https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

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The hydrodynamic and environmental characteristics of tributary bay influenced by backwater jacking and intrusion of 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 intrusion of 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 tributary bay influenced by the jacking and intrusion of the main reservoir. The flow field, water temperature and water quality of the Tangxi River were simulated using the hydrodynamic and 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 the main reservoir when the water level dropped and by intrusion of the main reservoir when the water level rose. An obvious 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 intrusion of 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 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).

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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 the water areas similar to lakes, and were known as 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). 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 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. The flow field distribution tends to gradually change with increasing

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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. Existing studies have shown that water level fluctuation has become a major cause of recent eutrophication and pollution problems in the 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 intrusion of the main reservoir is the 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 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

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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 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 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. There are few systematic studies on the variation in the hydrodynamic and water environment characteristics of tributary bays influenced by the backwater jacking and intrusion of the main reservoir. 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 are not yet clear.

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

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Tangxi River using the hydrodynamic and quality model CE-QUAL-W2. Then, we evaluated the eutrophication status of the tributary bay and systematically identified the influence of the backwater jacking and intrusion of the main reservoir on the tributary bay. The results of this study can help us to figure out how the backwater jacking and intrusion of 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 intrusion of the TGR was selected as the study area (Fig. 1).

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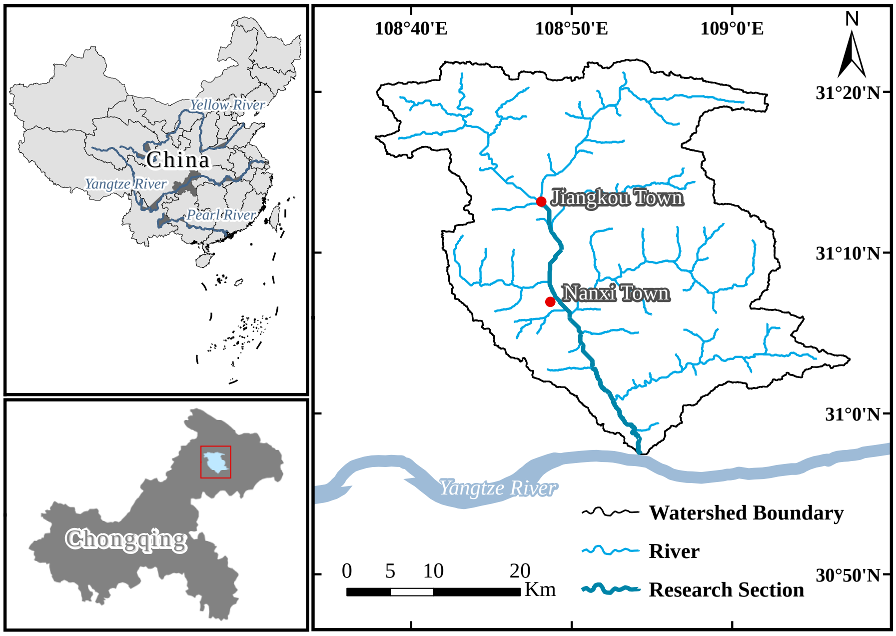

Fig. 1. Research area and hydrologic system of the Tangxi River Basin.

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 with average width 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.,

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2018). The model is solved by coupling governing equations, a transport equation and a surface heat exchange equation.

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:

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

Accurate hydrodynamic calculations require accurate water densities. Water densities are affected by variations in temperature and the concentration of solids. The following relationship is used in the model:

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

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

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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.

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

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evaporative heat loss; and H_c represents the heat conduction.

2.2.2 Model validation

The water quality at the Tangxi River Bridge was monitored in 2017, and the data were used to verify the model. 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 results showed that the simulated values of T, TP and TN fit well with the measured values. 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 characteristics and there are many

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factors affecting the degradation coefficient of NH_3-N, such as the 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 than other values.

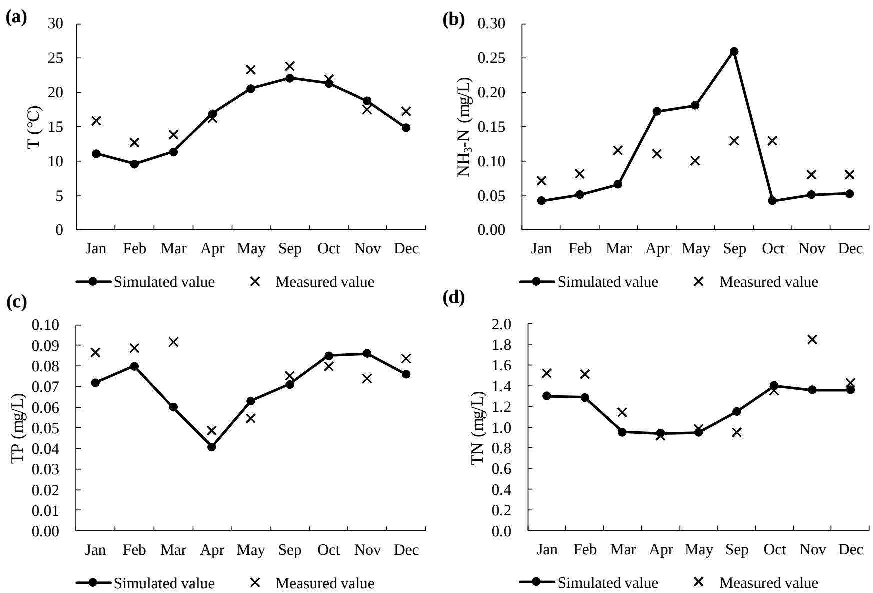

Fig. 2. The comparison between the simulated and measured values at the Tangxi River Bridge in each month. (a) Comparison of water temperature, (b) comparison of ammonia nitrogen, (c) comparison of total phosphorus, (d) comparison of total nitrogen. The points on the graph are simulated values, and the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

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The meteorological conditions of the Tangxi River and TGR were based on meteorological data from Yunyang County (Table 1), and the pollution loads of point and non-point sources were counted and then calculated in this study (Table 2). The boundary conditions of flow, water level and water quality are shown in Fig. 3.

Table 1.

Statistical table of meteorological data from the Yunyang meteorological station.

Month	Temperature	Wind speed	Wind direction	Cloudiness	Solar radiation	Relative humidity
	ºC	m/s	°	%	W/m^2	%
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.

