The feasibility principle in community ecology

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Abstract

The structure and function of ecological communities emerge from the interactions among populations within specific environmental contexts. Yet, it remains unclear whether general principles can explain the patterns and transitions of ecological communities across diverse settings. Identifying such principles is crucial for guiding conservation and restoration efforts aimed at mitigating the negative impacts of anthropogenic effects on biodiversity. To address this challenge, I propose the feasibility principle in community ecology. Grounded in a synthesis of theoretical work and empirical studies, this principle is articulated through three core hypotheses: (i) each ecological community possesses a feasibility domain—that is, a range of environmental conditions under which it can persist—determined by a time-specific, invariant internal structure; (ii) the likelihood of observing a particular community in nature is proportional to the size of its feasibility domain that aligns with local environmental conditions; and (iii) the probability of transitioning between two communities is inversely proportional to differences in their feasibility domains compatible with local environmental contexts. I summarize how the feasibility principle can be studied under a quantitative framework and contrasted with empirical data across a wide diversity of organisms and contexts. In the face of rapid climate change and habitat modification, I discuss how the feasibility principle can be used to assess the challenges and opportunities for community restoration.

KEYWORDS: assembly | interactions | feasibility | emergence | transitions | probability

> *"For science, there are many possible worlds; but the interesting one is the world that exists and has already shown itself to be at work for a long time. Science attempts to confront the possible with the actual" François Jacob (Jacob, 1994)*

A long-standing question in ecology is whether general principles exist that characterize the adaptability and evolvability of biological populations, irrespective of organismal type or environmental context (Alberch, 1991, Levins, 1968, Lotka, 1920, Margalef, 1968, Parisi, 1999, Volterra, 1926). The discovery of such principles would significantly advance our understanding of the fundamental processes that govern higher levels of biological organization (Flack, 2017, May and McLean, 2007*a*, Odum, 1969, Solé et al., 2024). In the field of community ecology, for instance, diversity within and among communities is often viewed as an emergent property—that is, one that cannot be reduced to the sum of its parts—arising from complex interactions among populations embedded in specific environmental contexts (Morin, 1999, Pascual and Dunne, 2005, Solé and Bascompte, 2005, Vellend, 2016). Yet, it remains uncertain whether common principles can account for the patterns and transitions observed in ecological communities across varying environmental conditions (Marquet et al., 2014). Importantly, uncovering such principles holds considerable promise for informing conservation and restoration strategies aimed at mitigating the detrimental effects of anthropogenic change on biodiversity (Lenton et al., 2021, Levin, 1999).

To understand the emergence and transitions of ecological communities across environmental contexts, I propose the *feasibility principle* in community ecology. This principle is rooted on a *structuralist perspective* (also known as the internalist perspective) (Alberch, 1989, Kirschner and Gerhart, 2005, Solé et al., 2024), which postulates that changes in the state of a living system are catalyzed by external perturbations within an environmental space, but such effects are constrained by an internal structure of interactions among the components of the system (Alberch, 1991). For instance, the expression of phenotypes may depend on a combination of morphogenetic parameters, some of which are environmentally invariant (i.e., internal constraints) and others that are environmentally variant (i.e., influenced by external factors). Building on this premise, the feasibility principle rests on three core hypotheses: (i) An ecological community possesses a feasibility domain—that is, a range of environmental contexts in which it can persist—determined by a time-specific, invariant internal structure; (ii) The probability of observing a given community is proportional to the extent of its feasibility domain that is compatible with local environmental conditions; (iii) the probability of transitioning between two communities is inversely proportional to differences in their feasibility domains compatible with local environmental contexts. I outline below how this principle can be formalized within a quantitative framework and empirically evaluated across a broad range of taxa and ecosystems. In the context of accelerating climate change and widespread habitat alteration, I further explore how the feasibility principle can inform assessments of ecological robustness and guide efforts in community restoration.

