OPTIMAL CONTROL OF AN INVASIVE USING REACTION DIFFUSION MODEL AND LINEAR PROGRAMMING

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Problem

- **Where and how much to allocate control effort?**

- In an ideal world:
  - **Survey**: to know where is the species.
  - **Experiment**: to understand the potential harms and the population's dynamic.
  - **Decide**: where and how much to control.

Problem

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Suitability Index
Species Distribution Model
Mark Recapture
Occupancy Model
Individual Based Model

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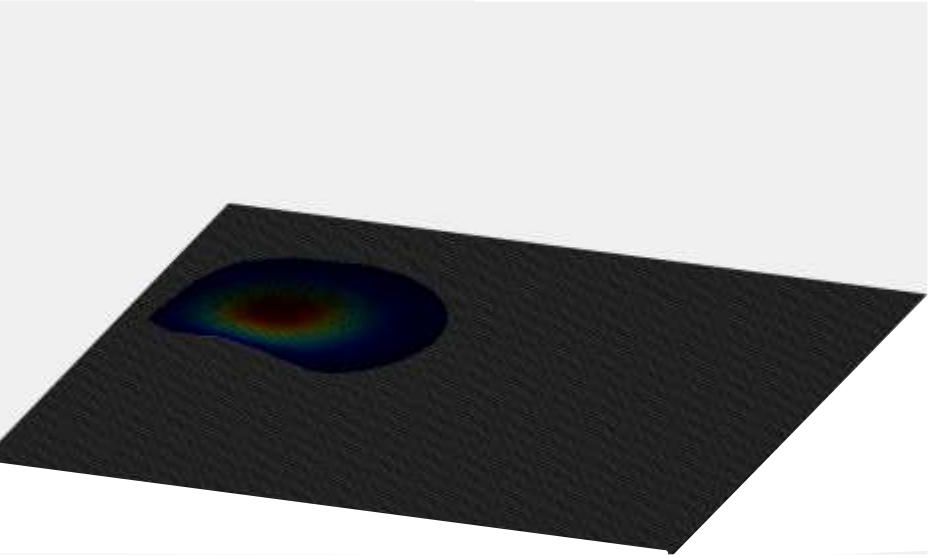
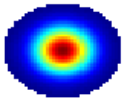
  - **Survey**: to know where is the species.
  - **Experiment**: to understand the potential harms and the population's dynamic.
  - **Decide**: where and how much to control.

Reaction-Diffusion (RD) Model





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- General Pattern
- Low number of parameters

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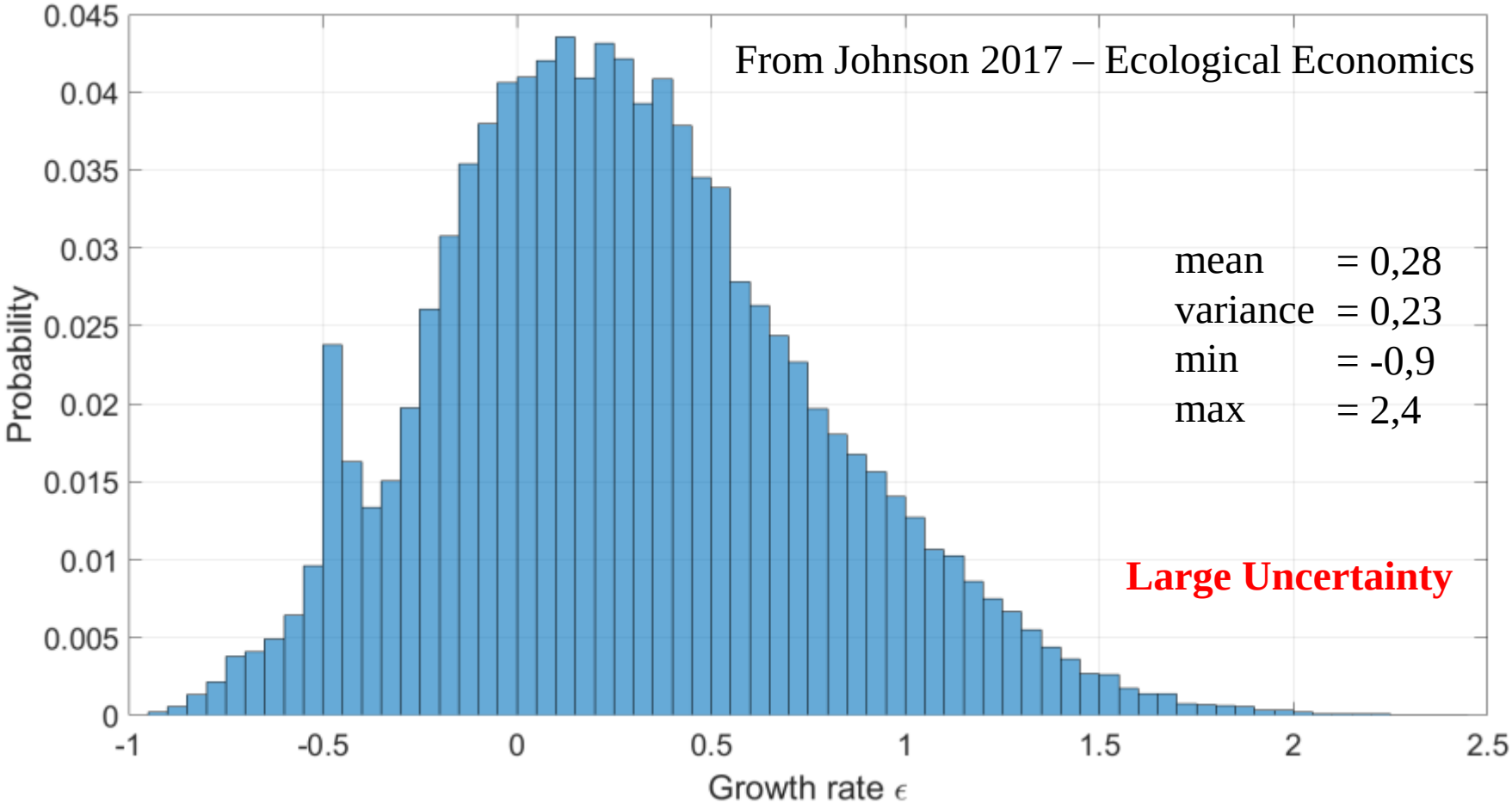
- Low number of parameters

HYPOTHESIS

- Point of first introduction.
- Population growth **€** and diffusion **D**.
- Smooth diffusion:
  - 98% of the population in the circle of radius $2\sqrt{4Dt}$

