

Interactive comment on “Synergism between elevated $p\text{CO}_2$ and temperature on the Antarctic sea ice diatom *Nitzschia lecointei*” by A. Torstensson et al.

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The authors wish to thank Dr. Ken Ryan and the two anonymous reviewers for their helpful comments. We are pleased that the three reviewers found the results interesting and we believe that we can further improve the quality of the manuscript with the help of the comments. We have separately addressed all the reviewers comment below.

Referee #1 (Ken Ryan)

This paper describes the effect of temperature and $p\text{CO}_2$ on growth and productivity of the sea ice diatom *Nitzschia lecointei*. The paper describes interesting results that should be of general interest to our readers.

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Most of the discussion centres on bottom ice communities, so I suggest you use the term “bottom ice algae” throughout rather than sea ice algae. You are probably aware that algae grow throughout the sea ice in brine channels, although they are usually in much lower concentrations there.

RESPONSE: Yes, most of the discussion focuses on bottom ice communities, especially when we discuss grazing and food quality. So technically speaking, the term “bottom ice algae” is more correct, and we will incorporate it in a revision. However, this strain was isolated from the middle section of flooded summer drift ice, where biomass peaks always were located in the middle section of the ice. Hence, it may also be important to clarify if discussing land fast or drift ice as the conditions may differ significantly.

Please delete Table 1, and incorporate the statistical data into the text. It saves a lot of space and is much easier to read and interpret. Most readers don't need f values and degrees of freedom. I assume you have that detail. Just quote the p value.

RESPONSE: Table 1 was an effort to make the result section short and concise. However, we realized that it was more confusing than clear, and we will remove the table in a revision and incorporate the statistical data in the text.

L73. The word “offset” does not seem to be the right one. I am not sure what your meaning is here. Do you mean the development of bottom ice algal biomass in early spring is very important for grazers? If so please clarify this sentence.

RESPONSE: Yes, we intended to refer to the importance of bottom ice algal biomass to grazer in early spring. This will be clarified in a revision.

Remember that some algae exist in sea ice even in winter when there is no light. Not very many it is true, but it is not just ice. The use of the term “bloom” in reference to bottom ice algal growth may be confusing. Often, this term is reserved for a bloom of algae at the ice edge as the ice melts and the algae and nutrients are released into the

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water column. When you talk of a bloom in ice algae it is still not clear that you mean growth of bottom ice algae rather than a bloom of these ice algae at the ice edge.

RESPONSE: Thank you for pointing this out. In the introduction, we are primarily referring to growth of bottom ice algae. We will revise this section by referring to "growth of bottom ice algae", hence avoiding the term "bloom".

L280. You say that there was an increase in Fv/Fm and primary productivity with temperature. Was there any effect of pCO₂?

RESPONSE: No, pCO₂ did not have an effect on Fv/Fm and primary productivity (normalized to cell counts). This will be stated more clearly in a revision.

L282 At the end of this line you mention data from Fig 1B saying that specific growth rate increased significantly with temperature. Firstly, if this is a significant increase, please provide statistical evidence. My reading of the ANOVA results posted in Table 1B however, indicates that there is an effect of temperature, but it does not say that there is an increase in growth rate with temperature. To claim that, you would need to show a regression fit with a significant slope, or perhaps a post hoc test to test for these changes (as described in the methods section). According to Fig 1B, at 5.6 °C, the specific growth rate drops to approximately the same value as at -1.8 °C. The trend goes up then down. Secondly, this observation should be described before Fig 2.

RESPONSE: We are not referring to Fig. 1B at L282, only to Fig. 2 and 3 (i.e. Experiment A). However, to claim that specific growth rate is increasing with temperature we would need a regression fit as you have stated (we only have two points in Experiment A). Hence, the correct statement should be "was significantly higher at 2.5°C compared to -1.8°C", and will be clarified in a revision. The data from Experiment B, including the post hoc test, is found in section 3.4. In revision we will add the statistical data from the ANOVA and the SNK test in the text.

