



HAL
open science

Optimal control of an invasive using reaction diffusion model and linear programming

Mathieu Bonneau, Fred Johnson A., Brian J. Smith, Christina M Romagosa, Julien Martin, Frank Mazzotti

► To cite this version:

Mathieu Bonneau, Fred Johnson A., Brian J. Smith, Christina M Romagosa, Julien Martin, et al.. Optimal control of an invasive using reaction diffusion model and linear programming. GEER 2017, Apr 2017, Coral Springs, Floride, United States. , 2017. hal-01607506

HAL Id: hal-01607506

<https://hal.science/hal-01607506>

Submitted on 2 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - ShareAlike 4.0 International License

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

Mathieu Bonneau¹, Fred A. Johnson², Brian J. Smith³, Christina M. Romagosa¹, Julien Martin², and Frank J. Mazzotti³.

¹ Department of Wildlife Ecology and Conservation.
University of Florida.
Gainesville, Florida.



² Wetland and Aquatic Research Center.
U.S. Geological Survey.
Gainesville, Florida.



³Research and Education Center
University of Florida.
Ft Lauderdale, Florida.

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

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

Suitability Index

Species Distribution Model

Mark Recapture

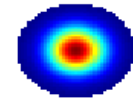
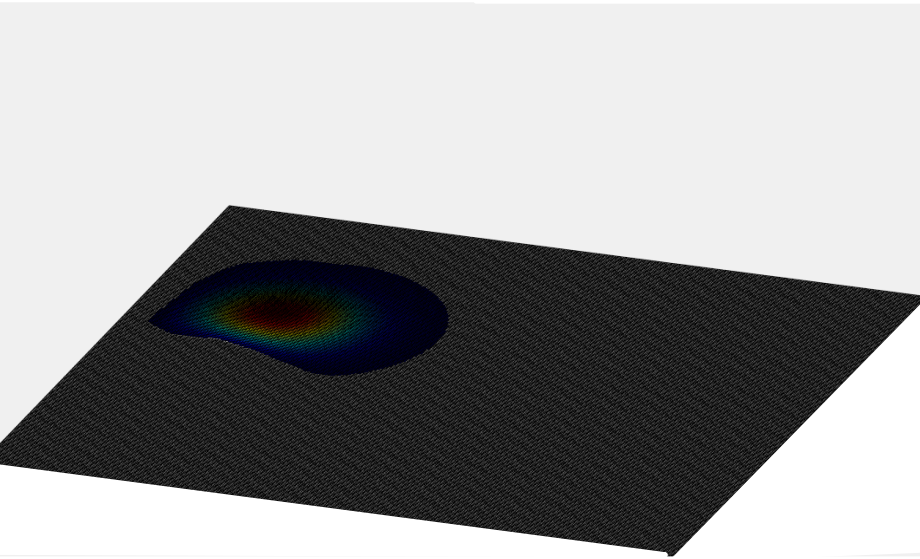
Occupancy Model

Individual Based Model

- 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.



Reaction-Diffusion (RD) Model



+

-

- General Pattern
- Low number of parameters

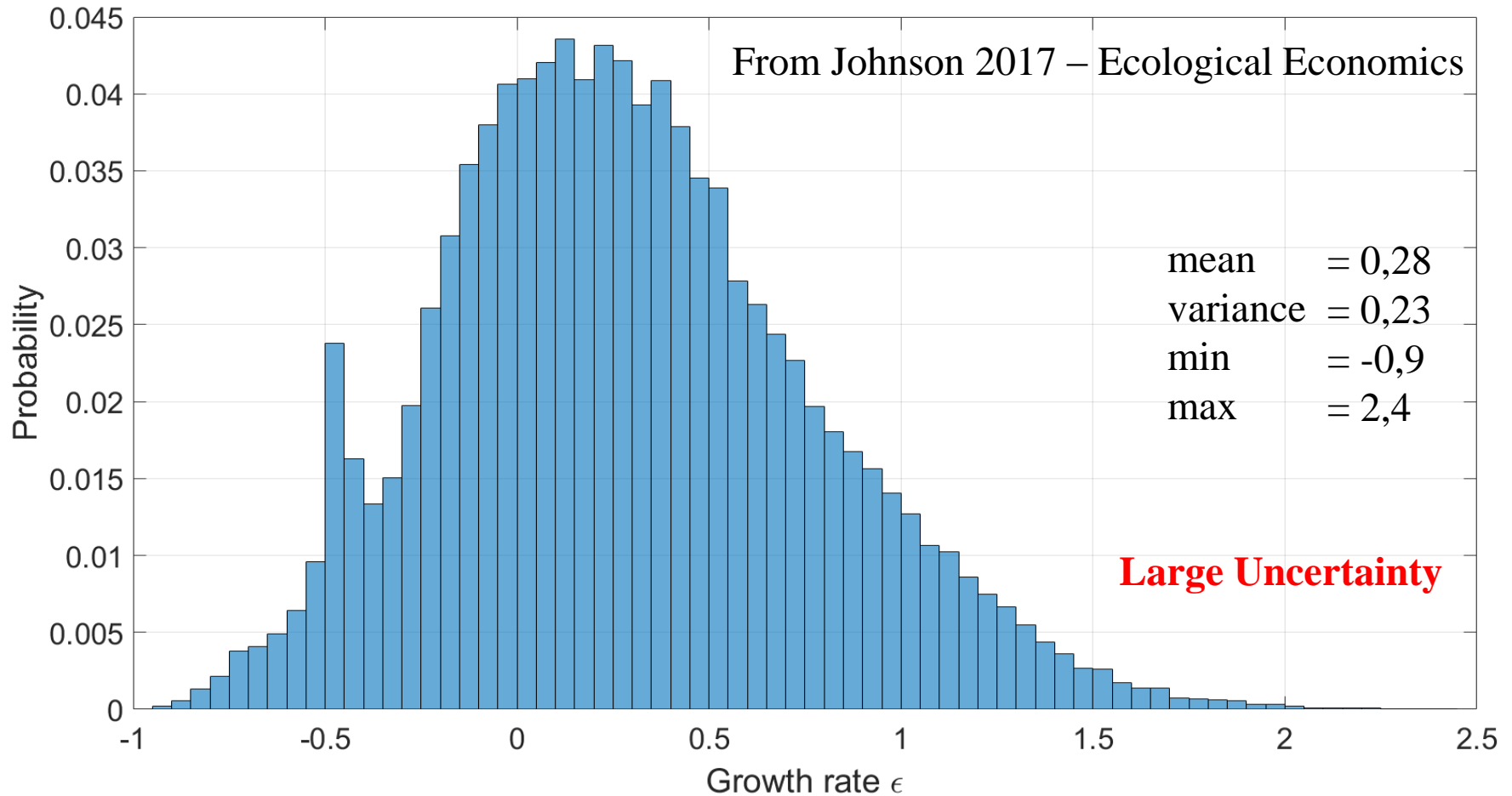
- General Pattern
- Low number of parameters

