

## ***Interactive comment on “Behaviour of Dissolved Phosphorus with the associated nutrients in relation to phytoplankton biomass of the Rajang River-South China Sea continuum” by Edwin Sien Aun Sia et al.***

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**General comments** The manuscript describes the results of water quality sampling procedures for the Rajang River - South China Sea continuum. The manuscript represents a contribution to scientific progress, presenting new spatially and seasonally varied data for the area of interest. The scientific methods and assumptions are clearly outlined, the estimation of DIP export to the sea is useful for understanding the system behavior. R: We would like express our gratitude to Ref #1. The comments and suggestions provided helped to improve the manuscript significantly.

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However, the major comments are related to a better definition of goals of the study, data visualization and interpretation of the results. R: Noted and improved as outlined below.

In my opinion, the data collected and analyzed, especially nutrient concentrations could be represented better, so that another type of comparison could be applied focusing more on measurements (e.g. faceted boxplots). R.: Thank you for highlighting this. For Figures 2-4, we chose to display nutrient concentrations on a map to ease the discussion of the spatial patterns. For Figures 3-6, the ratios help us to illustrate the importance of specific components. The theoretical line for both DIP and DOP concentrations were used to reflect conservative mixing and enable a discussion on the addition or removal of DIP/DOP. We do, however, agree that boxplots of the nutrient concentrations would be useful too and will add them in the supplement.

For example, it is hard to identify the type of the sediment or the time of the sampling in Figures 2-4 and relate them to Table 1. R: We do agree and will add the figures in the supplement to ease the discussion.

In addition, I would focus more of the actual measurements, rather than ratios, or report both (Table 1, Figures 2-4). R: Thanks for the suggestion. All values are now reported in Table 1. As mentioned above, new figures will be added in the supplementary section.

I would be more careful with statements about phytoplankton preferences of DIP and DOP based on correlations of these variables, in addition to low nutrient ratios leading to lower phytoplankton biomass. Furthermore, I think that conclusion about a particular nutrient limitation based on the ratios might be misleading, unless there are clear indications of low nutrient concentrations. The ratio can be high, however the concentrations of bioavailable nutrients could be also high, thus none of the nutrients might be limiting phytoplankton growth. R: Agreed and thank you for pointing this out. The nutrient concentrations are presented in the results section. We will add a note on

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the nutrient concentrations in the discussion and revise our argument regarding the correlation to phytoplankton.

Specific comments 1. 19-21 Rework the sentence “..for example, despite. . .” R: Done.

2. 25 “distribution fate?” R: The sentence was paraphrased to the following: Two sampling campaigns (August 2016, March 2017) were undertaken along ~300 km of the Rajang river-South China Sea continuum to study both spatial and seasonal distribution of nutrients along the continuum.

3. 25-27 Place abbreviations of water quality samples in parenthesis R: Agreed, changed as recommended. It now reads: The analyses for nutrients encompass both inorganic i.e Nitrate (NO<sub>3</sub><sup>-</sup>), Nitrite (NO<sub>2</sub><sup>-</sup>), Ammonium (NH<sub>4</sub><sup>+</sup>), Phosphate, DIP (PO<sub>4</sub><sup>-</sup>) and Silicate, (dSi) as well as organic i.e dissolved organic nitrate (DON) and dissolved organic phosphate (DOP) fractions.

4. 30-32 It is hard to understand what is “removal” means. Did DIP decreased by 57.78%? R: Thank you for pointing this out. The term “removal” here refers to the terms utilized in the conservative index of mixing. The sentence now reads: “Both DIP and DOP exhibited non-conservative behaviour in the mixing according to the conservative index of mixing.”

5. 32-33 Suggest rephrase, not clear: The bulk = major fraction of? R: Agreed, changed as recommended.

6. 33-35 Which preference is it? R: The term “preference” was changed with “stronger correlation”. The sentence now reads: Spearman’s correlations show that there was a stronger correlation of Chl a with DOP as compared to DIP when its concentrations are higher during the wet season.

7. 36-38 Back to general comments: what if the increased NO<sub>3</sub>:DIP ratio in wet season was due to higher discharge and consequently loading of NO<sub>3</sub>? How can ratios lead to anything? R: Thank you for this. It was assumed here that the wet season would result

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in different loading of the different components. Based on the phytoplankton biomass, the lower biomass in the wet season justifies the assumption that it is probable that only the NO<sub>3</sub> component increases, thus, increasing the ratio.

8. 65-67 Rephrase the sentence R: Agreed, this now reads: Due to the rapid economic development as a result of population growth, this results in the extensive modification tropical South East Asian rivers and degradation of catchments (Jennerjahn et al., 2008; Yule et al., 2010).

