An Ecological Approach to Framing Non-Native Plant Management

Bruce Maxwell & Lisa Rew
Preliminary Thoughts...

- Ecosystems are complex and thus inherently difficult to predict, resulting in high uncertainty of management outcomes.

- New approach to ecologically based management must embrace complexity, be placed in the context of high uncertainty, and be adaptive.

- Monitoring is a crucial step in obtaining feedback to improve management and be adaptive.

- Treat every management action as a learning experience with evaluation of progress toward the land management goals.
Chronology of Research Questions

• How do we best survey non-native plant species (NNP) in management areas that are too large to inventory?
• Which factors dominate in determining the distribution of NNPs at a site and time?
• Does identifying and targeting source NNPs populations improve our ability to slow invasions?
• Does the impact of NNPs on land use objectives vary across environments where they occur?
• Does management success vary across environments?
• How do we efficiently put ecological information about NNP into a framework that will facilitate incorporation of the science into management?
Linking our Invasive Plant Species Management Research Agenda to Crown of the Continent

• Create survey and monitoring protocols that managers can implement.
• Provide tools for managers to interpret survey and monitoring results.
• Provide predictive models that allow assessment of site-specific management alternatives.
• Develop management decision aids that include science-based models and local knowledge.
Survey, Inventory and Monitoring
Setting Goals and Objectives

Land use goals → Land management goals → Management objectives
Developing a Management Plan - Survey

Land use goals → Land management goals → Management objectives
Invasive Species Prioritization Framework

Management Goals

NNP Survey/Inventory

Create Probability of Occurrence or “RISK” Maps

Monitor, Evaluate and Prioritize
Roads and Vehicles Spread Plant Seeds

- 1-2 seeds/mile/vehicle even under dry conditions
- 14 X more under wet conditions
- 10-300 x more on trail and off road
Roads are a conduit and source of seeds: making good start for survey

Seipel et al., (2011)
Northern Range Study Area
152,785 ha

Elevation
2000 to 3500 m

Non-native Plant Species Survey
152,785 ha study area
590 ha sampled
0.39% area surveyed

- Stratified-random sampling
- 2000 m x 10 m continuous transects
- Presence/absence of NNP, vegetation types, environmental & disturbance variables
Sample environmental variables at presence/absence points for Logistic Regression
Predict Probability of NNP Occurrence (PO)

- Logistic Regression Model = Logistic Resource Use Probability Function

\[ P(y = 1 \mid x_j) = \frac{\exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_i x_j)}{1 + \exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_i x_j)} \]

Determined best model using AIC

Map Environmental Suitability by Species = Probability of Occurrence
Probability of Occurrence / Environmental Suitability Maps

http://ippf.msu.montana.edu
Study sites: different gradients

Idaho National Labs

Yellowstone National Park

Shallow environmental gradients

Steep environmental gradients

Modeled with logistic regression

Study performed by Tyler Brummer, Masters student
Results: how much to sample

Effect of Site

Only need to sample 0.13% of area of interest for maximum predictive performance of model

Brummer et al., 2012, Diversity & Distributions
Application of common predictive habitat techniques for post-border weed risk management

Neville D. Crossman\textsuperscript{1,2,*} and David A. Bass\textsuperscript{1}

This may not have been due to elevated levels of anthropogenic disturbance. If such limitations are in place, then outputs from Bayesian models are likely to underestimate true probabilities of \textit{O. europaea} presence. The process of calculating conditional probabilities via the ISO cluster algorithm provided useful information towards defining habitats conducive to \textit{O. europaea}. For example, clusters of greater probability of \textit{O. europaea} presences are characterized by relatively steep, mountainous terrain at high elevations, with lower temperatures and more precipitation. Soils tend to be more acidic and less fertile, and salinity is not recognized as a problem. Outputs from the ISO data cluster algorithm generally agree with variables identified in regression analyses except in the relationship with elevation. Identifying these relationships is an important component of risk management.