HYPOTHESIS

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

RD model for Tegus

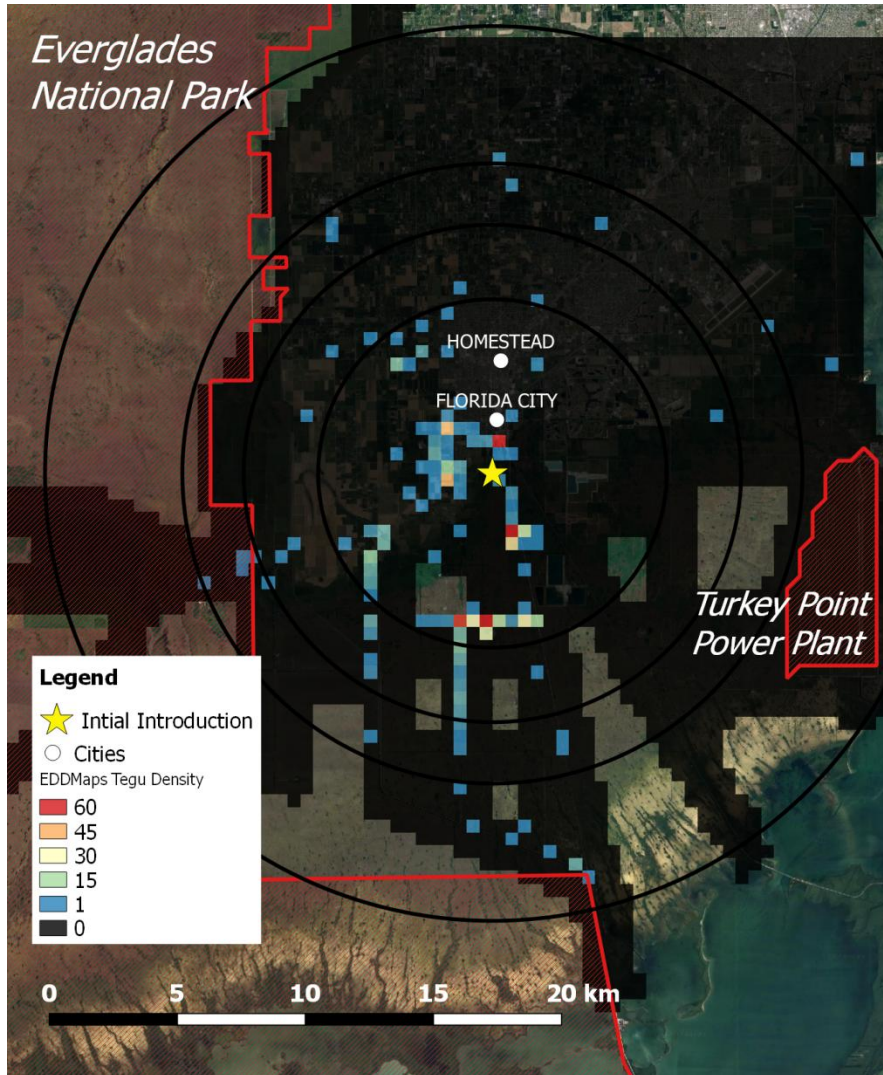
- Growth rate ϵ from expert elicitation



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

RD model for Tegus

- Diffusion coefficient from EDDMaps

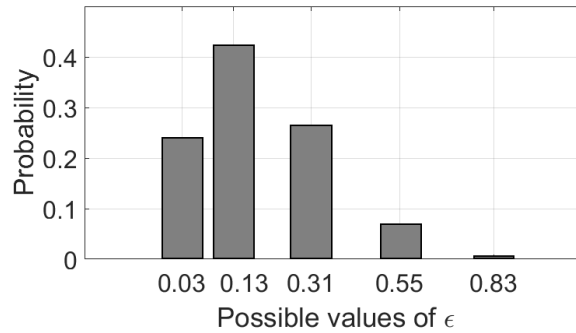


- EDDMaps presence only data, accessed in 2015.
- Estimation of the diffusion coefficient based on the cumulative occupied area.
- Not all the area is sampled equally.

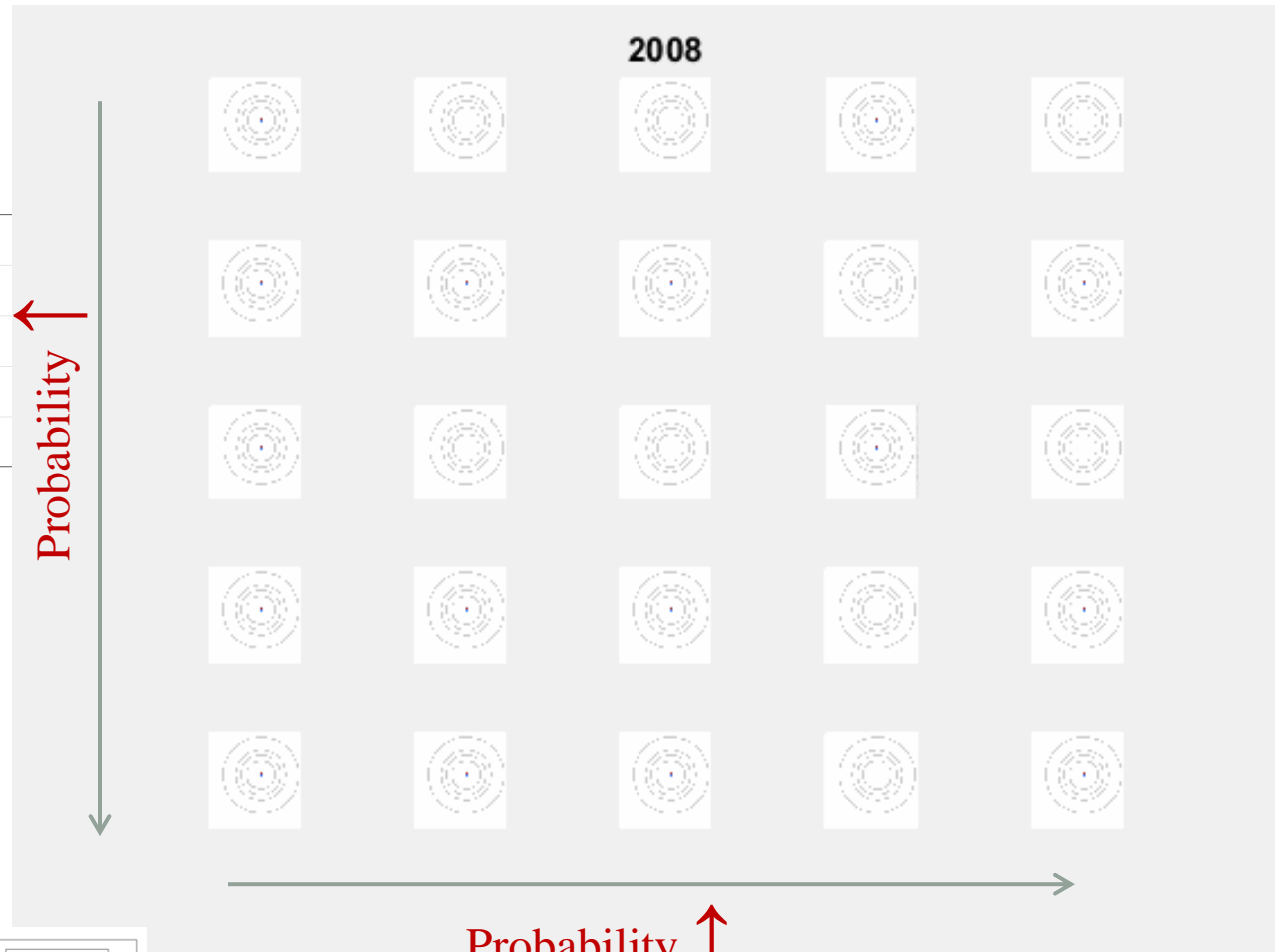
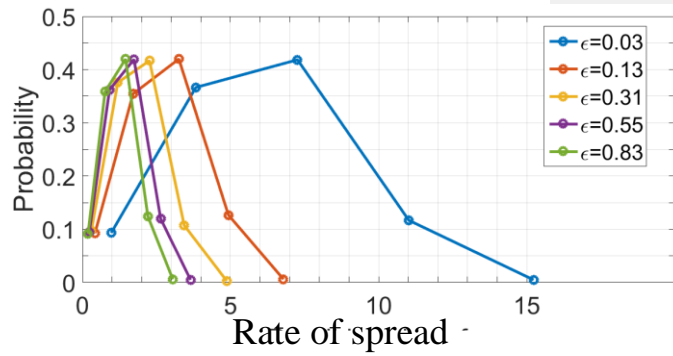
Large Uncertainty

