

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

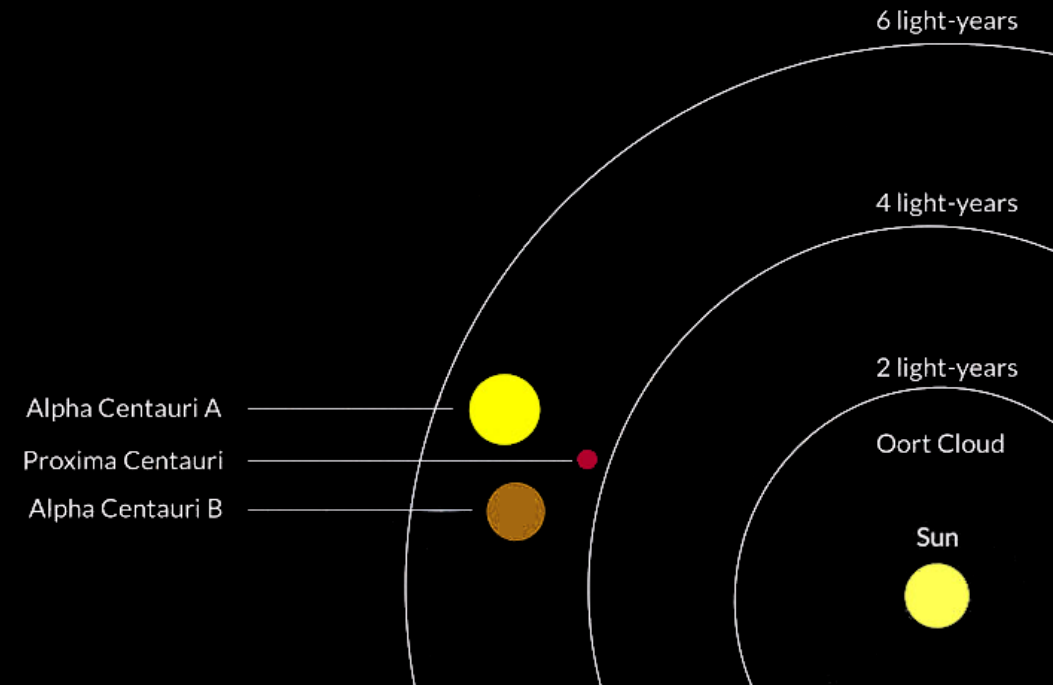


Found ABM model with mating logic but without any **selectiveness** (apart from simple checks) or **irrational behaviour**:

- 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)

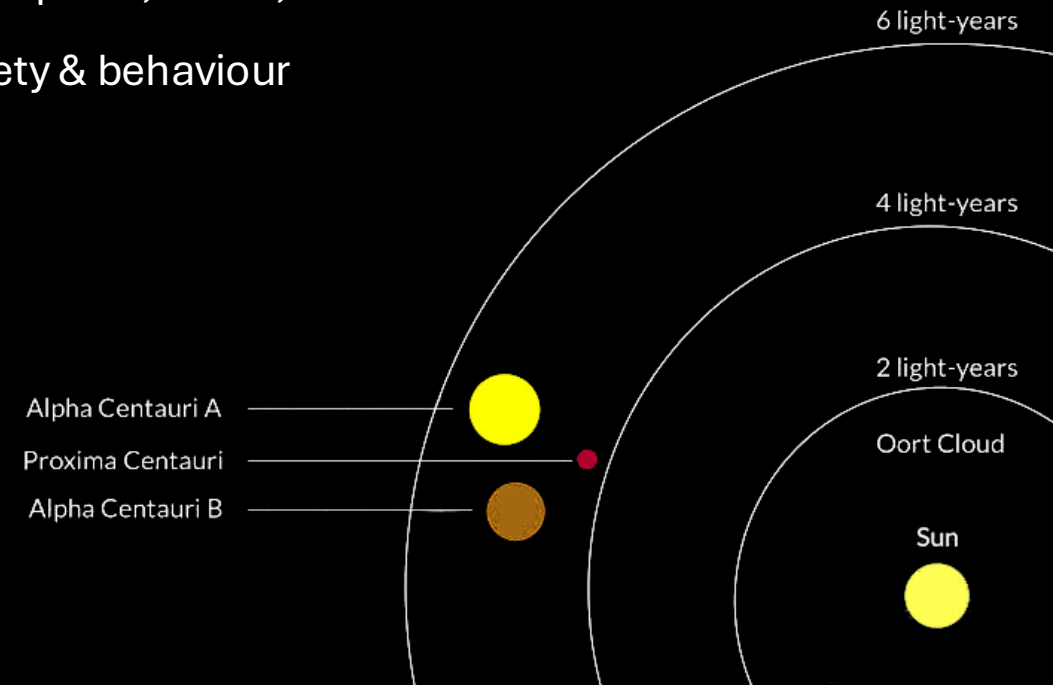
[2] "Simulation of a long-distance space flight" by Sommer & Thorsten (2019)