9. 76-79 Too convoluted sentence, suggest divide into 2 R: Agreed. The sentences now read: However, the Rajang river is tidal influenced and consists of fluvially-driven inputs of terrestrial mineral soils in the upper altitudes. It also drains peat domes in the lower altitudes (towards the coastal regions). Thus, it is imperative to understand the anthropogenic variability in nutrient dynamics in the landscape to better understand how such systems may respond to disturbance.

10. 81-83 Too convoluted, suggest divide into 2 R: Agreed, the sentences now read: A macronutrient that is essential but often limiting in freshwater systems is phosphorus (Elser et al., 2007). Under specific conditions, this macronutrient also limits the primary productivity of terrestrial and coastal ecosystems (Street et al., 2018; Sylvan et al., 2006).

11. 85-87 Rephrase, too wordy R: Agreed. The sentences now read: On a global scale, it was estimated that the riverine DIP loading for the world’s largest rivers is 2.6 Tg yr<sup>-1</sup> (Turner et al., 2002). These rivers represent 37% of the earth’s watershed area and half of the earth’s population.

12. 93-112 Talking about Carbon here, but that is not the focus of this study. Basically there is a need in a smoother transition between the gaps in knowledge and the goals of the study R: Thank you for highlighting this. We have modified this paragraph. The paragraph now reads: The disturbance of peatlands due to anthropogenic activities such as deforestation and conversion of peatlands for agricultural activities poses a

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threat to the environment. As the carbon pools in tropical peatlands are globally significant, with the current estimates ranging from 40 to 90 Gt of C (Yu et al., 2010; Page et al., 2011; Warren et al., 2014), there is cause for concern. This is because such peat systems are typically ombrotrophic (i.e nutrient limited) whereby additions of nutrients from anthropogenic activities would lead to a significant increase in the oxidation of soil organic matter (Murdiyarto et al., 2010). This peat soil, when disturbed, changes from carbon sink into carbon source, contributing to the greenhouse gases in the atmosphere (Hirano et al., 2012; Hooijer et al., 2010). Recent studies of lateral transport of CO<sub>2</sub> in tropical peat-draining rivers (Müller et al., 2015; Wit et al., 2015) showed that the tropical peat-draining river of Maludam National Park seems to have a moderate amount of outgassing of CO<sub>2</sub> as compared to other peat-draining rivers globally. While the Rajang River is considered a medium-sized river based on its discharge (Sa'adi et al., 2017), 11% of its catchment area is part of the 15-19% global carbon peat pool in Southeast Asia (Page et al., 2011). Therefore, due to the knowledge gaps of tropical peat-draining rivers, particularly the Rajang River, it is essential to understand the influence of peat on the riverine nutrient (particularly phosphate) loading into the South China Sea. As the South China Sea supports one third of the global marine biodiversity (Ooi et al., 2013), the contribution of the Rajang River towards the South China Sea in terms of primary productivity cannot be ignored.

Therefore, the aim of this study is to 1) better understand the spatial and temporal distribution of nutrients in the Rajang river, with particular focus on dissolved inorganic phosphate (DIP) and dissolved organic phosphate (DOP) in the Rajang River with consideration to the peat-draining nature, diverse inputs and influences and 2) consequentially determine its influence on the phytoplankton biomass.

13. 118-120 Should go to figure caption. And similar paragraphs just occupy space and R: Agreed. The sentence "The red triangles represent the samples collected from the dry season whereas the blue circles represent the samples collected for the wet season." was removed.

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14. 136-137 Change to "which can be thicker than 1 m" R: Agreed, changed as recommended.

15. 155-160 All these categories and classifications should be visualized on a study map (Fig. 1) R: The categories are rather difficult to visualize on a study map as it the main underlying classification is based on salinity does change according to seasons. We will try and create a supporting figure displaying the categories on a map.

16. 164-165 So in Methods it is stated that there were 2 surveys, while in Abstract 3 sampling campaigns (Line 23) are mentioned. How many were there? R: Thank you for pointing this out. There are 2 surveys. The value in the abstract was changed.

17. 194-201 Looks more like discussion R: Thank you for this. This was initially part of the discussion, but moved to the method section. We have moved it back to the discussion section.

18. 227 Change to "obtained from" R: Agreed, changed as recommended.

19. 248-254 Very confusing way of writing the equation. Why not state the equation, number it and explain the conversions, variables and units in the text? R: Agreed. The changes have been made in the corrected manuscript.

20. 260-262, 273-274 Again, should be in a figure caption, or removed. It is a strange way to start a paragraph/section R: Agreed, the sentences were removed.

21. 291 Starts with the same information as in 285. This should be cleaned R: Agreed, the sentences from 291 - 295 were removed.

