Assessment of Ecoregional Dissolved Oxygen Regimes
Data Report for 2007 Study Season

SECTION 6

DISCUSSION

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The overall goal of the AERDOR project is to identify factors affecting attainment of DO criteria in Missouri reference streams. To this end, data were collected and analyzed to assess the prevalence of DO below critical thresholds (5.0 and 3.0 mg/L), characterize trophic states and DO metabolism (sources and sinks), and investigate the relationships between DO and numerous physical, chemical, and environmental variables. The results of these analyses and their potential impacts on water resource management decisions are discussed below.

6.1. Prevalence of Dissolved Oxygen Concentrations Below Critical Thresholds

Dissolved oxygen concentrations below 5.0 mg/L and 3.0 mg/L were measured at all monitoring locations during both the 2006 and 2007 study seasons. Only 3 of the 13 continuous, stationary sites had median DO concentrations above 5.0 mg/L (HC1 = 5.9 mg/L in 2007, HC3 = 5.4 mg/L in 2006, HC3 = 7.01 mg/L in 2007). Only one site (EFCR1) had a median DO less than 3.0 mg/L (2.96 mg/L in 2007).

Even though low DO conditions are present in AERDOR streams, it is unclear as to whether they directly or solely impact the macroinvertebrate communities. For instance, in 2007 DO was lowest at sites LDC2 and EFCR2 but metric scores (MSCI = 20 & 18, respectively) following the low DO period were near their historic highs (Tables 1a and 2a). Conversely, DO was highest at site HC2 but the MSCI score (14) was low relative to historic data (Table 3). Further analysis of these relationships is beyond the scope of this report however DO is likely only one of many interrelated physiologic, trophic, physical, and biotic constraints that influence the macroinvertebrate community (Wallace and Anderson 1996).

AERDOR data confirm that low DO conditions are prevalent in the monitored reference streams and are likely indicative of summer DO conditions across EDUs in the Plains region. This conclusion is supported by MEC's (2007) investigation of DO conditions in the Osage Plains which showed approximately 40% of historical DO measurements collected in the region were below 5.0 mg/L.

Chronic low DO conditions during summer are not unique to Missouri reference streams. Numerous state agencies including those in Arkansas (Bennett *et al.* 1987, Giese *et al.* 1987), Texas (Twidwell and Davis 1989, Bayer *et al.* 1992, Hornig *et al.* 2000), Tennessee (Arnwine and Denton 2003, Arnwine *et al.* 2005), Florida (Weaver 2004) and Georgia (Davie *et al.* 2001) have documented reference waterbody DO concentrations below applicable water quality criteria. As a result, regional DO studies have been or are being conducted in an attempt to refine DO criteria in these states.

6.2. Trophic State and Stream Metabolism

Median nutrient and chlorophyll-a concentrations were lower in 2007 than in 2006 but individual samples (except for P-Chla at site LDC2 in 2007) did exceed ecoregional and/or RTAG benchmarks at all sites during both years. Although nutrient and chlorophyll-a concentrations were above EPA thresholds, photosynthesis rates were generally low relative to community respiration during both study seasons (Table 15, MEC 2007). These results suggest that heterotrophic conditions are maintained in AERDOR streams at nutrient and chlorophyll-a levels well above thresholds meant to protect against eutrophication. Therefore, aggregate ecoregional and RTAG benchmarks may not accurately reflect the reference condition in Missouri.

6.3. Factors Influencing Dissolved Oxygen in Missouri Reference Streams

Correlation analyses indicate that daily average stream discharge is positively related to daily average and daily minimum DO levels in the reference streams. Logistic regressions show the probability that a stream will attain critical DO thresholds increases with discharge (Figure 24). However, the discharge required to consistently meet those critical concentrations differs by site, indicating that stream-specific relationships may exist (Figure 24). Furthermore, data demonstrate that under critical flow conditions there is, at best, a 1 in 4 chance that AERDOR streams can attain a 5.0 mg/L daily average and 3.0 mg/L daily minimum DO concentration.

AERDOR results are supported by literature studies that found direct relationships between DO concentrations and flow (Ice 2003, Colangelo 2007, Garvey *et al.* 2007, Van Vliet and Zwolsman 2008). For example, Garvey *et al.* (2007) showed that streamflow accounted for as much as 63% of the variation in DO during low and high flow conditions in Illinois streams. In the literature, direct relationships between DO and flow are most often explained by changes in water temperature, respiration, and reaeration.