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L294. Take care with each claim you make. As it is written, this statement "Cellular PUFA content also decreased significantly with increasing pCO₂" is not correct. It didn't change at 2.5 °C, only at -1.8 °C.

RESPONSE: We agree, the correct statement should be "Cellular PUFA content also decreased significantly with increasing pCO₂ at -1.8°C". This will be added in a revision.

L301. Having defined the fatty acids above, use the abbreviation ALA, rather than a complicated FA formula. At the end of this sentence my maths gives a total PUFA of only 80%. Please add that other PUFAs are listed in Table 2.

RESPONSE: In a revision, we will use the abbreviations for the fatty acids. The last section refers only to omega-3 fatty acids (as stated in the beginning of the section). However, we will clarify this section in a revision and refer to Table 2, according to your recommendations.

L307 There was no reduction according to your stats. So you can't say that there was one! Simply state that there was no significant difference between treatments.

RESPONSE: We realized that this sentence was unclear and will revise it. We are referring to the reduction on primary productivity due to CA inhibition (i.e. the difference between AZ treated samples and controls), and not that there was treatment specific reduction. We intend to state that there was a reduction of primary productivity in 15 of 16 samples when adding CA inhibitor.

L412. This paragraph is two pages long. Can you break it up into several paragraphs and please consider shortening this section. There are many instances where sentences can be shortened without losing content. Phrases like "a previous study by. . ." "It has been reported that. . ." can be deleted.

RESPONSE: Thank you for pointing this out. The discussion section will be shortened in accordance with the reviewers' comments in a revision.

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L416. Your statement that PUFA concentration is high at optimum culture conditions, is not supported by your data. Fig 1B shows that optimum growth occurs between 2.4 – 5.1 OC. At the optimum temperature of 2.5 OC, PUFA concentrations are much lower than at -1.8 OC (Fig 4).

RESPONSE: This sentence was very unclear. We meant to state that PUFA content is generally higher in culture conditions compared to natural condition. However, we believe that this statement is redundant since we do not discuss it any further, and we list data from both cultures and natural samples in the next sentence. Therefore we will remove this sentence in a revision.

L518. This is incorrect. Under warming scenarios the brine would likely become less saline not more saline. In fact you have just said this yourself on L515.

RESPONSE: Yes, the brine would be less saline during a warming scenario (as stated on L515). On L518 we are referring to the up-concentration of solutes (and gases) in the brine during sea ice formation and not during a warming scenario. This will be clarified in a revision.

L534. Is it likely that these organisms may acclimate to higher temperatures?

RESPONSE: We believe that it is unlikely as long as they are in the ice as the temperature in the bottom ice is relatively stable. However, since most ice algae are not strictly growing in ice, many may experience higher temperatures (e.g. during sea ice edge blooms).

Editorial Comments.

Wording changes are underlined.

RESPONSE: We are very grateful for the editorial comments. We will revise the manuscript accordingly in order to improve the quality of the manuscript.

L138 and L152. Give units for your salinity measurement.

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RESPONSE: Since we have measured practical salinity (conductivity), salinity should technically be unitless in accordance with UNESCO (1985). Salinity data in Biogeosciences has also been suggested to be unitless by Gattuso (2005). However, if the editors of Biogeosciences prefer, we will add “psu” as a unit.

L153 You say “five temperature treatments but you list only 4.

RESPONSE: We will change to four temperatures in a revision.

L171. The temperature of the sample. . .

RESPONSE: “The” will be added in a revision.

L173. The pH was determined using the calculations of . . .

RESPONSE: “after” will be changed to “using” in a revision.

L251. Give the meaning of GC-MS. (perhaps this isn’t necessary? Depends on the editors requirements!) I prefer to read the statistical justifications for each claim alongside the claim as below.

