Monitoring Effects of Floodplain Drainage on Oxygen Levels with Guerilla Sensing

edited by

Andreas Winter
Carl von Ossietzky University, Oldenburg

Florian Schmalriede
Carl von Ossietzky University, Oldenburg

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Content

Monitoring Effects of Floodplain Drainage on Oxygen Levels with Guerilla Sensing

Hagen Eickhoff[1], Mathis Kölker[1], Paul Tepe[1], and Paula Wegerich[1]

Abstract: This project presents the design, deployment, and field validation of a low-cost, autonomous monitoring system to observe water quality dynamics in the Moorhauser Polder, a protected floodplain in northern Germany. The site serves as a seasonal habitat for migratory birds and undergoes controlled winter flooding, followed by spring drainage. In recent years, these drainage events have coincided with recurring fish mortality, likely caused by oxygen depletion in the downstream Wulfsgraft stream. The lack of systematic data has hindered targeted intervention.

To address this gap, a sensor-based system using *Guerilla Sensing* principles was implemented, emphasizing affordability, modularity, and remote operation in infrastructure-poor environments. Two sensor stations continuously measured dissolved oxygen in both the source and receiving water bodies. The system successfully detected key hydrological events, including sluice operations, water mixing, and a critical drop in oxygen levels. This triggered a manual validation and subsequent countermeasure that likely contributed to preventing a fish mortality event.

The project demonstrates that reliable environmental monitoring can be achieved with minimal resources and that it can enable timely, evidence-based management. The system also validated an environmental feedback loop in which autonomous sensing, manual verification and intervention work hand in hand. The project highlights the potential of decentralized, low-barrier technologies to support local environmental protection efforts, especially when paired with institutional collaboration.

Keywords: Guerilla Sensing, Environmental Information System, Dissolved Oxygen, Sensor Network
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1 Introduction

The Moorhauser Polder is a designated nature reserve located in Elsfleth, Lower Saxony, and part of the EU bird protection area “Hunteniederung” [Ot20]. This lowland floodplain, shaped by the Hunte river, serves as a seasonal resting and wintering site for large numbers of migratory waterbirds and waders in the broader Weser estuary region. During winter, water is retained in the polder to form temporary floodplains offering crucial resting, foraging, and breeding habitats.

In April, the accumulated water is released – primarily into the Wulfsgraft, a small, connected stream – using sluice gates. The manual draining is primarily driven by agricultural interests, as early drainage allows for the timely use of the grasslands for mowing and grazing. Figure 1 shows the polder region and the surrounding area.

[1] Carl von Ossietzky Universität Oldenburg, <firstname>.<lastname>@uni-oldenburg.de

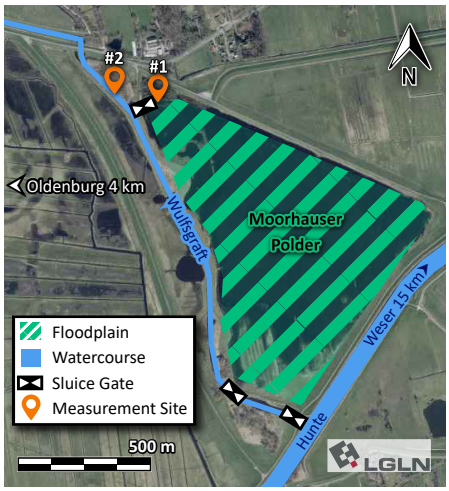

Fig. 1: The Moorhauser Polder and its vicinity

Fig. 2: Measurement station at site 1

In recent years, the seasonal water release has repeatedly coincided with fish extinction events, as reported in regional media [No24]. Preliminary assumptions point to oxygen depletion during drainage as a likely cause. However, no systematic data exists to confirm this hypothesis or to understand the broader environmental dynamics leading to these die-offs. As a result, no targeted mitigation measures could be planned or implemented.

