

Group 17

Agent-based Modelling (ABM)

Simulating Societal Collapse in Multi-Generational Space Travel

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Existing Literature

... about space settlements and survival:

- “Computing the minimal crew for a multi-generational space travel towards Proxima Centauri b”
Marin & Beluffi (2018)
- “Minimum Number of Settlers for Survival on Another Planet”
Salotti (2020)
- “Should and could humans go to Mars? Yes, but not now and not in the near future”
Szocik (2019)
- “Can Deep Altruism Sustain Space Settlement?”
Haqq-Misra (2019)

“... shows that ethical and social virtues, not current technological and medical threats, are the biggest risk for success of the mission.”
by Haqq-Misra (2019) cited in Szocik (2019)



Motivation

- Observe: complex social behaviour.
- Complex task: sustaining a society with limited resources for multiple generations
- Consider: social / human factors

Take Examples from Lecture:

- *Dating Choice Model* by Kalick and Hamilton (1986)
- *Simulating Irrational Human Behavior to Prevent Resource Depletion* by Sircova, Karimi, Osin, Holme, Strömbom (2015)
- Granovetter Threshold Model (1978)
- Opinion Dynamics



Base Model

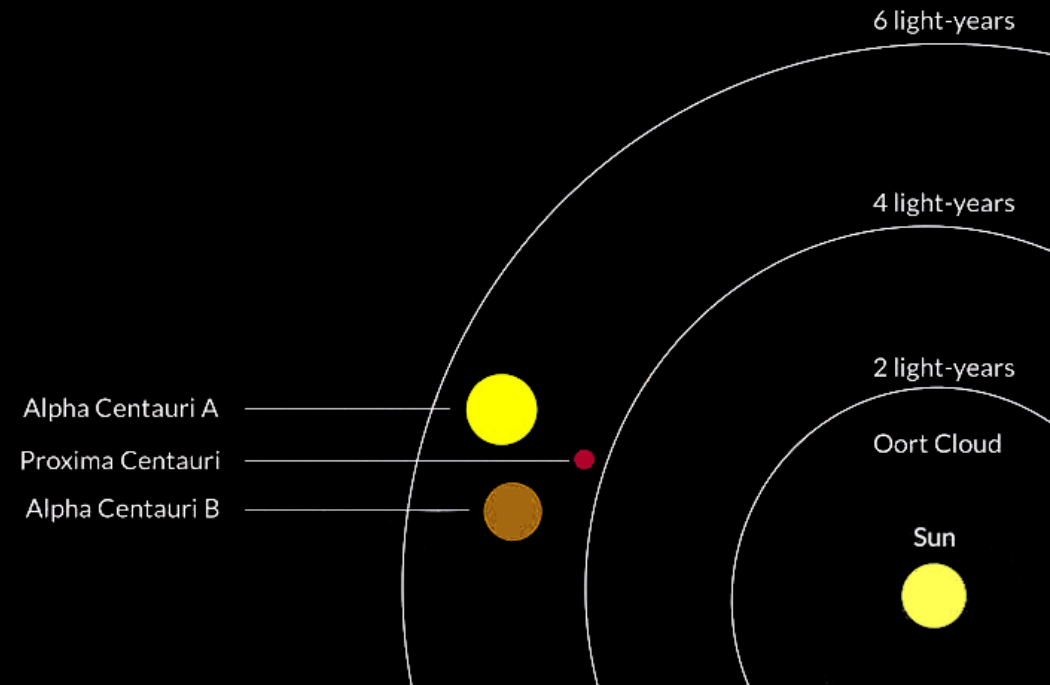


Found ABM model with mating logic but without any **selectiveness** (apart from simple checks) or **irrational behaviour**:

- Model initially based on an astrophysics paper [1]
- ABM approach based on **Netlogo model** [2]
 - Simulation of long-distance space flight
 - contains realistic data
 - parameters set based on research

[1] "Computing the minimal crew for a multi-generational space travel towards Proxima Centauri b" by Marin & Beluffi (2018)

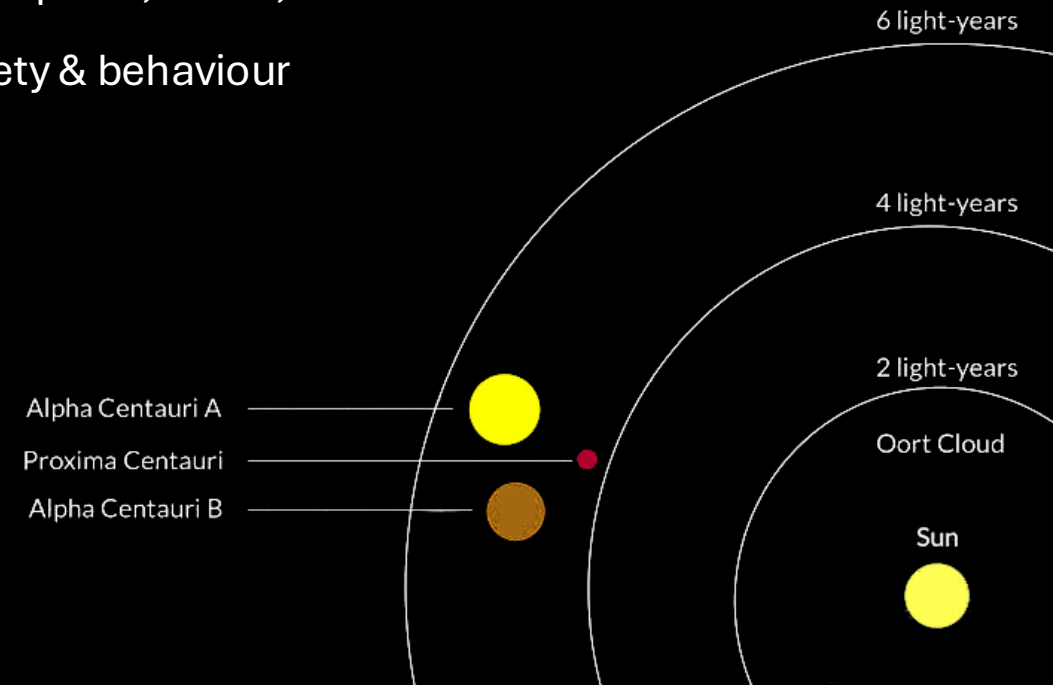
[2] "Simulation of a long-distance space flight" by Sommer & Thorsten (2019)