Uncertainty: 25 possible population's dynamic model

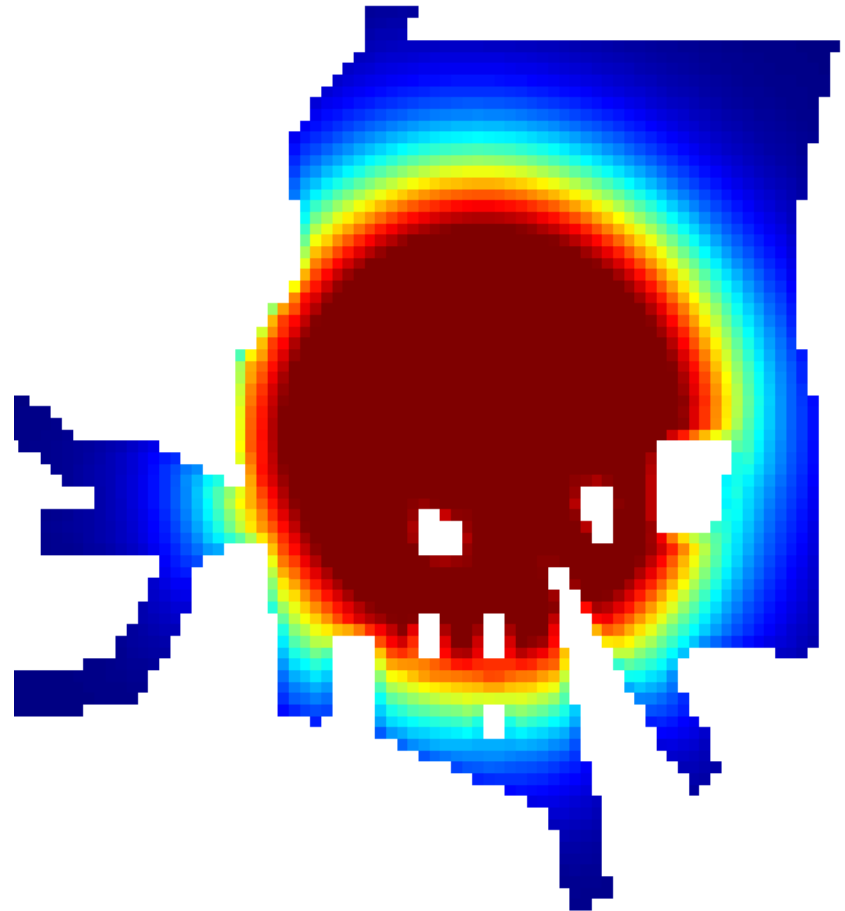
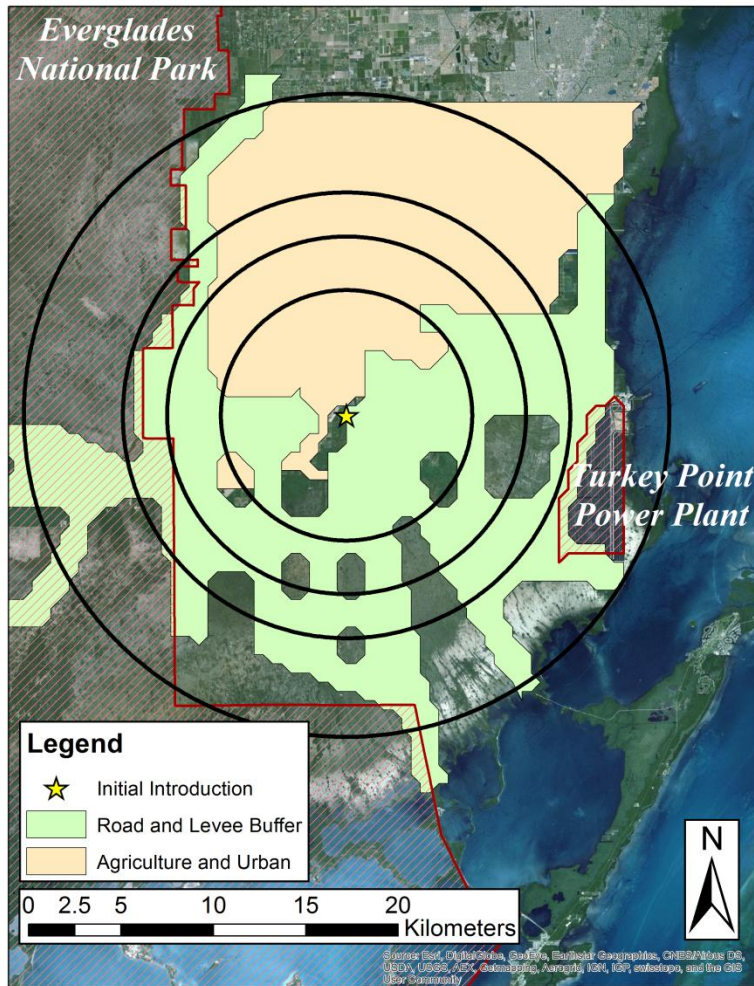
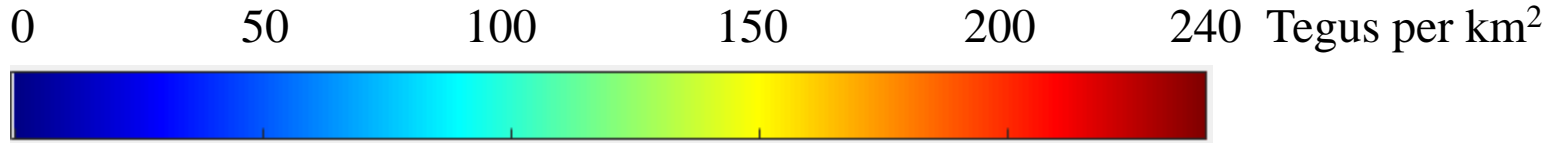
- Different **growth rates:**



