Anonymous Referee #1

In this manuscript F-Pedrera Balsells and colleagues present the results of a numerical modelling exercise in which the role of the wind and land-based freshwater discharge on the spatial distribution of phytoplankton in a microtidal bay is explored (Fangar Bay, SP). This is done by altering starting conditions and forcings on an existing coupled ROMS-NPZD model of said bay. In short, the authors conclude that the wind direction and intensity do indeed play a role, potentially causing large heterogeneity in phytoplankton concentrations in what is a relatively small bay. The manuscript is very clearly written with equally clear figures. The aims of the study are well articulated and are also addressed in the results and discussion. Since the modelling setup has previously been published I assume that the model represents the system well. However, three things are lacking for me: (1) more validation of the results coupled to (2) a longer reported output of the model, and (3) some sort of ecological discussion beyond a mention of the biomass.

The authors acknowledge the helpful comments and corrections of Reviewer 1, which helped to improve the quality of the manuscript. Below, each comment is answered point-by-point. We have analyzed your comments carefully. We have included the main corrections in the manuscript and the response to the reviewers' comments which we hope to meet with your approval. The answers or explanations are written in blue, and the newly added contents are in italics blue.

1. The validation of experiments is presented to the reader as two figures of satellite output (figure 5). These images to me personally are not very convincing and I would like to see more satellite images or field data and model output be compared, possibly also through difference plots such as figure 4a. If a time series of photos can be found, then perhaps multiple successive satellite images can be compared to show how realistic the model output also is when a longer output is considered.

We agree that the quality of these satellite images are not as we desired. The images shown in the paper are from a selection process of post-wind events. This means that the potential figures are somewhat limited and many of them do not present enough clarity because of cloud cover. Other images are shown in F-Pedrera Balsells et al. (2021), with similar "low quality". As you suggest the coupled model validation may be weak, so in the new version of the manuscript we include a qualitative validation of model outputs and *in situ* measurements which, jointly with remote sensing, we think provides credibility to our analysis. We also are considering improving these images for future work, using new satellite products combined with additional *in situ* field campaign oriented mainly for post-wind events.

2. Now the output of 5 days is presented, but it should be longer. Looking at figure 2 D for example, the phytoplankton concentration in M4 (UW12) is increasing exponentially. When I see this, I wonder how high the phytoplankton concentration gets on such a short timespan and whether this is realistic. What are the peak concentrations that are reached in this bay in the year? The dynamics of zooplankton are only mentioned, since the output is too short to show the lagged response of zooplankton the phytoplankton availability. Also, once such a wind-event occurs and all the nitrogen has been depleted, how long does it take before a second bloom occurs? Or how long before the dynamics return to "normal" for example? These are all dynamics that can be explored in this manuscript to make it more fulfilling. Some of these things are mentioned in the conclusion as "future work", but since the modelling setup was all there from previous work I wonder why some of it was not already included (e.g. including P).

The complexity of the hydrodynamic and biological variables suggests to face the analysis using "idealized" or "simplified" conditions instead of realistic (and long-term) simulations. We proved that these short simulations (of the order of the wind duration events) have been useful to understand the main hydro-biological coupled processes. It is true that more than 5 days would be required to simulate the evolution of the biological variables, but we wanted to adjust the simulations to the duration of the wind events observed in the region (Ràfols et al. 2017), to explore the response to this phenomenon (i.e. short-term response). This wind duration seems to be too short, but in order to understand the fundamental processes and the link of biological and hydrodynamic variables this duration was enough. In addition, we have observed that the spatial and temporal variability of Chl *a* is quite complex consistent with other coastal embayments (Demers et al., 1979; Díez-Minguito & de Swart, 2020; Masson & Peña, 2009; Mishra, S.; Mishra, 2012), so, using time limited simulations we tried to minimize the uncertainty and complexity isolating simple mechanisms. We think that is approach is quite new and may provide guidelines for the investigations of other regions focusing in specific events instead long-term simulations. In this sense the Introduction and Discussion has been modified to include this relevant point. As you suggested as additional simulations have been carried out paying attention to long-term evolution. Simulations have been carried out for up to 10 days (F-Pedrera Balsells et al., 2020). These simulations become pointless according to the results of primary production as we mentioned in the new version of the manuscript (see L301-310). However, we don't include these figures (see Figure R1) to not confuse the reader. Figure R1 shows how the Chl *a* concentration reaches values up to 500 mg·m^{-3} at some of the control points. Probably, the reason for these senseless results is based on the short duration of the simulations and the fact that the model is not taking into account phytoplankton consumption, so the values shoot up. It also does not take into account the interaction of nutrients, phytoplankton and zooplankton with outside the bay (Open Sea), so larger concentrations accumulate within the bay. Also, we have tested long simulations (10 days) where the wind stops after five days. We observed that these does not provide any direct conclusions and requires further analysis.

