Do fish actively avoid low DO areas of a waterbody caused by CSOs?

The Effect of Wet Weather Driven Dissolved Oxygen Sags on Fishes in Urban Systems (U3R09)

The Central Issue

Although many researchers have investigated the effects of low dissolved oxygen (DO) on fish responses in laboratory settings, there is a critical need to examine the impact of actual wet weather events, integrating field data with laboratory-derived data. Without the support of field evidence, regulatory DO criteria may be more stringent than necessary. If that is the case, regulators may require cities to install wet weather controls that are more elaborate than needed and with limited actual benefits to fish and other aquatic life.

Context and Background

Stormwater and wastewater discharges from wet weather events have long been identified as a significant cause of pollution and poor water quality, including low DO. The adverse effects of hypoxia, defined as DO concentrations less than 2 mg/L, on fishes and other aquatic life have been studied in laboratory settings. For example, Burleson et al. (2001) showed that largemouth bass preferred to inhabit water at approximately 4.0 mg/L and higher, and would not actively avoid water until DO concentrations fell below approximately 2.4 mg/L. However, examinations of the response of fish to hypoxia and CSOs in ‘real-world’ field situations are lacking. This lack of information makes it difficult to link laboratory-derived limits to oxygen and the sensitivity of fish in the wild. Anecdotal observations of the effects of low oxygen on fishes in the wild are inconclusive, and recent field research suggests that fishes may not necessarily ‘choose’ the highest oxygenated waters.

This research provides field-derived information on exposure and adaptation of fish to stresses from low DO during wet-weather events and the resulting CSOs within the Chicago Area Waterway System (CAWS). Recent advances in remote animal monitoring (biotelemetry) allow researchers to collect real-time data on the locations of and environments experienced by free-swimming fish. This project pioneered a new technique for using DO transmitters to monitor DO levels experienced by fish during wet weather events and to track their movement in response to low DO conditions. Fish movement in relation to DO levels was tracked using acoustic transmitters and dissolved oxygen transmitters. These results are coupled with a laboratory study. The results of this study can help inform the appropriate definition of oxygen standards for aquatic systems and assist with water quality management decisions.

Findings and Conclusions

- Concentrations of DO within the CAWS appeared to exert only a moderate influence on the movement or habitat choice of largemouth bass. While there was a reduction in the number of largemouth bass during low DO events, the fish did not depart the areas with reduced DOs entirely. Some fish remained in low DO areas, while others maintained ranges at the periphery of low DO areas. There was no threshold DO below which fish completely avoided a reach, specifically, fish were observed to stay in hypoxic reaches for periods of hours, even when monitored DO was less than 0.5 mg/L.

- Lab results from this study suggest that the largemouth bass in the study area are not in poor nutritional condition nor are they suffering from chronic stress when compared to the three control sites examined. They were quite tolerant of exposure to reduced DO, and did not show physiological responses to low DO that were different from fish collected from control sites.

- Results from the study indicate that factors other than low DO concentrations, such as habitat selection and prey abundance, could be influencing largemouth bass behavior in the study area. Further field studies of free-swimming tagged fishes in different waterways, including species other than largemouth bass, should be considered to increase our understanding of fish responses to low DO levels during CSO events.

- The external DO transmitters attached to fish show differences, sometimes lower and sometimes higher, when compared to the results from fixed-station DO monitoring. These results may support the spatial complexity and variability of DO in the water column. Because these are the results of a pilot study pioneering a new technique, they should be subject to follow-up investigations.
Executive Summary

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Management and Policy Implications

Regulatory authorities need to be aware of the spatial and temporal variability in DO concentrations within aquatic systems, as well as the ability of fish to actively select areas of differing DO concentration when assessing the impacts of low oxygen on biota. It is currently believed that these spatial and temporal variabilities are underappreciated and largely unexplored. Many DO standards have been set to ensure maintenance of oxygen levels of 4 mg/L or greater. While this level is undoubtedly important for many fish species and also for many different life stages for a long-term basis, the current study highlights the importance of species-specific quantification of oxygen preference as largemouth bass regularly inhabited DO concentrations below 2 mg/L for extended periods without apparent negative consequences as compared to those observable in the laboratory studies.

Related WERF Research

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<th>Project Title</th>
<th>Research Focus</th>
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<tr>
<td>Characterizing the Quality of Effluent and Other Contributory Sources during Peak Wet Weather Events (03CTS12PP)</td>
<td>Evaluates the impacts of blending on effluent and receiving water quality and estimated public health risks associated with recreation in surface waters receiving blended flows. This project which looked at potential impacts to humans from wet weather events complements U3R09 which focused on impacts to fish. Field samples were collected for in-plant processes and receiving waters during wet weather blending, wet weather non-blending, and dry weather events. This data was used to develop hydrodynamic and water quality computer models to predict receiving water conditions as well as a quantitative microbial risk assessment (MRA) to estimate risks of gastrointestinal and respiratory infections for people recreating in the waters receiving blended flows. Includes alternatives to reduce or eliminate blending, including rainfall-derived infiltration and inflow reduction, peak storm-flow storage, and treatment capacity expansion.</td>
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<td>Evaluation of WET Testing as an Indicator of Aquatic Health in Effluent-Dominated Streams: A Pilot Study (03EC02T)</td>
<td>Like U3R09, this project seeks to better link lab studies predicting instream impacts to the actual impacts that are taking place. This project establishes how a comprehensive study should be designed to adequately address relationships between Whole Effluent Toxicity (WET) lab test results and instream biological condition to evaluate the reliability of WET measurements in predicting in-stream responses downstream of wastewater treatment or other permitted facilities.</td>
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<td>Best Practices for the Treatment of Wet Weather Wastewater Flows (00CTS6)</td>
<td>Reviews available technoloiges to improve performance and efficiency of wet weather wastewater treatment and identifies potentially beneficial technologies and methodologies that are emerging. Assesses vortex separation, enhanced clarification, operational enhancements, flushing system, and disinfection technologies. Includes operation and maintenance requirements and cost for each. Can be used by stormwater owners and operators to choose the most appropriate, cost-effective technologies for their treatment plants.</td>
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<td>Collaborative Water Quality Solutions: Exploring Use Attainability Analyses (04WEM7)</td>
<td>A cooperative effort between WERF and NACWA, this project explored collaborative water quality solutions. The resulting UAA handbook is intended to be a practical UAA roadmap for stakeholders trying to determine whether a UAA is the right tool.</td>
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