Agent-based Modelling and Simulation 2

Questions answered last time

- What is an Agent-based Model Simulation?
  - A simulation of an agent-based model
- What is an Agent-based Model?
  - Stronger definition than last time: A simulation with many individual agents that are **autonomous**, **interactive**, and **situated**.
- In the simulation, things take place in time steps - time passes by, things happen

Questions answered last time

- What is an agent?
  - Could be a:
    - business
    - person
    - market
    - planet
    - bacterium
    - cat
  - Putting lots of these together with some communication rules and behaviours makes an agent-based model.

Questions answered last time

- What is the point?
  - We want “macro-behaviour”. Such as hordes of screaming shoppers trying to exit a building they think is on fire.
  - Answer questions:
    - Where do they run?
    - Where are they most likely to fall over?
    - What can we do to make them exit faster?
    - What can we do to make it safer?

Questions answered last time

- What is macro-behaviour?
  - The result of local micro-behaviours in an agent-based model.
- How do you get it?
  - By researching very carefully, and choosing agents, rules, spaces and interactions carefully.

Questions answered last time

- What is the relationship between graphics and agent-based simulation?
  - Agent-based simulations can be visualised using graphics
- Is there a central source of control in agent-based modelling?
  - No.

Other examples

- **Movies** – crowds, battles, orcs, etc
- **Crowd Simulation** – fire-fighter training
- **Military history** – simulations of battles
- **Game Theory** – prisoner’s dilemma networks, etc
- **Artificial Life** – “animats” (artificial animals) boids, flocking, predator-prey, etc…

This time

- Assignment feedback
  - Everyone submitted it!
- The battle of Isandlwana
- Predator-prey simulation
- (next time) Algal Photobioreactors

Recent example

An Agent-Based Model of the Battle of Isandlwana

The Winter Simulation Conference

Berlin, Germany

10th December 2012

The Battle of Isandlwana

22nd January 1879

20,000 Zulu vs 1,700 British

British had guns and Zulu had spears

British: 1,300 (77%) dead

Zulu: 1,000 to 4,000 dead

Movies

1964 – “Zulu”

Defence of Rorke’s Drift (same day)

Historically rubbish

Screened every New Years in UK

1979 – “Zulu Dawn”

Battle of Isandlwana (centenary)

Historically accurate

Forgotten (and poor digital quality)

Is available via YouTube

British Agents

<u>Rules in priority order:</u>

1. if Zulu adjacent:

then hand-to-hand

2. if rifle loaded:

fire at Zulu

3. if ammo available:

load rifle

24th Regiment with Martini-Henry .45 rifles

Zulu Agents

Rules in priority order:

1. if British adjacent:
then hand-to-hand

2. if Zulu adjacent:
then spread out

3. if British near by:
then charge

4. move using
preset vector

Zulu Movement

Each agent has a pre-set vector (“orders”)
– keep moving in a fixed direction
– stop when another rule can be applied

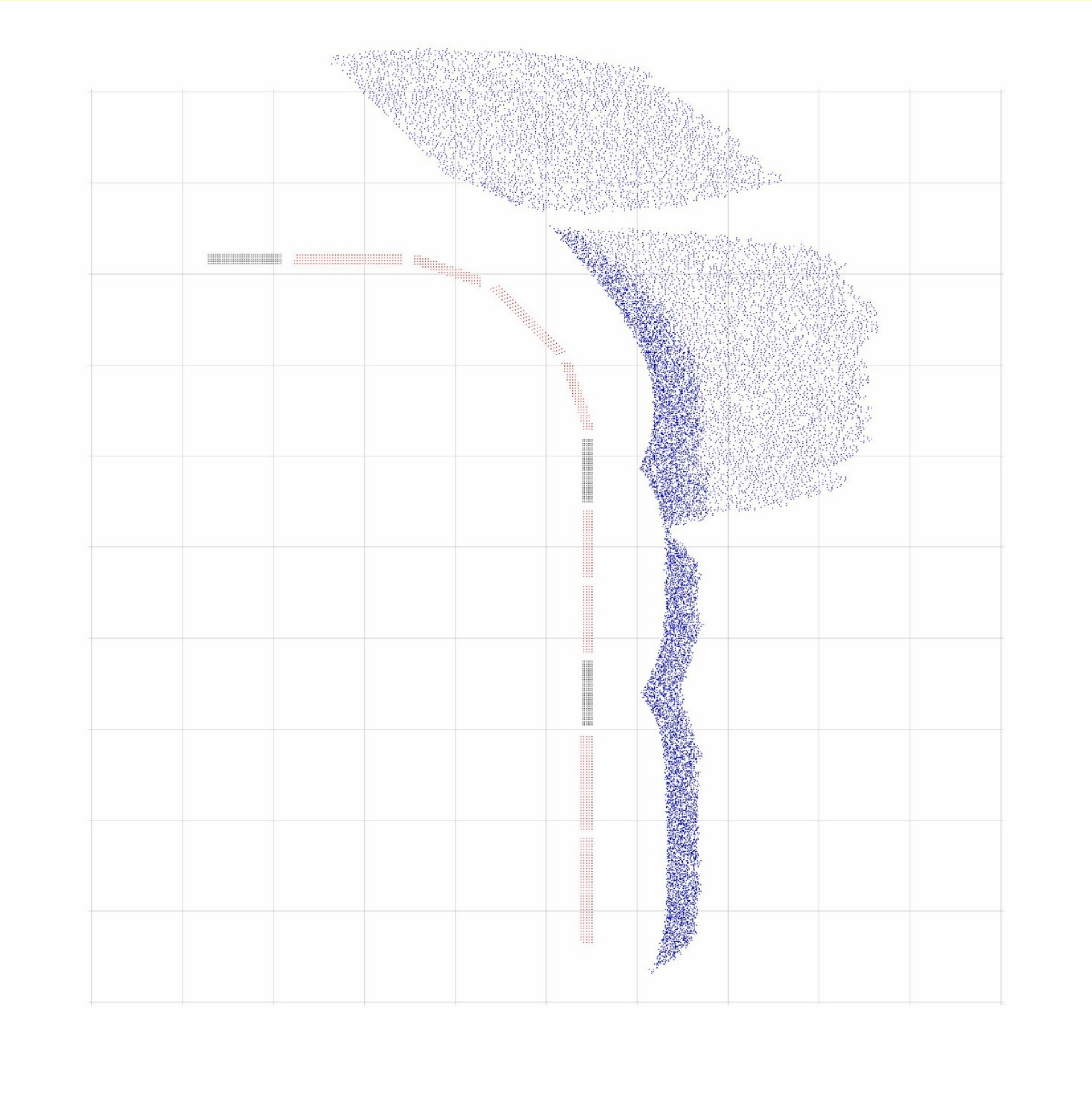
Avoid crowding
– use “flocking” or “herding” rules
– move away from adjacent neighbours
– similar to Boids (but 2D only)

