Water quality control plan with BATHTUB model for lake inflow rivers – a case study of total phosphorus in Northwest Lake Taihu, China

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ABSTRACT

Total phosphorus (TP) standards for lakes differ from those for rivers in GB3838-2002. This disjunction may lead to the failure of lake-water quality improvement plans that control nutrient inputs from inflow rivers. With monthly monitoring data for the period 2009–2015, Northwest Lake Taihu was regarded as a case study and the BATHTUB model was utilised to simulate the correspondence between concentrations of TP in the lake and in its inflow rivers. A control plan for TP in Northwest Lake Taihu's inflow rivers is proposed. To guarantee the fulfillment of the control goals of TP in the lake, concentration of TP in the inflow rivers of North Zone, Zhushan Bay, Meiliang Bay and Gonghu Bay should be reduced by 50%, 58%, 18% and 11%, respectively, and TP flux loads should be maintained under 227.35, 173.39, 113.69 and 90.62 ta^{-1}, respectively. Meanwhile, total TP influxes from Northwest Lake Taihu should be maintained under 604.63 ta^{-1}. A control plan that is more restrictive than GB3838-2002 should be proposed to address the TP pollution of the lake. This research provides the foundation for quantifying reduction of the nutrient loading from the catchment and for maintaining Lake Taihu and other typical eutrophic lakes.

Key words | BATHTUB, inflow rivers, Lake Taihu, total phosphorus, water quality control plan

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INTRODUCTION

With the rapid growth of industries and human population, lake water is being heavily polluted by multifarious sources and eutrophication in lakes has become a pressing issue (Huang *et al.* 2008; Bozelli *et al.* 2009; Niu *et al.* 2015). Numerous studies on eutrophication, which is a national concern, have focused on physical, chemical and biological parameters and land-use influences, including sediment dredging, aquatic organisms and hydrodynamic conditions (Wu *et al.* 2011; Bian *et al.* 2016; Wu *et al.* 2016). Rivers, especially inflows, have a significant impact on the eutrophication of lakes (Zhou *et al.* 2007; Chen *et al.* 2015a; Wu *et al.* 2018), and excessive phosphorus loading from inflow rivers is the main limiting factor causing lake eutrophication (Singh *et al.* 2005; Lewis & Wurtsbaugh 2008; Suttle & Harrison 2010).

Various researchers and institutes have investigated eutrophication in lakes in recent years (Kim & Kannan 2007; Orata *et al.* 2009). To effectively protect lakes, the US Clean Water Act requires the development of an appropriate total maximum daily load (TMDL) for each water body and for each identified pollutant (Havens & Schelske 2001). The amount of pollutant loading, such as, chemical oxygen demand (COD), total phosphorus (TP) and total nitrogen (TN), that a water body can receive while still serving its purpose is still debated (Havens & Walker 2002; Seo *et al.* 2009), and only a few studies have focused on the contamination levels in inflow rivers despite the fact that concentrations have been extensively analysed for monitoring pollution (Chen *et al.* 2015b; Niu *et al.* 2015; Ma *et al.* 2018). As concluded for Lake Constance (Gaedke 1998) and other eutrophic lakes, declining water quality in inflow rivers must be controlled and prevented in order to restore lakes (Chen *et al.* 2003). The amount of pollution that must be removed from a water body to improve water quality or the manner by which an increase in pollutant loading may degrade water quality can be determined by

doi: 10.2166/wcc.2018.201

the use of semi-empirical or empirical models (USEPA 2000; NRC 2001; MPCA 2006). Several such empirical models are made up of the Wisconsin Department of Natural Resource's (WDNR) Wisconsin Lakes Modeling Suite (Panuska & Kreider 2002) and Seepage Lake Model (WDNR 2004), and BATHTUB (Walker 1996). As a semi-empirical model, BATHTUB was designed by the U.S. Army Corps of Engineers (USACE) to apply empirical eutrophication models to morphometrically complex lakes and reservoirs. Based on the empirical relationships, which is previously developed and tested for applications to collections or networks of reservoirs, eutrophication-related water quality conditions are predicted (Walker 1984). Responding to modifications in nutrient concentrations, specific processes can dramatically change which cannot easily be foreseen; thus, as shown by differences that have been demonstrated in a wide range of systems, the use of empirical models is more advantageous than that of complex models to predicting the long-term effects of nutrient-load reductions (Robertson & Schladow 2008). BATHTUB is widely used for water environmental planning, evaluation and management in the USA. Numerous studies have shown that the simulation results of this simplified model are satisfactory (USEPA 1999; South Dakota Department of Environment & Natural Resources 2004; WDNR 2004; USEPA 2007). In 2013, the United States Environmental Protection Agency (USEPA) utilised the BATHTUB model to calculate downstream protection values for streams that flow into lakes and to identify models that compute TN and TP in streams for the protection of downstream lakes (USEPA 2013). Over other models, one major advantage of BATHTUB is its use of simple steady-state calculations to address eutrophication processes, which decreases data requirements (Wang *et al.* 2005).