Base Model



- Base Model simulates **life on spaceship**
- **Agents**: male & female, movement, mating, pregnancy
- **Parameters**: crew size, fertility, age, mating behaviour
- **Observation mechanics**: population over time, accidents, crew demographics, births, deaths
- **Assumptions**: infinite resources, no maintenance needed, simple society & behaviour
- **Environment**: safety zones on ship, accidents occur
- **Mission Completion Check**:
 - Year 6,300 is reached
 - overcapacity
 - or **extinction**



Analysis 1

Base Model (society survives with default parameters)

Initial parameters:

100 people

☐ On ☐ Off simulateMonthsInsteadOfDays

Crew's initial age:

20 years

20 years

22 years

Max. age:

85.0 years

79.0 years

15 years

Crew's bio parameters:

10 %

15 %

2.0 children

0.5

35 years

40 years

☐ On ☐ Off useDynamicPermittedMating

Females's bio parameters:

48.81 years

3.9 years

setup

go

Current Year

6300

Males' statistics:

211

29

43.68

Females' statistics:

216

19

46.48

Crew's statistics:

45.08

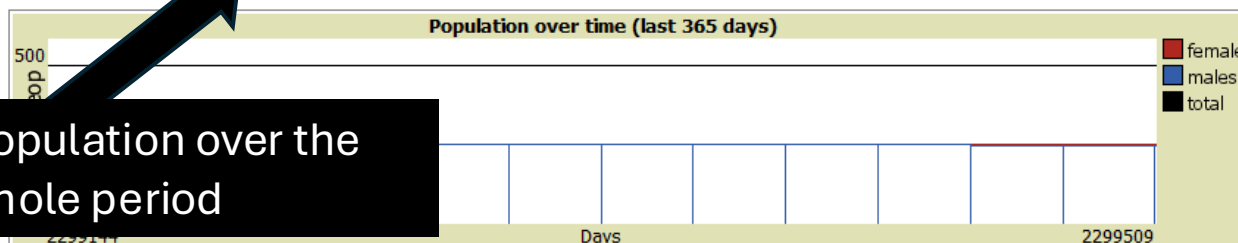
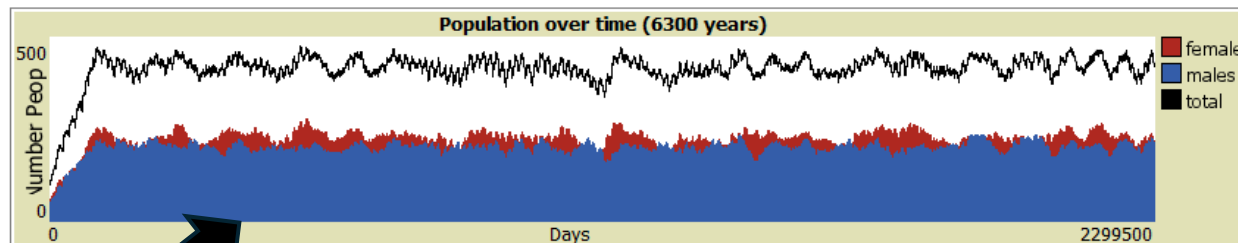
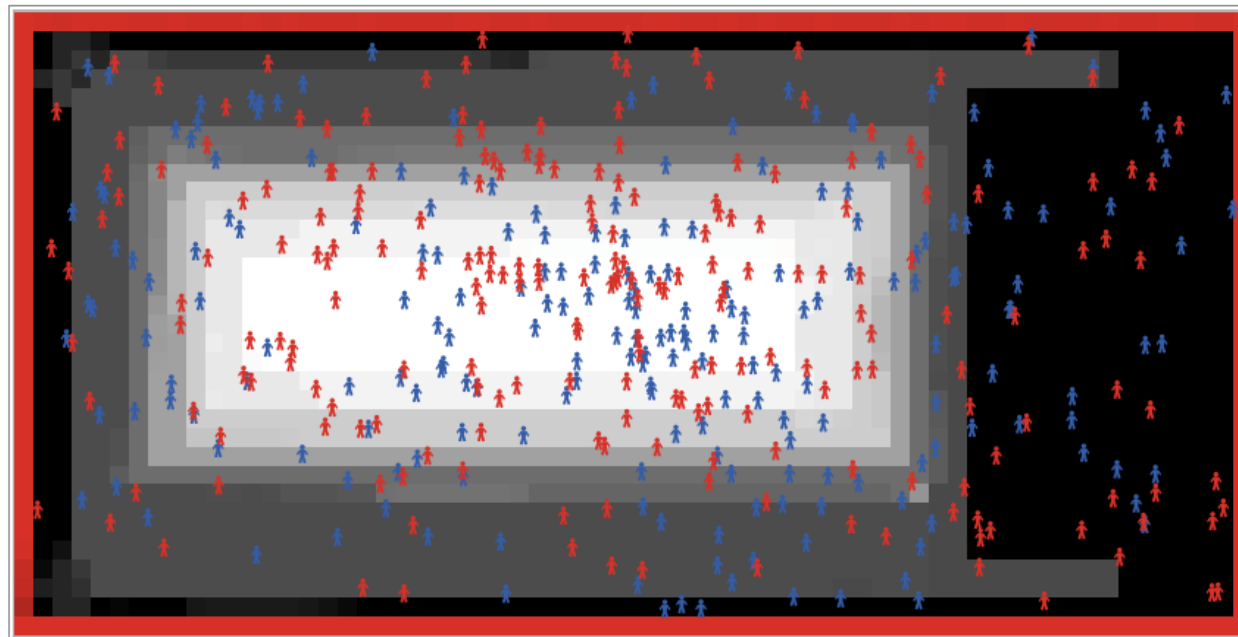
743