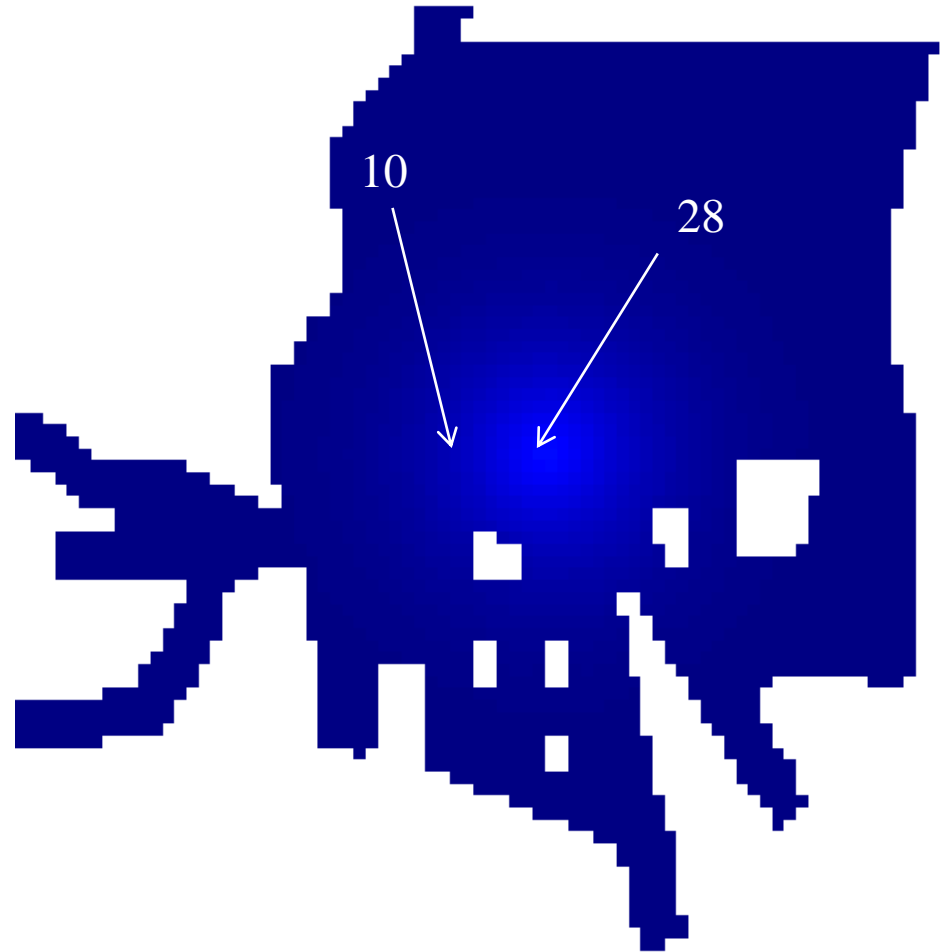
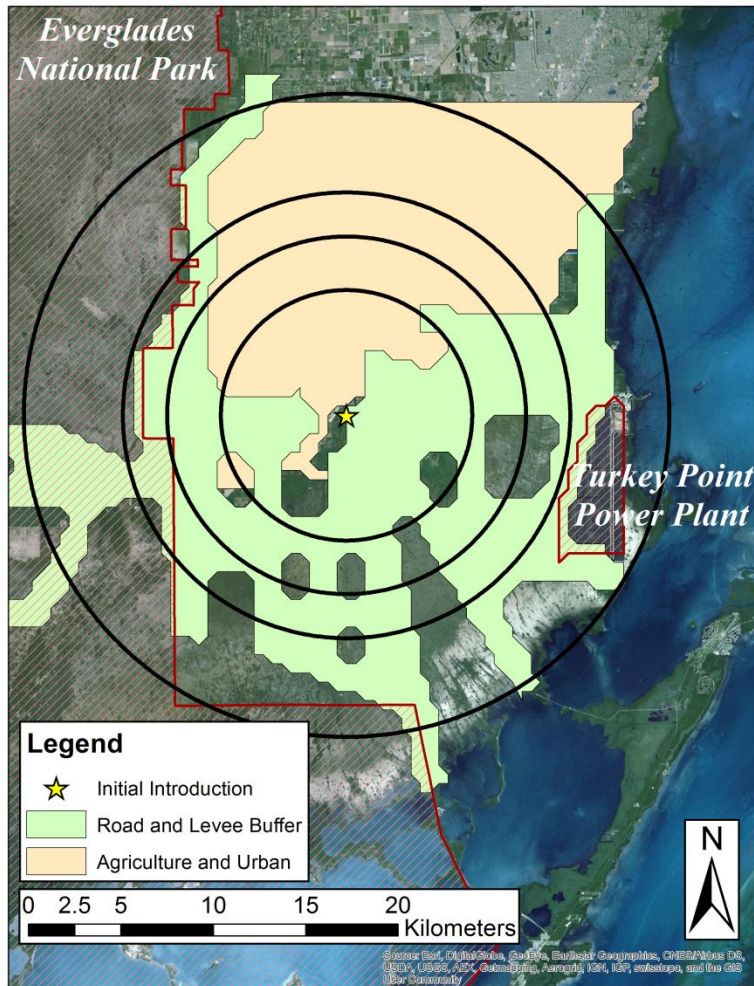
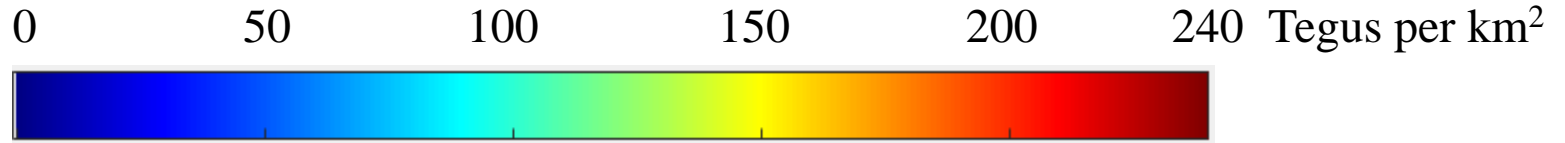
- Possible associated rates of spread:



