# Modelling effects of thermal pollution on water quality: Study on water temperatures and dissolved oxygen in the Rhine

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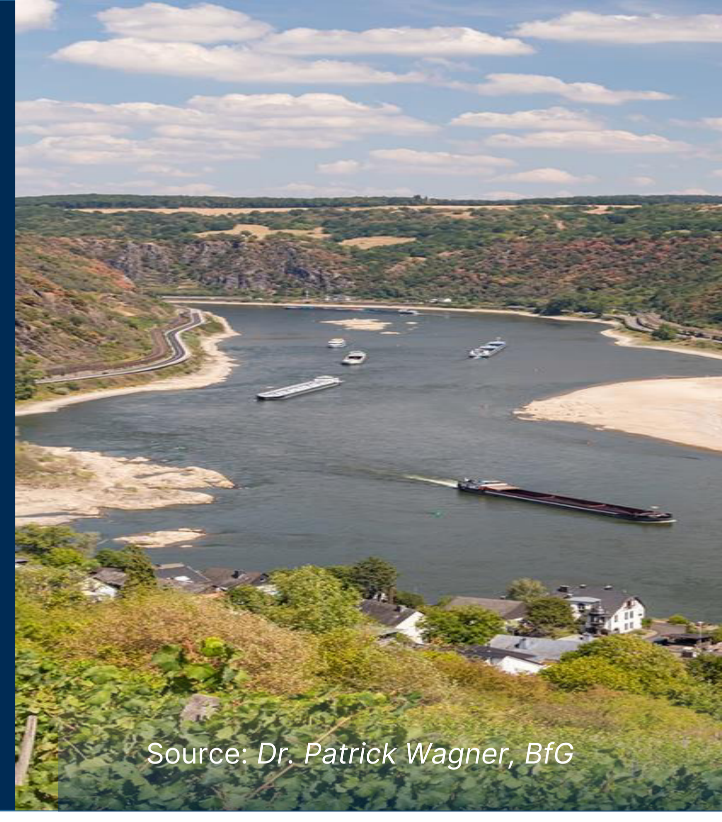



## Introduction

Thermal pollution arises due to discharge of heated water from power plants and industries into aquatic ecosystems. It affects water temperatures (wT) and causes variations in the concentration of dissolved oxygen (DO) in water [1,2].