The Historical Battle

British too spread out allowing Zulu to get around the flanks

British too far from the camp leading to ammunition shortages

British allies (local, untrained, no guns) holding important sections of the line



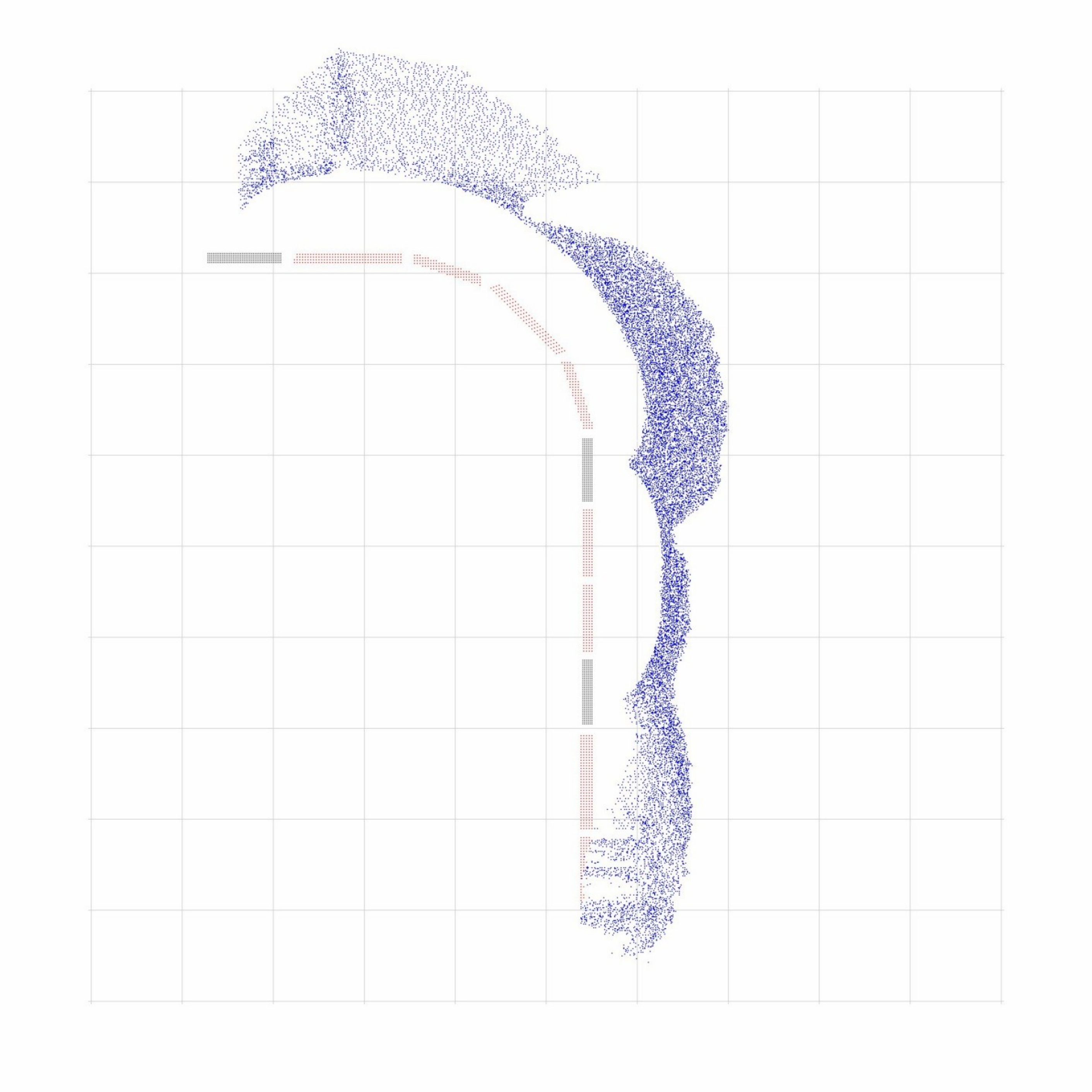
Step 480

An agent for every soldier (20,000+)

