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# Pico-Talk

## Forty years record of metalimnetic oxygen minimum (MOM) in Germany's largest drinking water reservoir

### What is the MOM?

- A negative heterograde oxygen profile
- Undercompensated oxygen demand at metalimnion
- Causes of MOM have been discussed controversially

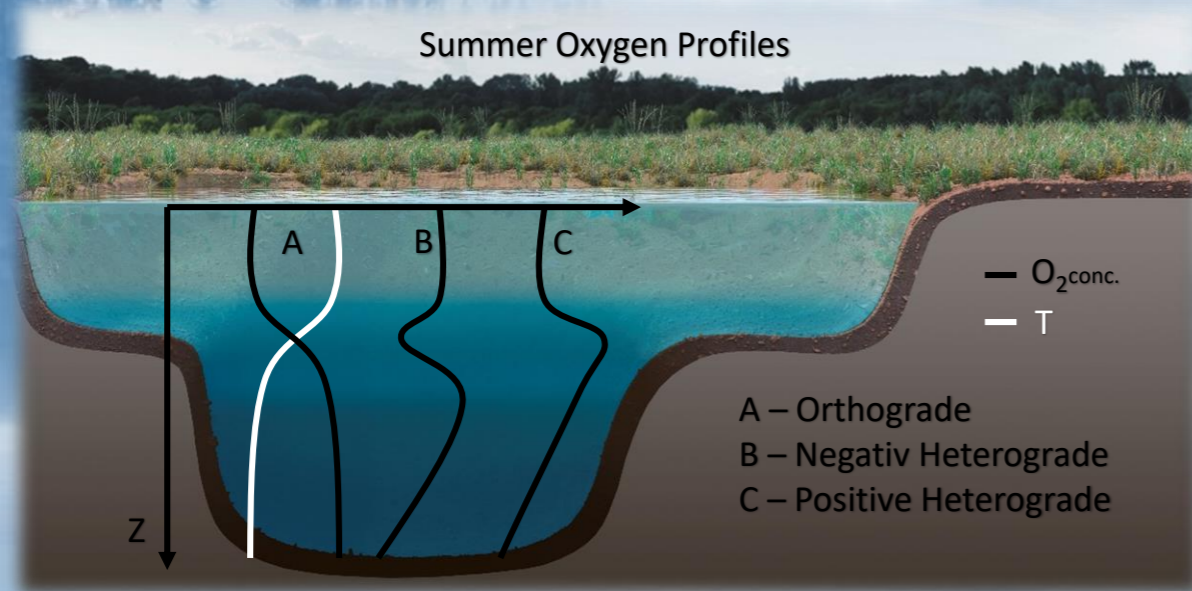


Figure 1

### Approach:

- Systematically analyzed 40 years of the available data to characterize the inter annual development of the MOM with respect to existing trends and to identify relevant environmental and management factors
- Linear regression model and multiple linear regression model
- Lake physics modeled with CE-QUAL-W2 to close gaps

### Working hypothesis:

Increasing surfacewater temperatures in summer (Mai to October) as well as an increasingly prolonged summer stratification are negatively effecting metalimnetic oxygen concentrations.

### Results:

- Increasing trend of summer surfacewater temperature
- Stratification duration is increasing due to earlier onset
- MOM is intensifying over time
- Stratification duration shows no effect on MOM
- Multiple linear regression model of MOM explained by blooming algae and bacteria in combination with wind speed was able to reproduce the MOM from 2009 to 2019

