The story of Lake Taihu interpreted from the scientific literature

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>2400

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Aim of the review

- to have an overview of relevant research on Lake Taihu,
- map the management recommendations to improve the ecological status

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Conducting the review

- Scientific papers were searched from the Web of Science database
- Search conducted in March-April 2019

Search strings	Hits	Relevant articles
Taihu AND eutrophication AND management OR restoration	183 (50 first selected)	28 (56 %)
Taihu AND sediment AND nutrient AND water AND quality AND management OR restoration	33	21 (63 %)
Taihu AND ecological AND restoration AND water AND quality	39	31 (79 %)
Taihu AND alga* AND bloom AND water AND quality AND management OR restoration	62 (50 first selected)	28 (56 %)
		=108

- Abstracts, discussions and conclusions were read for key results/recommendations
- Altogether 82 relevant articles were found

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What was excluded

- Studies not related to Taihu
- Studies on natural processes, e.g. sediment composition, nutrient cycle, species composition
- Climate impacts
- Model development

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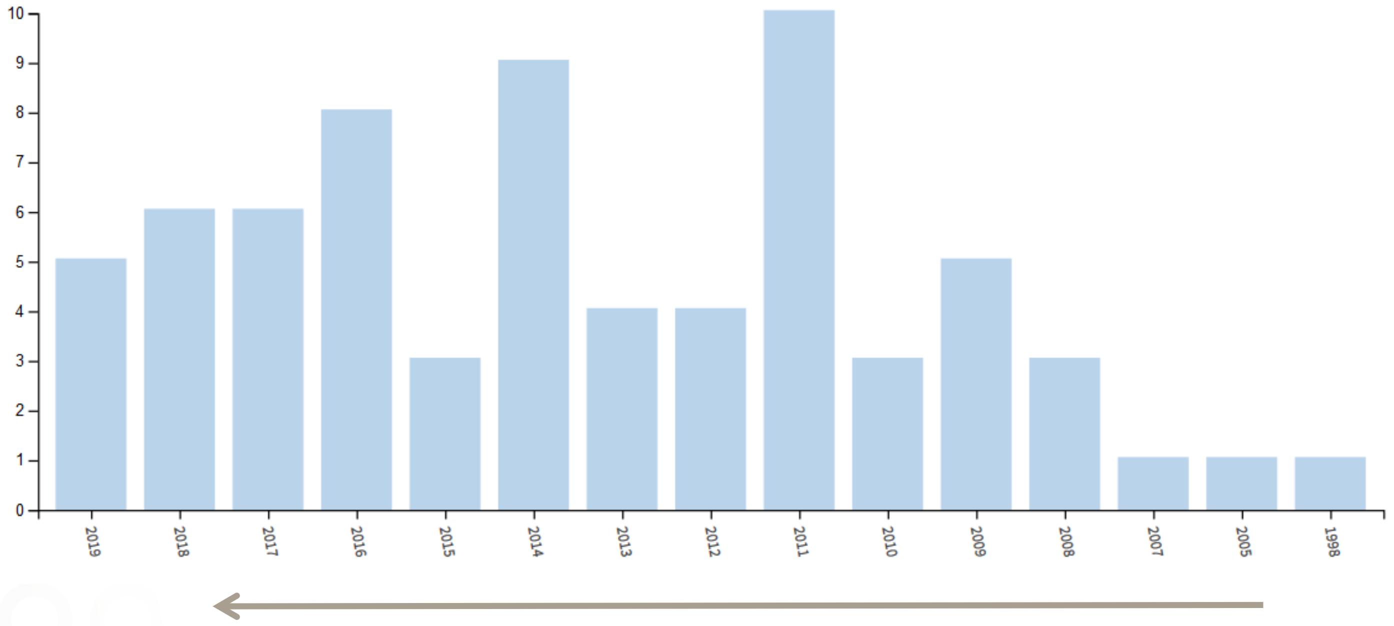
Years (1998-2019)



