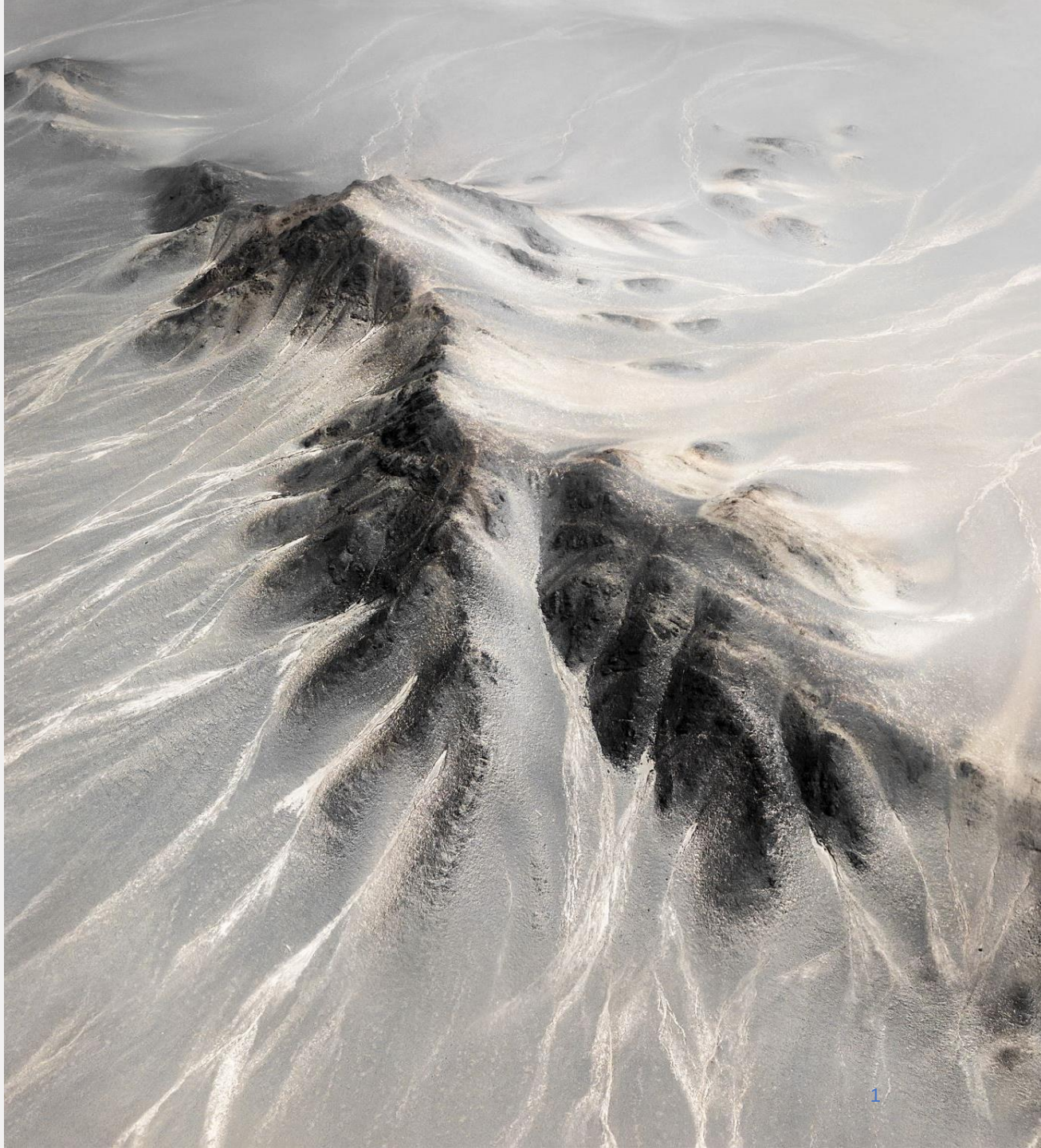
Model of Spatial Dynamics of Desert Locust Populations

By Clemens Wager and Jeremy Cook



Overview

INTRODUCTION INTO OUR TOPIC

DESCRIPTION OF MODEL

DEMONSTRATION OF MODEL

RESULTS AND DISCUSSION

- “Desert locust (*Schistocerca gregaria*) is the most widespread and highly mobile destructive pest in the world” (Guan et al., 2021)

(Moberly, 2020)

Introduction

- The Desert Locust (*Schistocerca gregaria*) is a member of the grasshopper family Acrididae.
- It is a generalist herbivore and can be found in grasslands and deserts throughout Africa, Middle East and southwestern Asia. (Meynard et al., 2017)
- It lays its eggs in moist, sandy soils. (Commission for Controlling the Desert Locust in the Central Region (CRC-EMPRES), n.d.)
- They differ from grasshoppers as they perform density-dependent phase changes, which affect behaviour, physiology, colour and shape. (Symmons et al., 2001)

(Solitarious and Gregarious Locusts Differ in Their External Morphology.... | Download Scientific Diagram, n.d.)

Solitary Phase Locusts

- Found in low numbers scattered throughout North Africa. (*Locust | Definition, Size, & Facts | Britannica*, n.d.)
- Low metabolic and oxygen intake rate (*Locust | Definition, Size, & Facts | Britannica*, n.d.)
- Shorter wings (*Locust | Definition, Size, & Facts | Britannica*, n.d.)
- Green/brownish colour/ camouflaged(*Locust | Definition, Size, & Facts | Britannica*, n.d.)
- Lay a large amount of eggs and are non-migratory (*Commission for Controlling the Desert Locust in the Central Region (CRC-EMPRES)*, n.d.)
- Actively avoid other solitarious locusts. (*Locust | Definition, Size, & Facts | Britannica*, n.d.)
- Touching of back legs causes phase change. (Simpson et al., 2001)

Gregarious Phase Locusts

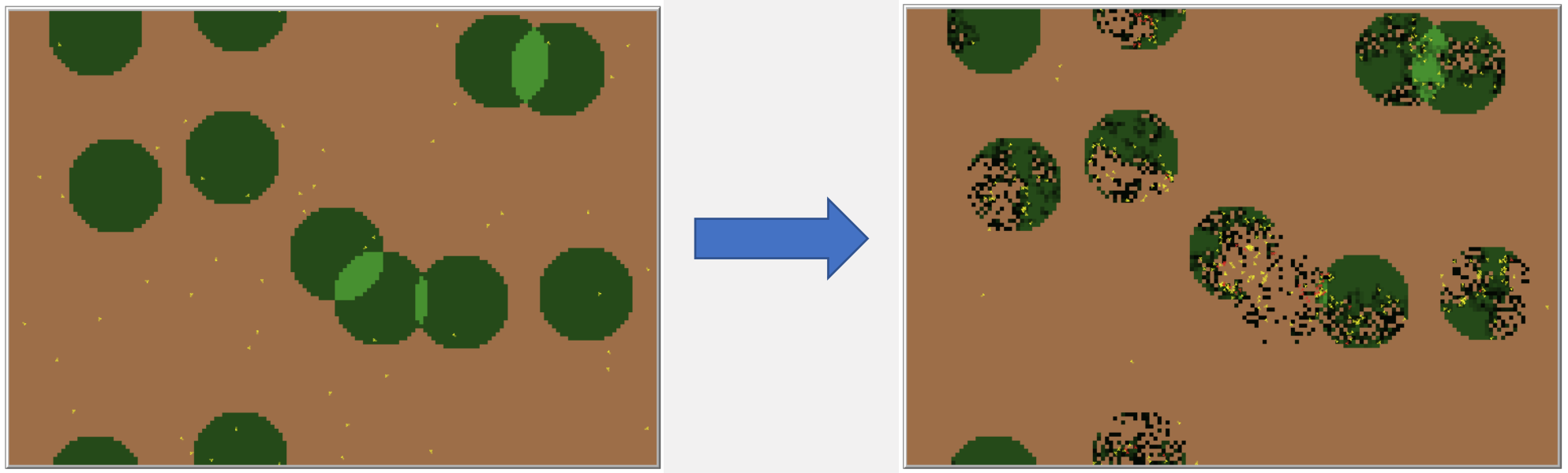
- Long winged (*Locust | Definition, Size, & Facts | Britannica*, n.d.)
- High metabolic and oxygen intake rate (*Locust | Definition, Size, & Facts | Britannica*, n.d.)
- Attracted to other locusts (Simpson et al., 2001)
- Highly migratory and can travel long distances
- Lay fewer eggs, these have a greater chance of survival (*Commission for Controlling the Desert Locust in the Central Region (CRC-EMPRES)*, n.d.)
- They form bands or swarms and can actively sense food (Chapman, 2009)
- Threaten food security and livelihoods in the region (Moberly, 2020)