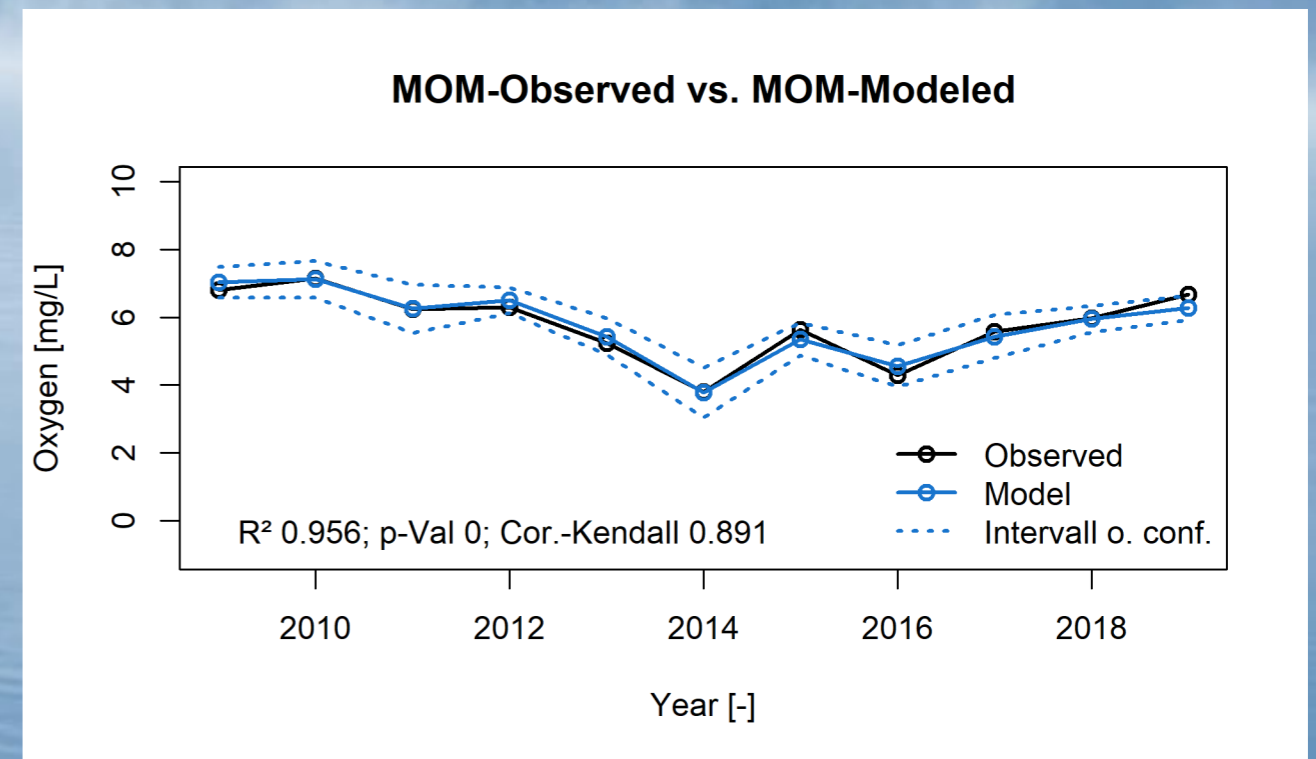


Figure 2

### Take home:

-Clear evidence that metalimnetic oxygen minimum in Rappbode Reservoir is caused by bacterioplankton, supported by phytoplankton blooms in the euphotic zone



## What is the MOM?

- A negative heterograde oxygen profile (please see Fig. 1 “B”) occurring in lakes and reservoirs:
  - Undercompensated oxygen demand at metalimnion