From a quantitative standpoint, feasibility in community ecology is formally defined as the existence of a real and positive solution—typically, positive population densities—within the framework of an ecological model. This condition implies the possible long-term persistence of a system $\mathcal{S}$ composed of n interacting populations (Case, 2000, Gilpin, 1975, May and McLean, 2007*b*, Vandermeer and Goldberg, 2013). Importantly, such persistence does not necessarily entail dynamical stability—that is, the ability of a system to return to its equilibrium state following small perturbations in population densities (Allesina and Tang, 2012, Song et al., 2020, Song and Saavedra, 2018*b*, Vandermeer and Goldberg, 2013). These ecological models are often represented in the form $\dot{N_i} = N_i f_i(\mathbf{N})$, where $\dot{N_i}$ denotes the time derivative of population density N_i, and the functions f_i represent the per capita growth rates, typically expressed as multivariate polynomials in the vector of population densities $\mathbf{N} = (N_1, N_2, \ldots, N_n)^T$ (Arditi et al., 2021). Under this framework, feasibility corresponds to the existence of at least one equilibrium point (i.e., $\dot{N_i} = 0$ for all $i \in \mathcal{S}$) such that all equilibrium densities are strictly positive: $\mathbf{N}^* = (N_1^{;} N_2^{;} \ldots, N_n^*)^T > \mathbf{0}$. If at least one of these equilibrium components is zero or negative—indicating the extinction or unsustainability of one or more populations—the solution is referred to as a boundary equilibrium (e.g., $\mathbf{N}^* = (N_1^{>}0, \ldots, N_{n-1}^{>}0, N_n^* = 0)^T$). The inclusion of boundary equilibria in this modeling approach allows for the analysis of partial feasibility, enabling researchers to assess the feasibility of specific subsets of populations—i.e., communities $\mathcal{C} \subseteq \mathcal{S}$—within the larger pool of potential species.

Traditionally, feasibility conditions—typically expressed as inequalities involving model parameters—have been derived by identifying the isocline equations $f_i(\mathbf{N}^*) = 0$ for all $i \in \mathcal{S}$ and solving for the equilibrium vector $\mathbf{N}^*$. Feasibility is then established by imposing the condition $\mathbf{N}^* > \mathbf{0}$, ensuring that all equilibrium population densities are strictly positive (AlAdwani and Saavedra, 2022, Case, 2000, Vandermeer and Goldberg, 2013). One of the most analytically tractable frameworks for conducting this analysis is the generalized Lotka–Volterra (gLV) model (Case, 2000, Lotka, 1920, Takeuchi, 1996, Volterra, 1926), which describes the temporal dynamics of interacting populations through a system of ordinary differential equations. In matrix form, the gLV model is written as: $\dot{\mathbf{N}} = \text{diag}(\mathbf{N})(\mathbf{r} + \mathbf{A} \cdot \mathbf{N})$, where $\dot{\mathbf{N}} = \{\dot{N_i}\}$ is the time-derivative vector of population densities, $\mathbf{r} = r_i$ is the vector of effective growth rates, and $\mathbf{A} = a_{ij} \in \mathbb{R}^{n \times n}$ is the pairwise interaction matrix, with a_{ij} denoting the per capita effect of population j on population i. The effective growth rate r_i represents the net contribution of both intrinsic biological properties and unmodeled environmental factors (abiotic and biotic) to the potential growth of population i. A negative r_i implies a growth deficit in the absence of interactions (e.g., for consumer populations), while a positive r_i implies a growth surplus (e.g., for producer populations) (Odum and Barrett, 2005, Pielou, 2001). In contrast, the interaction matrix $\mathbf{A}$ captures the explicitly modeled biotic interactions—often associated with bioenergetic transfers or mass conservation—between populations in the system $\mathcal{S}$. Thus, the gLV model can decouple direct environmental effects (embedded in $\mathbf{r}$) from internal system interactions (captured in $\mathbf{A}$), providing a mechanistic and phenomenological understanding of community dynamics. Importantly, the gLV model has a strong theoretical foundation, as it can be derived from principles of thermodynamics, mass and energy conservation, and chemical kinetics in the limit of large population sizes (Logofet, 1993, Lotka, 1920, Michaelian, 2005, Täuber, 2011). This grounding makes it a powerful tool for exploring the feasibility and persistence of ecological communities across a range of biological systems.

