The Biology and Ecology of Invasive Plants

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What is an invasive species?

Synonyms:
- exotic
- non-indigenous
- non-native

(1) **non-native** to the ecosystem under consideration

AND

(2) whose **introduction** causes or is likely to cause economic or environmental harm or harm to human health

(Federal Executive Order 13112, signed by Pres. Clinton 1999)
Why are there so many introduced species?

Increased global travel and trade → Intentional or accidental dispersal of species → Declines in biodiversity and changes in ecosystem functions

US and international flights

Shipping cargo internationally
Biological invasions as agents of global change

Potential effects:
• Declines in biodiversity, habitat quality, and system productivity
• Altered succession patterns
• Changes in ecosystem functions
• Pathogen epidemics/outbreaks

* Invasions provide unique opportunities for ecological and evolutionary research
The stages of biological invasions

Lockwood et al, 2007

Transport (dispersal)

Death or captivity

Introduction

Fail

Establish

Spread

Remain local

Spread

Impact

Impact

Human perception

Low

High

Community effects

Ecosystem functions
Plant invasion dynamics

Arrival → Establishment → Spread → Widespread/dominant

Widespread/dominant → Negative impacts on native community → Management/eradication → Recovery of native community
Invasive species as ‘drivers’ vs. ‘passengers’

- Native community
  - high diversity
  - high abundance of native species
  - altered ecosystem processes

- Invaded community
  - lower diversity
  - lower abundance of native species
  - altered ecosystem processes
Methods to evaluate the community and ecosystem consequences of plant invasions

1. Comparative – invaded and invader-free areas
   Advantage: Quick and easy, broad patterns
   Disadvantage: Cause and effect may be hard to disentangle

2. Removal experiments
   Advantage: Method may alter results, some effects cannot be removed
   Disadvantage: Native species may respond to removal

3. Experimental invasions
   Advantage: Provide controlled, realistic situation
   Disadvantage: Ethical concerns
Patterns in the use of research methods to evaluate impacts of plant invasions

- Literature search 1990 – 2010
- 207 published studies
Impacts of plant invasions

1. **Community effects**
   a. Biodiversity
   b. Productivity
   c. Composition
   d. Habitat quality
   e. Succession patterns

2. **Ecosystem effects**
   a. Nutrient (C, N, P) cycling
   b. Hydrology, water availability
   c. Erosion patterns
   d. Fire regimes
Cape ivy invasion, California

Cape ivy removal experiment

Alvarez and Cushman, 2002
**Microstegium vimineum**
(stiltgrass)

**Characteristics**
- Shade tolerant annual grass
- May fill “empty niche”
- Native to eastern Asia
- Few herbivores/pathogens
Design: Invasion experiment

All plots
9 tree sp
12 herb sp

tree saplings

Microstegium

x 8 replicates

tree seeds

Microstegium

Microstegium

Microstegium

Microstegium
Planting, fall 2005

Fall 2009

Control

Invaded

IU Research and Teaching Preserve
Bayles Road
Results: *Microstegium* reduces native plant productivity and diversity

Flory, S.L and K. Clay *Biological Invasions*, 2010
Life history stage (seeds vs saplings)

Prediction: stronger effects on seeds than saplings

*No effect on the survival or growth of tree saplings
**Microstegium** inhibits small-seeded tree regeneration

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**Small-seeded species**

- Sweetgum
- Tulip poplar
- Green ash

**Large-seeded species**

- Hickory
- Pin oak
- Black walnut
- White oak
- Bur oak

↓ survival of small-seeded species

- No effect on large-seeded species
- Additional research needed on oak spp.
Microstegium reduces natural tree regeneration

>400% greater natural tree regeneration in control plots
Results: *Microstegium* reduces arthropod abundance and diversity

Simao, C., Flory, S.L and J. Rudgers, *Oikos*, 2010

Civitello, D., S.L. Flory and K. Clay
*Journal of Medical Entomology*, 2008
Impacts of plant invasions

