

Exploring the water quality driving mechanism in Poyang Lake, the largest freshwater lake in China

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ABSTRACT

Poyang Lake, the largest freshwater lake and typical river-connected lake in China, was selected as a research area. A method was first proposed to quantitatively explore the mechanisms driving water quality evolution, in which the weights of horizontal boundary input, self-purification, vertical atmospheric deposition and sediment release could be determined. A two-dimensional water environment model for Poyang Lake was developed in the framework of the Finite Volume Method and calibrated against the field investigated data. Four typical months in a common-water year were determined for numerical experiments to investigate the temporal and spatial water quality driving mechanisms in Poyang Lake. The results suggested that boundary input and self-purification have the greatest effect on dominating the water quality in Poyang Lake, followed by atmospheric deposition and sediment release. The driving weights of these four factors are 57.2%, 26.5%, 9.3%, and 7.0%, respectively. However, the impact on lake water quality of external water quality, aquatic ecosystem structure, precipitation distribution, and meteorological conditions, which are attributed to the disparities in geographical situation, varied significantly with seasons and locations.

Key words | atmospheric deposition, boundary input, driving mechanism, Poyang Lake, sediment release, self-purification

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INTRODUCTION

Water quality has been identified as an important factor in freshwater lakes that plays a key role in shaping the aquatic ecosystem and dominates its health and stability (Kuppusamy & Giridhar 2006). However, attributed to the population increase and acceleration of industrialization, many lakes around the world, e.g. Lake Burdur (Semiz & Aksit 2013), Lake Tai (Li & Tang 2013), and Lake Saimma (Satu-Pia & Pertti 2001), were observed to have undergone a deterioration in water quality that resulted in series of subsequent environmental problems including algal blooms, imbalanced aquatic ecosystems, water scenery destruction, and drinking water crisis (Wetzel 1992; Cengiz 2008). Scientific estimate of the evolution mechanism for water quality

interacts with, and often dominates, the plans to solve different kinds of water environmental problems. So far, massive studies have been conducted over many years regarding water quality in freshwater lakes and these fluvial achievements have yielded insight into water quality evaluation and prediction, and accelerated the application of related mathematic methods (Wang & Ma 2001; Yu *et al.* 2010; Yerel & Ankara 2012), such as the synthesized trophic state index method and multivariate statistical method.

Multiple factors have superposition consequences for the water quality in a lake (Huston *et al.* 2009; Ban *et al.* 2014; Rokitnicki-Wojcik & Grabas 2015). Besides the general factors, such as boundary inputs, ecosystem characteristics

and atmospheric deposition, the sediment deposited on the lake bed may also induce the pollutant transport between the sediment and overlying water under the current's disturbance. Despite the considerable documented research on different factors, limited information is available concerning the exact description of water quality driving mechanisms in a lake – that is, how does each factor contribute to the final pollutant concentration (Hu 2010; Wu 2014). As the factors always fluctuate noticeably with seasons and meteorological conditions, the extent to which they drive water quality also shows a corresponding variation. The practical importance of separating these influencing weights arises in two ways. First, it will motivate further investigations of the underlying mechanisms of water pollution. Second, separation of the influencing weights makes the work of pollution control more accurate. A numerical model is an important tool for achieving water quality decoupling. There have been lots of long accepted water quality models, but most of them focused on water quality prediction, e.g. Magnus *et al.* (2006) established a combined suspended particle and phosphorus water quality model to assess the water parameters in Lake Vanern; Wang *et al.* (2014) developed an assessment model based on the variable fuzzy set and the information entropy theory to evaluate the water quality status of Taihu Lake in China; Mosaad & Mohamed (2017) investigated the capabilities of adaptive neuro-fuzzy inference model to predict water quality parameters of drains associated with Manzala Lake. These models contributed to a better water quality forecasting, yet little attention has been paid to quantifying the influencing weights of the dominant driving factors. An improved model that could yield accurate insight into the combined impacts of varied factors is needed to separate the water quality driving mechanisms. Thus, for the present work, we selected Poyang Lake, the largest river-connected freshwater lake in China, as the research area. The objectives are: (1) to propose a quantitative method aiming at the separation of the water quality driving factors including boundary input (BI), self-purification (SP), atmospheric deposition (AD), and sediment release (SR); (2) to develop and validate an improved water quality model that is capable of yielding realistic and accurate predictions considering the combined impacts of BI, SP, AD, and SR; and (3) to determine the influencing weights of each factor at different lake regions during

different periods by means of numerical experiment. This study may provide insights for the policy makers who try to prevent water quality pollution and improve the quality of inland freshwater lakes.

