Soil water sources for non-native species Japanese knotweed, phragmites and multiflora rose

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Abstract

Invasive plant species grow abundantly in New Jersey's riparian environments and have an impact on water availability and ecosystem structure, where they are often able to outcompete and replace native plant species. Several studies have linked successful competition in plant communities to root function and effective water sourcing, but little comparable research has been done in the Northeastern United States. Japanese knotweed (*Fallopia japonica*), phragmites (*Phragmites australis*) and multiflora rose (*Rosa multiflora*) are three non-native plant species that are common to the area. This study investigates the water use and water sources within the vertical soil profile for each of these species in order to understand how they compete for water resources under various hydrologic regimes. Results of this research are also useful for finding the effect that these plant species have on freshwater that would normally enter New Jersey's reservoir system.

Samples were collected in the early, middle and late summer 2014 from two sites in northern New Jersey where the three non-native plant species grow together. Sampled material included plant stems, roots, river water, and soil at selected depths in the profile. Rain water was also sampled over the course of the field season. All samples were analyzed for δ^2H_{VSMOW} and $\delta^{18}O_{VSMOW}$. Several mixing models, including IsoSource software, were used to calculate the proportions of plant tissue water coming from each of the soil depths. Physiological measurements, including transpiration rates and leaf water potential, were also taken from randomly selected plants of each species. Soil samples were collected under each species on all sampling days and analyzed for percent soil moisture.

Preliminary results suggest that Japanese Knotweed and Multiflora rose transpired water from shallow soil in the early summer, and accessed increasingly deeper sources later in the season. Phragmites used primarily shallow soil water throughout the summer, with an exception being dry periods during which shallow water is unavailable. In terms of water use, Multiflora rose had the highest transpiration rates and, unlike Japanese Knotweed and Phragmites, responded to increases in soil moisture with increased transpiration rates.

Methods

Collecting Samples

- Stems
- Roots
- River water
- Rain water
- Soil at multiple depths

Physiological Measurements

- Transpiration, hydraulic conductivity and a suite of related data using IRGA
- Leaf water potential using PMS Model 600 Pressure Chamber

Analyzing Isotopes

- δ^2H and $\delta^{18}O$ vs. VSMOW
- Analyzed using a Thermo Delta V isotope ration mass spectrometer (IRMS) interfaced to a Gas Bench II.

Soil Moisture

- Dried in oven for % moisture.

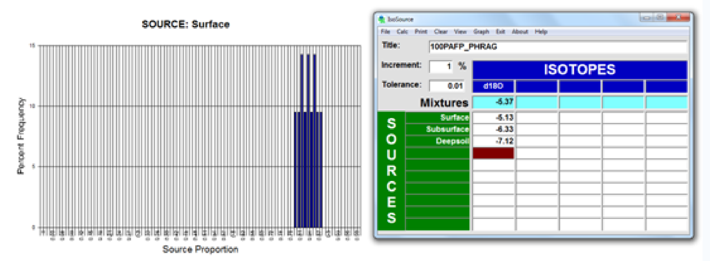
Mixing Models

- F_{ssw} Equation

(Darrouzet-Nardi et al. 2006)

$$F_{ssw} = (\delta^{18}O_{plant} - \delta^{18}O_{deepsoil}) / (\delta^{18}O_{shallowsoil} - \delta^{18}O_{deepsoil})$$

- IsoSource Software



Location

Two sites in northern New Jersey were selected for this study. Both were riparian ecosystems in which multiflora rose, phragmites and Japanese knotweed grew in close proximity of one another. The first site is along the Third River, a tributary of the Passaic River, in the Alfonso F. Bonsal Wildlife Preserve in Montclair. The second is along the Passaic River in Florham Park,.

