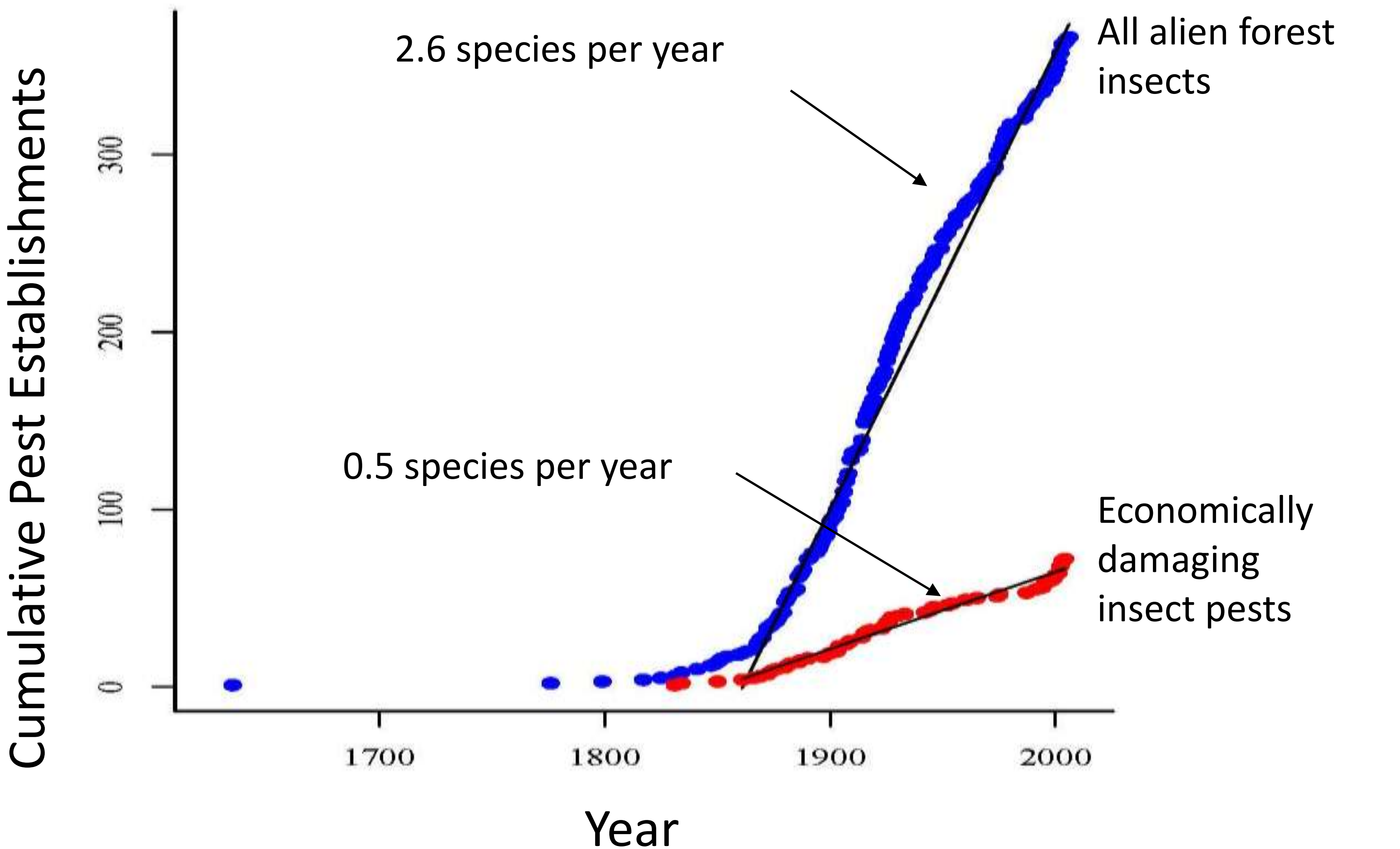
Alien Forest Insect Establishment in US Over Time



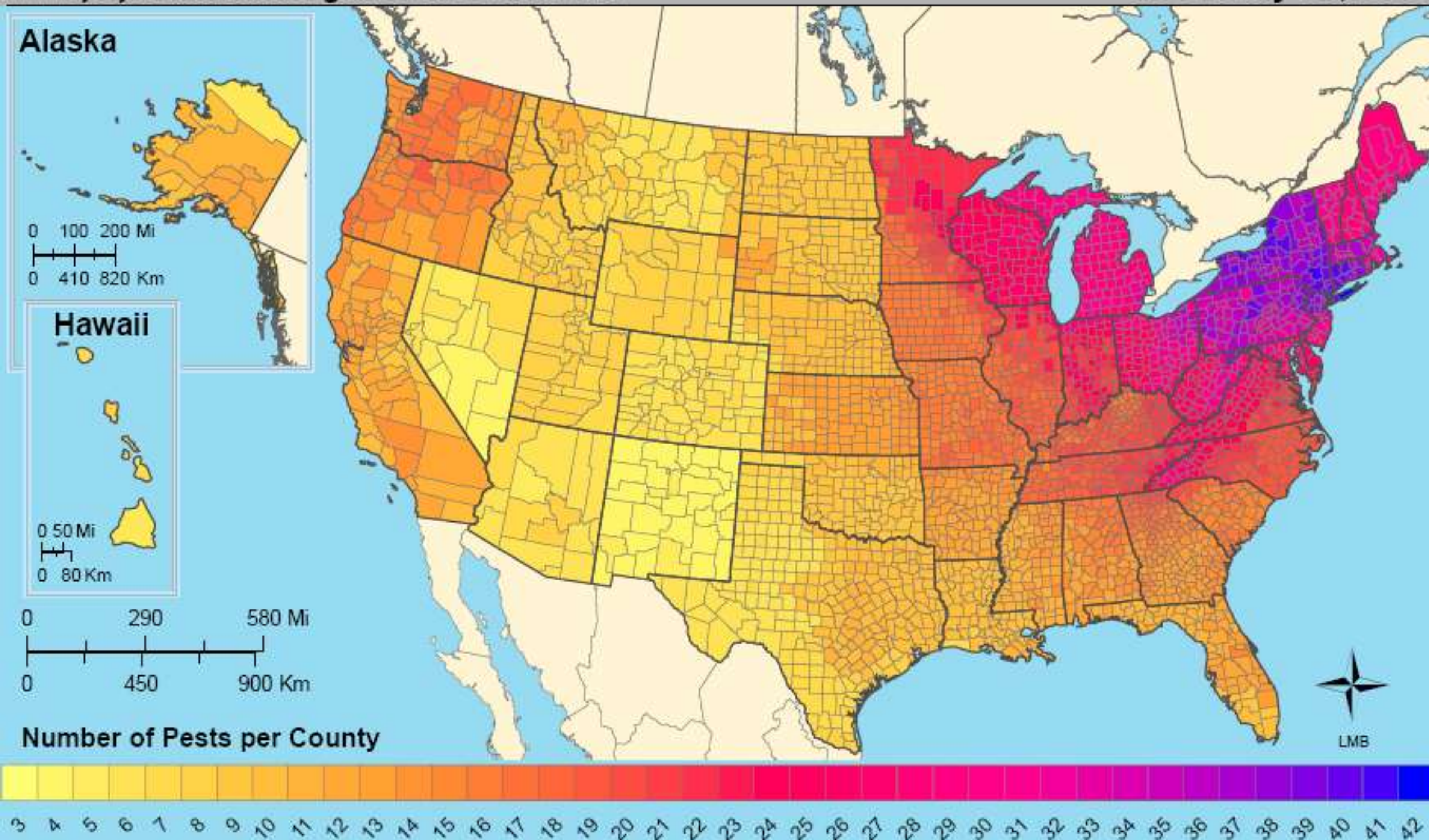
Aukema, J.E., D.G. McCullough, B. Von Holle, A.M. Liebhold, K. Britton and S.J. Frankel. 2010. Histo
Accumulation of Nonindigenous Forest Pests in the Continental US. Bioscience 60: 886-897

Alien Forest Pest Explorer

Species Richness

www.fs.fed.us/ne/morgantown/4557/AFPE/

as of July 28, 2008



USDA Forest Service

Northern Research Station

Forest Health Technology Enterprise Team

Remote Sensing Applications Center

Three Universal Phases of Biological Invasions

Arrival

↓

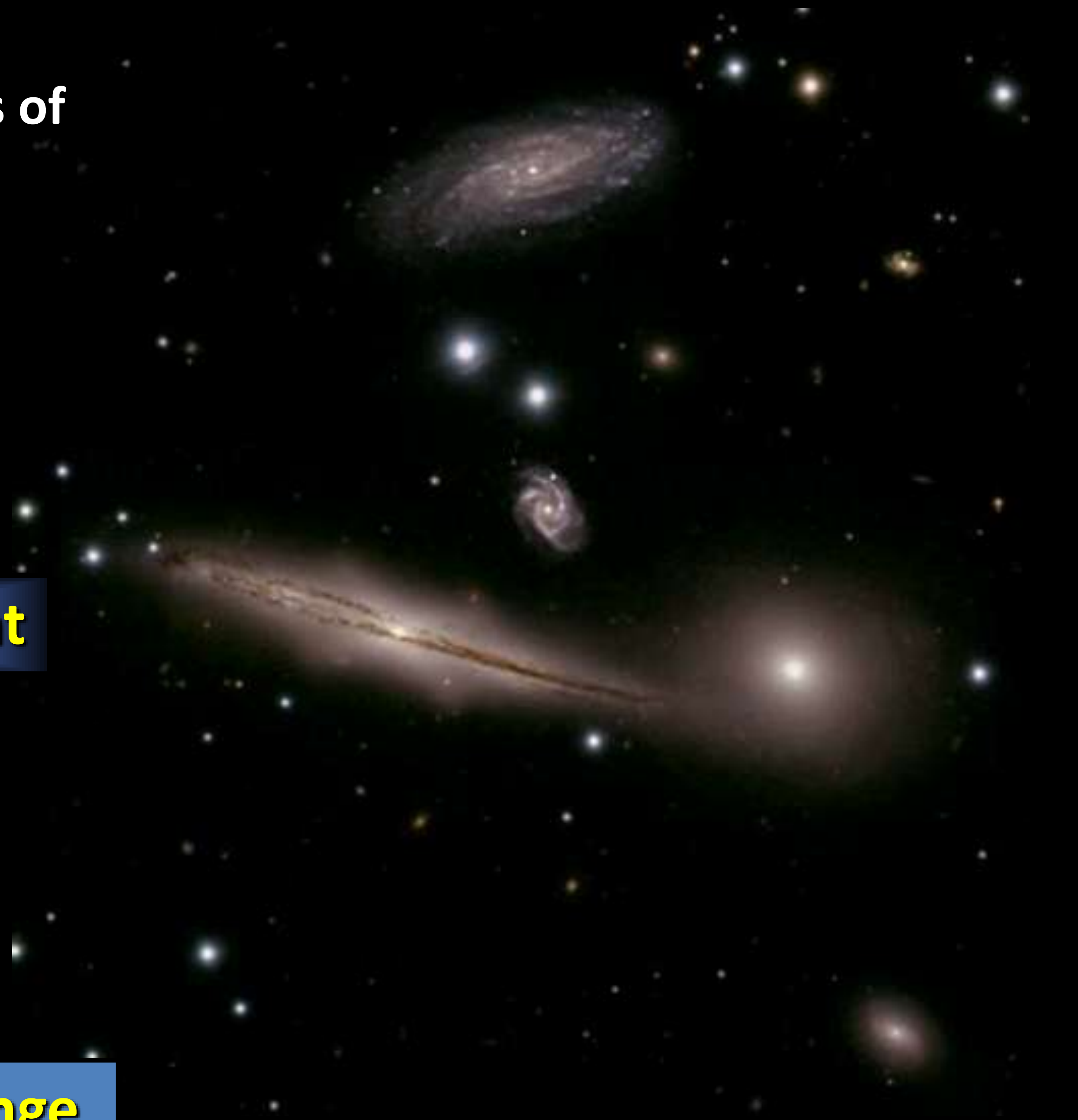
Establishment

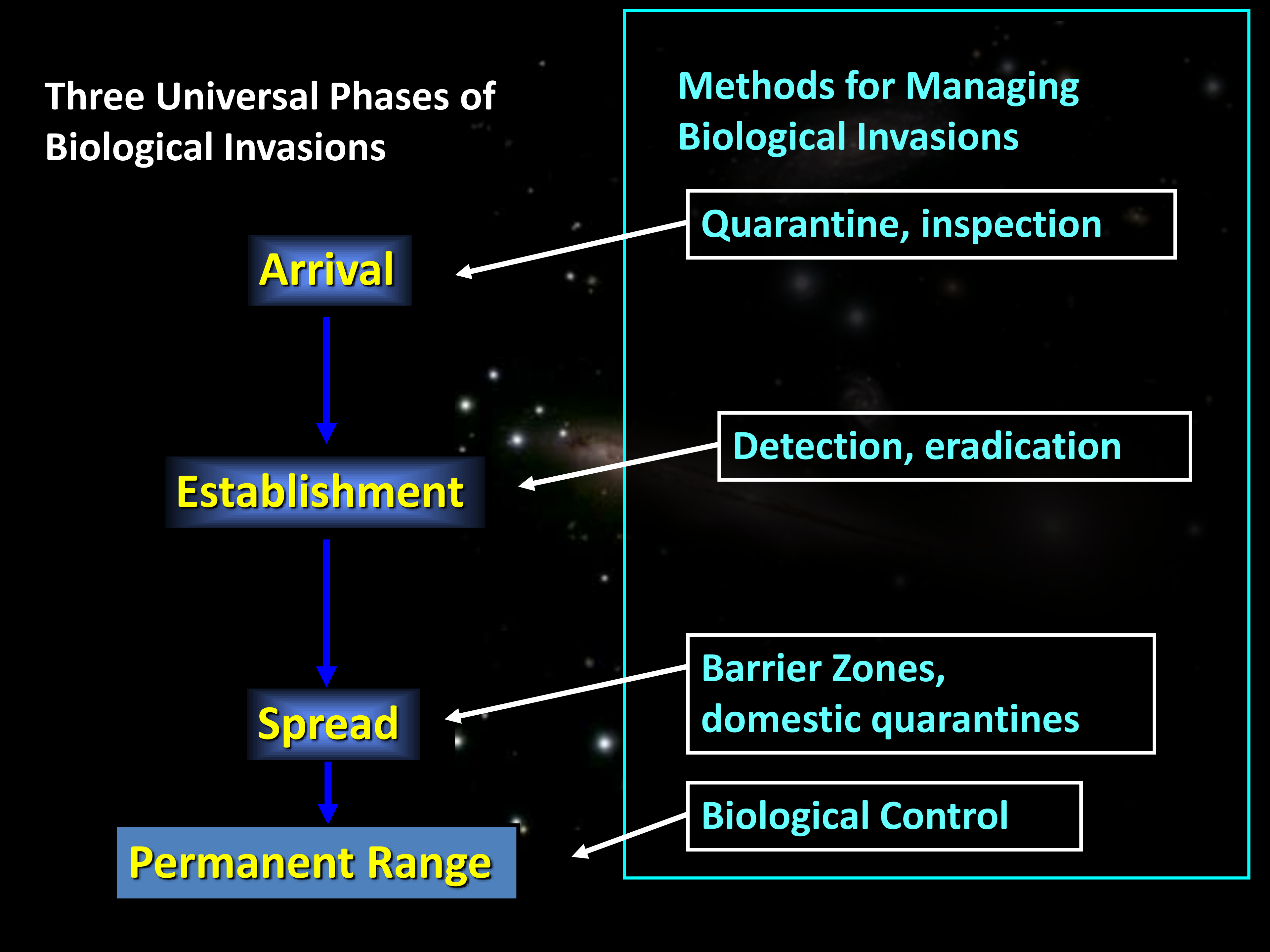
↓

Spread

↓

Permanent Range




Three Universal Phases of Biological Invasions
Arrival
Establishment
Spread
Permanent Range
Methods for Managing Biological Invasions
Quarantine, inspection
Detection, eradication
Barrier Zones, domestic quarantines
Biological Control

