

# *Compendium of Scientific and Practical Findings Supporting Eco-Restoration to Address Global Warming*

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## About Biodiversity for a Livable Climate

Biodiversity for a Livable Climate, [bio4climate.org](http://bio4climate.org), is a 501(c)(3) non-profit founded in 2013. Our mission is to support the restoration of ecosystems to reverse global warming. We are:

- **A think tank**, creating research and reports (such as this Compendium), and presenting conferences on the science and practice of eco-restoration with speakers from around the world.
- **An educational organization**, offering presentations, courses and materials, including over 250 videos of speakers (with over 250,000 views on YouTube) from

our 13 conferences since November 2014 ([bio4climate.org/conferences](https://bio4climate.org/conferences)), with many restoration and climate-positive examples from both scientists and practitioners.

- **An advocate** that reaches out to other organizations to encourage and facilitate the incorporation of eco-restoration as a climate solution into their own messaging and actions. We seek to connect to other groups and projects to help nourish and advance their own growth, and carry messages among groups to collaboratively learn and build on each other's efforts, and occasionally facilitate the emergence of new groups. Since climate affects everyone, every organization has to deal with it in its own way, and we strive to help with the transition.
- **An activist group** that engages in non-partisan political processes. For example, we helped shepherd a bill through the legislative process in 2017 to establish a Maryland Healthy Soils Program.
- **A partner** with John D. Liu's Ecosystem Restoration Camps movement (<https://ecosystemrestorationcamps.org>) in helping to apply eco-restoration knowledge and expertise towards the recovery of lands around the world.

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## Suggested Citation

Compendium of Scientific and Practical Findings Supporting Eco-Restoration to Address Global Warming, Vol 5 No 1, August 2021, <https://bio4climate.org/resources/compendium/>. This is a collection of article summaries and commentary that will grow as new literature becomes available and as older literature is re-discovered.

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We are most appreciative of the support from our sponsors over the past six years. In particular, the 11th Hour Project provided significant funding for our first two years, and the new and important institution that it helped create, the Regenerative Agriculture Foundation, is continuing

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## Conversion table

hectares vs. acres	1 ha ≈ 2.5 ac
megagrams vs. tons	1 Mg = 1 metric ton
teragrams vs. tons	1 Tg = 1 million metric tons
petagrams vs. gigatons	1 Pg = 1 billion metric tons (1 Gt)
weight <sup>1</sup> carbon vs. weight CO <sub>2</sub>	12/44
parts per million CO <sub>2</sub> vs. weight of carbon <sup>2</sup>	1 ppm CO <sub>2</sub> ≈ 2 Gt carbon

## The ecological role of native plants

Bio4Climate has been studying the Miyawaki Method of reforestation over the past several months. This 50-year-old technique involves densely planting native forest species from shrub to canopy layer to create tiny, fast-growing urban ecosystems<sup>3</sup>. Members of our staff have joined local efforts to establish Miyawaki “mini-forests” in Cambridge, MA, in Los Angeles, CA, and one in France.

The attractiveness of the Miyawaki Method should be understood in the context of a growing global zest for tree planting, such as the World Economic Forum’s 1 Trillion Trees campaign and the Bonn Initiative. In fact, tree planting initiatives can have various goals – including timber production and carbon capture, both of which favor fast-growing, often non-native trees, or

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<sup>1</sup> We refer to carbon in soils and biomass, etc. by weight of carbon; atmospheric carbon may be referred to by weight of carbon *or* by weight of CO<sub>2</sub>, a frequent source of confusion.

<sup>2</sup> ppm is a volume measurement; 1 ppm in the total volume of earth’s atmosphere is approximately equal to 2 gigatons of carbon by weight – and yes, this can be confusing too. Moving 1 ppm CO<sub>2</sub> from the atmosphere results in 2 Gt carbon added to soils or other carbon sinks.

<sup>3</sup> <https://www.theguardian.com/environment/2020/jun/13/fast-growing-mini-forests-spring-up-in-europe-to-aid-climate>

erosion control or improving ground permeability. When ecosystem restoration is the explicit goal, however, reforestation aims to reestablish the full complement of ecosystem functions and wildlife habitat inherent in native ecosystems.

Not only the Miyawaki Method, but many eco-restoration initiatives favor the use of native plants over exotic species. Indigenous plants are preferred because they are typically well-adapted to local environmental conditions. Additionally, native plants interact in important ways with other local species, such as by serving as food sources for herbivores, and thus transferring energy up the food chain. Many insects, for example, are specialists and can use only certain species in their diets. When these particular plant species are replaced by non-natives or otherwise lost locally, the insects that depend on them also disappear.

Several studies by Tallamy and his colleagues [Burghardt 2008, Burghardt 2010, Narango 2017, Tallamy 2020] working in eastern US illustrate the critical role of native plants for local moths and butterflies (also called “lepidopterans”), and thus also for the birds that depend on these insects. In 2010, Burghardt, et al. reported on a two-year experiment showing that lepidopteran richness (the number of species) and abundance were lower on non-native compared to native plants.

The authors explain that insect herbivores are adapted to the self-defensive toxins produced by plants for only certain plant species, which makes them especially vulnerable when those species are replaced by non-natives. This is particularly true for specialists, which make up the majority of insect herbivore species: “Most species are specialists that use only a few of the myriad plant lineages available to them for growth and reproduction. ... Specialists have followed an evolutionary path that has enabled them to circumvent particular plant defenses by developing highly specific behavioral and physiological adaptations that defuse such defenses” [Burghardt 2010: 2]. The authors add, however, that “even the most generalized insect herbivores use only a small fraction of the plants in their environments” [Burghardt 2010: 2].

As expected, specialist lepidopteran species fared worse on non-natives than did the generalists, which can eat a greater variety of foods and survive in wider habitat ranges, although both groups suffered. Non-native plants (Norway maple, for example) that were similar to native ones (red maple) were more commonly used by lepidopterans, than were non-natives with no related native counterpart. The authors explain that “insect herbivores adapted to the chemical challenges [toxic plant defenses] of particular native hosts may be able to adopt a novel plant species as a host if its phytochemistry is sufficiently similar to the original hosts” [Burghardt 2010: 10]. Only 7% of specialist species used non-natives with no similar native counterpart as hosts, while less than half of generalists did.

A Washington DC study [Narango 2017] showed that both lepidoptera and their bird predators prospered in the presence of native plants:

Native plants were more likely to host a higher biomass of caterpillars compared to non-native plants, and chickadees strongly preferred to forage in native plants that supported the most caterpillars. In addition, chickadees were less likely to breed in yards as the dominance of non-native plants increased [Narango 2017: 42].

A related study [Burghardt 2008] showed greater diversity and abundance of both lepidoptera and birds (including birds dependent on insects to feed their young) in suburban yards with native plants only, compared to yards with a mix of native and non-native plants. Interestingly, all yards in the study had similar levels of overall plant diversity, suggesting that it is native biodiversity rather than biodiversity per se that counts, at least for butterflies, moths and birds.

These studies illustrate the dependence of herbivorous insects on particular co-evolved plants, and how the food web is affected when that relationship is interrupted. A related line of inquiry is whether plants themselves depend on other plants with which they share a common history. The answer to this is less clear. Thorpe et al. [2011] point out that the effects of plant-plant interactions on evolution have received less attention from researchers:

Research on plant-consumer, plant-pollinator and plant-disperser interactions has been central to understanding the complex mutualistic and co-dependent interactions among species that structure communities. However, with some notable exceptions, interactions among plants have not been emphasized as processes that contribute to selection and evolution [Thorpe 2011: 730].

