SECTION 4

RESULTS

SECTION 4
RESULTS

A total of 46,754 validated continuous DO measurements were logged within reference reaches of Little Drywood Creek (n=17,360, 5 sites), Cedar Creek (n=11,854, 3 sites), and Heaths Creek (n=17,540, 3 sites) between the periods of July12, 2006 to September 14, 2006. Dissolved oxygen concentrations aggregated from all sites in Little Drywood Creek (LDC), Cedar Creek (CC), and Heaths Creek (HC) were measured below the statewide criterion of 5.0 mg/L approximately 86%, 64%, and 54% of the time, respectively, during predominantly low-flow or zero-flow conditions. Exposure to dissolved oxygen concentrations below 3.0 mg/L, an acute threshold concentration for aquatic life (Chapman 1986), ranged between 42% (~10 hours per day) at Little Drywood Creek to 21% (~5 hours per day) at Heaths Creek during the study period. Median discrete dissolved oxygen concentrations below 3.0 mg/L were measured in 5 of 7 classified tributaries to AERDOR reference streams.

In general, AERDOR reference streams exceeded applicable draft nutrient benchmarks for total phosphorus, total nitrogen, suspended chlorophyll-a, and benthic chlorophyll-a set forth in national and regional guidance. Median areal production and respiration rates (in units of gO m^{-2} day^{-1}) calculated from diel DO measurements ranged from 4.1 (gross P) and 5.9 (R) at Cedar Creek to 1.6 (gross P) and 3.1 (R) at Little Drywood Creek.

4.1 Quality Assurance Summary

Overall project documentation, training, and data quality objectives were met. Quality control parameters are described and documented in Appendix A. Data collected as part of 2006 sampling activities are available in a Microsoft Access database available on request to ERC.

4.2 Reference Stream Continuous Data

Nearly 300,000 continuous water quality related measurements (e.g. DO, temperature, conductivity, light etc.) were collected at approximately 15-minute intervals between July12, 2006 to September 14, 2006 (Table 4). Continuous data results are provided by parameter in Section 4.2.

TABLE 5. Sample Number of Validated Continuous Measurements Collected in AERDOR Reference Streams During the 2006 Study Season.

Site (#)	Period of Record (Range)	DO	DO Sat	Temp	SC	Level	Baro	Light
		(n=number of continuous measurements)						
LDC1	7/13/06 - 9/13/06	5920	5920	5920	5920	---	0	5933
LDC2	7/13/06 - 9/13/06	5527	5527	5527	5527	*5925	5940	5948
LDC3	7/13/06 - 7/31/06	1713	1713	1713	1713	---	0	1721
LDC4	7/31/06 - 8/14/06	1336	1336	1336	1336	---	0	1337
LDC5	8/14/06 - 9/13/06	2864	2864	2864	2864	---	0	2870
CC1	7/13/06 - 9/13/06	5916	5916	5916	5916	*5926	5926	5934
CC2	7/12/06 - 8/7/06	2386	2386	2386	2092	---	0	2475
CC5	8/7/06 - 9/13/06	3552	3552	3552	3552	---	0	3556
HC1	7/12/06 - 9/14/06	5746	5746	5746	5746	---	0	5169
HC2	7/12/06 -9/14/06	6120	6120	6120	6120	*6119	6119	5753
HC3	7/12/06 -9/14/06	5674	5674	5674	5674	---	0	5004
PARAMETER TOTALS		46,754	46,754	46,754	46,460	17,970	17,985	45,700

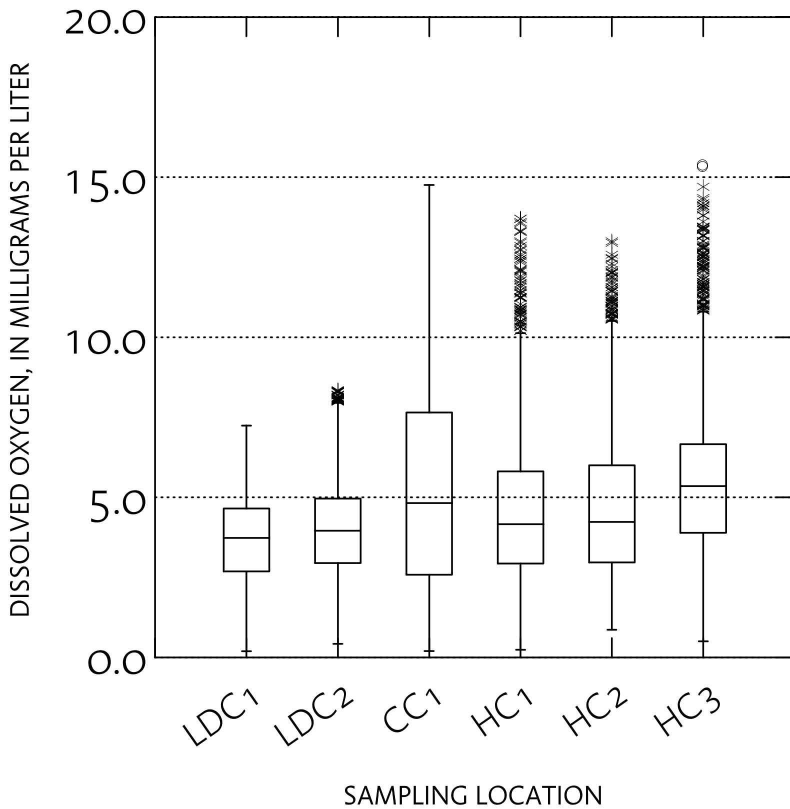
*Level Corrected for Barometric Pressure

DO = Dissolved Oxygen (mg/L)
DO Sat= DO Percent Saturation (%)
Temp = Temperature (°C)
SC = Specific Conductivity (uS/cm)
Level = Stream level above instrument (ft.)
Baro = Barometric Station Pressure (mm Hg)
Light = Light Intensity (lumens / ft²)

4.2.1 Dissolved Oxygen

4.2.1.1 Sites with Comparable Periods of Record

Median dissolved oxygen concentrations for sites having similar data density and period of record ranged from 3.7 mg/L at site LDC1 to 5.4 mg/L at site HC3 (Figure 5). Although site CC1 had the highest coefficient of variation (CV=0.58) among comparable sites, site HC3 had the greatest range (14.9 mg/L) and single day maximum value (15.4 mg/L) during the deployment period. Dissolved oxygen distributions from each site were statistically different (two-sided $p \leq 0.05$) from one another using the large sample approximation of the Wilcoxon rank sum test. Although statistically significant, some differences about the central tendency may not be meaningful, e.g. HC2 vs. HC1, as they are within data instrument error (±0.4 mg/L between any two instruments). Large continuous sample sizes (n>5,000 per site) are likely the source of statistically significant differences that are relatively low in magnitude. Descriptive statistics for collected parameters are provided in Appendix F.



Site (ID)	Mean (mg/L)	Mean Daily Range (max - min, mg/L)
LDC1	3.7	2.8
LDC2	4.0	3.5
CC1	5.2	8.8
HC1	4.5	4.8
HC2	4.6	4.8
HC3	5.4	5.9

FIGURE 5. Boxplot Comparison of Complete-Day (n≥84 per day) Dissolved Oxygen Concentration Data for AERDOR Reference Streams with Comparable Periods of Record (7/12/2006 – 9/14/2006).

With few exceptions, observed daily minimum concentrations were below the instantaneous warm-water fishery dissolved oxygen criterion of 5.0 mg/L for all comparable sites and deployment days (Figure 6, Appendix F). Percent time below 5.0 mg/L ranged from 83% to 44% at sites LDC1 and HC3, respectively, during the deployment period (Figure 7). Percent time below 3.0 mg/L ranged between 34 %(LDC1) and 13%(HC3) over the deployment period (Figure 7), with extremes of 0% occurring at several sites in July and 99% (23.8 hours) occurring on 8/25/2005 at site LDC2. In general, mean daily minimums for comparable sites are approximated by the 14th percentile (Table 5). Although site concentration distributions tended to be statistically different, daily minimums between sites did not. Mean daily minimums observed at site CC1 were different from all sites and minimums. Daily minimums between HC1 vs. HC3 were different at the $p \leq 0.05$ level.

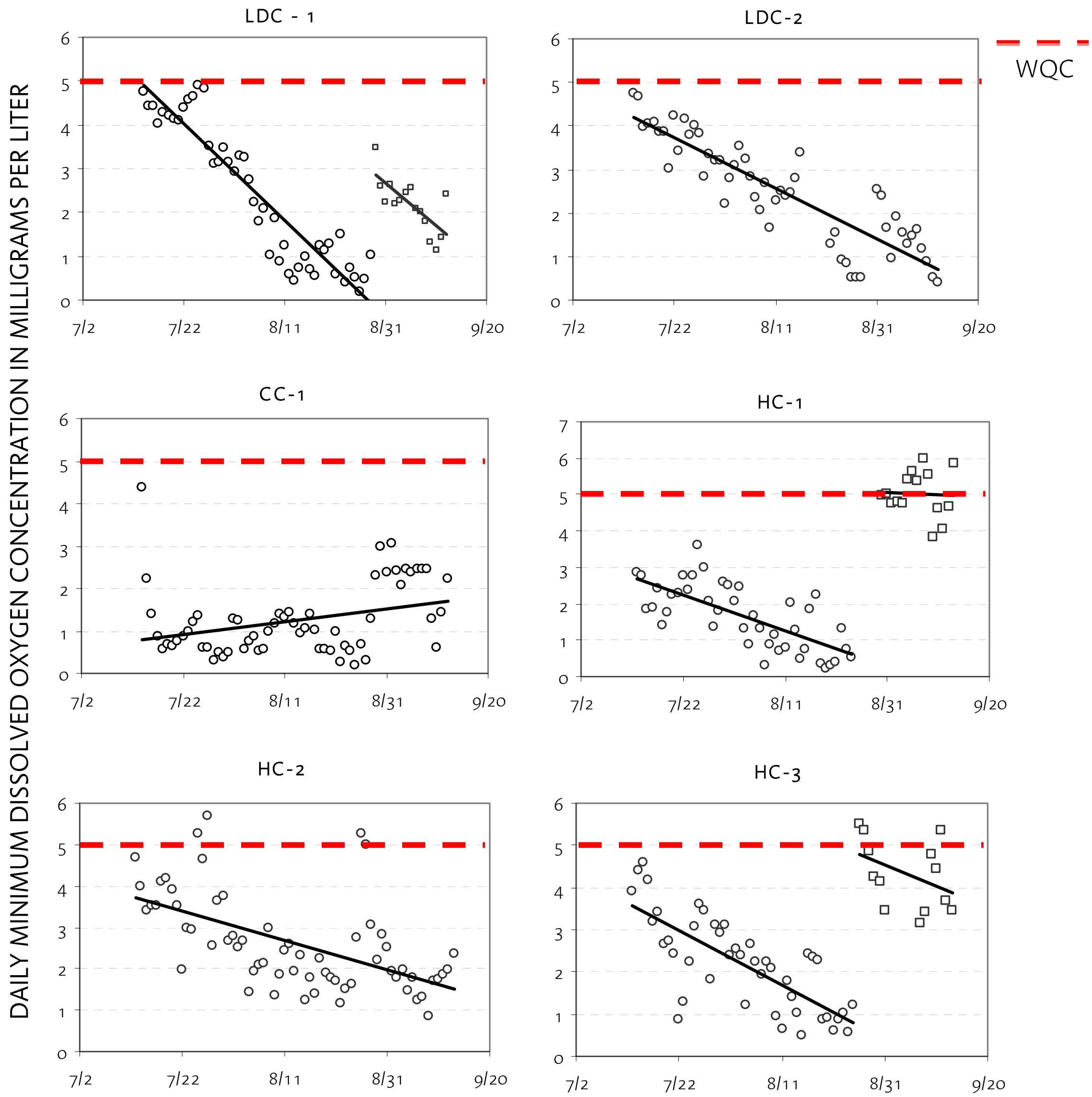


FIGURE 6. Time Trends in Observed Daily Minimum Dissolved Oxygen Concentrations (n=354) for AERDOR Reference Streams with Comparable Periods of Record (7/12/2006 – 9/13/2006).