Performance of the classification and regression tree models was, on average, disappointing relative to other model outputs. Despite their relatively poor performance, data preparation and model construction were fast and uncomplicated, and outputs were easily interpreted for quantitative descriptions of \textit{O. europaea} habitat predictors. The tree outputs point to temperature and elevation as influencing factors in both study areas. The highest elevations were predicted to contain low \textit{O. europaea} weed risk management, depending on available resources. If resources are scarce and the distribution of the invasive plant of interest is poorly mapped, then in a relatively short period of time several hundred weed presence/absence records could be collected across a region, such as a catchment, to be then used to train and test a simple logistic regression surface of predicted probability of suitable habitat based on a set of independent variables. The extent of the independent variables, and hence prediction, would be limited to the region of interest and would only be applied to weeds already present. The regression output would be used to calculate the weed's potential distribution, a core component of the post-border weed risk management process (AS/NZS HB 294:2006 Standards Australia/Standards New Zealand, 2006). Alternatively, if not constrained by resources, there should be significant investment into presence/absence data collection and habitat prediction modelling. The full suite of parametric and nonparametric statistical models presented here could be trained and tested, and an ensemble forecast be made, with the latter used to calculate the weed's potential distribution. The process would be repeated for many of the serious weeds to allow a regional agency charged with managing natural resources to prioritize resources for weed management.
Invasive Plant Prioritization Framework

What is this website about? It shares information and tools to help others use the Invasive Plant Prioritization Framework (IPPF). Here you will find a detailed description of what IPPF is, as well as survey techniques and tips. Secondly, we provide technical tools to analyze inventory and monitoring data (mapping and analysis tools). You can use the online analysis tool to create PO maps or download tools to create PO maps on your computer using R and ArcGIS.

Why do I need to know about IPPF? Land managers rarely have sufficient resources to target every non-indigenous plant species. Therefore, prioritization of NIS populations is a crucial component of the management process. Conceptually, effective management of NIS can be regarded as having four phases including: determining the land management goals, inventory/survey, monitoring, evaluation and prioritization.

Why the emphasis on survey techniques? A survey determines which species are present and their distribution on the landscape. These data can be used to develop probability of occurrence maps (PO), which help in the prioritized selection of populations for invasiveness and impact monitoring. Much of this website is dedicated to providing information on inventory and survey methods, including creation of PO maps.

What is a PO map and why do I need one? To manage nonindigenous species, we need to know where they are located on the landscape. But management areas are large, making them unfeasible to survey completely. Surveys can be performed on smaller areas, from which maps can be generated that predict the probability of occurrence across landscapes. The probability maps can be used to direct further sampling for new populations and to select populations to monitor for invasiveness and management efforts.

Want to know more about IPPF and management of non-indigenous plant species? We have compiled presentations and information on the four step process.
What you receive back:
Invasive Species Prioritization Framework

Management Goals

NIS Survey/Inventory

Create Probability of Occurrence or “RISK” Maps

Monitor, Evaluate and Prioritize
Framework For Adaptive NNP Management

1. Create Environmental Suitability Maps from presence/absence survey
2. Initial NNP population prioritization based on Environmental Suitability
3. Deploy at least 2 management alternatives
4. Monitor selected NNP populations and non-target species for response to management and impact on land management goals
5. Employ structured decision making

**Monitoring**: Populations grow differently across environmental suitability gradient & respond differently to management

Cheatgrass (*Bromus tectorum*)
Monitoring results: invasiveness increases along the gradient

Spotted knapweed (Centaurea stoebe)

Other species tested that have the same response:
- Cirsium arvense
- Linaria dalmatica
- Linaria vulgaris
- Tanacetum vulgare
- Senecio jacobaea
- Bromus tectorum

$p = 0.00087$
**Monitoring results:** impact is less where there are more target species

Bridges, M., B. Maxwell and L. Rew. IPSM. *In review*
Framework For Adaptive NNP Management

Create Environmental Suitability Maps from presence/absence survey

Initial NNP population prioritization based on Environmental Suitability

Repeat transects to obtain metapopulation colonization and extinction rates

Employ structured decision making

Create invasion model and assess management scenarios

Deploy at least 2 management alternatives

Monitor selected NNP populations and non-target species for response to management and impact on land management goals

Predicting Future Invasion of a Species
Predicting further invasion

\[ C_i = f(BP - d - dr + PO) \]

\[ E_i = f(BP + dr - PO) \]

<table>
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<th>2003</th>
<th>2007</th>
<th>2007 Absent</th>
<th>2007 Present</th>
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Absent Present

Road
Using Transition Probabilities To Simulate An Invasion

\[ \lambda M = 1.11 \]
Linaria dalmatica introduced ~1946

1968

1970
Simulation With No Management

\[ \lambda_M = 1.14 \]

10m x 10m grid
Manage 2000 invaded 10m x 10m cells

Simulate management along roads

$\lambda_M = 1.12$
Manage 2000 invaded 10m x 10m cells

Simulate management invasion edge

$\lambda_M = 1.03$
Simulate 1968 - 1988

Metapopulation growth rate ($\lambda_M$)