The Lake Taihu basin, a developed sub-lake in China, has received considerable attention due to its severe pollution (Paerl *et al.* 2011; Wu *et al.* 2018). The lake is experiencing numerous ecological problems, especially cyanobacterial blooms and eutrophication, and river inputs are the major source of pollutant loadings to the lake (Chen *et al.* 2003; Qin *et al.* 2007). This poses considerable challenges for the local government with regard to natural resource management and pollution control in the Lake Taihu basin. Although the water quality of inflow rivers is required to satisfy Grade III standards in Environmental Quality Standards for Surface Water (EQSSW) in China (GB3838-2002) for the eutrophication control target of the Chinese government, lake water quality has not improved to date (Qin *et al.* 2007). The GB3838-2002 standards, which are the primary standards for the protection of aquatic ecosystem in China, were derived from and/or based on the environmental standards or criteria of developed countries due to a lack of historical perspective and mature, established research on environmental criteria (Wu *et al.* 2010). Although these standards produced positive outcomes after application during the early period of social development and environmental protection in China (Li *et al.* 2012), GB3838-2002 remains plagued by several principal limitations, one of which is some standards for certain pollutant contents are not highly appropriate for aiming at a certain research area in the surface water of China (Zhao *et al.* 2016; Zheng *et al.* 2016). Moreover, the water quality standards of TP for lakes differ from those for rivers in GB3838-2002. Therefore, efforts to control the nutrient input from the catchment of Lake Taihu to reduce pollutant concentration and thus improve water quality can easily fail.

This research regarded Northwest Lake Taihu as a case study, based on monthly monitoring data from the period of 2009–2015 and the regionalisation of environmental ecological function in the lake, and used the BATHTUB model to simulate the correspondence between TP concentrations in the lake and its inflow rivers. Then, a TP control plan for the inflow rivers is proposed according to the goal of improving the lake water quality.

MATERIALS AND METHODS

Study area

Lake Taihu, the third largest freshwater lake in China, has a surface area of 2,338 km^2 and drainage area of 36,500 km^2; it is in southeast Jiangsu Province and in the lower reach of the Yangtze River basin in China (Lake Taihu Basin Authority 2012). Lake Taihu is the main drinking water source for neighbouring residents despite being heavily polluted and inferior to Grade V in GB3838-2002 (Bai *et al.* 2009; Zhang & Chen 2011). Spatial heterogeneity is evident in the water quality of Lake Taihu, i.e. water quality is relatively poor in the western and northern parts and relatively desirable in the southeastern part (Chi *et al.* 2007; Qin *et al.* 2010; Tao *et al.* 2012). Excessive nutrients from inflow rivers are the major source of pollutant loadings to the lake and subsequently lead to the spatial heterogeneity (Li *et al.* 2013; Liu *et al.* 2017). More than 200 rivers at different scales are connected with Lake Taihu. Inflow rivers in Northwest Lake Taihu contribute the most water discharge and nearly 80% of COD, nitrogen (N) and phosphorus (P) to the lake (Zhang & Chen 2011). Eutrophication studies in freshwater lakes often focus on TP because it is the most common limiting nutrient and thus typically targeted for loading reduction (Schindler 1974; Morton *et al.* 2003; Niu *et al.* 2004; Schindler 2006; Lewis & Wurtsbaugh 2008). Therefore, the present work focuses on the TP standards in Northwest Lake Taihu and studies monthly monitoring data covering the period 2009–2015.

Data analysis

Monthly TP concentrations of inflow rivers and of Northwest Lake Taihu from the period 2009–2015 were provided by Jiangsu Province Hydrology and Water Resources Investigation Bureau. The locations of the monitoring sites distributed across Northwest Lake Taihu and its inflow rivers are shown in Figure 1. The monitoring stations were located by GPS and water samples were collected from approximately one meter below the water surface monthly from 2009 to 2015, usually in the middle of every month. The samples were then delivered to a laboratory by cryopreservation, and the correlation processing was performed within 24 h, from sampling, through preservation and transportation to analysis. All samples were measured three times, and results were expressed in averages. All chemical analyses followed the standards established by the State Environmental Protection Bureau of China.

For the convenience of describing the impact of the inflow rivers, Lake Taihu was divided into eight sub-areas (Figure 1), namely North Zone, Zhushan Bay, Meiliang Bay, Gonghu Bay, Southwest Zone, Central Zone, East