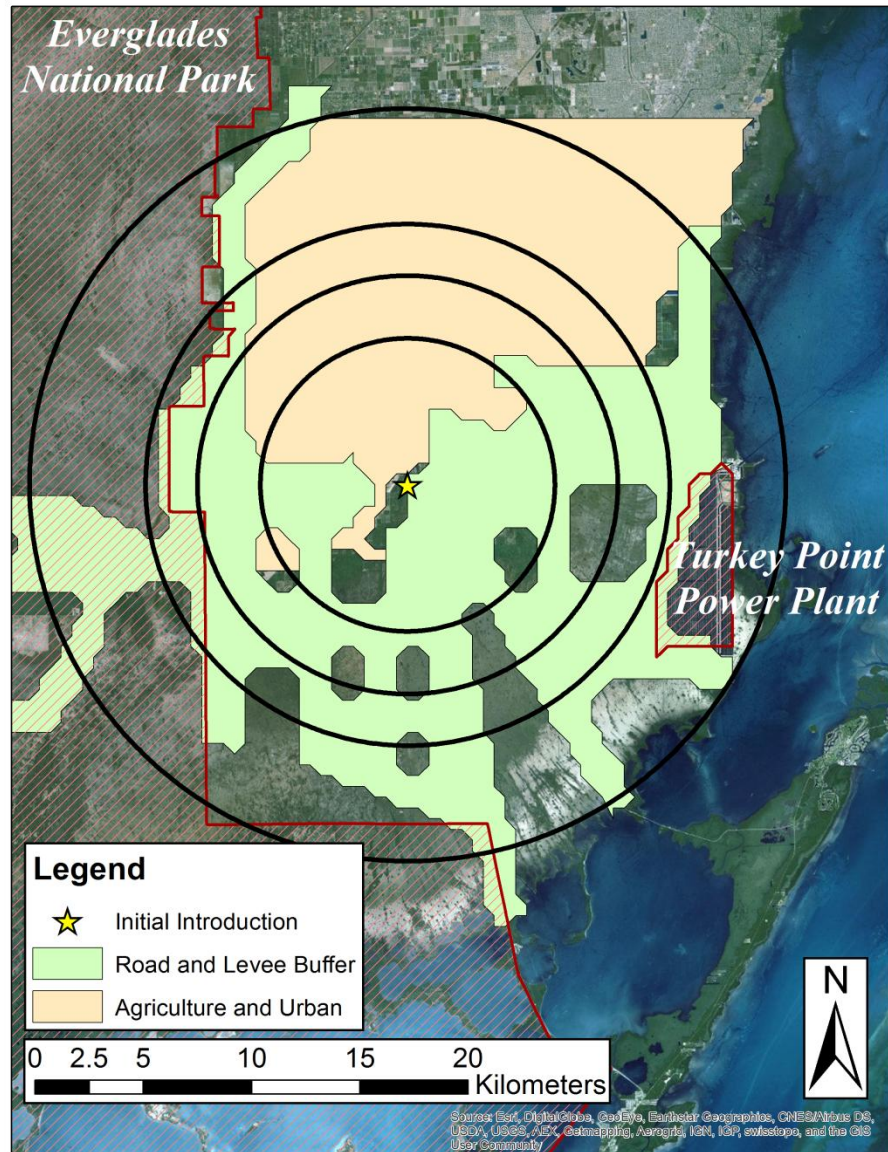
Predictions: Worst Case



Most likely out of the 25 models



Predictions: Envelope



Optimization

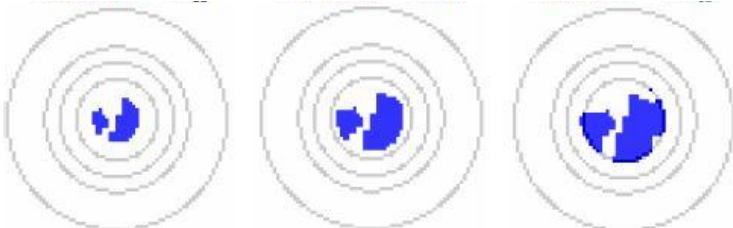
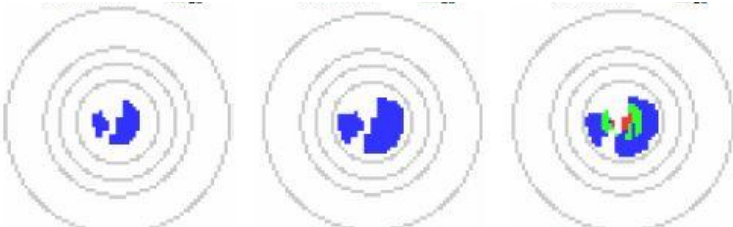
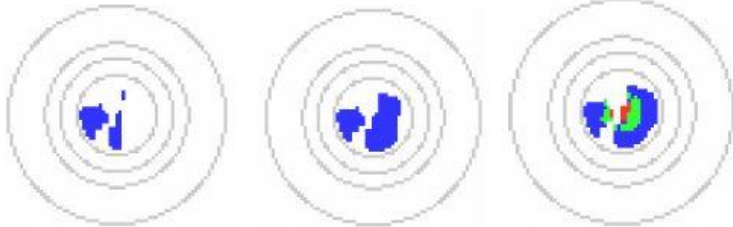
- How to minimize tegu's population with a fixed number of traps?
- Equivalently, how to maximize the number of removed tegus?