Importance of Study

Understanding distribution patterns and triggers of desert locust outbreaks under a changing and uncertain climate is essential in dealing with this potential threat. (Simpson et al., 2001)

About the model – **Environment**

+ Desert with some of grass patches
+ Each grass patch holds limited amount of food (overall constant)
+ After some ticks rainy season → regrows eaten grass patches over time



About the model – **Turtles**

- 50 solitary locusts spawn in random places once
- Each turtles has energy, memory of encounters and age
- Two breeds implemented:
  - Solitary locusts
  - Gregarious locusts

- Turtles wander, look for food and reproduce
  - After spawning a random number of offspring, they die

About the model – **Behaviour**

Solitary locusts (phase 1)

+Find food > avoid peers > random walk

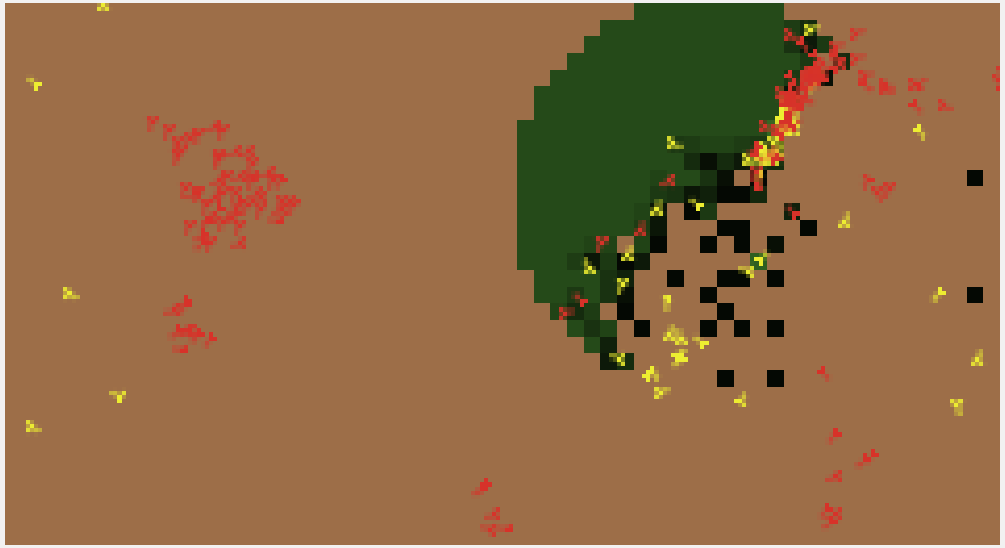
+Avoid contact with each other → turn backwards

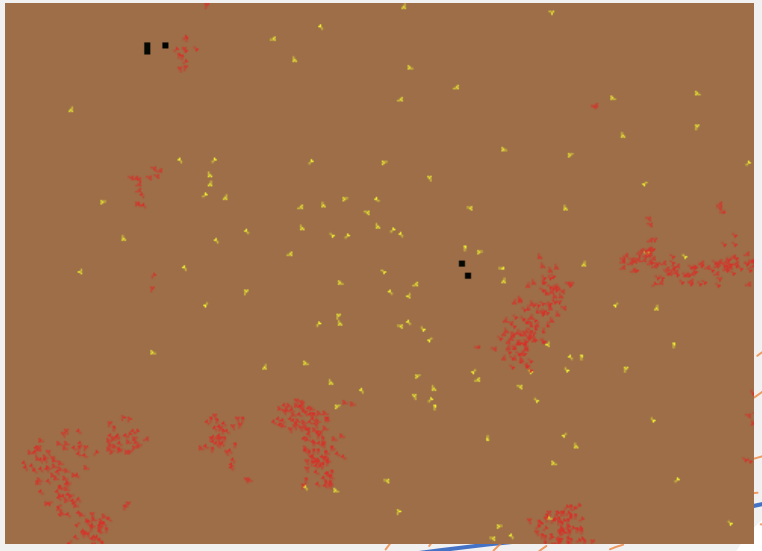
+If enough encounters in each individual → phase change

About the model – **Behaviour**

Gregarious locusts (phase 2)

+ Find food > flock/swarm > random walk
+ When no food around → flock and travel as swarm
+ Flocking is faster and more energy-efficient
+ If individuals spread out when eating → phase change