127

31701

5

# births	# females	# males
32028	16446	15582



After the mission ended, the reason why this was the case is given here:

The mission was successful: survivors reached the distant planet.

Stable population over the whole period

Extended Model: with Selectiveness logic



- NEW: Determine the probability of mating
- Process simulates a more realistic social interaction
- Attractiveness-based mate selection simulates mutual consent
- Attractiveness value assigned randomly
 - at birth of each agent (random 0-10)
- When two agents meet:
 - calculate individual differences in values
 - The smaller the difference, the higher the accept probability (%)
 - If attractiveness difference is large, the probability of mating decreases, leading to more rejections.

Research Question:

After the introduction of selective dating preferences, at what difference threshold in polarizing view values does the society go extinct because it cannot sustain itself any longer?

Analysis 2

Extended Model: Base Model that includes selectiveness



Initial parameters:

initialCrewSize 100 people

☒ On simulateMonthsInsteadOfDays

Crew's initial age:

initialAgeFemales 20 years

initialAgeMales 20 years

initialAgeStdDeviation 22 years

Max. age:

maxAgeFemales 85.0 years

maxAgeMales 79.0 years

ageStdDeviation 15 years

Crew's bio parameters:

infertilityFemales 10 %

infertilityMales 15 %

maxChildrenPerFemale 2.0 children

maxChildrenStdDeviation 0.5

startAgePermittedMating 35 years

endAgePermittedMating 40 years

☒ On useDynamicPermittedMating

Females's bio parameters:

meanAgeMenopause 48.81 years

ageMenopauseStdDeviation 3.9 years

setup

go

Current Year
6300

Males' statistics:

males
199

males (infertile)
41

mean age males
37.49

Females' statistics:

females
198

females (infertile)
18

mean age females
41.09

Crew's statistics:

