Functions of Ecosystems: Stream Metabolism as an efficient and effective means to gage the health and understand the interworking of urban streams in a watershed of Rock Island, IL

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INTRO

Metabolism, primary production and community respiration, is a key functional component of stream ecosystems (1), and represents an integrated response to hydrology, organic matter, nutrients, pollutants, and land use (2,3), and is therefore a useful indicator of ecosystem health (4). Urban streams face challenges including impervious surfaces, altered hydrology, and excess nutrients and pollution, which interact in complex ways (5,6) across the backdrop of economic variation in human communities (7), so there is a need to study functional responses in urban streams.

We report the metabolism of streams in the Rock Island watershed (Rock Island County, Illinois), a 782 Ha watershed that feeds the Rock river in the city of Rock Island, IL. Land use varies from city streets with underground storm sewers, to suburban ravines and parks (Figure 1).

METHODS

Empirical methods: Selected streams were a subset of a multi-year survey of water quality conducted by the Upper Mississippi Study Center. Our nine sites represent a range of surrounding habitat, stream order (first to fifth), and site type (ravines or headwaters) (figure 1). Hach Hydrolab DS5X sondes with luminous dissolved oxygen probes taking oxygen and temperature readings every half hour were deployedin pools 15-30cm deep in two time blocks. The first block was in sites 2, 3, 11, 12, and 15 from Oct 11-Oct 18th. The second was in sites 5, 6, 10, 12 from October 22nd to 25th. Irradiance data was collected from a central location (8). Cross sectional area and stream velocity were measured at each site (9).

