Integrated Pest Management for Prairie Dogs

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The Menace

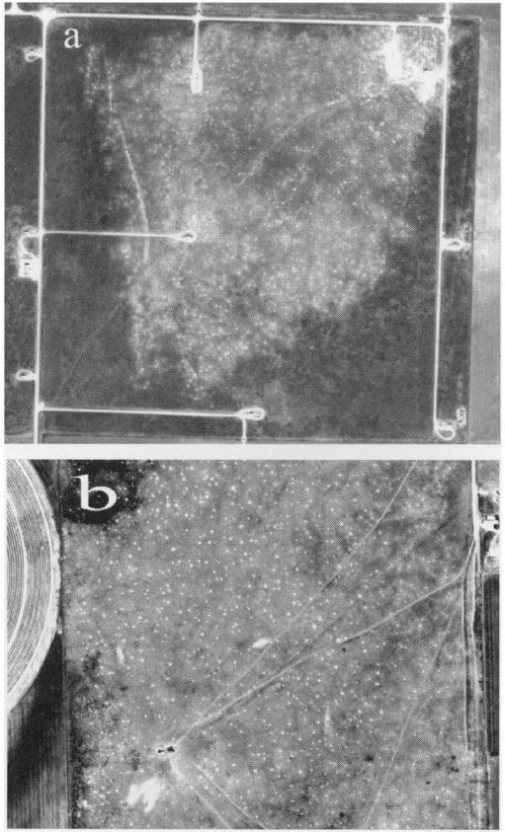
The Mission

The Management

- Xeric tall-grass encroachment and opening
- Visual barriers
- Fungal toxins
- Plague vaccination
- Variable rate contraception
- Limited physical relocation

Satellite Imagery

- Northern Prairie Wildlife Research Center
- 1-m resolution satellite image data
- Identifies active colonies
  - Burrows
  - Reduction of grasses
- Gold Standard



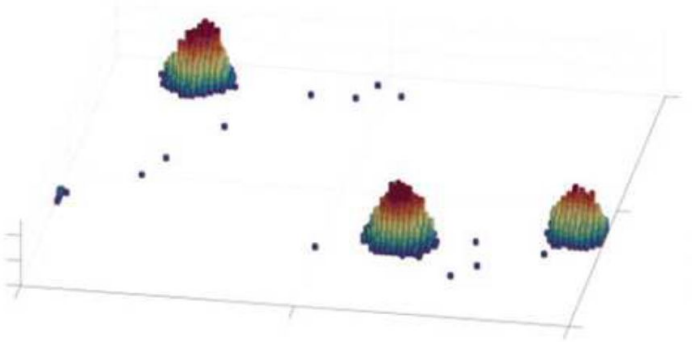
Comparison of Techniques

Technique	Pros	Cons
Regression Techniques	- Easy implementation - Leverage empirical data	- Difficult to validate - Does not elicit location - Some factors can be difficult - No information about individuals
Predictive Image Analysis	- Images easy to obtain - Location and size - Validate against gold standard	- Some factors can be difficult - No information about individuals
Multi-Agent Models	- Account for individuals - Location and size - Incorporate complex inputs - Validate against gold standard	- Can be complex to implement - Modifying parameters difficult - Not currently used in the field of prairie dog colonies

Flocking / Multi-Agent Model Studies

- Models obey three basic rules, have been applied to many types of animals and model many different applications such as nest structures, foraging trails, and social organizations (Roy et al, 2014).

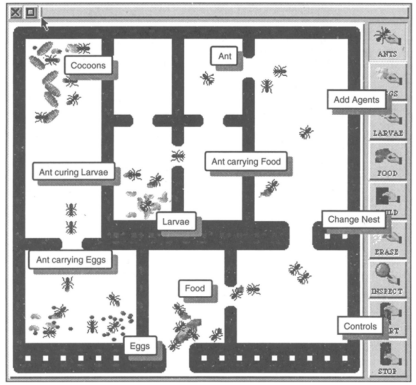
- Balancing forces within the swarm can elicit different behaviors, and this balance may be density dependent, such as found in fire ant towers (Nave et al, 2020)

