Water Security and Water Insecurity: UK-Ukraine Bridge Round Table

A global and historical analysis of eco-environmental changes in lakes due to hydrological regulations

Prof. Kam W. Tang
Department of Biosciences
Swansea University
U.K.

Collaborators

Jia Liang, Xiao Tang, Zhipeng Duan, Imran Ali
Key Laboratory of Integrated Regulation and Resource Development on Shallow Lakes, Hohai University, China

Xidong Zhang
Nanjing Foreign Language School, China

Jian Gao
Key Laboratory of Intelligent Health Perception and Ecological Restoration of Rivers and Lakes, Hubei University of Technology, China


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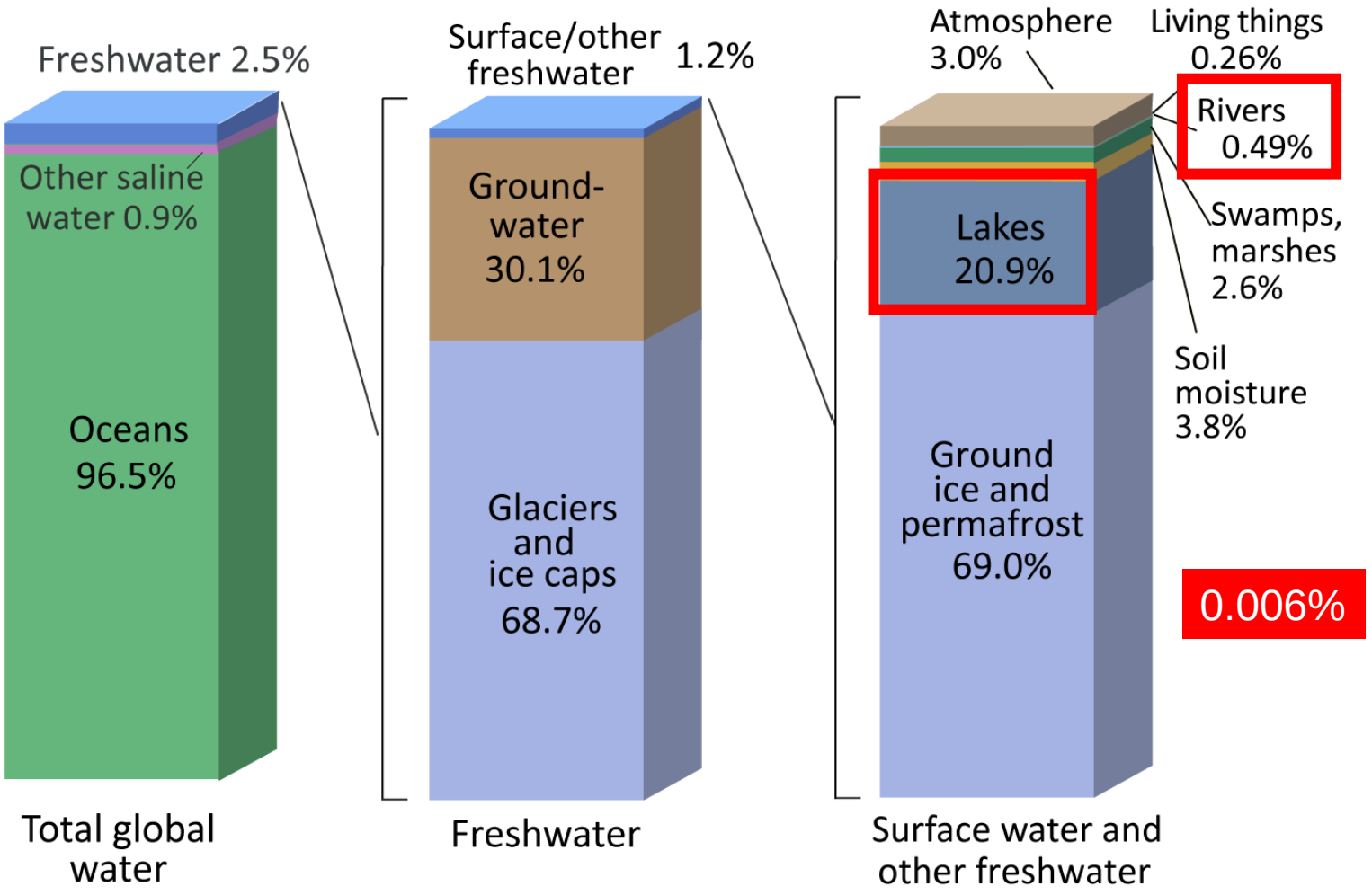
Where is Earth's Water?

