Response to Anonymous Referee #2 (original comments in black, responses in blue)

This manuscript reports spring nutrient variabilities determined in Sansha Bay, which is heavily influenced by mariculture activities. Then they used a two end-member mixing model and a mass balance model (LOICZ) to construct a nutrient budget for the bay, which is a key selling point of the paper.

Only one spring data is not rich enough. And the logic of writing is weak. It lacks detail and explanation of many statements and calculations, and it is full of speculations and weak discussion. Thus, it is quite difficult for the reader to follow the calculation. Most structures, data analysis, and discussion appear too similar to Han et al., 2021 (JGR) but without citation. Quite limited new knowledge is given from this manuscript. Furthermore, it also needs some major editing of grammar, sentence structures, and too many textual detail flaws. Biogeosciences is a high-quality journal, but the manuscript is far from the requirements of this journal (including the dataset, innovation, and writing (calculation)). Some improvements can be made to increase the readability and quality of the paper. My detailed suggestions are below.

[**Response**]: We thank the Reviewer for his/her time and efforts in reviewing our paper. This study aims to use Sansha Bay, characterized by very intensive mariculture activities but very limited terrestrial nutrient input, as a case to assess the role of mariculture as a driver of changes in the coastal environment and propose to science-based decision-making for transforming the mariculture activities in coastal waters into a more sustainable model. To do so and built upon a thorough literature data synthesis of the nutrient evolution (Fig 2(c) in the original manuscript), we further conducted a comprehensive bay-wide survey to examine quantitatively the variation in nutrient characteristics in spring, when environmental parameters such as nutrient and temperature changes easily lead to the algal blooms, particularly in mariculture areas, causing adverse effects on mariculture species. More importantly, we then zoomed into the fish farming system to establish a mass balance of N and P to assess the release of nutrients from the fish farming system using different feeds. This mass balance estimate was built on a comprehensive literature/parameter review along with our own lab experiments, including the determination of N and P contents for the mariculture species. Finally, we analyzed the external nutrient input/removal in this ecosystem that is affected by intensive mariculture (fish, kelp and oyster farming), river input and exchange with offshore coastal waters. Our results indeed showed that the addition of nutrients in Sansha Bay is predominantly attributed to mariculture activities. Here, we also analyzed the proportions of different forms of N and P released in the fish farming system and evaluated sustainable development pathways for mariculture, taking into account factors such as feed types.

In response to the Reviewer's general comments, we are thoroughly revising our manuscript to highlight the novelty of the study as spelled out above and also, following the suggestions from the Reviewer to optimize the structure and the logic flow, and to enhance the readability. Briefly, (1) we further reorganize the logic of "Section 1 Introduction". (2) We supplement and modify the calculation details in "Section 2.4 Budget of N and P in the fish farming system" (please refer to Response to Reviewer #1) and revise the statements that were not fully supported by the way presented. (3) We adjust the structure of Sections 3.3 & 3.4 as follows:

3.3 Nutrient budget in the mariculture system
- 3.3.1 Nutrient release from the fish farming system
- 3.3.2 Model sensitivity analysis for nutrient release
- 3.3.3 Nutrient removal by fish, macroalgae and oyster harvesting

3.4 Nutrient budget in Sansha Bay

We apologize for the oversight of not including the Han et al. (2021) citation, which was somehow deleted during the many rounds of revisions prior to our initial submission. The endmember mixing model has been a longstanding approach used by our group, as evidenced by a series of publications (e.g., Han et al., 2012; Wang et al., 2016; Su et al., 2017; Zhao et al., 2020). The Han et al. (2021) paper provides valuable insights specifically focused on nutrient stoichiometry and the biological responses at the same site, influenced by intensive mariculture. We are incorporating this reference back into our revised manuscript.

Major comments:

1 The Introduction is not well structured, and the logic is confused. The author may rewrite the first paragraph. The ideas mentioned in the Introduction should be relevant to the highlighted points in your following sections. For example, "Norwegian salmon farming industry....", "upwelling", "58%-62% carbon", are they mentioned/important in your Discussion?

