Responses to Reviewer 2:

Minor comments:

Chl validation: Here, modeled Chl is compared to satellite-derived Chl using a global algorithm. The Arctic has relatively unique ocean optics, and global ocean color algorithms do not typically replicate Arctic Chl well, so I'd recommend using an Arctic-specific algorithm. This will likely lead to a reduction in satellite-derived Chl, making this comparison look far better, and will also likely shift the seasonality of the phytoplankton blooms earlier.

- Thank you for your comment, which is similar to Reviewer 1's concerns about the comparison with satellite chlorophyll estimates. In the revised paper, we used chlorophyll estimated with an algorithm tailored to the Arctic Ocean (Lewis and Arrigo, 2020; https://doi.org/10.1029/2019JC015706). Please see our response to Reviewer 1 for the new figures and a detailed discussion of model-satellite chlorophyll comparison.

Nutrients: When nutrient limitation is discussed, does this refer exclusively to NO3 limitation? I imagine that diatoms are limited by Si at least seasonally or in some parts of the Arctic. A little more clarity about what nutrients limit phytoplankton growth would be appreciated.

- Thank you for your comment about limiting nutrients, which is similar to a comment by Reviewer 1. Nitrate is the limiting nutrient in most parts of the Arctic Ocean, most of the time for most taxa. In the revised manuscript, we added a figure that shows this, and provided language to make this clearer. Please see the detailed response to Reviewer 1 for figure and text changes.
- For Figure 5, we aimed for simplicity by comparing growth limitation by nutrients, light, and temperature, but see how this introduced uncertainty. By "nutrients" in this figure, we mean any nutrient, but this is usually nitrate (see Figure S2 in response to Reviewer 1). In a revised manuscript, we will add the following text to make this clearer:

  > L306-308: "In Figure 5, we assess whether phytoplankton growth was most limited by light, temperature, or nutrients. In this case, nutrients can refer to limitation by nitrate, phosphate, silicate, or iron, but in practice in the model, phytoplankton growth is most often limited by nitrate (Supp. Fig. S2)."

Results and Discussion overall: I think this section would benefit from greater contextualization with/ comparison to previous studies – perhaps a few sentences in each section.

In a revised manuscript, we incorporated greater contextualization with comparison to previous studies. We added the suggested text below, in response to individual points/questions.

For example, you describe how phytoplankton biomass shifts from largely dominated by diatoms to dominated by smaller functional types as nutrients are drawn down. This is common in global oceans, but has it been observed (or found in other model configurations) in the Arctic? What about the seasonal succession of zooplankton you observe?

- Thank you for your comment, we included the following in our discussion:
    - L349-351: "The model indicated a pronounced seasonal shift from large to small phytoplankton driven by the seasonal reduction of surface nitrate, which is largely consistent with observations from the region (Ardyna et al. 2017, Ardyna et al. 2011, Ardyna and Arrigo, 2020, Tremblay et al. 2009, Usov et al. 2024)."
- Regarding zooplankton seasonal succession, in our manuscript we included:
    - L351-354: "The seasonal succession of zooplankton is significantly influenced by the size structure of the phytoplankton, consistent with Usov et al. (2024), who found that distinct seasonal groups of phytoplankton and zooplankton in the Chupa Inlet (White Sea) are interconnected, with smaller species playing a larger role in summer and autumn, enhancing trophic coupling throughout the seasonal cycle."
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Similarly, discussion of the predominant limitation terms for phytoplankton growth in other models (or in CESM-1 with Krumhardt et al., 2020, for example) would be valuable.

- The Krumhardt et al (2020) paper evaluates the correlation between NPP variability with variations in the light, temperature, and nutrient limitation terms, with the aim of elucidating the factors that influence the potential predictability of NPP. This is distinct from identifying the most limiting factor for phytoplankton growth. Additionally, those analyses were done on annually averaged data and did not evaluate seasonal changes in limiting factors, which we think is more appropriate for understanding the factors limiting phytoplankton growth, particularly in highly seasonal seas such as the Arctic. We believe that the analysis of seasonal limitation factors is one of the major contributions of our manuscript. Still, in consideration of this suggestion, we added the following text to the manuscript: L325- 328: "Our results concerning factors limiting phytoplankton growth are broadly consistent with previous modeling studies that have shown that temperature and light strongly limit phytoplankton growth in the Arctic Ocean (Steinacher et al. 2010; Krumhardt et al. 2020), however we provide additional context on seasonal changes and how limiting factors vary across phytoplankton sizes."

For the fisheries production results, it might be useful to look at other modeled estimates of fisheries changes in the future (e.g. Tai et al., 2019). While this model is only run until 2009, your results about how biomass changes under low sea ice and warmer ocean temperatures suggest a more productive Arctic in the future. Is that consistent with other model findings? A few sentences about these results will better allow readers to assess which of your findings are new contributions and which are consistent with other observational studies or previous modeling studies, giving us confidence in this model configuration.

- Tai et al. (2019) projected that fish catch in the Canadian Arctic may increase by 2100 under high emissions scenario (RCP8.5). In a revised manuscript, we added the following sentences: L489-493: "While our analysis of fish production in the Arctic Ocean compares years with contrasting environmental conditions in the historic simulations, these results align with observations of fish physiology in the Kitikmeot region of the Canadian Arctic, where years with earlier ice breakup, as observed by both Inuit fishers and biophysical indicators, showed positive effects on Arctic Char quality as reflected by both fish condition and lipid content (Falardeau et al., 2022). Other studies suggest there could be an increase in fish catch and economic value potential (Tai et al., 2019). Conversely, some studies exploring the ongoing impacts of Arctic warming predict that by the end of the century, Arctic fish species like Arctic Cod may decline due to rising ocean temperatures and shifts in habitat and migration patterns (Florko et al., 2021; Steiner et al., 2019)."

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