Modeling the spatial dynamics of reinfestation by *Triatoma infestans*

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Outline

- Data set
- Overview of dynamics
- Modeling approach
- Results
- Conclusion
- Outlook

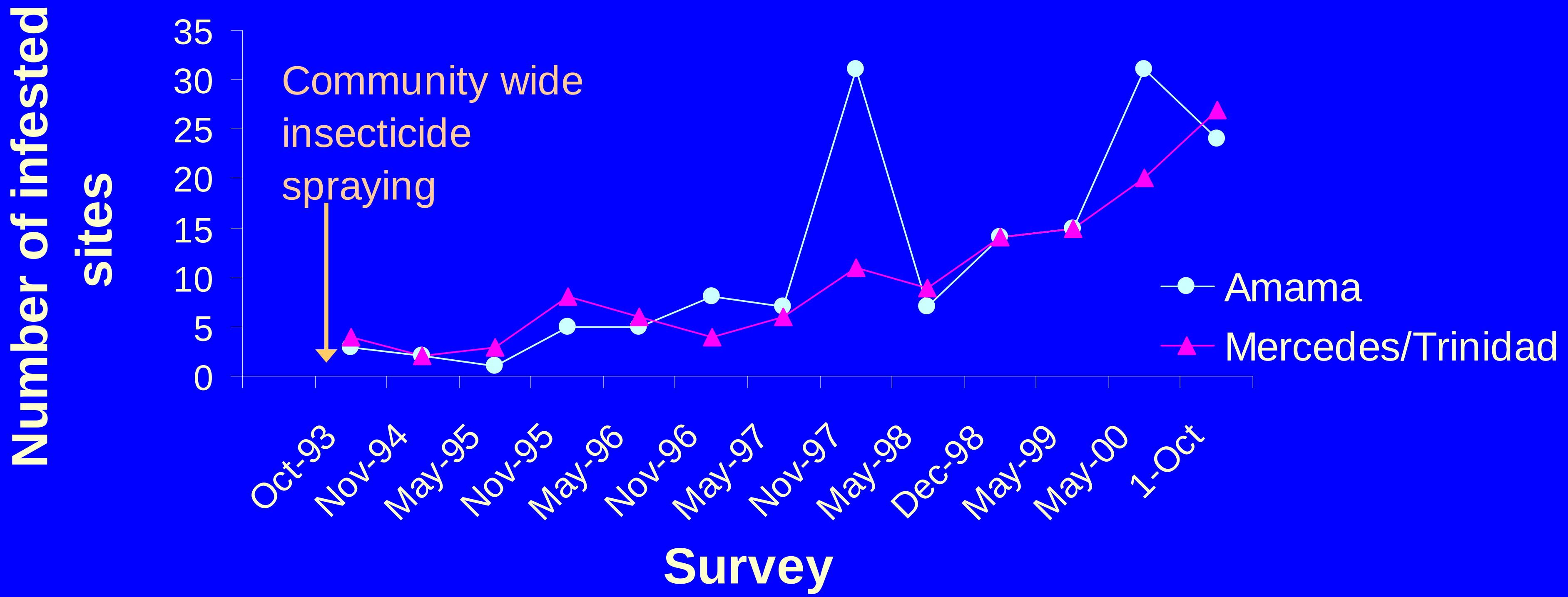
Data

- Surveys: Oct. 1993 - May 1999
  2 surveys per year (May & Nov) in three villages
- Each survey ~ 500 sites surveyed
- Sampling method: flushing out
- Data collected: number of bugs, grouped by life stage
- Additional information: dates of spraying, ecotype, x-, y-coordinates