[**Response**]: The main logic of "Section 1 Introduction" is as follows: Firstly, we introduced the rapid development of coastal aquaculture in China, followed by highlighting the environmental issues associated with mariculture, particularly concerning nutrient releases, along with the remaining science to be resolved. Then, we introduced the adoption of IMTA method to mitigate nutrient pollution and enhance the sustainability of mariculture. Finally, we selected Sansha Bay as the case study, focusing on the impact of mariculture on nutrient dynamics and aiming to provide scientific support for the sustainable development of mariculture through research.

In the revision, we further reorganize the logical flow of "Section 1 Introduction" and remove phrases such as "58-62 % carbon" that are not directly relevant to the main theme. However, we choose to keep examples such as the "Norwegian salmon farming industry" and "upwelling" to illustrate the different impacts of mariculture on nutrient dynamics. The Norwegian mariculture industry, as a typical representative of European aquaculture, still released significant amount of nutrients into the environment (Wang et al., 2012; Wang and Olsen, 2023); conversely, mariculture in the Yellow Sea weakened coastal upwelling, leading to a reduction in nutrient supply (He et al., 2022). Thus, these two examples highlight the complexity and ambiguity of mariculture on nutrient dynamics in the environment.

2 Alkalinity-salinity relationship is a useful tool to analyze (two) endmember mixing processes in general coastal areas. For intensive mariculture, is it possible that the base value of alkalinity itself is too large and unable to reflect the variations of three end-member mixing? Can the authors analyze the properties of end-member mixing via T-S diagram to see if there are other endmembers, which may be due to longer residence time and/or locations (for example, the authors defined mariculture zone/stations around Sandu Island (S1, S2, S6, S26, etc. In Figure 6). How is the uncertainty derived?

[**Response**]: In this semi-enclosed bay of intensive mariculture, the alkalinity values (~2200 μmol kg^{-1}) is comparable to those of the coastal areas in China (Zhao et al., 2020; Guo et al., 2023). And, there is a good linear relationship between alkalinity and salinity (Fig. R1(a)). This two-endmember water mass mixing scheme is further supported by the linear relationship between $Si(OH)_4$ and salinity (Fig. R1(b)) which is unaffected by feed input.

In response to the Reviewer's request, we plot the T-S diagram (Fig. R1(c)), which shows to some extent the temperature fluctuation caused by the daily variations in surface solar heating. Overall the T-S diagram further illustrates the mixing trend of the two endmembers.

Moreover, we select the Ca^{2+} as a conservative tracer (Wang et al., 2016; Su et al., 2017) to validate our endmember mixing model. It can be seen that the predicted values of Ca^{2+} (Ca^{2+}_{pre}) are in good agreement with the field observations (Ca^{2+}_{meas}) (Fig. R1(d)), which strongly supported our model predictions.

The uncertainty in the budget calculation is propagated from the standard deviations (SD) of the measurements of the multiple parameters in the equation. We will provide a more detailed explanation in the revision.