Red = British
Blue = Zulu
Grey = British ally

Every individual in formation

Leading Zulu drop prone under fire

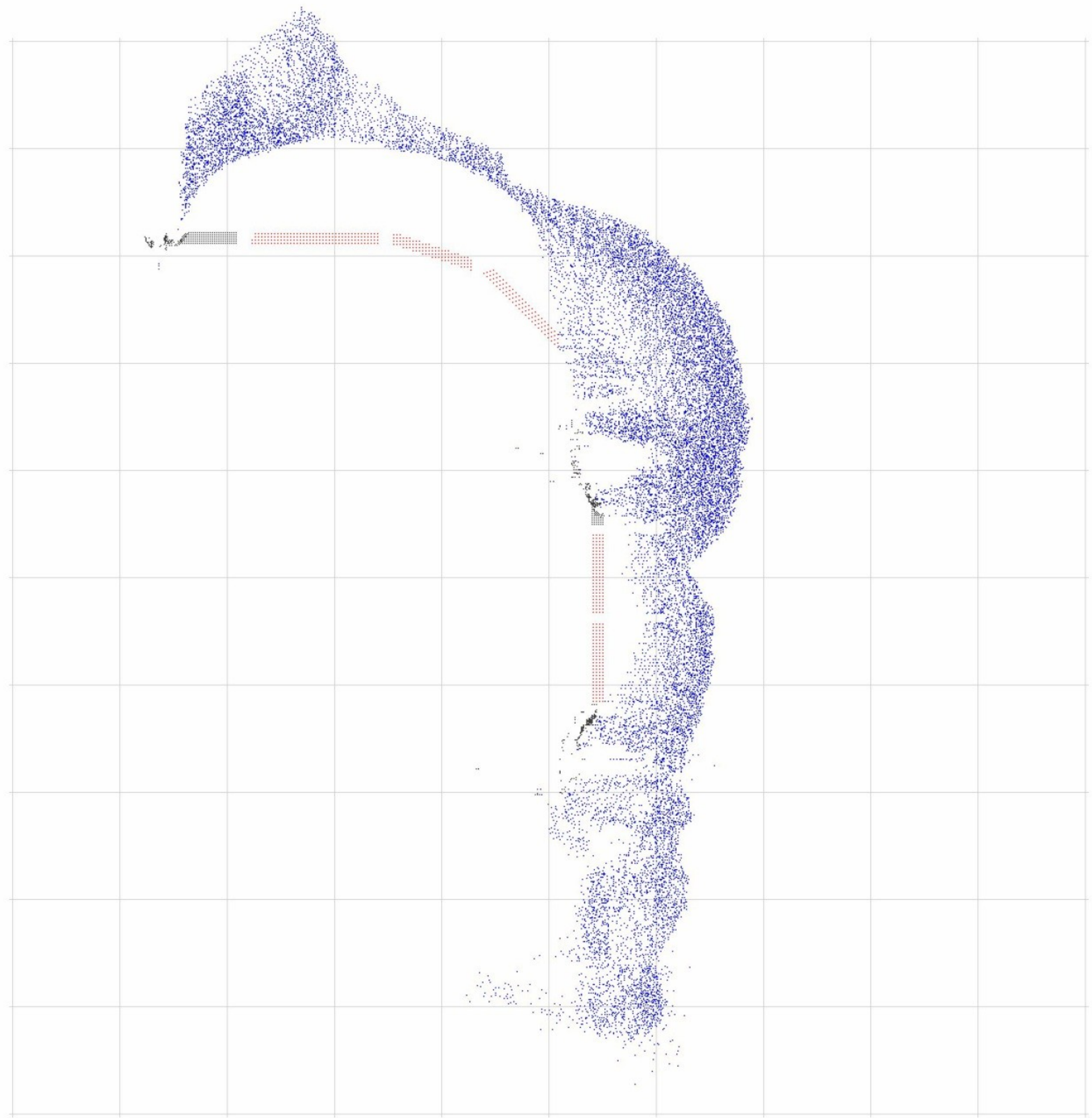


Step 680

Zulu in centre are bunched and taking cover (prone).

British right flank (bottom) run low on ammunition

Zulu right wing (top) moving in



Step 840

British run short of ammunition and British allies run away Zulu break through

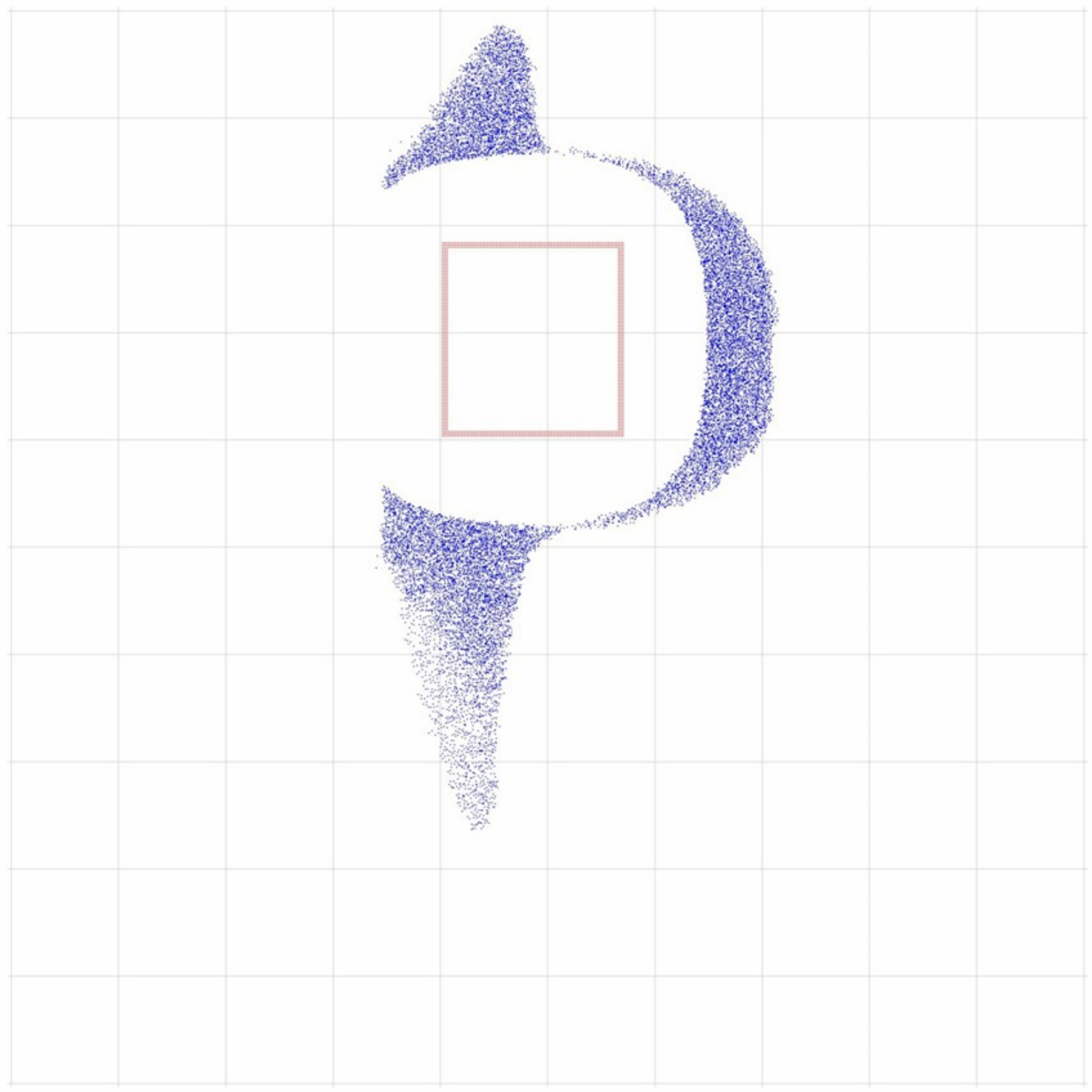
Zulu in centre are bunched

Matches history

(as far we know)

Alternative History

- **All simulation parameters are identical**
- Select a **realistic alternative**
- British allies are not present
- British set up in a square around the camp



Step 1360

Zulu wings are still advancing

Most Zulu remain prone

All British survive

Keys to creating a good simulation

- **Know the background**
- Ensure that your model "matches reality", while keeping your goal in mind
- **Create a few, simple rules**
- Can you produce an alternative scenario?

