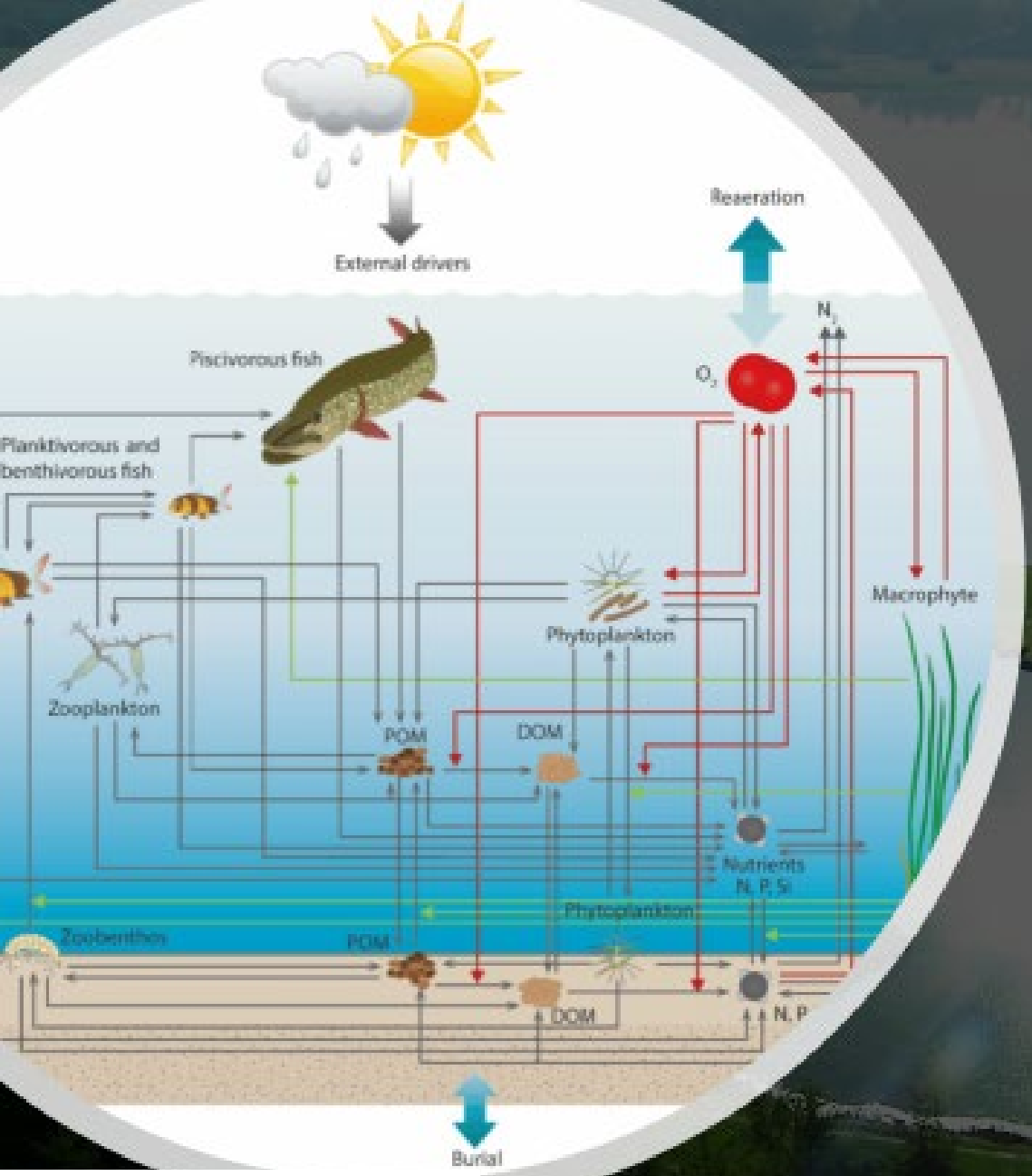

湖库水质水生态管理工具—湖泊生态模型

Dynamic Lake Ecosystem Modelling as supporting tool for drinking water management in lakes and reservoirs

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目录 content

- 湖泊的富营养化和生态修复- Lake eutrophication and restoration
- 湖泊生态模型概要- Lake ecosystem modelling
- WET模型概略- Introduction to WET
- 一维WET模型建模- WET 1D simulation
- WET实例：丹麦天然深水湖- WET case, Lake Fure
- WET实例：青岛棘洪滩水库 – WET case, Jihongtan Reservior
- WET开源应用：数字孪生湖泊 – Open-source WET in LakeTwin

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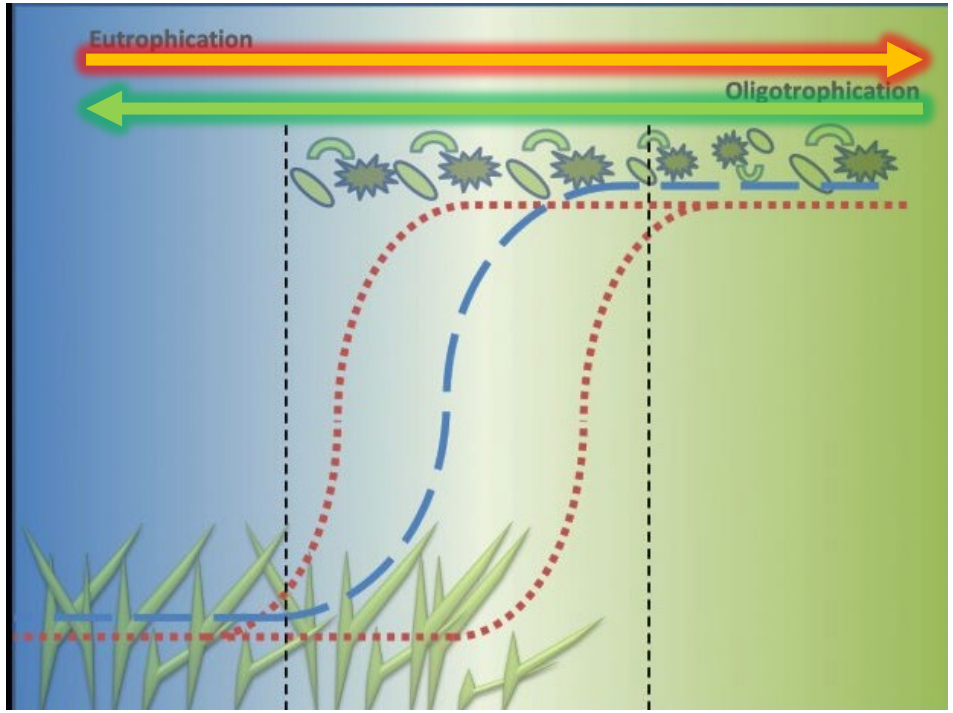
湖泊富营养化-- 湖泊生态系统的良性与恶性循环
Lake Eutrophication--the healthy and evil cycle of lake ecosystem