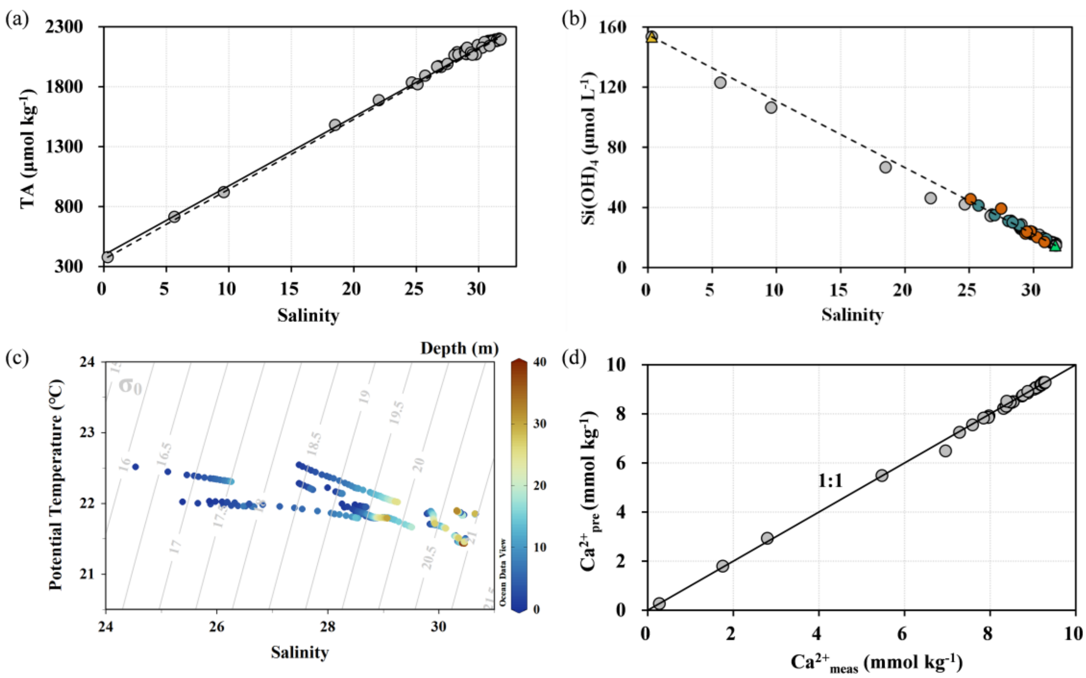

Figure R1. (a) Total alkalinity (TA) versus salinity diagram. (b) $Si(OH)_4$ versus salinity diagram (Figure 6(c) in the original manuscript). (c) Potential temperature versus salinity in Sansha Bay, with temperature data from Jiaoxi Stream stations missing. The color bar represents water depth. (d) Predicted Ca^{2+} (Ca^{2+}_{pre}) versus measured Ca^{2+} (Ca^{2+}_{meas}), the predicted values were calculated based on the two-endmember mixing model.

3 The interpretation and the estimation for the "mass balance of N and P in fish farming systems" in section 2.4 is not clear. It is difficult to follow the calculation processes. I cannot see the values of the parameters according to Table S1. In addition, is the "total

waste discharge (L)" the same as "feed loss (L)"? The author adopted some parameters from reference, it would be better if the authors could assess if is it feasible for this study first.

[**Response**]: In the revision, we are rewriting "Section 2.4 Budget of N and P in the fish farming system" on how we constructed the mass balance model. Briefly, (1) we explain the source and sink terms of nutrients and presentations of each parameter in the mass balance equation. (2) we revise the parameter names in Table S1 to match the abbreviations used in the revision. (3) we provide explanations why the values of some parameters from the reference can be adopted here.

Yes, in the original manuscript, the "total waste discharge (L)" and "Feed loss (L)" are considered the same. In the version, they are unified as "Feed loss (F_{loss})".

4 Section 2.5 kelp and oyster removal. The authors considered kelp and oyster and emphasized that the bay is an IMTA system, are there any other key/primary mariculture species/production in the bay? How to assess the individual species production related to the growth period and the sampling period? On the other hand, the oyster zone is located in Yantian Harbor. Does the oyster production/removal will influence the nutrient flux/budget in the bay/stations? Can the much more detailed functional areas of various aquaculture (fish, kelp, oyster, etc.) be shown on the map?

[**Response**]: We appreciate the comments. Please refer to our response to Reviewer #1 where we have detailed our revision on growing seasons and practices of mariculture species and parameters variation.

Yes, there are other mariculture species in Sansha Bay, such as gracilaria and razor clams. However, kelp cultivation accounts for approximately 88% of algal cultivation, oysters are one of the main shellfish species cultivated, and the production of *L. crocea* represents nearly 80% of the total fish farming in the bay (http://tjj.ningde.gov.cn/xxgk/tjxx/tjnj/). Therefore, in our study, we selected these three main cultured species.

Since our manuscript focuses on the amount of nutrients removed by species at the mature harvest stage, it is not necessary to consider the influence of the growing period.

As we consider Sansha Bay as a whole when assessing the nutrient budget, the geographical location of oyster does not affect the results.

We add a functional area map of aquaculture in Sansha Bay in the Supporting Information.

5 Section 3.3, it is quite difficult to follow the nutrient release estimation. How is the nutrient flux derived? What the data 21±1% and 10±1% come from? Is there any single cage for trash fish feed and formulated feed fish farming in the bay? How did they obtain the numbers in the manuscript?