mean age crew
39.29

accidents
777

deaths caused by accidents
128

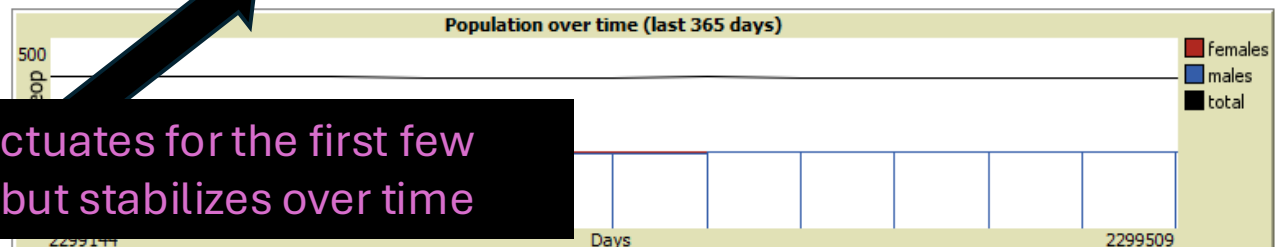
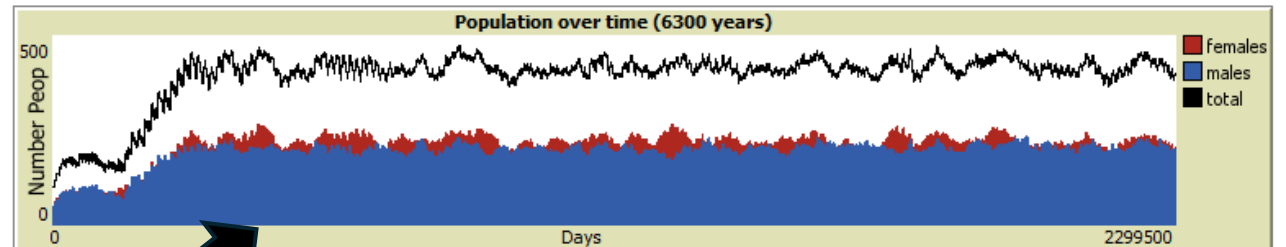
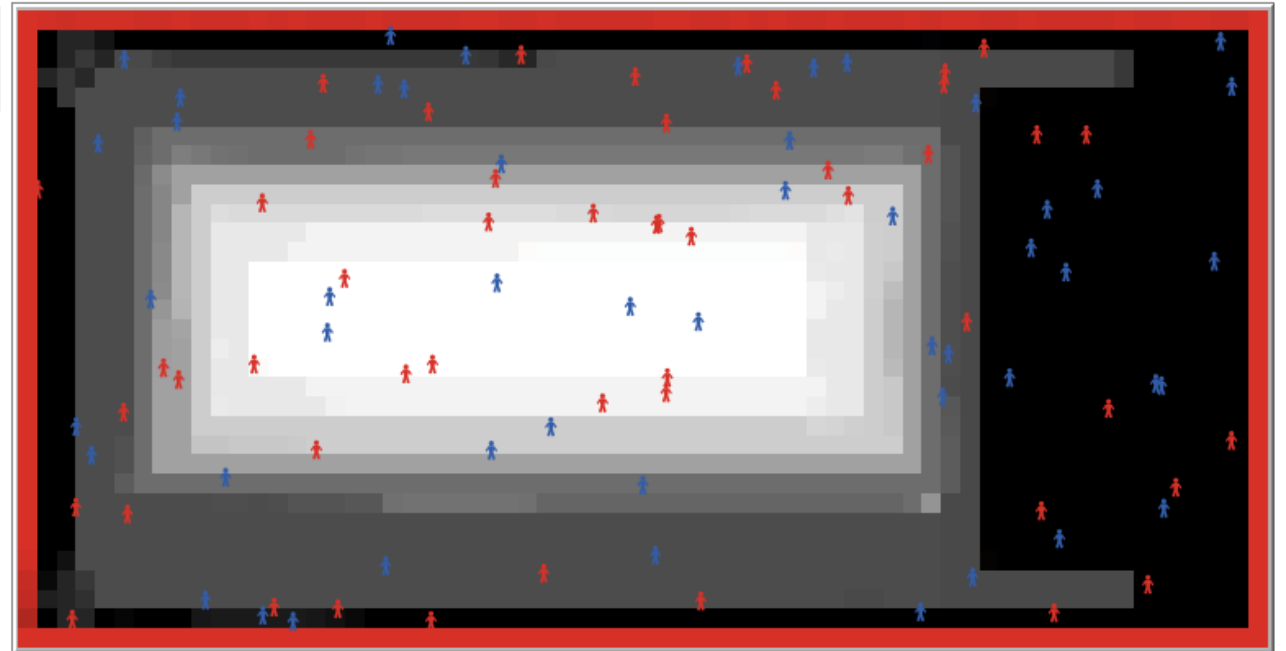
deaths
30124

pregnancies
1

# births	# females	# males
30420	15353	15067

After the mission ended, the reason why this was the case is given here:

The mission was successful:
survivors reached the
distant planet.



Society fluctuates for the first few centuries, but stabilizes over time

Extended Model: with Polarizing View logic

Representative for
opposing views:

religious,
political,
ethical,
national,
moral,
etc.

NEW: Killing possible based on polarizing view differences

- Each agent: born with random pv value between 0-10
- if two agents meet outside the safety-zone (white) on ship
 - check differences of polarizing view
 - if values are too far from each other: one of the two agents can get killed

Example: Agent A has pv value of 2

Depending on treshold of pv difference:

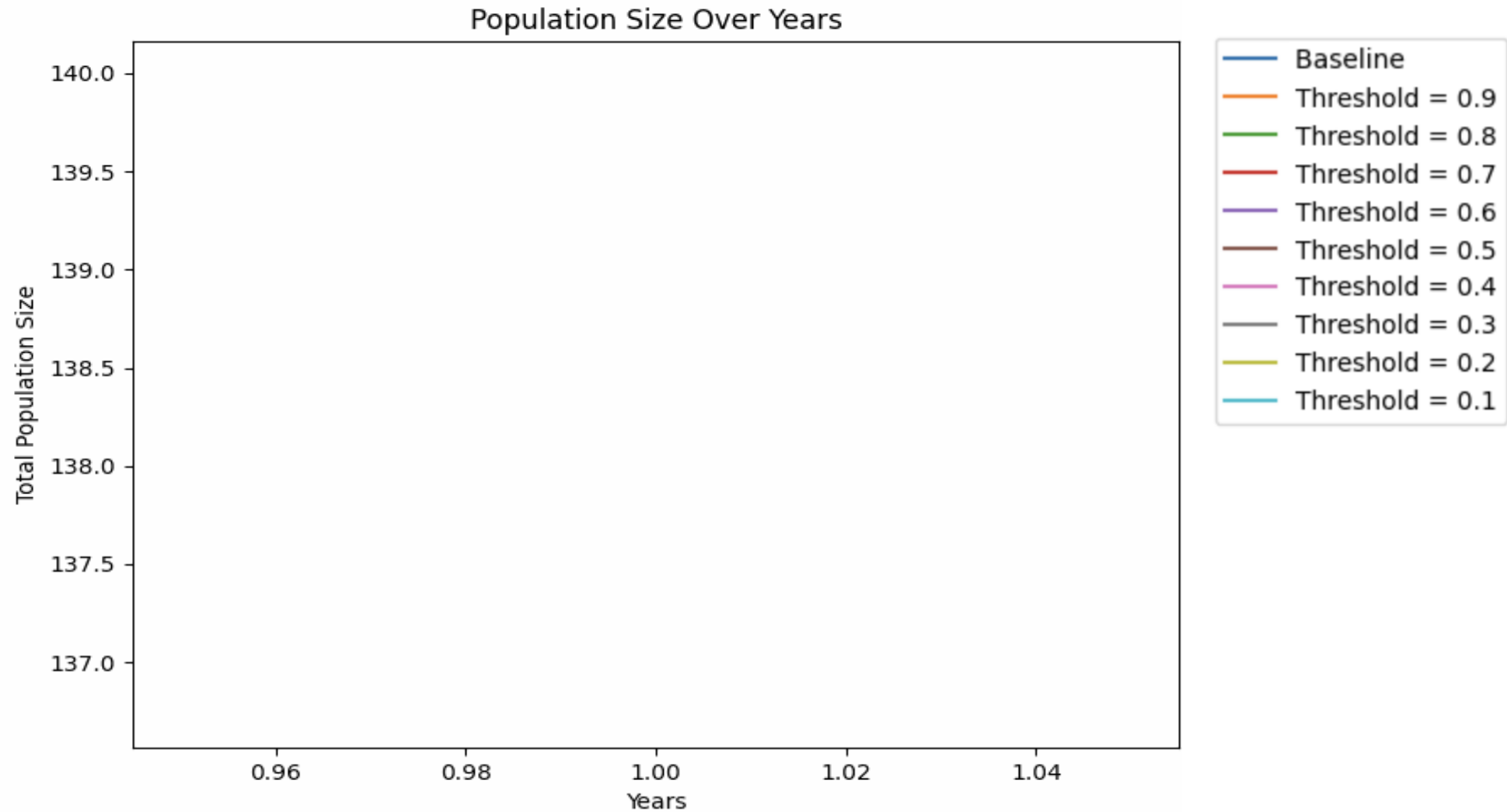
- A and B will try to kill each other if the difference is too big



