The International Environmental School «EUROPEAN GREEN DIMENSIONS: CHALLENGES FOR UKRAINE»

6 June 2024

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

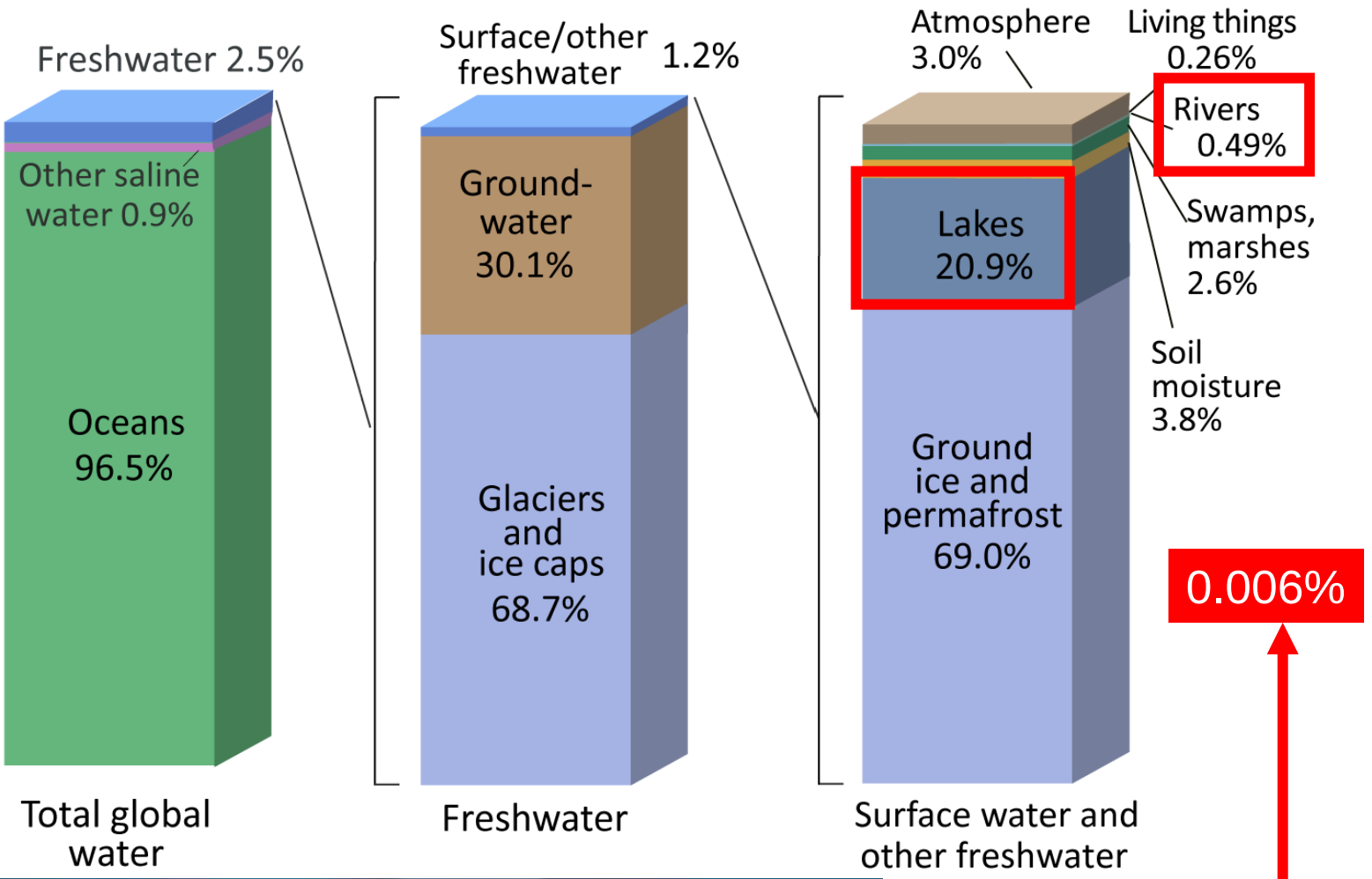
Jia Liang, Xiao Tang, Zhipeng Duan, Imran Ali
Key Laboratory of Integrated Regulation and Resource Development on Shallow Lakes, Hohai University, China

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

Water is the substance of life

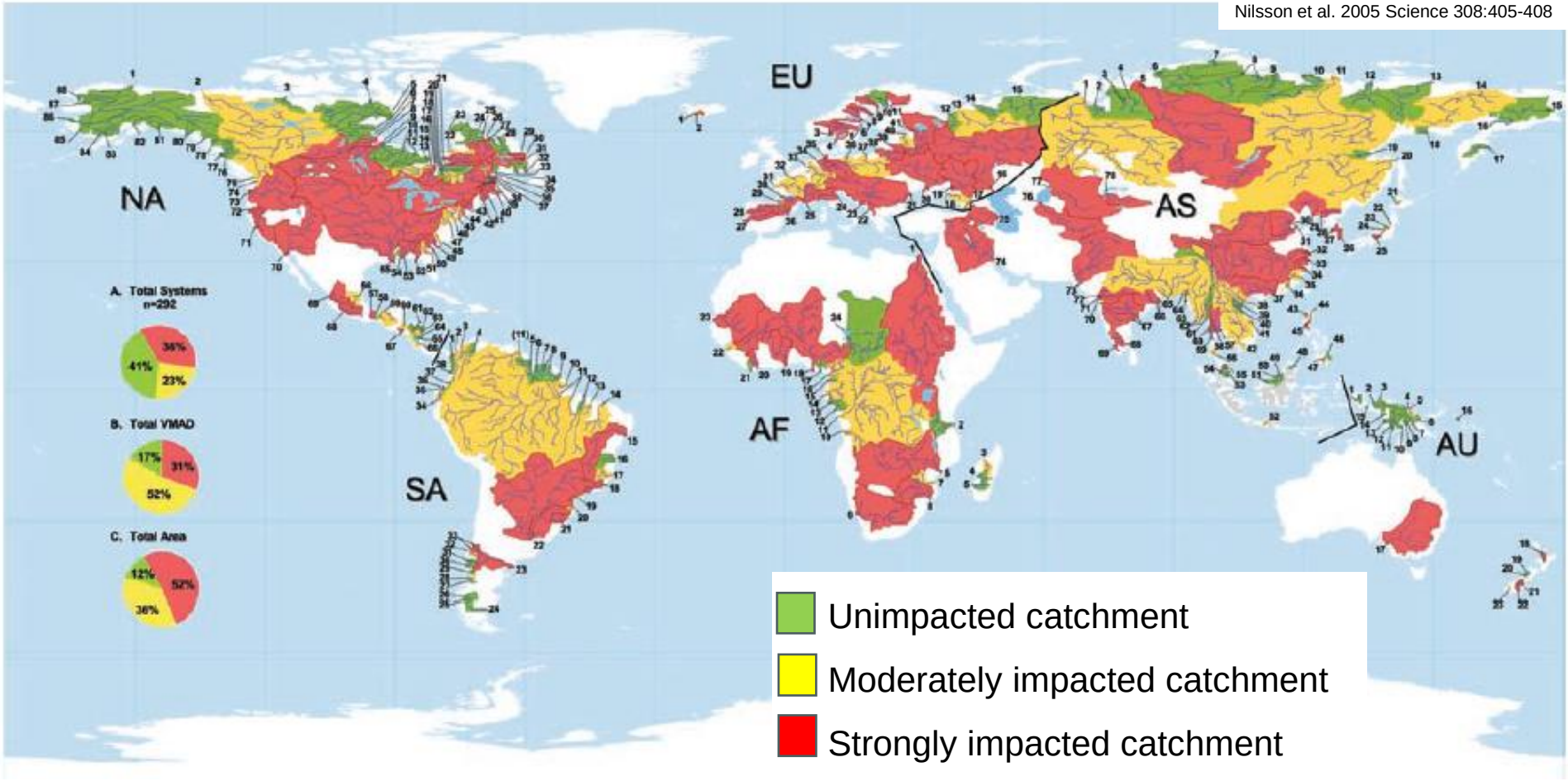
Where is Earth's Water?