Low summer streamflows are often correlated with high water temperatures. These associations are increasingly apparent during periods of drought (Van Vliet and Zwolsman 2008). Warm temperatures lower oxygen solubility and increase stream respiration rates (Van Vliet and Zwolsman 2008). As summer water levels drop and stream velocities slow, oxygen reaeration processes are also reduced (Ice 2003, Colangelo 2007, Garvey *et al.* 2007). During summer low-flow conditions, these processes interact and can lead to depressed DO concentrations that do not attain regulatory thresholds (Mulholland *et al.* 1997, Murdoch *et al.* 2000, Caruso 2002, Van Vliet and Zwolsman 2008).

In general, high streamflows (excluding runoff events) have the opposite effect on DO concentrations. Water temperature is generally cooler during periods of increased flow (Garvey *et al.* 2007). As a result, DO concentrations increase because oxygen solubility increases and respiration decreases (Mulholland *et al.*1997, Colangelo 2007, Van Vliet and Zwolsman 2008). Even if temperatures do not cool and rates do not decrease, elevated flows dampen their effects because increased water velocities enhance stream reaeration and raise DO levels (Ice 2003, Colangelo 2007, Garvey *et al.* 2007).

Positive DO:streamflow relationships observed during summer in AERDOR streams likely resulted from increased reaeration and not cooler water temperatures or lower respiration. In general, water temperatures were similar between sampling seasons (see Section 5.2.) and were not significantly related to DO concentrations or streamflow conditions (Tables 16, 17, and 19, MEC 2007). Because water temperatures were not cooler, calculated community respiration rates did not significantly change under higher flow conditions experienced in 2007 (Figure 22)[2].

[2] Figure 22 indicates a slight decrease in community respiration but it was not significantly related to streamflow or water temperature. Although the declining pattern of respiration cannot be explained by these factors, it may be explained by changes in SOD with depth. Sediment oxygen demand decreases as stream depth increases (Colangelo 2007). Because stream depth and flow are directly related (see Section 5.3.), SOD would decrease with increasing

Although temperature and metabolism effects were not apparent during summer conditions, extended deployment data suggest these variables impact DO seasonally. Water temperatures decreased by approximately 9°C during the extended deployment at both sites (Figure 14). Cooler temperatures should lead to lower stream metabolism rates (primarily respiration but also photosynthesis and reaeration), increased DO solubility, and overall higher levels of DO in the streams. Dissolved oxygen concentrations however, did not significantly increase at either site during the cool-water period (Figure 10).

The lack of response in the extended deployment DO indicates that stream metabolism was altered in such a way that DO concentrations could not increase. For example, although the community respiration rate would have decreased with temperature, overall community respiration may have increased due to an influx of allochthonous organic matter (e.g. leaf litter). Another possible explanation for the lack of change in DO concentrations is that seasonal succession of sestonic and benthic algae caused a decrease in overall productivity (EPA 2000b). Finally, decreasing streamflows may have lead to lower oxygen reaeration and depressed DO conditions. Unfortunately, stream metabolism was not calculated during extended deployment period so these relationships cannot be explored in detail.

Since the positive DO:streamflow relationships observed during summer in AERDOR streams cannot be explained by cool water temperatures or low respiration, they can only be attributed to greater oxygen reaeration at higher flows. These effects are apparent in the AERDOR data. Average daily streamflow during 2006 was 0.02 and 0.08 at sites HC2 and LDC2, respectively (MEC 2007). Under these stagnant conditions, median reaeration was 0.9 day^{-1} and 1.4 day^{-1} at the sites (MEC 2007). In 2007, mean discharge increased to approximately 0.5 cfs at both sites and reaeration increased to 2.0 day^{-1} and 1.6 day^{-1} at sites HC2 and LDC2, respectively (Table 15). Reaeration was significantly (and positively) related to streamflow when data were pooled across all AERDOR sites (Figure 22). These results suggest that reaeration associated with higher streamflow is a major determinant of summer DO in AERDOR reference streams.

6.4. Water Resource Management Implications

AERDOR study results indicate that several biocriteria reference reaches do not consistently attain current WWF DO criteria during the summer season. Data suggest that increased summer baseflows significantly enhance oxygen reaeration rates and raise stream DO levels. Although data show that DO increases with flow across ecoregions, stream-specific relationships appear to exist. In order to accurately characterize DO dynamics in state reference streams, future DO data collection and/or criteria development efforts should consider the effects of streamflow on DO.

streamflow and overall community respiration would decrease. More data are necessary to fully evaluate this relationship in AERDOR streams.