富营养化– 营养盐源增加
Eutrophication – nutrient load

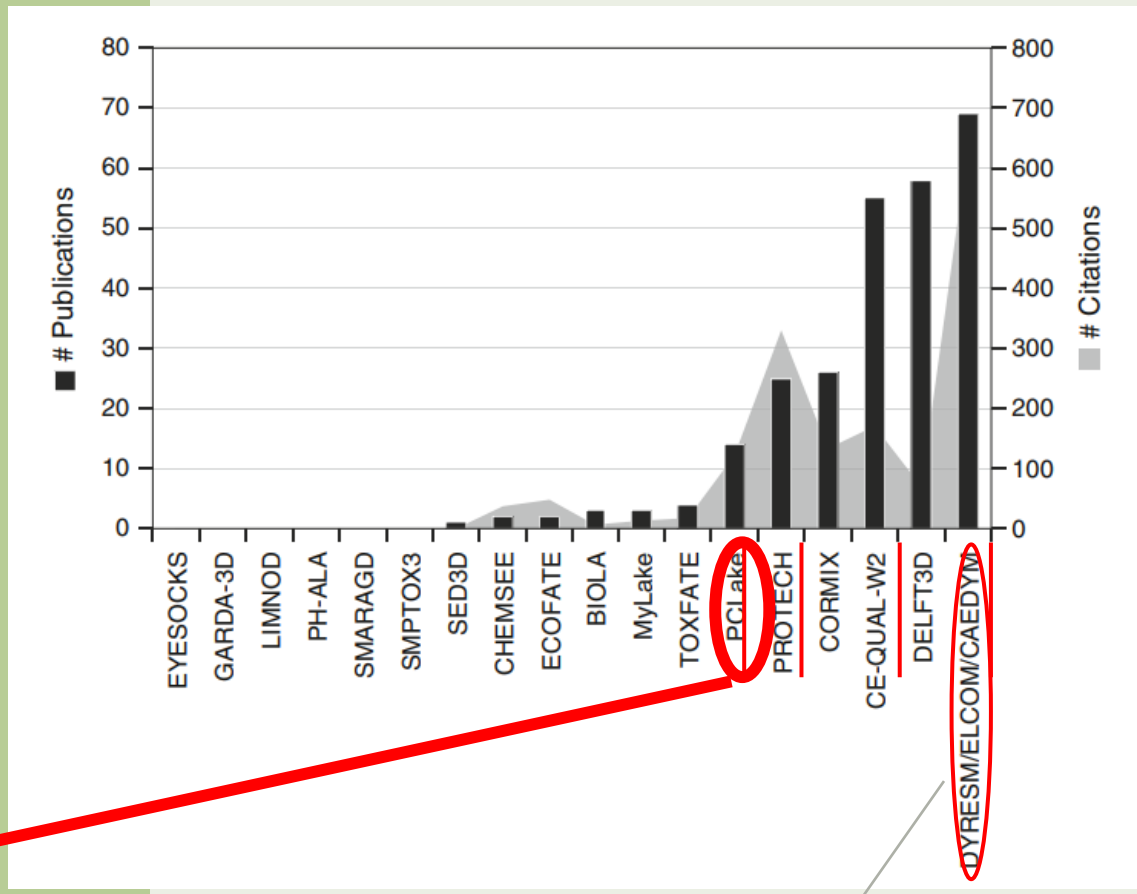
生态修复—营养盐源治理
Restoration – reduced nutrient input



Scheffer, Marten. Ecology of shallow lakes. Vol. 1. London: Chapman & Hall, 1998.
Jeppesen, E 1998, The Ecology of Shallow Lakes - Trophic Interactions in the Pelagial: Doctor's dissertation (DSc). NERI Technical Report, nr. 247, National Environmental Research Institute

水生态模型—WET，针对湖泊富营养化和修复的模型
Water Ecosystem Tool (WET)，ecosystem model for lake eutrophication and restoration

- 生态模型以不同目的开发的模型众多，一次性开发太多
- 三大针对湖泊宏观生态和富营养化过程的模型：
  - AED, PCLAKE, WET
- 水动力与水生态模型发展不平衡
- WET改进了PCLake，克服了以上不足



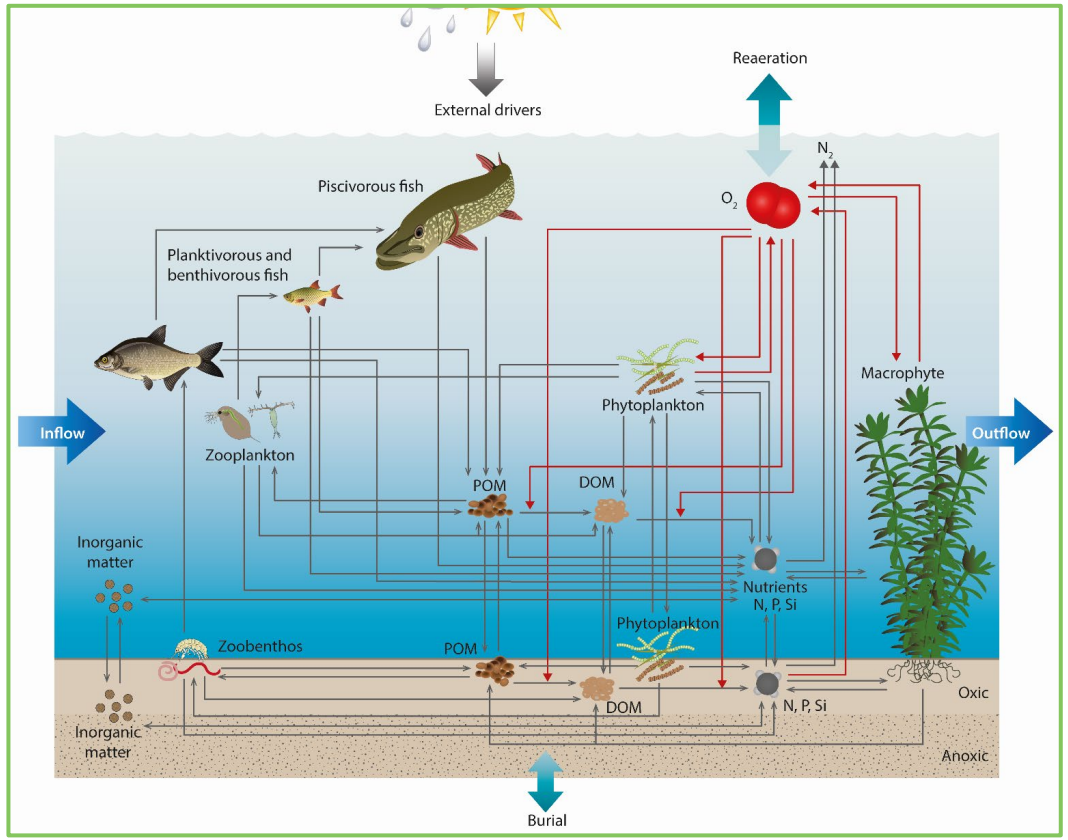
PCLake redeveloped into FABM-PCLake (By F.Hu), WET0 .1

