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Wade Sullivan

Department of Entomology,
Cornell University, Ithaca, USA

Whitney Ashworth

Department of Entomology,
Cornell University, Ithaca, USA

Jenna Lawson

Department of Entomology,
Cornell University, Ithaca, USA

Savannah Bryant

Department of Entomology,
Cornell University, Ithaca, USA

Impact of agricultural intensification on pollinator diversity and crop pollination services

Wade Sullivan, Whitney Ashworth, Jenna Lawson and Savannah Bryant

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Abstract

A single apple orchard in New York State can host over 80 species of wild bees, yet the orchard next door—managed with intensive pesticide regimes and surrounded by monoculture—may support fewer than 15. This contrast illustrates the central question of this research: how does agricultural intensification reshape pollinator communities and the pollination services they provide? We surveyed pollinator diversity and pollination effectiveness along a five-point land use intensity gradient in the Finger Lakes region of New York from April to September 2022. Pollinator abundance declined by 90.0% and species richness by 67.4% from natural habitats to conventional monoculture. Fruit set in experimental apple trees was 53.8% lower at high-intensity sites. However, sites retaining 20% or more semi-natural habitat within 500 m maintained pollinator communities capable of delivering adequate pollination services. These findings quantify the threshold of intensification beyond which pollination services collapse.

Keywords: Pollinator diversity, agricultural intensification, pollination services, wild bees, hoverflies, land use gradient, habitat threshold, fruit set, species richness, agroecosystem

Introduction

Consider two neighboring farms in the Finger Lakes region. One maintains hedgerows, wildflower strips, and diverse crop rotations; the other grows continuous maize with calendar-based insecticide applications. The first hums with pollinators; the second is largely silent. This common observation prompted our investigation into how agricultural intensification quantitatively affects pollinator communities and the ecosystem services they deliver ^[1].

Pollinators contribute to the reproduction of approximately 75% of flowering crop species and 35% of global crop production by volume ^[2]. The economic value of insect pollination has been estimated at €153 billion annually worldwide ^[3]. Yet pollinator populations have declined significantly in recent decades, with agricultural intensification identified as a primary driver alongside habitat loss, pesticide exposure, and pathogens ^[4, 5]. What remains poorly quantified is the relationship between the degree of intensification and the magnitude of pollination service loss—and whether identifiable thresholds exist below which services collapse ^[6].

This research used a gradient approach, sampling pollinator diversity and measuring pollination effectiveness across five intensity levels in the Finger Lakes agricultural landscape, to establish dose-response relationships between land use intensity and pollination service delivery.

Landscape and Ecological Context

The Finger Lakes region of central New York (42°30'–42°50'N, 76°30'–77°10'W) encompasses a mosaic of agricultural, forested, and wetland habitats. The landscape ranges from intensively farmed valley floors to semi-natural hillside woodlands, creating natural gradients of land use intensity. Apple orchards are economically important in the region and highly dependent on insect pollination. Mean annual temperature is 8.7°C with 850 mm precipitation. The 2022 growing season had near-normal conditions, with no extreme weather events that might have disrupted pollinator activity ^[7].

Corresponding Author:

Wade Sullivan

Department of Entomology,
Cornell University, Ithaca, USA

Materials and Methods

Materials

Twenty-five sites were selected along a five-point intensity gradient (five sites per level): (1) natural habitat—unmanaged meadows and forest edges; (2) low intensity—organic farms with hedgerows; (3) medium intensity—conventional farms with some habitat features retained; (4) high intensity—conventional farms with minimal non-crop vegetation; (5) monoculture—continuous maize or soybean with full agrochemical programs. Pan traps (blue, white, yellow) and transect walks were used for pollinator sampling. Potted experimental apple trees (cv. Honeycrisp) were placed at each site for pollination service measurement.