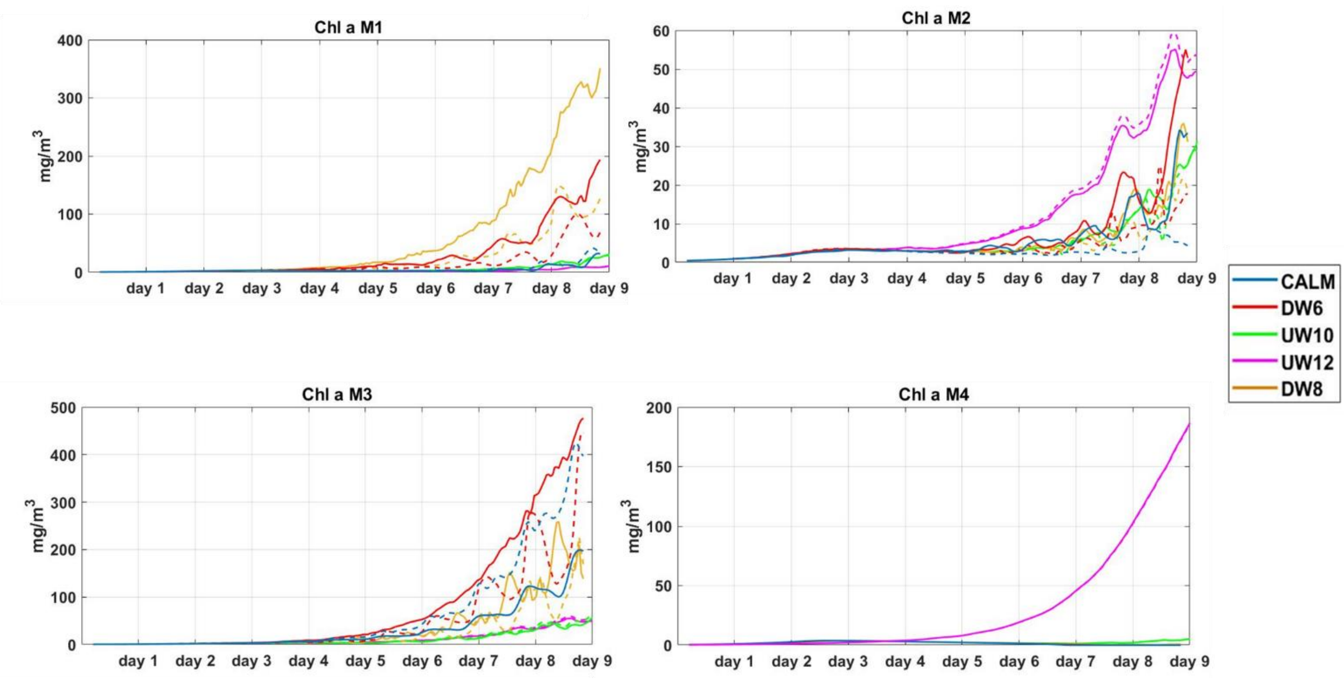

Figure R1. Time series of the Chl a *at different points of the bay: (a) M1, (b) M2, (c) M3 and (d) M4. The different colours show the different simulations with in function of the wind. Solid lines* *show the numerical results at the sea surface, dashed line shows numerical results at the sea bottom.*

Maximum reported concentration of Chl *a* measured in Fangar Bay has been 25 mg·m^{-3} in September 1983 at 4 m depth (Delgado 1987) and 11 mg·m^{-3} in October 2005 (Quijano-Scheggia et al., 2008). Also, vertical variability of Chl *a* has been measured within the Bay of the order of 5 mg·m^{-3}, suggesting the influence of the forcing mechanics and its interaction with primary production (L264-267).