RD model for Tegus

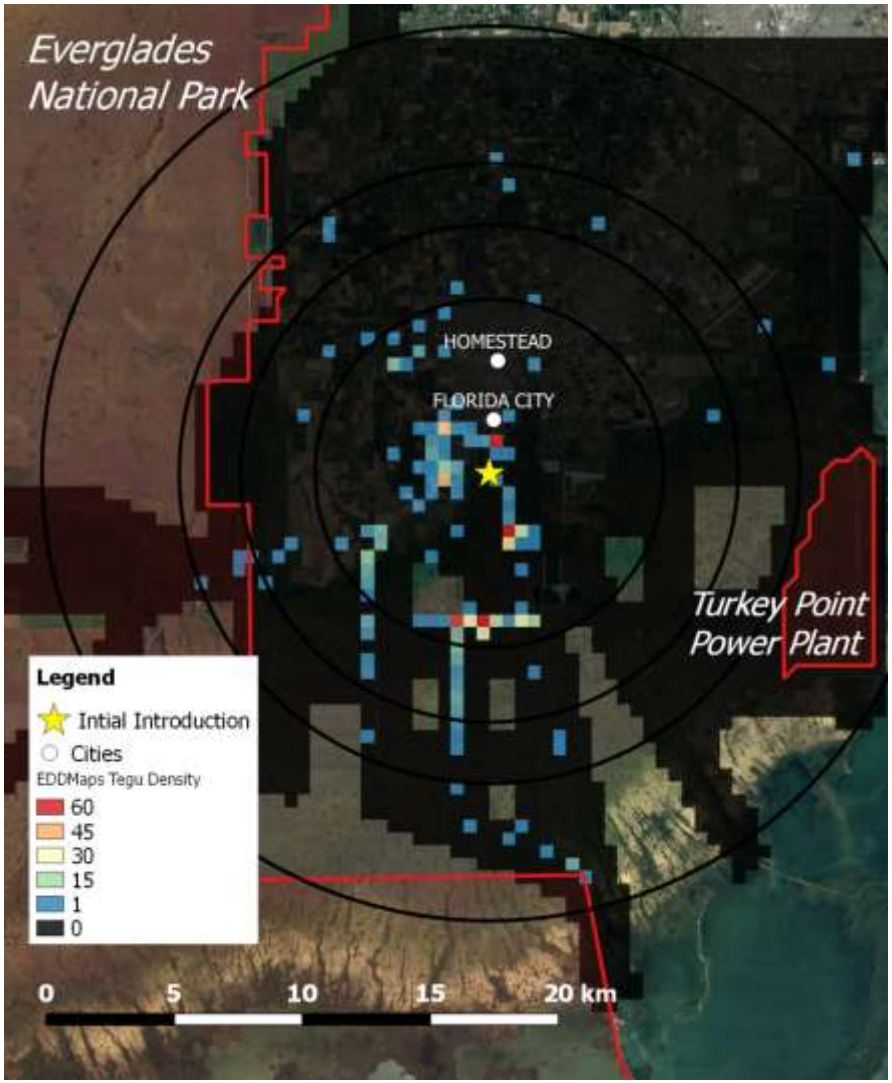
- Growth rate ϵ from expert elicitation



Distribution of simulated growth rates based on a 3-point elicitation from 10 equally weighted experts.

RD model for Tegus

- Diffusion coefficient from EDDMaps

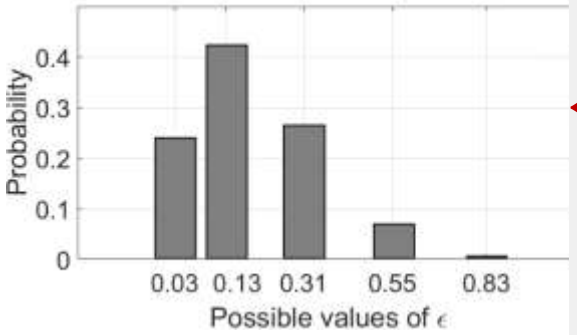


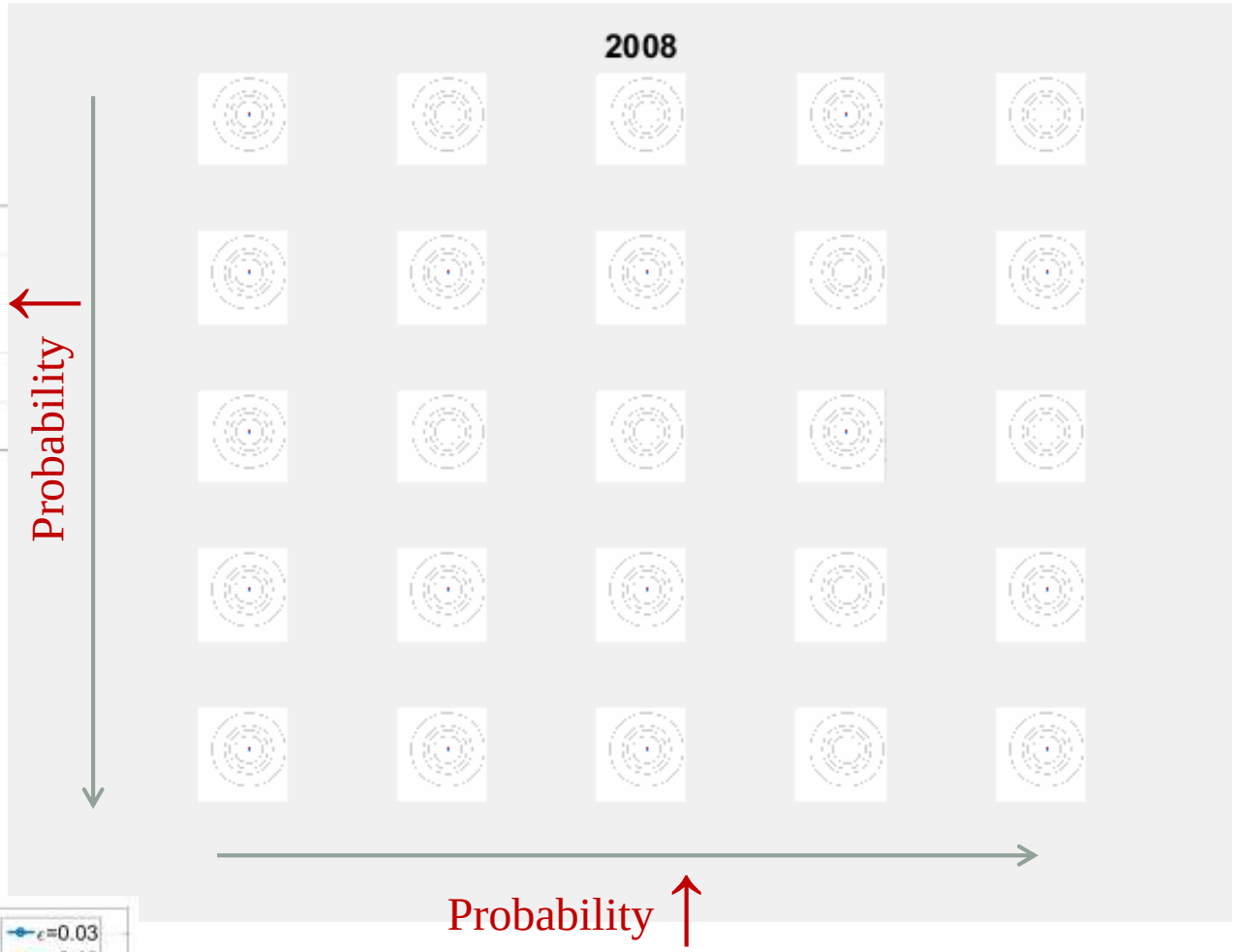
- EDDMaps presence only data, accessed in 2015.
- Estimation of the diffusion coefficient based on the cumulative occupied area.
- Not all the area is sampled equally.