RESPONSE: We will add the meaning of GC-MS in a revision, as it is commonly given in Biogeosciences. As previously stated, we will remove Table 1 and incorporate the statistical data alongside each claim.

L280. The growth rate was significantly higher in 960 uatm than at 390 uatm at 2.5 OC (SNK post hoc p=???)

RESPONSE: Since there was a significant interaction in a 2x2 ANOVA design, no post hoc test can be executed for the interaction. The interaction has simply been interpreted from the ANOVA table and the means. However, the interpretation of the interaction will be clarified in a revision.

L291 FA contents were 65-76% lower at 2.5 OC compared to -1.8 OC (stats needed).

RESPONSE: The stats will be added in a revision after each claim, as previously de-

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scribed.

L292 Fatty acid compositions for SAFA, MUFA, and PUFA are also shown in Fig 4.

RESPONSE: This sentence will be edited as suggested in a revision.

L299 More than 90% of the PUFA were the omega- fatty acids. . . .

RESPONSE: This sentence will be edited as suggested in a revision.

L311. This section refers to Fig 1B, and should be described after the description of Fig 1A. This is the wrong place.

RESPONSE: We will rearrange in the results section in order to present the graphs by increasing number.

L337. In the control temperature the growth rate was. . . .

RESPONSE: This sentence will be edited as suggested in a revision.

L359. Acclimation and the ability to acclimate. . . .

RESPONSE: "The" will be added in a revision.

L400. . . .suggested that low light stress may enhance the effect of low temperature on stored lipids.

RESPONSE: This sentence will be edited as suggested in a revision.

L402. . . .low light and low temperature may be a characteristic response. . . .

RESPONSE: This sentence will be edited as suggested in a revision.

L408. Delete the words from "e.g. . . ." to the end of the sentence. Adds nothing to your statement

RESPONSE: The words will be deleted in a revision.

L409. These findings suggest a major reduction of N. lecontei FA content is likely

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under future climate change scenarios of warmer water and thinner ice. I don't think the next bit about synergy is necessary. Are nutrient levels likely to drop under warmer conditions?

RESPONSE: We agree and will remove the part about synergy. Nutrient levels in the Southern Ocean will not necessarily drop under warmer conditions. We just intended to clarify that nutrient deficiency did probably not confound our results.

L412. Sea ice algae contain high. . . .

RESPONSE: This sentence will be edited as suggested in a revision.

L416. Delete "noticeable". This word is unnecessary as your previous use of "revealed" means you saw them anyway!

RESPONSE: "Noticeable" will be removed in a revision.

L419. 20-60% of what?

RESPONSE: 20-60% of the total fatty acid content. This will be added in a revision.

L423. A percentage composition is not a concentration. Here you should cite the actual concentrations from Fig 4, not percentage of total FA.

RESPONSE: Yes, concentration is an incorrect term in this sentence. We will change concentration to proportion in a revision.

L424 Delete sentence starting "these results.." you have said this earlier, and cited the paper. Start a new paragraph after this to discuss the effect of pCO₂.

RESPONSE: The sentence will be removed and a new paragraph will be started here in a revision.

L487. Delete this sentence. You describe the study in the next sentence.

RESPONSE: The sentence will be removed in a revision.

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L488 . . .CCMs would benefit from elevated. . .

RESPONSE: "Favor" will be replaced by "benefit" in a revision.

L493 . . .to be very taxon specific. The photosynthetic . . .

RESPONSE: These two sentences will be edited as suggested in a revision.

L494. . .brevis remained unaffected at. . .

RESPONSE: "Remains" will be replaced by "remained" in a revision.

L496. Sentences shortened as follows. "The growth rate of *T. pseudonana* was unaffected by pCO₂ at 1000 uatm, even though CCMs were down-regulated and photosynthesis up-regulated (Gao, 2012). This observation was explained by an increased rate of mitochondrial respiration. . ."

RESPONSE: Your helpful suggestion will be incorporated in a revision.