Major distinctions

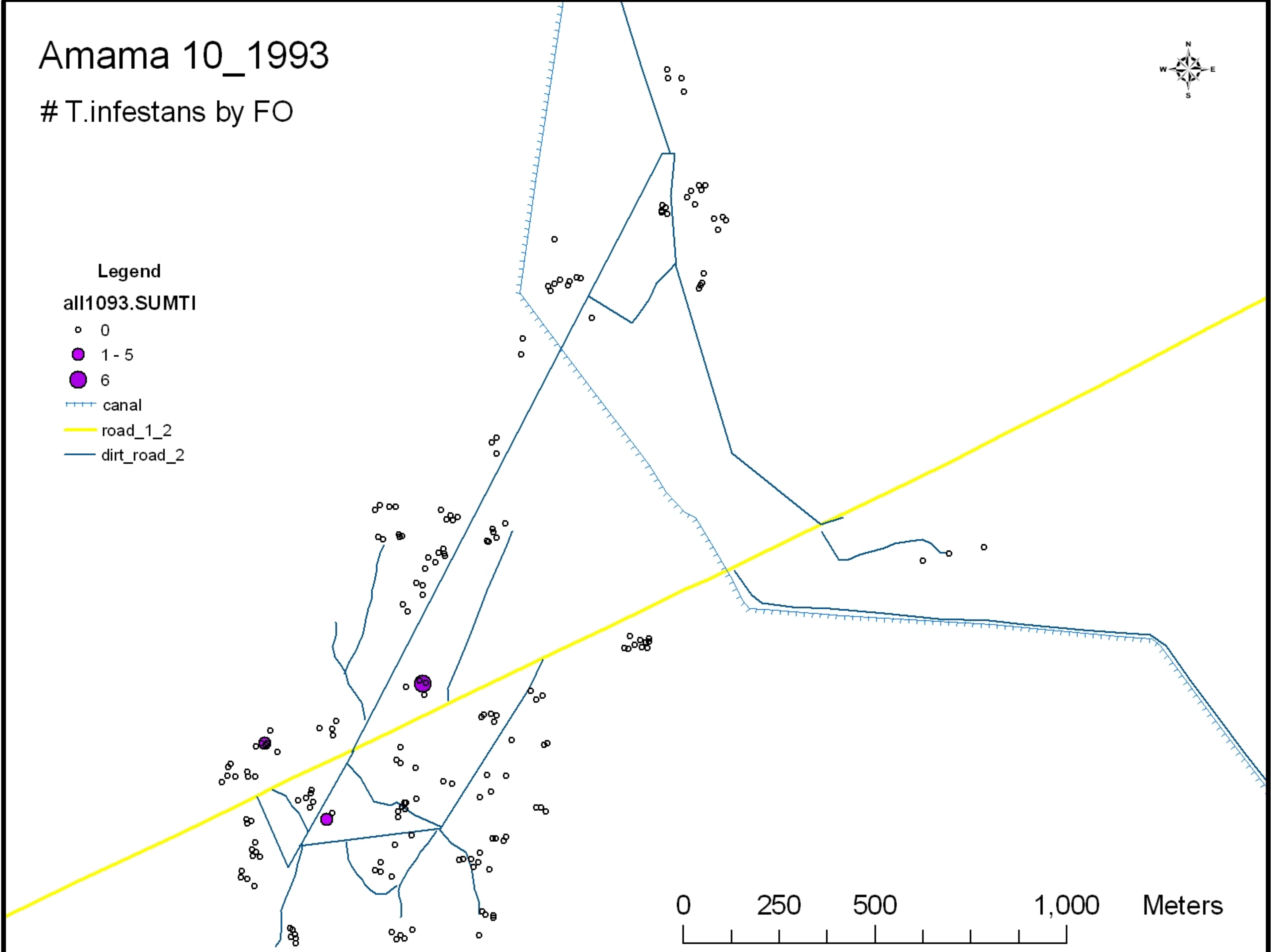
- Two villages:
  - Amama: sparse vegetation
  - Mercedes/Trinidad: dense vegetation
- Two seasons:
  - May – November
  - November - May