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

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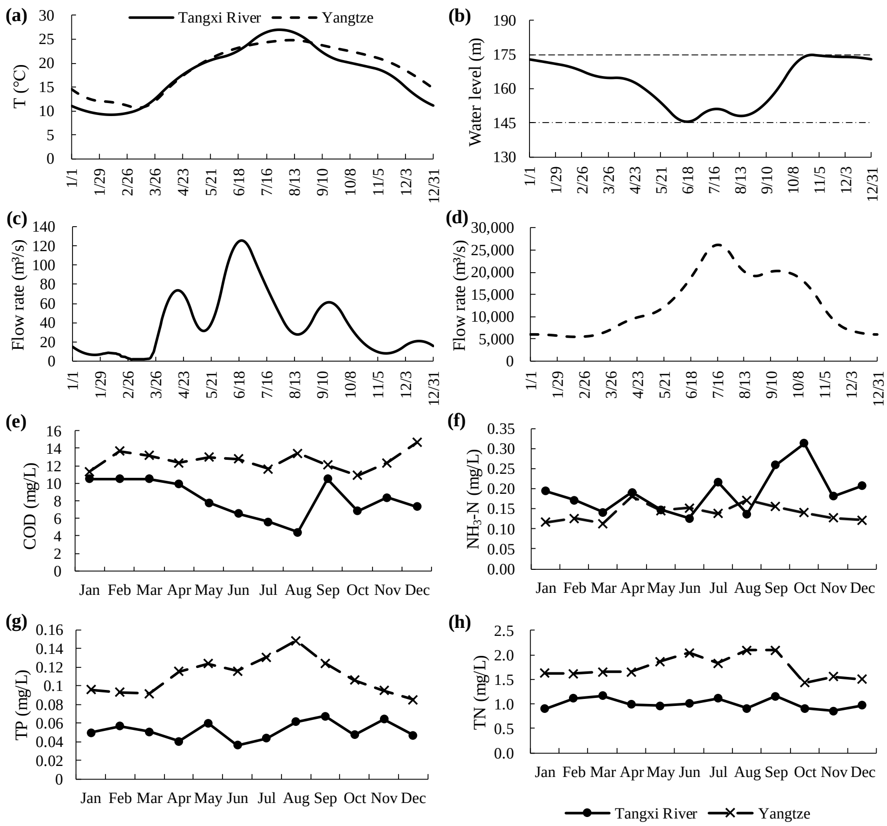

Fig. 3. Simulation boundary conditions. (a) Daily water temperatures of the main reservoir and tail of the tributary bay, (b) water level of the main reservoir, (c) daily inflow of the tributary bay, (d) daily inflow of the main reservoir, (e) - (h) monthly water quality (COD, NH_3-N, TP and TN) of the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

2.3 Simulation of eutrophication

The comprehensive nutrition index (TLI(∑)) 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(∑) values:

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TLI(∑)<30, oligotrophic

30≤TLI(∑)≤50, mesotrophic

TLI(∑)>50, eutrophic

50<TLI(∑)≤60, slightly eutrophic

60<TLI(∑)≤70, moderately eutrophic

TLI(∑) >70, severely eutrophic

The formula for calculating the *TLI(Σ)* is as follows:

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

where *TLI(Σ)* 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:

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

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 (Li and Zhang, 1993).

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Table 3

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_{ij}^2	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 the parameters above, TP and TN are pivotal. 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 statuses of the surface water in the Tangxi River tributary bay in different months were evaluated in this study according to the TLI(Σ) method. The influence of water temperature was also considered during the nutrient status evaluation.

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3 Results and discussion

3.1 Hydrological situation

The temporal variations in confluence flow and water level are shown in Fig. 4a. 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 intrusion from the main reservoir. In contrast, the tributary bay was mainly affected by the backwater jacking of main reservoir in other months (January - June and November - December). With the water level fluctuation through the whole year, the backwater intrusion weakened when the water level of the main reservoir dropped, and when the water level of the main reservoir rose, the backwater intrusion became obvious.

The temporal variation in confluence flow and the length of backwater are shown in Fig. 4b. With the change in the flow at the confluence, the length of backwater also changed. During January to April and October to December, the water level of the main reservoir rose to 160 - 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

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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 intrusion at this time.

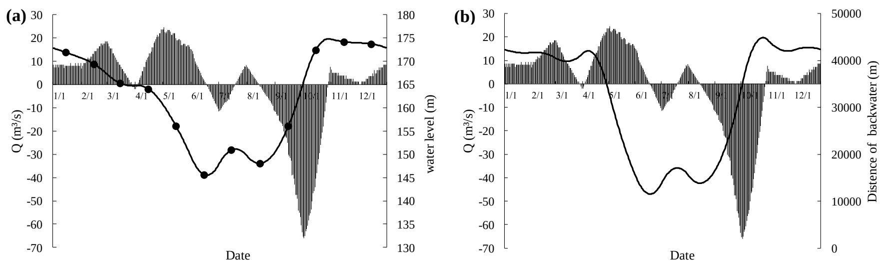

Fig. 4. The relationships among water level, length of backwater and confluence flow. (a) Daily variations in confluence flow and water level and (b) daily variations in confluence flow and length of backwater.

3.2 Hydrodynamics

The distribution of the flow field in each month is shown in Fig. 5. In each month, the 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.

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

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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 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.

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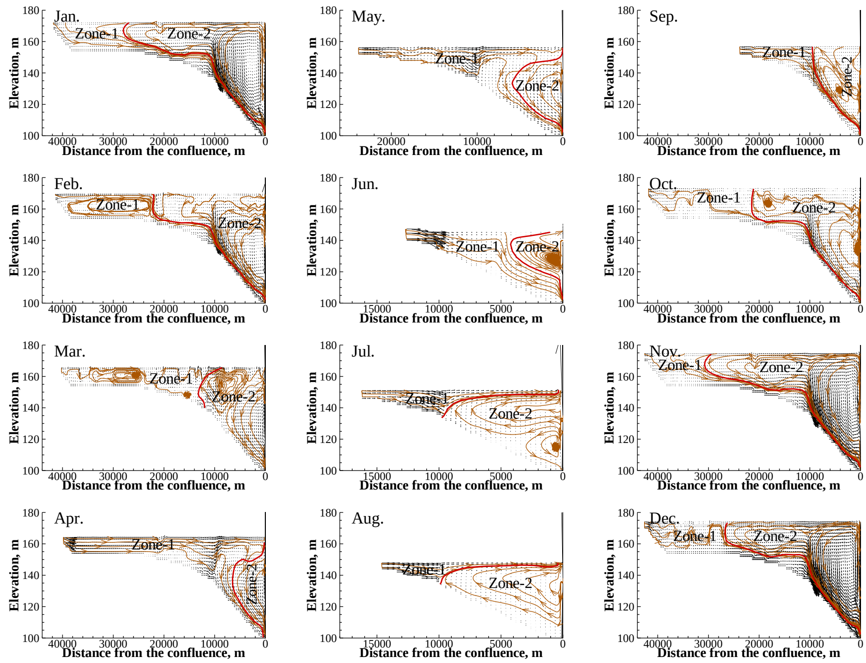

Fig. 5. The distribution of the flow field in each month. The flow field was divided into two areas (Zone 1 and Zone 2) according to the flow field characteristics. The red curve in the figure is the boundary between Zone 1 and Zone 2.