Became open source, and redeveloped into GLM-AED

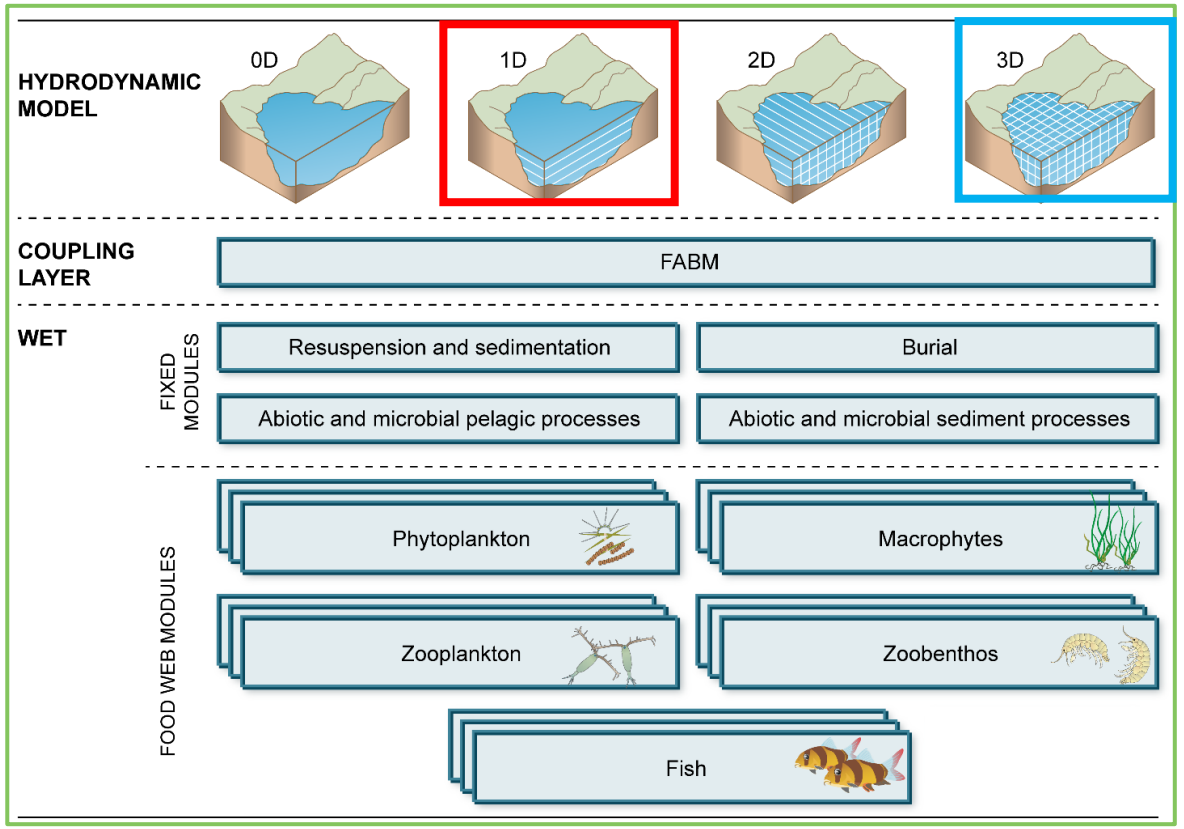
- **Hu, F**, et al. "FABM-PCLake–linking aquatic ecology with hydrodynamics." *Geoscientific Model Development* 9.6 (2016): 2271-2278.
- Trolle, D., Hamilton, D.P., Hipsey, M.R. *et al.* A community-based framework for aquatic ecosystem models. *Hydrobiologia* **683,** 25–34 (2012). https://doi.org/10.1007/s10750-011-0957-0
- Mooij, W.M., Trolle, D., Jeppesen, E. *et al.* Challenges and opportunities for integrating lake ecosystem modelling approaches. *Aquat Ecol* **44,** 633–667 (2010). https://doi.org/10.1007/s10452-010-9339-3

水生态模型—WET概述
overview of Water Ecosystem Tool (WET)

FABM-PCLake → WET



WET—1D and 3D framework



- **Hu, F**, et al. "FABM-PCLake–linking aquatic ecology with hydrodynamics." *Geoscientific Model Development* 9.6 (2016): 2271-2278.
- Schnedler-Meyer, N. A., Andersen, T. K**., Hu, F. R. S**., Bolding, K., Nielsen, A., and Trolle, D.: Water Ecosystems Tool (WET) 0.1.0 – a new generation of flexible aquatic ecosystem model, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2021-366, in review, 2022.

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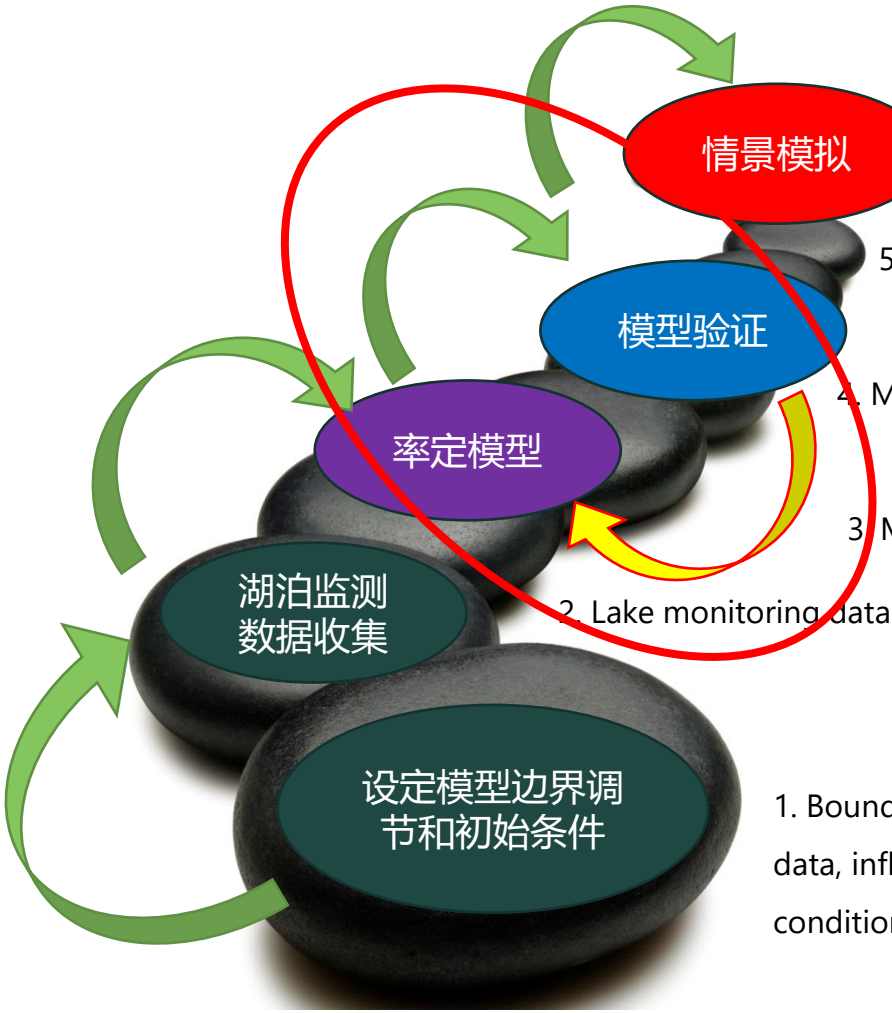
WET一维建模流程
WET 1D simulation set-ups



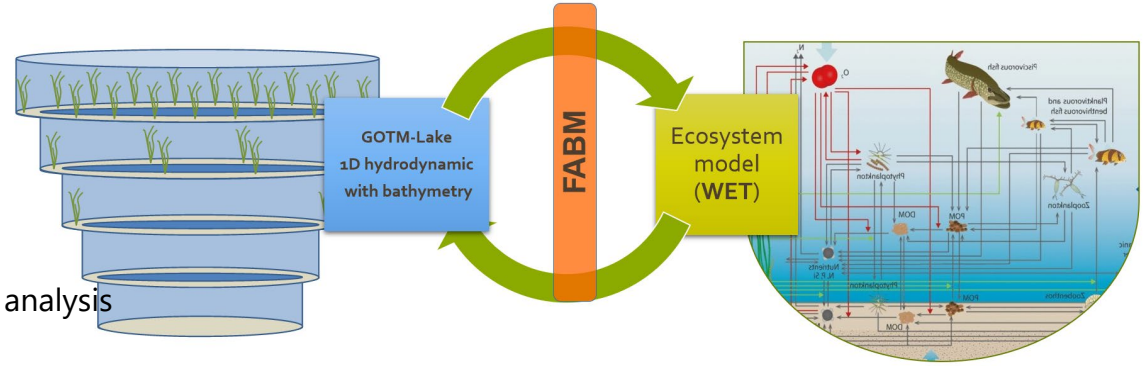
5. Ready for scenarios analysis

4. Model validation

3. Model calibration

2. Lake monitoring data collection

1. Boundary conditions (metrological data, inflows and outflows) and initial conditions



模型率定与验证使用 不同组的湖泊监测数据进行模型与数据的比较，需要往复进行，验证不通过需要重新验证，一直到验证通过

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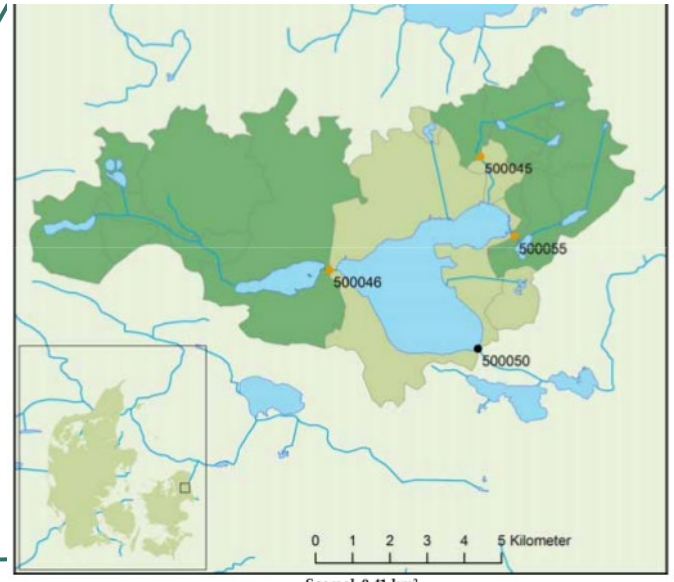
WET实例--丹麦深水湖生态修复--湖底泵氧过程模拟
WET application—oxygenation of Lake Fure, Denmark