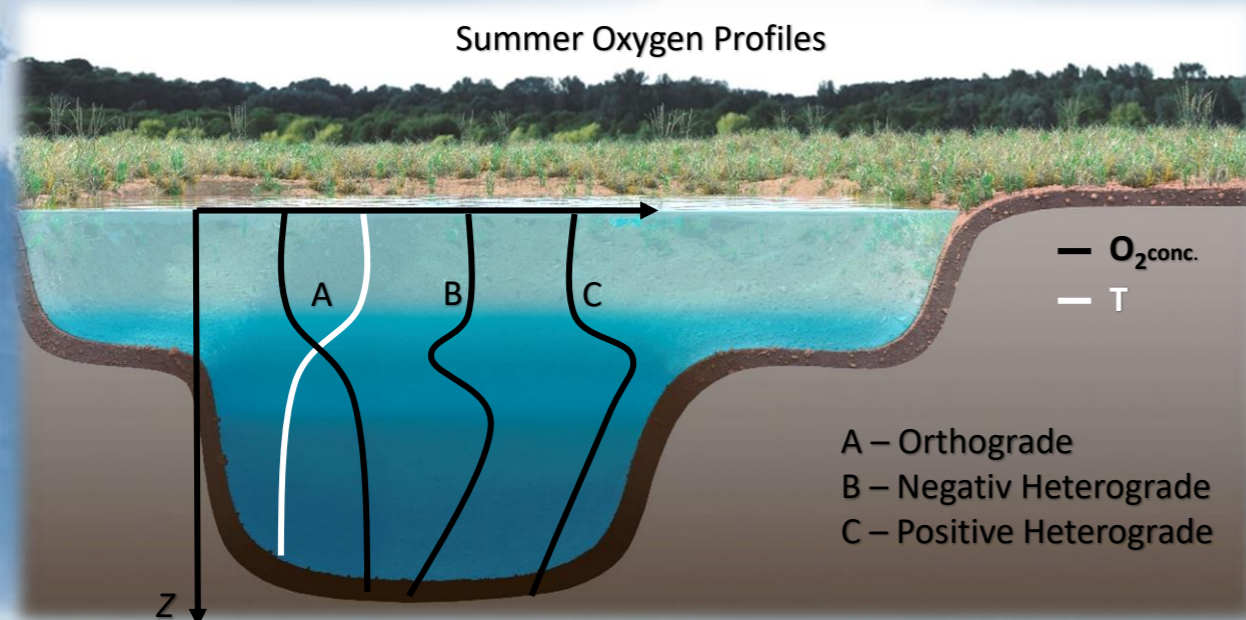


Figure 1

## Some facts about MOM!

- Likely appears between mid May and mid June (approximately one month after stratification onset).
- Disappears with eroding metalimnion between August and October.
- The depletion can be intense and so cause totally anoxic conditions.
- Phenomenon usually can be found within the upper third of thermal density gradient.
- Appears in stratified lakes and reservoirs of any trophic state.
- In some cases the oxygen minimum is accompanied by overlaying metalimnetic oxygen maximum.
- In some cases early metalimnetic oxygen maximum (May) is followed by oxygen minimum.
- In German reservoirs low light adapted filamentous cyanobacteria with mixotrophic capabilities (*Planktothrix rubescens*) often accompanies metalimnetic oxygen minimum.

- Causes of MOM are not fully understood. Likely causes:
  - Sediment oxygen demand of banks, bays and shallow areas of lakes propagates through metalimnion of the whole water body.
  - Interflow of any kind (upwelling, inflow) loads metalimnion with less oxygenated water, organic material or reduced chemical substances.
  - Production in the euphotic zone supplies metalimnion with organic matter.
  - High abundance of non-migrating copepods in metalimnion.
  - A combination of several of the before mentioned processes.

## Why is it important to find the causes?

- Dissolved oxygen is a central player in water quality management of lakes and reservoirs.
- Causes of MOM have been and still being discussed controversially.

## This study:

The causes of MOM have been discussed controversially. The Rappbode Dam, Germany's largest drinking water reservoir, forms a MOM every year and long-term observations indicate that the oxygen deficit may have increased in recent years. Although the data cover a long period (40 years), they are very heterogeneous in terms of temporal and spatial resolution. Our study aims at systematically analysing the available data to characterize the interannual development of the MOM with respect to existing trends and to identify relevant environmental and management factors.

## Working hypothesis:

- Increasing surfacewater temperatures in summer (May to October) as well as an increasingly prolonged summer stratification are negatively effecting metalimnetic oxygen concentrations.



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# Methods

## The Data

- Rappbode Reservoir data reach back to 1961 (first 20 years rejected; due to missing variables)
- Data provided by:
  - Fernwasserversorgung Elbaue-Ostharz GmbH
  - Helmholtz Centre for Environmental Research
- From 1980 to 2009 only wet chemical sampling
- After 2008 wet chemical plus probe sampling
  - OTT HydroMet, Hydrolab DS 5, Kempten, Germany
  - Xylem YSI EXO2 Multiparameter Probe, Rye Brook, USA)
- Monthly sampling: 1980 to 2009
- Weekly sampling: 2009 to 2019
- Bi-weekly sampling: 2019 to 2021
- Data contains:
  - Chemical analyses
  - Plankton counts
  - Probe data
- Weather data provided by DWD

## The Approach

- Linear regression model to find trends
- Multiple linear regression to find MOM predictors
  - For data after 2008
  - Model comparison (AIC, p-value, R<sup>2</sup> )

## Site of study

Rappbode Reservoir, Harz Mountains, Germany



Figure 2: Picture of Rappbode Reservoir; Ref.: Sieber, H. U., Talsperren in Sachsen-Anhalt; Talsperrenmeisterei des Landes Sachsen-Anhalt 1994



Figure 3

- Dimictic
- Mesotrophic
- Residence time: 344 d
- Surface area: 3.9 km<sup>2</sup>
- Elevation: ~ 400 m ASL
- Volume: 110 x 10<sup>6</sup> m<sup>3</sup>
- Mean depth: 28.6 m
- Maximum depth: 89.0 m
- Catchment area: 269 km<sup>2</sup>

# Results

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## Water Temperature (Fig. 4 "A")

- Obviously increasing epilimnion (0m and 5m) temperature

## Metalimnetic oxygen minimum concentration (Fig. 4 "B")

- Minimum concentration is slightly decreasing over time

## Stratification (Fig. 4 "C")

- Duration is increasing due to earlier stratification onset
- Duration is not related to MOM

