

Unavoidable Extinctions in Ecosystems of Extreme Isolation

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Presentation Outline

1. Introduction

1.1 Closed Artificial Ecosystems & Biosphere 2 Experiment

1.2 Neutral Theory of Biodiversity

2. Project Objectives

3. Methodologies

4. Results

5. Discussion

6. Conclusions

Closed Artificial Ecosystems

- Ecosystems reproducing the conditions of a natural one
- Effects of human activities on Earth
- Space colonisation prospects

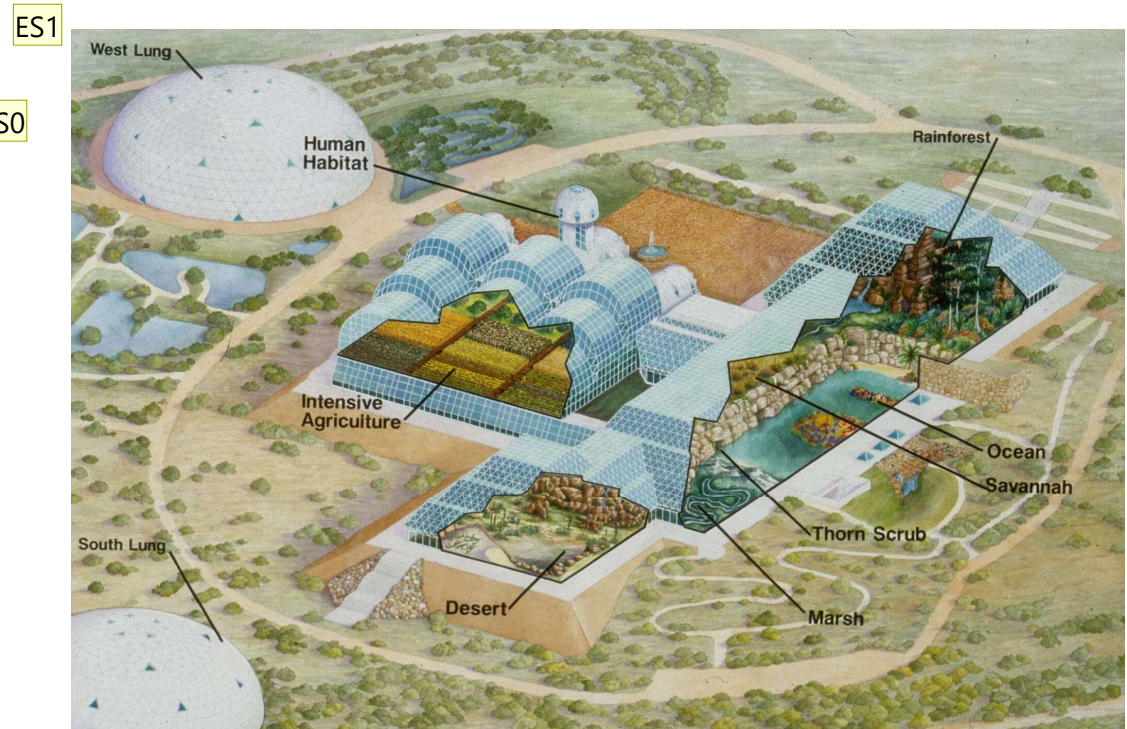


Slide 3

- ES0** Isolated ecosystems which reproduce the conditions of a natural one (or probably even more). Examples of these are terraria, aquaria and ecotrons
EFTYCHIA SYMEONIDOU; 2023-09-16T23:51:10.237
- ES0 0** They can be partly, and in that case in contact with exterior surroundings, or totally isolated
EFTYCHIA SYMEONIDOU; 2023-09-16T23:55:27.612
- ES1** What is their use or importance in that case? They can be used to study the interactions of ecosystem factors when isolated, or which are the effects of human activities on the Earthly ecosystems. But most importantly and related to the Astrobiological studies, closed artificial ecosystems can be used or would work for space colonisation prospects
EFTYCHIA SYMEONIDOU; 2023-09-16T23:54:38.147

Biosphere 2 Project

- Fully closed facility - no exchange between interior and exterior environment
- Different ecological biomes
- First mission from 1991 to 1993 - Faced many problems (2nd in 1994 - aborted early)
- Focus on tropical rainforest biome
- Initially 1571 individuals in 342 plant species / 744 individuals of 205 species remained by the end)