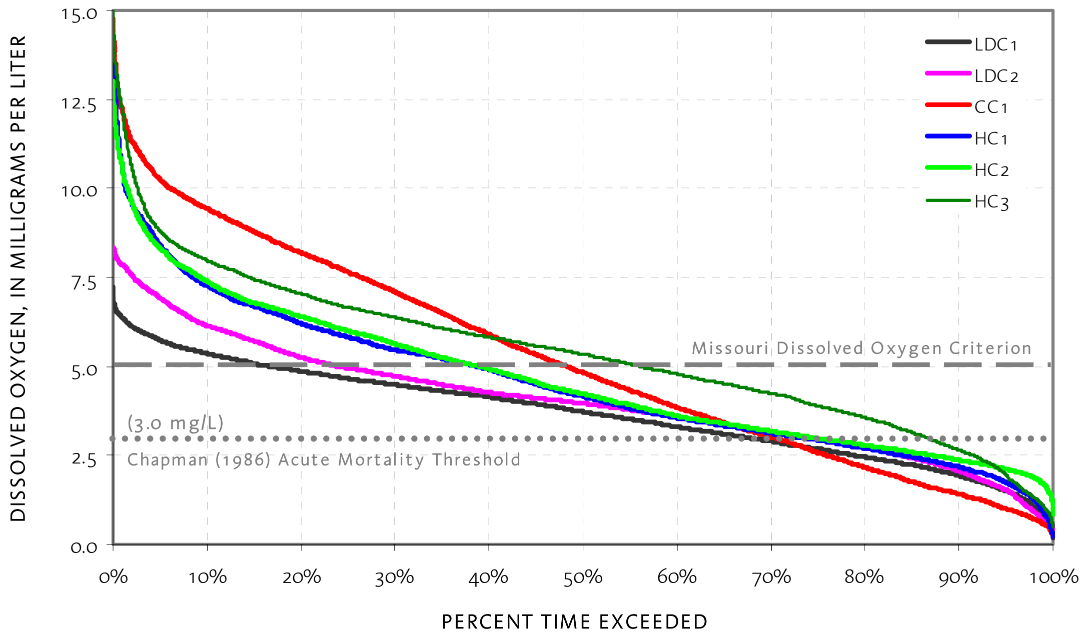


FIGURE 7. Frequency Comparison of Complete-Day (n≥84 per day) Dissolved Oxygen Concentration Data for AERDOR Reference Streams with Comparable Periods of Record (7/12/2006 – 9/14/2006).

TABLE 6. Mean Daily Site Minimums and Corresponding Percentiles for AERDOR Reference Streams. Complete-Day (n≥84 per day) Dissolved Oxygen Concentration Data Collected From 07/12/2006 to 09/14/2006.

Site	Mean Daily Minimum	Number of Daily Minimums	*Mean Minimum Percentile
LDC1	2.35	61	17.6
LDC2	2.50	54	16.1
CC1	1.25	61	7.6
HC1	2.52	58	16.2
HC2	2.60	63	15.6
HC3	2.67	57	10.1

*Percentile of Continuous Period of Record Corresponding To Mean Daily Minimum

Dissolved oxygen daily minima exhibited negative time trends ($p \leq 0.05$) at all sites except CC1 between 7/13/2006 to 8/26-8/29/2006 (Figure 6). Minimum dissolved oxygen concentrations were observed between 8:30 am to 12:40 pm while times corresponding to maximum values ranged from 12:50 pm to 5:30 pm (Table 6).

TABLE 7. Times Corresponding to Daily Minimums and Maximums for AERDOR Reference Streams. Complete-Day (n≥84 per day) Dissolved Oxygen Concentration Data Collected From 07/12/2006 to 09/14/2006.

Site	Mean Time of Minimum Dissolved Oxygen	Mean Time of Maximum Dissolved Oxygen
LDC1	12:38 PM	3:07 PM
LDC2	12:22 PM	12:49 PM
CC1	8:31 AM	5:27 PM
HC1	10:49 AM	4:53 PM
HC2	10:20 AM	3:58 PM
HC3	9:07 AM	3:46 PM

4.2.1.2 Dissolved Oxygen at Continuous Sites with Reduced Periods of Record

Sites CC2,CC5, LDC3,LDC4, and LDC5 were sampled for shorter durations compared to sites listed in Section 4.2.3. Sites LDC3, LDC4, and LDC5 were moved sequentially downstream along Little Drywood Creek to assess longitudinal variability. The fractured deployment period at sites CC2 and CC5 were the result of in-stream cattle use at site CC2.

The lowest DO conditions during the 2006 study period were observed at site LDC5 (29-day mean of 0.5 mg/L). Stationary monitoring sites deployed within Bushwacker Conservation Area (LDC1,LDC2) were consistently higher in DO than downstream sites located near (LDC3) or outside (LDC 4, LDC5) Conservation Area boundaries (Figure 8).

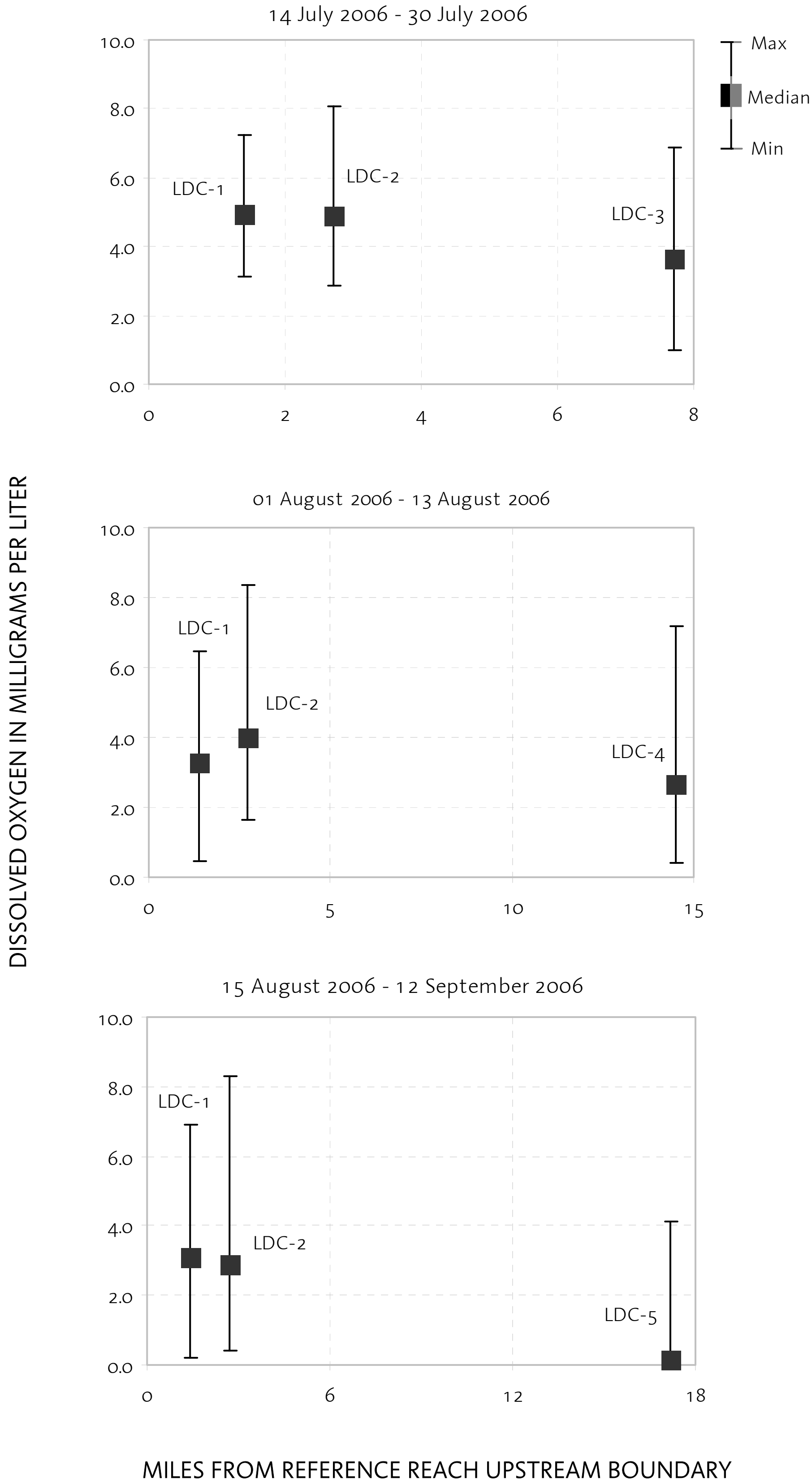


FIGURE 8. Longitudinal Dissolved Oxygen Comparison Between Stationary vs. Mobile Monitoring Sites for Little Drywood Creek.

Significant differences ($p<0.05$) were observed between sites CC1 (median=5.0 mg/L) and CC2 (0.6 mg/L) for the period of 7/14/06 to 8/6/2006 and between sites CC1 (median=4.8 mg/L) and CC5 (median=3.4 mg/L) for the period of 8/8/2006 to 9/12/2006 (Figure 9). The most upstream site, CC2, was influenced by in-stream cattle activity. The site CC2 median (0.6 mg/L) was substantially lower than the arithmetic mean (3.6 mg/L).