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

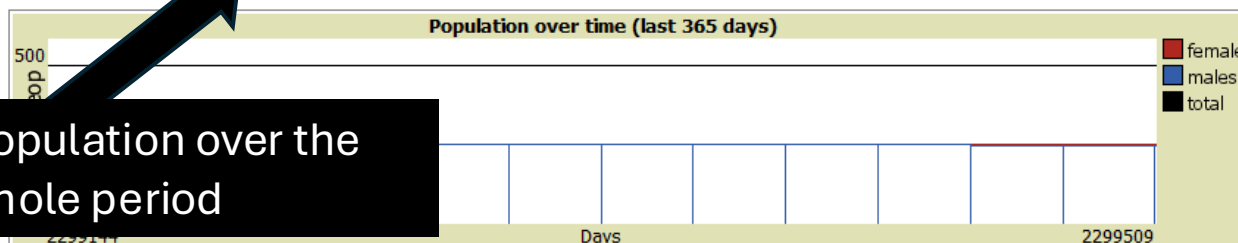
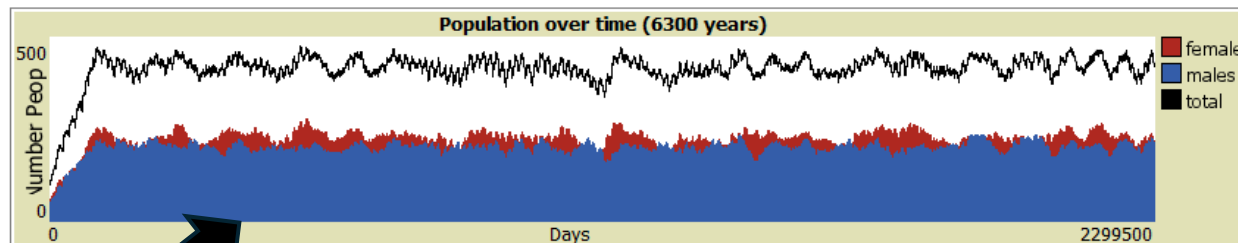
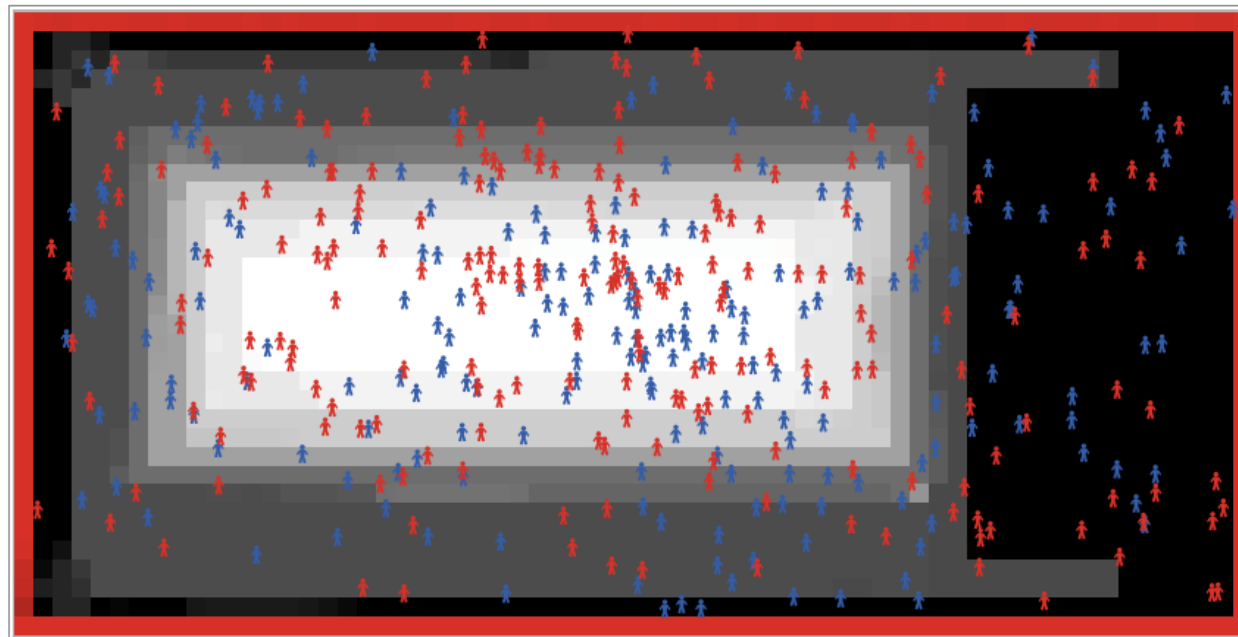
743