[**Response**]: We adjust Sections 3.3 & 3.4, dividing Section 3.3 into three subsections to elaborate on the topic. Please refer to the overall comment as of above.

The calculation processes of nutrient fluxes in the fish farming system will provide in Section 2.4 of the revised manuscript.

“21 ± 1 %" and "10 ± 1 %" represent the proportion of N and P entering the fish biomass compared to the N and P of feed input, respectively.

We note that the cages are generally not used for culturing the trash fish feed. Trash fish feed is usually made from low-value fish caught in the open sea that are not suitable for consumption, which are ground into minced meat using a meat grinder and then fed (Cao et al., 2015; Quan, 2017). Formulated feed is generally a slow-sinking pellet feed product produced by the enterprises (Quan, 2017). The data for trash fish feed and formulated feed were calculated by multiplying the fish production by feed conversion rate.

Minor comments:

Line 100, it is suggested to quote more classical hydrology and biogeochemical literature.

[**Response**]: The suggestion is taken. We add some classic literature on the China Coastal Current (Zhang et al., 2022), the Taiwan Warm Current (Qi et al., 2016), and the South China Sea Warm Current (Yang et al., 2008; Huang et al., 2019). And we retain the citation to Huang et al. (2019), as this paper provided a comprehensive overview of the current patterns in the East China Sea and the South China Sea.

Line 113, 69%, what is the data source, reference?

[**Response**]: We calculated this percentage based on the mariculture area and water area in Sansha Bay. The area of mariculture was derived from the Ningde Statistical

Yearbook (http://tjj.ningde.gov.cn/xxgk/tjxx/tjnj/202111/t20211104_1544289.htm), and the bay area was obtained from Han et al. (2021), and included the intertidal and water area. We add the footnotes to provide the data source in the revision.

Line 159, It is a nutrient manuscript. The measurement methods of nutrients are important but the authors did not cite any published paper.

[**Response**]: We add references where applicable for sampling method, measurement principles, and procedures for nutrients in the revision.

Line 226, “Nitrogen” should be “N”

[**Response**]: Modified as suggested.

Line 26, “Fao” should be capitalized “FAO”

[**Response**]: Modified as suggested.

Line 253, Chl a in the manuscript is too low with regards to the mariculture bay. Is there any in situ field measured Chl a data? Compare to historic references? The author displays Chl a in Figure 5e but does not introduce clearly, the value for Chl a is as high as 0.8 μg L-1?

[**Response**]: Yes, we measured Chl-a data at individual sampling stations. The range was 0.19-0.75 μg L^{-1} (average value: 0.40 ± 0.11 μg L^{-1}).

According to Xie et al. (2021), the annual average concentration of Chl-a in Sansha Bay from 1999 to 2012 is shown in Table R1. Our data are consistent with historical data, indicating the characteristic of low Chl-a and high nutrient levels in Sansha Bay. The primary reason for this phenomenon is nutrient competition (Huang et al., 2017), allelopathy (Cheng and Cheng, 2015), and shading effects (Fong and Zedler, 1993) caused by macroalgal cultivation, which inhibit the growth of phytoplankton (Xie et al., 2021).

We add an explanation for the Chl-a data in the revision.

Table R1. The annual average concentrations of Chl-a from 1999 to 2012

Year	1990	2000	2005	2007	2010	2012
Chl-a (μg L^{-1})	0.87	0.97	1.01	0.67	0.61	0.70

Line 315, Jia et al., 2003 is omitted in the References.

[**Response**]: We add the citation in the revision.

Line 395, how did the authors obtain 32.8% and 34.8%?

[**Response**]: The percentages were the proportion of nutrient sinks to nutrient sources. That is, it refers to the ratio of DIN and DIP fluxes from river and feed inputs to the exchange flux with the offshore coastal waters (depicted in Figure 10 of the manuscript). In the revision, we clarify the percentages.

Figures 6,7, the color should be constant.

[**Response**]: Modified as suggested.

Figure 7, most of the stations in the "mariculture zone" are actually of salinity >25, meanwhile, the relationship between DIN and DIP is ~23.38. The DIN/DIP ratio for the mariculture zone seems to be dominated by only two dots in Fig. 7a.