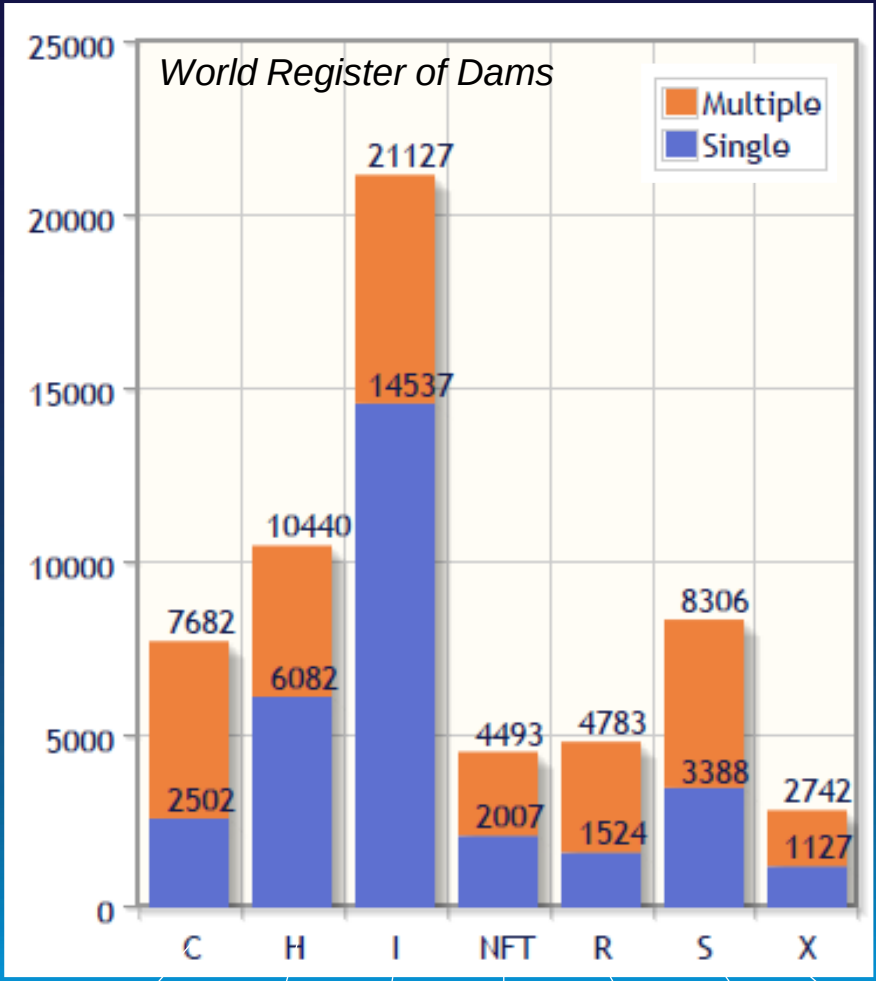
Credit: U.S. Geological Survey

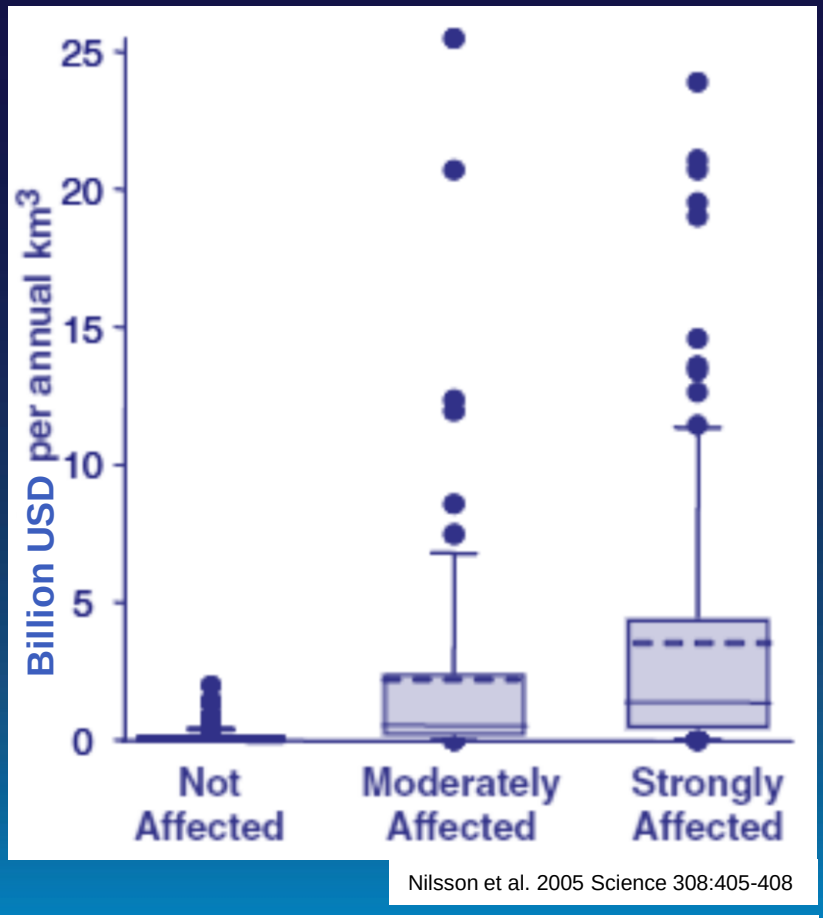
Davis Dam, Nevada

Humans have a long history of diverting and trapping surface water with dams and reservoirs



Hydrological regulations impact catchments around the world for different purposes…





