Dear Editor and Referees,

On behalf of my co-authors, I would like to thank you for the insightful comments and for the opportunity to revise our manuscript entitled “Hydrodynamic and environmental characteristics of a tributary bay influenced by backwater jacking and intrusions from a main reservoir” (ID: hess-2020-63).

The comments were valuable during the revision process and will further guide our research. We have carefully addressed the comments with point-by-point replies to the referees and revised the manuscript accordingly, which we hope will meet with your approval. We then sent our revised manuscript to a professional English editing service (American Journal Experts) to further improve the English language prior to resubmission. American Journal Experts has revised our manuscript for proper English language, grammar, punctuation, spelling and overall style, and we have ensured that the intended meaning has been maintained.

In the section below, we have provided detailed responses to the referees' comments and illustrated the primary corrections made in the paper.

Responses to the referee #1:

The manuscript presents how the backwater jacking and intrusion of the main reservoir influence the hydrodynamic and water environment characteristics of the tributary bay. To my knowledge, this is likely the first time the main reservoir’s backwater jacking and intrusion question is explained clearly. The different effects in different areas of the tributary bay are found. The results can provide guidance for water environment protection in the tributary bays. There are some minor comments listed as below.

Authors’ response: Thank you for your positive and constructive comments. Below we present our responses to each comment.

1) Line 59 - Line 61: “A tributary bay is always influenced by backwater jacking and intrusion with the rise of the water level of the main reservoir because such changes induce changes in the hydrodynamic conditions in the tributary bay”. “the rise of the water level” is not specific, “fluctuation” is better. And any relevant references for this statement?

Authors' response: We have changed "the rise of the water level" to "fluctuations of the water level" according to your suggestion (Page 3, Line 56). We also have added the studies of Ji et al (2010) and Wang et al (2014) as references to support this statement (Page 3, Lines 56 to Line 58).

2) Introduction section: Please explain what is backwater jacking and what is intrusion, which can make the paper more comprehensible to readers.

Authors' response: We have added the meanings of backwater jacking and intrusions from the main reservoir in the revised manuscript (Page 3, Line 52 to Line 55) as follows.

Backwater jacking occurs in tributaries when dams or other obstructions raise the surface of the water upstream from them. Intrusion is the process by which water from the mainstream intrudes into the tributary.

3) Line 61- Line 63, Line 64 - Line 66, and Line 91- Line 94: The statements need some more references to support.

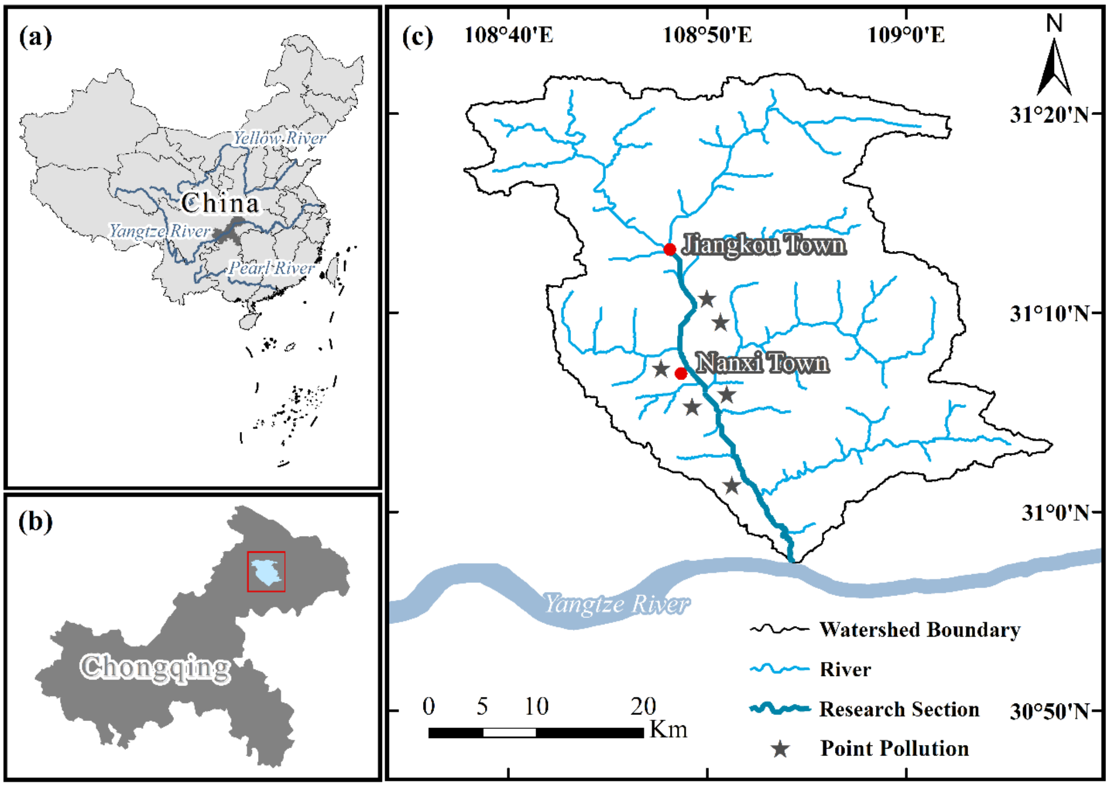
Authors' response: Thank you for your suggestion. We have added the studies of Hu et al (2013) and Yin et al (2013) to support the statement at previous Lines 61 - 63, added the studies of Fu et al (2010), Holbach et al (2013) and Yang et al (2013) and to support the statement at previous Lines 64 - 66, and added the studies of Zhao (2017) and Long et al (2019) to support the statement at previous Lines 91 - 94.

4) Line 101- Line 102: Please add the necessity of the study area selection and explain why you select Tangxi River but not other tributaries.

Authors' response: The Tangxi River is a typical tributary bay of the TGR, and it has been severely influenced by backwater jacking and intrusions in recent years. This phenomenon accelerates the deterioration of the water environment of Tangxi River. Thus, the Tangxi River was selected as the focus of this study. This information has been added in our revised manuscript (Page 5, Line 100 to Line 103).

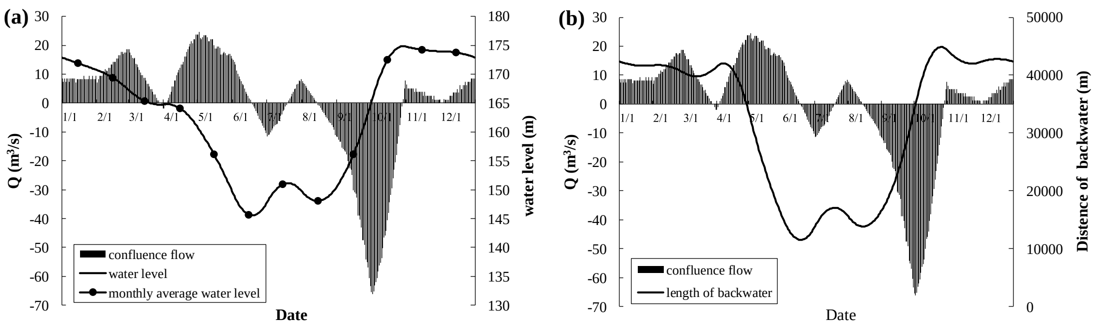
5) Line 220 - Line 221: Please specify the location of the point pollution load.

Authors' response: We have specified the location of the point pollution load on Fig.1 in the revised manuscript (Page 7, Fig.1). The new Fig.1 is shown as follows.



6) Fig. 4.: It is hard to understand the meaning of fig.4., please add the legend or explain the meaning of the lines in your figure.

Authors' response: We have added the legend of this figure as follows (Page 18, Fig.6).



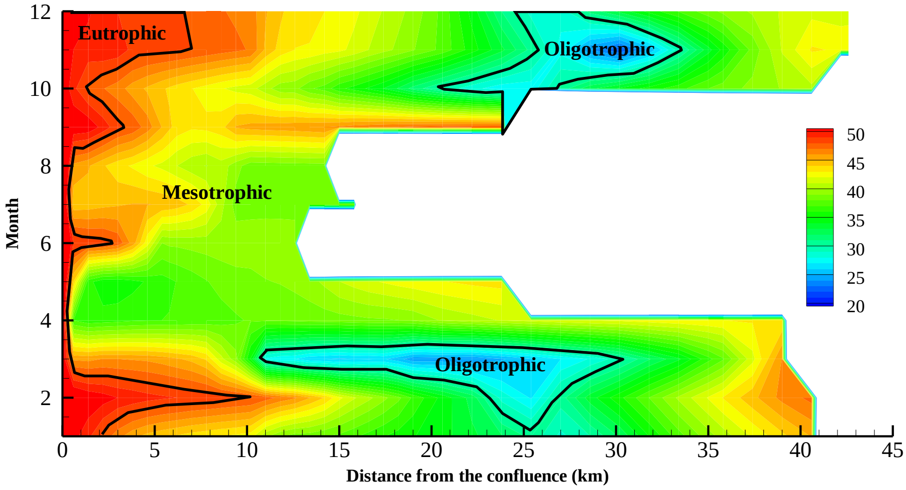
7) Line 417 - Line 418: "There was an obvious quality concentration boundary in the tributary bay, which was basically consistent with the regional boundary of the flow field". Are the boundaries of each month in Fig. 9. - Fig. 12. same to the boundaries of each month in Fig. 2. - Fig. 5.? If not, please make a comparison.

Authors' response: Yes, the boundaries of each month in previous Fig. 9. - Fig. 12.

are the same to the boundaries of each month in previous Fig. 2. - Fig. 5. We divided the tributary bay into two areas according to the flow field.

8) Fig. 16.: Title of horizontal axis in fig.16. is ". . . Yangtze River junction", which is not consistent with the previous description ". . .confluence".

Authors' response: We have changed the title of horizontal axis in this figure from ". . . Yangtze River junction" to ". . .confluence". The revised figure is shown as follows (Page 35, Fig.18).



9) What are the degradation coefficients of COD, NH_3-N, TP and TN?

Authors' response: The degradation coefficient of COD is 0.0032 d^{-1}, the degradation coefficient of NH_3-N is 0.0032 d^{-1}, the degradation coefficient of TP is 0.0018 d^{-1}, the degradation coefficient of TN is 0.0018 d^{-1}. We have added the degradation coefficients in our revised manuscript (Page 11, Line 205 to Line 206).

Responses to the referee #2:

This paper aimed at evaluating the hydrodynamic and water environment effect of back water jacking and intrusion of the main reservoir on the tributary bay. The topic is novel and of high interest for the relationship between main reservoir and tributary bay. The results are valuable for water environment treatment of the tributary bay. This paper is innovative and suitable to publish in HESS. However, there are also some comments that need to be addressed. After the revision, the paper can be accepted.

Authors' response: Thank you for your positive and constructive comments. Below we present our responses to each comment.

Specific comments:

1) Section 1 Introduction: Some sentences in Introduction need references to support.

Authors' response: Thank you for your suggestion. According to other reviewers' comments, we have added the studies of Ji et al (2010) and Wang et al (2014) to support the statement at Lines 55 - 58, added the studies of Hu et al (2013) and Yin et al (2013) to support the statement at Lines 58 - 60, added the studies of Fu et al (2010), Holbach et al (2013) and Yang et al (2013) to support the statement at Lines 61 - 64, and added the studies of Zhao (2017) and Long et al (2019) to support the statement at Lines 89 - 92.

2) Fig.1: The gray area in the upper left picture of Figure 1 should be the area of the picture in the lower left picture. Some irrelevant places in the upper left picture are marked as gray. Please modify them again.

Authors' response: We have revised the Fig.1 according to your comment in the revised manuscript (Page 7, Fig.1).

3) Line 131-139, the reason of selection CE-QUAL-W2 is better to put in introduction part.

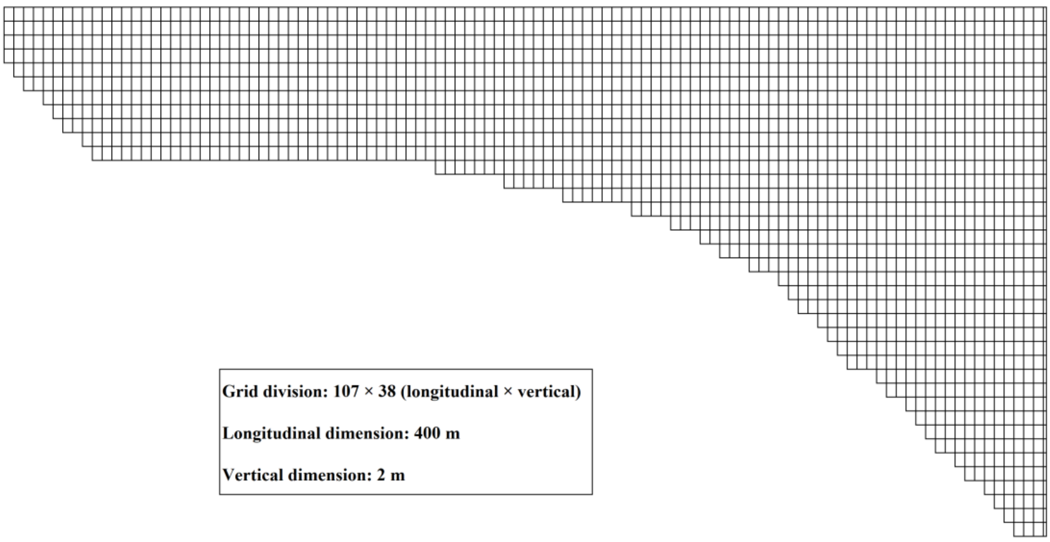
Authors' response: We have moved the sentences in Line 131 - Line 139 to the last paragraph of the introduction part according to your suggestion (Page 6, Line 106 to Line 111).

4) Section 2 Materials and methods: For the mathematical applications, it is necessary to illustrate the grid division of your study area. It's better to add some explanations.

Authors' response: Thank you for your suggestion. The research river was divided into 107 × 38 (longitudinal × vertical) rectangular cell grids with the longitudinal dimension of 400 m and the vertical dimension of 2 m. The figure of grid structure we added in the revised manuscript is shown in response 5.

5) A figure of grid structure in Section 2.

Authors' response: We have added the figure of structure in Section 2 in the revised manuscript as follows (Page 8, Fig.2).



6) Table 1, the format of the temperature unit is messy code. Please correct.

Authors' response: We have corrected the format of temperature unit and replaced the table 1 with a figure in the revised manuscript (Page 13, Fig.4).

7) TLI (∑), please uniform the format of ∑, in roman or in italics.

Authors' response: We have uniformed the format of in roman in the revised manuscript.

8) Fig. 4, the legend is necessary to be added.

Authors' response: We have added the legend of this figure in the revised manuscript (Page 18, Fig.6).

9) Section 2.2.3 Boundary conditions: What was the period of the boundary conditions used for simulation? Is it the data of a certain year or the average value of multi-year data? Please specify this in the corresponding section.

Authors' response: Thank you for your suggestion. The boundary conditions used for simulation were the daily average data of multi-year. This information has been added in Section 2.2.3 in our revised manuscript (Page 13, Line 232 to Line 234).

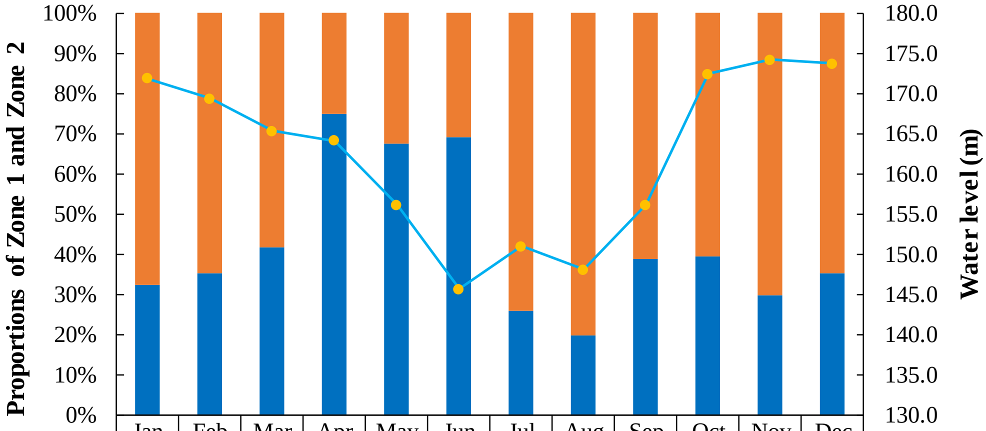
10) Section 3.1 Hydrological situation: To my knowledge, density driven water can intrude into the tributary bay in the process of TGR impoundment at the end of flood season in autumn, and you specific the backwater intrusion time is from July to October. Do you consider the density driven water in your simulation? The intrusion time you specific needs some references to support.

Authors' response: During the simulation, we considered the influence of density flow, and we have added references to support the intrusion time we specified. The following sentences were added in the revised manuscript (Page 17, Line 295 to Line 303).

Periods of intrusions that occurred in other tributaries were investigated in previous studies. Backwater intrusions were mainly concentrated in low water level operation period and impoundment period in the Daning River (Zhao, 2017). The water of the mainstream of TGR flowed backward into the Xiangxi Bay in the density current at different plunging depths during the process of TGR impoundment at the end of the flood season in autumn, and the intrusion was weak when the water level fell (Ji et al., 2010; Yang et al., 2018). Compared to the results of previous studies, the backwater intrusions showed obvious seasonal changes and the main intrusion time was almost the same.

11) Fig. 6: You'd better add titles to the vertical axes to make the figure easier to understand.

Authors' response: Thank you for your suggestion. We have added titles to the vertical axes in this figure and the revised figure is shown as follows (Page 21, Fig.8).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Zone 2	68%	65%	58%	25%	33%	31%	74%	80%	61%	60%	70%	65%
Zone 1	32%	35%	42%	75%	67%	69%	26%	20%	39%	40%	30%	35%
water level	171.9	169.4	165.3	164.1	156.1	145.7	150.9	148.1	156.1	172.4	174.2	173.7

12) Section 3.5 Water eutrophication: In your conclusion, the risk of eutrophication in the tributary bay was highest in the section within 0.5 km of the confluence from May to June. Any facts or references in tributary bays of the TGR that can support your conclusion?

Authors' response: Thank you for your suggestion. We have added the study of Wu et al (2010) to support our conclusion. The following sentences were added in the revised manuscript (Page 34, Line 523 to Line 526).

Wu et al (2010) constantly monitored the eutrophication of the Daning River, a tributary bay of the TGR, and found that algal blooms frequently occurred in the area close to the confluence from March to June, which was similar to the results of the present study.

13) Line 502- Line 508: You calculated the backwater intrusion time in Section 3.1 and it is a meaningful result. I think you should add this result in the first conclusion.