[**Response**]: Yes, the mariculture stations are located in the range with a salinity > 25.

Concerning the stoichiometric ratios of DIN and DIP in different regions, we can redefine their categorization for clarification. By combining the stations in the mariculture zone with those having S > 25 for linear regression (Fig. R2 (a-2)), the fitted slope is 20.06 ± 1.31. When we perform linear regression after removing two discrete points (black dashed ellipse), the fitted slope is 22.60 ± 1.33. Although the presence of these two discrete points cause a slight change in the slope, it still exceed the Redfield ratio (Redfield et al., 1963). Additionally, we provide the DIN:DIP ratio data for the mariculture stations (Table R2), where it is evident that the ratios for the two discrete stations (red box) are not significantly different from the others.

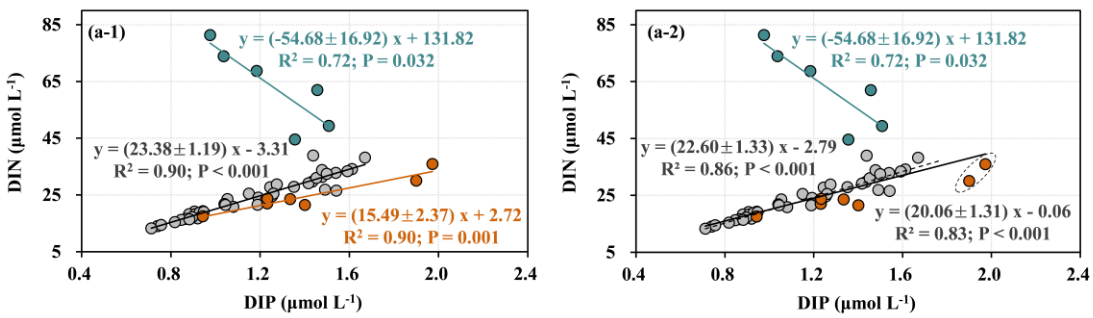

Figure R2. Dissolved inorganic nitrogen to phosphorus (DIN:DIP) ratios in Sansha Bay. Green, gray, and red circles represent stations with salinity < 25, salinity > 25 and the mariculture zone, respectively. In (a-1), the equations represent the fitting equations for the three categorized. While in (a-2), the equation y = (20.06 ± 1.31) x - 0.06 represents the fitting equation for stations within the mariculture zone and those with salinity > 25, and y = (22.60 ± 1.33) x - 2.79 represents the fitting equation after removing the two discrete points from the mariculture zone.

Table R2. The DIN:DIP ratios in mariculture stations of Sansha Bay

Mariculture Station	CDL10	CDL9	CB8	CHL7	CL6	CL2	CL1
DIN:DIP	17.64	15.34	18.59	17.87	15.81	18.21	19.22

Map 1, have you compared the satellite map with Google Earth map and/or other images? The mariculture zone is probably underestimated.

[**Response**]: Yes, we have compared our result with Google Earth map (Fig. R3). The results indicate that our classification fits well on Google map.

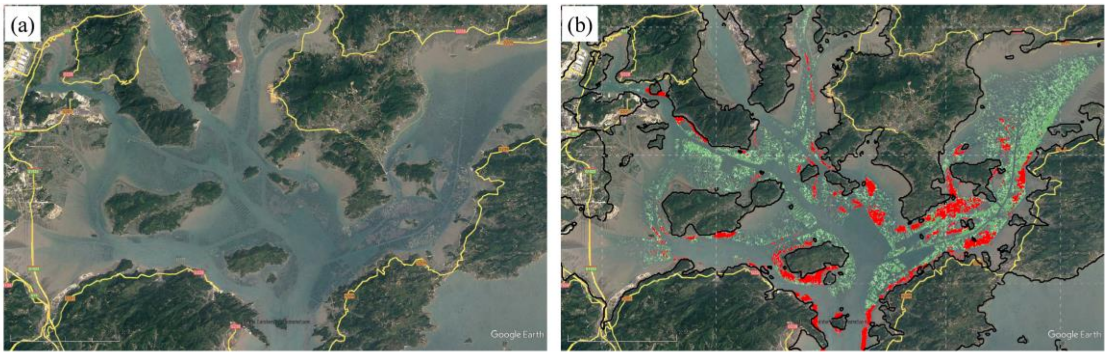

Figure R3. The accuracy verification of classification results. (a) Google earth map; (b) Overlay of classified mariculture zones in Google earth map.