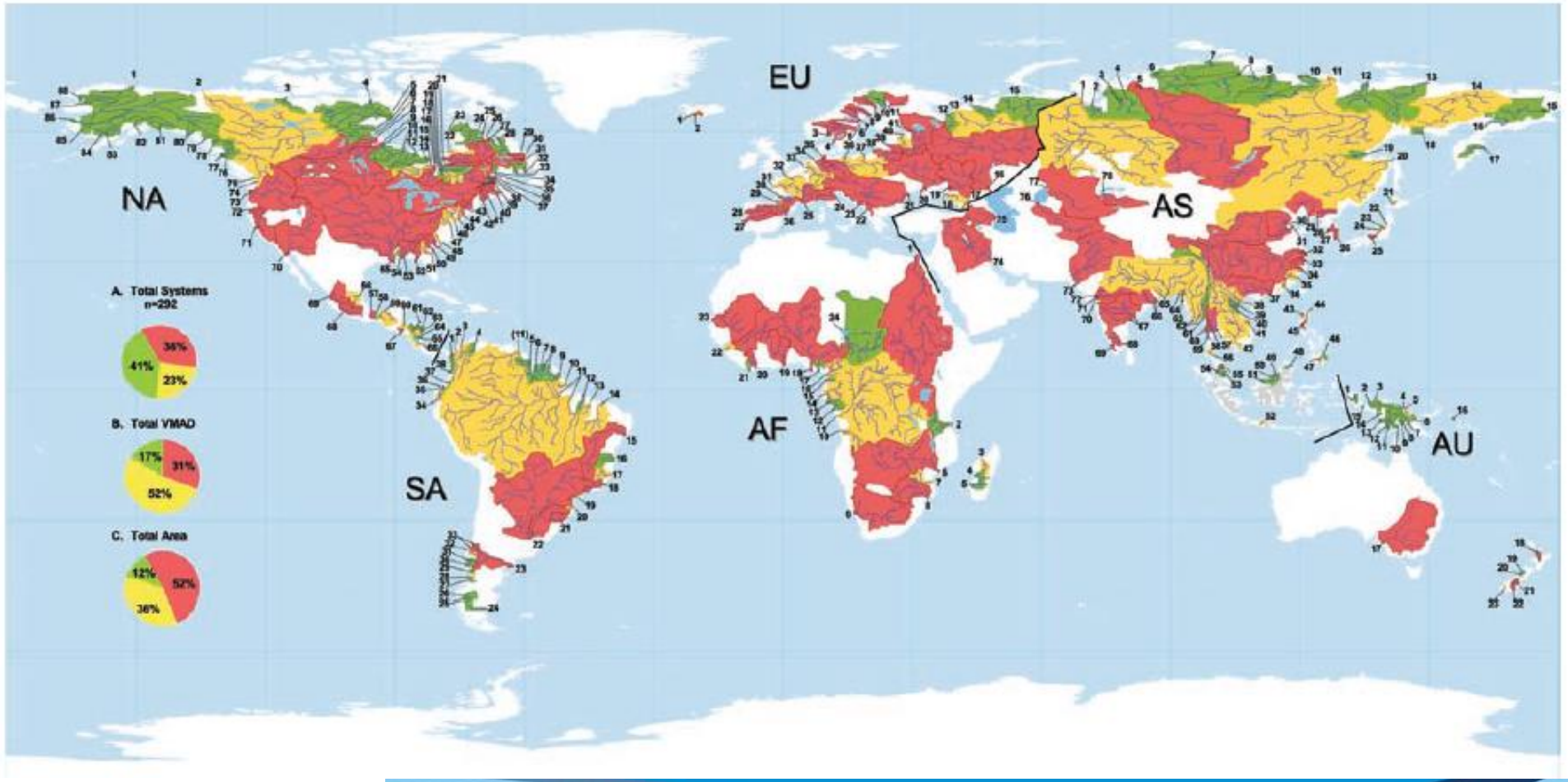


Credit: U.S. Geological Survey, Water Science School. https://www.usgs.gov/special-topic/water-science-school
Data source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources. (Numbers are rounded).

