Optimal Restoration Strategies for Plant-Pollinator Ecological Networks: Historical Patterns and Future Projections

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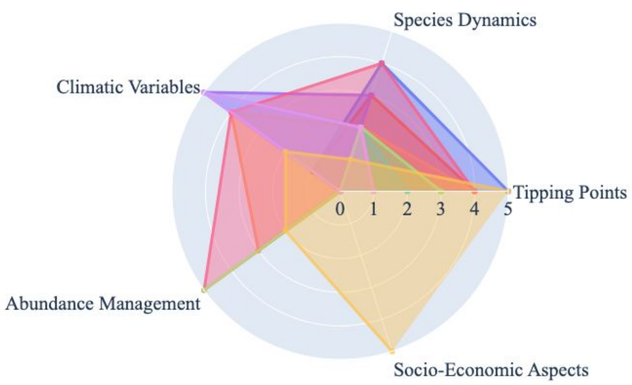
1. Introduction

- **Pollination** plays a pivotal role in maintaining the health of **food systems**, with over 75% of cross-pollinated crops are pollinated by animals (FAO).
- Over the past 25 years, observations reveal that **40%** of insect pollinators face **extinction** due to **habitat loss**, **temperature fluctuations**, and **pesticide use** (IBPES).
- United Nations have already declared 2021-2030 as **decade of ecosystem restoration** due to its urgency.
- Restoring ecology will help in achieving our four sustainable goals.

- Studying and mitigating **pollinator decline** is indispensable to ensure the well-being of both people and the global agricultural ecosystem.
- To accomplish this, understanding the **dynamics of plant-pollinator networks** under **changing climate scenarios** is imperative, allowing for the **quantification of ecological restoration** and its **associated costs**.

2. Literature Review



Predicting tipping points in mutualistic networks through dimension reduction (Jiang et al., 2018)
The sudden collapse of pollinator communities (Lever et al.,2019)
Coexistence Mechanism of Alien Species and Local Ecosystem Based on Network Dimensionality Reduction (Dongli et al., 2022)
Predicting phenological shifts in a changing climate (Scranton and Amarasekare, 2017)
Rising temperature drives tipping points in mutualistic networks (Bhandary et al., 2023)
Climate-mediated shifts in temperature fluctuations promote extinction risk (Duffy et al., 2022)
Harnessing tipping points in complex ecological networks (Jiang et al., 2019)
Reviving a failed network through microscopic interventions (Sanhedrai et al., 2022)
Impacts of climate warming on terrestrial ectotherms across latitude (Deutsch et al., 2007)
Evading tipping points in socio-mutualistic networks via structure mediated optimal strategy (Deb et al., 2023)

3. Research Gaps

- Studies have explored temperature effect on single species' population dynamics without considering interaction between plant and pollinators.
- A study has taken fixed temperature range (e.g., 0-40 degrees Celsius) to investigate the pollinator abundance based on interaction network without considering the regional variations.
- Lack of insight into the economic aspects of species restoration in socio-mutualistic networks under future scenarios.

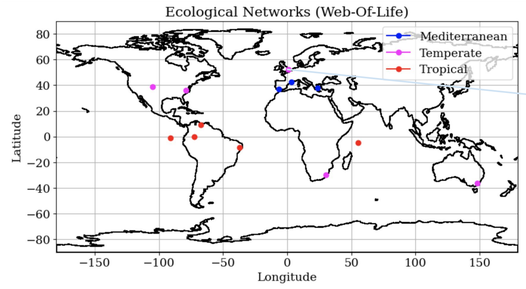
4. Scientific Questions

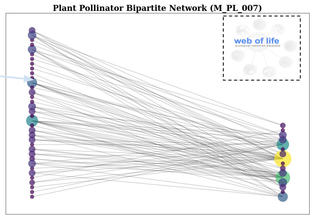
- How can the restoration of species (pollinator or plant) be identified within specific regional plant-pollinator networks under various future climatic projections?
- From the identified restoration strategies, which approach is optimal, taking into account ecologists' opinions and the cost of species management?

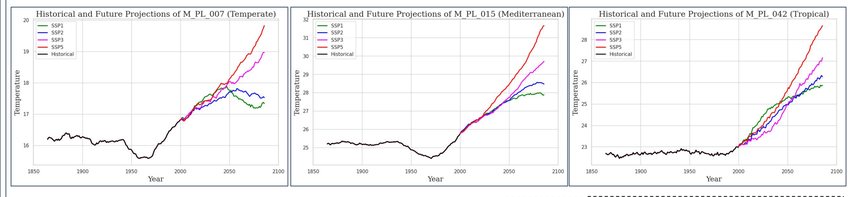
5. Objectives

- To study the effect of temperature on population dynamics of plant-pollinator networks in different regions like Temperate, Tropical, and Mediterranean under future climate scenarios.
- To determine optimal restoration strategy for plant-pollinator networks, taking into account ecologists' opinions and cost of restoration across different latitudes globally.