Large Uncertainty

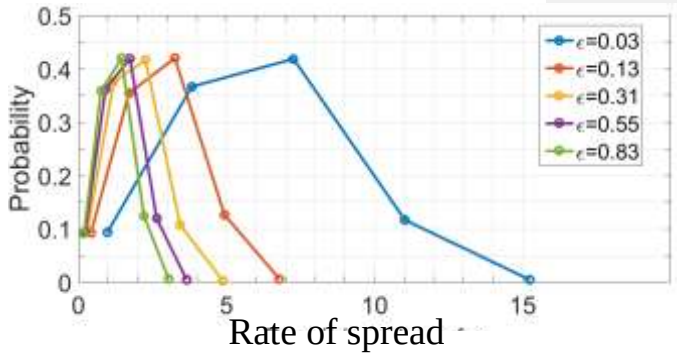
Uncertainty: 25 possible population's dynamic model

- Different **growth rates**:

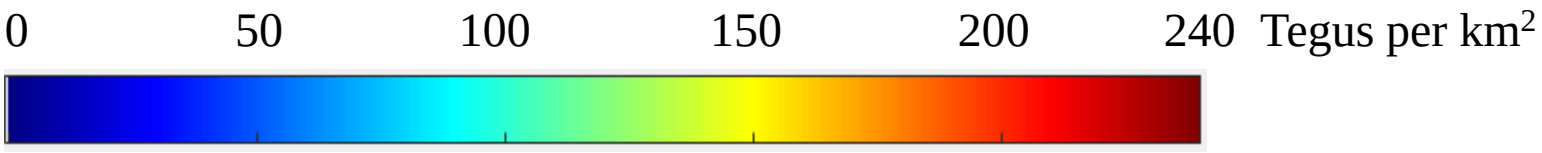


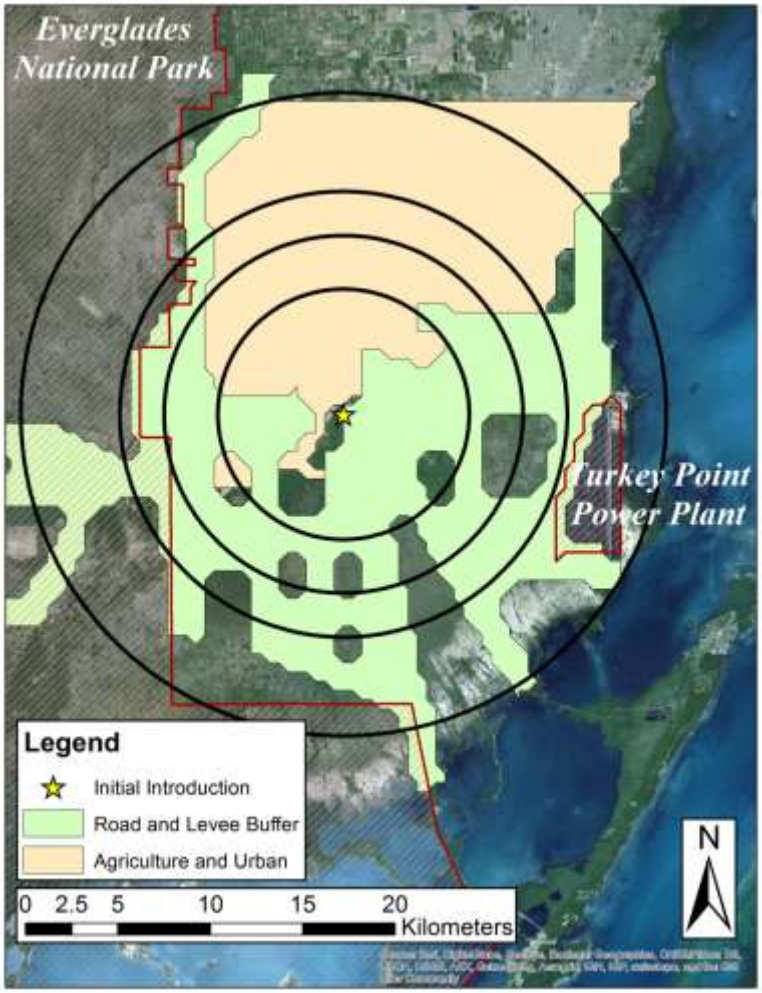


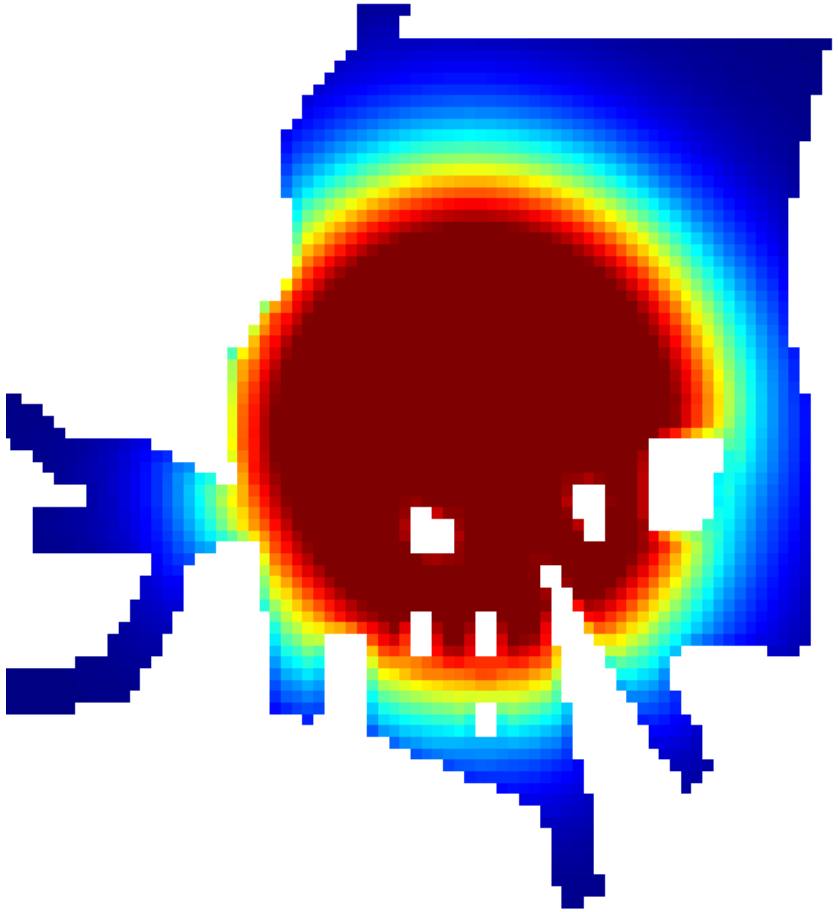
- Possible **associated rates of spread**:



