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Pollution Control Board

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
PROPOSED AMENDMENTS TO	)	**R 04-25**
DISSOLVED OXYGEN STANDARD	)	
35 Ill. Adm. Code 302.206	)	

NOTICE OF FILING

TO: See Attached Service List

PLEASE TAKE NOTICE that on **Monday, August 2, 2004,** we filed the attached **Written Testimony of Dr. James E. Garvey Fisheries and Illinois Aquaculture Center Southern Illinois University, Carbondale, Illinois** with the Illinois Pollution Control Board, a copy of which is herewith served upon you.

Respectfully submitted,

By: [signature]
One of Its Attorneys

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THIS FILING IS SUBMITTED ON RECYCLED PAPER

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WRITTEN TESTIMONY OF DR. JAMES E. GARVEY
FISHERIES AND ILLINOIS AQUACULTURE CENTER
SOUTHERN ILLINOIS UNIVERSITY, CARBONDALE, ILLINOIS

Thank you for the opportunity to testify before the Illinois Pollution Control Board during this second hearing in Springfield, Illinois. As I noted in the first hearing before the Board, I am an Assistant Professor in the Fisheries and Illinois Aquaculture Center and Department of Zoology at Southern Illinois University, Carbondale. My research interests revolve around fish and aquatic ecology in lakes and streams. The Illinois Association of Wastewater Agencies asked Dr. Matt Whiles and me to assess the current Illinois state dissolved oxygen standard which requires that at no time shall concentrations decline below 5 mg/L and for at least 16 hours each day they must remain above 6 mg/L. In our report, we concluded that this standard is unrealistic for most streams in the state, because oxygen concentrations fluctuate both seasonally and daily, often declining below the state standards. These conclusions were based largely on published studies summarizing research conducted outside of Illinois in addition to my unpublished data in tributaries of the Ohio River, which were discussed during the first hearing.

Proposed Recommendations

To make the state general use standard more realistic, Dr. Whiles and I recommended that during March 1 through June 30 when early life stages of sensitive species are present, a minimum identical to the current Illinois standard of 5 mg/L and a seven-day mean of 6 mg/L should be adopted. During warmer, productive months and the remainder of the year when species with sensitive early life stages have largely completed reproduction, we recommended a minimum of 3.5 mg/L and a seven-day mean minimum of 4 mg/L. It is important to emphasize that we included running means to avoid chronically low dissolved oxygen concentrations. For the proposed standard to be supported, minima must not be violated, ensuring that concentrations never approach critically lethal limits.

Analysis of Illinois Stream Data

In response to questions about fluctuations of oxygen in Illinois surface waters, I analyzed the applicability of both the current state standard and the proposed standard to eight Illinois streams, in which dissolved oxygen and temperature were intensively monitored. My analysis is attached as Exhibit 1. I was made aware of these data during a meeting with the USEPA on June 18, 2004. It is my understanding that the United States Geological Survey (USGS) and Illinois Environmental Protection Agency (IEPA) began collecting these data to address concerns about the applicability of the current state standard to streams in the state. I requested these data from Paul Terrio, a hydrologist with USGS, shortly following the first hearing. I also reviewed oxygen and temperature data in other reports for streams in Illinois. I have summarized my analysis of these data in a recent report submitted to the Illinois Association of Wastewater Agencies and submitted as exhibit ##. Paul Terrio (USGS), Robert Mosher (IEPA), and Matt Whiles (Southern Illinois University) have provided comments on this report that I have incorporated into the final draft. These long-term data are unprecedented. I am aware of no other similarly comprehensive data set for streams of the Midwestern United States. We now have access to robust data that will allow us to ground truth the proposed dissolved oxygen standards.

The eight, intensively studied stream reaches were North Fork Vermilion River near Bismarck, Middle Fork Vermilion River near Oakwood, Vermilion River near Danville, Lusk Creek near Eddyville, Mazon River near Coal City, Rayse Creek near Waltonville, Salt Creek near Western Springs, and Illinois River near Valley City. During late summer 2001 through fall 2003, semi-continuous dissolved oxygen and temperature data were collected by IEPA and USGS. The stream segments varied widely in physical characteristics, surrounding land use, and latitude. Five of the eight stream segments are currently considered impaired and included on the most recent 303-d list compiled by IEPA. The nature of impairment varies from nutrient enrichment in Rayse Creek to mercury and PCB contamination in the Illinois River.

Dissolved Oxygen Patterns in Illinois Streams

The results from this analysis uphold the conclusions of the Garvey and Whiles report. As expected, dissolved oxygen concentrations declined in all streams during summer, with diurnal fluctuations varying among them. All eight streams violated the Illinois state standard, although violations occurred as infrequently as 1% of days and as frequently as 65% of days. Among the unlisted, unimpaired stream segments, oxygen dynamics varied widely, with Lusk Creek, a functioning stream in a forested watershed, regularly violating the Illinois standard of 5 mg/L during 22% of days. In two of the impaired, 303-d listed streams, the Illinois standard was violated frequently, with concentrations often declining below 2 mg/L, which is regarded to be lethal for many aquatic organisms. However, in other listed streams, dissolved oxygen concentrations were typically greater than the 5 mg/L minimum.

We might expect that nutrient enrichment is the primary factor affecting dissolved oxygen dynamics. Streams with greater nutrient loading should have lower oxygen. However, Salt Creek, an impaired stream with low biotic integrity and high nutrient enrichment, had higher average dissolved oxygen concentrations than the Mazon River, which was only listed for PCB and pathogen contamination. Nutrient enrichment must interact with other factors such as stream physical habitat to affect oxygen dynamics.

Application of the Proposed Standard

Adoption of the proposed standard greatly reduced the number of violations in unimpaired streams such as Lusk Creek while still capturing violations in impaired streams. In fact, the proposed standard increased the frequency of violations in two of the severely oxygen-impaired streams and identified the time period when oxygen problems occurred. It may be tempting to regard Lusk Creek as an intermediate between a functioning and an impaired system and suggest that its frequent violations of the current state standard are a warning signal. However, this is quite far from the truth. This stream segment is in the Lusk Creek Wilderness area of the Shawnee National Forest and is considered to be in a pristine state, with a highly regarded, intact, and diverse fish and macroinvertebrate assemblage. A concern of the Board during the first hearing was that minimum oxygen concentrations of 3.5 mg/L which occurred during summer in Lusk Creek would negatively affect summer-spawned, early life stages of resident species. It is quite clear, given the robust assemblage in this system that natural, summer declines in dissolved oxygen concentration below the state mandated 5 mg/L and occasionally reaching 3.5 mg/L did not negatively affect fishes reproducing during this time. Lusk Creek demonstrates that the seasonally appropriate proposed standard protects both spring and summer reproducing species.

Temperature Effects

Dissolved oxygen concentrations were quantified in a pooled area of Lusk Creek as recommended in the implementation guidelines of the Garvey and Whiles report. It is in this area that we would expect to encounter the most conservative dissolved oxygen concentrations. In contrast, the Middle Fork of the Vermilion River, in which oxygen concentrations were consistently the highest, had a logger located about 100 m below a riffle area, where we would expect oxygenated water to be abundant. Although it may be argued that Lusk Creek is a southern Illinois stream and warm temperatures may be responsible for declines in oxygen during summer, dissolved oxygen concentrations were lowest at intermediate summer temperatures, indicating that it is not the seasonal maxima of streams that reduce oxygen concentrations. Further, I found no substantive differences in temperature among streams across the north-south gradient in the state. These data effectively show that the proposed standard effectively captures oxygen dynamics that occur in natural, fully functioning Illinois streams such as Lusk Creek. A revised general use dissolved oxygen standard in Illinois such as that proposed by Garvey and Whiles is needed.

Habitat Modification

Some investigators have argued that artificially pooling streams or rivers by building dams will reduce oxygen and therefore negatively affect resident species. Recent reports in the Fox and DuPage Rivers have shown that pooled areas of streams violate the current standard more than open reaches and that fish composition differs between them. The problem with implicating violations of the current dissolved oxygen standard as responsible for altering or degrading species composition in pooled reaches is that the habitat of the river changes as well as the oxygen dynamics. In short, flow declines, sedimentation increases, and more fish that rely on accumulation of organic matter and open water will prosper. Oxygen declines because of the increased biochemical oxygen demand of the sediment and increased retention time of the water. As long as oxygen concentrations remain above the proposed standard in pools, species adapted to pool conditions will be abundant while flow-dwelling species will be rare or absent. Of course, if oxygen concentrations decline below the proposed standards, even species adapted to pooled conditions will cease to persist. Garvey and Whiles recommend monitoring pooled areas of natural streams, because of their lower expected oxygen concentration.

