Predicting Invasion Rates for *Phragmites australis*

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Background

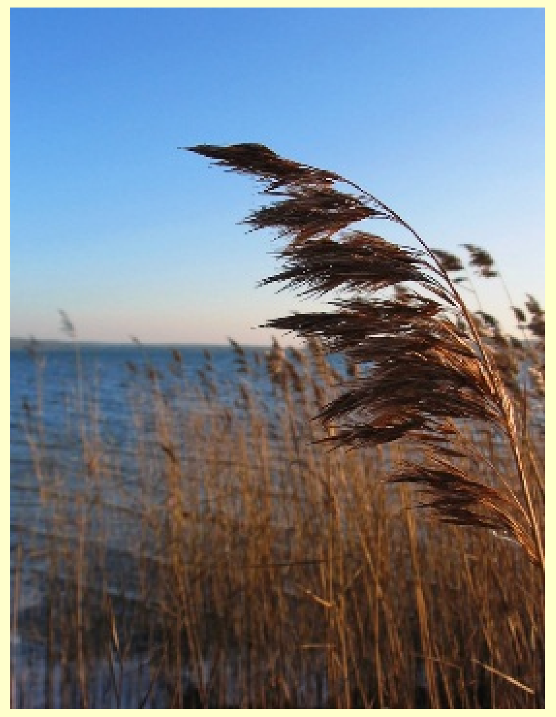

Figure 1: A *Phragmites* inflorescence contains hundreds of viable seeds on each adult stem.

In wetlands of Utah and southern Idaho as well as estuaries of the east coast, the ten-foot tall invasive grass *Phragmites australis* can be found near waterways, where it outcompetes native plants and degrades wildlife habitat. *Phragmites australis* is an obligate out-crossing plant that can spread sexually through seed dispersal, or asexually via stolons and rhizomes (Kettenring and Mock 2012). Small patches are usually a single genetic individual, spreading vegetatively (and slowly) via runners; when patches become genetically diverse viable seeds are produced and invasions rates can be increased by an order of magnitude (Kettenring et al. 2011).

Goals

Create a mathematical model to predict spread of *Phragmites* including:

- Complete life-cycle dynamics for both sexual and clonal reproduction,
- Effects of differential effects of competition with adult stems on seedlings and vegetative juveniles,
- Long-distance dispersal of seeds from genetically diverse stands,
- Short-distance vegetative dispersal which crowds out native competitors.

Model will be implemented in MATLAB and parameters determined in consultation with K. Kettenring's *Phragmites* research group.

Environmental Impacts

- Invades wetlands and crowds out native vegetation, lowering ecosystem diverstiy and impacting recreation.
- Thick stands provide poor habitat for local wildlife, particularly waterfowl.
- High concentration of dry litter in mature stands greatly increases risk of fire.

Jake Duncan illustrates how *Phragmites* crowds out native vegetation and provides bad wildlife habitat.

- By restricting free water flow across tidal flats *Phragmites* can channelize flow and increase flooding, destroying intertidal habitats.