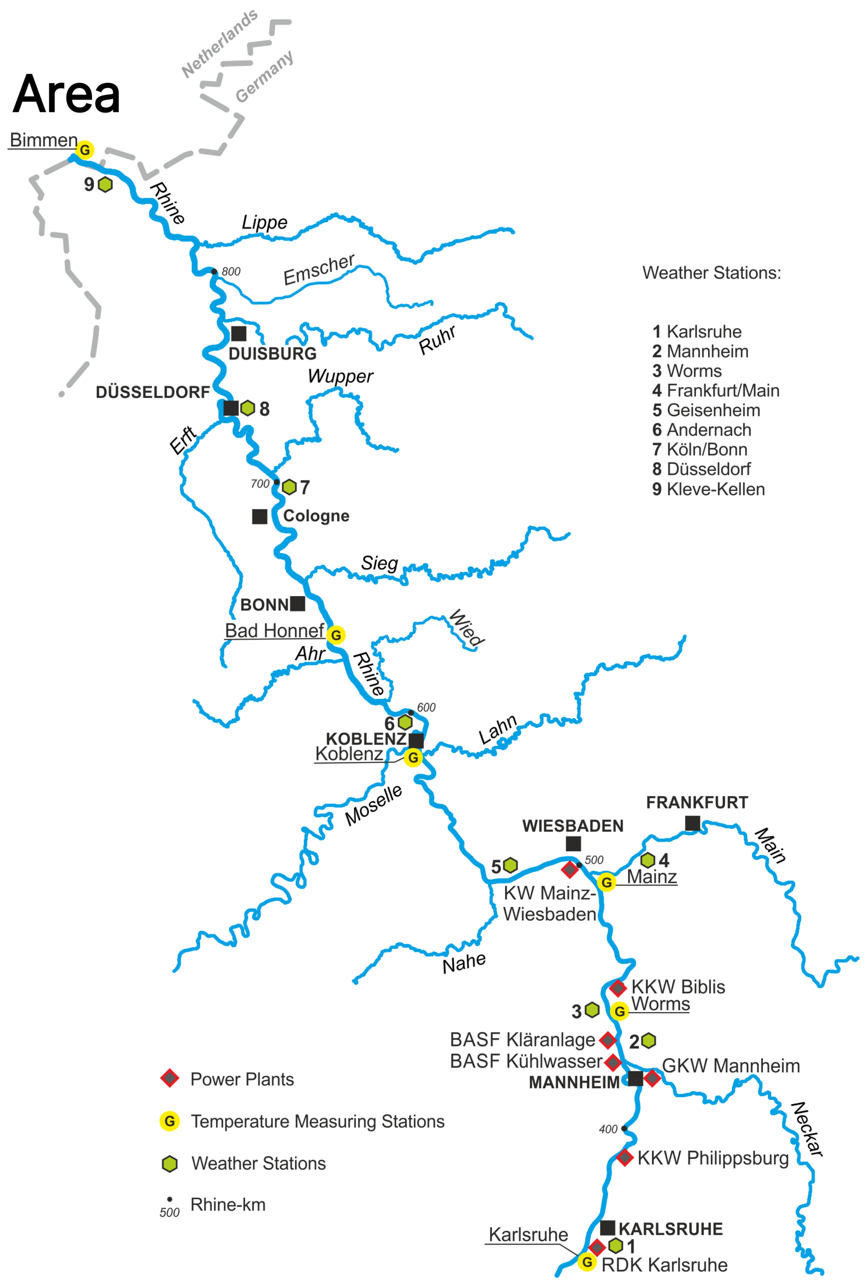
## Research Question

- How does thermal pollution affect water temperatures and dissolved oxygen in the Rhine River?

