Runoff and Stream Water Chemistry Responses to Simulated Emerald Ash Borer Invasion in Black Ash Wetlands in Northern Michigan

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Abstract

Black ash (Fraxinus nigra Marsh) is the dominant hardwood species in many northern forested wetlands, especially in the Great Lakes Region. Black ash is subject to extremely high rates of mortality following the infestation of Emerald ash borer (EAB, Agrilus planipennis Fairmaire). Our research expands upon previous work examining the hydrologic impacts of EAB on black ash wetlands by examining changes in baseflow and response to precipitation using a paired watershed design. To simulate anticipated long-term impacts, all ash stems greater than or equal to 2.54 cm in diameter at breast height were felled and left on site. We hypothesize that 1) the treatment watershed will become more responsive to rainfall events and have higher water yield relative to pre-treatment conditions; and 2) chemical (dissolved organic carbon (DOC), total dissolved nitrogen (TDN), chloride, and sulfate) and isotopic (2H and 18O) tracers in stream water will show a reduced wetland water signature relative to precipitation and local upland groundwater. During the two-year pre-treatment period we observed median water yield to rainfall ratios of 0.033 and 0.022 on an event basis in the control and treatment watersheds, respectively. During the four-year post-treatment period the ratio was 0.013 (-62.3%) for the control watershed and 0.018 (-17.1%) for the treatment watershed. We did not observe an increase in treatment watershed responsiveness relative to the pre-treatment period as expected. However, we did observe a significantly smaller reduction in responsiveness in the treatment watershed relative to the control. Climatic differences and a shift in hydrologic regime in the pre- and post-treatment periods are the likely explanation for the decreased responsiveness of both watersheds to rainfall. Results also show that the relationship between DOC and TDN concentrations in stream water and wetland water were weaker following the treatment. The slope of the relationship between stream water and both wetland surface water and soil pore water in the treatment watershed was reduced by approximately 60% for both DOC and TDN. The relationship did not significantly change within the control watershed. These findings suggest that the loss of black ash will lead to greater responsiveness to rainfall events relative to undisturbed wetlands.

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Major Finding

Stream water dissolved organic carbon concentrations increased following disturbance. Changes were driven by increased wetland water levels and a more continuous surface water – stream water connection.

Introduction

Black ash is a dominant canopy species in northern forested wetlands that is threatened by Emerald Ash Borer (EAB), which is continuing to spread into areas where black ash is prominent and loss of ash has been shown to affect wetland water levels. No previous work has examined water quality changes following simulation or how those changes are telegraphed downstream.

Methods

A paired watershed approach has been implemented on the Ottawa National Forest in western Michigan (Control: 1.1 ha, 503 m a.s.l.; Treatment: 0.8 ha, 476 m a.s.l.). Streamflow was monitored in a 6" Parshall flume with a Solinst Levellogger Edge and dissolved organic carbon (DOC) and total dissolved nitrogen (not shown) were collected by grab and automated sampling and processed on a Shimadzu Total Organic Analyzer. After 2 years of calibration all ash ≥ 1" dbh were cut and left on site in one watershed in March 2015. Changes in wetland water levels (Figure 1) were tested using Kruskall-Wallis Rank Sum tests. Hydrograph separation (Figure 2) was performed using three approaches to allow for sepearate measures of baseflow and quickflow (Lyne and Hollick (1979); Chapman and Maxwell (1996); and Eckhart (2005)). Pre-treatment models for stream water DOC concentration between sites (Figure 3), and for stream water DOC concentration by wetland water source (Figure 4 & Table 1) were fit using quantile regression models with $\tau = 0.5$. Quantile regression models avoid undue outlier influence on model fit and account for unmodeled environmental drivers (Cade and Noon 2003).

Summary Results

During the post-treatment period wetland water levels in the treatment watershed increased relative to pre-treatment conditions. During the same period the percent of water yield as baseflow increased relative to the control watershed. Increased wetland water levels likely led to a more continuous surface water – stream water connection, resulting in higher baseflow. This is supported by the wetland surface water model at the treatment site, which was the best performing post-treatment predictor of stream DOC. Over that same period in the control watershed baseflow decreased and wetland soil water was the best predictor of stream water DOC.