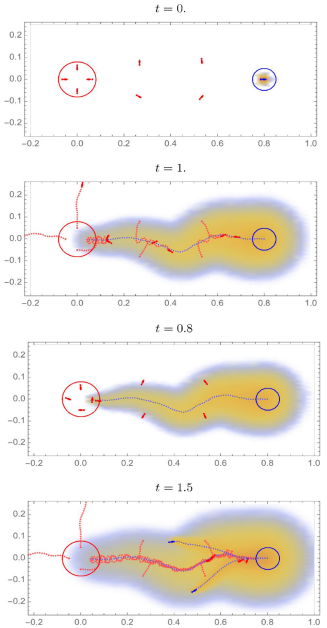


Flocking / Multi-Agent Model Studies

- 2D simulations displaying colony movement can provide insights to colony behavior over time (Drogoul and Ferber, 1994)

- A single properly implemented model will produce multiple emergent behaviors that parallel organism and colony behavior (Ramirez et al, 2018)





Future Directions

- Overarching Structure
  - Multi-agent modeling for coteries (through groups of individual agents - 1 male, 4 females)
  - Randomness in movement, search, behavior
  - Attraction, repulsion, heading
- Fine Grain Detail Additions
  - Granulated attractants/repellents
  - Ecosystem impacts/predators
  - Reproduction and contraception
  - Multi-modal behavior (seasonality)
  - Agent communication
  - Ecosystem impacts/predators
- Evaluation (bonus/stretch)
  - GIS/satellite validation

Additional Slides for Reference

Literature Review

1. Regression Techniques
2. Predictive Image Analysis
3. Flocking / Multi-Agent Models

Regression Techniques

Pros:

- Easy to implement
- Leverage empirical data
- Modifying input parameters is simple

Cons:

- Hard to validate against image data traditionally used
- Difficult to indicate *where* the colony may be growing
- Difficult to quantify some environmental factors

Predictive Image Analysis

Pros:

- Images are easy to obtain / cheap
- Not just how many but *where*
- Can be validated against traditional data collection

Cons:

- Modifying parameters can be difficult
- Individual animal behavior does not translate
- Prediction / projection is lacking in this field

Flocking / Multi-Agent Models

Pros:

- Collection of individuals and their behavior not just “a colony”
- Account for complex factors
- Can address quantity and location changes
- Can be validated against traditional data collection

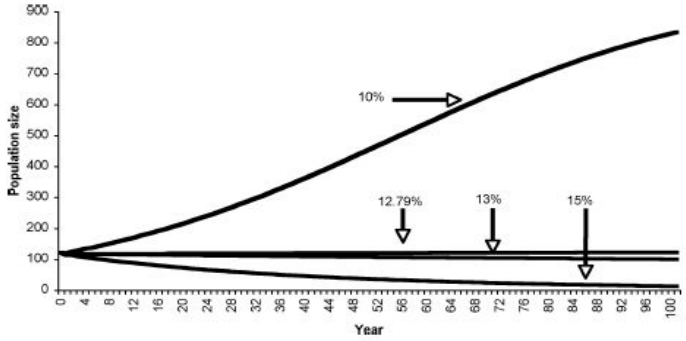
Cons:

- Models can be very complex to create
- Modifying parameters can be difficult
- None currently applied to prairie dog colonies

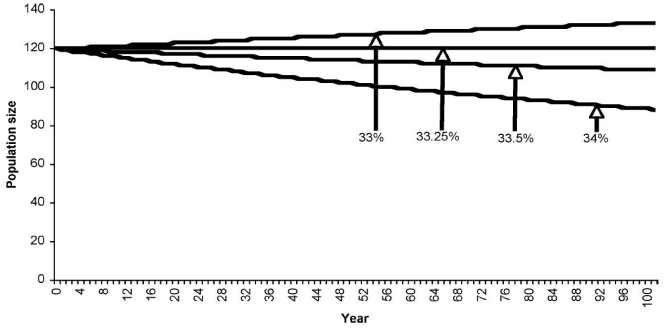
REGRESSION - EXTRA

Yoder et al - “Population Modeling of Prairie Dog Contraception as a Management Tool”

- Specifically studying prairie dogs
- Studies culling vs. contraception
- Modeled with density dependent growth
- Model not validated against empirical data



Culling (above) vs. contraception (below).



