the concerns of reviewer 1, and as per Reviewer 2's suggestion, we will add additional details of why such upscaling can be risky and possibly

incorrect, including limitations such as different hydrodynamic settings, different sediment composition, different delivery of dissolved and particulate matter from land and through aeolian deposition, etc.

Comment: Specific comments Introduction **(1)** Important to distinguish between photic and aphotic sediments. They differ greatly in their role and contribution to the larger net effects of coastal waters, which are outlined at the start of the introduction. **(2)** The last part of the introduction could be rephrased to be clearer. Lines 54-78. First formulate what the dominating mechanisms acting on DOC uptake/release from photic sediments are. Then address how these mechanisms can be influenced by warmer temperatures, high CO_2, and lowered pH, respectively. Then clearly state the hypothesis you had as the basis of your experimental design.

Reply: (1) We agree. To clarify our focus on euphotic sediments – the restatement of this focus will be added to the final paragraph. LN 70: "We expected that warming would promote a stronger heterotrophic, than autotrophic, microbial response in shallow euphotic sediments (Patching and Rose, 1970; Vázquez-Domínguez et al., 2012; Yang et al., 2016), and as such, there would likely be more DOC remineralisation (Lønborg et al., 2018) than 'new' DOC production (Wohlers et al., 2009; Engel et al., 2011; Novak et al., 2018)." The focus on euphotic sediment is also now made clear in the methods, LN 82: "Sediment at the site was unvegetated and characterised as a euphotic cohesive sandy mud…" (with underlined sections adjusted for clarity)

(2) As per the reviewer's suggestion, we will rearrange the last part of the introduction and include the recommended additions in the structure, as follows:

1 – dominating mechanisms acting on DOC:

"Primary producers fix DIC during photosynthesis and produce DOC through exudation and/or through degradation of the OM they produce. Photosynthetically produced DOC is the main source of DOC in the ocean (Hansell et al., 2009). DOC fuels local microbial mineralisation (Azam, 1998). Heterotrophic bacteria respire the carbon from DOC as CO_2, which can then be recaptured by photoautotrophs (Riekenberg et al., 2018), closing the microbial loop (Azam, 1998). DOC and DIC that is not captured is ultimately effluxed to the overlying water column and may be transported from estuaries to the coastal ocean." (with underlined sections added for clarity)

2 – how warming and OA may affect these mechanisms:

LN 56: "Individually, increased temperature and CO_2 can enhance primary productivity, and therefore DOC production, in arctic (Engel et al., 2013; Czerny et al., 2013) and temperate phytoplankton communities (Wohlers et al., 2009; Engel et al., 2011; Liu et al., 2017; Novak et al., 2018; Taucher et al., 2012), and temperate stream sediments (Duan and Kaushal, 2013). However, one study in a temperate fjord reported no enhancement of DOC production despite CO_2 enhanced phytoplankton productivity (Schulz et al., 2017). This uncertainty of response to individual climate stressors is exacerbated when considering how the combination of OA and warming will affect the production and degradation of DOC. To date, only one study has considered this combined stressor effect on DOC fluxes (Sett et al., 2018), observing no difference in DOC production by temperate phytoplankton relative to current conditions (Sett et al., 2018)."

3 – Experimental design and hypotheses:

LN 65: "To understand the potential effect of future climate on DOC fluxes, it is essential that both individual and combined effects of OA and warming are considered. Here we focus on changes in DOC fluxes in unvegetated estuarine sediments, as these systems have the potential for significant uptake of DOC that is currently exported to the coastal ocean. In this study, benthic DOC responses in unvegetated estuarine sediments were investigated over an 8 °C temperature range under both current and projected future high-pCO_2 conditions in an ex situ laboratory incubation." (with underlined sections adjusted for clarity)

LN 70: "We expected that warming would promote a stronger heterotrophic, than autotrophic, microbial response in shallow euphotic sediments (Patching and Rose, 1970; Vázquez-Domínguez et al., 2012; Yang et al., 2016), and as such, more DOC remineralisation (Lønborg et al., 2018) than 'new' DOC production (Wohlers et al., 2009; Engel et al., 2011; Novak et al., 2018)." (with underlined sections adjusted for clarity)

LN 72: "Moreover, despite the potential stimulation of primary productivity by OA in unvegetated muddy sediments (Vopel et al., 2018), and potential enhancement of DOC production (Engel et al., 2013; Liu et al., 2017), this increase in labile DOC may promote bacterial productivity and DOC mineralisation (Hardison et al., 2013). In addition, increased DOC availability alone may increase heterotrophic bacterial biomass production and activity (Engel et al., 2013). We therefore predicted that increases in DOC production from OA alone or in combination with warming may be counteracted by increased consumer activity, potentially depleting the available DOC pool under future climate conditions." (with underlined sections adjusted for clarity)

Comment: What influence would variable light conditions have on your findings? The cores are taken from a shallow estuarine site where one can expect considerable resuspension from tides, currents and winds. The light intensities used here are likely representative of best case. So, one can maybe amplify the dark scenario?

