Understanding Ecological Invasions on Complex Networks

Introduction

Understanding the structures and evolutions of ecological communities is a difficult task due to the **diversity of nature**. Yet, it is important as it can help us create **more efficient conservation methods** and possibly **mitigate the detrimental impacts** that may be brought about by ecological changes.

Direct effects

- Loss of **genetic, species** and **ecosystem diversity**[1]
- Large changes in **trophic level relationships** and **food web interactions**
- **Prey on native species, increase food competition** and may also **introduce diseases**[2]

Environmental & Economical effects

- Threatens **agricultural production, infrastructure**, and **animal and human health**[3]
- Significant annual **economic losses**[4]

Previous Research

- Most foreign species actually **die out quickly** due to **inability to adapt**
- The **timing of invasion** and **trophic position** can produce different results in the evolution and fates of the ecological community[5] [6]

Previous Model

- Population growth follows ***Verhulst Equation*** (discrete time logistical model)
- Predation process follows ***Lotka-Volterra Equation***[7]

Aim

To determine the conditions under which ecological invasion is successful

Model and Assumptions

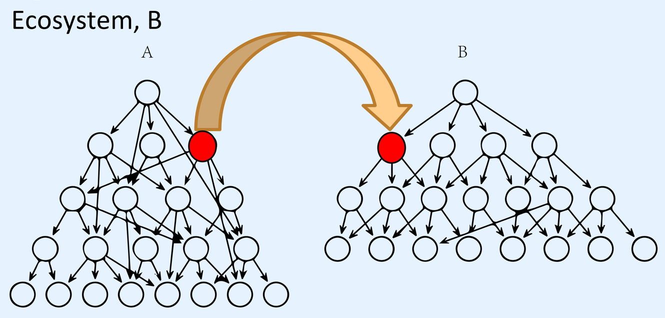
Assumptions

1. **Any species** in same trophic level will have same **number of preys** in the next trophic level, and the number will be given by a *function* related to the numbers of the species in these two trophic levels.
2. **Some species** may have preys located on trophic levels *much lower* than itself, and the probability is determined by an *exponential function*.

$$
\begin{aligned}
n_i(t+1) &= \underbrace{n_i(t) + \mu_i n_i(t)\left(1 - \frac{n_i(t)}{N_i}\right)}_{\text{Verhulst Equation}} \\
&\quad - \lambda_i n_i(t) \\
&\quad \underbrace{+ \sigma_i\Big[\sum_j \alpha_{ij} n_i(t) n_j(t)\Big] - \sum_j \alpha_{ji} n_j(t) n_i(t)}_{\text{Lotka-Volterra Equation}}
\end{aligned}
$$

n: current population of species i;
μ: growth rate per capita;
N: maximum population;
λ: non-predation death rate of the species;
σ: conversion rate of species, which affect the reproduction from predation;
α: predation efficiency

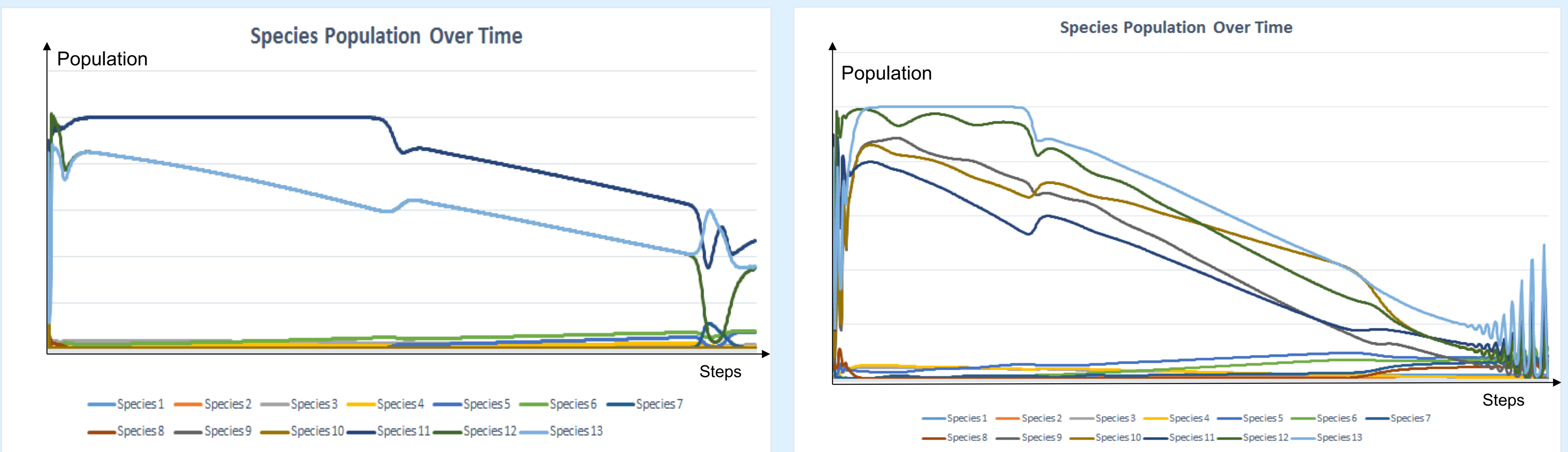
Figure 1: Home Ecosystem, A, and Destination Ecosystem, B