Future Work

Future work will incorporate seasonality as these systems are heavily influenced by snowfall, and analyze anion (Cl-, SO42-) concentrations and flourescence excitation emission matrices to improve source water separation and understand biogeochemical processing.

Cade, Brian S., and Barry R. Noon. 2003. "A Gentle Introduction to Quantile Regression for Ecologists." *Frontiers in Ecology and the Environment* 1 (8): 412–20.

Chapman, T.G., and A.I. Maxwell. 1996. "Baseflow Separation - Comparison of Numerical Methods with Tracer Experiments." In *Hydrology and Water Resources Symposium*, 539–45. Hobart, Australia.

Eckhart, K. 2005. "How to Construct Recursive Digital Filters for Baseflow Separation." *Hydrological Processes* 19: 507–15.

Lyne, V, and M Hollick. 1979. "Stochastic Time-Variable Rainfall-Runoff Modelling." In *Institute of Engineers Australia National Conference*.

Thorne, W. Brent. 2019. *Posterdown: An R Package Built to Generate Reproducible Conference Posters for the Academic and Professional World Where Powerpoint and Pages Just Won't Cut It.*

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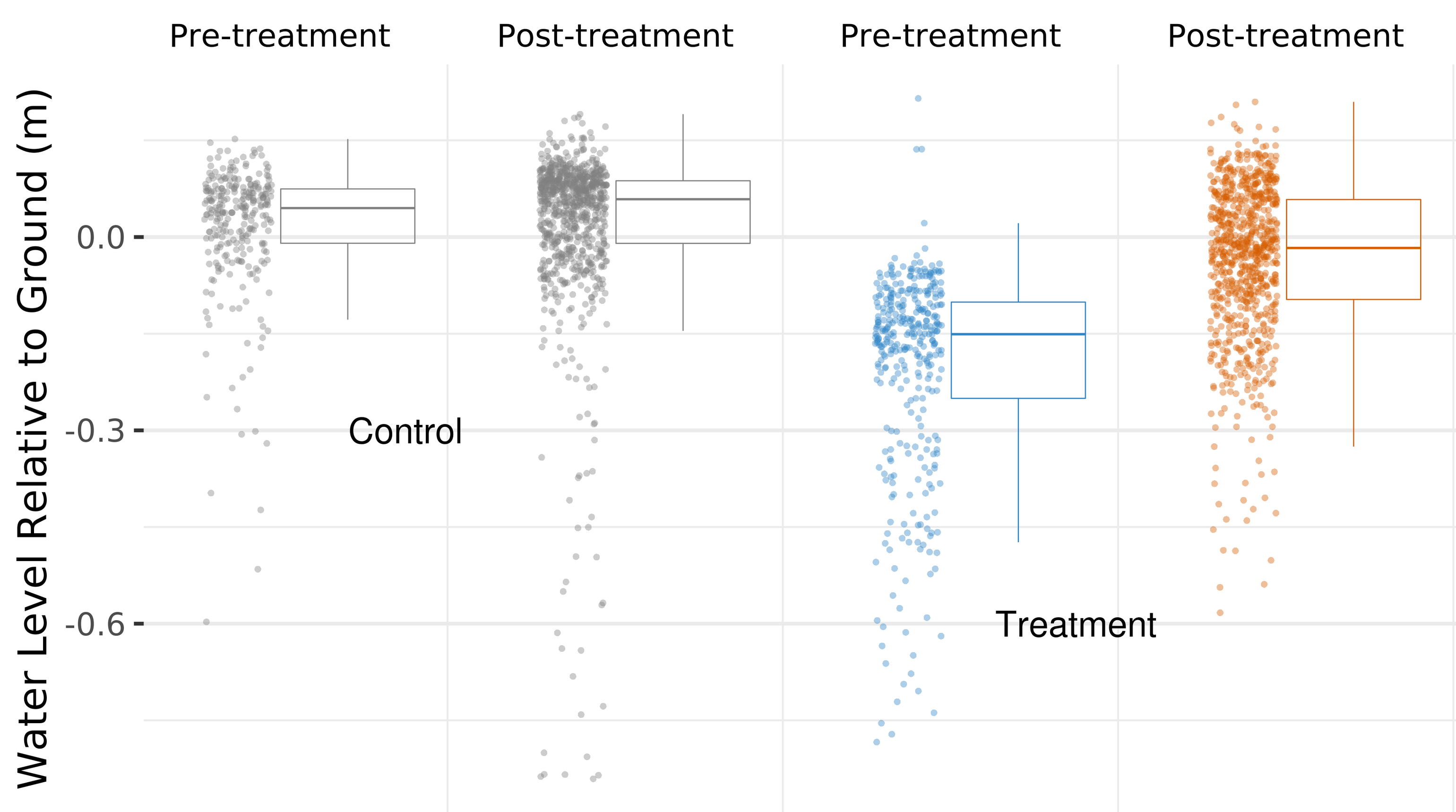