L500. The papers you cite are not "more recent" than the Gao 2012 paper.

RESPONSE: Correct. "More recent" will be removed in a revision.

L507. . .specific and depends on the concentration of the inhibitor. . .

RESPONSE: This sentence will be edited as suggested in a revision.

L513. This might affect organisms dependent on sea ice algae more so than the algae themselves.

RESPONSE: This sentence will be edited as suggested in a revision.

L515 However the upper and middle sections of the sea ice would become warmer. . .

RESPONSE: This sentence will be edited as suggested in a revision.

L524. However, it will be important to consider the natural variability of pCO₂, especially when . . .

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RESPONSE: This sentence will be edited as suggested in a revision.

L530 . . .optimum must be considered when assessing. . .

RESPONSE: "Is important to consider" will be changed to "must be considered" in a revision.

L534 . . .future ocean warming event and this must be considered when assessing. . .

RESPONSE: "May be important" will be changed to "must be considered" in a revision.

Anonymous referee #2

General comments: This paper described the synergistic effects of temperature and CO₂ on a sea ice diatom, it is an important issue since polar species are much more sensitive to ocean warming, while received few attention. The interesting finding of this paper is both temperature and CO₂ can reduce ice diatom's FA, which may affect their nutritional value. The weakness of this paper is lack of focusing, introduction and discussion parts are not well organized.

Specific comments: Introduction: P6640 L25-26, this group had an explanation why ocean acidification has positive, negative or neutral effects (Gao et al., 2012 Nature Climate Change)

RESPONSE: The explanation and reference will be added in a revision.

The statements of CCM (first paragraph of page 6641) is odd to be shown here, better to delete this paragraph, or the author should more specifically to rewrite this paragraph, relate it with particular environments of polar area.

RESPONSE: This paragraph will be rewritten and re-focused in a revision, as we believe it is important to explain CCMs to unfamiliar readers.

M&M 2.6 the title is misleading, PP measurement with AZ is not a method to determine

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CA activity, I suggest to delete the title, and incorporate this paragraph into “2.5 Primary productivity”.

RESPONSE: We agree. PP measurement with AZ is not a measure of CA activity, but of inhibition. We will replace activity with inhibition throughout the manuscript in a revision to make this clearer. We will also merge 2.6 with 2.5, as suggested.

Results: 3.1 Provide the enhanced percentage due to temperature and CO₂, I saw the increase is roughly 50% for both growth rate and PP, this is a good correlation, while not for Fv/Fm, which just a potential value under dark, not the real value when photosynthesis is active. If the author measured effective quantum yield, please add into Fig 2, which reflects the photosynthetic activity under light, and comparable with growth rate and PP.

RESPONSE: We will add the enhanced growth rates and primary productivity in percentages in a revision. We agree, Fv/Fm is just a potential value and should not be correlated with photosynthesis and growth. No such comparisons have been performed. Unfortunately, no $\Delta F/Fm'$ data is available. However, we have previously not seen any effects of CO₂ on Fv/Fm, $\Delta F/Fm'$ or NPQ in *N. lecontei* (unpublished data).

Delete “3.3 carbonic anhydrase activity” and merge the paragraph into “3.1”

RESPONSE: The two paragraphs will be merged together in a revision.

Table 1 is not necessary in this paper, better to remove it, the author can state the significance in the text. Fig3 and 5 can be put together as 2 panels and labeled with A and B.

RESPONSE: Table 1 was an effort to make the results short and concise. However, we realized that it was more confusing than clear, and we will remove the table in a revision and incorporate the statistical data in the text as the reviewers have suggested.

Discussion: This part to me is long-windedness, the author can use less words to say the same thing.

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RESPONSE: We will shorten this part in accordance with the reviewers' helpful comments in a revision.

P6649 L20-27 “However . . . 35°C”, these sentences are of no help to the discussion

RESPONSE: We agree. In a revision, we will remove these sentences in order to shorten the discussion.