Minimize tegus population

Nb Traps = 100

Nb Traps = 200

Nb Traps = 300



0 1 2 3 4 5

Nb of traps per cell

Risk attitude

Best – Worst

Does best in the worst case

Best – Average

Does best in the average case

Best – Best

Does best in the best case

Concentrate traps
close to the point
of first introduction

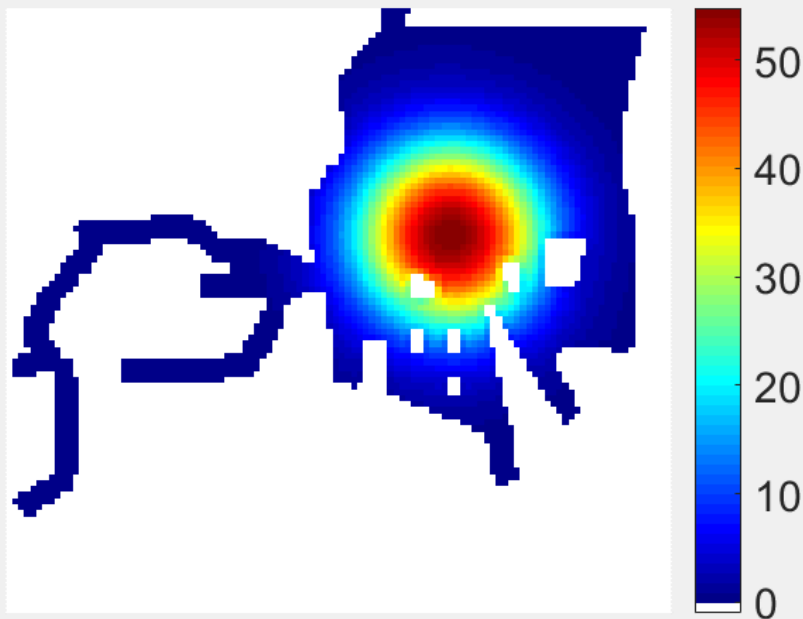
Spread the traps as
much as possible

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

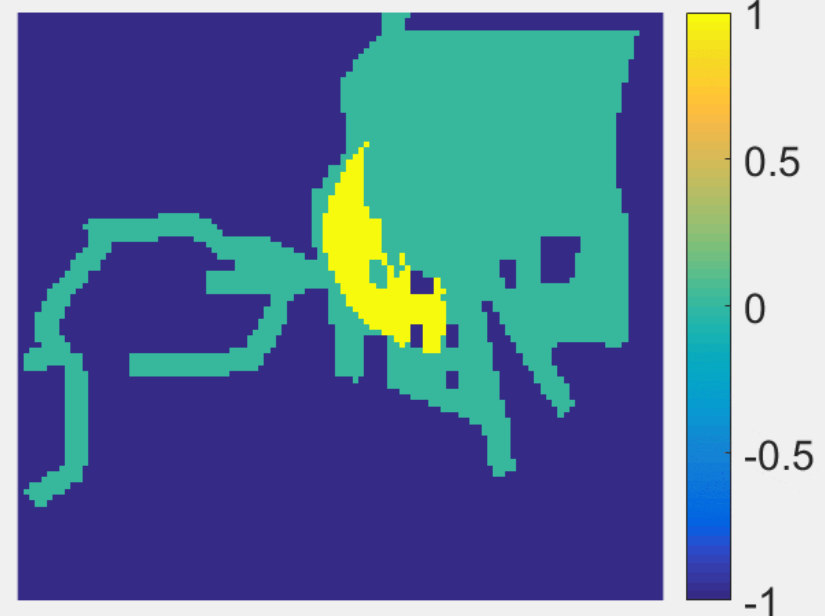
Minimize tegus population

- 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)

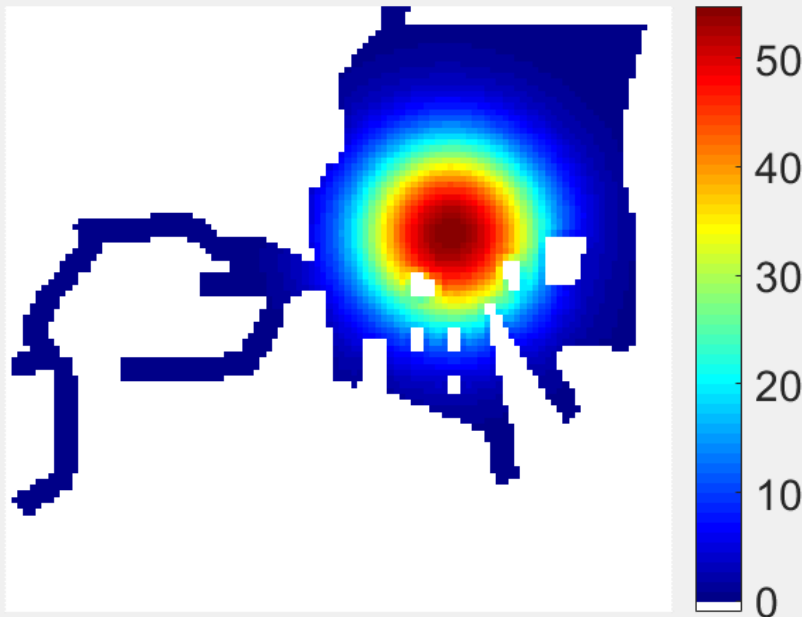


Minimize tegus population

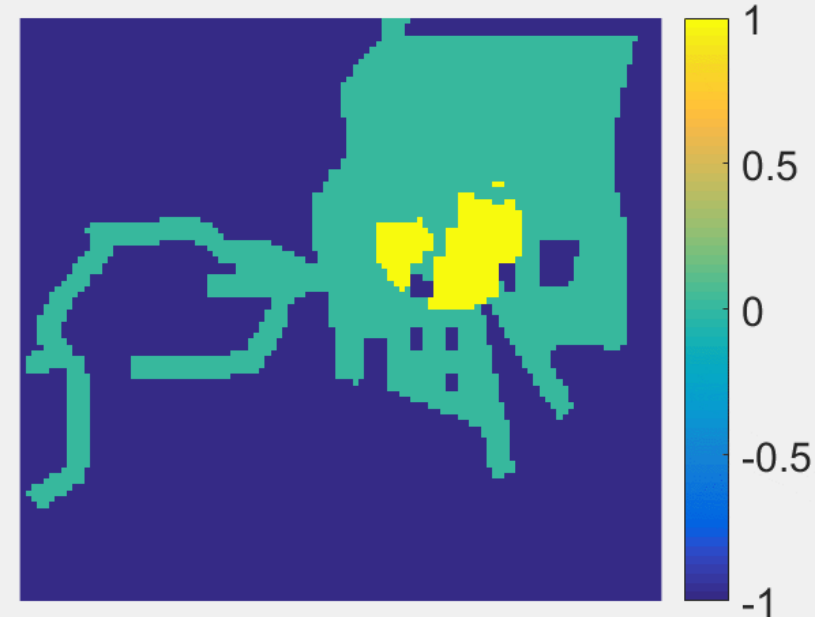
- $cpue = 5 * 0,035$ (41,6 catch per season) and 300 traps.
- 5 traps maximal per cell (500m by 500m).
- Control starts in 2016
- No traps in Ag and urban area

cpue increases

Predictions (number of tegus)



Control Strategy (number of traps)