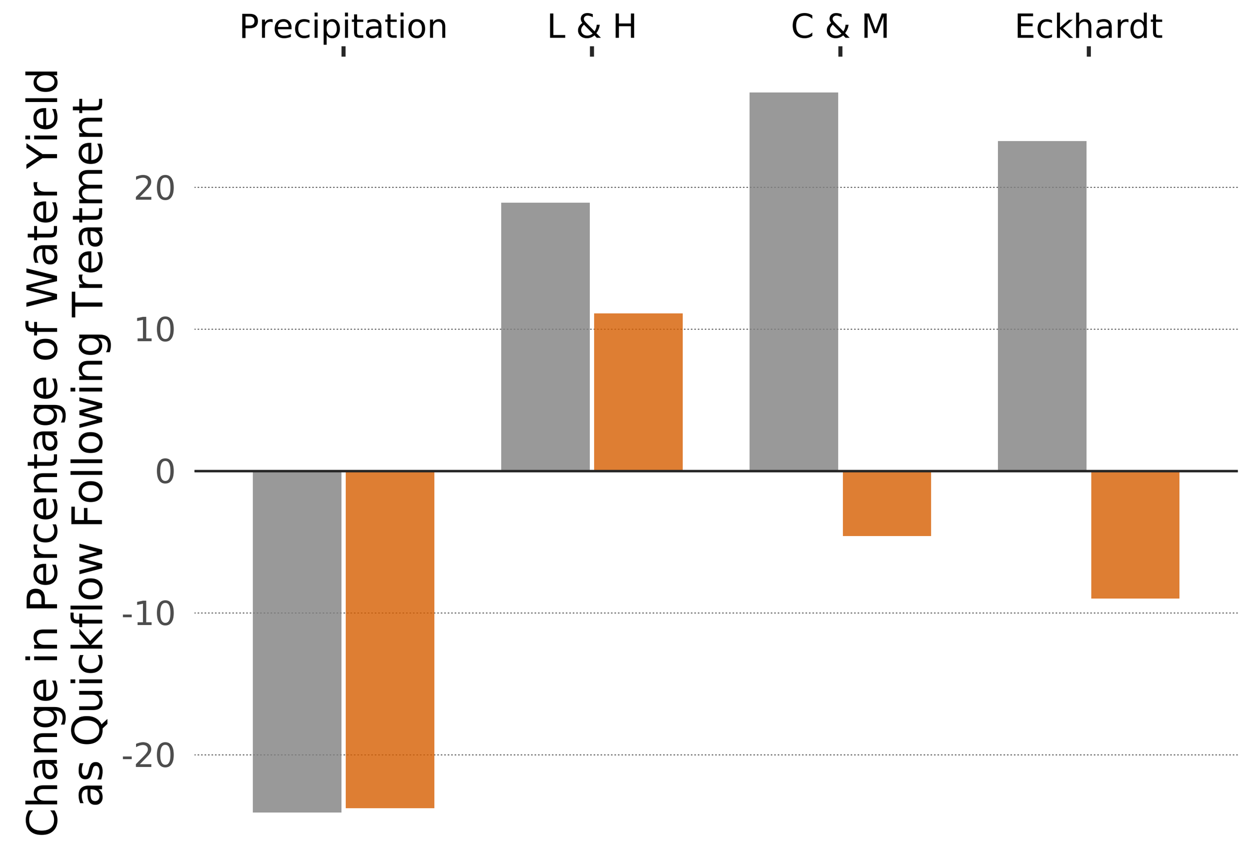

Figure 1 (top): Boxplot and jittered observations of daily mean wetland water level relative to the ground surface by treatment period.

