We thank you the reviewer for their suggestions. The response to the reviewers comments are in black while the original comments are in blue.

This paper details a new seagrass model incorporated into COAWST that includes twoway interactions with both physical and biological processes included in the model. The paper describes the complex set of equations used in the seagrass model and shows the model performance on two examples: an idealised case and a more realsitic case. In both examples, the effects of two-way coupling is shown, but there is a focus on the biological reactions, rather than the impact of seagrass changes on hydrodynamics. Overall the paper is generally well-written and clear, but lacks some sort of validation or verification of the sea grass model. My main criticism of the paper is that this verification is lacking and it is therefore difficult to ascertain if the model works compared to some lab or case study. Whilst the two examples seem sensible it does not show proper functioning of the code. I didn't attempt to run the code in question as part of the review, but I couldn't actually find the seagrass model in the code repository easily, so could not even check equation as written in the paper match the code.

The reviewers correctly point that the focus of the paper is on the biological growth of SAV and how the two way coupling is shown to work in an idealized and realistic model domain.

The impact of seagrass changes on hydrodynamics (seagrass-hydrodynamics coupling) in the model were detailed in an earlier work by Beudin et al. (2017) and also applied later in Chincoteague Bay (Beudin et al. 2017) . In this work, we have focused on the implementation of the seagrass growth model that also allows for the operation of a two-way coupled framework between different modeling components (seagrass, hydrodynamics, biology and sediment dynamics). We have added the following conclusions to clarify that the impact of seagrass on hydrodynamics were studied in a previous study (Page 2 in Introduction from Line 23 onwards).

"Recently, Beudin et al. 2017 implemented the physical effects of SAV in a vertically varying water column through momentum extraction, vertical mixing as well as accounting for wave dissipation due to vegetation. These processes were implemented within the open source COAWST (Coupled-Ocean-Atmospheric-Wave-Sediment Transport) modelling system that couples the hydrodynamic model (ROMS), the wave model (SWAN) and the Community Sediment Transport Modelling System (CSTMS) (Warner et al., 2010). Through this effort, the COAWST framework accounted for the coupled seagrass-hydrodynamics interactions. The model reproduced the turbulent shear stress across the canopy interface and peaked at the top of the canopy similar to the observations of Ghisalberti and Nepf (2004, 2006). The presence of seagrass patch led to a reduced shear-scale turbulence within the canopy and an enhanced wake-scale generated turbulence. For more details on the impact of seagrass on hydrodynamics, readers are referred to Beudin et al. 2017."

The main focus of this paper is to implement a seagrass growth model and couple various existing components seagrass, hydrodynamics, biological and sediment dynamics. We have added verification of the seagrass growth model with available observations in a new section (Section 4.3).

The following are a response to the reviewers major comments.

Major comments:

Comment 1: Add some sort of verification. I assume that this has been done as part of some sort of testing infrastructure, so should be trivial to add to the paper

Response: We would incorporate a section in discussion on model verification (Section 4.3)

Section 4.3. Model evaluation in West Falmouth Harbor

In order to qualitatively evaluate the seagrass growth model, we have compared the modeled results with observations by del Barrio et al. (2014) that measured the extent of seagrass coverage in West Falmouth Harbor (red outline in Fig. 11). The field data is only available for the northern region of WFH where the model-data comparisons are performed. The model results are compared by extracting the peak above ground biomass (AGB) on 14th day of the simulation and normalized with the initial above ground biomass. The ratio of $AGB/AGB_{initial}$ is considered as a representative of seagrass growth. We assume that for $AGB/AGB_{initial} > 1$, there is a potential for seagrass growth and for $AGB/AGB_{initial} <1$, the conditions are unfavorable for seagrass growth. In fig 11, the model and field data show a 89% agreement to determine the seagrass growth or dieback. The western region of outer harbor shows seagrass growth potential and agrees with the extent that the seagrass coverage is observed. In the eastern region, the field data shows no seagrass coverage and the model also predicts potential seagrass dieback. The model predicts seagrass dieback because of nitrate loading from shoreline point sources that leads to increased chlorophyll and light attenuation (figures 8a, b). The model and observations do not compare well in the central basin of outer harbor where the model shows seagrass dieback potential while the field data shows presence of seagrass. In the central basin, the field data shows the presence of seagrass while its density remains low in this region. On the other hand, the modelled seagrass suffers dieback due to the bathymetric controls in the deeper central basin (decreased near-bottom PAR Fig. 8c).