Reply: This is an interesting question that would be of interest to the general readership. We see value in addressing this question within the discussion and follow the same thought process as Reviewer 1, where the dark scenario responses would likely be amplified. The following sentence will be added, "Under conditions of reduced light availability/intensity, sediments are expected to have an amplified heterotrophic response in addition to a reduction in microalgal production of DOC."

Comment: Line 7. "Estuaries make a disproportionately". What do you mean here? With respect to what?

Reply: This was unclear, the statement will be adjusted to read LN 7: "Relative to their surface area, estuaries make a disproportionately large contribution of dissolved organic carbon (DOC) to the global carbon cycle, but it is unknown how this will change under a future climate." (with underlined sections adjusted for clarity)

Comment: Line 19. DOC is smaller than that retained in soils and also in fossil fuels.

Reply: While this statement by reviewer 1 is valid, we do not believe what we said is untrue, LN 19: "The aquatic dissolved organic carbon (DOC) pool is one of the largest pools of organic carbon on earth (Hedges, 1987) and roughly equivalent in size to the atmospheric

CO_2 reservoir (Siegenthaler and Sarmiento, 1993)." We do not say it is the largest, just one of the largest. For this reason, we intend to leave this sentence unchanged.

Comment: (1) Line 28. And **(2)** line 32-35. Here you state that 33% of the NPP in coastal waters is exported to the oceans and stored in the ocean interior. I question the validity of this statement/citation**. (3)** Is there evidence that the interior ocean is increasing in DOC? Why the large difference between mineralisation efficiency of DOC produced in surface water of the ocean to that produced in coastal waters?

Reply: (1) The line reads "up to 33 % of the associated DOC is exported offshore and stored in the ocean interior". This upper value is based on Krause-Jensen and Duarte (2016) who found substantial macroalgal DOC produced in the coastal zone and exported offshore was subducted below the mixed layer into the ocean interior (117 (36-194) Tg-C y^{-1}). The text can be adjusted for clarity, to avoid confusion that the 33% of NPP carbon reaches the ocean interior. The text will now read, LN 28: "The shallow coastal zone accounts for 1 to 10 % of global net primary production (NPP) (Duarte and Cebrián, 1996), with up to 33 % of the associated DOC exported offshore and reaching the ocean interior (Krause-Jensen and Duarte, 2016)." (with underlined sections adjusted for clarity)

(2) There was a lack of information in this paragraph regarding how the value of 3.5× was calculated. The paragraph now reads, LN 30: "Although shallow estuaries and fringing wetlands make up only ~22 % of the world's coastal area (Costanza et al., 1997) and 8.5 % of the total marine area (Costanza et al., 1997) they are quantitatively significant in terms of DOC processing and offshore transport (Smith and Hollibaugh, 1993). Assuming 1/3 of the DOC produced in the coastal zone (100-1900 Tg-C y^{-1}, Duarte, 2017) is subducted and reaches the ocean interior (Krause-Jensen and Duarte, 2016), 30 to 630 Tg-C y^{-1}, or up to 3.5× more DOC could reach the ocean interior from coastal areas than from the open ocean (180 Tg-C y^{-1}, Hansell et al., 2009). This is despite coastal areas having a DOC production rate only 0.2 to 3.9 % that of the open ocean (Duarte, 2017). As such, small changes to the coastal production and export of DOC may have a disproportionate influence on the global DOC budget." (with underlined sections adjusted for clarity)

(3) We are not trying to suggest that the interior ocean DOC pool is increasing, but instead, that a disproportionally large amount of DOC in the interior ocean could be sourced from the coastal zone relative to the surface ocean. This is based on previous work looking into the transport of DOC from the coastal zone and surface ocean to the ocean interior, respectively (calculations detailed in (2)).