Predictions: Worst Case

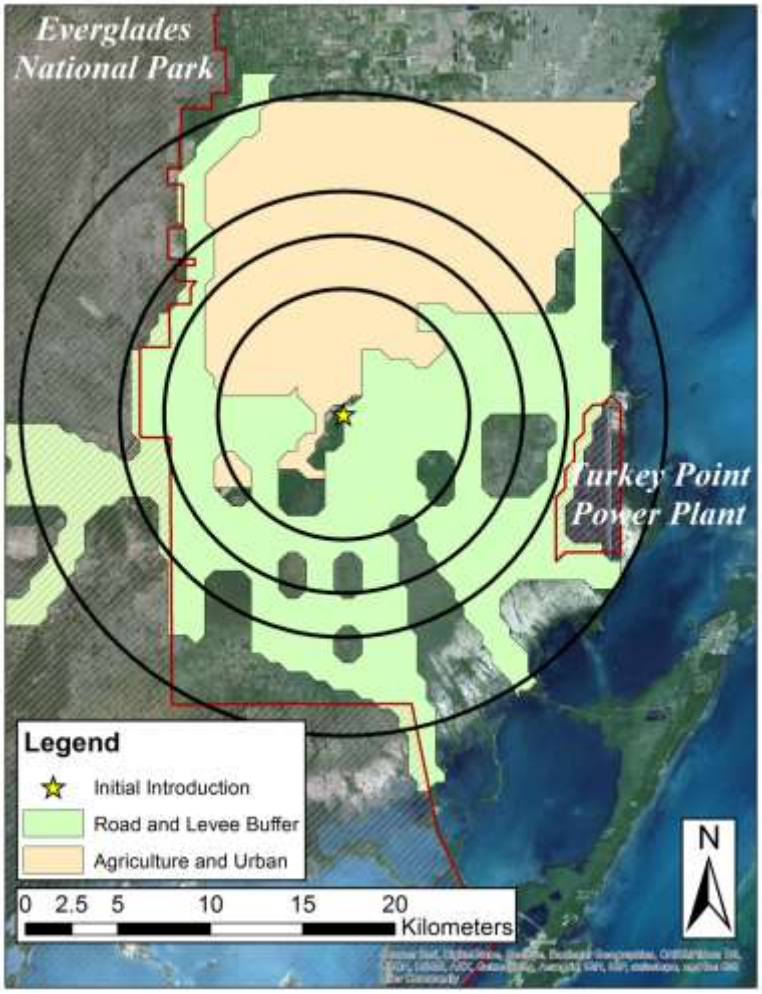


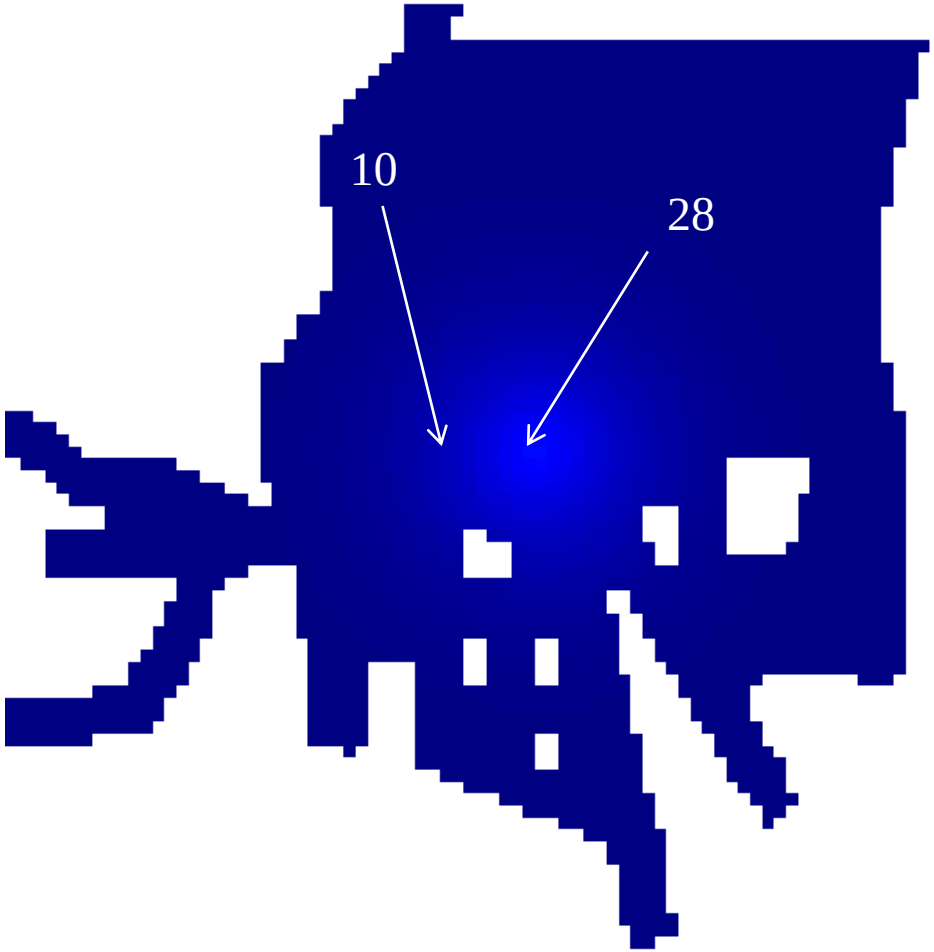




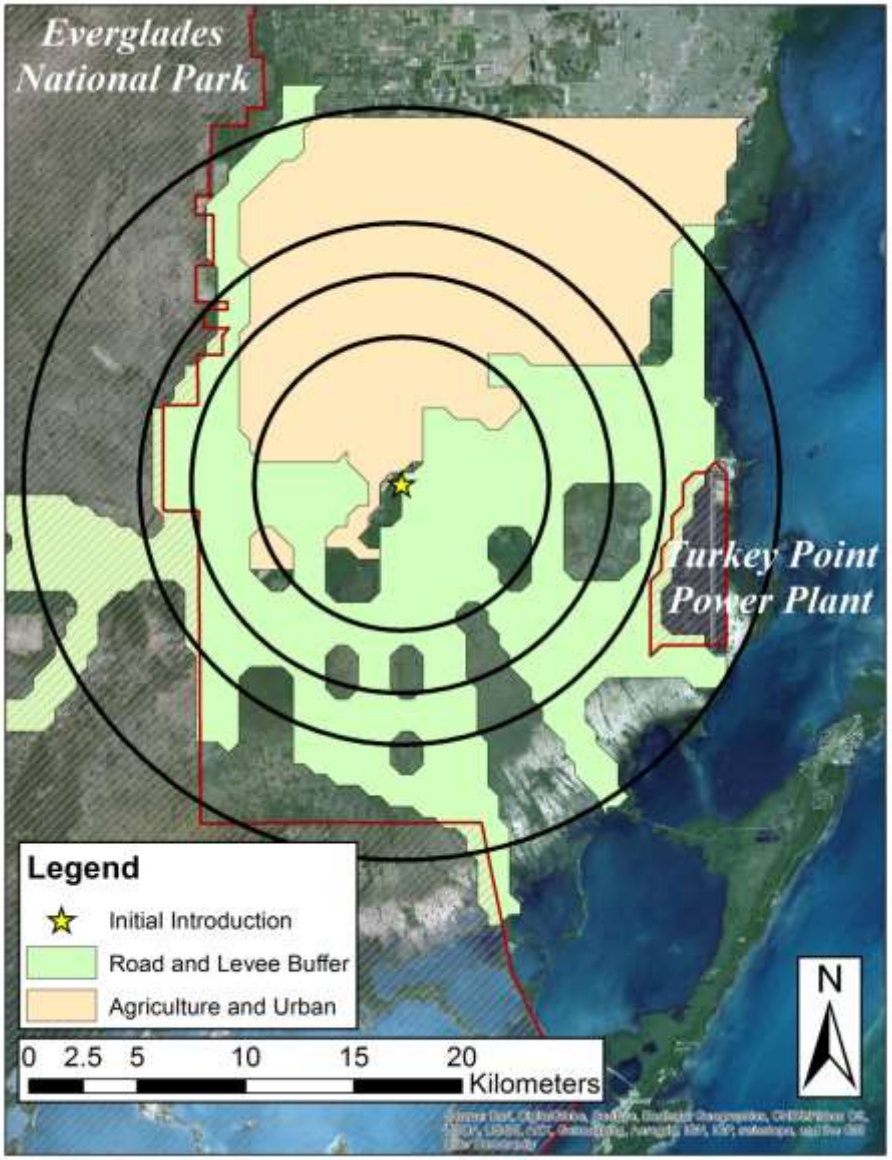
Most likely out of the 25 models