MATERIALS AND METHODS

Study area

Poyang Lake (28° 25'–29° 45' N, 115° 50'–116° 44' E), the largest freshwater lake in China, is a typical river-connected lake located in the middle reaches of the Yangtze River in Jiangxi Province (Figure 1). It plays an important role in maintaining the regional water and ecological balance (Zhang *et al.* 2012; Feng *et al.* 2013; You *et al.* 2015). The lake receives water from the five upstream rivers (Raohe, Xinjiang, Fuhe, Ganjiang, and Xiuhe) and drains into the Yangtze through a narrow outlet to the north. Due to the river–lake interaction, Poyang Lake expands to its maximum size during the wet season, but shrinks to little more than a river channel during the dry season (Gao *et al.* 2014). According to the data over a 50-year period, the minimum and maximum water level gaps within a single year were 9.59 m and 14.04 m, respectively (Guo *et al.* 2008; Wu *et al.* 2011). The transported water volume from the five upstream rivers into the lake is approximately $1.25 \times 10^{11} \text{ m}^3$, accounting for 87.1% of the total inflow water quantity. The multi-year mean water level of Poyang Lake was 13.30 m, with the corresponding water area and volume being 2,291.9 km² and $2.1 \times 10^9 \text{ m}^3$, respectively (Wu *et al.* 2007; Cui *et al.* 2013; Gao *et al.* 2014).

Poyang Lake is an important wetland in the Ramsar Convention List. It hosts millions of birds from over 300 species (Han *et al.* 2015). In particular, it is vital for conservation of the endangered Siberian crane as more than 95% of the world population congregates here during the winter. Water quality is an essential component for maintaining a healthy lake ecosystem. It has been reported that, before 2003, the water quality in Poyang Lake could meet Class III of the 'China Surface Water Environmental Quality Standards (GB3838-2002)', which represents the standard in secondary drinking water reserve and fishery areas (Wang *et al.* 2015). However, in recent years, the lake has

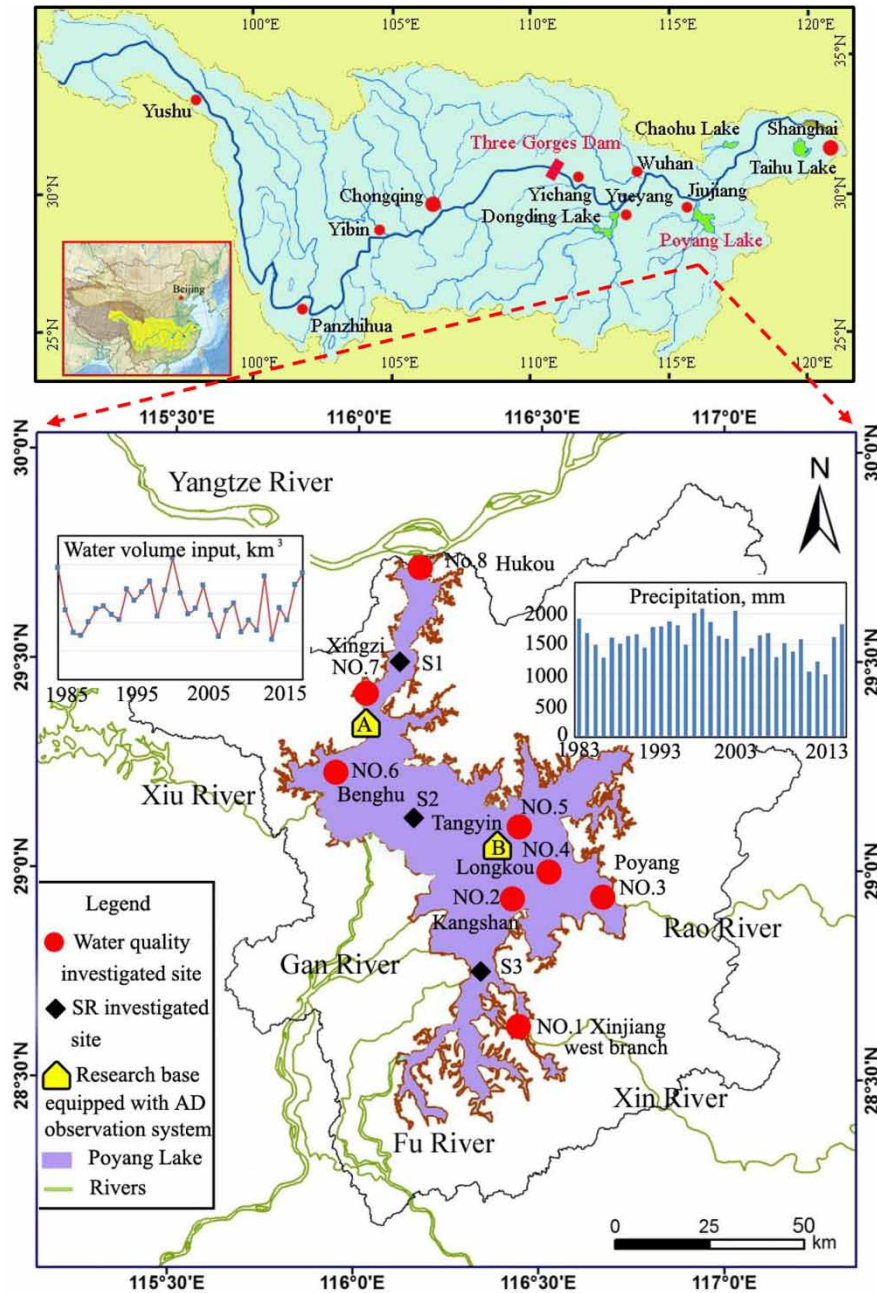


Figure 1 | Geographical location of Poyang Lake.

been found to have an increasingly pollutant load due to expanded urbanization, accelerated industrialization, and the high population density, which carries a variety of pollutants into the lake (Ni et al. 2015; Yao et al. 2015). As the water quality deterioration in Poyang Lake is threatening the ecological safety, urgent efforts are demanded to explore its driving mechanisms.