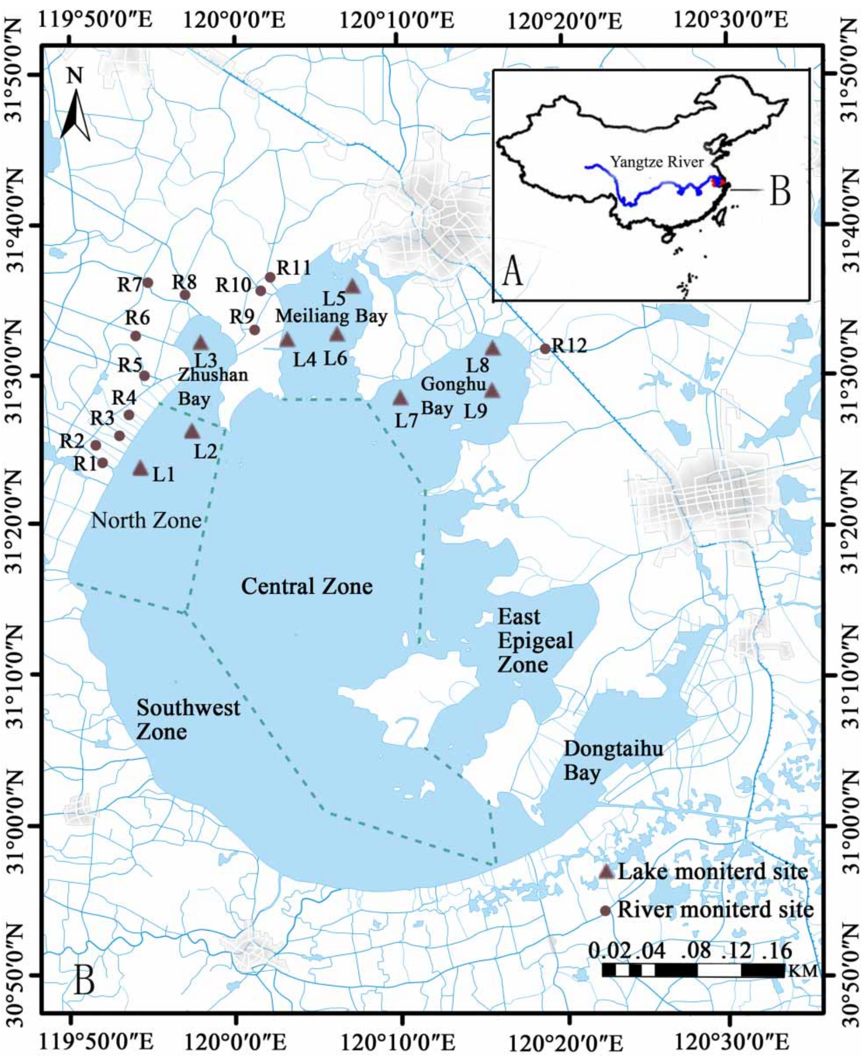

Figure 1 | Sampling stations in Lake Taihu and its inflow rivers.

Epigeal Zone and Dongtaihu Bay (Hu *et al.* 2008; Li *et al.* 2011). This study focuses on the TP concentration in Northwest Lake Taihu and thus included only the sub-lakes of North Zone, Zhushan Bay, Meiliang Bay, Gonghu Bay and their inflow rivers. With consideration for data availability and the links between the sub-lakes and their inflow rivers, corresponding sites were selected and are displayed in Table 1.

Model description

On the basis of empirical data from USACE's reservoirs previously described in a series of technical reports, BATHTUB was developed for modelling reservoir water quality (Walker 1985). This model is valuable for estimating the relative significance of several nutrient sources in watersheds with respect to the likely response of lakes. BATHTUB allows users to segment a lake into a hydraulic network, to which nutrient balance and eutrophication models can be applied for the assessment of dispersion, advection and nutrient sedimentation. Empirical relationships have been calibrated and tested for reservoir applications, which could be used to predict eutrophication-related water quality conditions. Expressed in probabilistic terms, inputs and outputs can account for intrinsic model errors and limitations in input data. Through a first-order error analysis procedure (Walker 1984), the output sensitivity to each input variable and sub-model was estimated by repeatedly executing the model core, then variance and confidence limits for each output variable were estimated. These programs and models have been applied to USACE reservoirs (Kennedy 1995) and other lakes and reservoirs. BATHTUB is an effective tool for water quality assessment and management in lake and reservoir, particularly under limited relevant data (Ernst *et al.* 1994). BATHTUB version 5.3 allows estimation of internal phosphorus loading (Walker 1996).

The mass balance concept is fundamental to eutrophication modelling. The water and nutrient balances in BATHTUB model was established using a control volume around each segment and can be defined as:

$$Inflows = Outflows + \ Increase\ in\ storage + \ Net\ Loss$$

As an empirical model, BATHTUB focuses on simulating empirical relationships to predict eutrophication-related water quality conditions. In comparison with other physical models, BATHTUB requires fewer inputs, including global parameters (e.g. morphometric and physical characteristics), hydrologic, water quality data and nutrient loading (Table 2). In this model, an averaging period for calculating tributary inflows must be selected. For the hydrologic and nutrient loading data used in BATHTUB, the time period depends on the P-turnover ratio or residence

Table 2 | Parameters of BATHTUB model

Parameter type	Parameter name
Global parameter	Precipitation, evaporation, water level, TP conc.
Hydrologic	Surface area, mixed layer depth, mean depth, total phosphorus conc., chlorophyll-a, non-algal turbidity, Secchi depth, correction factor
Tributary data	Flow, TP conc.