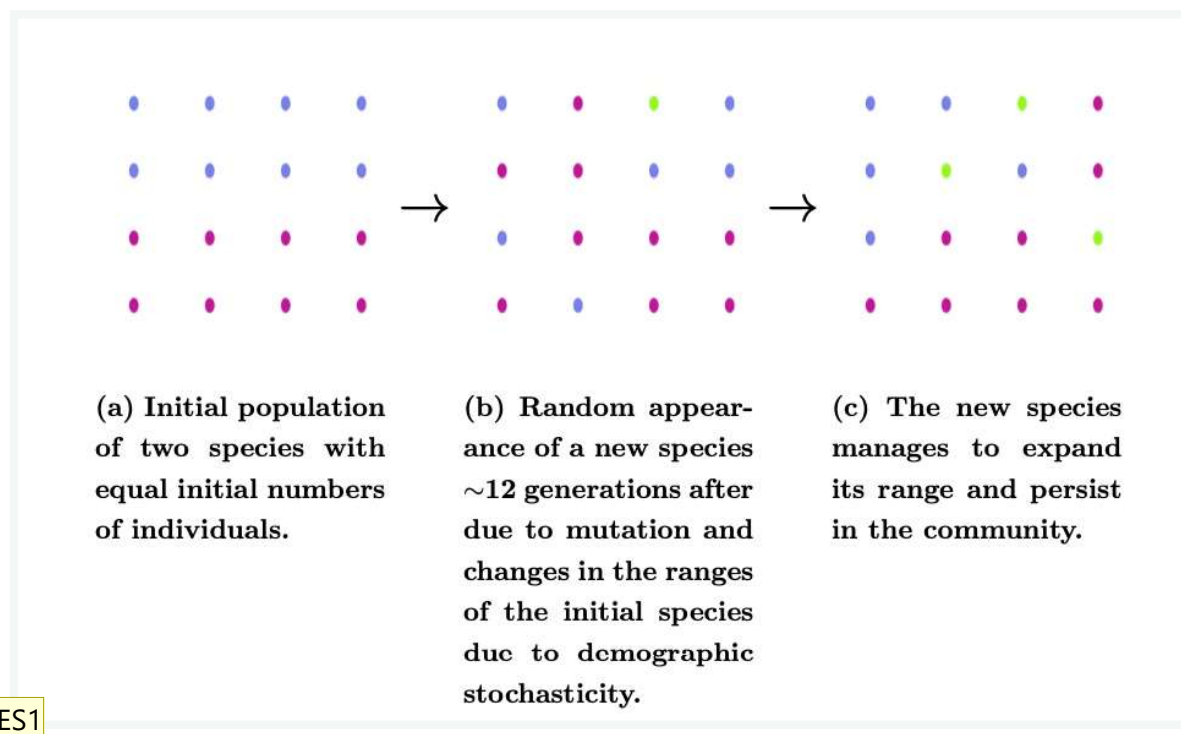
Depiction of the Biosphere 2 facility and its individual compartments

Slide 4

- ES0** Biosphere 2 when constructed was a fully closed facility with no exchange between interior and exterior environment. It's built in Oracle, Arizona. It hosts a variety of different biomes which can be seen in the figure and was built to also host humans.
EFTYCHIA SYMEONIDOU; 2023-09-17T00:02:52.698
- ES1** First mission started in 1991 and lasted two years until 1993. It hosted 8 humans - the Biospherians. Although quite ambitious, it faced many problems. The most important one was the reduction in the oxygen levels from about 21% to a bit less than 15% (14.4%) in about 6 months. Other problems include loss of pollinators and algal mats in the ocean biome which had to be removed manually. A second mission that started in 1994 was aborted early.
EFTYCHIA SYMEONIDOU; 2023-09-17T00:07:22.742
- ES1 0** In this work we focus on the tropical rainforest region of Biosphere 2 which initially hosted 1571 plant individuals belonging to 342 species. By the end of the first mission though, only 744 individuals were left belonging to 205 species
EFTYCHIA SYMEONIDOU; 2023-09-17T00:10:34.805

Neutral Theory of Biodiversity

- Equality in individuals' level
- each organism is per capita equal with the rest
- Communities under zero-sum dynamics
- In a population that has no immigration and speciation rates, monodominance finally ensues