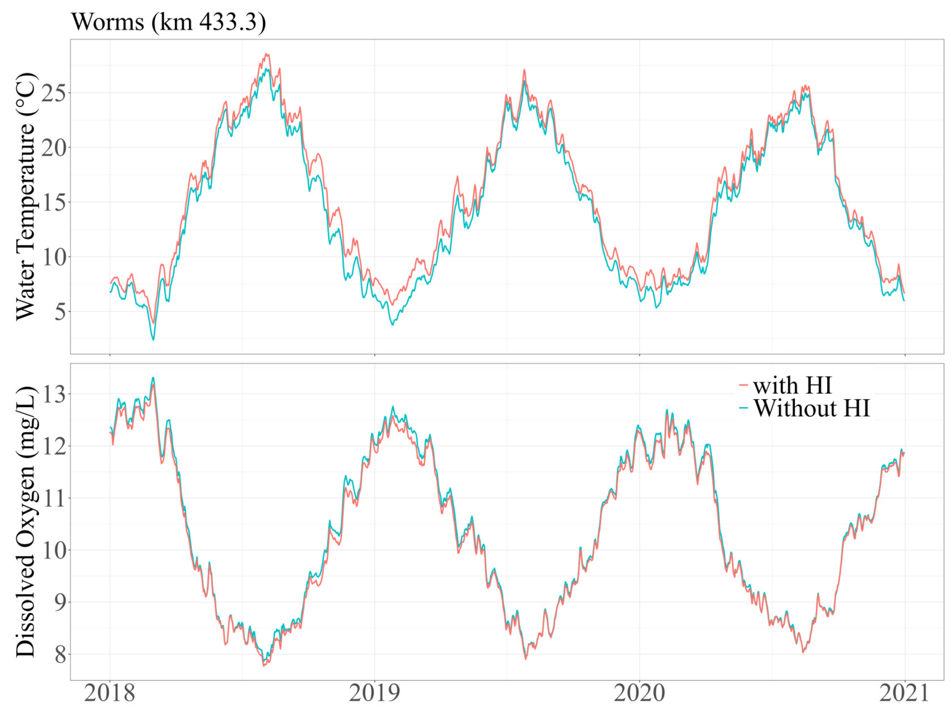
## Methods

- This study implements a deterministic model QSim (see QR-Code below) of BfG to simulate water quality focusing on water temperatures and dissolved oxygen in the free flowing German reach of the Rhine, from Karlsruhe (km 359) up to Bimmen (km 865).
- The influences of thermal emissions into the Rhine between 2018 and 2020 were assessed via comparison of two identical simulation runs only differing in heat inputs.

## Study Area

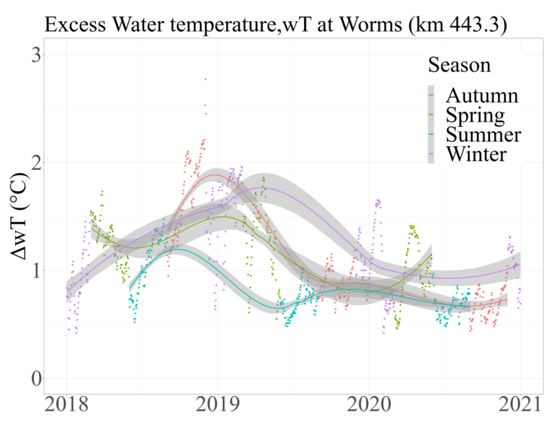



## Results

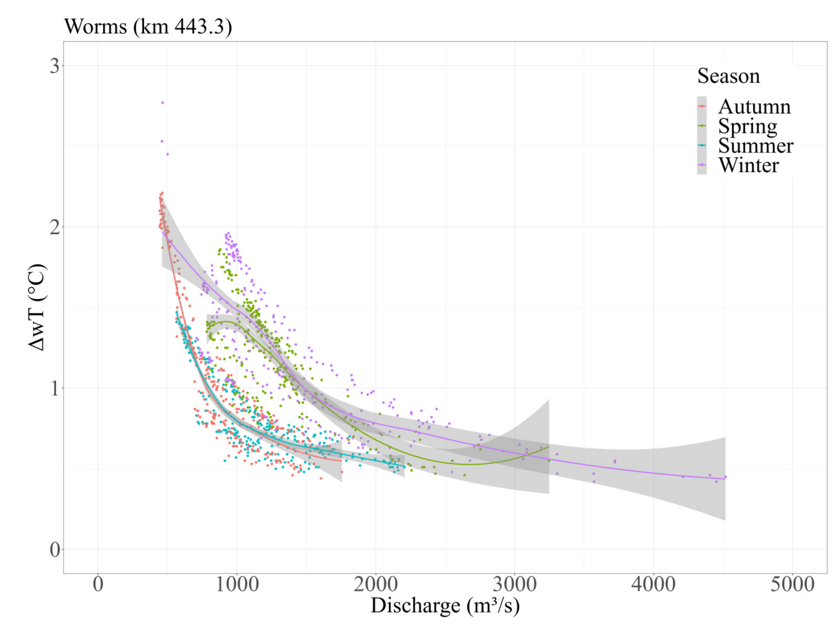



- HI (Heat Inputs)

