We thank Referee 2 for the additional comments and the positive response to our previous revisions. Our responses to the new comments are provided in the blue, bolded, and italicized text below with revised text indicated in purple.

General comments

I would like to thank the authors for their careful and constructive responses to my previous comments. They all have been addressed with remarkable care, precision, and goodwill, and the authors have provided thoughtful clarifications and substantial improvements throughout the manuscript.

In my view, these revisions have significantly strengthened the study, which now reaches a very high standard. In particular, the addition of a dedicated Discussion section is a very valuable improvement that greatly enhances the interpretation of the results and the overall narrative of the manuscript.

I find that the manuscript is now in excellent shape. I only have a few very minor comments and suggestions listed below. Once these small points are addressed, I believe this study will make a strong and valuable contribution and will be very well suited for publication in the journal.

Specific comments

- *L174-187: Could you briefly describe the trophic interactions among the different model components (diatoms, nanophytoplankton, Z1, Z2)? This information would be useful for interpreting the cascading effects observed during marine heatwaves.*

Thank you for this suggestion. We were happy to add more detail on the trophic interactions among the different model components in the Methods section of the revised manuscript. Section 2.3 now describes the prey items and grazing preferences for each of the zooplankton groups: "The Z2 biomass is distributed spatially throughout the model domain in proportion to food availability. Thus, spatial variability in the distribution of Z2 throughout the domain will directly reflect differences in the spatial distribution of Z2 prey items. Both Z1 and Z2 feed on diatoms, nanoflagellates, Z1, and PON, with each zooplankton class having different prey preferences set in the model. Z1 has the highest grazing preference for nanoflagellates (30%), followed by diatoms (26%), whereas Z2 has the highest preference for diatoms and Z1 (29% each). However, the actual proportion of grazing depends on both preference and the relative abundance of each prey item." L199-204.

  - Thank you for providing these additional elements, which greatly help in interpreting the results. I would suggest adding one or two sentences noting that Z2 is strongly constrained by the model's closure term and may therefore respond somewhat differently within the model framework. This would help nuance the statement: “The Z2 biomass is distributed spatially throughout the model domain in proportion to food availability. Thus, spatial variability in the distribution of Z2 throughout the domain will directly reflect differences in the spatial distribution of Z2 prey items.” L236

Thank you for this suggestion. We have added the sentence “Given the strong constraint of Z2 as the model’s closure term, Z2 biomass may respond differently compared to Z1 within the model framework.“ (Lines 199-200)

- *L195: “We focus our discussion mainly on the surface (0-50m) as this depth layer is most relevant to both phytoplankton and zooplankton.”, and L202: “Model output for phytoplankton (diatoms and nanoflagellates) and zooplankton (Z1 and Z2) biomass were depth-averaged over the 0-50 m depth range to capture the full extent of the euphotic zone across regions (mmol N m-3)”. The manuscript would benefit from including information on the vertical structure and migratory behavior of zooplankton in the different regions of the Salish Sea. First, this would support the assumption that a 0–50 m layer is appropriate for representing zooplankton. In addition, such information would be valuable for interpreting the results on the impacts of marine heatwaves on lower trophic levels (cf. my comment on Section 3.3.2).*

We appreciate the suggestion; however, the decision to focus on the 0-50 m layer had less to do with the vertical structure of “real world” zooplankton dynamics and more to do with model limitations and general oceanography in the Salish Sea. We have clarified our use of the 0-50 m depth layer in the Methods Section 2.4 with the addition of the following text: “We focus our discussion mainly on the surface (0-50m) as this depth layer is most relevant to both phytoplankton and zooplankton. A depth range of 0-50 m was chosen in order to balance where we know the phytoplankton are growing (i.e., the euphotic zone) and where we know the model Z1 and Z2 are concentrated. For our two regions of focus, JdF and Central SoG, zooplankton in the model are concentrated mainly in the upper 50 m of the water column (see Suchy et al., 2023). Furthermore, previous studies in the region commonly define the surface layer as the 0-50 m depth layer in order to clearly delineate between this layer and the underlying intermediate waters (e.g., Pawlowicz et al., 2007, Ianson et al., 2016).” L215-221.