Focusing on the gLV model, the equilibrium condition ($\dot{\mathbf{N}} = 0$) yields a linear solution of the form $\mathbf{N}^* = -\mathbf{A}^{-1} \cdot \mathbf{r}$. Integrating this formulation with a structuralist perspective, we can interpret community changes in ecological systems—specifically whether a species persists ($N_i^* > 0$) or goes extinct ($N_i^* = 0$)—as outcomes driven by environmental variability, yet constrained by the system's internal interaction structure. In this view, environmental influences are captured by different directions of the effective growth rate vector $\mathbf{r}$, while the internal constraints are encoded in the interaction matrix $\mathbf{A}$. Each direction of $\mathbf{r}$ reflects a distinct configuration or distribution of environmental pressures acting on the populations, modulating their intrinsic capacity to grow or decline. Crucially, under the gLV framework and in the absence of additional constraints, the direction of $\mathbf{r}$—rather than its magnitude—becomes the primary determinant of feasibility for a given interaction structure $\mathbf{A}$ (Grilli et al., 2017, Rohr et al., 2014, Saavedra et al., 2016*b*). This directional dependence emphasizes that environmental change reshapes feasibility landscapes by altering the relative, not absolute, strengths of growth potentials across species. Empirically, the interaction matrix $\mathbf{A}$ can be inferred from observational or experimental data using various methodologies and assumptions, including time series analysis, co-occurrence inference, and manipulative experiments (Bartomeus et al., 2021, Cao et al., 2016, Cenci et al., 2018, Deng et al., 2021, 2024, Flores-Arguedas et al., 2023, Luo et al., 2022, Saavedra et al., 2025, 2017*b*, Song et al., 2018*a*, Tabi et al., 2020, Xiao et al., 2017). While the classification of system parameters as invariant (e.g., $\mathbf{A}$) or variant (e.g., $\mathbf{r}$) may depend on model assumptions—such as those in the linear gLV framework—the overarching conceptual distinction between internal constraints (which define the feasible operational space of a system) and external drivers (which determine the realized state within that space) is model-independent. This dual structure applies broadly across different levels of biological organization (Alberch, 1991, Solé et al., 2024).

The first hypothesis of the proposed feasibility principle posits that a community $\mathcal{C} \subseteq \mathcal{S}$ is feasible within a set of environmental contexts constrained by its internal structure (see Fig. 1). In essence, this hypothesis asserts the existence of at least one possible world—whether empirically observable or purely theoretical—in which the community $\mathcal{C}$ can persist. Notably, this hypothesis is model-independent; it holds conceptually across different formalisms and does not rely on the assumptions of any specific modeling framework (Solé et al., 2024). To illustrate this within the context of the gLV model, feasibility is characterized by the set of directions in the effective growth rate vector $\mathbf{r}$ (representing the environmental context) that are compatible with positive equilibrium solutions for a given interaction matrix $\mathbf{A}$ (representing the internal structure). In this framework, it is the direction of $\mathbf{r}$, rather than its magnitude, that determines whether a community configuration is feasible. However, it is important to acknowledge that the classification of parameters as environmental (contextual) or structural is ultimately flexible and model-dependent (Flores-Arguedas et al., 2023). Mathematically, the gLV model establishes a one-to-one correspondence between equilibrium solutions and parameter configurations. For a given system $\mathcal{S}$ characterized by an interaction matrix $\mathbf{A}$, any feasible equilibrium $\mathbf{N}^*$ corresponds to a unique direction of $\mathbf{r}$, such that $\mathbf{N}^* = -\mathbf{A}^{-1} \cdot \mathbf{r}$, or equivalently, $\mathbf{r} = -\mathbf{A} \cdot \mathbf{N}^*$ (Medeiros et al., 2021*b*, Rohr et al., 2016, Saavedra et al., 2017*b*). This relationship allows, in theory, for the exploration of the full set of environmental contexts under which each of the 2^n possible subsets $\mathcal{C} \subseteq \mathcal{S}$ (i.e., community configurations in which each species is either present or absent) can be feasible, including cases involving boundary equilibria (Deng et al., 2021, 2022). The corresponding set of directions in $\mathbf{r}$ that satisfy feasibility for a given community $\mathcal{C}$—given an interaction matrix $\mathbf{A}$ and species pool $\mathcal{S}$—defines what is typically referred to as the feasibility domain, denoted $D(\mathcal{C}, \mathcal{S}, \mathbf{A})$ (Logofet, 1993, Saavedra et al., 2017*b*, Song et al., 2018*b*). This domain formally characterizes the range of environmental conditions compatible with the long-term persistence of a given community structure and serves as the foundational concept supporting the first hypothesis of the feasibility principle. This is consistent with the notion of biological redundancy, in which a given internal structure may be compatible with multiple environmental contexts (Waddington, 1942).