Table 1 | Sampling stations in Lake Taihu and its inflow rivers

Northwest Lake Taihu	Monitored lake site	Inflow river	Monitored river site
North Zone	Dapukou (L1)	Hongxiang Stream	R1
	Bibcock (L2)	Chendong Stream	R2
		Guandu River	R3
		Shendu River	R4
Zhushan Bay	Zhushanhu (L3)	Shaoxing Stream	R5
		Yinchun Stream	R6
		Caoqiao	R7
		Taige Canal	R8
Meiliang Bay	Mashan Waterwork (L4)	Yapu Bridge	R9
	Chongshan Waterwork (L5)	Wujin Stream	R10
	Xiaowanli Waterwork (L6)	Zhihu Stream	R11
Gonghu Bay	Nanquan Waterwork (L7)	Wangyu River	R12
	Xidong Waterwork (L8)		
	Baiyangwan Waterwork (L9)		

times of the P mass in the lake. One year is usually selected for lakes and reservoirs with relatively long hydraulic residence times, and one growing season (April–September or May–September) is typically chosen for those with relatively short residence times (see turnover ratio and nutrient residence time) (Walker 1996). Lake Taihu has an approximate theoretical renewal time of 308 days (Niu *et al.* 2004; Qin *et al.* 2010). Therefore, this study regarded one year as the averaging period for simulation, and loading data were summarised for the entire year.

The water, nutrient and eutrophication components (Table 2) required adjustment to characterise current lake-conditions and thus ensure the local applicability of BATHTUB in this work. Consequently, the model could diagnose the formulation of water and nutrient balances, including identification and ranking of potential error sources. Predictions were generated by the assessment of the impacts of nutrient loading changes, and empirical relationships were calibrated and tested. BATHTUB was then adopted to determine the 'effect' of the discharge on the lake and the need for an effluent-P limitation on the discharge to protect the lake. Consequently, a TP control plan for the inflow rivers was developed according to the goals for the water quality in the lake.

RESULTS

Phosphorus pollution status in Northwest Lake Taihu

The annual average TP concentrations in Northwest Lake Taihu and in its inflow rivers from 2009 to 2015 indicated that Lake Taihu suffered from substantial TP pollution (Figure 2). North Zone and Zhushan Bay experienced more phosphorus pollution than the monitoring sites in Meiliang Bay and Gonghu Bay. According to GB3838-2002 (Table 3), the overall TP concentrations in the lake was classified as Class IV or V and those in the inflow rivers as Class III or IV, which meant that the water quality grades of the inflow rivers in terms of TP were deemed superior to those of the corresponding lake region. For example, the TP concentrations ranged from 0.1 to 0.2 mg/L in North Zone, Zhushan Bay and Meiliang Bay and thus belonged to Class V. TP concentrations in the corresponding inflow rivers ranged from 0.17 to 0.3 mg/L and hence belonged to Class III or IV. This case was also true for Gonghu Bay. The concentrations were 0.08–0.12 mg/L (Class I or V) in the lake and 0.11–0.14 mg/L (Class III) in the inflow rivers. In summary, the water quality standards of TP in the lake differed from those in the river, according to GB3838-2002. The water quality grades of TP in the inflow rivers were higher than those in the lake, thereby leading to considerable hazard for the ecosystems of Lake Taihu. This disjunction may lead to a failure to reduce pollutant concentration in the lake and thus improve water quality through the control of the nutrient input from the catchment.

The TP flux loads of the surveyed area were then calculated by multiplication of the flow rates and water concentration values. The flux load of each river was obtained by multiplication of the water concentration of each pollutant by different flows. The sum load of each river for each sub-lake was the total flux load flowing into

Table 3 | TP standards in EQSSW in China (GB3838-2002) (mg/L)

Standard	I	II	III	IV	V
TP ≤	0.02	0.1	0.2	0.3	0.4
TP ≤ (Lake and reservoir)	0.01	0.025	0.05	0.1	0.2

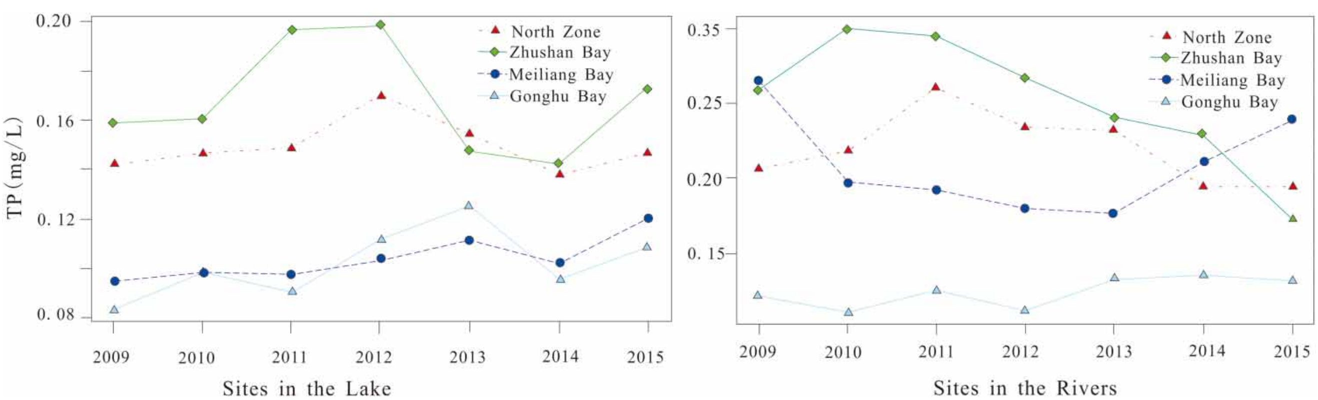

Figure 2 | Annual average TP concentrations in Northwest Lake Taihu and its inflow rivers (2009–2015) (mg/L).