Field investigation

Eight sites were arranged for field investigation to explore the fluctuation of water quality in Poyang Lake, including Xingjiang west branch (No. 1, 28° 46' 01" N, 116° 22' 14" E), Kangshan (No. 2, 28° 52' 49" N, 116° 25' 33" E), Poyang (No. 3, 28° 59' 03" N, 116° 39' 38" E), Longkou

(No. 4, 29° 01' 11" N, 116° 29' 30" E), Tangyin (No. 5, 29° 05' 09" N, 116° 21' 57" E), Benghu (No. 6, 29° 18' 22" N, 115° 58' 49" E), Xingzi (No. 7, 29° 26' 30" N, 116° 01' 13" E), and Hukou (No. 8, 29° 44' 42" N, 116° 12' 18" E) (Figure 1). The monitoring at each section was conducted monthly during 2011. Water samples were collected with 2-L plexiglass water samplers at 0.5 m below the surface, stored in 500-mL polyethylene bottles, and acidulated using sulfuric acid. The acid-washed polyethylene bottles were first disinfected by 70% alcohol and then washed sequentially with deionized water to eliminate the interference of any substances adhered to the bottle. Three indexes, COD (chemical oxygen demand), NH₃-N (ammonia nitrogen) and TP (total phosphorus), were determined within 72 h using the typical dichromate method, Nessler's reagent calorimetry, and ammonium molybdate spectrophotometric method, respectively, according to the Water and Exhausted Water Monitoring Analysis Method (fourth edition), which was proposed by the China State Environmental Protection Administration in 2002 (Wang et al. 2015).

Numerical experiment

Compared to the traditional model, the model used here is the Two-Dimensional Flow-Pollutant Riemann Approximate Solvers Model, in which the embodiments of SP, AD, and internal SR were improved. It divides the calculation area into a number of control units in the framework of Finite Volume Method (FVM) and integrates each control unit by the conservation equation to derive a discrete equation for better calculation accuracy and stability (Hu & Tan 1995; Zhao & Shen 2004). The two-dimensional momentum and continuity equations are as follows (Wang et al. 2015):

$$\begin{cases} \frac{\partial h}{\partial t} + \frac{\partial(hu)}{\partial x} + \frac{\partial(hv)}{\partial y} = 0 \\ \frac{\partial(hu)}{\partial t} + \frac{\partial(hu^2 + gh^2/2)}{\partial x} + \frac{\partial(huv)}{\partial y} = gh(S_{0x} - S_{fx}) + hfv + hF_x \\ \frac{\partial(hv)}{\partial t} + \frac{\partial(huv)}{\partial x} + \frac{\partial(hv^2 + gh^2/2)}{\partial y} = gh(S_{0y} - S_{fy}) - hfu + hF_y \\ \frac{\partial(hC)}{\partial t} + \frac{\partial(huC)}{\partial x} + \frac{\partial(hvC)}{\partial y} \\ = \frac{\partial}{\partial x} \left(E_x h \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y} \left(E_y h \frac{\partial C}{\partial y} \right) - KhC + hD + hR \end{cases} \quad (1)$$

where h is the water depth; t is time; u and v are the depth-averaged velocity components in the x and y directions, respectively; g is the acceleration of gravity; S_{0x} and S_{fx} are the bed slope and friction slope in the x direction; S_{0y} and S_{fy} are the bed slope and friction slope in the y direction; F_x and F_y are the friction force components in the x and y directions, which reflect the wind stress; f is Coriolis parameter; C is the water pollutant concentration; E_x and E_y are the dispersion coefficients of pollutant in the x and y directions under dynamic conditions; and K , D , and R are the coefficients of SP, AD, and SR, respectively. KhC stands for the items degraded by SP, which is mainly related to series of factors such as dynamic conditions and aquatic plant distribution. hD reflects the contribution of AD and is always influenced by regional air quality and rainfall intensity. As the current could disturb the sediment deposited on the lake bed, which may induce the pollutant transport between the sediment and overlying water, hR is used to express this deposited sediment-induced release, which is closely related to the background pollutants in sediment and hydrodynamic conditions. The related parameters were separately determined for different lake areas, including the north, middle, and south lake, using field monitored data and the calculated results of numerical experiments.

The computed area includes that of the entire lake and extends northward to the Yangtze River, 28 km upstream and 15 km downstream. The Yangtze River corresponds to downstream calculation boundaries, and the other five rivers correspond to upstream calculation boundaries. The spatial resolution of the computation was set to 700 × 700 m², giving a total of 7,533 nodes and 6,239 quadrilateral elements for the modeling area. One-tenth of the elements were given lake-bottom elevations based on field data, and the remaining bathymetry was numerically calculated by the model (Liu et al. 2013; Li et al. 2015).