0 50 100 150 200 240 Tegus per km^2





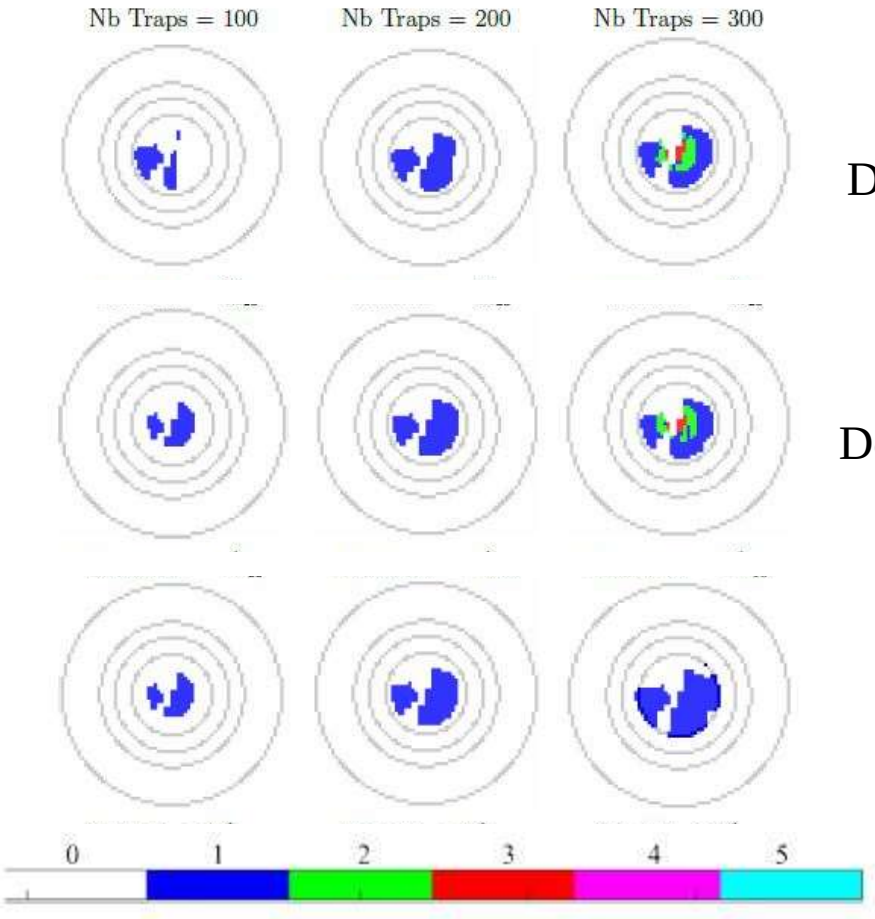
Predictions: Envelope



Optimization

- Where to allocate a fixed number of traps in order to remove as much tegu as possible?