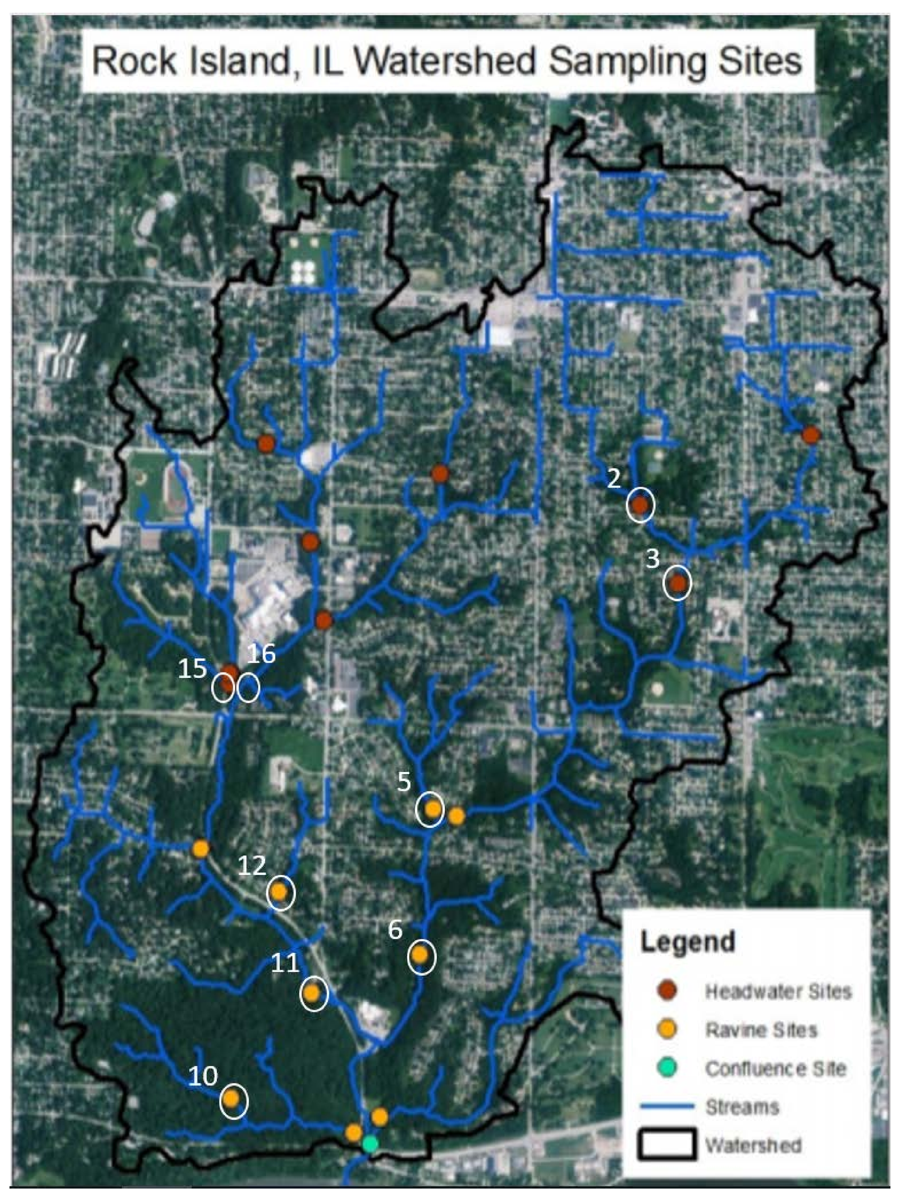

Figure 1. Map of the watershed, study sites are circled in white and marked by white numbering.

Metabolism Model: Rates of photosynthesis, community respiration, and gas exchange were approximated using a Bayesian Metabolic Model (10), which used a Monte Carlo-Markov Chain in a metabolic model incorporating measured dissolved oxygen, temperature, discharge and irradiance. Required priors for this model include stream slope, aspect, elevation, and salinity, which were estimated from Streamstats (11) or existing water quality data. Gas transfer velocity was estimated using reach hydraulics (1). The model ran for over nine million iterations with a thinning rate of 3000 for each stream. We present the mean of the saved iterations as an approximation of each parameter.

Data Analysis: Two sites, 15 and 12, experienced transient low oxygen. We re-ran the model excluding the transient data. The transient drops dramatically elevated respiration estimates for these sites, we therefore excluded the transient data from the analysis. We used regression analysis to compare metabolic rates with previously measured data from the sites including chloride, specific conductivity, total dissolved solids, nitrate, ammonium, ammonia, pH, biological oxygen demand, total suspended solids, temperature, fecal coliform, phosphate, and discharge.