Given that Poyang Lake experienced a complicated water exchange with the five upstream rivers and the Yangtze River, water quality in the lake shows a distinct variation with seasons. Thus, four typical months were selected for 24 × 30-h simulation studies, including March (spring), July (summer), October (autumn), and December (winter). For each period, five schemes were grouped for numerical simulation based on the fact that water quality changes in a certain computing unit take place under the combined impacts of BI, SP,

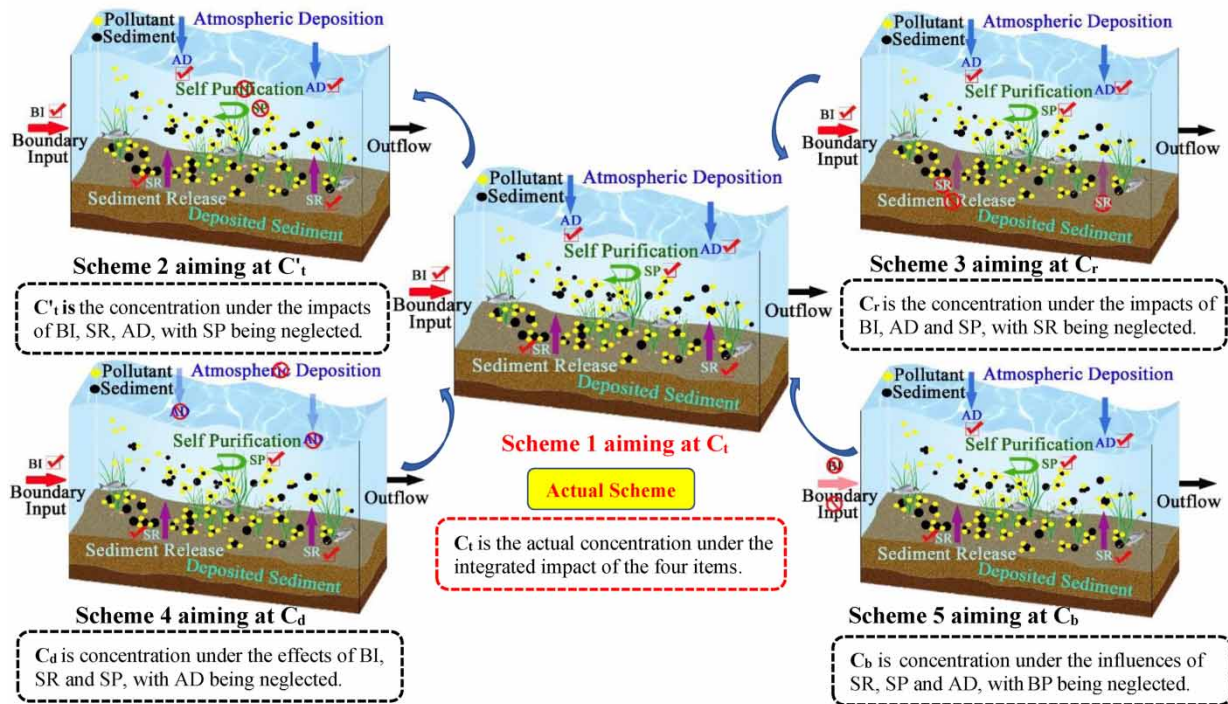


Figure 2 | Calculation schemes in the numerical experiment.

SR, and AD. Scheme 1 computes the actual process of water quality and aims at C_t , the concentration under the combined impacts of BI, SP, SR, and AD. Scheme 2 to Scheme 5 are hypothetical programs that target the separate contribution of each factor. Scheme 2 aims at the contribution of SP, and the output result C'_t is the concentration under the impacts of BI, SR, and AD. Scheme 3 explores the impact of SR, and the output result C_r is the concentration induced by BI, SP, and AD. Scheme 4 discloses the influence of AD, and the output C_d is the result of BI, SP, and SR. The goal of Scheme 5 is to study the effect of BI, and the output C_b is obtained by setting the inflow water quality as the initial value of the boundary calculation units and keeping the related parameters of SP, SR, and AD the same. The detailed schemes are shown in Figure 2.

Influence weight calculation

The approach is proposed on the hypothesis that the factors of BI, SP, SR, and AD affect water quality independently. Assuming that C_0 is the initial water concentration of a certain unit Ω , $\Delta C = C_t - C_0$ reflects the actual integrated impacts of BI,

SP, SR, and AD on water quality. Given the same BI condition, AD and SR are assumed to be the promoting factors for pollutant increase, while SP acts as a hindrance. The gap between C_t (Scheme 1) and C'_t (Scheme 2) can be attributed to the force of SP. Hence, the water quality changes of Scheme 2 in which SP is neglected can be recognized as the maximum variation range, and $\Delta C' = C'_t - C_0$ is utilized to measure the separated contributions of each factor. The concrete formula was written as follows:

$$\begin{cases} \lambda_D = (C_t - C_d) / \Delta C' \\ \lambda_R = (C_t - C_r) / \Delta C' \\ \lambda_B = (C_t - C_b) / \Delta C' \\ \lambda_S = (C'_t - C_t) / \Delta C' \end{cases} \quad (2)$$

where λ_D , λ_R , λ_B , λ_S are the influence weights of AD, SR, BI, and SP, respectively; $\Delta C'$ is the concentration increment without SP being considered; C_0 is the initial water concentration; C_t is the actual concentration under the integrated impact of the four items; C'_t is the concentration under the impacts of BI, SR, AD, with SP being neglected; C_d is the concentration under the effects of BI, SR, and SP, with AD being neglected; C_r is the concentration under the

impacts of BI, AD, and SP, with SR being neglected; and C_b is the concentration under the influences of SR, SP, and AD, with the boundary concentration being set the same as the initial value. For a given investigated site, the influencing weight for each index could be calculated, and the mean values of different indexes were used to determine the influencing weights of BI, AD, SR, and SP.