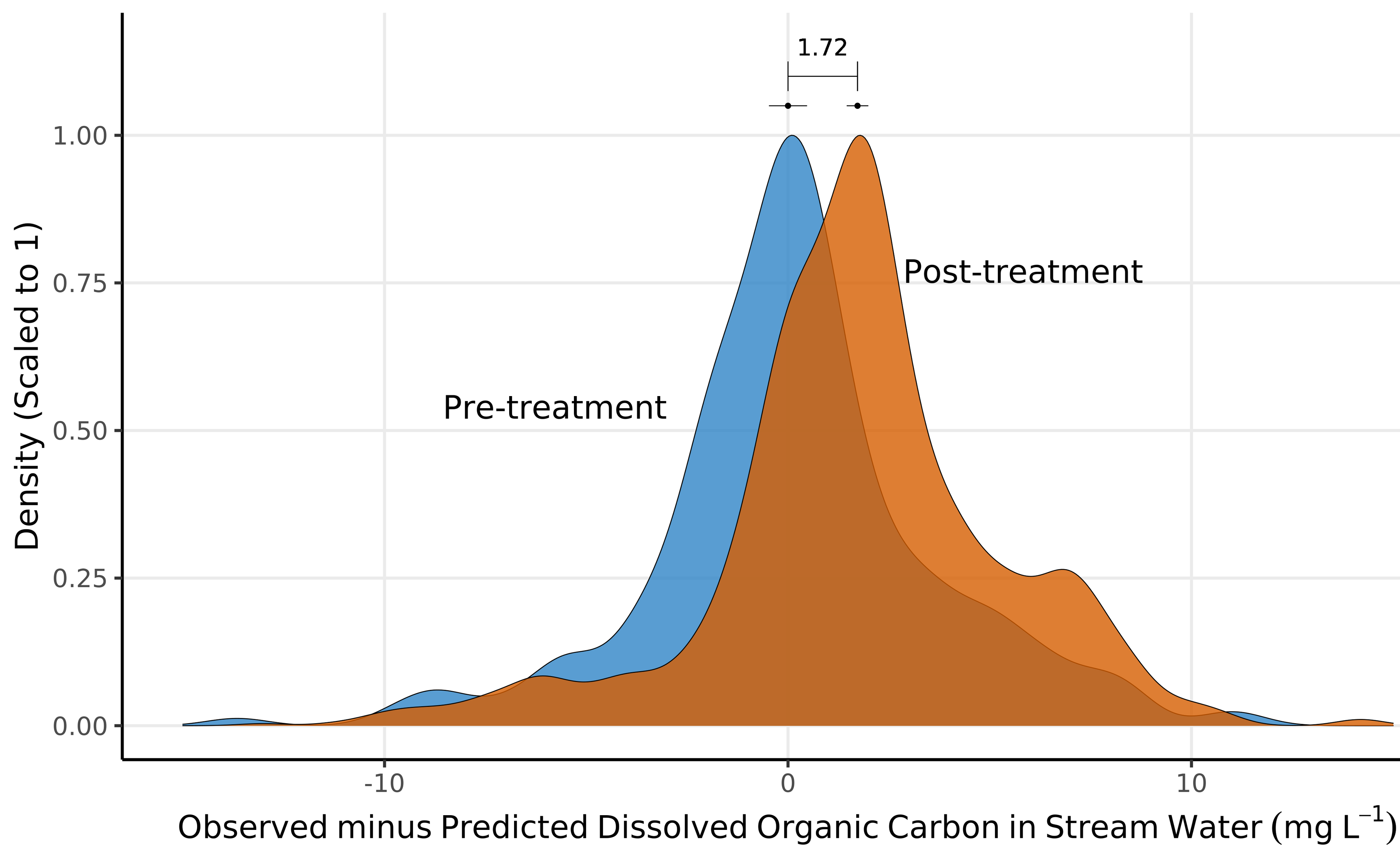

Figure 2 (top): Columns showing the percent change from pre-treatment calibration of the stormflow from each watershed. Stormflow was calculated by Lyne & Hollick (L & H), Chapman & Maxwell (C & M), and Eckhart. Change in mean annual precipiation is included for context. Filter parameters were estimated from pre-treatment data for both watersheds.