Thorpe et al. [2011] highlight studies suggesting that plants, like insects, are adapted to the toxins produced by plants with which they co-evolved. Several North American experiments show that exotic European plants strongly inhibit the growth of native plants, while not negatively affecting European members of the same genus as the inhibited native plants. “Biogeographical differences in the effects of allelopathic chemicals circumstantially suggest they have roles as drivers of evolution” [Thorpe 2011: 735], state the authors. They add, however, that invasive species exert selection pressure fairly quickly on the communities they enter, resulting in adaptation that is passed on to the next generations.

In addition, plants are able to divvy up limited resources through “niche complementarity,” which is “the idea that different species or functional groups occupy niches different enough from each other to more fully utilize resources or space, increasing and stabilizing productivity, and making it more difficult for other species to enter the community” [Thorpe 2011: 733]. The authors cite a 1976 study that “found that resource partitioning, as estimated from spatial overlap among root systems, was higher in stable prairie communities with a long community history than in early successional old-field communities composed of species without a common history” [Thorpe 2011: 733].

The question of whether plant interactions drive evolution is related to an ongoing debate about the nature of a plant community. Two competing schools of thought regarding the nature of a stand of plants growing together geographically are represented by two early 20<sup>th</sup> Century botanists. H.A. Gleason observed “that species are ‘individualistically’ distributed along omnipresent environmental gradients and thus cannot form bounded communities” [van der Maarel 2013: 2]. In this view, species distribution is driven by each species’ particular tolerance to various environmental conditions, and “that the level of interactions and interdependence is relatively low, or at least nonspecific” [Barbour 1987: 158].

Barbour et al. explain that E. Clements, by contrast, compared a plant community with an integral organism, where the whole is greater than the sum of its parts, and whose component species are interdependent in the sense that they are bound together by multiple positive (and neutral) interactions. Both camps have observed that particular plant species grow together reliably in identifiable groups, forming a vegetation type (like an oak-beech forest, for example).

Fossil records indicate that some of these groups (or very closely related precursors) have lived together for thousands or even millions of years. During that time, it is possible that an intricate balance has been fashioned. Community members share incoming solar radiation, soil water, and nutrients to produce a constant biomass; they recycle nutrients from the soil to living tissue and back again; and they alternate with each other in time and space [Barbour 1987: 155].

Do plant species grow together in definable communities simply because they share the same environmental needs or are they also somewhat interdependent members of a specific community? The jury seems still to be out on this question. Regarding the larger ecological community (including animals), Steen et al. [2017] propose the concept of an “evolutionary community,” which emphasizes interdependence among specific groups of species.

What processes cause a group of species to cohere into a community? We argue that the parts of Evolutionary Communities are bound together by interspecific interactions in a shared biotic and abiotic environment, which promote co-evolution and community structure and dynamics. For example, longleaf pine trees are conduits for lightning strikes that ignite a highly flammable understory, often including dropped longleaf pine needles. The resulting ground fires are necessary for reproduction of other species and maintain habitat suitable for others (e.g., gopher tortoises). Gopher tortoises, through the process of burrow creation, provide structure important to other species. The establishment of one or more of the species listed above facilitated the persistence of additional species [Steen 2017: 1025].

These authors add that the Evolutionary Community concept can “help us understand what many conservation and restoration efforts are trying to accomplish” [Steen 2017: 1031], in terms of reestablishing the interspecies interactions that drive ecosystem function. Similarly, Harvey et al. [2017] stress that interspecies interdependence is a key concept for conservation, and call for the latter to focus less on species and more on interactions among species.

We propose that a shift in focus from species to interaction networks is necessary to achieve pressing conservation management and restoration ecology goals of conserving biodiversity, ecosystem processes and ultimately landscape-scale delivery of ecosystem services [Harvey 2017: 371].

All of these studies shed some light on the role of native species in the Miyawaki Method and other eco-restoration approaches. Is it possible, though, that non-native species could replace certain native species in a way that fulfills the ecological role of the replaced natives? In some contexts, it seems that communities of non-local species can thrive. Jones [2013] cites a perhaps not-terribly representational study of the vegetation on an island stranded between Africa and Brazil. This study documents “a highly functional cloud forest on Ascension Island in the south Atlantic made up of species with no history of coevolution, having been introduced from various continents. Thus, plants do not necessarily need to have co-evolved together either locally or nonlocally to display desirable community-level interactions” [Jones 2013: 1114].

By contrast, numerous studies document local ecological decline resulting from the establishment of non-native species. Jones [2013] supports the premise that local species are generally the best choice for eco-restoration, but he notes that in the context of environmental change, it may sometimes be possible that local species are no longer the best adapted.

Globally, 13,168 plant species (3.9% of known vascular plants) have become naturalized outside their native range due to human activity [van Kleunen 2015]. The anthropogenically expanding distribution of generalist species is shrinking the range of regional, endemic, often specialist species. This process, referred to as biotic homogenization, results in a “global erosion of regional distinctiveness” [Olden 2004: 18].

At the genetic level, homogenization threatens to diminish the local adaptations of native species through mixing of populations; at the ecosystem level, functional homogenization “might reduce overall community and ecosystem functioning, stability and resistance to environmental change by simply narrowing the available range of species-specific responses” [Olden 2004: 20]. Thus, there are local, regional, and global consequences of biotic homogenization.

With respect to the role of native species in eco-restoration, the Society for Ecological Restoration [SER 2019] distinguishes between restoration and “rehabilitation.”



Rehabilitation activities are well suited to a broad range of land and water management sectors where substantial native ecosystem recovery is not possible or desirable due to competing and legitimate human needs. ... rehabilitation projects achieving some improvements in ecological conditions can later be targeted for ecological restoration. For instance, where revegetation of a degraded rangeland, or post-mine site, with a mix of native and nonnative plant species and native microsymbionts has resulted in improved soil function, restoration plans can be developed that include harvesting nonnative species and replacing them with native species as well as taking other actions to assist the system to recovering to the condition it would have been in if degradation had not occurred. In some cases where soil has been stabilized with nonnative species, native species can be added (or helped to recover spontaneously) and nonnative species removed to ultimately assist the recovery of a native ecosystem [SER 2019: 52].

In summary, it seems that while plant species can potentially adapt to growing with plants from outside their native range, this can sometimes take time, limiting growth of species or communities at least in the short term. By contrast, many native herbivore species are likely to become locally extinct rather than adapt to non-native plants when the latter displace natives. The loss of insects blocks the flow of energy from plants up the food chain, negatively affecting ecosystem function. While native plants are a more perfect ecosystem puzzle piece, non-native species certainly have important roles to play – at least in ecosystem “rehabilitation” as noted above and potentially to substitute for extinct natives of the same genus or functional group. Additional novel species groupings can be expected as climate change drives some species to migrate to more suitable latitudes.

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## Native plants article summaries

The following articles lay out a few key ecological concepts and terms that may be helpful to become familiar with for the growing number of biodiversity-conscious people and organizations that are beginning to plant more native plants on their land.

Native plants, native ecosystems, and native landscapes: an ecological definition of "native" will promote effective conservation and restoration, Wilson, Hibbs & Alverson 1991

Produced by the Native Plant Society of Oregon, this article argues that, while the use of native species is an accepted tenet of conservation, the term “native” is not necessarily well understood; they attempt to clarify the term.

“Any definition of a native species, native ecosystem, or native landscape requires an historical benchmark” [Wilson 1991: 16]. Over the past 20,000 years, “vegetation in the Willamette Valley has changed dramatically with changing climate. Vegetation in a single place has probably varied from boreal parkland, to conifer forest, to oak savanna, to prairie. Each climatic phase supported a different flora” [Wilson 1991: 16]. Each of these vegetation types was native to a particular place, according to particular climatic conditions that changed overtime. The vegetation that developed in the past 10,000 years - the current Holocene period of climate stability - is thus the relevant reference.

“For the Pacific Northwest, the period that ended with Euro-American settlement is a natural historical benchmark. This period lasted long enough to have a significant impact on the vegetation of the region. The climates of much earlier times were different enough to limit their usefulness in defining today's ecosystems” [Wilson 1991: 16]. Thus, “any species that had occurred in a particular ecological habitat [of the Pacific Northwest] before Euro-American settlement is a species native to that habitat” [Wilson 1991: 17].

