# A seasonal model for the endangered plant *Boltonia decurrens* in a stochastic flood and precipitation environment

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The demography of annual organisms is affected by short-term seasonal cycles, inter- annual environmental stochasticity, and longer-term trends in the environment. This talk presents a detailed analysis of such a situation, in the case of the endangered plant *Boltonia decurrens*. This species is restricted to floodplains of the Illinois River Valley in the central United States. It has a complex winter annual life cycle, which has evolved in response to the dynamics of the historic flood regime. Formerly abundant, it has declined dramatically in the last 100 years, during which time the hydrology of the river has changed because of flood control and navigation projects.

Here we describe a stochastic demographic analysis of *Boltonia*, the goals of which are to relate population growth to environmental factors (flood timing and precipitation), evaluate the effects of historical changes in the environment and test hypotheses about the effects of human activities. The models combine periodic matrix products within years and stochastic matrix products between years.

Our analysis shows that the timing of spring floods dramatically affects population growth. Flood timing fluctuates randomly from year to year, and stochastic models show that increases in the frequency of late-receding floods reduces the stochastic growth rate $\log \lambda_s$. Flood timing interacts

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with precipitation levels during the growing season, and we developed a stochastic model including both factors to document their effects on $\log \lambda_s$. Historical data from 1895-2000 indicate that prior to the 1930s, when levees and navigation dams were completed, the frequency of late-receding floods was much lower than it is now. Life for *B. decurrens* has become much more uncertain: $\log \lambda_s$ has declined, $\sigma^2$ has increased dramatically, and the probability of quasi-extinction has risen as the disturbance regime changed after 1900.

In addition, the changes in the disturbance regime have caused a shift in the pathways within the life cycle that are most responsible for population growth, from an annual to a biennial life history. This is the first time that a stochastic model has been coupled with historical data on a stochastic environment. Undoubtedly, many plant and animal species evolved in concert with stochastic environments and are now threatened by anthropogenic changes in the variability of those environments. The data and analyses used in this study can be applied to management and development strategies to preserve other dynamic systems.