In 1998, Bauer and Druffel reported their use of radioisotopic carbon (^{14}C) to identify the source and age of DOC and POC inputs into the open ocean interior. They found that the input from ocean margins "may be more than an order of magnitude greater than inputs of recently produced organic carbon derived from the surface ocean." We will include this in our introduction to further support the importance and potential significance of changing the supply of coastal DOC to the ocean.

Comment: Line 43. Delete extra "lability"

Reply: Thank you. This has been rewritten to avoid repeating "lability". LN 42-44: "These heterotrophic bacteria not only consume autochthonous DOC (Boto et al., 1989), but their biomass is influenced by the lability of sediment organic matter (OM) (Hardison et al., 2013),

which can be directly linked to and stimulated by MPB (Hardison et al., 2013; Cook et al., 2007).” (with underlined sections adjusted for clarity)

Comment: First three paragraphs contradict. You start by arguing that coastal waters are an important source of DOC to the open ocean but then finish by stating that coastal sediments are an important sink for DOC.

Reply: This can be clarified by exaggerating the distinction between coastal zone as a whole and estuarine sediments as a part of that whole in the third paragraph. The intention is to highlight that the coastal zone is an important source of DOC for the global ocean, however in sediments heterotrophic bacteria can make unvegetated estuarine sediments a sink of DOC produced elsewhere. As such, it is important to assess the role of this potential sink under conditions of warming and OA. The third paragraph has therefore been adjusted below:

LN 36: “Euphotic estuarine sediments occupy the coastal boundary between terrestrial and marine ecosystems. Microalgal communities (microphytobenthos, or MPB) are ubiquitous in these sediments, occupying ~40 to 48 % of the coastal surface area (Gattuso et al., 2020), and generating up to 50 % of total estuarine primary productivity (Heip et al., 1995; MacIntyre et al., 1996; Underwood and Kromkamp, 1999). MPB exude some of the carbon they fix as extracellular substances, including carbohydrates (Oakes et al. 2010), and can therefore be a source of relatively labile DOC in net autotrophic sediments (Cook et al., 2004; Oakes and Eyre, 2014; Maher and Eyre, 2010). However, microbial mineralisation by heterotrophic bacteria (Azam, 1998) within the sediment communities are a dominant sink of DOC in coastal sediments (Boto et al., 1989). These heterotrophic bacteria not only consume autochthonous DOC from upstream (Boto et al., 1989), but their biomass is influenced by the lability of sediment organic matter (OM) (Hardison et al., 2013), which can be directly linked to and stimulated by MPB (Hardison et al., 2013; Cook et al., 2007). As such, estuarine sediments are a potentially important sink for DOC.” (with underlined sections adjusted for clarity)

Comment: Line 48. Check referencing. Fischot and Benner paper does not address the processing of DOC by estuarine sediments.

Reply: This is true. Fichot and Benner (2014) looks at shelf processes, not estuarine. However, it is likely that the euphotic unvegetated shelf sediments in Fichot and Benner (2014) would not be dissimilar to euphotic unvegetated estuarine sediments. A more nearshore reference would be by Sandberg et al. (2004), who found that tDOC was the dominant carbon source for bacterial secondary production in the water column of Ore Estuary (Northern Baltic Sea).

Comment: Line 55-60. The increased DOC production in the Engel et al 2013 study was due to nutrient limitation. When they added nutrients, it was rapidly removed again. So, no net accumulation of DOC.

Reply: This reference will be removed from this section.

Comment: Line 287-289. This can be deleted.

Reply: Agreed, it will be deleted.

Comment: Line 340-343. Check phrasing and possible break into two sentences to make easier reading.

Reply: The sentence has been adjusted for clarity. "As well as differences in diffusive versus advective modes of solute transfer between the sediment types (Cook and Røy, 2006), differences may be partially due to sandier sediments being limited by other factors such as nutrient and OM availability, given that coarser sediments are generally more oligotrophic (Admiraal, 1984; Heip et al., 1995)." (with underlined sections adjusted for clarity)

Comment: Line 350-359. Here the authors begin to speculate about the lability of DOC without any measurements to support it. I am not sure it is necessary.

Reply: We see what Reviewer 1 is saying. This paragraph functions without that sentence. As such, it will be deleted.

Comment: Line 395. DOC is also produced continually from the detrital sediment POC. This contributes to dark DOC production.

Reply: We will add this source of dark DOC in the discussion.

Comment: Line 398-399. Are you inferring nutrient limitation in your set up? For now, I have assumed you had adequate nutrients.