The eight intensively monitored streams provide more insight into the problem of teasing apart changes among habitat, oxygen, and other water quality parameters. Across the streams, no relationship existed between biotic integrity scores and oxygen minima as estimated by frequency of violations of either the current or proposed standards. Typically, integrity scores are closely related to measures of habitat quality, which include factors such as a stream's substrate, habitat diversity, and riparian vegetation. Habitat quality fosters the diversity of organisms by providing food, shelter, and reproductive areas. As such, it appears that habitat rather than oxygen primarily influences species composition. Reduced oxygen concentrations and increased diurnal fluctuations are a secondary effect of habitat degradation or modification.

Comparison between Oxygen and Ammonia Standards

The most conservative ammonia standards for the state are designed to protect early life stages of all fish species for the duration of spawning, which may extend through October. In the first hearing, I was asked why the most conservative proposed oxygen standard extended only through June, while the conservative ammonia standard is extended through the entire reproductive cycle of fishes. Dynamics of total ammonia and oxygen differ in streams. The total concentration of ammonia in streams typically depends on discharge and does not vary naturally on a seasonal basis. Further, the toxicity of total ammonia increases with increasing temperature during summer, necessitating stringent standards for all early life stages of fish, particularly those that are produced during summer. Conversely, the data summarized in my report clearly show that oxygen concentrations in the pooled area of a natural, functioning stream do decline well below the current standard during summer but not below the proposed, seasonally appropriate one. As I noted earlier, because the community in such a stream is intact, summer-spawning fish species must reproduce successfully during this time, demonstrating that the proposed standard better reflects natural fluctuations in this system while protecting resident fishes.

Review by Gary Chapman, Author of the National Criteria Document

To determine whether the seasonal standard was consistent with the United States Environmental Protection Agency's 1986 National Criteria Document, I solicited a review from its author, Gary Chapman, following the first hearing. He had provided a review to the Water Quality Section of the Illinois Chapter of the American Fisheries Society on June 28, 2004 and forwarded this review to me. To summarize, he felt that the timing of seasonal standards depended on a working knowledge of the fish community in the state and should be "left to the experts". His largest concern was the omission of a 30-day running average of 5.5 mg/L in the proposed standards. Although I still think that such a standard is generated over such a large time scale that it is generally biologically meaningless, it may be worth considering as part of the proposed standards given his expert opinion. His other comments were relatively minor, revolving around the interpretation of recent findings in dissolved oxygen research. He supported our implementation recommendations and thought that they should be adopted. Regarding protection of fish during summer, he commented: "I have seen no data over the past 20 years that would indicate that the 3 mg/L minimum would not be adequately protective against lethal effects".

Chemical Interactions with Oxygen

In the first hearing, I was asked about the potential effects of low dissolved oxygen concentrations on water chemistry in streams and lakes. To the best of my knowledge, reduction–oxidation chemical reactions are unaffected by oxygen concentrations until they decline far below the proposed 3.5 mg/L minimum.

Conclusions

In summary, much more is known about fluctuations in oxygen and temperature in streams in the state of Illinois than during the first hearing. Results of the new analysis confirm the conclusions of the Garvey and Whiles report for other aquatic systems. Semi-continuous measurements in pristine, forested Lusk Creek were quantified in the appropriate location and provide a useful baseline by which general expectations for dissolved oxygen concentrations can be generated. Although the proposed standards may be generally applied across the state, either regional standards or a stream classification system should be adopted to better reflect use expectations. Such a system will need to incorporate biotic integrity, habitat quality, and water quality goals rather than focusing solely on dissolved oxygen expectations. Given the data from the eight Illinois streams and other systems in the state, the likelihood that the current dissolved oxygen standard will not apply to many of these systems and produce false violations is confirmed. Adopting the proposed standard and standardized monitoring outlined in the Garvey and Whiles report will not only reduce the probability of detecting a false violation in functioning streams but it will provide robust, long-term water quality data sets for improving management of surface waters in the state.

CERTIFICATE OF SERVICE

The undersigned certifies that a copy of the foregoing **Notice of Filing** and **Written Testimony of Dr. James E. Garvey Fisheries and Illinois Aquaculture Center Southern Illinois University, Carbondale, Illinois** was filed by hand delivery with the Clerk of the Illinois Pollution Control Board and served upon the parties to whom said Notice is directed by first class mail, postage prepaid, by depositing in the U.S. Mail at 191 N. Wacker Drive, Chicago, Illinois on Monday, August 2, 2004.

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CH02/ 22319597.1

Exhibit 1

Long term dynamics of oxygen and temperature in Illinois streams

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Prepared for Illinois Association of Wastewater Agencies

July 2004

Introduction

Garvey and Whiles (2004) concluded that the current Illinois dissolved oxygen standard is unrealistic, because naturally fluctuating dissolved oxygen concentrations in surface waters of the state should occasionally or frequently decline below the critical minimum. Specifically, the Illinois general use standard requires that dissolved oxygen concentrations within surface waters of the state never decline below 5 mg/L and remain above 6 mg/L at least 16 hours each day. Although the Garvey and Whiles (2004) report cited published studies showing that dissolved oxygen is heterogeneous within aquatic systems and that concentrations in natural systems often decline below 5 mg/L during summer, little stream data within Illinois were available to support this conclusion. Since that report was completed, a continuous monitoring data set has become available (Paul Terrio, United States Geological Survey and Robert Mosher, Illinois Environmental Protection Agency, unpublished data) in which dissolved oxygen concentrations and temperatures were quantified semi-continuously in eight stream reaches during a two-year period. These streams were distributed both along a north-south gradient and a gradient of land-use (i.e., urban, agriculture, and forest). Quality of streams was also considered in the selection of monitoring sites, with the streams varying from fully functioning to impaired, with some included on the 2004, IL-EPA 303d list.

I obtained these data and analyzed them relative to the current IL dissolved oxygen standard and the standards proposed in Garvey and Whiles (2004). Following the National Criteria Document (Chapman 1986), Garvey and Whiles (2004) recommended:

- A minimum of 5.0 mg/L spring through early summer (i.e., March 1 through June 30)
- A 7-d mean of 6.0 mg/L spring through early summer (i.e., March 1 through June 30)
- A minimum of 3.5 mg/L the remainder of the year (i.e., July 1 through February 28 or 29)
- A 7-d mean minimum of 4.0 mg/L the remainder of the year (i.e., July 1 through February 28 or 29)

In this report, I evaluate how the current and proposed standards characterize streams in the state relative to season, stream quality and geographic location. Oxygen and temperature dynamics are interpreted in light of the extant biotic communities and the location of the logger within each stream.

Study Sites

<u>North Fork Vermilion River near Bismarck, IL</u>. This east-central Illinois stream reach (IL-EPA, BPG-09) averages 20-m wide at base flow and is 0.3- to 1-m deep at the location of the logger. Total surface water for this stream is 1.14 km^2. The drainage for this stream reach is primarily agricultural. Substrate is gravel riffle with vegetation occurring in the channel during summer. Annual mean stream flow is 8.8 m^3/s. This stream was 303-d listed as a high priority for impairment by pathogens.

Middle Fork Vermilion River near Oakwood, IL. This east-central, "wild and scenic river" stream site (IL-EPA, BPK-07) is about 30-m wide, with 5.4 km^2 surface area at normal flows. The logger was placed at an area 1-m deep near a rock riffle on the outside of a gradual bend. Some growth of aquatic vegetation occurs in the riffle during late summer. Land-use in the area is primarily agricultural. Annual mean stream flow is 11.4 m^3/s.

Vermilion River near Danville, IL. This stream site (IL-EPA, BP-08) in east-central Illinois is located in an area with about 91% agricultural and 4% urban land-use. This stream has a gravel and sand substrate and is about 50-m wide at base flow. Surface area of this stream is 24.3 km^2. Depth at logger location was 2-3 meters at base flow. Annual mean stream flow is 28.9 m^3/s.

Lusk Creek near Eddyville, IL. Located in the southeastern - Illinois Shawnee National Forest and draining the Lusk Creek Wilderness area, this 0.22-km^2, meandering stream (IL-EPA, AK-02) has a bed composed of sand, gravel, cobble, and bedrock. The site was located in a pool of about 2-m deep and 10-m across. Land use is 76% forested and about 18% agricultural. Woody debris and vegetation occur in the channel; surface flow between the pool and the channel can become disconnected. Annual mean stream flow is 1.7 m^3/s.

Mazon River near Coal City, IL. This 17-km^2 north-central Illinois river (IL-EPA, DV-04) is listed as impaired for PCBs and pathogens. Agriculture dominates the land-use (94%), with urban being the next most abundant class (4%). Stream width averages at 50 m, with vegetation growing in the channel and on the rock and gravel riffle at the site. Annual mean stream flow is 9.9 m^3/s.