Detection and Eradication of Invading Populations to Prevent Establishment

- **Detection (e.g., trapping)**

  <u>Goal</u>: to find newly founded populations

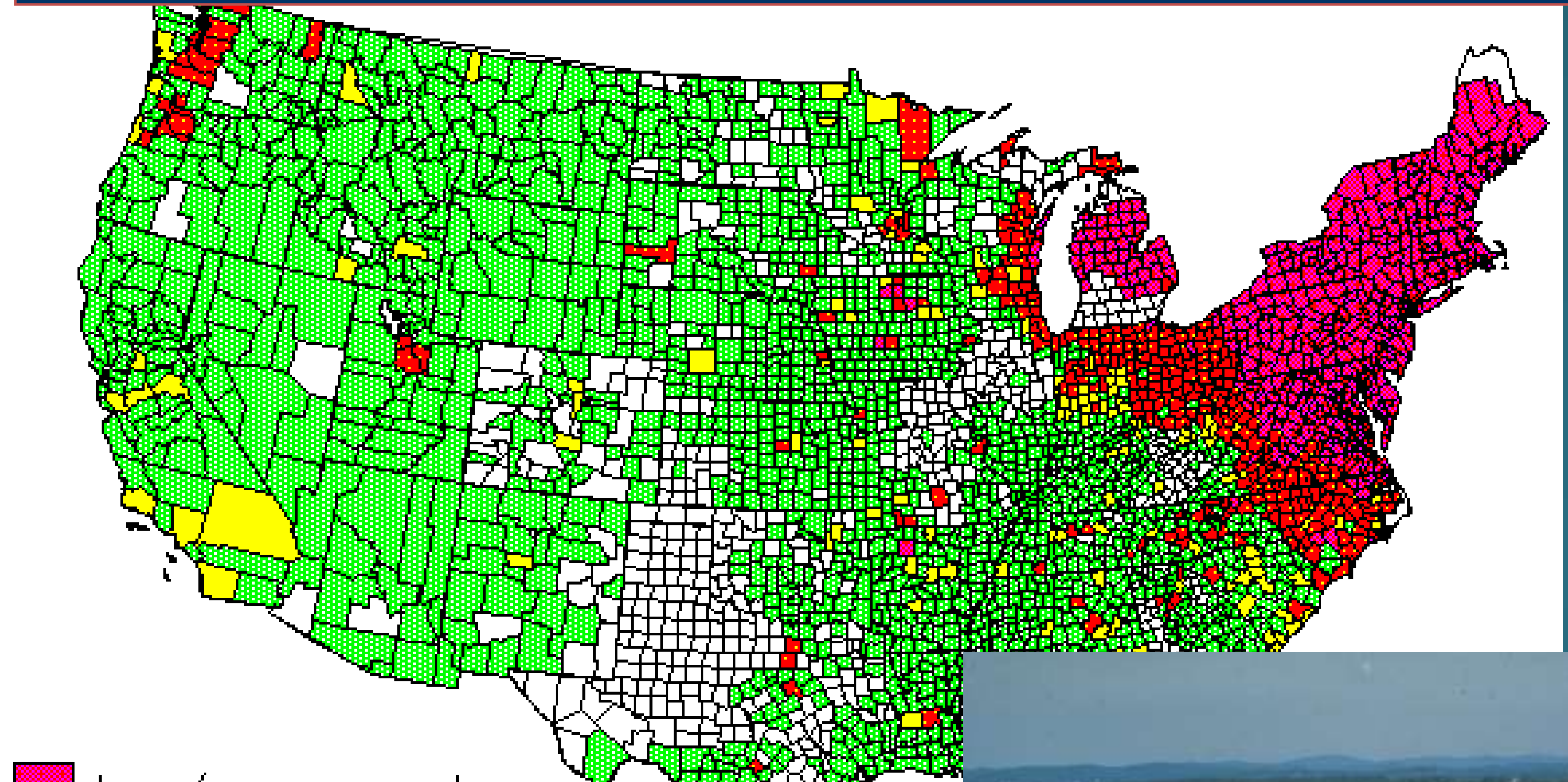
- **Eradication (e.g., spraying)**

  <u>Goal</u>: to force a population into extinction

Eradication:
"The total elimination of a species from a geographical area" *

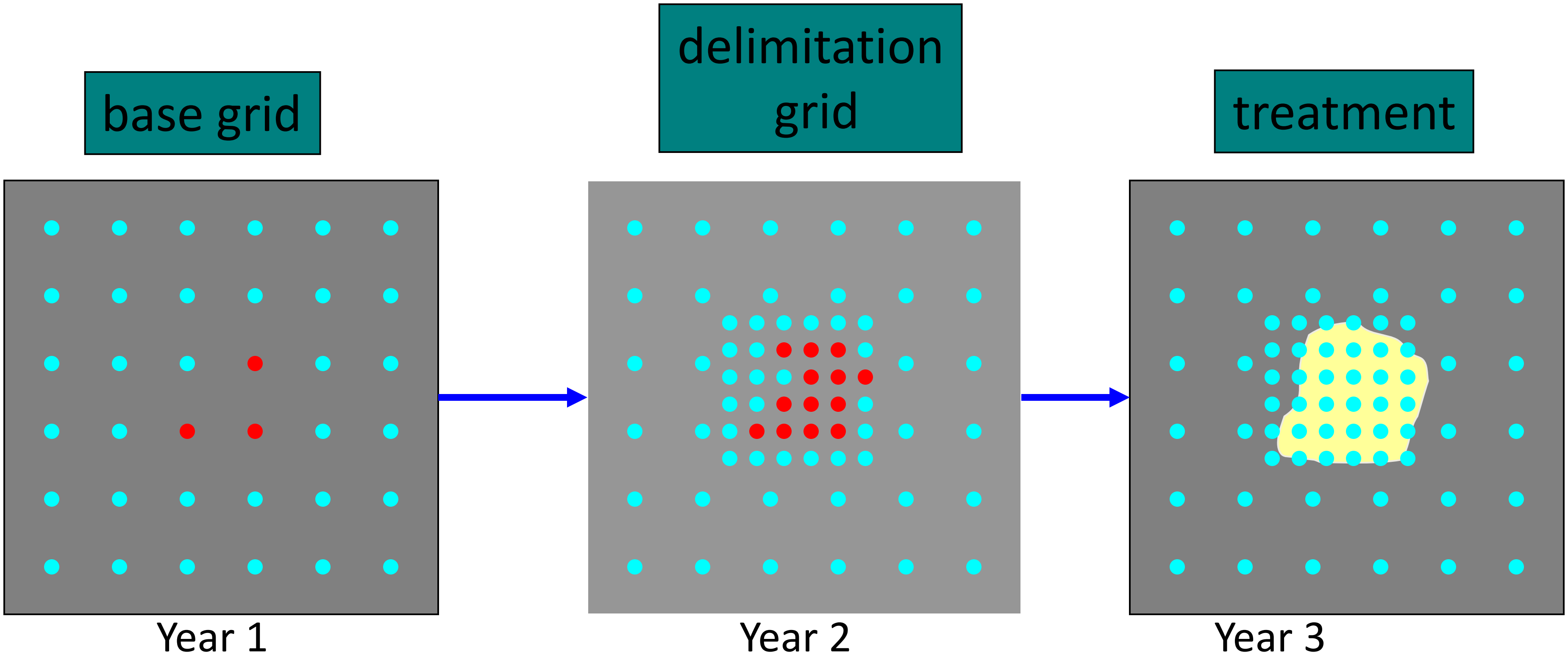
* Liebhold, A.M., P.C. Tobin. 2008. Population Ecology of Insect Invasions and Their Management. Annual Review of Entomology 53:387–408

Gypsy Moth Detection Survey Results, 1993



Eradication via aerial spraying of Bt

Use of pheromone traps to locate and delimit isolated colonies prior to eradication

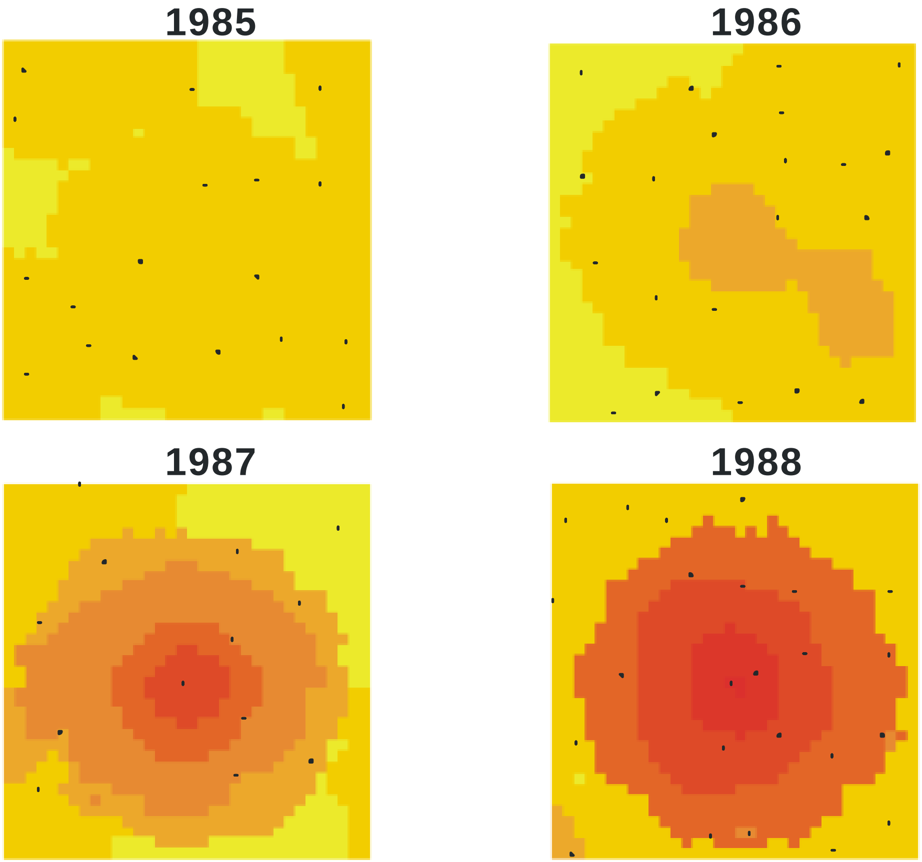


0 moths/trap

>0 moths/trap

treatment

Warren Co., NC, 1985-88 Population

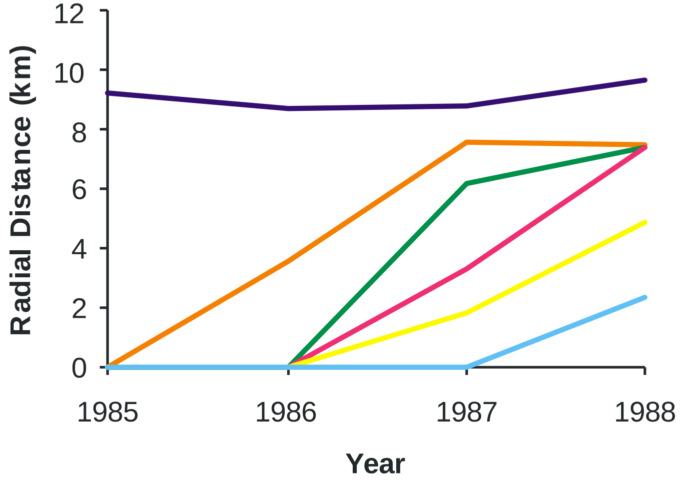


Kilometers
0 5 10 20 30 40

• Trapping Grid

Trap count threshold

- = 0
- > 0
- > 1
- > 3
- > 10
- > 25
- > 100
- > 300



Trap count threshold

- > 0
- > 1
- > 3
- > 10
- > 25
- > 100

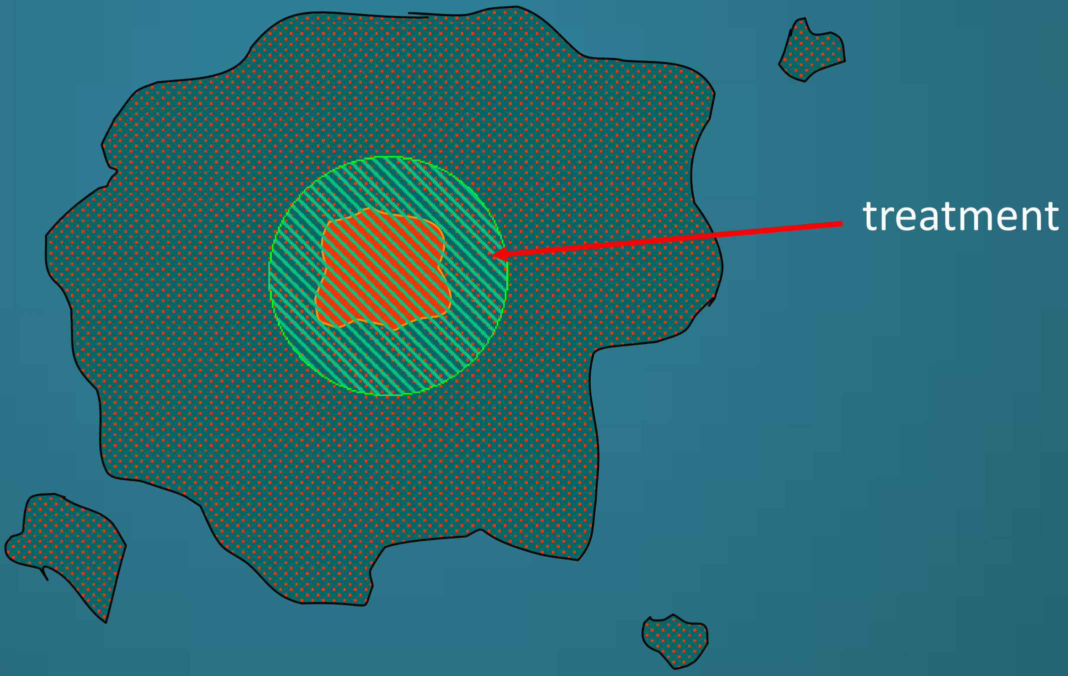
Locator Map

Painted apple moth eradication

- Initial eradication efforts used destruction of plant material and spraying of plant material from the ground

- Ultimately eradicated via a combination of aerial application of *Bacillus thuringiensis, and sterile insect releases*

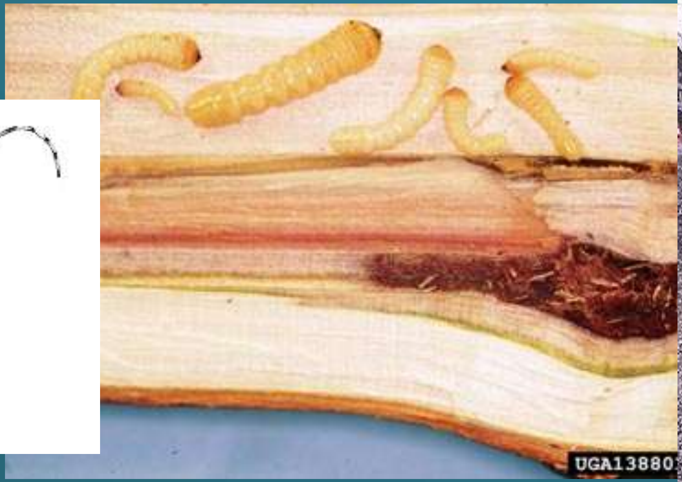
Eradication treatment area when core population can be easily located