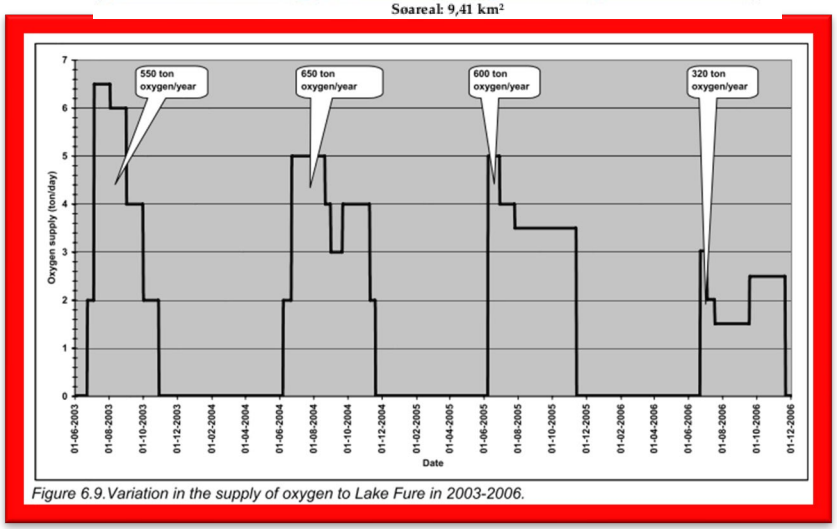
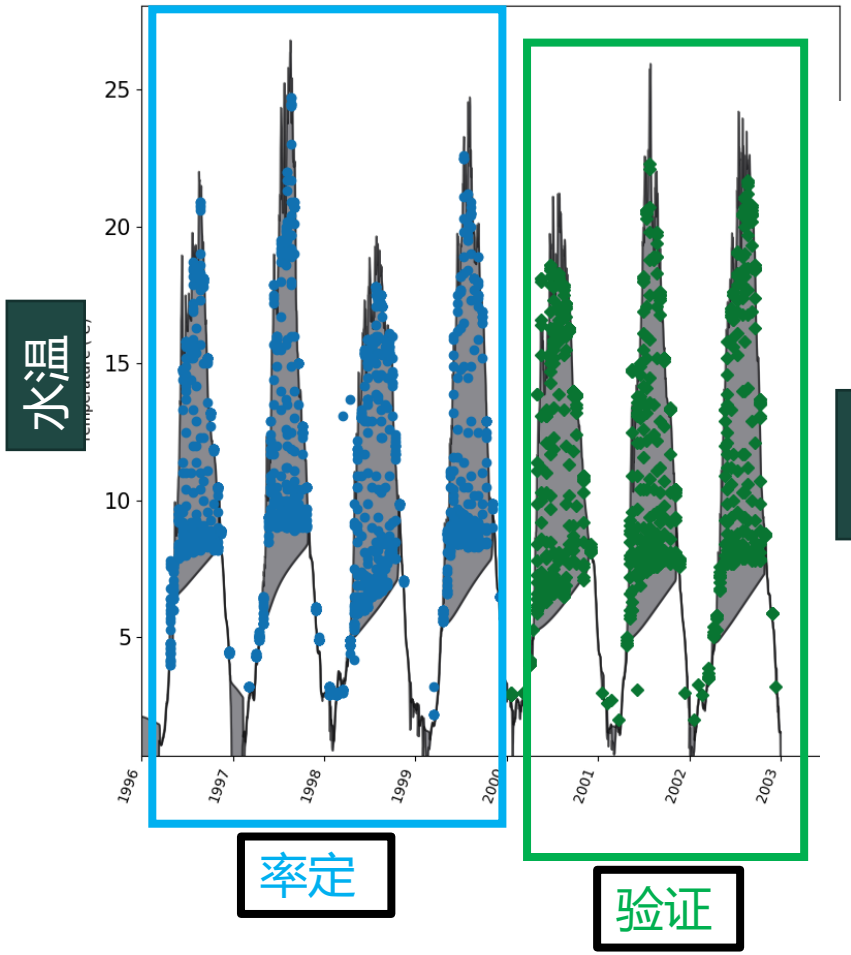


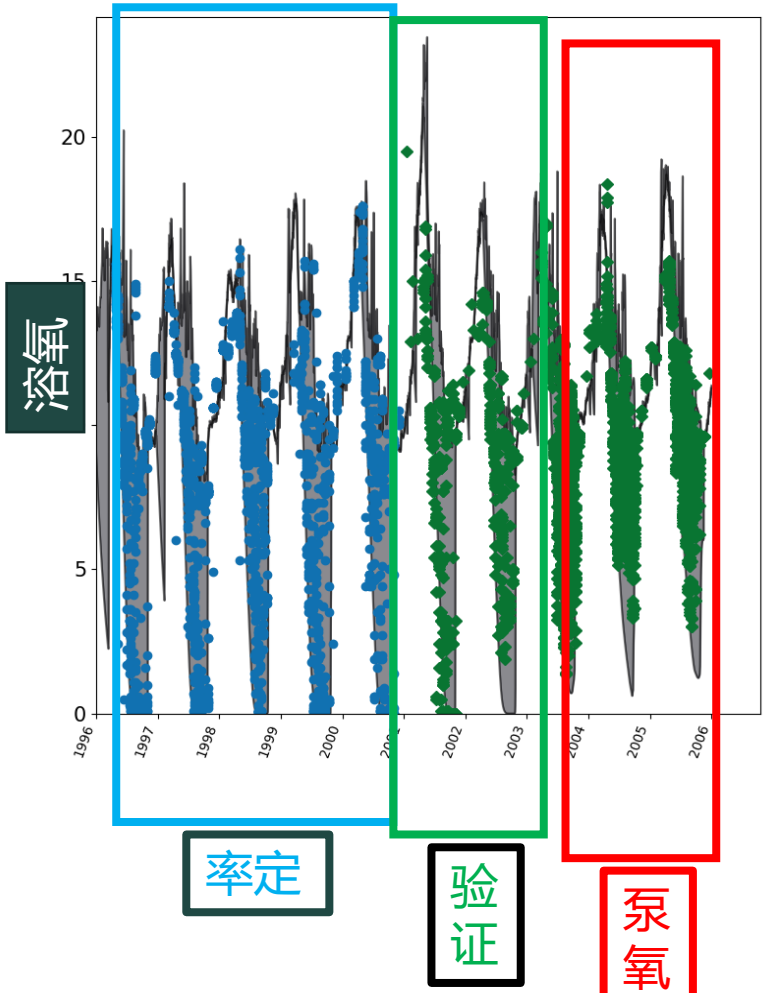
Figure 6.9.Variation in the supply of oxygen to Lake Fure in 2003-2006.