Table 4 | Ranges of calibrated parameters for each sub-lake and water quality module

Item	Module	Calibrated parameters			
		North Zone	Zhushan Bay	Meiliang Bay	Gonghu Bay
Total phosphorus	04 Canf&Bach	8–20	15–36	3–60	6–16
Chorophyll-a	03 P, N, Low-Turbidity	0.16–0.38	0.15–0.4	0.28–0.55	0.28–0.4
Turbidity	01 Chl-a&Turbidity	0.85–1	0.85–1	0.85–1.0	1.0

the region. Through aggregation of the survey results from the Hydrology Bureau of Jiangxi Province across the seven years (2009–2015), the annual flux load was calculated to be 1,810 ta^{-1} of TP and influxes from rivers surrounding Northwest Lake Taihu were found to account for nearly 90%. The estimated TP inflow load in 2015 was 1,610 t, and influxes from North Zone, Zhushan Bay, Meiliang Bay and Gonghu Bay were 593.73, 625.40, 150.71 and 107.57 t, respectively.

Model calibration and validation

The BATHTUB model was calibrated and validated using data for the periods 2009–2012 and 2013–2015, respectively. Model calibration by sub-lake considerably improved model prediction for all response variables. This process involved computation of calibration parameters providing minimum differences between predicted and observed values across segments within each region. The calibrated parameters for each module are presented in Table 4. The calibrated parameters for TP were unusually distant from 1.0. These extreme deviations resulted from differences in concentration between the tributary streams and the associated sub-lakes (Kennedy 1995), which are described in detail in Table 4. The correlation coefficient (R^2), the average relative error (MRE) and the mean square error (MSE) between the measured and simulated TP concentrations for each sub-lake in the validation period (2013–2015) are shown in Table 5. The R^2 values of TP simulation for each sub-lake in the validation period were 0.975, 0.992, 0.998 and 0.989, which indicated relatively high model precision. Moreover, the TP concentrations in the lake were in the same range as our forecast interval in the BATHTUB model in Figure 3.

Table 5 | Performance criteria of TP simulation for each sub-lake in validation period (2013–2015)

Performance criteria	North Zone	Zhushan Bay	Meiliang Bay	Gonghu Bay
R^2	0.975	0.992	0.998	0.989
MRE (%)	2.01	2.31	1	1.36
MSE (%)	2.25	2.48	1.22	1.34

Simulated results in BATHTUB

According to the water quality standards of TP for lakes in GB3838-2002, corresponding TP concentrations in the inflow rivers were forecast for each sub-lake. The setting of the TP concentration in the lake as the target value should continuously debug the TP concentration in the inflow rivers and allow the target value to be within the predicted range in the debugged BATHTUB model. Finally, best fits were selected and are shown in Figure 4 and Table 6.

Control plan of TP for inflow rivers into Northwest Lake Taihu

In May 2007, an outbreak of algal blooms resulted in a water supply crisis in Wuxi City, which became a sensation in China. After 2007, the Chinese State Council ratified the Master Plan of Integrated Regulation of Water Environment and the Water Function Zoning of the Lake Taihu basin, thereby initiating the comprehensive treatment of the water environment in the basin. These documents propose the checking and ratification of the assimilative capacity of water functional zones and clearing of the targets of the different ecological function regions in the Lake Taihu basin. With the computation in Table 7, a TP control plan for the inflow rivers was developed. Water function should be guaranteed, and the water quality goal was set to Grades II–III by the government. Thus, the inflow rivers into North Zone should control TP concentration with a range of 0.022 to 0.075 mg/L. Similarly, the inflow rivers into Zhushan Bay, Meiliang Bay and Gonghu Bay should control TP concentration with ranges of 0.039–0.071, 0.045–0.085 and 0.044–0.090 mg/L, respectively, to achieve the water quality goal of Grade III.

