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To Learn with Insects, Communities and Land: Ecological Knowledge in Urban Gardens

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TO LEARN WITH INSECTS, COMMUNITIES AND LAND: ECOLOGICAL KNOWLEDGE IN URBAN GARDENS

A dissertation submitted in partial satisfaction
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ENVIRONMENTAL STUDIES

by

Edith M. Gonzales

September 2024

The Dissertation of Edith M. Gonzales is approved:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

TO LEARN WITH INSECTS, COMMUNITIES, AND LAND: ECOLOGICAL KNOWLEDGE IN URBAN GARDENS

Edith M. Gonzales

Ecological knowledge emerges from different ways of knowing in urban gardens. Recognizing and identifying ways of amplifying dialogue across epistemologies in agroecology research is essential to address interrelated and complex challenges in the food system and agriculture. In my dissertation, I think across epistemologies with different forms and expressions of ecological knowledge. First, I consider the type of ecological knowledge that emerges from the scientific study of insect communities. I measure environmental features at the local (garden-based) and landscape (land cover surrounding urban gardens) scales to describe how insect and spider abundance and richness are associated with *Cucurbita pepo* (Chapter 1). Second, I reflect on how I came to learn about ecological knowledge held by Latinx and Indigenous Latinx urban gardeners (Chapter 2). Third, I analyze survey data collected from gardeners to consider how knowledge of insects is associated with gardeners' learning experience and background (Chapter 3). Urban gardens support a diversity of natural enemies, and habitat factors at the garden, and landscape scale differentially shape the abundance and richness of insect groups found on *C. pepo* plants. Gardening as practice creates opportunities for Latinx and Indigenous Latinx community members to recreate or continue expressing their ecological knowledge through food crops, and this practice nourishes a relationship with land. Lastly, gardening as practice develops knowledge of insect and spider functional roles among community gardeners through embodied and program-based learning experiences.

DEDICATION

For abuelita 'tivi, whose commitment to her *terrenito* launched me on this journey.

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Introduction

The study of ecological knowledge from an agroecological approach is plural; it builds from the recognition that knowledge emerges from diverse epistemologies (Altieri 1993). Agroecology approaches consider epistemic plurality in diverse ways through its expressions as science, movement, and practice (Wezel et al. 2009). Ecological knowledge has been studied in relation to people's decisions, preferences, interests, and worldviews to consider how these relations shape land-use patterns, agrobiodiversity, and cultural knowledge (Berkes and Folke 2000). Agroecological scientific approaches build on ecological knowledge held by communities to document and identify processes and relationships that support biodiversity and community well-being (Nazarea 2006). For example, in Mexico, agroecology as a science emerged from learning about agroecology as a practice among campesinos and Indigenous community knowledge systems (Hernández-Xolocotzi 2013). In the United States, agroecology as a science emerged out of an interest to challenge the rise of industrialized agriculture and to identify ecological farming practices to reduce pollution (Gliessman 2018). Thus, agroecology approaches express a vision or internal desire to work with Western knowledge and the changing nature of culture and community-based knowledge (Norgaard 1987).

Agroecology is now a contested approach–it straddles a politics of knowledge in terms of how it is practiced (e.g., scale, concepts, institutionally affiliated or community-led) (Giraldo and Rosset 2017).

Agroecologists face dominant criticisms from agroindustry, funders, and scientific fields (e.g. molecular biology and agronomy) tied to visions of the next green revolution (Patel 2013). The first green revolution that transformed weapons of war into agrochemicals to fight off pests and diseases now takes on other techno-scientific forms (e.g. molecular biology, AI) to delegitimize agroecology as unscientific, polemical, and value-driven (Montenegro de Wit 2016). The critiques "from below" come from community organizations that practice agroecology and shape agroecological movements, they call for formally trained scientists thinking about and working within or from an agroecological approach to distinguish their epistemological departure (Rossett et al. 2022).

Critiques of agroecology point out that agroecology as a science is problematic because a) it suggests that principles drawn from Indigenous knowledge can be generalized without recognition or consciousness about indigenous worldviews, b) it embraces concepts and frameworks rooted in a Western scientific approach of ecology as a science, and 3) it can succumb to capitalist orientations or norms tied to academic institutions (Lugo Perea et al. 2018). Critiques of agroecology call for decentering the agroecosystem and natural resources concept to allow communities and accompanying scholars to lead with relational ontologies (Losada Cubillos et al. 2023).