Nilsson et al. 2005 Science 308:405-408

Hydrological regulation is critical for socioeconomic development

Flood control

Hydropower

Irrigation

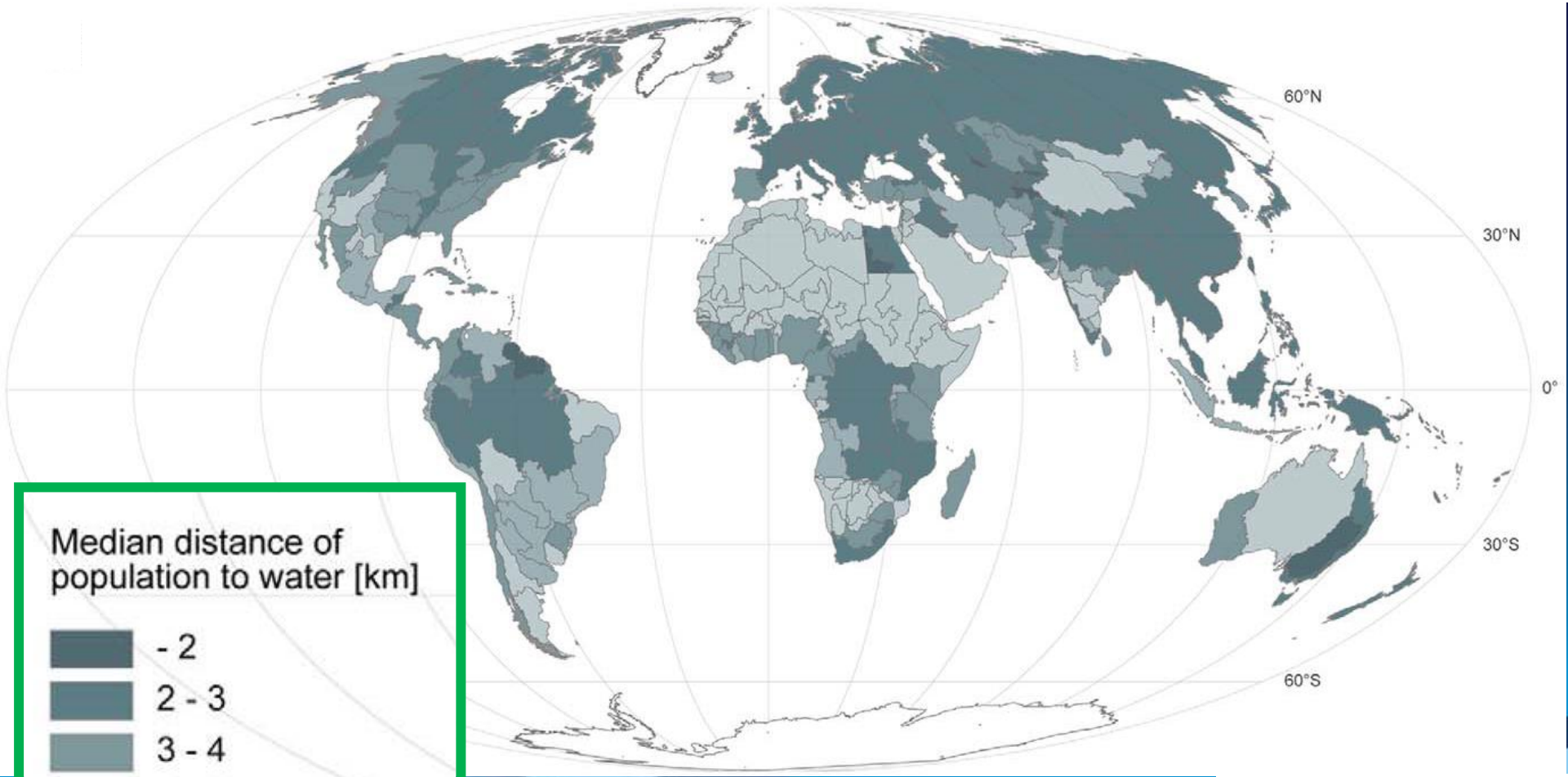
Navigation, fish farming, tailing

Recreation

Water supply

Others

Population distribution follows water distribution



Kummu et al. 2011 PLoS ONE 6:e20578

Aim of research

Meta-analysis of literature data to assess aquatic ecosystem responses to hydrological regulations

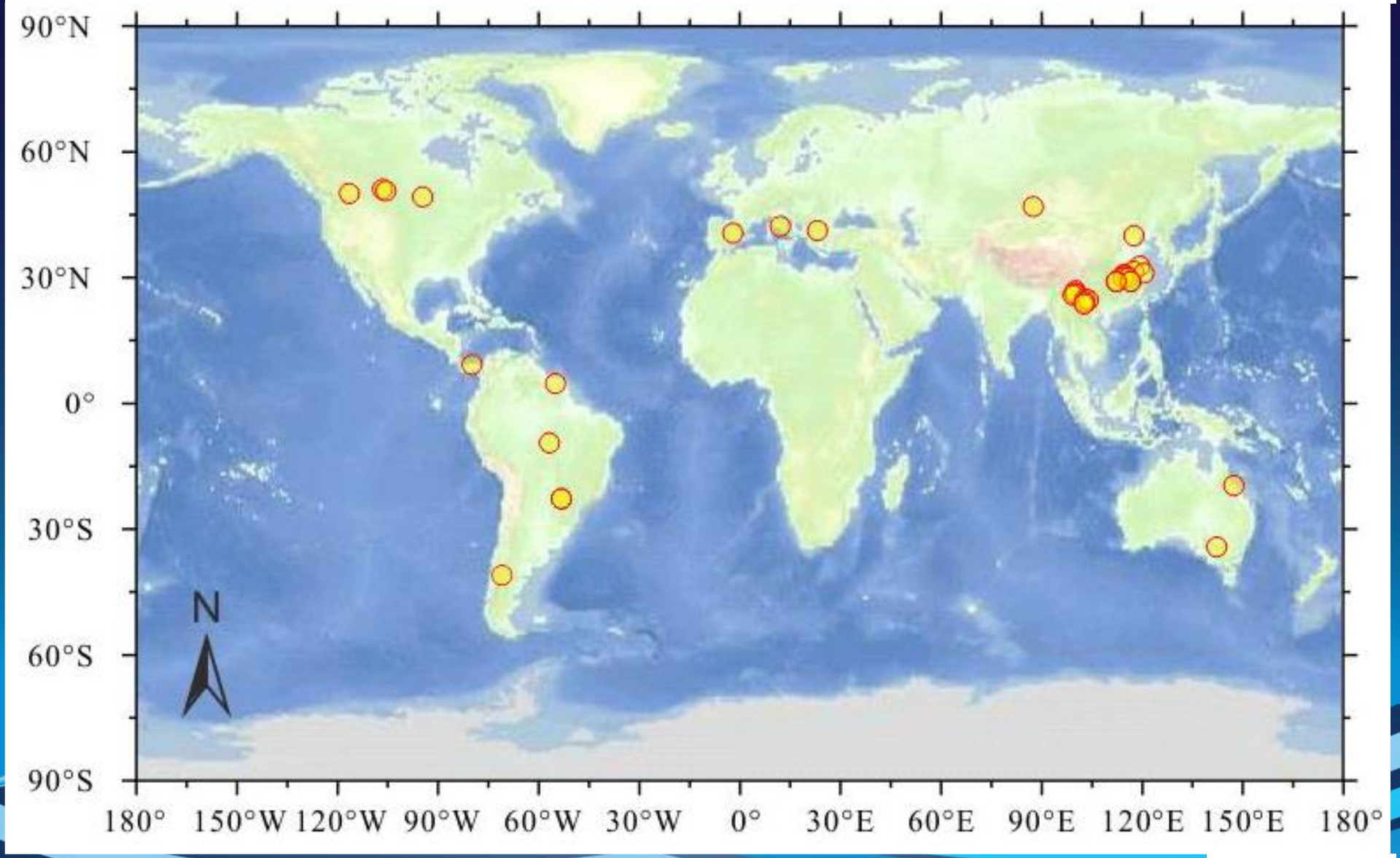
Hypotheses

- Growing population increases pressure on aquatic ecosystems
- Larger freshwater bodies can better buffer perturbations and delay ecological changes

Methods

- Databases e.g. Web of Science, Google Scholar, China National Knowledge Infrastructure and Wanfang database
- Using search parameters, 554 articles were shortlisted and further filtered for these criteria:
  1) Changes in hydrological conditions due to anthropogenic activities.
  2) Hydrological regulation as an important factor driving significant changes in biological communities.
  3) Known precise time of significant changes.
  4) Remove 'double counting' of multiple articles for the same lake.
- **Final selection: 39 reports for 36 lakes**