P6650 L10, delete “CA activity”

RESPONSE: We prefer to keep “CA inhibition” separated from primary productivity in this sentence, as we are referring to two different processes. However, we agree that the term “activity” is incorrect in this sense, and we will replace it with “inhibition” in a revision.

P6650 L14-17 “Engel . . . pCO₂”, can be shorten as “Engel et al. (2013) observed an increase in PPDOC of Arctic phytoplankton assemblage under high CO₂”. Please check the whole text carefully, some information (e.g. location, technique) provided by the author from the reference are irrelevant to the discussion, the reader can track to the cited papers if they are interested.

RESPONSE: We will rephrase the sentence accordingly and remove any irrelevant information throughout the discussion.

P6650 L23-25, some words are not necessary, e.g. “in earlier studies”, “from the Bering Sea”, “treated with elevated temperature” (you have said photosynthesis increased with temperature in the previous sentence,), actually, this sentence can be shorten as “as found by Hare et al 2007 in phytoplankton populations”, because you are trying to use this paper to support your findings in previous sentence.

RESPONSE: We will incorporate your suggestions in a revision in order to shorten the discussion section.

P6651 L16 delete “is well known to”

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RESPONSE: "Is well know to" will be removed in a revision.

P6654 Better to shorten CCM part

RESPONSE: The CCM part will be shortened in a revision.

References: Li et al (Biogeosciences 9, 3931-3942 2012) reported a synergistic effect of ocean acidification, UV and temperature on a diatom, might be useful for comparison with your data.

RESPONSE: Thank you for the reference. We will cite it in a revision in order to further highlight the importance of synergy when studying in global climate change.

The author should revise the discussion accordingly, to make sentences concise.

RESPONSE: With the help of the reviewers' comments, we will shorten the manuscript (especially the discussion section) and make sentences more concise in order to significantly improve the quality of the manuscript.

Anonymous referee #3

General comment

The manuscript "Synergism between elevated pCO₂ and temperature on the Antarctic sea ice diatom *Nitzschia lecontei*" is an interesting piece of research that contributes to a better understanding of the possible effects of warming and ocean acidification in the physiology and performance of a primary producer from an environment sensitive to climate change. The manuscript is well written and clear, the methods used are straightforward, the data presented is novel and the conclusions are supported by the observations and bibliography. However there are some points that have to be addressed to improve the overall quality of the manuscript.

Specific comments

Summary

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P(age) 6638-L(ine) 13. "Polyunsaturated fatty acids (PUFA) comprised up to 98% of the total acyl lipid fatty acid pool at $-1.8 \text{ }^{\circ}\text{C}$. However, the total content of fatty acids was reduced by 39% at elevated pCO₂, but only at the control temperature. PUFAs were reduced by 30% at high pCO₂." This paragraph is not clear.

RESPONSE: We agree, these sentences could be misleading. Instead of percentages we will show the actual numbers in a revision and further explain the PUFA reduction.

Introduction

P 6639- L 7. NSDIC Arctic Sea Ice News and Analysis can be supported/change by paper of Parkinson et al. (2013) noted in the bibliography below.

RESPONSE: Thank you for the reference. We will cite this paper instead of NSIDC in a revision.

P 6639-L 9. Can a time frame for the stability of climate in the Antarctica be provided?

RESPONSE: According to the Vostok cores, the climate has been oscillating between stable bonds during the last four glacial-interglacial cycles (420 000 years) (Petit et al. 1999).

P 6640-L 26. Yang and Gao (2012) manuscript refers to a single specie in their experiments, either reword to (Line 25) "in a marine diatom", add more references (eg. Wu et al. 2010) or refer to the citation provided within Yang and Gao (2012) manuscript.

RESPONSE: We will cite the papers referred to in Yang and Gao (2012) in a revision.