Authors' response: We have added the result of the backwater intrusion time in the first conclusion in the revised manuscript (Page 36, Line 552).

14) Line 552 - Line 555: What is the interaction between the main reservoir and the tributary bay? As the tributary is a much smaller water body compared with the main stream, so it's easy to understand the influence of main reservoir on

tributary. But can the tributary bay affect the main reservoir conversely? I think there needs more details.

Authors' response: The interaction between the main reservoir and the tributary bay means their hydrodynamics and water environmental characteristics can influence each other. One tributary bay can affect a small section of main reservoir near its confluence, maybe many tributary bays can influence the main reservoir together. A main reservoir's operation may have common influences on its tributary bays. We have added the following sentences in the revised manuscript (Page 37, Line 572 to Line 574).

The operations of the main reservoir may have common influences on the tributary bays, and tributary bays may also influence the main reservoir.

15) The conclusion part is better to be condensed and proposed some specific conclusion, or some quantify result.

Authors' response: Thank you for your suggestion. We have condensed the conclusion part and put the most quantify results in the conclusion part in the revised manuscript.

16) Future work: You mentioned some existing measures to improve the environment of tributary bays, can you propose some possible new methods in your future work section?

Authors' response: Thank you for your suggestion. We introduced some possible methods in the future work section. At present, the method of "double nutrient reduction", ecological methods, and manually controlled operation method have been proposed by some scholars. We added this information in the future work section in our manuscript (Page 37 to Page 38, Line 580 to Line 590).

Responses to the referee #3:

This paper reports on an investigation of the effects of water level fluctuations in the Three Gorges Reservoir on a tributary bay on the Tangxi River, the focus being on a number of water quality parameters. The study is based on a numerical simulation using the width-averaged vertically two-dimensional model CE-QUAL-W2. It was conducted for the year 2017 and water quality data collected at the Tangxi River Bridge located 18 km upstream from the confluence was used for validation.

Authors' response: Thank you for your commentary. Below we present our responses to each comment.

Major comments

1. While the results address an important problem they are rather limited in scope. The paper could be enhanced, for example, with a discussion of how sensitive the results are to the model forcing, e.g. winds and air temperature. Are the distributions/variations in the water quality parameters driven solely by the water level fluctuations in the reservoir or do the forcings make a contribution?

Authors' response: Thank you for your suggestion. The aim of our paper is to study how a tributary bay was influenced by backwater jacking and intrusions from the main reservoir. The link between the main reservoir and its tributary bay is the hydrodynamic condition, which is mostly affected by the water level fluctuations (Sha et al., 2015). So, we focused on the water level fluctuations in the main reservoir and its influence on the tributary bay in this manuscript.

We used the daily average data of multi-year on winds and air temperature as the boundary in our simulation. We have discussed the sensitivity of our results to the winds and air temperature at a new section in the revised manuscript (Page 35 to Page 36, Line 531 to Line 544).

We also have enhanced our paper in other aspects. For instance, we have added discussions with other tributaries in the results and discussion section. We also have added some references to support our study and added some details to improve the quality of this paper. We hope our efforts to enhance the paper can meet with your approval.

2. The model validation is limited to comparisons of water quality parameters at a single point: the Tangxi River Bridge. These measurements do not include measurements of currents so there is no validation of the circulation patterns shown in figure 5 or of the two-dimensional distribution of the water quality patterns. This should be commented on and ideally addressed somehow.

Authors' response: Thank you for your comment. We have tried our best to find the fundamental data, but only the data of water quality parameters in Tangxi River Bridge can be got at present. So, we used the data of Tangxi River Bridge to valid the model CE-QUAL-W2. Though the model validation was limited, many scholars have obtained good results by using it. Moreover, this model is mature and has been proved to perform well in simulating the hydrodynamics, water temperature and water quality of reservoirs and lakes. Therefore, we think our results and conclusions are credible. We also have added this information at the end of introduction section (Page 6, Line 106 to Line 111). We hope our explanations for this comment can get your understanding and support.

3. The title has some grammatical errors: "The hydrodynamic and environmental characteristics of a tributary bay influenced by backwater jacking and intrusions from a main reservoir"

Authors' response: Thank you for your suggestion. We have changed the title to "Hydrodynamic and environmental characteristics of a tributary bay influenced by backwater jacking and intrusions from a main reservoir".

4. The introduction should include a background discussion on what backwater jacking is and what intrusions from the main reservoir are and the conditions under which they occur. It does not have to be long.

Authors' response: We have added the meanings of backwater jacking and intrusions from the main reservoir and the conditions under which they occur in the revised manuscript (Page 3, Line 52 to Line 55).

5. The abstract is very long. Seems too long to me.

Authors' response: We have condensed the abstract in the revised manuscript.

6. Line 14. " ... is the key ...". Is it really true that this is the one an only key to solving eutrophication or is it one more several. I find it hard to believe that it is the only key to solving these problems. Similarly on line 74. Saying "is a key" seems more accurate.

Authors' response: We have changed "is the key" to "is a key" (Page 4, Line 72).

7. The introduction is very focused on the Three Gorges Reservoir. The paper could be enhanced by adding a discussion of tributary bays in other parts of the world which would help put the work in a wider context.

Authors' response: Thank you for your suggestions. We have tried our best to find the studies of tributary bays in other parts of the world, but the studies were few. However, we have added discussions of other tributary bays of the TGR in the revised manuscript (Page 17, Line 295 to Line 303; Page 22, Line 377 to Line 379; Page 34. Line 523 to Line 526). We hope our efforts to enhance the paper can meet with your approval.

8. Line 152. Here it is stated that the water density is affected by concentrations of solids (should be 'suspended solids') but equation (6) for the density is a function of temperature only – it does not depend on concentrations of suspended solids. Were these concentrations included in the model somehow? If so this should be explained. If not this should be made clear.

Authors' response: We are sorry that we made a mistake in this statement. The concentrations of suspended solids weren't included in the model. We have revised this sentence in the revised manuscript (Page 9, Line 168 to Line 170) as follows.

Accurate hydrodynamic calculations require accurate water densities. The following equation of state relating the density to the water temperature was used in the model.

9. What shortwave absorption model was used in this study? A two- or three-band model, or otherwise? With what attenuation coefficients? Fixed or a function of suspended sediments? In parts of the domain (e.g. figure 5) the water is shallow at some times of the year. Does shortwave radiation reach the bottom? If so how is it handled. Does it reflect off the bottom or is that heat absorbed by the bottom potentially creating unstable stratification?

Authors' response: The shortwave absorption we used was according to Bears Law (Thomas and Scott, 2008). The attenuation coefficients in the model include the fraction absorbed at the water surface and the extinction coefficient. The values of them were 0.45 and 0.45 m^{-1} respectively. This information has been added in the revised manuscript (Page 10, Line 191 to Line 194).

As the content of suspended sediments was low in the research area, we didn't consider the suspended sediments in the simulation.

According to our study, the water depth was around 5 m in the upstream from May to September. Most of the shortwave radiation was absorbed by the water, only a small amount of the radiation reached the bottom. Due to the exponential decay of the shortwave radiation, we didn't distinguish the heating after the radiation reached the bottom of the tributary in the simulation. This information has been added in the revised manuscript (Page 10 to Page 11, Line 194 to Line 196).

As for the stratification, the small amount of radiation that reached the bottom of upstream could not cause the vertical convection problem and it had little effect on the stratification. We hope our explanations for this comment can meet with your approval.

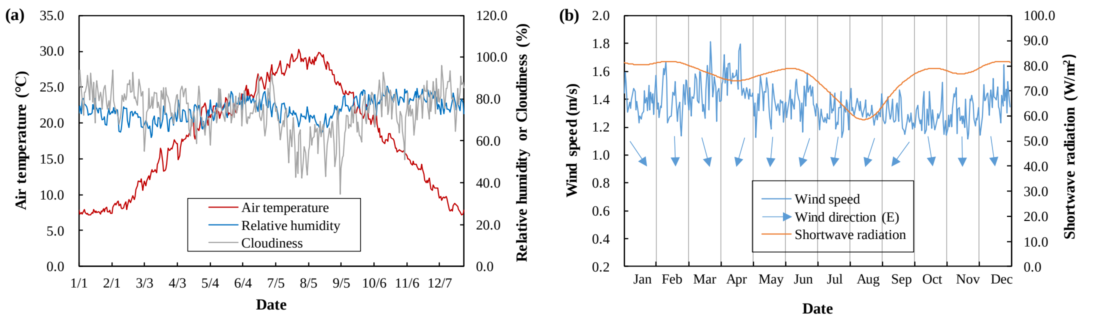
10. I suggest adding a figure showing some of the meteorological forcings: air temperature and wind in particular. The only information on winds and air temperature are the monthly averages in table 1. Why are averages enough? What was the temporal resolution of the forcings used to drive the model: hourly, daily? Were the monthly averaged values used to driving the model? If so why not more frequent values? No diurnal cycle in the forcing? Is the solar radiation in table 1 a combination of long and short wave radiation? These should be reported separately because shortwave radiation penetration penetrates into the water column and longwave radiation does not.

Authors' response: Thank you for your suggestion. Although the meteorological conditions were displayed in the form of monthly average value in the table 1, we used daily average data of multi-year in our simulation. We are sorry that this made you confused.

The diurnal cycle of our simulation last three years. We have added this information in our revised manuscript (Page 13, Line 234).

The solar radiation in table 1 was short wave solar radiation and we have specified this in the revised manuscript. The long wave atmospheric radiation was computed from air temperature and cloudiness.

According to your suggestion, we have replaced the table 1 with a figure of daily average values of meteorological data in the revised manuscript (Page 13, Fig.4) as follows.



11. Lines 192–193. The percentage error does not seem like a useful metric. A 25% error for a temperature of 4◦ is very different from a 25% error for a temperature of 20◦.

Authors' response: We agree with that the percentage error is not a useful metric, and we have used root mean squared error to reevaluate the model calculation accuracy. We have revised the description of the fitness between simulated values and measured values as follows (Page 11, Line 208 to Line 215).

The difference in T between the simulated value and the measured value was 0.6 - 4.7 ºC, and the root mean squared error was 1.8 ºC. The difference in TP between the simulated value and the measured value was 0.004 - 0.03 mg/L, and the root mean squared error was 0.01 mg/L. The difference in TN between the simulated value and the measured value was 0.02 - 0.26 mg/L, and root mean squared error was 0.16 mg/L. For NH_3-N, the difference between the simulated value and the measured value was 0.03 - 0.08 mg/L, the root mean squared error was 0.06 mg/L, and the relative error was greater than 30%.

12. Figure 5. The left side of the region plotted in each panel varies with month of year. How is this left boundary determined? The ranges of *x* values plotted also

varies from month to month which makes it a bit difficult to compare results from different months. The panels are also too small. I find them difficult to read. I suggest full page figures with two columns, all using the same range of *x* values. Also, the red curve that is the boundary between Zone 1 and Zone 2 is difficult to see because there is not enough contrast with the colors of the other contour lines. They should be very different. In figures 7 and 9 the curve separating the zones is in black. It would be best to use the same color in all figures. Same comments for other similar figures.

Authors' response: Thank you for your suggestions.

The left boundary was determined by the water depth. We set the minimum number of activation layers in the simulation, and the corresponding water depth is 4 m. The simulation stopped when the water depth is less than 4 m, and the left boundary was determined.

If we put the figures into two columns, the figures will become too long and look not good. So, we still arranged the figures into three columns, and we also ensured the accuracy of the figures. We have output clearer figures in the revised manuscript. We have used the same range of x values and uniformed the color of boundary between Zone 1 and Zone 2 in black in the revised manuscript according to your suggestion. We hope our revisions for these figures can meet with your approval (Fig.7, Fig.9, Fig.11 to Fig.14).

Minor comments

1. Line 9. "... by backwater ..." (delete 'the').

Authors' response: We have deleted 'the' in this sentence.

2. Line 10. "intrusions from the main reservoir". The main reservoir is not intruding into the bay, it is water from the main reservoir which is intruding.

Authors' response: We have corrected this sentence (Page 2, Line 23).

3. Line 15. "... relevant to the water environment"

Authors' response: We have added deleted this sentence.

4. Line 17. "... by backwater jacking and intrusions from the ..."

Authors' response: We have deleted this sentence.

5. Line 19. "... and water quality model ..."

Authors' response: We have added 'water' in front of 'quality model' (Page 5, Line 104).

6. Line 23. When the water level dropped where? In the main reservoir?

Authors' response: Yes, in the main reservoir. We have revised this sentence in the revised manuscript (Page 1, Line 17 to Line 20) as follows.

The tributary bay was mainly affected by backwater jacking from the main reservoir when the water level of the main reservoir dropped and by intrusions from the main reservoir when the water level of the main reservoir rose.

7. Line 24. What is a 'quality concentration boundary'?

Authors' response: It is a boundary of the water quality and we have added 'water' in front of 'quality concentration boundary' (Page 1, Line 20).

8. Line 38. "200 m or even 300 m" is a bit redundant. If dams are 300 m high then it is not necessary to say they are over 200 m high.

Authors' response: We have deleted 'over 200 m' in this sentence.

9. Line 40. Delete 'However,' and 'the': "These dams block fish .... and change fish communities..."

Authors' response: We have deleted them.

10. Line 51. "... thus forming water areas ... to lakes known as a tributary bay"

Authors' response: We have revised this sentence in the revised manuscript (Page 3, Line 43 to Line 45) as follows.

Backwater extends to some tributaries after the construction of dammed-river reservoirs, which causes the water depth to increase and the water velocity to slow in these tributaries, thus forming water areas similar to lakes known as a tributary bay.

11. Line 90. "... to a rise or decline in chlorophyll content depending ...."

Authors' response: We have revised this sentence in the revised manuscript (Page 5, Line 87 to Line 89) as follows.

A rise in the water level may lead to a rise or decline in the chlorophyll content depending on the water cycle mode in the tributary.

12. Line 91. Do you mean ’Past studies have paid ...”? If you mean the present study (i.e. this paper) then the grammar is incorrect.

Authors’ response: Yes, we mean the past studies. We have changed ‘present’ to ‘previous’ (Page 5, Line 89).

13. Line 96. “by backwater jacking and intrusions from the main ...” This needs fixing in many places.

Authors’ response: We have fixed the mistakes in the revised manuscript about this sentence (Page 5, Line 93 to Line 94).

14. Line 96. The sentence “How the .... tributary bay?” needs to be revised. Perhaps “There are many open questions regarding the functions of these types of systems: How does the operation of the main reservoir affect tributary bays?; How do hydrodynamic forces and the water environment of tributary bays respond to backwater jacking and the intrusion of water from the main reservoir?; What controls the water environment of tributary bays?”

Authors’ response: Thank you for your positive and constructive suggestions. We have revised the sentences according to your suggestion (Page 5, Line 95 to Line 98).

15. Line 103. “... by backwater jacking and intrusions from the TGR ...”

Authors’ response: We have revised this sentence (Page 5, Line 100 to Line 101).

16. Line 106. “ and water quality ...”

Authors’ response: We have added ‘water’ in front of ‘quality model’ (Page 5, Line 104).

17. Figure 2. The figure caption could be more informative, describing what is shown in each panel.

Authors’ response: We have described each panel in the caption of Figure 2. We also have added descriptions in each panel of Figure 1. The new caption of Figure 1 is as follows (Page 7, Line 132 to Line 134).

Fig. 1. Research area and hydrologic system of the Tangxi River Basin. (a) Location of the research area relative to China; (b) Location of the research area relative to Chongqing; (c) Hydrologic system of the research area.

18. Line 131. “The vertical two-dimensional ...W2 solves the width averaged equations and is appropriate from simulating flow in long narrow water bodies. It was adopted for ...”

Authors’ response: We have revised this sentence as follows (Page 7 to Page 8, Line 138 to Line 141).

The vertical two-dimensional model CE-QUAL-W2 solves the width averaged equations and is appropriate for simulating flow in long narrow water bodies. This model was adopted for the calculation of the hydrodynamic conditions, water temperature and water quality in the tributary bay.

19. Line 135. What density current? This is the first mention of a density current.

Authors’ response: It's the density-driven current. We mentioned this to explain the model can perform well in backwater intrusion issue.

20. Line 136. “... results using this ...”

Authors’ response: We have deleted ‘by’ in this sentence.

21. Line 140. Delete ’listed’.

Authors’ response: We have deleted ‘listed’.

22. Lines 156–158. This information should appear directly below equations (1) -(5).

Authors’ response: We have moved the explanations of each variable below equations (1) - (5).

23. Line 183. “... was used to ...”

Authors’ response: We have corrected this sentence (Page 11, Line 198).

**24. Line 200. What does “usually exhibits characteristics” mean? I do not

understand this.

Authors' response: We are sorry that we missed a word 'complex'. The correct sentence is "…usually exhibits complex characteristics" and we have corrected this in the revised manuscript (Page 11, Line 216).

25. Line 215. How far away from the tributary bay was the meteorological data collected?

Authors' response: The weather station is about 19.7 km away from the tributary bay. We have added this information in the revised manuscript (Page 12, Line 230).

26. Line 216. " sources were calculated and included as inputs to the numerical simulations"

Authors' response: We have revised this sentence as follows (Page 12, Line 231 to Line 232).

The pollution loads of point and non-point sources were calculated and included as inputs to the numerical simulations (Table 1).

27. Line 265. "... nutrient status of ..."

Authors' response: We have corrected this sentence (Page 16, Line 281).

28. Line 277. Correct grammar.

Authors' response: We have changed 'of' to 'from' in this sentence (Page 17, Line 290).

29. Line 278. Delete "With the water level fluctuation through the whole year"

Authors' response: We have deleted this.

30. Line 283. "... length of the backwater ..."

Authors' response: We have corrected this sentence (Page 17, Line 305).

31. Line 285. "... main reservoir was between 160 and 175 m and the ..."

Authors' response: We have revised this sentence as follows (Page 17, Line 305 to Line 307).

During January to April and October to December, the water level of the main reservoir was between 160 and 175 m and the backwater reached distances of 39.8 - 42.6 km from the confluence simultaneously.

32. Figure 4 caption. "The relationships among reservoir water level, length ....". The caption should say what the curves are and what the filled in regions are.

Authors' response: Thank you for your suggestion. We have added the legend of this figure in the revised manuscript (Page 18, Fig.6).

33. Line 302. What is 'water from the tail'?

Authors' response: We have revised this sentence as follows (Page 18, Line 323 to Line 324).

In each month, the upstream water flowed along the surface of the tributary bay or sank to the bottom.

34. Line 316. What does 'directly flowed to the confluence' mean? Flowed along the surface? This should be clarified. Where is the confluence in the figure?

Authors' response: Yes, we meant the upstream water flowed along the surface. The confluence is the right end of the tributary bay in the figure. We have revised this sentence as follows (Page 19, Line 339 to Line 341).

From July to August, the upstream water of the tributary bay directly flowed to the confluence along the surface layer.