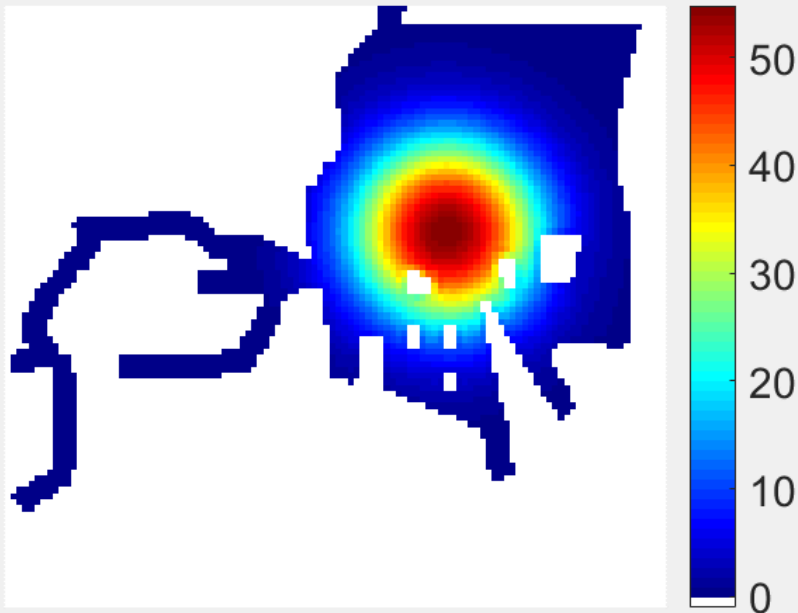
Minimize tegus population

- $cpue = 5 * 0,035$ (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

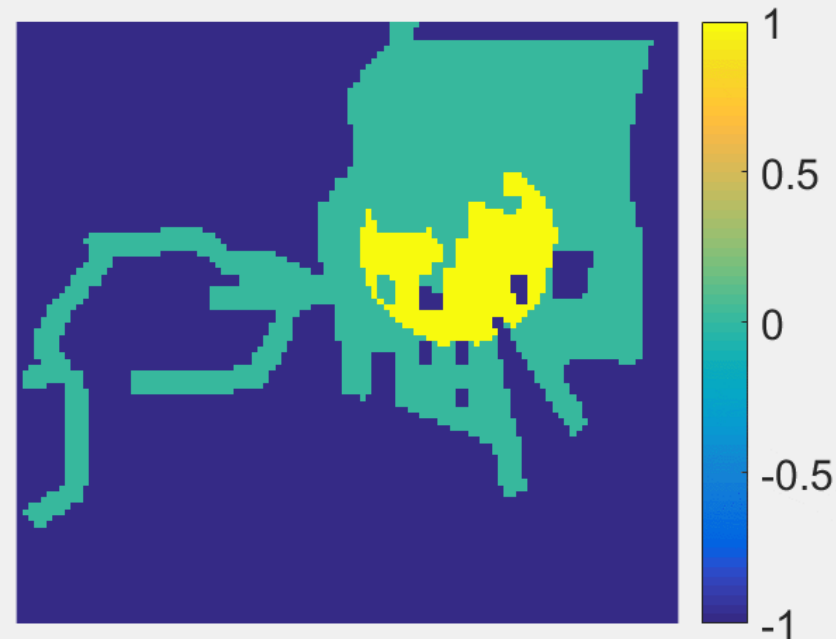
cpue increases

Number of traps increases

Predictions (number of tegus)



Control Strategy (number of traps)



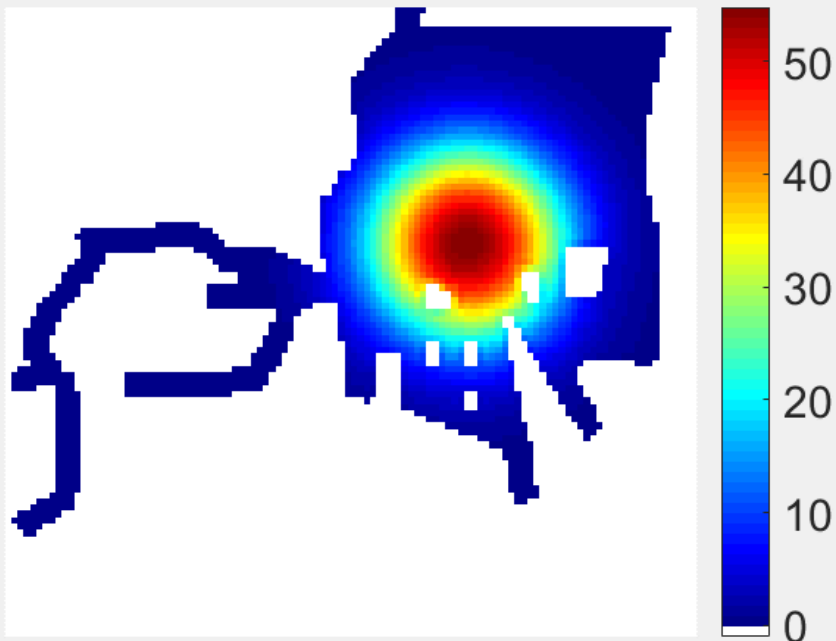
Minimize tegus population

- $\text{cpue} = 5 * 0,035$ (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