When model and observation data were considered together, we used full water column averages for zooplankton to avoid any confounding influence of the vertical structure and migratory behaviour of zooplankton on our results. We note that the model does not capture zooplankton vertical migration.

- Regarding your last paragraph, you state that when model and observations are considered together, full water-column averages were used for zooplankton. Could you please clarify whether you are referring to the model outputs or to the observational data?

If this refers to the model outputs, it is not clear to me in which results or diagnostics the 0–50 m depth-averaged biomass is used versus the full watercolumn averages. Is this specified somewhere in the manuscript? If the model represents zooplankton biomass below 50 m, could you clarify the rationale for restricting the analysis to the upper 50 m in some cases?

Yes, here we are referring to both model and observation data. Currently the text states this in Section 2.5: "To maximize the number of model-observation comparisons, nitrate and Chl a were averaged over the 0-10 and 0-50 m depth ranges, respectively, whereas zooplankton were averaged over the full water column for both model and observations." (Lines 252-254). Furthermore, all figure captions include information on which depth layer is being considered for a given parameter.

The rationale for restricting the model analyses to 0-50 m is provided in Lines 217-224; however, we further clarified the rationale in the revised text:

" Model results are discussed primarily for the surface (0-50m) as this depth layer is most relevant to both phytoplankton and zooplankton. A depth range of 0-50 m was chosen in order to balance where we know the phytoplankton are growing (i.e., the euphotic zone) and where we know the model Z1 and Z2 are concentrated. For our two regions of focus, JdF and Central SoG, zooplankton in the SalishSeaCast model are concentrated mainly in the upper 50 m of the water column (see Suchy et al., 2023). Furthermore, previous studies in the region commonly define the surface layer as the 0-50 m depth layer in order to clearly delineate between this layer and the underlying intermediate waters (e.g., Pawlowicz et al., 2007, Ianson et al., 2016). When comparing model output against observations, however, depth layers are defined by the available observational data and are described for each comparison accordingly in Section 2.5."

- "[…] where we know the model Z1 and Z2 are concentrated." Are there any observational studies that support this statement?

This statement is specifically referring to the known spatial distribution of Z1 and Z2 in the SalishSeaCast model. We have revised the text to specify this in the sentence "For our two regions of focus, JdF and Central SoG, zooplankton in the SalishSeaCast model are concentrated mainly in the upper 50 m of the water column (see Suchy et al., 2023)."

- *L204: "the extent to which temperature dependence and light/nutrient limitation was limiting to growth was calculated based on the phototrophic growth rate equations in the model". Could you please elaborate on the methodology of this diagnostic?*

Absolutely. We agree with Referee #2 that there is a lack of detail regarding the calculations of temperature dependence and nitrate limitation, which was evident in comments from both reviewers. The revised manuscript elaborates on this diagnostic in Methods Section 2.4.

"In addition, we calculated the extent to which temperature dependence and nitrate limitation was limiting to diatom growth based on phototrophic growth rate equations and parameters set in the model (Suchy et al., 2025a). Climatologies (2007-2022) for nitrate limitation coefficients and temperature dependence were calculated. Limitation coefficients range from 0 to 1, with higher values reflecting more nitrate limitation on growth. In contrast, higher values for temperature dependence mean that temperatures were more favourable for growth. Time series data are presented as monthly anomalies to highlight seasonal and interannual variability. Positive anomalies indicate less limitation/temperature dependence on growth, whereas negative anomalies mean growth was more limited/temperature dependent compared to the climatology. We focus our discussion on diatoms, which is the most variable prey item for Z1 and Z2 in the model. Limitation plots for nanoflagellates, which are less limited by nitrate and temperature compared to diatoms, are provided in the Supplemental Materials." L229-238.

