Diet, Dispersal, and Disease: How Food Supplemented Habitat Alters Metapopulation Disease Spread

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1. BACKGROUND

- Humans often provide food for animals, whether it is intentional (e.g., birdfeeders) or unintentional (e.g., exotic plantings).
- Provisioning across a landscape can either reduce animal movement by attracting and retaining individuals or increase movement by producing more offspring with higher dispersal success.
- These changes could influence the spread of zoonotic diseases, which might also reduce animal movement. This could have important public health implications.

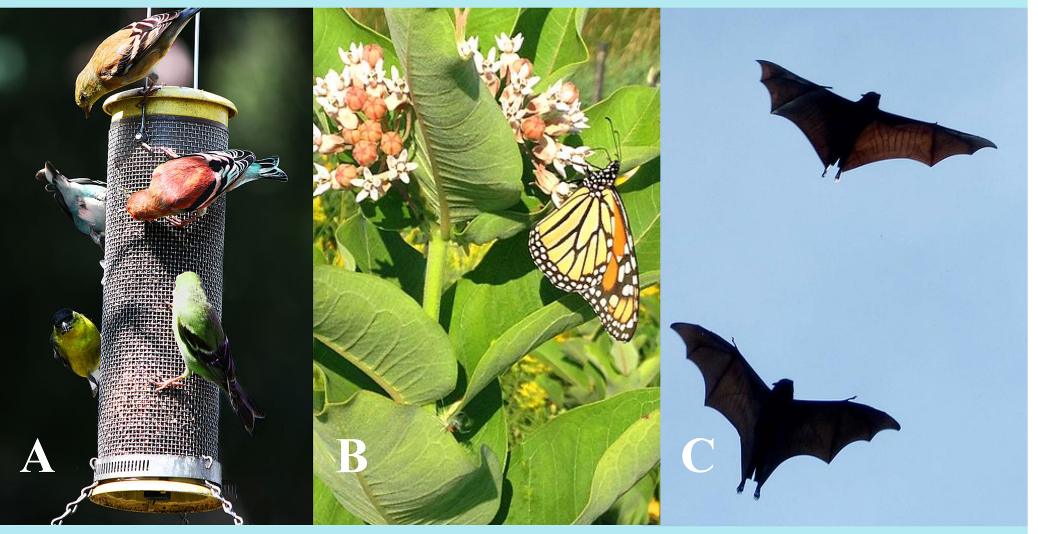

Fig. 1: Case studies where provisioning affects dispersal and disease. Feeders increase finch populations, which spreads infection (A); gardens create sedentary populations of (B) monarchs and (C) flying foxes; this increases local transmission, but may reduce infectious dispersers.

2. OBJECTIVES

- Model the effects of resource provisioning on animal movement in a metapopulation.
- Determine conditions under which supplemental feeding facilitates or impedes pathogen invasion and spread.
- Explore how A) increasing the fraction of provisioned habitat and B) introducing infection costs into movement influence host occupancy and infection prevalence.

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3. MODEL

- We modify the Levins metapopulation model to describe habitat patches by their provisioning status (**P**rovisioned or **U**nprovisioned) and their infection status (**S**usceptible or **I**nfected) (Fig 2A).
- A fraction, *f*, of all patches are provisioned (Fig 2B). Provisioning affects the baseline colonization rate, *c*, by altering the number of successful dispersers (θ), increasing patch attractiveness (Φ), and reducing the baseline extinction rate, *x*, by α (Fig 3A-C).
- The pathogen infects occupied patches with probability δ; infection increases the patch extinction rate by *v* and reduces dispersal success by *Ψ* (Fig 3D).