Reply: There were no apparent N limitations in the present study, however, **w**e were opening up the discussion to gauge what could happen if there was a limitation in nutrients. Above responses to Reviewer 1's comments add extra clarity to the nutrient availability for the sediments.

Comment: Line 401. A very bold statement and the reference (Costanza) does not seem to support it. Please check.

Reply: The reference was incorrect. Explanation for how this was calculated will be provided in the introduction "Assuming 1/3 of the DOC produced in the coastal zone (100-1900 Tg-C y^{-1}, Duarte, 2017) reaches the ocean interior (Krause-Jensen and Duarte, 2016), 30 to 630 Tg-C y^{-1}, or up to 3.5× more DOC could reach the ocean interior from coastal areas than from the open ocean (180 Tg-C y^{-1}, Hansell et al., 2009)." and this reference will now read, "Up to 3.5× more DOC reaches the ocean interior from coastal areas than the open ocean (Duarte, 2017; Krause-Jensen and Duarte, 2016; Hansell et al., 2009).

Comment: (1) Figures Error bars in the figure should go both plus and minus. **(2)** Check text in figure 4. Do you not mean aerobic respiration (with arrow pointing upwards)?

Reply: (1) The figures will be changed into box and whisker plots to show the full range of data. This will satisfy Reviewer 1 and 2's concerns.

(2) We thank Reviewer 1 for catching this oversight. The schematic is more complicated than just changing the anaerobic to aerobic. In the bottom two quadrats – the arrow is correct, but for the upper two quadrats – Reviewer 1 is correct, it should read aerobic. This figure will be adjusted to clarify this.

Admiraal, W.: The ecology of estuarine sediment-inhabiting diatoms, in: Progress in phycological Research, edited by: Round, F. E., and Chapman, D. J., Biopress, Bristol, 269-322, 1984.
Allen, H. L.: Low molecular weight dissolved organic matter in five soft-water ecosystems: a preliminary study and ecological implications: With 3 figures and 2 tables in the text and on 1 folder, Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen, 20, 514-524, 1978.
Azam, F.: Microbial control of oceanic carbon flux: the plot thickens, Science, 280, 694-696, doi: 10.1126/science.280.5364.694, 1998.
Bauer, J. E., and Druffel, E. R. M.: Ocean margins as a significant source of organic matter to the deep open ocean, Nature, 392, 482-485, doi: 10.1038/33122, 1998.
Boto, K. G., Alongi, D. M., and Nott, A. L.: Dissolved organic carbon-bacteria interactions at sediment-water interface in a tropical mangrove system, Mar. Ecol. Progr. Ser., 51, 243-251, doi: 10.3354/meps051243, 1989.
Brailsford, F. L., Glanville, H. C., Golyshin, P. N., Johnes, P. J., Yates, C. A., and Jones, D. L.: Microbial uptake kinetics of dissolved organic carbon (DOC) compound groups from river water and sediments, Sci. Rep., 9, 11229, doi: 10.1038/s41598-019-47749-6, 2019.
Chróst, R. J.: Ectoenzymes in aquatic environments: Microbial strategy for substrate supply, SIL Proceedings, 1922-2010, 24, 2597-2600, doi: 10.1080/03680770.1989.11900030, 1991.
Cook, P. L., Veuger, B., Böer, S., and Middelburg, J. J.: Effect of nutrient availability on carbon and nitrogen incorporation and flows through benthic algae and bacteria in near-shore sandy sediment, Aquat. Microb. Ecol., 49, 165-180, doi: 10.3354/ame01142, 2007.
Cook, P. L. M., Butler, E. C., and Eyre, B. D.: Carbon and nitrogen cycling on intertidal mudflats of a temperate Australian estuary. I. Benthic metabolism, Mar. Ecol. Progr. Ser., 280, 25-38, doi: 10.3354/meps280025, 2004.
Cook, P. L. M., and Røy, H.: Advective relief of CO_2 limitation in microphytobenthos in highly productive sandy sediments, Limnol. Oceanogr., 51, 1594-1601, doi: 10.4319/lo.2006.51.4.1594, 2006.
Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R. V., and Paruelo, J.: The value of the world's ecosystem services and natural capital, Nature, 387, 253, doi: 10.1038/387253a0, 1997.
Czerny, J., Schulz, K. G., Boxhammer, T., Bellerby, R., Büdenbender, J., Engel, A., Krug, S., Ludwig, A., Nachtigall, K., and Nondal, G.: Implications of elevated CO_2 on pelagic carbon fluxes in an Arctic mesocosm study–an elemental mass balance approach, Biogeosciences, 10, 3109-3125, doi: 10.5194/bg-10-3109-2013, 2013.
Duarte, C.: Reviews and syntheses: Hidden forests, the role of vegetated coastal habitats in the ocean carbon budget, Biogeosciences, 14, 301-310, doi: 10.5194/bg-14-301-2017, 2017.
Duarte, C. M., and Cebrián, J.: The fate of marine autotrophic production, Limnol. Oceanogr., 41, 1758-1766, doi: 10.4319/lo.1996.41.8.1758, 1996.
Engel, A., Händel, N., Wohlers, J., Lunau, M., Grossart, H.-P., Sommer, U., and Riebesell, U.: Effects of sea surface warming on the production and composition of dissolved organic matter during phytoplankton blooms: results from a mesocosm study, J. Plankton Res., 33, 357-372, doi: 10.1093/plankt/fbq122, 2011.
Engel, A., Borchard, C., Piontek, J., Schulz, K. G., Riebesell, U., and Bellerby, R.: CO_2 increases ^{14}C primary production in an Arctic plankton community, Biogeosciences, 10, 1291-1308, doi: 10.5194/bg-10-1291-2013, 2013.
Eyre, B. D., and Pont, D.: Intra-and inter-annual variability in the different forms of diffuse nitrogen and phosphorus delivered to seven sub-tropical east Australian estuaries, Estuar. Coast. Shelf Sci., 57, 137-148, doi: 10.1016/S0272-7714(02)00337-2, 2003.