Table 1. Four stations (LJ21, LJ22, ND41, and ND42) in offshore coastal waters should be introduced in the MS, and be shown on the map. What is the formulation for u? It seems the uncertainty u is too large for Vex, FDIN, and FDIP? Is it feasible to say outflow for DIN and DIP?

[**Response**]: In the revision we will show the four stations for offshore coastal waters on the map and in the main text.

u is propagated from the standard deviations (SD) of the measurements of the multiple parameters in the equation. Taking V_{ex} as an example, V_{ex} can be calculated by the following equation in Text 2 of the Supporting Information:

V_{ex}=(V_{riv}×S_{riv}+V_{res}×S_{res})/(S_{sys}−S_{oce}). The uncertainty of V_{ex} (u_{ex}) can then be expressed as a function of six parameters, that is, f (V_{riv}, S_{riv}, V_{res}, S_{res}, S_{sys}, S_{oce}):

$$u_{ex} = \sqrt{\left(\frac{\partial(f)}{\partial[V_{riv}]} \times \sigma_{V_{riv}}\right)^2 + \left(\frac{\partial(f)}{\partial[S_{riv}]} \times \sigma_{riv}\right)^2 + \left(\frac{\partial(f)}{\partial[V_{res}]} \times u_{V_{res}}\right)^2 + \left(\frac{\partial(f)}{\partial[S_{res}]} \times u_{res}\right)^2 + \left(\frac{\partial(f)}{\partial[S_{sys}]} \times \sigma_{sys}\right)^2 + \left(\frac{\partial(f)}{\partial[S_{oce}]} \times \sigma_{oce}\right)^2}$$

Even if the error of each parameter is small, after propagation a large u may result. However, the calculated true values for the nutrient outflow flux are similar to those estimated by Han et al. (2021), indicating their validity and reasonability.

References

Cao, L., Naylor, R., Henriksson, P., Leadbitter, D., Metian, M., Troell, M., and Zhang, W.: China's aquaculture and the world's wild fisheries, Science, 347, 133-135, https://doi.org/10.1126/science.1260149, 2015.

Cheng, F. and Cheng, Z.: Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy, Frontiers in Plant Science, 6, 1020, https://doi.org/10.3389/fpls.2015.01020, 2015.

Fong, P. and Zedler, J. B.: Temperature and light effects on the seasonal succession of algal communities in shallow coastal lagoons, Journal of Experimental Marine Biology and Ecology, 171, 259-272, https://doi.org/10.1016/0022-0981(93)90008-c, 1993.

Guo, X., Su, J., Guo, L., Liu, Z., Yang, W., Li, Y., Yao, Z., Wang, L., and Dai, M.: Coupling of carbon and oxygen in the Pearl River plume in summer: upwelling, hypoxia, reoxygenation and enhanced acidification, Journal of Geophysical Research: Oceans, 128, https://doi.org/10.1029/2022jc019326, 2023.

Han, A., Dai, M., Kao, S.-J., Gan, J., Li, Q., Wang, L., Zhai, W., and Wang, L.: Nutrient dynamics and biological consumption in a large continental shelf system under the influence of both a river plume and coastal upwelling, Limnology and Oceanography, 57, 486-502, https://doi.org/10.4319/lo.2012.57.2.0486, 2012.

Han, A., Kao, S. J., Lin, W., Lin, Q., Han, L., Zou, W., Tan, E., Lai, Y., Ding, G., and Lin, H.: Nutrient budget and biogeochemical dynamics in Sansha Bay, China: a coastal bay affected by intensive mariculture, Journal of Geophysical Research:

Biogeosciences, 126, https://doi.org/10.1029/2020JG006220, 2021.

He, Y., Xuan, J., Ding, R., Shen, H., and Zhou, F.: Influence of suspended aquaculture on hydrodynamics and nutrient supply in the coastal Yellow Sea, Journal of Geophysical Research: Biogeosciences, 127, https://doi.org/10.1029/2021jg006633, 2022.