Overview of dynamics



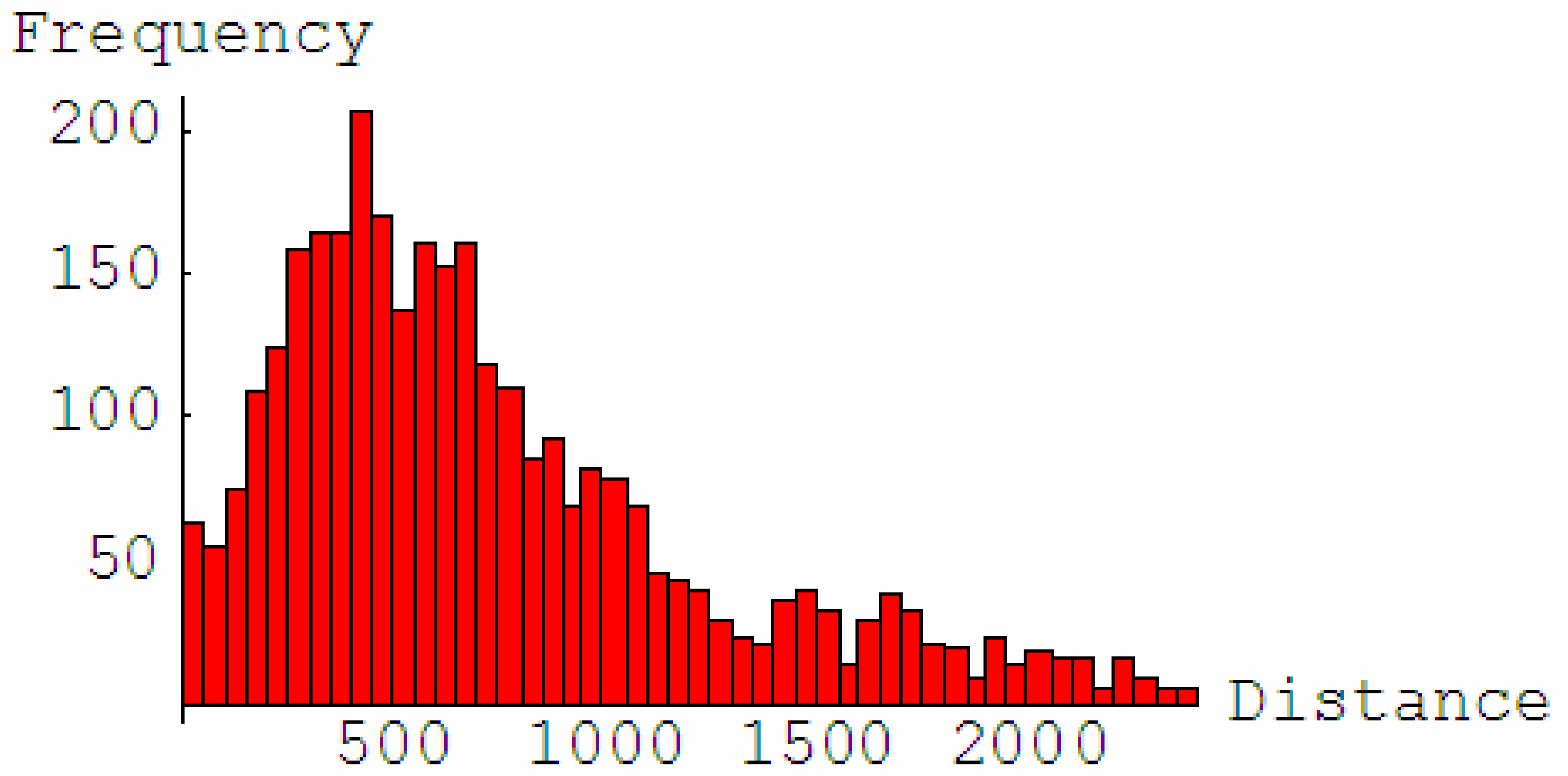
Overview of dynamics

- Average proportion infested
  - Nov: 0.21
  - May: 0.18
- Average proportion of uninfested sites changing to infested
  - Nov-May: 0.07
  - May-Nov: 0.21



Amama 10_1993
T.infestans by FO
Legend
all1093.SUMTI
0
1 - 5
6
canal
road_1_2
dirt_road_2
N
W
E
S
0
250
500
1,000
Meters

Distances within the village Amama



Mathematical modeling

- Previous efforts:

  Relationship between number of hosts, equilibrium number of bugs and transmission ***within*** a household (Cohen and Gürtler: Science 2001)

- Next goal:

  Understanding spatial vector dynamics ***between*** households

Spatial vector dynamics

Understanding spatial population dynamics of *T. infestans* means understanding dynamics of bug *establishment* and *extinction* on local sites

Terminology

- States of sites:
  - Uninfested site: 0 bugs
  - Infested site: > 0 bugs
- Transition of sites:
  - Establishment: change from uninfested to infested
- Site function:
  - Source sites: sites where dispersers are coming from
  - Target sites: uninfested sites which could become infested

Questions for spatial model fitting

- How does *establishment probability* of a target site depend on the *distance* to (and number of bugs) at source sites?
- Does this relationship depend on:
  - Village
  - Season