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). 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

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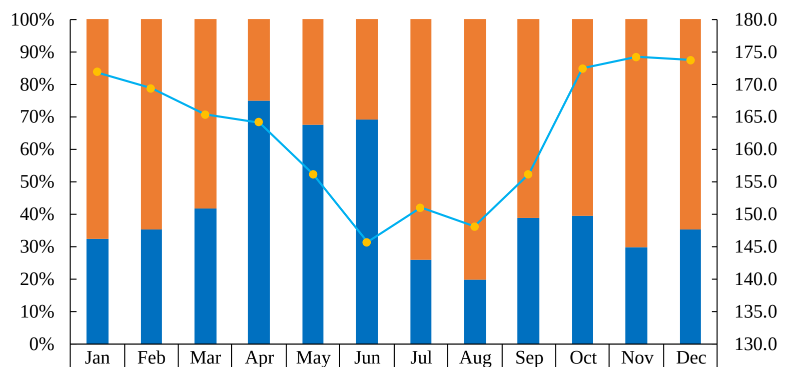
decreased. From May to September, the length of backwater decreased, and it only reached Nanxi Town. With the fluctuation in the water level in these months, the trend of the proportions of Zone 1 and Zone 2 became irregular. From October to November, with the rise in the water level, the proportion 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.



	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

Fig. 6. The 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

The water temperature distribution of the tributary bay in different months is

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shown in Fig. 7. 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.

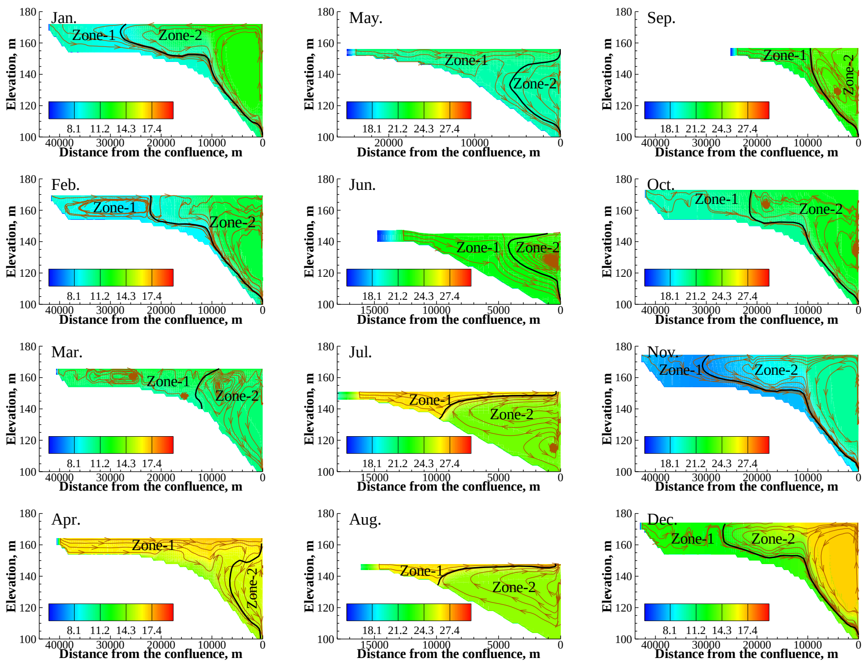

Fig. 7. The vertical two-dimensional distribution of water temperature in different months. The black curve in the figure is the boundary between Zone 1 and Zone 2.

The surface water temperatures of the tributary bay in each month are shown in

Fig. 8a. 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. 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. 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.

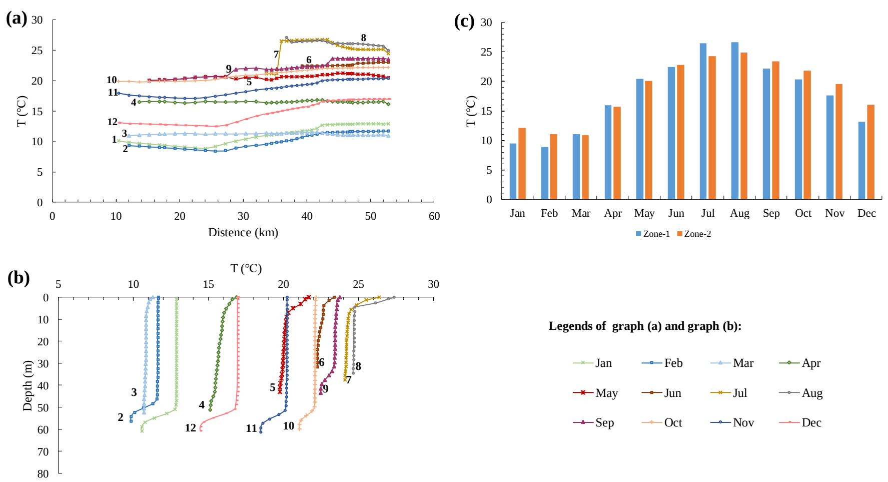

Fig. 8. Changes in water temperature. (a) The variation in surface water temperature in each month along the tributary bay, (b) the variation in the vertical water temperature at the confluence in each month, and (c) the average water temperatures of Zone 1 and Zone 2 in each month. The blue bar represents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

3.4 Water quality

As shown in Fig. 9, 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). Since the concentration of NH_3-N in the tail of the tributary bay was higher

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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 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.