RESULTS AND DISCUSSION

Water quality fluctuation in the lake

Water quality fluctuation at eight investigated sites is shown in Figure 3. The monitored data suggested that the

concentrations of COD, $\text{NH}_3\text{-N}$, and TP in Poyang Lake varied appreciably with seasons and locations. Sites in Poyang (No. 3) and Longkou (No. 4) were characterized by a higher pollutant concentration, with the annual mean values of COD, $\text{NH}_3\text{-N}$, and TP being $2.59 \text{ mg}\cdot\text{L}^{-1}$, $1.72 \text{ mg}\cdot\text{L}^{-1}$, and $0.24 \text{ mg}\cdot\text{L}^{-1}$, respectively. The lowest concentration was observed at Hukou (No. 8), which is located close to the Yangtze River, and the annual mean values of COD, $\text{NH}_3\text{-N}$ and TP were $2.3 \text{ mg}\cdot\text{L}^{-1}$, $0.60 \text{ mg}\cdot\text{L}^{-1}$, and $0.11 \text{ mg}\cdot\text{L}^{-1}$, respectively. The frequent water exchange and better external boundary quality contribute to a low concentration at this section. Tangyin (No. 5) and Benghu (No. 6) experienced an equivalent concentration that was close to the mean of the entire lake. Owing to the seasonal variation of hydrological conditions and aquatic ecosystem



Figure 3 | Water quality fluctuations at each investigated site in Poyang Lake ($\text{mg}\cdot\text{L}^{-1}$).

in Poyang Lake, the water quality at each site fluctuated notably with months. The annual variation coefficients of COD, $\text{NH}_3\text{-N}$, and TP covering the lake were 8.6%, 39.9%, and 36.2%, respectively. However, the ranges of fluctuation also differed with factors and geographical positions. For example, COD at Benghu (No. 6), $\text{NH}_3\text{-N}$ at Longkou (No. 4), and TP at Poyang (No. 3) had the highest variation coefficients, which were 12.5%, 48.9%, 57.7%, respectively. Nevertheless, COD at Tangyin (No. 5), $\text{NH}_3\text{-N}$ at Xingjiang west branch (No. 1), and TP at Benghu (No. 6) had been maintained within a smaller range, showing no obvious departure from the annual mean.

Model performance

The coefficients of SP, AD, and SR (Equation (1)) were calibrated and determined against the field monitoring data by tentative calculation. Considering data continuity, the monitoring results from January to September in 2011 at the sites of Kangshan (No. 2 in the south lake), Tangyin (No. 5 in the middle lake), and Xingzi (No. 7 in the north lake) were applied. The data were separated into two series for calibration and validation. Based on the experimental and observational results, the coefficients of SP, AD, and SR were adjusted referring to their sensitivities to achieve the best model performance. It can be observed that the simulated results were in good agreement with measured values (Figure 4). The mean of the absolute value of the relative error (ARE), i.e., $\text{ARE} = |\text{calculated} - \text{measured}| / \text{measured}$, for the calibration and validation period ranged between 15% and 18%. To gain an insight into the model performance, the root mean square error and coefficients of determination (CoD) were computed. The CoDs of COD, $\text{NH}_3\text{-N}$, and TP were respectively 0.78, 0.82, and 0.81, which also suggested that the developed model was capable of simulating the water quality process in Poyang Lake with a reasonable accuracy.

Water quality driving weights

For this work, the indexes of COD, $\text{NH}_3\text{-N}$, and TP were selected for analysis for two reasons: (1) they are conventional indicators to reflect lake water quality; and (2) these three indexes are the indicators determined by

the government for total load control and assessment. For each scheme, the processes of COD, $\text{NH}_3\text{-N}$, and TP were simulated simultaneously. According to the calculated results, the water quality driving mechanisms at eight investigated points were analyzed quantitatively for different seasons (Figure 5). The percentages in the figure represent the mean driving weights of BI, AD, SR, and SP in four typical months. The following results were deduced.

BI was generally the strongest force driving water quality in Poyang Lake, followed by SP. Compared with SR, AD exerted a higher contribution to the lake water quality, but neither affected water quality as evidently as BI and SP. The mean driving weights of BI, SP, AD, and SR covering the entire lake in a year were 57.2%, 26.5%, 9.3%, and 7.0%, respectively. The differences in geographical location, combined with the variations of external water quality fluctuation, aquatic ecosystem alternation, uneven rainfall distribution, and meteorological conditions, made the impacts of BI, SP, AD, and SR vary with time and space.

The driving weights of BI, SP, AD, and SR are observed to be spatially variable according to the local dynamic conditions, aquatic plant distribution, and deposited sediment thickness. The force of BI was closely related to the distance between the site and the lakeshore. Appreciable statistical relationships were observed between the spatial distance and BI driving weight. The influencing rate from No. 3 and No. 4 were reduced by approximately 1.16% per kilometer, while that between No. 4 and No. 5 increased by 2.74% per kilometer. The results suggested that the closer a site is located to the lake center, the less BI affected water quality.