ES1

Evolution of a community governed by random drift and zero-sum dynamics

Slide 5

- ES0** This quick loss does not though look similar to the natural rates of species loss. To gain some insight on how a natural community of the same size would evolve we employed a neutral community concept.
EFTYCHIA SYMEONIDOU; 2023-09-17T00:14:48.567
- ES0 0** A Well known ecological theory studying ecological communities under isolation is the Neutral Theory of Biodiversity
EFTYCHIA SYMEONIDOU; 2023-09-17T00:17:05.105
- ES0 1** The species are competing with each other for space. Each organism belonging to such a community has equal chances of surviving and reproducing with the rest.
EFTYCHIA SYMEONIDOU; 2023-09-17T00:39:20.202
- ES0 2** In this case also zero-sum dynamics are in force and thus the total number of individuals remains the same. One is replaced by one.
EFTYCHIA SYMEONIDOU; 2023-09-17T00:40:53.035
- ES1** In the presented figure the initial population undergoes a speciation event which slowly changes the community structure and each species' standings. The number of individuals nevertheless remains constant. In a population that has no immigration and speciation rates, such one in a closed ecosystem, monodominance finally ensues
- Monodominance is the prevalence of one species that overtakes all the space.
EFTYCHIA SYMEONIDOU; 2023-09-17T00:41:08.761

Project Objectives

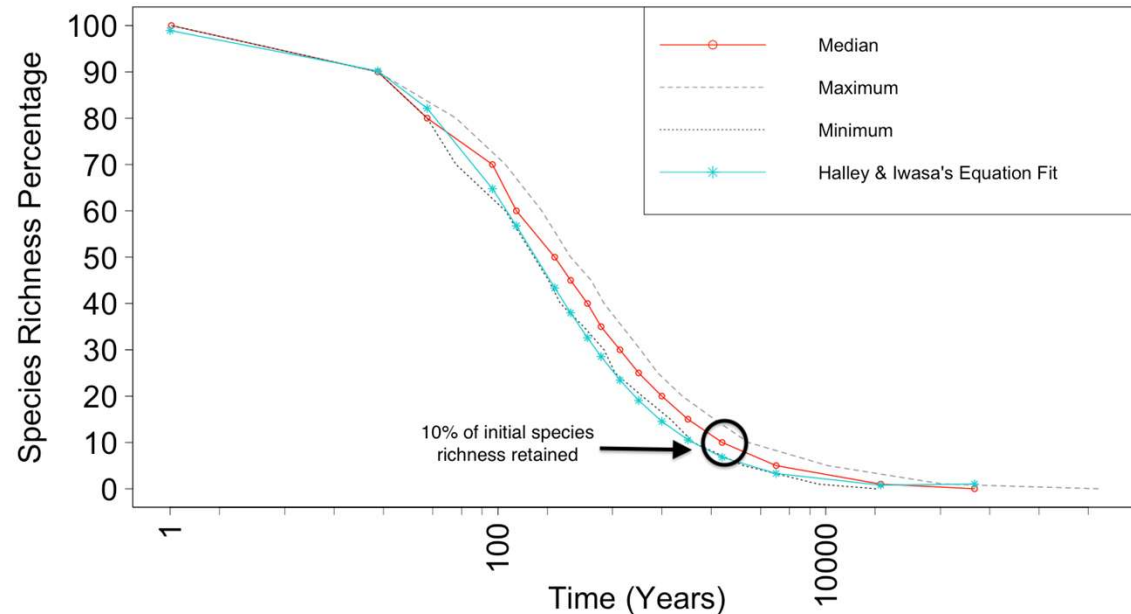
- Simulate what would be the expected plant succession times until monodominance is reached
- How the Tropical Rainforest biome's plant biocommunity should have evolved if zero-sum dynamics were in action
- Compare the accuracy of our simulation results with other neutral models

Methodologies

- Data extracted from past papers concerning the structure of the Tropical Rainforest biome of Biosphere 2
- Search for average plant lifetime using the **TRY Database** - Mostly perennial trees and lianas with total average lifetime ~37 years
- In this project we considered as **generation time** the **half average lifetime** (~18.5 years)
- Simulation of initial data incorporating commands from the **UNTB package** (R.S. Hankin) in **R programming language**