Rayse Creek near Waltonville, IL. Although this southern-Illinois stream (IL-EPA, NK-01) resides in a predominantly agricultural watershed, about 17% of the surrounding land is forested. The stream site is a slow moving and turbid pool, with a flashy hydrograph and much debris. The stream will dry during periods of low precipitation. The reach is about 6-m wide and < 1 m deep, although these measurements vary widely with stream flow. This 0.62-km^2 stream is a tributary of the Big Muddy which is impounded downstream to form Rend Lake. Annual mean stream flow is 2.5 m^3/s. It is 303-d listed with nutrients, low pH, enrichment, pathogens, and suspended solids as causes of impairment.

Salt Creek near Western Springs, IL. This is the northernmost stream (IL-EPA, GL-09) located primarily in the urban (80% of land use) Chicago area. Surface area is about 7 km^2 and width averages 23 meters. The site has a partial riffle with heavy aquatic growth occurring during summer. Annual mean stream flow is 3.8 m^3/s. This stream segment also is 303-d impaired, with nutrients, salinity, and pathogens as causes.

Illinois River near Valley City, IL. This large segment (1,003 km^2 surface area; IL-EPA, D-32) in east-central Illinois averages at 200-m wide. Location of logger was about 8-m deep. Annual mean stream flow is 643.5 m^3/s. Surrounding land use is about 77% agriculture with the remainder being approximately half forested and half urban. This segment is also 303-d listed for metal and PCB contamination.

Data Collection and Analysis

Data collection was a joint effort between the USGS and IEPA. At each stream site, temperature and dissolved oxygen concentration (mg/L) were quantified every 30-minutes during late summer 2001 through fall 2003. Monitors were typically mounted in areas where they remained continually submerged, including bridge piers. Depth of loggers ensured that they were 3-5 centimeters below the point of zero flow in the streams. At routine or high flow, probes were likely at > 50% depth.

For each stream, I calculated daily averages and daily minima. For the Illinois standard, I determined the hours within each day that dissolved oxygen concentration was less than 5 mg/L and 6 mg/L.

For the proposed standard (Garvey and Whiles 2004), a minimum dissolved oxygen concentration was defined as the lowest allowable concentration during any given day. A 7-day mean was derived by generating daily averages and then determining a running average across 7 days. Maximum water concentrations that exceeded air saturation were corrected (i.e., decreased) to air saturation values. Seven-day mean minima were calculated by generating a running mean of daily minima across 7 days.

Within the proposed standard, seasons reflect times when most early life stages of warmwater fishes (i.e., eggs, embryos, and larvae, typically 30-d post spawning) are either present (March through June) or absent (July through February) in Illinois waters. We hypothesized that warmwater species that spawn later during summer should have adaptations for naturally occurring reductions in dissolved oxygen concentrations expected to occur during warm months. Hence, in systems in which dissolved oxygen concentrations declined during summer near the proposed minimum, we should still expect the stream to be unimpaired (i.e., unlisted) with a robust biota. Those that frequently declined below the minima would likely show impairment and be 303-d listed by IL-EPA.

Results

As expected, dissolved oxygen concentrations declined in all streams during summer, with each segment violating the current Illinois standard as infrequently as 2% and as frequently as 65% of the days across the two-year period. These patterns were not clearly delineated by latitude, stream quality, or stream size.

North Fork Vermilion River near Bismarck, IL. Although 303-d listed, this stream segment declined below 5 mg/L only 1% of days (Figure 1; Table 1). This stream only violated the rule of declining below 6 mg/L no more than 8-h each day only 2% of days as well (Figure 1; Table 1, 2). With the proposed standard, the violations of the spring and summer critical minima and 7-d means declined to near zero (Table 1).

Middle Fork Vermilion River near Oakwood, IL. This full attainment stream site below a riffle area had the consistently highest dissolved oxygen concentrations of the eight segments (Figure 2). It still violated the Illinois standards on greater than 1% of days (Table 1, 2). With the proposed standard, no violations occurred during either season (Table 1).

Vermilion River near Danville, IL. Although unlisted, this stream site violated the Illinois standard on 6% and 7% of days for the 5 and 6 mg/L rules, respectively (Figure 3; Table 1, 2). Adoption of the proposed standard reduced the frequency of violations (Table 1). However, violations still occurred during the summer months – particularly the 7-d mean minimum of 4 mg/L when this rule was violated 9% of the time (Table 1). This suggests that dissolved oxygen concentrations in this reach may be chronically low during summer, requiring some restoration efforts.

Lusk Creek near Eddyville, IL. This heterogeneous stream residing in a predominantly forested watershed very frequently (22% and 32% of days) violated the current state standard (Figure 4; Table 1, 2). Adoption of the proposed standard greatly reduced the frequency of violations during spring months; however, the 7-d mean minimum of 4 mg/L was violated 3% of days (Table 1). The critical minimum during summer of 3.5 mg/L was violated 1% of dates (Table 1). However, the minimum dissolved oxygen concentration typically declined by < 0.5 mg/L below this threshold (Figure 4).

Mazon River near Coal City, IL. This 303-d listed stream frequently experienced very low dissolved oxygen concentrations during summer (Figure 5), violating both the Illinois standard and the proposed standard (Table 1, 2). The higher frequency of violations of the proposed summer standards suggests that summer eutrophication is a problem in this stream (Table 1).

Rayse Creek near Waltonville, IL. This impaired stream violated the Illinois standard and the proposed standard most frequently (Figure 6; Table 1, 2). The proposed 7-d mean minimum of 4 mg/L was in fact more sensitive than the Illinois standard to violations in this system (Table 1). Spring dissolved oxygen concentrations were chronically below 6 mg/L and often declined below the proposed spring minimum of 5 mg/L (Table 1; Figure 6). Dissolved oxygen concentrations often declined to chronically low levels (< 2 mg/l) during summer through fall (Figure 6).

Salt Creek near Western Springs, IL. This 303-d listed stream violated the Illinois standards of 5 mg/L and 6 mg/L on 9% and 16% of days, respectively (Table 1, 2; Figure 7). When the proposed standard was applied, violations declined somewhat. The majority occurred during the spring months when the 5 mg/L critical minimum was violated 6% of days (Table 1).

Illinois River near Valley City, IL. This largest of the stream segments violated the current Illinois standard of 5 mg/L on 11% of days and 6 mg/L on 21% of days (Table 1, 2; Figure 8). Violations declined with the proposed standard, although violations continued to occur most frequently during the spring. The 7-d mean minimum of 6 mg/L was violated 16% of days (Table 1).

Temperature-Dissolved Oxygen Relationships among Streams. Lusk Creek, the southernmost stream, was warmest during winter months, typically remaining above freezing (Figure 9). During summer months, considerable overlap in monthly average temperatures occurred, although Salt Creek and North Fork Vermilion River had lower average temperatures. Mazon River, another northern system, had consistently warmer averages than its counterparts. Differences in monthly averages among all streams were < 4°C during summer (Figure 9), with the greatest differences occurring between Rayse (the warmest) and Salt (the coolest).

Temperature and dissolved oxygen concentration were negatively related in all streams (Table 3). However, the strength of the relationship varied among streams, with temperature only explaining 33% of the variation in oxygen in the Mazon River and 84% in the Illinois River (Table 3). In Lusk Creek, an apparently sound system with dissolved oxygen concentrations that approached the proposed critical minimum of 3.5 mg/L during summer, low oxygen occurred most frequently during intermediate (25°C), rather than high, summer temperatures (Table 4). This refutes the assumption that the greatest oxygen declines occur during the warmest temperatures in streams. Rather periods of reduced flow coupled with intermittently high production in the pool of Lusk Creek was responsible for the observed patterns.

Discussion

My goal was to identify expected seasonal and diel oxygen curves for streams in Illinois by which we can set realistic standards. With the current Illinois standard, all streams within the state will likely produce violations. The frequency of violations of the current Illinois standard does not appear to be associated with stream impairment. To illustrate, a forested, functioning stream (i.e., Lusk Creek) violated the current standard far more frequently than two of the listed streams (i.e., North Fork Vermilion and Salt Creek). The proposed standards greatly reduced (although did not eliminate) the probability of a violation in Lusk Creek, while not greatly reducing the violations in the clearly oxygen-impaired Rayse Creek and Mazon River. In fact, the proposed standard increased the frequency of violations for Rayse Creek, and provided a seasonal context for interpreting the violation. Land use and alteration of the watershed in addition to flow likely are major factors influencing the oxygen dynamics in these streams, and the proposed standard would lend insight into the degradation of the biota within them.

Implementation of the proposed oxygen standards and interpretation of the oxygen dynamics resulting from monitoring depend greatly on the location of the probes. Garvey and Whiles (2004) recommend placing loggers in pools at two-thirds depth to ensure that areas with the greatest oxygen reductions are sampled. The loggers used in this study were typically at depths > 50% of the water column in areas where they could be conveniently deployed (Paul Terrio, personal communication). Thus, the largely microbial oxygen demand of stream bottoms was likely integrated into oxygen dynamics in many of the deeper stream sites.