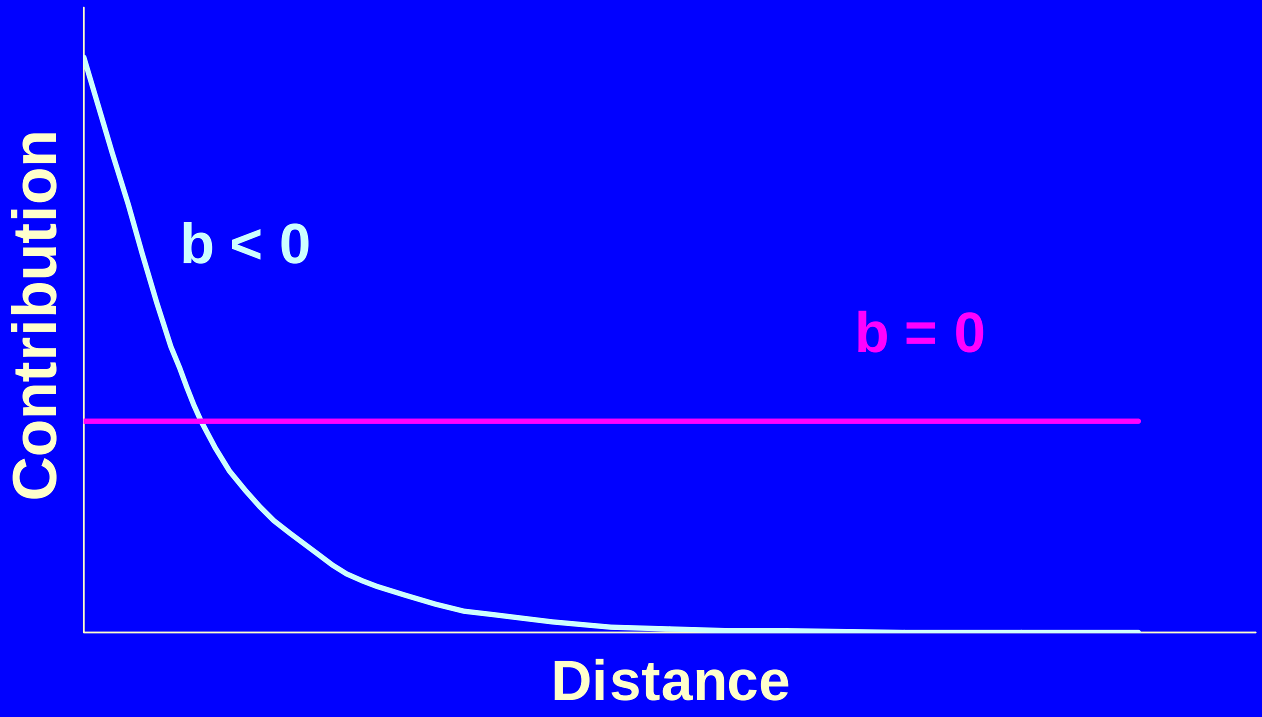
Data input for spatial model fitting

- Distances between sites ($dist_{ij}$)
- Number of bugs found on source sites at t ($bugs_{tj}$)
- Transitions of sites uninfested at t to infested at t+1 (δ_{ti})

Model component: distance function

The contribution of a bug from an source site *i* to the bug establishment probability on a target site *j* is modeled to change with distance according to

$$f(dist_{ij}) = e^{a+b*dist_{ij}}:$$



Model component: establishment probability

Assumption: Establishment events are independent of each other

→ Probability of establishment on a target site *i* equals

1 – Product of all probabilities of not receiving a successful disperser from each infested site *j*

Establishment probability

$$P_{it}(establishment) = 1 - P_0 \prod_{sites(j)} P_{ijt}(no\_establishment) =$$

$$= 1 - e^{-c - \sum_j bugs_{jt} \cdot f(dist_{ij})}$$

$$f(dist_{ij}) = e^{a + b \cdot dist_{ij}}$$

Establishment probability

$$P_{it}(establishment) = 1 - P_0 \prod_{sites(j)} P_{ijt}(no\_establishment) =$$

$$= 1 - e^{-c - \sum_j bugs_{jt} \cdot f(dist_{ij})}$$

$$f(dist_{ij}) = e^{a + b \cdot dist_{ij}}$$

Statistical model:

$$P(data) = \prod_{surveys(t)} \prod_{sites(i)} \left[1 - P_0 \prod_{sites(j)} P_{ijt}(no\_establishment) \right]^{\delta_{it}} \times$$

$$\times \prod_{surveys(t)} \prod_{sites(i)} \left[P_0 \prod_{sites(j)} P_{ijt}(no\_establishment) \right]^{1-\delta_{it}}$$

