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Project Summary

Photosynthesis and Respiration Rates in the Monticello Experimental Streams: 1976/77 Diel Field Data and Computed Results

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Two-station diel dissolved oxygen measurements collected during 1976-77 at the Monticello Ecological Research Station (Monticello, MN) were analyzed by a graphical-analytical method and by a computer model, Dissolved Oxygen Routing Model (DORM), to determine daily community respiration and photosynthesis. A third set of values was generated by using the DORM model to simulate the graphical method. The complete DORM included surface oxygen exchange, longitudinal dispersion, a higher-order curve extrapolation between upstream dissolved oxygen measurements, and the dependence of respiratory rate on water temperature and dissolved oxygen concentrations: however, neither the graphical nor the simulated graphical models included these factors. The complete DORM gave consistently higher rates of respiration and photosynthesis than either the graphical-analytical method or the computer simulation.

This Project Summary was developed by EPA's Environmental Research Laboratory, Duluth, MN, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

During 1976 and 1977, two-station diel dissolved oxygen (D.O.) measurements were taken at the Monticello Ecological Research Station in ambient and heated experimental streams. The data were made available to the authors for analysis. Three methods of analysis were used in treating the data: a graphical-analytical routing method, a numerical dissolved oxygen routing method (DORM) and a computer simulated graphical method.

In the graphical-analytical method, the hydraulic residence time in a channel reach was calculated, after which the upstream station diel oxygen curve with the residence time added to the dissolved oxygen time was plotted on the same graph with the downstream station diel oxygen curve. The difference in D.O. during the night hours divided by the residence time yielded an hourly nighttime respiration rate. All nighttime respiration rates were averaged and used as an estimate of the respiration rate that occurred during daylight hours. The photosynthetic rate was graphically determined by measuring the D.O. difference each hour during the daylight. Each value was divided by the residence time to give an hourly rate; adding the average respiration rates gave an hourly photosynthetic rate (g m^{-3} hr^{-1}). The photo-

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synthetic rates were multiplied by the hydraulic mean depth to produce photosynthetic rates per unit surface area (g m^{-2} hr^{-1}). Addition of all hourly photosynthetic rates yielded an accumulated rate for the period of record.

The numerical Dissolved Oxygen Routing Model (DORM) involved determination of total stream community photosynthesis and respiration rates through successive routing of the two-station diel D.O. measurements. This model included surface oxygen exchange, longitudinal dispersion, a higher order curve extrapolation between upstream D.O. measurements, and dependence of respiratory rate on water temperature and D.O. concentration. A sensitivity analysis was conducted with DORM to investigate the influence of residence time on respiration and photosynthesis rates.

The graphical-analytical procedure was also simulated by DORM numerically. This was accomplished by making the same assumptions as in the graphical method; namely, no surface oxygen exchange (reaeration) or longitudinal dispersion occurred, respiration was independent of temperature and D.O. concentration, and a linear interpolation between D.O. measurements was used.

Conclusions

The complete routing (DORM) gave consistently higher rates of respiration and photosynthesis than either the graphical method or its simulation by DORM. This was due to the omission of reaeration (surface oxygen exchange) in these methods. The effect of reaeration on photosynthesis and respiration appeared to be channel-position dependent, at least in spring and late summer.

Total daily rates of respiration and total daily rates of photosynthesis obtained by the graphical method were consistently smaller than those obtained by DORM. The average fractions were 87% and 89%, respectively, for the upper channel reach and 76% and 81%, respectively, for the lower channel reach.

Photosynthesis and respiration rates increased with increasing residence time in the channel in a nonlinear relationship. For a +20% change in residence time, respiration changed from +1.7% to +11.0%; for a −20% change in residence time, respiration changed between −2.3% to −9.6%. The associated rate changes for photosynthesis were +2.9% to +13.6%, and −2.6% to −12.7%.

Recommendations

In future studies using diel dissolved oxygen routing, particular care must be taken to measure channel cross sections and flow rates or hydraulic residence time directly by tracer routing.

Application of a constant correction coefficient to the results of the graphical method implies that reaeration effects are of the same magnitude in spring, summer and fall. Application of the numerical method DORM would eliminate the assumption.

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The complete report, entitled "Photosynthesis and Respiration Rates in the Monticello Experimental Streams: 1976/77 Diel Field Data and Computed Results," (Order No. PB 82-242 066; Cost: $16.50, subject to change) will be available only from:
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