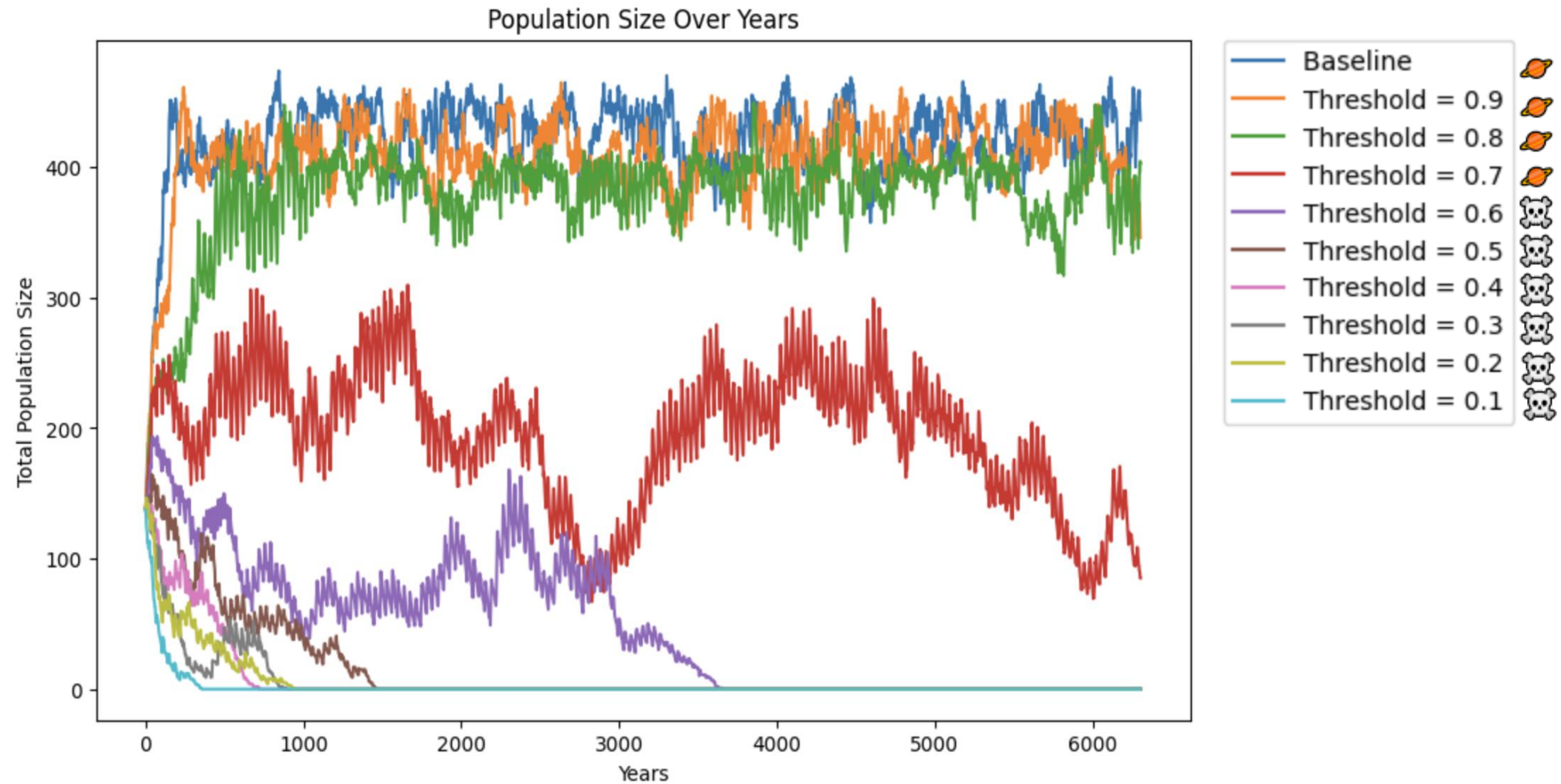
We want to test
these diff_tresholds in
the remaining slides!