A native ecosystem, then, is one dominated by native plants, animals and microorganisms that occurred together before the time of Euro-American settlement. Key species – for example, the dominant photosynthesizing plants, the top carnivores, the important decomposers, the nitrogen-fixers – must be present for a native ecosystem to persist and function on its own. To artificially maintain a conserved or restored ecosystem without all of its crucial components is both difficult and expensive. The species of native ecosystem must also occur together in nature. For example, landscaping with an artificial mixture of native species like vine maple, blue bunch wheatgrass, and Jeffrey pine does not produce a native ecosystem. These species are native to different areas within Oregon, but they would not naturally grow together in the same ecosystem. Restoration of native ecosystems must also account for proper structure and appearance. For example, a red fescue lawn does not have the structural complexity and species diversity exhibited by native bunchgrass prairies [Wilson 1991: 17].

Key species – for example, the dominant photosynthesizing plants, the top carnivores, the important decomposers, the nitrogen-fixers – must be present for a native ecosystem to persist and function on its own. To artificially maintain a conserved or restored ecosystem without all of its crucial components is both difficult and expensive [Wilson 1991: 17].

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## The community as an ecological unit, Barbour, Burk & Pitts 1987

This article provides an overview of types of plant communities and the process of succession in those communities.

In each type of habitat, certain species group together as a community. Fossil records indicate that some of these groups (or very closely related precursors) have lived together for thousands or even millions of years. During that time, it is possible that an intricate balance has been fashioned. Community members share incoming solar radiation, soil water, and nutrients to produce a constant biomass; they recycle nutrients from the soil to living tissue and back again; and they alternate with each other in time and space. Synecologists attempt to determine what is involved in this balance between all the species of a community and their environment [Barbour 1987: 155].

### *Community concepts and attributes*

A plant community is an identifiable stand of plants growing together in a certain spot. Clusters of species, called associations, are often found growing together in several different places within a larger region. “An association is a particular type of community, which has been described sufficiently and repeatedly in several locations such that we can conclude that it has: (a) a relatively consistent floristic composition, (b) a uniform physiognomy [appearance], and (c) a distribution that is characteristic of a particular habitat” [Barbour 1987: 156].

There are opposing views about why particular plant species are often found growing together in a plant community. The continuum view posits that species distribution is driven individualistically by each species’ particular tolerance to various environmental conditions. By contrast, the association view suggests that a plant community is an integrated whole, whose component species are interdependent.

Whatever the reasons that particular species tend to grow together in stands, however, such stands “exhibit collective or emergent attributes beyond those of the individual populations” [Barbour 1987: 159]. Examples of such community attributes include its vertical structure, canopy cover, species composition and diversity, biomass, productivity, stability, and nutrient cycling, for example.

### *Succession*

Ecological succession is an important concept that helps explain the particular assemblage of plants growing in a given location.

“Plant succession is a directional, cumulative change in the species that occupy a given area through time” [Barbour 1987: 230]. This does not refer to cyclical changes that occur over seasons, nor to changes occurring in response to climate shifts over extremely long time spans like thousands or millions of years. Rather, succession is when the composition of plants at a particular site changes over a period of decades to centuries.

Succession begins when pioneer species colonize bare ground. These first arrivals tend to be opportunists that grow fast, reproduce quickly, and do not live long. The early successional plants start to improve the habitat conditions for other, more competitive plants to then take over, displacing the pioneers. “One of the driving forces behind succession is the effect plants may have on their habitat. Plants cast shade, add to the litter, dampen temperature oscillations, and increase the humidity, and their roots change the soil structure and chemistry. ... Both the environment and the community change, and this metamorphosis is due to the activities of the organisms themselves.” [Barbour 1987: 233]

Overtime, slower-growing, larger, longer-living plant species outcompete the earlier successional species, eventually forming a climax community, which is not subsequently replaced by any other community. “Succession often leads to communities with greater and greater complexity and biomass and to habitats that are progressively more and more mesic (moist)” [Barbour 1987: 233]. Such changes result in climax communities tending to be self-sustaining due to efficient nutrient cycling and internal moderation of external fluctuations in temperature and humidity.

The particular plant composition of a climax community depends on the regional climate, as well as local soil conditions and topography, meaning that several climax communities can exist in a given landscape.

Typically, many plant communities coexist in a complex mosaic pattern. That is, one climax community does not cover an entire region. ... In [some] cases, the mosaic reflects topographic differences, such as south-facing versus north-facing slopes, basins with poor drainage and fine-textured soil versus upland slopes with good drainage and coarser soil, or different distances from a stress such as salt spray. In such cases, the communities within the mosaic do not bear a successional relationship to one another; they constitute a toposequence. Each community in a toposequence may, in fact, be a climax community [Barbour 1987: 238].

Understanding ecological succession can help us to predict the future vegetation of a site by observing its current vegetation. “It is often possible to estimate a community’s future composition by extrapolation from changes measured in a short time, by comparing other communities that have plants of different ages, or by noting differences between overstory

plants and understory seedlings” [Barbour 1987: 231] In some cases, the understory seedlings will later become the canopy, provided the localized conditions support this succession.

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## Vegetation Ecology: Historical Notes and Outline, van der Maarel & Franklin 2013

These authors define the concept of a plant community through discussion of its evolution. They start by defining the term ‘vegetation’ in a way that may surprise some readers because it excludes plants growing in certain situations. To be considered vegetation, plants need to emerge spontaneously.

Vegetation, the central object of study in vegetation ecology, can be loosely defined as a system of largely spontaneously growing plants. Not all growing plants form vegetation, for instance, a sown corn field or a flower bed in a garden do not. But the weeds surrounding such plants do form vegetation. A pine plantation will become vegetation after some years of spontaneous growth of the pine trees and the subsequent development of an understory [van der Maarel 2013: 1].

Two competing schools of thought regarding the nature of a stand of plants growing together geographically are represented by two early 20<sup>th</sup> Century botanists. H.A. Gleason observed “that species are ‘individualistically’ distributed along omnipresent environmental gradients and thus cannot form bounded communities” [van der Maarel 2013: 2]. By contrast, E. Clements compared plant community with an integral organism, where the whole was greater than the sum of its parts. During the same time period, the Braun-Blanquet approach was developed, which “paid much attention to the relations of plant communities with the environment and the interactions within communities, which is now incorporated in the concept of ecosystem” [van der Maarel 2013: 2].

The authors state that while individual plant species are distributed according to abiotic environmental conditions, the fact of being co-located with particular sets of other species in a particular environment results in interspecies interactions, which are in fact ecosystem processes (emergent properties).

In conclusion, a plant community is generally recognized as a relatively uniform piece of vegetation in a uniform environment, with a recognizable floristic composition and structure, that is relatively distinct from the surrounding vegetation. Even if the populations of the participating species are usually distributed individualistically in the landscape, they may well interact within the community and build up an integrated unit

with emergent properties. At the same time, plant communities can be convenient units for conveying information about vegetation and its environment [van der Maarel 2013: 4].

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## Vegetation types and their broad-scale distribution, Box & Fujiwara 2013

A vegetation type, or plant community, is identifiable by its distinct appearance compared to other landscape types within a landscape. For example, a grassland and a wetland differ in appearance from each other and from a forest, while a wetland-forest is yet another visibly different vegetation type. Plant species are recognizable by their form, which is related to how the plant functions. For example, in dry environments, plant leaves are more compact with harder surfaces to limit water loss, while plants in wetter environments have larger, “softer” leaves that release water readily when pores open to take in CO<sub>2</sub>. Such leaves have more surface area for photosynthesis, resulting in faster growth.