Generate → Invade & Simulate → Results

Results and Analysis

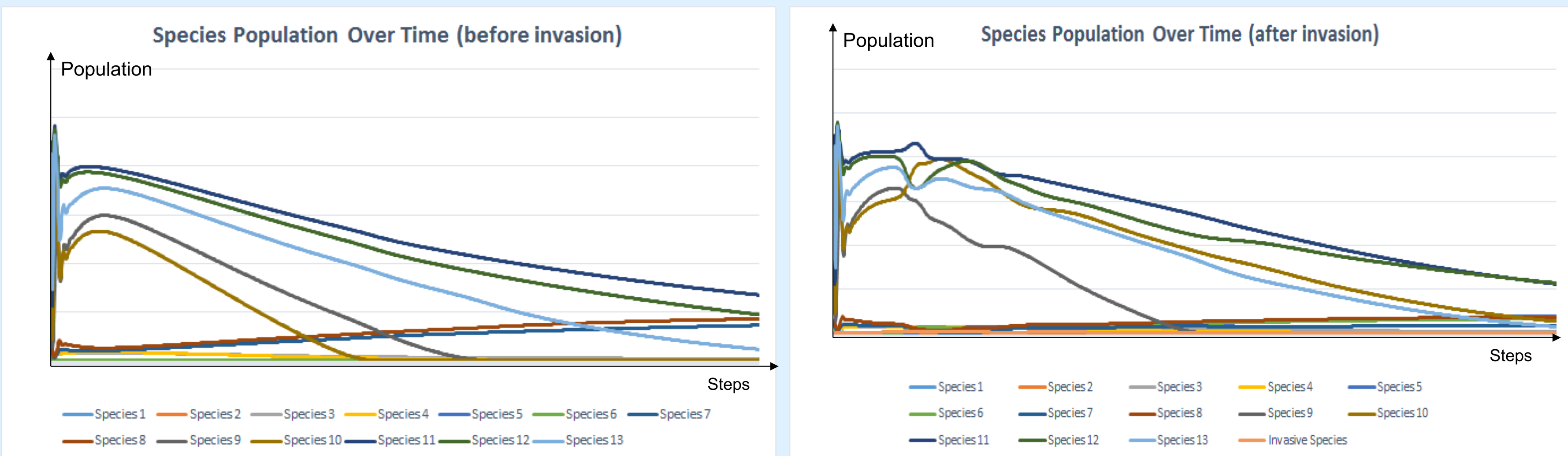
- **Death rate** variable, λ, was fixed as **zero** (i.e. death can only occur through predation)
  → **predator-prey interactions** of the food web are more **distinct**
- **Initial population** of the invasive species was set as **0.1**



Figures 2.1.1 and 2.1.2 : Difference between species populations as result of increase in initial population