RESULTS

A

B

C

D

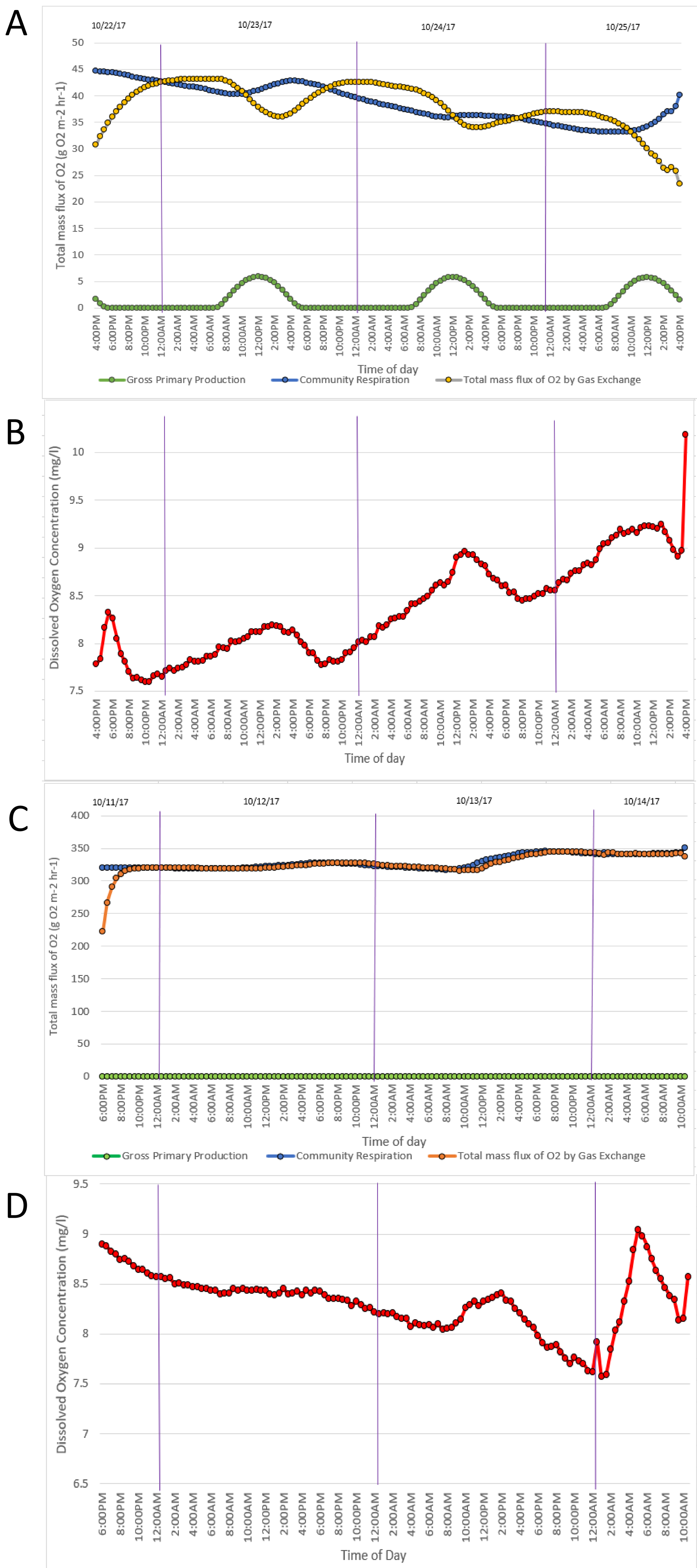

Figure 3: Comparison of model approximations with measured oxygen data in two streams. Panels A and B are model approximations of rates of photosynthesis, respiration, and gas exchange, as a function of time. Panels C and D are the measured oxygen concentrations over the same time interval. Panels A and C are from site 16, which showed typical diel peaks and troughs in oxygen, while panels B and D are from site 11, which showed weak to no diel pattern. All rates of stream metabolism parameters are in g O_2 m^{-2} hr^{-1}, while all O_2 concentrations are in mg/l. Color Scheme info: blue=community respiration, green=Gross Primary Production, orange=total mass flux of O_2 by gas exchange, red=O_2 conc.