Minimize tegus population



Nb of traps per cell

Risk attitude

Best – Worst
Does best in the worst case

Best – Average
Does best in the average case

Concentrate traps close to the point of first introduction

Best – Best
Does best in the best case

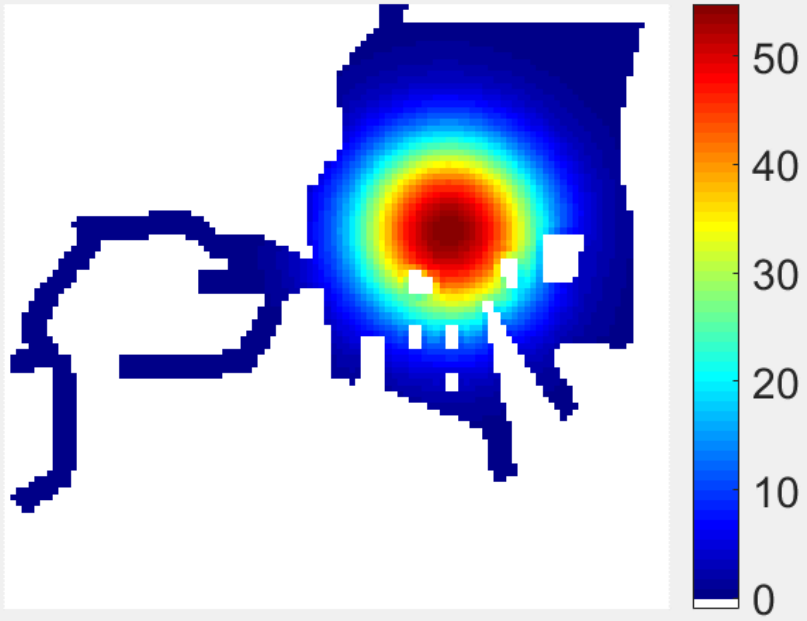
Spread the traps as much as possible

➢ Go where it is most likely to find the highest density

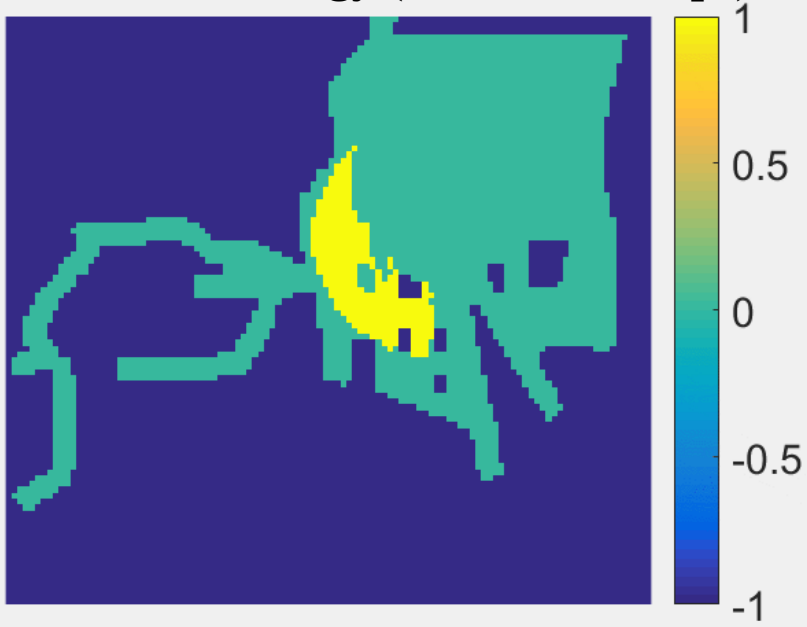
Minimize tegus population

- Current cpue = 0,035 (8,33 catch per season) and 300 traps.
- 5 traps maximal per cell (500m by 500m).
- Control starts in 2016
- No traps in Ag and urban area

Predictions (number of tegus)



Control Strategy (number of traps)

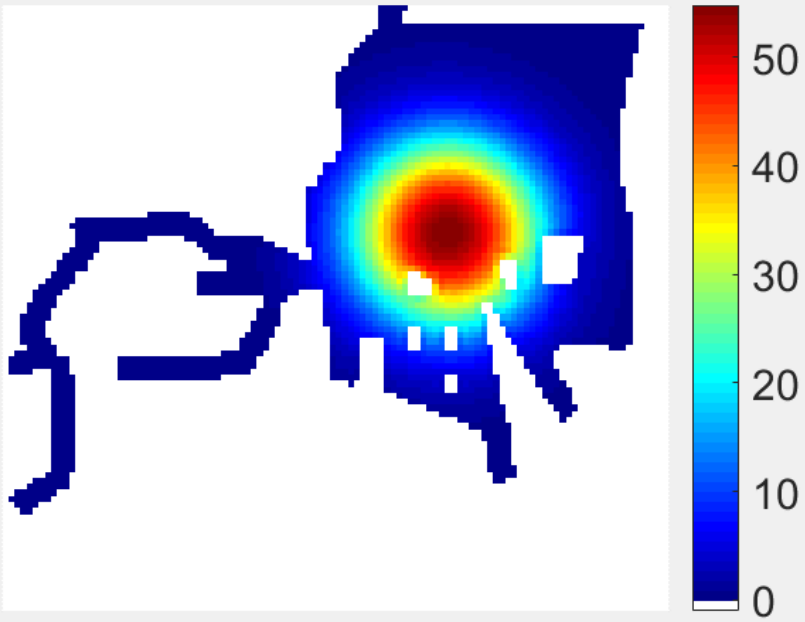


Minimize tegus population

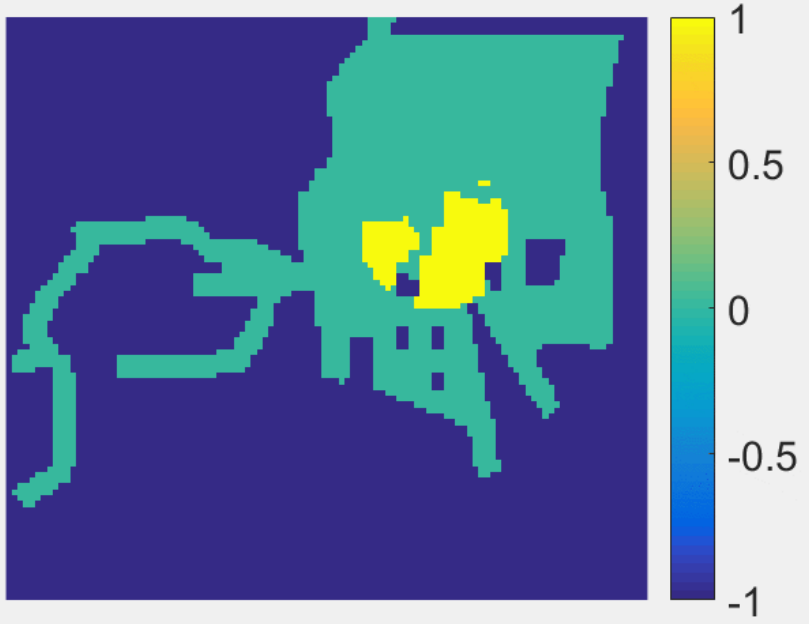
- cpue = 5 * 0,035 (41,6 catch per season) and 300 traps.
- 5 traps maximal per cell (500m by 500m).
- Control starts in 2016
- No traps in Ag and urban area

cpue increases

Predictions (number of tegus)



Control Strategy (number of traps)



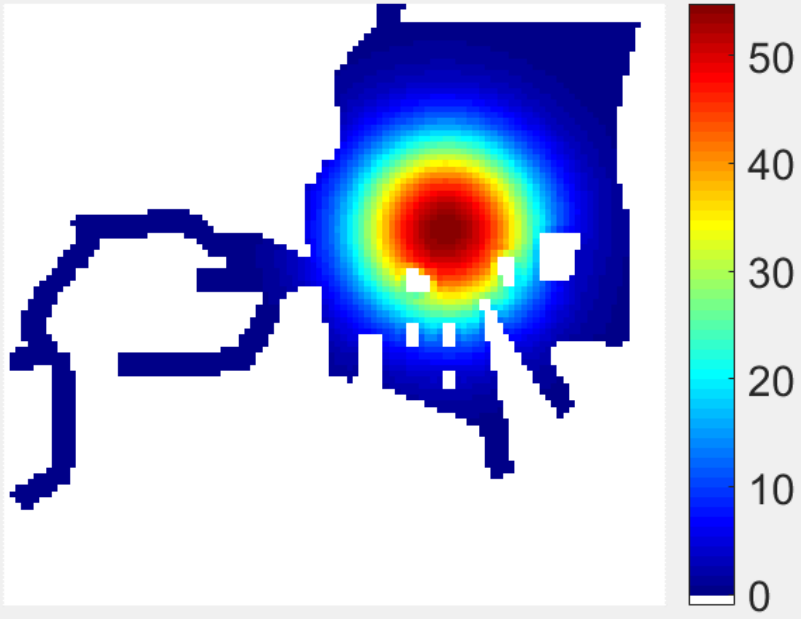
Minimize tegus population

- cpue = 5 * 0,035 (41,6 catch per season) and 500 traps.
- 5 traps maximal per cell (500m by 500m).
- Control starts in 2016
- No traps in Ag and urban area