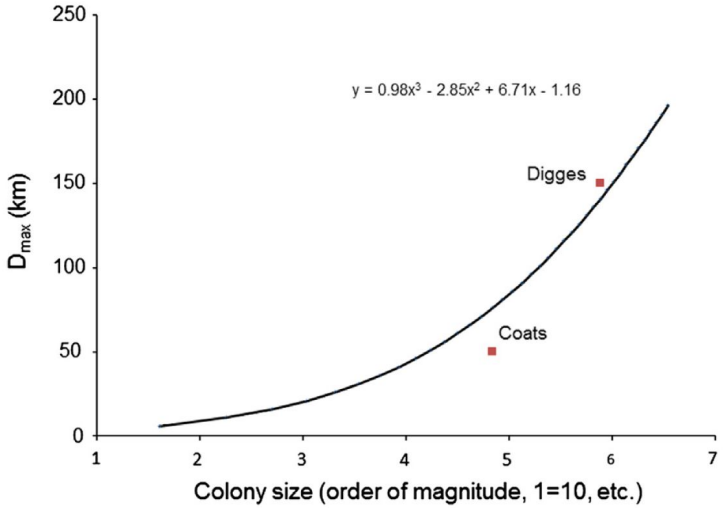
REGRESSION - EXTRA

Gaston et al - “Modeling foraging range for breeding colonies of thick-billed murres…”

- Studying birds that nest in dense colonies
- Examining foraging range overlaps with industrial development
- Assume foraging optimally with respect to distance traveled
- Validated using GPS data

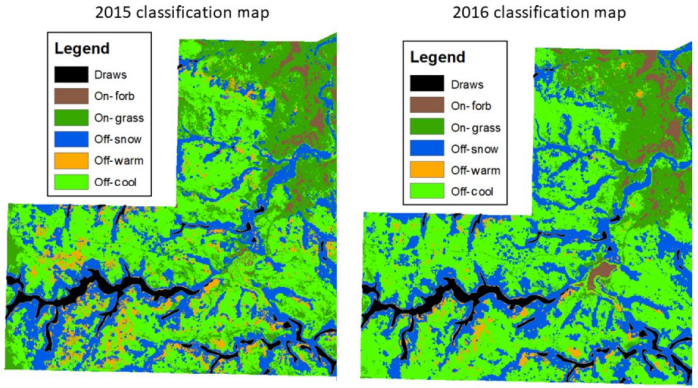
Table 1
Constants used in CPF model. Energy expenditure values are from Elliott et al. (2012), based on the best-fit model not invoking diving depth (unknown for the Digges Island colony).

Input constants	Unit	Value
Flight speed	(km/h)	63
Trip frequency	Trips/day	1
Time at the colony	(h)	12
Energy expenditure at the colony	(kJ/h)	32
Energy expenditure in flight	(kJ/h)	533
Energy exp. on other activities away from the colony	(kJ/h)	99

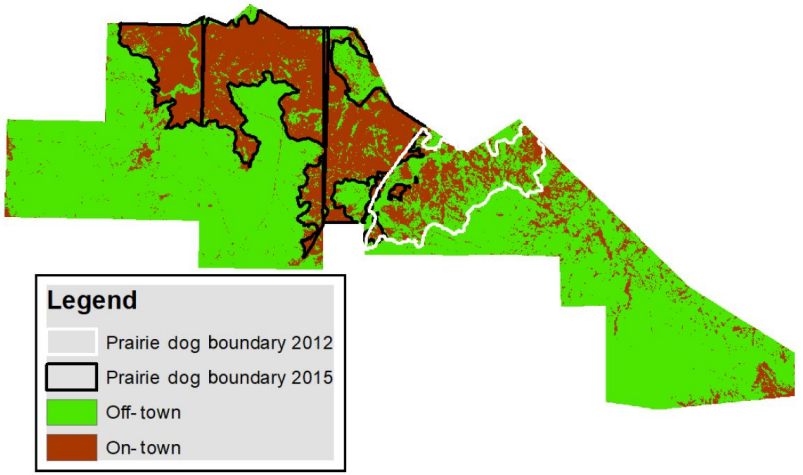


PRED. IMAGE ANALYSIS - EXTRA

Brennan et al - “Comparing stability ir [RF] models to map Northern Great Plains plant communities”



