the country. The project's strategic plan is updated every seven years and includes operational objectives, performance measures, reporting standards, identification of risks and opportunities, and annual reviews. Lessons learned: 1) predator and weed control are intensive, long-term management activities; 2) wetland restoration and construction techniques cannot be applied to the more dynamic braided river areas; 3) public outreach is essential to creating a volunteer pool and broad-based support for restoration efforts; 4) research and monitoring are integral to effective planning, implementation, and evaluation of restoration activities; and 5) adaptive management is necessary for long-term success.

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Economic Values of River Restoration. 2005. Loomis, J., Colorado State University. **Colorado Water,** December, Pp. 9-11.

Loomis argues that economic assessments of restoration projects must incorporate passive-use values, which are the benefits that people experience from the presence of native species and intact habitats and their survival for the benefit of future generations. The U.S. Court of Appeals has upheld consideration of these existence and bequest values when determining natural resource damages on public lands. Loomis posits that passive-use values can contribute more than half of the economic benefit of river restoration. He cites a contingent valuation method survey in Washington to assess the value of Elwha River restoration, which indicated that this project is worth $94 million in annual statewide passive-use benefits compared to the $250 million in estimated project costs.

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Can We Really Restore Rivers? 2005. Wohl, E., Colorado State University and Colorado River Water Conservation District; B. Bledsoe, D. Merritt and L. Poff. **Colorado Water,** December, Pp. 5-8.

According to the authors, restoration is the facilitation of ecological integrity—the ability of an ecosystem to maintain its parts and necessary processes. They contend that many small and mid-size river restoration projects fail because they operate at insufficient spatial and temporal scales, lack an appropriate scientific conceptual context, and have rigid structural goals that do not acknowledge the dynamic nature of river ecosystems. The authors recommend that projects focus on 1) restoring processes at the watershed scale to address underlying causes of degradation, 2) using adaptive management and long-term monitoring to increase scientific understanding and develop conceptual models, and 3) accepting that variability is natural.

Coastal Communities

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Ecological Values of Shallow-water Habitats: Implications for the Restoration of Disturbed Ecosystems. 2006. Lopez, C.B., J.E. Cloern, U.S. Geological Survey, 345 Middlefield Rd. MS 496, Menlo Park, CA 94025, jecloern@usgs.gov; T.S. Schraga, A.J. Little, L.V. Lucas, J.K. Thompson and J.R. Burau. **Ecosystems** 9(3):422-440.

The authors mapped plankton biomass and productivity in the Sacramento-San Joaquin River Delta in California to determine if shallow-water restorations would ultimately benefit native fish species by enhancing their food resources. They concluded that phytoplankton biomass did not correlate with growth rate in shallow areas because a portion was transported into deep-water areas. In addition, non-native Asian clams (*Corbicula fluminea*) grazed 800 percent faster than zooplankton, creating localized phytoplankton sinks. Given their findings, the authors caution that 1) biomass alone is a poor indicator for assessing important functional responses in aquatic systems, 2) rates and patterns of connectivity between different habitats in an ecosystem influence the success of restoration activities, and 3) the most important restoration strategy is limiting future transportation and establishment of non-native species, since a single invasive species can have ecosystem-scale effects and create unpredictable restoration outcomes.

Other Communities

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Ecohydrological Implications of Removing Encroaching Woody Vegetation From a Bur Oak Savanna (Iowa)

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Oak savanna ecosystems throughout the midwestern United States have become overgrown by shade-tolerant, fire-sensitive tree species (for example, maple [*Acer* spp.] and elm [*Ulmus* spp.]), due to altered fire and grazing regimes (Anderson 1998). Woody encroachment of grasslands and savannas worldwide has led to increased water uptake by vegetation (Huxman and others 2005), although the potential to reestablish ecohydrologic functioning is not well understood. In another paper, we and our colleagues (Asbjornsen in press) investigated the effects of removing encroaching American elm (*U. americana*) trees on water uptake dynamics in a bur oak (*Quercus macrocarpa*) savanna. Here, we highlight these findings and discuss potential implications of altered landscape hydrology for restoration success, as well as possible consequences of savanna restoration on ecohydrology in agriculturally dominated landscapes.

We conducted this study in a 19.7-acre (8-ha) savanna remnant surrounded by agricultural fields at the Neal Smith National Wildlife Refuge in central Iowa. We removed elms from a roughly 2.5-acre (1-ha) portion of the remnant, reducing the basal area from 137.4 ft^2/acre (31.9 m^2/ha) to 53.4 ft^2/acre (12.4 m^2/ha). The basal area for the remainder of the stand (non-thinned control; hereafter "woodland") was 164.4 ft^2/acre (38.2 m^2/ha). To assess water uptake by trees, we monitored sap flux for six overstory oak trees (three each for savanna and woodland sites) and three *mid-canopy* elms (woodland site only) of representative size for each species using thermal dissipation probes constructed after Granier (1987). Using a data logger, we collected continuous sap flux data on 38 dates between June and September 2004. We converted these data to daily sap flow rates per tree (J_d) and calculated mean daily stand transpiration (E_c) by multiplying J_d by the estimated total sapwood area in each stand.