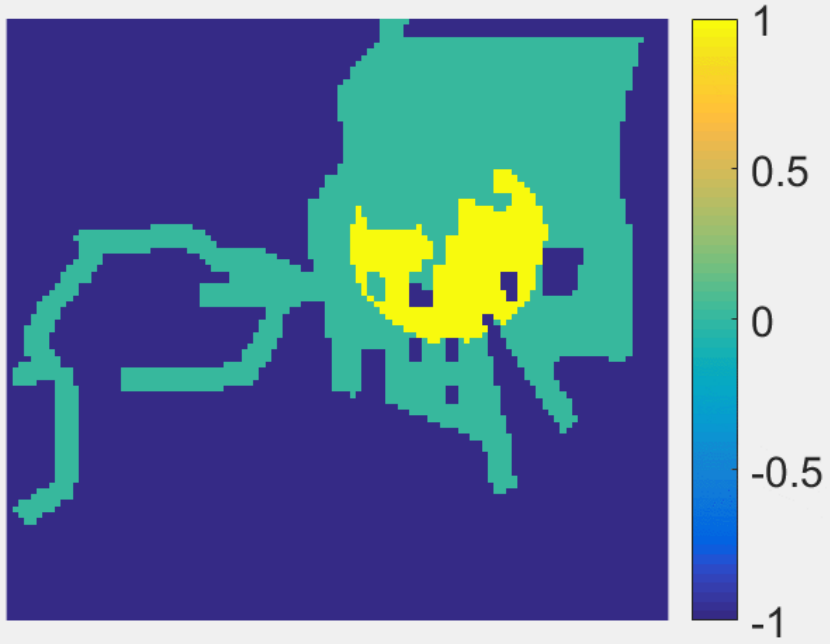
cpue increases

Number of traps increases

Predictions (number of tegus)



Control Strategy (number of traps)



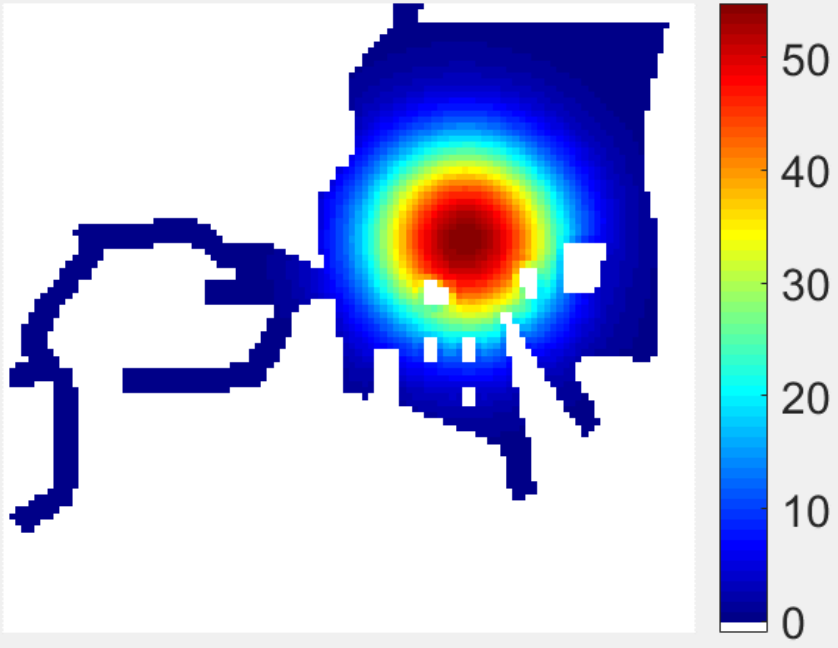
Minimize tegus population

- cpue = 5 * 0,035 (41,6 catch per season) and 800 traps.
- 5 traps maximal per cell (500m by 500m).
- Control starts in 2016
- No traps in Ag and urban area

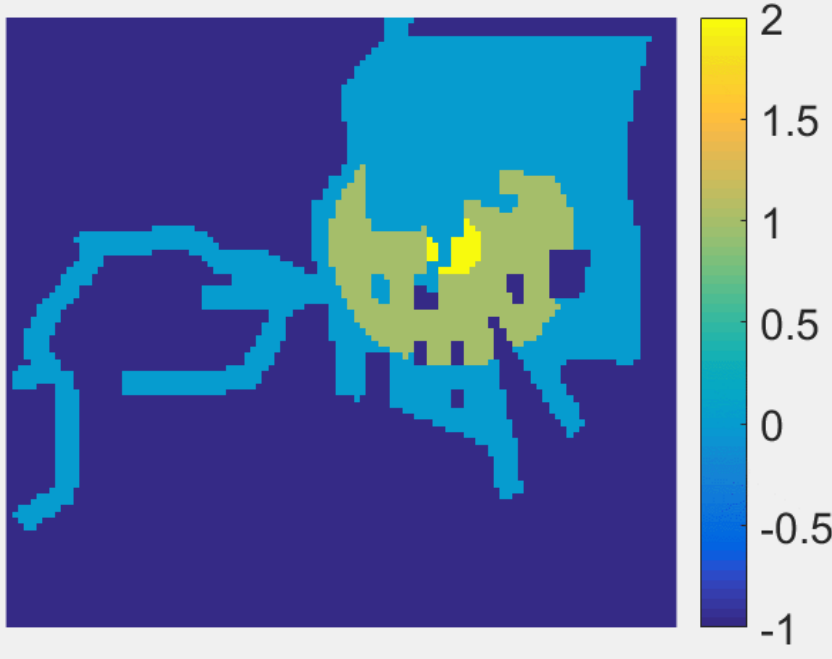
cpue increases

Number of traps increases

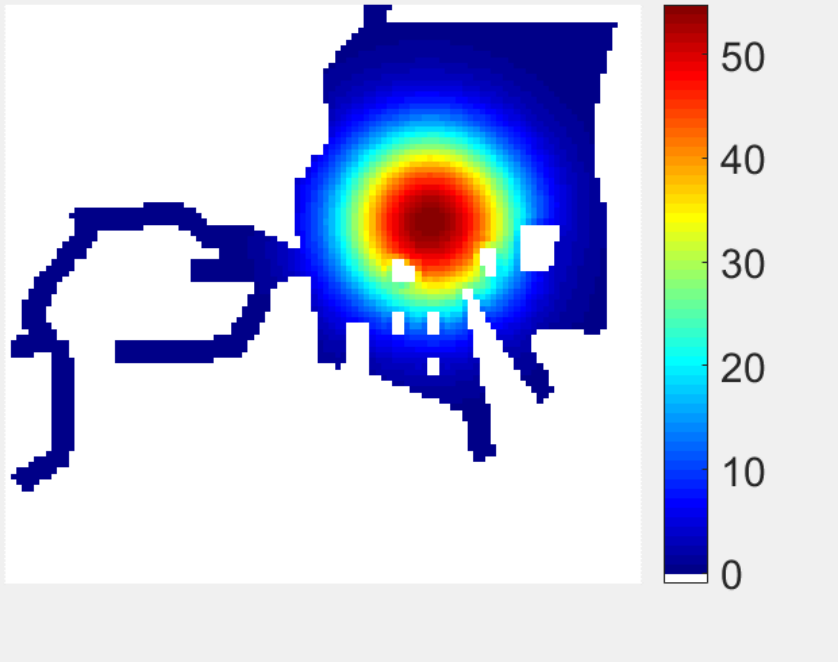
Predictions (number of tegus)