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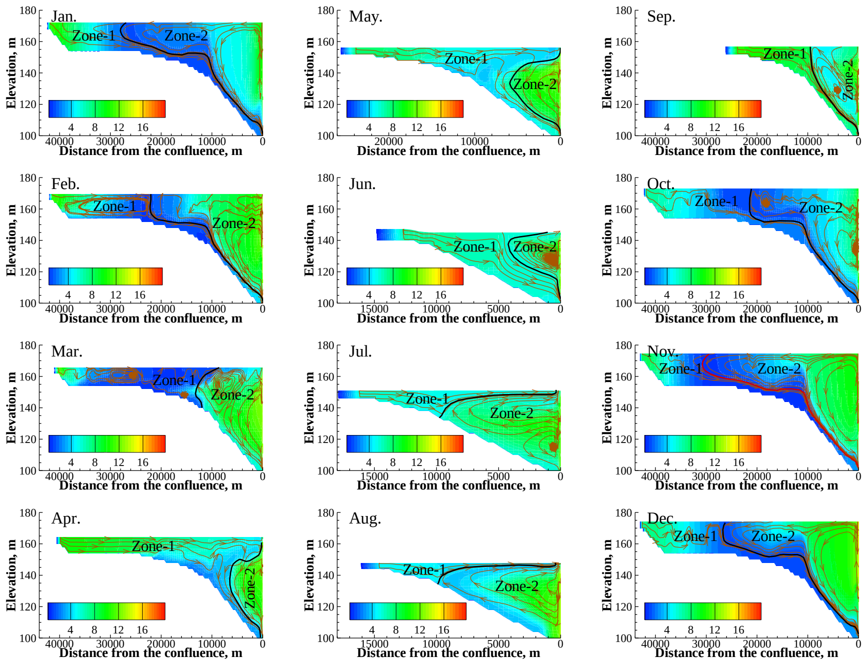

Fig. 9. The vertical two-dimensional distribution of COD in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2.

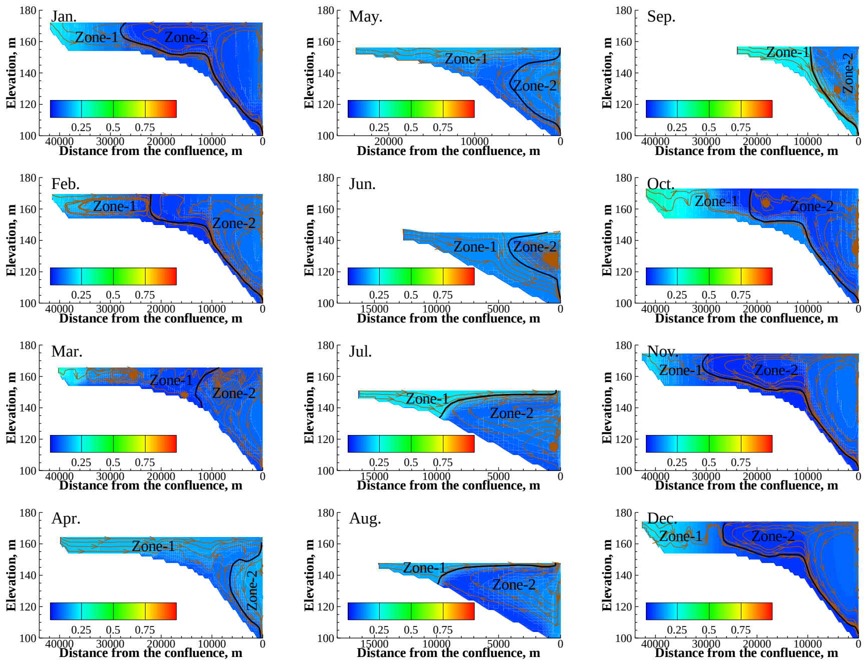

Fig. 10. The vertical two-dimensional distribution of NH_3-N in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2.

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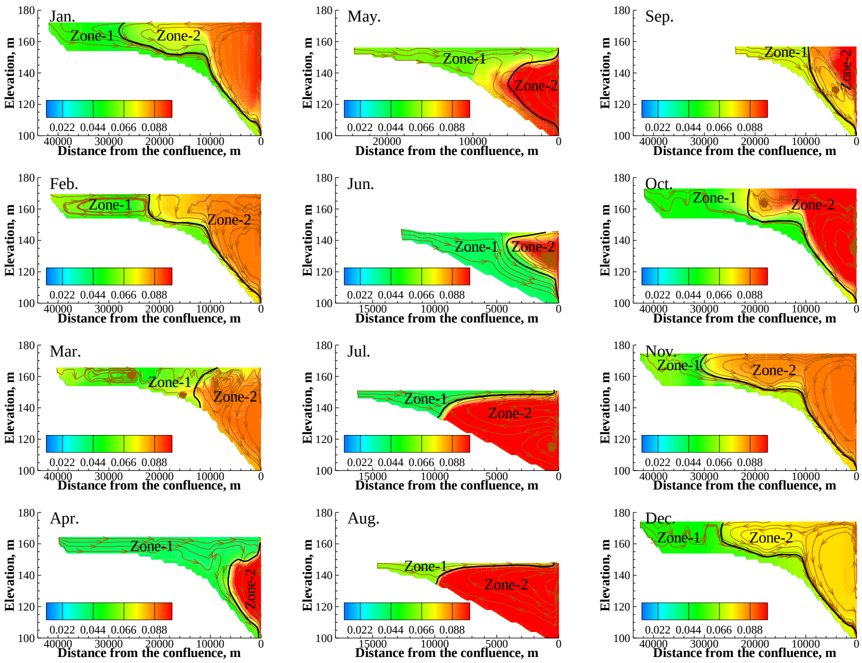

Fig. 11. The vertical two-dimensional distribution of TP in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2.

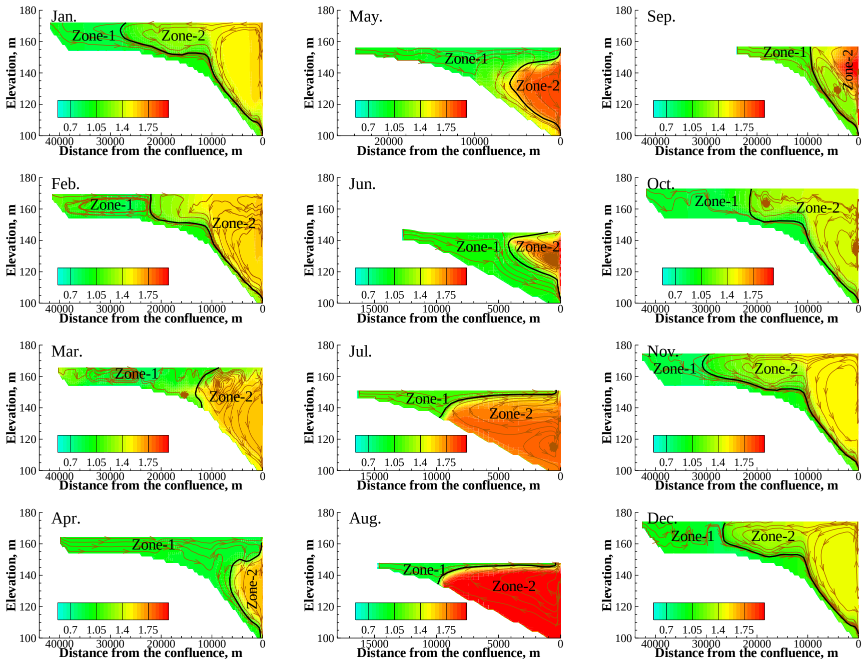

Fig. 12. The vertical two-dimensional distribution of TN in each month. The black curve in the figure is the boundary between Zone 1 and Zone 2.