Locations of studies selected for our analysis

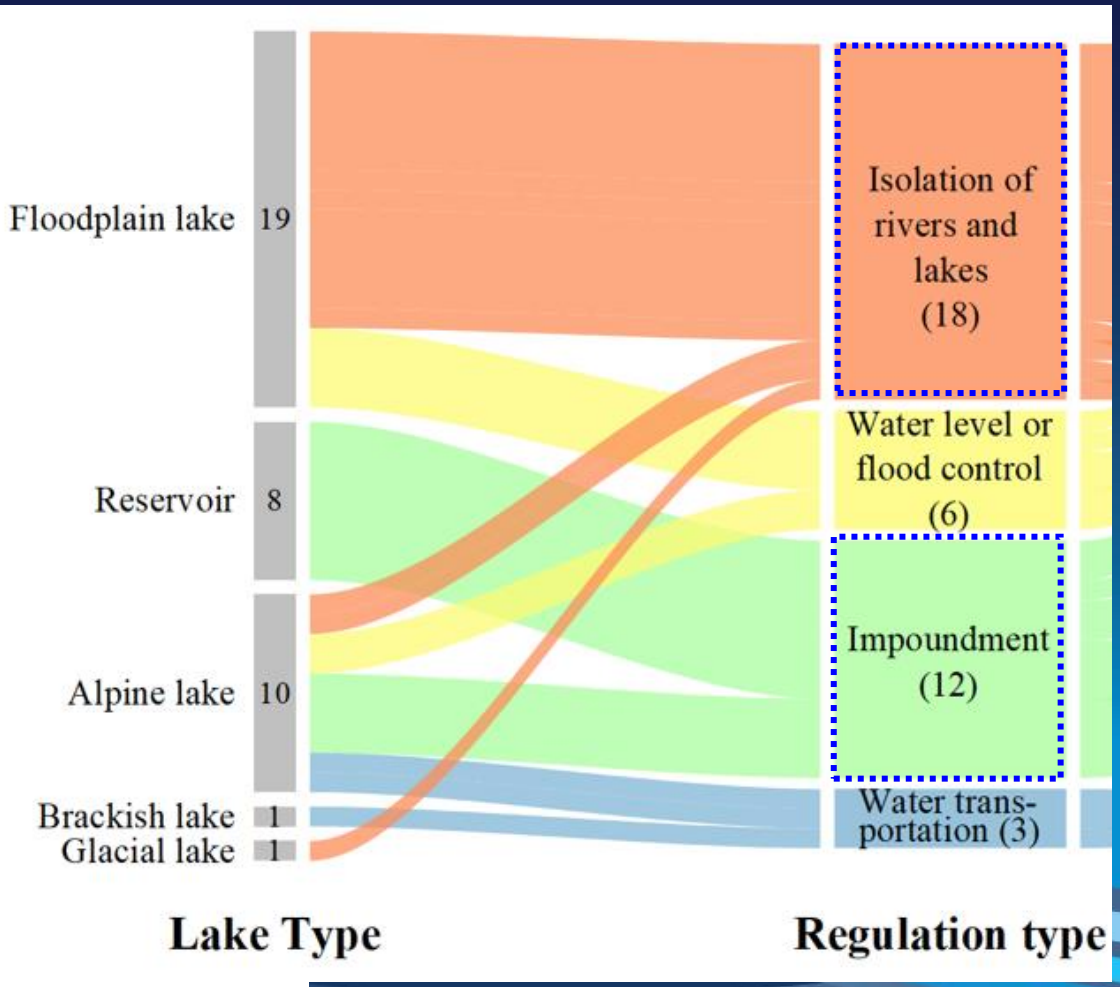


Liang et al. (unpubl.)

Data extracted

- Lake location, area, depth and type
- Type and time of hydrological regulation:
  (1) Impoundment; (2) Isolation of rivers and lakes; (3) Water level or flood control; (4) Water transportation
- Environmental and biological changes; e.g.
  (1) Transition between lotic and lentic environment
  (2) Increase/decrease in plankton, benthos, epiphytes and indicator species
  (3) Changes in biodiversity, vegetation, fish community
- Biological indicator categories:
  (1) Biological subfossils; (2) Aquatic vegetation; (3) Fishes and others; (4) Micro- vs. macro-scopic; (5) Heterotrophic vs. autotrophic
- **Response time interval (RTI)**

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



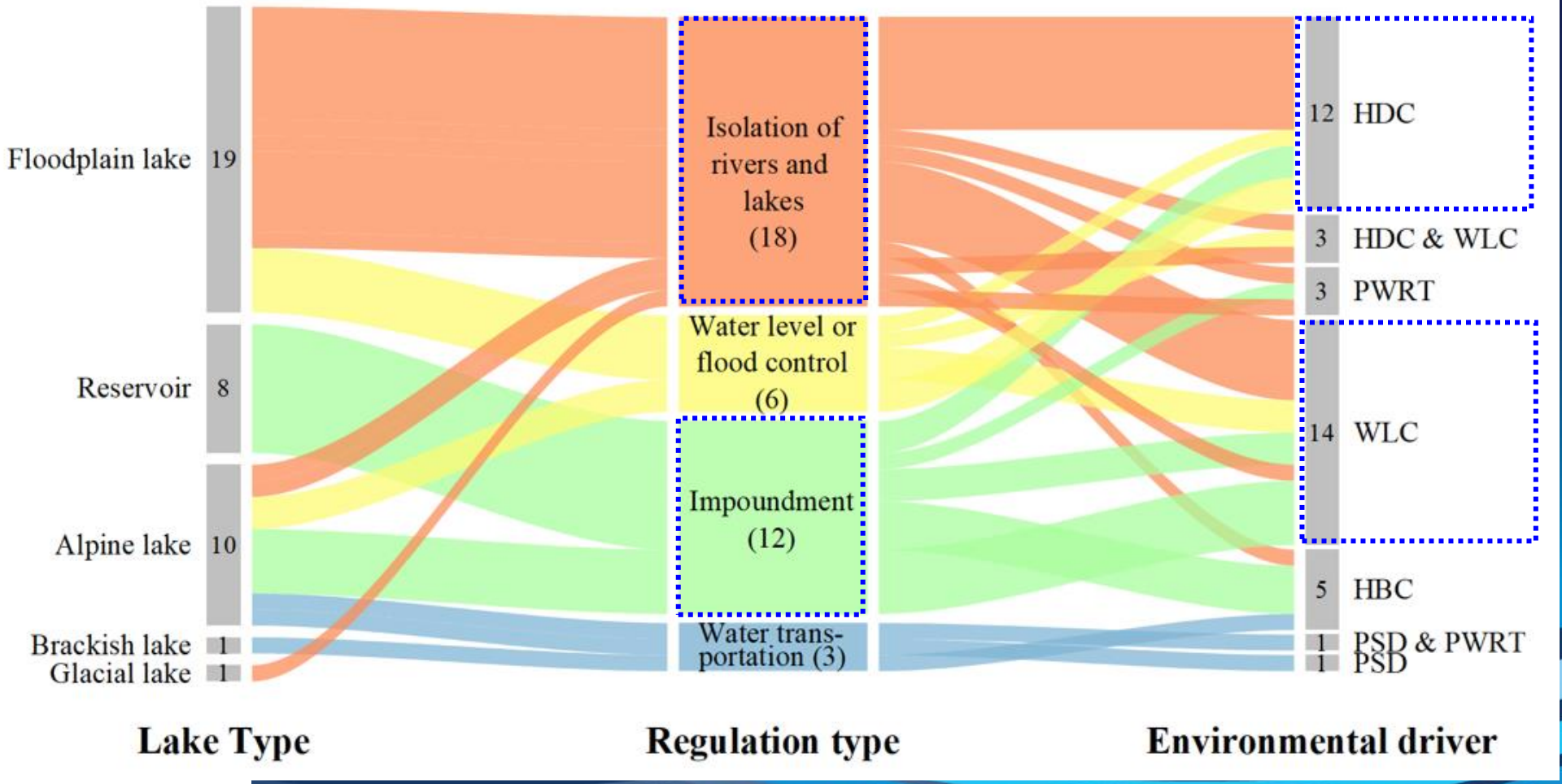
Liang et al. (unpubl.)