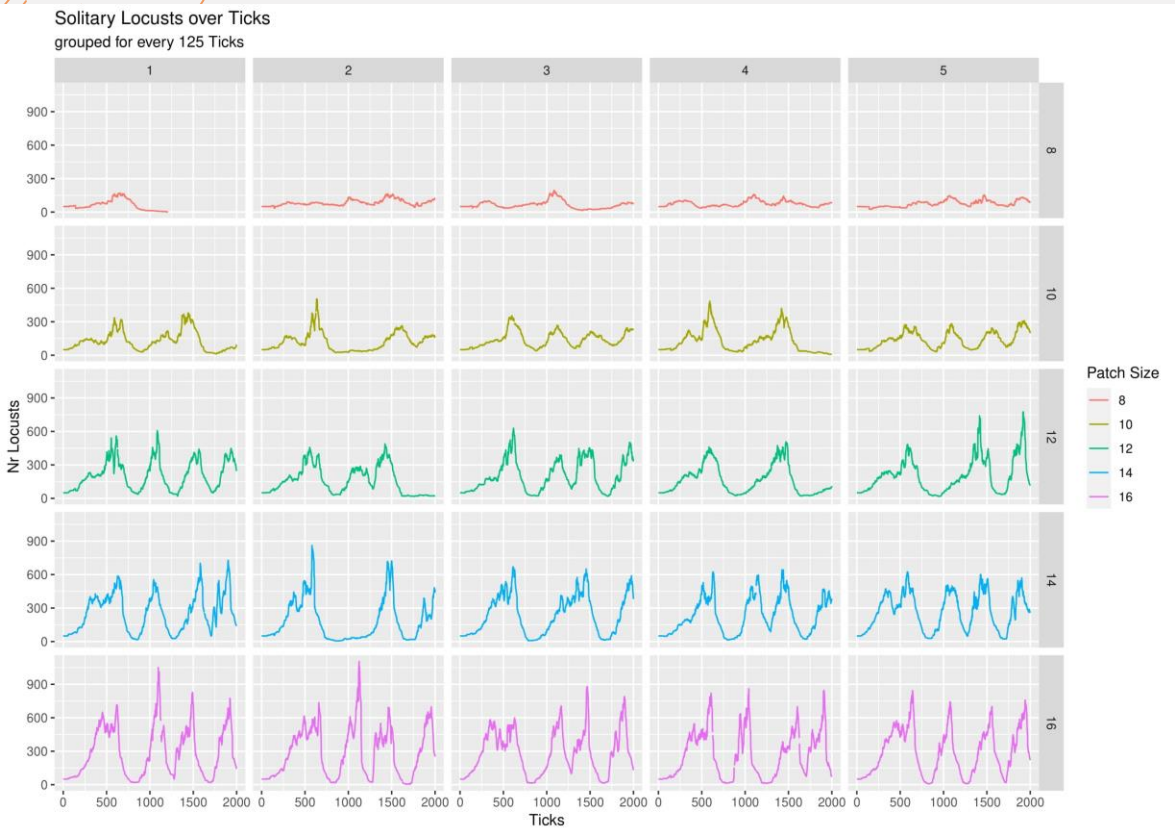
About the model – **Balance**

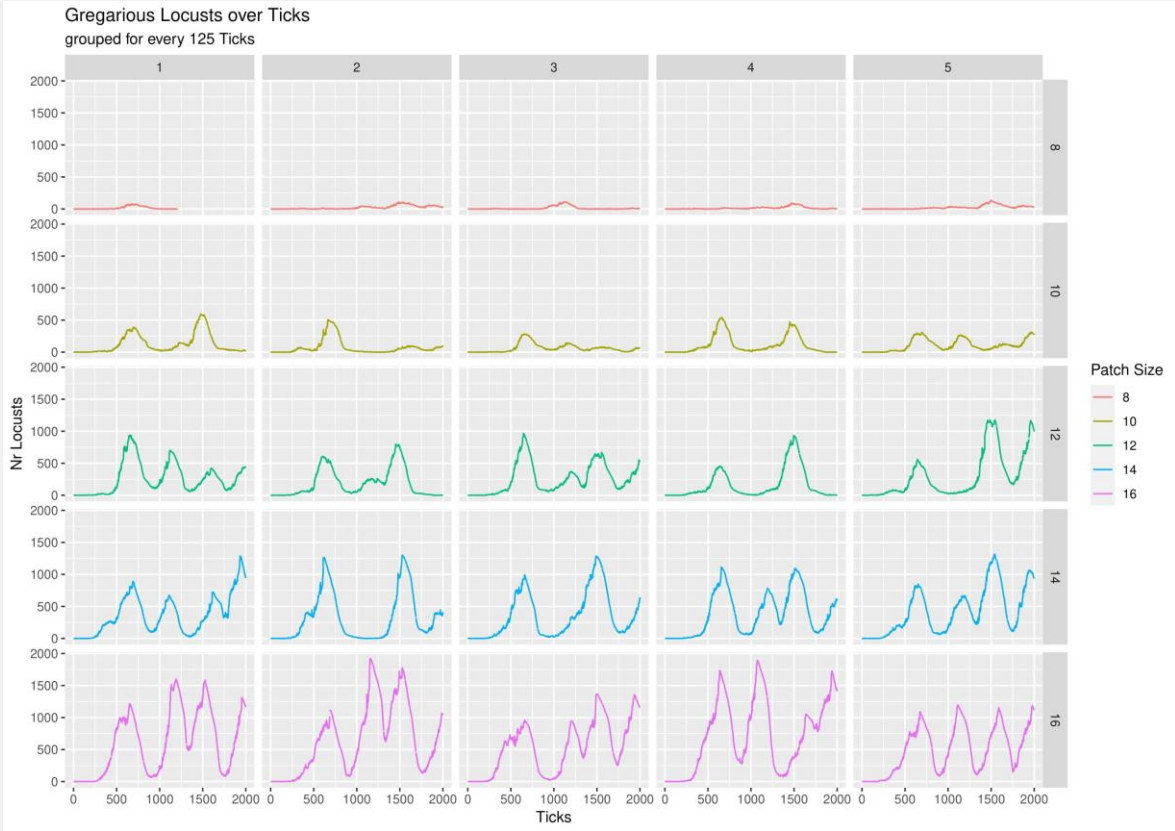
- Tuned model a lot to find a good reference system
- Simulation runs stable over 10,000 ticks
- Periodic behavior change visible
- Environment regenerates periodically

Live demonstration

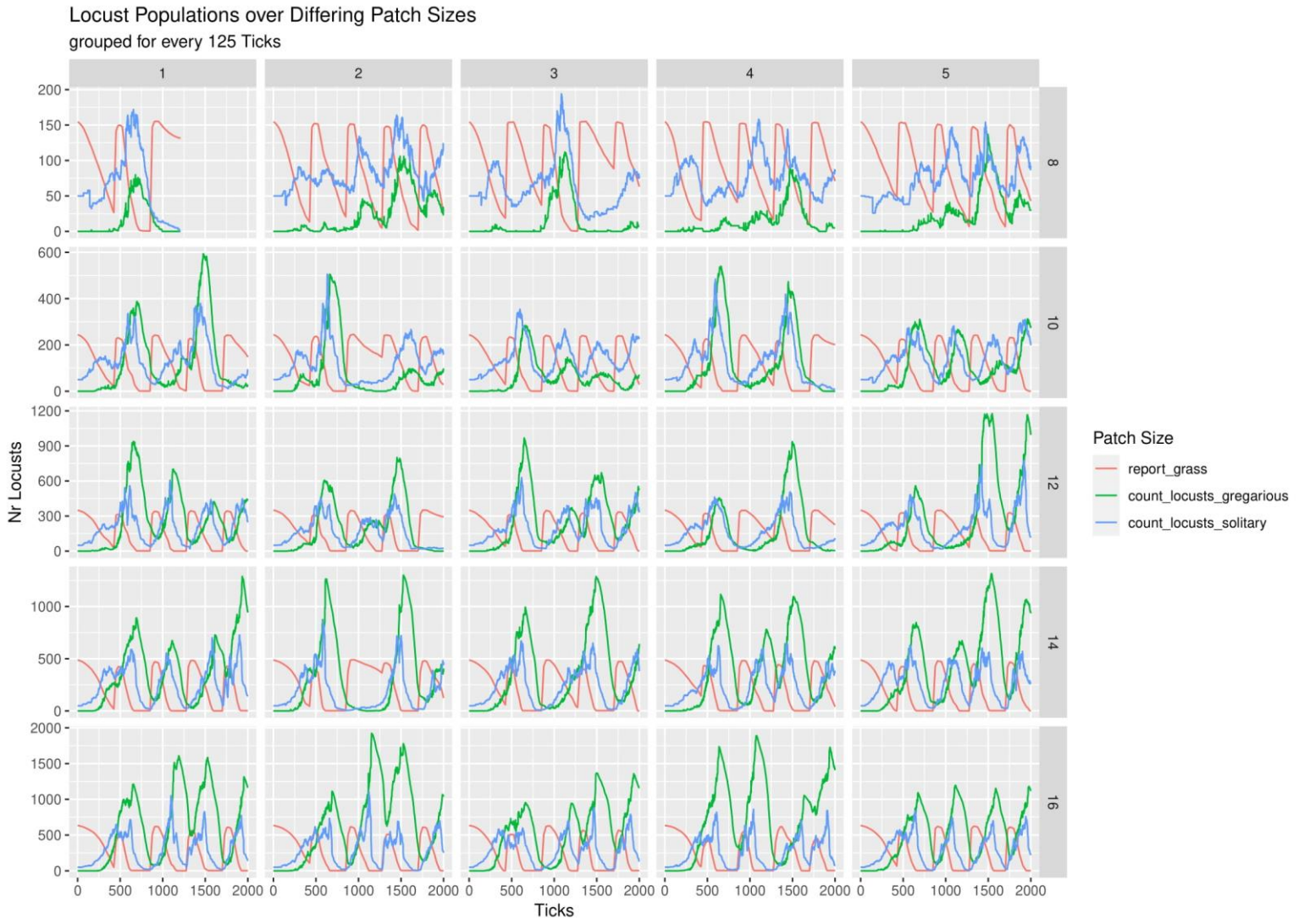
Paramter: **Size of grass patches**

Solitary vs. Gregarious





Paramter: **Size of grass patches** (total)