P limitation has not been introduced in this work because the model used, ROMS-NPZD, does not include this mechanism. This is a model based on the N cycle only. We explain this in lines 335-339.

3. In the first sentences of the introduction a mention is made of socio-economic services, problems caused by aquaculture, ecosystem value, … Please couple back to this in the discussion. Because of the very short output of results, and a no discussion of the meaning in a biogeochemical sense, it is not clear why the results are important.

The new version of the manuscript includes a new paragraph in the Discussion analysing the importance and the potential interest of our investigation in terms of the bay activities management (e.g aquaculture, early warning systems, operational products, natural based solution, etc.) which pointed out the importance of the results.

L 372-386: Added in the manuscript: "*Hydro-ecological coupled models can be useful in the characterization of the evolution and prediction of nutrient variables as a tool of aquaculture management. Cerralbo et al. (2019) suggest the need to implement numerical tools in Ebro delta bays for early warning systems to prevent eventual mussel mortality during summer. Moreover, it is possible to combine this type of models, where the biogeochemistry of the bay is analyzed together with the hydrodynamics, with simpler models such as those of carrying capacity (Weitzman and Filgueira 2020; Guyondet et al., 2022) for better aquaculture management including harvest planning and early warning systems to avoid mortality (Hargreaves 1998; Yu and Gan 2021). They can even be extended to socio-economic study models of the area to cover all aspects related to aquaculture activity. Also, the use of hydrodynamic and biological models supports Nature Based Solutions (NBS) as an alternative to traditional engineering, with growing relevance to design integrated solutions for building coastal bay resilience (Pontee et al.,2016; F-Pedrera Balsells et al. 2020b) under climate change. Initial set of environmentally adapted alternatives in Fangar Bay may be: i) self-regulating connection with the open sea, ii) adjustable connection with land discharges or iii) adaptive reallocation of aquaculture activities; whose will require specific investigations on the hydro-biogeochemical response* "

Minor remarks.

L20: no dynamic

Corrected. Thanks.

L35-36: This sentence seems out of place here.

Corrected. Thanks.

L39: may control the inner water

Corrected. Thanks.

L42: Please add older references here describing this phenomenon.

Added in the text: de Madariaga, 1995.

L48: create hypotheses and numerical experiments

Corrected. Thanks.

L50: What is meant with "the biological mechanisms"?

Changed in the text to clarify: "physical mechanisms and biological behaviour mechanisms become more complex due to the geometry of the basin itself"

L54-55: …an important source of both organic and inorganic nutrients for coastal areas.

Corrected. Thanks.

L59: a larger variability compared to other Mediterranean coastal domains (?). In more northern latitudes such seasonality is highly common. Please indicate here also the phytoplankton values that can be expected throughout the year, and how they usually fluctuate.

Changed in the text to clarify: *In this sense, Chl* a *concentrations in Fangar Bay tend to show a distinct seasonal fluctuations entailing larger variability in comparison to other coastal domains such as the Ría de Arousa (Ramón et al., 2007) or Alfacs Bay (Artigas et al. 2014)* (L57-60).

L68: spatial-temporal -> spatio-temporal.

L70: Corrected. Thanks

L77-82: This paragraph is not necessary as this is obvious from the text itself.

OK, so we have removed it from the text.

L87: I don't understand how the delta can reach 25 km offshore, please clarify this.

The Delta itself, the deltaic sediments that form it, covers an area of 25 km (figure R2). However, if this information leads to confusion, we have decided to delete this sentence so as not to confuse the reader.