The second hypothesis of the feasibility principle posits that the probability of observing a given community $\mathcal{C} \subseteq \mathcal{S}$ is proportional to the size of its feasibility domain that is compatible with local environmental contexts (see Fig. 1). Here, "local" refers to environmental conditions that are actually realizable by a given system (such as the directions of the vector $\mathbf{r}$ that can occur in the real world under the gLV framework). These local contexts may themselves occur with different probabilities, reflecting empirical distributions of environmental variability. In the absence of specific information about such local distributions, one may assume all environmental directions are equally probable, treating the entire space of possible contexts as the relevant domain. This hypothesis implies that the observability of a community depends on how well its internal structure aligns with environmental conditions that are likely to be encountered. In other words, communities with larger feasibility domains—i.e., those compatible with a broader set of environmental directions—are more likely to be observed among all possible community configurations in a system $\mathcal{S}$. Conversely, if two communities possess feasibility domains of equal size within the local context, then they should be equally likely to occur, akin to a fair coin toss. However, if the distribution of environmental contexts is skewed toward the feasibility domain of one community, its likelihood of being observed increases accordingly. This hypothesis has been formalized and evaluated within the gLV framework, where the size of a community's feasibility domain (denoted as $D(\mathcal{C}, \mathcal{S}, \mathbf{A})$) can be estimated analytically or numerically. These estimates can be performed under assumptions of either uniform (equiprobable) or biased distributions of environmental directions (Grilli et al., 2017, Saavedra et al., 2016*b*, Song et al., 2018*b*). Such analyses allow the identification of communities with maximal feasibility—those with the greatest potential for persistence under variable conditions (e.g., $\max D(\mathcal{C}, \mathcal{S}, \mathbf{A})$) (Bartomeus et al., 2021, Deng et al., 2021, Medeiros et al., 2021*a*). Fundamentally, this hypothesis aligns with the logic of natural selection: communities that are structurally compatible with a wider range of environmental conditions are more likely to emerge, persist, and be observed in nature.

The third hypothesis of the feasibility principle asserts that the probability of transitioning between two communities (denoted as $\mathcal{C}_i \to \mathcal{C}_j$) is inversely proportional to the differences in their feasibility domains, as defined within the topology of the environmental space (see Fig. 1). These differences are evaluated as distances between feasibility domains, where the environmental space is conceptualized as the mapping between environmentally dependent parameters (e.g., the effective growth rate vector $\boldsymbol{r}$ in the gLV model) and the regions in which each possible community is feasible (Alberch, 1991, Solé et al., 2024). Crucially, this environmental space is shaped by the community's invariant internal structure (e.g., interaction matrix $\mathbf{A}$), which governs how external environmental factors project onto feasibility outcomes. One may envision this space as a multidimensional landscape where each point corresponds to a specific configuration of environmental conditions, and each community occupies a subregion of this landscape—the feasibility domain—in which it can persist. The topology of this landscape is constrained by time-invariant physico-chemical laws and system interactions (Alberch, 1989, 1991). In practice, when precise information about the system's initial state is unavailable, transitions between communities can be approximated by computing the geometric distance between the centroids of their feasibility domains (Long et al., 2024). Importantly, this distance (denoted $d(\mathcal{C}_i, \mathcal{C}_j)$) is not based on compositional similarity (e.g., shared species or richness) but rather on the similarity of the environmental contexts that support each community's persistence (Deng et al., 2024, Long et al., 2024, Saavedra et al., 2016*a*). Consequently, two communities with structurally different species assemblages may still be close in environmental space (and hence more likely to transition between one another) if their feasibility domains substantially overlap or are proximate. This perspective emphasizes that transitions between communities are not governed solely by biotic composition, but by the position and shape of their feasibility domains within the broader environmental landscape. As such, this hypothesis evokes conceptual parallels with the principle of least action (Ferrer-i Cancho and Solé, 2003), suggesting that ecological transitions tend to follow the path of minimal resistance—that is, through regions of overlapping or closely aligned feasibility within environmental space (Alberch, 1991).