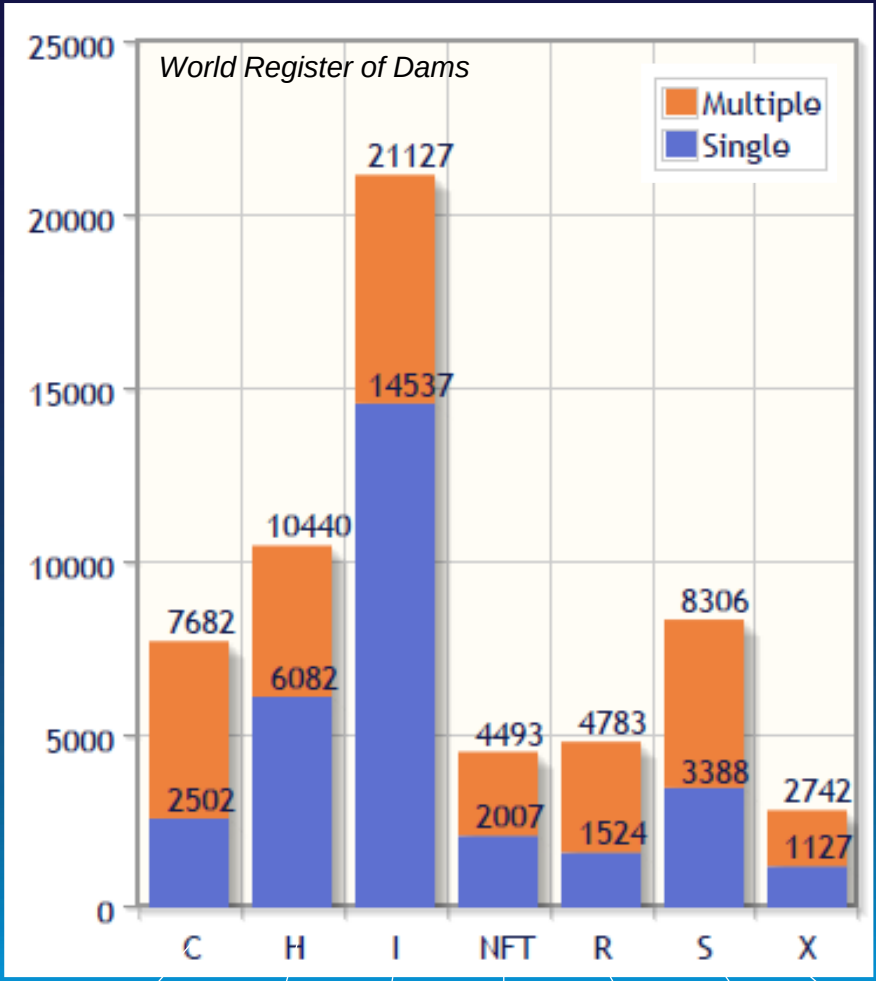
Davis Dam, Nevada

Humans have a long history of diverting and trapping surface water

River fragmentation and flow regulation



Nilsson et al. 2005 Science 308:405-408



Flood control

Hydropower

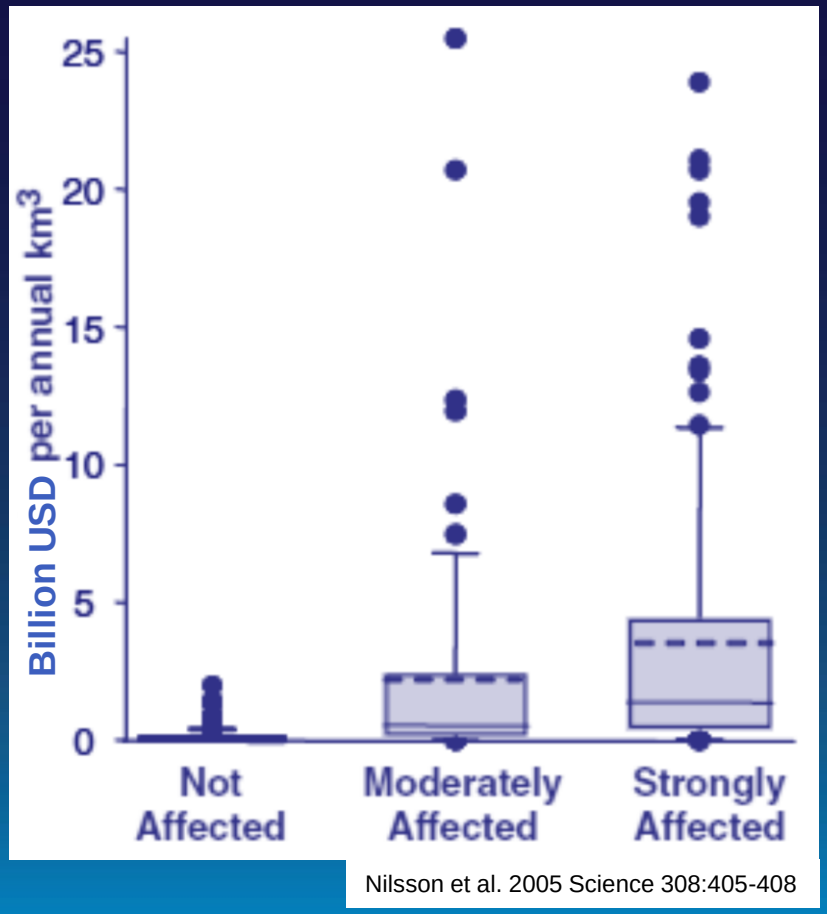
Irrigation

Navigation, fish farming, tailing

Recreation

Water supply

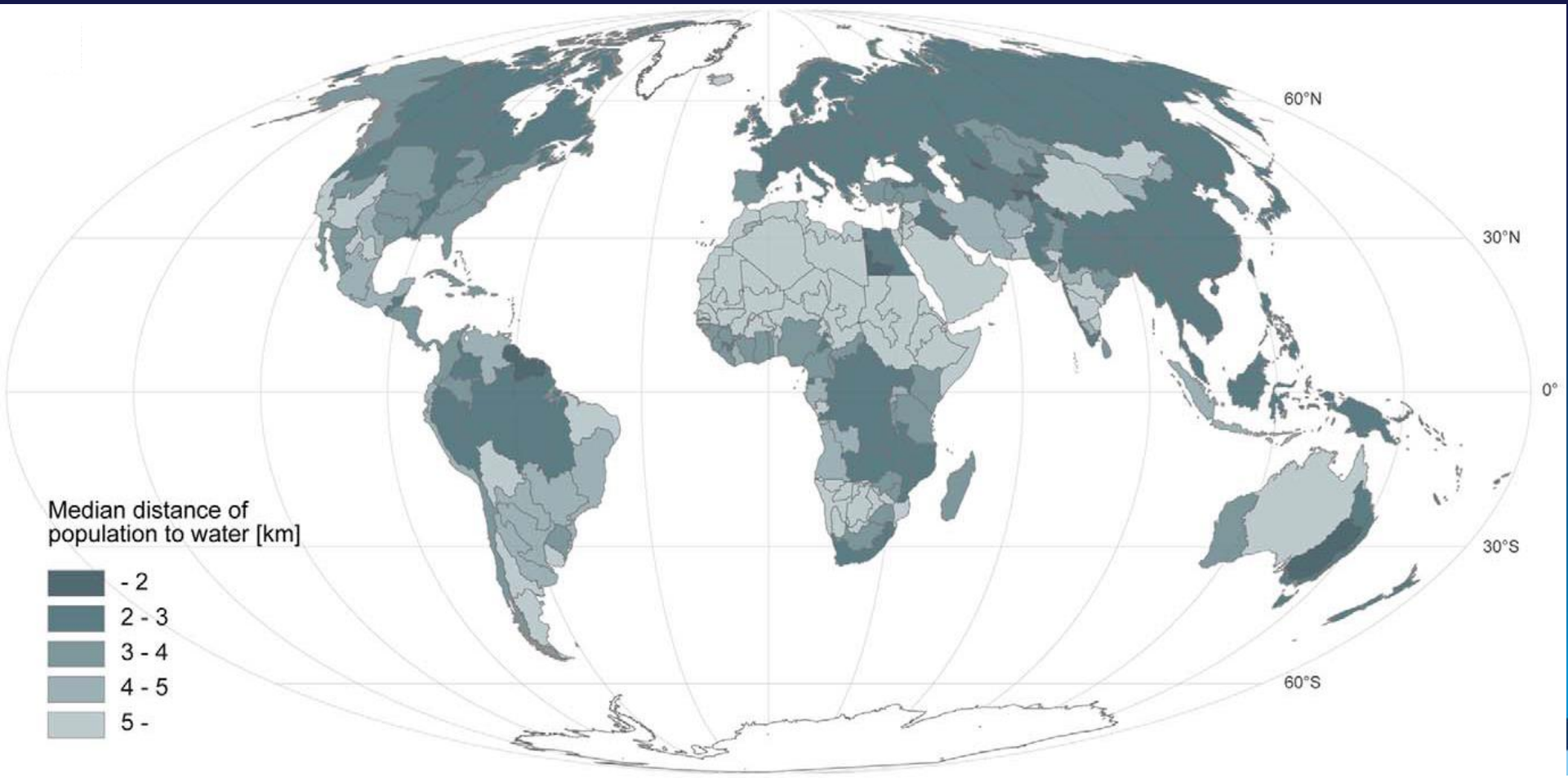
Others



Nilsson et al. 2005 Science 308:405-408

Hydrological regulation is critical for socioeconomic development

Population distribution follows water distribution



Kummu et al. 2011 PLoS ONE 6:e20578

Aim:

Assess the resilience of aquatic ecosystem to external pressure such as hydrological regulation

Hypotheses:

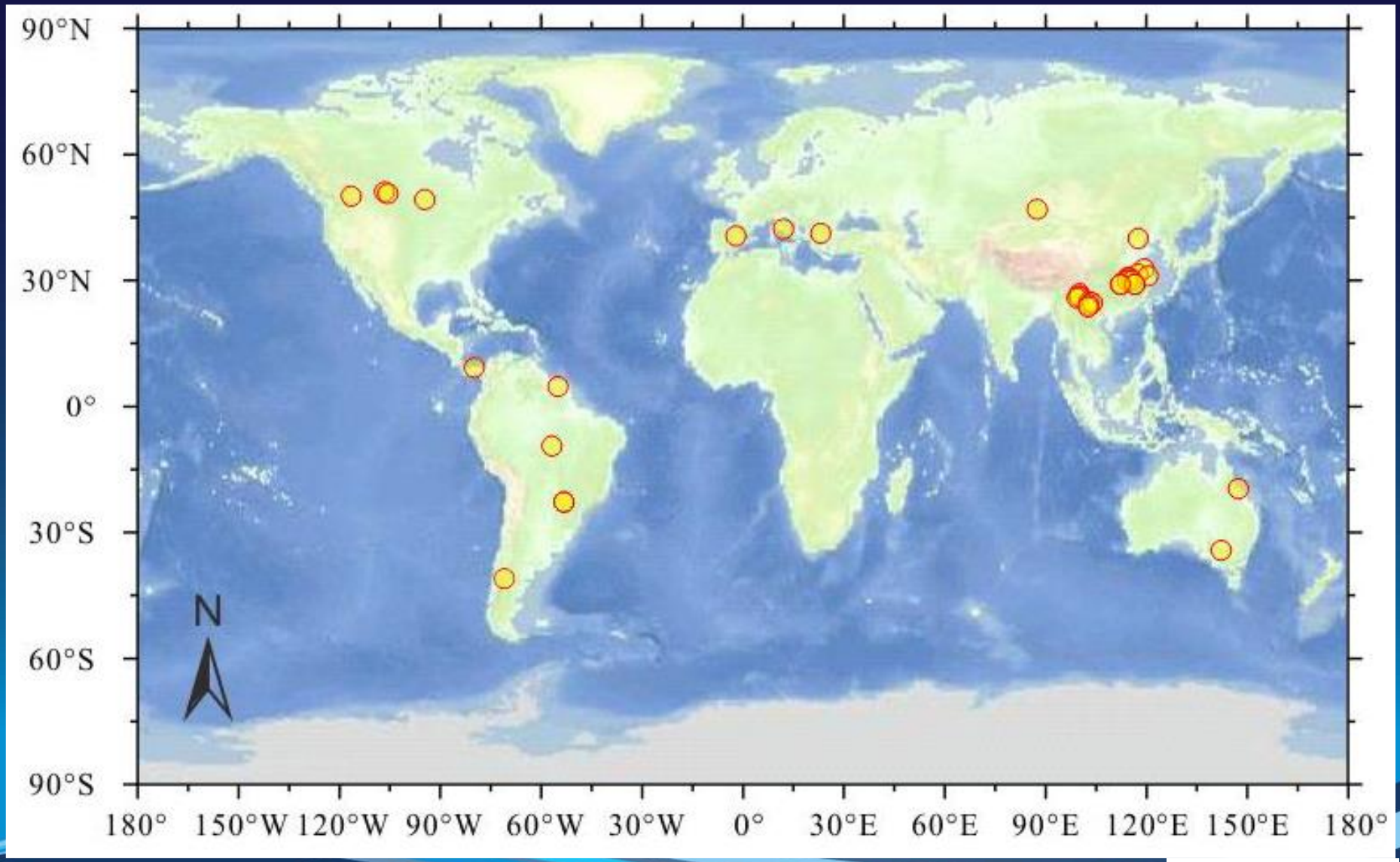
- Extent of perturbation has increased over time due to rising demand for freshwater resources by the growing population
- Larger freshwater bodies could better buffer the perturbation and delay changes to the ecosystem state

Approach:

Meta-analysis of the literature data to examine the ecological responses to different hydrological regulations in lakes, and differences in the response patterns as a function of lake characteristics and anthropogenic pressure

Methods:

- Databases e.g. Web of Science, Google Scholar, China National Knowledge Infrastructure (CNKI, http://www.cnki.net) and Wanfang database (https://g.wanfangdata.com.cn/)
- Using a combination of search parameters, a total of 554 articles were shortlisted and further filtered for these criteria:
    1) Changes in the lake hydrological conditions affected by anthropogenic activities.
    2) Hydrological regulation confirmed as an important driving factor for the significant changes of biological communities.
    3) Chronological data indicate precise time of significant changes.
    4) For multiple articles drawing similar conclusions on the same lake, only one article would be included to avoid 'double counting'.
- Final selection: 39 reports for 36 lakes