Overall:

- severe impact on carrying capacity → much larger populations possible
- 1 extinction event in smallest size run

Gregarious:

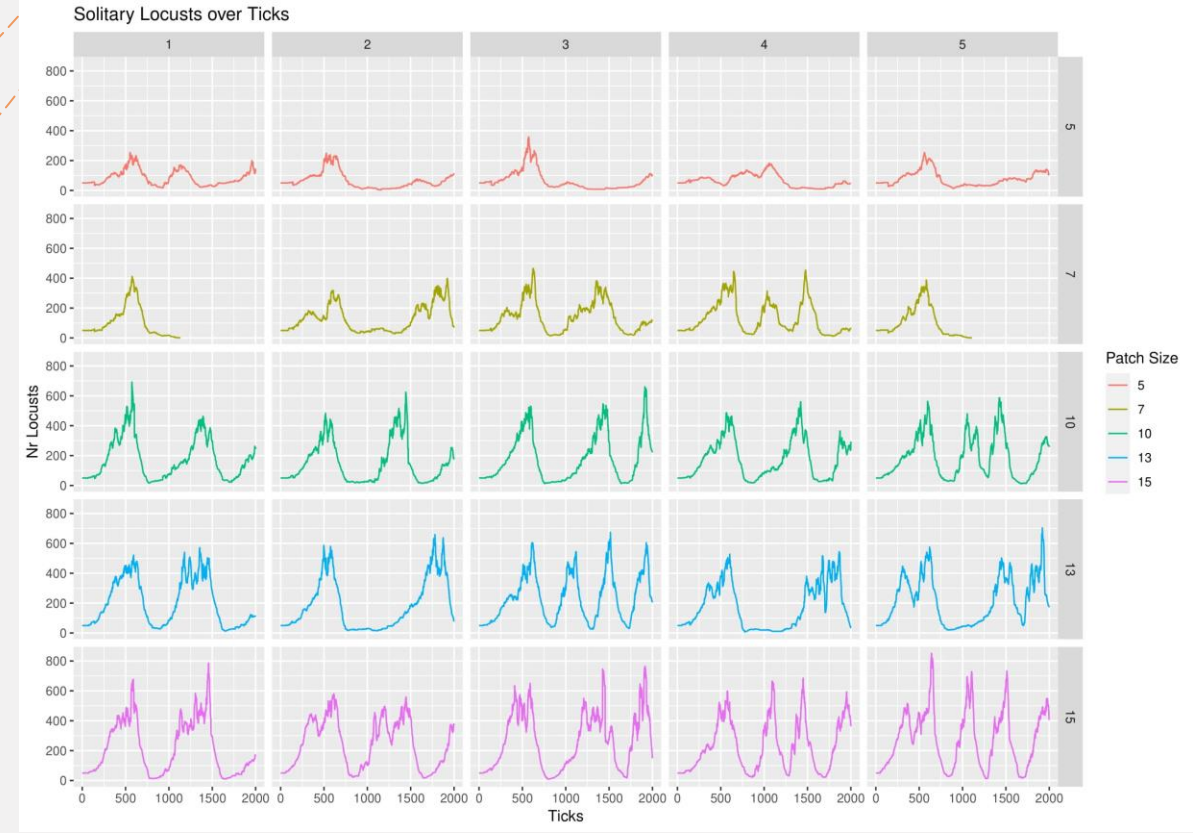
- direct relation between patch size and population peak height

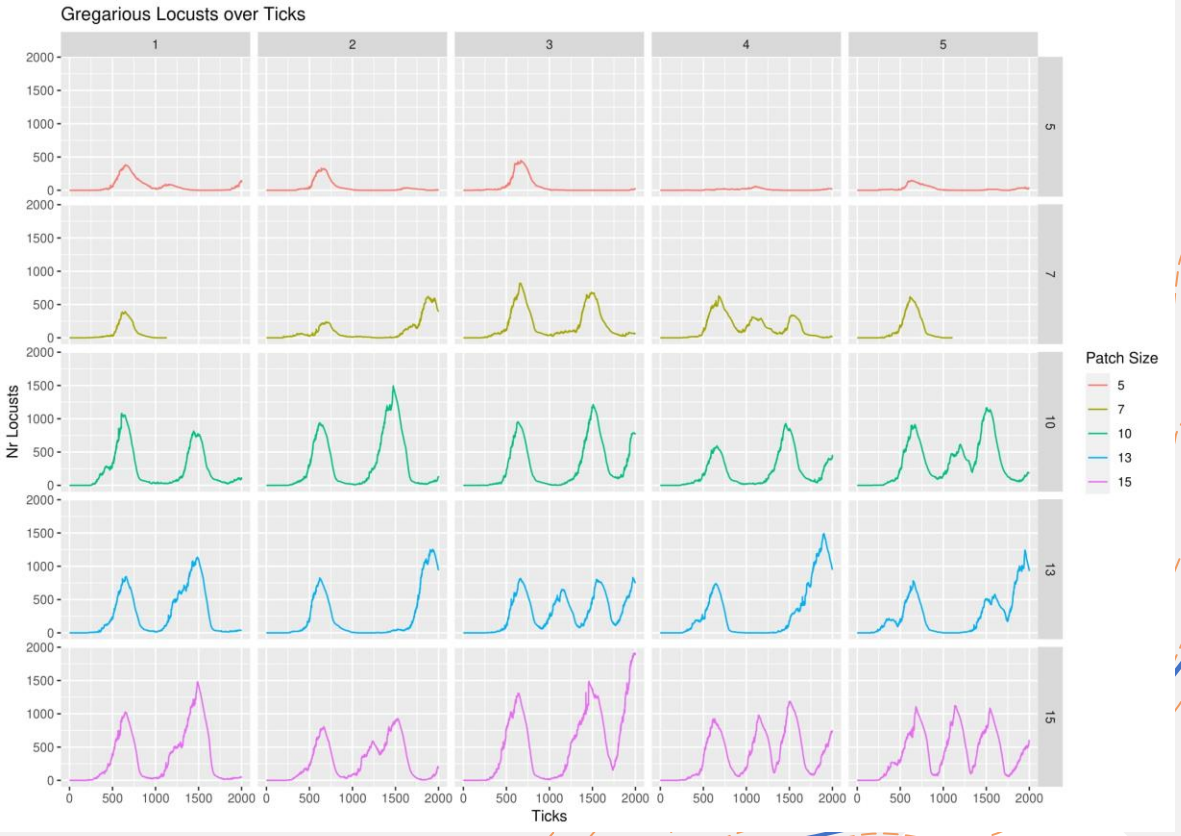
Solitary:

- not extreme growth
- damped relation, less visible than in gregarious

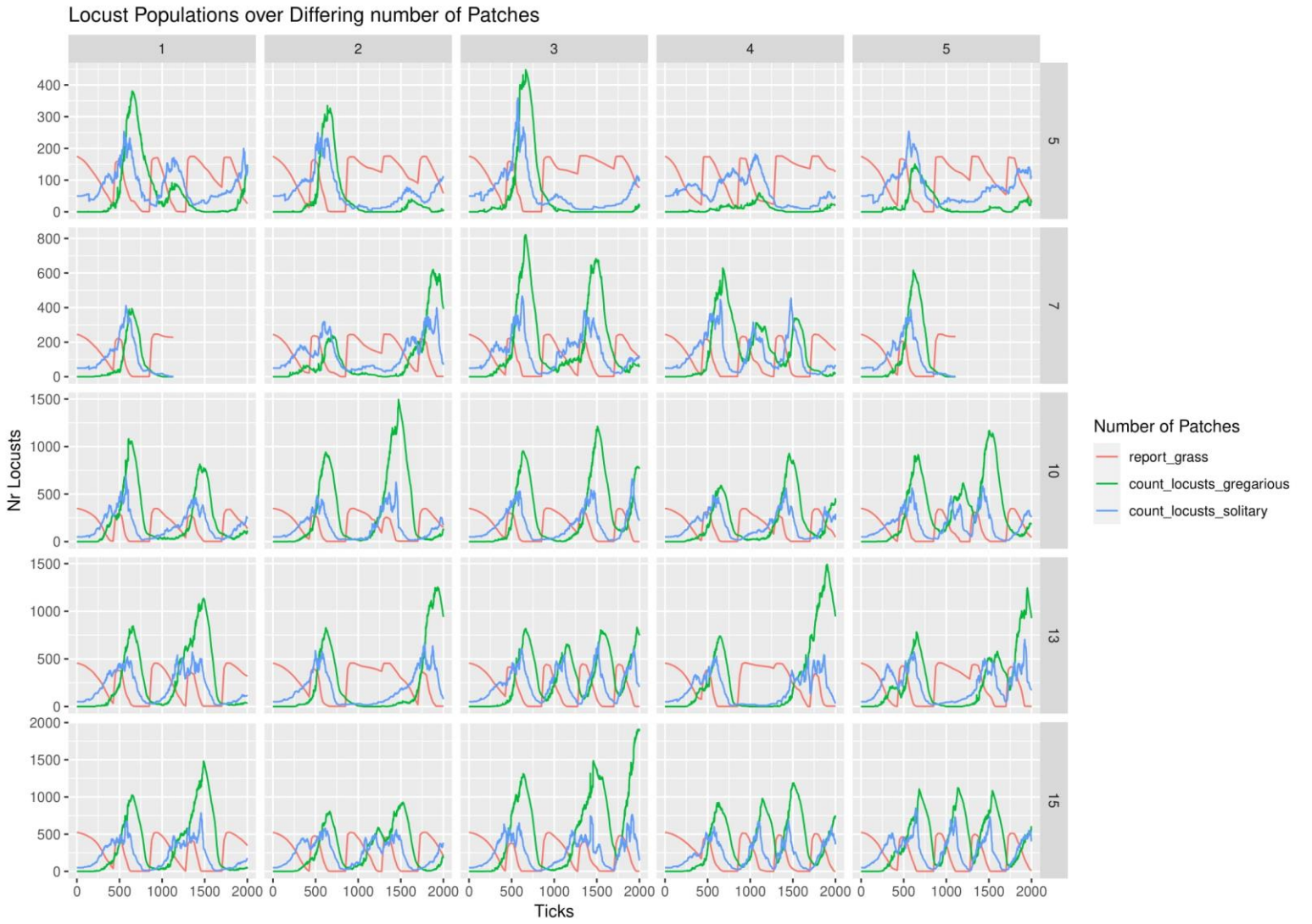
Parameter: **Number of grass patches**

Solitary vs. Gregarious





Parameter: **Number of grass patches** (total)

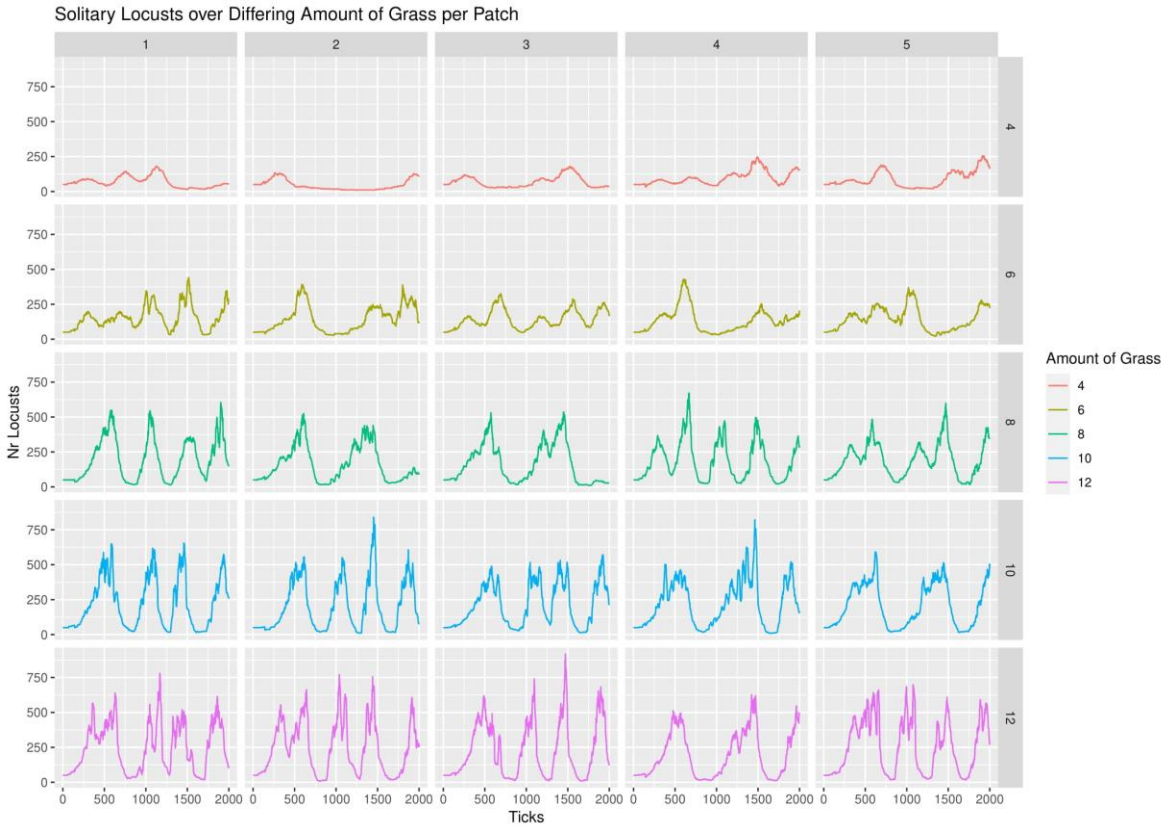


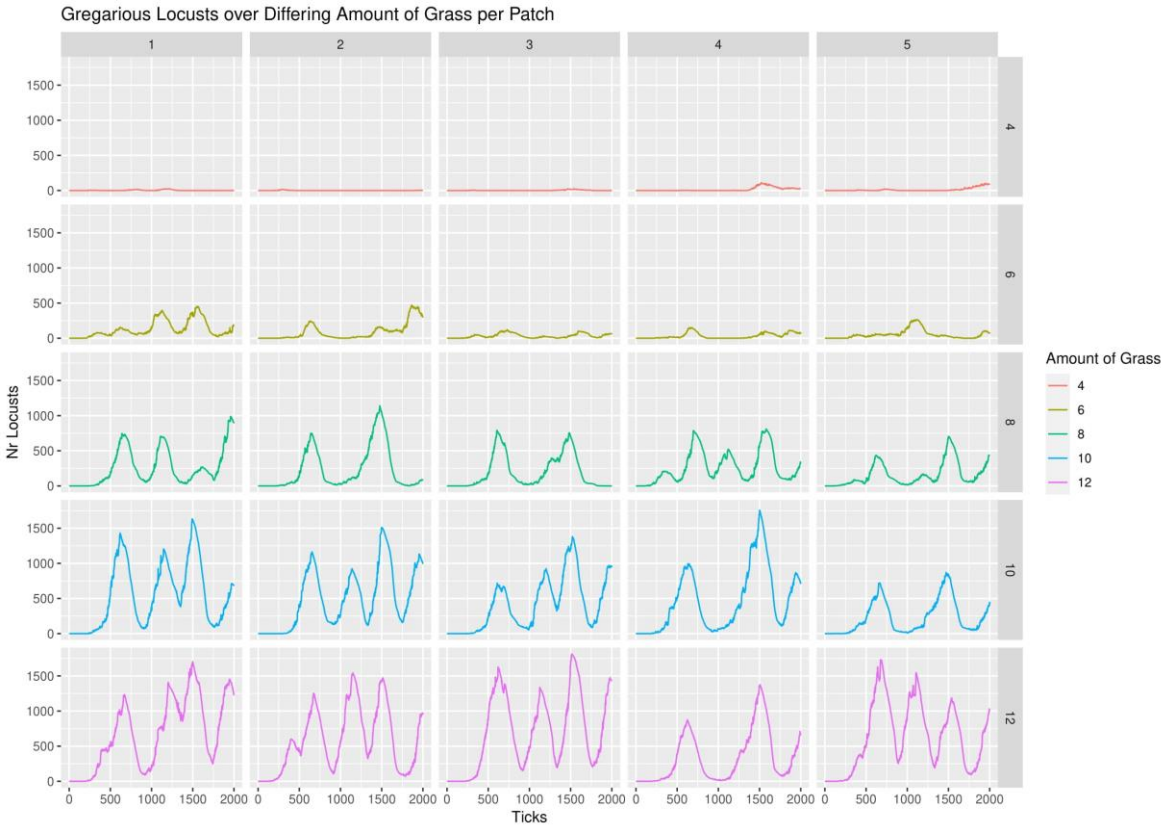
Overall:

- 2 extinction events, but not in smallest number run
- similar situation to size of patches

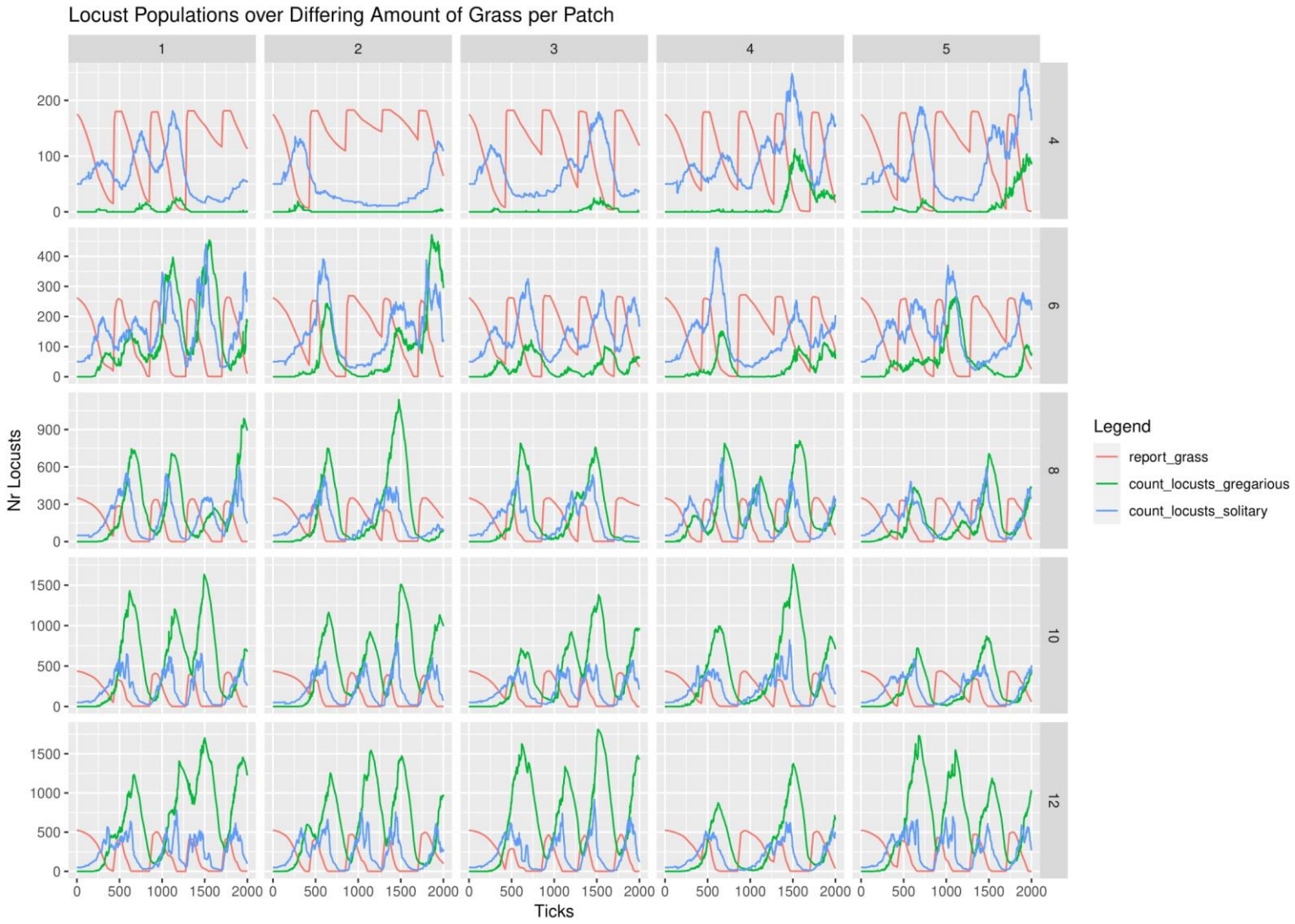
Parameter: **Maximum grass amount per patch**

Solitary vs. Gregarious





Parameter: **Maximum grass amount per patch** (total)