Fichot, C. G., and Benner, R.: The fate of terrigenous dissolved organic carbon in a river-influenced ocean margin, Global Biogeochem. Cycles, 28, 300-318, doi: 10.1002/2013gb004670, 2014.
Gattuso, J. P., Gentili, B., Antoine, D., and Doxaran, D.: Global distribution of photosynthetically available radiation on the seafloor, Earth Syst. Sci. Data Discuss., 2020, 1-21, doi: 10.5194/essd-2020-33, 2020.
Hansell, D. A., Carlson, C. A., Repeta, D. J., and Schlitzer, R.: Dissolved organic matter in the ocean: A controversy stimulates new insights, Oceanography, 22, 202-211, doi: 10.5670/oceanog.2009.109, 2009.
Hardison, A., Canuel, E. A., Anderson, I. C., Tobias, C., Veuger, B., and Waters, M.: Microphytobenthos and benthic macroalgae determine sediment organic matter composition in shallow photic sediments, Biogeosciences, 10, 5571, doi: 10.5194/bg-10-5571-2013, 2013.
Hedges, J. I.: Organic matter in sea water, Nature, 330, 205-206, doi: 10.1038/330205a0, 1987.
Heip, C., Goosen, N., Herman, P., Kromkamp, J., Middelburg, J., and Soetaert, K.: Production and consumption of biological particles in temperate tidal estuaries0078-3218, 1-149, 1995.
Krause-Jensen, D., and Duarte, C. M.: Substantial role of macroalgae in marine carbon sequestration, Nat. Geosci., 9, 737-742, doi: 10.1038/ngeo2790, 2016.
Liu, X., Li, Y., Wu, Y., Huang, B., Dai, M., Fu, F., Hutchins, D. A., and Gao, K.: Effects of elevated CO_2 on phytoplankton during a mesocosm experiment in the southern eutrophicated coastal water of China, Sci. Rep., 7, 6868, doi: 10.1038/s41598-017-07195-8, 2017.
Lønborg, C., Álvarez–Salgado, X. A., Letscher, R. T., and Hansell, D. A.: Large Stimulation of Recalcitrant Dissolved Organic Carbon Degradation by Increasing Ocean Temperatures, Front. Mar. Sci., 4, doi: 10.3389/fmars.2017.00436, 2018.
MacIntyre, H. L., Geider, R. J., and Miller, D. C.: Microphytobenthos: the ecological role of the "secret garden" of unvegetated, shallow-water marine habitats. I. Distribution, abundance and primary production, Estuaries, 19, 186-201, doi: 10.2307/1352224, 1996.
Maher, D. T., and Eyre, B. D.: Benthic fluxes of dissolved organic carbon in three temperate Australian estuaries: Implications for global estimates of benthic DOC fluxes, Journal of Geophysical Research: Biogeosciences, 115, doi: 10.1029/2010jg001433, 2010.
Novak, T., Godrijan, J., Pfannkuchen, D. M., Djakovac, T., Mlakar, M., Baricevic, A., Tanković, M. S., and Gašparović, B.: Enhanced dissolved lipid production as a response to the sea surface warming, J. Mar. Syst., 180, 289-298, doi: 10.1016/j.jmarsys.2018.01.006, 2018.
Oakes, J. M., and Eyre, B. D.: Transformation and fate of microphytobenthos carbon in subtropical, intertidal sediments: potential for long-term carbon retention revealed by ^{13}C-labeling, Biogeosciences, 11, 1927-1940, doi: 10.5194/bg-11-1927-2014, 2014.
Patching, J., and Rose, A.: Chapter II The Effects and Control of Temperature, in: Methods in microbiology, Elsevier, 23-38, 1970.
Riekenberg, P. M., Oakes, J. M., and Eyre, B. D.: Short-term fate of intertidal microphytobenthos carbon under enhanced nutrient availability: a ^{13}C pulse-chase experiment, Biogeosciences, 15, 2873-2889, 2018.
Sandberg, J., Andersson, A., Johansson, S., and Wikner, J.: Pelagic food web structure and carbon budget in the northern Baltic Sea: potential importance of terrigenous carbon, Mar. Ecol. Progr. Ser., 268, 13-29, 2004.
Schulz, K. G., Bach, L. T., Bellerby, R. G. J., Bermúdez, R., Büdenbender, J., Boxhammer, T., Czerny, J., Engel, A., Ludwig, A., Meyerhöfer, M., Larsen, A., Paul, A. J., Sswat, M., and Riebesell, U.: Phytoplankton Blooms at Increasing Levels of Atmospheric Carbon Dioxide:

Experimental Evidence for Negative Effects on Prymnesiophytes and Positive on Small Picoeukaryotes, Front. Mar. Sci., 4, doi: 10.3389/fmars.2017.00064, 2017.
Sett, S., Schulz, K. G., Bach, L. T., and Riebesell, U.: Shift towards larger diatoms in a natural phytoplankton assemblage under combined high-CO_2 and warming conditions, J. Plankton Res., 40, 391-406, doi: 10.1093/plankt/fby018, 2018.
Siegenthaler, U., and Sarmiento, J. L.: Atmospheric carbon dioxide and the ocean, Nature, 365, 119-125, doi: 10.1038/365119a0, 1993.
Smith, S., and Hollibaugh, J.: Coastal metabolism and the oceanic organic carbon balance, Rev. Geophys., 31, 75-89, doi: 10.1029/92RG02584, 1993.
Taucher, J., Schulz, K. G., Dittmar, T., Sommer, U., Oschlies, A., and Riebesell, U.: Enhanced carbon overconsumption in response to increasing temperatures during a mesocosm experiment, Biogeosciences (BG), 9, 3531-3545, doi: 10.5194/bg-9-3531-2012, 2012.
Underwood, G., and Kromkamp, J.: Primary Production by Phytoplankton and Microphytobenthos in Estuaries in: Advances in Ecological Research - estuaries, edited by: DB, N., and DG, R., Academic Press, San Diego, CA, 93-153, 1999.
Vázquez-Domínguez, E., Vaqué, D., and Gasol, J. M.: Temperature effects on the heterotrophic bacteria, heterotrophic nanoflagellates, and microbial top predators of the NW Mediterranean, Aquat. Microb. Ecol., 67, 107-121, doi: 10.3354/ame01583, 2012.
Vopel, K., Del-Rio, C., and Pilditch, C. A.: Effects of CO_2 enrichment on benthic primary production and inorganic nitrogen fluxes in two coastal sediments, Sci. Rep., 8, 1035, doi: 10.1038/s41598-017-19051-w, 2018.
Wohlers, J., Engel, A., Zöllner, E., Breithaupt, P., Jürgens, K., Hoppe, H.-G., Sommer, U., and Riebesell, U.: Changes in biogenic carbon flow in response to sea surface warming, Proc. Natl. Acad. Sci., 106, 7067, doi: 10.1073/pnas.0812743106, 2009.
Yang, Z., Zhang, L., Zhu, X., Wang, J., and Montagnes, D. J.: An evidence-based framework for predicting the impact of differing autotroph-heterotroph thermal sensitivities on consumer–prey dynamics, ISME J., 10, 1767, doi: 10.1038/ismej.2015.225, 2016.