Although the recommendation of logger depth was generally upheld, longitudinal location of loggers varied among streams. For example, the least violations of either the current or proposed oxygen standard occurred in the Middle Fork Vermilion River, which is a highly valued stream resource. However, the logger at this site was placed below a riffle. High gaseous oxygen exchange with the atmosphere may have elevated dissolved oxygen concentrations relative to an area with slower, less turbulent upstream flow. Conversely, in small, intermittently flowing Lusk Creek, the logger was placed in a pool with surface flow that becomes disconnected from the stream. In Garvey and Whiles (2004), this is considered the best location for quantifying oxygen dynamics because it provides a clear picture of the "worst case" of oxygen declines in a stream. Clearly, the heterogeneous vertical and horizontal distribution of oxygen within stream sites will render standardization challenging. Further, the dynamic effects of factors such as flow, geomorphology, geology, groundwater, shading, sediment, land use, and temperature will make interpretation of resulting oxygen curves a daunting task.

The Garvey and Whiles (2004) report did not develop standards unique to cool and warm water assemblages in the state. Although some temperature differences did appear to occur across the latitudinal gradient in the state, they appeared to be most pronounced during winter when oxygen stress is unimportant rather than during summer. During summer, slightly warmer conditions occurred in southern streams, particularly in small Lusk Creek, which has the lowest average flow. However, given that the lowest oxygen concentrations occurred at intermediate summer temperatures, the linkage between oxygen stress and high temperature stress for resident organisms appears to be relatively unimportant.

Rather than linking temperature and oxygen, understanding the relationship between flow and oxygen will likely be more informative for predicting effects on resident organisms. As noted earlier and in Garvey and Whiles (2004), pooled areas of streams and rivers, albeit natural or artificial, should have lower oxygen concentrations and should be targeted for monitoring. These sites will elicit the most conservative estimate of oxygen dynamics in a stream reach. Recent studies in the Fox River and DuPage River systems support this, in which oxygen concentrations were typically lower in the pooled portions (Santucci and Gephard 2003; Hammer and Linke 2003). In pooled areas, species with adaptations to increased siltation, reduced flow, and increased open water are abundant while flow-dwelling species are rare or absent. In artificially pooled reaches, altered habitat rather than reduced oxygen likely is ultimately responsible for shifts in the community. Aquatic life adapted to these modified, lentic environments will persist whereas species adapted to flowing water will not be present because the appropriate flow and substrate will be unavailable. Of course, if oxygen concentrations in pools do not meet the proposed standards for aquatic life outlined in Garvey and Whiles (2004), few organisms will be able to persist, regardless of habitat adaptations.

Conclusions

I have summarized the most comprehensive, long-term dissolved oxygen and temperature data set available in the state of Illinois and perhaps for streams in general. It is clear that the proposed standards better capture oxygen violations in truly impaired streams (i.e., those with modified biota such as Rayse Creek) relative to fully functioning streams such as Lusk Creek with high quality habitat and a diverse aquatic biotic assemblage. If the frequent violations of the Illinois standard were biologically meaningful, then Lusk Creek would have a greatly reduced or modified assemblage and would be listed as impaired. This is not the case and the frequent declines in dissolved oxygen concentration approaching the proposed summer minimum within the pools of this system during summer do not compromise spawning fishes or other organisms. As noted in Garvey and Whiles (2004), those species reproducing during summer clearly have adaptations for natural fluctuations in oxygen that occur during this time of year. Although it may be argued that the southern Lusk Creek is much warmer and thus may have a warm-water assemblage adapted to naturally low oxygen, the apparently minor (< 4°C average) differences in stream temperatures across the state coupled with weak oxygen-temperature relationships makes this argument tenuous. More likely, modifications to streams that alter both surface and below-ground flow and habitat quality will greatly affect the composition of stream communities. Of course, strongly impaired, enriched streams which frequently violate the proposed standard will have high incidences of oxygen stress and loss of aquatic life.

References

Chapman, G. 1986. Ambient water quality criteria for dissolved oxygen. EPA 440/5-86-003, United States Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC.

Garvey, J.E., and M.R. Whiles. 2004. An assessment of national and Illinois dissolved oxygen water quality criteria. Final Report. Prepared for the Illinois Association of Wastewater Agencies. Southern Illinois University, Carbondale.

Hammer, J., and R. Linke. 2003. Assessments of the impacts of dams on the DuPage River. Final Report. The Conservation Foundation.

Santucci, V.J., Jr., and S.R. Gephard. 2003. Fox River fish passage feasibility study. Final Report. Max McGraw Wildlife FOudnation. Submitted to Illinois Department of Natural Resources.

Table 1. Proportion frequency of days in which the current Illinois standard and the proposed standards were violated in each stream reach during late summer 2001 through fall 2003. Running means were only generated if seven contiguous days of data were present in the data set. For the proposed standard, spring is defined as March through June and other as July through February. Number of days is the number of days by which either a critical minimum was determined or a mean with seven preceding dates was available.

	Illinois Standard Minima			Proposed Minima				Proposed 7-d running averages			
Stream	IL <5	IL <6	N days	<5 spring	< 3.5 other	Spring days	Other days	Spring mean < 6	Other < 4 mean	Spring days	Other days
*NF Vermilion near Bismark	0.01	0.02	751	0	0	231	520	0	0.01	190	369
MF Vermilion near Oakwood	0.01	0.02	574	0	0	140	434	0	0	132	390
Vermilion near Danville	0.06	0.07	458	0	0.04	84	374	0	0.09	66	250
Lusk near Eddyville	0.22	0.32	653	0.01	0	204	449	0	0.03	182	429
*Mazon near Coal City	0.17	0.15	606	0.05	0.11	181	425	0.05	0.18	152	335
*Rayse near Waltonville	0.62	0.65	523	0.13	0.7	139	384	0.23	0.78	96	380
*Salt at Western Springs	0.09	0.16	590	0.06	0.02	208	382	0	0	167	365
*Illinois River at Valley City	0.11	0.21	638	0.03	0.02	240	398	0.16	0.03	159	334

*Denotes 303-d listed stream segment (2002 cycle).

Table 2. Frequency of days that dissolved oxygen concentrations was lower than 5 and 6 mg/L at 4-h increments in eight Illinois streams during summer 2001 through spring 2003.

		Number of Days per Stream Reach							
Violation	Total Number of Hours per Day	NF Vermilion	MF Vermilion	Vermilion	Lusk Creek	Mazon River	Rayse Creek	Salt Creek	Illinois River
< 5 mg/L	0	740	567	431	508	504	200	536	569
	4	5	2	7	51	18	8	3	14
	8	3	5	4	24	37	8	7	10
	12	1	0	12	28	38	12	21	12
	16	1	0	4	15	8	31	19	8
	20	1	0	0	10	1	43	4	2
	24	0	0	0	17	0	221	0	23
< 6 mg/L	0	721	553	402	415	454	175	471	465
	4	8	4	14	12	27	7	15	17
	8	7	7	12	17	32	2	10	24
	12	4	8	12	34	58	5	24	18
	16	4	2	11	49	32	9	41	17
	20	5	0	5	29	1	16	20	7
	24	2	0	2	97	2	309	9	90

Table 3. Linear regression results of temperature (°C) versus dissolved oxygen concentration (mg/L) quantified each half hour in eight Illinois streams during late summer 2001 through fall 2003.

Stream	N	F	A	b	r^2
NF Vermilion near Bismark	37022	75493	-0.28	14.5	0.67
MF Vermilion near Oakwood	27982	32959	-0.20	13.5	0.54
Vermilion near Danville	22907	23361	-0.31	15.6	0.50
Lusk near Eddyville	32034	125863	-0.31	13.7	0.79
Mazon near Coal City	29906	14910	-0.23	13.3	0.33
Rayse near Waltonville	25812	26061	-0.36	12.1	0.50
Salt at Western Springs	26975	85886	-0.29	13.4	0.76
Illinois River at Valley City	29155	163067	-0.30	13.7	0.84

Table 4. Frequency of half-hour intervals in Lusk Creek, Illinois in which dissolved oxygen concentrations declined below 5 or 4 mg/L as a function of temperature (°C) during late summer 2001 through fall 2003. This stream was chosen due to the wide variation in temperatures and dissolved oxygen concentrations that occurred.