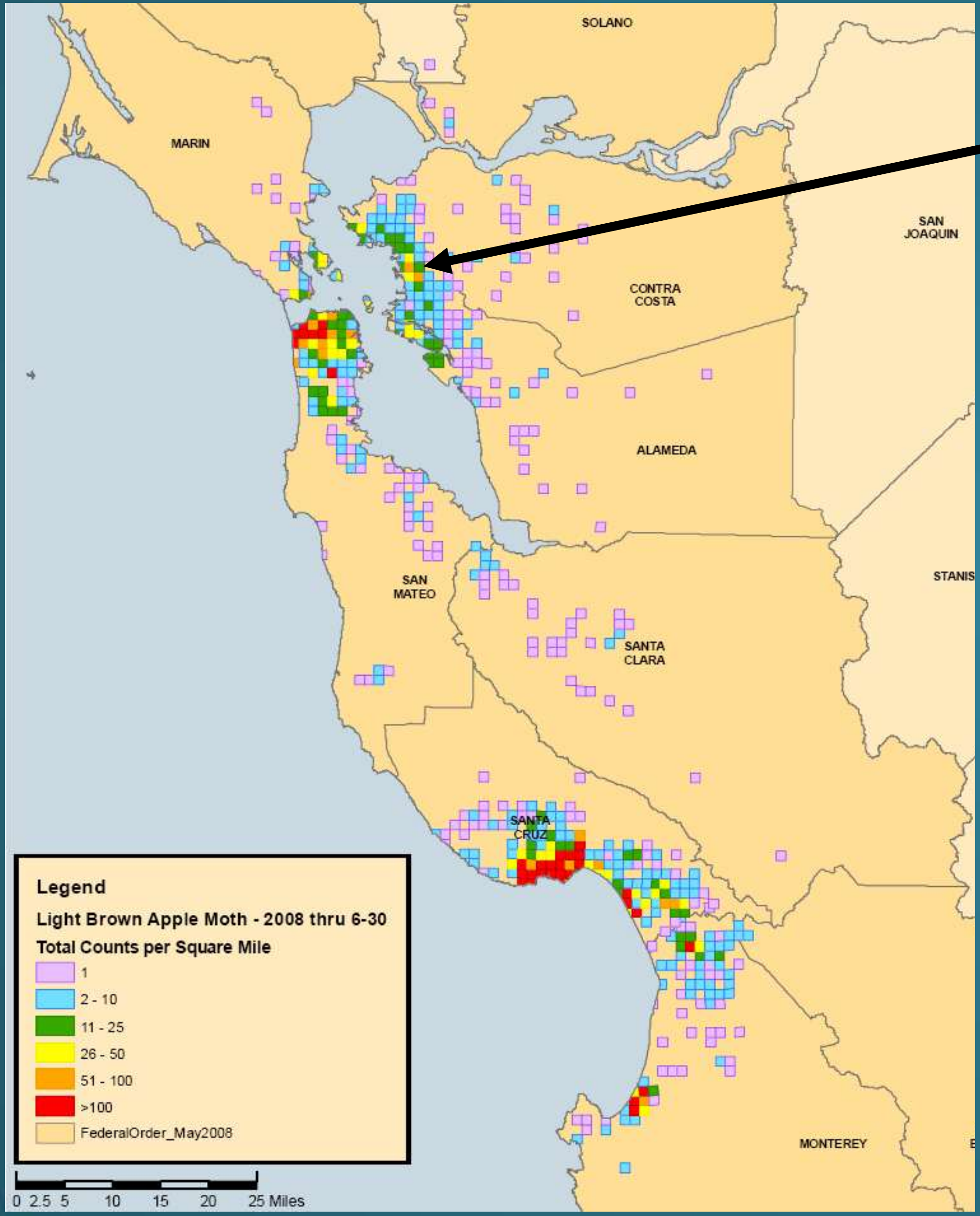
Eradication treatment area when core population cannot be easily located

Asian Longhorned beetle eradication from Chicago

- Discovered in 1998
- Surveyed via visual inspection by tree climbers
- Over 1550 trees cut and chipped/burned
- Imidacloprid treatments of all host species within ½ mile of known infestations
- Declared eradicated in 2006

Lightbrown Apple Moth



Jerry Powell runs light trap for 22 years and detects one *E. postvittana* in July, 2006 and 4-5 moths in 2007


Santa Cruz Beach Boardwalk
AERIAL SPRAY ZONE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It's Human Dusting.


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DON'T SPRAY ME


STOP THE SPRAY!
STOP THE SPRAY!

Eradication is impossible because it requires killing 100% of all individuals

James R. Carey declaration to Federal Court, November 20, 2007

“Eradication of populations of exotic insect species is especially difficult for the same reason that metastatic cancer is so difficult to cure--anything short of 100% elimination is control (management) and not eradication (cure). Thus even a 99% success in the elimination of metastases is ultimately a failure in the sense that small residual pockets of insects can regenerate the entire population.“

Most Invasions Fail!

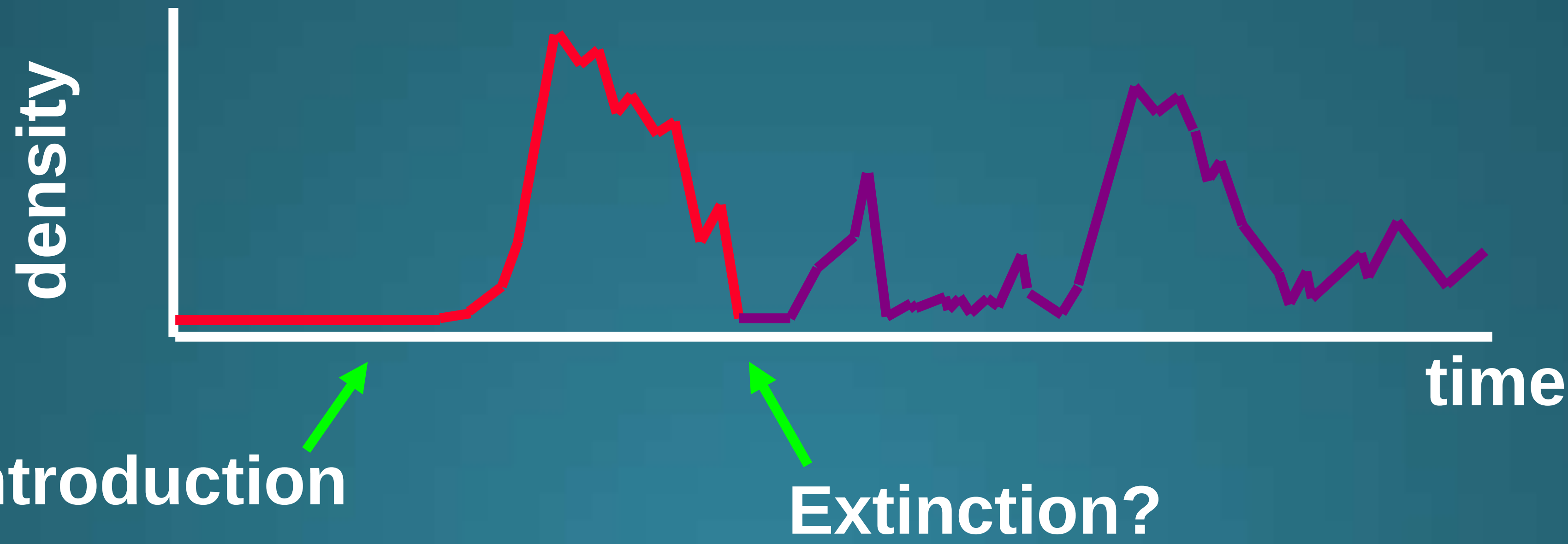





Success rate in natural enemy introductions in Canada

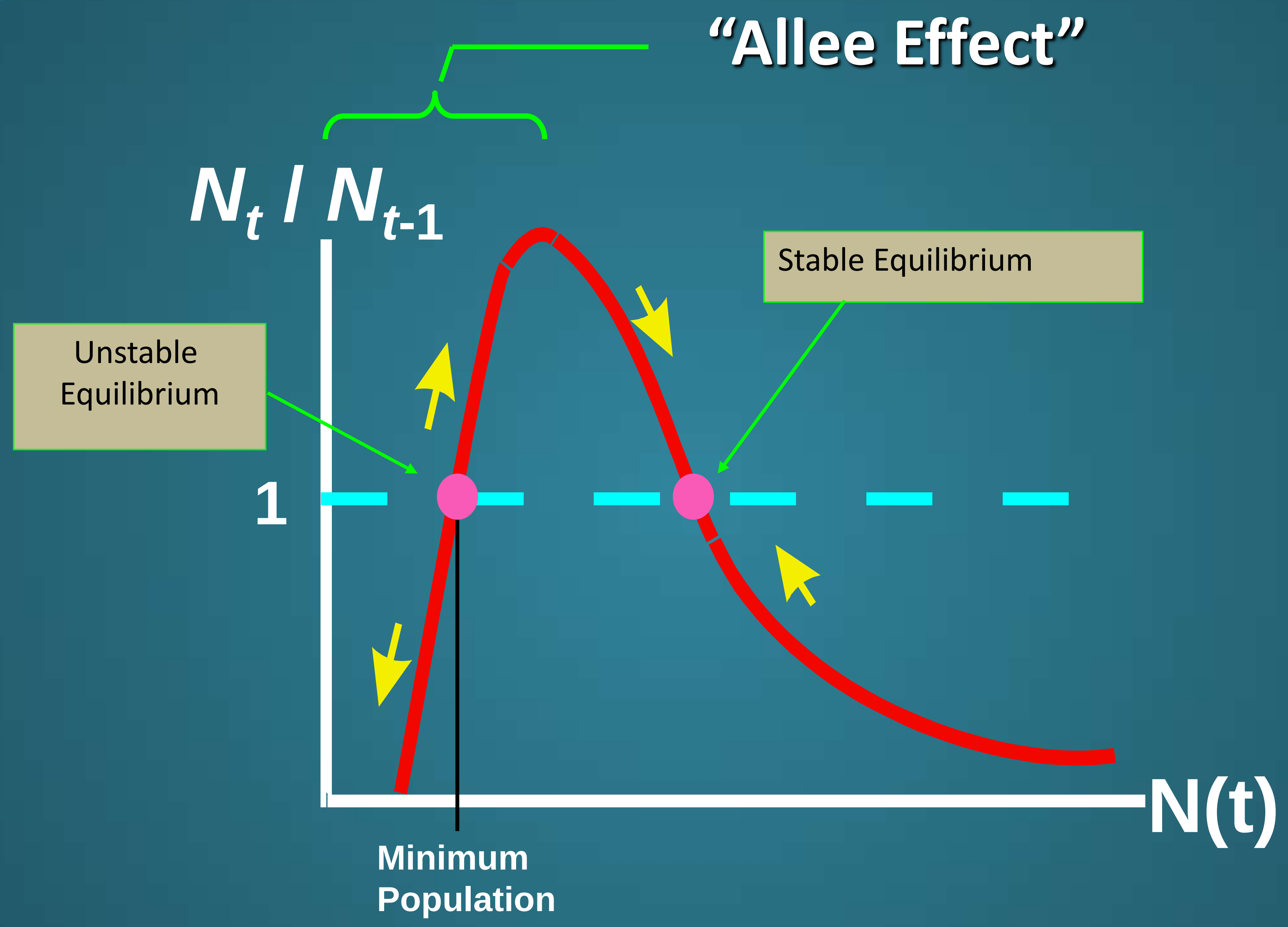
Number of Individuals Released	% Success	Failure	Success
< 5,000	9	89	9
5,000 –30,000	13	20	39
> 30,000	22	6	79

From Beirne (1975)



Processes affecting low-density populations:

- **Stochasticity**
- **Allee Effects**


"Allee Effect"
N_t / N_{t-1}
1
Unstable Equilibrium
Stable Equilibrium
N(t)
Minimum Population

Warder Clyde Allee (1885-1955)

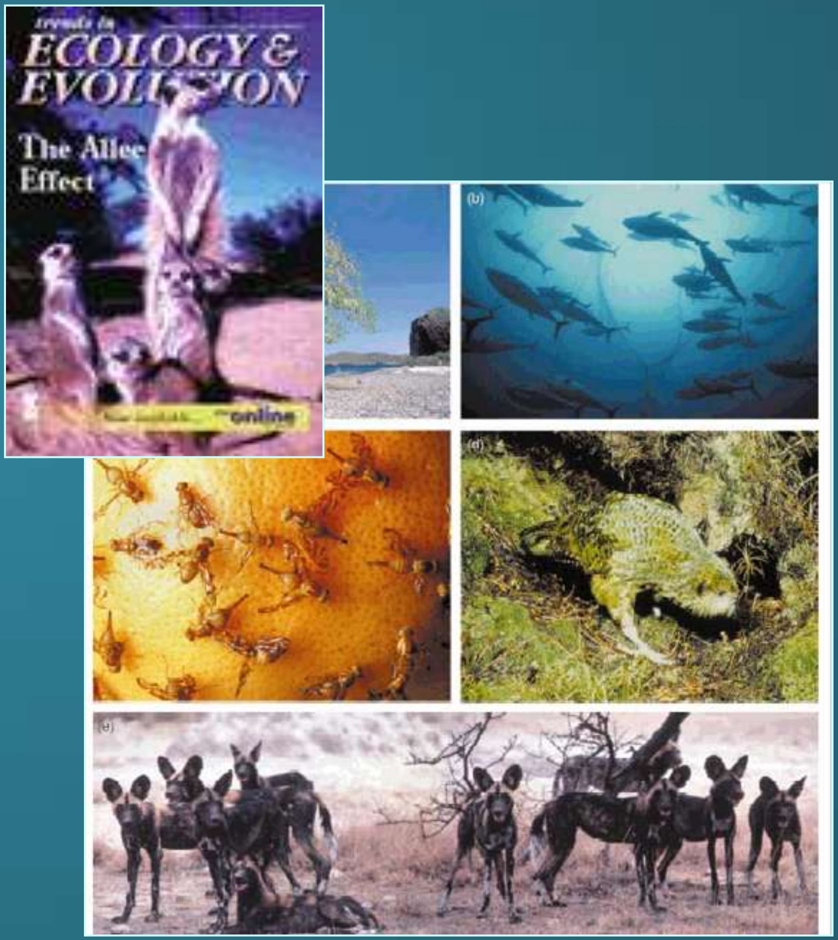
Larger group size or some degree of crowding may stimulate reproduction and survival

Allee, W.C. 1938. Cooperation among **Animals**. New York: H. Schuman.

Alee, W. C. 1931. Animal Aggregations. A study in General Sociology. University of Chicago Press, Chicago.