The COD, NH_3-N, TP and TN in the surface water of the tributary bay in different months are shown in Fig. 13. 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.

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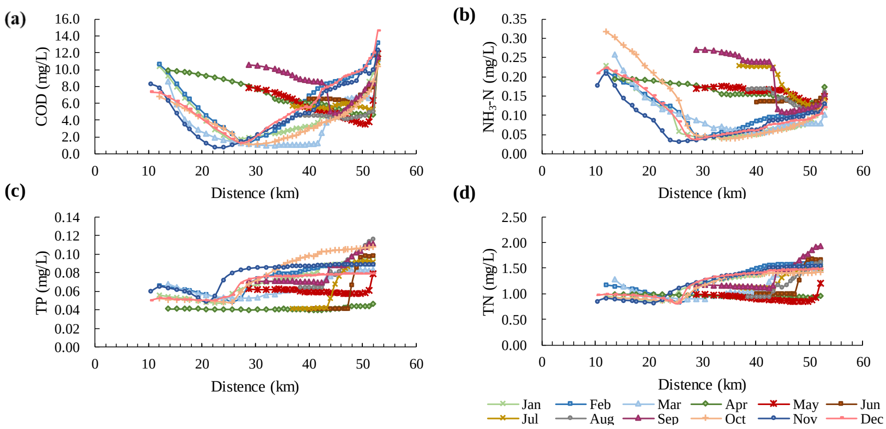

Fig. 13. The variation in surface water quality in different months along the tributary bay. (a) Variation in chemical oxygen demand, (b) variation in ammonia nitrogen, (c) variation in total phosphorus, and (d) variation in total nitrogen.

The vertical changes in COD, NH_3-N, TP and TN in different months at the confluence are shown in Fig. 14. 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

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increased and then decreased from the surface to the bottom. The concentration gradient in the upper 10 m surface layer was relatively large.

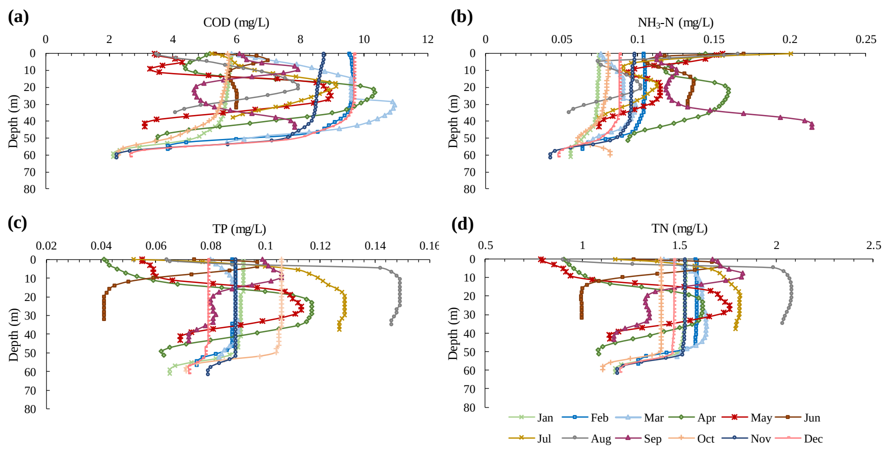

Fig. 14. The vertical variation in the water quality in different months at the section that was 6 km away from the confluence. (a) Variation in chemical oxygen demand, (b) variation in ammonia nitrogen, (c) variation in total phosphorus, and (d) variation in total nitrogen.

The average concentrations of COD, NH_3-N, TP and TN in Zone 1 and Zone 2 are shown in Fig. 15. 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 higher than that in Zone 2 due to the higher concentration of NH_3-N in the water of the tail of the tributary bay. For TP and TN, the concentrations in Zone 2 were higher than those in Zone 1.

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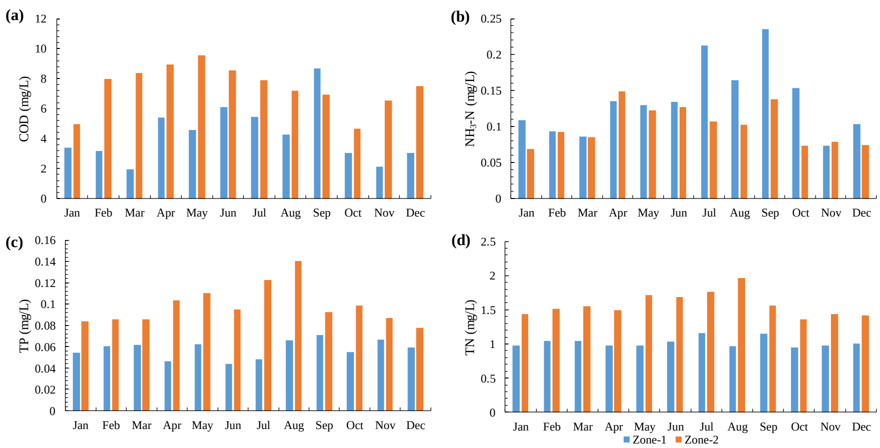

Fig. 15. The average water quality changes in Zone 1 and Zone 2. (a) Variation in chemical oxygen demand, (b) variation in ammonia nitrogen, (c) variation in total phosphorus, and (d) variation in total nitrogen. The blue bar represents Zone 1, and the orange bar represents Zone 2.

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. 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 intrusion of 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.

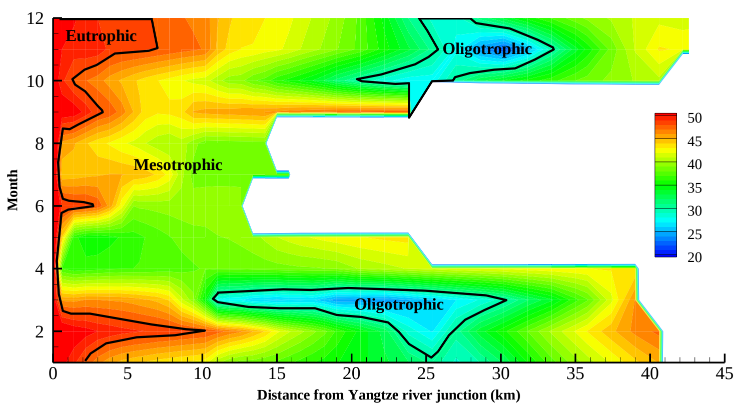

Fig. 16. Eutrophication results of surface water in the tributary bay. The nutrient status of the tributary bay is divided into three states (oligotrophic, mesotrophic and

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eutrophic) according to the comprehensive nutrient index.