Figure 3 (left): Density plots showing the residuals from a quantile regression (τ = 0.5) model predicting treatment watershed DOC concentration from control watershed DOC concentration. Model fit to pre-treatment data with RMSE = 3.8. R^2 = 0.77.

Figure 4 (bottom): Two-dimensional density plots showing the residuals from quantile regression (τ = 0.5) models predicting streamwater DOC concentration from wetland surface water, soil water, and both sources. See Table 1 for model and prediction metrics

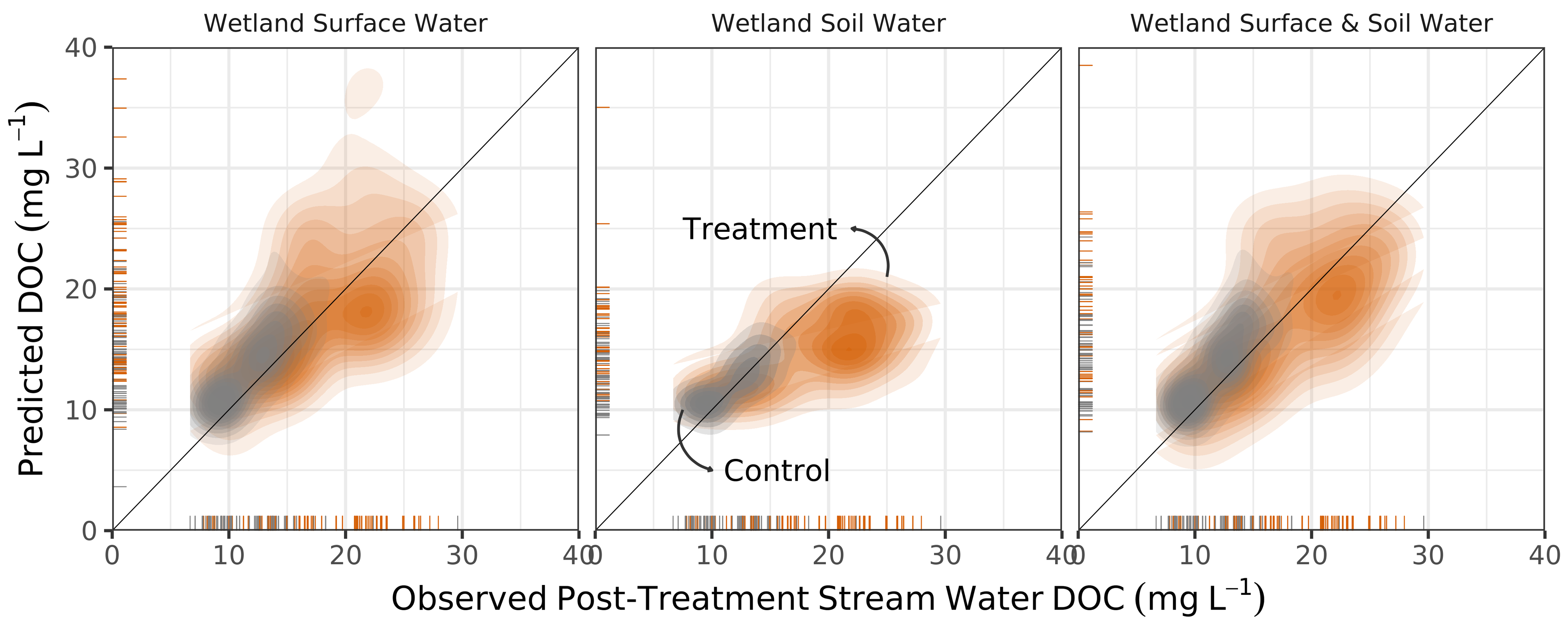

Table 1: Model fit and prediction metrics for surface water, soil water. and combined driver models.

	Site	RMSE	R^2	Prediction RMSE	Median Prediction Error
Wetland Surface Water	Control	1.39	0.75	3.27	1.83
	Treatment	4.79	0.52	4.80	-0.18
Wetland Soil Water	Control	2.91	0.22	2.39	0.57
	Treatment	4.82	0.51	5.67	-3.50
Wetland Surface & Soil Water	Control	1.38	0.77	2.79	1.79
	Treatment	4.23	0.60	4.09	-0.91