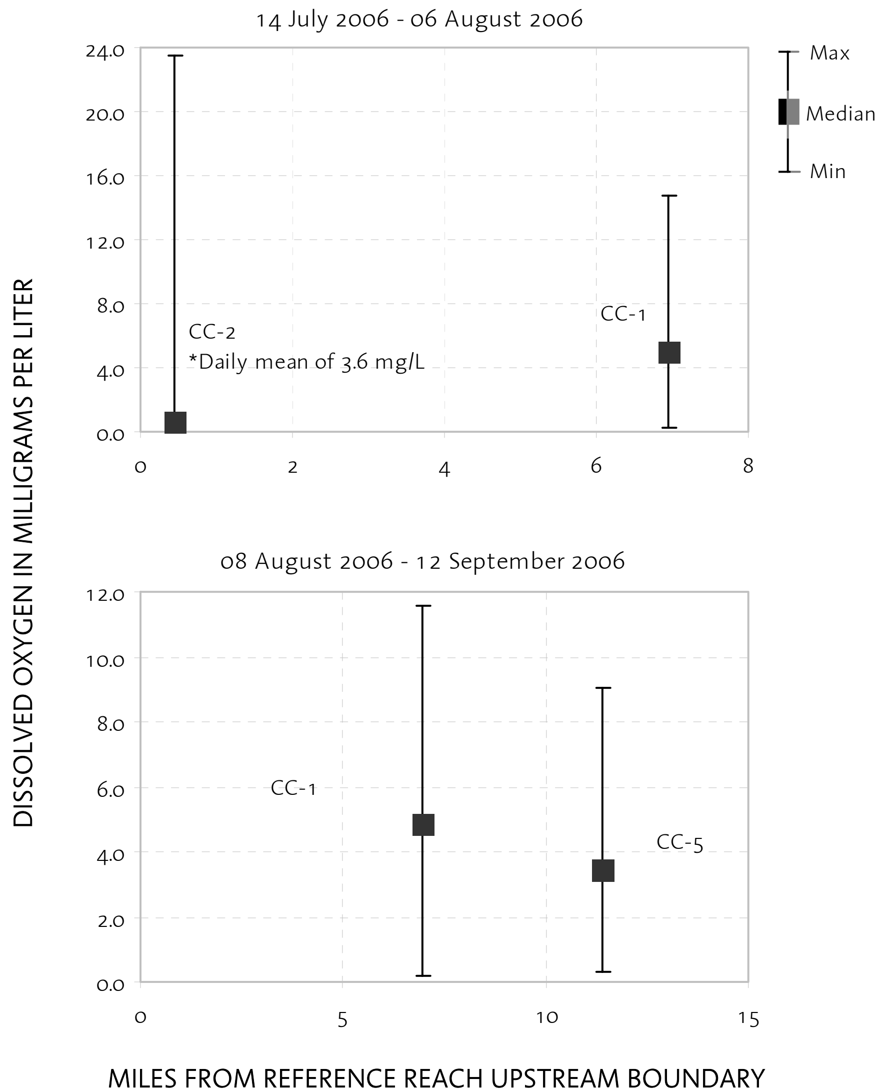
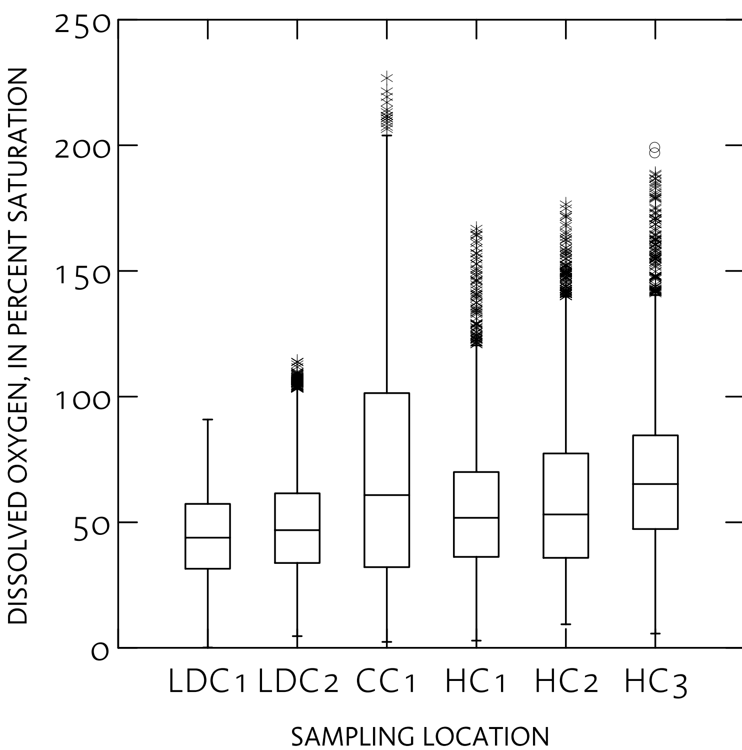


FIGURE 9. Longitudinal Dissolved Oxygen Comparison Between Monitoring Sites for Cedar Creek.

4.2.2 Percent Saturation of Dissolved Oxygen

4.2.2.1 Percent Saturation at Sites with Comparable Periods of Record

Median DO percent saturation values for sites having similar data density and period of record ranged from 44% at site LDC1 to 65% at site HC3 (Figure 10). Variability was pronounced at site CC1 where values ranged from 2% to 226% while LDC1 exhibited the least variation (range = 91%) among comparable sites during the study period. With the exception of sites LDC2 and HC1, percent saturation distributions were statistically different (two-sided $p<0.05$) from one another using the large sample approximation of the Wilcoxon rank sum test. Percent saturation values corresponding with a concentration of 5.0 mg/L ranged from 58% at HC1 to 66% at site CC1 (Figure 10). Descriptive statistics for percent saturation data are provided in Appendix F.



Site (ID)	Mean (%)	Mean Daily Range (max% - min%)	% Sat. ~ 5.0 mg/L (%)
LDC1	44.3	35.6	61.1
LDC2	49.3	47.1	62.8
CC1	68.8	124.3	66
HC1	54.9	63.7	58.2
HC2	58.9	65.3	64.2
HC3	67.3	78.5	62.3

FIGURE 10. Boxplot Comparison of Complete-Day ($n \geq 84$ per day) Dissolved Oxygen Percent Saturation Data for AERDOR Reference Streams with Comparable Periods of Record (7/12/2006 - 9/14/2006).

4.2.2.2 Percent Saturation at Continuous Sites with Reduced Periods of Record

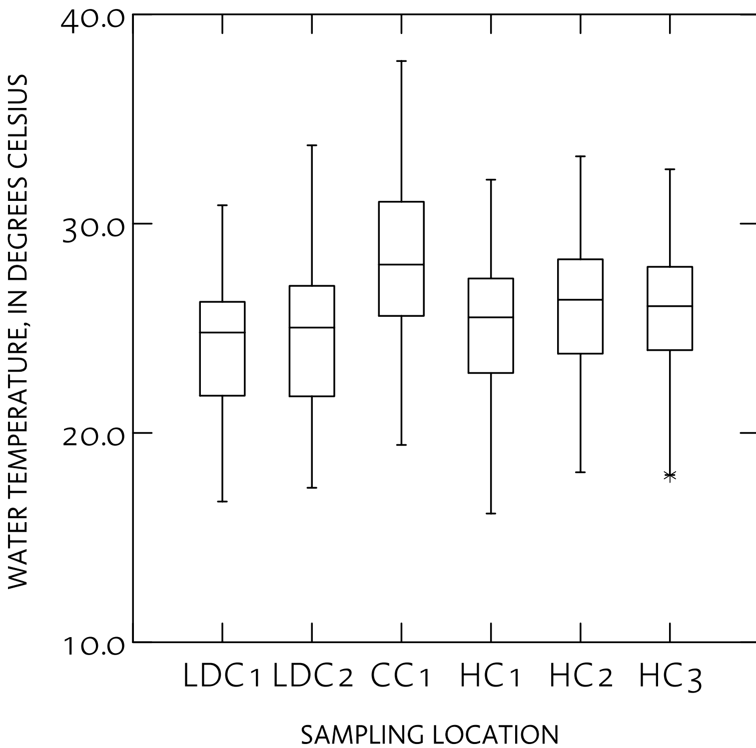
Percent saturation data expressed similar longitudinal trends as DO concentration records. The lowest percent saturation values observed during the 2006 study period were collected at site LDC5 (29-day mean saturation of 5.6%).

4.2.3. Water Temperature

4.2.3.1 Water Temperature at Sites with Comparable Periods of Record

Similar water temperature distributions were observed at sites LDC1 and LDC2 (two-sided $p=0.235$) while sites CC1, HC1, HC2, and HC3 were statistically dissimilar at the $p\leq0.05$ level using the large sample approximation of the Wilcoxon rank sum test. Cedar Creek (CC1) exhibited the largest diurnal range and daily maximum value among sites with comparable periods of record (Figure 11). Seventeen percent of site CC1 records exceeded 90°F, the Missouri Water Quality Criterion for warm-water fisheries. Deployment period medians at Little Drywood Creek sites within Bushwacker Conservation Area (LDC1 & LDC2) were the lowest observed during the 2006 study season.

Maximum daily temperatures were observed near 5:15 p.m. at most sites while daily minimums occurred near 8:00 a.m. Daily average temperature could be approximated by collecting a single discrete measurement around 12:30 p.m. at most sites.



Site (ID)	Mean (°C)	Mean Daily Range (max°C -min°C)	≥ 90°F (% time exceeded)
LDC1	24.2	3.1	0%
LDC2	24.8	4.3	0.5%
CC1	28.2	7.1	17%
HC1	25.1	4.7	0%
HC2	25.9	3.5	1%
HC3	25.8	4.5	0.2%

FIGURE 11. Boxplot Comparison of Complete-Day ($n\geq84$ per day) Water Temperature Data for AERDOR Reference Streams with Comparable Periods of Record (7/12/2006 – 9/14/2006).

4.2.3.2 Water Temperature at Continuous Sites with Reduced Periods of Record

Longitudinal gradients within Little Drywood Creek were not substantive as the largest between site difference occurred between LDC4 and LDC1 (median difference=1.3°C) for the period of 8/1/2006 through 8/13/2006. A larger median difference of 3.1°C was observed in Cedar Creek between sites CC1 (30.1°C) and CC2 (27.0°C) from 7/14/2006 through 8/6/2006. Of note, site CC2 had a mean daily temperature range of 7.0°C while site CC5 had a substantially smaller range of 2.6°C. In addition to being comparable to site CC1 based on daily range, site CC5 also exceeded 90°F more frequently (5.3%) than other reduced period of record sites. Sites LDC4 (range=1.6°C) and LDC5 (range=1.7°C) exhibited the lowest daily temperature range observed during the 2006 study season.

4.2.4 Specific Conductivity

Conductivity increased through time in Heaths and Little Drywood Creeks during periods of minimal rainfall and falling stream levels (Figure 12). Despite declining stream levels at Cedar Creek, conductivity remained relatively stable. Sites HC3 and CC2 hosted the highest observed conductivity levels. Of note, cattle were observed in Cedar Creek at site CC2.

Diurnal variability was most pronounced at site CC2 (median range=38 uS/cm) and least evident at site LDC4 (median range=3 uS/cm).

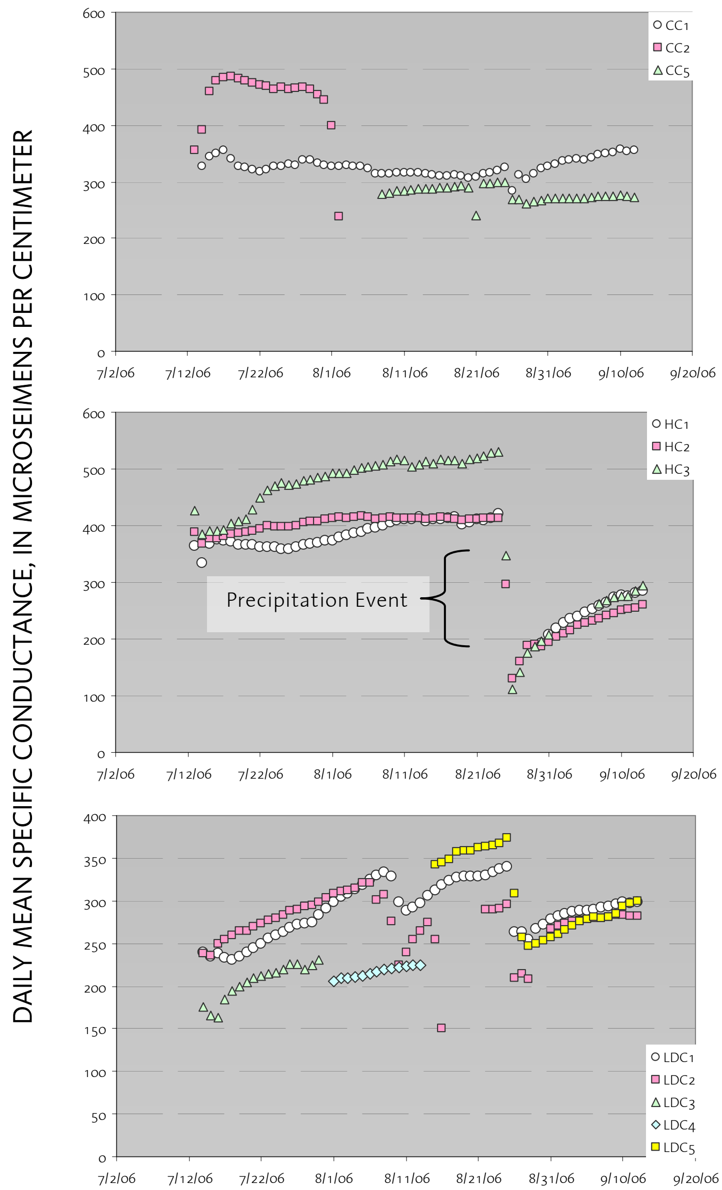


FIGURE 12. Timeseries Comparison of Complete Day ($n \geq 84$ per day) Specific Conductance Data for AERDOR Reference Streams (7/12/2006 – 9/14/2006)

4.2.5 Level and Streamflow

Pressure corrected stream level data and discrete open-channel flow measurements were collected at sites LDC2, CC1, and HC2 during the 2006 study season. Estimated streamflows were at or below 0.1 cubic feet per second (cfs) during the majority the 2006 study season (Figure 13) reflecting one of the driest summers in the last 30 years. Stream levels decreased throughout the summer of 2006 until late August when a brief rainfall spate elevated waterways in much of southwest and central Missouri.