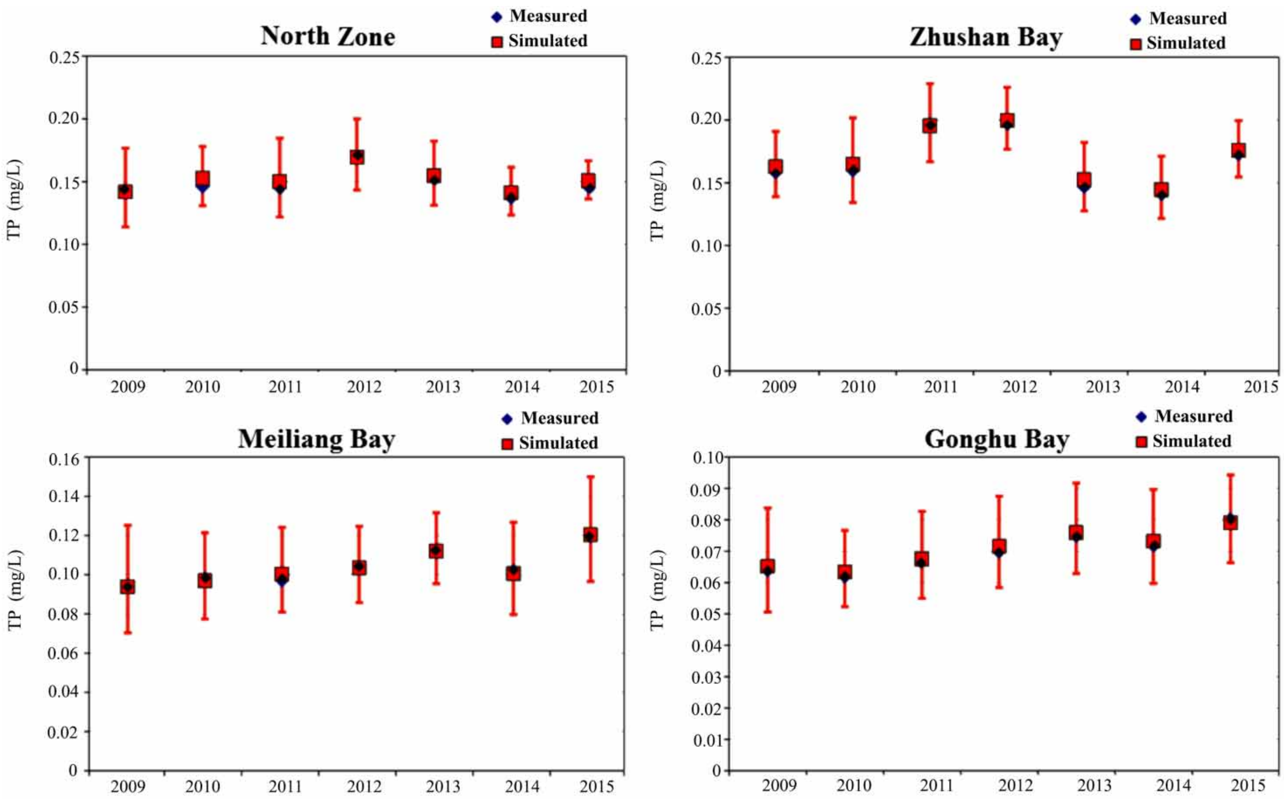

Figure 3 | Measured and simulated TP concentrations for each sub-lake in calibration and validation periods.

DISCUSSION

Model reliability

BATHTUB has been widely used for water environmental planning, evaluation and management, and the model can calibrate empirical relationships for predicting eutrophication-related water quality conditions. It has been cited as an efficient tool for water quality assessment and management in lake and reservoir. This research utilised the BATHTUB model to simulate the correspondence between TP concentration in the inflow rivers and lakes, and the parameters between the measured and simulated TP concentrations in verification period were good. The TP control plan for the inflow rivers into Northwest Lake Taihu was deemed reliable, and this result is significant for lake protection and improvement. In addition to the external loadings of pollutants, the characteristics and distribution of nutrients have a close relationship with hydrodynamics and lake current, amongst others (Jin *et al.* 1990; Li *et al.* 1994). Submerged plants can effectively change flow conditions and inhibit sediment resuspension and reservoir water quality (Lewis & Wurtsbaugh 2008). To improve the water environment in Lake Taihu, the internal and external nutrient loadings to the lake should be considered.

Implications of discrepancy between simulation results and current river TP standards

Figure 5 shows a comparison of the current and simulated TP standards in the inflow rivers for each sub-lake according to TP standards for lakes. Due to the different response relationships amongst water quality and circumstances in the various sub-lakes and their inflow rivers, a more detailed water quality standard than GB3838-2002 is needed to ensure that the entire lake area meets the protection goals for Lake Taihu. Preventing, changing and controlling eutrophication in Lake Taihu effectively while depending only on GB3838-2002 is challenging. A control plan that is more restrictive than GB3838-2002 is required, and TP concentration control in the inflow rivers should aim for lower concentrations than those in the TP river standards in GB3838-2002. In detail, when water quality was controlled