This form-function relationship explains why vegetation types differ around the globe. Plant species are adapted to particular climatic conditions according to their proximity to the equator or a coastline, for example, or their elevation.

The geographic regularity of vegetation distribution arises, of course, from the geographic regularity of Earth’s main climatic regions, driven by the global circulation pattern of the Earth’s atmosphere [Box 2013: 466].

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## Predictive modeling of the potential natural vegetation pattern in northeastern China, Liu et al. 2009

This study uses the concept of Potential Natural Vegetation (PNV), developed in the mid-1900s by German botanist Reinhold Tüxen. Described by the authors as “one of the most successful novelties in vegetation science over the last decades” [Liu 2009: 1313], PNV can be defined as a projection of the natural vegetation that would exist in a given area in the absence of human interference.

“By showing the relationships between environmental variables and vegetation types, maps of the PNV are an important instrument in the study and planning of the environment, and act as decision-support tools for the solutions to environmental issues” [Liu 2009: 1313]. Such maps are informed by studying remnant natural (old growth) vegetation in the area and site observations of the area to be mapped.

Computer modeling can be used to predict “the geographic distribution of vegetation composition across a landscape from mapped environmental variables, such as climate, soils, and geology. When a predictive vegetation modeling is calibrated using observation of vegetation composition taken from mature or ‘climax’ vegetation stands, then potential natural vegetation is portrayed in a predictive map” [Liu 2009: 1314].

Focusing on northeastern China, the study identified 16 vegetation types in the region, along with the environmental factors influencing their distribution. Climatic factors included: mean annual temperature, mean temperature of the coldest month, relative humidity, and potential evapotranspiration rate. Topographical factors were elevation and slope.

“Generally, as the elevation increases, the change of temperature and moisture leads to the obvious differentiation phenomenon in vegetation vertical zones. Slope is related to the hydrology (overland and subsurface flow velocity and runoff rate) and potential soil moisture and soil development of a habitat” [Liu 2009: 1315].

They compared the map created by their model to existing vegetation maps of the region. “Visual comparison of the predicted PNV distributions with their actual equivalents indicates a good agreement” [Liu 2009: 1317]. Some modeled vegetation types did not agree with existing maps, however, meaning that “some more important environmental factors may have been missing in the model” [Liu 2009: 1318]. The authors also state that calibrating their model with additional field data on what is currently growing, collected from throughout the region, would improve the model’s accuracy.

The article concludes by stating that a ‘vegetation-environment’ model can help to determine PNV under not only current, but also predicted future environmental conditions.

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## Conceptualizing communities as natural entities: a philosophical argument with basic and applied implications, Steen et al. 2017

Ecological restoration aims to recreate lost or degraded ecological communities. However, “community” has been a difficult concept to define – should the definition stress dominant species, species interactions, or a subset of strongly interacting species? These authors propose defining community on the basis of co-evolutionary relationships among species.

We propose that an Evolutionary Community is conceptualized as a unique grouping of species, which occur in a given geographic area and are connected by interspecific and abiotic interactions that have evolved over time [Steen 2017: 1021].

By treating communities “as entities that have formed over evolutionary time; this [Evolutionary Community] concept allows for a philosophical platform to help us understand what many conservation and restoration efforts are trying to accomplish” [Steen 2017: 1031]. That is, it offers a way to conceptualize the end goal of a restoration project. A particular evolutionary community could be recreated by assembling the constituent species, resulting in the ecological interactions among the species resuming as before.

What processes cause a group of species to cohere into a community? We argue that the parts of Evolutionary Communities are bound together by interspecific interactions in a shared biotic and abiotic environment, which promote co-evolution and community structure and dynamics. For example, longleaf pine trees are conduits for lightning strikes that ignite a highly flammable understory, often including dropped longleaf pine needles. The resulting ground fires are necessary for reproduction of other species and maintain habitat suitable for others (e.g., gopher tortoises). Gopher tortoises, through the process of burrow creation, provide structure important to other species. The establishment of one or more of the species listed above facilitated the persistence of additional species [Steen 2017: 1025].

Likewise, the demise of one species will negatively affect, or even cause the demise of, other species that depend on it. Thus, the reason to preserve or recreate an integral community is to support the interdependent component species, each of which in turn support the community as a whole.

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## Bridging ecology and conservation: from ecological networks to ecosystem function, Harvey et al. 2017

This article emphasizes the importance of species interactions as drivers of ecosystem function.

The classic conservation approach is to set aside national parks or to target specific species for protection, based on their rarity or endangered status. However, these approaches can have trade-offs for non-target species, while also potentially failing to protect ecosystem function. The authors, therefore, suggest that species interactions based on their functional significance should be the main focus on conservation efforts.

We propose that a shift in focus from species to interaction networks is necessary to achieve pressing conservation management and restoration ecology goals of conserving biodiversity, ecosystem processes and ultimately landscape-scale delivery of ecosystem services [Harvey 2017: 371].



Species depend on many other species in their communities, either directly or indirectly. An example of indirect dependence is the Phengaris arion butterfly's need for European rabbits. The butterfly uses ant nests made in the open areas supplied by rabbit grazing for development of its larvae. Thus, no rabbits means no ants, which means no Phengaris arion.

Focusing on species interactions is more meaningful even than measuring species richness (the number of different species), because interactions can disappear - even if both species are present - if either group's abundance has significantly dropped. The authors offer the example of 59 regionally extinct lepidoptera (butterfly and moth) species of central Europe. Eight of these extinctions were associated with the loss of particular host plant species, which actually occurred after the lepidoptera went extinct.

Focusing on species interactions is more meaningful even than measuring species richness (the number of different species), because interactions can disappear - even if both species are present - if either group's abundance has significantly dropped.

Thus, strong declines of host plants can have cascading extinction effects on higher trophic levels before the plants actually go extinct, illustrating that interactions can be lost before any actual decline in species richness (plants persisted at low abundance). This illustrates that preserving keystone interactions, rather than species, can be a proactive way to maintain ecosystem integrity in the face of global change instead of allocating resources to already endangered species [Harvey 2017: 372].

There is interdependence among species even between neighboring ecosystems. For example, a manta ray species in the Palmyra Atoll south of Hawaii depends on two species of native trees to maintain its ocean plankton diet. When these trees were replaced with cultivated coconut palms, marine-foraging birds no longer nested on that shore, depriving the coastal waters of the nitrogen runoff from their guano, which had been feeding the plankton population.

The authors recommend that "the main lever to restore or conserve ecological network structure and stability is the management of spatial configuration" [Harvey 2017: 377]. Reflecting on the Palmyra Atoll, for example, it's clear that a marine conservation plan would be incomplete without considering the nutrient flow from the tree-bird interactions on land.

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## Interactions among plants and evolution, Thorpe et al. 2011

This review explores the question of whether plant-plant interactions drive evolutionary changes. “If such evolution is common, plant communities are not random assemblages of species.” The topic is under-studied compared to plant interactions with other groups.

Research on plant-consumer, plant-pollinator and plant-disperser interactions has been central to understanding the complex mutualistic and co-dependent interactions among species that structure communities. However, with some notable exceptions, interactions among plants have not been emphasized as processes that contribute to selection and evolution [Thorpe 2011: 730].

“The simplest interactions among plants are direct interactions, such as facilitation, resource competition and allelopathy” [Thorpe 2011: 731]. Facilitation is when one plant protects an adjacent plant, such as from drought and heat by providing shade, for example, or from browsing by being thorny or toxic to herbivores and surrounding the facilitated plant. Allelopathy refers to plants’ release of toxic substances that suppress the growth of another organism, including other plants. In natural communities, any given plant may be interacting with several different plants at the same time.

In natural communities, any given plant may be interacting with several different plants at the same time.

Competition for sunlight, water, and nutrients drives niche differentiation, or the carving out by species of particular spaces or timing within an ecosystem to obtain a share of limited resources. “The exceptionally rich body of ecological literature on the niche is based in part on the idea that competition can drive the evolution of niche differentiation, thus allowing species to coexist” [Thorpe 2011: 732].