Results

Figure 1

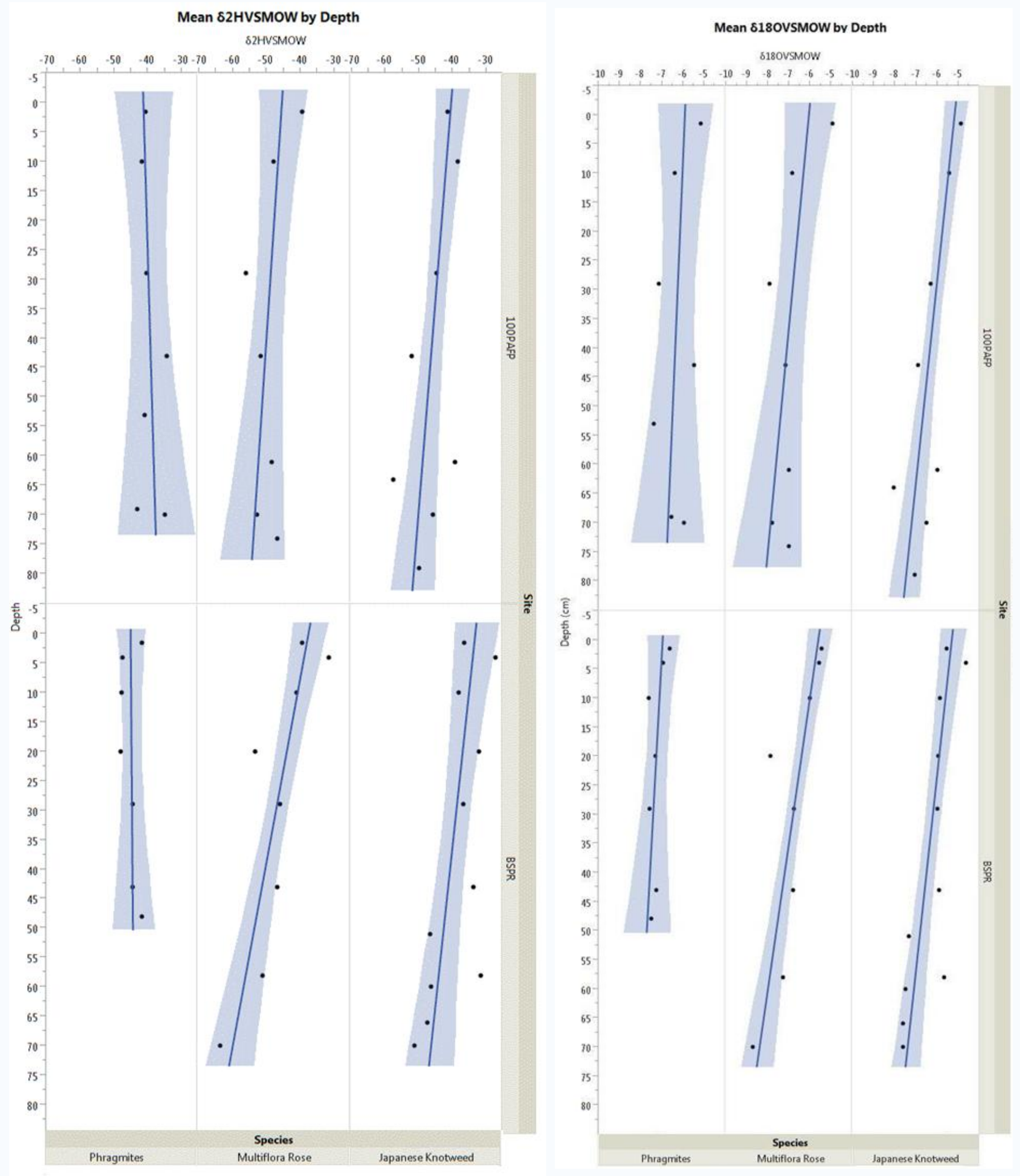


Figure 1. (Above) Isotope ratios plotted against depth, by species, by site. δ^2H_{VSMOW} and $\delta^{18}O_{VSMOW}$ are negatively correlated with depth, with the exception of the soil under phragmites.