Bur oaks in the savanna treatment had about 42 percent greater sap flow rates (35.9 L/dm^{-2}/day) than woodland oaks (20.7 L/dm^{-2}/day), while woodland elms had significantly lower sap flow rates (12.4 L/dm^{-2}/day) than both the savanna and woodland oaks (ANOVA, $p < 0.01$) (Asbjorsen and others in review). We did not have baseline data because restoration treatments at the site had been conducted several years before our study. However, because the density of oaks in the adjacent stands was similar, our results suggest woody encroachment has led to competition for water between the oaks and elms, reducing total water uptake by the oaks. Groundwater level was more than 13 ft (4 m) lower under the woodland compared to the savanna (Asbjornsen and others in review), suggesting that trees in the woodland may partly compensate for increased competition by extracting water from deeper supplies.

At the stand level, daily stand transpiration was more than four-fold higher in the woodland (1.23 mm/day) than the savanna (0.36 mm/day) (Asbjornsen and others in review). Thus, although elms have relatively low water uptake per sapwood area, the high density of encroaching elms resulted in much higher stand-level water uptake compared to the more open savanna. These results suggest that increased stand density and altered species composition may dramatically affect the water balance in this remnant oak savanna by greatly increasing total transpiration and reducing groundwater levels.

In the Midwest, hydrologic alterations resulting from agriculture have increased base flow and groundwater recharge and raised water tables (Schilling 2005) due to the limited growing season and/or rooting depths of dominant annual crops (Brye and others 2000). We propose that these hydrologic changes may, at least in part, facilitate woody encroachment in savanna remnants existing in agricultural landscapes by increasing water availability above historic levels. This possibility raises important questions for savanna restoration, since surplus moisture could maintain conditions that favor encroachment. This could increase the frequency of management interventions needed to deter encroachment, thereby increasing restoration costs and logistical requirements.

Restorationists also need to consider the potential trade-offs with respect to achieving particular—and often conflicting—goals. If reestablishment and conservation of savanna biodiversity and structure are the primary goals, then restoration efforts should target larger remnants, as they likely have greater buffering capacity from external landscape influences (Asbjornsen and others 2004). Higher landscape positions would be least susceptible to hydrologic effects of surrounding land uses. Additionally, maintaining a buffer that is densely vegetated with deep-rooted species could minimize lateral water movement from the cropland that could otherwise interfere with restoration efforts and alter ecohydrologic functioning within the savanna. Conversely, if the overall goal is to restore groundwater quality or balance groundwater flows at the landscape scale, then maintaining or even expanding woodlands in strategic locations may be a more effective means of removing excess water. Further study of how woody encroachment and savanna restoration affect ecohydrologic functions at both stand and landscape scales will help better inform restoration decisions and the potential for achieving multiple goals.

References

Anderson, R.C. 1998. Overview of Midwestern oak savanna. *Transactions of the Wisconsin Academy of Science, Arts, and Letters* 86:1-18.

Asbjornsen, H., M. Ashton, D. Vogt and S. Palacios-Mayorga. 2004. Effects of habitat fragmentation on the buffering capacity of edge environments in a seasonally-dry tropical oak forest ecosystem in Oaxaca, Mexico. *Agriculture, Ecosystems and Environment.* 103:481-495.

Asbjornsen, H., M.D. Tomer, M.Gomez-Cardenas, L.A. Brudvig, C.M. Greenan and K. Schilling. In review. Tree transpiration in a midwestern bur oak savanna after elm encroachment and restoration thinning. *Forest Ecology and Management.*

Brye, K.R., J.M. Norman, L.G. Bundy and S.T. Gower. 2000. Water-budget evaluation of prairie and maize ecosystems. *Soil Science Society of America Journal* 64:715-724.

Granier, A., 1987. Sap flux measurements in Douglas-fir tree trunks by means of a new thermal method. *Annales des Sciences Forestieres* 44:1-14.

Huxman, T.E., B.P. Wilcox, D.D. Breshears, R.L. Scott, K.A. Snyder, E.E. Small, K. Hultine, W.T. Pockman and R.B. Jackson. 2005. Ecohydrological implications of woody plant encroachment. *Ecology* 86:308-319.

Schilling, K.E. 2005. Relation of baseflow to row crop intensity in Iowa. *Agriculture, Ecosystems and Environment* 105:433-438.