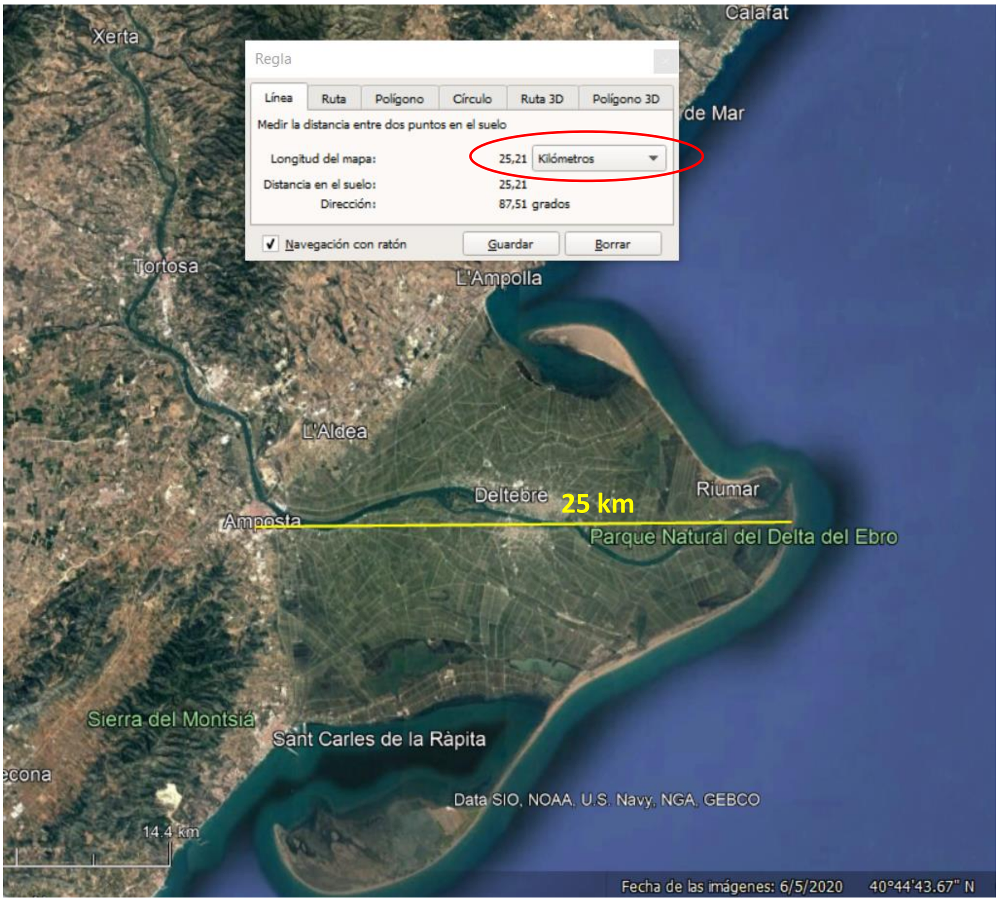

Figure R2. Distance of the Delta offshore as seen from the satellite

L108: How does nutrient input fluctuate with this opening and closing of the canals?

When the channels are closed (because drying process of the rice fields), there is no new input of nutrients from freshwater, so the bay functions only with the nutrients present in the water and those that can be supplied from the open seawater that enters from the bottom.

L129: A set of numerical experiments was…

L130: Corrected. Thanks

L136: double brackets around the references.

L138: Corrected. Thanks

L145: coupled with the ROMS model

L147: Corrected. Thanks

L151: What is the mole fraction of Chl a? I do not see it in the table.

L153: Right. Added in the text: 893.51 g/mol.

L157: Six experiments were designed with varying wind intensity and direction, and varying freshwater input from channels.

Remaining questions about the model after reading the materials and methods and appendix:

- Does it include wave activity?

No, we did not introduce wave activity into the model simulations. Here is a graph of the significant swell height in the Fangar Bay. The maximum swell we can find are waves of 0.5m (see Figure below). Moreover, to reach this order of magnitude, a very strong wind must be blowing, and the duration of this swell is only a few hours, so does not seems very relevant for phytoplankton dynamics.