35. Figure 7. The red contours in the figure should be explained in the caption.

Authors' response: We have added the explanation of the brown contours in the caption. The revised caption of this figure is shown as follows (Page 23, Line 389 to Line 391).

Fig. 9. Distribution of water temperature in different months. The black curve in the figure is the boundary between Zone 1 and Zone 2. The brown curves with arrows are streamlines.

36. Figure 9. Revise caption: "Distribution of COD ...".

Authors' response: We have revised the caption of previous Fig.9 and we also have revised the same errors in the previous Fig.10 - Fig.12.

37. Line 462. "... was generally higher ..." (it was not higher in every month).

Authors' response: We have added 'generally' in front of 'higher' in this sentence (Page 32, Line 492).

38. Lines 506. I don't understand what the authors are trying to say here: "brought serve vertical"

Authors' response: We are sorry that this sentence made you confused, and we have deleted this sentence in the revised manuscript.

39. Line 507. What is meant by "could contrapuntally be proposed"?

Authors' response: We are sorry we used an inappropriate word 'brought' and we have deleted it in the revised manuscript.

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~~The hydrodynamic~~ Hydrodynamic and environmental characteristics of a tributary bay influenced by backwater jacking and intrusions ~~of~~ from a main reservoir

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Abstract. The construction of large reservoirs results in the formation of tributary bays, and tributary bays are inevitably influenced by ~~the~~ backwater jacking and intrusions ~~of~~ from the main reservoir. ~~The hydrodynamic conditions and the environmental factors of tributary bays exhibit complex distribution characteristics and eutrophication occur frequently. Thus, exploring the distribution and evolution of the hydrodynamic and water environment characteristics of tributary bays in response to backwater jacking and intrusion is the key to solving eutrophication and other problems relevant to water environment.~~ In this paper, a typical tributary bay (Tangxi River) of the Three Gorges Reservoir (TGR) was selected to study the hydrodynamic and environmental characteristics of ~~the~~ a tributary bay influenced by the jacking and intrusions ~~of~~ from the main reservoir. The flow field, water temperature and water quality of the Tangxi River were simulated using the hydrodynamic and water quality model CE-QUAL-W2, and the eutrophication status of the tributary bay was also evaluated. The results showed that the main reservoir had different effects on its tributary bay in each month. The tributary bay was mainly affected by backwater jacking ~~of~~ from the main reservoir when the water level of the main reservoir dropped and by intrusions ~~of~~ from the main reservoir when the water level of the main reservoir rose. An obvious water quality concentration boundary existed in the tributary bay, which was basically consistent with the regional boundary in the flow field. The flow field and water quality on both sides of the boundary were quite different. The results of this study can help us figure out how the backwater jacking and intrusions ~~of~~ from the main reservoir influence the hydrodynamic and water environment characteristics of the tributary bay and provide guidance for water environment protection in ~~the~~ tributary bays.

Keywords: tributary bay, main reservoir, backwater jacking, intrusion, hydrodynamic conditions, environmental factors

1 Introduction

The functions of water conservancy and hydropower projects include power generation, flood control, irrigation and shipping, which play an important role in human social life (Deng and Bai, 2016; Zhang, 2014; Peng, 2014). In recent years, ~~with the construction of the Yangtze River Economic Belt and urban agglomeration of China,~~ a large number of high dams, with heights of ~~over 200 m or~~ even 300 m, have been planned or completed in the middle and upper reaches of the Yangtze River to meet the increasing energy demand (Zhou et al., 2013). ~~However, these~~ These dams block ~~the~~ fish migration routes between upstream and downstream regions (Oldani and Claudio, 2002; Ziv et al., 2012) and change the fish communities (Gao et al., 2010). In the flood season, flood discharge produces water that is supersaturated in dissolved gas in the downstream river channel (Feng et al., 2014; Lu et al., 2011; Wang et al., 2011; McGrath, 2006). In the reservoir area, the elevated water level produces a much slower water velocity, which results in sediment deposition, eutrophication, and stratification in terms of water temperature and water quality (Zhu, 2017; Wu, 2013; Zhang et al., 2011).

Backwater extends to some tributaries after the construction of dammed-river reservoirs, which causes the water depth to increase and the water velocity to slow in these tributaries, thus ~~formed~~ forming ~~the~~ water areas similar to lakes~~, and were~~ known as a tributary bay (Yu et al., 2013). Backwater areas represent the connection between different habitats in the main stream and the tributary and are also an important location for physical, chemical and biological exchanges between adjacent habitats (Zhang et al., 2010). After the impoundment of a reservoir, the hydrodynamic conditions and the environmental factors (water temperature, water quality, etc.) of the tributaries in the reservoir area are affected by the main stream and exhibit complex distribution characteristics (Xiong et al., 2013). Backwater jacking occurs in tributaries when ~~A tributary bay is always influenced by backwater jacking~~dams or other obstructions raise the surface of the water upstream from them. ~~and i~~Intrusion is the process by which water from the mainstream intrudes into the tributary. A tributary bay is always influenced by backwater jacking and intrusions ~~with the~~under ~~rise~~fluctuations of the water level of the main reservoir because such changes induce changes in the hydrodynamic conditions in the tributary bay (Ji et al., 2010; Wang et al., 2014). The velocity of water in the horizontal direction becomes uneven, and the velocity on the side near the confluence is obviously higher than that on the other side (Hu et al., 2013; Yin et al., 2013). The flow field distribution tends to gradually change with increasing distance from the confluence (Yin et al., 2013). The water level of a reservoir changes constantly to meet multiple requirements, which results in changes in water temperature and water environment in tributary bays (Fu et al., 2010; Holbach et al., 2013; Yang et al., 2013). Existing studies have shown that water level fluctuation has become a major cause of recent eutrophication and pollution problems in the Three Gorges Reservoir (TGR), particularly within its tributary backwaters (Holbach et al., 2015). After the impoundment of reservoirs, eutrophication and eutrophication-related problems often occur in tributary bays due to changes in nutrient patterns (Yang et al., 2010; Liu et al., 2012; Ran et al., 2019). Therefore, exploring the distribution and evolution of the hydrodynamic and water environment characteristics of tributary bays in response to backwater jacking and intrusions ~~of~~ from the main reservoir is ~~the~~a key to solving eutrophication problems.

Many recent studies have paid attention to the deterioration of the water environment in tributary bays. In response to the operation of cascade reservoirs, a series of profound geological, morphological, ecological, and biogeochemical responses will appear in the estuary, delta, and coastal sea of the Yangtze River subaqueous delta (Hu et al., 2009). Some scholars have found that the water quality of the TGR was relatively stable before and after impoundment but that the water quality of tributary bays deteriorated, resulting in frequent algal blooms (Liu et al., 2016; Zou and Zhai, 2016; Cai and Hu, 2006). Changes in the vertical mixing of layers driven by stratified density currents were the key factor in the formation of algal blooms (Tang et al., 2016; Zhang et al., 2015). Through isotopic measurements in the Xiangxi River or other tributaries of the TGR, it has been found that the nutrients in tributary bays did not originate solely in the tributary basins but instead were mainly from the main stream of the Yangtze River and that the nutrient levels were affected by constantly changing hydrodynamic conditions across seasons (Holbach et al., 2014; Yang et al, 2018; Zheng et al., 2016). ~~Some scholars found that a~~ A rise in the water level may lead ~~either~~ to a rise ~~in the chlorophyll content~~ or ~~to a~~ decline in the chlorophyll content~~,~~ depending on the water cycle mode in the tributary (Ji et al., 2017). ~~The present~~ Previous studies have paid considerable attention to changes in hydrodynamic characteristics and the deterioration of the water environment in the tributaries but have not considered the influence of the main reservoir (Zhao, 2017; Long et al., 2019). There are few systematic studies on the variation in the hydrodynamic and water environment characteristics of tributary bays influenced by ~~the~~ backwater jacking and intrusions ~~of~~ from the main reservoir. There are many open questions regarding the functions of these types of systems: How does the operation of the main reservoir affect tributary bays? How do hydrodynamic forces and the water environment of tributary bays respond to backwater jacking and the intrusion of water from the main reservoir? What controls the water environment of tributary bays?~~How~~

~~the operation of the main reservoir affects the tributary bays, how the hydrodynamic forces and water environment of the tributary bays respond to the backwater jacking and intrusion of the main reservoir, what controls the water environment of the tributary bay?~~ These questions have not yet been resolved~~are not yet clear~~.

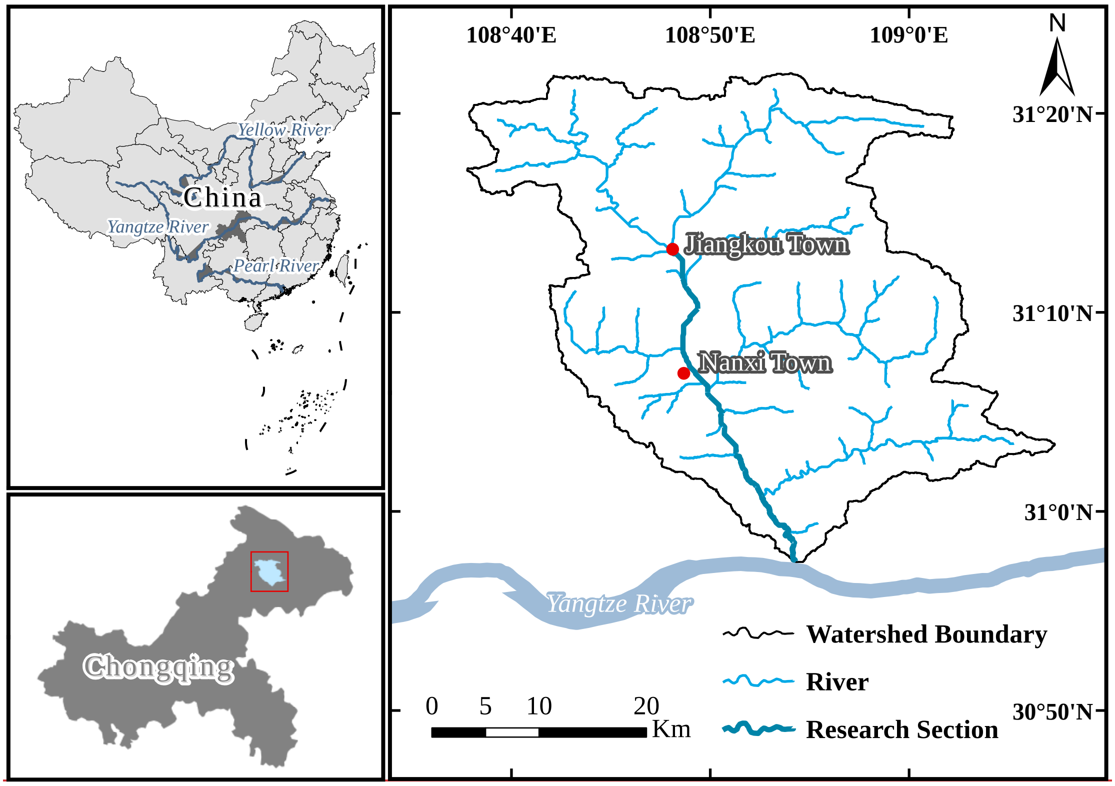
The Tangxi River is a typical tributary bay of the TGR, and it has been severely influenced by backwater jacking and intrusions in recent years. This phenomenon accelerates the deterioration of the water environment of Tangxi River. Thus, the Tangxi River was selected as the focus of this study.~~The Tangxi River, a tributary in the upper reaches of the Yangtze River, was selected as the focus of this study. The hydrodynamic and water environmental characteristics of the Tangxi River have inevitably been affected by the backwater jacking and intrusion of the TGR in recent years.~~ Based on the collection and analysis of basic data, we simulated the flow field, water temperature, and water quality of the Tangxi River using the hydrodynamic and water quality model CE-QUAL-W2. This model performs well in computing the velocity, the intrusion layer at the plunge point, and the travel distance of the density-driven current (Long et al., 2019), and many scholars have obtained good results ~~by~~ using this model to simulate the hydrodynamics, water temperature and water quality of reservoirs and lakes (Bowen and Hieronymus, 2003; Lung and Nice, 2007; Berger and Wells, 2008; Debele et al., 2008; Noori, 2015; Long et al., 2018). ~~Then, we~~ We also evaluated the eutrophication status of the tributary bay and systematically identified the influence of ~~the~~ backwater jacking and intrusions ~~of~~ from the main reservoir on the tributary bay. The results of this study can help us to figure out how the backwater jacking and intrusions ~~of~~ from the main reservoir influenced the hydrodynamic and water environment characteristics of the tributary bay and provide guidance for water environment protection in ~~the~~ tributary bays.

2 Materials and methods

2.1 Research area

The main stream of the Yangtze River has a total length of approximately 6300 km and a drainage area of approximately 1.8 million km^2. The reach between Yichang City and Hubei Yibin City in Sichuan is considered the upper reaches of the Yangtze River, which has a length of 1045 km and a natural drop of 220 m. The drainage area of the upper Yangtze River is 527000 km^2, and its average annual flow is 14300 m^3/s (Fan, 2007).

The Tangxi River is a first-order tributary of the upper Yangtze River and has a total length of 104 km, a drainage area of 1707 km^2 and an average annual flow of 57.2 m^3/s. After the completion of the TGR, the Tangxi River became a tributary bay of the TGR. In this paper, the 42.6 km long reach of the Tangxi River affected by the backwater jacking and intrusions ~~of~~ from the TGR was selected as the study area (Fig. 1).



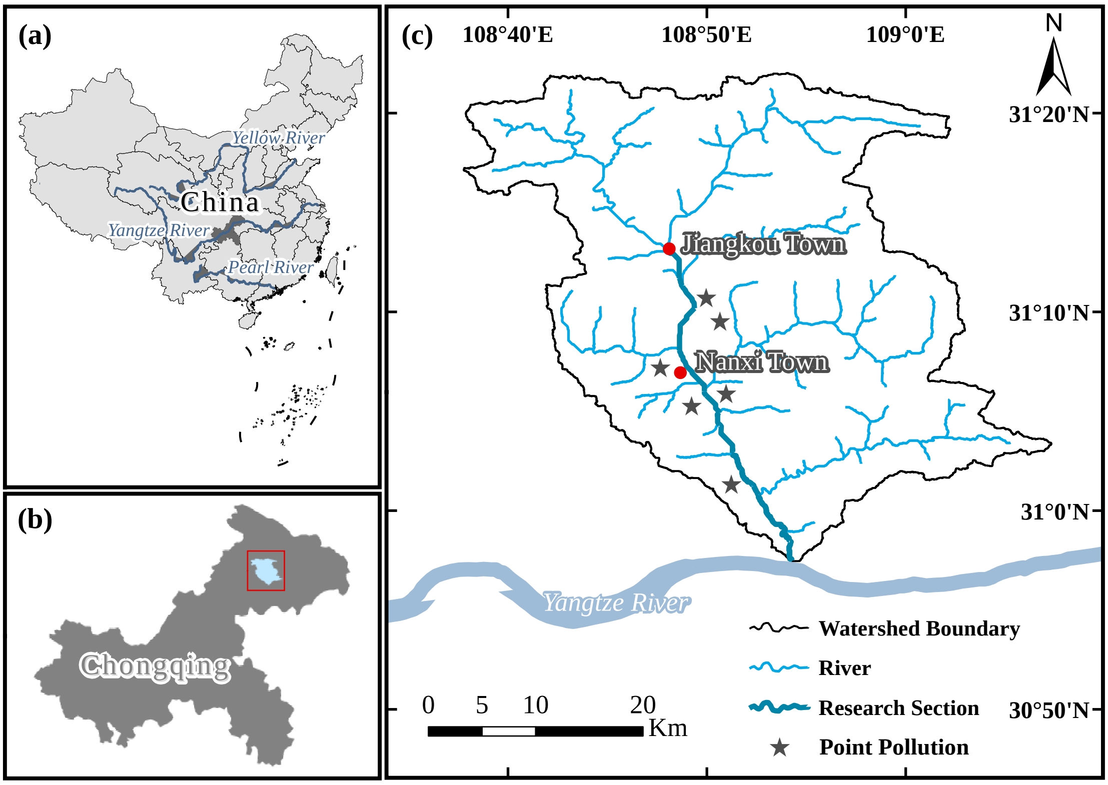


Fig. 1. Research area and hydrologic system of the Tangxi River Basin. (a) Location of the research area relative to China; (b) Location of the research area relative to Chongqing; (c) Hydrologic system of the research area.

2.2 Numerical simulation of hydrodynamic and environmental factors in the tributary bay

2.2.1 Mathematical model

The vertical two-dimensional model CE-QUAL-W2 solves the width averaged equations and is appropriate for simulating flow in long narrow water bodies. ~~with average width~~This model was adopted for the calculation of the hydrodynamic conditions, water temperature and water quality in the tributary bay (Thomas and Scott, 2008). ~~This model performs well in computing the velocity, the intrusion layer at the plunge point, and the travel distance of the density current (Long et al., 2019), and many scholars have obtained good results by using this model to simulate the hydrodynamics, water temperature and water quality of reservoirs and lakes (Debele et al., 2008; Noori, 2015; Long et al., 2018).~~ The model is solved by coupling governing equations, a transport equation and a surface heat exchange equation. The research river was divided into 107 × 38 (longitudinal × vertical) rectangular cell grids with a longitudinal dimension of 400 m and vertical dimension of 2 m (Fig. 2).

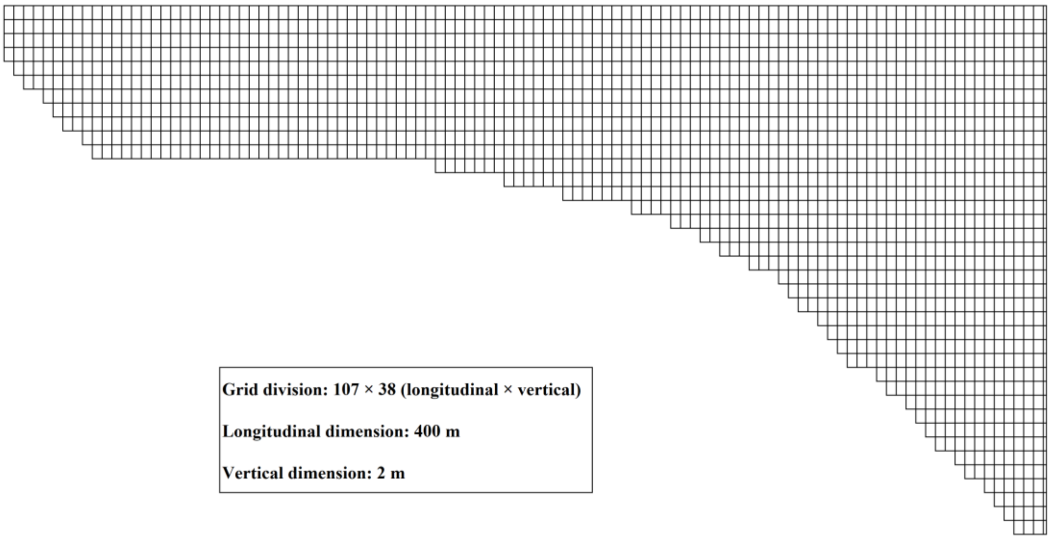


Fig. 2. Grid structure of the research area.