Temperature	< 5 mg/L	< 4 mg/L
15	0	0
17	1	0
19	13	0
21	21	0
23	196	4
25	826	41
27	1105	35
29	434	12
31	49	0
33	0	0
35	0	0

List of Figures

North Fork Vermilion near Bismarck

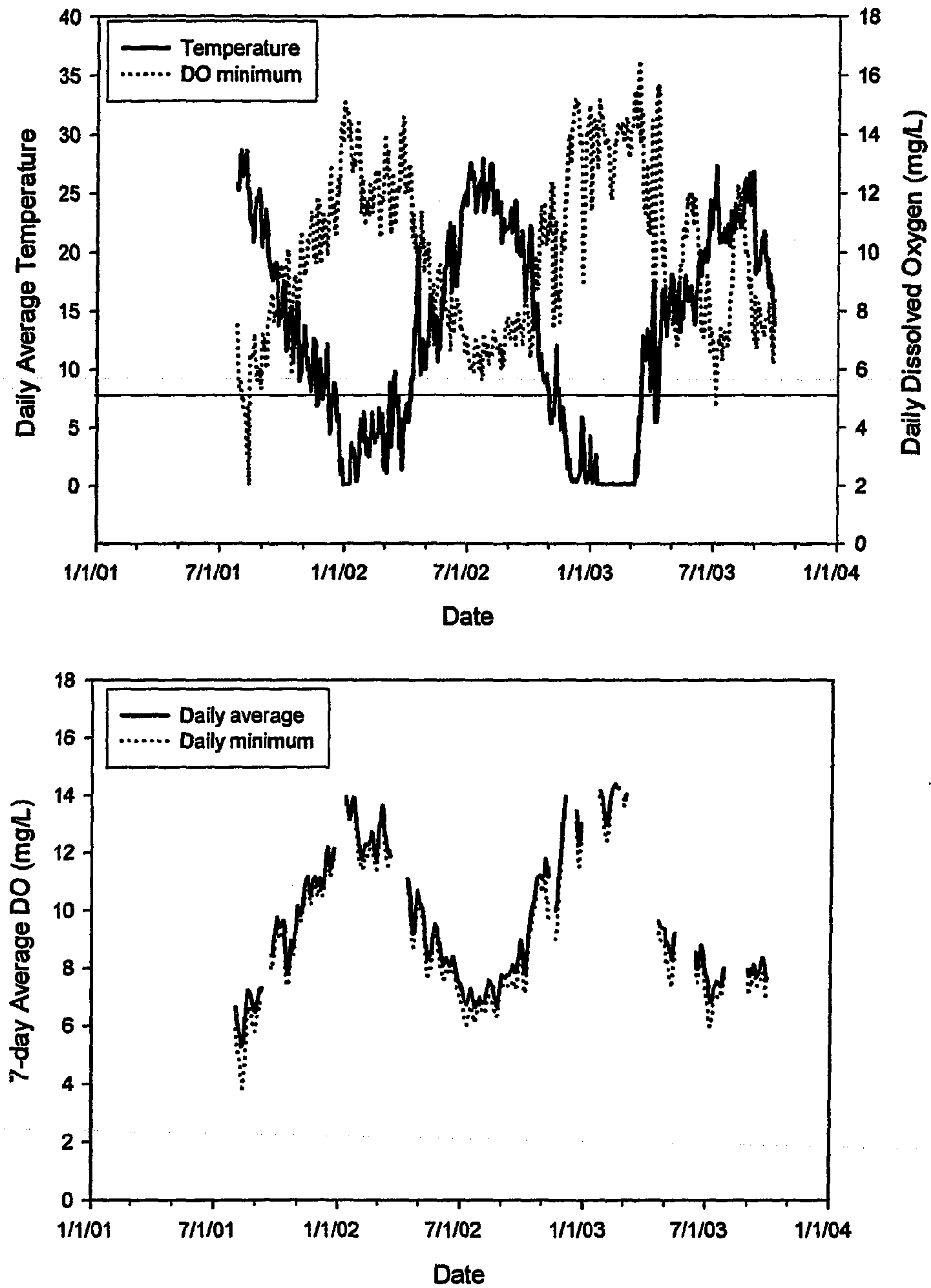


Figure 1

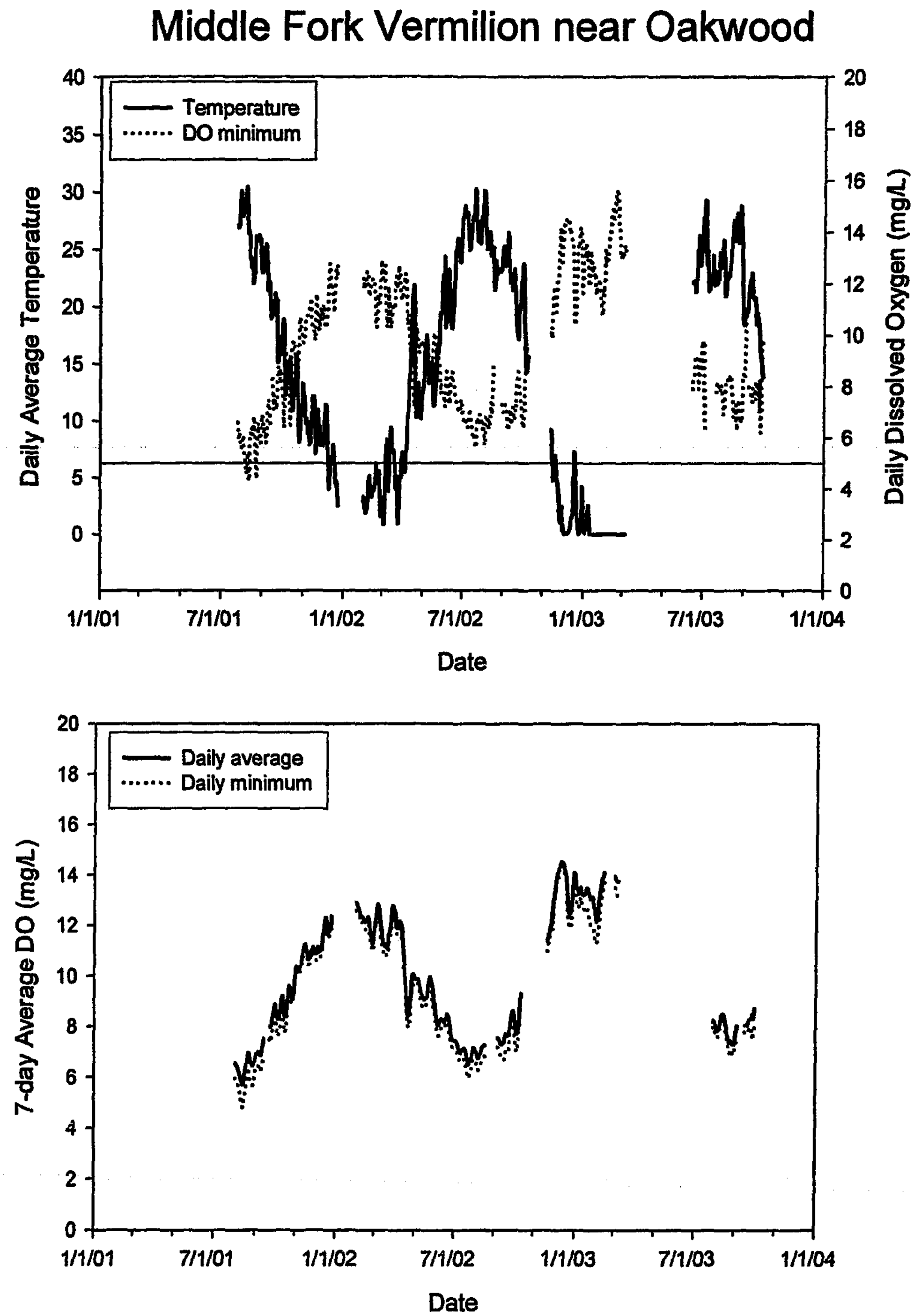

Middle Fork Vermilion near Oakwood
Temperature
DO minimum
Daily Average Temperature
Daily Dissolved Oxygen (mg/L)
40
35
30
25
20
15
10
5
0
20
18
16
14
12
10
8
6
4
2
0
1/1/01
7/1/01
1/1/02
7/1/02
1/1/03
7/1/03
1/1/04
Date
Daily average
Daily minimum
7-day Average DO (mg/L)
20
18
16
14
12
10
8
6
4
2
0
1/1/01
7/1/01
1/1/02
7/1/02
1/1/03
7/1/03
1/1/04
Date