P 6641-L 6. Hopkinson et al., (2011) refers in general terms to the CCM as being an evolutionary response to the change of atmospheric gases and then cite other manuscripts, however a more detailed explanation about this process is given by Giordano et al. (2005) on page 118.

RESPONSE: In a revision, we will cite Giordano et al. (2005) here instead of Hopkinson et al. (2011) as it is a more relevant paper.

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Material and Methods

P 6646-L 5. Specify if during the Fatty Acid (FA) extraction 1 ml of Chloroform:Methanol:Water (1:2:0.8) was added after the submersion in 2-propanol to ensure the total FA extraction.

RESPONSE: This was performed, and will be specified in a revision.

P 6646-L 6. Specify the type of detector used in the Agilent 7820 GC (FID or other).

RESPONSE: We used the mass detector Agilent 5975 as a detector (i.e. no detector in the GC), as was already specified in the text.

P 6646-L 13. Specify the number, type and origin of the lipid standards.

RESPONSE: This information (supelco; synthetic 37 FAME mix and marine PUFA no 3 from Menhaden oil) will be included in a revision.

P 6646-L 21. Specify the statistical software used.

RESPONSE: This information will be specified in a revision (SuperANOVA).

Results

Introduce all the statistical results where they are mention, going back and forth to Table 1 difiñAçult the manuscript's readability.

RESPONSE: Table 1 was an effort to make the results short and concise. However, we realized that it was more confusing than clear, and we will remove the table in a revision and incorporate the statistical data in the text.

P 6647-L4. "Growth rate increased signiñAçantly at 960 μ atm compared to the 390 μ atm pCO₂ at 2.5 ^\circ C". Give the actual difference once again (even if already mentioned in the summary), this would be helpful for a better appreciation of the real magnitude of the increase in growth rate.

RESPONSE: The actual difference should be included in this section as well. This will
C3237

be added in a revision.

P 6647-L12. "At -1.8^\circ C, total FA content was reduced by 39% in the 960 μ atm treatment" Give the standard error of the FA percentages mentioned here and elsewhere.

RESPONSE: Since the percentages seem to be confusing, we will give the actual concentrations in a revision together with the standard error.

P6647-L 15. "FA contents decreased with 65–76% at 2.5 ^\circ C compared to -1.8^\circ C" Is not clear to which pCO₂ each percentage refers to.

RESPONSE: We agree. 65% and 76% are the average reduction at 960 and 390 μ atm, respectively. Since the percentages are confusing, we will instead give the actual concentrations in a revision, and present them separately.

P 6647-L 18. "Cellular PUFA content also decreased signiñAçantly with increasing pCO₂" This is only true for the -1.8^\circ C treatment, please clarify.

RESPONSE: Correct, this was not clarified by mistake. The correct statement should be "Cellular PUFA content also decreased significantly with increasing pCO₂ at -1.8^\circ C". This will be added in a revision.

Figure 4. Was the molarity of each speciñAç FA take in to account when calculating its concentration? Consider presenting the data in milligrams cell⁻¹ or other gravimetric unit as for example Riebesell et al. (2000) Rossoll et al. (2012) or Mayzaud et al. (2013).

RESPONSE: We assume that the reviewer is referring to the molecular weight of each specific FA in order to convert it into a gravimetric unit. No, we have only expressed it as mole when calculating the concentrations in Fig 4. For comparison, N. lecointei contained on average 150 and 36 fg PUFA cell⁻¹ in low and high temperature, respectively. In a revision, we will express the data in fg cell⁻¹ for easier comparison with previous studies. This will only have a minor effect on the statistical output, but will not

affect the overall interpretations of the results.

P 6648-L 10. Give a more elaborate explanation of the reasons for using ANOVA in spite of the heterogeneity of variance in instead of non parametric statistics; Underwood's citation alone do not explain the rationale of that decision.