Most common regulation types:

- **Isolation of rivers and lakes**
- **Impoundment**

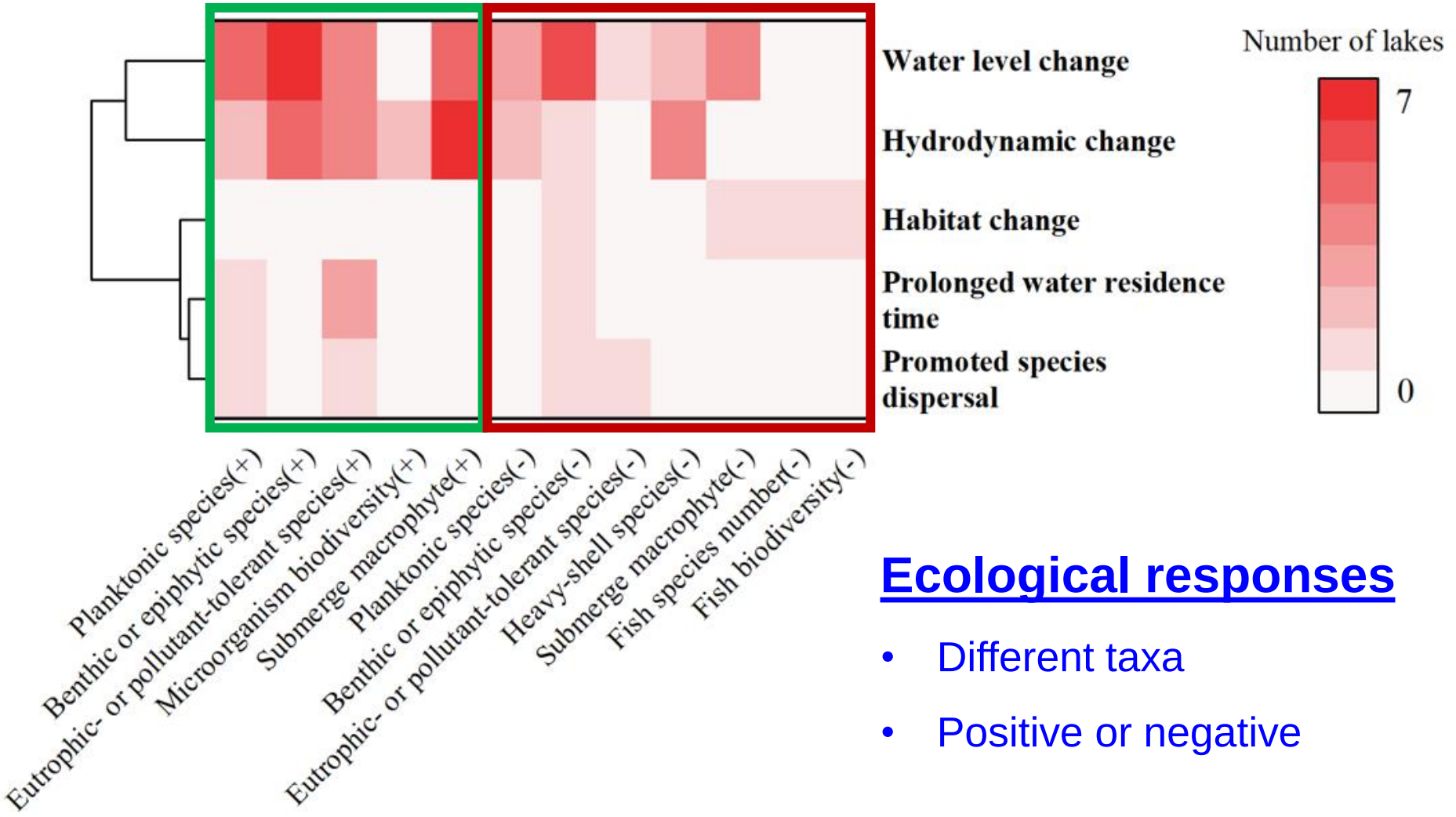
Most common environmental drivers after regulation

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



Liang et al. (unpubl.)

+ve response -ve response

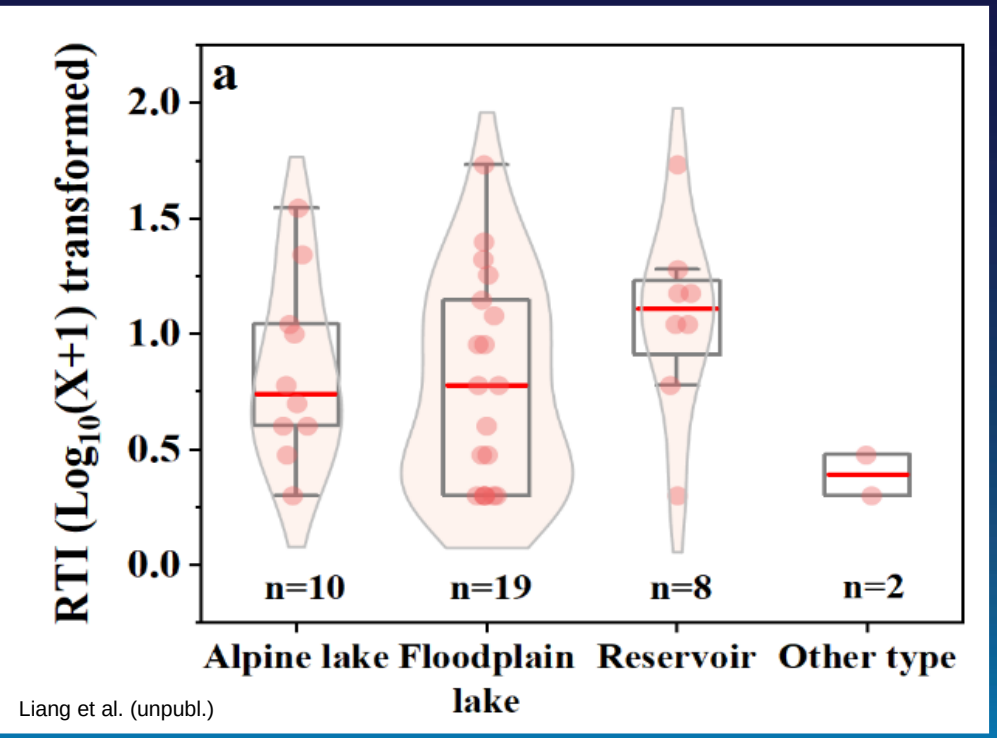


Ecological responses

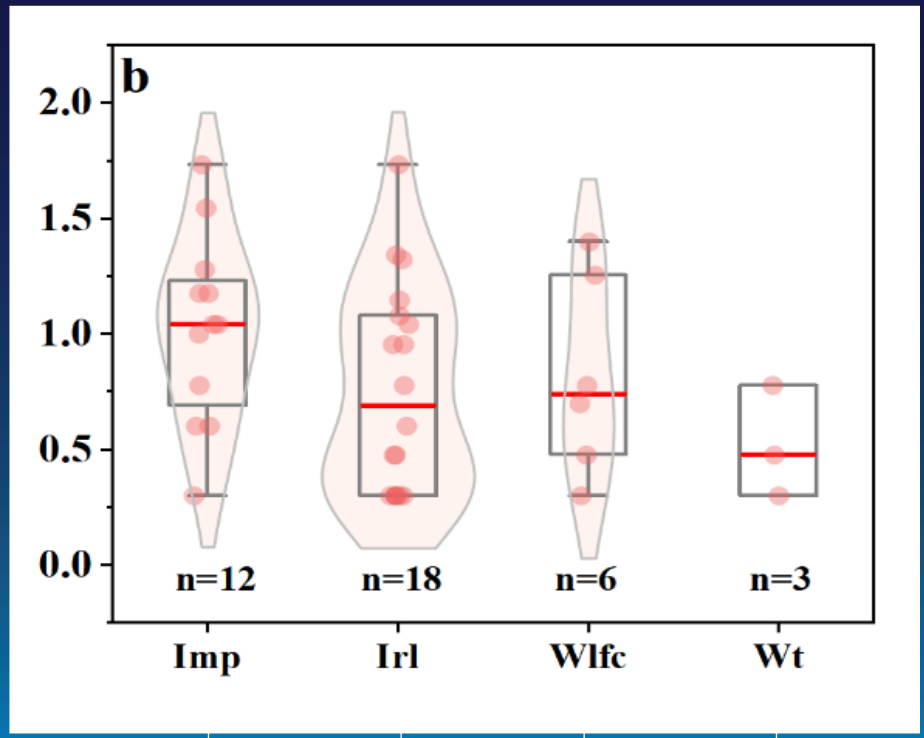
- Different taxa
- Positive or negative

Liang et al. (unpubl.)