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:

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:

199

41

37.49

Females' statistics:

198

18

41.09

Crew's statistics:

39.29

777

128

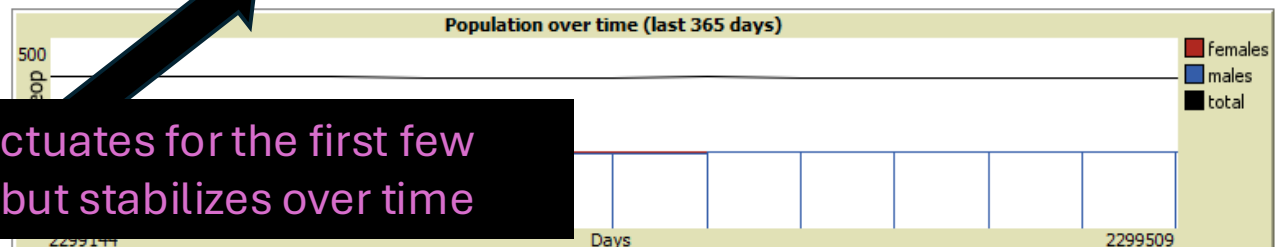
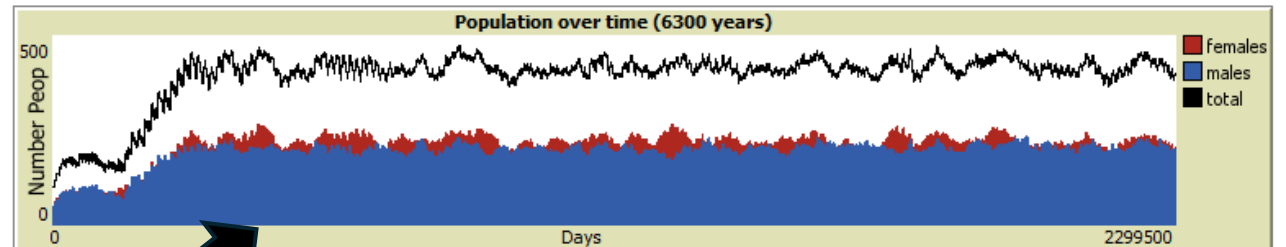
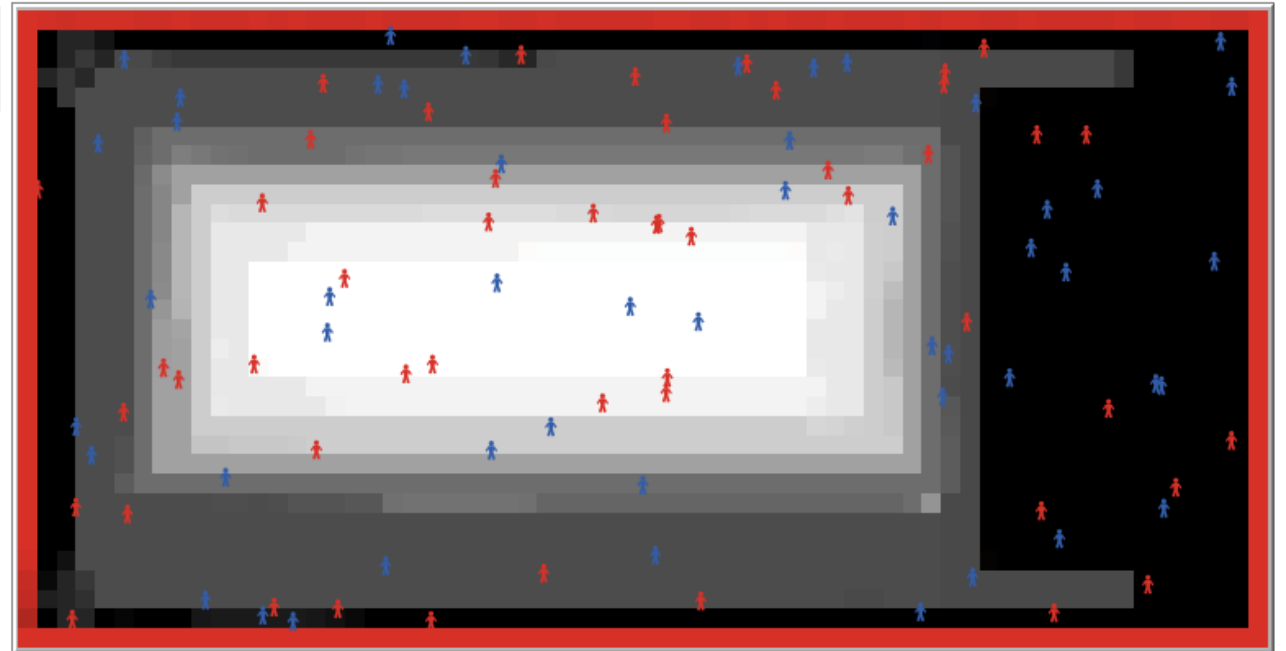
30124