Although direct estimates of above ground biomass are not available for West Falmouth Harbor, the model range of 0-114 mmol N m^{-2} is consistent with annual mean *Z. marina* biomass (10-88 mmol N m^{-2}) reported in nearby shallow systems on Cape Cod (Hauxwell et al. 2003) assuming a literature-based average that above ground SAV biomass is 1.5% N. The range in the model is computed based on the minimum and maximum values of AGB during the 18 day simulation period.

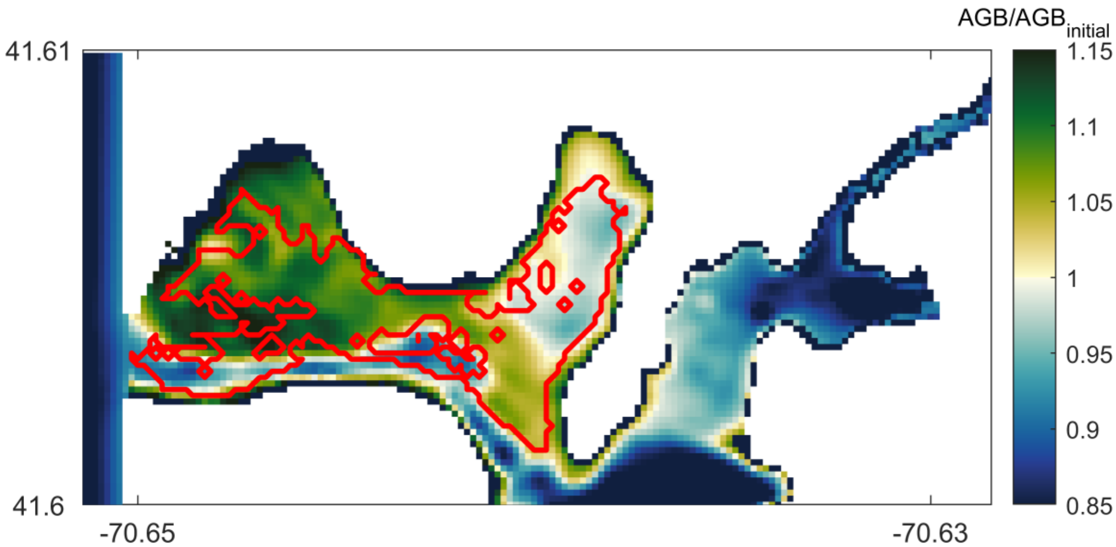


Fig 11: Modeled $AGB/AGB_{initial}$ (above ground biomass) distribution compared with field data showing seagrass coverage extent (red solid line). Values of $AGB/AGB_{initial} > 1$ represent seagrass growth potential and below 1 indicate potential seagrass decline at day 14 of the simulation.

Comment 2: Check code availability and make it clearer which parts of COAWST are a part of the paper. As the editor has indicated, a Zenodo archive, coupled with some indication of which code this paper refers to would be a great help

Response:

We have followed the official USGS policy to archive and release the model. These links detail the process of going through a review and approval process to release USGS software:

https://www.usgs.gov/about/organization/science-support/survey-manual/im-osqi-2016-01-review-and-approval-software

https://github.com/usgs/best-practices

Following these policy steps, the source code was made available for distribution at https://code.usgs.gov/coawstmodel/COAWST.

The major code development that was done for this project is contained within the COAWST folder on the following path.

"https://code.usgs.gov/coawstmodel/COAWST/blob/master/ROMS/Nonlinear/Biology/"

This folder contains several methods of computing water column biogeochemistry. Other than the I/O component of our implementation, the algorithmic development in this study only modifies two files on this path: "estuarybgc.h" and "sav_biomass.h". The file "sav_biomass.h" contains all the newly added equations for the growth of SAV based on the nutrient loading in the water column. The forcings to the SAV growth model (temperature, light, nutrient availability, exchanges nutrients, detritus, dissolved inorganic carbon, and dissolved oxygen) are provided through the file "estuarybgc.h" that calls "sav_biomass.h". The file "estuarybgc.h" solves for the water column biogeochemistry and was based on existing modelling framework developed by Fennel et al. (2006) (also coded as "fennel.h").

Other important paths that existed in the framework prior to the current modeling effort but are being used in the modeling process include:

1. "https://code.usgs.gov/coawstmodel/COAWST/blob/master/ROMS/Nonlinear"-

The main kernel of the 3-D non-linear Navier-Stokes equations is contained within this part and links all the submodels: biological, vegetation and sediment models.

2. "https://code.usgs.gov/coawstmodel/COAWST/blob/master/ROMS/Nonlinear/Vegetation/"

The kernals that account for seagrass-hydrodynamics interactions.