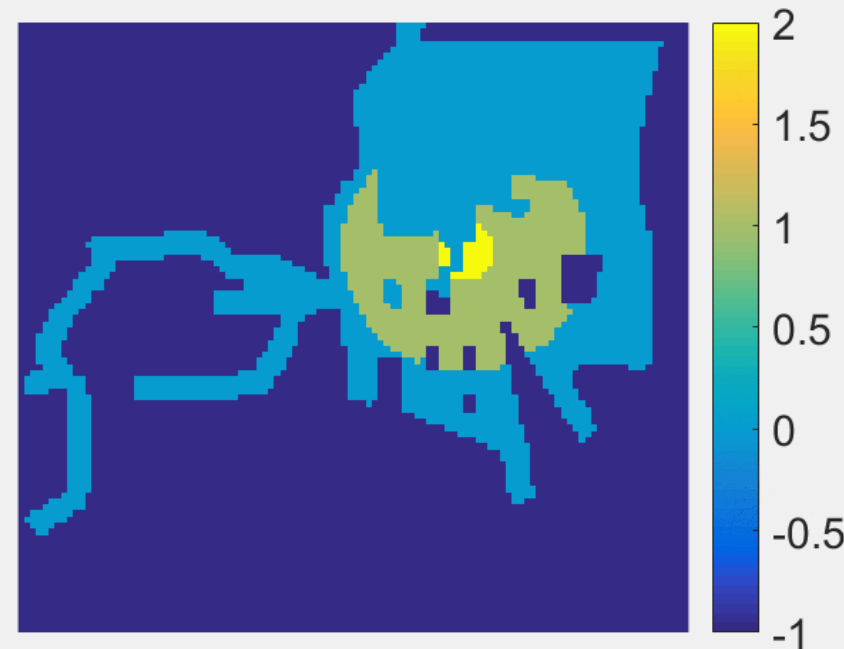
cpue increases

Number of traps increases

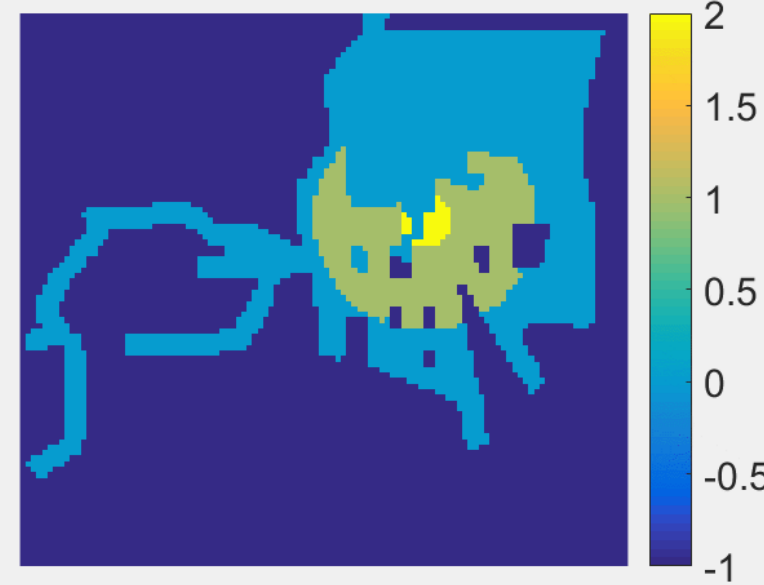
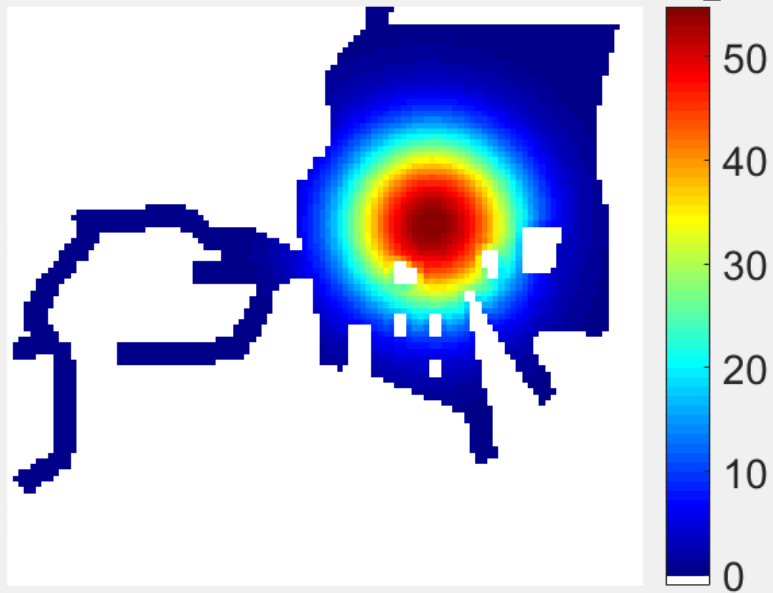
Predictions (number of tegus)



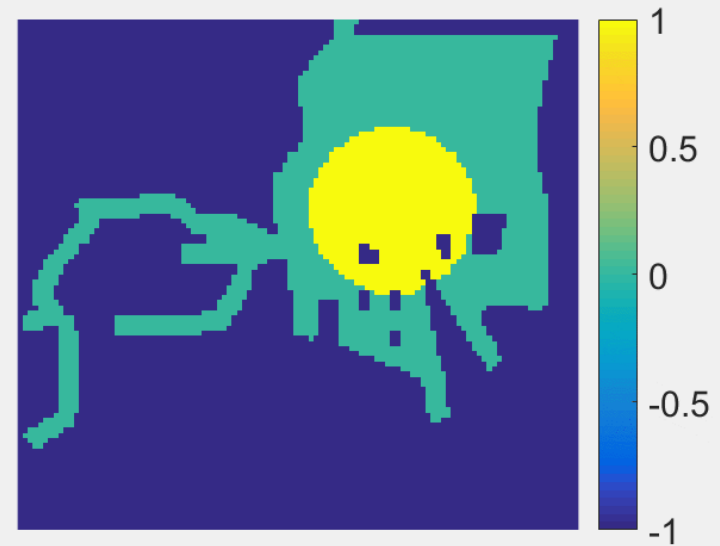
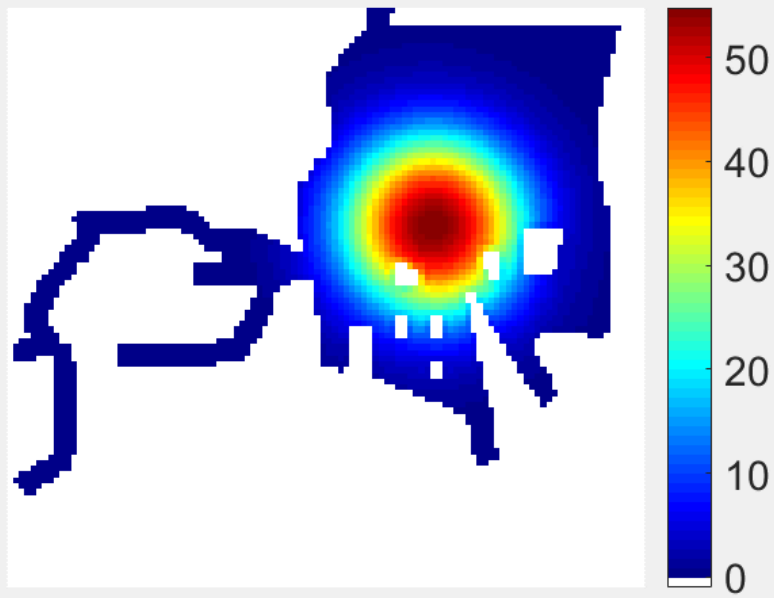
Control Strategy (number of traps)



No traps in Ag and urban area

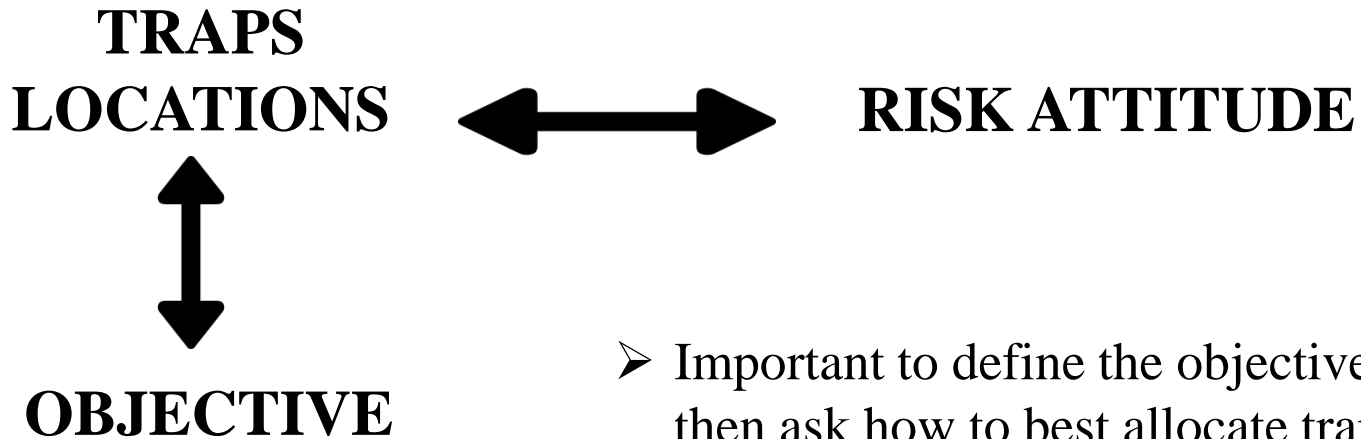


Traps everywhere



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.