22. 316-317 DIN:DIP would be definitely correlated with DIP, because there is DIP on both sides R: The term "correlated" was removed and replaced with "attributed". The sentence was to demonstrate that the high ratios were not due to the reduction in nitrogen but due to the lower overall DIP concentrations.

23. 320-321 Change or remove this sentence R: Agreed. The sentence now reads:

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“Hence, for comparisons and discussion in this study, the NO<sub>3</sub>-N:DIP were utilized instead of overall DIN:DIP.”

24. 322-327 Which parameters are discussed? Was there any parameterization? R: The parameters are stated in the Method section under 2.5 Data Analyses. “For statistical correlations, SPSS (IBM SPSS Statistics 22) was utilized for calculations of independent sampling t-test (between seasons), one-way ANOVA (between source types) and Spearman’s ranking (Bivariate correlation, for nutrients correlation).”

25. 350-351 DIP increases towards the sea while 358-359 says that there is a removal of DIP towards the coast. I am confused R: Thank you for highlighting this. The concentrations of DIP did increase towards the coastal region, however, in theory, the actual concentration should be higher than measured, as some of this DIP was removed along the river-sea continuum due to biogeochemical processes.

26. 374 Use “is” instead of “are” R: Agreed, changed as recommended.

27. 378-385 It is hard to understand the connection between the citation and the idea. I see that Funakawa et al 1996 stated that N and P are fairly high in soil solution, but how from this sentence 383- 383 can be concluded? R: Thank you for pointing this out. The sentence from 383 - 385 is an assumption that was inferred from the study done by Funakawa et al. whereby the loss of P during the rainy season was a result of run-off. We added the sentence “However, this inference requires further validation.” as it is not a verified conclusion and removed the sentence of 378-381.

28. 394-395 Instead of “addition” it is better to use “increase” R: Thank you for pointing this out. However, the term “addition” here is specific as it refers to the conservative index of mixing. If the data falls on theoretical dilution line, no removal or addition occurs.

29. 411-412 How can DOP and DOC be compared? R: Thank you for this question. The DOC is used here as a proxy for peat which we then use to compare to the organic

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portion of P.

30. 416-420 Back to general comments: the ratio can be high but the concentrations also can be high R: As mentioned above, we will add a note on the nutrient concentrations in the discussion.

31. 443-444 Chl a can be uncorrelated with DIP, but how is this reflected by NO<sub>3</sub>:DIP ratios? R: As mentioned above as well, we will revise our argument regarding the correlation to phytoplankton.

32. 447 Change “mass transport of biomass” R: Agreed, changed to “transport of biomass”.

33. 473 Why use “Thus”? It is not clearly following from the previous sentence R: The word “thus” was removed.

34. 473-477 Is it really evident? I agree that DOP can be possibly utilized by phytoplankton, but the increase of DOP concentration does not indicate a preference switch. It is actually supported by discussion at 469-470 that DIP is easier to consume. R: Thank you for pointing this out. From the spearman’s ranking, there was indeed a stronger correlation of Chl a with DOP as compared to DIP in the wet season. We have removed the sentence in question. It now reads: “As the Rajang River has a greater pool of DOP as compared to DIP (Fig.3.5(C)), the change of Chl a being positively correlated to DIP to DOP (Table 3) reflects a probable switch in the preference and utilization of DOP as compared to DIP as the preferred phosphate sources for the phytoplankton biomass.”

35. 491-493 Still did not understand why the estimated figures are useful R: Thank you for this statement. Most of the work regarding global P estimations is based on models. Having an estimation based on actual concentrations of P in the river branches will hopefully aid to make P estimations more accurate.

36. 495-498 Too convoluted R: Agreed. The sentence now reads: Globally, it was

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predicted that the river basins in both Central America and Southeast Asia (particularly Malaysia and Indonesia) would be hot spots (within the top 10% globally) for nutrient yields of various P forms (Seitzinger et al., 2005). However, based on calculations, the export of P from the Rajang River is comparatively minor when compared to other major rivers.

37. 498-499 It is unclear what exactly Seitzinger et al 2005 justifies R: The sentence has been rephrased to highlight the justification (discharge as a key driver of nutrient concentrations). The sentence now reads: The lower export of P from the Rajang river can be justified by Seitzinger et al., (2005), whereby the major driver that controls export of P and P forms is influenced by water discharge.

38. 505-508 Too convoluted, suggest split into at least 2 sentences R: Agreed, the sentence now reads: The comparison of dSi:DIP ratios to the yields of the Rajang showed that the DIP yields were variable and were likely due to anthropogenic sources. On the other hand, dSi originates from natural chemical and physical weathering, which are relatively stable compared to riverine N and P loads (Beusen et al., 2009).

39. 532-555 Needs additional work as Conclusion is largely based on the points mentioned above R: Agreed and revised based on corrections undertaken.

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