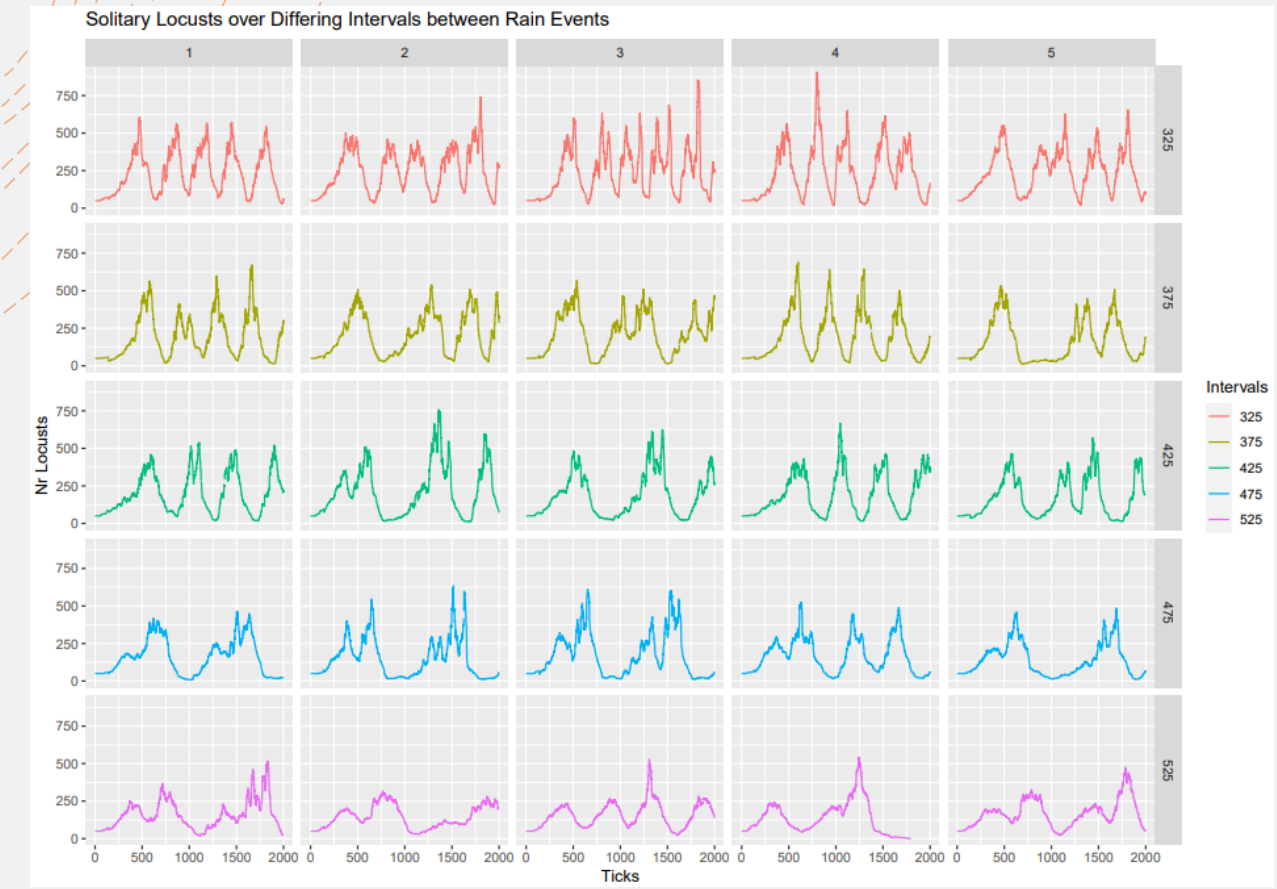


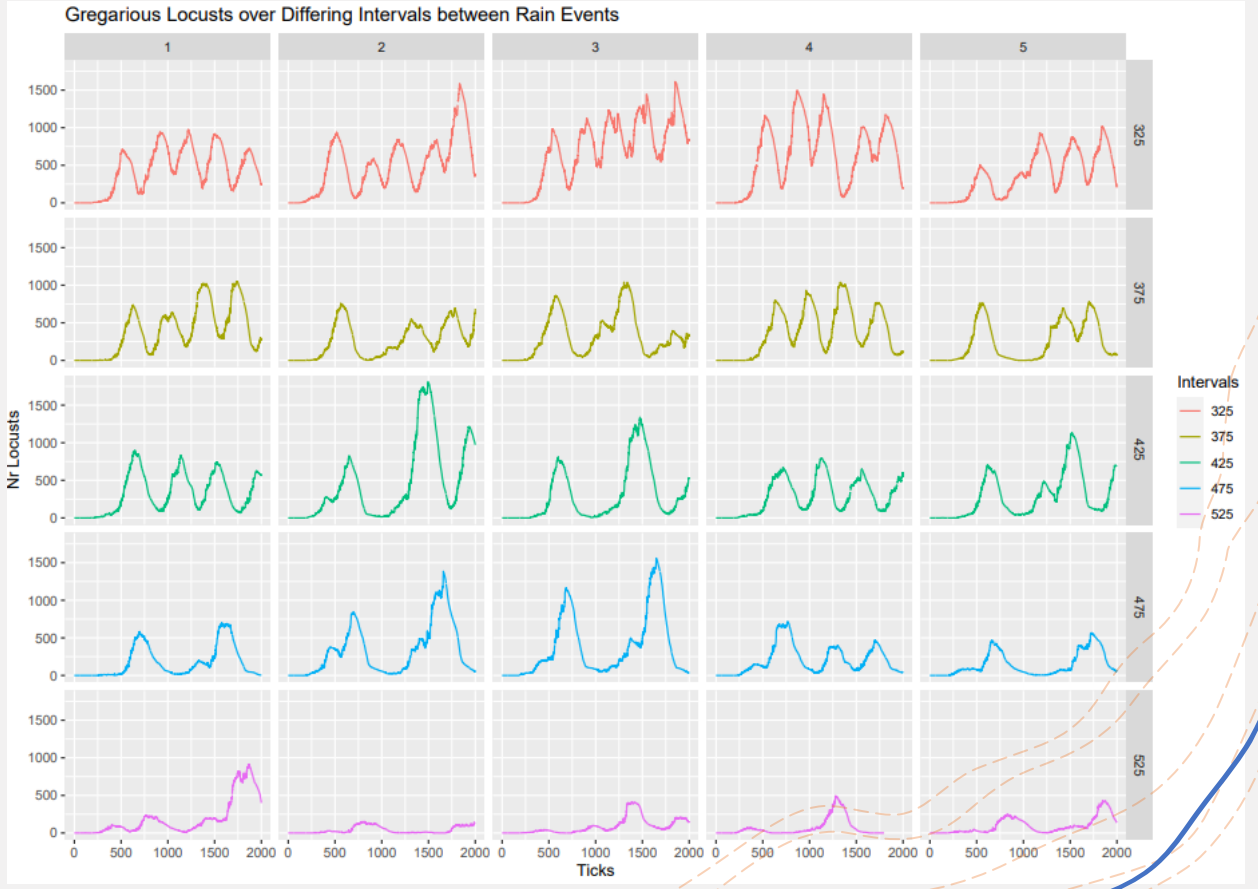
Overall:

- direct relation between max-grass-amount and population size peak height
  → extreme amplitudes