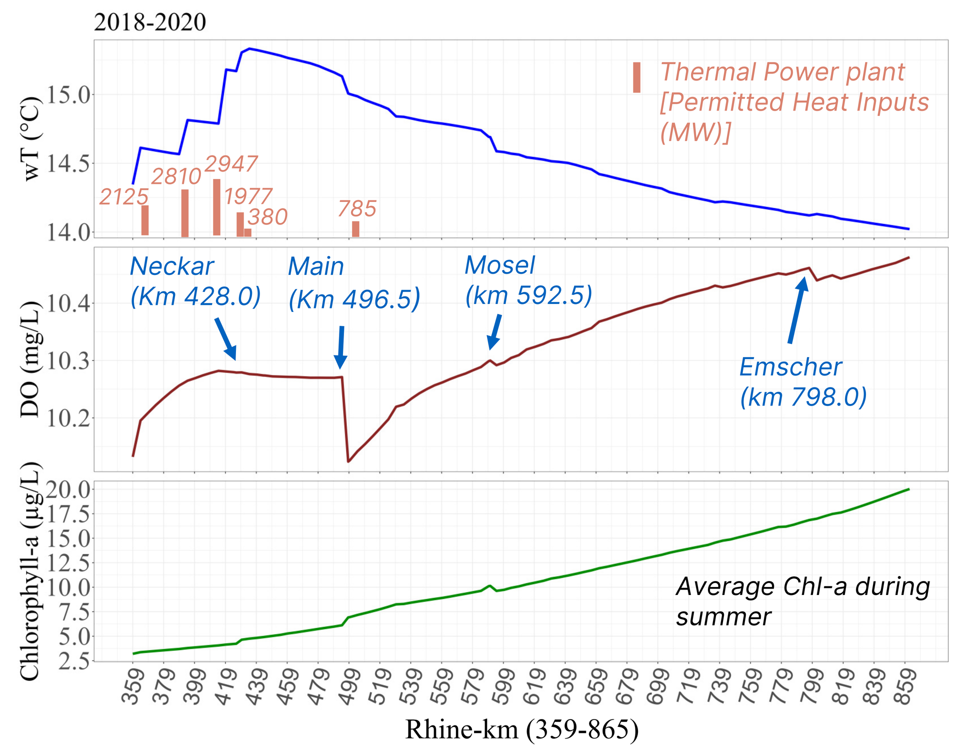
| Water Quality Measuring Stations | Worms | | | | |
|---|---|---|---|---|---|
| | RMSE | MAE | PBIAS | NSE | R² |
| Water Temperatures | 1.15°C | 1.07°C | 7.50% | 0.97 | 0.99 |
| Dissolved Oxygen (DO) | 0.10 mg/l | 0.09 mg/l | 0.80% | 0.99 | 0.99 |



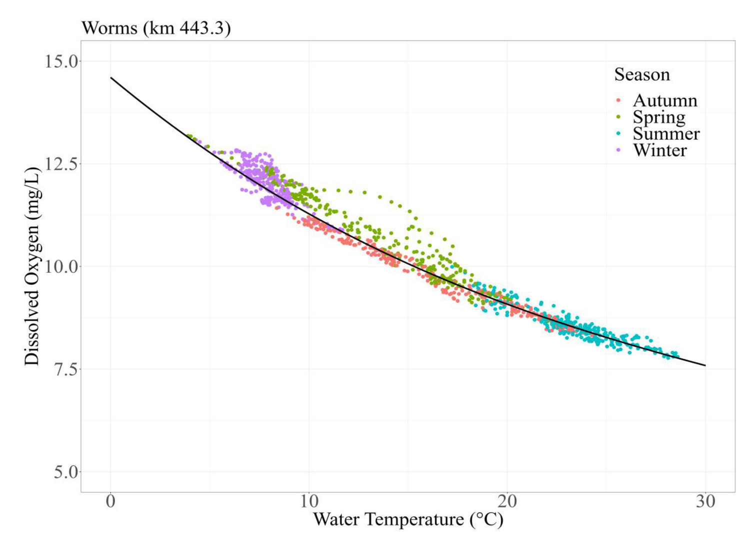

- Discrepancies in water temperatures were larger during winter and autumn when thermal emissions were higher.
- Further, heated Rhine water resulted in less DO in the river compared to cooler water without thermal emissions.
- With an increase in discharge, influence of thermal loads was diluted resulting in smaller deviations in water temperatures.