Parameter estimation

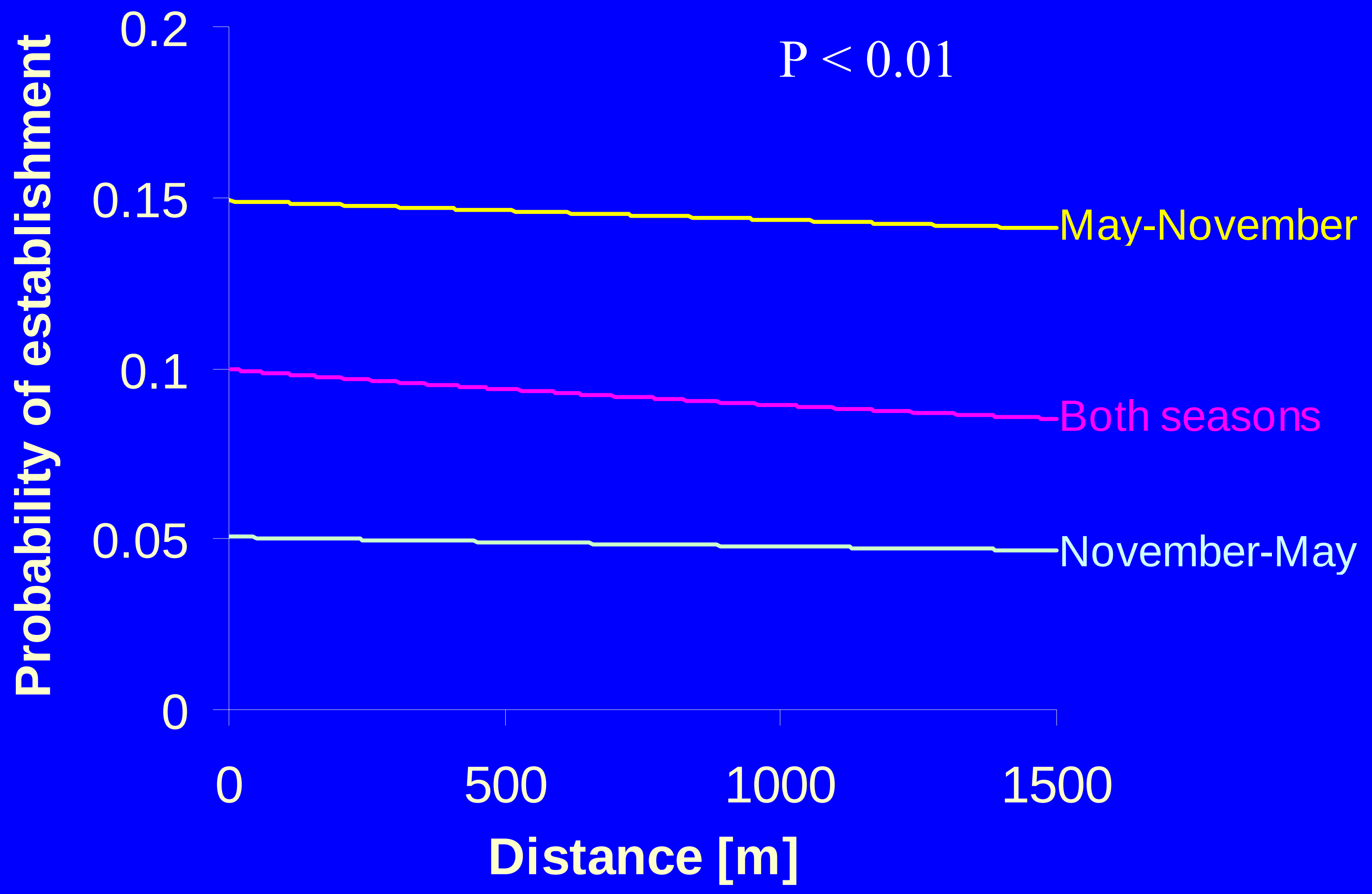
- 3 Parameters
- Estimated by maximum likelihood
- Algorithms:
  - Newton-Raphson
  - Fisher-Scoring
- Issues: Convergence, local maxima