Parameter: **Rain-Interval**

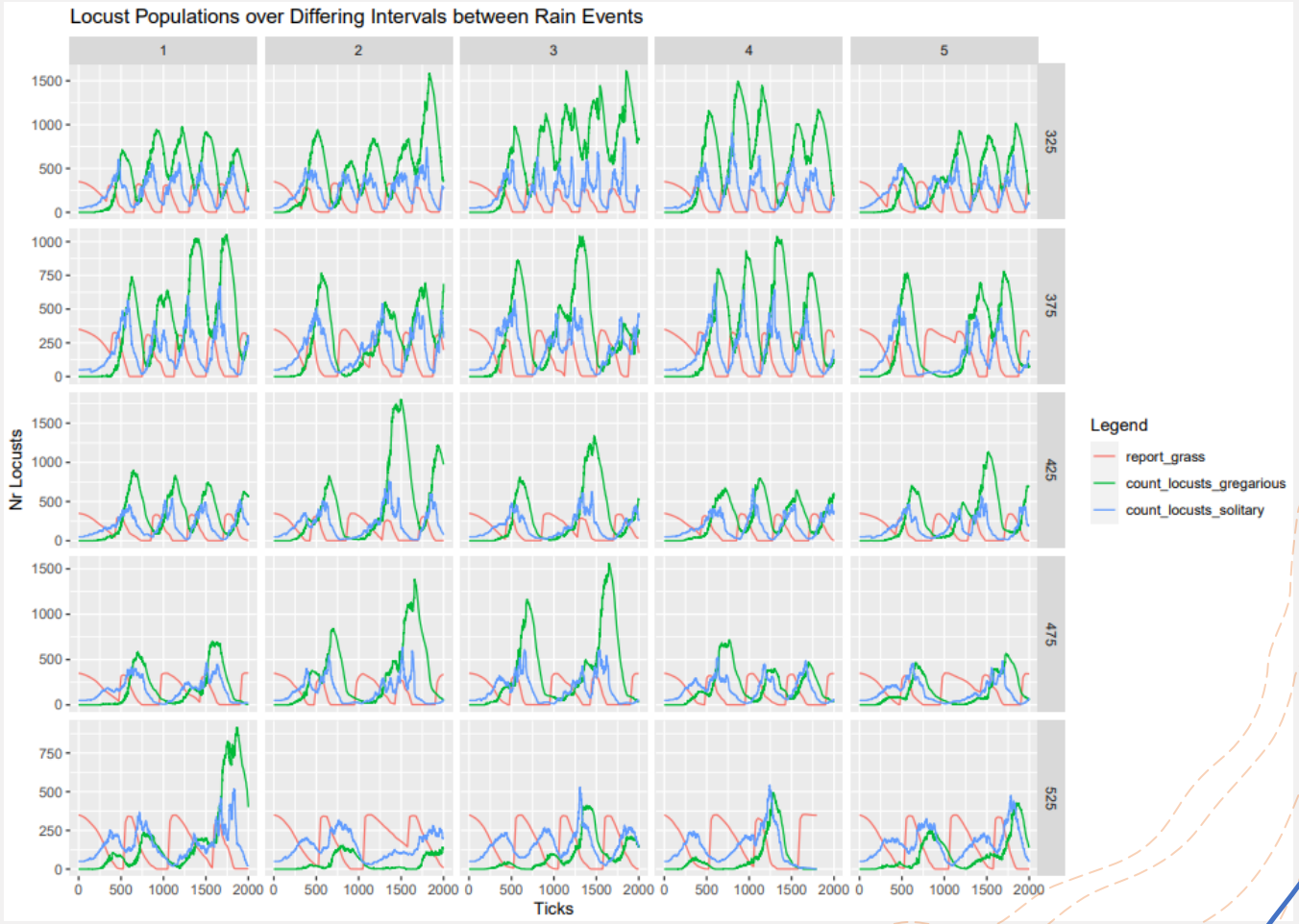
Solitary vs. Gregarious





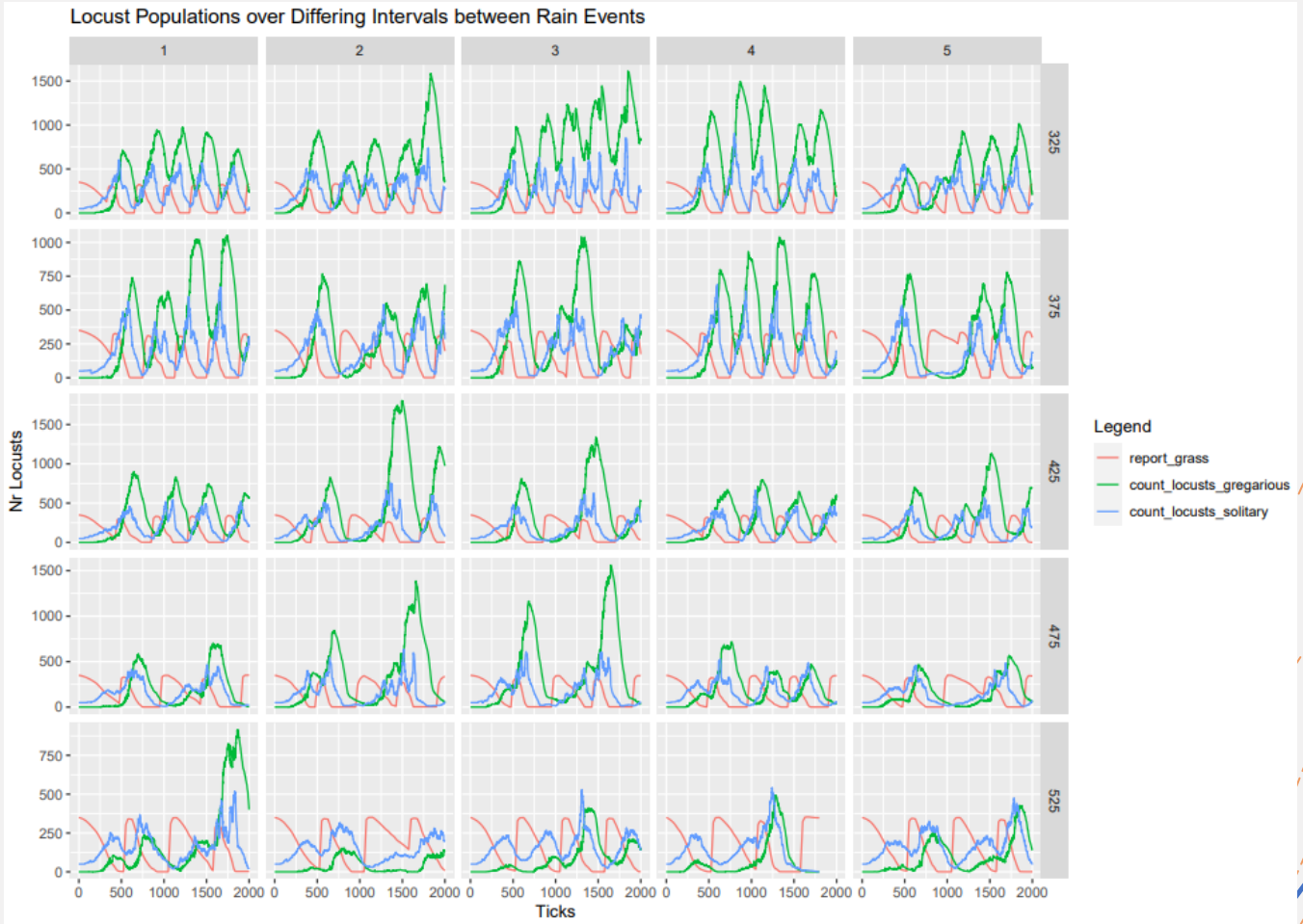
Parameter: **Rain-Interval (total)**

- Gregarious
  - Short rain intervals cause more population surges
  - Short rain intervals result in very high populations
  - Surges are followed by rapid decline in population
  - Probably due to limited resources



Parameter: **Rain-Interval (total)**

- Solitary
  - Growth not as extreme as with gregarious
  - Smaller populations on average
  - At longer rain intervals solitary phase is predominant
  - Phase change is induced by change in rain regime.



Conclusions

- Phase change and outbreaks of desert locust swarms are induced by environmental fluctuations which increase food availability.
  - Cause more frequent population surges
  - Cause much higher population densities

- Model is suited to depict phase change and population growth of solitary and gregarious desert locusts.

References

- Chapman, R. F. (2009). Locusts. *Encyclopedia of Insects*, 589–591. https://doi.org/10.1016/B978-0-12-374144-8.00162-4
- *Commission for Controlling the Desert Locust in the Central Region (CRC-EMPRES)*. (n.d.). Retrieved June 23, 2022, from http://desertlocust-crc.org/pages/About.aspx?id=127&lang=EN&I=0&DId=0&CId=0&CMSId=7
- Guan, J., Li, M., Ju, X., Lin, J., Wu, J., & Zheng, J. (2021). The potential habitat of desert locusts is contracting: Predictions under climate change scenarios. *PeerJ*, *9*. https://doi.org/10.7717/PEERJ.12311
- *locust | Definition, Size, & Facts | Britannica*. (n.d.). Retrieved June 23, 2022, from https://www.britannica.com/animal/locust-insect
- Meynard, C. N., Gay, P. E., Lecoq, M., Foucart, A., Piou, C., & Chapuis, M. P. (2017). Climate-driven geographic distribution of the desert locust during recession periods: Subspecies' niche differentiation and relative risks under scenarios of climate change. *Global Change Biology*, *23*(11), 4739–4749. https://doi.org/10.1111/GCB.13739

References

- Moberly, T. (2020). Locusts devastate east African crops. *BMJ*, *368*, m856. https://doi.org/10.1136/BMJ.M856
- Simpson, S. J., Despland, E., Hägele, B. F., & Dodgson, T. (2001). Gregarious behavior in desert locusts is evoked by touching their back legs. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(7), 3895–3897. https://doi.org/10.1073/PNAS.071527998/ASSET/08A43E0C-EEB0-49EF-A4E8-BD9762423F01/ASSETS/GRAPHIC/PQ0715279002.JPEG
- *Solitarious and gregarious locusts differ in their external morphology....* | *Download Scientific Diagram*. (n.d.). Retrieved June 23, 2022, from https://www.researchgate.net/figure/Solitarious-and-gregarious-locusts-differ-in-their-external-morphology-Although-there_fig1_306434425
- Symmons, P. M., Cressman, K., & Fresco, L. O. (2001). *Desert Locust Guidelines 1. Biology and behaviour*.