Results - Simulation under zero-dynamics

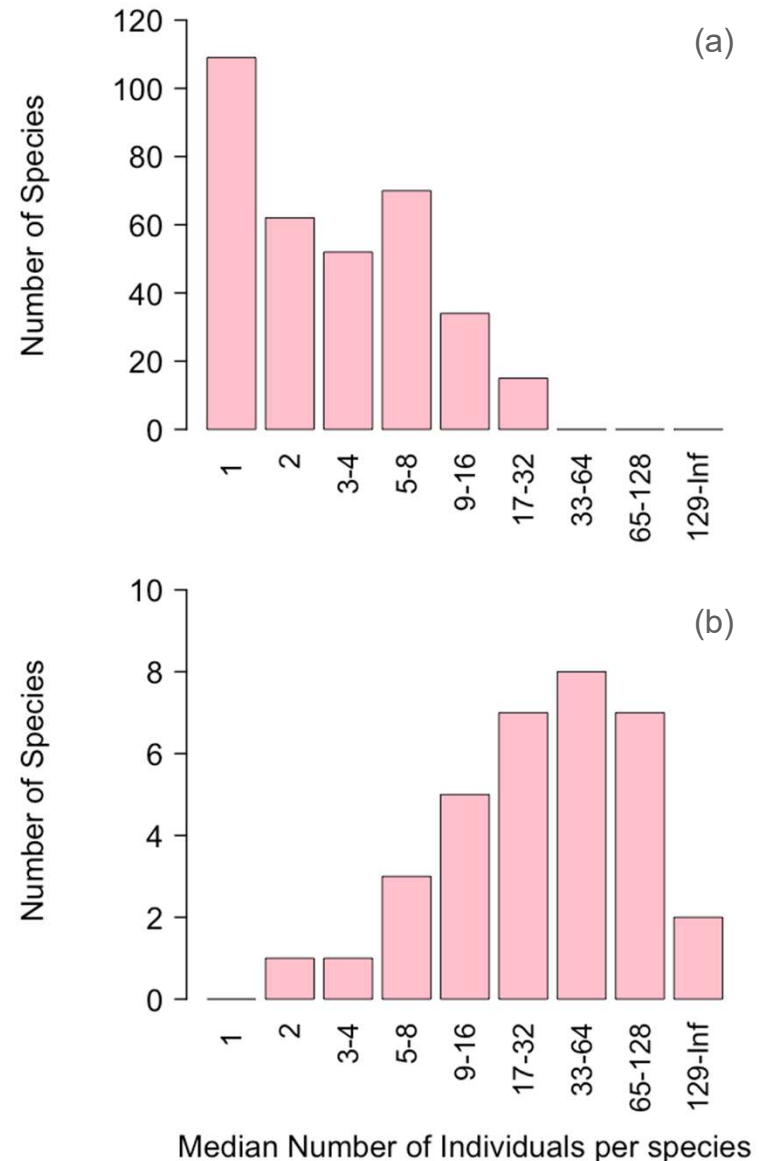
- Initially quick species loss is predicted - steep slope in the graph
- Later greater plant persistence times are predicted
- Turning point when 10% of initial species richness is retained - approaches asymptote
- Linear fit of simulation results to the equation of Halley & Iwasa (2011) - Good fit



Species richness retained along with time. Each line represents the percentage of species richness that is retained along with generation number.

Results

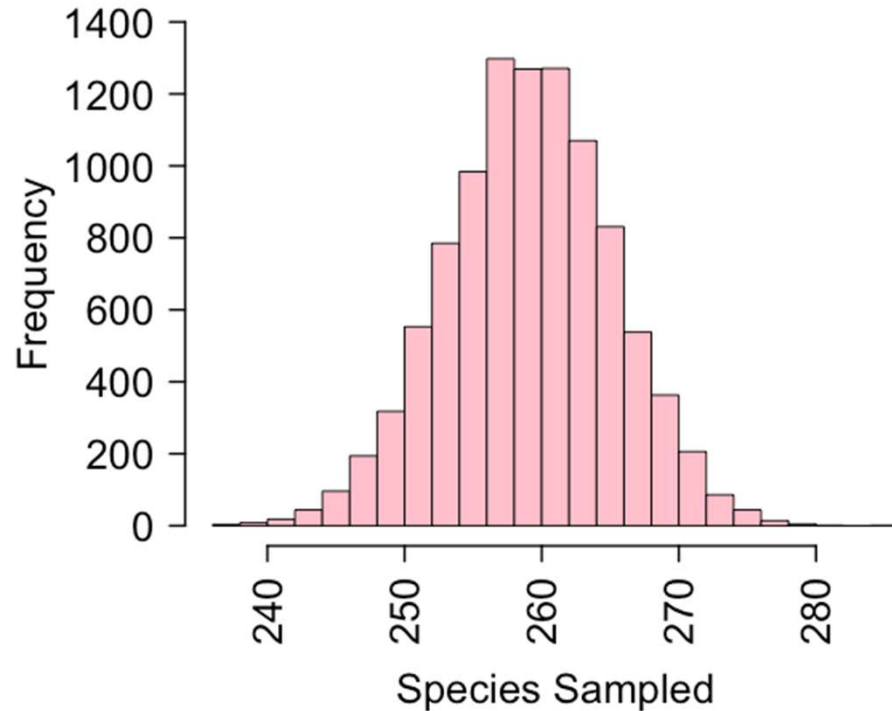
- Preston Abundance Plots - Changes in the structure of the community
- Initial community of Biosphere 2 with a great amount of singleton species
- Last 10% of species retained in simulation - More individuals per species - shift of the numerically most abundant group