In this dissertation, I practice agroecology as a self-reflexive and embodied experience. Two dimensions of agroecology- as a science and practice–guide this dissertation. In this way, I see ecological knowledge as emergent and not as a universal expression of constant and already existing knowledge, simply awaiting "discovery." Diverse ways of knowing by formally trained scientists and communities shape relationships and understanding of insects, food crops, and land in urban gardens. While I see and think with the agroecosystem concept, I am aware that this concept emerges within a Western scientific approach that reflects agroecology as a scientific approach to the study of land and agriculture. Yet, I also see and hear urban gardeners speak about Land on earth as an entity with agency and power that reflects Native Science and Indigenous epistemologies (Cajete 2000, pg. 180). Cajete says that Indigenous people are the first ecologists because they studied, observed, and cared for the land because they were always connected to land (Cajete 2000, pg. 207). The agroecosystem concept is only as old as the early 1900s (Francis et al. 2008).

Many scholars perceive reconciliation or integration of knowledge as an ineffective goal, while articulating epistemic diversity is perceived as a more effective and viable approach. The framework of "Diálogo de Saberes" (or DS) is a conceptual framework that emerges from land-based organizing efforts among campesino and accompanying scholars and activists in the global south (Leff 2004, Martínez-Torres and Rosset 2014). The DS framework encourages discussion and exchange of assumptions, power dynamics, and frameworks, and practicing self-awareness of how roles have conditioned us to carry, engage with, or speak about knowledge. At its core, this framework builds on the concept of *dialogo*. Historically, Communities have used this practice to build structures, arrive at common understandings, and shape community-based knowledge. For example, *dialogo* in community spaces can entail a discussion of what and how types of knowledge are helpful, under what governance structure, and how it can provide long-term benefits and for whom (Guillen and C2C 2017). For formally trained scientists, *dialogo* can be helpful to to identify how we situate ourselves with our academic interests, community-based responsibilities, and worldviews and how they are woven into our research work (Nicklay et al. 2023).

While this dissertation aligns itself with the values of the DS framework because it recognizes multiple expressions of ecological knowledge, it is not a community-led research project. Yet, all my learning with gardeners is relational. Through engagement with human communities, insects, and land, I have engaged in a deep and self-reflexive process of learning, unlearning, and relearning how ecological knowledge can be communicated and understood. In practice, this is a multilayered process of self-inquiry that has required me to retrace my own pedagogical experiences, and how it intersects with current role as a student and researcher. As such I have been digesting how my own lived experiences, and my situated perspective in the world. This approach can open future possibilities for discussions about how to change training and pedagogical experiences for those of us training in academic institutions.

Research work for this project occurred in urban garden spaces that are non-commercial and distributed across the central coast of California. These gardens often feature garden beds, potted plants, and direct soil planting. Urban gardens are often managed by local city government and community-based organizations, or exist as home gardens. Gardeners are community members who cultivate a garden featuring food crops, ornamentals, and diverse vegetation.

Urban gardening in the central coast of California is not new or novel; it is a practice rooted in diverse histories and place-based relationships with land. Among diasporic communities it has been one of many ways to support the livelihoods of many migrants and urban dwellers who experience hemispheric and regional transformations (Van der Ploeg 2018; p. 125-148, Carney 2021, Nazarea et al. 2021; p. 3-19). Considering how urban agriculture already supports and maintains ecological and social diversity is then vital for a collective future.

Dissertation chapter summaries

Chapter 1 considers how environmental features shaped by community gardeners (local scale) and the surrounding landscape create a “habitat” that can support diverse insect and spider species. In this chapter, I am in conservation with habitat management approaches that consider how the design and structure of agroecosystems can support synergistic ecological interactions. This chapter considers how various vegetation, ground cover, focal crop density, and urban cover features may facilitate ecological resources (e.g. shelter, food, sites for reproduction) for insect and spider groups that interact with *Cucurbita pepo.* I asked the following question: How do local and landscape factors shape the abundance, richness, and diversity of insects and spiders in urban gardens? *C. pepo*, a common garden crop, is also an integral food crop member of the milpa system in Mesoamerica. Identifying garden features supporting ecological health and pest prevention in highly fragmented and urbanized landscapes supports balanced environmental systems.