Acknowledgements

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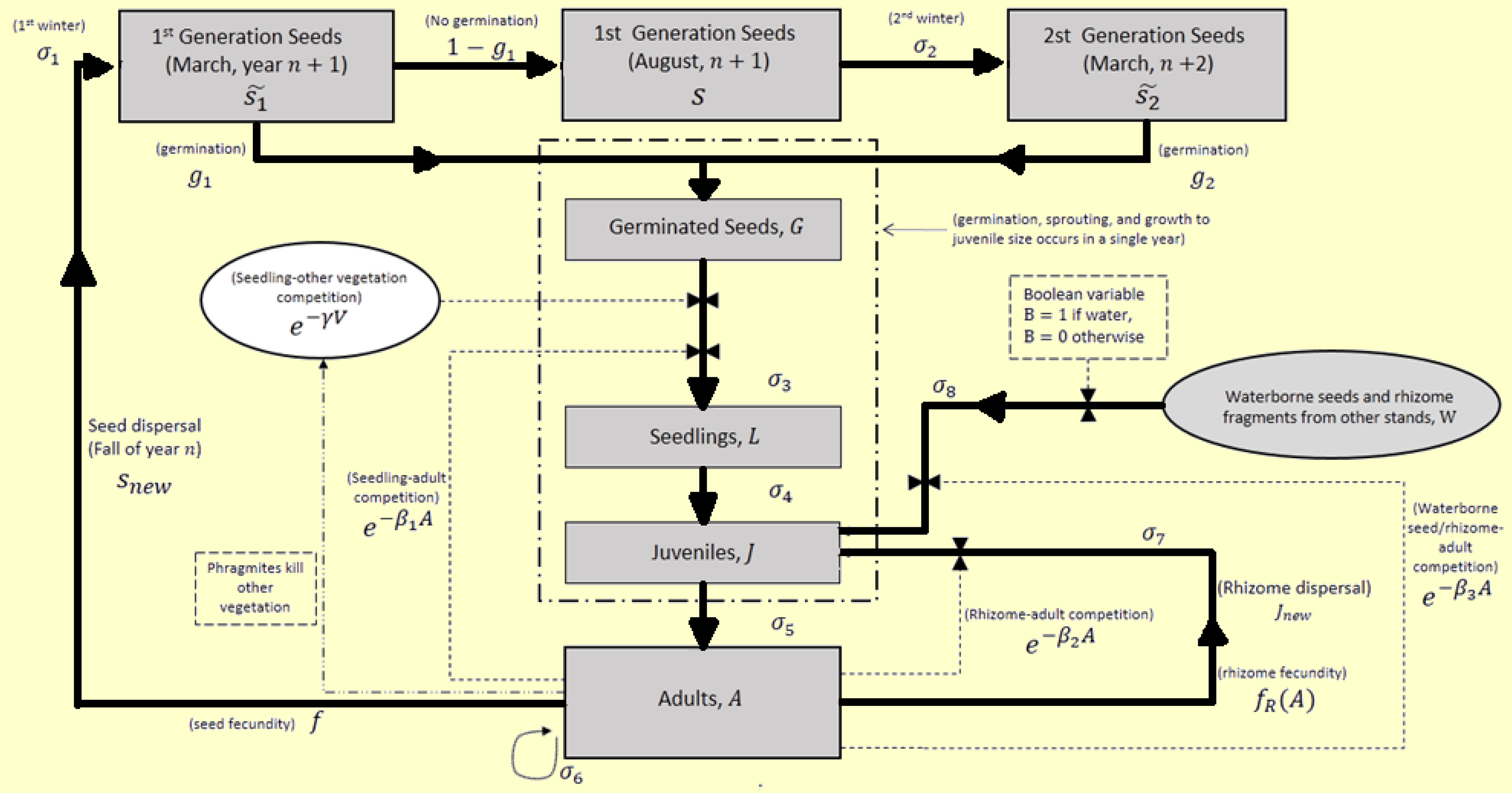
Life Cycle Diagram



Life Cycle Model

- $S_{n+1} = \sigma_1(1-g_1)S_{new}$
  - Seeds that were dispersed in the fall, survived the winter, but did not germinate are added to the seed bed for the following year.
- $J_{n+1} = (\sigma_1\sigma_3\sigma_4 g_1 S_{new} + \sigma_1\sigma_3\sigma_4 g_2 S_n)e^{-(\beta_1 A_n + \gamma V)} + J_{new}\sigma_7 e^{-\beta_2 A_n} + W_{new}\sigma_8 e^{-\beta_3 A_n}$
  - New juveniles come from germinating seeds (S_{new} or S_n), clonal spread (J_{new}), or waterborne dispersal of broken stems (W_{new}). All juveniles compete against adults ($e^{-\beta_j A_n}$ terms).
- $A_{n+1} = \sigma_5 J_n + \sigma_6 A_n$
  - Next year's adults are either surviving juveniles or adults from the previous year.

Dispersal Modeling

Ecological diffusion (Garlick et al. 2011) of airborne seeds from starting position x' and seed settling at new locations, $K(x, x')$:

$$\frac{\partial P}{\partial t} = \nabla^2[DP] - \lambda P \quad \frac{\partial K}{\partial t} = \lambda P$$

New seeds arrive at location x conditioned by dispersal, $K(x, x')$, and fecundity of adults, fA_n:

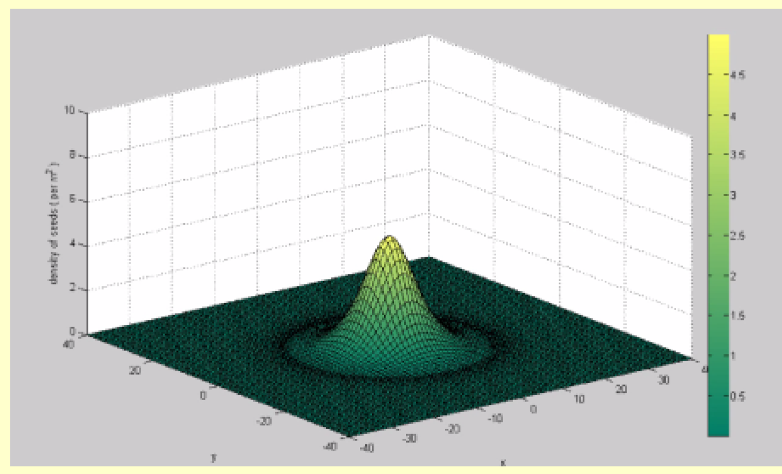
$$S_{new} = \int K(x, x') f A_n(x')\, dx'$$

New clonal juveniles at location x depend on **vegetative spread from adults** at x', $K_R(x, x')$:

$$J_{new} = \int K_R(x, x') f_R\big[A_n(x')\big]\, dx'$$

Adults have **limited vegetative fecundity**,

$$f_R(A) = \frac{\varphi A}{r + A}$$



Total seed spread in homogenous circumstances from a single seed source at origin, using the diffusive spread model.

Condensed list of parameters

σ	survivorship constants
g	germination rates
β, γ	competition constants
f	adult seed fecundity
φ	maximum vegetative production

Simulations

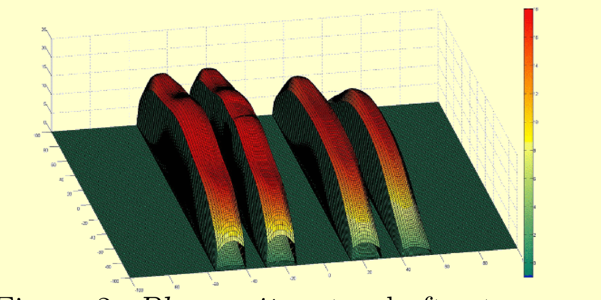


Figure 2: *Phragmites* stand after ten years of seed dispersal over disturbed ground lining two canals. The stands spread from a small patch centered along the first canal.

Figures 2 and 3 show adult phragmites density after a decade of expansion, starting with a small, genetically diverse patch on one side of a canal. Since the patch can self pollinate and produce thousands of viable seeds per square meter, airborne dispersal allows the invader to spread across dry barriers between canals (green area in figure 3) as well as across the water barrier of the canal itself (blue in figure 3).

The pictured stand is assumed to be genetically diverse, but simulations done for a stand with only one genome show drastically reduced spread. The canals are too large a barrier to be overcome by vegetative dispersal, as are the dry areas between canals. The single genetic individual can only spread about one-tenth as far as the diverse patch shown in Figures 2 and 3.

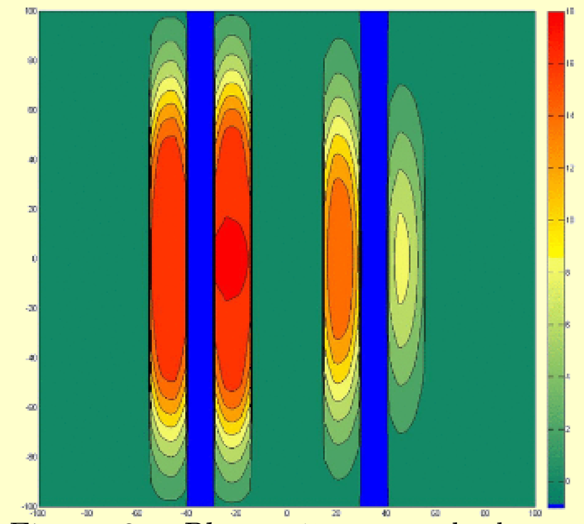


Figure 3: *Phragmites* spread along disturbed ground next to canals.

Discussion

Scenario studies using the *Phragmites australis* model indicate that genetically diverse stands of the invader spread 15 times more rapidly than pure clones, consistent with observations in Great Salt Lake wetlands.) We are working with the *Phragmites* research group to improve parameter estimates and make more careful comparisons with observations. Model extensions include:

Figure 4: Using a tarp to bake the soil after chemical application or mechanical scraping is one possible method of *Phragmites* contyrol.

- spatially heterogenous dispersal due to variability in wind/terrain,
- terms describing the effects of mechanical/chemical control measures (e.g. the tarp in Figure 4),
- explicit measures of genetic diversity.

References

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