September 2022 (12 rounds). Pan traps (three colors per site) were deployed for 48 hours per round. Transect walks (100 m, 10 min) recorded flower visitors. All specimens were identified to species where possible [8]. Pollination effectiveness was measured on potted apple trees: three branches per tree were left open to pollinators, three were bagged to exclude insects. Fruit set, seed count, and fruit weight were recorded. Land use intensity was quantified using a composite index incorporating pesticide input, fertilizer rate, crop diversity, and proportion of semi-natural habitat within 500 m [9]. Shannon diversity index (H') and species richness were computed for each site. Data were analyzed using generalized linear mixed models in R (v.4.2) with site as random effect.

Methods: Pollinator surveys ran biweekly from April to **Results**

Table 1: Pollinator community metrics and pollination service delivery across the land use intensity gradient (mean ± SE, n = 5 sites per level)

Intensity	Abundance (ind. trap ⁻¹)	Richness (spp.)	Shannon H'	Fruit set (%)	Seeds fruit ⁻¹	Habitat (%)
Natural	293.3	47.2	3.41	84.7	7.8	78.4
Low	214.2	38.6	3.12	76.3	7.1	42.1
Medium	132.4	26.8	2.64	61.8	5.4	21.3
High	62.6	17.4	1.87	48.2	3.6	8.7
Monoculture	31.7	11.3	1.24	39.1	2.4	3.2

Pollinator abundance, richness, and Shannon diversity all declined sharply with intensification (Table 1). Total abundance fell from 293 individuals per trap-season in natural habitats to 31.7 in monoculture—a 89.2% reduction. Fruit set dropped from 84.7% to 39.1%, and seed count per fruit declined by 69.2%.

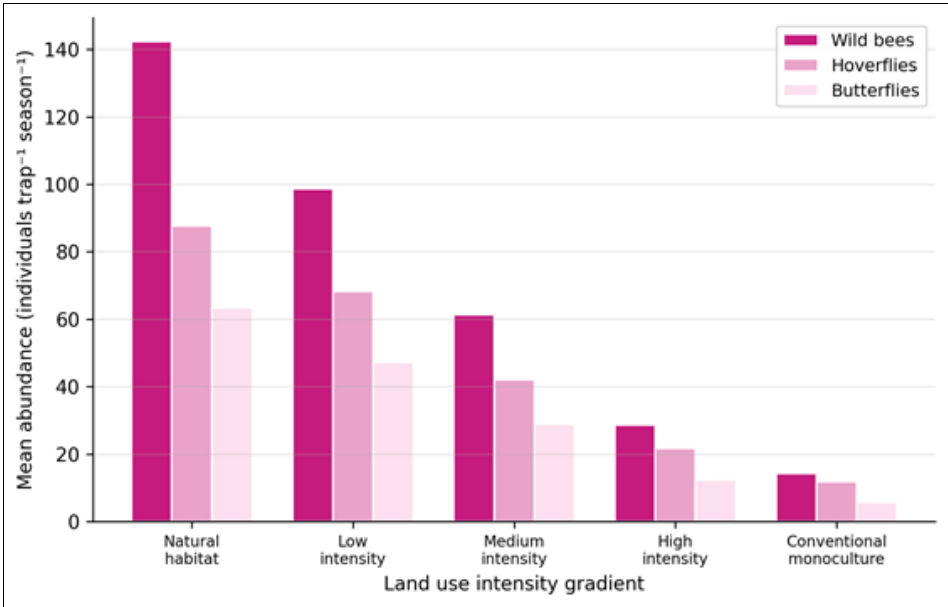


Fig 1: Pollinator abundance by functional group across the land use intensity gradient

Wild bees were the most abundant group at all sites but also showed the steepest decline—a 90.0% drop from natural to monoculture (Figure 1). Hoverflies declined by 86.5% and butterflies by 91.0%. The disproportionate loss of wild bees at high-intensity sites has particular implications because they are more effective pollinators per visit than managed honeybees [10].