## Multiple linear regression model of MOM (Fig. 4 "D")

- was able to reproduce the MOM from 2009 to 2019
- 2020 was treated as outlier due to Cooks Distance plot and limnological conclusions

$$y = -22.67\beta_1 - 2.40\beta_2 + 2.39\beta_3 - 0.50$$

- |             |                    |                        |         |     |
|-------------|--------------------|------------------------|---------|-----|
| • $\beta_1$ | Planctomycetes 40m | April to incl. October | median  | *** |
| • $\beta_2$ | Diatoms 5m/10m     | April to incl. May     | median  | **  |
| • $\beta_3$ | Windspeed          | May to incl. October   | average | **  |

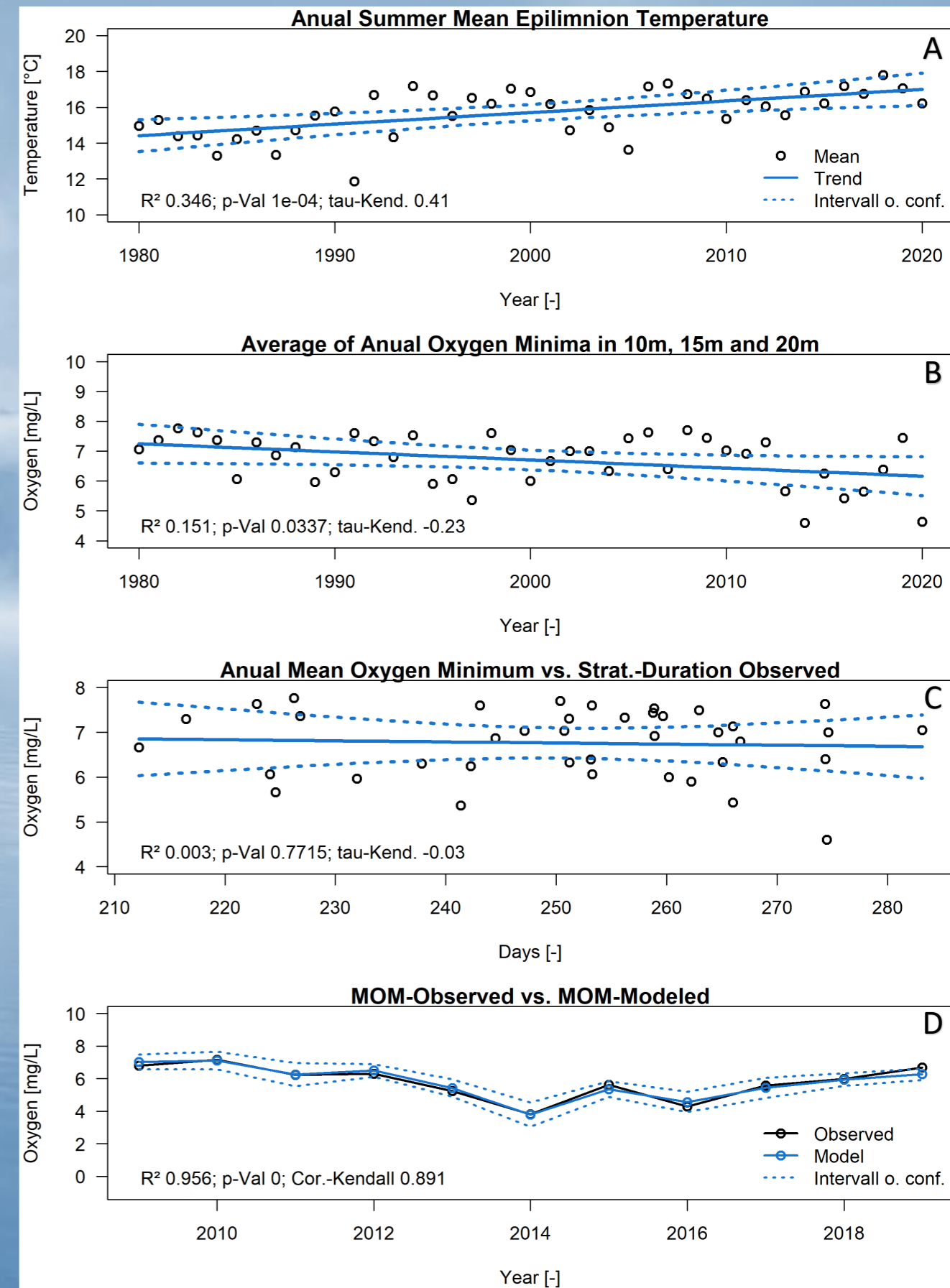


Figure 4



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## Conclusion

- **Long time series of Epilimnion temperature and metalimnetic oxygen concentration reflect increasing air temperature**
- **Stratification duration does not affect MOM**
- **Clear evidence that metalimnic oxygen minimum in Rappbode Reservoir is caused by bacterioplankton (Planctomycetes as proxy), supported by phytoplankton blooms in the euphotic zone**