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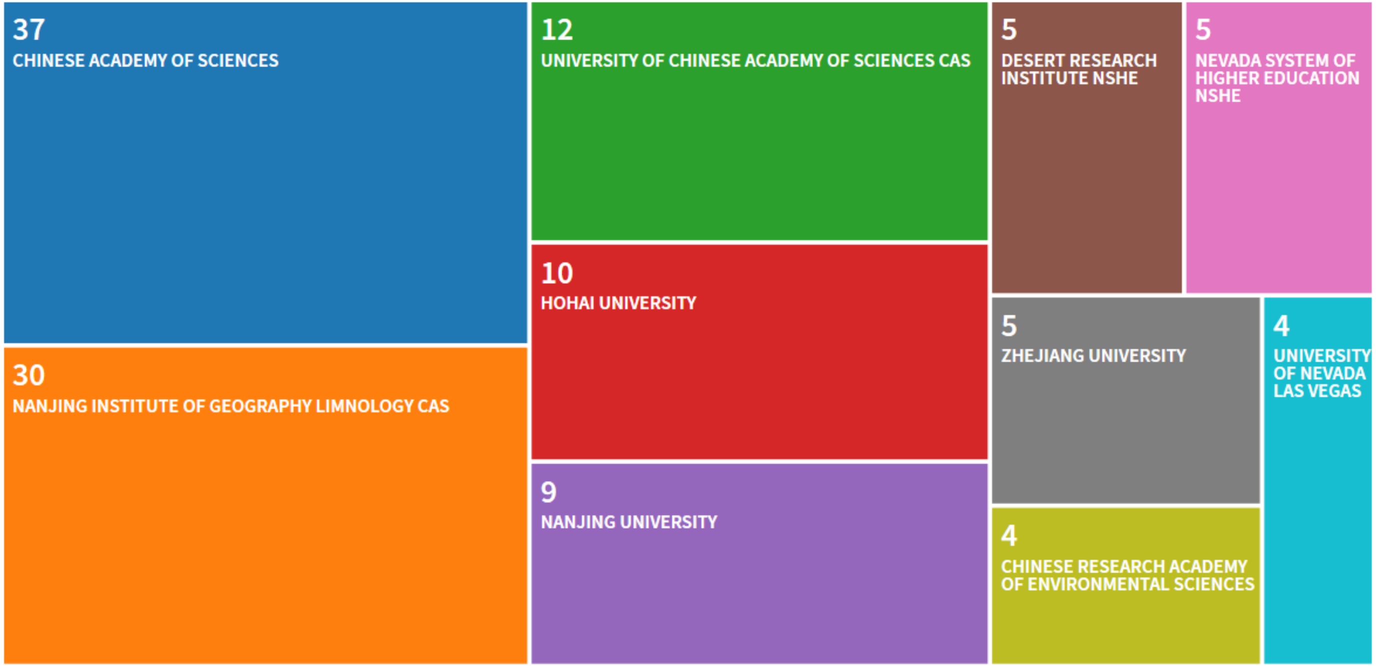
Organisations