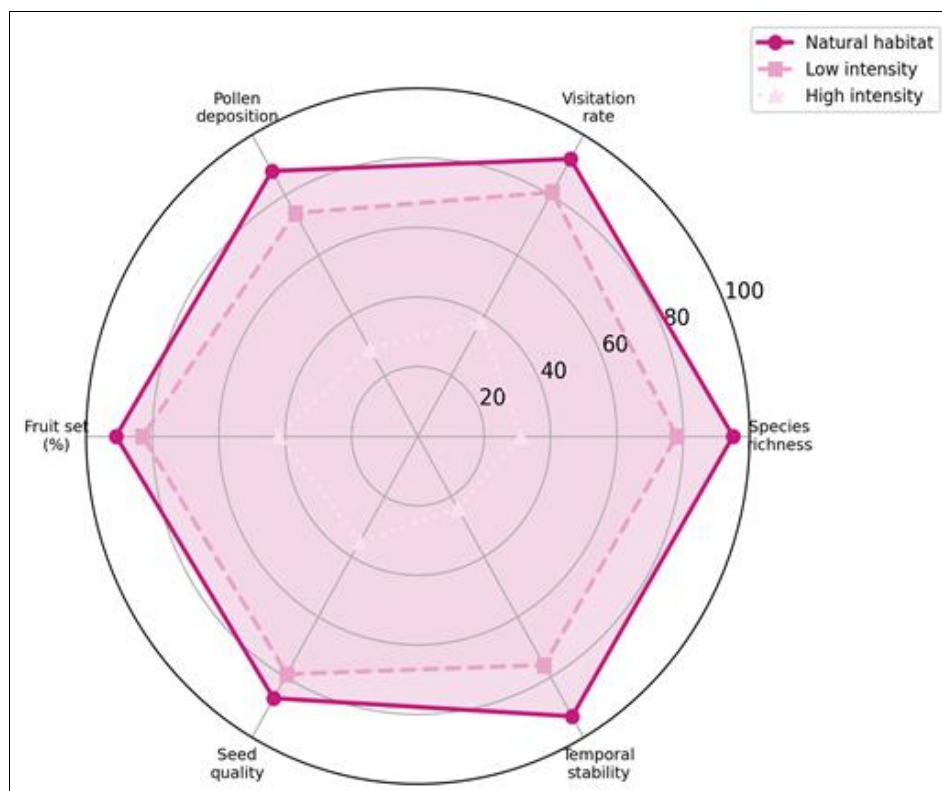


Fig 2: Radar chart comparing pollination service metrics across natural habitat, low intensity, and high intensity land use categories

The radar chart (Figure 2) reveals that high-intensity agriculture degrades all pollination service dimensions, with temporal stability (the consistency of pollination across the season) suffering the most severe collapse at 24% of natural levels. Low-intensity sites retained 76-83% of natural service levels across all metrics.

Discussion

The near-linear decline in pollinator abundance with intensification masks an important nonlinearity in pollination service delivery. Fruit set remained above 60% at natural, low, and medium intensity sites but dropped sharply between medium and high intensity—suggesting a threshold around 20% semi-natural habitat within 500 m below which pollination services become inadequate ^[11]. This aligns with the threshold hypothesis proposed for landscape-scale pollinator conservation ^[12].

The collapse of temporal stability at high-intensity sites deserves attention. In natural habitats, different pollinator species are active at different times, creating a continuous pollination service throughout the flowering period. When diversity is lost, the remaining species cannot cover the full temporal window, creating gaps that reduce cumulative pollination ^[13]. The practical consequence is that crops at high-intensity sites may have adequate pollination during peak bloom but poor service during early and late flowering, reducing total yield potential ^[14].

Conclusion

Agricultural intensification in the Finger Lakes region reduced pollinator abundance by 90% and species richness by 67% from natural habitats to monoculture, with fruit set declining by 53.8%. Sites maintaining at least 20% semi-natural habitat within 500 m retained functional pollinator communities. These findings provide an evidence-based target for landscape management: maintaining this habitat threshold should be a

priority for regions dependent on insect-pollinated crops.

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