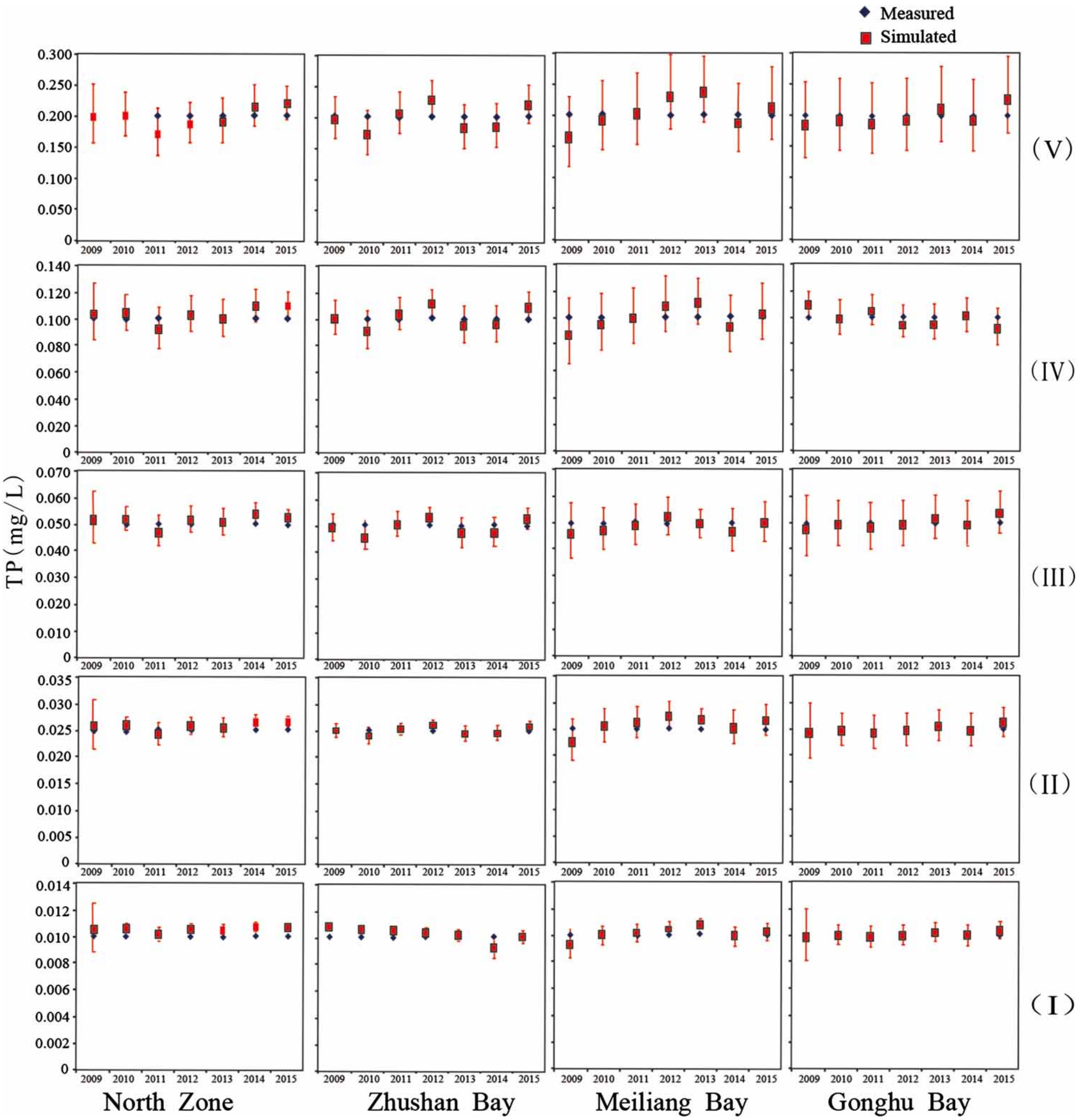

Figure 4 | Simulated and measured TP concentrations in Lake Taihu under best scenarios of inflow river TP concentration.

to range from Grade V to Grade III, the simulations results in different sub-lakes exhibited a certain disparity. When water quality was controlled to range from Grade II to Grade I, the simulations result in the different sub-lakes were nearly the same and resembled those in GB3838-2002.

Implications for TP reduction in inflow rivers

According to the water environmental ecological function regionalisation in the Lake Taihu basin and the TP control plan for the inflow rivers of Northwest Lake Taihu given in Table 6, the TP concentration in the inflow rivers of

Table 6 | Simulated TP concentrations in inflow rivers based on TP standard for lakes in GB3838-2002 (mg/L)

	Simulated TP concentrations in corresponding inflow rivers			
TP standard for lakes	North Zone	Zhushan Bay	Meiliang Bay	Gonghu Bay
V (0.2)	0.340	0.330	0.550	0.590
IV (0.1)	0.155	0.150	0.190	0.240
III (0.05)	0.075	0.071	0.085	0.090
II (0.025)	0.040	0.039	0.045	0.044
I (0.01)	0.022	0.021	0.022	0.022

Table 7 | Water environmental ecological function regionalisation in Lake Taihu basin and control plan of TP for inflow rivers into Northwest Lake Taihu (mg/L)

Sub-lake	Water functional zone	Goal	Control plan of TP for inflow rivers
North Zone	Conservation areas of Lake Taihu	II–III	0.022–0.075
Zhushan Bay	Conservation areas of the Zhushan Lake	III	0.039–0.071
Meiliang Bay	Conservation areas of water scenery	III	0.045–0.085
Gonghu Bay	Conservation areas of drinking water source	III	0.044–0.090