Chapter 2 centers on the lived and learning experiences of Latinx and Indigenous Latinx community gardeners who practice gardening. In this chapter, I am in conversation with critical food scholars and Indigenous and diasporic scholars who reorient my thinking to emphasize how ecological knowledge processes shape gardening as practice. In this chapter, I ask: How do Latinx and Indigenous Latinx gardeners in the central coast of California express their relationships to land in the contexts where they live now? I held semi-structured interviews, conducted garden plant surveys, and engaged in participant observations with 20 urban gardeners in the cities of San Jose, Salinas, Watsonville, and Santa Cruz.

Drawing from agrobiodiversity data with all gardeners, I center three food crops: the milpa, tomatoes, and quelites. I describe how I hear urban gardeners articulate embodied, relational, and experiential ecological knowledge that ultimately nourishes a relationship with land.

Chapter 3 centers on insect and human connections that emerge through gardening as a practice. I consider gardeners' ecological knowledge of insects and how lived and learning experiences can shape a gardener's ability to classify insects into distinct functional roles. The questions that guide this chapter are: (1) How well can gardeners recognize insects that are members of particular functional groups (e.g., pollinators, natural enemies of pests, and herbivore insects)? and (2) What gardener demographics and learning experiences are associated with the likelihood of identifying insects that are members of particular functional groups (e.g., pollinators, natural enemies of pests, and herbivore insects) groups? Using online surveys in English, we collected data from gardeners across the central coast. We learn that, overall, gardeners can identify many insect and spider species and that gender and program-based learning experiences (e.g., the University of California Agriculture Natural Resources Master Gardener program) are associated with a higher likelihood of identifying different insect functional groups.

This dissertation research contributes to a transdisciplinary understanding of ecological knowledge in urban agroecosystems. As a linked system, social and cultural processes shape garden agrobiodiversity, and gardening as practice shapes food production and ecological communities. Ecological knowledge in the garden space is shaped by and emerges from the garden space--this nourishes relationships with land. Agrobiodiversity is an expression of gardeners’ ecological knowledge, and this knowledge contributes to the environment that insect, spider, and plant communities exist within. The presence of insects and spiders in the garden allows gardeners to develop further ecological knowledge of insect-plant interactions and the functional roles of diverse insect species. Together, gardeners and insects co-create the emergent features of urban gardens, including ecosystem services and biodiversity processes at the local and landscape scales.

Methods Overview

This dissertation analyzes data collected and processed in five phases between 2021 and 2023. The data was collected using a mixed-methods approach that includes ecological field methods, interviews and participant observations, garden plant analyses, and online survey data collection.

Phase 1:

In the summer of 2021, I visited 21 urban gardens in Santa Clara, Santa Cruz, and Monterey counties to conduct ecological field research. Fieldwork was a collaborative effort led by a team of undergraduate and graduate researchers who are members of the Biodiversity in Urban Gardens Research Group (BUGS). We sampled

10 cucurbit (*C. pepo*) plants across the 21 urban gardens and conducted vegetation and ground cover surveys. We also used land cover data from the U.S. National Land Cover Database to capture the percentage of urban cover within 2km surrounding each garden.

Phase 2:

In the summer of 2022, an undergraduate student and I identified all collected insect specimens and classified them to family, species, or morphospecies when possible. Simultaneously, we worked to develop semi-structured research questions for interviews with community gardeners. I connected with a collective of gardeners based in Watsonville, CA, who managed three gardens where we conducted ecological research and worked to build a relationship with this organization.

Phase 3:

I volunteered with a collective of gardeners in Watsonville, CA, from 2022-2023. I was invited to accompany the organization and support a campaign for land tenure in a community garden site. With support from the organization, I recruited community gardeners to participate in interviews to support this dissertation work. I asked permission from the community garden manager to post recruitment posters in 3 garden locations managed by the collective of gardeners. I also posted recruitment posters in 3 additional gardens that support ecological fieldwork by the BUGS team. Then, I resorted to snowball sampling and direct outreach.

