# Sustainable pollinator habitats

**Jarrod Fowler**
Stockbridge School of Agriculture
University of Massachusetts Amherst
USDA NRCS TSP-13-9558
j@jarrodfowler.com

## Introduction

Sustainable and sustainably developed pollinator habitats are defined following descriptions of sustainability, sustainable development, unsustainability, and pollinator habitats. Definitions are provided for transdisciplinary management and planning that question assumptions and gaps of extant pollinator habitat knowledge to further intergenerational agro-ecological equity through viable econo-environmental productivity, bearable socio-environmental justice, and equitable socio-economic growth.

## What is sustainability?

Sustainability is the capacity for systems to persist with resilience. Systems are defined by contextually dynamic nonlinear interactions amongst diverse and meaningfully organized components (Laszlo 1996; Skyttner 2005). System inputs, loops, and outputs adapt and evolve over spatiotemporal scales or resolutions and across or within disciplines or system types. Interconnected micro-, meso-, and macro- patterns and processes lead to complex adaptive system behavior, including emergence, self-organization, and self-similarity. Complex adaptive system behaviors such as cooperation, reproduction, and spatiotemporal organization enable resiliency after perturbation.

Sustainability is associated with 'sustainable development', which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Lebel, Kane, *et al.* 1989) Sustainable development is a precautionary and skeptical organizing principle that deploys transdisciplinary inquiry to foster growth and development, manage economic, environmental, and social standards, and reduce environmental damage and finite resource depletion (De Vries 2012; Nicolescu *et al.* 2008). For example, sustainable agriculture is an organizing principle that provides materials and methods for intergenerational ecological equity through viable econo-environmental productivity, bearable socio-environmental justice, and equitable socio-economic growth (Gold 2009; Wojtjkowsji 2004).

Sustainable development concepts can be illustrated according to two diagrams from ecological and environmental economics (Adams 2006; Cato 2009; Costanza *et al.* 1997). Each model charts the three non-exclusive pillars of sustainable development: economics, environment, and society. The first diagram visualizes 'strong sustainability' by nesting economy within society, which is nested within environment. Such hierarchical organization proposes both limits to growth and irreplaceable ecological functions and resources. The second diagram visualizes 'weak sustainability' by converging spheres of economy, environment, and society. Such relative organization proposes equitable, responsible, and viable substitution of human with natural capital, but fails to recognize ecological constraints.

## What is unsustainability?

Unsustainability is the capacity for systems to damp with damage and depletion. Unsustainable systems fragment, obscure, and substitute interactions amongst disorganized components through specialization for reflexive and short-term efficiency, growth, or productivity. Self-reinforcement by accelerated and ignorant consumption, opposition, and progression results in unviable econo-environmental efficiency, unbearable socio-environmental justice, and inequitable socio-economic growth. Such unsustainable results lead to equilibrium or maximum disorder wherein system adaptation and change cease. Contemporaneously dominant cultures of unsustainable development are associated with idealistic assumptions and optimistic self-reinforcement through technological innovation (Kagan 2011). Idealistic unsustainable development atomizes, disjoins, and reduces disciplines as aloof and autonomous activities. Once detached, disciplines are subsumed within romantic and technological orders that estrange nature from culture.

Unsustainable development affects declines in pollinator populations. Pollinator declines are synergistically affected by anthropogenic habitat degradation, fragmentation, and obliteration, geo-temporal range and phenology modification, pathogen infection, and pesticide pollution (Kremen *et al.* 2007; United States National Research Council 2007). Such perturbations negatively impact habitat, provisioning, regulating, and cultural ecosystem services provided and supported by pollinators. For example, worldwide pollination services are directly or indirectly responsible for reproduction of 85% of wild plants and production of 35% of human food, which is currently valued at approximately $150 billion per year. Thus, hierarchical production of ecosystem services and associated material and non-material benefits and products are threatened by unsustainable development.

**What are pollinator habitats?**
Pollinator declines are combated with pollinator habitats, which are site-specific conservation practices that that address the creation, enhancement, or restoration of abundant, diverse, and nutritional floral resources, nesting opportunities for cavity- and ground-nesting pollinators, and/or refugia, which support managed and/or unmanaged pollinators, thus enriching overall biodiversity and ecosystem services (United States Department of Agriculture Natural Resources Conservation Service 2012; Wratten *et al.* 2012). Pollinator habitats are supported by policy initiatives, meet client and government criteria and objectives, and comply with laws, regulations, and requirements. Pollinator habitat objectives include:

- Upgrading pollination service by unmanaged pollinators
- Upgrading pollination service by managed pollinators
- Sheltering pollinators from ecological perturbations
- Promoting abundance and diversity of pollinator host-plants
- Promoting abundance and diversity of conservation biological pest control insects
- Preventing or reducing pesticide risks to beneficial insects
- Preventing or reducing erosion and nutrient runoff
- Maintaining or improving soil and water quality
- Maintaining or improving habitat for non-pollinating wildlife
- Improving agro-ecological or horticultural cost-efficiency
- Informing ecological awareness, knowledge, and conservation
- Beautifying environments for recreation and tourism

Present site conditions such as farmscape or gardenscape and landscape features, foraging and nesting habitats, and land use practices are analyzed and assessed to accurately design pollinator habitats that meet future goals (Xerces Society 2014). Future goals may include providing continuous bloom, promoting large and undisturbed areas with host-plant and nesting opportunities, lessening needs for pesticides, and monitoring bloom and insect activity. For example, conservation buffer, cover crop, field border, and hedgerow plantings composed of annual, biennial, and perennial forbs, grasses, shrubs, and trees are agro-ecological or horticultural conservation practices for pollinator habitat creation, enhancement, or restoration. Such conservation practices select and propagate native or naturalized pollen, nectar, oil, or resin producing angiosperms with known pollinator associations in well-prepared sites with low weed pressure. Propagated habitats are subsequently maintained with short-term methods to reduce weeds and supplement rainfall and long-term methods to mimic “natural” disturbances that maintain early-successional characteristics.