Huang, T. H., Chen, C. A., Lee, J., Wu, C. R., Wang, Y. L., Bai, Y., He, X., Wang, S. L., Kandasamy, S., Lou, J. Y., Tsuang, B. J., Chen, H. W., Tseng, R. S., and Yang, Y. J.: East China Sea increasingly gains limiting nutrient P from South China Sea, Scientific Reports, 9, 5648, https://doi.org/10.1038/s41598-019-42020-4, 2019.

Huang, Y., OU, L., and Yang, Y.: Nutrient competition between macroalgae Gracilaria Lemaneiformis and phytoplankton in coastal waters of Nan'ao Island, Guangdong, Oceanologia et Limnologia Sinica, 048, 806-813, https://doi.org/10.11693/hyhz20170200031, 2017.

Qi, J., Yin, B., Zhang, Q., Yang, D., and Xu, Z.: Seasonal variation of the Taiwan Warm Current Water and its underlying mechanism, Chinese Journal of Oceanology and Limnology, 35, 1045-1060, https://doi.org/10.1007/s00343-017-6018-4, 2016.

Quan, H.: The effect comparisons among several feeds for the large yellow croaker (Larimichthys crocea), Journal of Fisheries Research, 39, 106-113, https://doi.org/10.14012/j.cnki.fjsc.2017.02.004, 2017.

Redfield, A. C., Ketchum, B. H., and Richards, F. A.: The influence of organisms on the composition of sea-water, The sea: ideas and observations on progress in the study of the seas, Wiley Interscience: New York1963.

Su, J., Dai, M., He, B., Wang, L., Gan, J., Guo, X., Zhao, H., and Yu, F.: Tracing the origin of the oxygen-consuming organic matter in the hypoxic zone in a large eutrophic estuary: the lower reach of the Pearl River Estuary, China, Biogeosciences, 14, 4085-4099, https://doi.org/10.5194/bg-14-4085-2017, 2017.

Wang, C. D. and Olsen, Y.: Quantifying regional feed utilization, production and nutrient waste emission of Norwegian salmon cage aquaculture, Aquaculture Environment Interactions, 15, 231-249, https://doi.org/10.3354/aei00463, 2023.

Wang, H., Dai, M., Liu, J., Kao, S. J., Zhang, C., Cai, W. J., Wang, G., Qian, W., Zhao, M., and Sun, Z.: Eutrophication-driven hypoxia in the East China Sea off the Changjiang Estuary, Environmental Science Technology, 50, 2255-2263, https://doi.org/10.1021/acs.est.5b06211, 2016.

Wang, X., Olsen, L. M., Reitan, K. I., and Olsen, Y.: Discharge of nutrient wastes from salmon farms: environmental effects, and potential for integrated multi-trophic aquaculture, Aquaculture Environment Interactions, 2, 267-283, https://doi.org/10.3354/aei00044, 2012.

Xie, B., Huang, C., Wang, Y., Zhou, X., Peng, G., Tao, Y., Huang, J., Lin, X., and Huang, L.: Trophic gauntlet effects on fisheries recovery: a case study in Sansha Bay, China, Ecosystem Health and Sustainability, 7, https://doi.org/10.1080/20964129.2021.1965035, 2021.

Yang, J., Wu, D., and Lin, X.: On the dynamics of the South China Sea Warm Current, Journal of Geophysical Research, 113, https://doi.org/10.1029/2007jc004427, 2008.

Zhang, Y., Chai, F., Zhang, J., Ding, Y., Bao, M., Yan, Y., Li, H., Yu, W., and Chang, L.: Numerical investigation of the control factors driving Zhe-Min Coastal Current, Acta Oceanologica Sinica, 41, 127-138, https://doi.org/10.1007/s13131-021-1849-4, 2022.

Zhao, Y., Liu, J., Uthaipan, K., Song, X., Xu, Y., He, B., Liu, H., Gan, J., and Dai, M.: Dynamics of inorganic carbon and pH in a large subtropical continental shelf system: Interaction between eutrophication, hypoxia, and ocean acidification, Limnology and Oceanography, 65, 1359-1379, https://doi.org/10.1002/lno.11393, 2020.