Phase 4:

In April 2023, the BUGS team designed and shared an online survey with garden managers of all 21 garden sites and reached out to garden managers to share with garden members. Additionally, a University of California Urban Agriculture Advisor in Santa Clara County shared this survey with the Master Garden network. Online survey data collection occurred during June-August 2023. During June-September 2024, I conducted direct outreach to gardeners in various gardens in Santa Clara, Santa Cruz, and Monterey counties. I held semi-structured interviews, conducted garden plant surveys, and engaged in participant observations with gardeners. All data collection for this dissertation concluded in September 2023.

Phase 5:

From September 2023 to June 2024, I iteratively analyzed semi-structured interviews, agrobiodiversity data, and qualitative research coding. Additionally, I analyzed survey data and ran analyses to identify model-based associations between insect identification and gardeners’ lived and learning experiences.

CHAPTER 1: Insect and spider diversity associated with *C. pepo* and habitat management in urban gardens

Abstract

Identifying which habitat management factors impact insect and spider community structure in urban gardens is crucial for agroecosystem health and conservation biological control. Top-down trophic regulation by natural enemies can be enhanced or dampened by the effect of local and landscape habitat factors on insect and spider communities. Thus, understanding which factors may alter the abundance and species richness of herbivores and natural enemies in urban gardens is essential. We examined how herbivores and natural enemies respond to local habitat factors (e.g., ground cover vegetation features) and landscape factors (e.g., urban cover) in urban gardens. We collected insects and spiders from aboveground foliage, stems, and flowers using visual surveys from 10 randomly selected plants of the focal crop *Cucurbita pepo* across 21 urban gardens on the central coast of California in 2021. We identified all specimens to family and species or morphospecies. Different taxonomic and feeding groups responded to other local and landscape factors, suggesting that life-history strategies are essential for understanding management effects in urban gardens. Only local factors were predictive of the abundance or richness of herbivores, while predatory Hemiptera was the only taxa associated with a landscape factor. We discuss why and how specific local and landscape habitat factors may influence insect and spider community structure for a common garden crop and consider implications for garden management processes.

Key Words: Herbivores, natural enemies, urban agriculture

Introduction

Insects and spiders can support food production, regulate herbivores, and facilitate the delivery of ecosystem services. Identifying insect and spiders' natural histories and ecological roles can be informative for urban agricultural systems (i.e., community gardens). Conservation biological control (CBC) approaches identify and evaluate how habitat management efforts can enhance the regulation of herbivores through various ecological interactions (i.e., predation, parasitism, facilitation) (Barbosa 1998, Rusch et al. 2017). CBC research has historically taken place in rural agricultural contexts. Yet, the rise of fragmented habitats and a reframing of urbanized landscapes (i.e., cities and residential neighborhoods) as capable of supporting biodiversity has propelled a shift toward the study of urban agriculture (McIntyre 2000, Alberti et al. 2003, Raupp et al. 2010). Spatially explicit approaches help consider how local garden features and surrounding urban landscape cover (i.e., impervious cover) may impact insect community structure and diversity (Philpott and Bichier 2017).

Food production is one of several motivations and goals that urban community gardeners express. Many community organizations and food sovereignty activists see urban agriculture as “food-enabling” spaces that can catalyze social action to confront and address calls for justice and well-being (Tornaghi and Dehaene 2020). The number of people involved in urban agriculture is growing, with reinvigorated interest during the COVID-19 pandemic (Diekmann et al. 2023). About 24 million hectares of urban land are estimated to be irrigated agriculture (Thebo et al. 2014). Still, global statistics on participation in urban agriculture are limited to case studies (FAO et al. 2022). Urban growth projections suggest that 68% of the world's population could reside in urbanized areas by 2050 (Economic U.N.D and Affairs 2019). Urban gardens' multifunctionality and potential to support food access could benefit from identifying ecological mechanisms to contribute to agroecosystem health and social well-being (Liere et al. 2017).