Attributed to the different degradation abilities induced by water currents and aquatic plants, the influence of SP changed markedly with geographic situations. At sites No. 7 and 8, located in the long and narrow northern part of the lake where the average water velocity could reach $0.85 \text{ m}\cdot\text{s}^{-1}$, pollutants could be easily transferred and diffused and the driving force of SP was enhanced. Site No. 8, located at the intersection of the Yangtze River and Poyang Lake, was characterized by the strongest SP impact, and the mean driving weight could reach 32.1%. At site No. 5, where the dynamic conditions were poorer and the average flow velocity was approximately $0.23 \text{ m}\cdot\text{s}^{-1}$, the influence of SP was decreased to 27.2%. Relative to No. 8, SP impact was not reduced dramatically with the

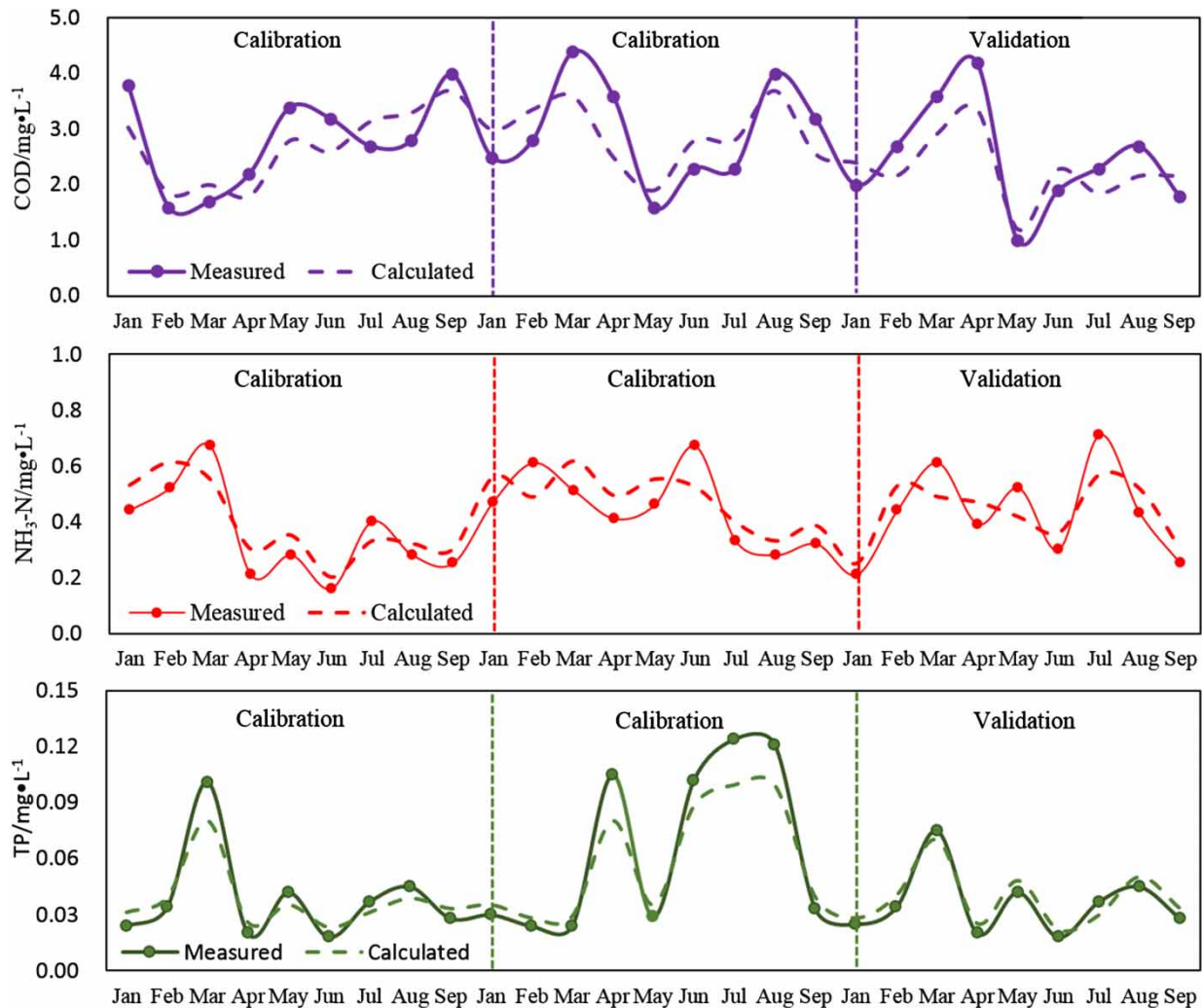


Figure 4 | Calibration and validation of the numerical model.

water velocity decrease from $0.85 \text{ m}\cdot\text{s}^{-1}$ to $0.23 \text{ m}\cdot\text{s}^{-1}$ because there are a number of *Polygonum efiopolitanum* communities distributed in the No. 5 area, which consumed a certain amount of nutrients and strengthened SP impact (Hu et al. 2010). Sites No. 1 and 3 at the peripheral area of the lake were also equipped with good dynamic conditions, and the mean flow velocity could reach $0.62 \text{ m}\cdot\text{s}^{-1}$. However, the SP driving parameter was inversely decreased to 23.1% because BI played the dominant role at these points and the aquatic system in these areas was poorly maintained.