Figure 2

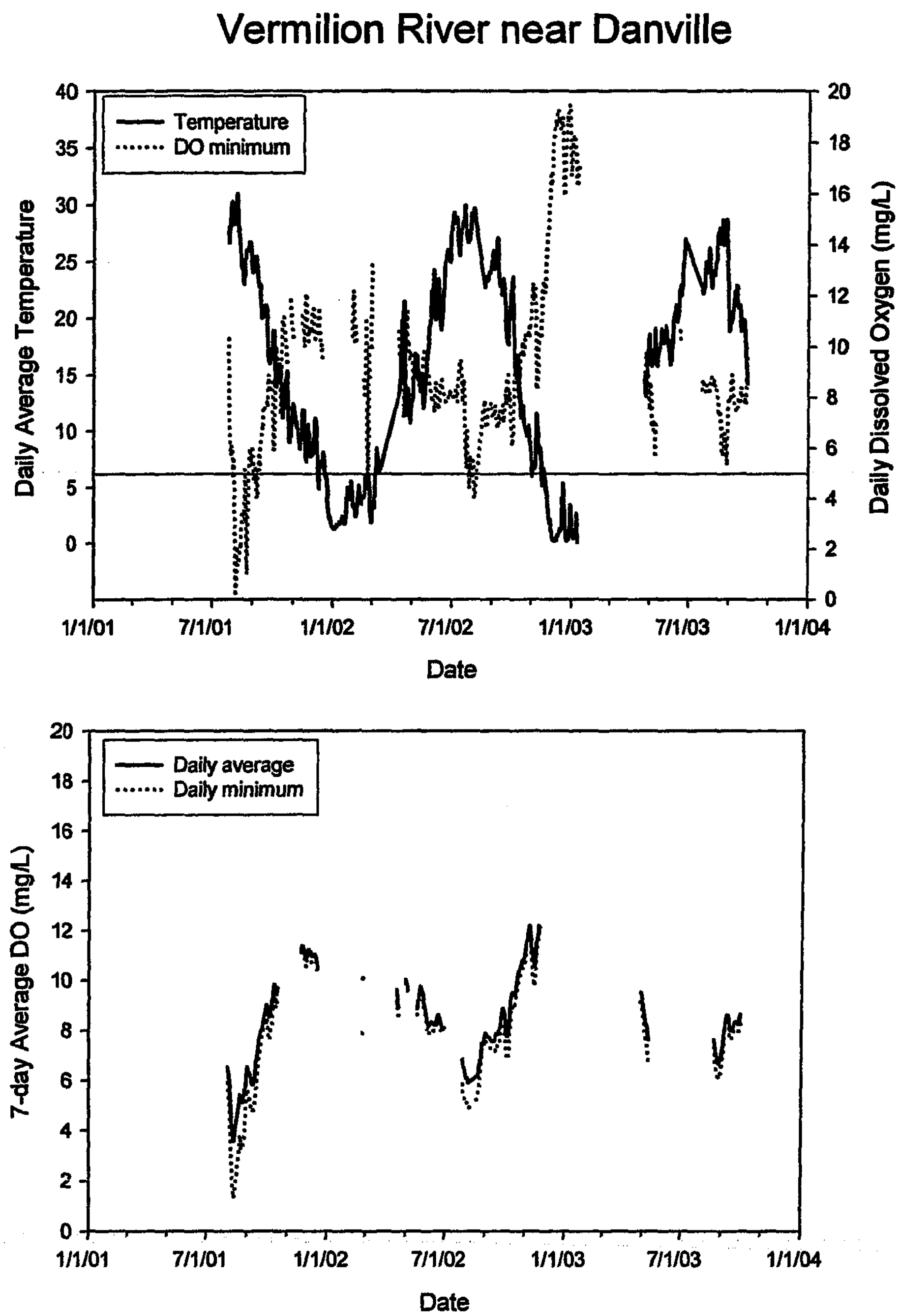

Vermilion River near Danville
Temperature
DO minimum
Daily Average Temperature
Daily Dissolved Oxygen (mg/L)
Date
1/1/01
7/1/01
1/1/02
7/1/02
1/1/03
7/1/03
1/1/04
Daily average
Daily minimum
7-day Average DO (mg/L)

Figure 3

Lusk Creek near Eddyville

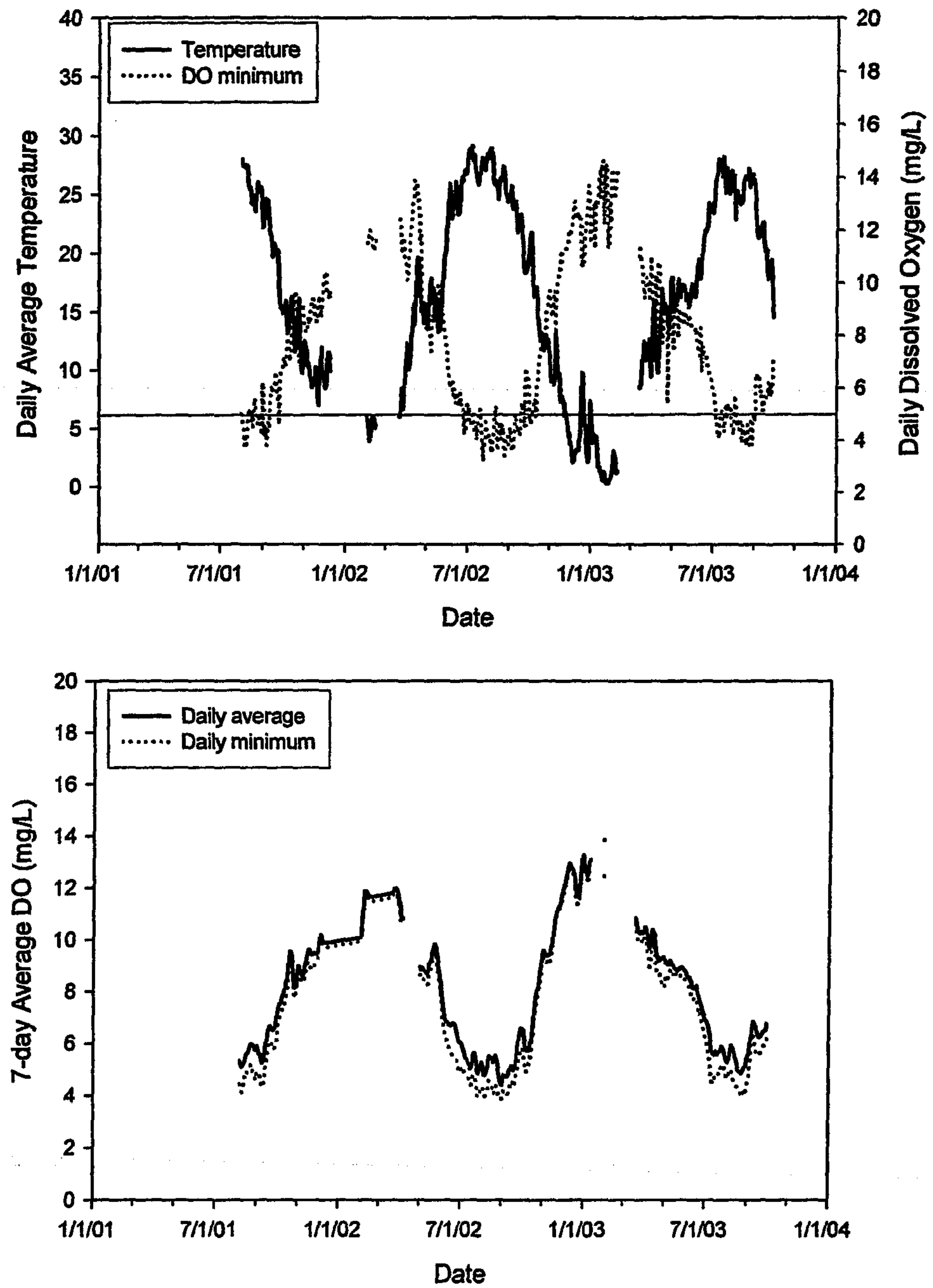
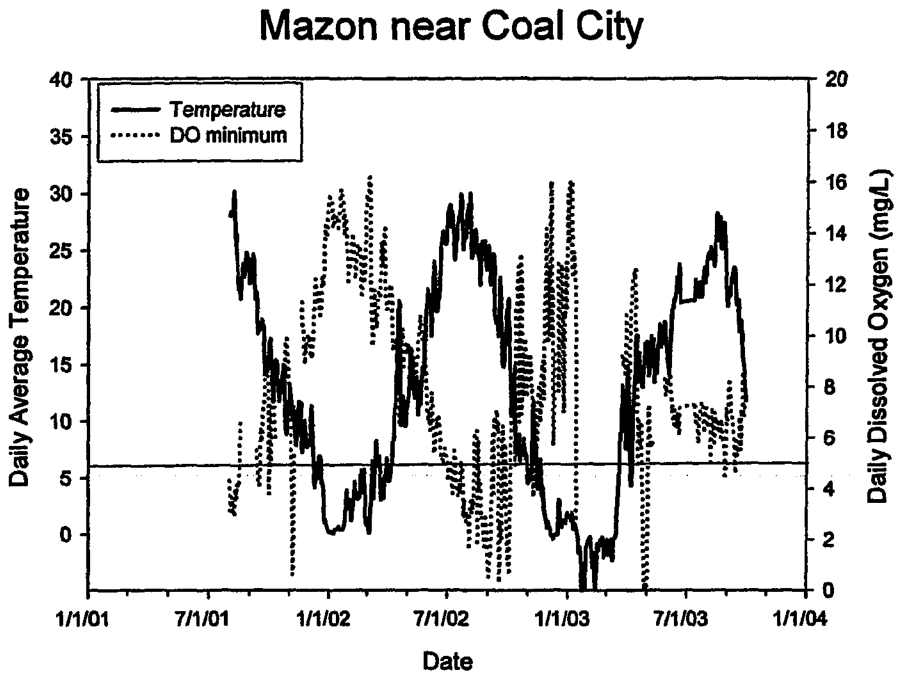