Screen capture from Web of Science

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Countries

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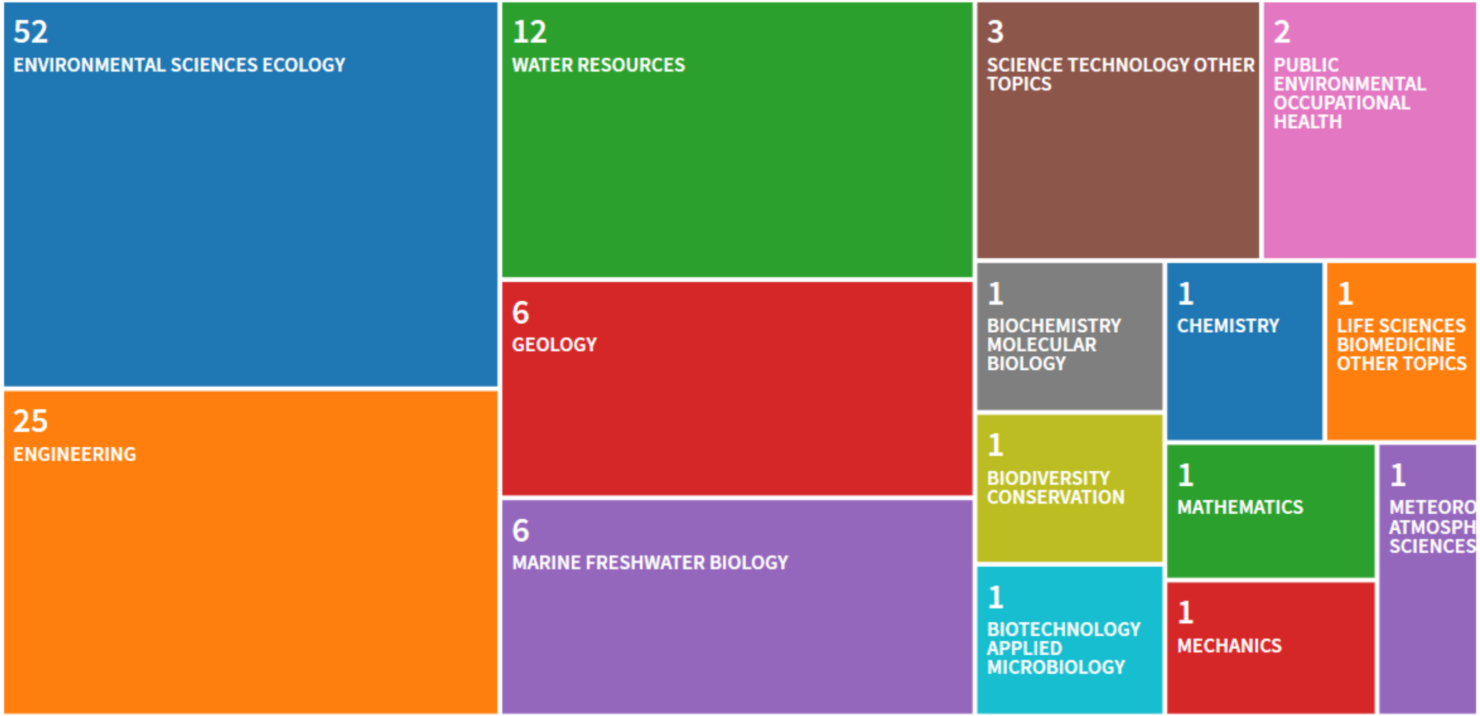
Research areas



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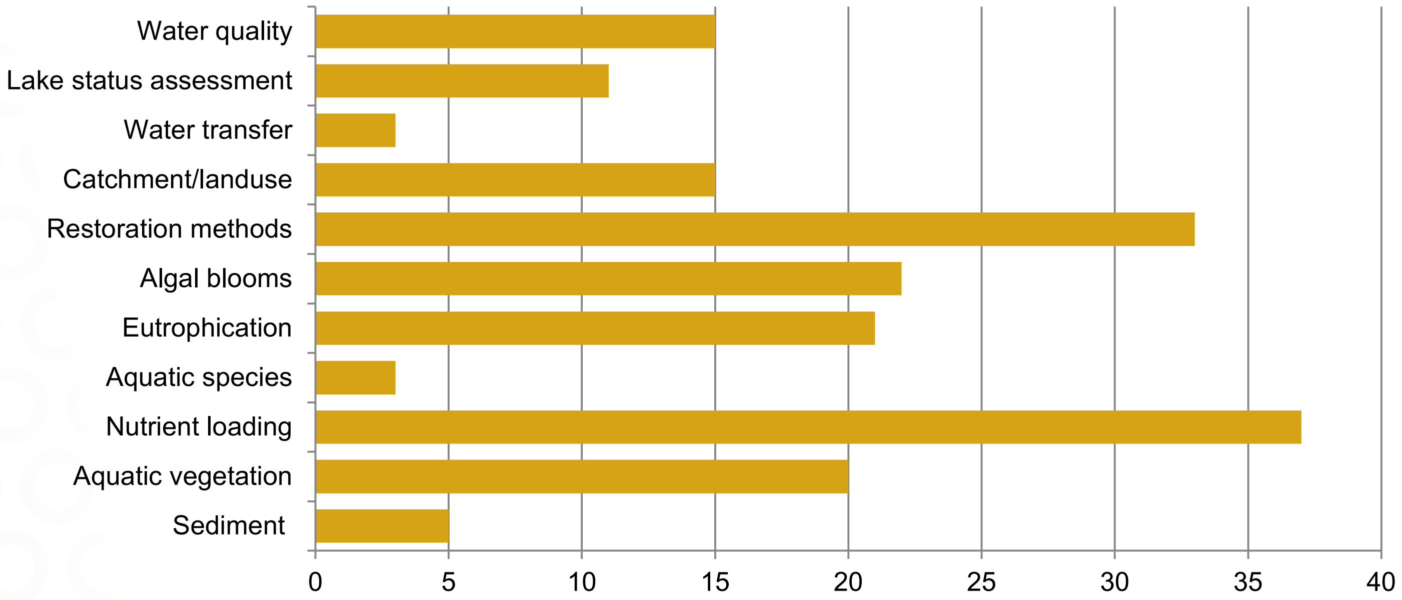
Key Words