- No management
- Manage along road
- Manage on high PO along road
- Manage anywhere
- Manage on high PO anywhere
- Manage invasion edge
- Manage high PO on edge
Framework For Adaptive NNP Management

Create Environmental Suitability Maps from presence/absence survey

Initial NIS population prioritization based on Environmental Suitability

Repeat transects to obtain metapopulation colonization and extinction rates

Create invasion model and assess management scenarios

Employ structured decision making

Deploy at least 2 management alternatives

Monitor selected NNP populations and non-target species for response to management and impact on land management goals

Structured Decision Optimization

Meta-population Model predicted Probability of outcome

Management Actions

Herbicide

Increase or Persistence

Decline or Extinction

No Action

Increase or Persistence

Decline or Extinction

Minimum Score = best

20 x 0.5 + 90 x 0.5 - 80 x 0.5 + 10 x 0.5 = 10

NPP Species considered for management

100 x 0.95 + 90 x 0.5 - 0 x 0.05 + 10 x 0.5 = 120

Objectives

Monitoring Pops for growth and impact on management objectives

Value

(Managers perception)

(Statistical results)

Significant pos. impact on mgmt objectives

No pos. impact on mgmt objectives

Significant pos. impact on mgmt objectives

No pos. impact on mgmt objectives

100 x 0.5 = 50

100 x 0.95 + 90 x 0.5 - 0 x 0.05 + 10 x 0.5 = 120
Decision Tree Optimization

NIS Species is discovered

Informed management score 2.23

2.20

2.85

3.84

0.01

Spray along road

Mean probabilities for map

0.26 Increasing
0.38 Decreasing

Spray along road in high PO

0.26 Increasing
0.39 Decreasing

Spray anywhere

0.21 Increasing
0.40 Decreasing

Spray invasion edge

0.10 Increasing
0.24 Decreasing

No Action

0.24 Increasing
0.34 Decreasing

Managers perception

40

60

40

60

40

60

40

60

40

60

99

1
**Summary:** Survey and Monitoring

- Estimate distribution and environmental suitability
- Serve as first management prioritization
- Identify populations for monitoring
- Be repeated to model metapopulation dynamics and estimate invasion rates, and assess management alternatives
- Provides background information for structured decision making.
Implementation of environmental suitability mapping and monitoring in the Crown of the Continent
Overview:

- **Ecology and management of invasive species: what are we trying to do?**
  Dean Pearson

- **Non-native plant (NNP) distribution and priorities in the Crown of the Continent (CoC)**

- **Potential effects of climate change on NNP’s in CoC**

- **Vulnerability Assessment: (Sohlgren and Schnase 2006)**
  - Problem formation and assessment endpoints
  - Analysis (species traits, habitat suitability, potential to invade)
  - Risk characterization (estimate distribution, rate of spread, extent of potential distribution, impact and cost)
  - Risk management (containment, costs, legal mandates)

- **Develop a common set of NNP control objectives. What does success look like?**

- **Management strategies, tools and tactics from a regional perspective.**

SRES 6 B1: a moderate climate change scenario with 550 parts per million (ppm) carbon dioxide (CO2) concentration stabilization @ 2100.

SRES A1FI: aggressive fossil fuel use in the next century with CO2 emissions stabilizing @ 2080 but with concentrations exceeding 1000 ppm in 2100.
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Risk Analysis for Biological Hazards: What We Need to Know about Invasive Species

Thomas J. Stohlgren and John L. Schnase

Risk analysis for biological invasions is similar to other types of natural and human hazards. For example, risk analysis for chemical spills requires the evaluation of basic information on where a spill occurs; exposure level and toxicity of the chemical agent; knowledge of the physical processes involved in its rate and direction of spread; and potential impacts to the environment, economy, and human health relative to containment costs. Unlike typical chemical spills, biological invasions can have long lag times from introduction and establishment to successful invasion, they reproduce, and they can spread rapidly by physical and biological processes. We use a risk analysis framework to suggest a general strategy for risk analysis for invasive species and invaded habitats. It requires: (1) problem formation (scoping the problem, defining assessment endpoints); (2) analysis (information on species traits, matching species traits to suitable habitats, estimating exposure, surveys of current distribution and abundance); (3) risk characterization (understanding of data completeness, estimates of the “potential” distribution and abundance: estimates of the potential rate of spread; and probable risks, impacts, and costs); and (4) risk management (containment potential, costs, and opportunity costs; legal mandates and social considerations and information science and technology needs).

KEY WORDS: Nonnative species; potential species distributions; risk assessment; risk management