Thorpe et al. refer to an example from a 1976 article by Parrish & Bazzaz , who “found that resource partitioning, as estimated from spatial overlap among root systems, was higher in stable prairie communities with a long community history than in early successional old-field communities composed of species without a common history” [Thorpe 2011: 731]. In other words, plants with a long coexistence history more efficiently divvy up resources than do species lacking a common community history.

The primary hypothesis for positive diversity-ecosystem function relationships has been niche ‘complementarity’, the idea that different species or functional groups occupy niches different enough from each other to more fully utilize resources or space, increasing and stabilizing productivity, and making it more difficult for other species to enter the community [Thorpe 2011: 733].

The authors are somewhat inconclusive, however, about what drives niche complementarity (resource partitioning).

We do not yet know whether complementarity is produced by interactions causing evolutionary shifts in niche space (and thus coexistence and more complete resource use) or by sorting of the existing species pool [Thorpe 2011: 733].

Plants can also adapt to one another’s allelopathic substances over time, a fact that contributes to the argument that plant-plant interactions produce evolutionary changes. “Recent experiments raise the possibility that some invaders may exude allelochemicals that are relatively ineffective against neighbors in natural communities, but highly inhibitory to plants in invaded communities” [Thorpe 2011: 734].

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## Non-native plants reduce abundance, richness, and host specialization in lepidopteran communities, Burghardt et al. 2010

This research evaluates the impact of the invasion of non-native plants in the distribution of lepidopteran (butterfly, skipper, and moth) communities. The authors assert that although the introduction of non-native plants has not resulted in a “global extinction”, they have had a considerable impact on how ecosystems function—they often result in significant bottom-up reductions of energy available in local food webs.

The experiment established four gardens near mature woodlots containing most, if not all, of the native species planted within the treatment. The richness and abundance were then compared for lepidopteran communities found on native versus corresponding non-native congener<sup>4</sup> species of 13 woody plant genera. For example, the genus *Acer* (maple) was selected for this study because the native and non-native maples were widespread in that area. In separate plots, the researchers also compared native plants and unrelated (non-congeneric) non-native plants for lepidopteran richness and abundance.

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<sup>4</sup> Congener: Something of the same kind or category as another; in this case, different species within the same genus, such as Norway maple and red maple.

The study found that lepidopterans suffer from the replacement of native plants by non-natives, especially when those non-natives are unrelated to any native plant species. The authors explain that “insect herbivores adapted to the chemical challenges [toxic plant defenses] of particular native hosts may be able to adopt a novel plant species as a host if its phytochemistry is sufficiently similar to the original hosts” [Burghardt 2010: 10]. Over the two-year study, lepidopteran abundance and richness were depressed both on congener and (unrelated) non-congener non-native plants, but especially on the latter.

The study found that lepidopterans suffer from the replacement of native plants by non-natives, especially when those non-natives are unrelated to any native plant species.

Specialist lepidopteran species, which require specific diet and habitat conditions to survive, fared worse on non-natives than did generalists, which can eat a variety of foods and survive in many different habitats. The authors note, for example, that “geographically novel congeners were acceptable hosts to less than half of the generalists and only one fourth of the specialists that we found on native congeners in 2009” [Burghardt 2010: 11]. Only 7% of specialist species used non-congener non-natives as hosts.

The authors argue that the loss of lepidopteran diversity and abundance due to the displacement of native plant species with non-natives can ripple up the food chain, reducing diversity at higher trophic levels. Reduced diversity leads to lower ecosystem productivity and stability, thus disrupting the whole system.

The authors argue that the loss of lepidopteran diversity and abundance due to the displacement of native plant species with non-natives can ripple up the food chain, reducing diversity at higher trophic levels. Reduced diversity leads to lower ecosystem productivity and stability, thus disrupting the whole system.

Because insect herbivores are near the hub of most terrestrial food webs, comprising essential food stuffs for an incredible diversity of insect predators and parasitoids, spiders, amphibians, lizards, rodents, bats, birds, and even higher predators such as

foxes and bears, it is particularly important to understand changes wrought by non-native plants on this critical taxon [Burghardt 2010: 13].

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## Impact of Native Plants on Bird and Butterfly Biodiversity in Suburban Landscapes, Burghardt, Tallamy & Shriver 2008

In this study, the insect and bird populations of six pairs of suburban yards were measured. Each pair contained one conventionally landscaped yard containing native canopy trees and a mixture of native and non-native shrubs, grasses and understory trees; and one yard with native species only (canopy, understory, shrub and grasses). The level of plant diversity was comparable between each of the pair; only the proportion of native species differed. The authors found that:

Avian abundance, diversity, richness, and biomass (particularly bird species of conservation concern) were all greater on native properties. Native nesting birds that are mostly dependent on insect populations to feed their young were more abundant on native properties. Lepidoptera [butterfly and moth species] abundance and diversity were also higher on native properties, suggesting that food availability might account for the differences detected in the bird communities between native and conventionally landscaped sites [Burghardt 2008: 223].

These results support the authors' hypothesis based on an understanding of the co-evolutionary roots of species interactions.

Theory backed by decades of empirical evidence predicts that up to 90% of all species of insect herbivores can successfully reproduce only on plant lineages with which they have shared an evolutionary history [Burghardt 2008: 220].

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## Native plants improve breeding and foraging habitat for an insectivorous bird, Narango, Tallamy & Marra 2017

This study examined whether non-native plants in residential Washington DC limited the presence of the Carolina chickadee, a local breeding insectivore.

We predicted that areas with more native plants would support more chickadees, and chickadees would forage more often in the most insect-producing native plants [Narango 2017: 43].

The authors had also considered the possibility that non-native plants could promote increases in other food items (e.g. non-native arthropods), keeping overall prey biomass similar between native and non-native plants. What they found, though, affirmed their prediction: native plants produce more caterpillars, which in turn support more chickadees. In fact, the birds avoided foraging in non-native plants, including non-native species of the same tree genera: the chickadees preferred maples native to the eastern US compared to European-origin maples.

*Native plants produce more caterpillars, which in turn support more chickadees.*

Native plants were more likely to host a higher biomass of caterpillars compared to non-native plants, and chickadees strongly preferred to forage in native plants that supported the most caterpillars. In addition, chickadees were less likely to breed in yards as the dominance of non-native plants increased [Narango 2017: 42].

Also unique to our study is that we measured the probability of caterpillar occurrence between congeneric species (e.g. native vs. non-native *Acer* [maple]). This is particularly important considering the popularity and invasive qualities of congeneric species in this region such as *Acer platanoides* and *Quercus acutissima*. Although non-native congeners support more caterpillars in comparison to plants unrelated to any native species, congeners had a 47% (CI: 34%–59%) lower probability of having caterpillars compared to native species [Narango 2017: 47].

The authors state that local insects are adapted to local plants, presumably due to their shared co-evolutionary history.

This occurs in part because herbivorous insects have adapted to circumvent the phytochemical defenses of particular plant lineages, resulting in a radiation of specialized plant-insect associations. During urban conversion, native plants are replaced by non-native species with novel chemical, physical, and phenological features for which native herbivorous arthropods have few physiological or behavioral adaptations [Narango 2017: 42].

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## Do non-native plants contribute to insect declines? Tallamy, Narango & Mitchell 2020

The widespread distribution of plants outside of their native range due to human activity is a significant yet underrecognized cause of global insect decline, according to this article. To illuminate the issue, the authors: “examine the evidence for and against the hypothesis that long term changes in the species composition of plant assemblages have contributed to local and global declines in the abundance and diversity of the insect communities dependent upon those assemblages” [Tallamy 2020: 2].