Fig. 2: Model Structure

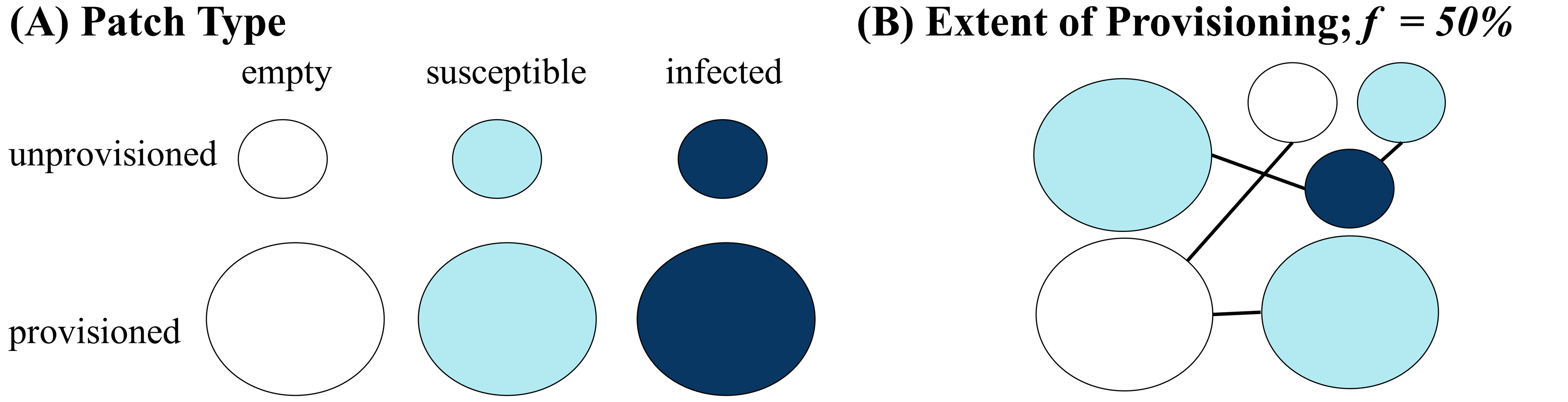


Fig. 3: Effects of Provisioning and Infection

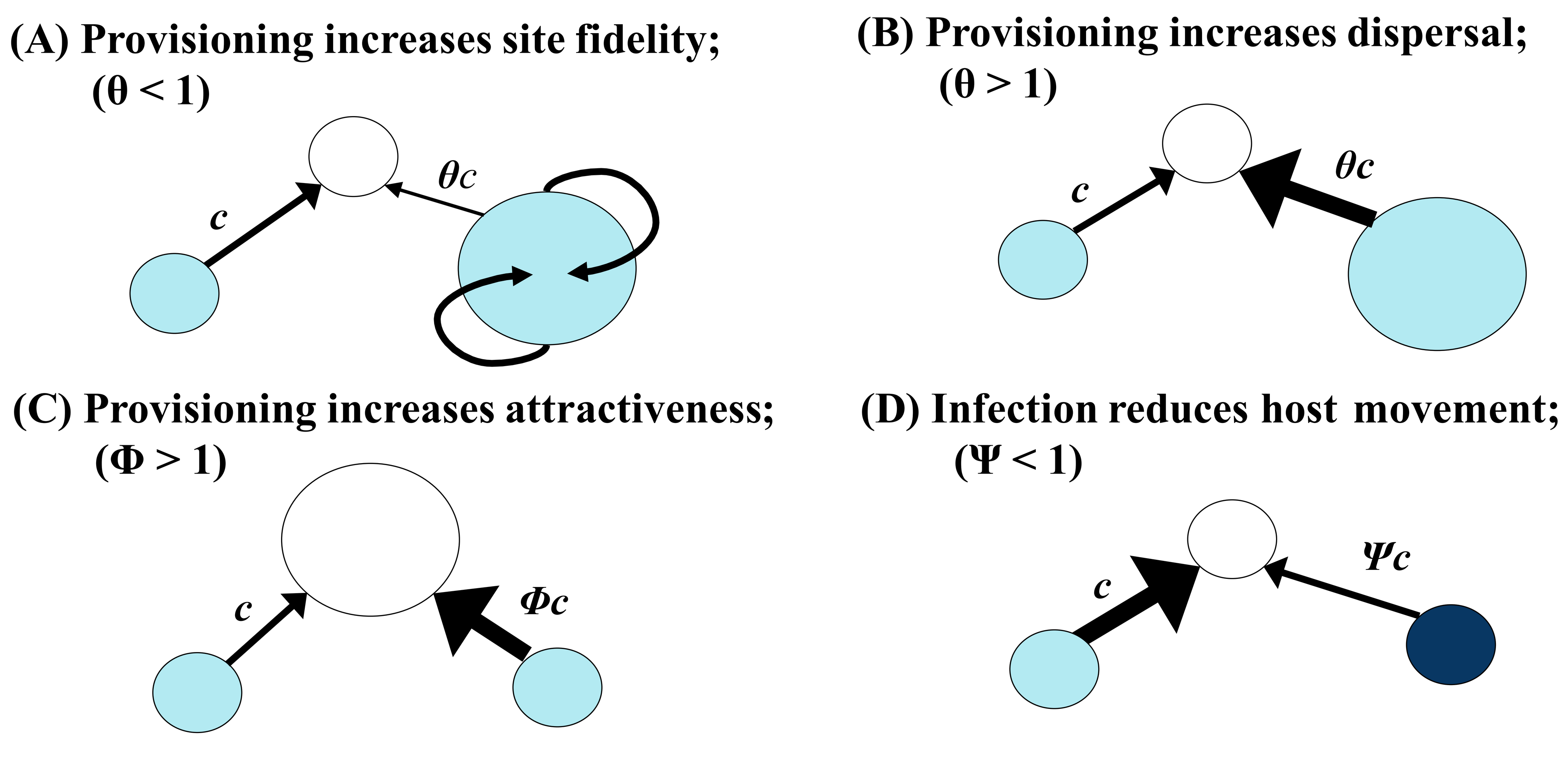


Fig. 4: Model Differential Equations

Colonization | Infection | Extinction

$$dS_U/dt = c(1-f-S_U-I_U)(S_U+\theta S_P) - \delta\psi c S_U(I_U+\theta I_P) - xS_U$$

$$dI_U/dt = \psi c(1-f-S_U-I_U)(I_U+\theta I_P) + \delta\psi c S_U(I_U+\theta I_P) - (x+v)I_U$$

