Are Nitrogen to Phosphorus Ratios of Chinese Lakes Actually Increasing?

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Tong et al. documented that many lakes in China had increasing total nitrogen to total phosphorus (TN:TP) mass ratios and decreasing TP concentrations in association with widespread construction of sewage collection and treatment plants during 2008-2017 (1). Here we refute this conclusion and express concerns that it may reduce pressure for nutrient emission reductions.

We examined the difference in TP and TN:TP between 2008 and 2018 in 30 lakes (15 lakes are included in dataset of Tong et al.), and found that TP increased ($P < 0.05$) in 47% of lakes and decreased in 23% of lakes (P

< 0.05), and TN:TP increased in 13% lakes ($P < 0.05$) and decreased in 20% lakes ($P < 0.05$).

We collated monthly monitored TP and TN:TP for 12 representative large lakes (9 lakes are represented in Tong et al.) during 2007-2018. TP increased in 7 lakes and decreased in 5 lakes (Fig. 1a), and TN:TP mass ratios increased in 2 lakes and decreased in 9 lakes (Fig. 1b). We further compared the slopes of regressions of nutrients with time for 9 lakes. TP decreased in 8 lakes and TN:TP increased in 7 lakes in Tong et al., but TP decreased in 2 lakes and TN:TP increased in 3 lakes in our dataset.

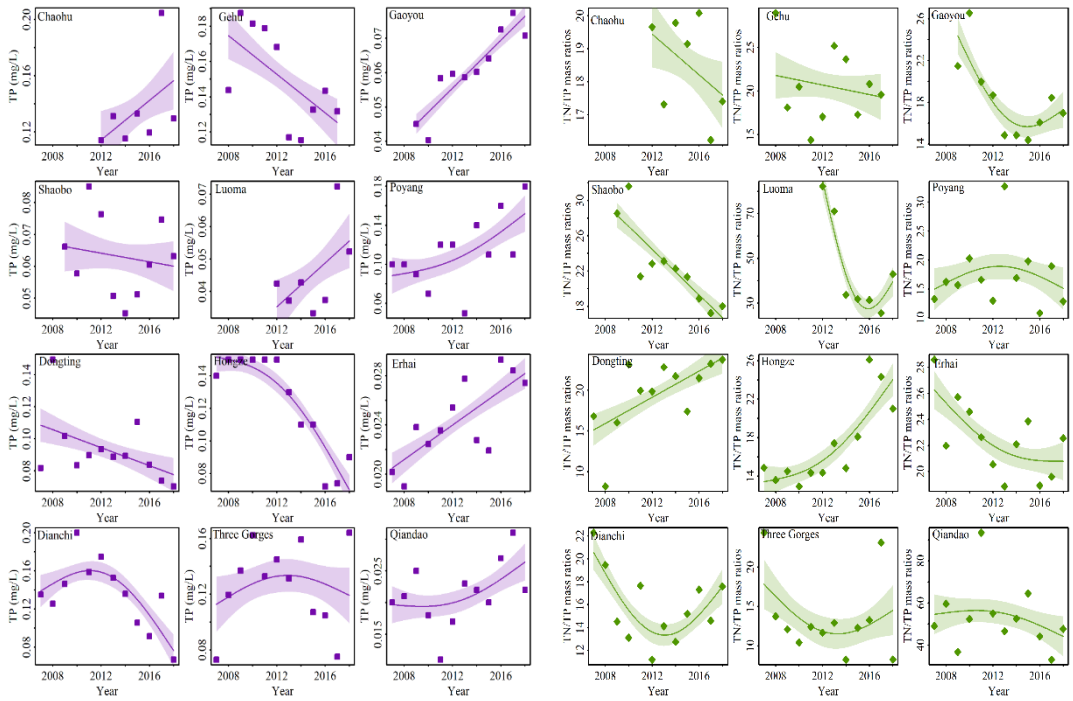

Fig. 1 Variability of TP concentrations (left panel) and TN:TP mass ratios (right panel) in twelve representative large lakes over the period of 2007-2018. Data source: Poyang (Poyang Lake Ecosystem Research Station, Chinese Academy of Science (CAS)), Dongting (2), Erhai (School of Ecology and Environmental Science, Yunnan University), Three Gorges Reservoir (Institute of Three Gorges Reservoir, Chongqing Institute of Green and Intelligent Technology, CAS), Chaohu (Nanjing Institute of Geography & Limnology, CAS), Gehu (3). Nonlinear trends for time-series data fitted by generalized additive models (GAMs) according to Harding

et al. (2016) (4). The solid lines represent the long-term trends estimated by additive models (AMs), and the shaded areas are the standard error of the estimate.