Figure 4


Mazon near Coal City
Temperature
DO minimum
Daily Average Temperature
Daily Dissolved Oxygen (mg/L)
40
35
30
25
20
15
10
5
0
20
18
16
14
12
10
8
6
4
2
0
1/1/01
7/1/01
1/1/02
7/1/02
1/1/03
7/1/03
1/1/04
Date

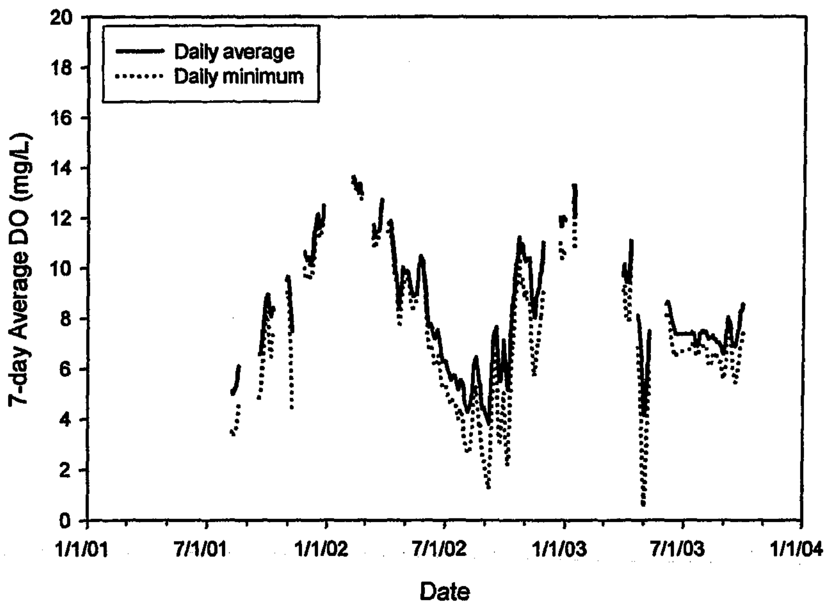
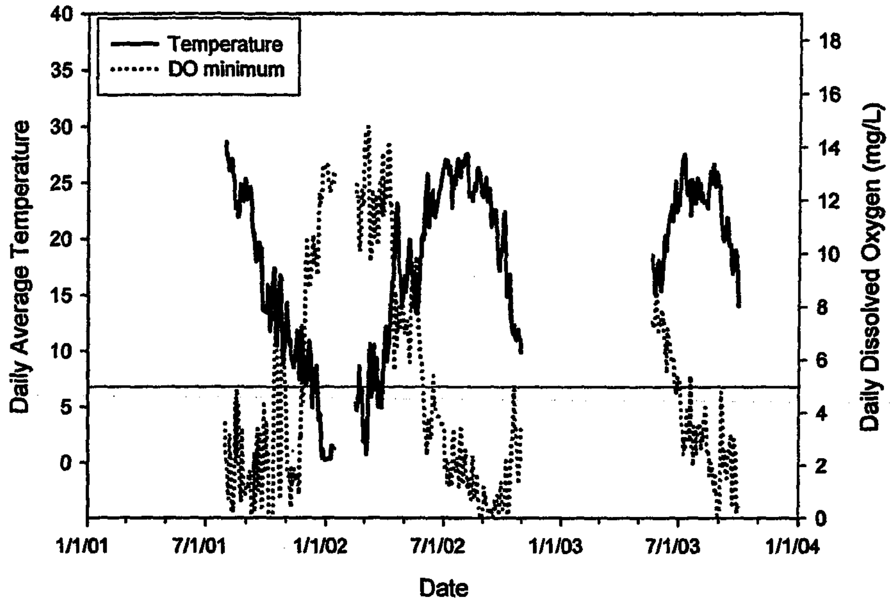

Daily average
Daily minimum
7-day Average DO (mg/L)
20
18
16
14
12
10
8
6
4
2
0
1/1/01
7/1/01
1/1/02
7/1/02
1/1/03
7/1/03
1/1/04
Date