- Thank you for providing these additional details about the diagnostic. However, the manuscript still does not explicitly describe how the 0 to 1 values of nitrate limitation coefficients and the temperature dependence are computed. Clarifying this point in the text would help the reader better understand how these diagnostics are derived.

Thank you for this important comment. The detailed phototrophic growth rate equations, previously published in Olson et al., (2020) and Suchy et al., (2025a), are now provided in the Supplemental Material with appropriate modifications for the current version (v202111) of SalishSeaCast model. We hope that including these calculations, coupled with the code provided for the limitation plots cited in the data availability statement (https://doi.org/10.5281/zenodo.18964405), will provide adequate clarity to help the reader better understand how these diagnostics are derived.

Revised text, Lines 234-235:

"In addition, we calculated the extent to which temperature dependence and nitrate limitation was limiting to phytoplankton growth based on phototrophic growth rate equations and parameters set in the model. Detailed equations, first described in Olson et al., (2020) and Suchy et al., (2025a) but modified for v202111 are provided in the Supplemental Material."

New text on pages 1-2 of Supplemental Material:

Phototrophic Growth Rate Equations

Phytoplankton (diatom and nanoflagellate) growth in SalishSeaCast model may be limited by temperature, light, or nutrients (nitrate, silicon, or ammonium). The phototrophic growth rate equations (1-9), first described in Olson et al., (2020) and Suchy et al., (2025a), are modified for v202111 of the model and listed below. These equations can be used to calculate the extent to which *each parameter is limiting to growth. Here, DIAT is diatoms, FLAG is nanoflagellates, C_i is the concentration of each phytoplankton group in mmol N m^{-3}, Θ is Conservative Temperature in degrees Celsius, I is photosynthetically active radiation (PAR) in units of W m^{-2}, $[NH_4]$ and $[NO_3]$ are the ammonium and nitrate concentrations, respectively, in mmol N m^{-3}, and [dSi] is the dissolved silicon concentration in mmol Si m^{-3} (see Olson et al., 2020 for details). Phototrophic growth parameters for diatoms and nanoflagellates for v202111 are provided in Supplemental Table S1.*

$$r_i = \{\mu_i C_i,\ \ i \in (DIAT, FLAG) \qquad (1)$$

$$\mu_i = \mu^i_{max} f(\Theta)\hat{L}_i(I, [NH_4^+], [NO_3^-], [dSi]) \qquad (2)$$

where $f(\Theta)$ and $\hat{L}_i$ are defined as:

$$f(\Theta) = exp\,[0.07(\Theta - 20°C)] \cdot \begin{cases} 1,\ \Theta \leq \Theta_{max} - \Theta_{range} \\ \frac{\Theta_{max}-\Theta}{\Theta_{range}},\ \ \Theta_{max} - \Theta_{range} < \Theta < \Theta_{max} \\ 0,\ \ \ \Theta \geq \Theta_{max} \end{cases} \qquad (3)$$

$$\hat{L}_i = min\left(L^i_I, L^i_{Si}, L^i_N\right) \qquad (4)$$

$$L^i_I = 1.06 exp\left(-\frac{I}{30 I^i_{opt}}\right)\left[1 - exp\left(-\frac{I}{0.33 I^i_{opt}}\right)\right] \qquad (5)$$

$$L^i_{Si} = \frac{[dSi]}{k^i_{Si} + [dSi]} \qquad (6)$$

$$L^i_N = L^i_O + L^i_H \qquad (7)$$

$$L^i_O = \frac{K^i[NO_3^-]}{K^i_N + K^i[NO_3^-] + [NH_4^+]} \qquad (8)$$

$$L^i_H = \frac{[NH_4^+]}{K^i_N + K^i[NO_3^-] + [NH_4^+]} \qquad (9)$$

- *In the JdF region, the marine heatwave has been described as being linked to the NEPMHV and SOI, with the end of positive temperature anomalies and negative nitrate anomalies around 2020. From 2020 to 2022, negative temperature anomalies reappear, along with positive nitrate anomalies. A similar shift is observed for both nanophytoplankton and diatoms, with predominantly negative anomalies over the 2020– 2022 period. Consequently, negative anomalies are also observed for Z1, but we do not observe the same response of Z2 (except for a peak in 2022). How can these contrasting responses between Z1 and Z2 be explained?*