#1

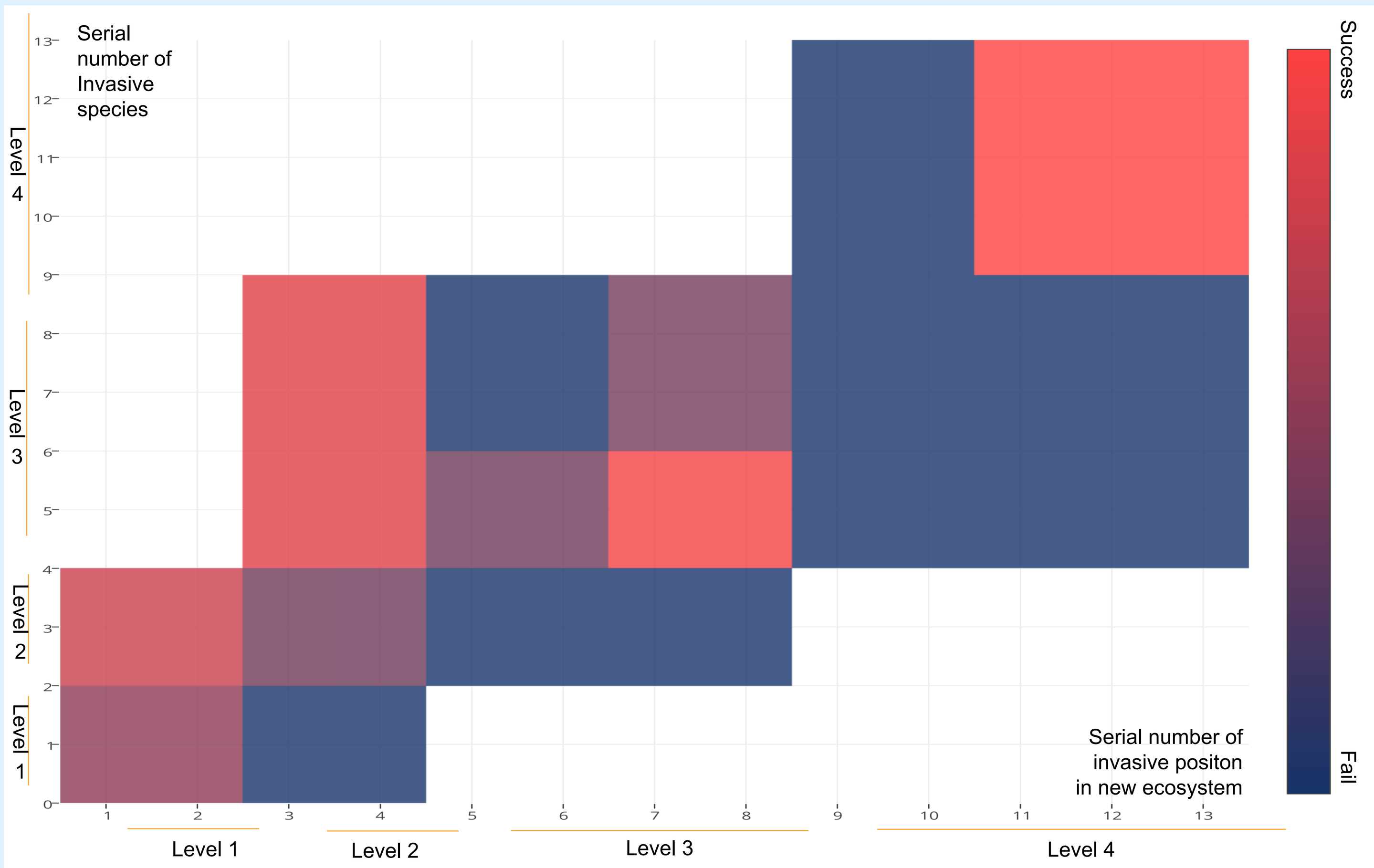
- Initial number of preys and predators in a new ecosystem played a significant role in the survival of other species in the web
- A **slight increase** in the population of any species other than a basal species can spark a **large change** in the populations of other species, both directly and indirectly



Figures 2.2.1 and 2.2.2 Difference in species population owing to successful invasion

#2

- Successful invasions would create chaos in the population dynamics of the ecosystem
- Effects of invasion were **not significant** as the population of the invasive species was **small** at first



Figures 2.3 Heatmap which represents results of invasion

#3

Level up
Species that move one trophic level up will **always fail**, unless it becomes a top-level predator

Level down
Species that move one trophic level down will **always succeed**, unless it was a top-level predator or drops to bottom level

Same Level

- No particular condition which guarantees invasion success
- For basal species, it only succeeds when the new environment and predators are similar with the home ecosystem.
- Success rate is 81.3% (3 s.f.) in this system

Note: Any invasion with the final population of the invasive species ≥10% is a successful one.

Conclusion

Low initial population of invader for two systems sharing similar or identical structures → Unlikely to experience population increase; System self-adjusts to a stable state

Invasive species → UP → Failure; DOWN → Success

Future Work

- Increase the **accuracy** of model
- **Include** other *predator-prey* models
- **Test** model using actual data
- **Expand** model by including other *variables*

References

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7. Lotka, A.J., "Contribution to the Theory of Periodic Reaction", *J.Phys. Chem.*, **14** (3), pp 271-274, 1910

All data was self-created.
All figures, heatmaps and graphs are self-drawn.
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