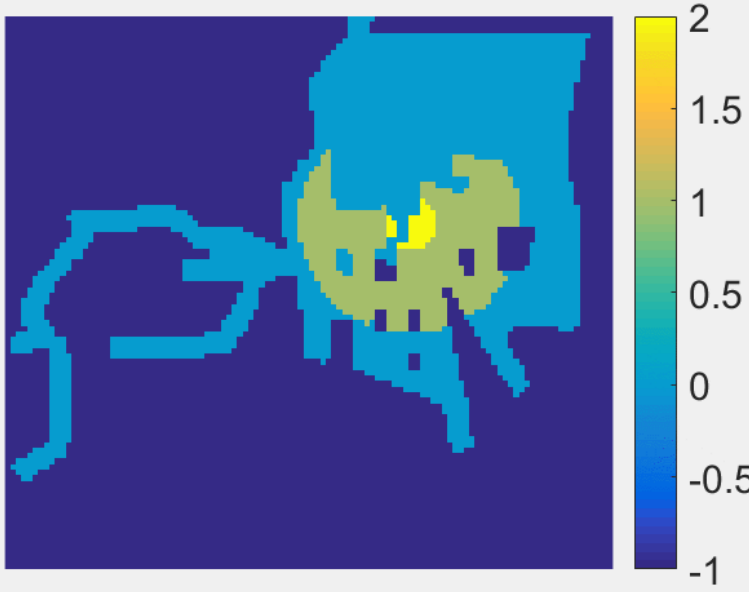


Control Strategy (number of traps)

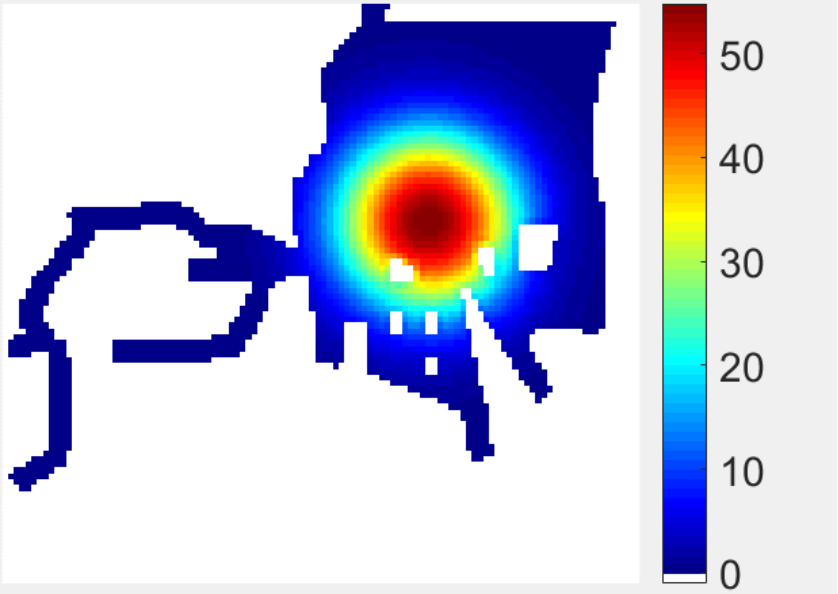


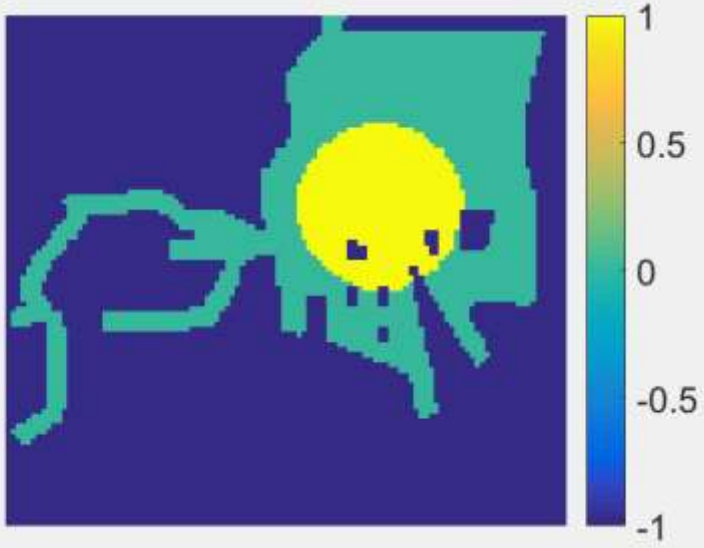
No traps in Ag and urban area





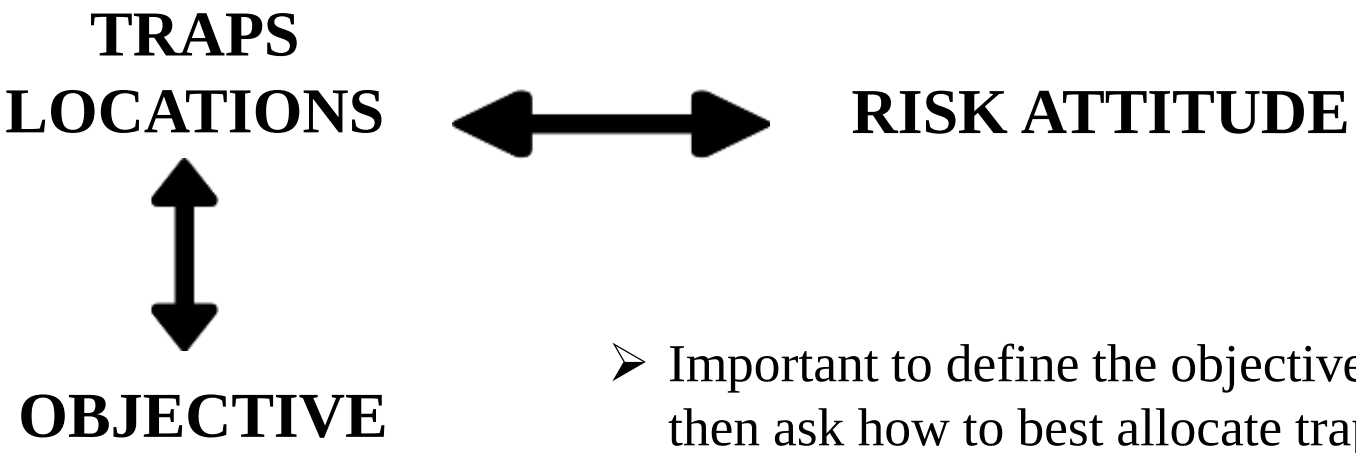
Traps everywhere





Conclusion

- An optimization framework to optimize allocation of control effort under constraints
  - Budget / Containment / Area prioritization



- Important to define the objective(s) and then ask how to best allocate traps

- Even if density can decrease punctually, if there is several satellite populations, they may explode later and the situation will become out of control.

- Toward a dynamic optimization framework to increase efficacy.

Acknowledgment

- USGS Invasive Species Program.
- Greater Everglades Priority Ecosystem Science.
- University of Florida
  - IFAS and Department of Wildlife Ecology and Conservation.