Predator-prey Simulations

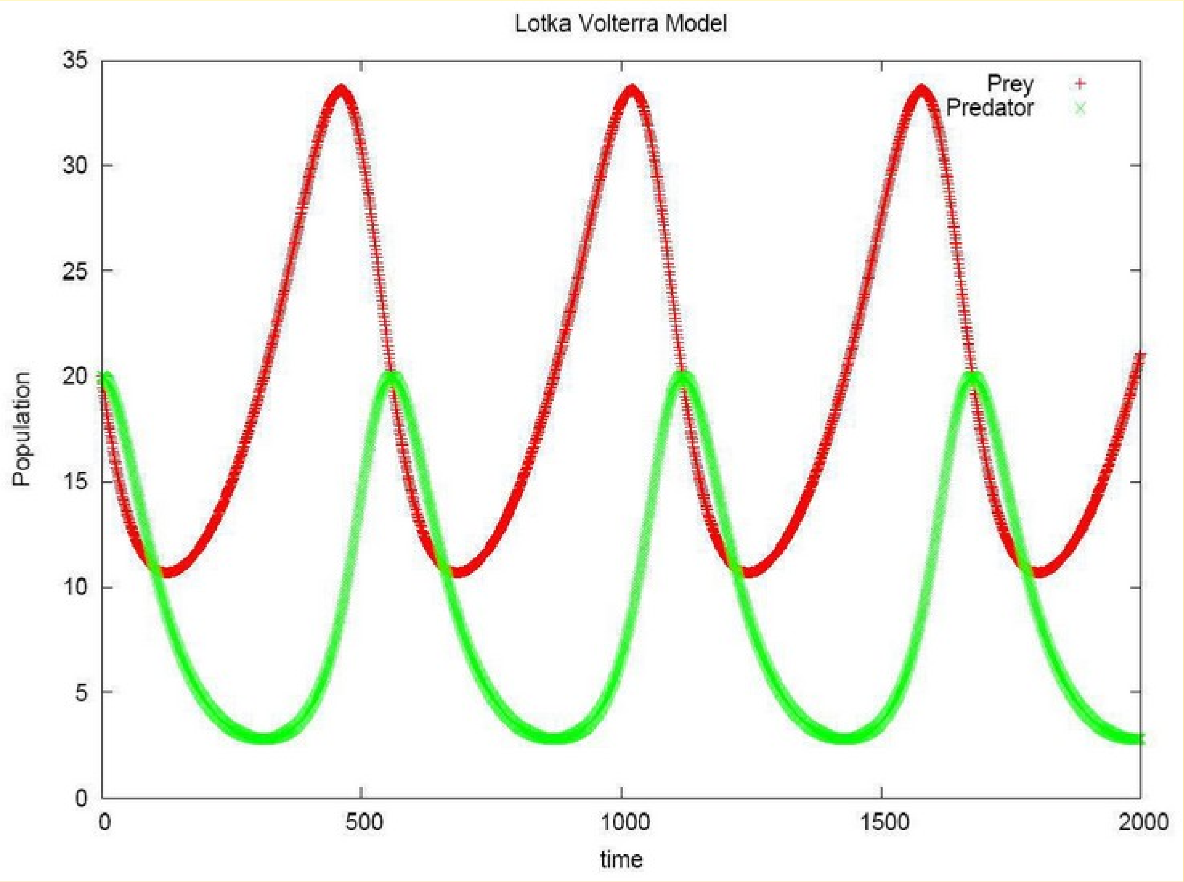
- **Lotka-Volterra equations (1925)**
- Well known model that is widely used
- Prey equation:

$$\frac{dx}{dt} = \alpha x - \beta x y$$

- Predator equation:

$$\frac{dy}{dt} = \delta x y - \gamma y$$

Lotka-Volterra example



Predator population lags behind prey in "boom-bust" sequence

Prey “animats”

Rules in priority order:

1. if adjacent to a predator – move away

2. if health < 50% and located on grass – eat grass

3. if health > 50% and potential mate adjacent – breed

4. if health > 50% – move nearer to potential mate

5. move randomly to an adjacent position

Predator "animats"

Rules in priority order:

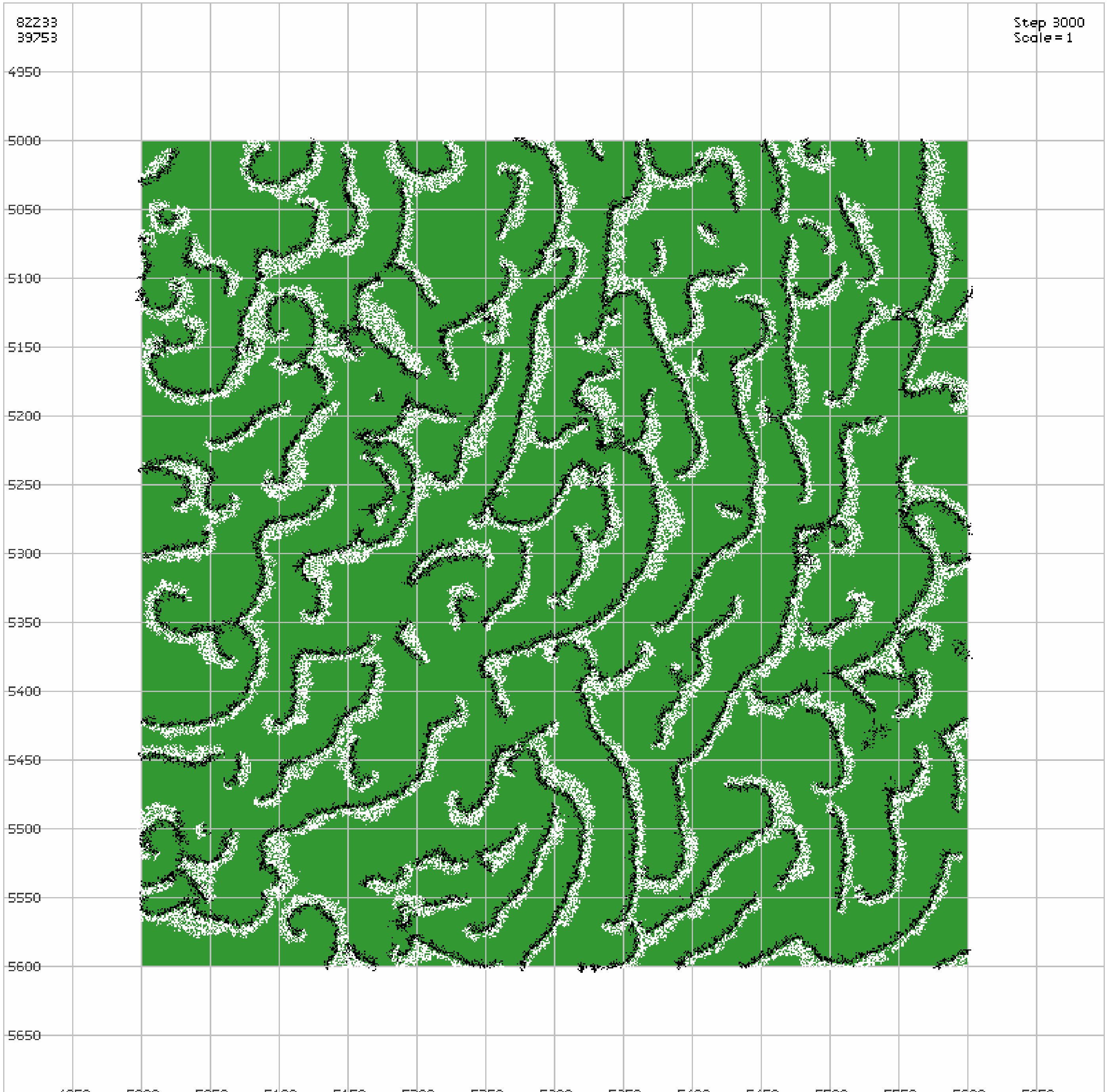
1. if health > 50% and potential mate adjacent – breed