3. "https://code.usgs.gov/coawstmodel/COAWST/blob/master/ROMS/Nonlinear/Sediment/"

The kernals that account for sediment transport.

This information is also added in the code availability section of the current manuscript.

Comment 3: Equations - Equations in 2.2 are very difficult to read with "words" being used as symbols in a lot of cases; especially when "lim" is used in a symbol it makes it difficult to know of this is the mathematical limit of or a symbol at a glance. Symbols such as lambda_SAVmax (eq 3) should be altered to remove operation symbols from them. There are also symbols such as kl. Is this k * l or a symbol kl? I would recommend the use of single symbols where possible and remove as many "words" as possible. Same applies to table 1.

Response:

"lim" is a symbol in the equations and is not defining a mathematical limit. To avoid confusion, it has been replaced with the symbol "lmt".

"$\lambda_{SAV-max}$: Removed the dashed part in the symbol name and the new one is $\lambda_{\mathrm{SAV,max}}$. We did the same change to other variables that had the same issue such as $\lambda_{\mathrm{EPB,max}}$

“kl” – This symbol is changed $klmt$ i.e. the half-saturation for light limitation. The "lmt" part is then consistent with the symbol of light limitation.

The reason we used multiple letters in the equations is to be consistent with the legibility of the code. In the larger framework of the COAWST model where there are several variables, single letter symbols do not suffice.

Minor comments:

Comment 1: Recent observational studies have addressed feedbacks between SAV meadows, current velocity, sedimentation, and nutrient cycling and suggest SAV are ecosystem engineers whose growth can be self-reinforcing.

Response: Modified to : “Recent observational studies have addressed feedbacks between SAV meadows and their role in modifying current velocity, sedimentation, and nutrient cycling.”

Comment 2: Modelled SAV biomass is represented as a function of temperature, light, and nutrient availability and exchanges nutrients, detritus, dissolved inorganic carbon, and dissolved oxygen with the water-column biogeochemistry model.

Response: This sentence is split into two sentences.

“Modelled SAV biomass is represented as a function of temperature, light, and nutrient availability. The modelled SAV community exchanges nutrients, detritus, dissolved inorganic carbon, and dissolved oxygen with the water-column biogeochemistry model.”

Comment 3: Line 25, pg 2 – extra() round reference

Response: The lines 22-25 were altered to remove the extra () reference.

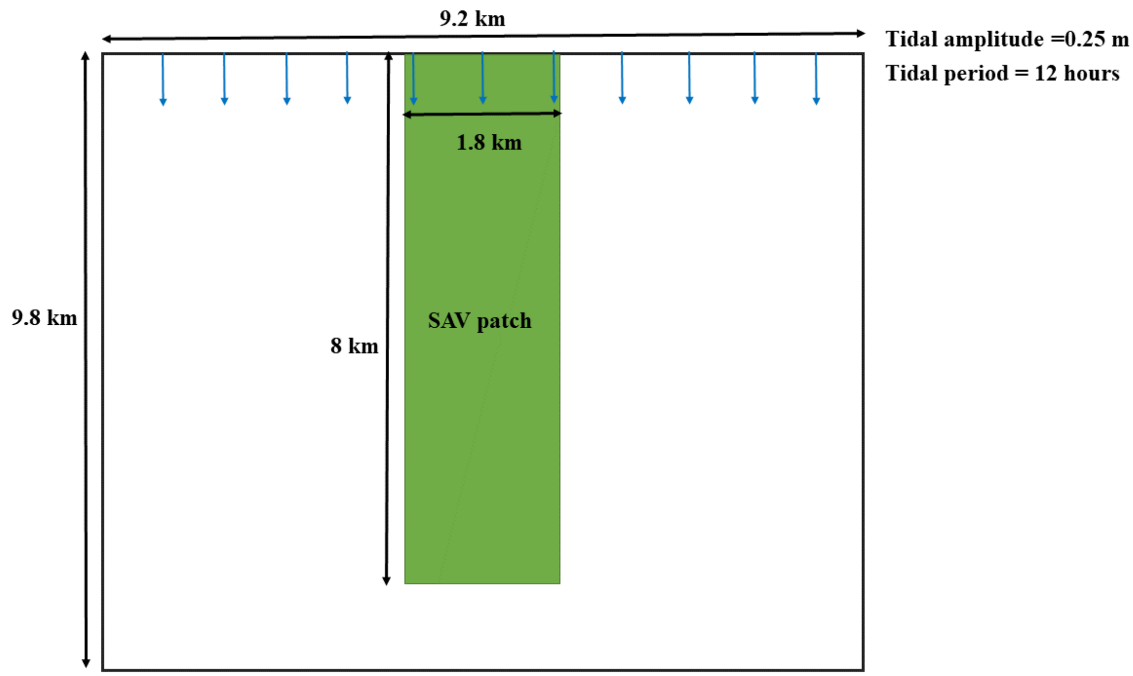
These processes were implemented within the open source COAWST (Coupled-Ocean-Atmospheric-Wave-Sediment Transport) modelling system (Warner et al., 2010) that couples the hydrodynamic model (ROMS), the wave model (SWAN) and the Community Sediment Transport Modelling System (CSTMS).

