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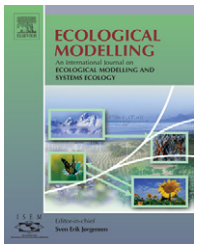

Developing a dynamic model to predict the recruitment and early survival of black willow (*Salix nigra*) in response to different hydrologic conditions

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ABSTRACT

Disruption of the natural flood regime in floodplain-river ecosystems can decrease plant diversity and lead to dominance by one or a few species that can tolerate the altered conditions. Restoration of native plant communities requires naturalization of the flood regime, to prevent dominance by one species and to promote germination and growth of a variety of native species. Black willow (*Salix nigra*), cottonwood (*Populus deltoides*) and silver maple (*Acer saccharinum*) are native, flood-tolerant trees that often form monocultures and shade out moist-soil plants (e.g., millets) in waterfowl management areas and restoration sites on floodplains along the Illinois River and some portions of the Upper Mississippi River. Since the moist-soil plants provide ecological goods and services that are not provided by pioneering tree species alone, such as food for migratory waterfowl, wetland managers try to limit recruitment of these pioneering tree species with herbicides, disking and mowing. Other natural resource managers value the same species for reducing bank erosion or as potential sources of rapidly growing biomass for generation of electricity. From either perspective, it is important to identify characteristics of flooding regimes that might encourage these tree species or keep them in check. We developed a dynamic simulation model to predict the recruitment and seedling growth of one of these pioneering trees (black willow, *Salix nigra*) in response to flood timing and duration over three growing seasons following germination. Tree germination and survival respond to capillary water depth, flood duration, length of growing season and timing of seed dispersal. The model was tested over a range of elevations (132.3–132.9 m) that were observed on aerial photos as the tree line in the vicinity of River Km 201 along the Illinois River. The model was validated to the extent that it simulated establishment of black willow at the elevation of the observed tree line and variability of seedling growth in response to the flooding regime (i.e., poor or no survival or growth at elevations below the tree line where floods were longer-lasting and more frequent). Although more experimental or field-based information on seedling physiology should be gathered to refine the model, the prototype model is useful for exploring effects of alternative water level regimes. The model provides a framework for simulating any pioneering tree species that colonizes floodplains, if the required species-specific physiological information is available.

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1. Introduction

Disruption of the natural flood regime in floodplain-river ecosystems can decrease plant diversity and lead to dominance by one or a few species that can tolerate the altered conditions (Middleton, 1999, 2002). In the floodplains of the Illinois River and the Upper Mississippi River, changes in disturbance patterns from presettlement times to the present probably contributed to dramatic shifts observed in vegetation patterns (Nelson et al., 1998). According to data recorded in 1817 by surveyors from the U.S. General Land Office at the confluence of the Illinois and Mississippi rivers, upstream of St. Louis, prairies covered 46% of the floodplain and trees covered 35% (Nelson et al., 1998). The term "prairies" would have included low-lying, open areas without trees that were occupied by what today are termed "wet prairies" or "moist soil plant communities". Today, 56.5% of the floodplain in the same area is developed, mostly for agriculture and trees occupy three times more of the remaining area (18.6%) than do the prairies (5.6%). The contemporary forest in the lower Illinois River is dominated (44.9%) by just one species (*Acer saccharinum*, silver maple), whereas the presettlement forest had a more even distribution of abundance among species and *A. saccharinum* only ranked seventh in relative dominance (5.8%; Nelson et al., 1994).

Nelson et al. (1998) attribute the presettlement prevalence of prairies in the floodplains and the species diversity of the forests to a combination of two disturbances: fire in the higher elevations and flooding in the lower elevations. They recommend a return to an intermediate level of disturbance (*sensu* Connell, 1978); i.e., prescribed flooding and fire regimes to restore plant communities on floodplains managed by state and federal agencies, but they do not specify what these regimes should be in terms of frequency, intensity and seasonal timing. Plant models that respond to flooding would be useful in predicting the effects of alternative disturbance regimes. As described next, waterfowl managers and conservationists along the middle Illinois River and portions of the Upper Mississippi regard black willow (*Salix nigra*) and cottonwood (*Populus deltoides*) as major problems, although the relative dominance of the remaining floodplain forests by willows, at least along the lower Illinois River, was actually less in 1992 (5.3%) than in 1817 (8.3%) and dominance by cottonwood was likewise less (4.7% in 1992 versus 10.1% in 1817; Nelson and Sparks, 1998). The differences in the pioneering tree species that currently dominate particular river reaches within the same climatic zone may be attributable to differences in the regulated water regimes within and among reaches that favor one species over another (Yin and Nelson, 1996). The problem with the three pioneering tree species mentioned above (silver maple, black willow and cottonwood), from a natural resource manager's point of view, has less to do with dominance in the remaining floodplain forests than with competition with the moist-soil plant community.

The moist-soil plant community includes at least one federally listed threatened species (the decurrent false aster, *Boltonia decurrens*) and several state-listed species (Smith et al., 2005). This plant community also provides ecological goods and services that are not provided by the pioneering tree species alone (e.g., the millets, *Echinochloa* sp., provide food for migratory waterfowl). Once established, these pioneering trees are persistent and expensive for managers to control. For example, tens of thousands of dollars are spent annually in individual wildlife refuges in Illinois and Missouri trying to control black willow by spraying with herbicide and disking and mowing (Laubhan and Hamilton, 1988; personal communication with Ross Adams at The Chautauqua National Wildlife Refuge, Havana, Illinois). "Naturalization" of the flood regime (defined as an approximation of the presettlement flood regime, to which the native plant communities were presumably adapted), by modifying dam operations or using gates to control inundation in leveed areas of the floodplain, might provide an alternative to physical and chemical control. However, the exact flooding requirements are not known and would have to be specified in areas where water levels are now controlled. In contrast to the view that black willows, cottonwoods and silver maple need to be controlled, others regard these same species as potential sources of biomass for energy production. Douglas Blodgett, the Great Rivers Area Director for The Nature Conservancy (personal communication), believes that some parts of the floodplain might be restored and other parts might be used for commercial production of flood-tolerant species for fuel, while still accommodating floods and providing some degree of moist-soil habitat for wildlife. The power station on the Illinois River at Havana, and some other power stations along the Mississippi River, are capable (with some modifications of operation) of burning wood or other renewable fuel sources, as well as fossil fuels. Black willow is a good candidate for biomass for energy production (Kuzovkina and Quigley, 2005). A model that predicts responses of candidate species to water levels would be a useful tool for site selection and water management to optimize production.

Here, we report the development of a dynamic simulation model to predict the recruitment and seedling growth of one of the pioneering trees mentioned above, black willow, in response to flood timing and duration over three growing seasons following germination. The prototype model is akin to and intended to supplement the moist-soil plant model developed by Ahn et al. (2004b). We apply the model to a representative site along the Illinois River, near Havana, Illinois, where there are state and federal wildlife refuges and hunting and fishing areas, and where The Nature Conservancy is converting an agricultural drainage and levee district back to a floodplain.

2. Site description

During the past 100 years, the hydrologic regime of the Illinois River has been altered by urban and agricultural development of the watershed; locks and dams for commercial navigation; levees that protect floodplain agriculture from flooding; water diversion from Lake Michigan (Sparks et al., 1998; Schneider, 2000). Recently, public interest in the conservation and recovery of natural services has prompted major public and private investments along the Illinois River in habitat rehabilitation