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 threshold of pv difference:

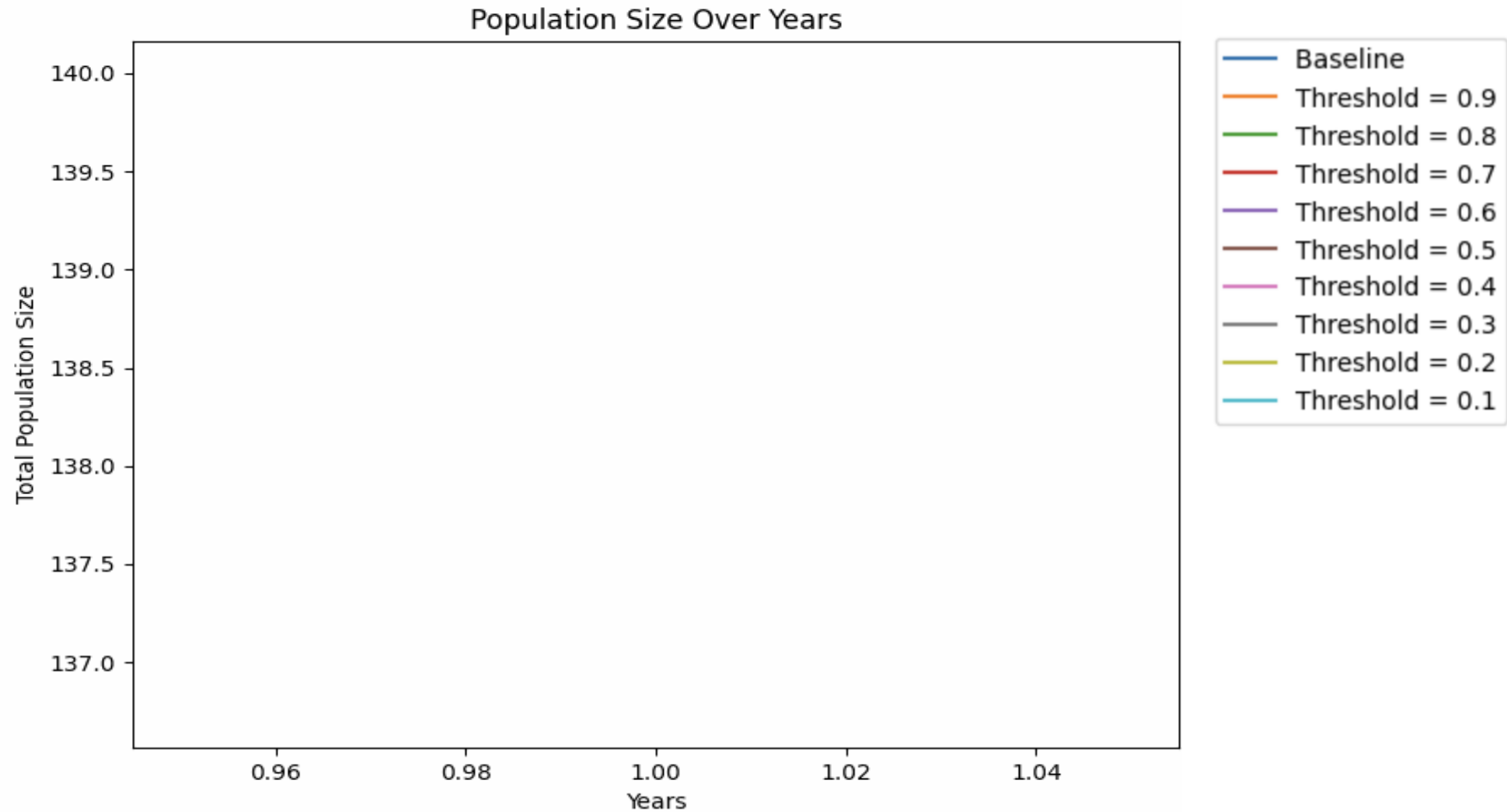
- A and B will try to kill each other if the difference is too big