Response time interval (RTI)



Liang et al. (unpubl.)



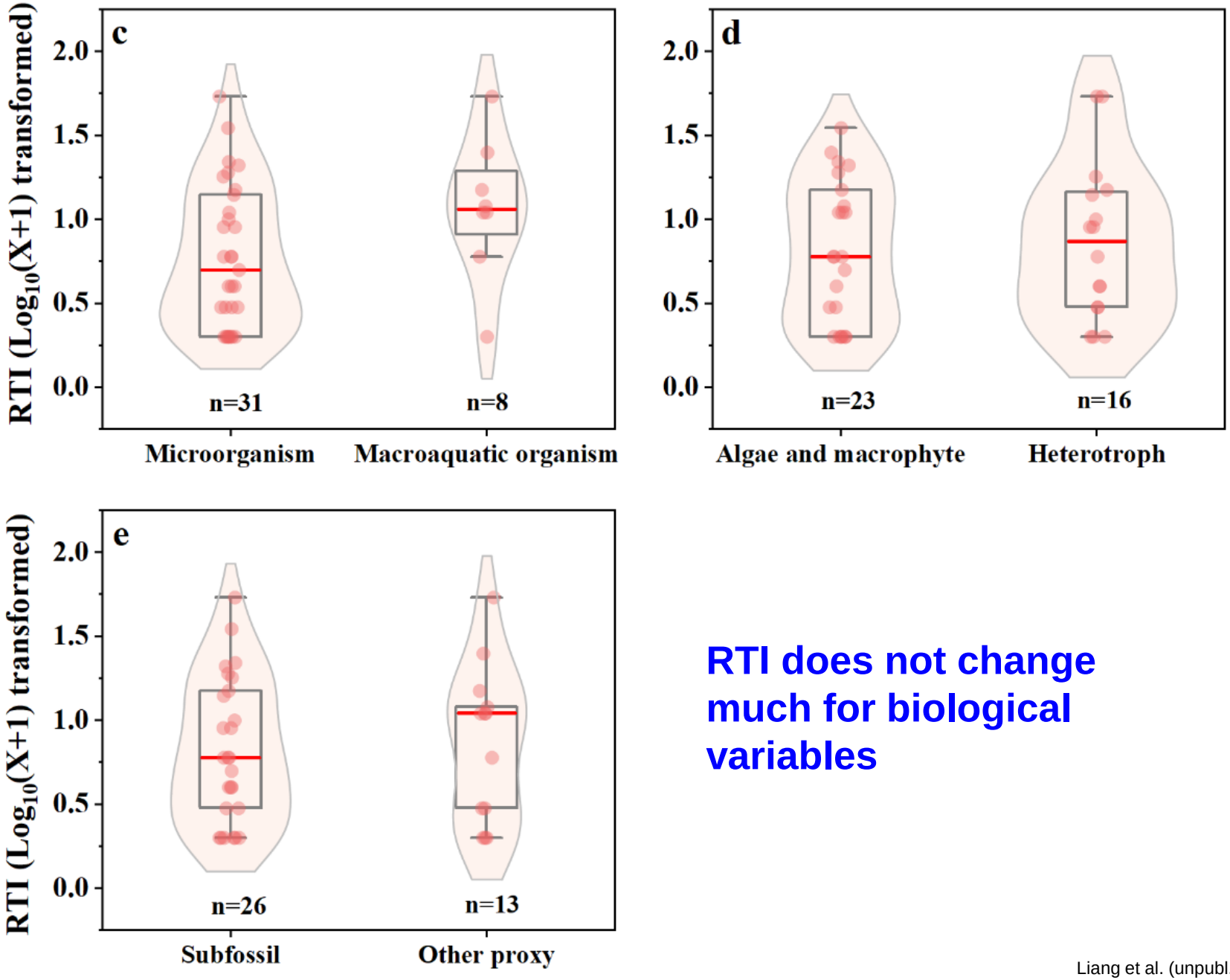
RTI varies based on types of habitat and regulation