Comment 4: Line 26 pg.11 typo: diel

Response: Could not find this typo.

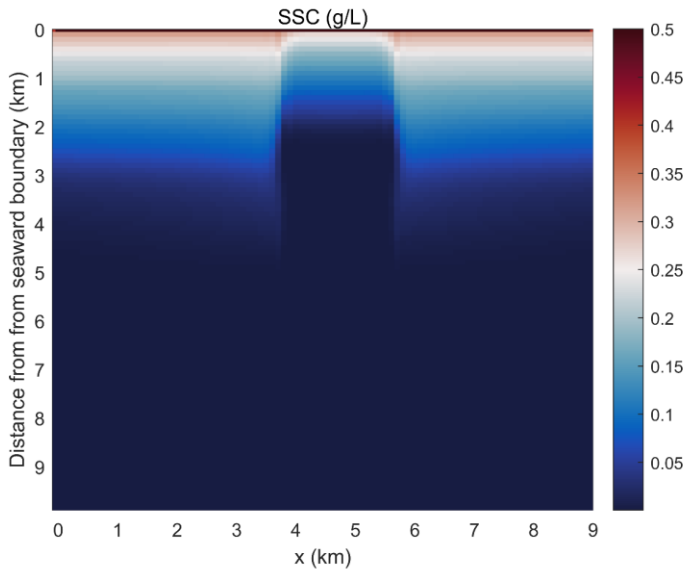
Comment 5: Figure 3 Remove orientation axis. Its plan view, so z isn’t on !

Response: Removed the axis

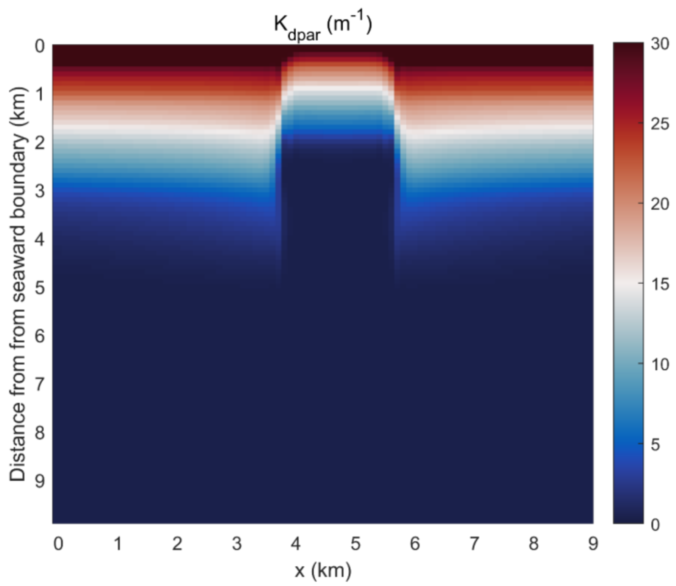


Comment 6: Figure 4 – Capital letters in axes title

Response: Fixed this in the figure.



(a)

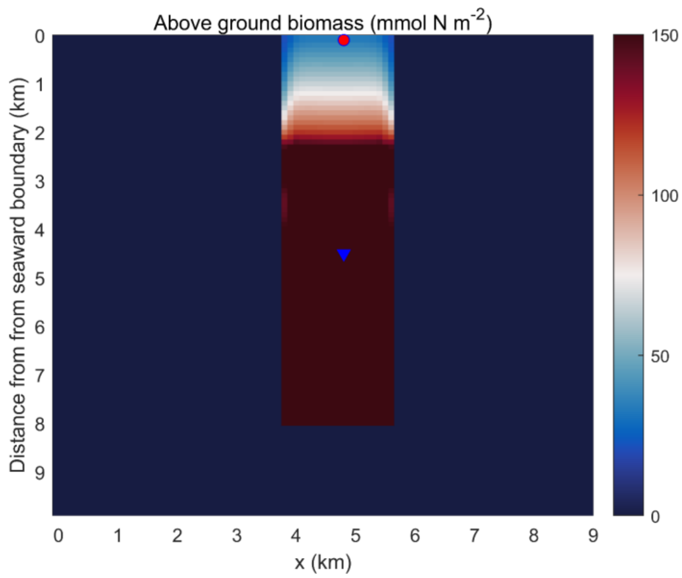


(b)