Next, I summarize current work supporting the proposed feasibility principle in community ecology using the gLV model as the characteristic model. Focusing on the first hypothesis, a growing body of theoretical research has demonstrated that the feasibility domain of a community is an emergent property of its internal structure (Grilli et al., 2017, Rohr et al., 2014, Saavedra et al., 2016*b*, Song et al., 2018*b*). In particular, it has been shown that the feasibility domain is non-reducible—that is, it cannot be decomposed additively based on the number or identity of populations alone (Deng et al., 2022, Saavedra et al., 2017*b*). For example, adding a new population j to a system of n populations (i.e., $\mathcal{S} \cup j$) may increase or maintain the feasibility domain of the original n-species system. However, the feasibility domain of the new, expanded community ($D(\mathcal{C}, \mathcal{S} \cup j, \mathbf{A}')$), with $\mathbf{A}'$ as the augmented interaction matrix, may have no overlap with the feasibility domain of the original configuration ($D(\mathcal{C}, \mathcal{S}, \mathbf{A})$). Crucially, similar discontinuities in feasibility can arise not only from species additions or deletions but also from species replacements—i.e., changing the identity of species within a community (Deng et al., 2022, Saavedra et al., 2017*b*, 2016*b*). These results emphasize that higher diversity—or merely different species identity—can either create new opportunities for observing a given community under certain environmental contexts, or eliminate previously feasible configurations. Experimental work on community assembly under changing environmental conditions has provided empirical support. In particular, studies have shown that specific subsets of populations can emerge in later stages of community assembly (i.e., in systems with higher diversity), even when those same subsets were not feasible in earlier stages (systems with lower diversity) (Angulo et al., 2021, Deng et al., 2021, Saavedra et al., 2017*a*, 2020). Conversely, populations observed in early stages may disappear in later stages, despite initially appearing feasible (Angulo et al., 2021, Deng et al., 2021, Saavedra et al., 2017*a*, 2020). These findings strongly support the idea that the feasibility of a community is not static—it is shaped by the broader interaction structure of the system. Collectively, these results reinforce the central tenet of the first hypothesis: that any possible community $\mathcal{C} \subseteq \mathcal{S}$ is feasible within a specific range of environmental contexts, but this range is determined by the internal structure (e.g., $\mathbf{A}$) of the entire system. As a result, communities with similar species richness or even similar species identity do not necessarily share the same feasibility domain. The implications are important: community observability and persistence are sensitive to interaction structure, not just to species composition or richness.

Turning to the second hypothesis of the feasibility principle—that the probability of observing a given community is proportional to the size of its feasibility domain compatible with local environmental contexts—recent studies provide growing empirical support across a range of ecological systems. These investigations consistently show that communities with greater feasibility are more likely to be observed in nature. Empirical analyses have explored this hypothesis in diverse systems, including plant–pollinator networks (Cenci et al., 2018, Rohr et al., 2014, Saavedra et al., 2016*b*), plant–herbivore interactions (Medeiros et al., 2021*a*), multi-trophic food webs (García-Callejas et al., 2023), and microbial communities (Deng et al., 2021, Saavedra et al., 2020). Across these contexts, a consistent pattern emerges: the higher the feasibility of a community—among all possible combinations within a given species pool $\mathcal{S}$—the higher its probability of being observed. More specifically, studies have examined how the feasibility domain influences the presence or absence of individual populations within observed communities. For example, the probability of observing a given population i in a system $\mathcal{S}$ increases with the extent to which the remaining populations ($\mathcal{S} \setminus \{i\}$) support the feasibility of population i—that is, how much they enlarge its feasible parameter space (Deng et al., 2021, 2022, Saavedra et al., 2020). Conversely, populations are more likely to be absent when the rest of the community structure constrains or reduces their feasibility. Collectively, this body of work supports the interpretation that feasibility acts as a necessary condition for the emergence and assembly of ecological communities across varying environmental contexts. Communities that are feasible under a broader range of environmental conditions—and thus occupy a larger volume in the environmental space—are simply more likely to arise and persist. In this way, feasibility serves as a filter shaping which community configurations are ecologically realizable.