The driving forces of BI, SP, AD, and SR all differed remarkably with seasons. In March, July, October, and

December, the influencing weights of BI were, respectively, 56.4%, 52.2%, 55.4%, and 64.8%. The results in July showed the strongest driving force of SP, whereas the lowest was observed in winter. The influencing weights were, respectively, 31.5% and 20.0% on average. The mean driving weight of SP in March and October was approximately 27.2%. The driving weight of AD reached a maximum of 10.2% in October, while the mean value for the other three months decreased to 8.9%. In December, SR played the weakest influence on water quality with the driving weight being 6.0%, while in July its effect was significantly enhanced by 28.3%. The mean driving rate of SR in March and October was approximately 7.2%.

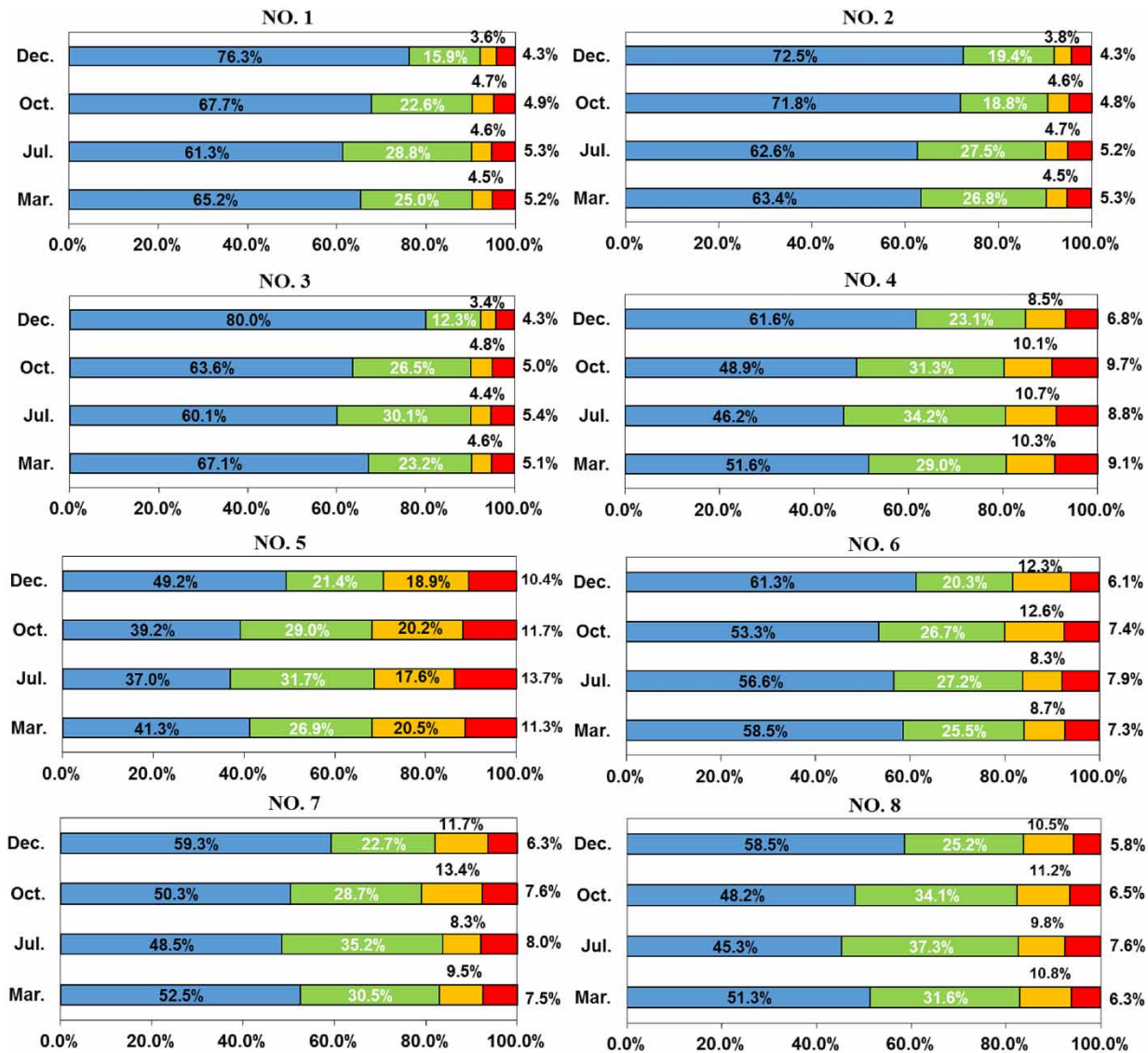


Figure 5 | Water quality driving mechanisms in Poyang Lake.