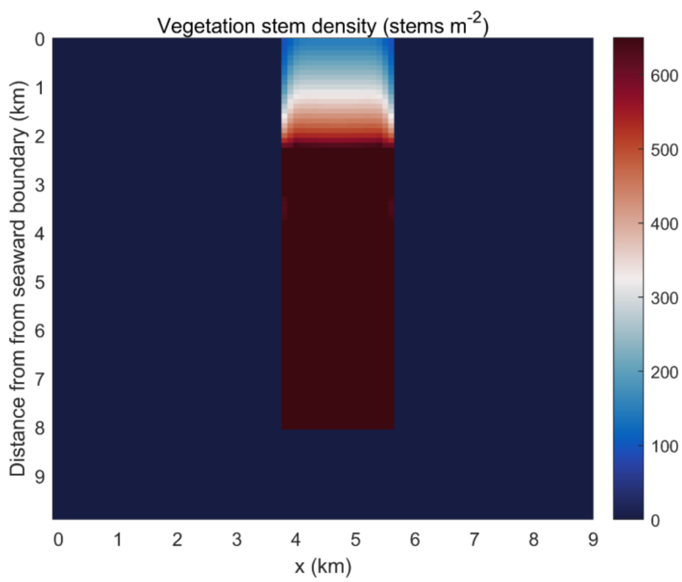
Figure 4: Planform view of (a) depth-integrated SSC, (b) light attenuation averaged over the last day of the simulation in the idealized domain.

Comment 7: Figure 5 – Triangle and dot not explained in caption. Capital letters in axes title

<u>Response</u>: Red dot and blue star represent two points that are located at 0.1 km and 4.5 km into the SAV bed.



(a)

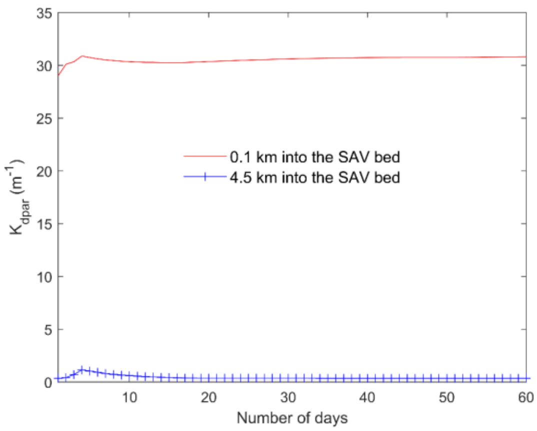


(b)

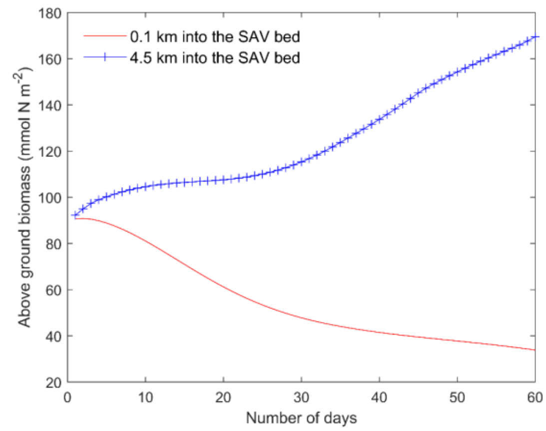
Figure 5: Planform view of (a) above ground biomass and (b) vegetation stem density averaged over the last day of the simulation in the idealized domain. Red dot and blue star represent two points that are located at 0.1 km and 4.5 km into the SAV bed respectively.