Insects and spiders, like other organisms, rely on resources distributed across landscapes composed of different habitats with different ecological features (Rand et al. 2006). Both local and landscape features thus impact insect and spider communities. A focus on plant diversity and structure first guided analyses of herbivores and natural enemy community structure (Risch 1981, Andow 1991) where on-the-farm (local habitat) factors (i.e., canopy cover, monoculture vs. polyculture designs) were considered the primary drivers of agroecosystem impacts. In urban gardens specifically, various urban garden features and disturbances influence insect abundance and diversity. For instance, the activity density of generalist predators (i.e., spiders, ants, and beetles) shifts depending on urban habitat type (i.e., forest, urban, vacant lots) as well as specific habitat features (i.e., mulch, grass, shrubs) (Philpott et al. 2014). However, in other studies, no significant changes in activity density are identified for generalist predators across habitat types (Burkman and Gardiner 2014). Predators like spiders have higher species richness in urban gardens with more mulch, flowering vegetation, and trees (Otoshi et al. 2015, Lowe et al. 2018). Ant species diversity can be reduced by disturbance in gardens (i.e., tillage intensity, clay or wet soils); however, different ant species respond differentially to grass and wooded areas potentially due to life-history strategies (Edwards 2016). Ladybeetles express sensitivity to mulch but can benefit from garden features that create habitat complexity (i.e., ornamental plant richness, shrubs, trees, and flowering plants) (Egerer et al. 2016). Parasitoid abundance can grow in urban gardens with additional floral resources (Egerer et al. 2018a), whereas, in other cases, no positive effect on parasitoids has been found potentially due to hyper parasitism, dispersal, or habitat fragmentation (Arnold 2022). Plant host density in rural agroecosystems has historically been linked to herbivore abundance and could be a factor in urban agroecosystems (Root 1973, Risch 1981).

Additionally, garden management strategies like crop rotations or repetitive planting can result in patch-size outbreaks of herbivorous insects and shift abundances (Taylor et al. 2017). Yet, predicting herbivore abundance and richness is often not possible with measured variables suggesting that other factors (e.g., additional factors related to feeding strategies and low-sampling availability) impact herbivores (Lowenstein and Minor 2018, Lucatero et al. 2024). Overall, natural enemy and herbivore groups vary in their responses to garden-based (local) and landscape features, highlighting the significance of life histories and specific habitat requirements among insect families or groups.

Insect diversity and communities also respond to temporal and spatial shifts across entire landscapes, as has been pointed out by studies of both metapopulation biology and landscape ecology (Levins 1969, Vandermeer and Carvajal 2001). For example, incorporating non-crop resources outside of cultivated crops (e.g., flower field strips, weeds, and grasses) as well as shifts in landscape composition (e.g., increases in semi-natural habitat, native vegetation) can support overall insect abundance and diversity (Tscharntke et al. 2005). These non-crop resources can provide sites for reproduction, plant hosts or prey items, and support dispersal (Bianchi et al. 2006). Ladybeetles, for example, can seek refuge in urban gardens surrounded by low amounts of natural cover (i.e., forests) (Egerer et al. 2018a); however, in other cases, impervious cover (i.e., vacant parking lots) can dampen the positive effect of urban gardens (Parker et al. 2020). Other natural enemies like parasitoids are susceptible to urban cover, and this often results in decreased species richness (Bennett and Gratton 2012, Burks and Philpott 2017), suggesting that urbanization can act as a filter on specialized feeding strategies (Rocha and Fellowes 2020). Yet more recent studies demonstrate that landscape contexts mediate the local responses of insects, and context-dependent approaches may be needed to advance insect responses to habitat resources (Jha et al. 2023). In rural farms, legacy effects of land management and context-dependent effects play a role in insect responses (Tylianakis and Romo 2010). Given the cultural significance and preference for specific food crops, learning if insect communities express crop-specific differences across different local and landscape features remains vital.

Understanding the impacts of local and landscape management in and around urban gardens on natural enemies is essential because they contribute to herbivore regulation (Snyder et al. 2006, Gardiner et al. 2009). However, changes in natural enemy diversity and composition only sometimes lead to pest suppression, potentially due to context-specific habitat factors, indirect effects, or limitations to measurement efforts (Letourneau et al. 2011, Karp et al. 2018). Thus, enhancing conservation efforts for natural enemies and increasing the potential of CBC through habitat management represents a challenge in urban gardens. Although landscape-level changes strongly impact insects, landscape management is usually outside individuals' control; community garden or plot-level adaptations remain essential to study because these options are accessible to gardeners (Tooker et al. 2020).