4 Conclusions and future work

In this paper, the effect of the backwater jacking and intrusion of 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 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. Conversely, when the water level of the main reservoir rose, the tributary bay was mainly affected by backwater intrusion 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

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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, 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 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 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, 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 influence of the tributary bay on the main reservoir and the interaction between the main reservoir and the tributary

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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 work reported in this paper.

Acknowledgements. This work was sponsored by the fund of Sichuan Province under permission number 2018SZYZF0001.

Author contribution. All co-authors participated in the field collection, data analysis, and/or writing of this manuscript. Ruifeng Liang was primarily responsible for preparation and process of this manuscript. Xintong Li and Yuanming Wang conceived of the study design and data analysis with input from all co-authors.

References

Bennett, M. G., Schofield, K. A., Lee, S. S. and Norton, S. B.: Response of chlorophyll a to total nitrogen and total phosphorus concentrations in lotic ecosystems: a systematic review protocol, Environmental Evidence, 6(1), 18, https://doi.org/10.1186/s13750-017-0097-8, 2017.

Bockelmann, B. N., Fenrich, E. K., Lin, B. and Falconer, R. A.: Development of an ecohydraulics model for stream and river restoration, Ecological Engineering, 22(4-5), 227-235, https://doi.org/10.1016/j.ecoleng.2004.04.003, 2004.

Cai, Q. and Hu, Z.: Studies on eutrophication problem and control strategy in the Three Gorges Reservoir, Acta Hydrobiologica Sinica, 30(1), 7-11 (in Chinese), https://doi.org/10.3321/j.issn:1000-3207.2006.01.002, 2006.

Carey, C. C., Ibelings, B. W., Hoffmann, E. P., Hamilton, D. P. and Brookes, J. D.: Eco-physiological adaptations that favour freshwater cyanobacteria in a changing climate, Water Research, 46(5), 1394-1407, https://doi.org/10.1016/j.watres.2011.12.016, 2012.

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

Carlson, R. E.: A trophic state index for lakes. Limnology and Oceanography, 22(2), 361-369, https://doi.org/10.4319/lo.1977.22.2.0361, 1977.

Debele, B., Srinivasan, R. and Parlange, J. Y.: Coupling upland watershed and downstream waterbody hydrodynamic and water quality models (SWAT and CE-QUAL-W2) for better water resources management in complex river basins, Environmental Modeling & Assessment, 13(1), 135-153, https://doi.org/10.1007/s10666-006-9075-1, 2008.

Deng, S. and Bai, Y.: Analysis on the role of environmental impact assessment in the construction of water conservancy and hydropower projects, Environment and Sustainable Development, 41(5), 101-102 (in Chinese), https://doi.org/10.19758/j.cnki.issn1673-288x.2016.05.030, 2016.

Fang, J.: The Operating Simulation of Cascade Reservoirs and it's Impacts on River Eco-environment—A Case Study on Upper reaches of the Yangtze River. Ph.D, Institute of Mountain Hazards and Environment Chinese Academy of Sciences, 2007.

Feng, J., Li, R., Liang, R. and Shen, X.: Eco-environmentally friendly operational regulation: an effective strategy to diminish the TDG supersaturation of reservoirs, Hydrology and Earth System Sciences, 18, 1213-1223, https://doi.org/10.5194/hess-18-1213-2014, 2014.

Gao, Q., He, G., Fang, H. and Huang, L.: Effects of vertical mixing on algal growth in the tributary of Three Gorges Reservoir, Journal of Hydraulic Engineering 48(1),

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

96-103 (in Chinese), https://doi.org/10.13243/j.cnki.slxb.20160239, 2017.

Gao, X., Zeng, Y., Wang, J. and Liu, H.: Immediate impacts of the second impoundment on fish communities in the Three Gorges Reservoir, Environmental Biology of Fishes, 87, 163-173, https://doi.org/10.1007/s10641-009-9577-1, 2010.

Holbach, A., Bi, Y., Yuan, Y., Wang, L., Zheng, B. and Norra, S.: Environmental water body characteristics in a major tributary backwater of the unique and strongly seasonal Three Gorges Reservoir, China, Environmental Science Processes: Processes & Impacts, 17(9), 1641-1653, https://doi.org/10.1039/C5EM00201J, 2015.

Holbach, A., Norra, S., Wang, L. Yuan, Y., Wei, H. and Zheng, B.: Three Gorges Reservoir: Density Pump Amplification of Pollutant Transport into Tributaries, Environmental Science & Technology, 48(14), 7798-7806, https://doi.org/10.1021/es501132k, 2014.

Hu B., Yang Z., Wang, H., Sun, X., Bi, N. and Li, G.: Sedimentation in the Three Gorges Dam and the future trend of Changjiang (Yangtze River) sediment flux to the sea, Hydrology and Earth System Sciences, 13, 2253-2264, https://doi.org/10.5194/hess-13-2253-2009, 2009.

Huisman, J., Pham Thi, N. N., Karl, D. M. and Sommeijer, B.: Reduced mixing generates oscillations and chaos in the oceanic deep chlorophyll maximum, Nature, 439(7074), 322-325, https://doi.org/10.1038/nature04245, 2006.

Ji, D., Wells, S. A., Yang, Z., Liu, D., Huang, Y., Ma, J. and Chris, J. B.: Impacts of water level rise on algal bloom prevention in the tributary of Three Gorges Reservoir, China, Ecological Engineering, 98, 70-81, https://doi.org/10.1016/j.ecoleng.2016.10.019, 2017.

Kasai, A., Kurikawa, Y., Ueno, M., Robert, D., and Yamashita, Y.: Salt-wedge intrusion of seawater and its implication for phytoplankton dynamics in the Yura Estuary, Japan, Estuarine, Coastal and Shelf Science, 86(3), 408-414, https://doi.org/10.1016/j.ecss.2009.06.001, 2010.

Lewis, W. M., Wurtsbaugh, W. A. and Paerl, H. W.: Rationale for control of anthropogenic nitrogen and phosphorus to reduce eutrophication of inland waters, Environmental Science & Technology, 45(24), 10300-10305, https://doi.org/10.1021/es202401p, 2011.

Li, K., He, W., Hu, Q. and Gao, S.: Ecological restoration of reclaimed wastewater lakes using submerged plants and zooplankton, Water and Environment Journal, 28(3), 323-328, https://doi.org/10.1111/wej.12038, 2013.