Causes of the Allee Effect

- Failure to find mates
- Cooperative feeding
- Predator satiation
- Inbreeding
- …

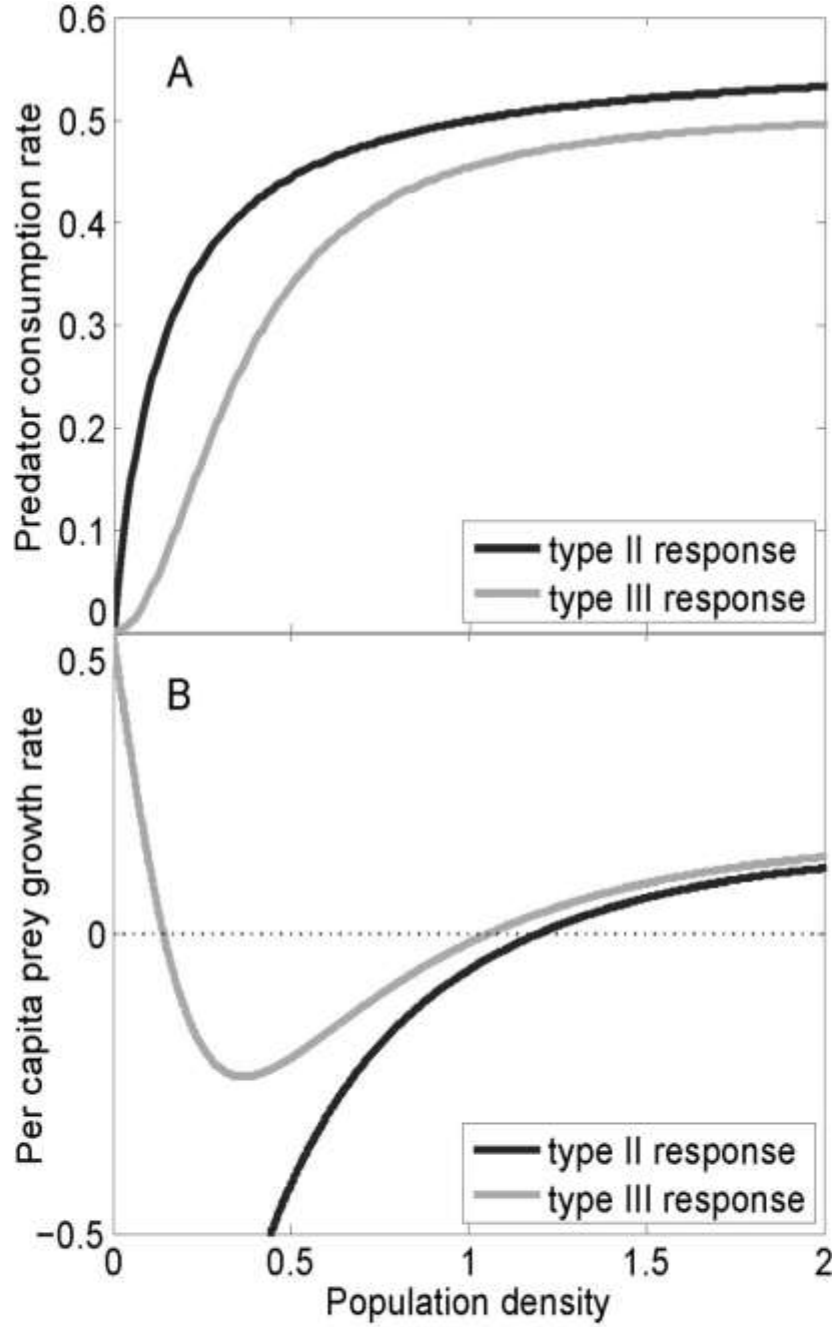


Mass attack by bark beetles to overcome host resistance., a cause of Allee effects

Pitch tubes, mountain pine beetle mass-attack

Tree attacked by the mountain pine beetle

Component Allee effects arising from generalist predators and parasitoids



mate-location failure

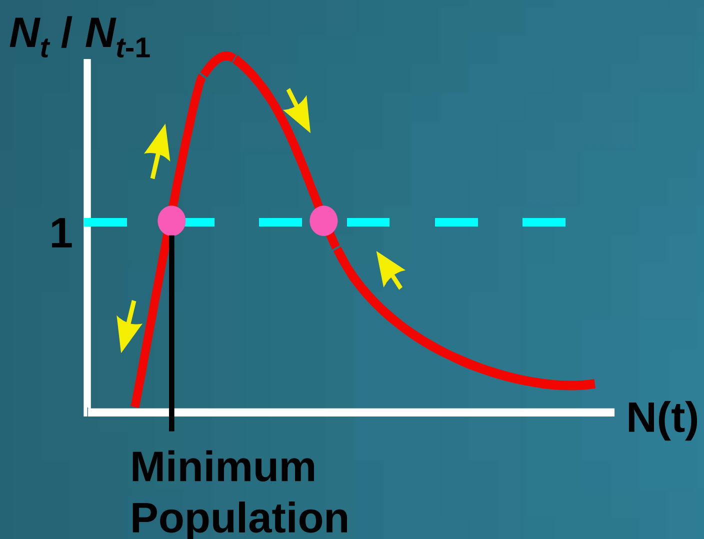
- Males can become lost in space
- Males can become lost in time

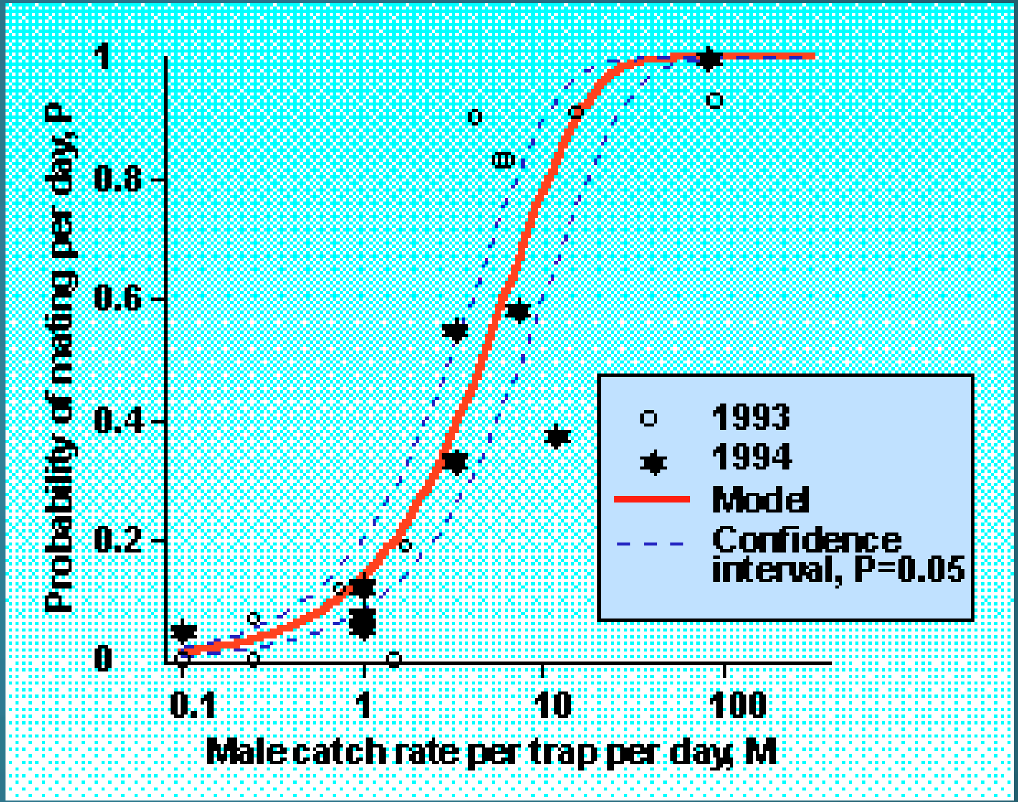
“Disparlure”, cis-7, 8-epoxy-2-methyloctadecane

male

female

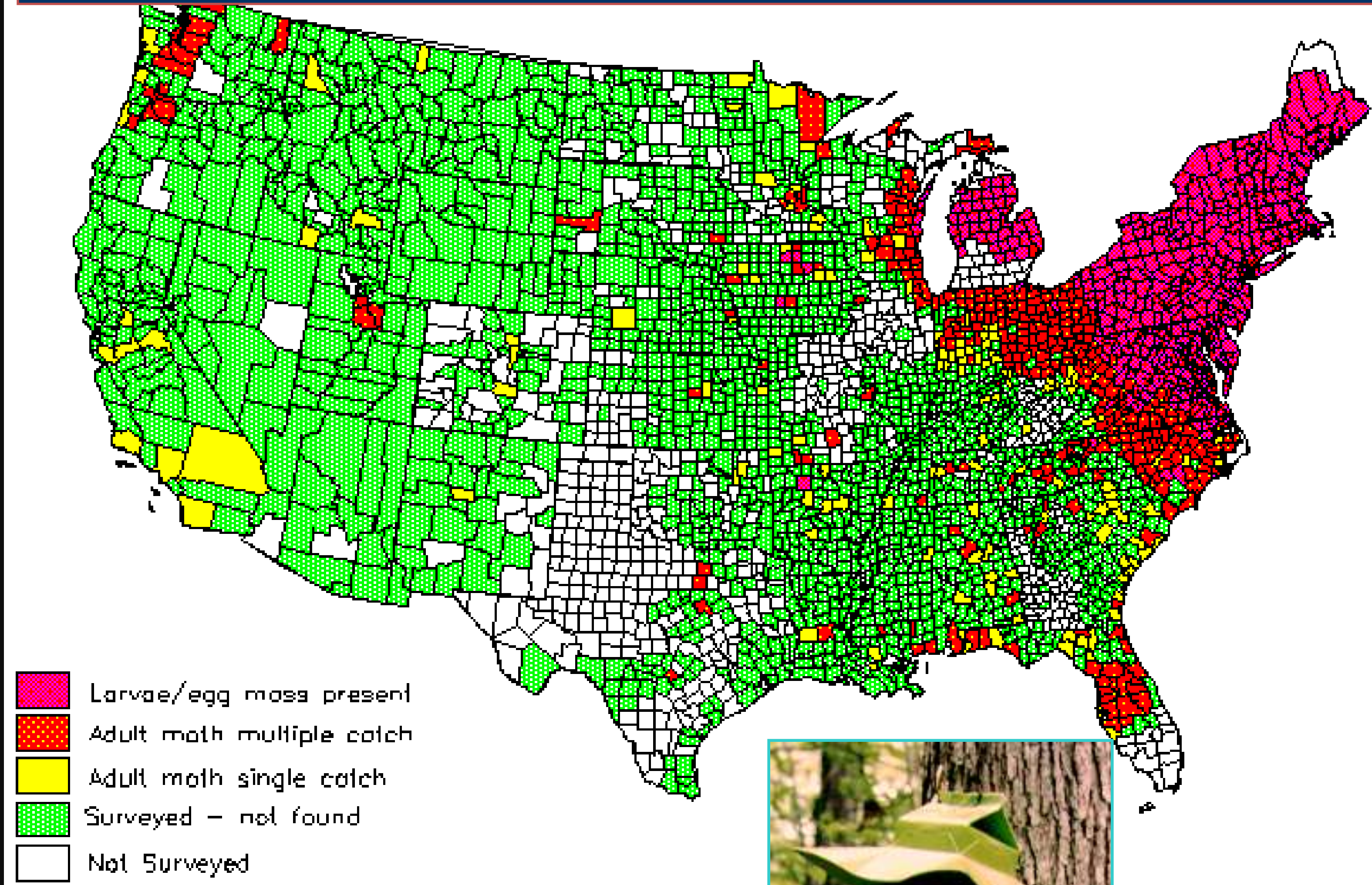
Lack of Mating Success: A Cause of the Allee Effect in the Gypsy Moth?



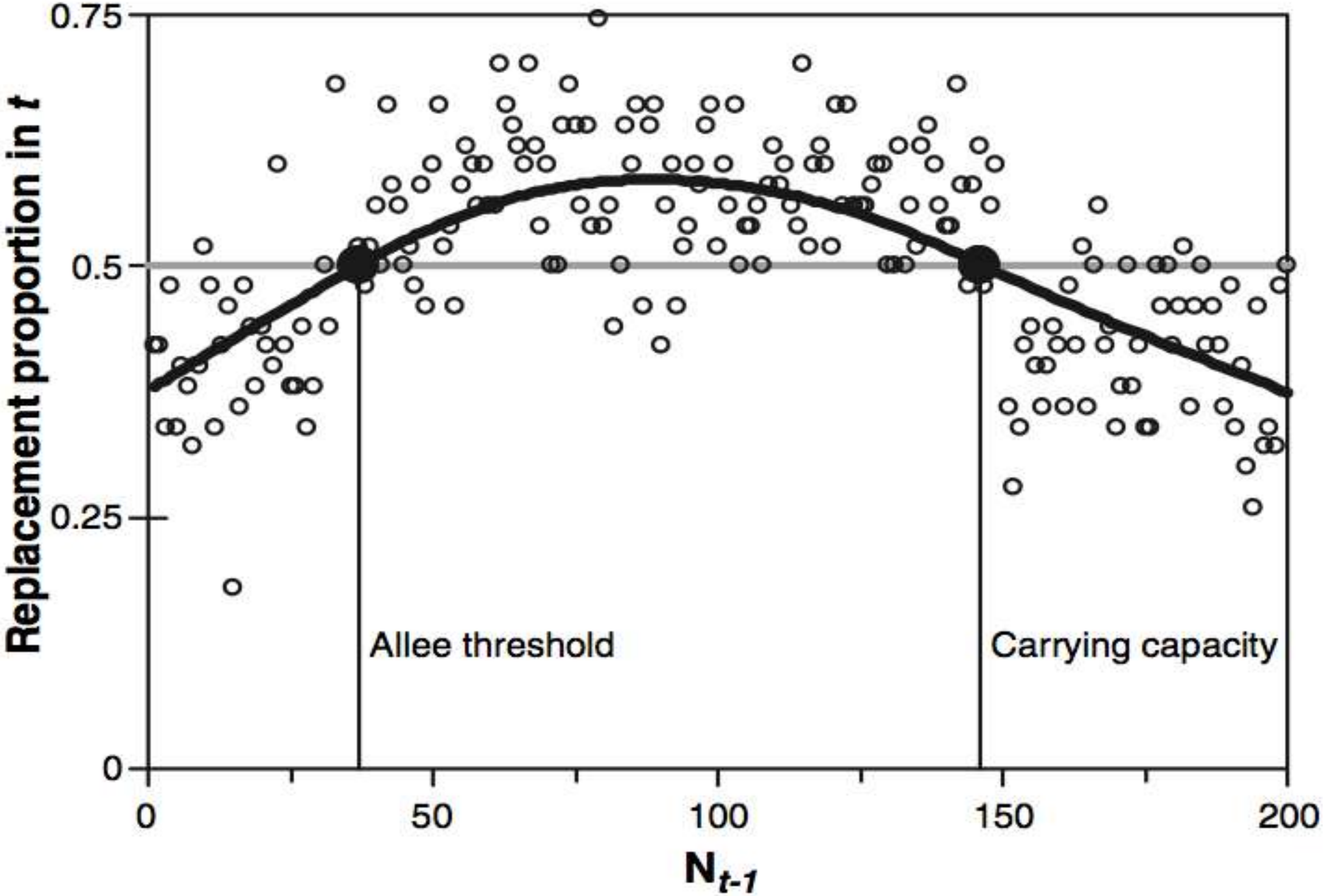


Sharov, A.A., A.M. Liebhold and F.W. Ravlin. 1995. Gypsy Moth (Lepidoptera: Lymantriidae) mating success and predation on females. Environ. Entomol. 24: 1239-1244.