The overarching aim of this project is understanding the ecological processes associated with water management in the Moorhauser Polder more thoroughly, particularly with regard to fish mortality during drainage events. To achieve this, a continuous, autonomous, and remote monitoring system is needed, capable of collecting relevant environmental data in a timely manner. This allows the detection of critical changes and enables initiation of timely countermeasures to critical environmental developments. Manual measurements alone are too infrequent, delayed and both travel- and labor-intensive to capture critical events.

This monitoring initiative was initiated following a request by the Lower Saxony Water Management, Coastal and Nature Protection Agency (NLWKN) on March 24th, 2025. With limited time before the scheduled drainage in late April, a measurement system had to be rapidly designed and deployed. The system was developed and implemented cooperatively by two successive student research teams[2] at the University of Oldenburg, financially supported by forschen@studium. It extends the existing Guerilla Sensing system (see section 2).

The following section describes the development and deployment of the monitoring system. Next, the recorded data are presented and key hydrological events are discussed, concluding with lessons learned and recommendations for future deployments.

[2] We thank our fellow members of the groups *Diek un Dat* and *Guardians of the River*, supervised by Marvin Banse, Florian Schmalriede, Prof. Dr. Oliver Theel and Prof. Dr. Andreas Winter

2 Development of an Oxygen Monitoring System

Being a nature reserve, the Moorhauser Polder offers little to no infrastructure to support a monitoring system: Devices cannot be connected to the power grid, and connections to wireless networks like LTE may be difficult. As such, any monitoring system used in the area needs to respect the environment and these conditions.

One proven option for such a system is Guerilla Sensing, an environmental information system developed at the University of Oldenburg [Ba21]. It relies on low-cost *GBoxes* that feature modular and reusable hard- and software components, enabling rapid development of a wide range of sensor implementations for measuring environmental phenomena. The measurements collected by GBoxes are sent to a central platform, which allows users to view and analyze the gathered data. Users can also set up automated notifications for when measurements violate user-defined thresholds, enabling timely responses.

Guerilla Sensing is specifically applicable for the Moorhauser Polder for three main reasons: (1) It allows measurements to be transmitted via public and private LoRaWAN networks. This enables wireless transmission even in remote areas such as the Moorhauser Polder, which is located about 5 km from a public LoRaWAN gateway. (2) GBoxes may be equipped with batteries and/or a solar panel, allowing them to operate independently of power grids. (3) GBoxes can be built as *AdHoc* GBoxes using non-permanent, easily assembled and disassembled fastening material. This allows them to be fully removed from their measurement site once the experiment is over, leaving no lasting traces in the nature reserve.

To monitor the effects of the drainage and therefore the mixing of two waters, one GBox was built for each. While many components could be reused from previous projects [We25], a sensor for dissolved oxygen was newly implemented. Limited by short-term availability and cost considerations, the *SenseCAP Dissolved Oxygen Sensor* was selected. Although not officially certified, it offers a precision of ±0.4 mg/L [Se23], which environmental experts considered sufficient. In favor of rapid assembly and deployment, the sensors' factory calibration was kept in place. A measurement cycle of 15 minutes was deemed continuous in consultation with the same environmental experts.

Each GBox is built around a custom PCB and an ESP32 microcontroller, powered by a Lithium-Ion battery pack, a solar panel, and a charge controller. To minimize energy consumption, the microcontroller enters deep sleep between measurement cycles, with a cut-off circuit disabling peripheral components. This setup enables reliable, continuous operation without reliance on the power grid. According to local conditions, all electronic components were placed in waterproof housing. The housing, LoRa-antenna and solar panel were mounted using a combination of aluminum tubes and custom 3D-printed components.

To enable communication, the GBoxes were equipped with a transceiver module based on the *ASR6501* chip and a directional antenna. Building upon LoRaWAN, the transport-layer protocol implemented in [Ha24] was used to ensure that no measurements are lost during transmission, ensuring measurements continuously reach the central platform.

The total component cost per GBox is approximately 545€, including 280€ for the sensor, 100€ for the antenna, 95€ for electronics, and 70€ for case and mounting materials.