6. Study Area, Datasets, and Equations







Holling type II functional Response

$$\frac{dA_i}{dt} = A_i\left(\alpha_i^{(A)}(T) - k_i(T) - \sum_{j=1}^{S_A}\beta_{ij}^{(A)}A_j + \frac{\sum_{k=1}^{S_P}\gamma_{ik}^{A}P_k}{1+h(T)\sum_{k=1}^{S_P}\gamma_{ik}^{A}P_k}\right) + \mu_A$$

$$\frac{dP_i}{dt} = P_i\left(\alpha_i^{(P)}(T) - \sum_{j=1}^{S_P}\beta_{ij}^{(P)}P_j + \frac{\sum_{k=1}^{S_A}\gamma_{ik}^{P}A_k}{1+h(T)\sum_{k=1}^{S_A}\gamma_{ik}^{P}A_k}\right) + \mu_P,$$

$$\alpha_i(T) = \alpha_{opt}\, e^{-(T-T_0)^2/2\sigma_\alpha^2}$$

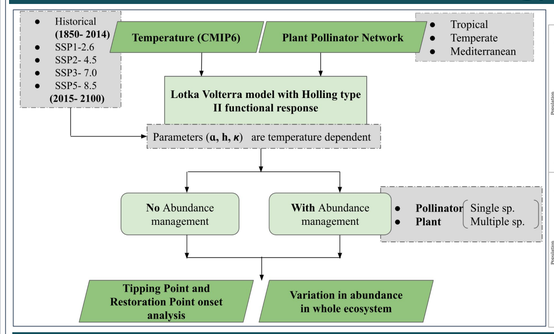
$$h(T) = h_{opt}\, e^{(T-T_0)^2/2\sigma_h^2}$$

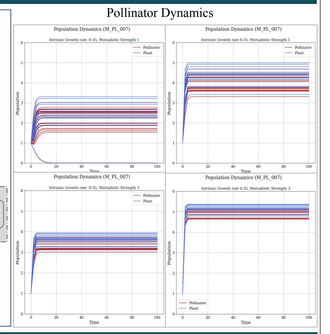
$$k_i(T) = K_{opt}\, e^{A_k(1/T_0-(1/T))}$$

Parameters

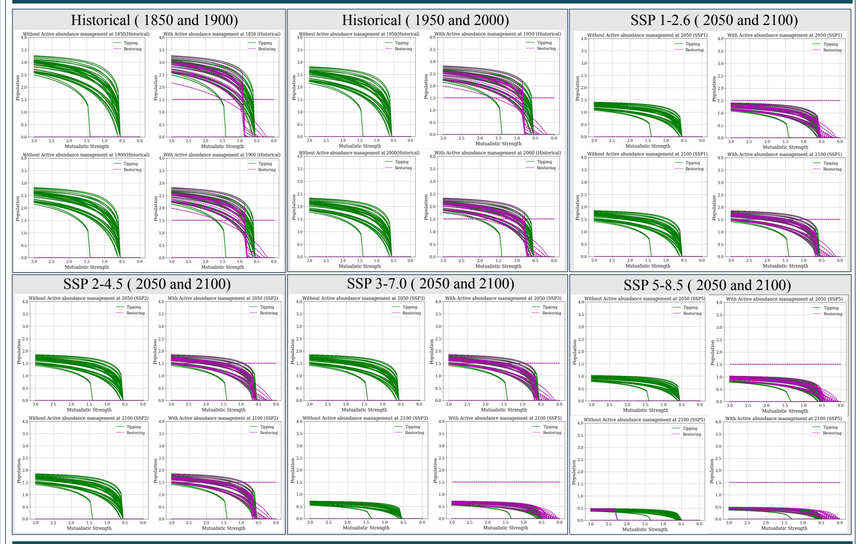
- Intrinsic growth rate(α)
- Inter/Intraspecific competition(β)
- Mutualistic strength(γ_{ij})
- Decay rate of pollinators(κ)
- Immigration(μ)
- Mutualistic connections(d_i)
- Trade off between degree and mutualistic strength(δ)
- Presence of interaction(ε)
- T= Temperature
- T_0= Optimum temperature
- α_{opt}, h_{opt}, k_{opt}= performance at optimum temperature
- A_k = Arrhenius constant

7. Methodology





8. Results



9. Expected Outcomes

- Region-specific guidelines can be provided for optimal restoration strategies for plant-pollinator interactions under risk.
- Effective resource allocation for implementing the identified strategies while considering the cost of restoration for each region.
- Enhanced understanding of plant-pollinator network structure and spatial dynamics across regions, contributing to informed restoration strategies.

10. References

- FAO report: https://www.fao.org/3/i1046e/i1046e00.pdf
- IBPES:https://www.ipbes.net/sites/default/files/spm_deliverable_3a_pollination_20170222.pdf
- Bhandary, S., Deb, S., & Sharathi Dutta, P. (2023). Rising temperature drives tipping points in mutualistic networks. Royal Society Open Science, 10(2), 221363.

11. Acknowledgement

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