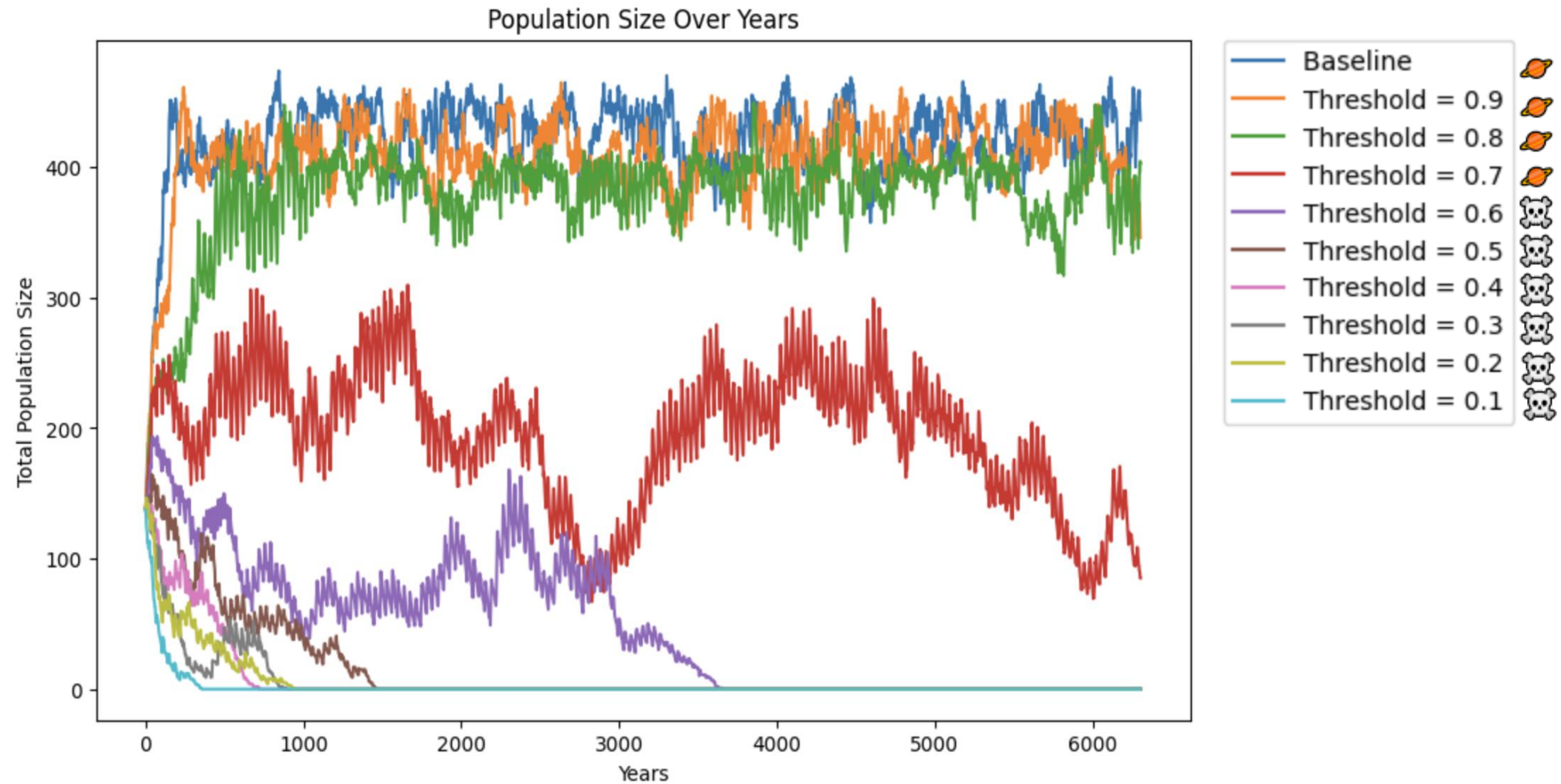
We want to test
these diff_thresholds in
the remaining slides!