The governing equations of the model are ~~listed~~ as follows.

The continuity equation:

$$\frac{\partial UB}{\partial x} + \frac{\partial WB}{\partial z} = qB \tag{1}$$

The x-momentum equation:

$$\frac{\partial UB}{\partial t} + \frac{\partial UUB}{\partial x} + \frac{\partial WUB}{\partial z} = gB \sin\alpha - \frac{B}{\rho}\frac{\partial P}{\partial x} + \frac{1}{\rho}\frac{\partial B\tau_{xx}}{\partial x} + \frac{1}{\rho}\frac{\partial B\tau_{xz}}{\partial z} \tag{2}$$

The z-momentum equation:

$$\frac{1}{\rho}\frac{\partial P}{\partial z} = g \cos\alpha \tag{3}$$

The free water surface equation:

$$B_\eta \frac{\partial \eta}{\partial t} = \frac{\partial}{\partial x}\int_\eta^h UB\,dz - \int_\eta^h qB\,dz \tag{4}$$

The equation of state:

$$\rho = f(T_W, \Phi_{TDS}, \Phi_{ISS}) \tag{5}$$

where x and z represent the horizontal distance and vertical elevation, respectively; U and W are the temporal mean velocity components in the horizontal and vertical directions; B is the channel width; q is the discharge; t denotes the time; g is the acceleration of gravity; α is the angle of the riverbed with respect to the x-direction; P represents pressure; τ_{xx} and τ_{xz} are the lateral average shear stress in the x-direction and z-direction, respectively; ρ ~~and ρ_{Tw}~~ represents densit~~ies~~y; η and h are the water surface and water depth, respectively; and ~~T_W is the water temperature.~~ $f(T_W, \Phi_{TDS}, \Phi_{ISS})$ is a density function dependent upon temperature, total dissolved solids or salinity, and inorganic suspended solids.

Accurate hydrodynamic calculations require accurate water densities. ~~Water densities are affected by variations in temperature and the concentration of solids.~~ The following equation of state relating the density to the water temperature was used ~~The following relationship is used~~ in the model:

$$\rho_{Tw} = 999.845259 + 6.793952 \times 10^{-2} T_w - 9.19529 \times 10^{-3} T_w^2 + 1.001685 \times 10^{-4} T_w^3 - 1.120083 \times 10^{-6} T_w^4 + 6.536332 \times 10^{-9} T_w^5 \quad (6)$$

~~where x and z represent the horizontal distance and vertical elevation, respectively; U and W are the temporal mean velocity components in the horizontal and vertical directions; B is the channel width; q is the discharge; t denotes the time; g is the acceleration of gravity; α is the angle of the riverbed with respect to the x-direction; P represents pressure; τ_{xx} and τ_{xz} are the lateral average shear stress in the x-direction and z-direction, respectively; ρ and ρ_{Tw} represent densities; η and h are the water surface and water depth, respectively; and T_W is the water temperature.~~ where ρ_{Tw} denotes density and T_W is the water temperature.

The universal transport equation for scalar variables, such as temperature and chemical oxygen demand (COD), is as follows:

$$\frac{\partial B\Phi}{\partial t} + \frac{\partial UB\Phi}{\partial x} + \frac{\partial WB\Phi}{\partial z} - \frac{\partial\left(BD_x\frac{\partial\Phi}{\partial x}\right)}{\partial x} - \frac{\left(BD_z\frac{\partial\Phi}{\partial z}\right)}{-\partial z} = q_\Phi B + S_\Phi B \quad (7)$$

where Φ is the laterally averaged constituent concentration; D_x and D_z are the temperature and constituent dispersion coefficient in the horizontal and vertical directions, respectively; q_Φ represents the lateral inflow or outflow mass flow rate of the constituent per unit volume; and S_{Φ} denotes the laterally averaged source/sink term.

Heat exchange at the water surface includes net solar shortwave radiation, net longwave radiation, evaporation and conduction. The surface heat exchange is computed as follows:

$$H_n = H_s + H_a + H_e + H_c - (H_{sr} + H_{ar} + H_{br}) \quad (8)$$

where H_n is the net rate of heat exchange across the water surface; H_s is the incident shortwave solar radiation, ; H_a represents the incident longwave radiation; H_{sr} and H_{ar} represent the reflected solar radiation of shortwave and longwave radiation, respectively; H_{br} is the back radiation from the water surface; H_e is the evaporative heat loss; and H_c represents the heat conduction.

The shortwave absorption model we used was based on Bears Law (Thomas and Scott, 2008). The attenuation coefficients in the model include the fraction absorbed at the water surface and the extinction coefficient, which were 0.45 and 0.45 m^{-1}, respectively. Due to the exponential decay of the shortwave radiation, we did not distinguish the heating after radiation reached the bottom of the tributary in the simulation.

2.2.2 Model validation

The water quality at the Tangxi River Bridge was monitored in 2017, and the data were was used to verify the model and the degradation coefficient of each water quality parameter. The Tangxi River Bridge is 18 km from the confluence. Due to the low water level of the main reservoir, the backwater did not reach the Tangxi River Bridge from June to August. Therefore, only the data from January to May and from September to December were selected to verify the simulated results of water temperature (T), ammonia nitrogen (NH_3-N), total phosphorus (TP), and total nitrogen (TN). COD values were not measured. The degradation coefficients of COD, NH_3-N, TP and TN are 0.0032 d^{-1}, 0.0032 d^{-1}, 0.0018 d^{-1}, and 0.0018 d^{-1} respectively .

The results showed that the simulated values of T, TP and TN fit well with the measured values. The difference in T between the simulated value and the measured value was 0.6 - 4.7 ºC, and the root mean squared error was 1.8 ºC. The difference in TP between the simulated value and the measured value was 0.004 - 0.03 mg/L, and the root mean squared error was 0.01 mg/L. The difference in TN between the simulated value and the measured value was 0.02 - 0.26 mg/L, and root mean squared error was 0.16 mg/L. For NH_3-N, the difference between the simulated value and the measured value was 0.03 - 0.08 mg/L, the root mean squared error was 0.06 mg/L, and the relative error was greater than 30%.~~The minimum difference in T between the simulated value and the measured value was 0.6 ºC, the maximum difference was 4.7 ºC, and the error percentage between the simulated values and the measured values ranged from 3 - 29%. The minimum difference in TP between the simulated values and the measured values was 0.004 mg/L, the maximum difference was 0.03 mg/L, and the error percentage between the simulated and measured values ranged from 5 - 34%. The minimum and maximum differences in TN between the simulated and measured values were 0.02 mg/L and 0.26 mg/L, respectively, and the error percentage ranged from 3 - 38%. For NH_3-N, the differences between the simulated and measured values were greater than 0.3 mg/L, and the error percentage was greater than 30%.~~ The degradation process of NH_3-N usually exhibits complex characteristics, and ~~there are~~ many factors affect~~ing~~ the degradation coefficient of NH_3-N, such as the water microbial properties~~ of the water~~, hydrodynamic conditions, water pollution degree, suspended solids and pH (Bockelmann et al., 2004; Wang et al., 2016; Pan et al., 2020), which resulted in a higher simulation error compared with ~~than~~ the other values.

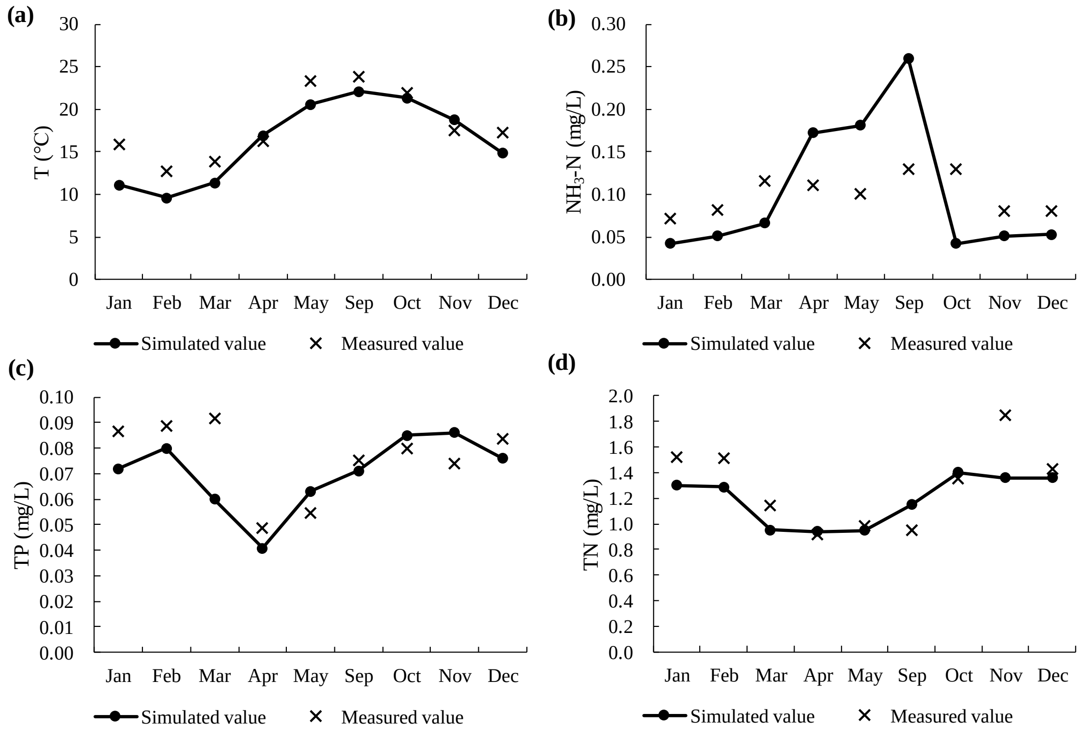


Fig. ~~2~~3. ~~The c~~Comparison between the simulated and measured values at the Tangxi River Bridge in each month. (a) Comparison of water temperature~~,~~; (b) ~~comparison~~ Comparison of ammonia nitrogen~~,~~; (c) ~~comparison~~ Comparison of total phosphorus~~,~~; (d) ~~comparison~~ Comparison of total nitrogen. ~~The points on the graph are simulated values, and the cross marks on the graph are measured values.~~

2.2.3 Boundary conditions

The boundary conditions of the calculation included the meteorology, water temperature of the inflow, discharge flow, water quality and water level of the TGR. The daily average multi-year meteorological data (2011-2018) were obtained from ~~The meteorological conditions of the Tangxi River and TGR were based on meteorological data from~~ Yunyang County weather station, which is 19.7 km away from the tributary bay (Fig. 4)~~(Table 1)~~.~~,~~ ~~and t~~The pollution loads of point and non-point sources were calculated and included as inputs to the numerical simulation~~counted and then calculated in this study~~ (Table ~~2~~1). The daily average multi-year data on the boundary conditions of flow, water level, water temperature and water quality were also considered ~~are shown in~~ (Fig. ~~3~~5~~.~~). The diurnal cycle of the simulation lasted three years.

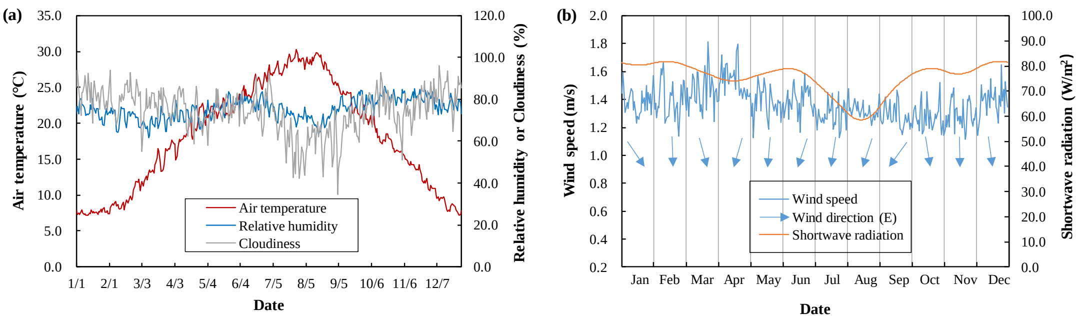


Fig. 4. Meteorological conditions. (a) Daily average nulti-year values of air temperature, humidity and cloudiness and (b) daily average multi-year values of wind conditions and shortwave radiation.

~~**Table 1.**~~

~~Statistical table of meteorological data from the Yunyang meteorological station.~~

~~Month~~	~~Temperature~~	~~Wind speed~~	~~Wind direction~~	~~Cloudiness~~	~~Solar radiation~~	~~Relative humidity~~
	~~℃~~	~~m/s~~	~~°~~	~~%~~	~~W/m²~~	~~%~~
~~1~~	~~7.6~~	~~0.8~~	~~146~~	~~81~~	~~57.1~~	~~78.5~~
~~2~~	~~9.8~~	~~0.9~~	~~178~~	~~82~~	~~74.3~~	~~75.8~~
~~3~~	~~14.3~~	~~1.0~~	~~165~~	~~78~~	~~121.2~~	~~72.7~~
~~4~~	~~19.0~~	~~1.1~~	~~196~~	~~75~~	~~146.3~~	~~74.6~~
~~5~~	~~22.9~~	~~1.1~~	~~185~~	~~77~~	~~149.1~~	~~76.9~~
~~6~~	~~25.8~~	~~1.1~~	~~198~~	~~78~~	~~158.7~~	~~78.6~~
~~7~~	~~29.1~~	~~1.2~~	~~189~~	~~68~~	~~197.5~~	~~72.9~~
~~8~~	~~29.0~~	~~1.2~~	~~198~~	~~60~~	~~203.9~~	~~69.4~~
~~9~~	~~24.7~~	~~1.1~~	~~216~~	~~71~~	~~138.3~~	~~76.4~~
~~10~~	~~19.6~~	~~0.9~~	~~171~~	~~78~~	~~103.9~~	~~81.4~~
~~11~~	~~14.5~~	~~0.8~~	~~179~~	~~77~~	~~73.0~~	~~83.0~~
~~12~~	~~9.1~~	~~0.8~~	~~172~~	~~81~~	~~55.5~~	~~82.4~~
~~Annual~~	~~18.8~~	~~1.0~~	~~183~~	~~76~~	~~123.2~~	~~76.9~~

Table ~~2~~1.

Statistics of pollution load in the Tangxi River research area.

Factors	COD (t/a)		NH_3-N (t/a)		TP (t/a)		TN(t/a)	
	Point	Non-point	Point	Non-point	Point	Non-point	Point	Non-point
Pollution Load	2093.58	1537.35	354.21	154.46	35.08	23.90	2093.58	1537.35

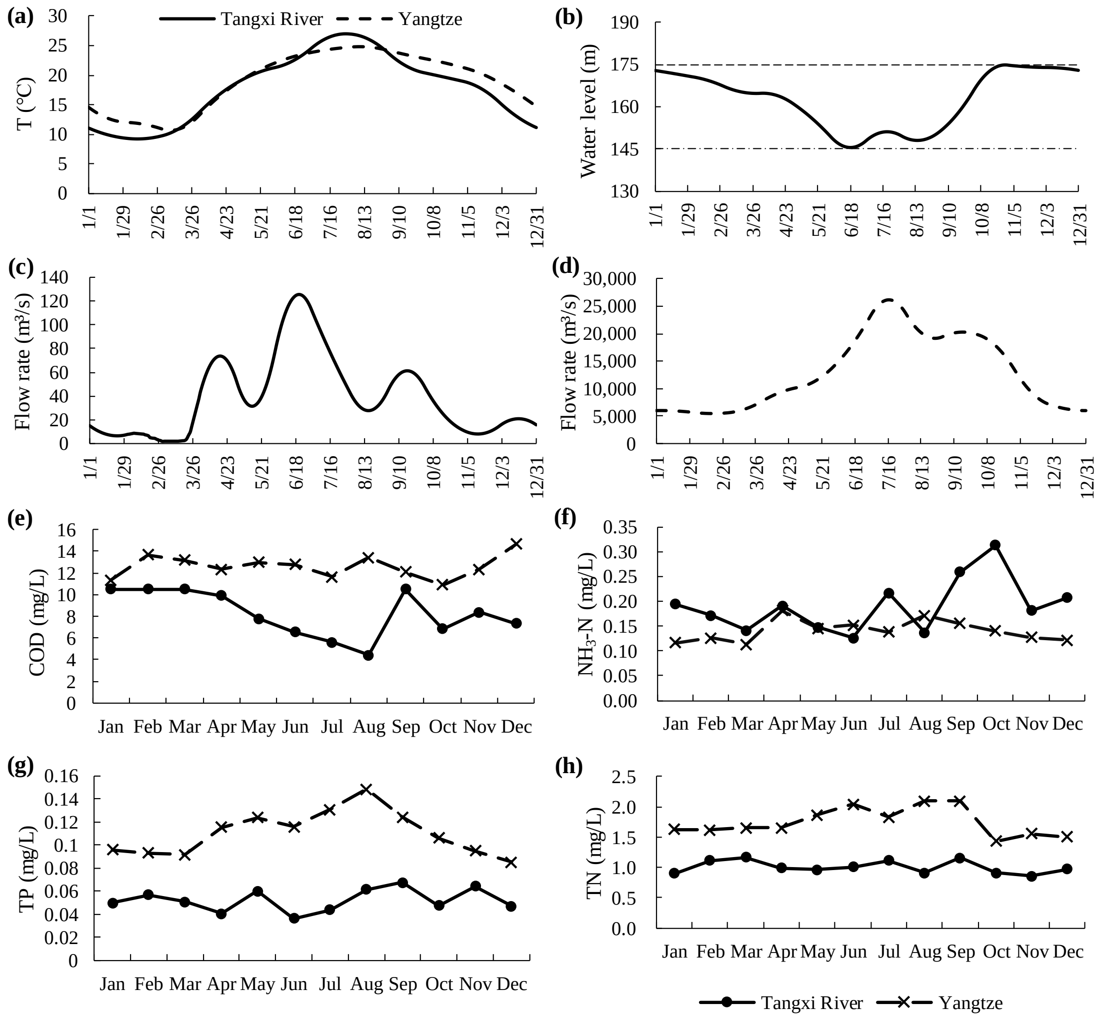


Fig. ~~3~~5. Simulation boundary conditions. (a) Daily water temperatures of the main reservoir and tail of the tributary bay~~,~~; (b) ~~water~~ Water level of the main reservoir, (c) ~~daily~~ Daily inflow of the tributary bay~~,~~; (d) ~~daily~~ Daily inflow of the main reservoir~~,~~; (e) - (h) ~~monthly~~ Monthly water quality (COD, NH_3-N, TP and TN) of the main reservoir and tributary bay, respectively.