Impoundment

Water level and flood control

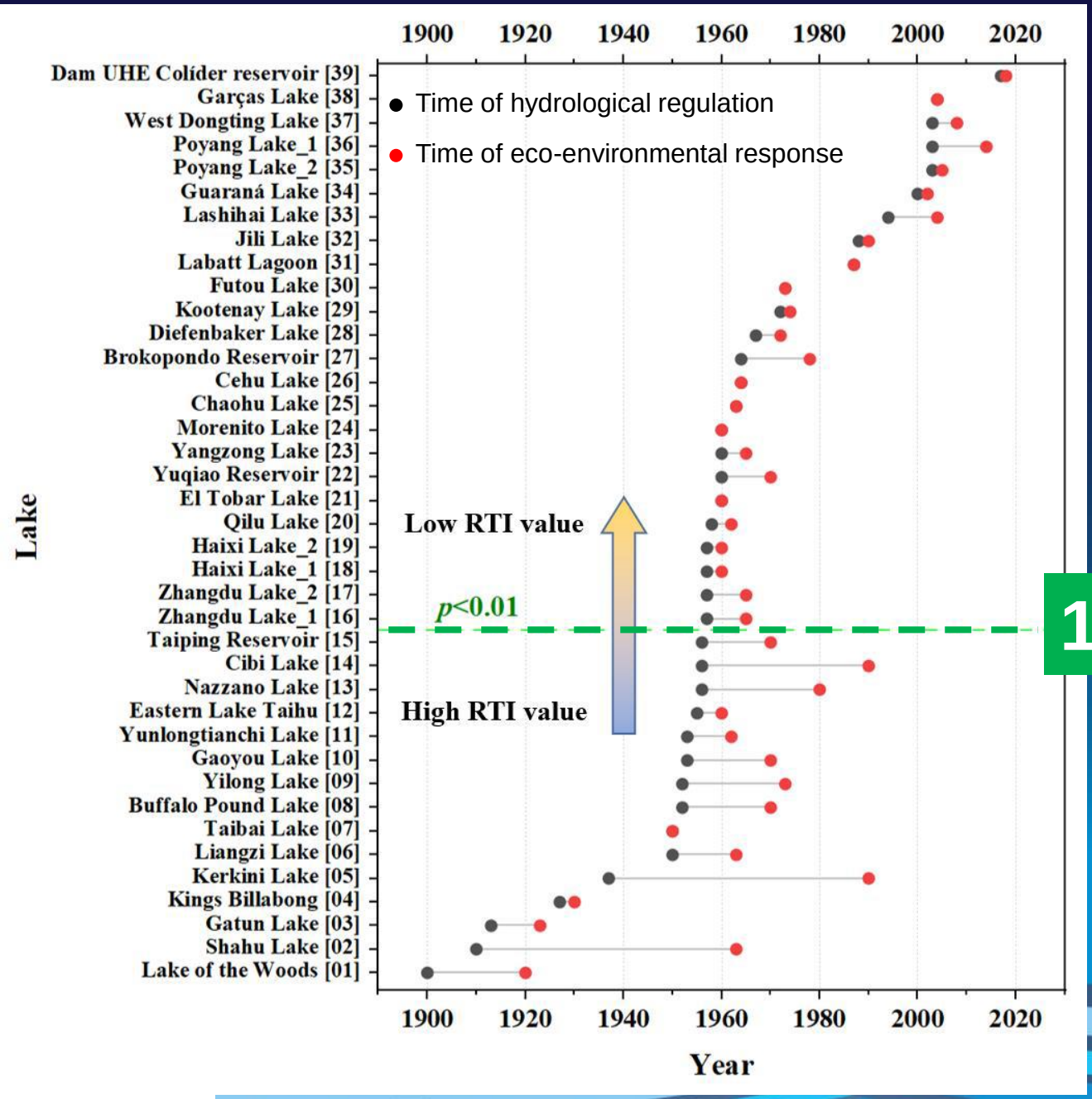
Isolation of rivers and lakes

Water transportation

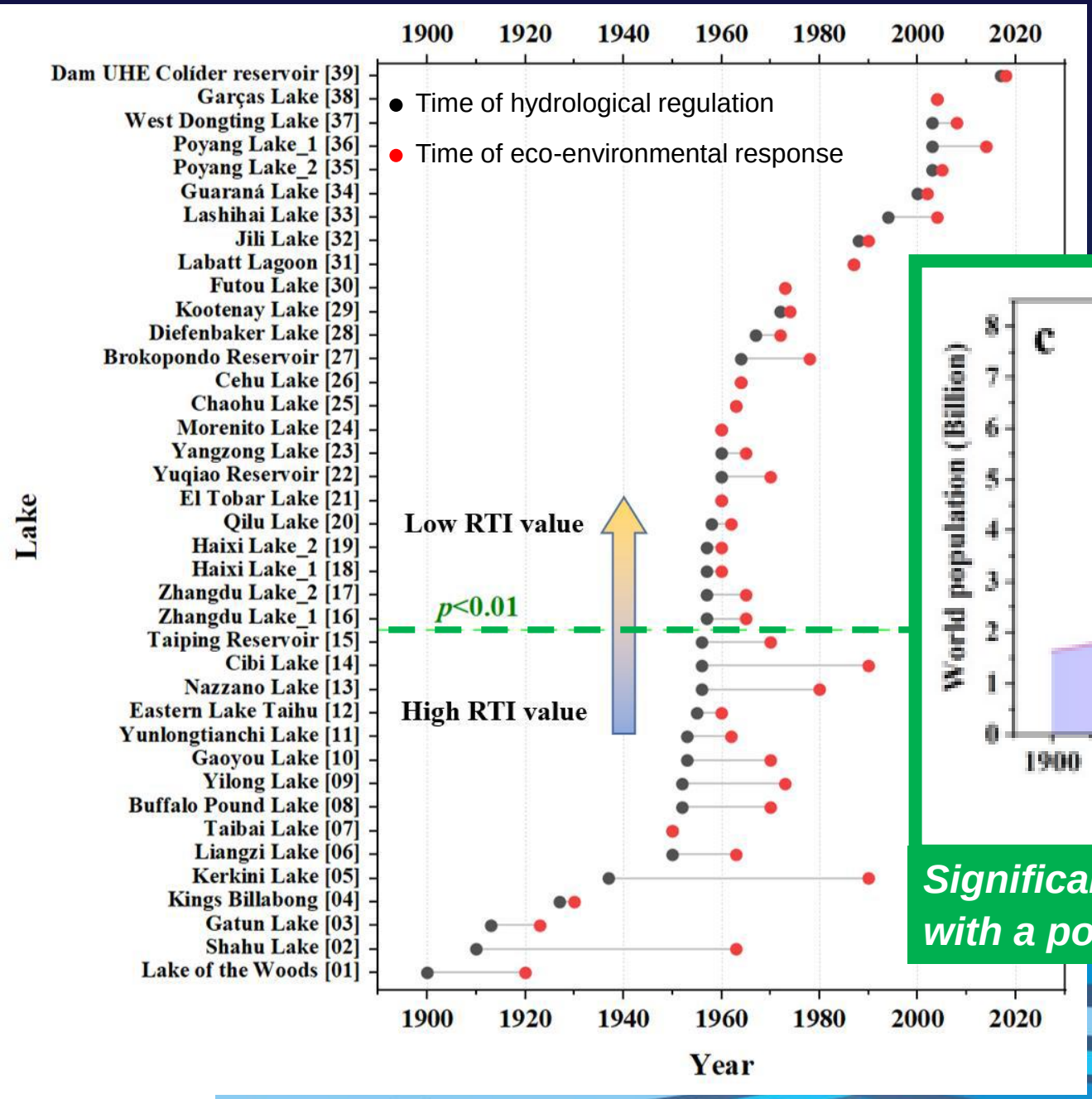


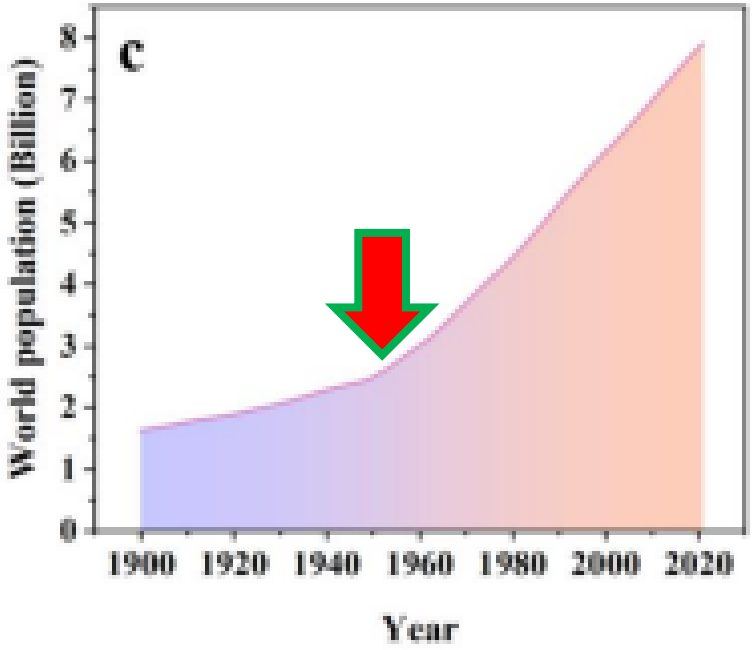
RTI does not change much for biological variables

Liang et al. (unpubl.)