- Studying plants as they are affected by prairie dogs
- Classification of plant communities
- Models did show some stability issues
- Did not project beyond their data range



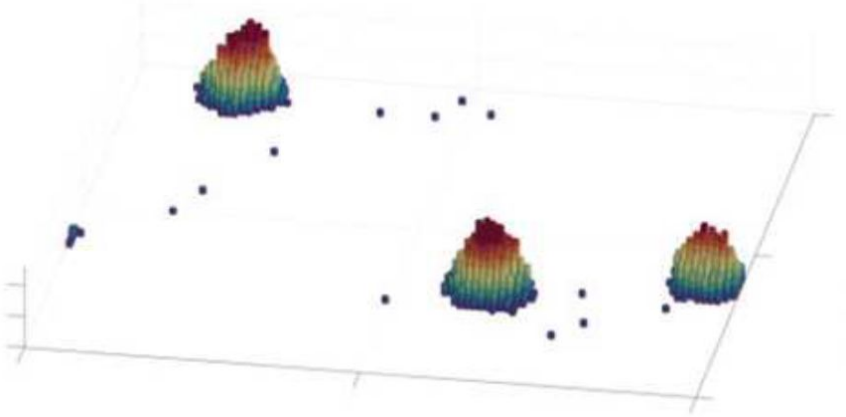
FLOCKING - EXTRA

Roy et al - “Nature-Inspired Swarm Intelligence and its Applications”

- Survey of swarm intelligence algorithms
- Organisms include insects, fish, monkeys, bats, eagles, krill
- Models obey three rules
  - Move in the same direction as your neighbors
  - Remain close to your neighbors
  - Avoid collision with your neighbors
- Nest structures, foraging trails, social organizations

FLOCKING - EXTRA

Nave et al - “Attractions, Dynamics, and Phase Transitions in Fire Ant Tower-Building”

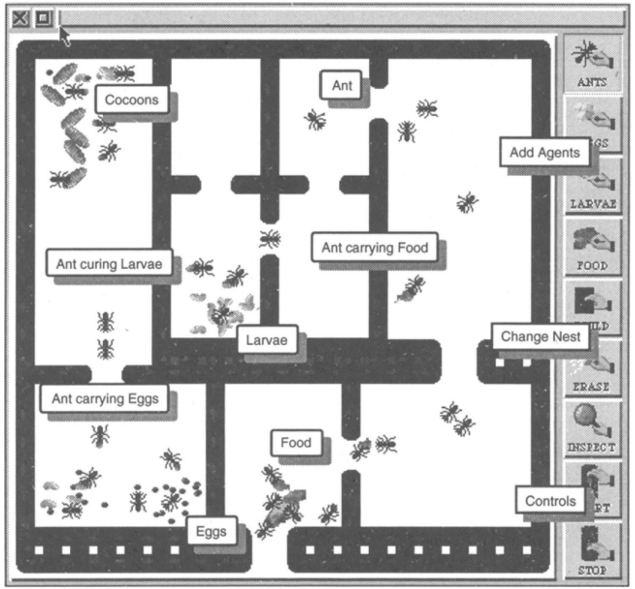


- Set of behavioral rules, incorporating local sensing
- Explores tradeoff on inputs as relates to animal behavior
- Model factors can be attributed to natural organism behavior
- Compared to naturally observed behavior

FLOCKING - EXTRA

Drogoul and Ferber - “Multi-Agent Simulation as a Tool for Modeling Societies: Application to Social Differentiation in Ant Colonies”

- Model applied to ant colonies
- Nest modeled to reflect laboratory nests
- Modeling agents governed by rules and simple task objectives
- GUI and visualization
- Future work to model entire ant societies
- Model performance is inferred but not quantified



FLOCKING - EXTRA

Ramirez et al - “Modeling tropotaxis in ant colonies: recruitment and trail formation”

- Fixed number of ants in 2D space, fixed nest
- Multiple attractants: nest and other ants
- No trail polarization
- Consider two modes: foraging and recruitment
- Not intended as predictive model