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1. Challenges

- External loading
  - Sources
- Resuspension and erosion
- Objectives for nutrient loading and algea bloom control

External loading sources

- **Point sources contributed approximately 75%** of the total pollutant load from the basin as determined by chemical oxygen demand (Li, Y.P. et al. 2011)
- Diffuse sources contributed 90% to river export of TDN with a relatively large share of synthetic fertilizers. (Wang, M. et al. 2019)
- Point sources contributed 52% to river export of TDP with a relatively large share of sewage systems. (Wang, M. et al. 2019)
- For the flux loads influxes from **surrounding rivers accounted for 61.1% for TN (atmosph. deposition 23,5 %, sediments 15,4 %), and 42,8 % for TP (atm. Dep. 17,9 %, sedim. 39,3 %) (Wang, J.J. et al. 2017)**
- The sites located in the **west of Lake Taihu** were influenced by **farmland runoff** which may contribute to nitrogen pollution of Lake Taihu, whereas in **the eastern of Lake Taihu urban residential subsistence and domestic wastewater** are the major contaminants. (Zhao, G.J. et al. 2011)

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Internal processes: erosion and resuspension

- **Severe surface erosion in the rivers** cannot be ignored; the high erodibility is an important factor in the increase of TP and TSM concentrations in the estuary. (Du, C.G. et al. 2017)

- **Sediment resuspension** may be one of the most important factors delaying the recovery of Lake Taihu. (Zhu, M.Y. et al, 2015)

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Setting the objectives for Lake Taihu

- The **baseline TP value of about 50 micro g/l**, can be used as a restoration target for Taihu Lake. (Dong, X.H. et al. 2008)

- **Regime shifts: Some lakes have changed permanently** to a different state, which should be seen as a reality and avoid unnecessary restoration practices that are not feasible and affordable. The priority of managing these lakes is to avoid the new states degrading to an even more degraded and resilient state (Zhang, K. et al. 2018)

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External loading should by reduced by 50%

- External total nitrogen (TN) and total phosphorus (TP) loads should be reduced by **41–55 and 25–50%,** respectively, to prevent nutrient accumulation in Lake Taihu and to meet the planned water quality targets. (Peng, J.T. et al. 2018)
- 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%. (Xu, C. et al. 2019)
- Total **nutrient loads need to be more than halved** to reach chlorophyll-a concentrations of 30–40 μg L−1 in most sections of the lake. (Janssen, A.B. et al. 2017).
- To meet the specified **total maximum daily load** condition in Zhushan Bay watershed, approximately 25–35%, 50–55%, 50–55% and 70–75% reductions in watershed loadings for CBOD, NH4–N, TN and TP, respectively, should be achieved by future management practices. (Wang, C. et al. 2015)