North Zone, Zhushan Bay, Meiliang Bay and Gonghu Bay should be reduced by nearly 50%, 58%, 18% and 11%, respectively, against the average TP concentration in the inflow rivers from 2009 to 2015. The TP flux loads from North Zone, Zhushan Bay, Meiliang Bay and Gonghu Bay should be maintained under 227.35, 173.39, 113.69 and 90.62 ta^{-1}, respectively. The total TP influxes from Northwest Lake Taihu should be kept under 604.63 t a^{-1}, which is 59.19% lower than that in 2015. Noticeably, the decreasing amplitude was larger in the inflow rivers of North Zone and Zhushan Bay than in others where the pollution is relatively heavier. According to data from 1998, pollutants produced by industry and agriculture (cropping, rice growing, etc.) and nonpoint pollutants in the Lake Taihu basin came mostly from North Zone (Huang *et al.* 2004). Hundreds of chemical plants are densely distributed and wastes from settlement areas and industrial facilities are discharged without any refinement, thereby affecting water quality and increasing the degree of eutrophication and pollution in Zhushan Bay rapidly (Yao & Xue 2010). The two areas are heavily polluted, and the control plans were similar. Gonghu Bay is surrounded by many woodlands with low population density and small towns. A large water channel connects Lake Taihu with Yangtze River, and the resulting flux of lake inflow is increased and leads to the dilution of pollutants in Gonghu Bay and Meiliang Bay. Therefore, the TP concentrations in these areas were lower than those in other sub-lakes, and the control plans reflected this pattern.

CONCLUSIONS

In the present study, monthly TP water quality data in inflow rivers and corresponding sub-lakes were used to calibrate

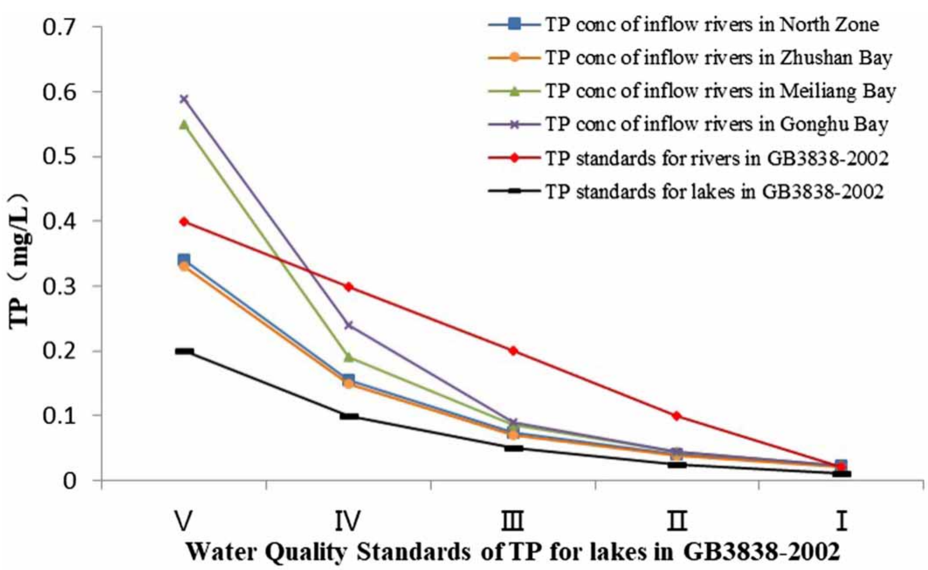

Figure 5 | Comparison of current TP standards in rivers and simulated TP concentrations in inflow rivers for each sub-lake according to TP standards for lakes.

and validate the BATHTUB model. Different scenarios were adopted to simulate the corresponding relationship between Northwest Lake Taihu and its inflow rivers. According to the water quality standards of TP for lakes in GB3838-2002, corresponding TP concentrations in the inflow rivers were forecast for each sub-lake, and a TP control plan for the inflow rivers in Northwest Lake Taihu was developed. Results showed that the TP concentration in the inflow rivers of North Zone, Zhushan Bay, Meiliang Bay and Gonghu Bay should be reduced by 50%, 58%, 18% and 11%, respectively. The TP flux loads from North Zone, Zhushan Bay, Meiliang Bay and Gonghu Bay should be maintained under 227.35, 173.39, 113.69 and 90.62 ta^{-1}, respectively. The total TP influxes from Northwest Lake Taihu should be kept under 604.63 ta^{-1}, a 59.19% decrease in comparison with that of 2015. The model considers several hydroclimatic factors, and the model error is small. To control TP pollution in Lake Taihu, a control plan more restrictive than GB3838-2002 must be implemented. When the water quality in lakes was controlled to range from Grade V to Grade III, the simulations results of inflow rivers into different sub-lakes had a certain disparity. By contrast, when the water quality was controlled to range from Grade II to Grade I, the simulation results were nearly the same and resembled GB3838-2002.

This study provides the foundation for the reduction of the nutrient loading from the catchment and maintenance of Lake Taihu. However, only the Northwest Lake Taihu basin was studied instead of the entire lake, and only monthly TP monitoring data from the period 2009–2015 instead of other indices were utilised as modelling variables. Additional water quality indices and increasingly thorough theoretical explorations are still needed in further study.

ACKNOWLEDGEMENT

This study was supported by the Project of Water Resources Department of Jiangsu Province (No. 2018042 and No. 2014031). We thank Jiangsu Province Hydrology and Water Resources Investigation Bureau for the assistance during our research.

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First received 2 August 2018; accepted in revised form 15 August 2018. Available online 25 September 2018