Results

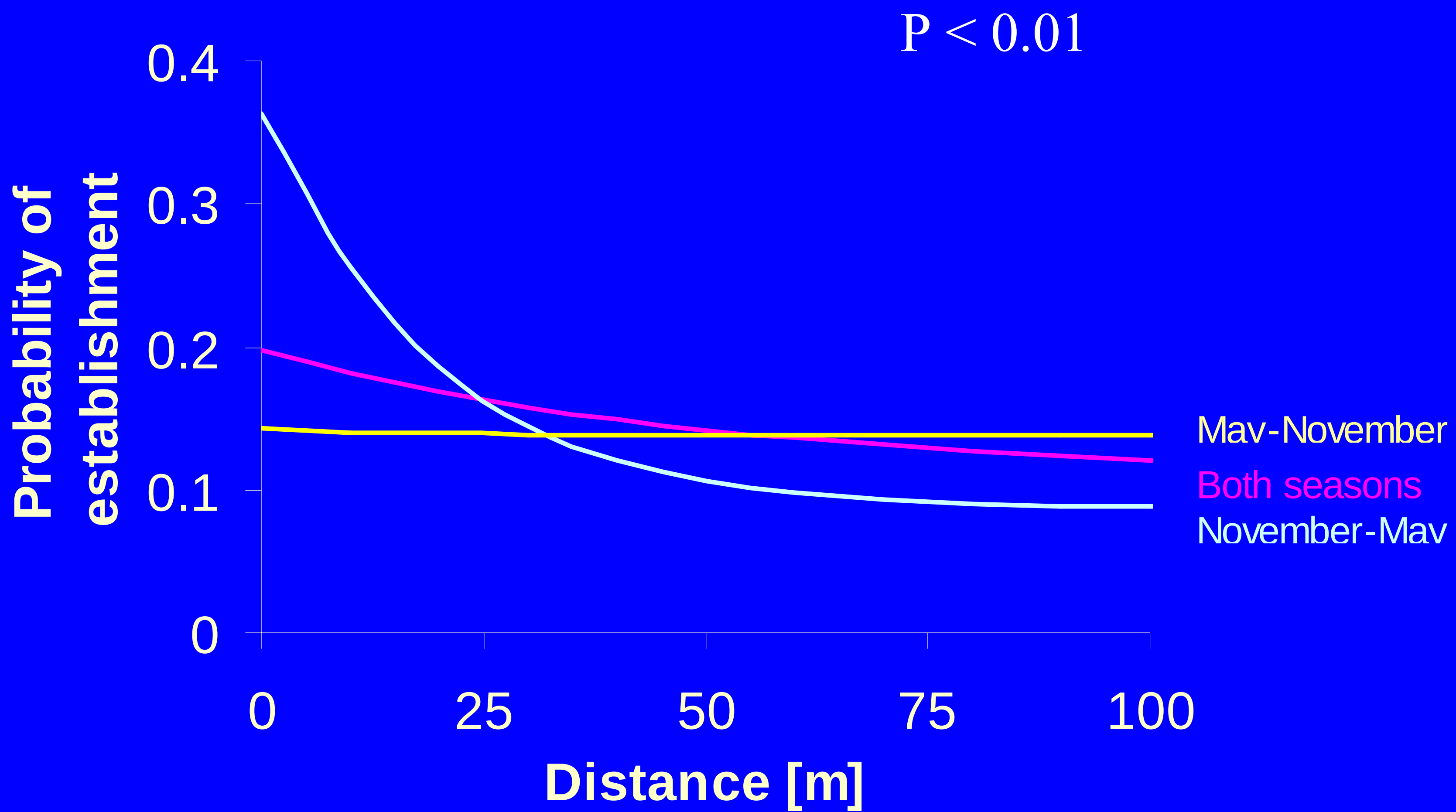
Values and P-values for distance parameter *b* (null hypothesis: *b* = 0):