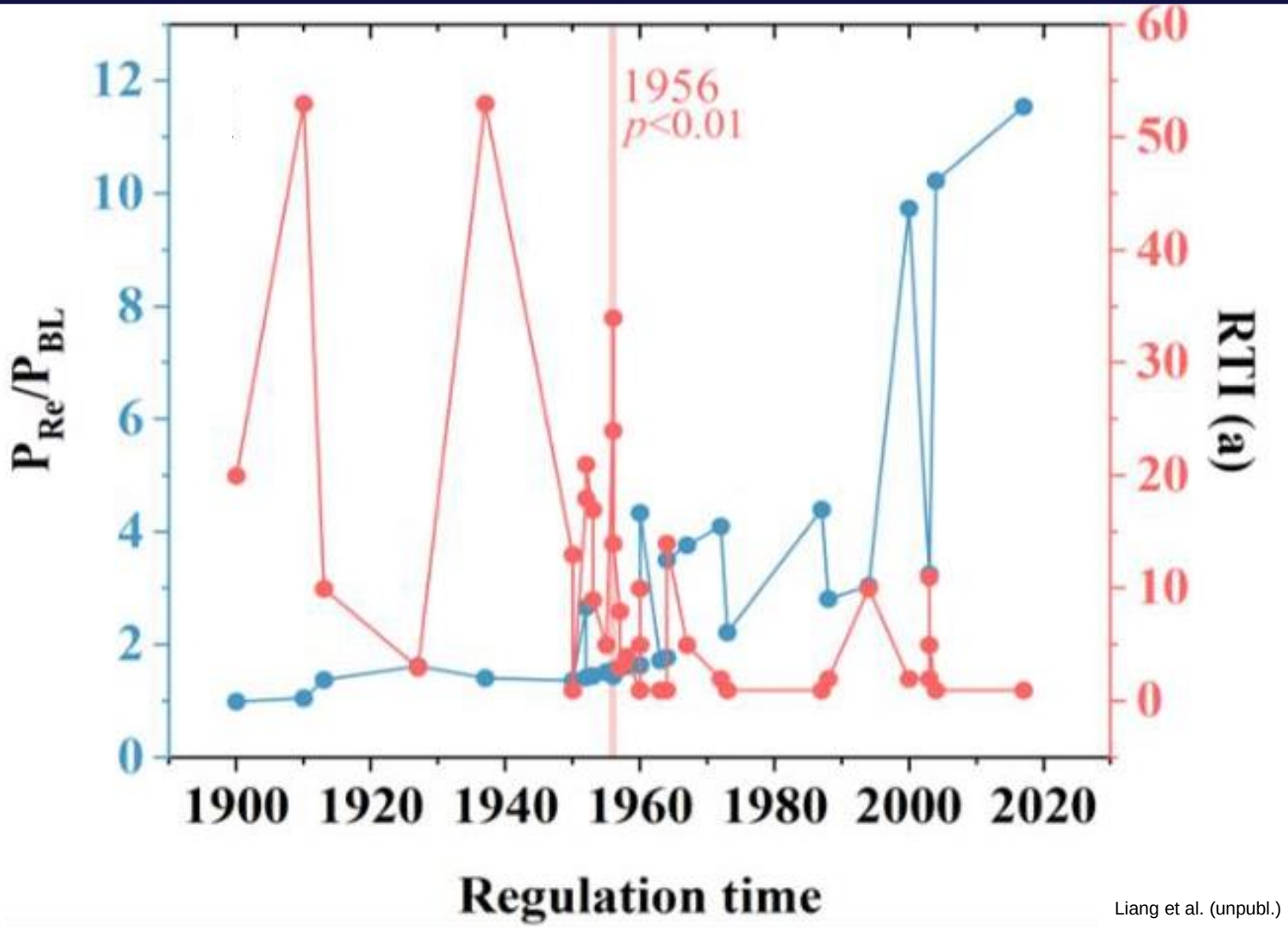
Liang et al. (unpubl.)





Significant shift in RTI coincides with a population surge

Liang et al. (unpubl.)

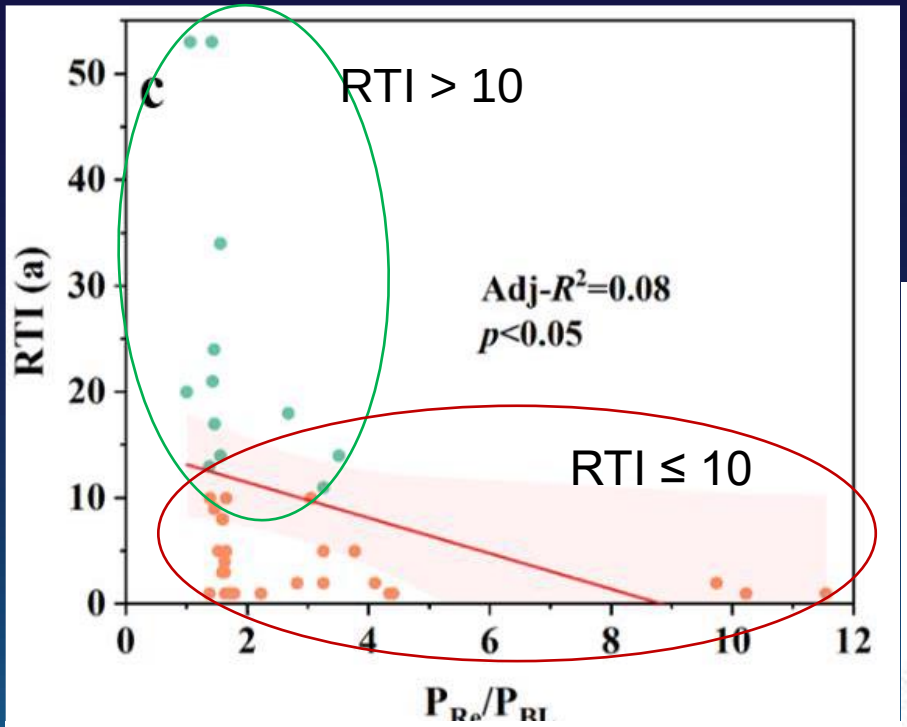


Liang et al. (unpubl.)

P_{Re} = Population at time of regulation

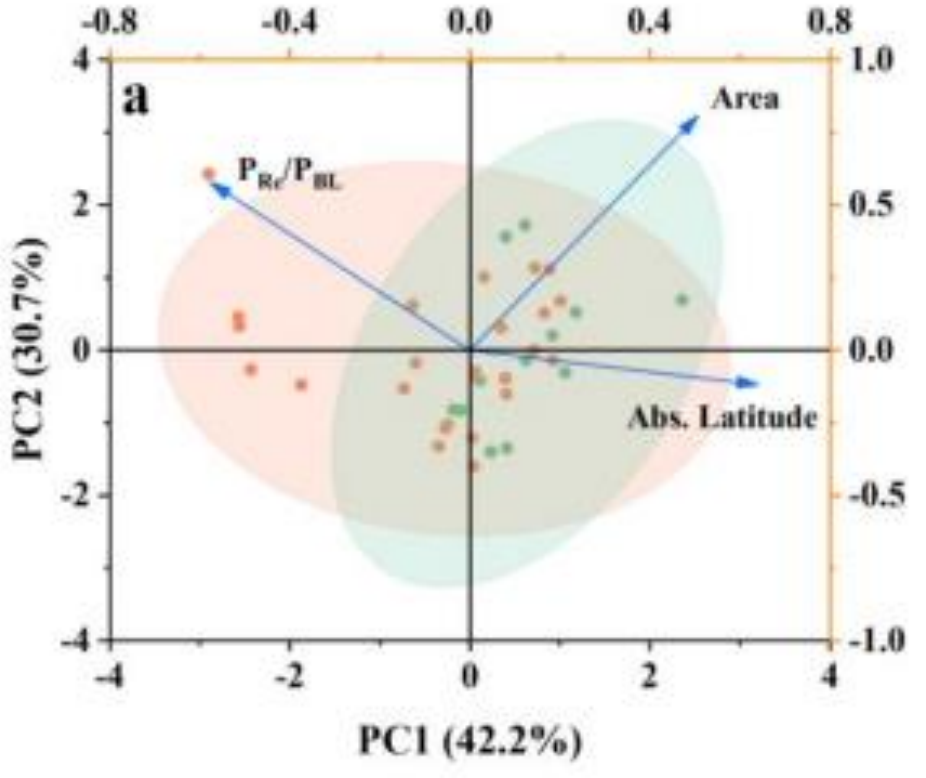
P_{BL} = Baseline population in 1900

Significant decrease in RTI post 1956 driven by population surge



P_{Re}/P_{BL} has a strong effect in lakes with RTI ≤ 10.

Lake area (size) has a strong effect in lakes with RTI > 10.



Liang et al. (unpubl.)

MAIN FINDINGS

- Isolation of rivers and lakes and impoundment often lead to changes in hydrodynamics and water level.
- Prolonged water residence time increases eutrophic or pollution-resistant species.
- Habitat change decreases fish abundance and diversity.
- Water diversion increases dispersal and interactions between native and foreign species.

MAIN FINDINGS (cont.)

- 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, coinciding a population surge.
- Larger lakes can better buffer changes prior to 1956.

IMPLICATIONS

- Different biological indicators can be used to assess short-term (e.g. diatoms) and long-term (e.g. macrophytes) changes.
- Emergence of opportunistic species may nullify restoration effort and lead to further environmental degradation.

IMPLICATIONS (cont.)

- 69% of the world's population experiences some water stress; 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 will prolong 'recovery debt' in ecosystem functions and services

(Moreno-Mateos et al. 2017 Nat. Comm. 8:14163).

THANK YOU!