Figure 2

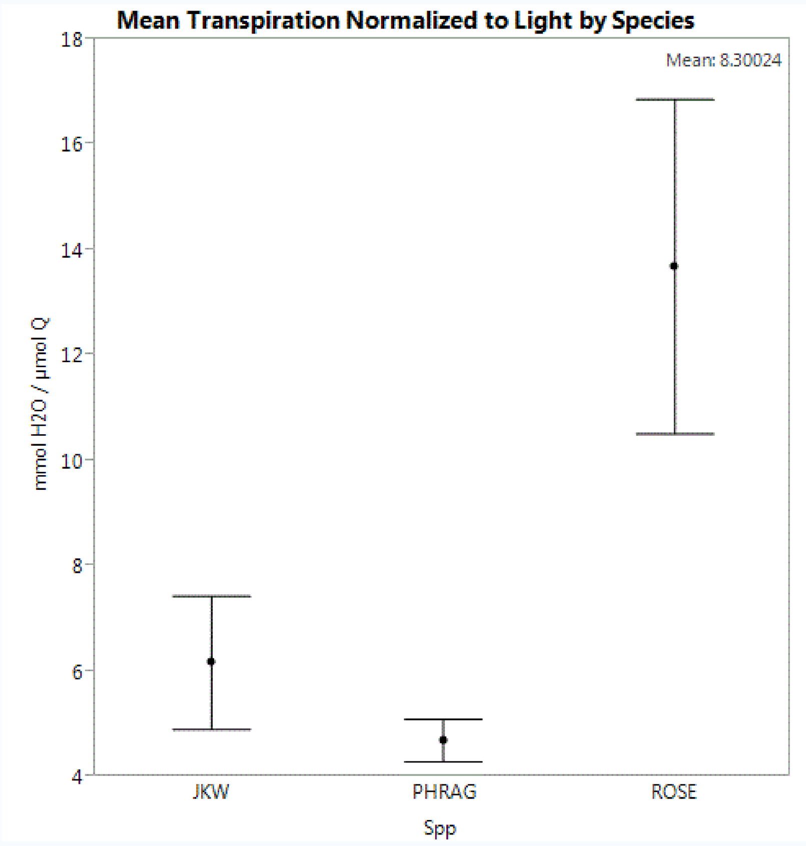


Figure 2. (Top right) Mean transpiration normalized to light, by species. Phragmites has the lowest average transpiration rate and multiflora rose has the highest transpiration rate. Phragmites and Japanese knotweed are comparable in their transpiration rates, while multiflora rose is significantly different. Anova Prob > F = 0.0051*