Prolonged drought conditions impeded development of robust level and streamflow rating curves. Measurable flow was observed twice in Heaths Creek, twice in Little Drywood Creek, and at three occasions in Cedar Creek during weekly site maintenance visits (Figure 13). Measurable streamflows were low in magnitude and infrequent. Streamflows estimates were limited to stream levels at or below those observed during the maximum measured streamflow.

Despite drought conditions, collected discharge and level data do support reliable estimates of days with low or no flow and days dominated by runoff (>50% of flow composed of runoff) (Table 7). Little Drywood Creek experienced fewer stagnation days (days during which the flow drops below 0.1 cfs for any part of that day) than Heaths or Cedar Creeks and the least disparity between observed stagnation days and predicted stagnation days based on flow data from USGS gages in the same EDU (Table 7, Appendix G).

TABLE 8. Critical Streamflow Indicators for AERDOR Reference Streams.

Deployment Period (Range)	Monitoring Site (#)	Observed Stagnation (Days)	Expected Stagnation (Days)*	Runoff Dominated (Days)
7/13/06 - 9/13/06	LDC2	51	22	8
7/12/06 -9/14/06	HC2	57	7	7
7/13/06 - 9/13/06	CC1	63	14	1

*Normalized to the number of deployment days

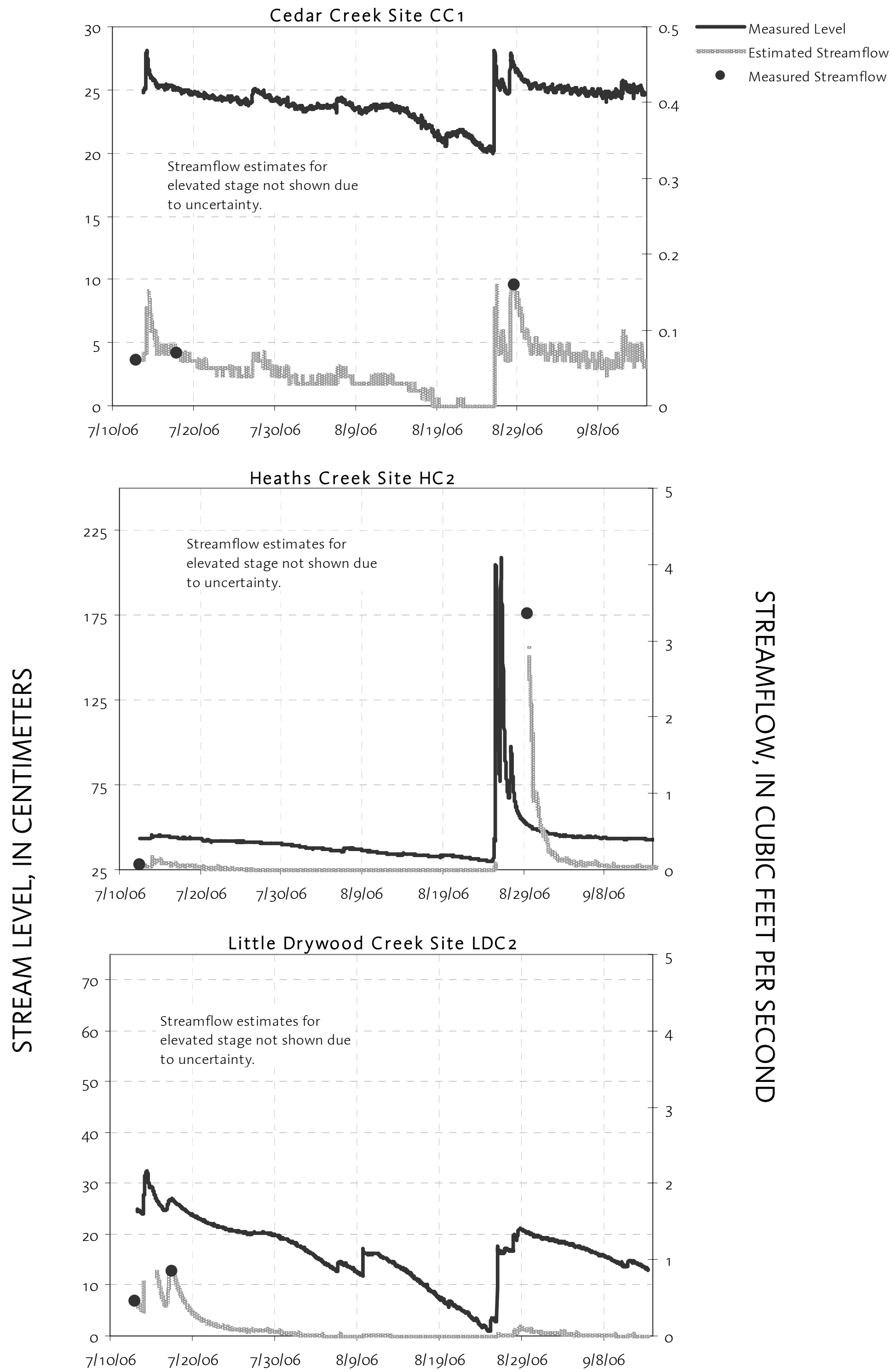


FIGURE 13. Level and Streamflow Timeseries for AERDOR Reference Streams Collected During 2006 Study Season (07/12/2006 to 09/14/2006).

4.2.6 Barometric Pressure

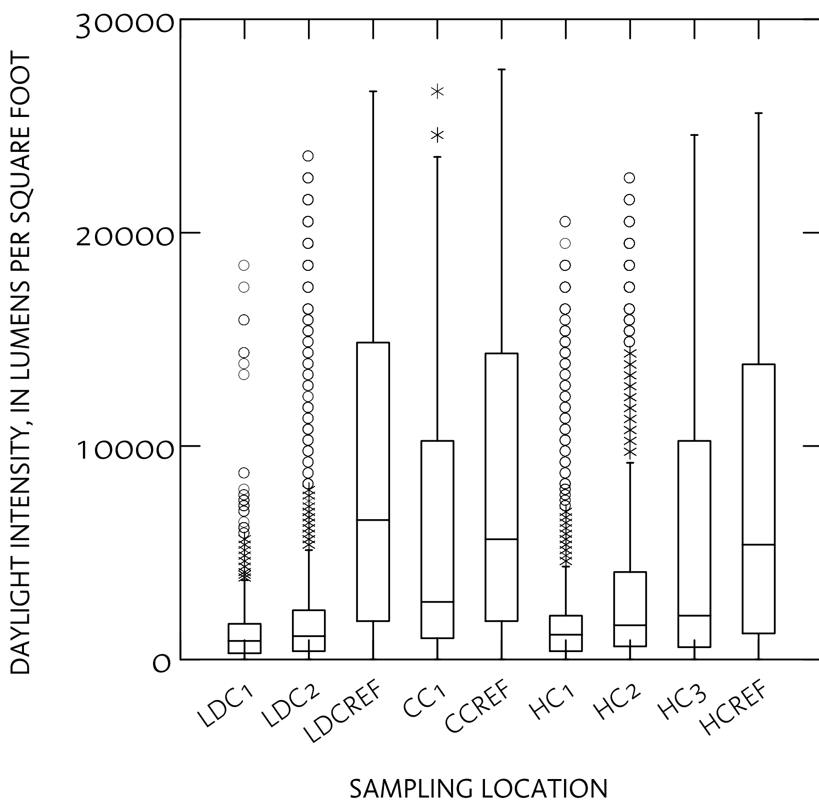
Barometric station pressure data were collected continuously at sites LDC2, CC1, and HC2 during the 2006 study season to correct stream level data for atmospheric pressure influences and refine dissolved oxygen solubility estimates. Median site pressure over the deployment period was measured to be 744 mmHg at site CC1, 748 mmHg at site HC2, and 749 mmHg at site LDC2. Station pressure medians reflect elevation differences between streams.

4.2.7 Photopic Light Intensity

4.2.7.1 Photopic Light Intensity at Sites with Comparable Periods of Record

Continuous incident light intensity data were collected within the stream channel at each ambient sampling location and at one location (per stream) in the adjacent floodplain (LDCREF,CCREF, and HCREF). Differences (relative intensity) between open-field floodplain measurements and stream channel data represent shading from channel incision and riparian vegetation. Light intensity measured at open-field locations are presumed to be limited by topography and cloud cover.

Daylight intensity differed (two-sided $p \leq 0.05$) between all stream sites while exhibiting significant and increasing longitudinal trends ($p<0.05$) in the downstream direction. Daily peak intensity and range at Sites CC1 and HC3 were substantially higher than other in-stream sites (Figure 14).



Site (ID)	Median (lumens/ft.^{2})	Median Relative Light (%)
LDC1	864	13%
LDC2	1088	17%
LDREF	6528	-------
CC1	2688	48%
CCREF	5632	-------
HC1	1152	21%
HC2	1600	30%
HC3	2048	38%
HCREF	5376	-------

FIGURE 14. Boxplot Comparison of Complete-Day ($n \geq 84$ per day) Photopic Daylight Intensity Data for AERDOR Reference Streams with Comparable Periods of Record (7/12/2006 – 9/14/2006).

Cedar Creek (CC1) was least shaded (48%) compared to open-field measurements (CCREF). Little Drywood Creek at sites LDC1 and LDC2 received the least light during the deployment period (Figure 14).

4.2.7.2 Photopic Light Intensity at Sites with Reduced Periods of Record

Little Drywood Creek

During the period of 7/14/2006 through 7/30/2006, median light intensity at site LDC3 (928 lumens/ft.^{2}) was significantly lower (one-sided $p<0.05$) than sites LDC1 (1008 lumens/ft.^{2}) or LDC2 (1152 lumens/ft.^{2}). Respectively, median relative light for the same period was 12%,13%, and 11% for sites LDC1, LDC2, and LDC3.
From 8/1 through 8/13 sites LDC4 and LDC2 had similar (1280 lumens/ft.^{2}) median light intensities although variability at site LDC2 (s =5923) was twice that of site LDC4. Median relative light for sites LDC1,LDC2, and LDC4 for the 8/1/2006- 8/13/2006 period was 12%, 17%, and 17% respectively. From 8/15/2006 through 9/12/2006, median light intensity at site LDC5 (992 lumens/ft.^{2}) was significantly higher than site LDC2 (960 lumens/ft.^{2}) and LDC1 (800 lumens/ft.^{2}). Median relative light for sites LDC1,LDC2, and LDC5 for the 8/15/2006- 9/12/2006 period was 15%, 18%, and 18% respectively. Increasing longitudinal gradients were observed between sites LDC1, LDC2, and LDC5 while sites LDC3 and LDC4 were at or below median intensities observed at upstream sites (absent or decreasing gradient).

