A spatial decision framework for cost effective invasive species management

Kim Hall
Applied Economics/Forest Ecosystems and Society
Oregon State University

Invasive Species

* Economically and Ecologically costly
  * Impact:
    * biodiversity, ecosystem services, recreation, landowners, industry
  * Management:
    * Ecologists, economists, policy makers, resource managers, landowners, government agencies

Invasive Species Ecology

- Ecological processes driving spread
  - dispersal, propagule pressure, species competition
  - spatial
- Ecosystem impacts
- Eradication/restoration

Invasive Species Economics

Focus:

- Trade-offs between policies and/or policy level
  - Eradication/control/prevention
- Models:
  - Anthropogenic spread
  - Spatial models usually steady state

Research

* Integrated bio-economic model of invasive species management in a river network

* NSF project in Computational Sustainability

Bio-economic Model

GOAL: Decision framework describing optimal placement of management resources over space and time

* Economic Optimization
  * Objective: minimize costs
    * Population based cost function

  * Subject to ecological process and annual management budget constraint
    * Eradicate
    * Restore
    * Do Nothing

Economic Optimization

$$\min_{m_{it}} \sum_t \sum_i \rho(c_{it}(n_{it}, m_{it}))$$

$$s.t. \ \sum_i c_{it}(n_{it}, m_{it}) \le b_t \forall t$$

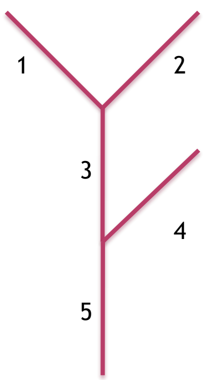
$$s.t. \ \text{ecological model}$$

Where:

ρ	discount factor
$c_{it}(\cdot)$	cost function
$n_{it}(\cdot)$	invasive population size
$m_{it}(\cdot)$	management action
b_t	budget constraint

Ecological Simulation

- Ecological Simulation
  - Network dispersal (Muneepeerakul et al. 2007)
    - Metapopulation model
  - Species competition (invasive vs. native)
  - Stochastic
  - Process:
    - Natural death/policy, propagule production, dispersal, establishment



Dispersal Model

$$K_{ij} = Cu^{NU_{ij}}d^{ND_{ij}}$$

Where:

C	is a normalization constant
u	is the upstream propagule survival rate
d	is the downstream propagule survival rate
NU_{ij}	is the # of upstream reaches between reach i and j
ND_{ij}	is the # of downstream reaches between reach i and j

Establishment Model

$$p_k(wins) = \frac{\beta g_k}{\beta g_k + g_o}$$

Where:

p_k	Probability that species k wins
β	"competitive advantage" of an invasive seed versus a native seed
g_k	Number of propagules of species *k*
g_o	Number of propagules of the other species (not *k*)

Solution Method

- Markov Decision Process
- Dimensionality issues – 14 billion combinations
- Near-optimal policy for each possible state
  - Estimate transition probabilities matrix
  - Use value iteration on approx. transition matrix
- Pathways program defines possible evolutions from a starting state

Current Policies

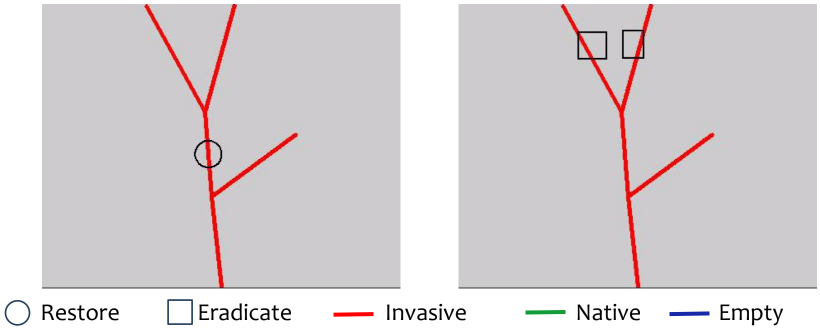
Current Rules of Thumb:

- Focus control at leading edge/satellite populations
- Focus on most connected reach first
- Focus on most upstream reach first (Chades et al. 2010)
- Target most invaded/degraded reaches first

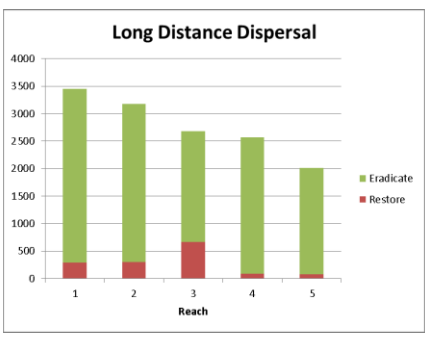
Results: Establishment strategy

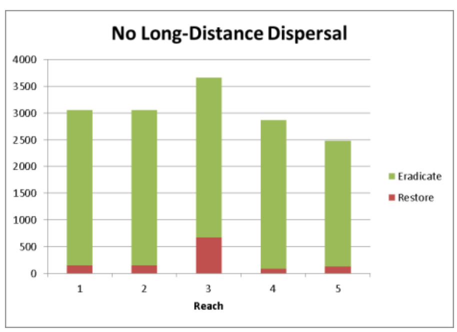
Case 1: high propagule production, low survival rate

Case 2: low propagule production, high survival rate

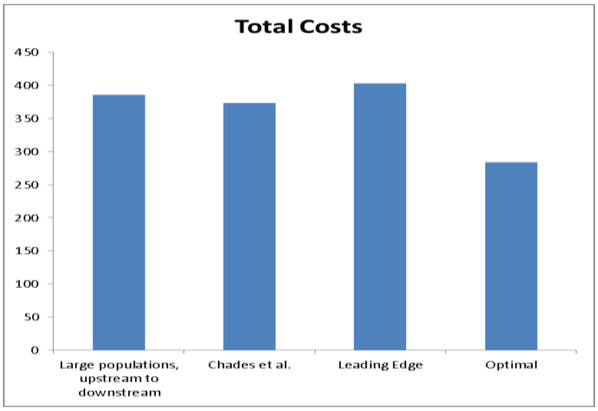


Results: Long Distance Dispersal





Results Rules of Thumb



Conclusions

* Optimal strategies are likely to be a combination of current policies and dependent on ecological characteristics of the invader
  * Results also show that characteristics of the river system matter too
* We can more efficiently allocate IS management efforts through integrated policies

Thank you

Future Work

* Alternative competition models and cost functions
* Include more perspectives
  * Landowners, policy makers, resource managers
    * Inform objectives
* Extension work