Finally, we investigated Lake Taihu, as it is located in a densely populated delta of Yangtze River (>1000 ca/km^2). Since the highly publicized drinking water crisis in 2007 (5), a variety of restoration measures have been implemented, including construction of 24,500 km sewage pipelines and 103 new wastewater treatment plants (6). To date, TN has declined significantly, TP has increased slightly, but TN:TP mass ratio has declined significantly (Fig. 2). These changes are related to increase in water use, resulting in increased external loading, and enhanced mobilization of phosphorus from bottom sediments due to recycling following intense algal blooms (6).

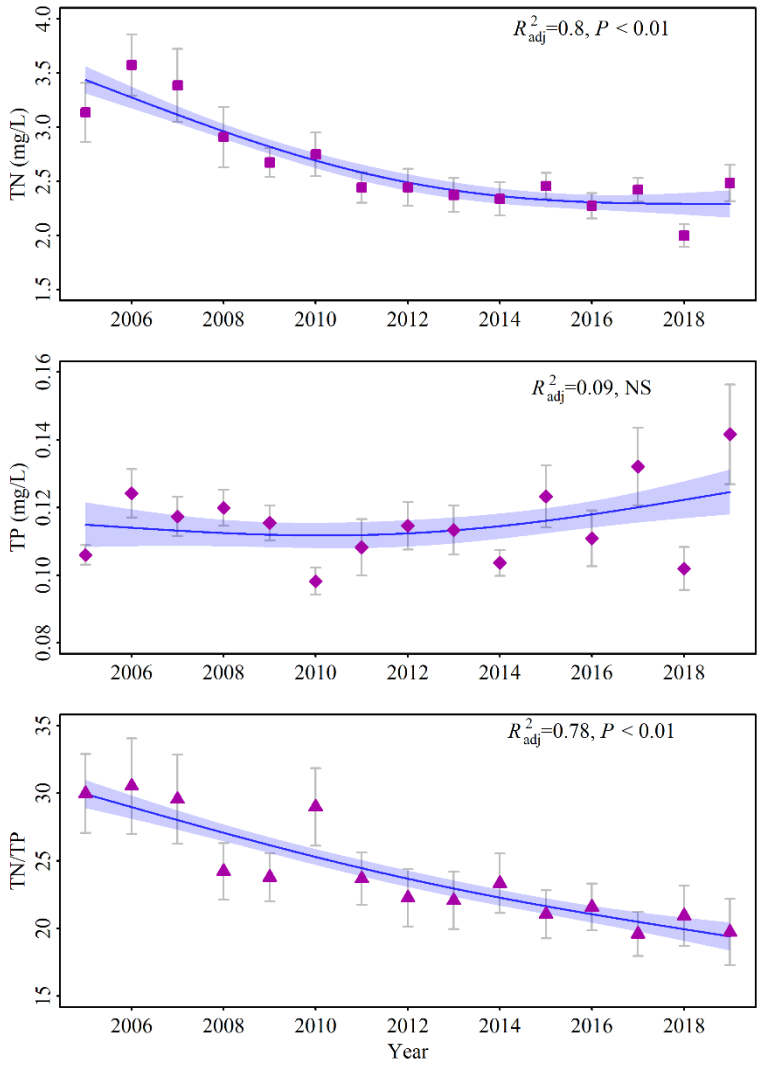

Fig. 2 Concentrations of TN and TP and TN:TP mass ratio of Lake Taihu during 2005-2019. Data is from Taihu Laboratory for Lake Ecosystem Research (TLLER), Chinese Academy of Science. The solid lines represent the long-term trends estimated by additive models (AMs), and the shaded area is the standard error of the estimate. R^2_{adj}: adjusted R squared value of additive models (AMs). Significance level is determined with *t*-test. NS is not significant.

Why do our results differ from those Tong et al.? The primary cause is field sample pretreatment. Because Tong et al. used data from the China National Environmental Monitoring Centre (EMC) who require field sample filtration and settling to remove large algal colonies and suspended solids (EMC method) (7). However, samples pretreated by other institutions are often analyzed directly without filtering and settling

(NEMC method). The different sample processing methods caused TP of EMC to be lower than that of NEMC. For example, the average TP over 2007-2017 in Lake Taihu was reported 0.074 mg/L by the EMC method and 0.114 mg/L by the NEMC method, resulting in a TN:TP mass ratio of 30.3 (EMC) versus 22.75 (NEMC).

Many lakes in China continue to suffer from eutrophication (8), which is evidenced in the China Water Resource Bulletin (published by Ministry of Water Resources of China, http://www.mwr.gov.cn/sj/#tjgb). Eutrophication and cyanobacterial blooms are still a key challenge facing Chinese lakes. China needs more aggressive nutrient management, especially focusing on reduction of phosphorus emissions.

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