Comment 8: Figure 6- Capital letters in axes titles. Remove “Figure” from subcaptions

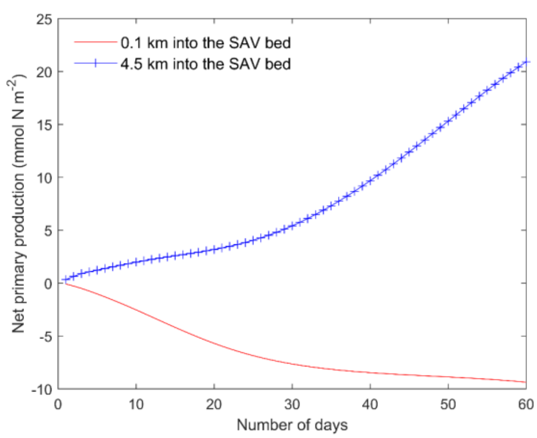
Response:



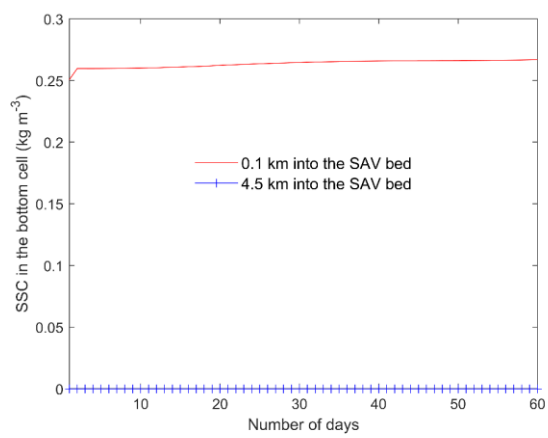
(a)



(b)



(c)

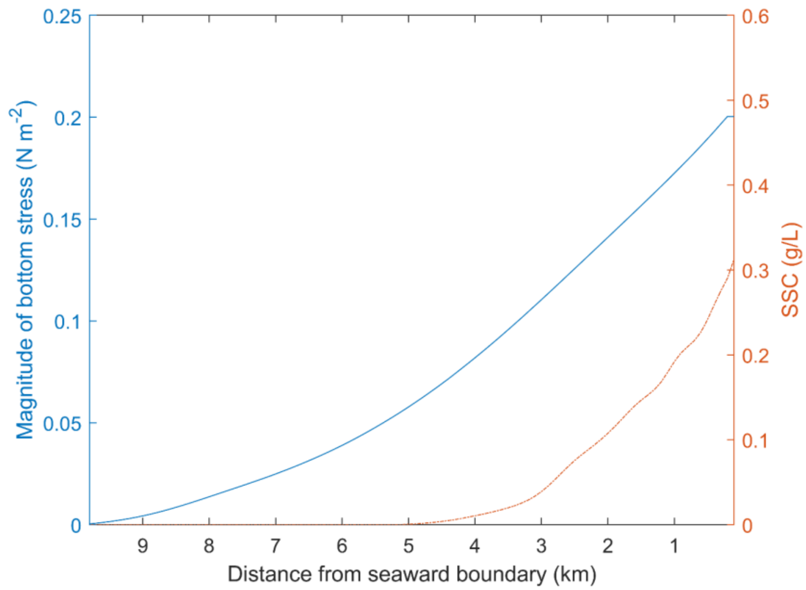


(d)

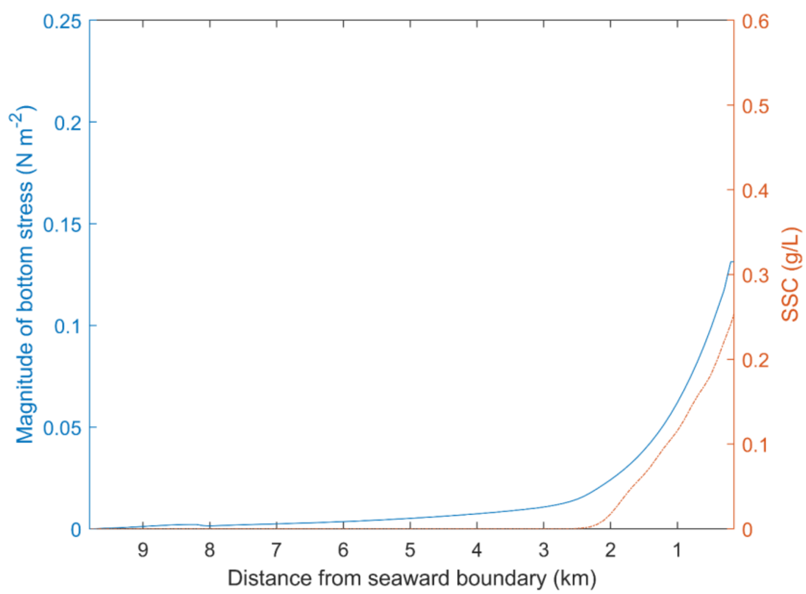
Figure 6: Time-series of a) light attenuation, b) above ground biomass, c) net primary production of SAV ($pp_{SAV} - agar_{SAV} - bgr_{SAV}$), and d) SSC in the bottom cell averaged every day from the two locations identified in Fig. 5a.