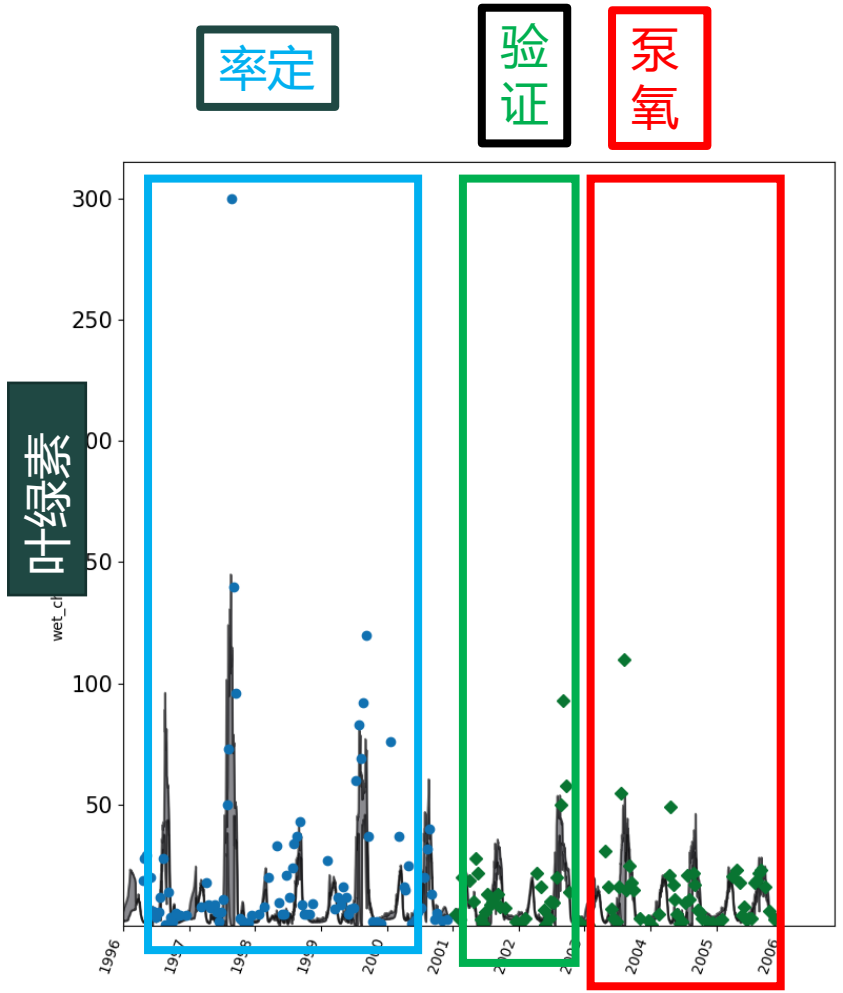
- 典型北欧温带海洋气候区深水湖
- 丹麦最深、北欧湖泊生物多样性排名第一
- 最深37. 7m，平均水深7. 4m, 湖面面积 9.4 km^2 ，流域面积69.6 km^2
- 2条入湖河流，一条出湖河流
- 2003年污染源调查，磷的外源2吨每年，内源释放15吨每年。
- 2003年开始进行湖泊生态修复主要包括：对植食性鱼类的捕捞和湖底厌氧区泵氧
- 本研究主要关注泵氧对该湖生态系统的影响

- **Hu, F.R.S**, et al. Does Lake Fure need respirator any longer? -- diagnosis and prognosis from a 1-D aquatic ecosystem model, in prep.

湖泊水温、溶氧和叶绿素模拟 –模型率定与验证
Temperature& oxygen & *chla*- Model calibration and validation

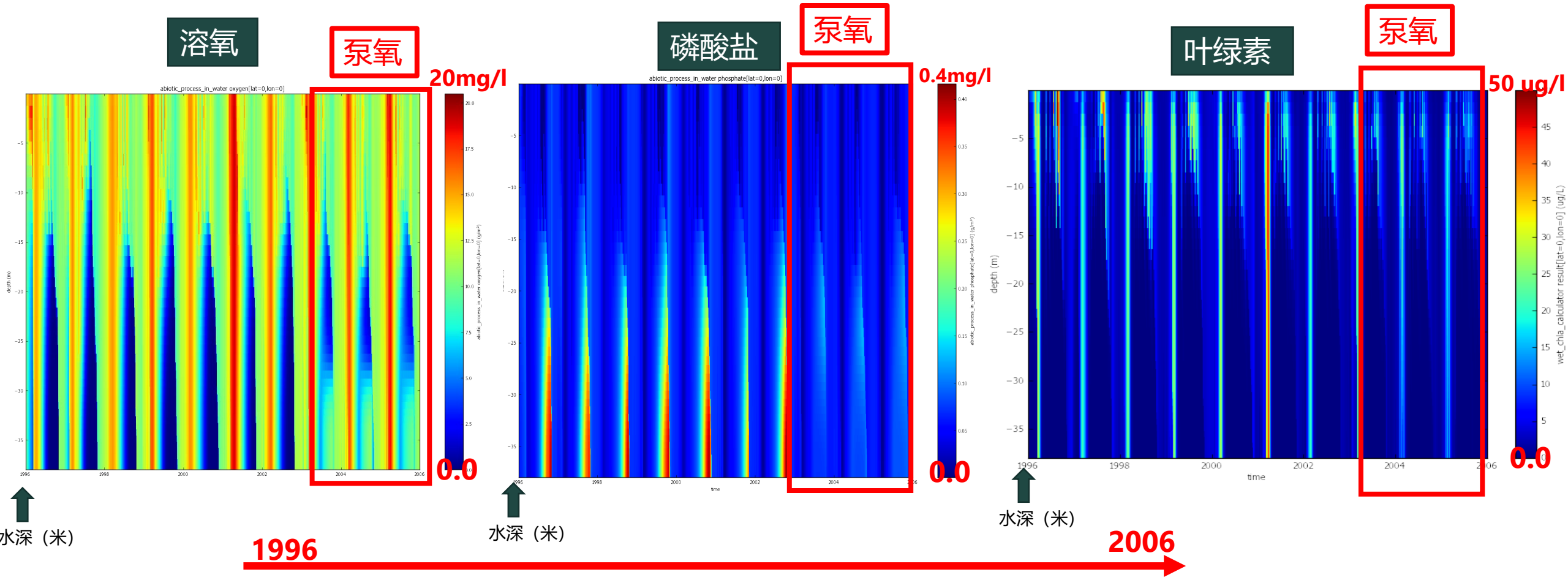






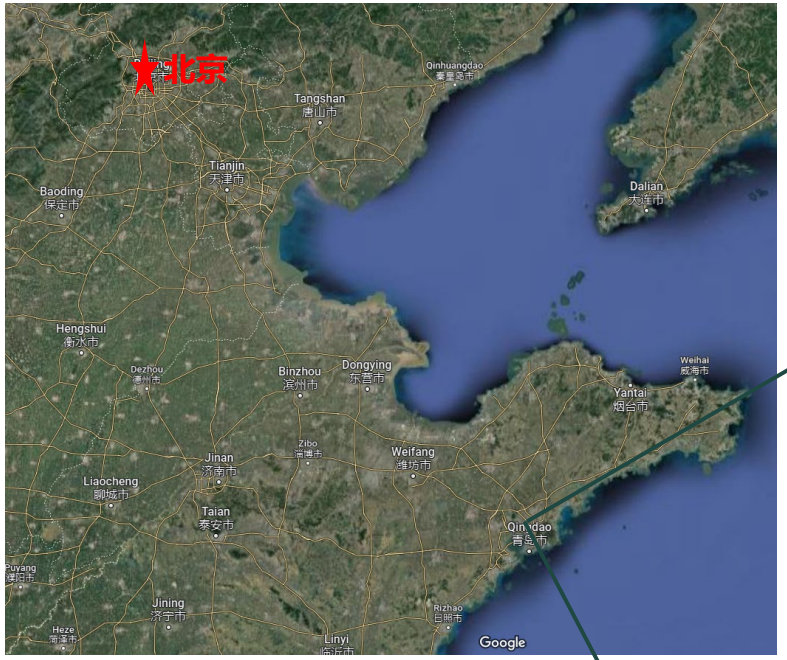
- **Hu, F.R.S**, et al. Does Lake Fure need respirator any longer? -- diagnosis and prognosis from a 1-D aquatic ecosystem model, in prep.