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:

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
53
males (infertile)
11
mean age males
47.97

Females' statistics:

females
65
females (infertile)
9
mean age females
47.3

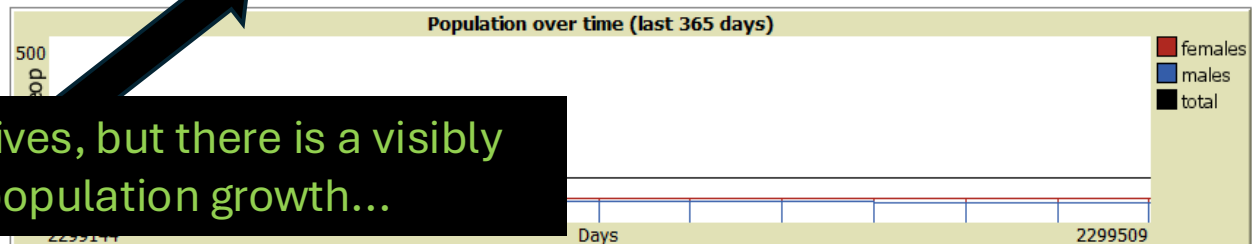
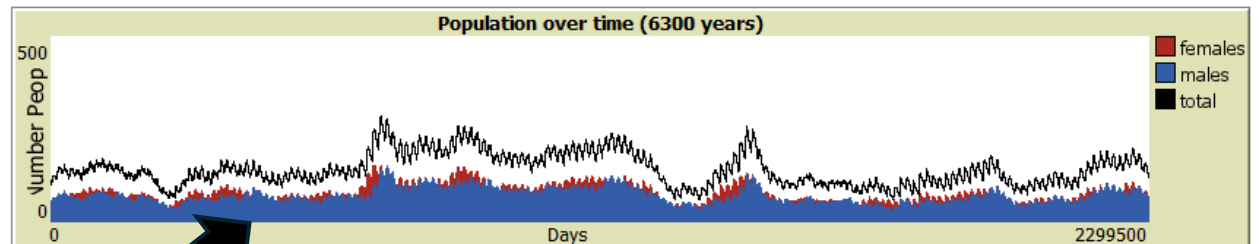
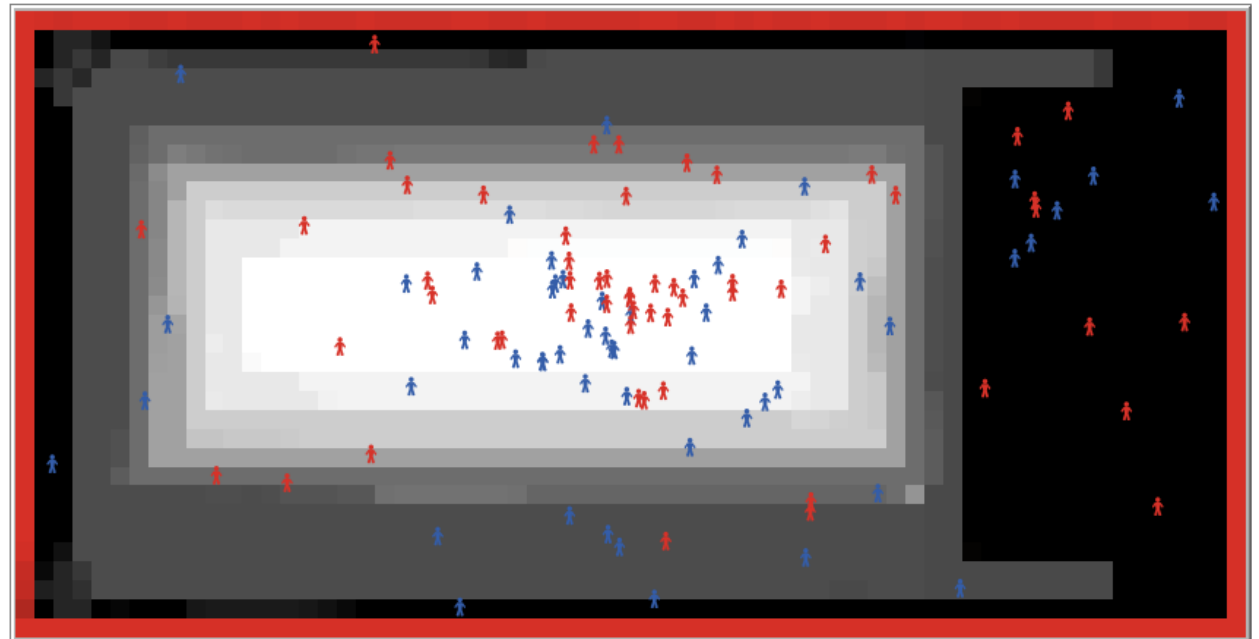
Crew's statistics:

mean age crew
47.63
accidents
727
deaths caused by accidents
125
deaths
10344
pregnancies
2
births
12173
females
6205
males
5968