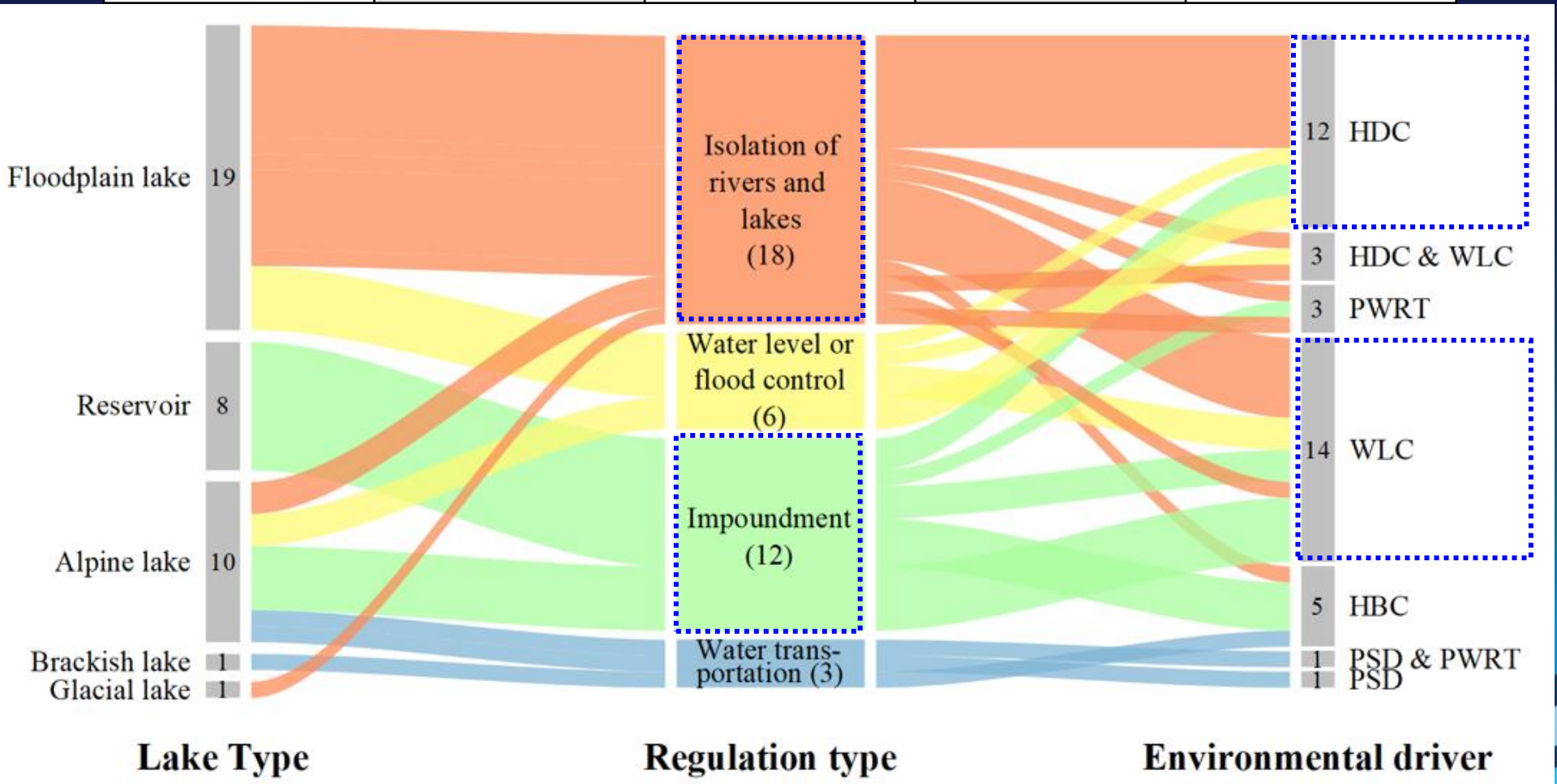


Liang et al. (unpubl.)

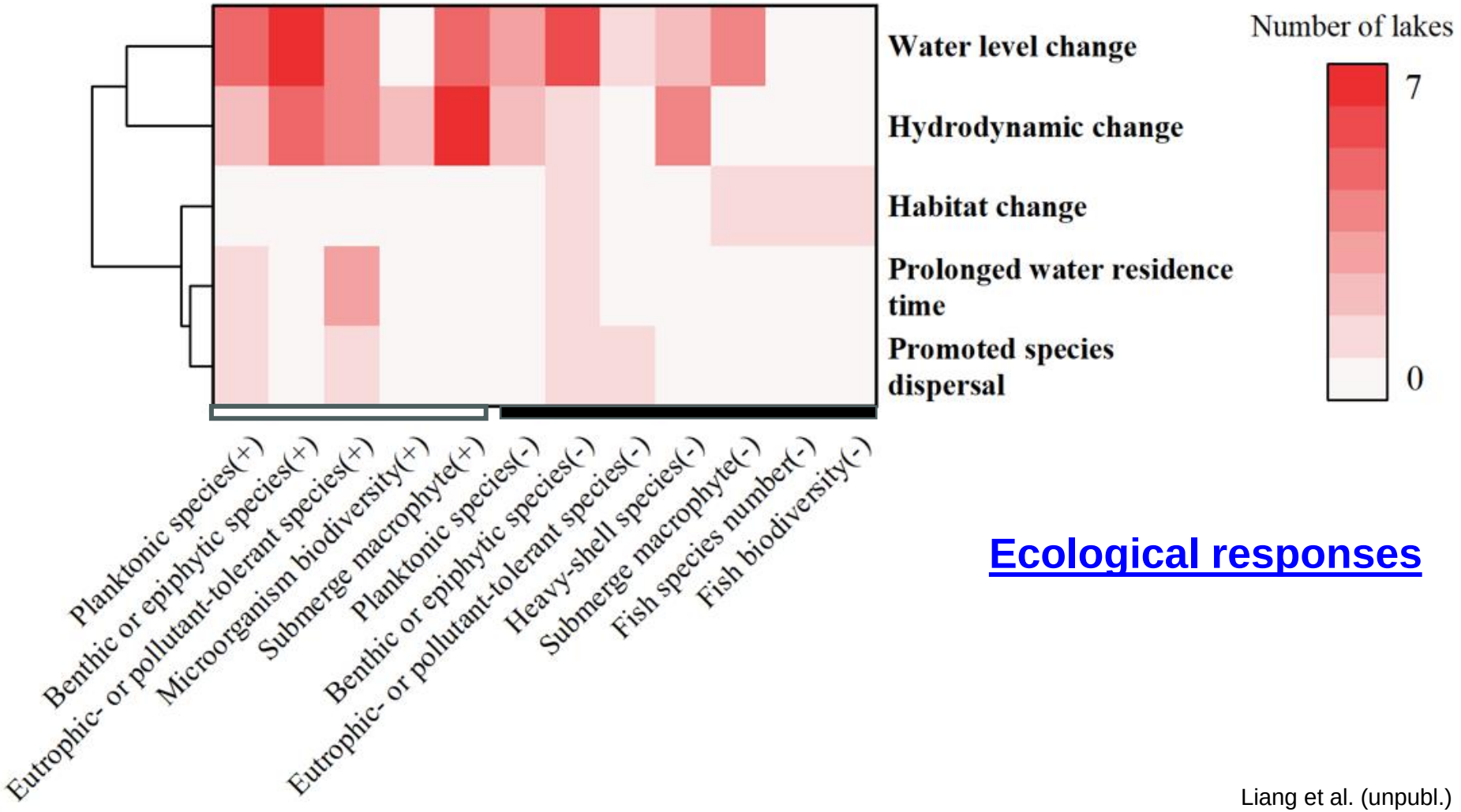
Data extracted:

- Lake location, area, depth and type
- Type and time of hydrological regulation:
  - Impoundment
  - Isolation of rivers and lakes
  - Water level or flood control
  - Water transportation
- Environmental and biological changes; e.g.
  - Transition between lotic and lentic environment
  - Increase/decrease in plankton, benthos, epiphytes and indicator species
  - Changes in biodiversity, vegetation, fish community
- Biological indicator categories:
  - Biological subfossils
  - Aquatic vegetation
  - Fishes and others
  - Micro- vs. macro-scopic
  - Heterotrophic vs. autotrophic
- Response time interval (RTI) = Difference in time (year) between hydrological regulation and significant change in biological community