溶氧，磷酸盐和叶绿素水深纵向模拟图
Oxygen,phosphate and *chla*，vertical profile



- **Hu, F.R.S**, et al. Does Lake Fure need respirator any longer? -- diagnosis and prognosis from a 1-D aquatic ecosystem model, in prep.

WET实例，棘洪滩水库饮用水水质藻类动态模拟
WET application, nutrient loads and phytoplankton dynamics in a Chinese reservoir

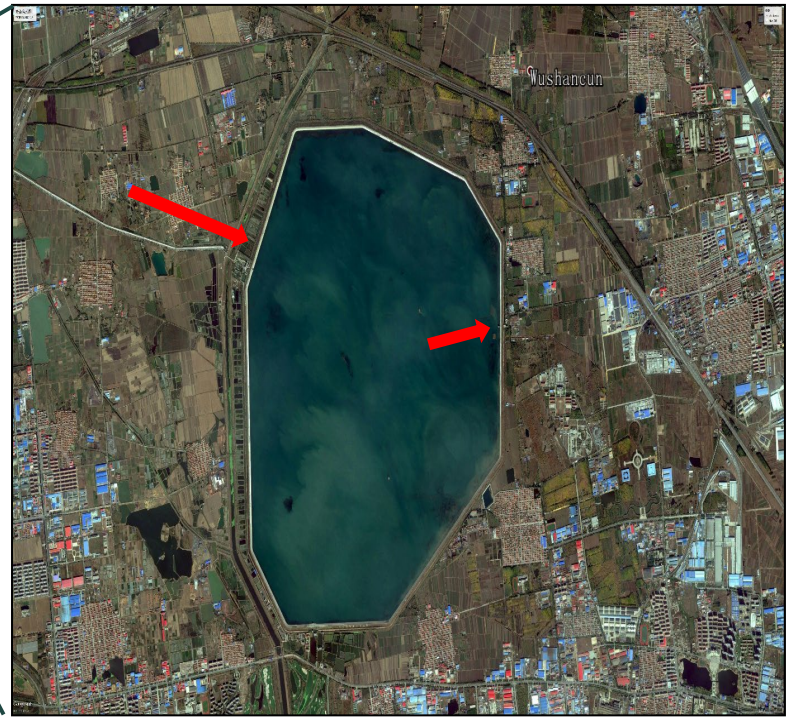


模拟期限：2000-2013

模型预热：2000-2003

模型校准：2004-2011

模型验证：2012-2013



总库容：1.57亿立方米

调蓄库容：1.11亿立方米

设计水位：14.20 m

围坝长：14.23 km

坝顶高程：17.24 m

最大坝高：15.24 m

库区面积：14.42 km^2

入流TN: 1.4-3.6 mg/L

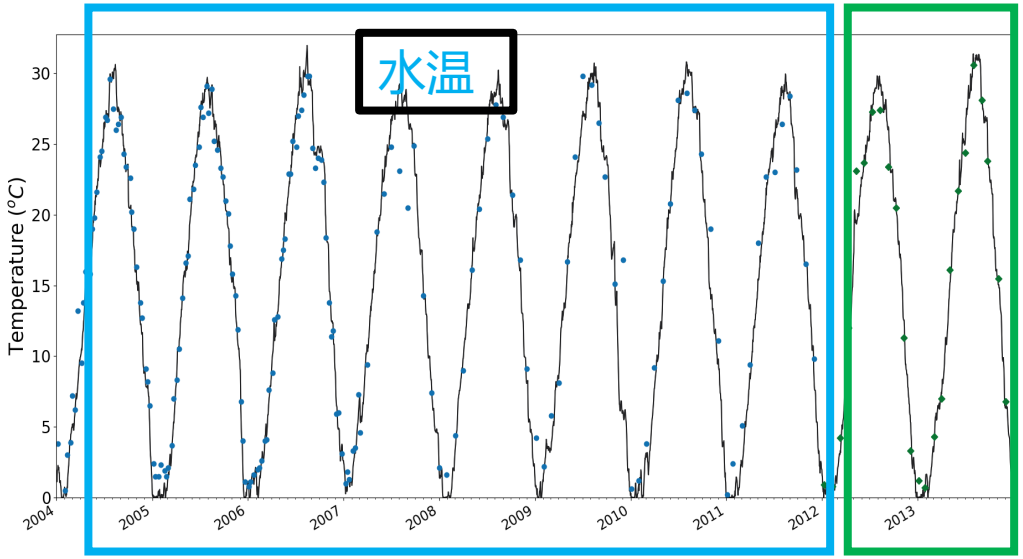
入流TP: 0.01-0.05 mg/L

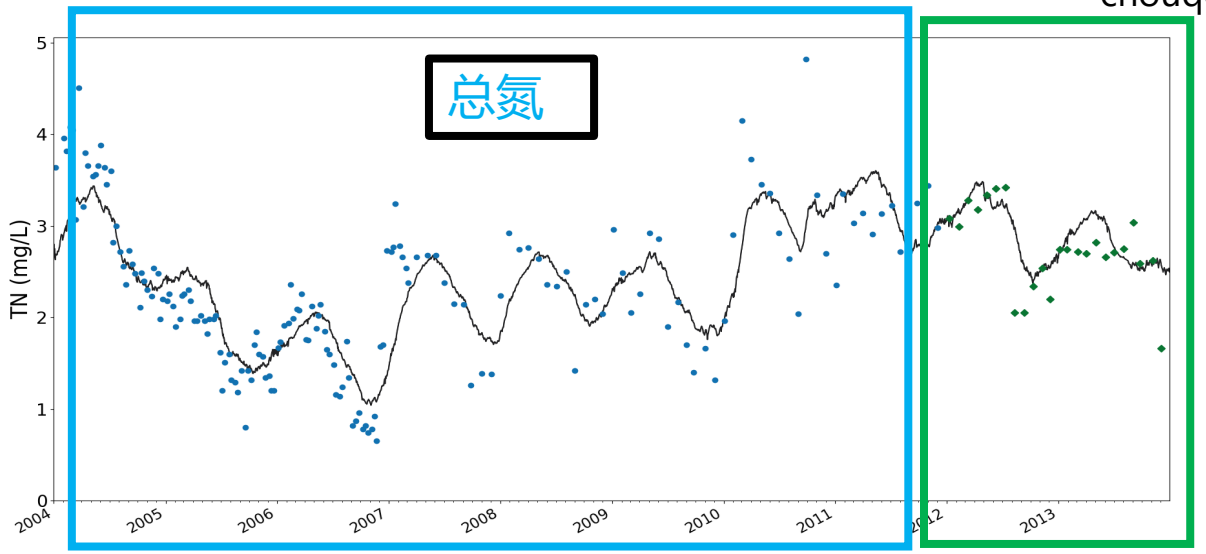
chouqc@ihb.ac.cn

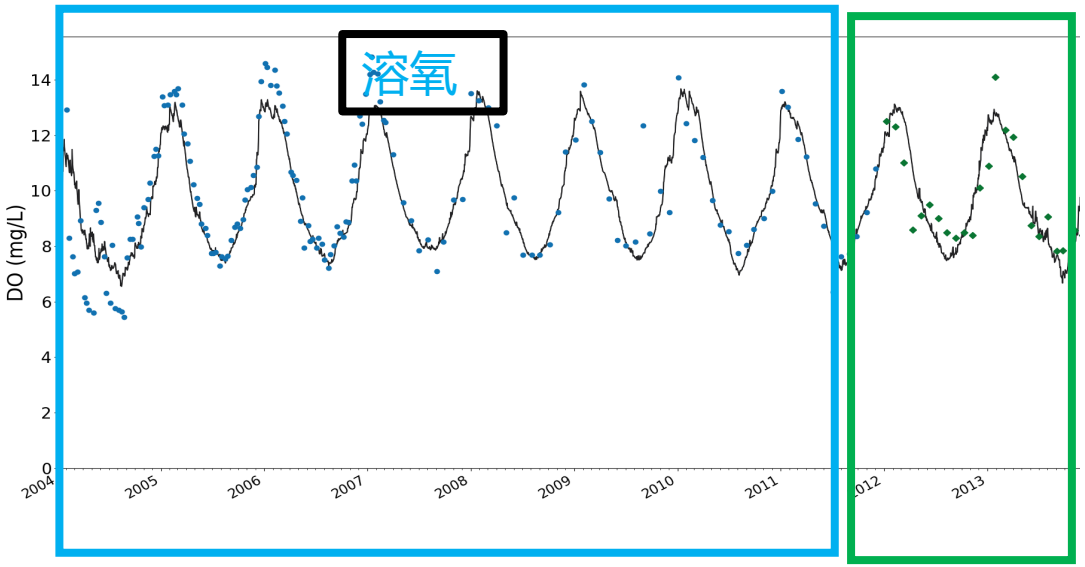
- **Chou Q**, Nielsen A, Andersen TK, **Hu F**,et.al, Assessing Impacts of Changes in External Nutrient Loadings on a Temperate Chinese Drinking Water Reservoir.Front. Environ. Sci. 9:632778. doi: 10.3389/fenvs.2021.632778

