"Response of ocean phytoplankton community structure to climate change over the 21st century: partitioning the effects of nutrients, temperature and light",
by I. Marinov, S.C. Doney and I.D. Lima.

Responses to Anonymous Referee 1 Comments:

Please find referee comments in regular font, and our responses in Bold letters underneath. I am attaching a pdf version of the improved paper, where these changes have been made to the text and are shown in color.

4566:2 The response of ocean phytoplankton community structure to climate change will likely depend on many additional factors in addition to those three described here, including grazing, viruses, toxins, mixing, acidification, evolution, and many others, so the first sentence is vastly incomplete. Perhaps add 'We study' to the beginning of the sentence. Otherwise it sounds like the factors are the only ones. Missing in the methods is a description of the scope of analysis – was it restricted to the surface, the mixed lay, or some modal value? Was depth variation considered? Was the seasonal cycle considered?

Corrected line 15 (of my new .pdf manuscript) and added "The present analysis focuses on the surface, annual mean dynamics" on page 3, line 25.

4577:10 - Is this response just because the base growth rate for small is higher, or is the relative growth rate change also higher for small?

The temperature response discussed here is the one detailed by Equation 19, so it refers to the absolute changes in the growth rate. Because of an increase in temperature, the absolute growth rate of small phytoplankton will increase more than the absolute growth for diatoms. It is not clear apriori what would happen with the relative growth rate of small versus diatoms in the absence of light and nutrient effects. In general, since the base growth rate for small phytoplankton is higher in the low-midlatitudes, we would expect that the relative growth rate of small phytoplankton might actually increase less with temperature (even though their net growth rate increases more with temperature). A lot of subtleties here, some of which we discuss later on in Section 3.5. Here we discuss the absolute changes in growth rates.

I also added at the beginning of Section 3.3 a clarification: "Since the temperature sensitivity of growth rate (T_f in Eq. 3) is the same for all modeled phytoplankton groups, changes in temperature do not lead directly to differential effects on phytoplankton growth (ΔT_f same for all species in Eq. 12c). Rather, the temperature impact is indirect. Differences in the initial nutrient functional response V_x and light limitation function L_x contribute to differences in $\Delta\mu_x^{temp}$ between species, as explained below. "

4577:17 – This section leads a lead-in sentence. . . Otherwise, why should the reader bother assuming small and diatoms are limited by the same nutrient?

We modified the paragraph to clarify this and include the following:

"Where two or more phytoplankton species co-exist, they can interact via competition for light and nutrients. Previous work with multifunctional group marine ecosystem models, such as the one used here, indicates that there are large portions of the global surface ocean where the growth of simulated small phytoplankton and diatoms are limited by the same nutrient allowing for species competition (Moore et al, 2004). We focus here our analysis on those regions where nitrogen and iron are limiting for both small phytoplankton and diatoms (Fig 1b,d,f), acknowledging that the results are not applicable in regions where the phytoplankton groups are limited by different nutrients (e.g., silicon for diatoms). While not discussed here, phosphorus limitation may be important on the smaller regional basis and the same basic analysis framework would apply. In order to consider the role of each individual term in Eq. 11 on the overall growth rates, we first analyze the contribution of nutrients to growth rate $\Delta\mu_x^{nutr}$."

4578:4-5 - Figure 10 is not introduced and discussed sufficiently. What do the authors mean by 'win' when saying that diatoms 'win' under no3 and fe limitation – higher biomass? higher growth rates? Why does the model not exhibit the yellow, blue and orange areas predicted by the theory? I would consider this a very significant difference.

Figure 10 is now introduced later in the text (after Eq 17) and discussed in more detail. We were trying to do more than necessary in Fig. 10 and confused the readers instead. We redid the figure and caption, and one can see now that the model predicts well the model results. A new, more clear caption was added for Figure 10, explaining that "small phytoplankton expected to win over diatoms" means that "small phytoplankton growth rates are expected to respond more to nutrient change than diatom growth rates"

4581:2,23 – The phrasing of 'Now we turn' and 'We next try' is not an appropriate way to introduce the new analysis, partially because of tense, partially because of the lack of context. Instead, something like, 'In order to consider the role of each individual term on the overall growth rates, we first' and then, 'Moving from the temperature effect to the nutrient effect, we next'

Good suggestion. We now introduce both Sections 3.2, 3.3. using the proposed text.

4581:8 – The rationale for invoking this toy function is unclear here. Equations 3 and 12c are listed, but their relationship to the function is not readily apparent. The previous sentence suggests that Vx and Lx are going to be the focus. . . would it simply be appropriate to add, 'These two variables are linked via Equation 6 which is a function with several notable properties.'? That would help guide the reader (if I am inferring the authors' logic correctly.