In this study, we consider the community of insects foraging on one common crop within urban gardens to assess local and landscape drivers of insect and spider communities. Specifically, we examined the abundance and species richness of insects found on *Cucurbita pepo*, squash, in urban gardens. We add to research studies considering *C. pepo* as a model system to identify management features that can enhance CBC in urban agriculture. We specifically asked two research questions: (1) How do local and landscape factors impact the abundance and richness of herbivores associated with *C. pepo*? (2) How do local and landscape factors impact the abundance and richness of natural enemies associated with *C. pepo?* Given that herbivores typically respond to the availability of their preferred host crop, we predicted that herbivore abundance would increase with the area of *C. pepo* in gardens. Given that parasitoids and predators often respond to both impervious cover and floral resources, we predicted that floral resources would increase the richness of parasitoids and predators.

Methods

Study System

We collected data from 21 urban gardens where vegetables, fruits, and ornamental plants were cultivated between June and August of 2021 in three counties (Monterey, Santa Clara, and Santa Cruz) in the Central Coast region of California. Gardens typically consist of plots managed by individuals or a single garden manager (i.e., community gardens), whereas shared garden spaces (i.e., walking paths, tree orchards) often reflect group management decisions. We selected gardens surrounded by natural, urban, and agricultural cover to varying degrees and located at least 2 km away from each other (Table S1.1). The gardens ranged in age from 5 to 47 years old, and the garden size ranged between 1,000 to 20,000 m^2. Each site was visited once between June 21-25 and once between August 9-13.

Focal crop selection and ecology

We selected *Cucurbita pepo (C. pepo),* commonly called the green zucchini squash and summer squash, as the focal crop for this study. Using a focal crop to base the study design follows Philpott et al. (2020) and Lowenstein and Minor (2018), who surveyed brassica crops for insects to learn about insect diversity across urban gardens. *C. pepo* is a food crop and a companion plant of a polyculture system (corn-beans-squash) known as milpa system or three sisters across native communities in North America (Lira et al. 2016). This crop has been sampled across several urban and peri-urban areas by Gregory et al. 2016 and Ploessel et al. 2023 for insect and herbivore species and by Egerer et al. 2020 to learn about plant protection provided by fungivorous lady beetles (i.e. *Psyllobora).*

C. pepo is a model crop across many types of ecological research, including pollination biology (Knapp and Osborne 2019), analyses of mechanisms of resistance to plant herbivores (Brzozowski et al. 2019), and pest regulation associated with farm management (i.e., organic, polyculture vs. monoculture) (Mabin et al. 2020). Specific herbivore species have been studied due to their potential for plant damage. For example, polyphagous herbivores like cucumber beetles (*Diabrotica undecimpunctata* and *Acalymnna vittatum)* form a pest complex that expresses unique group behavior and interactions with semiochemicals released by male individuals (Rojas et al. 2015, Haber et al. 2021). Herbivores like Hemiptera Coreidea (e.g., *Anasa tristis)* have been observed to express ovipositional preferences in specific cucurbit varieties (Cornelius et al. 2019*).* Hemiptera insects like aphids and whiteflies can incur various types of plant damage, including vectoring diseases like the Zucchini Yellow Mosaic Virus and Cucumber Mosaic Virus (Nyoike and Liburd 2010) and contribute to Cucurbit Leaf Crumple Virus (Akad et al. 2008). The diversity of ecological interactions that diverse insect and spider communities can have with cucurbits make *C. pepo* an excellent model system to learn about insect diversity and their responses to local and landscape features. Visits for this study coincided with the summer growing season of *C. pepo* in California. *C. pepo* has an 8-week growing cycle after planting; flowers start to emerge between 30-45 days and fruits can appear 4 to 8 days after pollination (Molinar et al. 1999).