2. if health < 50% and prey adjacent – eat prey

3. if health > 50% – move nearer to potential mate

4. if health < 50% – move nearer to prey

5. move randomly to an adjacent position



Predators = black
Prey = white

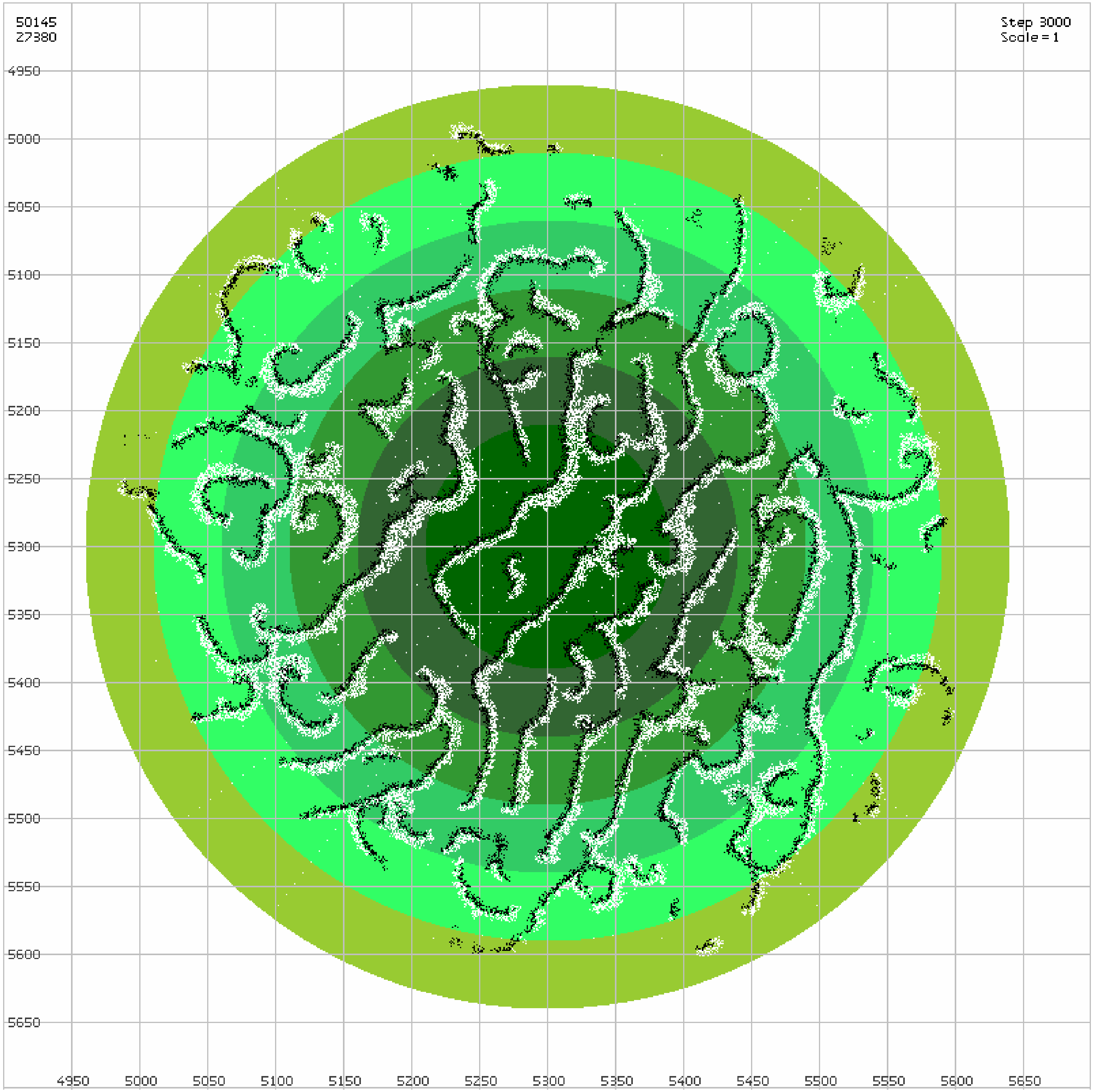
Time step 3000
82,233 prey
39,753 predators