Water quality driving mechanisms

The loads of COD, $\text{NH}_3\text{-N}$, and TP in Poyang Lake were determined by the combination of vertical and horizontal input. Given the external water quality fluctuation, aquatic ecosystem alternation, uneven precipitation distribution, meteorological condition changes, and geographical situation, the impacts of BI, SP, AD, and SR varied appreciably with seasons and locations. Generally, BI and SP dominated the water quality evolution in the lake, while the impacts of AD and SR were observed at a relatively lower level. As

Poyang Lake is located in the central region of China where the industrialization process is not fast, the background content of pollutants in regional atmosphere and deposited lake sediment was markedly less than in the lakes located in eastern China (Luo *et al.* 2011). For example, in Jinshan Lake, a smaller river-connected lake located in Zhenjiang City of Jiangsu Province, the influences of SR and AD were remarkably higher than those in Poyang Lake as it was surrounded by highly developed towns (Wang & Pang 2009). A distinct statistical relationship could be detected between the spatial distance and the driving weight

of BI. The influencing rates at No. 3, No. 4, and No. 5 were 67.7%, 52.1%, and 41.7%, respectively. This suggested that BI impact was gradually reduced from the lakeside area to the central lake due to pollutant diffusion and degradation. With the increasing flow-distance from lakeshore, the decreasing rate of BI was enhanced. It was markedly increased by 1.36 times from No. 4 to No. 5 compared with that from No. 3 to No. 4. The closer the site to the lake center, the less the BI dominates the pollutant concentration.

Dynamic conditions have an important consequence for SP contribution. The area located in the long-narrow region of the northern lake was characterized by the strongest SP intensity due to the high flow velocity that made pollutants transfer and diffuse easily. In some areas of the central lake, the flow disturbance was evidently reduced, but SP did not show the dramatical reduction in accordance with it. The main reason was that in these areas the process of SP was determined by the combined effects of water current and aquatic plants. At the site where the velocity was markedly lower but aquatic plants such as *P. efiopolitanum* were abundantly distributed, the influence of SP could still be maintained at a good level. However, in some peripheral areas where dynamic conditions were observed the driving weight of SP was inversely decreased as a result of the dominant BI and the poor aquatic system. Apart from AD, the influences of BI, SP, and SR were closely related to the hydrodynamic conditions in Poyang Lake, which were observed to be temporally variable. Based on the investigated long-term hydrology data, water currents in Poyang Lake can be divided into the following three types.

- (1) Gravity-style current: Water flows from the south to north in accordance with the main channel, and the flow velocity is mainly driven by the water surface slope.
- (2) Backflow-style current, mainly observed between August and September: It is induced by the flooding of the Yangtze River.
- (3) Jacking-style current, a transitional current between gravity-style and backflow-style current: It is formed when water levels in the upstream five rivers and the downstream Yangtze River rise at the same time, or at the end of the flood season of the upstream five rivers,

during which the water level of the downstream Yangtze River is still rising.

These different flow patterns have a great effect on the water quality driving mechanisms in Poyang Lake, e.g. in July the remarkable water surface slope could generate good hydrodynamic conditions that are beneficial to SP improvement, while in winter, the poor water exchange between the lake and external rivers and the extended water residence time reduced the purification ability.

These results could show the time-space driving mechanisms for water quality evolution in Poyang Lake. The findings here were also in agreement with other relevant research (Jennifer *et al.* 2013; Karen *et al.* 2013). However, there are two uncertainties that may need further investigation. First, the numerical model used here was the Two-Dimensional Flow–Pollutant Riemann Approximate Solvers Model, in which the expressions of SP, AD, and SR were improved compared to traditional models. However, the established model was weak in vertical water quality distribution. As in some lake areas, lake stratification should be considered, and a three-dimensional model will be developed to focus on this point in subsequent studies. Second, because the numerical model was a depth-averaged one and the present emphasis was placed on the influence weights of BI, SP, AD, and SR, some biological and chemical processes on water quality had been generalized into the calculation parameters. For example, the consumptions of nitrogen and phosphorus by aquatic organisms have been embedded to the SP coefficient, and the inner-production of COD and the release from decaying phytoplankton and other organic matter in the water column were incorporated into the SR coefficient. Despite the discrepancies that may have been generated by the above uncertainties our study could provide some evidence regarding water driving mechanism in Poyang Lake.

CONCLUSIONS

BI, SP, AD, and SR dominate the water quality evolution in a freshwater lake, but little attention has been paid to an in-depth exploration on their individual impacts. Here, the largest freshwater lake, Poyang Lake, was selected for case

study. We attempted to quantify the separated contributions of BI, SP, AD, and SR by means of numerical experiments. The most significant results of our work are, first, water quality in Poyang Lake was driven by the combination of different factors, generally with 57.2% of the variation being the result of BI, 26.5% owing to SP, 9.3% to AD, and the remaining 7.0% being attributable to SR. Second, given the inflow water quality fluctuation, aquatic ecosystem alternation, uneven precipitation distribution, and different meteorological conditions, the driving weights of BI, SP, AD, and SR varied appreciably with seasons and locations. Third, different flow patterns induced by the river–lake interaction have great effects on the water quality driving mechanisms in Poyang Lake. This work has important implications for decoupling the water quality driving mechanisms, not just in Poyang Lake but also in other freshwater lakes, rivers, or offshore areas. In addition, the proposed approach here may motivate further investigations of the underlying mechanisms of water quality evolution.

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CONFLICT OF INTEREST

None.

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