HDC	WLC	HBC	PWRT	PSD
Hydrodynamic change	Water level change	Habitat change	Prolonged water residence time	Promoted species dispersal



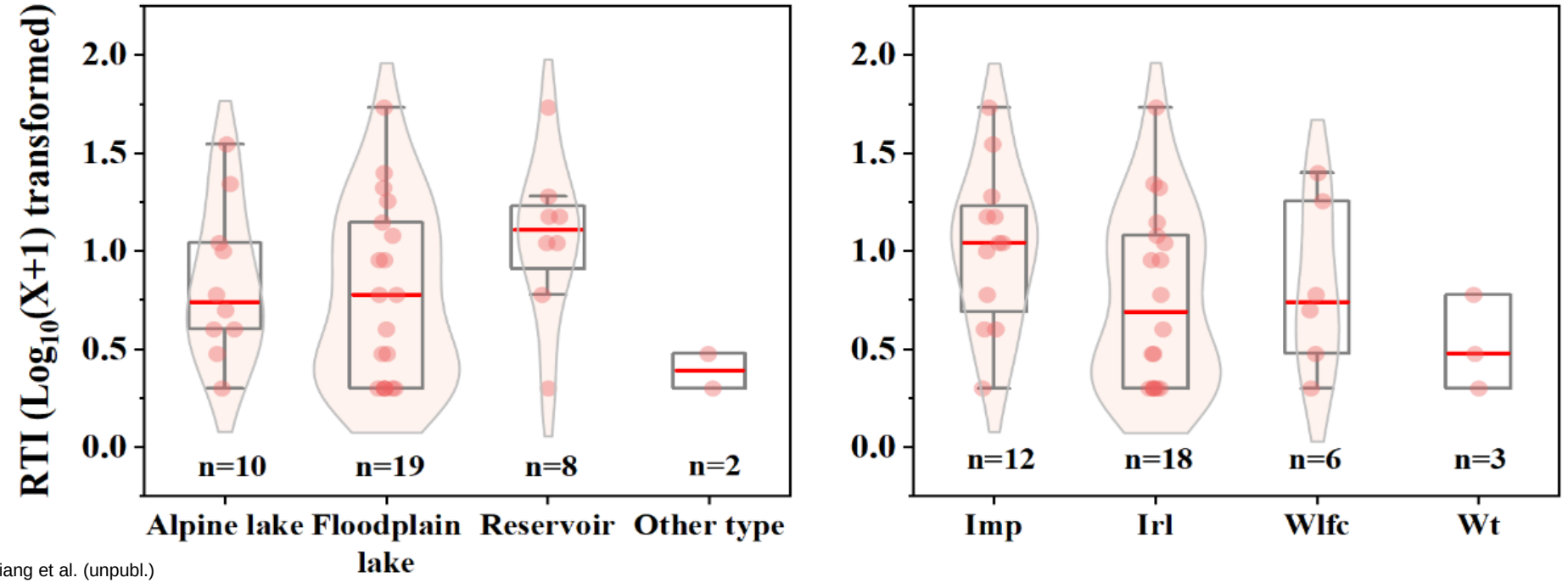
Liang et al. (unpubl.)



Ecological responses

Liang et al. (unpubl.)

Response time interval = Difference in time (year) between hydrological regulation and significant change in biological community



Liang et al. (unpubl.)

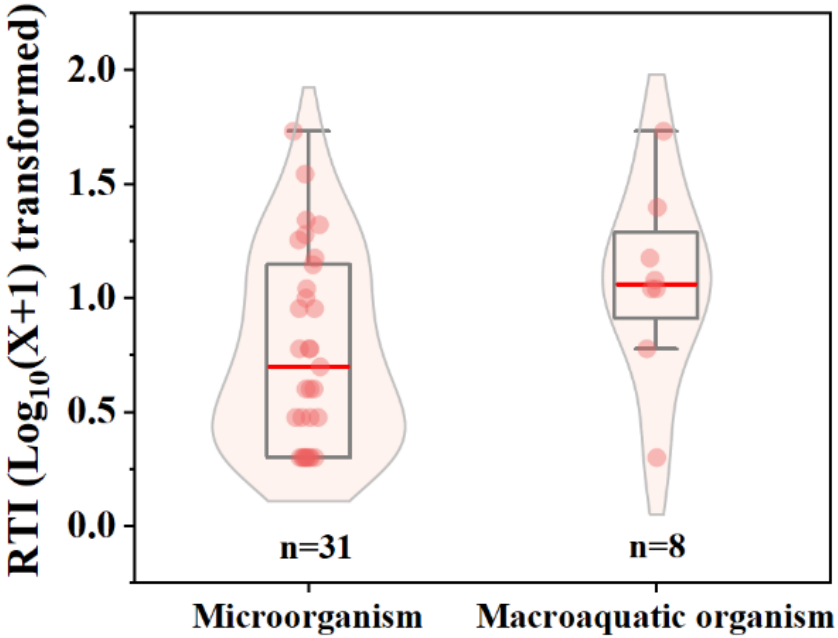
RTI varies based on types of habitat and regulation