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

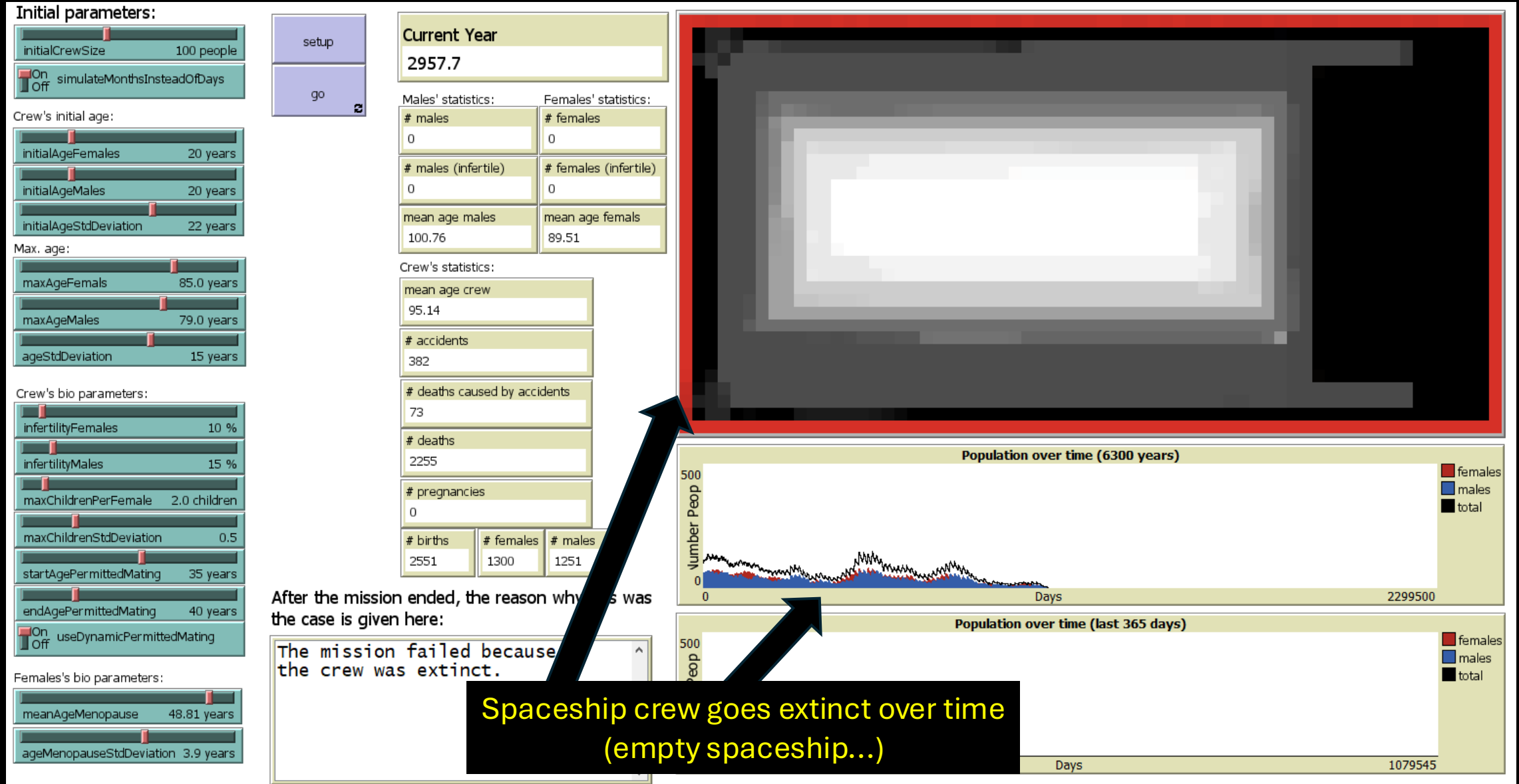
The mission was successful: survivors reached the distant planet.