Emergence of spatial patterns such as battle lines and **spirals**

Note the “grass”
No “edge” effects

Effects of grass and edges

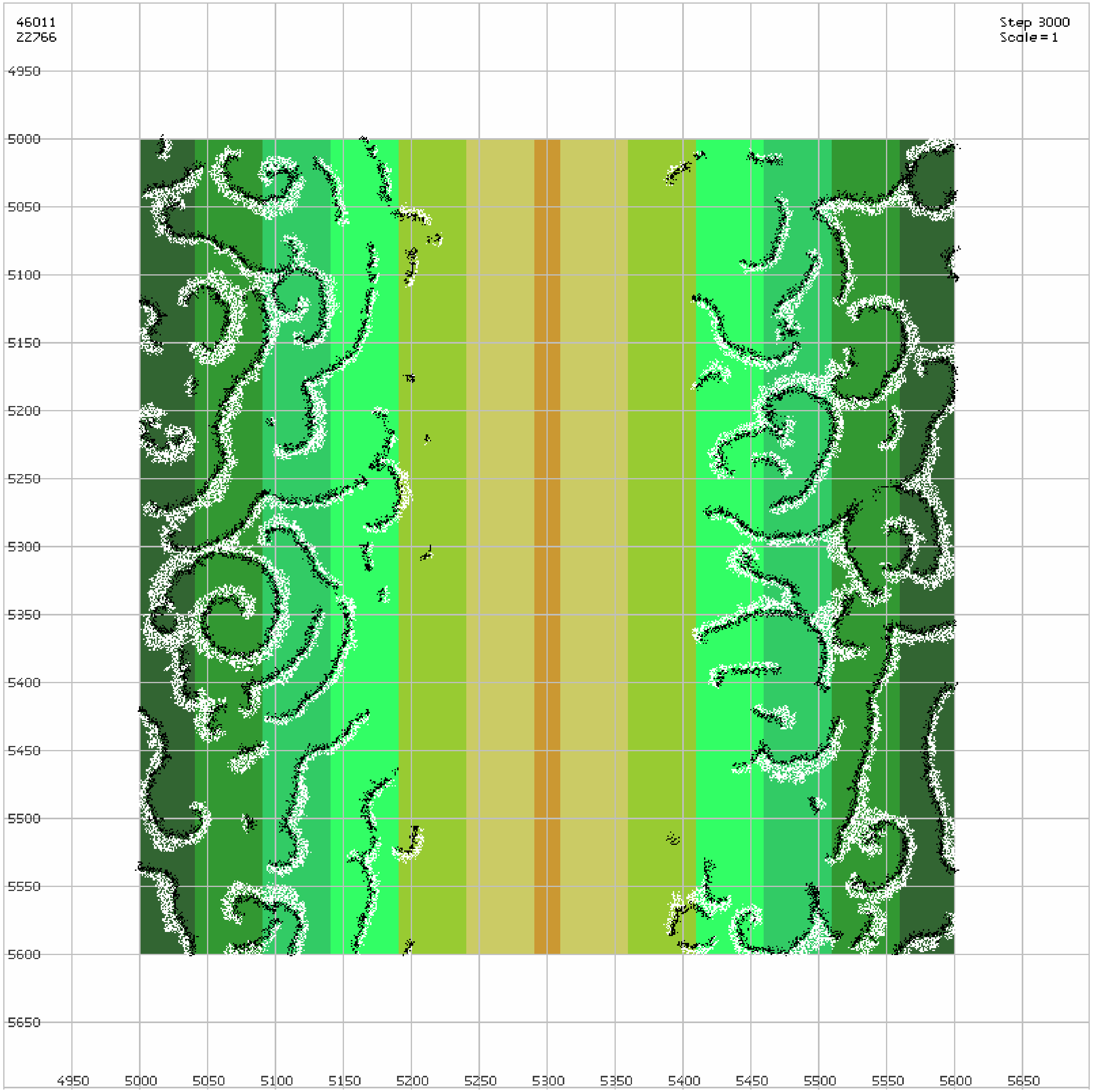
- Original model (no grass) = endless expansion
- Grass is useful to contain the model
- No “edge” effects – everything is local
- Grass with different “nutritional” values



