Population Modeling: an Agent-Based Approach

In this project, we used the agent-based modelling program COBWEB to investigate varying population systems.

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VOLUNTARY EXTINCTION

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INTRODUCTION

Much of the world's population has been characterized by decreasing fertility rates over recent decades. One-half of the population lives in countries where the total fertility is lower than 2.1 births per woman and many countries are facing historically low numbers of births (Sobotka, 2019). Our study aims to understand the underlying causes of the recent decrease in fertility and to assess the efficacy policies to reverse this decline. We are using COBWEB, an agent-based software, to simulate the effect of different government policies on the population.

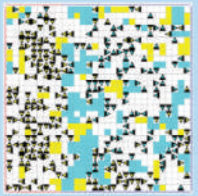
METHODS & RESULTS

t=0

Time

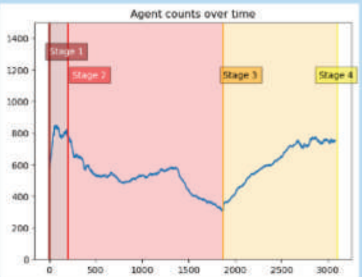
Stage 1:
Urban and rural zones initial set up

Using COBWEB, we modeled an arbitrary country with a low birth rate and divided it into rural and urban zones. Urban (yellow zone) and rural agents (blue zone) have different characteristics, e.g. breed energy, and preferences. Agents have more favorable conditions in their respective zones



Stage 2:
Gradual population decline, agents prefer their respective zone

We investigated how population was affected by economic, environmental cultural, and social factors .



Introduce policies

Stage 3:
Policies stop population decline and lead to stable population

We simulated the implementation policies, such as financial incentives, and immigration policies to stabilize populations.

Stage 4: Results

After many repeated simulations, we can evaluate the efficacy of these policies by analyzing the agent counts and their respective graphs.

NEXT STEPS

We will implement different government policies, such as financial incentives, and immigration policies by using subzones with enhanced resources and additional agents with lower breeding energy requirements. Then by running many simulations and using statistical methods, we will evaluate the efficacy of the policies. Furthermore, real-world data can be used to model specific countries.

Alternatively, other approaches can be used to complement COBWEB, including gray models (Liu, 2012). These equations are useful for working with small, incomplete, or uncertain sets of data. For example, they can model the effects of policies, or changes in population over short time frames in the future.

SOURCES

Sobotka T., Matysiak A., Brzozowska Z. (2019). Policy responses to low fertility: How effective are they? Working Paper No. 1 https://www.unfpa.org/publications/policy-responses-low-fertility-how-effective-are-they

Liu, S., Forrest, J., & Yang, Y. (2012). A brief introduction to grey systems theory. Grey Systems, 2(2), 89–104. https://doi.org/10.1108/20439371211260081

Exploring Arctic Tundra Dynamics: Trophic Interactions and Ecosystem Resilience

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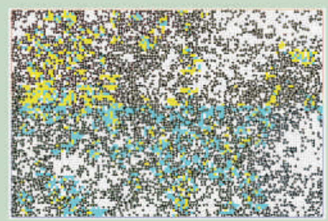
INTRODUCTION

The Arctic tundra ecosystem, often considered one of the last frontiers of wilderness, plays a pivotal role in the global ecological landscape. This vast, seemingly inhospitable landscape is home to a unique array of flora and fauna adapted to harsh conditions, making them both resilient and vulnerable in the face of environmental changes. However, this unique habitat, characterized by its low temperatures, short growing seasons, and unique biodiversity, is undergoing rapid transformations due to global warming. The consequences of these changes are far-reaching, affecting not only individual resident species but also reverberating through the entire ecosystem. We present two models exploring various tundra dynamics- one on trophic interactions, and the other on tundra recession.

TUNDRA RECESSION

METHODS: This model investigates how animal interactions impact the rate of shrubification of the tundra and also looks at local extinctions caused by this northward shift in vegetation and animal life. The model itself uses a moving zone to slowly shift the territory of boreal shrubs northward into the territory of tundra bryophytes- this movement primarily represents permafrost melt. The model includes arbitrary predator and prey organisms for each respective biome. The dynamics of these organisms were monitored as recession proceeded.

RESULTS: The model shows a repeated outcome where boreal organisms eventually outcompete tundra organisms as the boreal habitat grows, often to extinction.

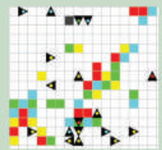


Model displaying tundra(yellow)-boreal(blue) ecotone. Interactions gradually shift northwards (up).

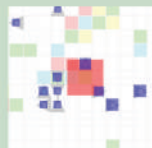
TROPHIC INTERACTIONS

METHODS: This model explores the predator protection of brent geese by snowy owls from the red fox, as red foxes are nest predators of the brent goose while snowy owls are not, while snowy owls will actively chase red foxes out of their territory. This is observed in parallel with the bird-lemming hypothesis- that geese population numbers are positively related to lemming population numbers. Additionally, snowy owls will eat lemmings. Agents representing brent were programmed to swarm around agents representing owls. Lemmings and foxes were given free motion.

RESULTS: It was found that the ratio of owls to foxes directly influenced the outcome of the model: too many owls would drive foxes out of the simulation, and too little owls would have no effect on the dynamics of the other animals.



Brent (yellow) swarm around owls (red) while foxes (green) stay out of the way. The blue agents are lemmings.



A energy-overlay analysis shows higher breeding energy (red) around the owl.

NEXT STEPS

Given the context of these models, a direct next step would be to incorporate more real data into the models, such as a realistic timescale, seasons, populations from collected numbers, etc. There is space for the addition of mathematical modeling. These models do not run on a specific space or time scale given the constraints of the program, so modeling through a different method that applies spatial and time scales can generate more insight.

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