Gypsy Moth Detection Survey Results, 1993



Allee effect estimated from historical trap catch data from VA & WV



Tobin, P.C., S.L. Whitmire, D.M. Johnson, O.N. Bjørnstad and A.M. Liebhold. 2007. Invasion speed is affected by geographic variation in the strength of Allee effects. Ecology Letters, 2007 10: 36–43

Population Ecology of Insect Invasions and Their Management*

Andrew M. Liebhold and Patrick C. Tobin

Forest Service, U.S. Department of Agriculture, Northern Research Station, Morgantown, West Virginia 26505; email: aliebhold@fs.fed.us, ptobin@fs.fed.us

Annu. Rev. Entomol. 2008. 53:387–408

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This article's doi: 10.1146/annurev.ento.52.110405.091401

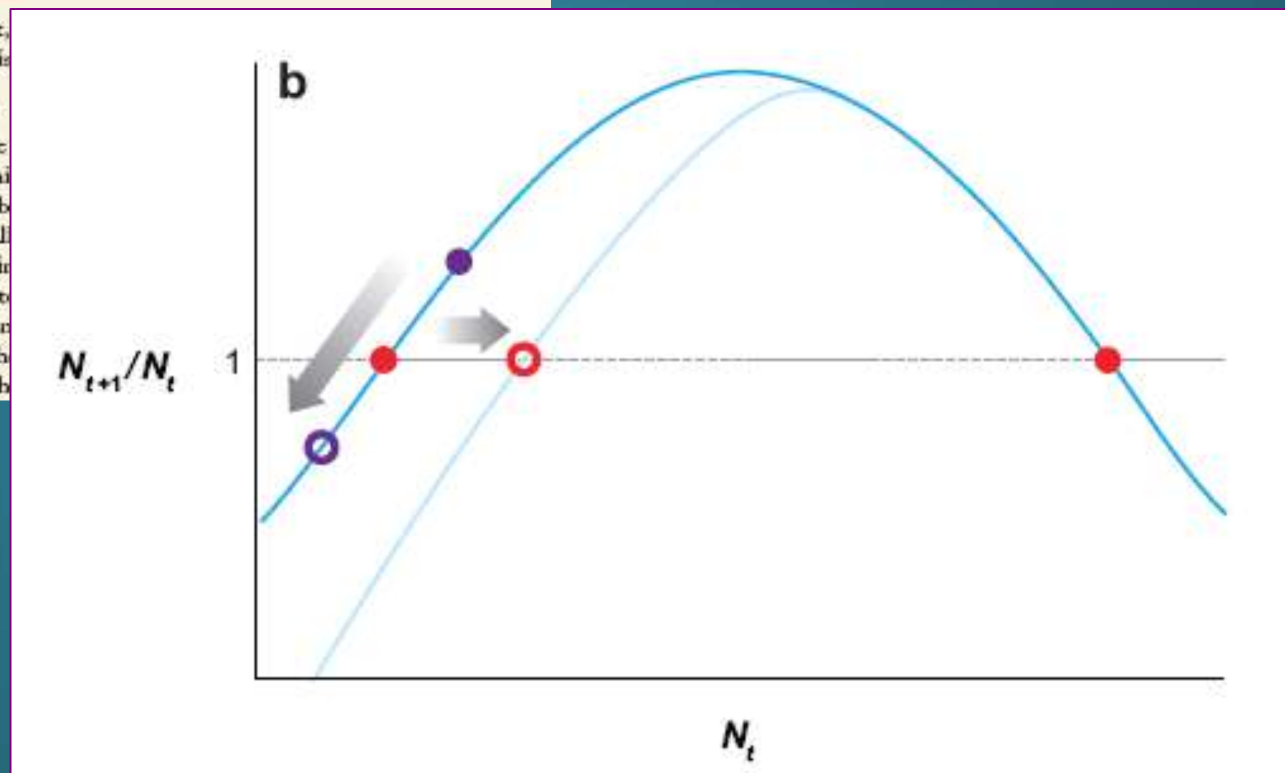
0066-4170/08/0107-0387$20.00

Key Words

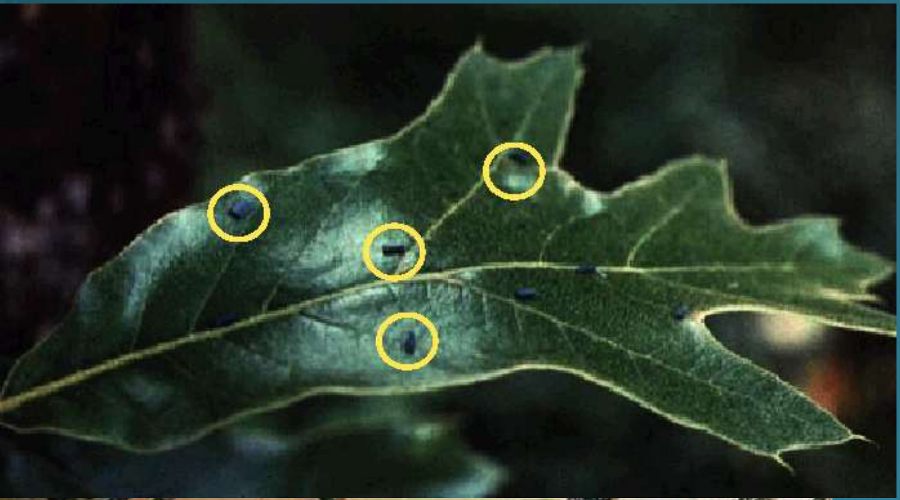
Allee effect, stratified di

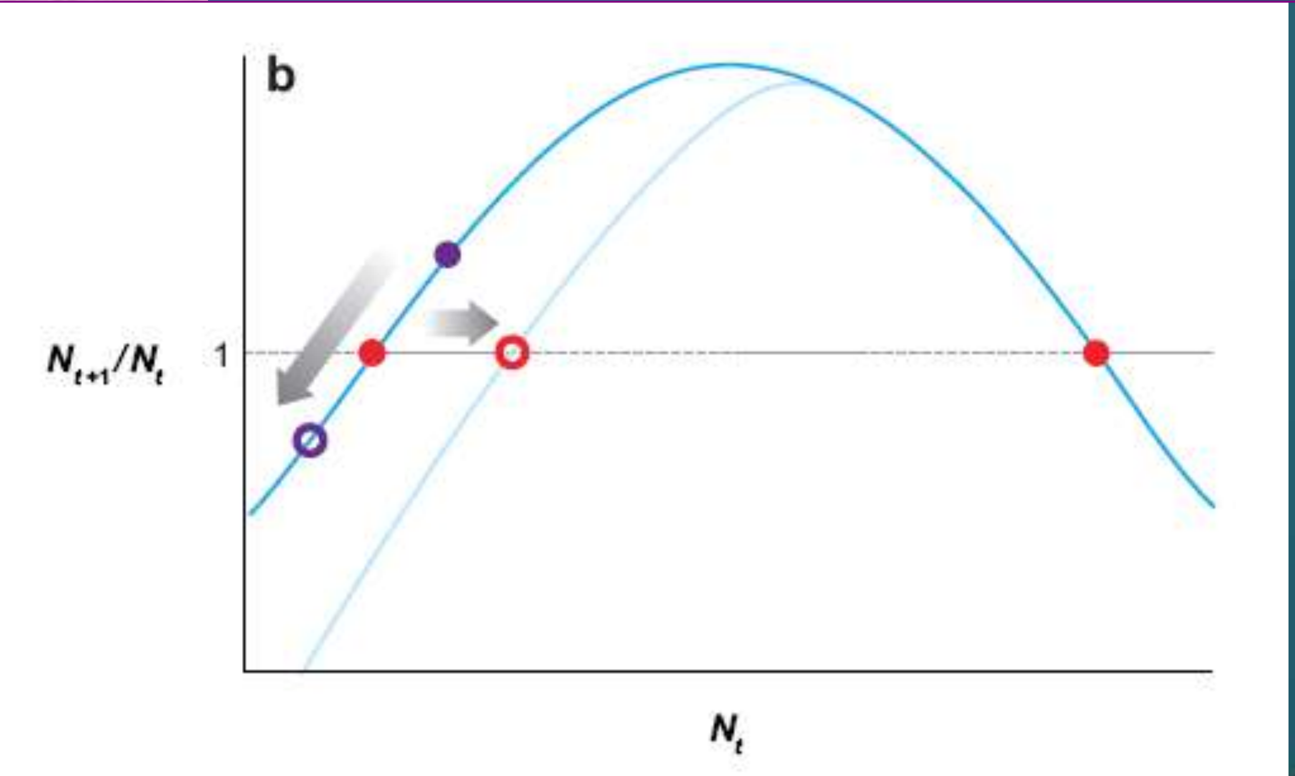
Abstract

During the tion dynami dynamics, b ulations. Al with a declin Strategies t on either en Allee thresh vention. Th

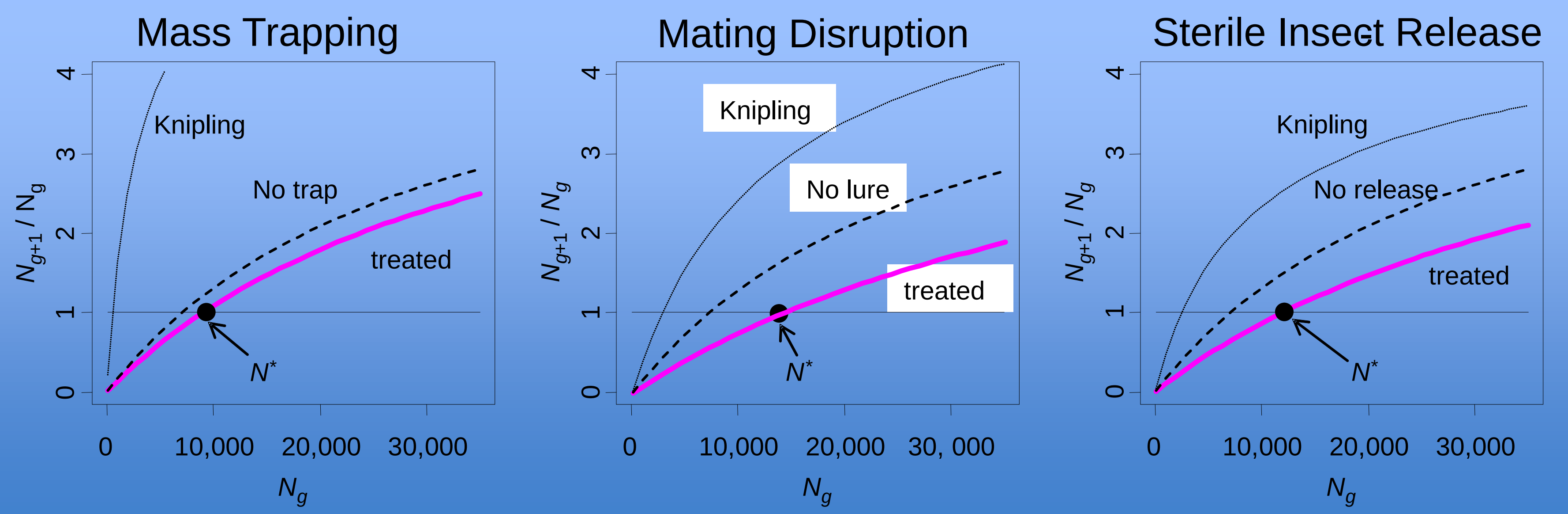


Mating Disruption



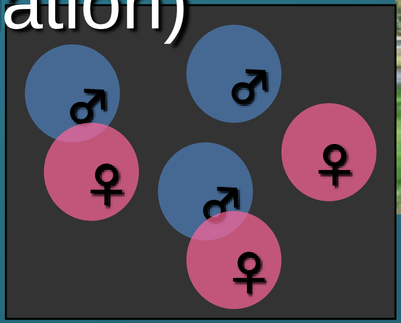


Spatially implicit and temporally explicit models of mating success (Yamanaka & Liebhold)



Management Methods

- Mass Trapping (= male annihilation)
- Mating disruption
- Sterile Insect Release



Takehiko Yamanaka

Shattering myths about eradication

False: Eradication can only be achieved by killing 100% of all individuals

True: Eradication can be achieved in most cases by killings some fraction of the population

A combination of Allee dynamics and stochasticity will cause most isolated populations to go extinct on their own once their populations have been reduced below some critical level

Liebhold, A.M. and J. Bascompte. 2003. The allee effect, stochastic dynamics and the eradication of alien species. Ecology Letters 6: 133-140.

The “Achilles Heel” of Biological Invasions

<u>The Allee effect</u>: decreasing per capita growth with increasing abundance

National Center for Ecological Analysis and Synthesis

NCEAS Project 12378
Applying population ecology to strategies for eradicating invasive forest insects

Berec, Ludek	Institute of Entomology
Blackwood, Julie	University of Michigan
Epanchin-Niell, Rebecca	Resrources for the Future
Haight, Robert	USDA Forest Service
Hastings, Alan	Univ. of California, Davis
Herms, Dan	Ohio State University
Kean, John	AgResearch
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McCullough, Deborah	Michigan State University
Suckling, Max	New Zealand Int. Plant and Food Res.
Tobin, Patrick	US Forest Service
Yamanaka, Takehiko	Japanese Inst. Agricl. Environ. Sci.

John Kean

agresearch

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g@rda
global eradication and response database

Home · FAQ · Target taxa · Countries · Bibliography · Publications · Sponsors · Log in

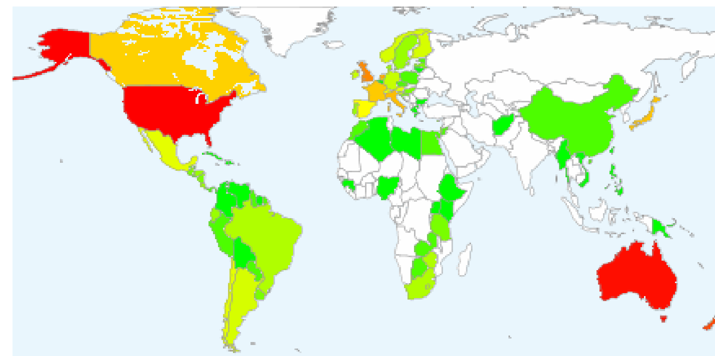
Gerda · global eradication and response database

This database summarises incursion response and eradication programmes from around the w

The scope of the database is terrestrial arthropod pests and plant pathogens. Weeds, vertebrate pests, aquatic pests, and animal diseases are not currently included. Read more about the scope and purposes of the database in the frequently asked questions (FAQ) section.

The database currently contains:

- 851 incursion responses
- including 814 eradication programmes
- in 99 countries
- against 209 target taxa
  - · 139 arthropods
  - · 8 nematodes
  - · 3 molluscs
  - · 9 bacteria/phytoplasmas
  - · 26 fungi/oomycetes
  - · 21 viruses/viroids
  - · 3 other
- documented in 525 references



Please cite this resource as:

Kean JM, Tobin PC, Lee DC, Stringer LD, McCullough DG, Flores Vargas R, Herms DA, Suckling DM, Yamanaka T, Pluess T, Smith GR, Campbell D 2009. Global eradication and response database. http://b3.net.nz/gerda (accessed 10 November 2011).