**What are sustainable pollinator habitats?**
Sustainable pollinator habitats are systems that persist with resilience. Sustainable pollinator habitat systems are dynamic networks of interactions amongst diverse yet interdependent abiotic and biotic components that form a complex and integrated whole. Abiotic components comprise air, humidity, light, soil, temperature, and water, which are influenced by altitude, climate, latitude, organisms, parent material, and terrain. Abiotic components interact with biotic components such as immigrating and emigrating producers, consumers, and decomposers, and endogenous/exogenous disturbance regimes such as fire, flood, herbivore, and wind-throw, which all feedback, synergize, or vary over spatiotemporal scales or resolutions and across or within system types. For instance, interconnected hierarchical scales of ecological patterns and processes nested within biogeochemical cycles lead to evolution, food webs, and resource partitioning, which in turn promote structural and functional behaviors that enable trans-system resiliency after disturbance (Gunderson, Allen, and Holling 2009). Explicitly, nitrifying and nitrogen fixing bacteria enable plants to assimilate nitrogen, which is a key constituent of pollen proteins, which

drive reproduction of plants and pollinators, which further drive reproduction of plants, herbivores, and predators, which comprise diverse communities, which enhance resiliency.

Sustainably developed pollinator habitat concepts may be visualized by locating pollinator habitat objectives within the diagrammatic space of 'strong' and 'weak' sustainable development models. 'Strong' sustainably developed pollinator habitats are managed and planned within ecological constraints and with concern for ecosystem drivers and irreplaceable environmental structures and functions. For example, 'strong' sustainably developed pollinator habitats are comprised of ecoregional native species and recognize that unmanaged pollinator functions cannot be duplicated by managed pollinator functions (Garibaldi *et al.* 2013). 'Strong' sustainably developed pollinator habitats can be propagated-without-propagation according to four 'Do Nothing Farming' principles (Fukuoka 1978):

1. No plowing or turning of the soil
2. No chemical fertilizers or prepared compost
3. No weeding by tillage or herbicides
4. No dependence on chemical pesticides

'Do nothing' pollinator habitats ethically propagate site-specific native plant ecotypes with no-till, no-amendment, and no-spray methods such as cover cropping, carefully timed seeding, sheet mulching, and supporting biodiversity. Through radically local and low-intermediate disturbance site preparation and maintenance with associated materials and methods, unsustainable system inputs and perturbations are suspended and outputs and resilience are supported.

'Weak' sustainably developed pollinator habitats are managed and planned with natural capital substitution, which fails to recognize ecological constraints. For instance, 'weak' sustainably developed pollinator habitats may prepare or treat sites with non-local or synthetic amendments or herbicides or substitute ecoregional native species for adventive or naturalized species to increase financial profits. Thereby, direct positive correlations of pollinator habitat and increased crop yield are required by 'weak' sustainably developed pollinator habitat initiatives to show anthropocentric short- and long-term benefits and savings, which drive adoption of conservation practices by clients (Garibaldi *et al.* 2014). Overall, 'weak' sustainably developed pollinator habitats risk unviable econo-environmental efficiency, unbearable socio-environmental justice, and inequitable socio-economic growth and thus hazard unsustainability.

Further, sustainably developed pollinator habitats are systems designed with scenario thinking, complex systems thinking, and transdisciplinarity to meet present economic, environmental, and social needs without compromising abilities to meet future needs. Complex habitats are designed with attention paid to spatiotemporal site conditions and are comprised of numerous chaotically organized and dynamically interacting components that support abundance and diversity of pollinator networks. For example, fine to coarse spatiotemporal landscape patterns and processes with patch, edge, and matrix dynamics are analyzed to design dynamic and highly connective habitats of abundant and diverse native or naturalized forbs, shrubs, and trees (Beck 2013; Mollison 1988). Communities of native plant ecotypes are selected relative to interdependent factors, including climatic and micro-climatic hardiness, competition, ecological niche, ecoregional adaptation, life-history strategy, local presence and reproducibility, plant-pollinator phenology, plant-pollinator dispersal or foraging ability or range, pollinator preference, and varied size or age structure. Maintained according to organismal needs and site-specific disturbance regimes, such dynamic communities may appear ephemeral at patch scales, but are in stability at landscape scales.

Future human and non-human needs are met consistent with scenarios produced according to frameworks of assumptions and drivers. Scenarios skeptically simulate future outcomes for precautionary management and planning practices. For example, feasibility of regional crop and non-crop pollination security for economy, environment, and society during the next decade may be narrated with varying levels of uncertain environmental perturbations to forecast adaptive management and planning strategies. Adaptive management of pollinator habitats informed by scenario thinking can be actively or passively performed to accomplish economic, environmental, and social sustainability, while gaining knowledge of pollinator habitat systems. Thus, transdisciplinary teams of inquiry-driven artists, agriculturists, philosophers, politicians, and scientists collaboratively question assumptions and gaps of extant pollinator habitat knowledge to further intergenerational agro-ecological equity through viable econo-environmental productivity, bearable socio-environmental justice, and equitable socio-economic growth.

## Conclusion

To reiterate, sustainable pollinator habitats are dynamic systems that persist with resilience. Sustainably developed pollinator habitats are transdisciplinary management and planning praxes that proceed according to precautionary and skeptical organizing principles, which recognize constraints to development, embody economic, environmental, and social standards though actions and decisions, and prevent or repair environmental damage and finite resource depletion. Further inquiry is required to strengthen pollinator habitat praxis for overall intergenerational equity.

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