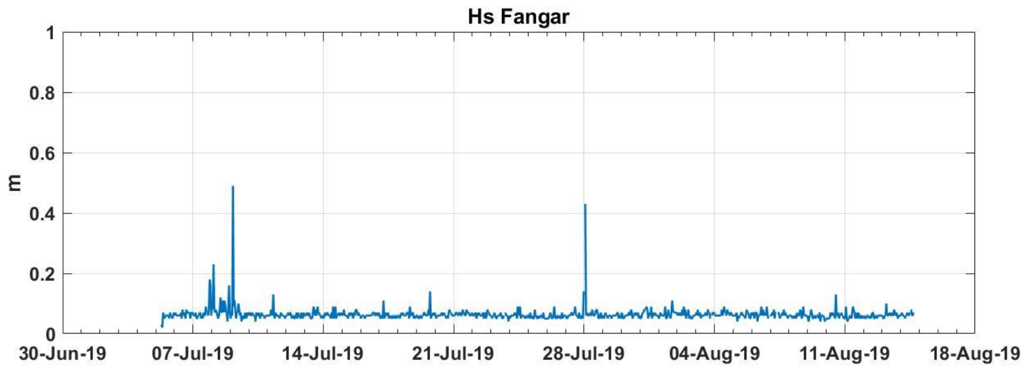

Figure R3. Significant wave heights in Fangar Bay

- There is a finer scale 23 m grid available, why was this not used? Please also show

the performance of the 70 m grid in the appendix as validation.

In previous tests of the modelling scheme performance, it was noticed that the results of the 23 m grid did not provide significantly different results from those of the 70 m grid, although it did imply an important increase of the computational time. We have corrected the text to avoid confusion, removing the "23 m" paragraph.

- Do the channel inflows represent a nutrient input in ROMS as well?

Yes, both freshwater inputs from the drainage channels have a nutrient input in the model (L169-170).

- Are processes such as sediment input and water column turbidity included (referred

to in line 270) and if so do they affect the light profiles used in the NPZD model?

No, sediment input and turbidity are not taken into account in our simulations. Chlorophyll dynamics are quite complex in this area and the purpose is to simplify the processes in order to obtain robust conclusions. Also, the biochemical model considers simplified processes, which the equations are photosynthetic growth and nitrogen uptake by phytoplankton, grazing of phytoplankton by zooplankton, mortality of phytoplankton and zooplankton, and sinking and remineralisation of detritus. Suspended sediment and turbidity entails wave and sediment transport mechanics which are included in the future work (see L417-L421).

L182: Four points within the bay were chosen

L184: Corrected. Thanks.

L187: consistently - > consistent

L189: Corrected. Thanks.

Figure 2: Why are the results of UW12fr not shown?

We considered that for what we want to show in this figure (wind event response), the results of the UW12fr (freshwater discharge) simulation were not relevant.

L195-196: Remove “for strong wind episodes”.

Corrected. Thanks.

L202: Leading to a larger presence

Corrected. Thanks.

L204: lesser -> less

Corrected. Thanks.

L208: perhaps change “comparison” to “similarity”? Also suggestions are best kept for the discussion.

Corrected. Thanks.

L210: Please show longer output so that these differences in growth rates can be observed by the reader as well.

L202: As mentioned above, the approach of this study has been to simplify the processes using short simulations, due to the complexity of the chlorophyll evolution and the hydrodynamics of the area. Thanks to our previous work (F-Pedrera Balsells et al., 2020, 2021) we have been able to quantify the intuitive behaviour of the dynamics within the bay, so our manuscript pursues to take advantage of this skills to face simplified numerical modelling in order to investigate the Chl *a* as a function of the different winds. We think that is approach is quite new and may provide guidelines for the investigations of other regions.

L239: Is it possible to add a panel to figure 4 with the nitrate concentrations? I wonder if the increasing phytoplankton concentrations may also be caused by nutrient inputs in the plumes.

Here we show the NO_3 concentration. As it can be seen in Figure R3, there is nutrient input at the initial moment (continuous lines) and then there is a consumption by phytoplankton that reduces this concentration (dashed lines). With this simple model, where there is no further contribution of nutrients neither by the suspended sediment nor by the input from the open sea they are almost depleted by the end of the simulation. Added in the manuscript, L246-250.