Predators = black
Prey = white

Best (high value) grass in centre

No effect on the emergence of battle lines and spirals



Predators = black

Prey = white

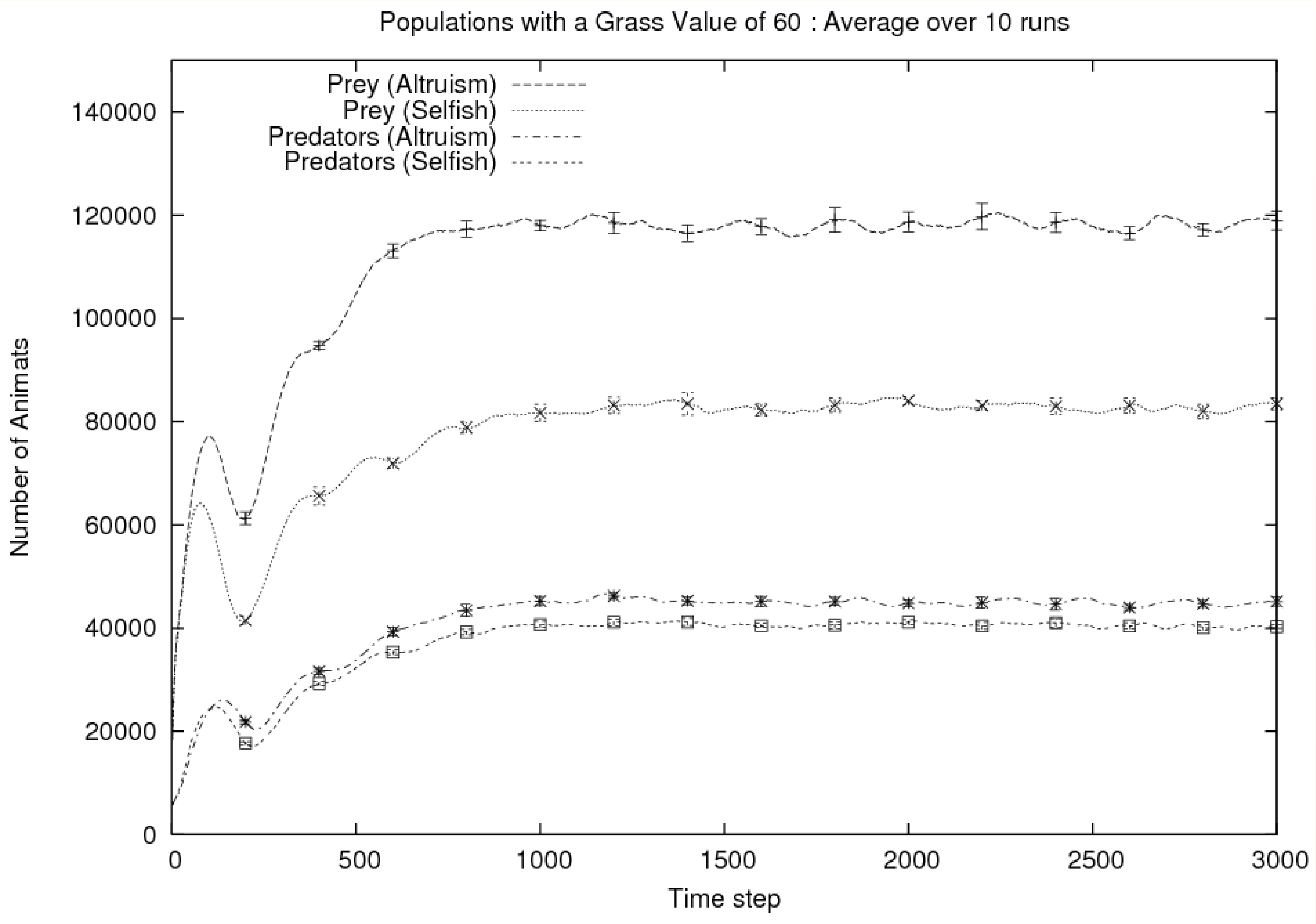
Worst (low value) grass in centre

No effect on the emergence of battle lines and spirals

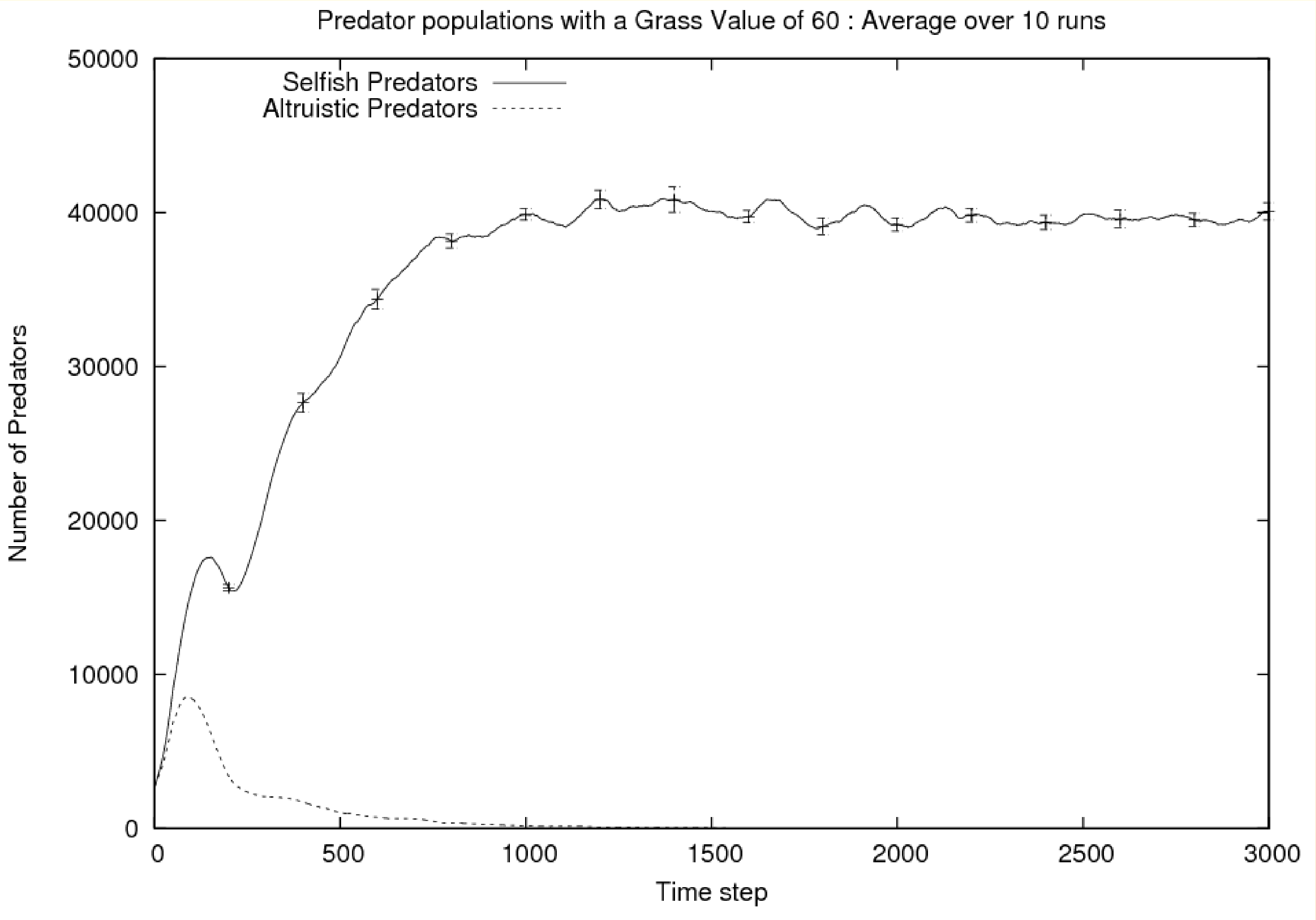
Experiment: Altruistic Predators

- New “share your lunch” rule for predators:
- if adjacent predator health < own health then both predators receive equal combined share
- For example: Predator A has 80 health and is adjacent to Predator B with 40 health then both predators change health to 60