Z1 biomass in the model follows closely with the diatom and nanoflagellate patterns because this class freely evolves based on model dynamics. Z2 is more constrained by the model's settings as it represents the model closure term and is thus expected to respond differently in the model. We now discuss these contrasting results more carefully in Sections 4.3.1 of the Discussion.

- Thank you for this explanation; it makes sense. However, I am still not fully understanding the sentence: "As such, Z2 is more strongly influenced by the spatial distribution of its prey throughout the entire model domain as well as by a prescribed seasonal cycle." Could you please elaborate further on this point? In particular, it would be helpful to clarify how the closure term is defined in the model to lead to the specific influence described here.
- Moreover, do you have any hypothesis about the contrasting results we observe in Z2 response between the Central SoG and the JdF regions?

We can see how this statement remains confusing. The text has been revised to elaborate on the model closure term, and how this influences the different dynamics between Z1 and Z2.

"In comparison, Z2 is more constrained by model settings as it represents the model closure term, which is more nuanced than in other biogeochemical models in the region (see Suchy et al., 2023). Specifically, at any given time, the Z2 concentration is distributed throughout the model domain in proportion to its prey; however, the temporal variability of Z2 is also constrained by a prescribed seasonal cycle. Therefore, in contrast to Z1, Z2 dynamics are not driven solely by local conditions. Nevertheless, the highest Z2 biomass was seen immediately following the NEP-MHW, in response to the increased availability of both diatoms and Z1 which are the preferred prey of this class representing larger-bodied taxa with longer life cycles (e.g., overwinter copepods, euphausiids)." (Lines 656-661)

Our hypothesis for the contrasting results in Z2 between the Central SoG and the JdF regions is that there are better feeding conditions for Z2 in the JdF region post-NEP MHW (and even from 2020-2022). See Lines 418-420: "Given that spatial variability in Z2 biomass in the model reflects differences in the spatial distribution of their prey, our results suggest that zooplankton

experienced better feeding conditions in the JdF region compared to the Central SoG during the latter half of our study period."

Additionally, we have expanded upon this hypothesis in the text in Section 4.3.2 to read: "The contrasting results we observed in the modelled zooplankton response between the Central SoG and the JdF regions suggest that post-NEP-MHW conditions were more favourable for Z2 in the JdF region, where nitrate-replete waters supported diatom growth. In the Central SoG, persistently low nitrate favoured the nanoflagellate-Z1 pathway instead. Together, these differences highlight the need for comprehensive, long-term regional analyses of lower trophic level dynamics throughout the Salish Sea." (Lines 697-701)

Minor comments

L617: "We discuss the cascading processes by which variability in temperature and nitrate propagated through the **food** by focusing […]" food web* ?

Thank you. Corrected.

L634: "Although phytoplankton biomass was slightly elevated during NEP-MHW years, even higher diatom biomass occurred post-NEP-MHW, but during the second MHW in 2018 and 2019 (Fig. 8)." The sentence is slightly confusing as written, particularly the phrasing "post-NEP-MHW, but during the second MHW in 2018 and 2019," which makes the temporal relationship unclear. Please consider rephrasing for clarity.

This sentence has been clarified and now reads: "Although phytoplankton biomass was slightly elevated during NEP-MHW years, even higher diatom biomass occurred during the second MHW in 2018 and 2019 (Fig. 8)." (Lines 638-639)