2.3 Simulation of eutrophication

The comprehensive nutrition index ($TLI(\sum)$) method (Carlson, 1977) was used to evaluate the nutritional status of the tributary bay. Lakes and reservoirs can be classified into different nutritional statuses based on their $TLI(\sum)$ values:

$$TLI(\sum) < 30, \text{ oligotrophic}$$

$$30 \leq TLI(\sum) \leq 50, \text{ mesotrophic}$$

$TLI(\sum) > 50$, eutrophic

$50 < TLI(\sum) \leq 60$, slightly eutrophic

$60 < TLI(\sum) \leq 70$, moderately eutrophic

$TLI(\sum) > 70$, severely eutrophic

The formula for calculating the $TLI(\sum)$ is as follows:

$$TLI(\sum) = \sum_{j=1}^{m} W_j \cdot TLI(j) \quad (9)$$

where $TLI(\sum)$ is the comprehensive nutrition index; W_j represents the correlation weight of the nutrition state index of the j-th parameter; and $TLI(j)$ denotes the nutritional status index of the j-th parameter.

Considering chlorophyll-a (*chla*) as the reference parameter, the normalized correlation weight formula of the j-th parameter is as follows:

$$W_j = \frac{r_{ij}^2}{\sum_{j=1}^{m} r_{ij}^2} \quad (10)$$

where r_{ij} is the correlation coefficient between the j-th parameter and the reference parameter *chla* and m represents the number of evaluation parameters.

The correlation coefficients r_{ij} and r_{ij}^2 between *chla* and other parameters are shown in Table ~~3~~ 2 (Li and Zhang, 1993).

Table ~~3~~2

The correlation coefficients r_{ij} and r_{ij}^2 between *chla* and other parameters.

Parameter	TP	TN	SD	COD_{Mn}
r_{ij}	0.84	0.82	-0.83	0.83
r^2_{ij}	0.7056	0.6724	0.6889	0.6889

The calculation formula of the nutritional status index of each parameter is shown as follows:

$$TLI(TP) = 10(9.436 + 1.624 \ln TP) \quad (11)$$

$$TLI(TN) = 10(5.453 + 1.694 \ln TN) \quad (12)$$

$$TLI(SD) = 10(5.118 + 1.94 \ln SD) \quad (13)$$

$$TLI(COD_{Mn}) = 10(0.109 + 2.661 \ln COD_{Mn}) \quad (14)$$

where TP is total phosphorus; TN represents the total nitrogen; SD represents the Secchi depth, a measure of transparency; and COD_{Mn} is the chemical oxygen demand.

~~In~~ Among the parameters listed above, TP and TN are pivotal, and a limitation~~.~~ ~~Limitation~~ of ~~one of these,~~ TP or TN~~,~~ can limit algae blooms (Bennett et al., 2017; Morgenstern et al., 2015; Lewis et al., 2011). The nutrient status~~es~~ of the surface water in the Tangxi River tributary bay in different months ~~were~~ was evaluated in this study according to the $TLI(\sum)$ method. The influence of water temperature was also considered during the nutrient status evaluation.

3 Results and discussion

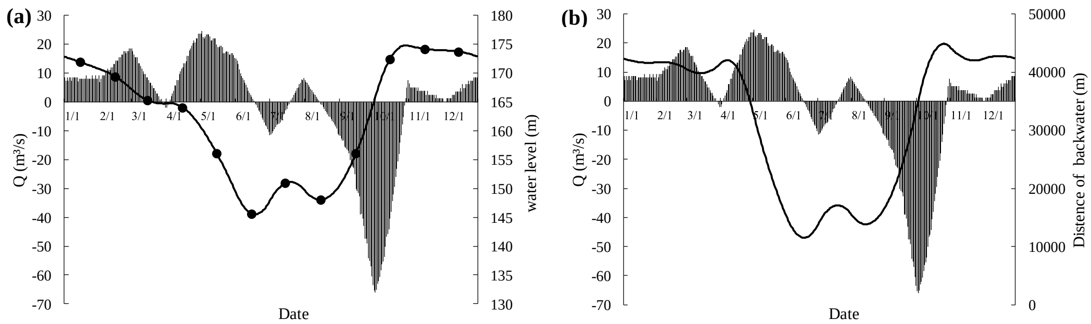
3.1 Hydrological situation

The temporal variations in confluence flow and water level are shown in Fig. ~~4a~~6a. During July and from August to October, the flow value at the confluence was negative, which indicated that the tributary bay was mainly affected by backwater intrusions from the main reservoir. In contrast, the tributary bay was mainly affected by ~~the~~ backwater jacking ~~of~~ from the main reservoir in other months (January - June and November - December). ~~With the water level fluctuation through the whole year, the~~ The backwater intrusion weakened when the water level of the main reservoir dropped, and it became obvious when the water level of the main reservoir rose~~, the backwater intrusion became obvious~~.

Periods of intrusions that occurred in other tributaries were investigated in previous studies. Backwater intrusions were mainly concentrated in low water level operation period and impoundment period in the Daning River (Zhao, 2017). The water of the mainstream of TGR flowed backward into the Xiangxi Bay in the density current at different plunging depths during the process of TGR impoundment at the end of the flood season in autumn, and the intrusion was weak when the water level fell (Ji et al., 2010; Yang et al., 2018). Compared to the results of previous studies, the backwater intrusions showed obvious seasonal changes and the main intrusion time was almost the same.

The temporal variation in confluence flow and the length of backwater are shown in Fig. ~~4b~~6b. With the change in the flow at the confluence, the length of the backwater also changed. During January to April and October to December, the water level of the main reservoir ~~rose to~~was between 160 ~~-~~and 175 m~~,~~ and the backwater reached distances of 39.8 - 42.6 km from the confluence simultaneously. During May to September, the water level of the main reservoir remained at 145 - 160 m, and the backwater reached distances of 12.6 - 23.8 km from the confluence.

The water level and the length of backwater had a negative correlation with the confluence flow. When the water level dropped, the value of the confluence flow was positive, and the length of backwater decreased. The tributary bay was mainly affected by the jacking of the main reservoir during this period. Conversely, when the water level rose, the water flow at the confluence was negative, and the length of the backwater increased. The tributary bay was mainly affected by backwater intrusions at this time.



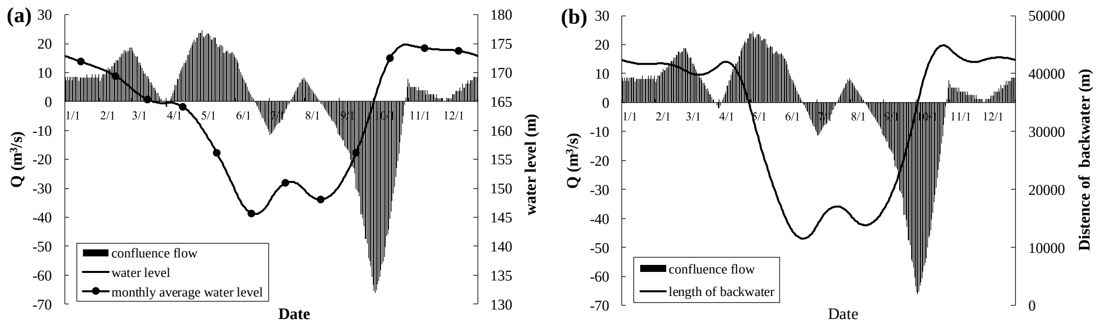


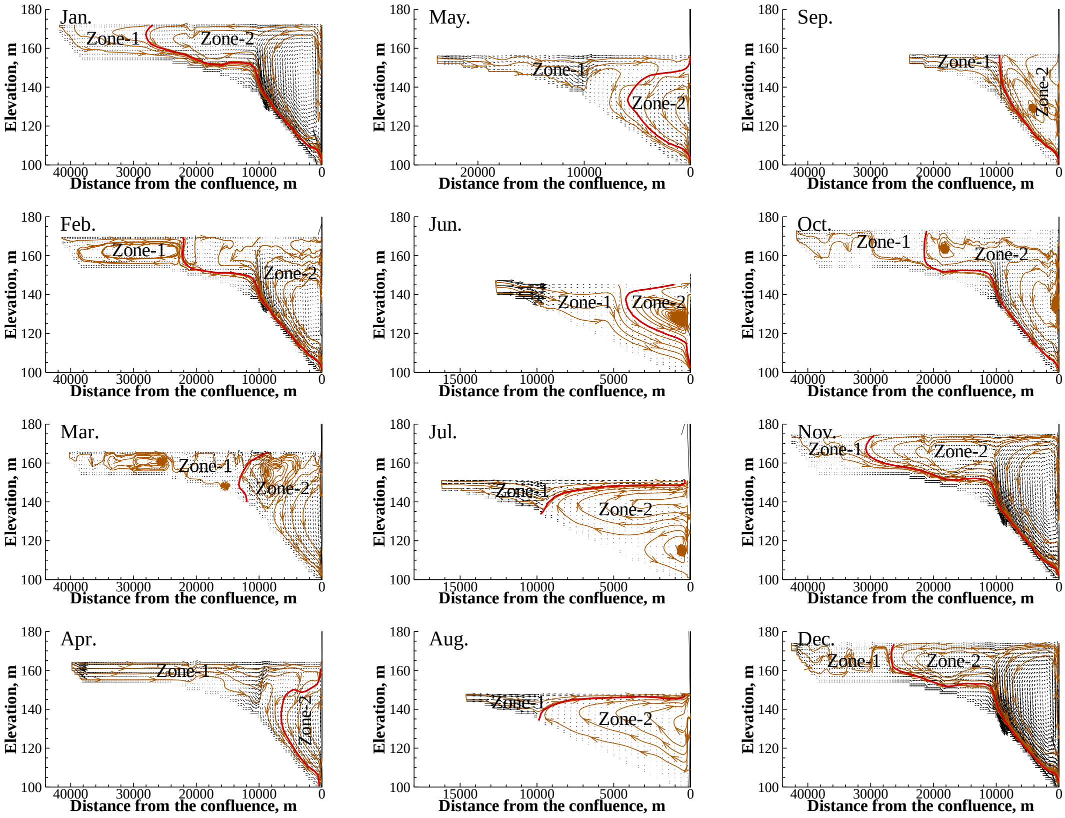
Fig. ~~4~~6. ~~The r~~Relationships among water level, length of backwater and confluence flow. (a) Daily variations in confluence flow and water level and (b) daily variations in confluence flow and length of backwater.

3.2 Hydrodynamics

The distribution of the flow field in each month is shown in Fig. ~~5~~7. In each month, the upstream water ~~from the tail~~ flowed along the surface of the tributary bay or sank to the bottom. The backwater from the main reservoir entered the confluence at different depths simultaneously, forming one or two flow circulation patterns in the tributary bay. A similar flow field distribution occurred in other tributary bays of the TGR (Ji et al., 2017).

In response to the jacking of the main reservoir in January, the water from the tail of the tributary bay first flowed along the surface and then sank to the bottom. Under the influence of geography, the backwater from the main reservoir formed two large counterclockwise circulations in the tributary bay. The water level gradually decreased from February to March, and the backwater effect of the main reservoir also gradually weakened. The water from the tail formed one circulation (February) or two circulations (March) in the tributary bay. From April to June, as the upstream water of the tributary bay joined the surface layer, the circulation zone disappeared. The upstream water gradually sank as it neared the confluence, and at the same time, the backwater from the main reservoir entered the tributary bay in the upper middle layers and formed a small counterclockwise circulation. From July to August, the upstream water of the tributary bay directly flowed to the confluence ~~from~~ along the surface layer, and the backwater from the main reservoir entered the tributary bay in the middle and lower layers, forming one circulation in August and two circulations in July. In September, the upstream water first flowed through the surface layer and then sank to the middle of the tributary bay. The backwater from the main reservoir inclined upward from the lower layer and formed two circulations. The upper circulation was a smaller clockwise circulation, while the lower circulation was a larger counterclockwise circulation. The water level increased significantly from October to December, and the influence of the backwater increased simultaneously.

The upstream water of the tributary bay flowed through the surface layer and then sank to the bottom.



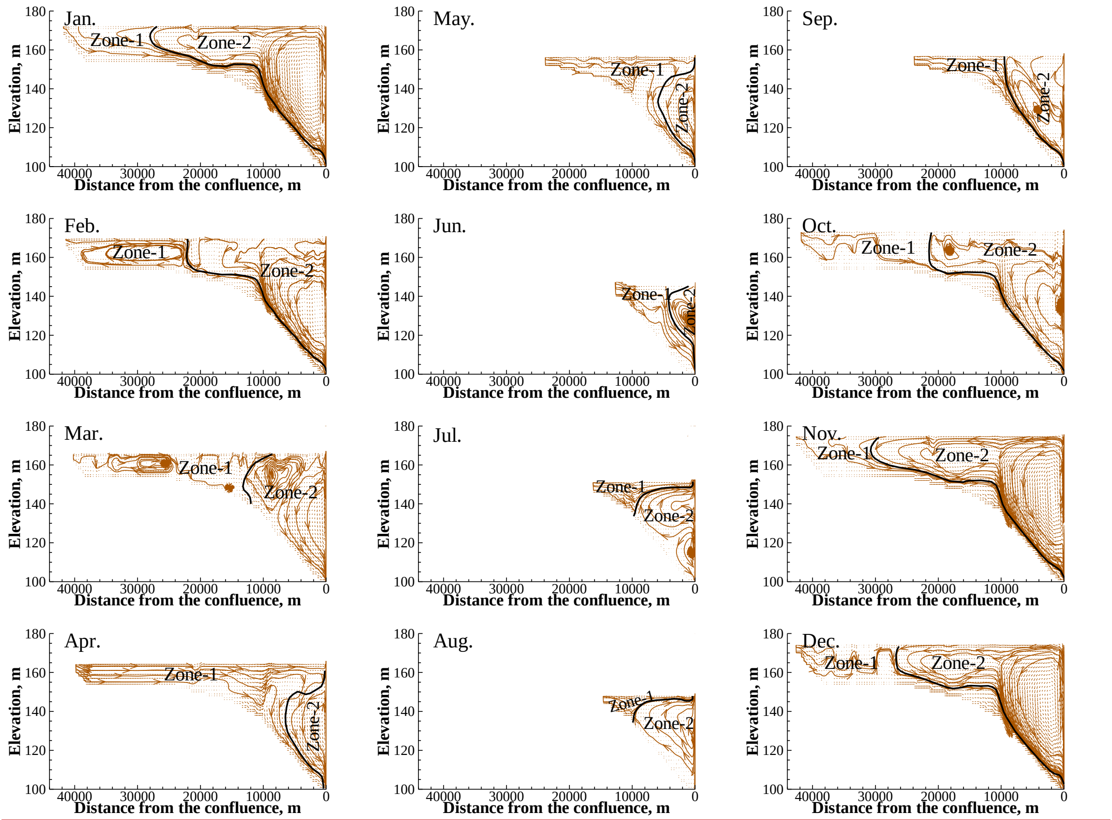
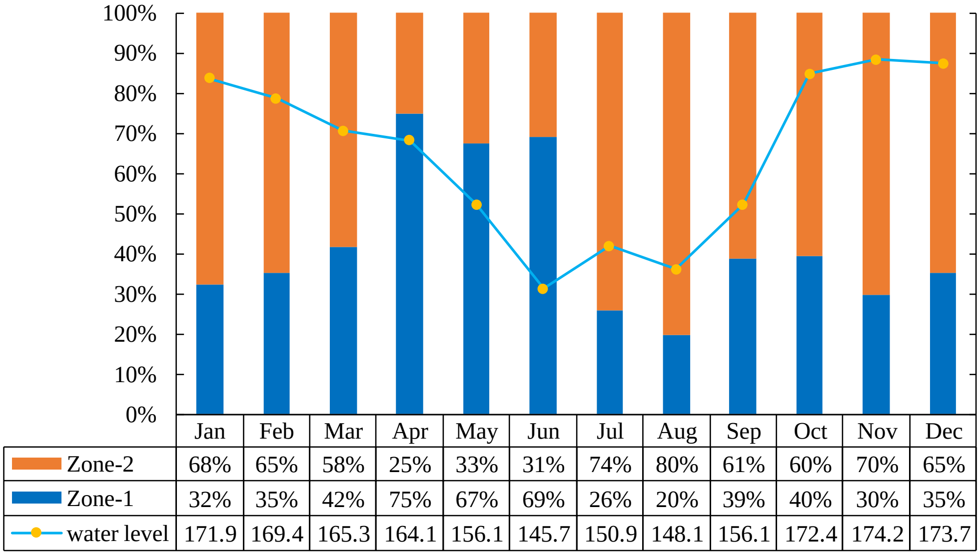


Fig. ~~5~~7. ~~The d~~Distribution of the flow field in each month. The flow field was divided into two areas (Zone 1 and Zone 2) according to the flow field characteristics. The ~~red~~ black curve in the figure is the boundary between Zone 1 and Zone 2.

According to the distribution of the flow field, the tributary bay was divided into two different areas. Zone 1 represented the area mainly affected by the water from the tail of the tributary bay, and Zone 2 was the area mainly affected by the backwater from the main reservoir. Due to the variations in water level and flow value, the ranges of Zone 1 and Zone 2 differed in each month. The proportions of Zone 1 and Zone 2 varied with the water level and time (Fig. ~~6~~8). From January to April, the backwater reach was from the confluence to Jiangkou Town. With the decrease in the water levels, the proportion of Zone 1 increased, while the proportion of Zone 2 decreased. From May to September, the length of backwater decreased, and it only reached Nanxi Town. With the fluctuation in the water level in these months, the trend of the proportions of Zone 1 and Zone 2 became irregular. From October to November, with the rise in the water level, the proportion of Zone 1 decreased, while the proportion of Zone 2 increased. The opposite results were obtained from November to December when the water level gradually decreased. From October to December, the backwater again reached Jiangkou Town. These results suggested that the backwater had a greater impact on the tributary bay when the main reservoir was at a high water level and had a smaller impact when the main reservoir was at a low water level.