RESPONSE: We chose to use ANOVA although inability to transform the heteroscedastic data due to the robustness of the F-test in a balanced design (Underwood 1997, p. 192-194). According to Underwood (1997, p. 130-132), choosing a non-parametric test (e.g. Kruskal-Wallis) will not solve the problem of heteroscedasticity. If the ANOVA is invalidated due to violation of the assumptions, so will another test be. Heteroscedastic data indicate that the distributions have different shapes, i.e. a non-parametric test (e.g. Kruskal-Wallis) would also be invalidated. Hence, we believe that performing the ANOVA with heterogeneous variances is our best option. By visually inspecting the data we believe that there are obvious differences between the treatments, and the chance of the effect being a Type I error is minimal. A shortened explanation will be added in a revision.

Discussion

P 6649-L 15. "Choosing a temperature close to the optimum growth temperature, rather than at ambient conditions, might paradoxically both over- and underestimate the effect of carbon enrichment." Add a few more words clarifying how this happen.

RESPONSE: This will be clarified in a revision by adding "due to a temperature dependency of the response".

P 6650-L 1. "Since growth was faster in the warmer treatment, the number of generations exceeded the numbers in the colder treatment. There is a possibility that more generations of *N. lecontei* acclimated to high pCO₂ in the high temperature treatment, hence the promoted growth rate." This is a circular reference, is not clear which factor is actually pointed as the promoter of growth or if it is a synergistic effect of both.

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RESPONSE: These sentences are unclear and will be revised. We are discussing the potential error produced from having a higher growth rate in one treatment, and the possibility of a higher acclimation rate due to more accumulated generations. However, we believe that the differences in accumulated generations are too small to promote acclimation during the duration of the experiment. Hence, we believe that synergy is the main promoter of growth.

P 6650-L 6 to 25. The paragraph have no clear point and does not lead to any conclusion related with the study.

RESPONSE: As this paragraph appear redundant, we will be removed in a revision in order to shorten the discussion section.

P 6650-L 14. A similar observation to Engel et al. (2013) have been done earlier by Riebesell et al. (2007).

RESPONSE: This paragraph will be removed in a revision (see previous comment).

P 6654-L 14. Why is the statement by Hopkinson et al. (2011) contrary to Raven (1991)? Both actually mean the same in terms of CCM down regulation and energy utilization.

RESPONSE: You are correct; they are not contradicting each other. This was an editing mistake, and will be changed in a revision.

P 6654-L 22. Wu et al. (2010) Show a positive growth rate and enhanced photosynthetic carbon fixation rates of high CO₂ grown cells in the diatom *Phaeodactylum tricornutum*. Pointing this out may help to emphasize the relevance of the species effect.

RESPONSE: We are grateful for the reference and will include it in a revision.

P 6654-L 26. "However, down-regulation of CCMs has more recently been suggested to occur at high pCO₂ (Wu et al., 2008; Hopkinson et al., 2011)." This line seems to be

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redundant as this was already mention above.

RESPONSE: We agree, this sentence will be removed in a revision.

P 6656-L 1. "Hence, the physiological effects of pCO₂ may be more pronounced closer to the optimal temperature of the species, although this temperature is generally higher than ambient conditions" This statement somehow sound contradictory to the results that show no effect of pCO₂ in the FAs at +2.5°C (closer to the optimal +5.1°C) (Fig. 4).

RESPONSE: We agree. We were referring to growth rate here, and not physiological effects (e.g. fatty acids). This will be clarified in a revision.

Technical corrections

P 6638-L 26. the reference Steinarche et al., 2009 is missing in the bibliography.

RESPONSE: We appreciate your observation, and will add the reference in the bibliography in a revision.

P6640-L 21. L 23, the correct term is Psychrophilic.

RESPONSE: Yes, this was a misspelling. We will carefully check the manuscript for additional misspellings.

P 6642-L 9 and L 22. Add salinity units.