- Δ wT (Excess water temperatures from thermal emissions)

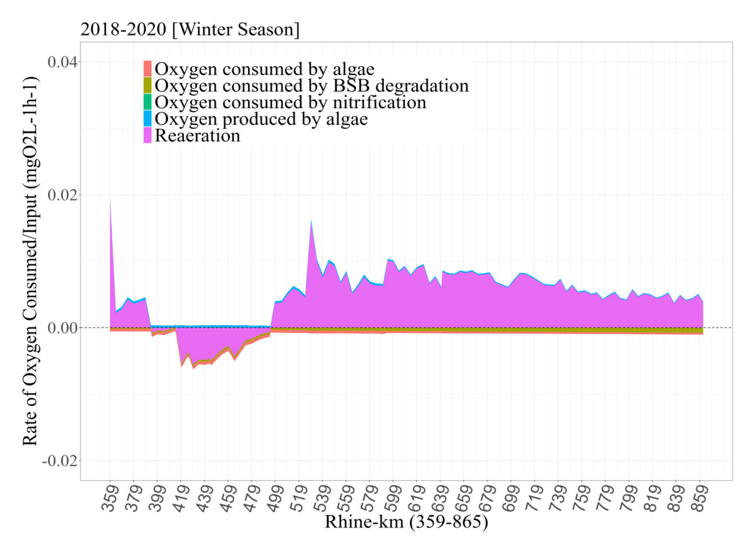


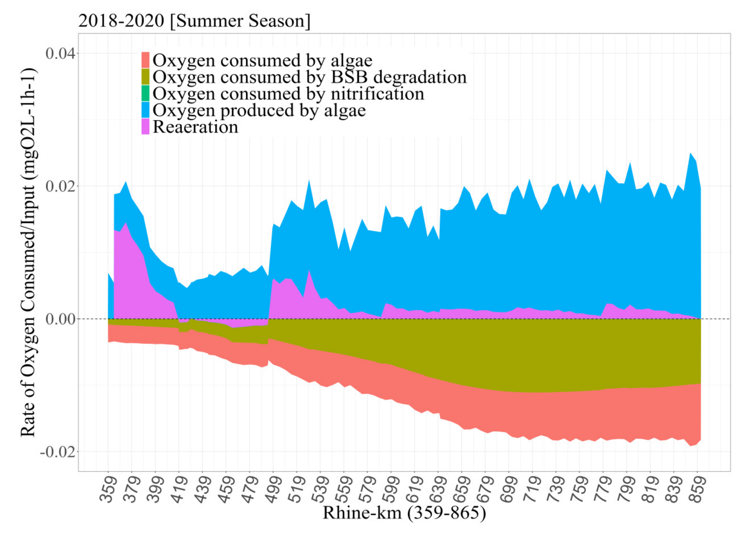

- During winter, reaeration was dominant for balancing DO levels whereas during summer with lower discharge, processes such as phytoplankton oxygen production and consumption, BSB (BOD) degradation were also regulating DO concentrations.




- DO in the Rhine between km 400-500 remained roughly constant as an effect of thermal emissions before it decreased with the confluence of the Main River.
- Downstream after km 500, DO increased with decreasing water temperature and higher photosynthetic activity of phytoplankton.

- Summer : June, July and August
- Winter: December, January and February




## Conclusions

- Thermal pollution increased water temperatures in the Upper Rhine (between km 359-500) whereas the Lower Rhine was less influenced from thermal emissions. This energy effect was highest during autumn and winter at low discharge.
- Oxygen concentration was differently controlled in summer, predominantly via phytoplankton production whereas in winter concurrently with high discharge via air-water oxygen exchange. Water temperatures elevated due to thermal emissions, resulted in actual oxygen concentrations above the saturated concentrations between km 395 and 495. Hence, oxygen was aerated to the atmosphere for the restoration of the equilibrium DO condition.

BfG
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Refrences: [1] Råman Vinnå, L., A. Wüest, and D. Bouffard (2017). Physical effects of thermal pollution in lakes, Water Resour. Res., 53, 3968–3987, doi:10.1002/2016WR019686.
[2] Akbari, P., Sadrinasab, M., & Bateni, F. (2016). Three-Dimensional Numerical Modeling Study of Thermal Pollution and its effect on dissolved oxygen and chlorophyll.

BfG water quality model QSim