Simulating Populations with Different Thresholds



Simulating Populations with Different Thresholds



Analysis 3

Extended Model: includes selectiveness &
homicide caused by polarizing views (at view_difference > 7)

Initial parameters:

100 people

☐ On simulateMonthsInsteadOfDays

Crew's initial age:

20 years

20 years

22 years

Max. age:

85.0 years

79.0 years

15 years

Crew's bio parameters:

10 %

15 %

2.0 children

0.5

35 years

40 years

☐ On useDynamicPermittedMating

Females's bio parameters:

48.81 years

3.9 years

setup

go

Current Year
6300

Males' statistics:

males
53

males (infertile)
11

mean age males
47.97

Females' statistics:

females
65

females (infertile)
9

mean age females
47.3

Crew's statistics:

mean age crew
47.63

accidents
727

deaths caused by accidents
125

deaths
10344

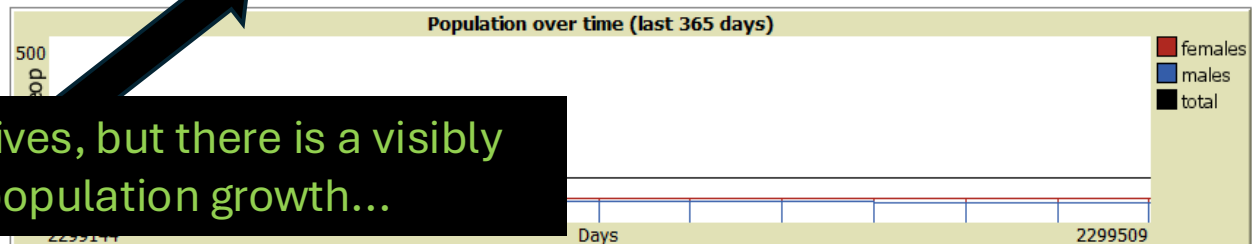
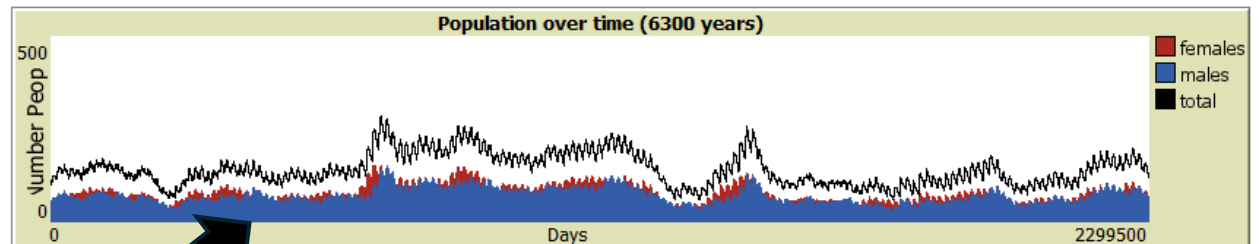
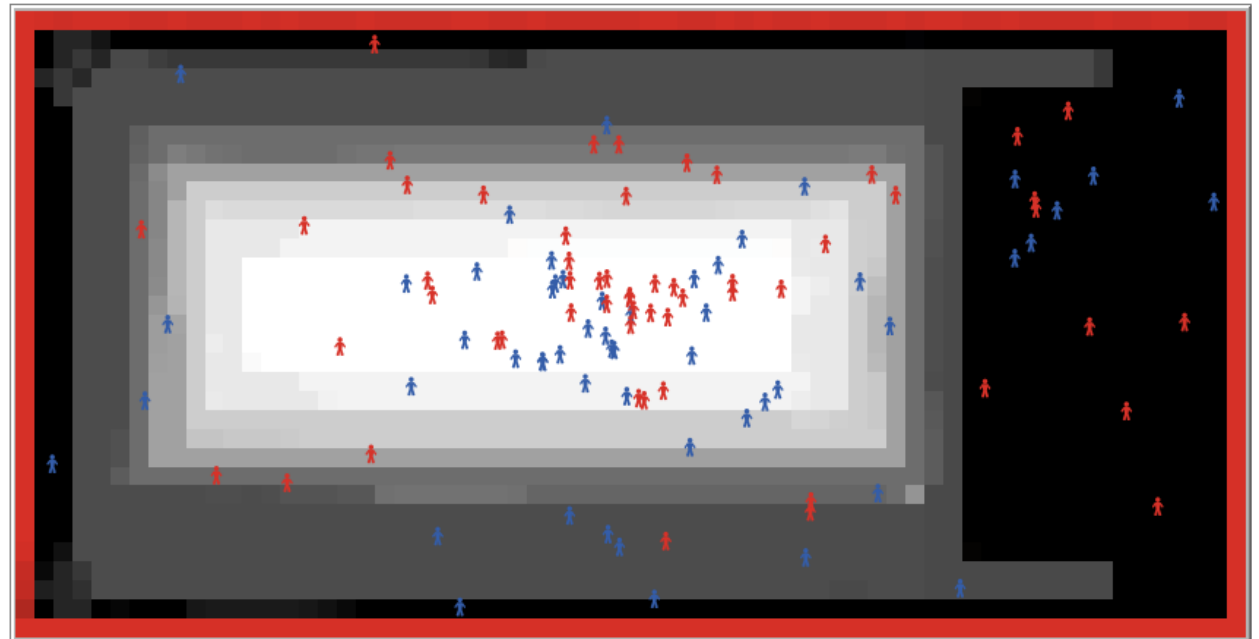
pregnancies
2