Comment 9: Figure 7 – Capital letters in axes titles

<u>Response:</u>



(a)



(b)

Figure 7. Magnitude of bottom stress (left) and depth-integrated SSC (right) at the end of the simulation plotted along the y axis of the idealized domain at two locations, including one outside (x=1.8 km; panel a) and one inside the SAV bed (x=4.8 km, panel b).

Comment 10: Figure 8 – replace color scheme with color-blind friendly scheme.

Response: Used the "balance" map from the cmocean package

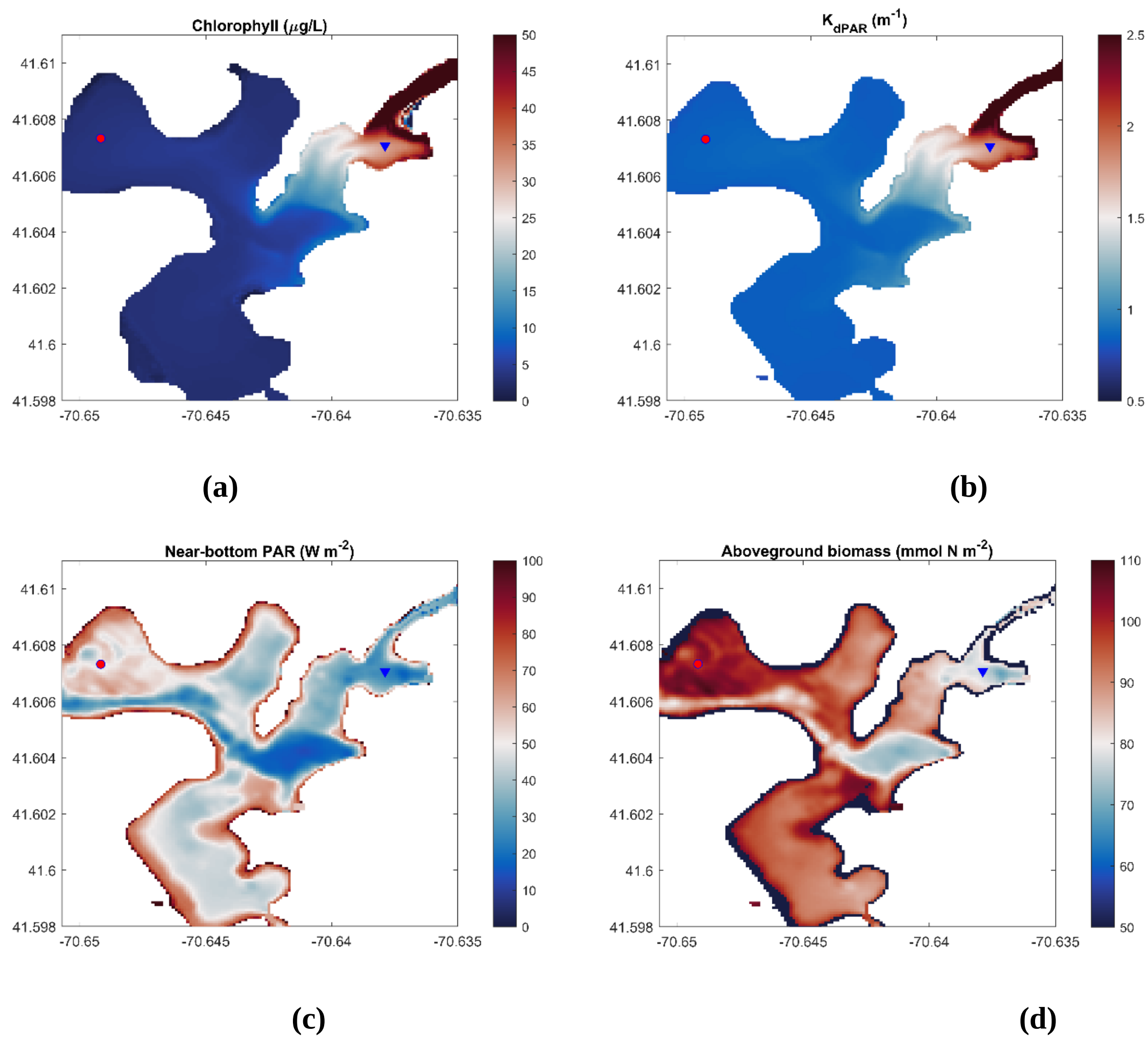


Figure 8. Mean over 22 days of a) depth-averaged chlorophyll, b) light attenuation, c) near-bottom PAR, and d) peak above ground biomass at day 14 of the simulation. Red circle indicated outer harbor (left) and blue triangle indicated inner harbor (right) points for time-series data in Figure 9.