To be sure, insect conservationists have long noted the importance of habitat containing appropriate native host plants, but the widespread replacement of native host plants with non-native species has yet to penetrate the growing literature on insect declines in any meaningful way [Tallamy 2020: 1].

It is not simply the absence of native plants harms plant-eating insects, however, but also the presence of non-natives. While some insects feed successfully on non-native plants, this is the minority. Most either avoid non-native plants, or do use them and are killed or malnourished by doing so. For example,

Swallowworts (*Vincetoxicum* spp.) are confamilials of milkweeds (*Asclepias* spp.) and have become invasive in parts of the northeastern United States. Similar phytochemistry between swallowworts and milkweeds can lead monarch butterflies (*Danaus plexippus*) and milkweed beetles (*Chrysochus auratus*) to fatally mistake these chemically protected plants as hosts. The degree to which *Vincetoxicum* act as ecological traps for these taxa is likely to become more pronounced as the plants become dominant and displace milkweeds in the landscape [Tallamy 2020: 3].

Species that share a particular environment over hundreds or thousands of years evolve in relation to one another. For plant-eating insects, adapting to certain plants meant developing “traits to detect and tolerate plant defenses over time” [Tallamy 2020: 2]. Most herbivorous insects adapted to only a particular set of plants, specializing in feeding on those plant hosts.

The diet of most insects is constrained to a single plant family in any one habitat or location, with dietary specialization even narrower both in many temperate lineages and hyper-diverse tropical lineages. In fact, diet specialization increases with decreasing latitudes, concurrent with theories of increased plant and animal diversity in the tropics [Tallamy 2020: 2].

When native plants are displaced in the landscape by non-native species, phytophagous [plant-eating] insects typically do not recognize the novel host for feeding or oviposition [egg laying], or may be unable to overcome novel plant defenses. The concurrent loss of native plant hosts and dominance of non-native plants can lead to local extirpation of phytophagous insects and thus to changes in the composition and structure of local food webs [Tallamy 2020: 2].

The most likely successful substitute for a native plant is a non-native plant in the same genus or family.

Non-native congeners [members of the same genus] or confamilials [members of the same family] that are similar in foliar chemistry and nutrition, phenology, and morphology, may occasionally serve as novel hosts for herbivorous insects and support higher diversity and abundance than non-native, non-congeners. However, novel use of congeners may increase larval mortality, extend development or pupation time, reduce biomass, and reduce fitness compared to that of native hosts [Tallamy 2020: 3].

The narrower the native plant diet an insect species has, the less likely to tolerate novel, non-native food sources. However, there are more species of specialist insects than of generalists, meaning a larger proportion of susceptible species. Adaptability to exotic host plants also depends on an insects' feeding habits.

Insects with chewing (mandibulate) mouthparts are typically more susceptible to defensive secondary metabolites contained in leaf vacuoles than are insects with sucking (haustelate) mouthparts that tap into poorly defended xylem or phloem fluids. Thus, sucking insects find novel non-native plants to be acceptable hosts more often than do chewing species [Tallamy 2020: 4].

Considering that there are more than 4.5 times as many mandibulate insect herbivores as haustelate species, there is reason for concern when non-native plants replace native hosts; the largest guild of insect herbivores is also the most vulnerable to non-native plants and the most valuable to insectivores [Tallamy 2020: 5].

“The dispersal and spread of invasive plants has been driven by global trade networks and colonialism” [Tallamy 2020: 6] and, more specifically, from agroforestry, forestry, agriculture, and horticulture.

Although plants have always distributed themselves around the globe, the increased temporal and spatial mobility of humans has resulted in an extraordinary increase in the rate of plant movements and most species' introductions have happened in the last 200 years. Habitat is rapidly being converted from coevolved native ecosystems into novel



assemblages of plants and animals, making the conversion of native plant communities into plant assemblages dominated by non-native species one of the most ubiquitous threats to biodiversity today. The introduction of non-native plants has completely transformed the composition of present-day plant communities in both natural and human-dominated ecosystems around the globe and the magnitude of introductions is staggering. An estimated 13,168 plant species (about 3.9% of global vascular flora) have been introduced and naturalized beyond their native ranges as a result of human activity [Tallamy 2020: 6].

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## Global exchange and accumulation of non-native species, van Kleunen et al. 2015

The ecological, economic, and social damage of human-mediated dispersal of species into new regions, where they possess the ability to naturalize (become self-sustaining their new homeland), is one of the defining features of the Anthropocene Epoch. Globally, human activity has led to the naturalization of nearly 13,168 plant species (equal in size to the native European flora). The results from this research provide a baseline for monitoring global changes in biodiversity while highlighting the immediate action that has to be taken to comprehend and determine the spread of alien species on an international scale.

The ecological, economic, and social damage of human-mediated dispersal of species into new regions, where they possess the ability to naturalize (become self-sustaining their new homeland), is one of the defining features of the Anthropocene Epoch.

At least 3.9% of all currently known vascular plant species have become naturalized outside their natural ranges as a result of human activity. With the continued practice of international traffic and trade and globalization, the likelihood of more and more species being introduced and getting naturalized outside their native range is high.

To assess the accumulation of naturalized species in each continent as well as which continents have been the major donors of alien naturalized plant species globally, the researchers used a novel database, Global Naturalized Alien Flora (GloNAF), in addition to the data on the origin of naturalized species and estimates of the number of native species per continent. They found that when not taking into account the differences in total area, North America has accumulated

the highest number of naturalized species (n=5,958). However, when considering the difference in total area, Australasia (a region comprising Australia, New Zealand, and neighboring islands) was found to have more extra-continental species than North America.

One possible explanation is that Australia's long biogeographical isolation and drying climate have resulted in a native flora that is phylogenetically distinct, but not well-adapted to exploit the novel habitats created by European settlers [van Kleunen 2015: 101].

The major donors of alien species are Europe and temperate Asia, while North America is also a significant donor.

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## Ecological and evolutionary consequences of biotic homogenization, Olden et al. 2004

Anthropogenic environmental change and global dispersal of a wide variety of species outside their native ranges has expanded the range of "cosmopolitan," non-native species and shrunk the range of regional and endemic species. "This replacement of specific native forms by generalist non-natives in space and time has mixed the taxonomic composition of once disparate biotas, an occurrence termed 'biotic homogenization'" [Olden 2004: 18].

The authors explore the effect of this "global erosion of regional distinctiveness" [Olden 2004: 18] at three levels: Genetic homogenization reduces genetic variability within species or among populations of species, while taxonomic homogenization reduces distinctiveness among communities. Functional homogenization refers to a reduction of functional traits within an ecosystem. The identity of species making up a community, along with their respective functional traits, determines "ecosystem functions (such as nutrient retention or energy flow)" [Olden 2004: 20], so that narrowing species compositions risks diminishing ecosystem function.

A decrease in functional diversity might reduce overall community and ecosystem functioning, stability and resistance to environmental change by simply narrowing the available range of species-specific responses. Consider a severe drought that strongly affects a subset of species in a community that has (or lacks) a particular suite of functional traits. Historical communities, with much greater breadth in functional space, should exhibit higher resistance or resilience when compared with homogenized communities [Olden 2004: 20].

Genetic homogenization occurs when two distinct locally adapted populations of the same species interbreed. It also occurs when a single variety (such as captive fish bred in a central

location) are released in many places to replenish dwindling native stocks. While such mixing has the potential to increase species diversity, this outcome is not assured.

Intraspecific hybridization can homogenize the unique characteristics of geographically distinct populations, as well as compromise the fitness of individuals by disrupting local adaptations [Olden 2004: 19].

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## Linking Restoration and Ecological Succession, Walker, Walker & Hobbs (eds) 2007

This book draws lessons from ecological succession theory to inform ecological restoration, stating that: “restoration is fundamentally the management of succession” [Walker 2007: vi]. The latter is the natural process by which plants first colonize “new” land (post landslide, glacial retreat or volcanic eruption, for example) or degraded land, and over time develop into mature ecosystems through a series of changing plant communities. Ecological restoration is a human-led initiative to restore functioning ecosystems, or at least vegetation, on land degraded through human activity. The ultimate goal of restoration is to “establish a self-sufficient ecosystem that requires minimal or no continuing human inputs in order to provide a continuing supply of goods and services” [Hobbs 2007: 177].