# births	# females	# males
12173	6205	5968

After the mission ended, the reason why this was the case is given here:

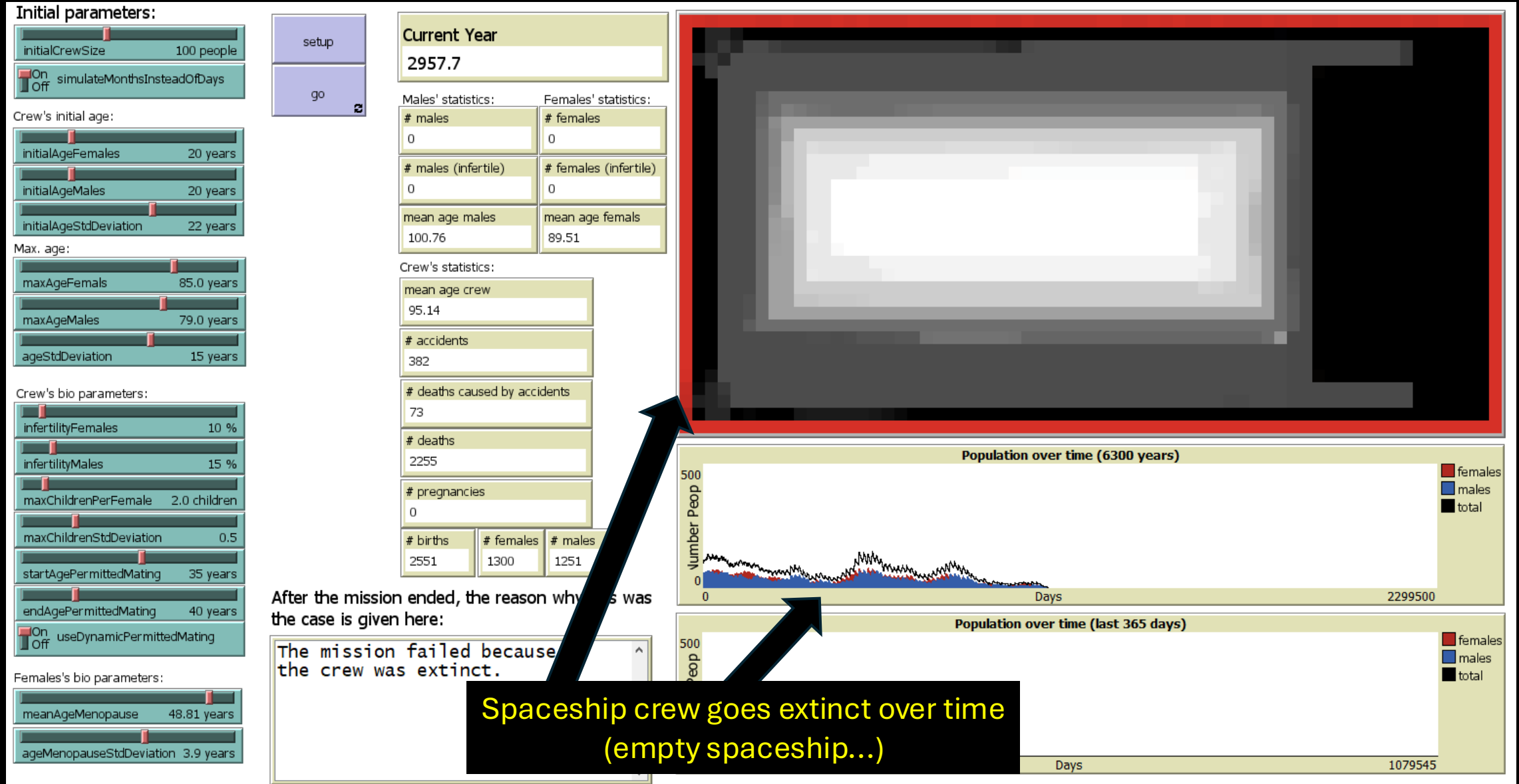
The mission was successful:
survivors reached the distant planet.

Society survives, but there is a visibly lower population growth...