Cedar Creek

Median and relative light intensity for sites CC1 and CC2 for the period of 7/14 through 8/6/2006 were 2,432 lumens ft.^{2} (34%) and 1,984 lumens ft.^{2} (28%), respectively. For the period of 8/8/2006 through 9/12/2006, median and relative light intensity for sites CC1 and CC5 were 2,688 lumens ft.^{2} (53%) and 1,152 lumens ft.^{2} (23%), respectively. All median intensity differences were significant at the $p<0.05$ level. Light intensity at site CC1 was higher than CC2 or CC5 negating meaningful longitudinal gradients.

4.2.8 Air Temperature

Median air temperatures were 24.5°C, 26.5°C, and 24.1°C for sites LDC2, CC1, and HC2, respectively, during the 2006 deployment period. Standard deviation was higher at site CC1 (s=6.3) compared to LDC2 (s=5.5) or HC2 (s=5.7).

4.3 Reference Stream Discrete Data

Approximately 4,300 discrete water quality measurements across 17 parameters or parameter suites, were collected between 7/12/2006 and 9/14/2006 (Table 8). Discrete data results are provided by parameter in Sections 4.3 and 4.4.

TABLE 9. Sample Number of Validated Discrete Measurements Collected in AERDOR Reference Streams and Classified Tributaries During the 2006 Study Season (7/12/2006 - 9/14/2006).

Site	TP	TN	NH3N	NO3N	CBOD	TSS	VSS	S-Chla	B-Chla	pH	DO	DO %	T	SC	Rip	Chan	Hydrog	TOTALS
(#)	(n=discrete measurements, including quality assurance duplicates and blanks)																	
LDC1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	33	5	41	79
LDC2	15	15	15	15	15	15	15	15	*45	9	---	---	---	---	33	17	45	269
LDC3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	558
LDC4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0
LDC5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	252	40	266	0
LDC6	---	---	---	---	---	---	---	---	---	3	3	3	3	3	---	---	---	15
LDC7	---	---	---	---	---	---	---	---	---	3	3	3	3	3	---	---	---	15
CC1	13	13	13	13	13	13	13	13	*45	9	---	---	---	---	212	54	348	772
CC2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0
CC3	---	---	---	---	---	---	---	---	---	**	**	**	**	**	---	---	---	0
CC4	---	---	---	---	---	---	---	---	---	**	**	**	**	**	---	---	---	0
CC5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	222	40	284	546
HC1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	234	40	294	568
HC2	17	17	17	17	17	17	17	17	*45	9	---	---	---	---	231	44	226	691
HC3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	295	46	412	753
HC4	---	---	---	---	---	---	---	---	---	3	4	4	4	4	---	---	---	19
HC5	---	---	---	---	---	---	---	---	---	3	4	4	4	4	---	---	---	19
HC6	---	---	---	---	---	---	---	---	---	**2	**3	**3	**3	**3	---	---	---	14
HC7	---	---	---	---	---	---	---	---	---	3	4	4	4	4	---	---	---	19
HC8	---	---	---	---	---	---	---	---	---	**1	**1	**1	**1	**1	---	---	---	5
TOTALS	45	45	45	45	45	45	45	45	135	45	22	22	22	22	1,512	286	1,916	4,342

* weekly periphyton samples consisted of 5 replicate collections during nine sampling events
**Absence of water in channel prevented sampling of tributary water quality during scheduled sampling events

TP- Total Phosphorus
TN- Total Nitrogen
NH3N- Total Ammonia as Nitrogen
NO3N- Nitrite+Nitrate N
TSS- Total Suspended Solids
CBOD- 20 day CBOD
VSS- Volatile Suspended Solids
S-Chla- Suspended Chlorophyll-a
B-Chla- Benthic Chlorophyll-a
pH- *potential hydrogenii*
DO- Dissolved Oxygen
DO%- DO Percent Saturation
T- Stream Temperature
SC- Specific Conductance[
Rip- Riparian Charactieriscs
Chan- Channel Characteristics
Hyrdog- Hydrogeometry

4.3.1 Total Phosphorus

Little Drywood Creek had the lowest median (82 ug/L) total phosphorus (TP) concentration measured during the 2006 study season, followed by site CC1 (146 ug/L) and HC2 (172 ug/L). Only 2 of 9 samples (22%) at Site LDC2 were above the TP benchmark set forth by U.S. EPA Nutrient Criteria guidance (USEPA 2000a) (Figure 15). All samples collected at sites CC1 and HC2 exceeded the ecoregional benchmark associated with these sites (USEPA 2000b, 2000c)(Figure 15). In addition to benchmarks set forth in national guidance, the Regional Technical Assistance Group (RTAG) for EPA Region 7 identified a TP benchmark of 0.075 mg/L (G. Welker pers. comm.). On a median basis, all sites exceeded the Region 7 RTAG benchmark for TP.

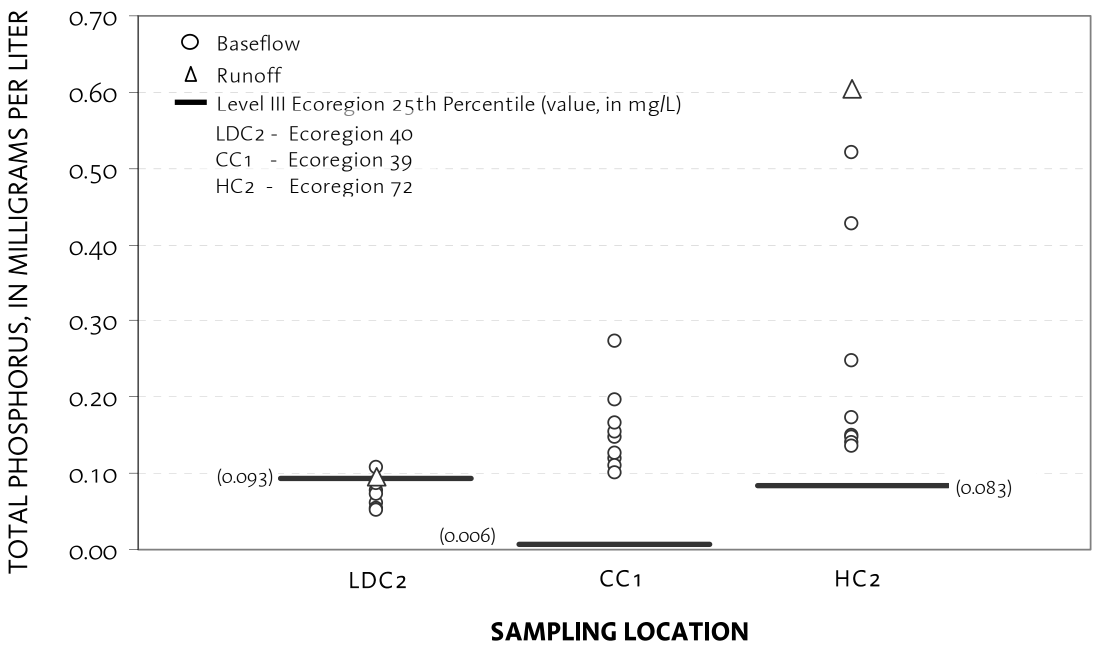


FIGURE 15. Baseflow and Runoff-Influenced Total Phosphorus Concentrations in Relation to 25th Percentile Level III Ecoregion Nutrient Benchmarks. Data Collected in AERDOR Reference Streams from 7/12/2006 to 9/14/2006 (n=9 samples per stream).

4.3.2 Total Nitrogen

The highest median total nitrogen (TN) concentration observed during the 2006 study season was observed at site HC2 (1.4 mg/L), followed by CC1 (1.32 mg/L) and LDC2 (1.16 mg/L). As with TP, all TN samples collected at site CC1 exceeded 25th percentile nutrient benchmarks for the Ozark Highlands (ecoregion 39) (Figure 16). Site HC2 exceeded applicable TN benchmarks the fewest times (2 out of 9 samples). Little Drywood Creek site LDC2 exceeded applicable benchmarks 7 out of 9 samples.

The EPA Region 7 RTAG has identified a TN benchmark of 0.9 mg/L (G. Welker pers. comm.). On a median basis, all sites exceeded the Region 7 RTAG benchmark for TN. A runoff sample collected on 08/29/2006 was substantially higher than HC2 baseflow values. A spike in Nitrite plus Nitrate on the same date contributed to the elevated runoff-influenced TN value.

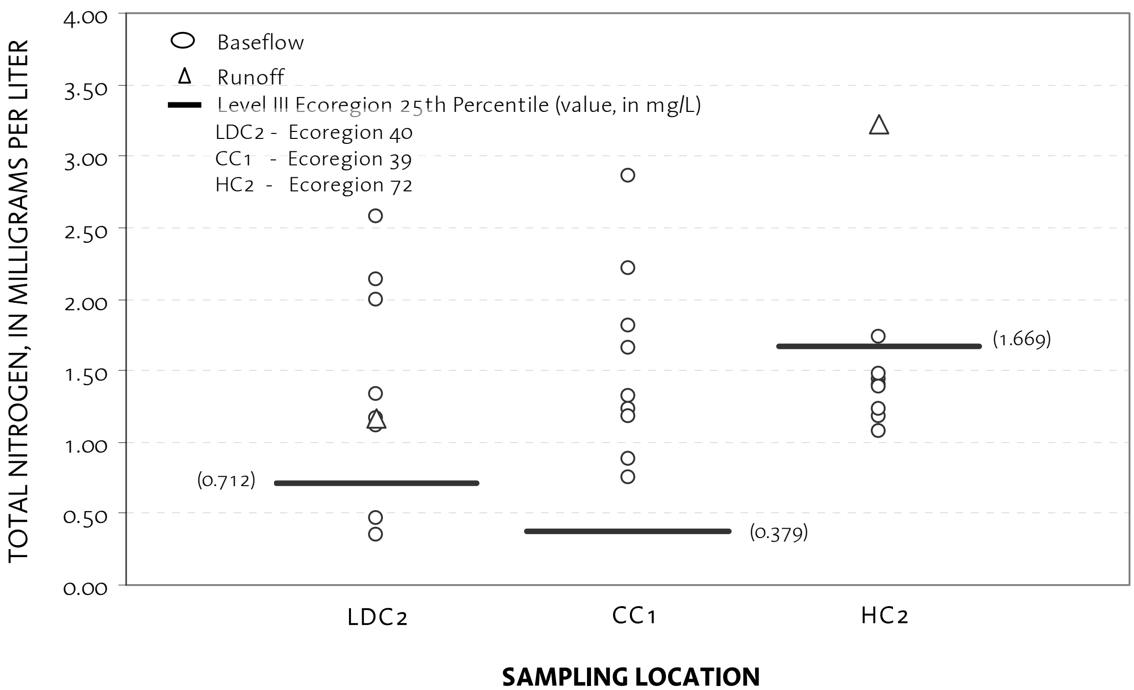


FIGURE 16. Baseflow and Runoff-Influenced Total Nitrogen Concentrations in Relation to 25th Percentile Level III Ecoregion Nutrient Benchmarks. Data Collected in AERDOR Reference Streams from 7/12/2006 to 9/14/2006 (n=9 samples per stream).