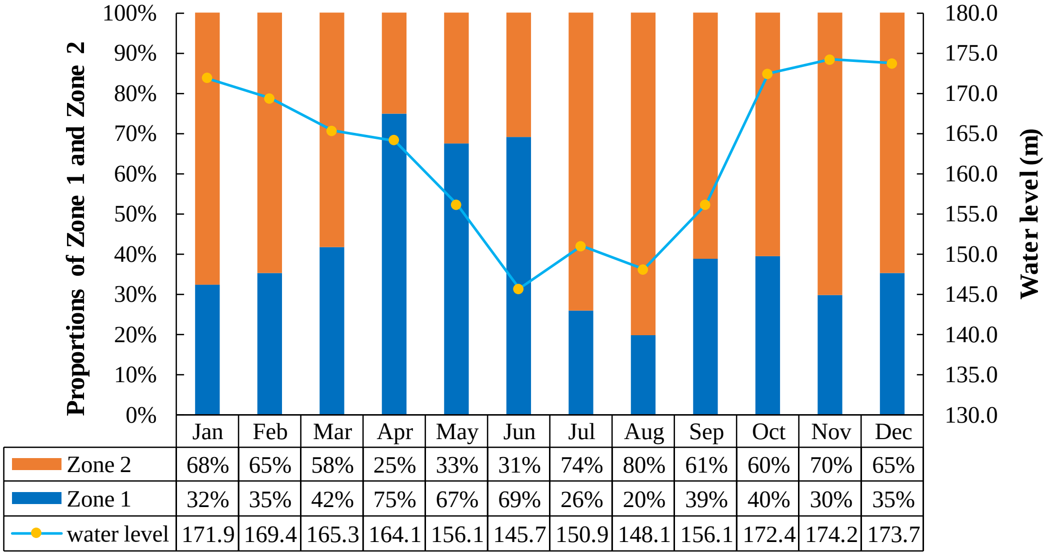
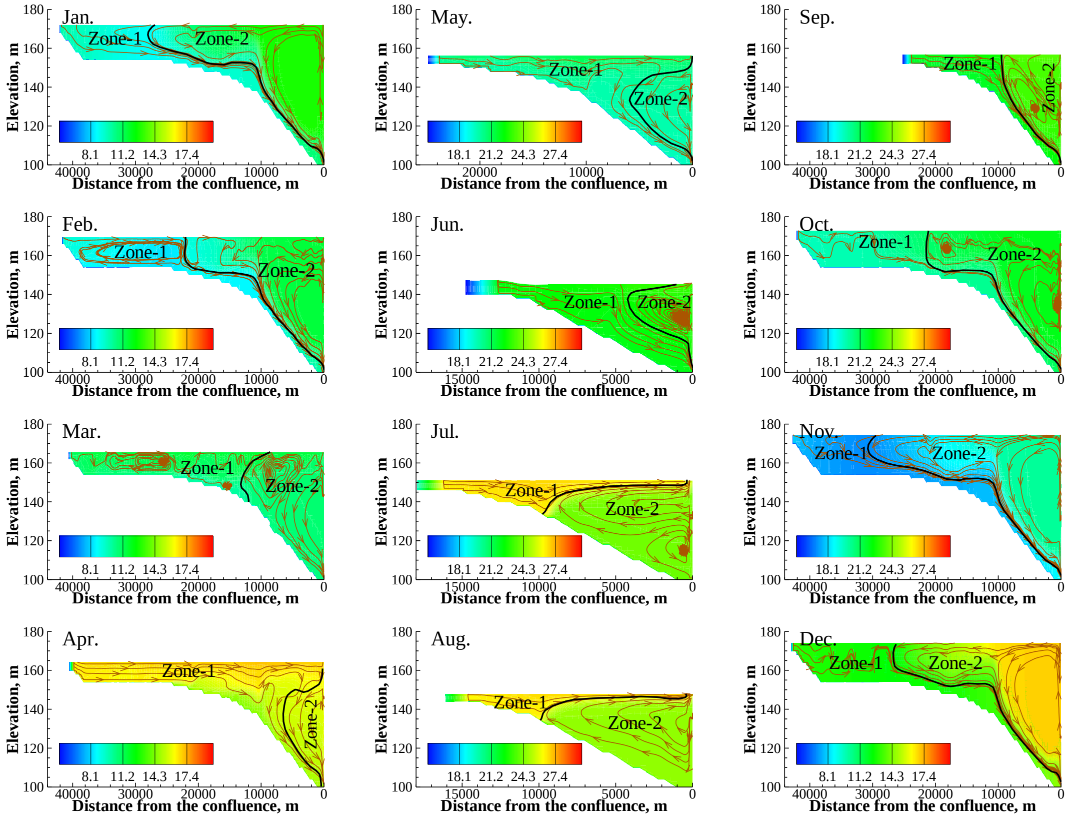


Fig. ~~6~~8. ~~The p~~Proportions of Zone 1 and Zone 2 and the variation in water level. The orange bar represents Zone 2, and the blue bar represents Zone 1. The blue dashed line represents the variation in water level.

3.3. Water temperature

Previous studies showed that the water temperature between the main reservoir and tributary bays were different, which led to the stratification of water temperature in the tributary bays (Ji et al., 2013). The water temperature distribution of the tributary bay in different months is shown in Fig. ~~7~~9. From January to February, July to August, and October to December, the water temperatures in Zone 1 and Zone 2 were quite different. There was an obvious temperature boundary, which was mainly affected by the large difference between the upstream water temperature in the tributary bay and the backwater temperature from the main reservoir. From March to June and in September, the water temperature in Zone 1 was similar to that of Zone 2 due to the small difference between the water temperature at the tail of the tributary bay and the water temperature of the backwater from the main reservoir.



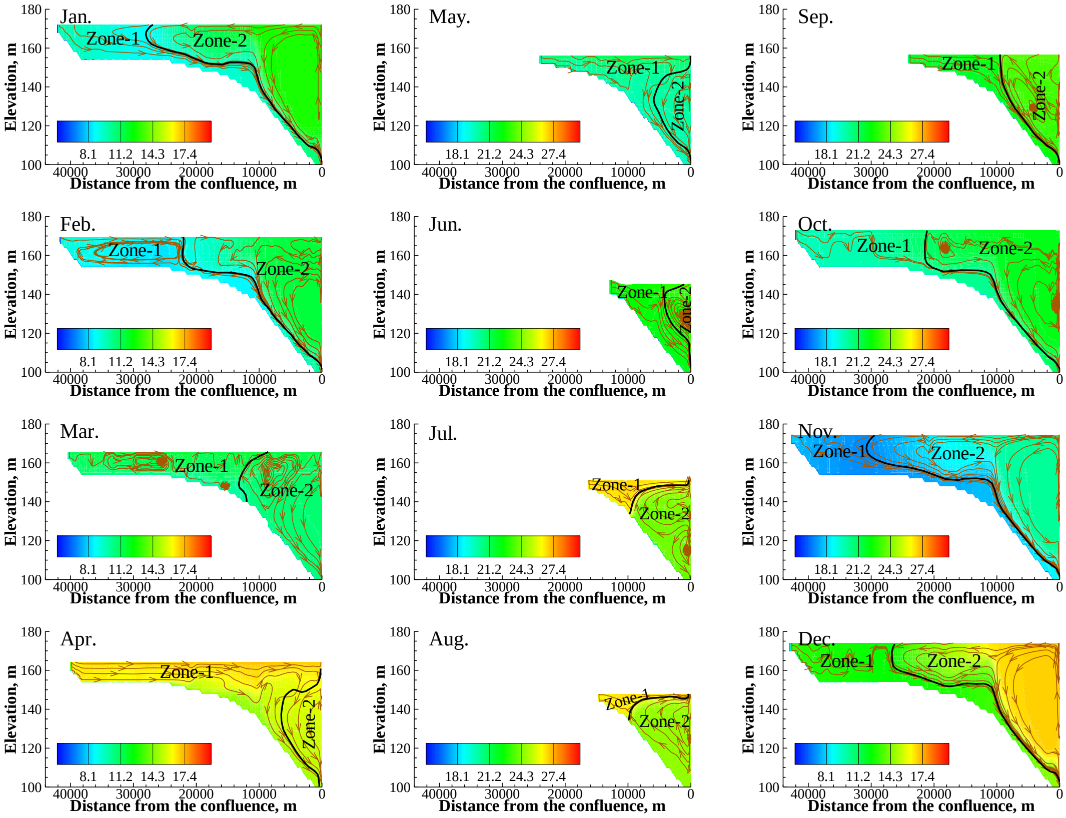


Fig. ~~7~~9. ~~The vertical two-dimensional d~~Distribution of water temperature in different months. The black curve in the figure is the boundary between Zone 1 and Zone 2. The brown curves with arrows are streamlines.

The surface water temperatures of the tributary bay in each month are shown in Fig. ~~8a~~10a. From March to June, due to the small difference between the upstream water temperature of the tributary bay and the backwater temperature of the main reservoir, the surface water temperature changed gently across the bay. The water temperature gradually decreased from the confluence to the tail of the tributary bay from July to August and gradually increased from September to October. The water temperature in the middle reaches was slightly lower than the temperature at the confluence and the tail of the tributary bay from January to February and from November to December.

The vertical water temperature in the confluence is shown in Fig. ~~8b~~10b. Affected by solar radiation and air temperature, the water temperature at the surface was relatively higher than that at the bottom (Zeng et al., 2016; Carey et al., 2012). The temperature in the middle layers changed little. There was a small thermocline in the surface water from May to August, and sinking of cold water occurred in January, February, and September to December.

The average water temperatures of Zone 1 and Zone 2 in different months are shown in Fig. ~~8c~~10c. The average water temperatures of Zone 1 and Zone 2 were similar from March to June and in September, while a difference of more than 1.5 ºC existed in other months. As the water of Zone 1 mainly came from the upstream of the tributary bay, it was significantly affected by the air temperature (Mohseni and Stefan, 1999). Zone 2 was mainly affected by the backwater from the main reservoir. Therefore, the average water temperature in Zone 1 was higher than that in Zone 2 in summer, and the average water temperature in Zone 1 was lower than that in Zone 2 in winter.

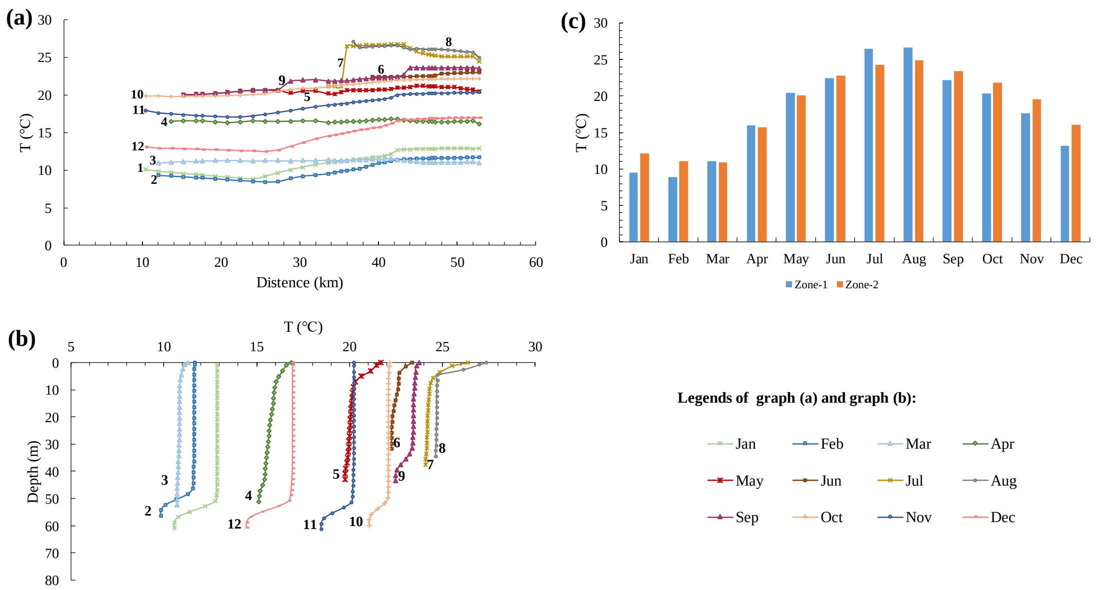


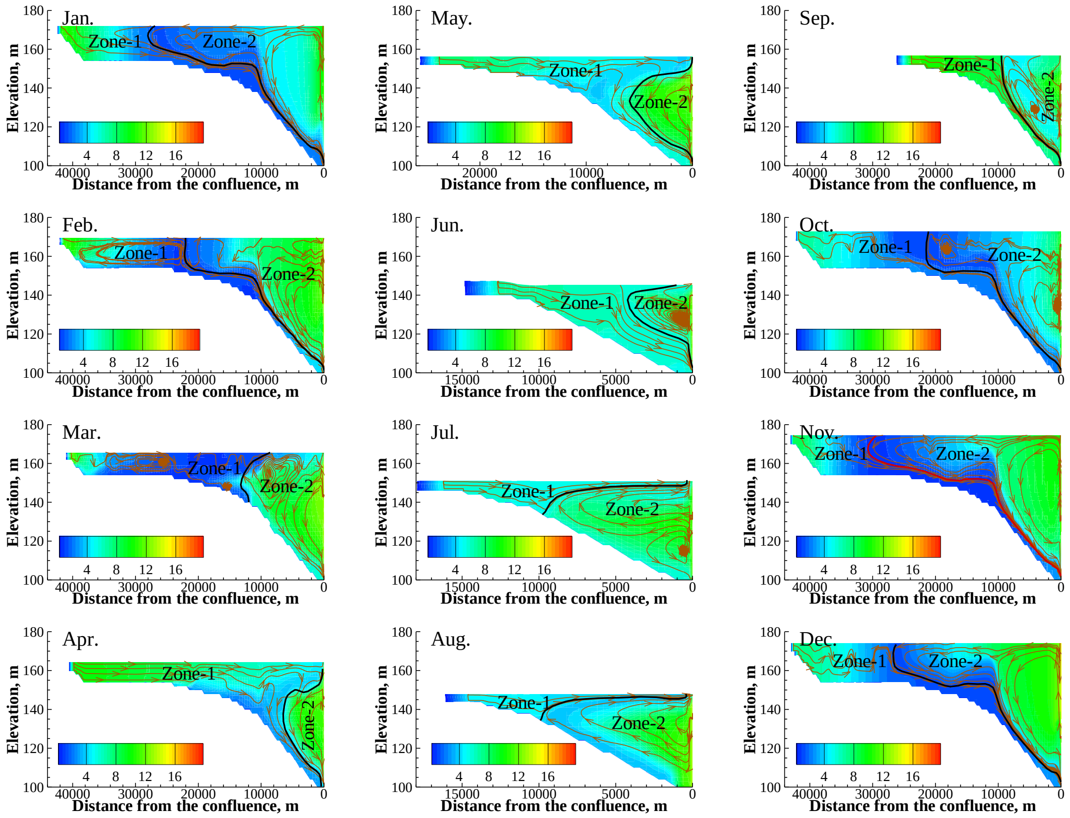
Fig. ~~8~~10. Changes in water temperature. (a) ~~The v~~Variation in surface water temperature in each month along the tributary bay~~,~~; (b) ~~the V~~variation in the vertical water temperature at the confluence in each month~~,~~. ~~and~~ (c) ~~the A~~average water temperatures of Zone 1 and Zone 2 in each month. The blue bar represents Zone 1, and the orange bar represents Zone 2 in panel (c).

3.4 Water quality

The water exchange between the main reservoir and tributary bay was an important factor driving the variation of water quality distribution and nutrient structure in the tributary bay (Zhao et al., 2015; Han et al., 2020). As shown in Fig. ~~9~~11, the COD concentration in the tributary bay ranged from 0 - 13 mg/L. There was no significant difference in COD concentrations between the tail of the tributary bay and the backwater from the main reservoir, both of which had values between 8 and 11 mg/L. With a decreasing trend along the bay, the concentration of COD reached a minimum value at the intersection of Zone 1 and Zone 2.

The NH_3-N concentration in the tributary bay was in the range of 0 - 0.3 mg/L (Fig. ~~10~~12). Since the concentration of NH_3-N in the tail of the tributary bay was higher than that of the backwater from the main reservoir, the concentration of NH_3-N in Zone 1 was higher than that in Zone 2 from January to March and July to December. There was no significant difference in NH_3-N between the tail of the tributary bay and the backwater from the main reservoir in April to June. Additionally, with a decreasing trend along the bay, the concentration of NH_3-N was lower at the intersection of Zones 1 and 2 than at the tail of the tributary bay or the confluence.

The distributions of TP and TN proved that the nutrients in tributary bays did not originate solely in the tributary bays but instead were mainly from the main reservoir, and they also showed that the nutrient levels were different across seasons. The distributions of TP and TN in the tributary bay were almost the same. The concentration near the confluence was relatively high. With the mixing of the water from the tail of the tributary bay and the backwater from the main reservoir and with the degradation of water quality, the concentrations of TP and TN gradually decreased. In particular, the concentration of TP was in the range of 0.04 - 0.12 mg/L, and the concentration of TN was in the range of 0.8 - 2.1 mg/L. The concentrations of TP and TN in Zone 2 were higher than those in Zone 1. There was an obvious quality concentration boundary in the tributary bay, which was basically consistent with the regional boundary of the flow field. Furthermore, there was an obvious transition zone near the quality boundary in January to May and September to December, while the transition zone in June to August was very weak.