Rephrase the entire paragraph as follows (to avoid introducing the new toy function) "Referring back to the light limitation equation (Eq. 6), the product L_xV_x, which enters into Eq. 12c, has the general form $L_xV_x = (1 - e^{-\alpha_x\theta_x^c I_{par}/(\mu_{ref}V_xT_f)}) \cdot V_x$. The

function $(1-e^{-a/V_x})\cdot V_x$ is monotonic and increasing in V_x for a positive a. Small phytoplankton have lower half saturation coefficients and larger nutrient functional response than diatoms everywhere in the ocean, i.e., $V_{sp} > V_{diat}$, which necessarily implies $(1-e^{-a/V_{sp}})\cdot V_{sp} > (1-e^{-a/V_{diat}})\cdot V_{diat}$. Since $\alpha_{diat} = \alpha_{sp}$ and the variability in θ_x^c is negligible compared to that in V_x, we can show that: …"

4581:11 and Equation 18 – With respect to theta_c_x / Vx, are the authors trying to assert that theta_c_x itself is invariant or that the variability in theta_c_x is driven by Vx such that the ratio is relatively invariant? Why no light modulation?
Actually, there are changes in theta_c_x but these changes are much smaller than relative changes in V_x. The text now says so.

Throughout this section, it is often unclear to me whether the authors are intending the 'x > y' type statements to indicate the proof of a global truism (i.e. we have just proven that x must always be greater than y), or a conditional case that is being examined (i.e. under conditions of x being greater than y, another set of conditions follow). This would be clarified by replacing the phrasing of 'we have:', 'we can now write:', 'we can show that' with the appropriate descriptive introduction to introduce the conditional statement that tells the reader from whence the statement follows.

Corrected throughout (bottom of page 15 to middle of page 16)

Equation 21, and 4582:16: Where does the left hand inequality come from? I cannot get it by combining equations 20, 12b, and 12c. Also, what does the two-way arrow symbolize? Given my uncertainty, the paragraph introductory statement 'Equation (21) intuitively makes sense' seems inappropriate to me given that I could not follow either where is came from or what it signified.

We have altered the presentation of the equation by removing the two-way arrow and making the conditions under which the statement is true more explicit.
One can derive Eq. 21 from eqs 20, 12b, 12c and Vx=N/(N+K), and we have modified the text to indicate this. We have also modified the phrase "intuitively makes sense" to:
"Analysis of the inequalities on the RHS of Eq. (21) can help us understand the spatial patterns of dominance of $\Delta\mu^{nutr}$ versus $\Delta\mu^{temp}$ in Fig. 11. Etc."

4588:7-9 – A stronger response overall, or incrementally relative to the present day conditions?
Stronger response overall.

4588:22 – 'suggesting increase cloudiness' implies that the authors are attempting to make inferences about the atmospheric model behavior based on the ocean interior light fields – why not just look at the atmospheric model directly?

The only way to alter downwelling solar radiation in the model (that we can think

of) is by increasing cloudiness so this is a statement we are confident about.

4588:27-28 – What does "In the biome average' mean? Is this a global average, just the subpolar South Pacific, or perhaps small+diatoms across the subpolar biome?

Changed sentence to "Averaged over the Southern Ocean subpolar biome, there is almost no change in zooplankton carbon."

4588:28-9 – This statement seems in contradiction with the one in 4588:7-9 – is the subpolar southern ocean biome defined as not effected by sea ice?

Corrected the above statement to: In contrast to the marginal ice biome, diatoms become more competitive than small phytoplankton in the Southern Hemisphere subpolar biome because they are less sensitive to decreases in light and they are grazed less than the small phytoplankton (Fig. 8d). The subpolar biomes are defined on page 10 as " all areas poleward of 45^{0}N or 45^{0}S not included in the marginal sea ice biome."

4589:17 – 'decay' seems an odd word to use here – perhaps 'decrease'?
Corrected.

4589:19-20 – I think the authors intend to add 'community composition' after 'phytoplankton' – Otherwise, it makes it sound like the authors are unaware of the CZCS, SeaWiFS and other ocean color datasets. Beyond this, and while I understand that the author's intention is to motivate further research on satellite and field phytoplankton compositional variability, the sentence currently reads a bit insulting in the face of all of the existing studies in addition to Alvain (e.g. Mouw, Sathyendranath, Bracher, Balch, Uitz, Peloquin and others). Perhaps the authors should rather stress the lack of consistency and robustness between these data products.
See improved Discussion section, last paragraph on satellite data now reads:
"Mapping phytoplankton community composition and its temporal variability from satellite and in-situ measurements is essential for validating our critical nutrient hypothesis and model results and generally for forecasting the evolution of ocean ecology and carbon cycle. A number of investigators have developed algorithms to estimate phytoplankton functional types (e.g., Uitz et al., 2006, Alvain et al, 2008; Uitz et al., 2010) and size structure (e.g. Kostadinov et al., 2009, 2010; Mouw and Yoder, 2010) from satellite data. We suggest that satellite estimates of interannual variability in size structure can provide a potential test for our proposed "critical nutrient hypothesis". One idea would be to compare the variability in small and large phytoplankton at locations where plankton variability is primarily due to nutrient changes, both in areas where nutrients are lower and where nutrients are higher than critical values."

4589:27-28 – This sentence comes off as a terse non sequitur and should be either removed or clarified.
Removed, see also improved Discussion section. We have added one page to the Discussion section, discussing more broadly the implications of our result and the broader scientific background for the problem.