Figure 3

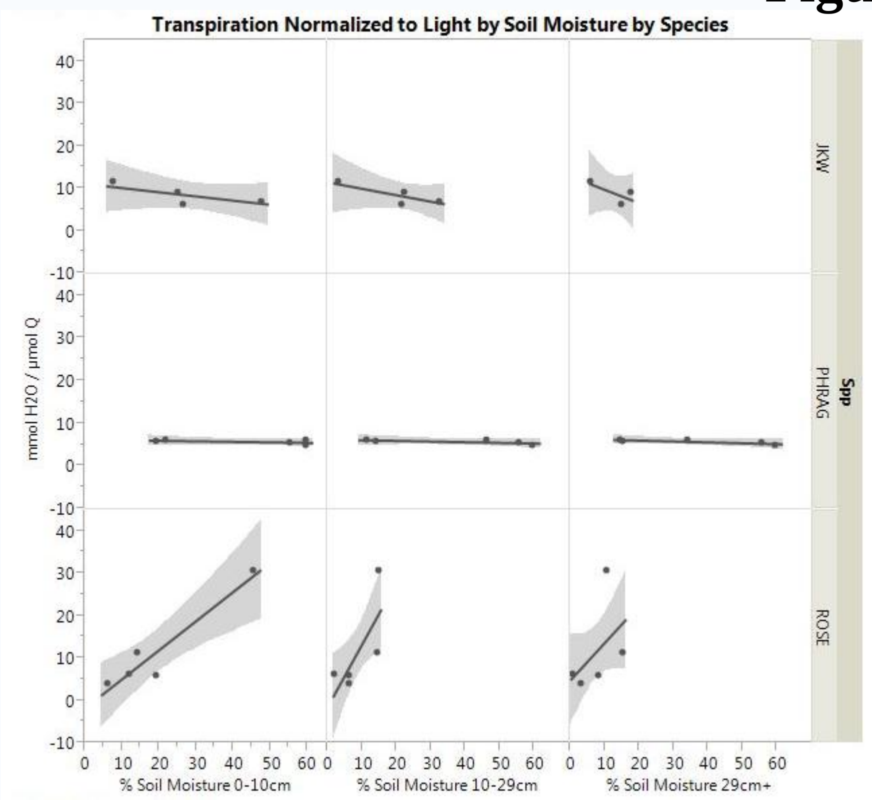


Figure 3. (Above) Transpiration rate plotted against soil moisture, by species, by site. Multiflora rose has a transpiration rate positively correlated with percent soil moisture. Japanese knotweed and phragmites show no trend.

Conclusion / Discussion

Isotope Signatures vs. Soil Depth

- Shallow soil is often more isotopically enriched (less negative) than deep soil due to the fractionating effect of transpiration (Allison et al. 1983). The δ^2H_{VSMOW} and $\delta^{18}O_{VSMOW}$ values of the soils sampled beneath multiflora rose and phragmites supported this trend.
- Phragmites often grew in saturated soils in which the water moved freely through the vertical soil profile. The δ^2H_{VSMOW} and $\delta^{18}O_{VSMOW}$ values in this soil therefore did not display the gradient expected in non-saturated soils. In most instances, isotopic values in this soil showed no clear change with depth.

Water Sources

- The δ^2H_{VSMOW} and $\delta^{18}O_{VSMOW}$ values for Japanese knotweed and multiflora were closest to the isotopic signature of shallow soil layer (<10 cm) in the early summer 2014.
- Results using the Fssw mixing model proposed by Darrouzet-Nardi et al. (2006) support that these two species used primarily shallow water early in the season and increasingly accessed deeper sources in the late summer/early autumn 2014.
- Phragmites δ^2H_{VSMOW} and $\delta^{18}O_{VSMOW}$ values indicate that the species sourced primarily shallow water except during dry periods when it was less available.

Soil Moisture and Transpiration

- Multiflora rose had consistently higher transpiration rates on average than phragmites or Japanese knotweed.
- Multiflora rose was also the only species of the three that responded to high and low soil moisture with increased and decreased transpiration, respectively. One reason may be that multiflora rose typically grows in soil that is relatively dry compared with Japanese knotweed and phragmites, and water stressed species are often more water efficient.
- Phragmites, the species typically found in inundated soil, correspondingly had the lowest average transpiration rates.

Future Research

- Extend this study to more non-native and native species to make a complete set of baseline data on riparian species water use.
- Monitor riparian plant water sources across more field seasons for a fuller understanding of water sourcing and use under a suite of hydrologic regimes.
- Quantify the total water transpired by each species to compare their impacts on water availability.
- Investigate the ways in which soil type affects isotope ratio changes with depth.

References

Allison G B, Barnes C J and Hughes M W. 1983. The distribution of deuterium and ^{18}O in dry soil. Exp. J. Hydrol. 64, 377-397.

Darrouzet-Nardi A, D'Antonio C M, Dawson T E. 2006. Depth of water acquisition by invading shrubs and resident herbs in a Sierra Nevada meadow. Plant and Soil. 285, 31-43.

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