Using Multiple Lines of Evidence to Prioritize Assisted Migration of Both Rare and Common Species

Pati Vitt and Shannon Still
Chicago Botanic Garden
Assisted Migration: Generally thought of in the context of climate change

Native Species  People
Assisted Migration: Generally thought of in the context of climate change

Native Species

- In Situ Adaptation

People
Assisted Migration: Generally thought of in the context of climate change

Native Species  People

• In Situ Adaptation
• Local Extirpation
Assisted Migration: Generally thought of in the context of climate change

Native Species
• In Situ Adaptation
• Local Extirpation
• Natural Migration
• Extinction

People
• In Situ Conservation
• Ex situ Conservation
• Assisted Migration
• Acceptance
Stochastic long-distance dispersal  Liske, 1999
Species Distribution Modeling

- Essentially model the realized niche of a species
- Use locality data and environmental layers (including climate variables)
- Several studies, including my own, my graduate students and PostDoc Shannon Still, have shown that MaxEnt outperforms many other modeling approaches... and..
- It’s FREE!
Flow diagram detailing the main steps required for building and validating a correlative species distribution model: PART 1

1. Map the known species' distribution (localities where the species has been observed, and sometimes also localities where the species is known to be absent)

2. Apply modeling algorithm (e.g. Maxent, artificial neural network, general linear model, boosted regression tree)

3. Model calibration (select suitable parameters, test importance of alternative predictor variables)

4. Process environmental layers to generate predictor variables that are important in defining species' distributions (e.g. maximum daily temperature, frost days, soil water balance)

5. Collate GIS database of environmental layers (e.g. temperature, precipitation, soil type)

Slides borrowed liberally from Richard G. Pearson’s course on SDM’s [Link](http://biodiversityinformatics.amnh.org/index.php?section=sdm)
Flow diagram detailing the main steps required for building and validating a correlative species distribution model: PART 2

- Test predictive performance through additional fieldwork or data-splitting approach (statistical assessment using test such as AUC or Kappa)
- Create map of current distribution
- If possible, test prediction against observed data, such as occurrence records in an invaded region, or distribution shifts over recent decades
- Predict species’ distribution in a different region (e.g. for an invasive species) or for a different time period (e.g. under future climate change)
Diagram illustrating the relationship between species’ position in geographical space and environmental space.

- **Geographical space**
  - Regions: A, B, C

- **Environmental space**
  - Regions: E, D

Legend:
- **+**: Observed species occurrence record
- **grey**: Actual distribution (left panel)/Occupied niche (right panel)
- **white**: Potential distribution (left panel)/Fundamental niche (right panel)
Illustration of the general species’ distribution modeling approach

- Geographic space
- Environmental space
- Observed species occurrence record
- Actual distribution (upper panels)/Occupied niche (lower panel)
- Potential distribution (upper panels)/Fundamental niche (lower panel)
- Species distribution model fitted to observed occurrence records
Examining current range of species models and ground-truthing

Examining future range of species models for 3 time periods in the future 2020s, 2050s, 2080s, low and high emissions range changes on public lands

Examining methods to improve modeling for current and future
Define current suitability range

- Model
  - Complete current suitability models
- Test
  - ground-truth to test the model
- Model again
  - incorporate new occurrences and absences
- Test new model
  - ground-truth to test the model
- Model again
WHY GROUND-TRUTHING IS NEEDED

- Rare plants are often under-surveyed
- Rare plants can be difficult to find
- We want more occurrences
  - positive and negative occurrences
FINDING PLANTS CAN BE DIFFICULT

do you see the cactus?
FINDING PLANTS CAN BE DIFFICULT

do you see the cactus?
FINDING PLANTS CAN BE DIFFICULT

do you see the cactus?
Finding plants can be difficult.

do you see the cactus?

Pediocactus despainii
Predicted suitable habitat in April (before groundtruthing)
Predicted suitable habitat in September (after groundtruthing)
Incorporating new occurrence information.
Predicted suitable habitat in April (before groundtruthing)
Predicted suitable habitat in September (after groundtruthing)
Incorporating new occurrence information.
# Field Results: Pediocactus Sileri

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HOW ASSESS VULNERABILITY:
OVERALL LOSS OF SUITABLE HABITAT

• Threshold suitable habitat
• Use testing data to evaluate the modeled distribution and then set a likelihood value above which plants are likely to be found
Variables used:
- bio 1 (ann. mean T)
- bio 8 (mean T wettest qtr)
- bio 9 (mean T driest qtr)
- bio 18 (precip warmest qtr)
- bio 19 (precip coldest qtr)
- soil (pH and clay content)
- elevation SD

Projected change in suitable habitat for *Pediocactus sileri* between now and 2050s.
ASSESS VULNERABILITY: CHANGE IN CENTER OF DISTRIBUTION

current

Pediocactus sileri

2080s
• Compare suitability between current and future climates for currently known locations
  - for each location, is suitability getting better or worse
• mean of suitability of current and future distributions for each species.
• Compare suitability between current and future climates for currently known locations
  – for each location, is suitability getting better or worse
• Mean of suitability of current and future distributions for each species.
A: Movement to increase potential adaptation to climate change. When resulting in purposeful introgression = “Facilitated Adaption” or augmentation

B: Natural dispersal that has been disrupted by loss of habitat connectivity restored through assisted migration.

C: Translocation outside of historic range
Assisted Migration: What is it?