4.3.3 Nitrite Plus Nitrate as Nitrogen

Nitrite plus Nitrate Nitrogen (NO2+NO3N) concentrations were generally low at all sites with non-detectable levels (<0.02 mg/L) occurring in 13 out of 27 total samples (not including duplicates or field blanks). Median concentrations at sites LDC2, CC1, and HC2 were 0.05 mg/L, 0.08 mg/L, and <0.02 mg/L, respectively. Samples at all sites were below applicable 25th percentile nutrient benchmarks except for one runoff sample (0.69 mg/L) collected on 08/29/2007 at site HC2. Applicable nutrient benchmarks for NO2+NO3N are very similar at all sites (~0.23 mg/L). The HC2 runoff sample collected 08/29/2007 was substantially higher than the greatest baseflow value (0.69 mg/L vs. 0.13 mg/L). Runoff-influenced samples were not collected at site CC1.

4.3.4 Total Ammonia as Nitrogen

Total Ammonia Nitrogen (NH3N) concentrations were low at all sites but considerably higher at HC2 (median=0.14 mg/L) compared to other site medians (LDC2=0.054 mg/L, CC1=0.039 mg/L). All samples were below applicable chronic and acute aquatic life criteria (Carnahan 2005). Eutrophication-based NH3N benchmarks have not been established by U.S. EPA or the Missouri Department of Natural Resources. Runoff-influenced and baseflow NH3N samples were similar.

4.3.5 Suspended Chlorophyll-a

Measured suspended chlorophyll-a (S-Chla) values at all sites were generally higher than expected. Median S-Chla concentrations for sites LDC2, CC1, and HC2 were 16 ug/L, 42 ug/L, and 21 ug/L, respectively. Only 1 (HC2, 08/29/2006) of 27 total samples (not including duplicates or field blanks) were below applicable aggregated 25th percentile benchmarks of 2 ug/L (Little Drywood & Heaths Creek) and 1.6 ug/L (Cedar Creek) (Figure 17). The EPA Region 7 RTAG has identified a S-Chla benchmark of 8 ug/L (G. Welker pers. comm.). On a median basis, all sites exceeded the Region 7 RTAG benchmark for S-Chla.

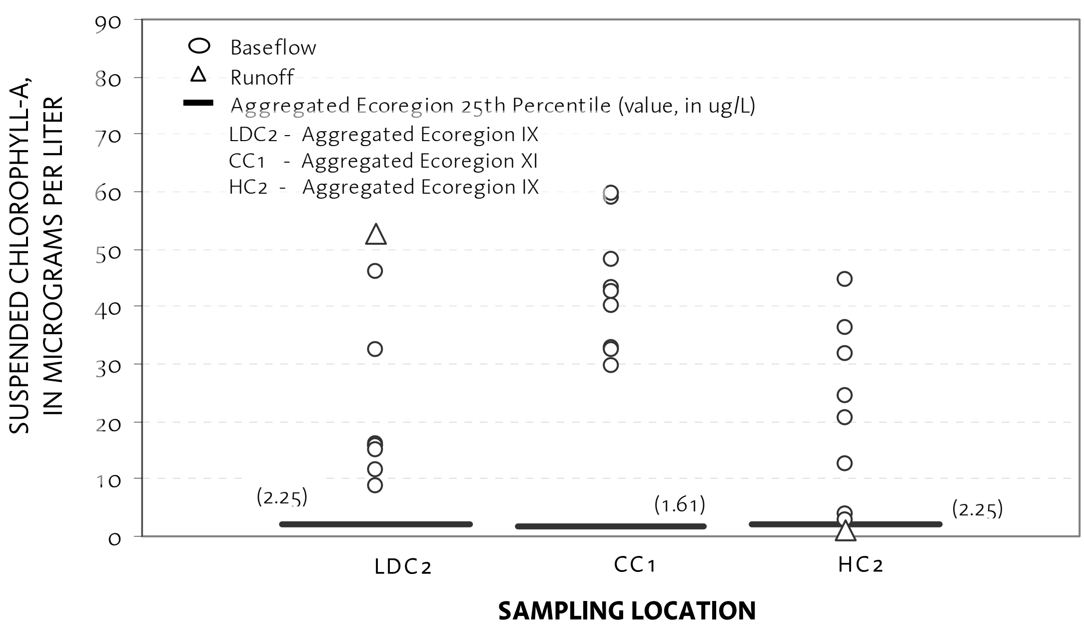


FIGURE 17. Baseflow and Runoff-Influenced Suspended Chlorophyll-a Concentrations in Relation to 25th Percentile Aggregated Ecoregion Nutrient Benchmarks. Data Collected in AERDOR Reference Streams from 7/12/2006 to 9/14/2006 (n=9 samples per stream).

4.3.6 Benthic Chlorophyll-a & Periphyton Percent Bottom Coverage

Five replicate periphyton scrapings from natural substrates were collected per site during each of nine sampling events conducted between 7/12/2006 to 9/14/2006. The geometric mean of five replicates were calculated to serve as the final data point for a given site resultant from a single sampling event. Scrapings were collected randomly within the stream reach containing continuous dissolved oxygen sampling equipment. Benthic chlorophyll-a data obtained from scrapings are expressed as mg Chla/m^2 and represent areal biomass estimates *where benthic forms were present.* Benthic chlorophyll-a data does not infer that the entire wetted perimeter of a study stream is covered with a quantity of algae determined through multiplication of bed area by areal mass of chlorophyll-a. Rather, estimates of percent bottom coverage by periphyton *in combination with* areal Chla and hydrogeometry data can be used to estimate total biomass within a designated stream reach. Percent bottom coverage of benthic algae were evaluated once during the study period at sites having continuous dissolved oxygen instrumentation.

The highest study period mean occurred at site CC1 (68 mg Chla/m^2), followed by sites LDC2 (50 mg Chla/m^2) and HC2 (48 mg Chla/m^2). Variability was least evident at site CC1 (CV=0.21), followed by sites LDC2 (CV=0.26) and HC2 (CV=0.43). National nutrient criteria databases offer little benthic chlorophyll-a data for comparative purposes. However, the EPA Region 7 RTAG has identified a benthic chlorophyll-a benchmark of 40 mg Chla/m^2 for use in Nebraska, Iowa, Kansas, and Missouri. Uncorrected for percent bottom coverage, monitored reference streams exceeded the benthic algae benchmark developed by the RTAG in 22 of 27 total samples (Figure 18). Four of the five values below the RTAG benchmark were collected from Site HC2.

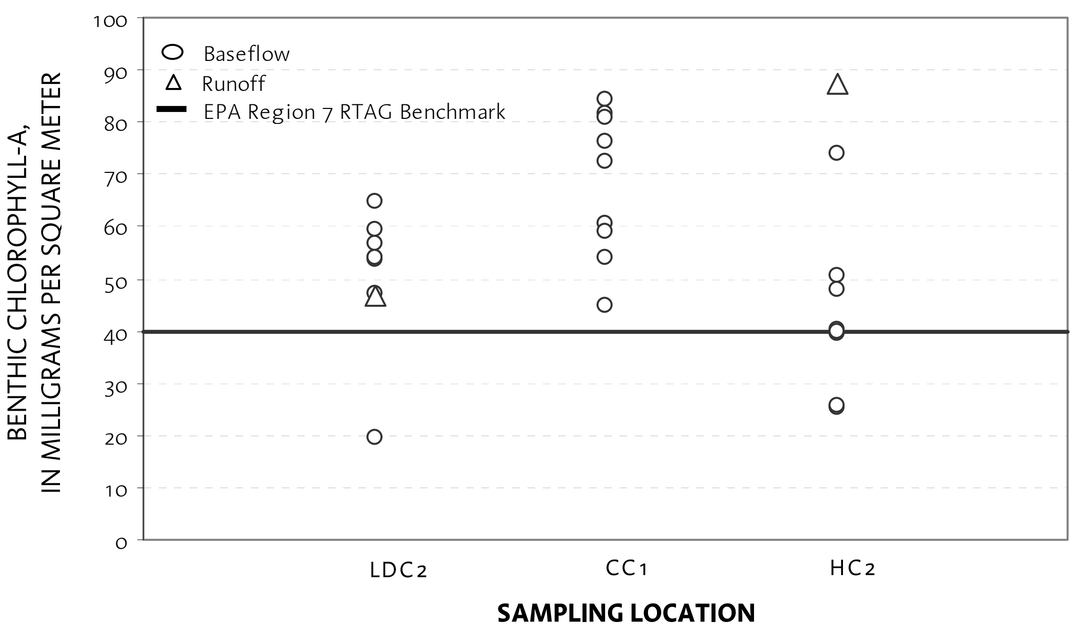


FIGURE 18. Baseflow and Runoff-Influenced Discrete Benthic Chlorophyll-a Scrapings in Relation to Benchmarks Developed by the USEPA Region 7 Regional Technical Assistance Group. Data Collected in AERDOR Reference Streams from 7/12/2006 to 9/14/2006 (n=9 samples per stream).

Percent bottom coverage of periphyton was observed at or below 5% of total substrate area in all reference streams during single-day surveys conducted in late summer. Little Drywood Creek had the least available substrate conducive to benthic algae growth (~10%) while 80% to 40% of streambed area in Heaths and Cedar Creeks, respectively, offered favorable attachment substrates.

4.3.7 Volatile Suspended Solids

Detectable levels (>4 mg/L) of volatile suspended solids were observed at all sites during all sampling events. Median concentrations (n=9 samples) ranged from 10 mg/L at site CC1 to 7 mg/L and 6 mg/L at sites HC2 and LDC2, respectively. A reasonable maximum stochiometry of 100 gDW to 500 mg Chlorophyll-a (Chapra *et al.* 2005) suggests that a minimum of 2-3 mg/L VSS within reference streams are non-algal. Concentrations of non-algal organic matter appear unrelated to event loading.

4.3.8 Total Suspended Solids

Total Suspended Solids (TSS) and Non-Volatile Suspended Solids (NVSS=TSS-VSS) were generally higher than expected for low-flow or baseflow conditions. Cedar Creek site CC1 had the highest study period median TSS (31 mg/L) and NVSS (18 mg/L) values. The site LDC2 median ranked second in suspended solids (TSS=18 mg/L, NVSS=12 mg/L) followed by HC2 (TSS=14 mg/L, NVSS=6mg/L). Total suspended solids were generally composed of greater than 50% NVSS (Figure 19). Regional TSS nutrient benchmarks have not been proposed in state or national guidance. However, 25th percentile turbidity benchmarks have been proposed by USEPA and could be translated to TSS values through regional regression techniques. Sampling error resulted in one non-valid (TSS<VSS) measurement, collected at Site HC2 on 07/18/2007, and was not included in these analyses.

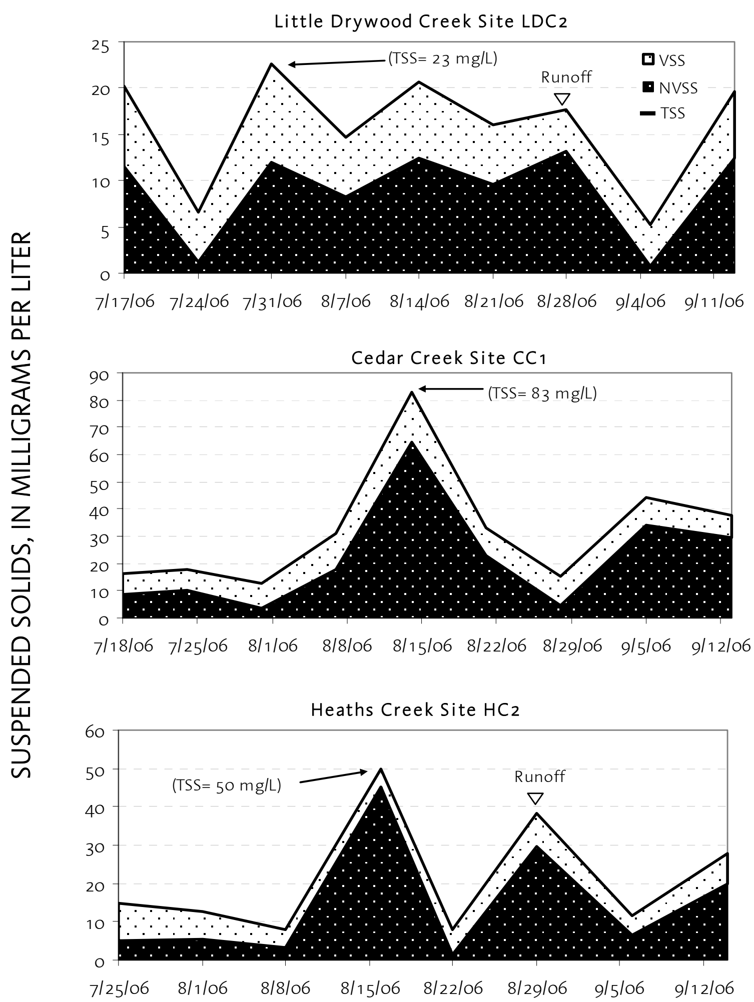


FIGURE 19. Suspended Solids Composition Timeseries in AERDOR Reference Streams for the Period of 7/12/2006 to 9/14/2006.