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Algae bloom control

- **Limiting factor** for the dominant algae (cyanobacteria) depended on **seasonality and location** (Li, Y.P. et al, 2014).
  - Phosphorus (P) and Nitrogen (N) impacted algal growth from spring to autumn.
  - Water temperature affected algal growth in winter,
  - light was important for deeper water columns in all seasons
- **A dual nutrient strategy** (N+P reduction), is the most effective near-term strategy for reducing phytoplankton biomass and bloom potentials (Paerl, H.W. et al. 2014).
  - Algal biomass production may be controlled by P availability in the spring, while N availability may determine the magnitude, spatial extent and duration of the bloom during summer-fall (Paerl, H.W. et al, 2014)
- The essential option to control algae blooms is to **reduce nutrients, especially nutrient release from sediment** (Chen, Q. et al. 2014).

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2. Solutions

- Reduction of external loading
  - Improving the effectiveness of wetlands
- Restoration within the lake
  - Macropyhtes
  - Nutrient removal from the lake
  - Biomanipulation
  - Yangtse water diversion
  - Sediment dredging

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Reducing external loading

- **Remedial strategies directed at either N or P control can negatively impact the other nutrients.** Whatever strategies are implemented, they should be done in an adaptive manner. (Sharpley & Wang, 2014)
- **Agriculture and rural areas:**
  - **Lowcost sanitation options and nutrient recycling** will probably be the most suitable methods to control **P loading** (Kelderman et al. 2005, see also Huang, L. et al, 2013) .
  - We suggest that **agricultural field N and P management be optimized** based on N and P requirement of crops and N and P content in soil and organic manure (Wan,R.R. et al 2014)
  - Reducing **N inputs from synthetic fertilizers** (Wang, M. et al. 2019)
- **Urban areas:**
  - Management efforts to improve water quality should focus on **3 urban subbasins** Chendonghe, Taigeyunhe, and Wujingang with a priority placed on **controlling point sources from urbanized** areas. (Li, Y.P. et al. 2011)
  - Reducing **P from sewage systems** may be sufficient to meet the least strict critical loads (50 micro g/L chl-a). (Wang, M. et al. 2019)

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Increasing the effeciveness of wetlands

- The sediment of the tested wetlands could retain external P from agricultural land by as much as 10–30 times the area of itself. **3.3–10% of watershed area is suggested for wetland to balance agricultural impact** (Wang, Z. et al. 2013)

- Since the majority of external P stored in sediment is in the form of Al-P (e.g., for Xiazhuhu wetland), **the application of alum to water column could potentially increase the P retention capacity of wetland sediment.** (Zhang, Z.J. et al. 2011)

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Restoration of macrophytes

- **Lowering the WL to increase underwater light availability** is a potential method of promoting aquatic vegetation recovery in large shallow lakes. (Zhang, Y.L. et al. 2016)
- **Decreasing water levels in the dry season** could increase the area occupied by aquatic vegetation in tens of square kilometers. (Zhao, D. et al. 2012)
- It was difficult to restore submerged macrophyte where the **water depth more than 2 m.**
- **Modified local soil induced ecological restoration** make it possible for a quick restoration of submerged macrophytes in eutrophic shallow lakes (Pan, G. et al. 2011)
- **Improvement of habitats is a prerequisite for re-vegetation** by submerged macrophytes and the **selection of appropriate tolerant plant species** is of great importance in conducting ecological restoration in eutrophic lakes. (Dong, B.L. et al, 2014)

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Nutrient removal from the lake

- **Harvest of aquatic plants** was useful in removing nitrogen and phosphorus from lake water. (Ye, C. et al. 2011)
- **Harvesting** a large amount of *N. Peltata* has a positive effect on total nitrogen (TN), ammonium nitrogen (NH3-N), and chemical oxygen demand (CODMn) control but **can lead to different consequences** (e.g., increase in total phosphorus (TP) and algal concentration) (Zhu, J.G. et al, 2019)

