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Hyporheic hotspots - inferring groundwater-surface water exchange with continuous monitoring of dissolved oxygen

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The recent development of optical sensors that facilitate continuous, accurate in situ measurement of dissolved oxygen (DO) levels have revolutionised our ability to monitor the hydrochemistry of the hyporheic zone; an important ecological and biogeochemical hot spot in streams. In addition, this has also provided invaluable insight into the nature of local groundwater - surface water exchange in stream-aquifer systems. This contribution will report the use of optode technology over a 2 year period in a gravel-bed stream draining a 30km2 montane watershed in the Scottish Highlands. Laboratory calibration of the optodes before and after installation confirmed excellent reliability and data quality. Two contrasting sites were monitored where previous work had suggested the hyporheic zone was respectively characterised by upwelling groundwater and downwelling surface water. At each site, replicated logging optodes recorded DO levels in the stream and in hyporheic water at depths of 15cm and 30cm in the stream bed. At the upwelling site, DO levels in the stream were close to 100% throughout the 2 years; levels in the hyporheic zone were highly dynamic and could range between 0 and 100% saturation in a matter of hours. Associated piezometry indicated that such changes were strongly influenced by high water table levels in hillslope groundwater, which resulted in positive pressures allowing the discharge of groundwater through the hyporheic zone. As such, hyporheic DO levels exhibited marked seasonal and inter-annual variability with values close to 100% saturation for prolonged periods during summer and other times when rainfall was low and there was

poor connectivity between groundwater and the stream. In contrast, winter and wetter times, when hillslope groundwater-hyporheic connectivity was good, resulted in prolonged periods - up to several months - when hyporheic DO levels were at or close to zero. In addition, short transient spells of low DO followed some small summer events where in site O2 consumption might be expected from microbial respiration following the influx of organic material. At the downwelling site, streamwater was also close to 100% saturation throughout, and hyporheic DO levels also remained high, with no apparent relationship with water tables, though there was also evidence of transient O2 consumption following small summer spates. The optode technology characterised the dynamics of the hyporheic environment in a way that traditional ex situ sampling at weekly or fortnightly intervals could not. The 15 minutes time series data were statistically analysed to show the loss of information and resulting uncertainty that would have occurred had samples been collected at the daily, weekly, fortnightly or monthly intervals that are common in hyporheic studies. The additional information gained was found to be fundamentally important to hydroecological interpretation, as well as invaluable in indicating groundwater - surface water dynamics.