RESPONSE: Since we have measured practical salinity (conductivity), salinity should technically be unitless in accordance with UNESCO (1985). Salinity data in Biogeosciences has also been suggested to be unitless by Gattuso (2005). However, if the editors of Biogeosciences prefer, we will add "psu" as a unit.

P 6660-L 1. Name of second author in Rossoll et al. (2012) is misspelled.

RESPONSE: Thank you for observing the misspelled name. We will change the name in a revision.

C3241

Bibliography

Engel, A., Borchard, C., Piontek, J., Schulz, K. G., Riebesell, U., and Bellerby, R.: CO₂ increases 14C primary production in an Arctic plankton community, *Biogeosciences*, 10, 1291–1308, doi:10.5194/bg-10-1291-2013, 2013.

Giordano, M. Beardall, J. Raven, J.: CO₂ concentrating mechanisms in algae: mechanisms, environmental modulation, and evolution. *Annual Review of Plant Biology* 56: 99-131, 2005.

Hopkinson, B. M., Dupont, C. L., Allen, A. E., and Morel, F. M. M.: Efficiency of the CO₂-concentrating mechanism of diatoms, *Proc. Natl. Acad. Sci.*, 108, 3830–3837, 2011.

Mayzaud, P., Boutoute, M., Noyon, M., Narcy, F., and Gasparini, S.: Lipid and fatty acids in naturally occurring particulate matter during spring and summer in a high arctic fjord (Kongsfjorden, Svalbard), *Mar. Biol.*, 160, 383–398, 2013.

Parkinson, C. L., and Comiso, J.C.: On the 2012 record low Arctic sea ice cover: Combined impact of preconditioning and an August storm, *Geophys. Res. Lett.*, 40, 1356–1361, doi:10.1002/grl.50349, 2012.

Raven, J. A.: Physiology of inorganic C acquisition and implications for resource use efficiency by marine phytoplankton: relation to increased CO₂ and temperature, *Plant Cell Environ.*, 14, 779–794, 1991.

Riebesell, U., Revill, A., Holdsworth, D., Volkman, J.: The effects of varying CO₂ concentration on lipid composition and carbon isotope fractionation in *Emiliania huxleyi*. *Geochimica et Cosmochimica Acta* 64, 24: 4179-4192, 2000.

Riebesell, U., Schulz, K. G., Bellerby, R. G. J., Botros, M., Fritsche, P., Meyerhöfer, M., Neill, C., et al. Enhanced biological carbon consumption in a high CO₂ ocean. *Nature*, 450(7169), 545–8. 2007

C3242

Rossoll, D., Bermúdez, R., Hauss, H., Schulz, K. G., Riebesell, U., Sommer, U., and Winder, M.: Ocean acidification-induced food quality deterioration constrains trophic transfer, PLoS ONE, 7, e34737, doi:10.1371/journal.pone.0034737, 2012.

Wu, Y.P., Gao, K.S., Riebesell, U.: CO₂-induced seawater acidification affects physiological performance of the marine diatom *Phaeodactylum tricorutum*. Biogeosciences 7, 2915e2923, 2010.

Yang, G. and Gao, K.: Physiological responses of the marine diatom *Thalassiosira pseudonana* to increased pCO₂ and seawater acidity, Mar. Environ. Res., 79, 142–151, 2012.

REFERENCES

Gattuso 2005, Interactive comment on “The effect of temperature and salinity on the stable hydrogen isotopic composition of long chain alkenones produced by *Emiliana huxleyi* and *Gephyrocapsa oceanica*” by S. Schouten et al. Biogeosciences Discussions 2, S828-829.

Petit et al 1999, Climate and atmospheric history of the past 420 000 years from the Vostok ice cores, Antarctica. Nature vol. 399, 429-436

UNESCO 1985, The international system of units (SI) in oceanography. UNESCO Technical papers in marine science, vol. 45. UNESCO, Paris

Interactive comment on Biogeosciences Discuss., 10, 6637, 2013.