Li, Z. and Zhang, H.: Trophic State Index and its Correlation with Lake Parameters in China, Acta Scientiae Circumstantiae, 13(4), 391-397 (in Chinese), https://doi.org/10.13671/j.hjkxxb.1993.04.002, 1993.

Liang, L., Deng, Y., Zheng, M. and Wei, X.: Predicting of Eutrophication in the Longchuan River Based on CE-QUAL-W2 Model, Resources and Environment in the Yangtze Basin, 23(1), 103-111, https://doi.org/10.11870/cjlyzyyhj2014Z1015, 2014.

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

Lindim, C., Pinho, J. L. and Vieira, J. M. P.: Analysis of spatial and temporal patterns in a large reservoir using water quality and hydrodynamic modeling, Ecological Modelling, 222(14), 2485-2494, https://doi.org/10.1016/j.ecolmodel.2010.07.019, 2011.

Liu, D., Yang, Z., Ji, D., Ma, J. and Cui, Y.: A review on the mechanism and its controlling methods of the algal blooms in the tributaries of Three Gorges Reservoir, Journal of Hydraulic Engineering, 47(03), 443-454 (in Chinese), https://doi.org/10.13243/j.cnki.slxb.20151304, 2016.

Liu, L.: Effects of vertical mixing on phytoplankton blooms in Xiangxi Bay of Three Gorges Reservoir: Implications for management, Water Research, 46(07), 2121-2130, https://doi.org/10.1016/j.watres.2012.01.029, 2012.

Long, L., Ji, D., Yang, Z., Ma, J., Scott, A. W., Liu, D. and Andreas, L.: Density - driven water circulation in a typical tributary of the Three Gorges Reservoir, China, River Research and Application, 35(7), 1-11, https://doi.org/10.1002/rra.3459, 2019.

Long, L., Xu H., Bao, Z., Ji, D. and Liu, D.: Temporal and spatial characteristics of water temperature in Xiluodu Reservoir, Journal of Hydroelectric Engineering, 37(4), 79-89 (in Chinese), https://doi.org/10.11660/slfdxb.20180408, 2018.

Lu, Q., Li, R., Li, J., Li, K. and Wang, L.: Experimental study on total dissolved gas supersaturation in water, Water Science and Engineering, 04(4), 396-404, https://doi.org/10.3882/j.issn.1674-2370.2011.04.004, 2011.

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

McGrath, K. E., Dawley, E. M. and Geist, D. R.: Total Dissolved Gas Effects on Fishes of the Lower Columbia River, PNNL-15525, Pacific Northwest National Laboratory, Richland, Washington, https://doi.org/10.2172/918864, 2006.

Mohseni, O. and Stefan, H. G.: Stream temperature/air temperature relationship: a physical interpretation, Journal of Hydrology, 218(3), 128-141, https://doi.org/10.1016/S0022-1694(99)00034-7, 1999.

Morgenstern, U., Daughney, C. J., Leonard, G., Gordon, D., Donath, F. M., and Reeves, R.: Using groundwater age and hydrochemistry to understand sources and dynamics of nutrient contamination through the catchment into Lake Rotorua, New Zealand, Hydrology and Earth System Sciences, 19, 803-822, https://doi.org/10.5194/hess-19-803-2015, 2015.

Naselli-Flores, L. and Barone, R.: Water-Level Fluctuations in Mediterranean Reservoirs: Setting a Dewatering Threshold as a Management Tool to Improve Water Quality, Hydrobiologia, 548, 85-99, https://doi.org/10.1007/s10750-005-1149-6, 2005.

Noori, R., Yeh, H. D., Ashrafi, K., Rezazadeh, N., Bateni, S. M., Karbassi, A., Kachoosangi, F. T. and Moazami, S.: A reduced-order based CE-QUAL-W2 model for simulation of nitrate concentration in dam reservoirs, Journal of Hydrology, 530, 645-656, https://doi.org/10.1016/j.jhydrol.2015.10.022, 2015.

Oldani, N. O. and Claudio R. M. Baigún: Performance of a fishway system in a major South American dam on the Parana River (Argentina–Paraguay), River Research and Application, 18(2), 171-183, https://doi.org/10.1002/rra.640, 2002.

Paerl, H. W., Hall, N. S. and Calandrino, E. S.: Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change, Science of the Total Environment, 409(10), 1739-1745, https://doi.org/10.1016/j.scitotenv.2011.02.001, 2011.

Pan, X., Tang, L., Feng, J., Liang, R., Pu, X., Li, R., and Li, K.: Experimental Research on the Degradation Coefficient of Ammonia Nitrogen Under Different Hydrodynamic Conditions, Bulletin of Environmental Contamination and Toxicology, 104, 288, https://doi.org/10.1007/s00128-019-02781-0, 2020.

Peng, C., Chen, L., Bi, Y., Xia, C., Lei, Y., Yang, Y., Jian, T. and Hu, Z.: Effects of flood regulation on phytoplankton community structure in the Xiangxi River, a tributary of the Three Gorges Reservoir, China Environmental Science, 34, 1863-1871, https://doi.org/10.1097/NEN.0000000000000183, 2014.

Ran, X., Alexander, F. B., Yu, Z. and Liu, J.: Implications of eutrophication for biogeochemical processes in the Three Gorges Reservoir, China, Regional Environmental Change, 19(1), 55-63, https://doi.org/10.1007/s10113-018-1382-y, 2019.

Reynolds, C. S.: The ecology of phytoplankton, Cambridge University Press, London, 2006.

Romarheim, A. T., Tominaga, K., Riise, G., and Andersen, T.: The importance of year-to-year variation in meteorological and runoff forcing for water quality of a

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

temperate, dimictic lake, Hydrology and Earth System Sciences, 19, 2649-2662, https://doi.org/10.5194/hess-19-2649-2015, 2015.

Singh, S. P. and Singh, P.: Effect of temperature and light on the growth of algae species: A review, Renewable and Sustainable Energy Reviews, 50, 431-444, https://doi.org/10.1016/j.rser.2015.05.024, 2015.

Soares, M., Vale, M. and Vasconcelos, V.: Effects of nitrate reduction on the eutrophication of an urban man-made lake (Palάcio de Cristal, Porto, Portugal), Environmental Technology, 32(9), 1009-1015, https://doi.org/10.1080/09593330.2010.523437, 2011.

Srivastava, A., Chun, S. J., Ko, S. R., Kim, J., Ahn, C. Y. and Oh, H-M.: Floating rice-culture system for nutrient remediation and feed production in a eutrophic lake, Journal of Environmental Management, 203, 342-348, https://doi.org/10.1016/j.jenvman.2017.08.006, 2017.