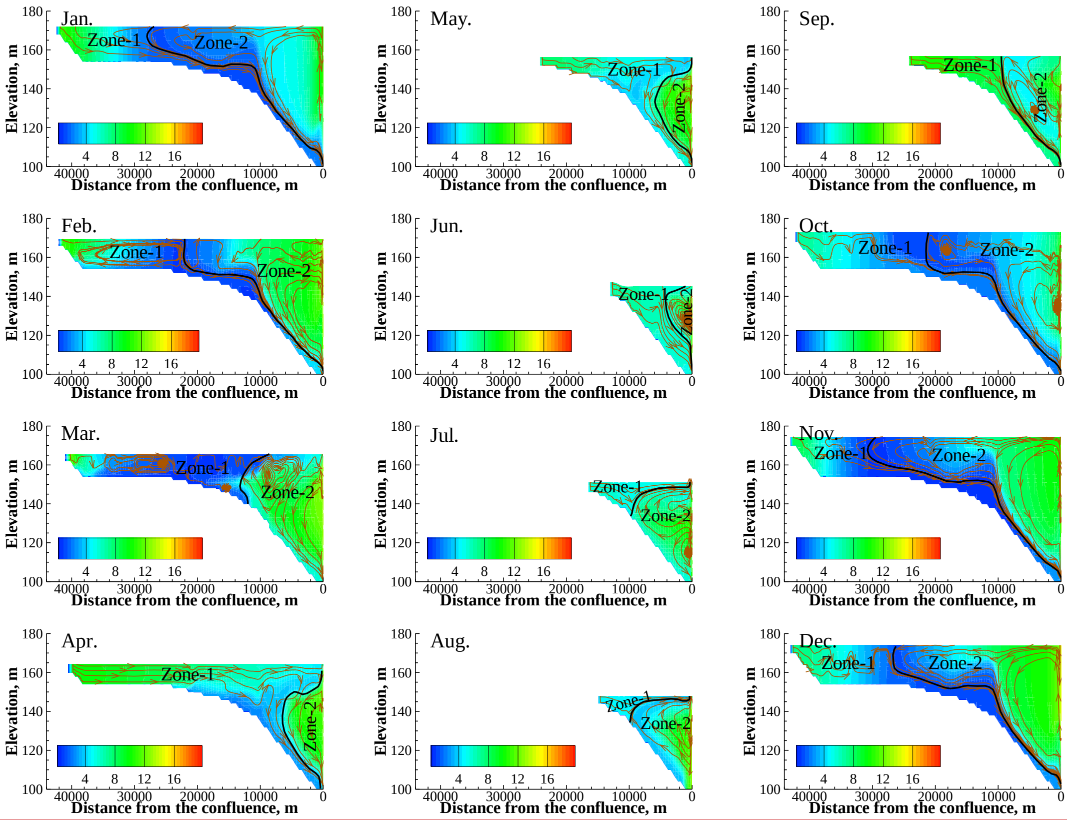
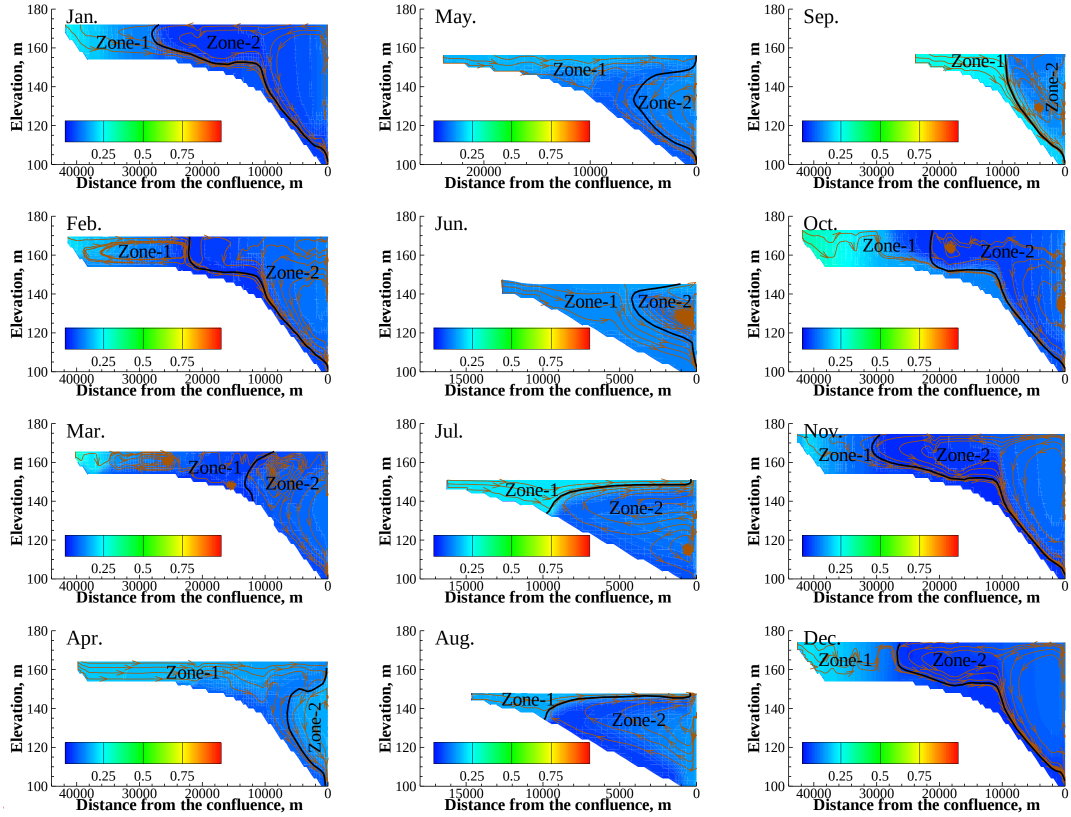


Fig. ~~9~~11. ~~The vertical two-dimensional distribution~~ Distribution of COD in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2. The brown curves with arrows are streamlines.


Jan.
Feb.
Mar.
Apr.
May.
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Zone-1
Zone-2
Elevation, m
Distance from the confluence, m
0.25
0.5
0.75

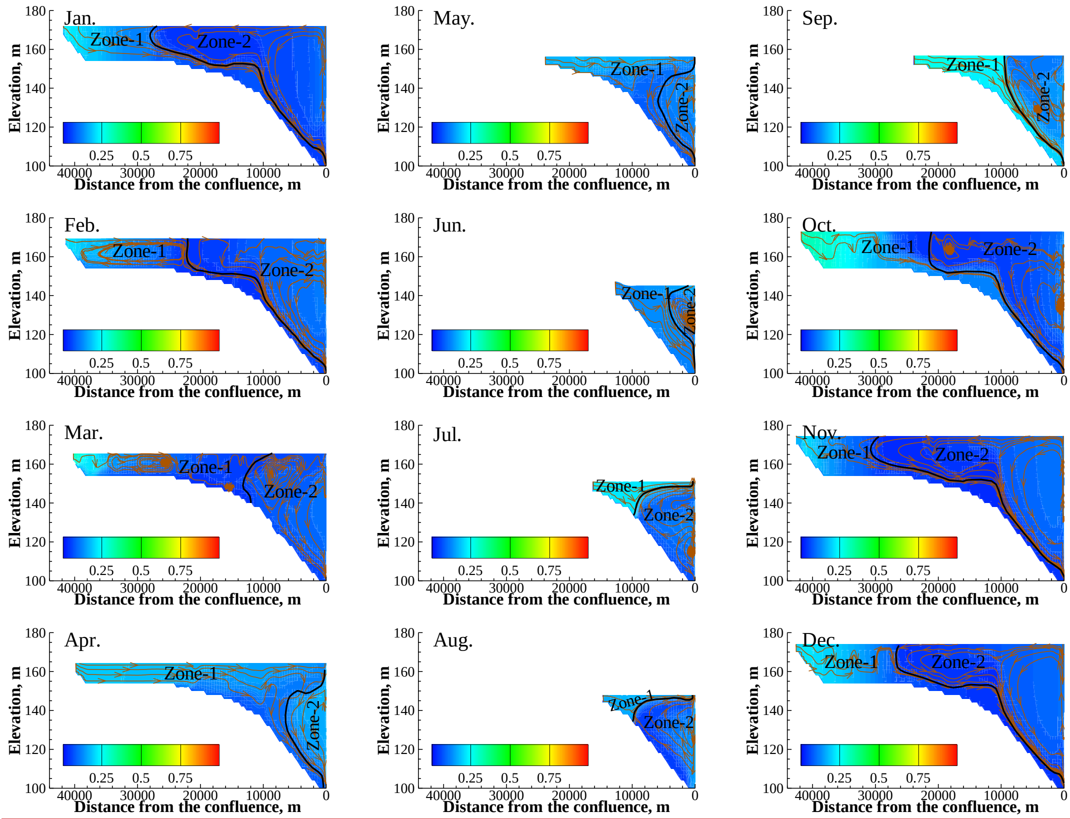
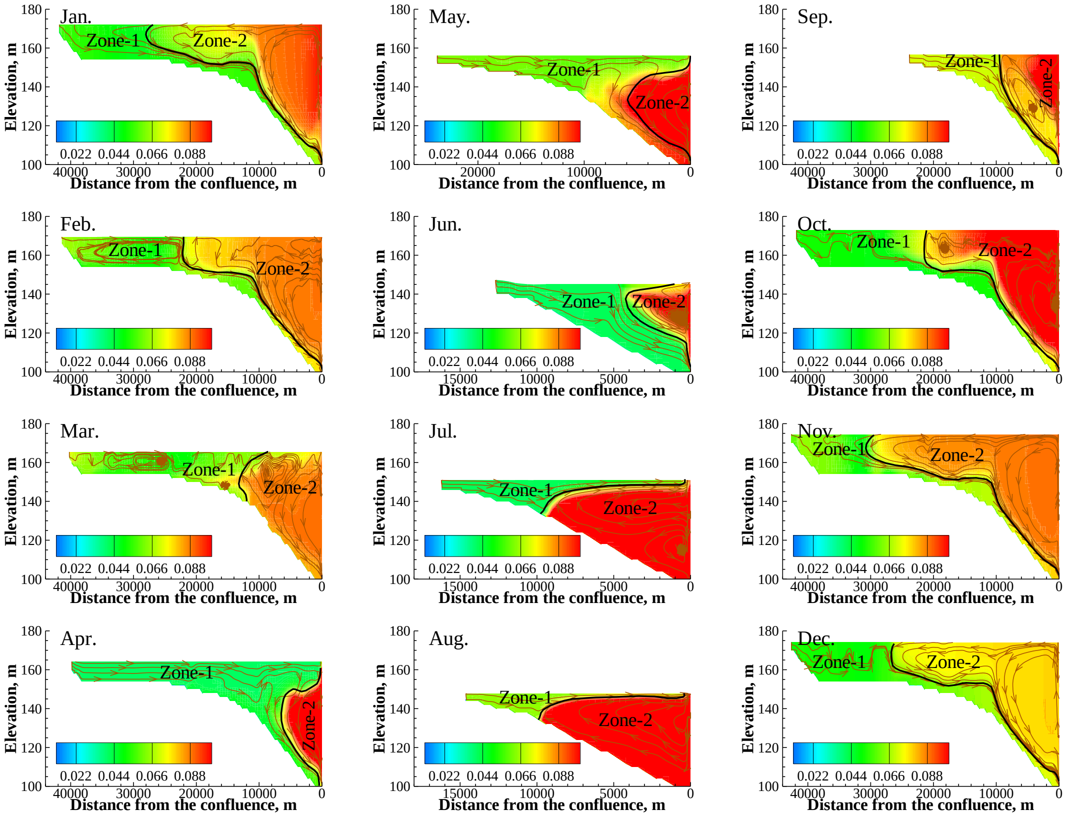

Jan.
Feb.
Mar.
Apr.
May.
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Zone-1
Zone-2
Elevation, m
Distance from the confluence, m
0.25
0.5
0.75

Fig. 1012. The vertical two-dimensional distribution Distribution of NH_3-N in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2. The brown curves with arrows are streamlines.



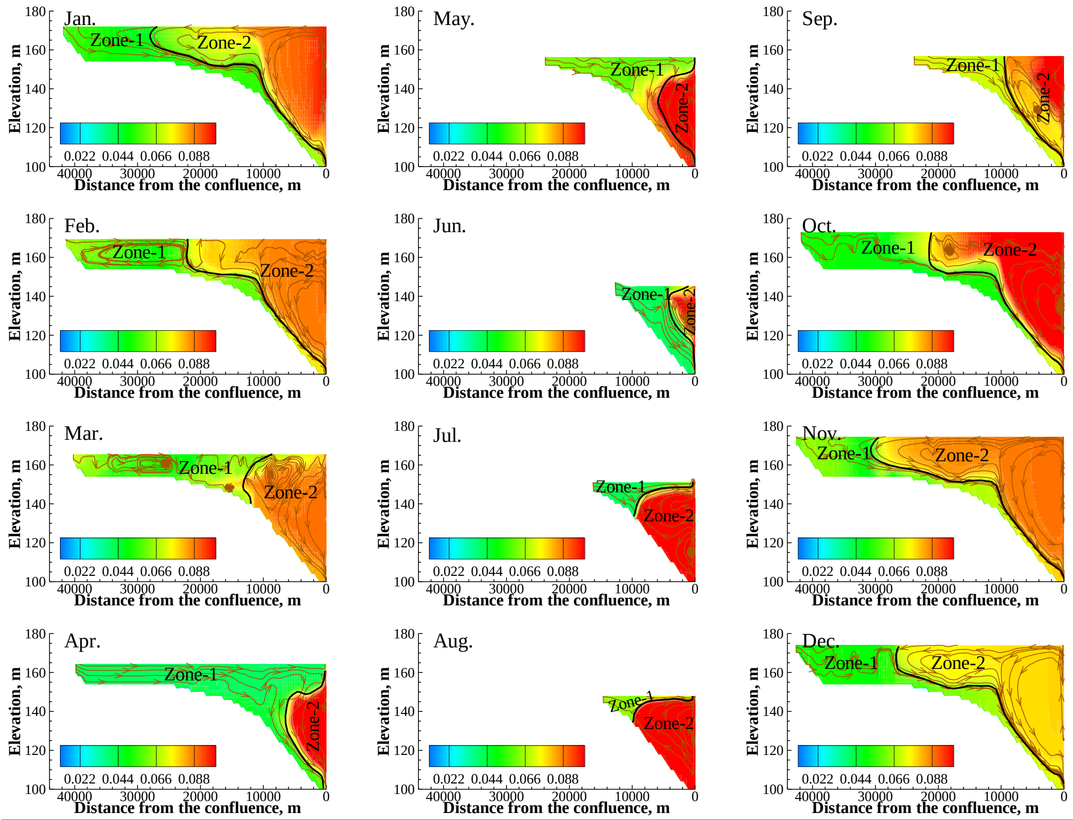
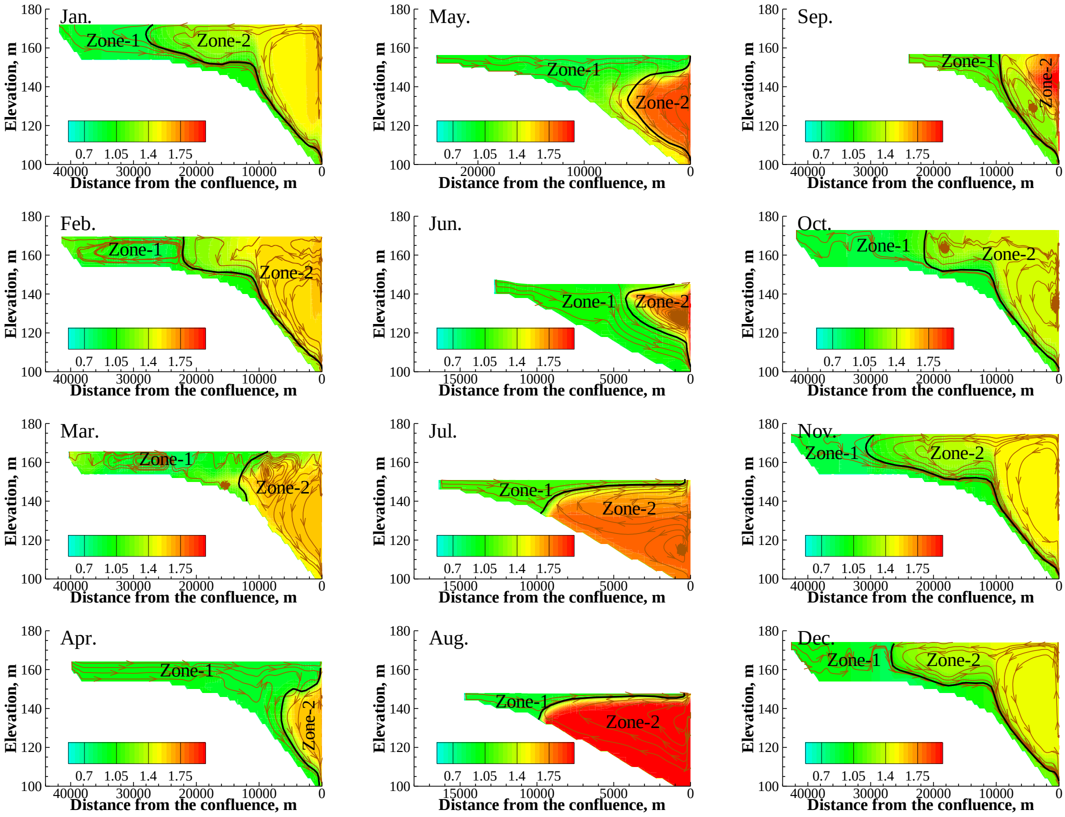
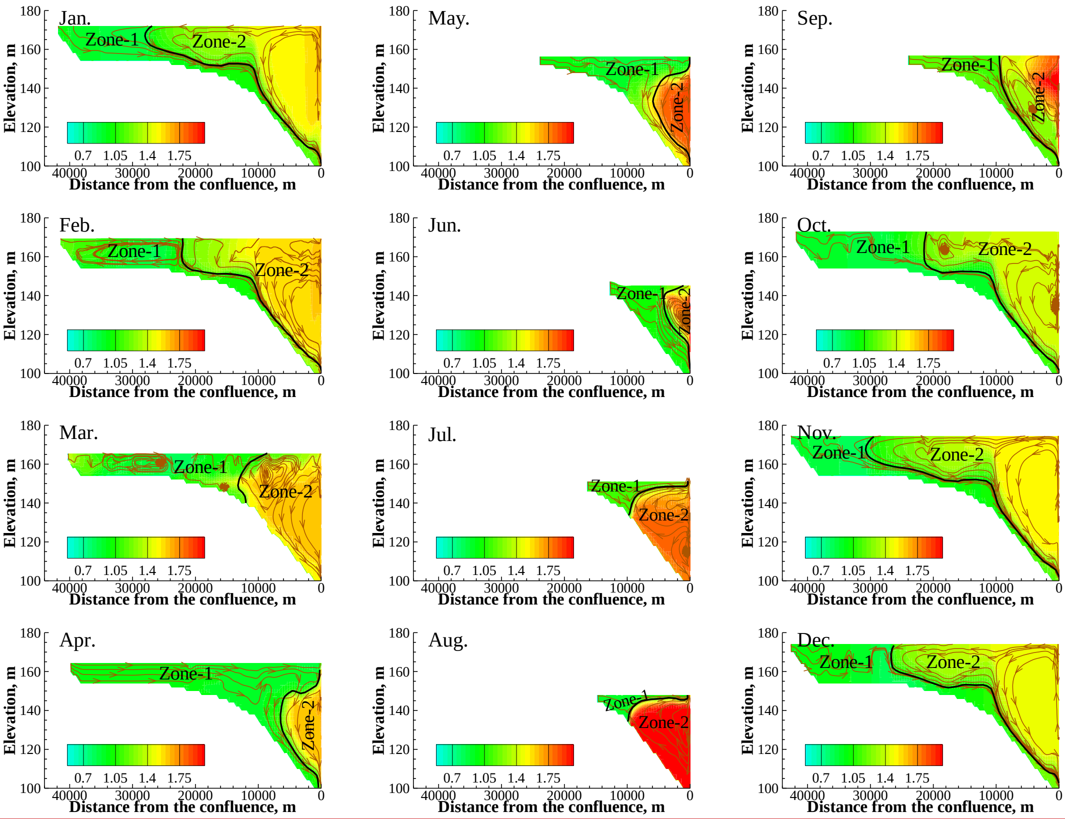


Fig. ~~11~~13. ~~The vertical two-dimensional distribution~~ Distribution of TP in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2. The brown curves with arrows are streamlines.