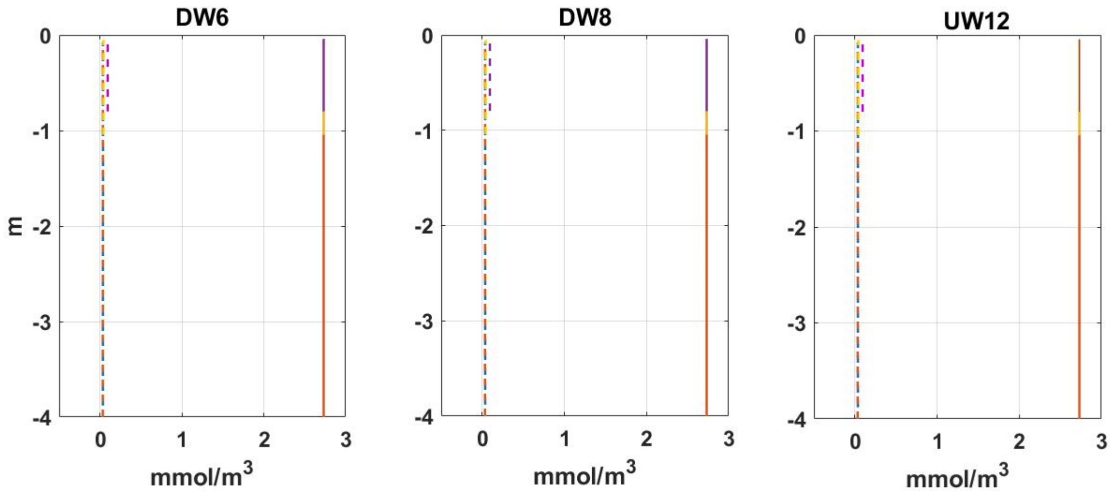

Figure R4. Nitrates concentration. The solid lines show the initial concentrations and the dashed lines show the final concentrations

L271: Again, please discuss how these factors are included in the ROMS-NPZD model and how they have affected the phytoplankton dynamics.

As mentioned above, the NPZD model only accounts for nitrate as a nutrient in addition to photosynthetic growth and nitrogen uptake by phytoplankton, grazing of phytoplankton by zooplankton, mortality of phytoplankton and zooplankton, and sinking and remineralisation of detritus. We suspect that the sediment resuspension and turbidity has influence on the dynamics but this would increase the complexity adding a sediment transport model. However, in discussion we draw some ideas to face this point in future works based on our current skills (see L414-419).

L274: is complex due to its intricate bathymetry. (its shallowness is part of the bathymetry already).

Corrected, thanks.

L275-281: please move this part to the introduction to better frame the study.

Done.

L281: What is meant with “the bio-hydrodynamics are well defined” ?

L79: In the previously published article (F-Pedrera Balsells et al, 2021) we explained the behaviour of surface chlorophyll concentration according to wind-driven currents.

L282-283: Where is the magnitude of currents and the formation of fronts discussed in the results section?

The influence of wind on currents can be seen in the freshwater plume shown in Figure 3b. The magnitude is also included in the new version of the manuscript (L297).

L293: the presence of sea breezes -> the absence of sea breezes?

This means that during periods of calm wind or even sea breeze winds, the phytoplankton biomass is governed by the estuarine circulation.

L304: Non-uniformly -> non-uniform / heterogeneous.

Corrected, thanks.

L307: What is this classification, why does it matter, and in which typologies may Fangar bay be included?

L331-334: Jiang et al. (2020) in their paper entitled *'Drivers of the spatial phytoplankton gradient in estuarine-coastal systems: generic implications of a case study in a Dutch tidal bay'* classify estuaries according to the distribution of phytoplankton biomass. We refer to this article because it is one of those which classifies estuaries according to a biological parameter. With our results we have determined that the Fangar Bay can be classified according to this method in an estuary with an irregular biomass pattern, since depending on the wind blowing we obtain one pattern or another of distribution.