Analysis 4

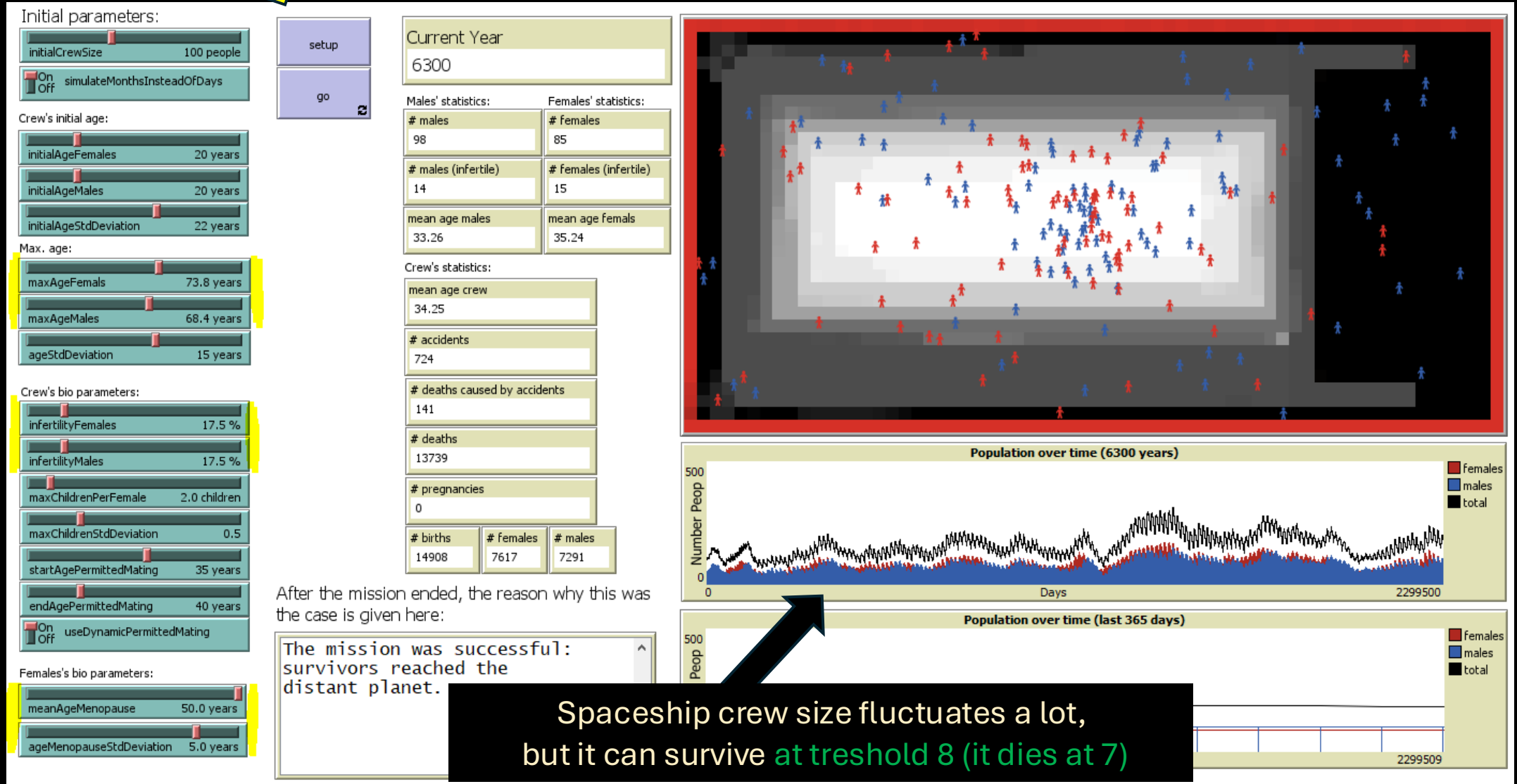
Extended Model: includes selectiveness & homicide caused by polarizing views (at view_difference > 6)



Analysis 5

Extended Model: includes selectiveness & homicide caused by polarizing views

Alternative: with our own parameters (based on background research)



Conclusion



After the introduction of selective dating preferences, at what difference threshold in polarizing view values does the society go extinct because it cannot sustain itself any longer?



- Selective mating preferences have an influence on the crew size over time

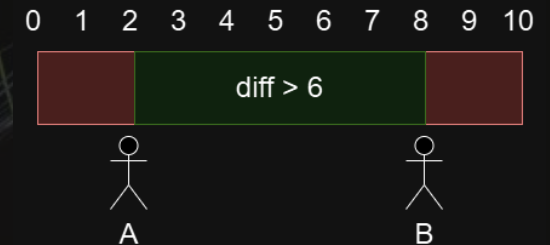
- Extended model incl. attractiveness and polarizing view:

- o Tested with default parameters: (more tolerant!)

- view_difference extinction threshold is between 6 and 7

- o Tested with our own parameters:

- view_difference extinction threshold is between 7 and 8



Limitations & Future Research

- Computational intensity restricts options
- Trying different distributions
 - of attractiveness
 - of polarizing view
- Different model for mating preferences
 - e.g. maximizing attractiveness
- Examining the unique impact of individual variables
- ABM modelling of a society is a complex process



Thank you for your attention!

Group 17

References

- [1] Github: Simulation of a 6,300-year intergalactic journey
<https://github.com/SommerEngineering/Simulation-of-long-distance-space-flight?tab=readme-ov-file>
- [2] Sommer, Thorsten (2019). Simulation of a long-distance space flight. DOI: 10.5281/zenodo.3382912
- [3] Sommer, Thorsten (2019). Simulation of a 6,300-year intergalactic journey. DOI: 10.17504/protocols.io.676hhre
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- [9] Haqq-Misra, J., Wolf, E. T., Welsh, W. F., Kopparapu, R. K., Kostov, V., & Kane, S. R. (2019). Constraining the Magnitude of Climate Extremes From Time-Varying Insolation on a Circumbinary Terrestrial Planet. *Journal of Geophysical Research: Planets*, 124(12), 3231–3243. <https://doi.org/10.1029/2019JE006222>
- [10] Marin, F., & Beluffi, C. (2018). *Computing the minimal crew for a multi-generational space travel towards Proxima Centauri b* (Version 1). arXiv. <https://doi.org/10.48550/ARXIV.1806.03856>
- [11] Haqq-Misra, J. (2019). Can Deep Altruism Sustain Space Settlement? In K. Szocik (Ed.), *The Human Factor in a Mission to Mars* (pp. 145–155). Springer International Publishing.
https://doi.org/10.1007/978-3-030-02059-0_8