Blank data sheet: pdf · doc

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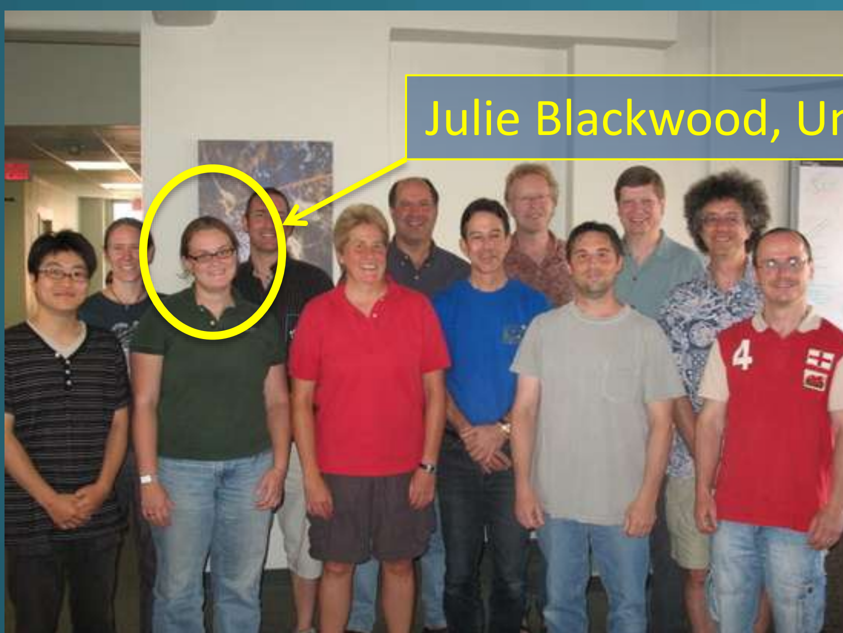
NCEAS Project 12378
Applying population ecology to strategies for eradicating invasive forest insects

Western Wildland Environmental Threat Assessment Center



Julie Blackwood, University of Michigan

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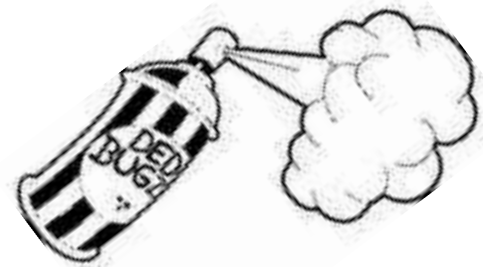
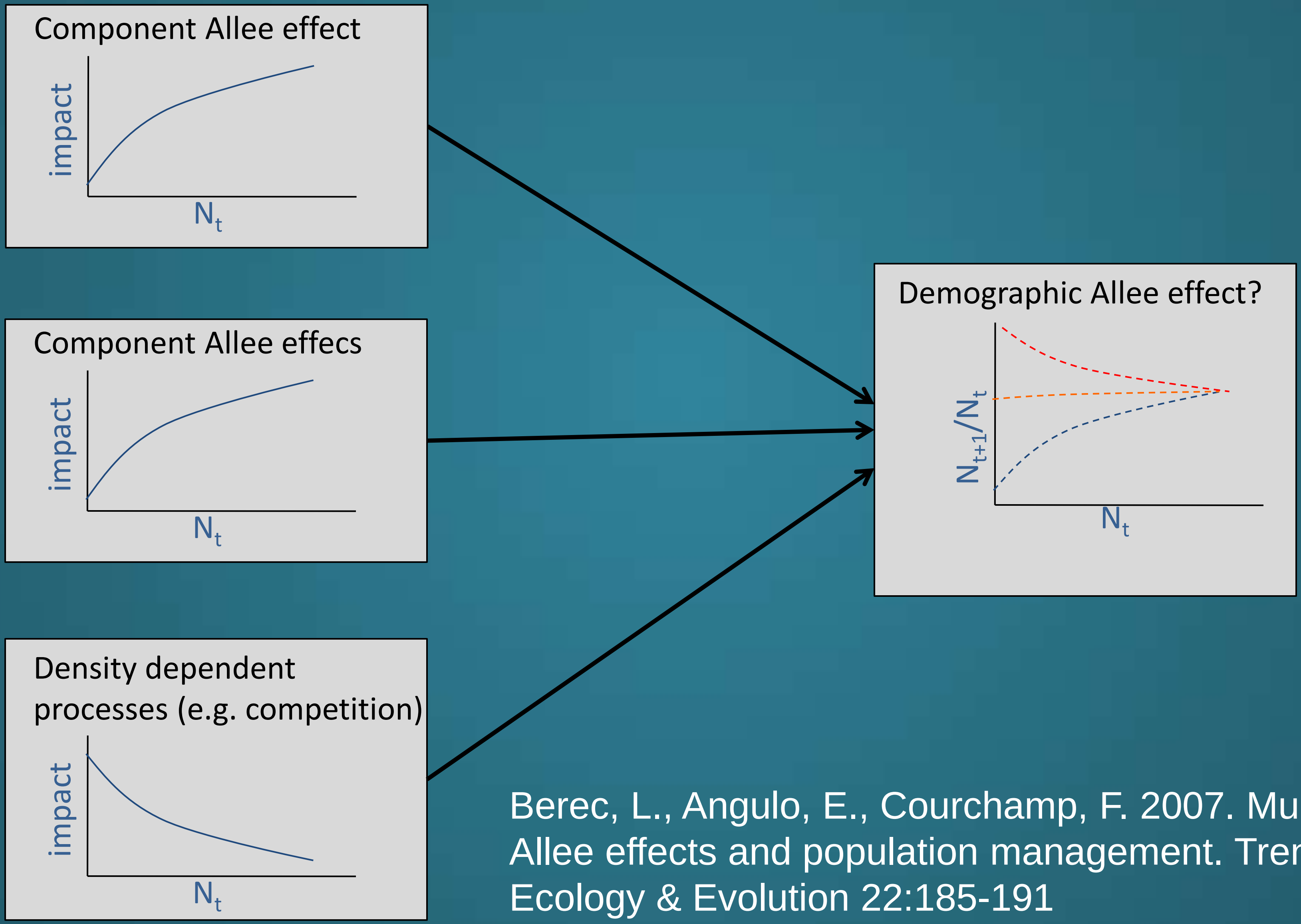
Eradication via Simultaneous Application of Two or More Tactics



Multiple Component Allee Effects Interact with Density Dependent Processes to Determine Whether Demographic Allee Effect Exists



Berec, L., Angulo, E., Courchamp, F. 2007. Multiple Allee effects and population management. Trends in Ecology & Evolution 22:185-191

Population Ecology of Insect Invasions and Their Management*

Andrew M. Liebhold and Patrick C. Tobin

Forest Service, U.S. Department of Agriculture, Northern Research Station, Morgantown, West Virginia 26505; email: aliebhold@fs.fed.us, ptobin@fs.fed.us

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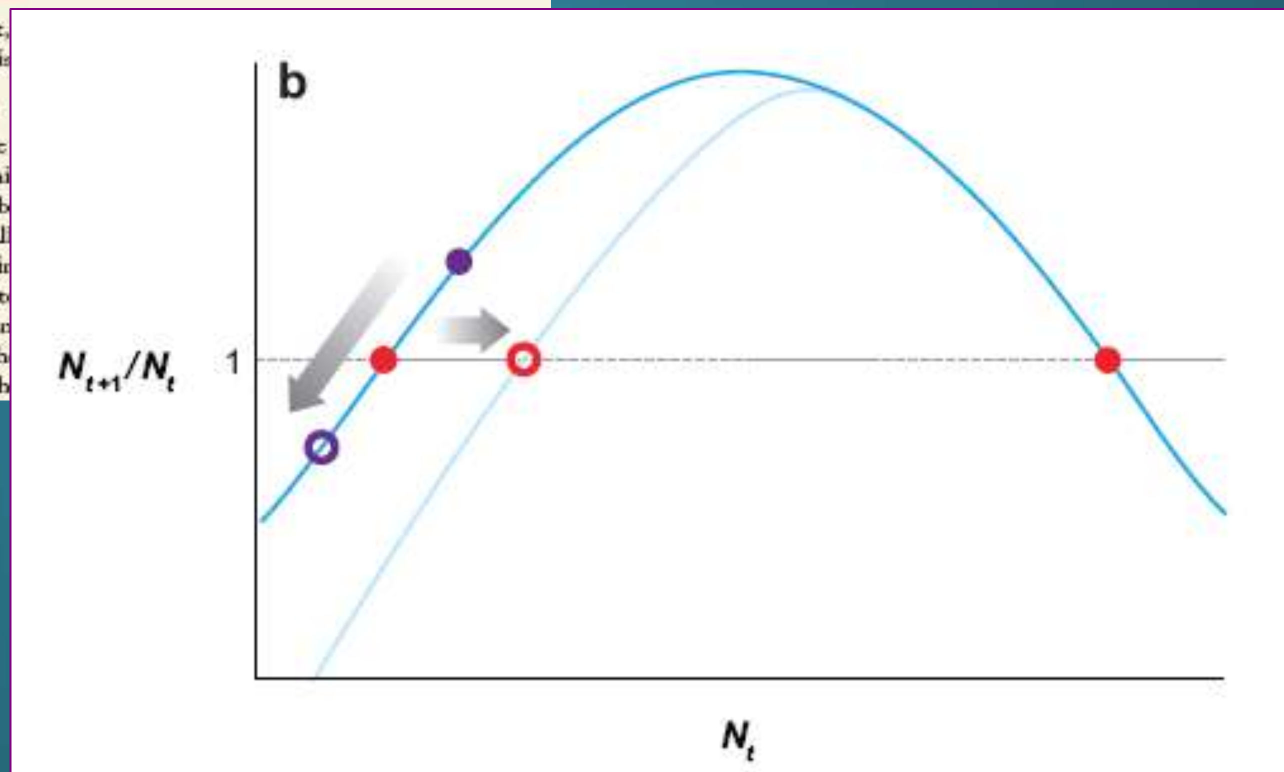
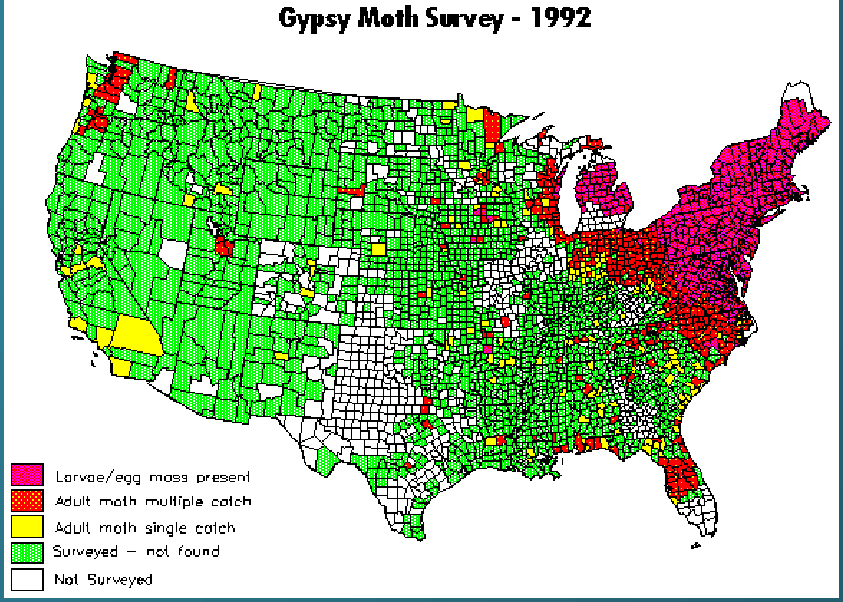


Multiple Eradication Tactics Interact to Determine Strength of Demographic Allee Effects

Julie Blackwood, Univ. Michigan

Gypsy Moth Eradication Tactics

- Pesticide (e.g., Bt)
- Mating Disruption
- Predator Augmentation



PROCEEDINGS OF THE ROYAL SOCIETY B

Proc. R. Soc. B (2012) **00**, 1–9
doi:10.1098/rspb.2012.0255
Published online 00 Month 0000

Bioeconomic synergy between tactics for insect eradication in the presence of Allee effects

Julie C. Blackwood[1,2,*], Ludek Berec[3], Takehiko Yamanaka[4], Rebecca S. Epanchin-Niell[5], Alan Hastings[6] and Andrew M. Liebhold[7]

[1]*Department of Ecology and Evolutionary Biology, and* [2]*Center for the Study of Complex Systems, University of Michigan, Ann Arbor, MI 48109, USA*

[3]*Department of Biosystematics and Ecology, Institute of Entomology, Biology Centre ASCR, Branisovska 31, 37005 Ceske Budejovice, Czech Republic*

[4]*Biodiversity Division, National Institute for Agro-Environmental Sciences, Kannon-dai 3-1-3, Tsukuba-city, Ibaraki, Japan*

[5]*Resources for the Future, Washington, DC 20036, USA*

[6]*Department of Environmental Science and Policy, University of California-Davis, Davis, CA 95616, USA*

[7]*US Forest Service Northern Research Station, Morgantown, WV 26505, USA*

Preventing the establishment of invading pest species can be beneficial with respect to averting future environmental and economic impacts and also in preventing the accumulation of control costs. Allee effects play an important role in the dynamics of newly established, low-density populations by driving small populations into self-extinction, making Allee effects critical in influencing outcomes of eradication efforts. We consider interactions between management tactics in the presence of Allee effects to determine cost-effective and time-efficient combinations to achieve eradication by developing a model that considers pesticide application, predator augmentation and mating disruption as control tactics, using the gypsy moth as a case study. Our findings indicate that given a range of constant expenditure levels, applying moderate levels of pesticides in conjunction with mating disruption increases the Allee threshold which simultaneously substantially decreases the time to eradication relative to either tactic alone. In contrast, increasing predation in conjunction with other tactics requires larger economic expenditures to achieve similar outcomes for the use of pesticide application or mating disruption alone. These results demonstrate the beneficial synergy that may arise from nonlinearities associated with the simultaneous application of multiple eradication tactics and offer new prospects for preventing the establishment of damaging non-native species.

Keywords: Allee effect; eradication; management cost; interaction of control tactics

Implications of model

- Gypsy moth can be eradicated via augmentation of predator populations, mating disruption or Bt application
- Eradication via predator augmentation alone is very expensive
- Combining mating disruption with the use of Bt provides more cost-effective eradication than either method alone

National Center for Ecological Analysis and Synthesis

Eastern Forest Environmental Threat Assessment Center

WWETAC Western Wildland Environmental Threat Assessment Center

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Becky Epanchin-Niell, Resources for the Future

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Yamanaka, Takehiko	Japanese Inst. Agricl. Environ. Sci.