The third hypothesis of the feasibility principle posits that the likelihood of transitioning between two communities ($\mathcal{C}_i \to \mathcal{C}_j$) is inversely proportional to the difference in their feasibility domains within the environmental space. Empirical studies across multiple systems have provided support for this hypothesis, demonstrating that smaller feasibility differences between communities correlate with a higher probability of observing transitions between them. This hypothesis has been investigated in the context of various ecological systems, including predator–prey interactions (Saavedra et al., 2016*a*), microbial communities (Deng et al., 2024, Long et al., 2024), tree assemblages (Deng et al., 2024), and herbivore communities (Deng et al., 2024, Song et al., 2018*a*). In systems with a fixed species pool $\mathcal{S}$, transitions tend to occur between communities whose feasibility domains are closer in environmental space. For example, work has shown that the most frequently observed transitions occur between communities with minimal geometric distances between the centroids of their feasibility domains (Long et al., 2024). When the species pool or internal structure changes over time—as often happens in natural ecosystems—community transitions tend to favor those configurations with larger feasibility domains (Deng et al., 2024, Song et al., 2018*a*). These transitions reflect a shift toward more environmentally compatible or robust configurations, reinforcing the idea that both proximity and size of feasibility domains jointly influence transition probabilities. These findings support the view that observed community transitions are more likely when communities occupy adjacent or overlapping regions of the environmental space, and when they share structural compatibility with prevailing environmental conditions. Since the feasibility domain is a function of the internal structure (e.g., interaction matrix $\mathbf{A}$), transitions are expected to follow the path of least action—that is, they are more likely to occur between communities with minimal differences in either their internal structure or their compatibility with local environmental contexts. Taken together, this body of evidence supports the third hypothesis: community dynamics are not random but instead follow possible pathways shaped by the geometry of feasibility domains within environmental space (Long et al., 2024).

The story of planet Earth is one of relentless ecological and environmental transformation. However, the current pace of change—driven by anthropogenic forces—is unprecedented, with rates of climate change and habitat modification estimated to be 10 to 100 times faster than historical baselines (Scheffers et al., 2016). This dramatic acceleration underscores the urgent need to understand the challenges that biological populations and ecological communities face in adapting to rapidly shifting environments (Levins, 1968). In this context, the feasibility principle in community ecology offers a powerful, probabilistic framework for guiding conservation and restoration strategies (Cody et al., 1975, Hill et al., 2004, Moreno-Mateos et al., 2017). According to the first hypothesis of the principle, each community is characterized by a feasibility domain—defined by its internal structure—that determines its compatibility with a range of environmental contexts. In other words, every community has the potential to persist under a specific set of conditions, whether those conditions are currently realized or merely theoretical. These feasible conditions are modulated by a set of internal constraints (e.g., species interactions), which act as filters on what is environmentally possible. The central challenge, then, lies in identifying both the internal structures that define a community and the environmental contexts in which that community can be feasibly maintained (Tabi et al., 2023). Empirical studies support this view. For example, it has been shown that changes in the structure of biotic interactions—particularly those associated with an expansion of a community's feasibility domain—are linked to increased environmental variability, such as fluctuations in temperature (Song et al., 2017, Song and Saavedra., 2020, Tabi et al., 2020). In particular, communities at higher latitudes, which tend to experience greater climatic variability, are often associated with broader feasibility domains. This evidence suggests two important implications: (1) for a fixed environmental condition, there may exist multiple candidate communities—each with a distinct internal structure—that are compatible with that condition; and (2) for a given community, there may exist multiple environmental conditions under which it remains feasible.

Building on the second and third hypotheses of the feasibility principle, we hypothesize that increasing environmental stress—such as that induced by climate change or habitat degradation—reduces community diversity by selectively filtering for configurations with larger feasibility domains, i.e., those more compatible with prevailing environmental conditions (Cenci et al., 2018, Song et al., 2018*a*, Song and Saavedra, 2018*a*, Song et al., 2023). Under such constraints, the survival and assembly of ecological communities may become less dependent on the taxonomic identity of their constituent species and more constrained by their compatibility with local abiotic and biotic conditions. Empirical evidence further suggests that sequential species introductions are more effective for community restoration than simultaneous reintroductions (Deng et al., 2024). This strategy takes advantage of the fact that stepwise restoration allows the system to pass through intermediate community states with larger feasibility domains—effectively increasing the likelihood of successful transitions at each step. In contrast, attempting to reassemble an entire community at once may target configurations that are less feasible or more sensitive to perturbation. Importantly, the feasibility domain of a multi-species community is not necessarily the union of the feasibility domains of its subsets, particularly when those subsets are introduced sequentially. As such, restoration trajectories that progressively move through increasingly feasible configurations are expected to be more robust. Moreover, when multiple candidate communities exhibit similarly sized feasibility domains, choosing the one that requires the smallest structural deviation from the predecessor's domain may further enhance the probability of success. This aligns with the principle of minimizing energetic or structural shifts across restoration steps. While the feasibility principle has largely been explored through the generalized Lotka–Volterra (gLV) model, future work could extend this framework by integrating it with broader ecological theory (Marquet et al., 2014). In particular, coupling feasibility domains with metabolic and bioenergetic theories may yield deeper mechanistic insights into how internal constraints (e.g., interaction structure, physiological limits) interact with external drivers (e.g., temperature, nutrient availability) (Angulo et al., 2025, Saavedra et al., 2025). This integration could advance a unified probabilistic framework for understanding and guiding community assembly and restoration under environmental change.

