The Influence of Groundwater Depth and Nutrient Limitation on Plant Water Use in Owens Valley, California

Diane E. Pataki
Departments of Earth System Science, and Ecology & Evolutionary Biology
University of California, Irvine

While previous studies in Owens Valley have focused largely on the direct effects of groundwater depth on plant water stress as a control on plant community composition, particularly the abundance of grasses vs. shrubs, our results suggest that indirect effects of declining soil moisture on soil N availability are a key control. The interactions between water and N cycles may play a primary role in influencing vegetation dynamics in shallow groundwater ecosystems such as in the central Owens Valley, and should be considered in projections of the effects of water extraction and redistribution on plant communities.

Owens Valley, California is a closed hydrologic basin at the base of the Sierra Nevada Mountains. In 1913, the Los Angeles Department of Water and Power (LADWP) began diverting water from this semi-arid basin, which supports vegetation from both the Great Basin and the Mojave Deserts. Despite several decades of water management and monitoring in the valley, the current and potential impacts of water redistribution on local vegetation and ecosystem processes remain highly uncertain, in part due to a limited understanding of the interactions between vegetation dynamics and hydrology. In this study, we evaluated species differences in plant water and nitrogen sources to explore potential drivers of the success of grass and shrub functional types within the central Owens Valley. The study focused on three sites with shallow groundwater, generally within 3 m of the surface, but with varying community composition. Plant water sources were identified with measurements of the isotopic composition of plant water, soil water, and groundwater. Ecosystem nitrogen (N) cycling was evaluated with measurements of soil organic and inorganic N content, and plant and soil N content and isotopic composition. We also measured plant gas exchange and water potential (a measure of plant water stress), to determine the extent to which different species were water versus N limited. We found that shrub species generally utilized soil water from deeper sources than the grass species as indicated by greater isotopic enrichment (more water containing the heavy isotope ^{18}O) in the grasses. The isotopic composition of water in the shrub species indicated that shrubs largely utilized groundwater as a water source. This is consistent with the hypothesis that grasses are more sensitive to lowered water tables than shrubs. However, both grasses and shrubs showed little evidence of seasonal water stress. All species showed a decline in leaf N throughout the growing season which was consistent with a trend of decreasing plant available N in the soil. Losses of N during the growing season may be attributable to volatilization of N in gaseous form (eg. soil nitrous oxide and ammonia emissions) and to reduced microbial release of N in the shallow soil during progressive soil drying in summer. The decline in soil N influenced photosynthesis of the grass species *Distichilis spicata*. Photosynthesis of the shrub species *Atriplex torreyi* and *Ericameria nauseosa* remained relatively constant throughout the season and was not correlated with water sources, water potential, or leaf N. However, leaf N was significantly correlated with photosynthesis in *D. spicata* (Figure 1). Seasonal losses in soil inorganic N caused by declining surface soil moisture

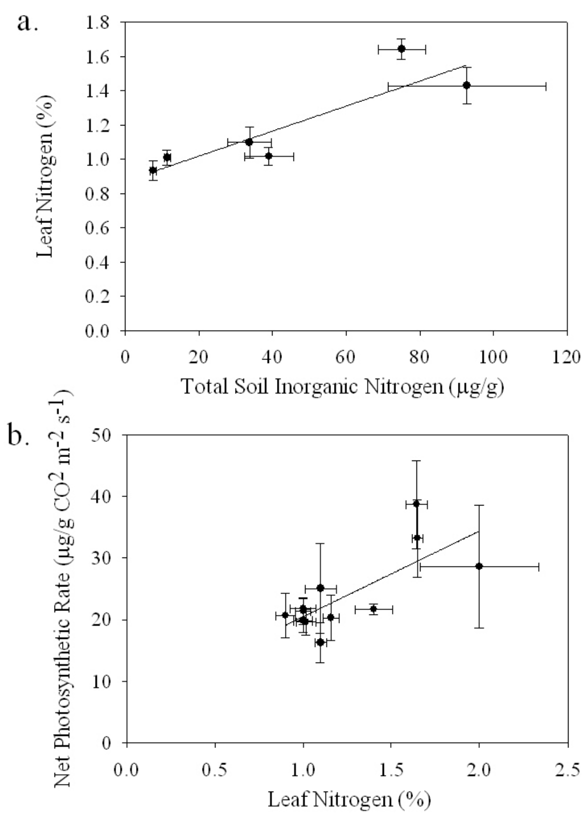

Figure 1. a) Leaf level photosynthesis versus percent leaf N for the grass species *Distichlis spicata* in both 2005 and 2006 (R^2=0.50, p<0.01). b) Percent leaf N versus total soil inorganic N for *D. spicata* in 2006 (R^2=0.71, p<0.05). Error bars show the standard error (n varies from 3-5 replicates).

appeared to largely explain seasonal declines in photosynthesis of this species. Transpiration showed a similar trend to photosynthesis, and was therefore limited by N availability for the grass species. Previously, seasonal declines in ecosystem gas exchange have been attributed largely to direct, water stress-related seasonal declines in soil moisture and the depth of the water table. Our results suggest that both the spatial and temporal variability of plant gas exchange of grasses was more strongly influenced by an indirect effect of declining soil moisture: reductions in inorganic, plant available soil N concentrations. While previous studies in Owens Valley have focused largely on groundwater depth as a control on species composition, particularly the abundance of grasses vs. shrubs, our results suggest that controls on N cycling are likely to be an important determinant of the distribution of grasses in this region. The interactions between water and nitrogen cycles may play a primary role in influencing vegetation dynamics in shallow groundwater ecosystems such as in the central Owens Valley, and should be considered in projections of the effects of water extraction and redistribution on plant communities.

Collaborative Efforts

We collaborated with Prof. Sharon Billings at the University of Kansas to obtain the soil inorganic N data for this study. In addition, the Los Angeles Department of Water Power helped us select our study sites and gave us permission to conduct this research on their property.

Professional Presentations

Goedhart C.M., D.E. Pataki, S.A. Billings. Controls on plant gas exchange across a grassland to shrubland gradient in Owens Valley, California. Ecological Society of America meeting, San Jose, CA, Aug. 2007.

Pataki, D.E., S.A. Billings, E. Naumburg, C. Goedhart. Water sources and nitrogen relations of grasses and shrubs in phreatophytic communities of the Great Basin Desert. (poster) Ecological Society of America meeting, San Jose, CA, Aug. 2007.

Goedhart C.M., D.E. Pataki, S.A. Billings. Controls on plant gas exchange across a grassland to shrubland gradient in Owens Valley, California. Annual Meeting of the Southern California Academy of Sciences, Fullerton, CA. June 2007.

For further information please contact:

Diane E. Pataki
dpataki@uci.edu
(949) 824-9411
http://www.ess.uci.edu/~dpataki/