Tang, Q., Bao, Y., He, X., Fu, B., Adrian, L. C. and Zhang, X.: Flow regulation manipulates contemporary seasonal sedimentary dynamics in the reservoir fluctuation zone of the Three Gorges Reservoir, China, Science of the Total Environment, 548-549: 410-420, https://doi.org/10.1016/j.jenvman.2017.08.006, 2016.

Thomas, M. C. and Scott A. W.: CE-QUAL-W2: A two-dimensional laterally averaged hydrodynamic and water quality model, Version 3.6, Department of Civil and Environmental Engineering, Portland State University, Portland, 2008.

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

Wang, Q.: Influence on fishes of dissolved gas supersaturation caused by high-dam discharging and its countermeasures, Proceedings of 2011 International Symposium on Water Resource and Environmental Protection, Xi'an, https://doi.org/10.1109/ISWREP.2011.5893398, 2011.

Wang, R., Huang, T. and Wu, W.: Different factors on nitrogen and phosphorus self-purification ability from an urban Guandu-Huayuan river, Journal of Lake Sciences, 28(1), 105-113, https://doi.org/10.18307/2016.0112, 2016.

Wu, W.: Change of Channel Conditions of the Reach from Wanzhou to Fuling in the Yangtze River at Incipient Stage of Three Gorges Reservoir, Journal of Chongqing Jiaotong University (Natural Science), 32(3), 475-479 (in Chinese), https://doi.org/10.3969/j.issn.1674-0696.2013.03.25, 2013.

Xiong, C., Liu, D., Zheng, B., Zhang, J., Hu, N., Zhang, Y. and Chen, Y.: The Influence of Hydrodynamic Conditions on Algal Bloom in the Three Gorges Reservoir Tributaries, Applied Mechanics and Materials, 295-298, 1981-1990, https://doi.org/10.4028/www.scientific.net/amm.295-298.1981, 2013.

Yang, Z., Cheng, B., Xu, Y., Liu, D., Ma, J. and Ji, D.: Stable isotopes in water indicate sources of nutrients that drive algal blooms in the tributary bay of a subtropical reservoir, Science of The Total Environment 634, 205-213, https://doi.org/10.1016/j.scitotenv.2018.03.266, 2018.

Yang, Z., Liu, D., Ji, D. and Xiao, S.: Influence of the impounding process of the Three Gorges Reservoir up to water level 172.5 m on water eutrophication in the

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

Hydrology and Earth System Sciences
Open Access
Discussions

Xiangxi Bay, Science China Technological Sciences 53(4), 1114-1125, https://doi.org/10.1007/s11431-009-0387-7, 2010.

Yao, X., Liu, D., Yang, Z., Ji, D. and Fang, X.: Preliminary Studies on the Mechanism of Winer Dinoflagellate Bloom in Xiangxi Bay of the Three Gorges Reservoir, Research of Environmental Sciences, 25(6), 645-651 (in Chinese), https://doi.org/10.13198/j.res.2012.06.40.yaoxj.001, 2012.

Yin, W., Ji, D., Hu, N., Xie, T., Huang, Y., Li, Y. and Zhou J.: Three-dimensional Water Temperature and Hydrodynamic Simulation of Xiangxi River Estuary, Advanced Materials Research, 726-731(2013), 3212-3221, https://doi.org/10.4028/www.scientific.net/AMR.726-731.3212, 2013.

Yu, Z., Wang, L., Zhang, L., Yang Y., Yan, L., Zhang, J. and Yang, Y.: Hydrodynamic characteristics in a valley type tributary bay during the raising and falling temperature periods, Applied Mechanics and Materials, 353-356(2013), 2567-2571, https://doi.org/10.4028/www.scientific.net/AMM.353-356.2567, 2013.

Zeng, M., Huang, T., Qiu, X., Wang, Y., Shim J., Zhou, S. and Liu, F.: Seasonal Stratification and the Response of Water Quality of a Temperate Reservoir—Zhoucun Reservoir in North of China, Environmental Science, 37(4): 1337-1344 (in Chinese), https://doi.org/10.13227/j.hjkx.2016.04.019, 2016.

Zhang, H.: Ways to effectively improve the design level of water conservancy and hydropower projects, China Science and Technology Information 5, 89-90 (in

Chinese), https://doi.org/10.3969/j.issn.1001-8972.2014.05.024, 2014.

Zhang, S., Song, D., Zhang, K., Zeng, F. and Li, D.: Trophic status analysis of the upper stream and backwater area in typical tributaries, Three Gorges Reservoir, Journal of Lake Sciences, 22 (2), 201-207 (in Chinese), https://doi.org/10.1017/S0004972710001772, 2010.

Zheng, B., Zhao, Y., Qin, Y., Ma, Y. and Han, C.: Input characteristics and sources identification of nitrogen in the three main tributaries of the Three Gorges Reservoir, China, Environmental Earth Sciences, 75(17): 1219, https://doi.org/10.1007/s12665-016-6028-0, 2016.

Zheng, T.: The Study of Water Environment and Sedimentation Regimes in the Upper Three Gorges Reservoir. Proceedings of 2011 International Symposium on Water Resource and Environmental Protection, Xi'an, https://doi.org/10.1109/ISWREP.2011.5893641, 2011.

Zheng, T., Mao J., Dai H. and Liu D.: Impacts of water release operations on algal blooms in a tributary bay of Three Gorges Reservoir, Science China (Technological Sciences), 54(6), 1588-1598, https://doi.org/10.1007/s11431-011-4371-7, 2011.

Zhou, J., Zhang M. and Lu, P.: The effect of dams on phosphorus in the middle and lower Yangtze river, Water Resource Research, 49, 3659-3669, https://doi.org/10.1002/wrcr.20283, 2013.

Zhu, S.: Preliminary Study on Physical Characteristics of Sediment Deposition in the

https://doi.org/10.5194/hess-2020-63
Preprint. Discussion started: 18 February 2020

Hydrology and Earth System Sciences
Discussions

Three Gorges Reservoir, MA.Sc. Changjiang River Scientific Research Institute (in Chinese), 2017.

Ziv, G., Baran, E., Nam, S., Rodriguez-Iturbe, I. and Levin, S. A.: Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin, Proceedings of the National Academy of Sciences of the United States of America, 109 (15), 5609-5614. https://doi.org/10.1073/pnas.1201423109, 2012.

Zou, J. and Zhai, H.: Impacts of Three Gorges Project on water environment and aquatic ecosystem and protective measures, Water Resources Protection, 32(05), 136-140 (in Chinese), https://doi.org/10.3880/j.isssn.1004-6933.1016.05.025, 2016.