Figure 5

Rayse Creek near Waltonville



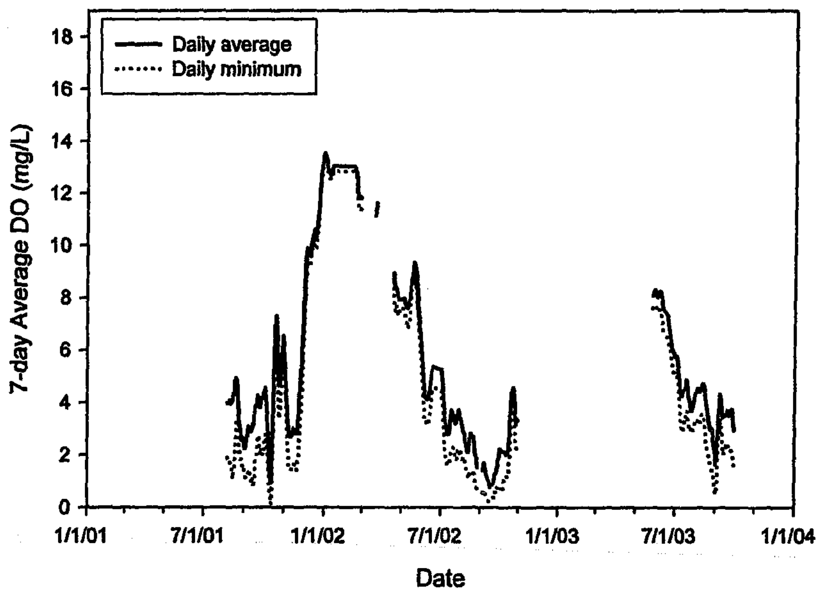


Figure 6

Salt Creek near Western Springs

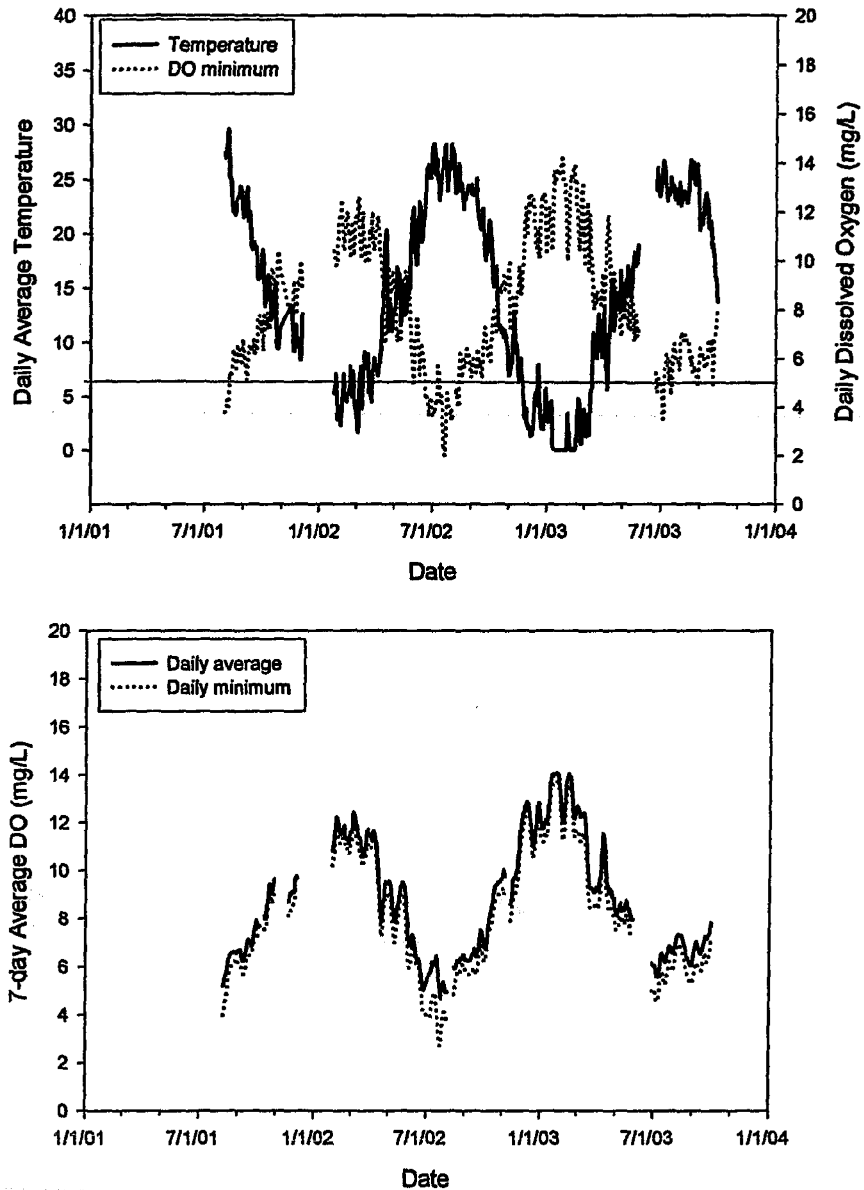


Figure 7

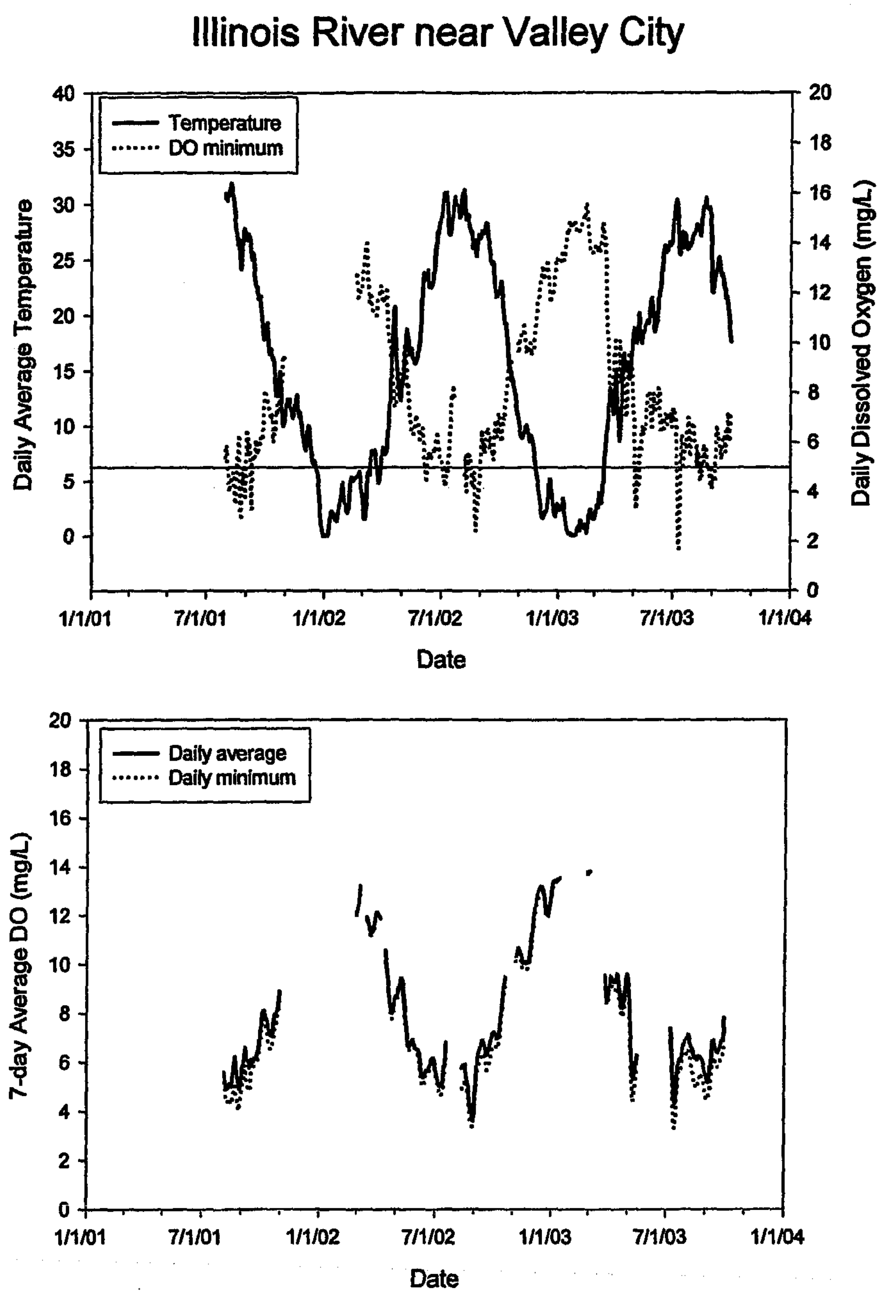
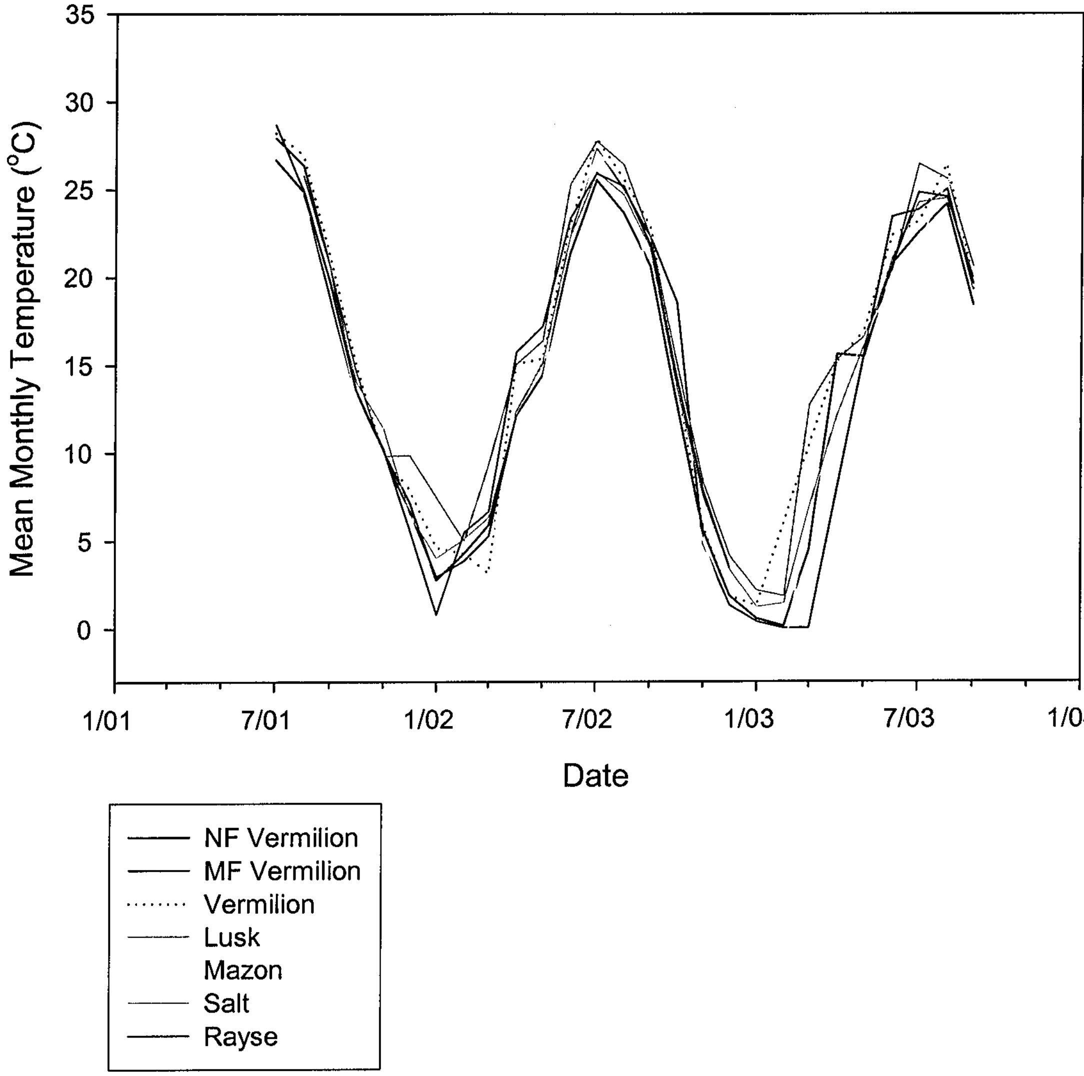

Illinois River near Valley City
Temperature
DO minimum
Daily Average Temperature
Daily Dissolved Oxygen (mg/L)
40
35
30
25
20
15
10
5
0
20
18
16
14
12
10
8
6
4
2
0
1/1/01
7/1/01
1/1/02
7/1/02
1/1/03
7/1/03
1/1/04
Date
Daily average
Daily minimum
7-day Average DO (mg/L)
20
18
16
14
12
10
8
6
4
2
0
1/1/01
7/1/01
1/1/02
7/1/02
1/1/03
7/1/03
1/1/04
Date

Figure 8



35
30
25
20
15
10
5
0
Mean Monthly Temperature (°C)
1/01
7/01
1/02
7/02
1/03
7/03
1/04
Date
NF Vermilion
MF Vermilion
Vermilion
Lusk
Mazon
Salt
Rayse

Figure 9