Median number or individuals per species (a) for the initial species richness and (b) for the last 10% of species richness retained

Results

- Biosphere 2 - 744 out of initial individuals were left
- Random sampling of 744 individuals
- Average ~260 species remaining
- Not random loss of individuals



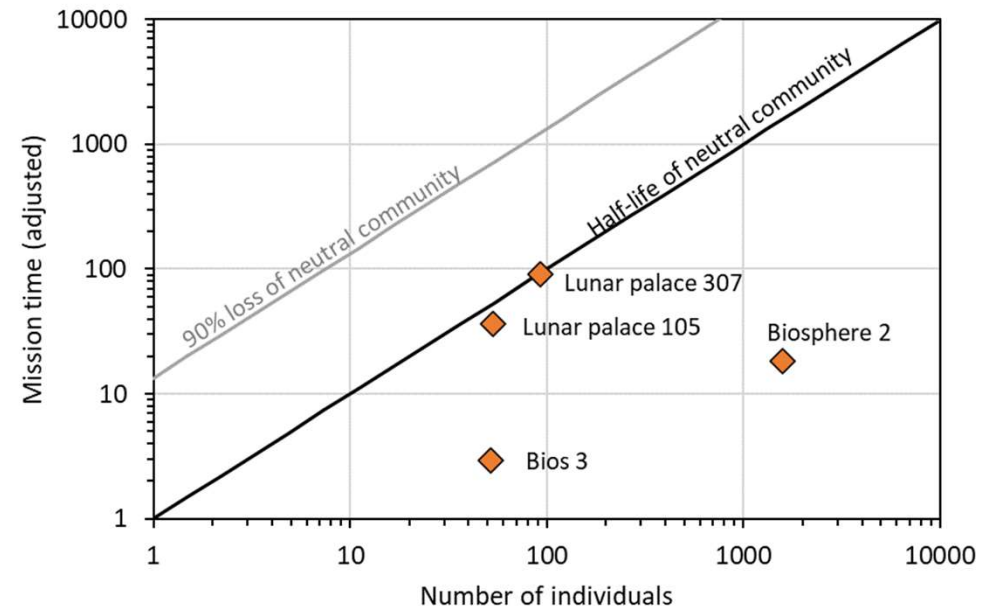
Summed appearances of individuals per species for 10.000 iterations of random sampling.

Discussion of Unified Neutral Theory

- Simulation results - quick loss of first species that is slowing down in the later stages
- Last 10% of initial species retained in simulation - turning point for loss rhythm and community shape
- Most of the species when last 10% of species is left, belong to big sized groups of individuals
- Fit of simulation results to Halley & Iwasa's equation show good correlation between model and formula

Comparison

- Actual Experiment - plant biodiversity was actually lost too quickly and there were no new germinations
- Community not in neutral equilibrium state - Possible explanation from the Self-Thinning rule
- Not much existing literature of similar experiments in such a large scale



Comparison of different systems used to study ecosystems of extreme isolation. Loci for half life and 90% loss are presented. Mission time has been adjusted by factor S_0/τ . Only the tropical rainforest data were used for Biosphere 2

Conclusions

- Simulated possible succession stages until monodominance is attained
- Rapid loss of first species followed by the decelerating loss of the remaining ones - Centuries needed until only one species is left
- Initially big amount of singleton species - when 10% of species richness is retained most of species have multiple individuals



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