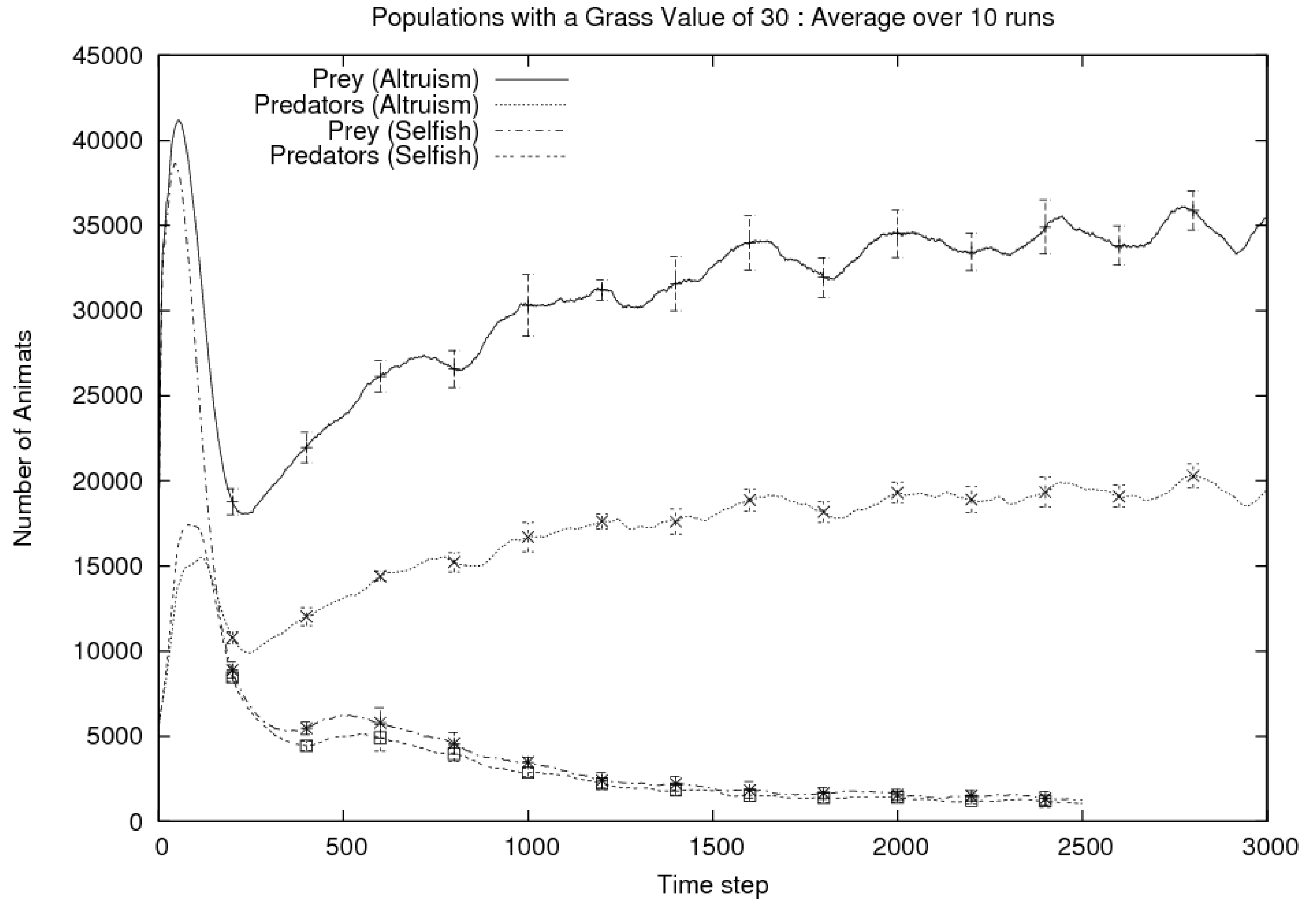
No competition (prey plentiful)



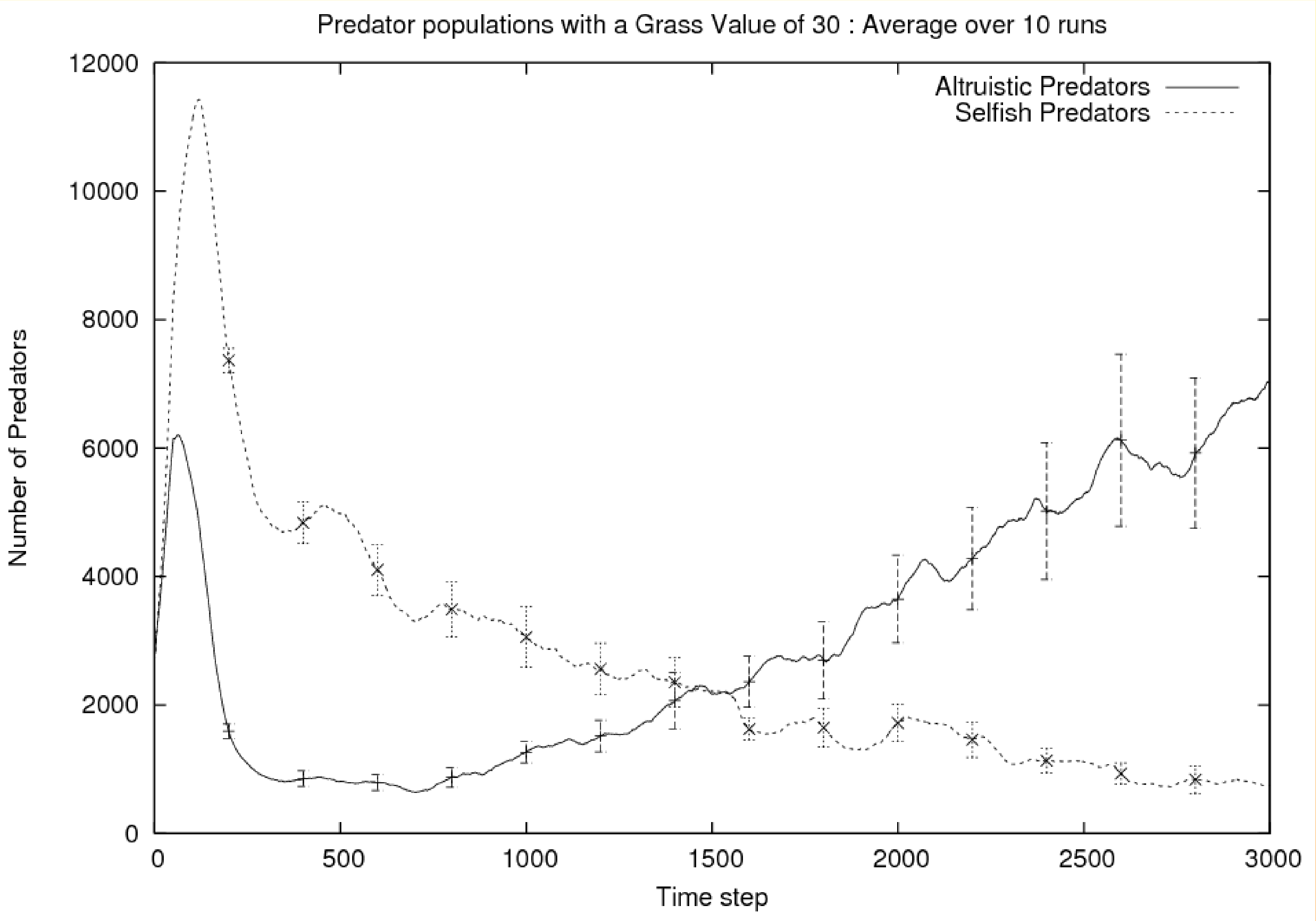
Competition (prey plentiful)



No competition (prey scarce)



Competition (prey scarce)



Experiment: Spatial Patterns

- Does spatial location matter?
- Set all animats in fixed pattern and run…