Data and code availability: No new data or code were generated. All previous data and code can be found on Github (`https://github.com/MITEcology`) and the R package feasiblityR (`https://doi.org/10.5281/zenodo.8289566`).

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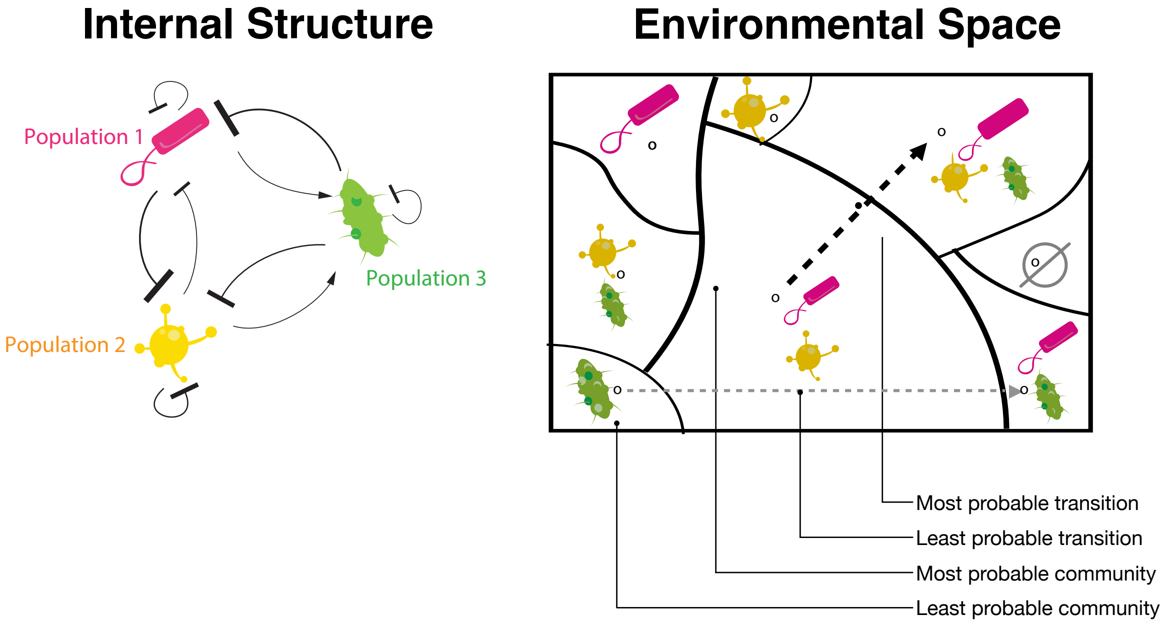

Figure 1: **Graphical representation of the feasibility principle in community ecology**. A central goal of theoretical ecology is to synthesize hypotheses within a quantitative, explanatory, and predictive framework. The feasibility principle offers such a framework by providing a probabilistic understanding of biodiversity patterns across environmental contexts. This principle is composed of three interrelated hypotheses: (i) Ecological communities are feasible within specific regions of environmental space, and these regions are constrained by each community's internal structure (i.e., species interactions define the feasible partition of environmental space). (ii) The probability of observing a particular community is proportional to the size of its feasibility domain that overlaps with locally realized environmental conditions. (iii) Transitions between communities are more likely to occur along paths of least feasible change—i.e., transitions are more probable when communities have larger feasibility domains and smaller distances between those domains in environmental space. In formal models (e.g., the generalized Lotka–Volterra model), the environmental space is defined by environmentally-dependent parameters (e.g., effective growth rates). Each possible community from a given system occupies a distinct region of this space in which it is feasible. These regions are delimited by the system's internal structure. The empty set—representing regions where no community is feasible—is intentionally placed arbitrarily to emphasize that communities with similar species richness or composition are not necessarily proximal in environmental space. Small circles within each region denote the geometric centers (centroids) of feasibility domains, used to approximate distances between communities.

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