Translocating species beyond their historic boundaries

Translocating species within and without historic boundaries (*introduction*)

Translocating species to a previously occupied site (*reintroduction*)

Introduction of individuals into an existing population (*augmentation*)

Translocating groups of species into any site (*restoration*)
Assisted Migration

It’s already being done

• Experimental

• Anecdotal – Torreya Guardians

• Active Management – Canadian Forest Service (Black Walnut), Restoration

The best criterion for success has to be naturally reproducing (viable) populations
**Placing Forestry in the Assisted Migration Debate**

<table>
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<tr>
<th>Topic</th>
<th>Forestry AM</th>
<th>Species rescue AM</th>
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<tbody>
<tr>
<td>Intended outcome</td>
<td>Maintain forest productivity and health under climate change</td>
<td>Avoid extinctions among species threatened by climate change</td>
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<tr>
<td>Target species</td>
<td>Widespread, commercially valuable species</td>
<td>Species of conservation concern</td>
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<tr>
<td>Focal biological unit</td>
<td>Focuses on the movement of populations</td>
<td>Focuses on the movement of species</td>
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<td>Movement logistics</td>
<td>Often within the current range of the species or within modest range extensions</td>
<td>Often well outside the current natural range of species</td>
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<td>Risks</td>
<td>Limited potential for creating an exotic invasive, limited potential to hybridize with new species, and limited potential to introduce disease to new populations or to other species</td>
<td>Some potential for creating an exotic invasive, some potential to hybridize with new species, and some potential to introduce disease to other species</td>
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<td>Feasibility of science-based</td>
<td>Provenance data for many commercial tree species, established seed</td>
<td>Provenance data not typically available, seeds not typically procured or stored, establishment best practices often not known, and autecology well described for relatively few high-profile and well-studied species</td>
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<tr>
<td>implementation</td>
<td>procurement and storage methods, established best practices around plantation establishment, and autecology often well described</td>
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<td>Scope</td>
<td>Potential to be employed across the millions of hectares that are</td>
<td>Likely limited to suitable microsites</td>
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<td>regenerated annually in North America</td>
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<tr>
<td>Cost</td>
<td>Adds little to existing forest regeneration costs (see the text for</td>
<td>Costs vary widely with the scope of the initiative</td>
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<tr>
<td></td>
<td>caveats)</td>
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<tr>
<td>Practice</td>
<td>Already implemented in several regions</td>
<td>Very few known cases being implemented</td>
</tr>
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</table>

Pedlar et al 2012 Bioscience 835-842
**Torreya taxifolia** quick facts.

- Dioecious conifer that suffered a disease epidemic that wiped out the adult population in the 1960s.
- Federally listed as *endangered* under the Endangered Species Act.
- There are fewer than 1000 individuals in the wild, all juveniles, and the population is experiencing a slow but steady decline.
- Captive populations of over 150 genotypes exist in more than three botanic gardens in the southeastern United States.
- Several *ex situ* trees produce seed.
- Torreya Guardians released 31 plants from legally obtained material in North Carolina in July of 2008.

**Managed relocation release site**

**Post-Pleistocene historic range**

Schwartz et al Bioscience 2012
(Re) Introduction

Plant Reintroduction in a Changing Climate
Center for Plant Conservation

145 projects – various taxa and lifeforms, approximately 90% had survivorship of original propagules or their offspring
Assisted Migration: What is it?

Translocating species beyond their historic boundaries

Translocating species within and without historic boundaries (introduction)

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Introduction of individuals into an existing population (augmentation)

Translocating groups of species into any site (restoration)
(Re) Introduction: unregulated

Reintroductions are a management option when no others are available

32 countries; earliest record in 1955, but possibly as early as 1783

“...the unregulated use of seed and plant translocations has confused the debate and provided evidence that reintroductions for conservation of threatened plants are prone to failure and a waste of resources.” Dalrymple et al 2012
(Re) Introduction

None are a total success – meaning that they resulted in viable populations without need for ongoing intervention and monitoring.

Monitoring needs to be long term, as it took more than a decade for biological failure of the annual *Stephanomeria malheurensis* to be apparent.

Most reintroductions in the scientific literature have not been monitored long enough to assess their success.
(Re)Introduction – Research Needs

1. Strategies for determining donor and recipient sites

2. Reproductive biology of the species (including pollinators and seed dispersers)

3. Genetic divergence of wild versus ex situ populations, studies of inbreeding and potential for outbreeding depression if mixing sources from 2 or more donor sites
(Re)Introduction- Recommendations

1. Founder sizes greater than 50

2. Use transplants rather than seed for perennials/woodies

3. For annuals introduced by seed, watering is crucial

4. Recruitment limitation a challenge – management

5. Genetic composition, horticultural treatment, competitive and disturbance regimes matter greatly

6. Seed sourcing and habitat matching is critical, and not yet well understood
Cirsium pitcheri – seed source model for Southern Lake Michigan Populations/Sites
Cirsium pitcheri – seed source model for Southern Lake Michigan Populations/Sites
Andropogon gerardii Ecoregion 47 Seed Source Model
Andropogon gerardii Ecoregion 47 Seed Source Model
Conclusions

• Reintroduction literature has some lessons for AM, as does the larger restoration literature

• Seed sourcing is key, the problem is long-term – we should be seed banking

• We compared our results with NatureServe, comparable. We know what’s in trouble, we need to find the will to triage

• AM may be best undertaken in a restoration or overall management context, else as an experiment

• Resulting outcomes need to be shared – database such as CPC
Concerned by the decline in the birth rate in Australia, the Lyons Ministry plans the resumption of assisted migration of British stock, and an increase in the scope of the maternity allowance.
For more information, please visit the US Forest Service Reforestation, Nurseries & Genetics Resources website at http://rngr.net