Effective ecosystem restoration requires ecological knowledge. Likewise, the outcomes of such projects demonstrate our comprehension, or lack thereof, of ecological concepts: “Restoration is the acid test of our ability to understand not only how ecosystems are assembled and held together but also how they change over time” [Walker 2007: vi]. The authors contend, however, that restoration projects are more often guided by engineering, horticulture, and agronomy than by ecology. Aiming to clarify the ways in which ecological succession theory can and should inform restoration, this book poses the question: “What is the minimum amount of biophysical and successional information needed to restore a specific landscape or area” [Walker 2007b: 2]?

Succession comprises many ecological processes that underpin all ecological restoration and ecological restoration is a manipulation of these processes to achieve its goals. This means it is essential to understand how succession operates, and when and how to manipulate it [Prach 2007: 121].

Restoration can explicitly embrace a hands-off approach, where land is simply left to repair itself through natural ecological succession. On the other hand, understanding the successional process allows manipulation of various stages to speed up the process. For example, in the first stage of primary succession “winds deposit dust, pollen, seeds, and insects crucial to reducing

infertility” [del Moral 2007: 23], on bare, inhospitable ground. Tough pioneer plants are able to establish then create shade, trap sediment, and deposit organic matter when they die, creating slightly better conditions for the next wave of colonizing plants. To mimic this first stage of site “amelioration”, the site can be physically manipulated by reshaping the ground for improved drainage or adding organic matter, for example.

Biological manipulation involves sowing or planting local/native varieties of later successional species that may not be otherwise present in the area due to human transformation of the broader landscape. While earlier successional species tend to have small, easily transported seeds, the later successional species (such as large canopy trees) that are often the target of restoration efforts often have large, less mobile seeds. Thus, if those plants are not present in the immediate environment as seed stock, they may never establish in the restored site without human assistance.

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## Near-Natural Silviculture: Sustainable Approach for Urban Re-naturalization Assessment Based on 10 Years Recovering Dynamics and Eco-Benefits in Shanghai, Guo et. al 2015

As one of China’s major cities, Shanghai’s natural sub-ecosystem<sup>5</sup> has suffered drastic damage due to human activities and urbanization. Although urban re-naturalization has gained attention from city leaders, urban tree planting has largely consisted of two methods with limited ecological potential. One favors fast-growing monocultures to produce timber products and other benefits, while the other approach is to plant non-native species for decorative purposes. The authors believe the restoration progress of the natural sub-ecosystem could be further improved by adopting the “near-natural” method based on the concepts of potential natural vegetation<sup>6</sup> and ecological succession.

The near-natural forest uses all native species and aims to create a complex structure with high biodiversity, high biomass and multi-layer canopies. It was adopted successfully in many countries, but the authors thought long-term studies of these forests were lacking. Therefore, they conducted a 10-year study at a near-natural forest established in 2000 in Pudong New Area of Shanghai to investigate the effectiveness of the forest in providing ecological benefits.

Results showed that the near-natural forest had higher sustainability value than artificial (“even-aged, managed”) forest in Shanghai based on its ecological and economic benefits. The high tree density and multiple vertical structures of the forest improved the air quality and soil

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<sup>5</sup> “Sub-ecosystem” here refers to the interdependent social, economic, and natural systems operating within an urban ecosystem.

<sup>6</sup> The vegetation that would be growing in the absence of human intervention.

fertility and decreased the concentrations of air bacteria and dust. It also had a much lower planting and maintenance cost than artificial traditional methods. Although the near-natural forest could not transcend the benefits of the natural forest, the study successfully proved its important role in urban re-naturalization by bridging the difference between the artificial and natural forests.

Results showed that the near-natural forest had higher sustainability value than artificial (“even-aged, managed”) forest in Shanghai based on its ecological and economic benefits

Over the course of the study, authors discovered a potential limitation of the approach, at least in its application in Shanghai. They observed high evergreen seedlings mortality, attributable to over-exposure to sunlight. Therefore, in subsequent plantings in 2003 and 2004, the authors modified the approach to optimize it to local conditions:

The key to the new method is to create a mixed deciduous-evergreen community by simultaneously planting shade-tolerant evergreen broad-leaved species and light-demanding deciduous broad-leaved species, but using smaller individuals for the former and larger individuals for the latter to form a multilayer vegetation structure. The shade-tolerant evergreen species benefit from the rapid growth of the light-demanding deciduous species, which offer shade and nutrients in the form of litter layer-based fertilizer, improving the soil for the evergreen species [Guo 2015: 5].

Overall, they suggest that the near-natural forest is a very sustainable method to be applied in Shanghai.

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## Tree planting is not a simple science, Holl & Brancalion 2020

Well-planned tree-planting projects are an important component of global efforts to improve ecological and human well-being. But tree planting becomes problematic when it is promoted as a simple, silver bullet solution and overshadows other actions that have greater potential for addressing the drivers of specific environmental problems, such as taking bold and rapid steps to reduce deforestation and greenhouse gas emissions [Holl 2020: 580].

Some of the pitfalls to avoid in tree planting initiatives, according to the authors, include:

- Use of non-native species, which does not result in a true forest and can result in ground water depletion in arid environments.
- Planting trees in historic grasslands and savannas, harming those native ecosystems and species.
- Abandoning trees after they are planted, which can result in high mortality due to insufficient water for developing saplings, being shaded out by faster growing herbaceous plants, grazing, or being re-cleared.
- Planting trees in agricultural land, which risks pushing crop production into native forest land, which is then deforested.

The authors insist that reforestation takes careful planning, stakeholder engagement, clear goal-setting, and long-term monitoring and adaptive management of planted tree stands to ensure their survival. Above all, existing mature, native forests should be preserved.

The authors insist that reforestation takes careful planning, stakeholder engagement, clear goal-setting, and long-term monitoring and adaptive management of planted tree stands to ensure their survival. Above all, existing mature, native forests should be preserved.

The first priority to increase the overall number of trees on the planet must be to reduce the current rapid rate of forest clearing and degradation in many areas of the world. The immediate response of the G7 nations to the 2019 Amazon fires was to offer funding to reforest these areas, rather than to address the core issues of enforcing laws, protecting lands of indigenous people, and providing incentives to landowners to maintain forest cover. The simplistic assumption that tree planting can immediately compensate for clearing intact forest is not uncommon. Nonetheless, a large body of literature shows that even the best-planned restoration projects rarely fully recover the biodiversity of intact forest, owing to a lack of sources of forest-dependent flora and fauna in deforested landscapes, as well as degraded abiotic conditions resulting from anthropogenic activities [Holl 2020: 581].

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# Worthy miscellany

Symbiosis: Structure and Functions, Ecological and Evolutionary Role,  
Sélosse 2000

*(La Symbiose : Structures et Fonctions, Rôle Écologique et Évolutif)*

Book review by Ehsan Kayal

What is symbiosis? How is it defined? What does it involve? And how did it come to be? These are some of the questions French Biologist Marc-André Sélosse explores in this book.

It is not simple to define “symbiosis,” which differs between the English and French languages. Sélosse focuses on the narrower French definition, which involves “long-term coexistence of two different organisms throughout their life with reciprocal benefits” [Sélosse 2000: 22]. In English, the term “symbiosis” refers not only to mutualism (reciprocal benefits), but also to parasitism or commensalism (one partner benefit without impacting the other partner). One important aspect of the study of mutualistic symbiosis is exploring reciprocal physiological exchanges that happen between symbionts (organisms involved in symbiosis). Such exchanges are facilitated by morphological changes in one, the other or both partners.