4.3.9 Biochemical Oxygen Demand

Water column carbonaceous biochemical oxygen demand were measured as an unfiltered twenty-day nitrification-inhibited BOD measurement (CBOD-20). Ultimate nitrogenous BOD (NBODU) were estimated by multiplying observed ammonia plus estimate organic nitrogen (non-algal) by a 4.57 stochiometric conversion (Chapra 1997). Algal-adjusted CBOD-20 and NBODU data were summed to represent Total Biochemical Oxygen Demand (TBODU). Mean TBODU concentrations at sites CC1, HC2, and LDC2 were 12 mg/L, 9 mg/L, and 8 mg/L, respectively. Concentrations of BOD were not statistically correlated with stream level at the p≤0.05 level. Notable however was an increase in algal-adjusted NBODU following a 5.6-foot rise in stream level at site HC2 in late August 2006 (Figure 20).

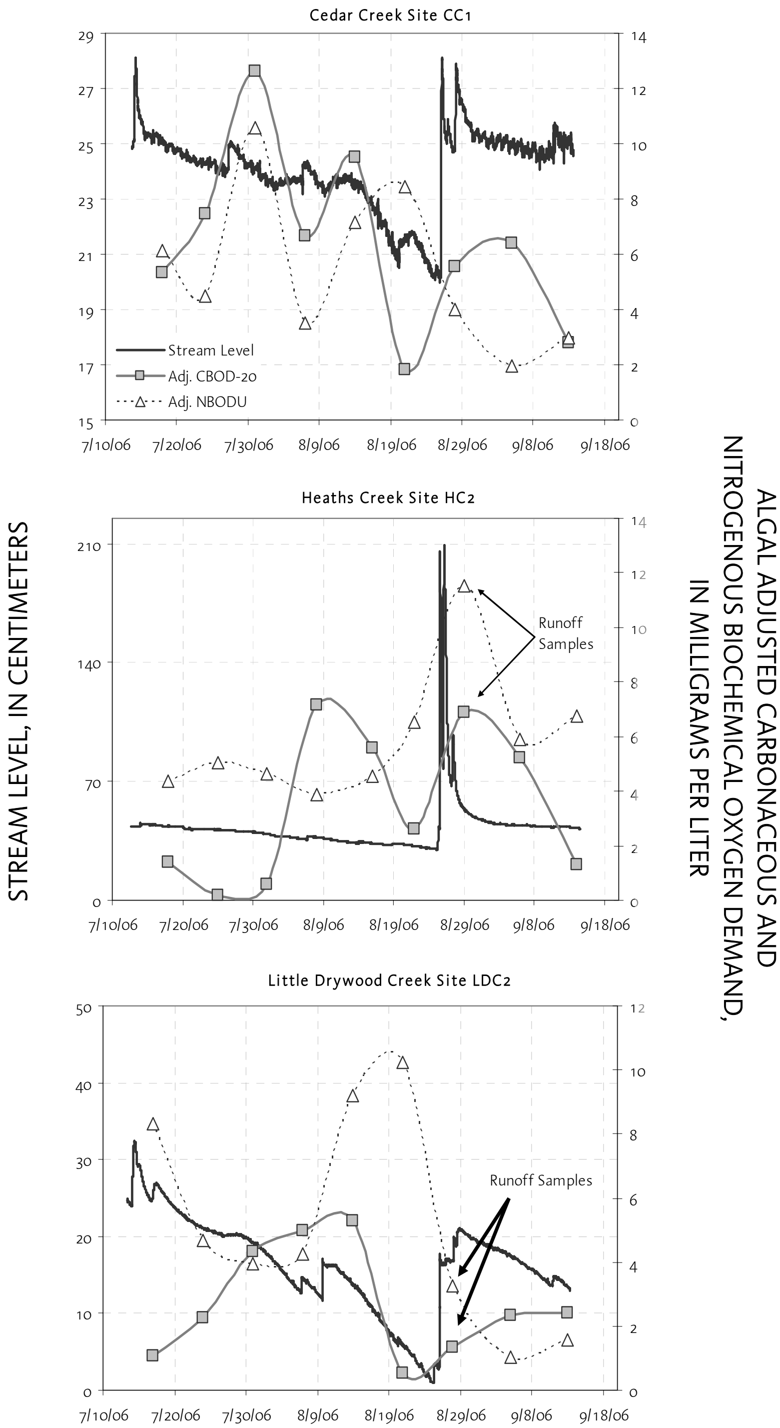


FIGURE 20. Biochemical Oxygen Demand and Stream Level Timeseries in AERDOR Reference Streams for the Period of 7/12/2006 to 9/14/2006.

4.3.10 Sediment Oxygen Demand Coverage

Median percent bottom coverage of sediment oxygen demand were observed to be 95%, 33%, and 20% at sites LDC2, HC2, and CC1, respectively, during single-day surveys conducted in late summer.

4.3.11 pH

The highest median pH measured at continuous sites occurred at site CC1 (8.1). Site CC1 also had the highest mean areal productivity rate (4.5 gO m^{-2} day^{-1}, see Section 4.5). Sites LDC2 and HC2 had the same median pH of 7.3.

4.3.12 Canopy Cover and Shade

Canopy coverage measured by a spherical densiometer were 13% (2688 lumens ft^{-2}), 54% (1,600 lumens ft^{-2}), and 68% (1,088 lumens ft^{-2}) at sites CC1, HC2, and LDC2, respectively. Canopy coverage is inversely related to median light intensity observed between sites.

4.4 Tributary Discrete Data

4.4.1 Dissolved Oxygen and Percent Saturation

All (100%) discrete early morning (7:00 am - 9:00 am) dissolved oxygen measurements (n=22) collected within five classified tributaries that feed reference reaches were below 5.0 mg/L (Table 9). Cedar Creek tributary channels at sites CC3 (Snag Branch) and CC4 (Teague Branch) were dry and therefore not measured. Additional sites such as HC8, Greer Branch at Deer Park Rd. (Class C) eventually ceased surface flow and lost all residual pool volume.

TABLE 10. Median Dissolved Oxygen Concentration and Percent Saturation Values Collected in AERDOR Reference Stream Tributaries during the 2006 Study Season (7/12/2006 - 9/14/2006).

Site	Tributary	Median Dissolved Oxygen (mg/L)	Median Percent Saturation (%)	Sample Number
HC4	Greer Br.	1.7	21	4
HC5	Long Grove Br.	1.5	18	4
HC6	Pointer Br.	1.5	10	3
HC7	Marlin Br.	1.0	13	5
HC8	Greer Br.	*3.6	47	1
LDC6	Pleasant Cr.	3.1	36	3
LDC7	Pleasant Cr.	2.7	34	3

*Single value

4.4.2 Temperature, Specific Conductivity, and pH

Early morning temperature, specific conductance, and pH values measured in reference reach tributaries are generally typical of summer conditions (Table 10). Notable is relatively low specific conductivity measured in Pleasant Creek, a Class C tributary to Little Drywood Creek.

TABLE 11. Median Temperature, Specific Conductance, and pH Values Collected in AERDOR Reference Stream Tributaries during the 2006 Study Season (7/12/2006 - 9/14/2006).

Site	Tributary	Median Temperature (°C)	Median Specific Conductance (uS cm^{-1})	Median pH (SU)
HC4	Greer Br.	25.2	516	7.4
HC5	Long Grove Br.	25.3	411	7.4
HC6	Pointer Br.	21.9	461	7.5
HC7	Marlin Br.	26.2	427	7.3
HC8	Greer Br.	29.6	405	7.4
LDC6	Pleasant Cr.	26.2	185	7.1
LDC7	Pleasant Cr.	24.6	171	7.0

4.5 Stream Metabolism

Community respiration (R), community photosynthesis (P), and stream reaeration (K_a) rates were calculated for days and sites where nutrients, BOD, and chlorophyll data were collected to estimate sources and sinks (Section 5.5) of dissolved oxygen. An enhanced version of the Delta Method (single-station) approach employed by Butcher and Covington (1995) was used (Figure 21) to calculate stream metabolism.

$$D_{t+1} = D_t - (K_a*\theta_{ka}*D_t*\Delta t)+(R*\theta_r*\Delta t)-(P(t)*\theta_p)+C_{s,t+1} - C_{s,t-1}$$

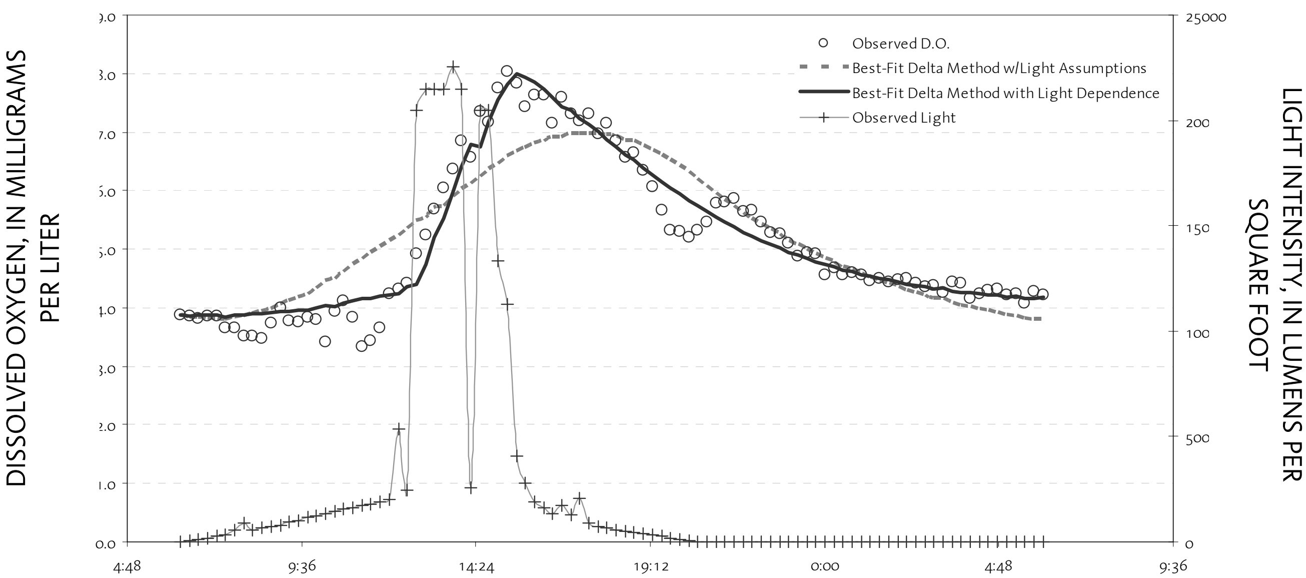
$$P(t) = F_L*P_{max}$$

D_{t+1}=D.O. Deficit (mg/L) at future time step
D_t=D.O. Deficit (mg/L) at current time step (observed)
K_a=Daily Average Reaeration (day^{-1}) at 20°C
Δt=time step (days)
θ_{ka}=Temperature Correction Factor for Reaeration
R=Community Respiration Rate (mg Oxygen L^{-1} day^{-1}) at 20°C
θ_r=Temperature Correction Factor for Respiration
P(t)= Photosynthesis (mg Oxygen L^{-1} day^{-1}) at current time step
F_L =Observed Intensity (lumens ft^{-2}) / (K_L+ Observed Intensity)
F_L =Photosynthesis Attenuation Factor (%, not depth averaged - shallow conditions)
K_L =Half-Saturation Coefficient
$C_{s,t+1}$ = D.O. Saturation at future timestep
C = D.O. Saturation at past time step

FIGURE 21. Light and Temperature Dependent Stream Metabolism Equation.