Bioeconomic Optimization of Detection / Eradication

Becky Epanchin-Niell,
Resources for the Future

Eradication costs:

- **Detection (trapping)**

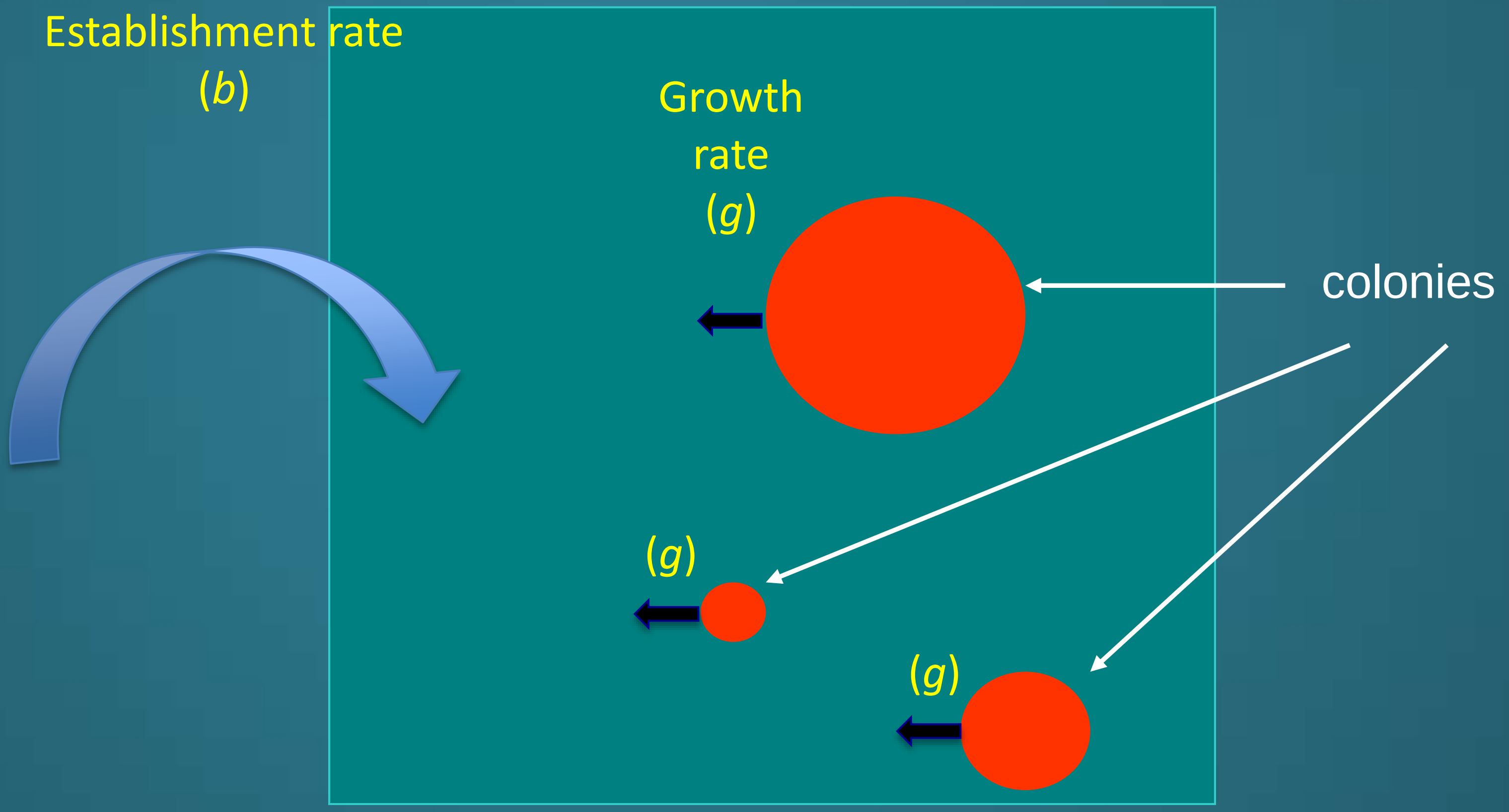
  Goal: to find newly founded populations

- **Eradication** (i.e., spraying)

  Goal: to force a population into extinction

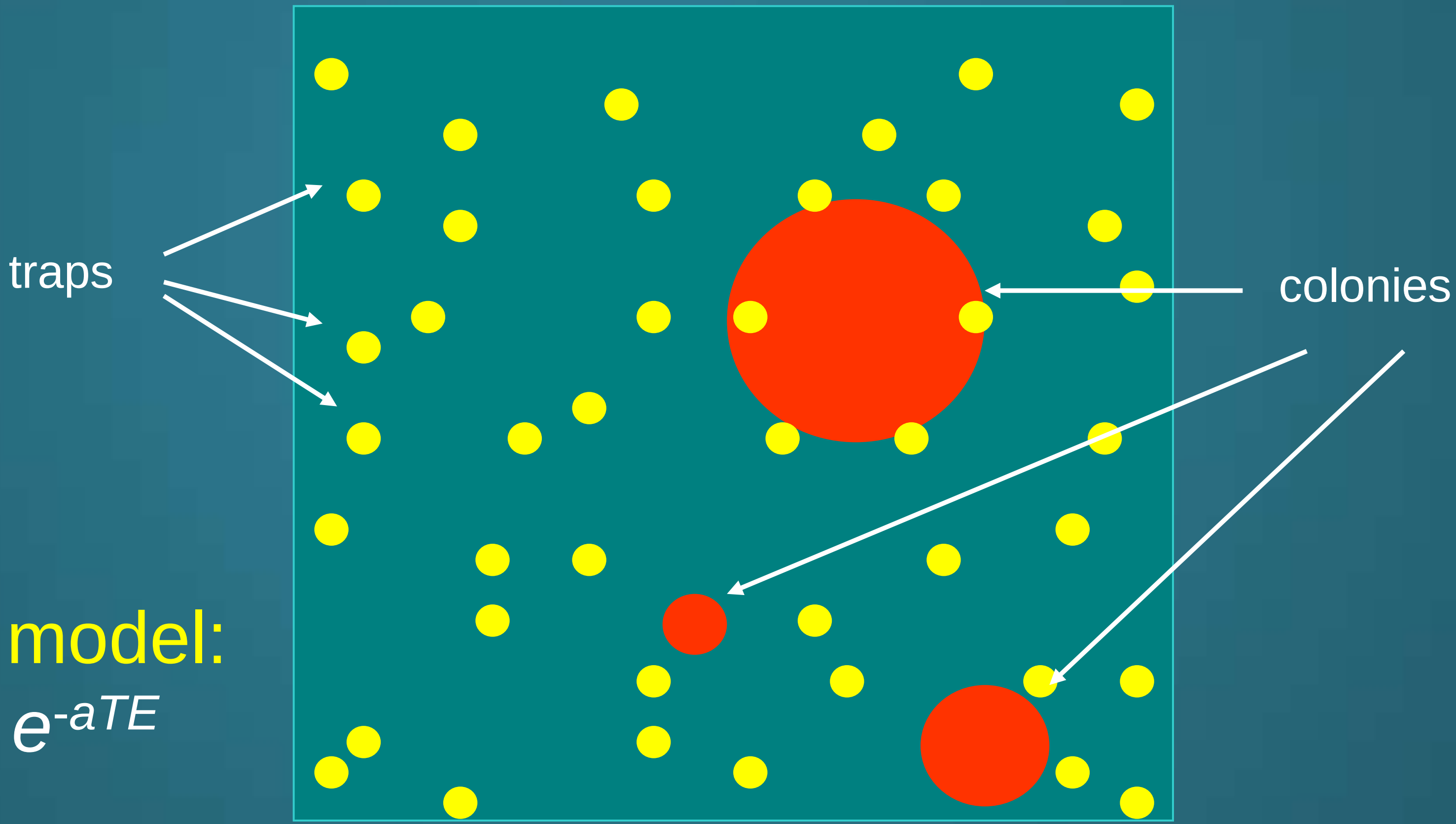
Invasion process:

- Colonies arrive and establish randomly
- Colony area grows



Probability of detecting a colony depends on:

- Size of colony - *a*
- Density of traps - *T*
- Trap sensitivity/effectiveness - *E*



Poisson model:

$$P = 1 - e^{-aTE}$$

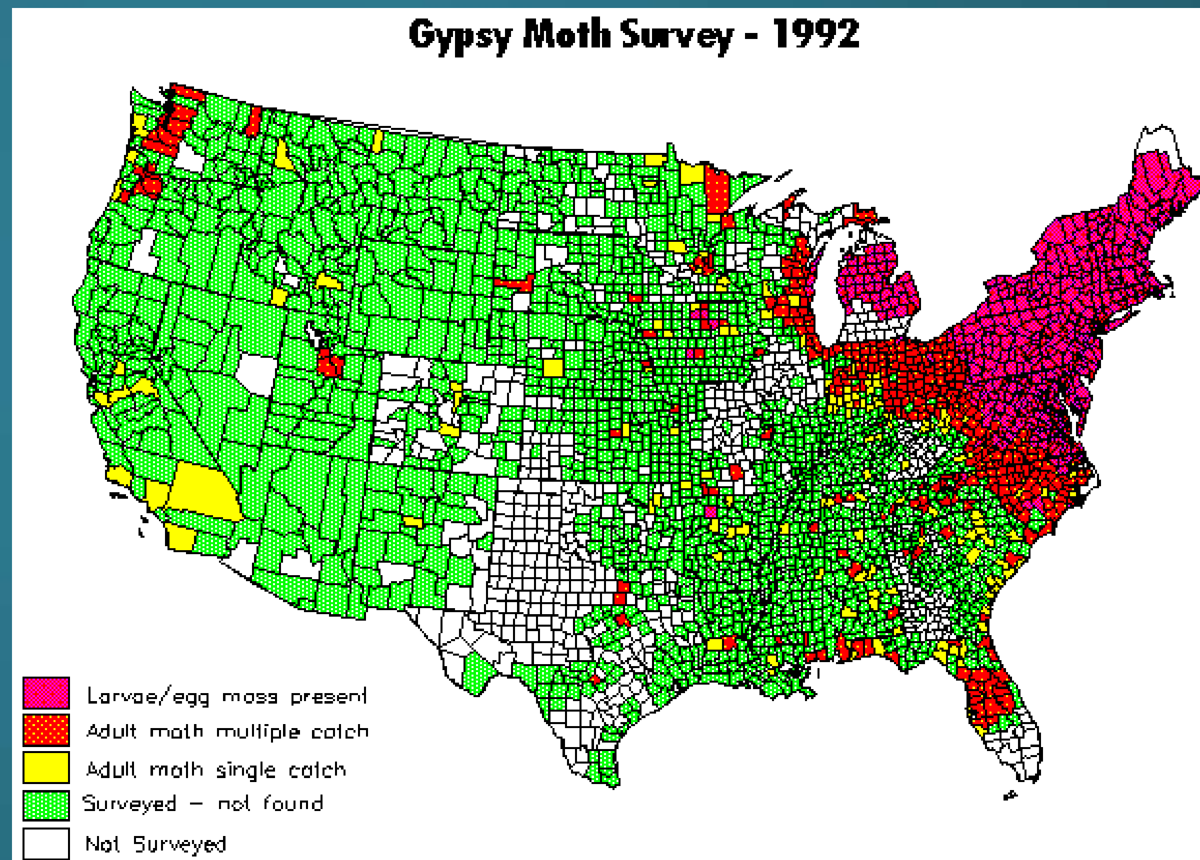
Bioeconomic model

- Probabilistic size (age) class model $s \in (1,2,\ldots S_{max})$
  - Establishment rate
  - Detection effort
- Determine optimal equilibrium trap density

Choose T to minimize:

$$\underbrace{c_{trap}(T)}_{\text{Trapping costs}} + \underbrace{\sum_{s=1}^{S_{\max}} c_{erad}(s) * E(\text{detections}_s)}_{\text{Eradication costs}} + \underbrace{c_{big} E(S_{\max})}_{\text{Penalty costs}}$$

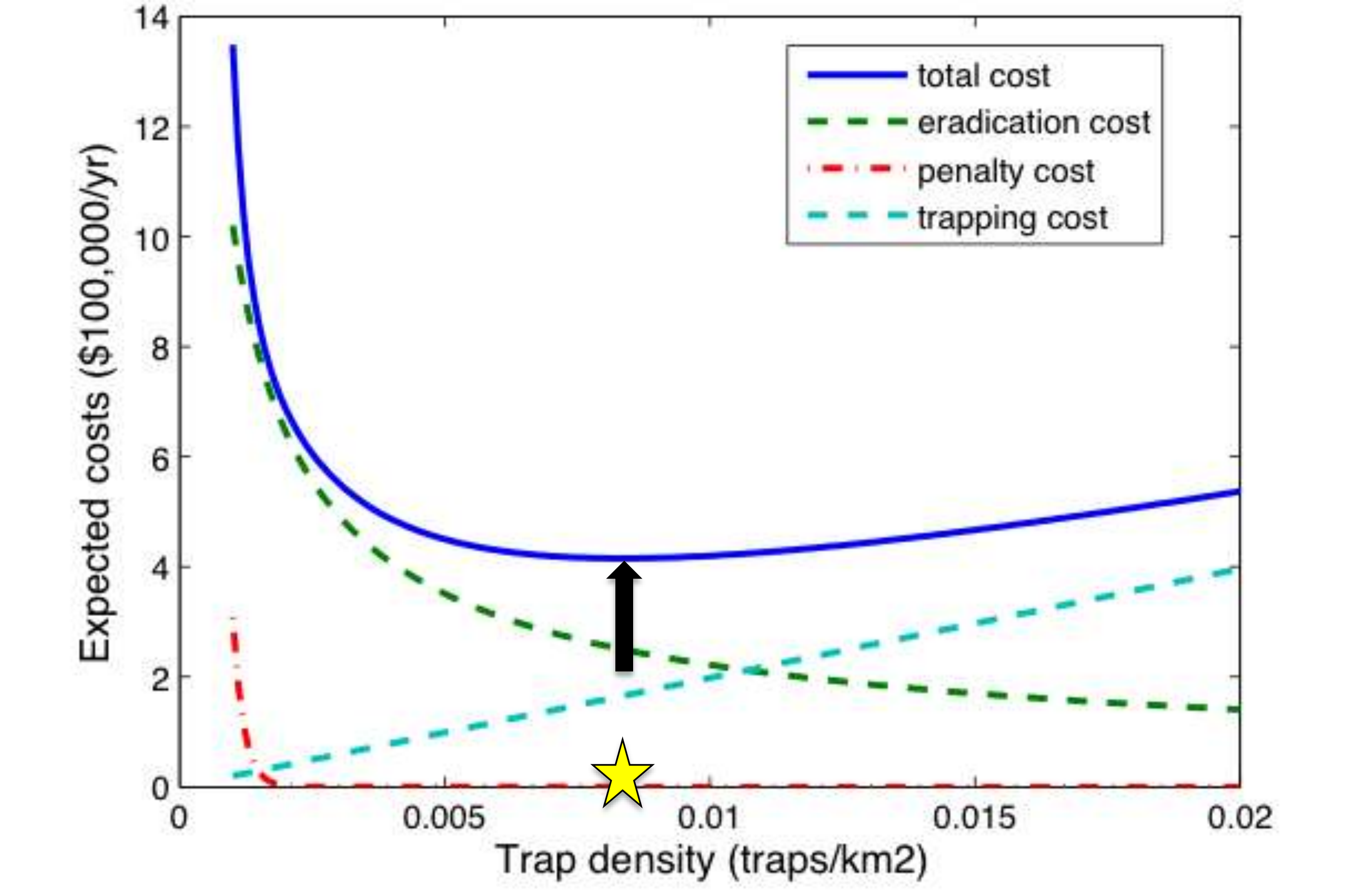
Case study: Gypsy moth (*Lymantria dispar)* eradication in California



State and County Specific Parameterization

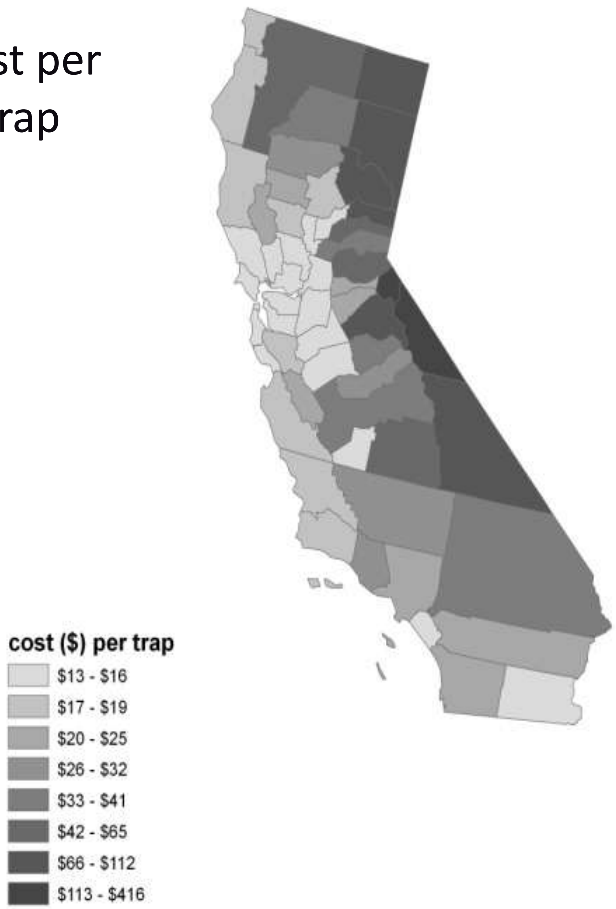
Parameter	California	Counties
Colony growth ($km^2/year^2$), g	2	same
Maximum colony age	20	same
Penalty cost	$50,000,000	same
Trap sensitivity/effectiveness	1	same
Cost of eradication ($/$km^2$), c_e	5,000	same
Forest area (km^2), A	414,633	7,149 (s.d.=8,187)
Cost of search ($/trap), c_s	47.78	43.15 (s.d=68.74)
Colony establishment rate (col/10,000km^2/yr), b	0.021	0.142 (s.d=0.657)