Comment 11: Figure 10 – as above

<u>Response</u>: Used the “balance” map from the cmocean package

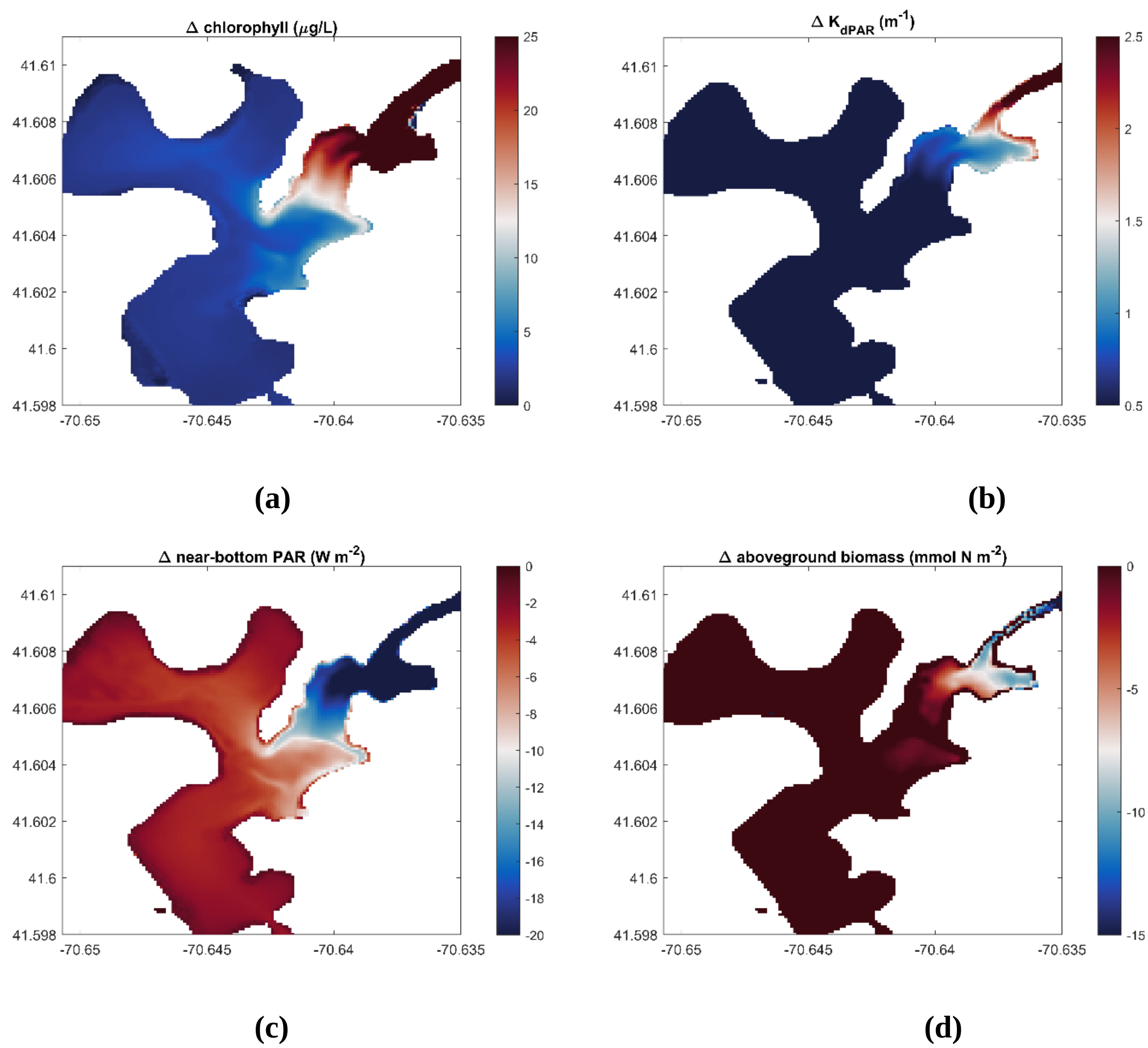


Figure 10. Change in outcomes between impacted and non-impacted scenario (nitrate loading scenario – no loading scenario). Difference in mean over 22 days of (a) depth-

averaged chlorophyll, (b) light attenuation, (c) near-bottom PAR, and (d) peak above ground biomass at day 14 of the simulation.