Common spatial gradients	Example ecosystems and references	Flushing mechanisms	Main drivers of phytoplankton biomass
Seaward increasing (Phytoplankton biomass; Land – Ocean)	(1) Oosterschelde, the Netherlands (this study)	Tide dominated	Grazing loss and tidal import
	(2) Rías Baixas of Galicia, Spain (Figueiras et al., 2002); Willapa Bay, USA (Hickey and Banas, 2003; Banas et al., 2007)	Tide dominated	Tidal import
	(3) Chilika Lagoon, India (Srichandan et al., 2015)	River dominated	Light limitation
Seaward decreasing (Phytoplankton biomass; Land – Ocean)	(1) Westerschelde Estuary, the Netherlands and Belgium (Kromkamp and Peene, 1995; Krompkamp et al., 1995; Muylaert et al., 2005; Soetaert et al., 1994, 2006)	River and tides, or river dominated	Salinity stress, grazing loss, and transport
	(2) Chesapeake Bay outflow plume, USA (Jiang and Xia, 2018); Mississippi River plume, USA (Gomez et al., 2018)	River and tides	Nutrient limitation
Chl-a maximum (Phytoplankton biomass; Land – Ocean)	(1) Chesapeake Bay, USA (Jiang and Xia, 2017); Delaware Bay, USA (Fisher et al., 1988); York River, USA (Sin et al., 1999); Neuse-Pamlico Estuary, USA (Valdes-Weaver et al., 2006); Logan River and Moreton Bay, Australia (O'Donohue and Dennison, 1997)	River and tides, or river dominated	Upper reach limited by light or transport loss; lower reach limited by nutrients
Spatially uniform or weak spatial gradient (Phytoplankton biomass; Land – Ocean)	(1) San Francisco Bay, USA, after 1987 (Cloern et al., 2017; Kimmerer and Thompson, 2014)	River and tides	Grazing loss
	(2) Hudson River estuary, USA (Fisher et al., 1988; Howarth et al., 2000; Strayer et al., 2008)	River dominated	Transport and grazing loss
Patches/irregular patterns (Phytoplankton biomass; Land – Ocean)	(1) Baie des Veys Estuary, France (Grangeré et al., 2010)	River and tides	Grazing loss
	(2) Krka Estuary, Croatia (Ahel et al., 1996)	River dominated	Point-source nutrient input
	(3) St. Lucia Estuary, South Africa (van der Molen and Perissinotto, 2011)	River dominated	DIN:DIP ratio, salinity, temperature, and irradiance

Figure 13. Common spatial patterns of phytoplankton biomass in estuarine–coastal systems. For comparison with the Eastern Scheldt, example ecosystems for each type are given along with references, the dominant flushing mechanisms, and main drivers of phytoplankton accumulation.

L316-317: Which data is being interpreted?

L337: An interpretation of the nitrogen data, as we do not take into account the phosphorus limitation in these simulations.

L325: Ultimately, in a small, shallow,….

Corrected, thanks.

L329: So please show also plots of the nitrate concentrations as suggested previously. It is now not really clear whether the plume effect is only due to the nutrient inputs or also the salinity differences. It would be interesting to also discuss which phytoplankton species are present: are these marine species or more estuarine adapted species that thrive towards fresh water?

Added in figure 4 in the manuscript.

L331: Chl a concentrations are higher in… and decrease as salinity decreases.

Corrected, thanks.

L350: Which in situ observations are presented in the manuscript?

L385: Right, in this manuscript, there are no *in situ* observations. Thanks.

Figure 6: Very nice figure to explain what is going on. I suggest to use it also in the discussion to clarify processes.

We agree. We have moved the figure 6 to the Discussion and added a sentence (L328).

L373: I am missing more evidence of these different phytoplankton patterns in need of an explanation, besides the two satellite pictures shown.

L411. Below are shown all the available Sentinel 2 images for the study period. Here is a summary of some of them where you can see the same behaviour in the two situations we mentioned: downwind and upwind periods. We did not add more figures to not confuse the reader.