Sélosse offers readers a glimpse of the breadth of symbiotic relationships found in nature. For example, there are bacteria living inside worms around deep-sea vents in the ocean that use chemical energy seeping from the earth to create organic compounds that nourish their worm hosts. The author also highlights the case of lichen, which appears to be a single species, but is actually formed by a symbiosis between fungi and algae. Sélosse focuses especially on symbiosis involving mycorrhiza, which are the “symbiotic organs formed by a root and a fungus” [Sélosse 2000: 140], and on root nodules, the “symbiotic organs of legumes, often around roots, containing bacteria of the Rhizobiaceae family responsible for fixing nitrogen” [Sélosse 2000: 140].

Leguminous plant hosts provide their Rhizobia symbionts with carbon, while protecting these bacteria from harmful oxygen, in exchange for nitrogen. The efficiency of these symbiosis is such that the “rhizobiaceae-containing root nodules fix as much atmospheric nitrogen per year as the fertilizer industry” [Sélosse 2000: 54]. Similarly, plants with mycorrhizal associations supply their symbionts with carbon in exchange for water, phosphate and other nutrients furnished by the fungi. Studies have linked “an increasing diversity of mycorrhiza” with “increasing diversity of plants” [Sélosse 2000: 67].

Symbiosis can short-circuit the mineralization-immobilization cycle (conversion of inorganic compounds to organic compounds by micro-organisms or plants) by bringing together partners

that thrive on each other's by-products. This results in a "concentration of resources" [Sélosse 2000: 49] that allows organisms to conquer new ecological niches as exemplified by lichen and corals, but also playing a key role in the evolution of the soil that promotes vegetation successions [Sélosse 2000: 60]. For example, lichen is the first to colonize bare rock, where it produces citric acid and holds water, slowing altering the rock in the early stage of soil creation. Rhizobial symbioses then pitch in by fixing nitrogen, otherwise absent in a rocky substrate.

The book also flips some of the common understandings of organismal biology. For instance, many herbivores lack digestive enzymes to break down plant material. Rather, they feed on the population of microorganisms of their rumen, or the "pocket situated upstream of the stomach in ruminants that harbors a symbiotic microflora" [Sélosse 2000: 141]). The rumen is a large organ, whose volume can represent "8 to 15% of total body weight" [Sélosse 2000: 32]. That makes those microorganisms (protists, fungi and bacteria) the "true" herbivores, while the ruminants are secondary consumers.

The older traces of symbiosis predate the origin of the eukaryotic cell (cell with a nucleus enclosed within a nuclear envelope), where the mitochondrion (the energy-producing organelle of the cell) are descendants of a likely unique endosymbiotic event occurring some two billion years ago. In that event, an anaerobic archaean (third kingdom of life composed of unicellular organisms lacking a nucleus; the other two kingdoms are eukaryotes and bacteria) captured a facultative aerobic type of bacteria, which became mitochondria. Similarly, the acquisition by some eukaryotic cells of a chloroplast originating from cyanobacteria gave way to photosynthetic plants.

In some sense, "no organism lives alone, and each carries a symbiotic cortege without which one cannot understand neither the physiology nor the ecological success of the organism" [Sélosse 2000: 134].

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## Biophilia: the human bond with other species, Wilson 1984

*A book review by Rachel West*

As I read the first chapter, Wilson brought me far into the forests of the Amazon Basin to encounter canopy-dwelling birds and frogs found nowhere else on Earth; he showed me the life cycle of a tiny moth so specialized that the adult lives only in the fur of the 3-toed sloth, and held up fistfuls of forest soil teeming with tiny life to demonstrate that "the woods were a biological maelstrom of which only the surface could be scanned by the naked eye."

With his astonishing eye for detail and his fluid prose, he fascinated me, he drew me in, he fed my curiosity...and then he reminded me: "Eliminate just one kind of tree out of hundreds in such



a forest, and some of its pollinators, leaf eaters, and wood borers will disappear with it, then various of their parasites and key predators, and perhaps a species of bat or bird that depends on its fruit... and when will the reverberations end?”

Throughout this book, Wilson brought me close to the beauty of living systems across the world. He taught me enough about them to make me curious, and then to make me care; and then, when he showed me how easily that entire system could be disrupted, he had my undivided attention. This kind of understanding and connection, Wilson argues—this human bond with other species—is an essential ingredient in motivating us to change our behaviors in order to slow the rate at which “the wildernesses of the world [are shriveling] into timber leases and threatened nature reserves.”

One of the challenges with building these connections and then acting upon them, Wilson suggests, is that we are programmed to operate in physiological, not ecological, time; that our minds “travel back and forth across hours, days, or at most a hundred years. The forests may all be cut, radiation slowly rise, and winters grow steadily colder, but if the effects are unlikely to become decisive for a few generations, very few people will be stirred to revolt.” But in recent times, our impact on ecosystems has been compressing “ecological time” to align with “physiological time,” and the results are becoming visible in the span of single generations; the massive Florida manatee die-off due to the destruction of their seagrass pastures is but one starkly visible example of the reverberation felt by the loss of a single species from an ecosystem.

In the chapter “The Conservation Ethic”, near the end of the book, Wilson explores the relationship between the human drive to perpetually expand—and the related desire for personal freedom, at least in Western cultures—and the necessity for conscious stewardship of the environment to ensure our ultimate survival—not only our physical survival, but our spiritual survival. He writes “The only way to make a conservation ethic work is to ground it in ultimately selfish reasoning.” In other words, it is likely that wild species and places will be best understood and protected with respect to their perceived value, such as the vast array of plant compounds that have shown promise as anti-cancer compounds, or, as has been increasingly recognized in recent years, for the ability of wild places to improve the emotional and spiritual well-being of the people who spend time there.

This book is even more relevant now than it was when it was released in 1984, and thus has the potential to reach a broader audience today. More people may be ready to hear some of the truths held in this book because now, more than ever before, the human race is seeing, and feeling, the long-term effects of the way we have treated the planet.

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## An Okanagan Worldview of Society, Armstrong 2020

Jeannette Christine Armstrong is a Canadian author, educator, artist, and activist, who wrote this article about the traditional decision-making process in Okanagan, called “*enowkinwixw*,” which demonstrates a great practice of biophilia.

Okanagan, the Penticton Indian reservation in Canada where the author was born and raised, has a very fragile ecosystem. However, the author discovered that this community treats the land differently compared to other communities. They treasure natural resources and believe that the land is the people. They bear in mind that everything they have come from the land and that their every decision has a possibility to destroy the land. Therefore, they not only pay attention to the relationship among human beings but also how human relationships affect the land.

When the author was searching to understand how the community developed this form of interaction, the traditional decision-making process *enowkinwixw* caught her attention. The model is accomplished with four criteria:

This word demands four things from us: 1) that we solicit the most opposing views; 2) that we seek to understand those views using non-adversarial protocols; 3) that we each agree to be willing to make adjustments in our own interests to accommodate diverse needs expressed; and 4) that we collaboratively commit to support the outcomes [Armstrong 2020: 166].

Through this process, the minority voice is valued as it could point out the most important things that have been ignored. It is how the Okanagan could bring the minority into balance with the majority, minimize the conflicts and bring everyone to work together.

If we begin to think about the minority, about why there is a minority, why there is poverty, then we should be able to find creative ways to meet the needs of the minorities [Armstrong 2020 : 167].

The author believes that this is why the Okanagan community could add preservation of land into the decision-making process. By adopting *enowkinwixw*, the community respects every opinion from every perspective. Therefore, they train people to speak for different components that make up their existence, such as the children, the elders, and the water; while the author herself was appointed as a land speaker, who thinks and speaks for the land. In this way, the people realize that material things are not as important as the power of the land, which is what sustains them.

This mindset is meant to help the world achieve a harmonic relationship between people and nature.

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