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



Analysis 4

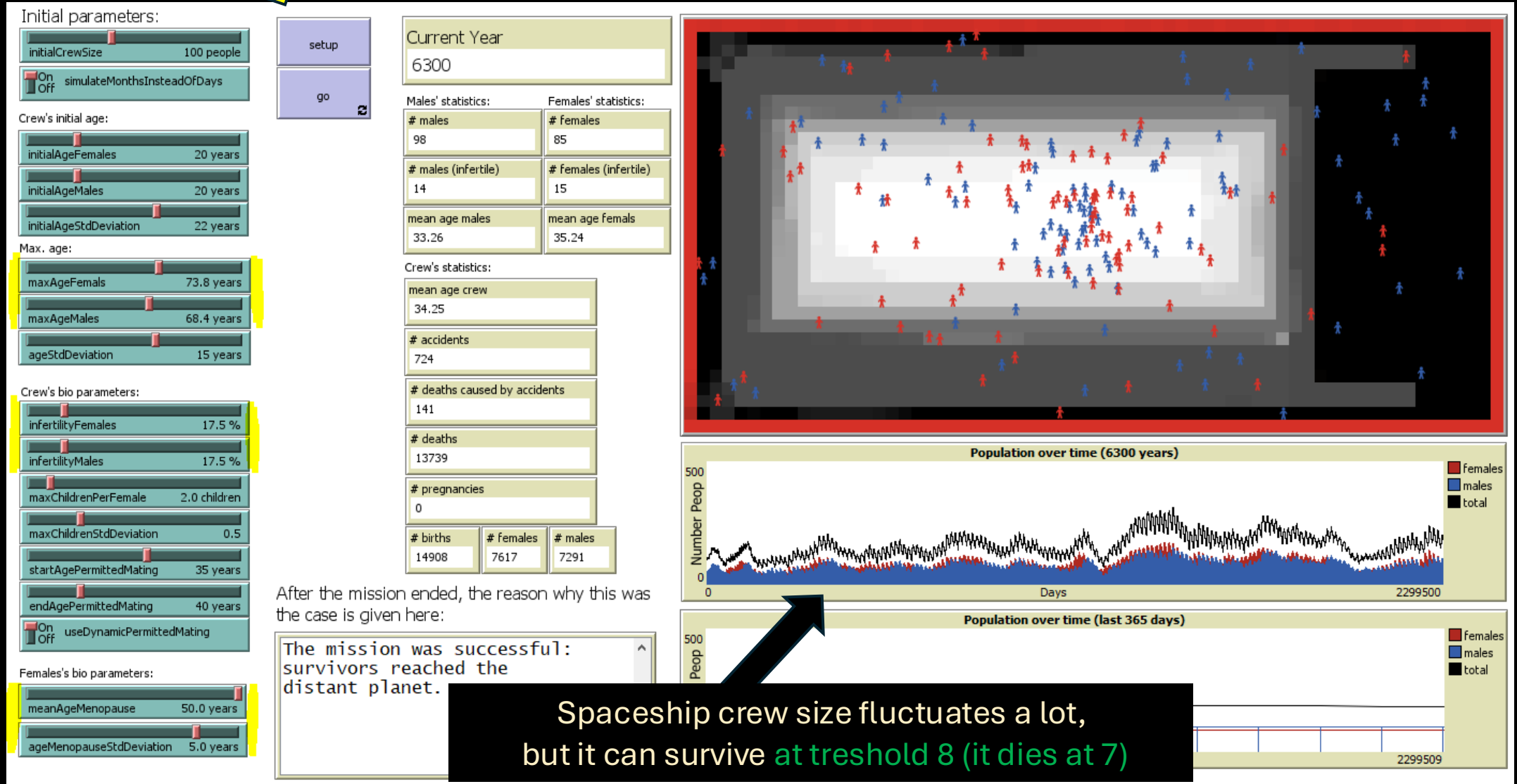
Extended Model: includes selectiveness & homicide caused by polarizing views (at view_difference > 6)



Analysis 5

Extended Model: includes selectiveness & homicide caused by polarizing views

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



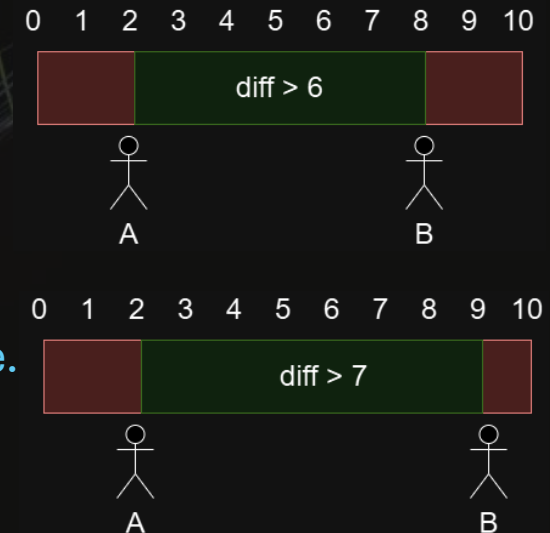
Conclusion



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*:
 - Tested with default parameters:
view_difference extinction threshold is between 6 and 7
 - Tested with our own parameters: *survival* requires more tolerance.
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
- [4] Experiment of Frédéric Marin and Camille Beluffi from 2018: <https://arxiv.org/abs/1806.03856>
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- [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