Following the NLWKN's request on March 24th, the units (see Figure 2) were installed near the northernmost sluice gate (see Figure 1) on April 15th. To ensure reliable measurements, the sensors were placed between 20 and 50 cm below the water's surface. On April 27th, the water level of the Moorhauser Polder fell below the respective sensor's position, causing temporary spikes in measured values until the sensor was manually repositioned.

3 Results and Discussion

Figure 3 shows an excerpt of the roughly two months of data recorded by the GBoxes, offering a clear account of water quality dynamics during the monitoring period. Although the sensors were not calibrated, the data supplies valuable insights into hydrological trends and events in both the Moorhauser Polder and the Wulfsgraft.

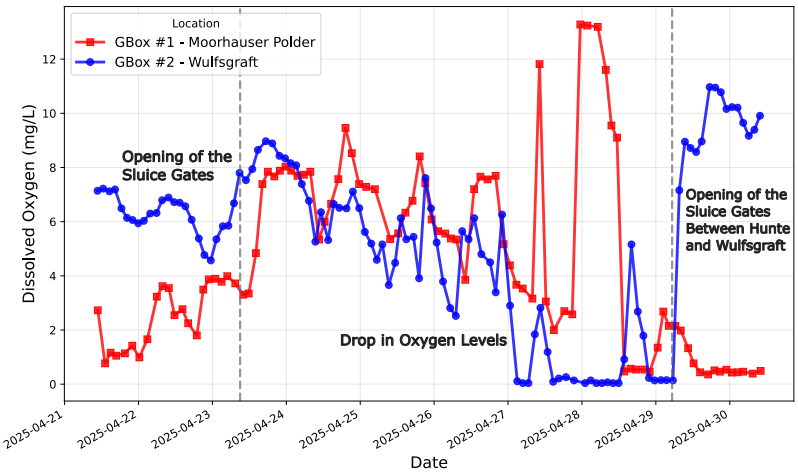

Fig. 3: Dissolved oxygen levels over time by location

While the sluice gates were closed, the oxygen levels in the Wulfsgraft were consistently higher than those of the Moorhauser Polder. Following the opening of the sluice gates on the 23rd, a downward trend is visible in oxygen levels of the Wulfsgraft as the oxygen in the polder rises, indicating mixing between the two water bodies. Manual measurements were taken, confirming these observations. Acting on this information, the sluice gates between the Hunte and the Wulfsgraft were opened on April 29th to prevent the possibility of another fish mortality event by increasing oxygen levels in the Wulfsgraft. Figure 3 shows the effectiveness of this intervention as a distinct and immediate rise in dissolved oxygen, indicating the inflow of oxygen-rich water from the Hunte.

4 Conclusion

This project demonstrated the feasibility of rapid, low-cost environmental monitoring using the Guerilla Sensing framework. Despite limited preparation time and low-infrastructure measurement sites, the deployed system operated reliably and captured meaningful data during a critical hydrological phase. No fish mortality event occurred during this years drainage, likely due to the countermeasures taken based on the data gathered in this project. The measurement stations measured continuously and consistently for about two months.

The results underline the potential of Guerilla Sensing–based systems as practical tools for the early detection of ecological risks, particularly in remote regions. Their modular, low-cost design suits contexts lacking traditional monitoring infrastructure.

Beyond this specific use case, the campaign highlights the broader value of adaptive and decentralized sensing platforms for water quality assessment. Future deployments may benefit from integrating pre-deployment calibration, mechanically reinforced components, and additional sensor types to monitor parameters such as turbidity or nutrient concentrations.

Crucially, the success of this deployment was enabled by close collaboration with local stakeholders and authorities. This partnership model, combining autonomous sensing, expert validation, and institutional response, provides a promising foundation for scaling up the Guerilla Sensing approach in environmental management and protection. Given the system's promising performance, a follow-up deployment, using fully calibrated sensors to ensure improved data accuracy and comparability, in the next year is strongly recommended.

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