Expected Management Costs
- California -

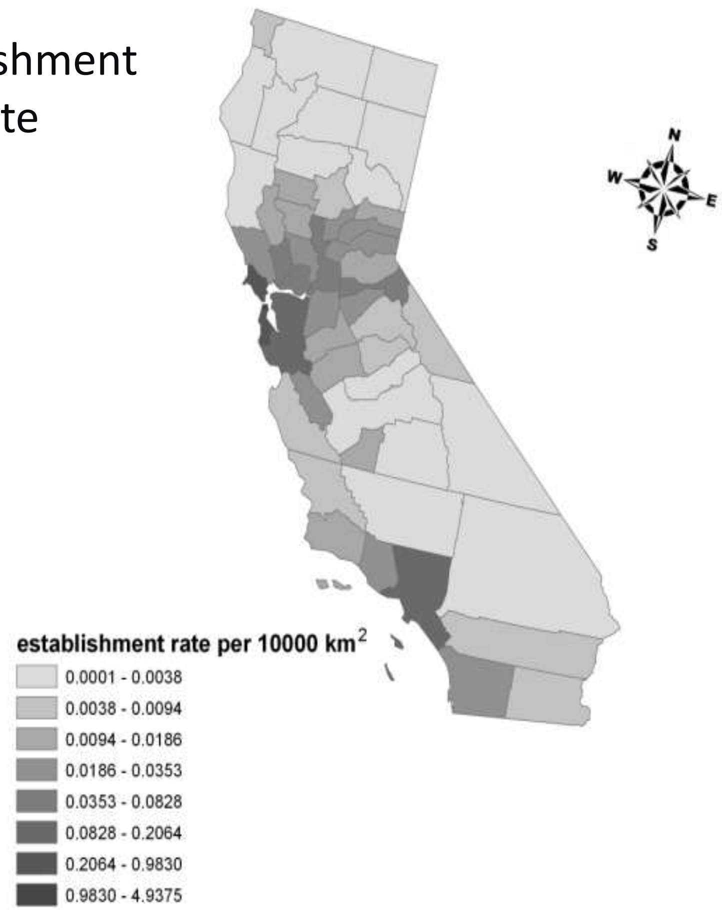


Variation in trapping cost and establishment rate among counties

Cost per trap

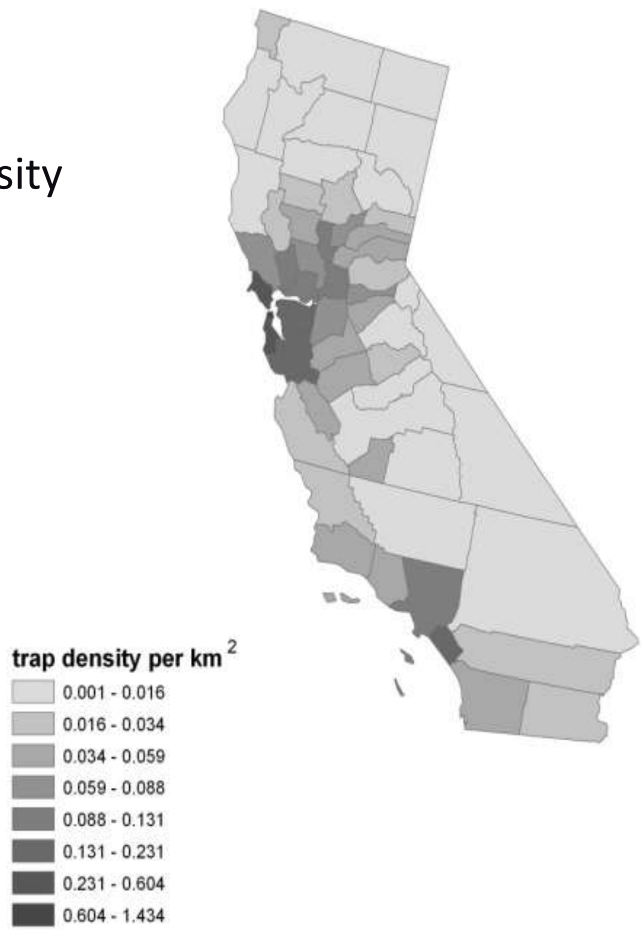


Establishment rate

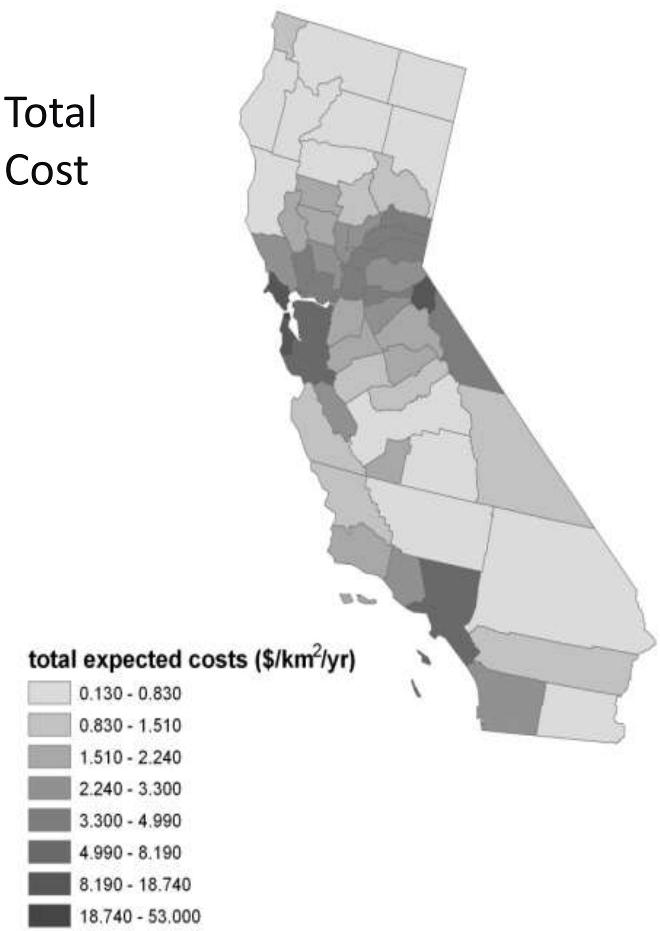


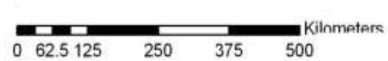
Optimal trap densities by county

Trap
Density



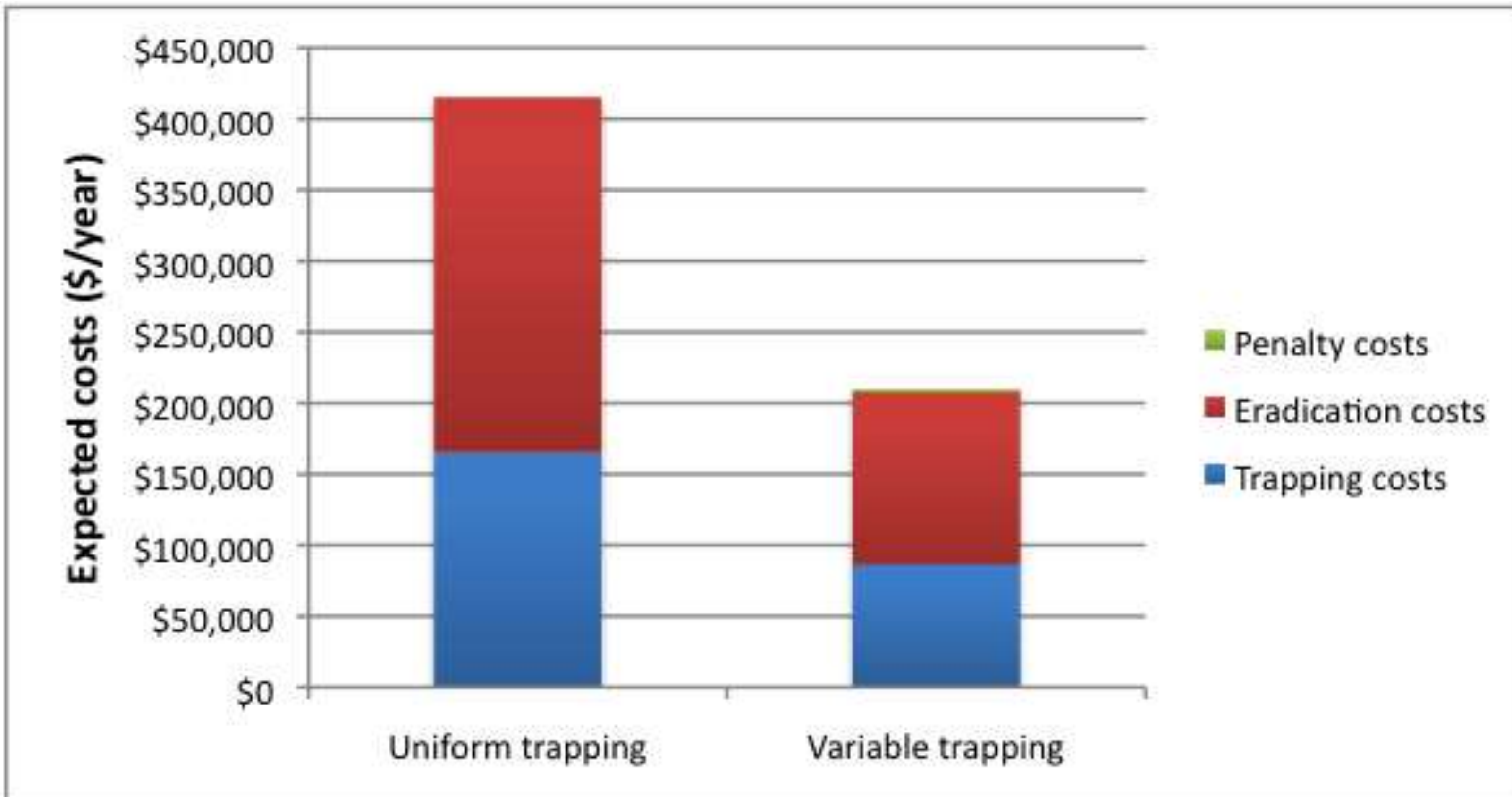
Total
Cost



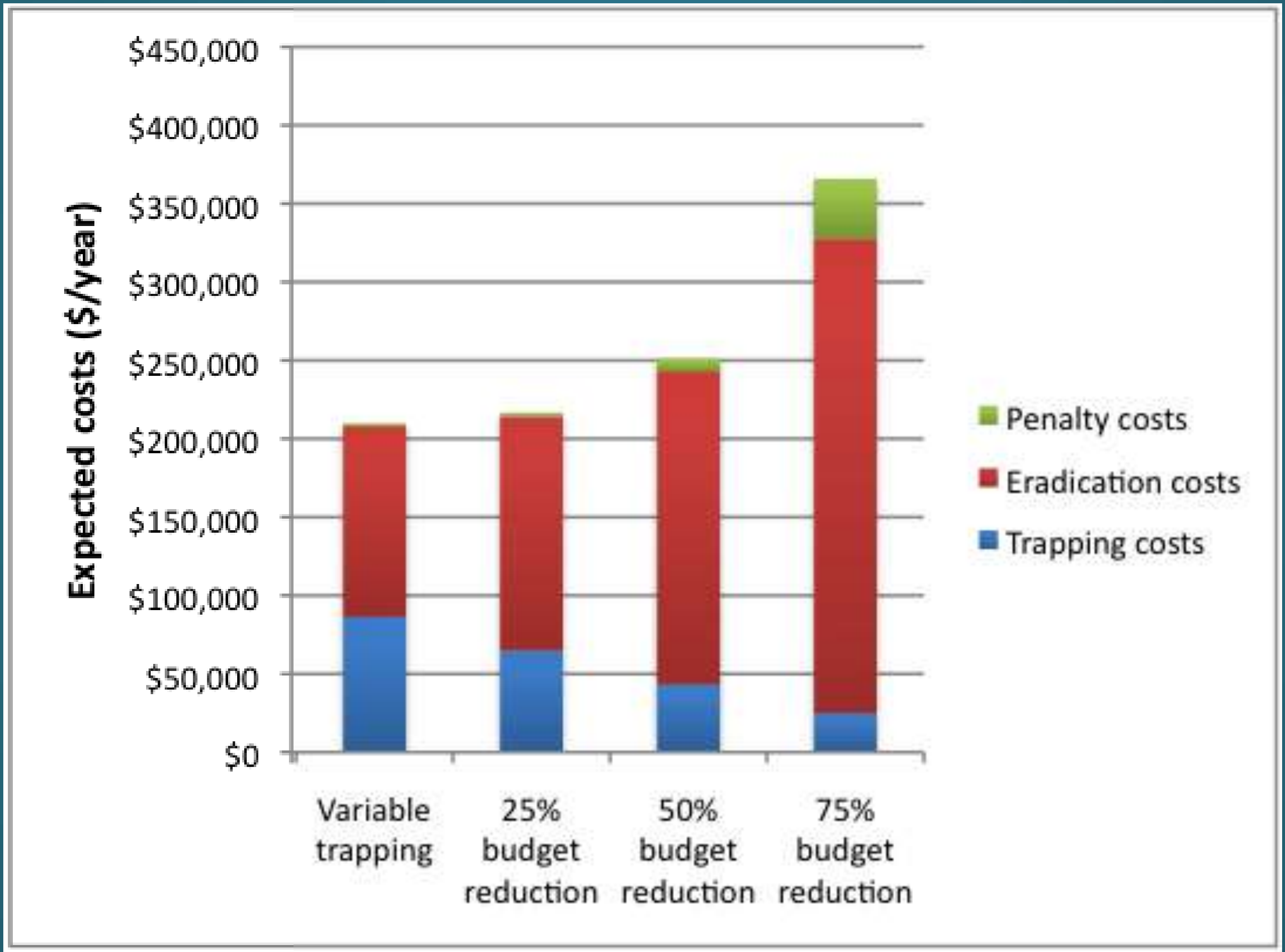


Optimize trap density across entire state

- Uniform trap density across state
- Allow varying trap densities by county



Budget constraints on trapping



Summary

- Bioeconomic modeling can help inform improved surveillance and eradication
- Specific findings:
  - Allowing for variable trap densities that accommodate heterogeneity in trapping costs and establishment rates increases efficiency
  - Budget constraint on detection increases overall costs
  - Too few traps is worse than too many traps

Eradication:
"The total elimination of a species from a geographical area" *

* Liebhold, A.M., P.C. Tobin. 2008. Population Ecology of Insect Invasions and Their Management. Annual Review of Entomology 53:387–408