	Amama	Merc./Trin.
Both seasons	$-5*10^{-4}$ 3228 m P = 0.37	$-2*10^{-2}$ 47 m P = 0.07
Nov-May	$-4*10^{-4}$ 5727 m P = 0.22	$-4.6*10^{-2}$ 7 m P = 0.04
May-Nov	$-2*10^{-4}$ 6054 m P = 0.25	$-1.6*10^{-3}$ 966 m P = 0.01

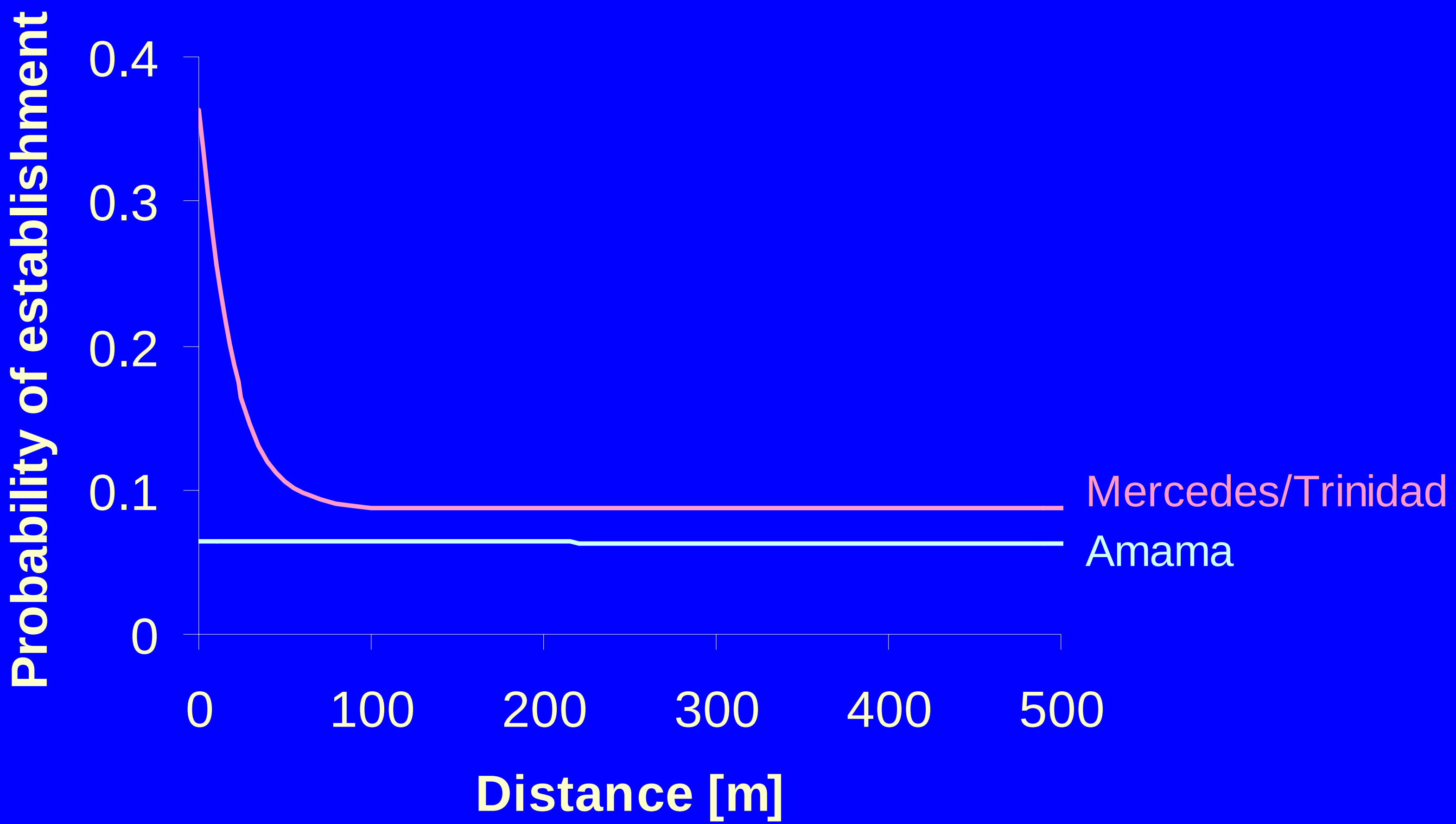
Amama: season matters more than distance