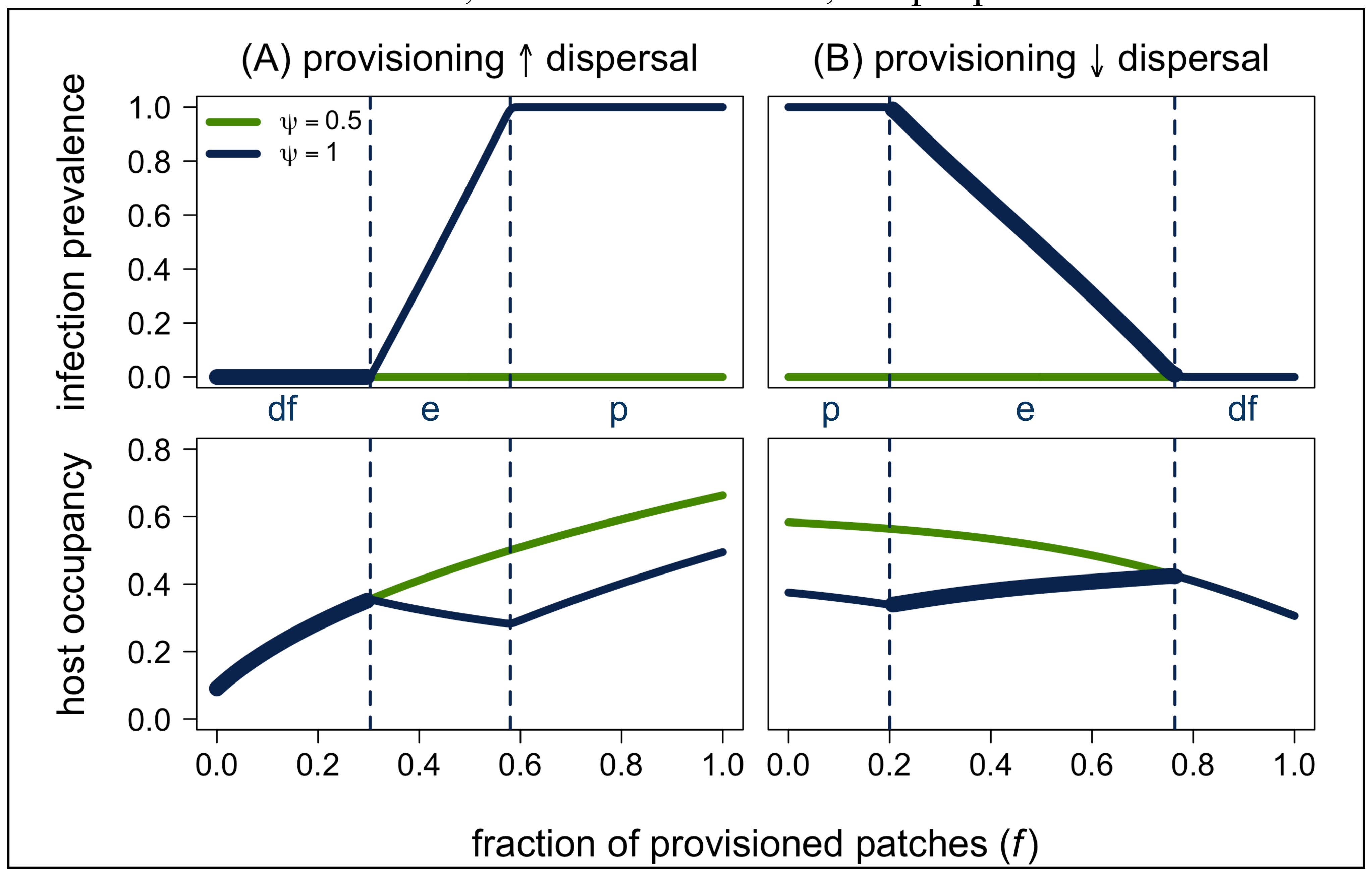
$$dS_P/dt = \phi c(f-S_P-I_P)(S_U+\theta S_P) - \delta\psi c S_P(I_U+\theta I_P) - \alpha x S_U$$

$$dI_P/dt = \phi c(f-S_P-I_P)(S_U+\theta S_P) - \delta\psi c S_P(I_U+\theta I_P) - \alpha(x+v)S_U$$

4. RESULTS

- We derive two key parameters that control infection in provisioned metapopulations:
- The **net effect of provisioning on movement,** $\rho = \theta\phi/\alpha$; provisioning reduces movement when $\rho < 1$ and increases movement when $\rho > 1$.
- The **pathogen basic reproductive number,** $R_0 = \frac{\psi}{x+v}[x(1-\delta)+\delta c(1+f(\rho-1))]$; pathogen invasion is only possible when $R_0 \geq 1$.
- Provisioning is "beneficial" when it increases host occupancy but not pathogen prevalence.

Fig. 5: The net effect of provisioning on pathogen prevalence and host occupancy; where df = disease free, e = endemic infection, and p = pandemic infection



- When provisioning increases dispersal ($\rho > 1$) and high costs of infection on movement prevent pathogen invasion ($R_0 < 1$), provisioning is always beneficial (Fig 5A, green).
- If infection doesn't reduce movement, provisioning is only beneficial when provisioned patches are scarce enough that it prevents pathogen invasion (Fig 5A, bold blue).
- When provisioning reduces dispersal ($\rho < 1$) and the pathogen is unable to invade, supplementation is never beneficial (Fig. 5B, green).
- When a highly-transmissible pathogen is present, provisioning can reduce pathogen spread through increased site fidelity if enough sites are provisioned (Fig 5B, bold blue).

5. CONCLUSIONS

- Provisioning should be avoided when infection has only small effects on animal mobility and supplementation increases net movement.
- Provisioning can be beneficial when (i) infected patches produce fewer dispersers or (ii) when highly transmissible pathogens are present and provisioning promotes site fidelity.
- Management should consider both how infection affects host movement and how supplemental feeding influences dispersal before provisioning wildlife.