1. **Community effects**
   a. Biodiversity
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2. **Ecosystem effects**
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   c. Erosion patterns
   d. Fire regimes
Reed canary grass invasion
Example: *Myrica* (shrub) invasion in Hawaii

*Myrica* has N-fixing bacteria in roots

In low nitrogen (volcanic) areas with no native nitrogen-fixing plants, *Myrica* dramatically alters the N-cycle
1. *Microstegium* Invades

2. Dense, continuous litter layer

3. Increased fire severity and extent

4. Damage to native community

**Hypothesized Microstegium – Fire Cycle**

*Prescribed fire in Microstegium-invaded area*
Research plan: Fire and *Microstegium* invasions

1. Prescribed fires

2. Experimental fires
Research plan: fire intensity, effects

Prescribed fires

a. Fire intensity
b. Tree/plant community responses
Research plan: fire intensity, effects

Methods:

a. Paired plots (10x25m) invaded/uninvaded
b. Vegetation before and after
c. Experimentally planted trees
d. Temperature, flame height, area burned

Thermocouple data loggers

Experimental trees

Flame height

Video
Results: fire intensity

- **Peak fire temp (°C)**
  - 0
  - 200
  - 400
  - 600
  - 800
- **Over 300 °C (sec)**
  - 0
  - 3
  - 6
  - 9
  - 12
  - 15
  - 18
  - 21
- **Over 100 °C (sec)**
  - 0
  - 10
  - 20
  - 30
  - 40

- **Flame height (cm)**
  - 0
  - 10
  - 20
  - 30
  - 40

- **Control invaded**

The diagrams show a comparison between control and invaded conditions.
Results: tree survival and regeneration

Experimental trees:
White oak (*Quercus alba*)
Bur/black oak (*Quercus macrocarp/velutina*)
Tulip (*Liriodendron tulipifera*)
Maple (*Acer rubrum*)

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<th>Control</th>
<th>Invaded</th>
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Control and Fire treatments:

Invasion x burn P = 0.01
Results: tree survival and regeneration

Most common: sweetgum, poplar, red maple, oak spp., ash spp
Consequences of invasion

- Native plant diversity
- Forest succession
- Arthropod diversity
- Nutrient dynamics
- Decomposition
- Disease vectors
- Carbon storage
- Fire behavior

Microstegium vimineum
Plant invasion dynamics

- Arrival
- Establishment
- Spread
- Widespread/dominant
- Management/eradication
- Recovery of native community
- Negative impacts on native community
Management goals

- **Eradication**: Remove current invasions
- **Containment**: Slow or stop the spread of further invasions
- **Mitigation**: Restore native community diversity and ecosystem functions
- **Prevention**: Avoid future invasions
Adapted from Hobbs and Humphries 1995
4 Treatments

- Reference (control)
- Hand-weeding
- POST herbicide
- POST + PRE herbicide

Grass specific

Post-emergent herbicide plus Pre-emergent herbicide

Post-emergent: fluazifop-P-butyl (Fusilade DX)
Pre-emergent: pendimethalin (Pendulum AquaCap)

Results: Efficiency of removal

**Fall**

- Microstegium biomass (g)
- 2005
- 2006
- No data

**Spring**

- Microstegium cover (%)
- 2006
- 2007

Results: Native community responses

Management: successful removal with hand weeding or post-emergent grass specific herbicide

Restoration: removal results in return of native plants, greater diversity, and increased tree regeneration

Impacts: positive response of native community suggests negative effects of invasion

Take home messages

1. Global travel and trade will continue to result in non-native plant introductions
2. Plant invasions can have significant community and ecosystem consequences
3. Understanding plant invasion dynamics will increase management efficiency and inform priorities
4. Consider goals when managing invasions: Aim to restore native communities and ecosystem functions, not just remove invasions