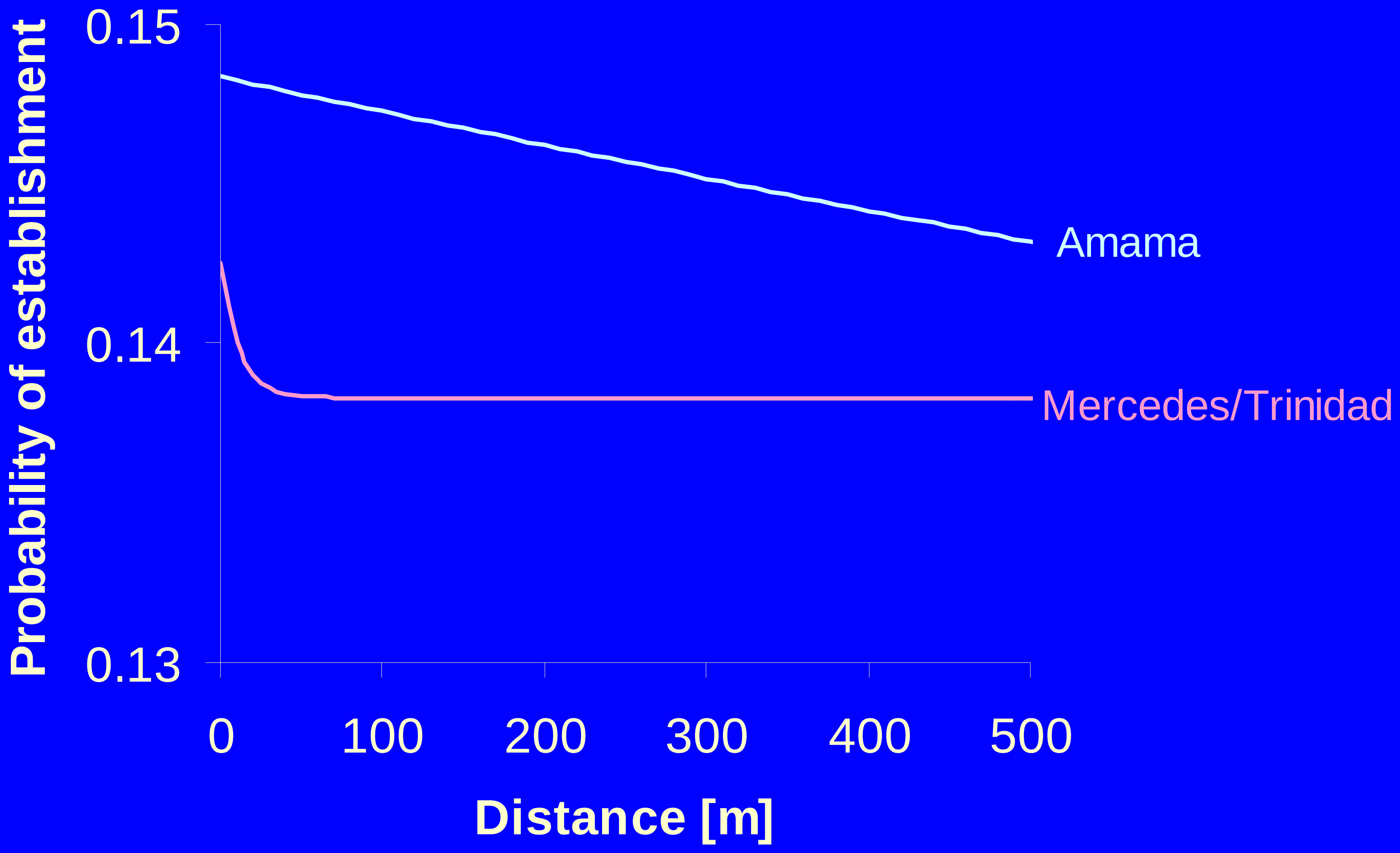
Mercedes/Trinidad: distance matters more than season



Village comparison November-May



Village comparison May-November



Conclusion:

- Effect of distance to source site on establishment probability is not significant in the village with less vegetation
- Effect of distance more visible during Nov-May (seasonal variation in detection?)

Outlook

- Extend present model:
  - Relax assumption of independence
  - Incorporate differences among ecotypes
  - Introduce variable time lags
- Build simulation model to explore control strategies
- Couple with transmission dynamics

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