Jan.
Zone-1
Zone-2
Feb.
Zone-1
Zone-2
Mar.
Zone-1
Zone-2
Apr.
Zone-1
Zone-2
May.
Zone-1
Zone-2
Jun.
Zone-1
Zone-2
Jul.
Zone-1
Zone-2
Aug.
Zone-1
Zone-2
Sep.
Zone-1
Zone-2
Oct.
Zone-1
Zone-2
Nov.
Zone-1
Zone-2
Dec.
Zone-1
Zone-2
0.7 1.05 1.4 1.75
Elevation, m
Distance from the confluence, m


Jan.
Zone-1
Zone-2
Feb.
Zone-1
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Mar.
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Zone-2
Apr.
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May.
Zone-1
Zone-2
Jun.
Jul.
Zone-1
Zone-2
Aug.
Zone-2
Sep.
Zone-1
Zone-2
Oct.
Zone-1
Zone-2
Nov.
Zone-1
Zone-2
Dec.
Zone-1
Zone-2
0.7 1.05 1.4 1.75
Elevation, m
Distance from the confluence, m

Fig. ~~12~~14. ~~The vertical two-dimensional distribution~~ Distribution of TN in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2. The brown curves with arrows are streamlines.

The COD, NH_3-N, TP and TN in the surface water of the tributary bay in different months are shown in Fig. ~~13~~15. The concentrations of COD and NH_3-N were generally higher on the two sides and lower in the middle. The concentrations of TP and TN were higher in the confluence and lower in the tail of the tributary bay.

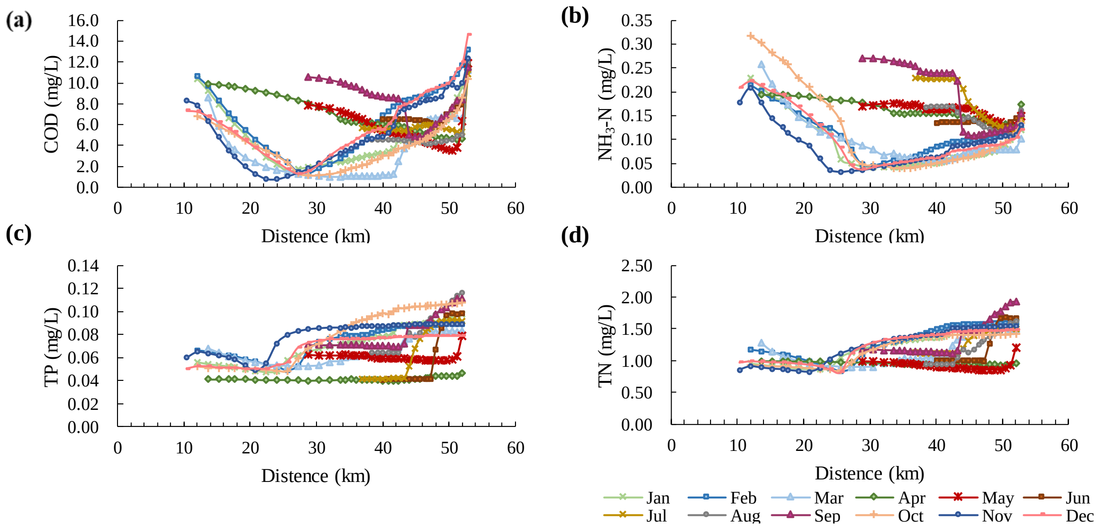


Fig. ~~13~~15. ~~The v~~Variation in surface water quality in different months along the tributary bay. (a) Variation in chemical oxygen demand~~,~~; (b) ~~variation~~ Variation in ammonia nitrogen, (c) ~~variation~~ Variation in total phosphorus~~,~~; ~~and~~ (d) ~~variation~~ Variation in total nitrogen.

The vertical changes in COD, NH_3-N, TP and TN in different months at the confluence are shown in Fig. ~~14~~16. There was no obvious regularity in the vertical water quality distributions of COD and NH_3-N. The average vertical variation in COD was 4.6 mg/L over 12 months. The largest change appeared in December, with a value of 7.0 mg/L, and the smallest change appeared in June, with a value of 1.6 mg/L. The average vertical variation in NH_3-N was 0.06 mg/L. The largest change appeared in January, with a value of 0.02 mg/L, and the smallest change appeared in July, with a value of 0.12 mg/L.

The concentrations of TP and TN were higher in the surface water and lower in the bottom in January to March and September to December, which was contrary to that in July and August. From April to June, the concentrations of TP and TN first increased and then decreased from the surface to the bottom. The concentration gradient in the upper 10 m surface layer was relatively large.

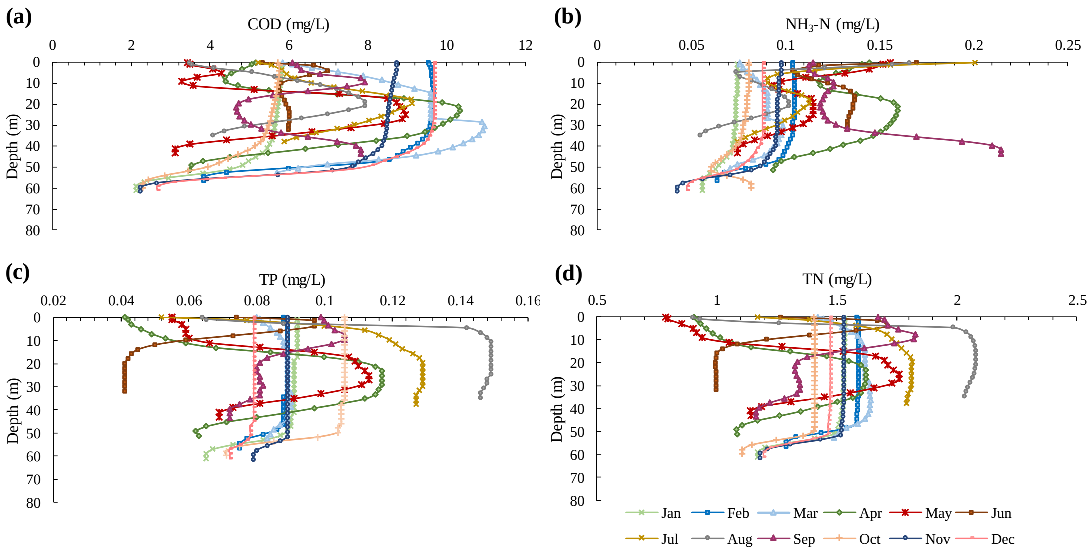


Fig. ~~14~~16. ~~The v~~Vertical variation in the water quality in different months at the section that was 6 km away from the confluence. (a) Variation in chemical oxygen demand~~,~~; (b) ~~variation~~ Variation in ammonia nitrogen~~,~~; (c) ~~variation~~ Variation in total phosphorus~~,~~; ~~and~~ (d) ~~variation~~ Variation in total nitrogen.

The average concentrations of COD, NH_3-N, TP and TN in Zone 1 and Zone 2 are shown in Fig. ~~15~~17. The COD concentration in Zone 2 was higher than that in Zone 1 in all months except September. The concentration of NH_3-N in Zone 1 was generally higher than that in Zone 2 due to the higher concentration of NH_3-N in the water ~~of~~ from the tail of the tributary bay. For TP and TN, the concentrations in Zone 2 were higher than those in Zone 1.

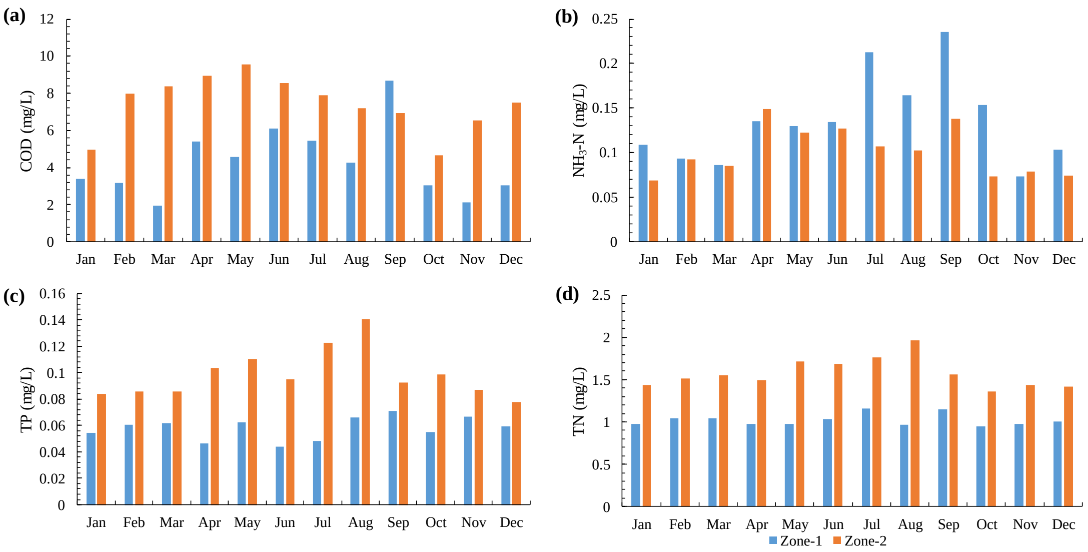
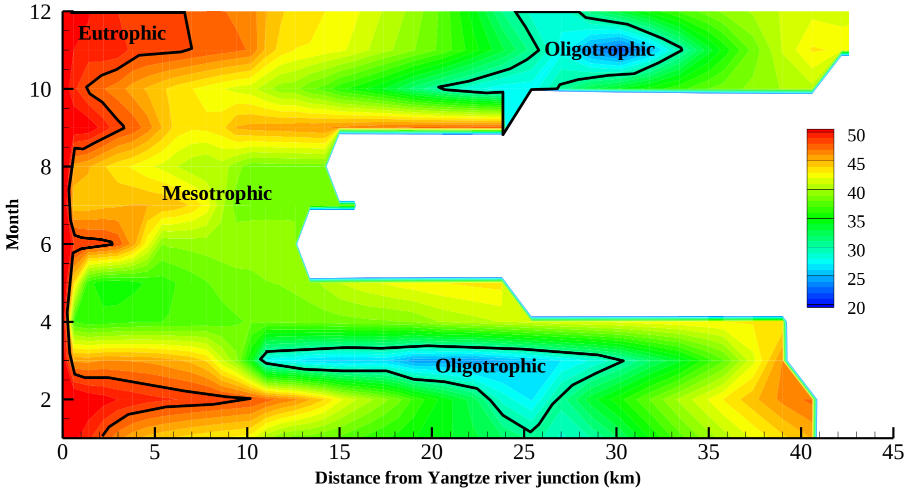


Fig. ~~15~~17. ~~The a~~Average water quality changes in Zone 1 and Zone 2. (a) Variation in chemical oxygen demand~~, ~~; (b) ~~variation ~~Variation in ammonia nitrogen~~, ~~; (c) ~~variation ~~Variation in total phosphorus~~, ~~; ~~and ~~(d) ~~variation ~~Variation in total nitrogen. The blue bar represents Zone 1, and the orange bar represents Zone 2.

3.5 Water eutrophication

The distribution of the TLI(∑) values in the surface water of the tributary bay in different months is shown in Fig. ~~16~~18. The TLI(∑) within 0.5 km of the confluence was relatively higher than in other areas throughout the year, reaching the level of light eutrophication. Additionally, the reach with high TLI(∑) values in February and in September to December had a long range. From January to March and September to December, the reach approximately 25 km from the confluence had low TLI(∑) values, reaching oligotrophic status. In the rest of the time and area, the TLI(∑) values correspond to a medium nutrient level. Additionally, the water temperature near the confluence was less than 20 ºC, and the light conditions were poor in January to April and November to December. Temperature and light conditions are important factors in the occurrence of eutrophication, and neither low temperatures nor poor light conditions are conducive to the growth of algae (Singh and Singh, 2015; Romarheim et al., 2015; Paerl et al., 2011; Reynolds, 2006). Physical dynamics play a critical role in estuarine biological production, material transport and water quality (Kasai et al., 2010). The results of this study showed that the tributary bay was mainly affected by backwater intrusions ~~of~~ from the main reservoir in July and from August to October. During this time, the vertical mixing of water near the confluence was severe, which was also not conducive to the growth of algae (Gao et al., 2017; Lindim et al., 2011; Huisman et al., 2006). In conclusion, considering the influence of hydrodynamics, water temperature and water quality, the risk of eutrophication in the tributary bay was highest in the section within 0.5 km of the confluence from May to June. Wu et al (2010) constantly monitored the eutrophication of the Daning River, a tributary bay of the TGR, and found that algal blooms frequently occurred in the area close to the confluence from March to June, which was similar to the results of the present study.



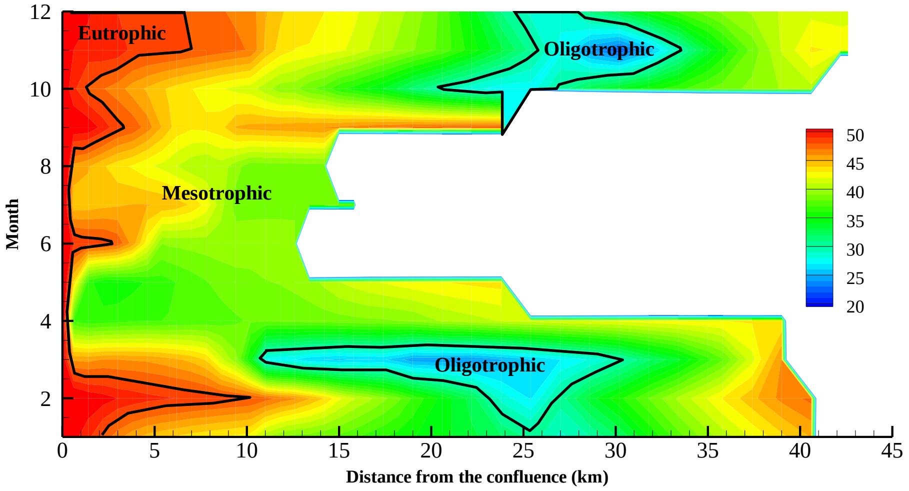


Fig. ~~16~~18. Eutrophication results of surface water in the tributary bay. The nutrient status of the tributary bay is divided into three states (oligotrophic, mesotrophic and eutrophic) according to the comprehensive nutrient index.

3.6 Sensitivity of the results to the model forcing factors

The link between the main reservoir and its tributary bay is the hydrodynamic condition, and it is mostly affected by water level fluctuations (Sha et al., 2015). Thus, in previous chapters, we mainly discussed the effect of water level fluctuations in detail. Air temperature and winds conditions were also important factors affecting the results (Yu et al., 2013; Huang et al., 2016). Air temperature can affect the surface water temperature by promoting the formation of thermal stratification (Jin et al., 2019). From July to August, air temperature was a dominant variable and the stratification of water temperature was obvious. A comparison of the distributions of the water temperature and water quality showed that air temperature had almost no effect on the water quality distribution, while the water level fluctuation was a determining factor. The results were not sensitive to wind conditions because the wind varied little throughout the year and the wind speed was small (1 - 1.8 m/s) in the study area.

4 Conclusions and future work

In this paper, the effect of the backwater jacking and intrusions ~~of~~ from the main reservoir on the hydrodynamics and water environment of the Tangxi River, a tributary bay of the TGR are studied. The following conclusions were reached as a result of ~~the~~ this research:

(1) The intrusion was weak when the water level of the main reservoir dropped, and the tributary bay was mainly affected by the backwater jacking of the main reservoir. The periods of intrusions in the tributary bay ranged from July to October. Conversely, when the water level of the main reservoir rose, the tributary bay was mainly affected by backwater intrusions from the main reservoir. ~~Since the backwater~~

~~intrusion brought serve vertical mixing of water that was not conducive to the growth of algae, the controlling measures of eutrophication could contrapuntally be proposed in the time that the water level of the main reservoir dropped.~~

(2) The water from the tail flowed along the surface of the tributary bay or sank to the bottom in each month. The backwater from the main reservoir entered the confluence at different depths simultaneously, forming one or two circulations in the tributary bay. The backwater had a greater impact on the tributary bay when the main reservoir was at high water level and had a smaller impact when the main reservoir was at a low water level.

(3) The water temperature of the tributary bay was not greatly affected by the backwater from the main reservoir. ~~The water qualities in different parts of the tributary bay were quite different.~~ The concentrations of COD and NH_3-N in the tributary bay were generally higher at the two ends of the bay and lower in the middle. ~~The concentrations of TP and TN were higher at the confluence and lower at the tail of the tributary bay. Moreover, f~~For TP and TN, there was an obvious quality concentration boundary in the tributary bay, which was basically consistent with the regional boundary of the flow field. The concentrations of TP and TN were higher ~~in~~ at the side near the confluence~~ than that in the other side~~.

(4) Nutrients in tributary bays were mainly from the main reservoir and the nutrient levels were affected by the constantly changing hydrodynamic conditions and environmental factors across seasons. ~~According to the simulation of eutrophication, the TLI(∑) values within 0.5 km of the confluence were relatively high. Considering the influence of hydrodynamics, water temperature and water quality, t~~The risk of eutrophication of the tributary bay was high within 0.5 km of the confluence in May and June.

~~(5) Though the nutrients in tributary bays were mainly from the main reservoir, the backwater effect of the main reservoir didn't influence the water environment of~~

~~the whole tributary bay. Therefore, we can focus on the areas that are more affected by the main reservoir and propose protective measures targeted at these areas.~~

This paper only studied the influence of the main reservoir on the tributary bay in terms of hydrodynamics and water environment. The operations of the main reservoir may have common influences on the tributary bays, and tributary bays may also influence the main reservoir. The influence of the tributary bay on the main reservoir and the interaction between the main reservoir and the tributary bay are still unclear. In the future, numerical simulation of the main reservoir's hydrodynamics and water environment based on the results of this paper should be carried out to explore the interaction between the main reservoir and the tributary bay.

Future work should also explore control measures to improve the water environment of the tributary bay based on its interaction with the main reservoir. At present, some scholars have proposed that preventing and controlling eutrophication in tributary bays can be achieved by the method of "double nutrient reduction", which involves the simultaneous control of the nutrient inputs from the main stream and the tributary (Liang et al., 2014). It is also possible to use ecological methods, such as emergent plants, submerged plants, phytoplankton, benthic organisms and fish, to improve water eutrophication (Srivastava et al., 2017; Li et al., 2013; Soares et al., 2011). In addition, the concept of improving the hydrodynamic conditions of the main stream and controlling the eutrophication of the water body through manually controlled operation has been widely accepted by many experts and scholars (Yao, 2011; Zheng et al., 2011; Naselli-Flores and Barone, 2005). Based on future research on the interaction between the main reservoir and the tributary bay with the goal of ensuring the main function of the main reservoir, water environment protection measures should be reasonably proposed for tributary bays in the future.

Declaration of Competing Interest. We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the

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