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Biomanipulation

- Biomanipulation technology provides another natural way of recovering eutrophic water bodies through adjusting the food chain of aquatic ecosystems (Liu et al 2007).
  - Some issues have yet to be clarified, such as
    - the interactions between planktonic food webs,
    - the optimum ratio between filter-feeding fish and predatory fish,
    - the appropriate proportions of juvenile and adult fish,
    - the effects of micro-organisms in nutrition cycling,
    - and nutrient competition by attached algae.
- Biomanipualation can also help in macrophyte restoration.
  - It is necessary to **maintain higher biomass of piscivorous fish and remove omnivorous fish** in order to help growth of submerged macrophytes and maintenance of clear-water state. (Chen, K.N. et al. 2009)

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Yangtze River water transfer

- Could provide some **relief for serious water supply crises** as an emergency measure if well managed (Li, Y.P. et al. 2013)
- Unless **nutrient concentrations in the transferred water** are lowered to reasonable levels, dilution effects are going to be nominal and significant ecological improvements are not going to occur. (Li, Y.P. et al. 2011, Hu, W.P. 2008)
- **Careful consideration** is essential for ecological impact of water transfer projects in future. (Li, Y.P. et al. 2013)
- **More water should be transferred regularly** to deter algal congregation and improve water exchange velocity in Lake Taihu especially in warm season (Zhai, S.J. et al. 2010)
  - **Compared with the benefits from the water transfers the negative impacts can be ignored for the social development.**

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Sediment dredging

- Apparently, sediments in the north-western sub-lake have virtually **reached their maximum P uptake capacities** (Kelderman, P., 2005)
- Sediment dredging could be used to **remove the relatively nutrient-rich sediment top layer**, thus preventing or reducing future P release. (Kelderman, P., 2005)
- Results confirmed that **solidification effectively reduces the risk of phosphorus leaching** from dredged sediments (Wang, S. et al. 2016)
- It is difficult to control such projects with respect to balancing the protection of the original ecosystem and the dredging of sediment (Liu, W. et al. 2007)

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3. Challenges in restoration projects

- Lake status trends or responses to management actions may be **specific to the station(s) selected for monitoring and analysis.** (Akyuz, D.E. et al 2014)
- High level of **nutrient concentration**, internal and external loading. (Chen, F.Z. et al. 2009)
- The intended macrophyte-dominant system did not emerge during the experiment, which might be associated with **high nutrient levels** and **low transparency.** (Qin, B.Q. 2013)
- **Dense cyanobacterial bloom.** An increase in algal density occurred within the engineering area even though there was a decrease in the concentrations of dissolved nutrients. (Chen, F.Z. et al. 2009)
- Biomanipulation is very delicate and can only be used with sufficient investigation and great caution (Chen, Q. et al. 2014).

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4. Some recommendations

- The improvement of water quality was contributed to the **multiple restoration technologies** rather than any single technology (Ye, C. et al. 2011)
- **Catchment scale nutrient source apportionment** should be conducted before pinpointing and prioritizing where control measures should best be targeted (Gao, C. et al. 2010).
- The **environmental standardization of economic activities** (agriculture) should be stressed. Governmental **efforts to improve public environmental attitudes** are crucial in rural areas (Huang, L. et al. 2013)
- **A long-term plan for pollution and eutrophication control** should be based on accurate prediction of economic development and contaminant sources. (Qin, B.Q, et al. 2007)
- Three aspects of **integrated env. management** are emphasized: **institutional cooperation** (three administrative systems with different interests), **public participation** (to control non-point source loading), and **internalization of environmental externalities** (water pricing reform to reflect all the costs). (Wang, Q.G et al, 2006)

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5. Further research needs

- China must perform **systematic research** on management, pollution control and treatment, ecological restoration, and related water treatment and purification technologies (Qu & Fan, 2010)
- Additional studies should be focused on (1) environmental effects of physical processes; (2) nutrient cycles and control and ecosystem responses; (3) cyanobacteria bloom monitoring, causes, forecast, and management; (4) eutrophication and climate change interactions; and (5) ecosystem degradation mechanisms and ecological practice of lake restoration.(Zhang, Y.L et al, 2016)

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Thank you for your attention!