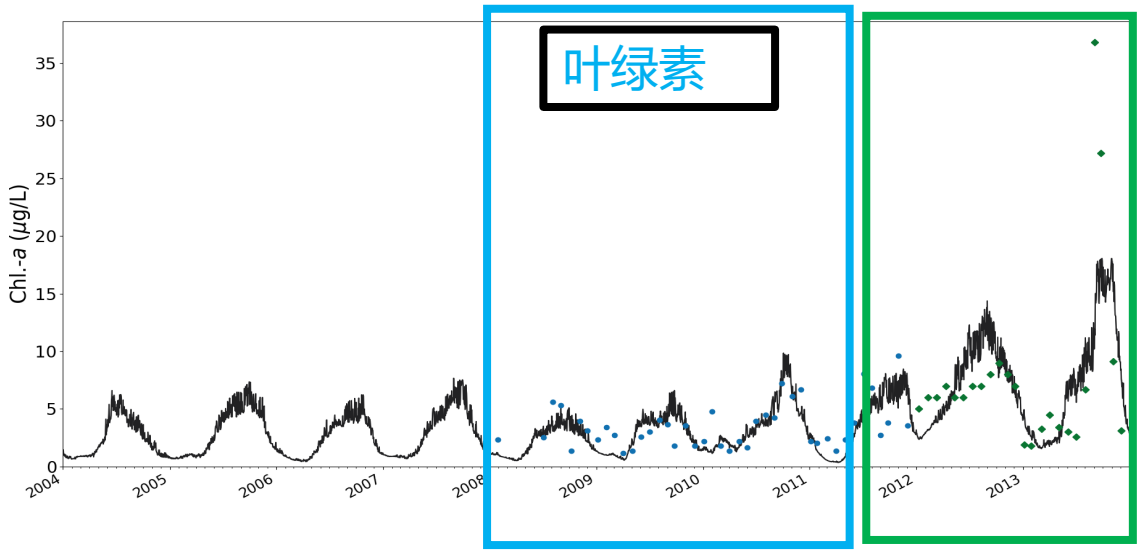
湖泊水温，溶氧，总氮和叶绿素模拟 –模型率定与验证
Temperature & oxygen& TN& chla- Model calibration and validation

chouqc@ihb.ac.cn









• **Chou Q**, Nielsen A, Andersen TK, **Hu F**,et.al, Assessing Impacts of Changes in External Nutrient Loadings on a Temperate Chinese Drinking Water Reservoir.Front. Environ. Sci. 9:632778. doi: 10.3389/fenvs.2021.632778

情景模拟—营养盐负荷变化
Scenario analysis –nutrient loading changes

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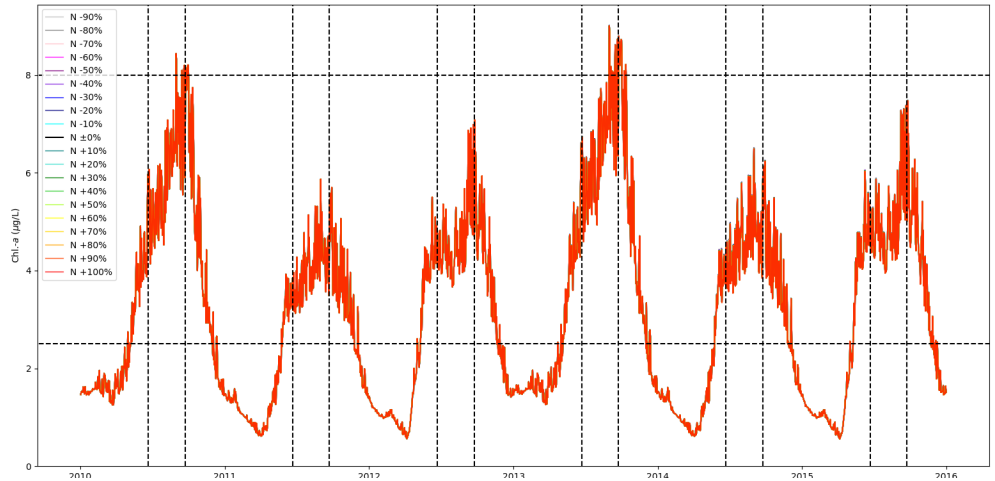
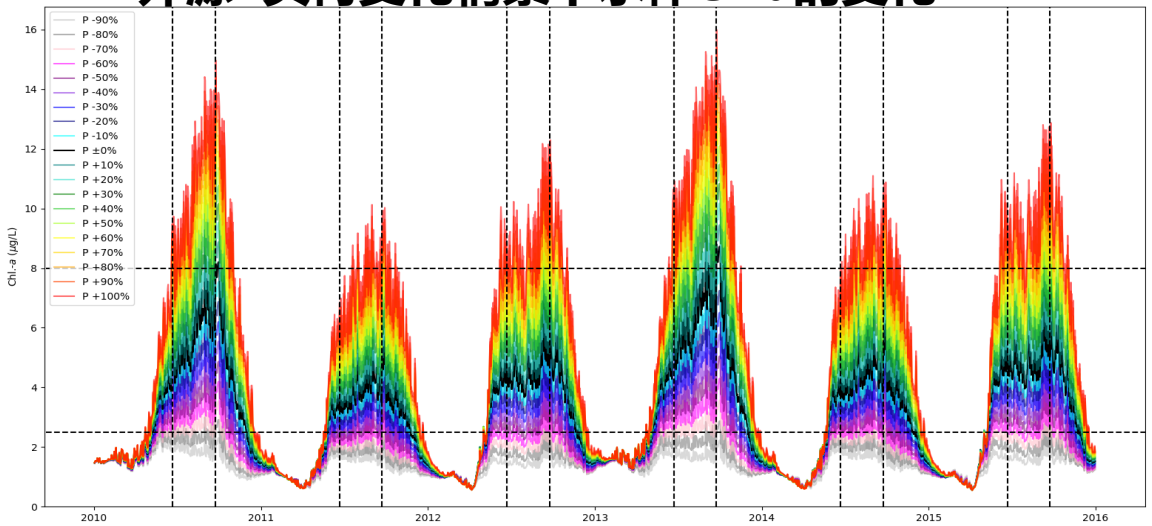
外源N负荷变化情景下水体Chla的变化