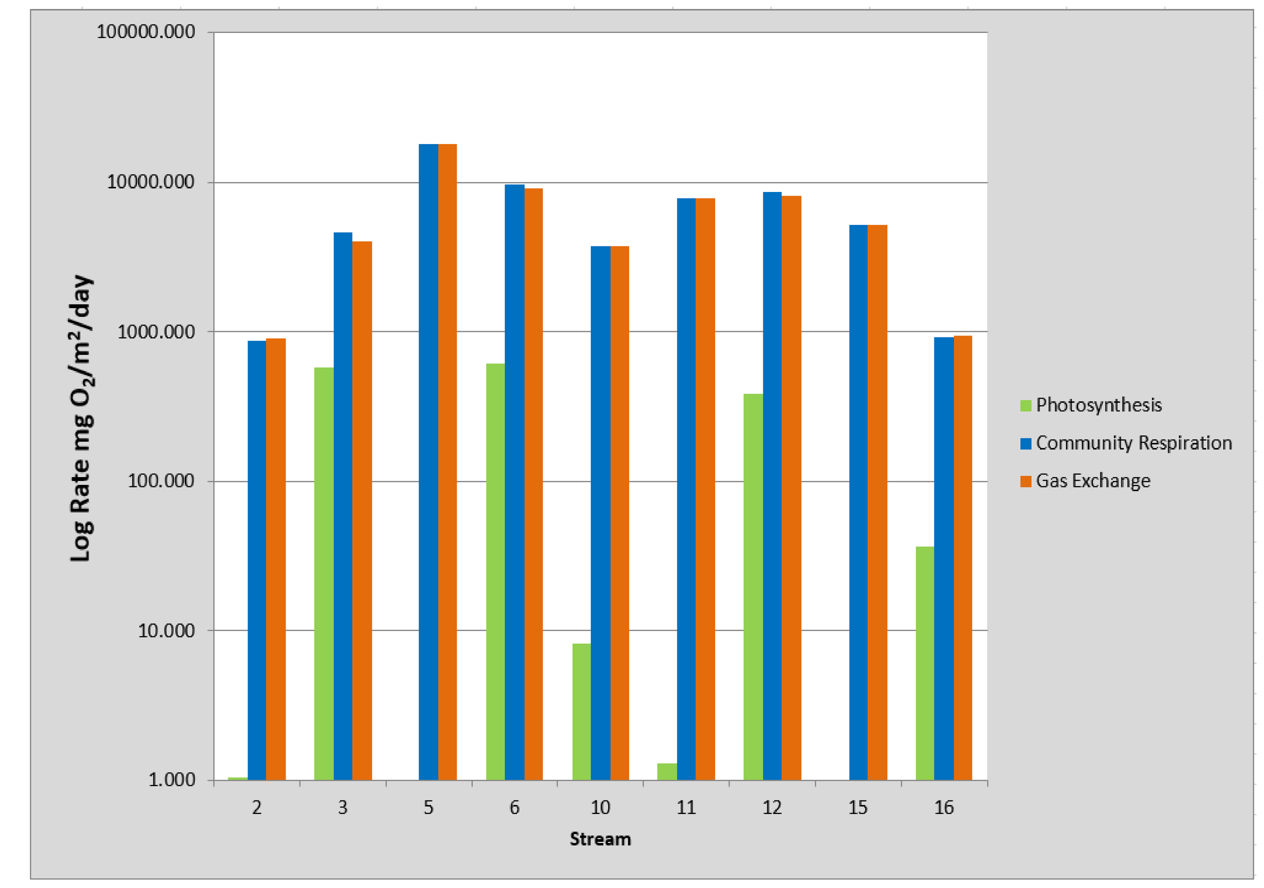

Figure 2: Integrated gross primary production, community respiration respiration, and total mass flux of O_2 by gas exchange over a 24 hour period for all sites. All integrated values of stream metabolism parameters are in log transformed g O_2 m^{-2} d^{-1}. The Y-axis is log transformed in order to show the huge difference between community respiration, gas exchange, and gross primary production

The model's approximations of Gross Primary Production (GPP), Community Respiration (CR) and Gas Exchange (GE) varied widely across the watershed (Figure 2). High and low CR sites differed by as much as a factor of ten. GPP was from one to three orders of magnitude lower than CR (Figure 2). There is no apparent covariation between CR and GPP (Figure 2). The model predicted non-zero GPP in sites that showed diel oxygen changes (Figure 3). The model predicted little to no GPP in sites that showed either little diel or anomalous oxygen patterns (Figure 3). The water quality variables explain little of the variation in GPP and CR; resulting r^2 values ranged from 0.00 to 0.35, and none of these regressions were statistically significant at the $p<0.05$ level.

DISCUSSION

Our range of GPP and CR values are comparable to published data (12,13,14,15). Our range of CR spans low to high published values, while GPP ranges from zero to moderate values. This suggests different reaches in this watershed experience very different levels of ecosystem function. CR is much higher than GPP at all sites (GPP/CR <<1), suggesting allochthonous processes strongly dominate autochthonous ones. GPP may be low in this watershed due to the closed tree canopy that is present even at higher order sites, since light is a significant driver of GPP (13,16,12,17). Perhaps existing variation in GPP is associated with spatial and temporal variation in canopy cover. Variability in CR may be associated with variability in hydrology which in turn affects sediment accumulation and organic matter deposition (18).

There is a large consensus in the literature that many common water quality parameters have an impact on both CR and GPP (5, 12, 18, 3, 13, 14, 16, 19, 17). However, we found no strong association between the water quality variables we measured and observed rates of GPP and CR. Much of the literature discussed how these water quality variables have different impacts at different points in the year (16, 19, 17) and may change from year to year (5). The water quality data used for the regression analysis were means of multiple years of data from spring through late fall. Therefore, these data may not be an accurate representation of water quality at the time of metabolism measurement.

Finally, our use of continuous monitoring let us catch transient high (stream 2) and low (streams 5 and 12) oxygen events. In streams 2 and 12, these events were preceded by precipitation in the watershed, but not for stream 5. Site 2 is the outlet for multiple storm drains (figure 1) and may therefore experience high drainage density and flashiness (20). The ability to capture transient environmental events can help pinpoint the location of point-source pollution or impaired ecosystem function.

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