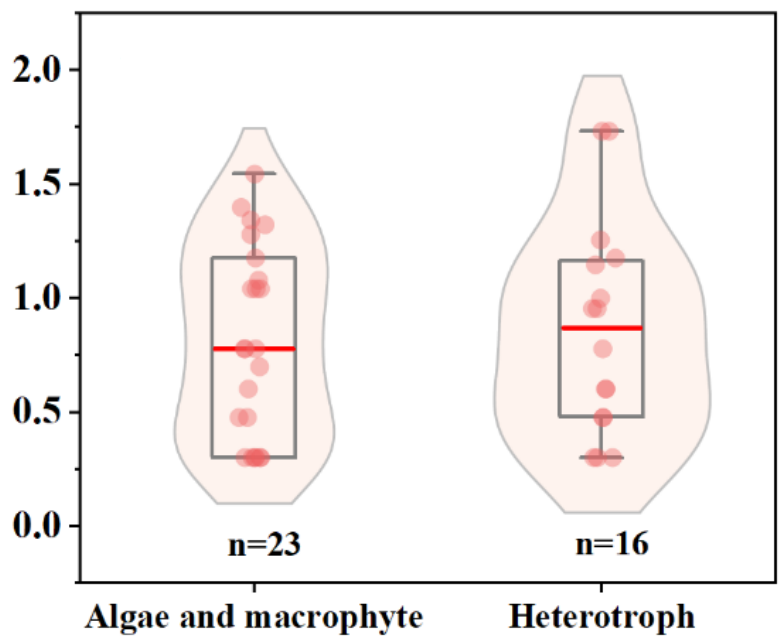
Impoundment

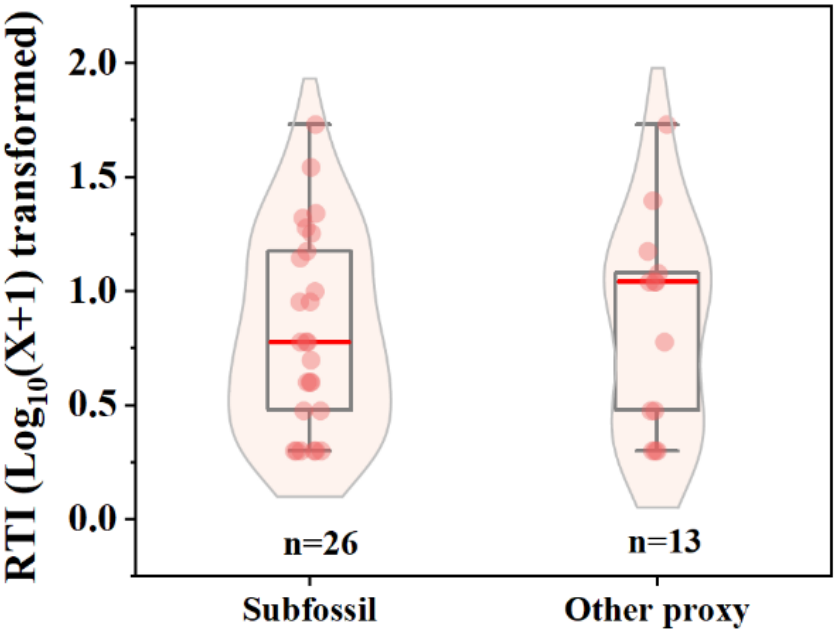
Water level and flood control

Isolation of rivers and lakes

Water transportation

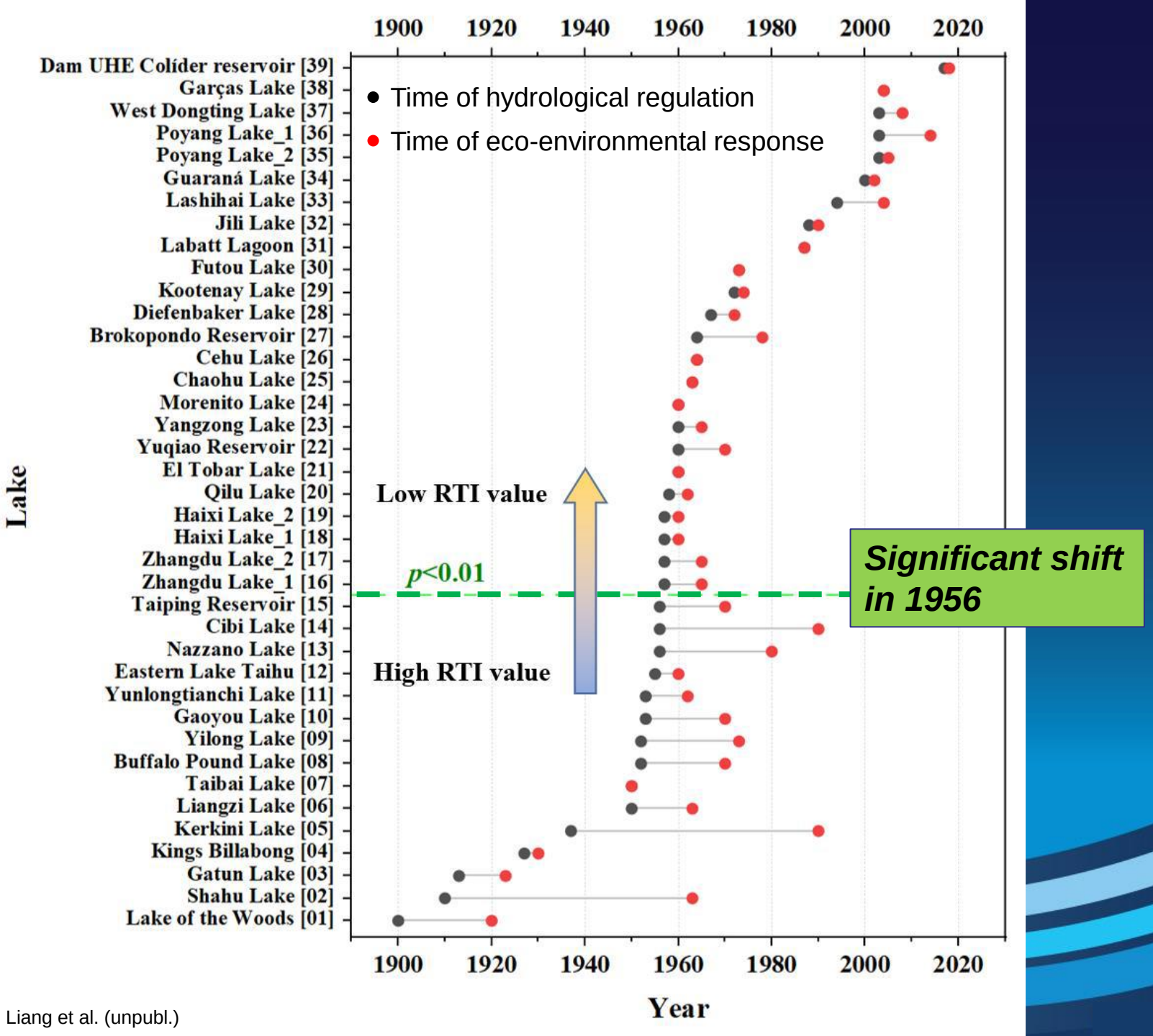




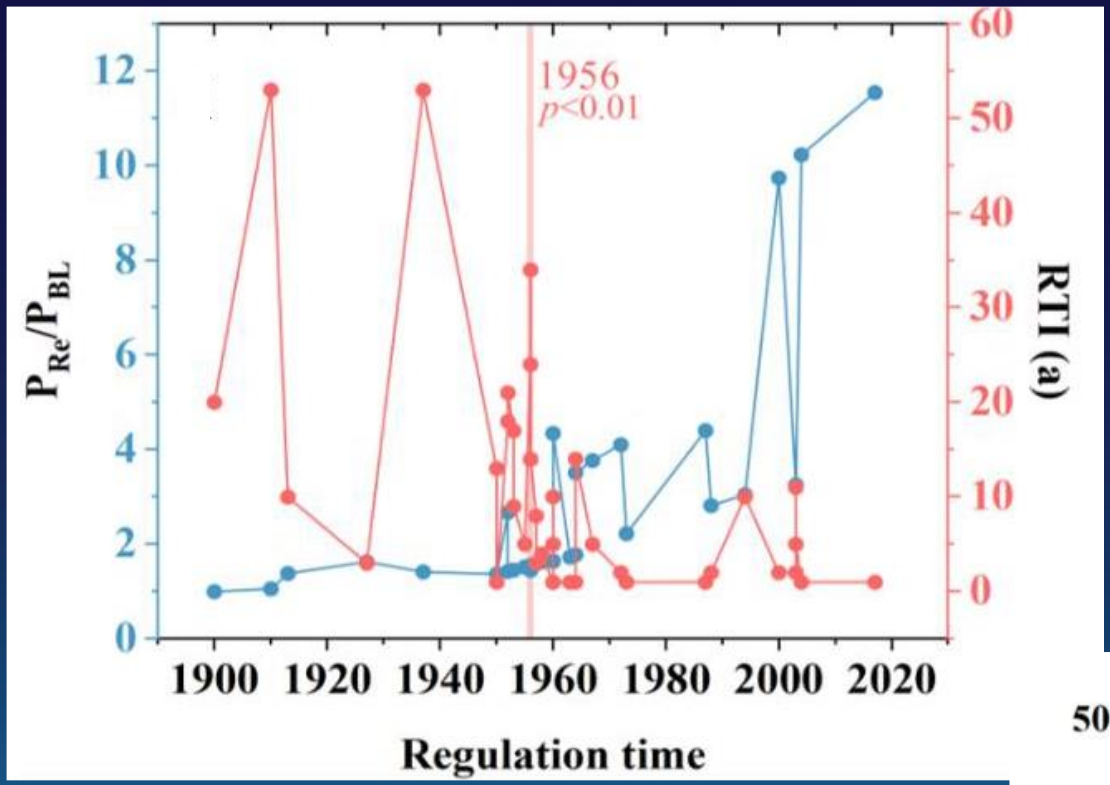


RTI does not change much for biological variables

Liang et al. (unpubl.)



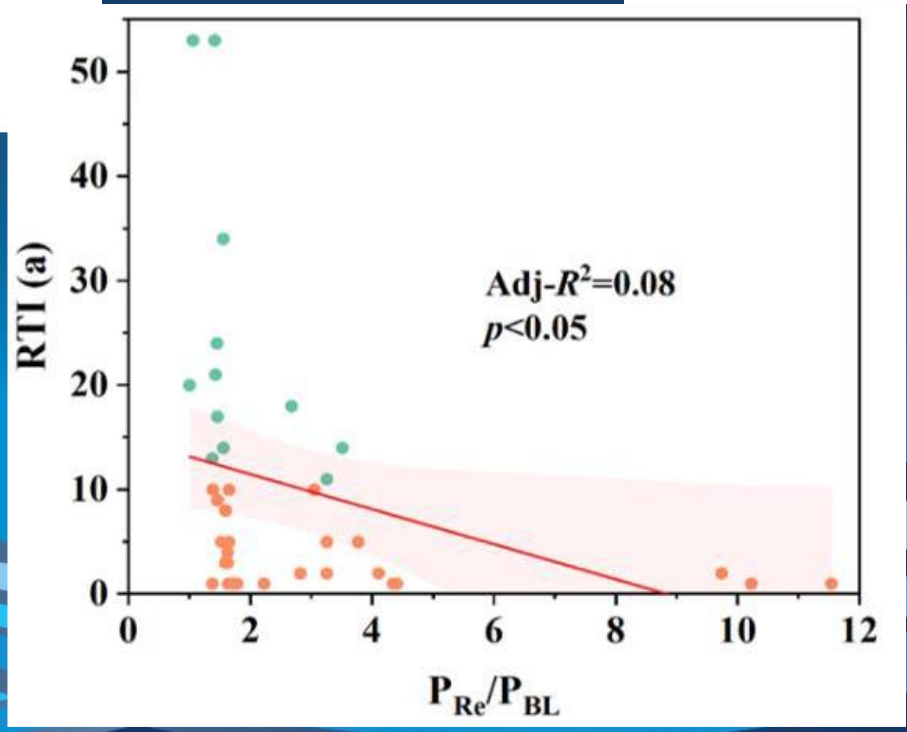
Liang et al. (unpubl.)



P_{re} = Population at time of regulation

P_{BL} = Baseline population

Liang et al. (unpubl.)



Significant shift in RTI coincides with large surge in population around 1956

SUMMARY

- Changes in hydrodynamics and water level were the most common results of isolation of rivers and lakes and impoundment.
- Changes in biological communities depend on habitats and taxonomic groups.
- Prolonged water residence time increases eutrophic or pollution-resistant species.
- Habitat change results in decrease in fish abundance and diversity.
- Water diversion increases dispersal and interactions between native and foreign species.
- Most cases result in deterioration of water quality, likely due to increased input and residence time of anthropogenic wastes.
- Year 1956 represents the turning point when RTI decreases significantly, reflecting increasing pressure from growing populations.

IMPLICATIONS

- Different biological indicators can be used to assess short-term (e.g. diatoms) and long-term (e.g. macrophytes) changes after hydrological regulation.
- Emergence of opportunistic species may nullify restoration effort and lead to further environmental degradation.
- 69% of the world's population experiences some degree of water stress, and 10% lives in high-to-critical water stress level. Climate change will further disrupt water supply and require even more drastic habitat modification and hydrological regulations.
- Asymmetry in time between disturbance and recovery means prolonged 'recovery debt' in ecosystem functions and services *(Moreno-Mateos et al. 2017 Nat. Comm. 8:14163)*.

THANK YOU!