Chla



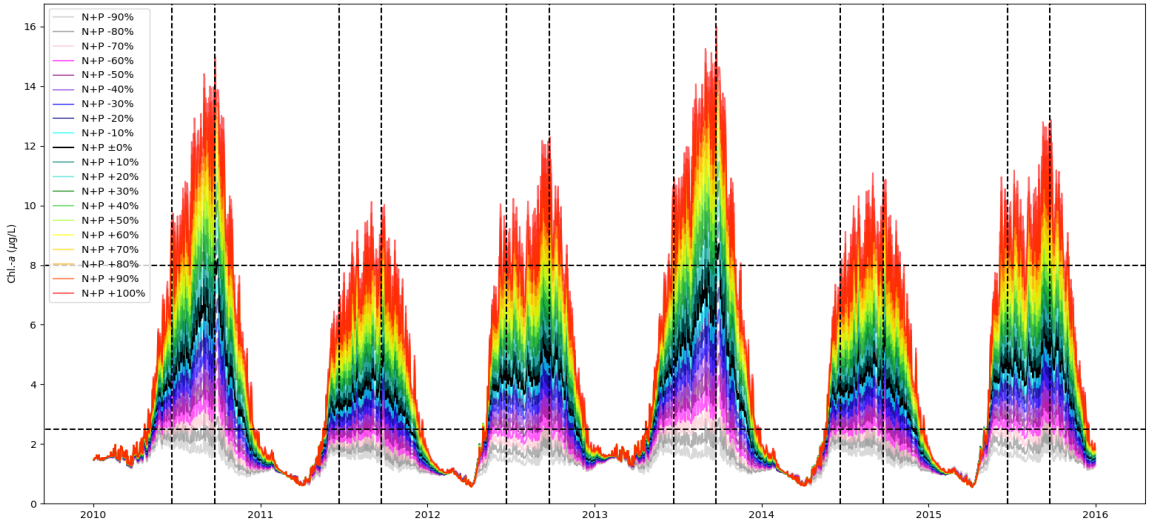
外源P负荷变化情景下水体Chla的变化

Chla



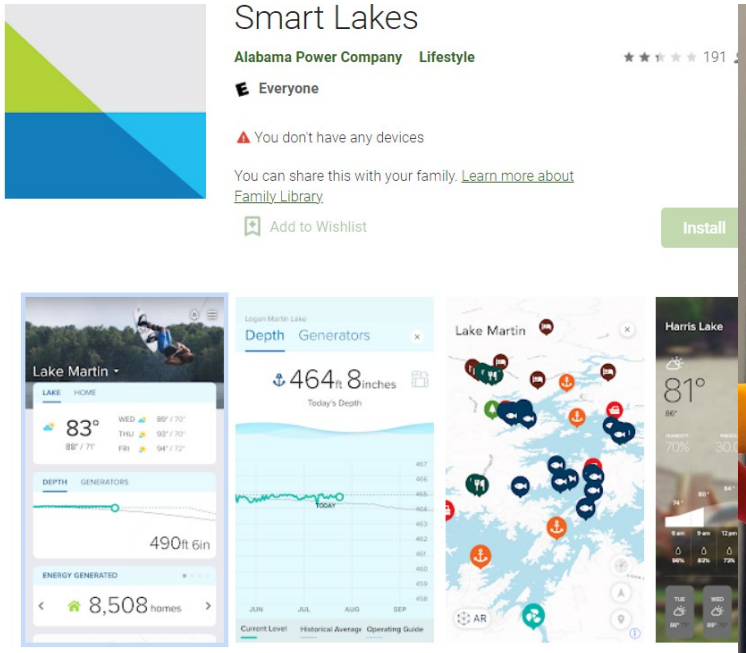
外源N+P负荷变化情景下水体Chla的变化

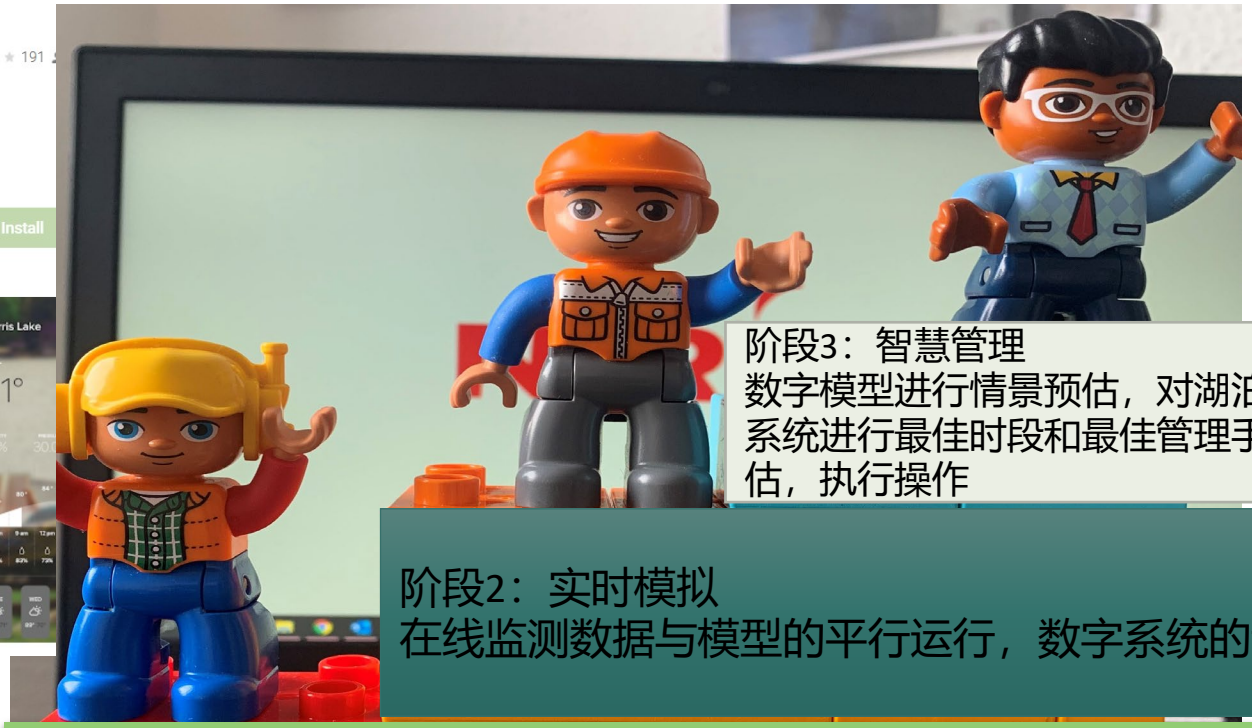
Chla



- **Chou Q**, Nielsen A, Andersen TK, **Hu F**,et.al, Assessing Impacts of Changes in External Nutrient Loadings on a Temperate Chinese Drinking Water Reservoir.Front. Environ. Sci. 9:632778. doi: 10.3389/fenvs.2021.632778

开源模型在湖泊智慧环保系统中的应用
--NIRAS 孪生湖泊项目经验

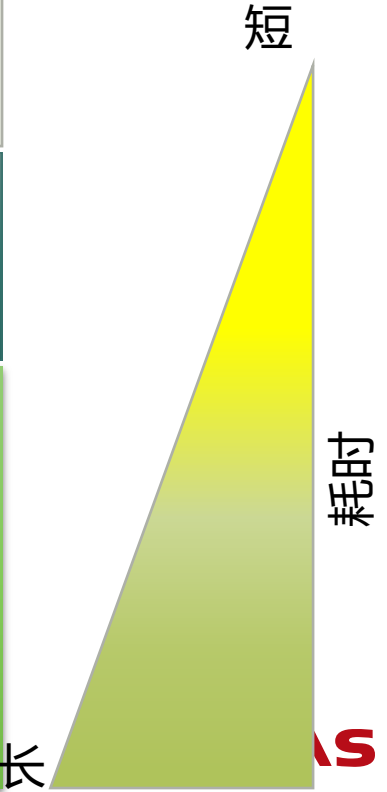




阶段3：智慧管理
数字模型进行情景预估，对湖泊生态系统进行最佳时段和最佳管理手段预估，执行操作

阶段2：实时模拟
在线监测数据与模型的平行运行，数字系统的调试

阶段1：数字模型构建
湖泊水文、生态调查，常规水文、生态监测系统设计，数据库建立，湖泊生态模型率定与验证，可视化展示界面开发 （此阶段耗时耗力，并且非一日之功，要注重已有模型和技术引入）



西子三千个，群山已失高，峰峦成岛屿，平地卷波涛！

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+ 45 4299 5369

谢谢！ Thank you!