Enhancements include observed light intensity data as a photosynthesis forcing function. The Delta Method (Chapra and DiToro 1991) assumes a symmetric, half-sinusoid representation of photosynthesis and light intensity. A combination of topographic and riparian shade truncated effective photoperiods reducing model fit (Figure 22) at all sites evaluated and produced unrealistic estimates of areal P and R in several instances. As Chapra and DiToro note, use of the Delta Method (1991) may not be appropriate to shaded systems. Delta method rate parameters for evaluated days were determined through least-squares optimization of observed vs. predicted diel dissolved oxygen concentrations. Predicted and observed dissolved oxygen plots for evaluated days are available on request to ERC. Model performance statistics and parameter estimates for evaluated sites and days are included within Appendix H.

Similar model fit scenarios were obtained through minor adjustment of rate parameters. In most instances, photosynthesis, respiration, or reaeration parameters could be perturbed and model fit retained through a 10% or less adjustment of another parameter. An estimate of metabolic rate rate accuracy is ±10%.



Performance Metric	Delta Model with Light Assumptions	Delta Model with Light Dependence
Sum of Squares	32.7	8.3
Median Relative Error	6.2%	2.7%
Nash-Sutcliffe	0.80	0.95

FIGURE 22. Model Performance Resulting From the Presence vs. Absence of Light Dependence Functions within the Delta Method Framework. Little Drywood Creek on 07/29 to 07/30.

4.5.1 Community Production

Cedar Creek site CC1 had the highest effective areal production rates (median=4.1 gO m^{-2} day^{-1}) followed by HC2 (median=2.1 gO m^{-2} day^{-1}) and LDC2 (median=1.6 gO m^{-2} day^{-1}). Due to elevated summertime water temperatures, rates adjusted to 20°C are noticeably lower than effective or expressed field rates (temperature correction factor=1.066). Median production rates adjusted to 20°C are 2.4 gO m^{-2} day^{-1}, 1.4 gO m^{-2} day^{-1}, and 0.9 gO m^{-2} day^{-1} for sites CC1,HC2, and LDC2, respectively. Reduced production followed precipitation events in late August at sites CC1 and HC2 (Figure 23). Moderately productive systems are described by a range of average daily areal production rates of 0.3 to 3.0 gO m^{-2} day^{-1} while highly productive systems may reach 20 gO m^{-2} day^{-1} (Chapra 1997). Cedar Creek areal production at observed field temperatures exceeded the upper 'moderate production' boundary during 8 of 9 evaluated days (Figure 23).

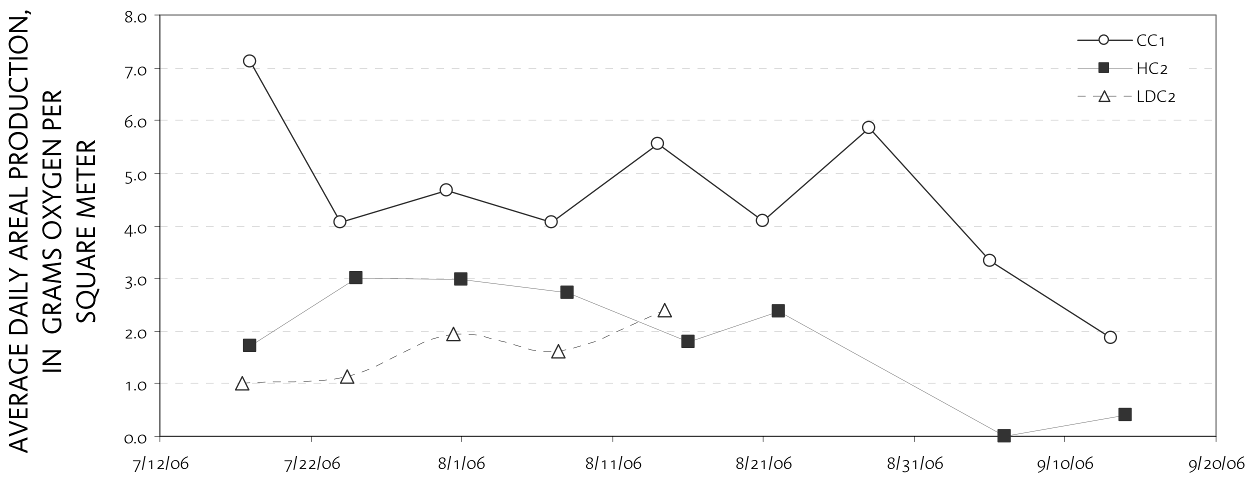


FIGURE 23. Timeseries of Expressed Average Daily Areal Production Rates for AERDOR Reference Streams During Chemistry Sampling Events.

Diel D.O. curves exhibited unusual behavior and hysteresis at LDC2 following late August precipitation. Diel behavior at LDC2 in late summer could be explained by photorespiration processes (Parkhill and Gulliver 1998). Quality assurance checks indicate that data sondes were in control and collecting representative data at the time of instrumentation servicing during late August and early September. As the cause of diel behavior at LDC2 in late summer is uncertain, metabolism calculations for post-event periods in Little Drywood Creek were not performed.

4.6.2 Community Respiration and Ratios

Expressed areal respiration rates were highest at CC1 (median=5.9 gO m^{-2} day^{-1}) followed by HC2 (median=3.5 gO m^{-2} day^{-1}) and LDC2 (median=3.1 gO m^{-2} day^{-1}). Precipitation events in late August reduced community respiration in addition to production (Figure 24).

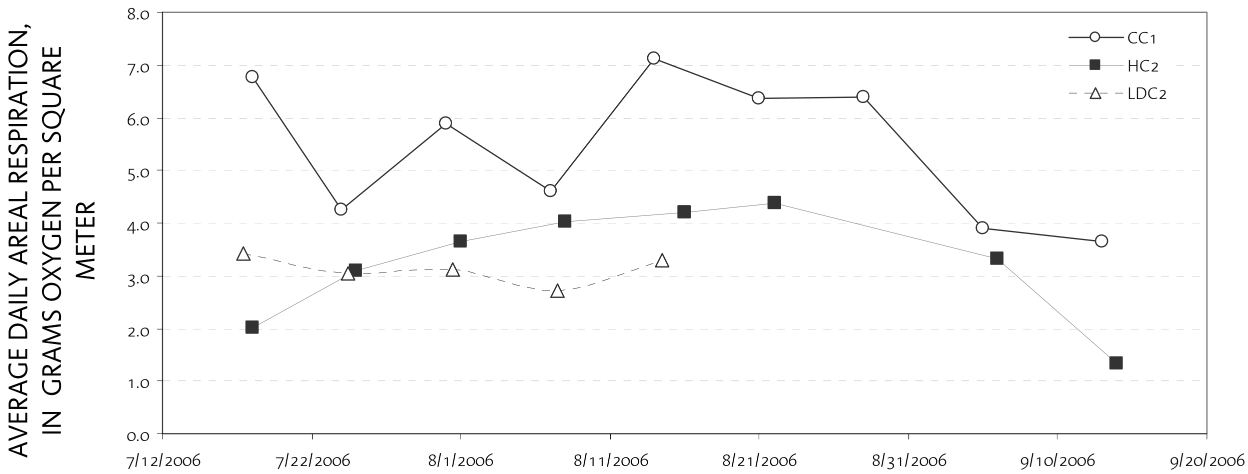


FIGURE 24. Timeseries of Expressed Average Daily Areal Respiration Rates for AERDOR Reference Streams during Chemistry Sampling Events.

Gross photosynthesis to respiration (P/R) ratios were below 1 (net heterotrophy) during 21 out of 22 evaluated days (Figure 25). Site LDC2 ratios increased during the deployment period while ratios at sites CC1 and HC2 declined (Figure 25).

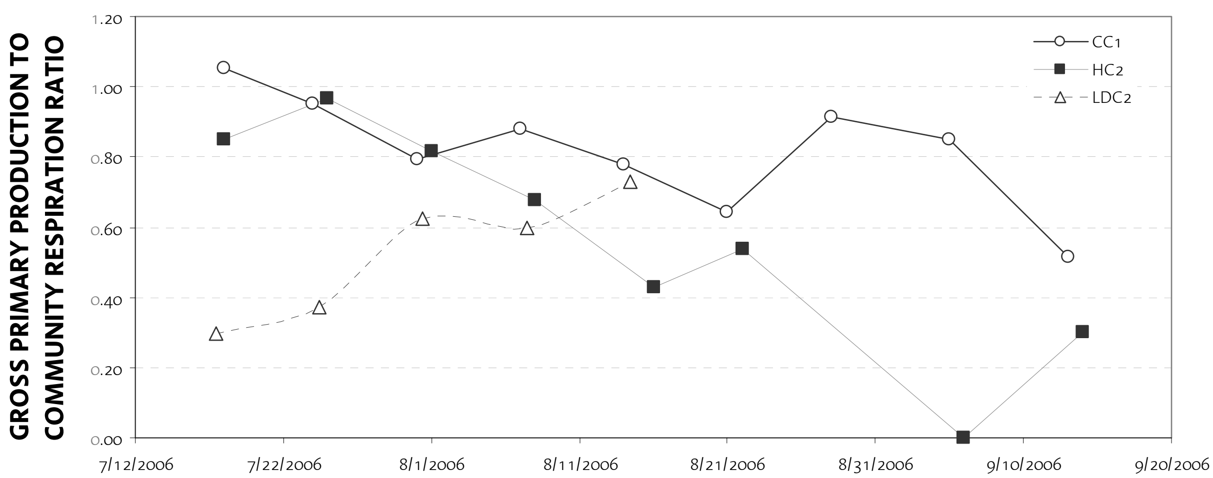


FIGURE 25. Timeseries of Gross Photosynthesis to Community Respiration (P/R) Ratios for AERDOR Reference Streams During Chemistry Sampling Events.

4.6.3 Stream Reaeration

During periods of measurable surface flow, stream reaeration estimates derived during least-squares metabolism calculations were frequently bounded by empirical predictive equations developed by Melching and Flores (1999) and Owens *et al.* (1964). Calculated median reaeration rates at 20°C were 1.3 day^{-1}at LDC2, 1.0 day^{-1} at CC1, and 0.9 day^{-1} at HC2. Reaeration estimates during days of non-detectable surface flow were erratic. Although site-specific wind data were not collected, local wind patterns likely dominate reaeration during stagnant conditions (Chu and Jirka 2003, Wanninkhof 1991). Model performance statistics and parameter estimates for evaluated sites and days are included within Appendix H.