Garden-based management (local factors)

To understand how urban garden habitat management features may be impacting the insect and spider communities associated with *C. pepo* we measured various local factors. We noted garden age and measured each garden's total area (size). We established a 20 m x 20 m plot at the center of each garden, within which we sampled for various vegetation and ground cover features. Within the 20 x 20 m plot, we randomly selected eight 1 m x 1 m plots within which we estimated plant cover from each herbaceous plant species and from bare ground and mulch. We measured herbaceous vegetation height (cm), number of flowers, number of herb species in flower, and tallied total herb species richness, as well as tree and shrub species richness. Plant species identified within 1 m x 1 m plots were categorized as crops, weeds, grasses, or ornamental plants. Lastly, we measured the height (cm) and width (cm) of up to 10 *C. pepo* plants per garden that were surveyed for insects (see below).

Urban cover within 2 km of garden sites (landscape factor)

Landscape cover surrounding each garden site was calculated as the percentage of different land cover classes within 2 km buffers from the center of each garden. To do this, we used the USDA National Land Cover Database (NLCD, 30-m resolution (Homer et al. 2015) land cover classes. Land cover was grouped as 1) natural (combining the NLCS categories for deciduous, evergreen, and mixed forests, dwarf shrub/scrub, and grassland/herbaceous), 2) open (described by the NLCD as lawn grass, park, and golf courses), 3) urban (combining NLCD cover classes for low, medium and high intensity developed land), or 4) agriculture (including the NLCD categories of pasture/hay and cultivated crops) (Philpott et al. 2020). We selected a spatial radius of 2 km for all land cover classifications following Egerer et al. (2017a), who identified that this was an appropriate scale to measure the abundance of most insects and spiders (e.g., bees, ants, ladybeetles), but not parasitoids whose abundance was best predicted by a 200-500 m scale.

Herbivore and predator surveys and identification

Insect sampling consisted of the haphazard selection of 10 *C. pepo* plants within 20 m x 20 m plots. Each of the 10 *C. pepo* plants was visually inspected for approximately 10 min. Moreover, *C. pepo* plant size varied dramatically between sites. For this reason, we also considered the area of *C. pepo* sampled in each garden. We sampled all we could find if there were not 10 *C. pepo* plants in the garden. In one site, we sampled only 19 *C. pepo* plants over the two sample periods. We visually surveyed aboveground plant parts and noted the presence of herbivores and natural enemies. We collected any insects that could not be identified readily in the field. We identified all insects to order, family, genus, and species or morphospecies utilizing identification keys and guides (Borror and White 1970, Marshall 2006, Fisher and Cover 2007, Has and Jones 2015) as well as online resources (BugGuide 2022, Spencer Entomological Collection 2021, UC IPM 2021, UF and IFAS 2021, and collections residing in the Philpott lab at UC Santa Cruz.

Data Analysis

We first log-transformed and square-rooted response and predictor variables to adjust the data distribution to fit linear models. We log-transformed the count data for herbivore species richness, natural enemy species richness, ant abundance, aphid abundance, whitefly abundance, and herbivorous chrysomelid abundance. Because aphids and whiteflies were hyperabundant in our data set compared to all other herbivores, we also created response variables for all herbivores not including aphids and whiteflies (hereafter other herbivores) and for hemipteran herbivores not including aphids and whiteflies (hereafter other Hemiptera). We also used log-transformed count data to measure the abundance of other herbivores and other hemipteran herbivores. We also took the square root of the percent of urban cover at 2 km and log-transformed the number of flowers.

Next, we tested for correlations between groups of predictor variables using Pearson correlations tests with the ‘metan’ package in R (Olivoto and Lucio 2020) (Fig. S1.1). The predictor variables that we included in the correlations were grouped into four types of variables: (1) garden size and age (2) ground cover factors, including grass and mulch (3) vegetation factors, including the area of *C. pepo*, the number of flowers, the number of herb species in flower, the number of tree and shrub species richness, herbaceous species richness, and herbaceous vegetation height, and (4) landscape factors including open cover within 2 km of the garden, natural cover within 2 km of the garden, agricultural cover within 2 km of the garden, and urban cover within 2 km. We removed variables within each group that were highly correlated with others. For instance, we removed herb species richness because it was associated with the number of species in flower. We also removed tree and shrub species richness because it was strongly correlated with the number of flowers. Garden size and age slightly covary, but they were both included in our models because garden age is associated with specific vegetation features (i.e., spontaneous vegetation) (Philpot et al. 2023a).

Additionally, we included the height of the tallest vegetation, the number of flowers, and plant species in flower, and the total estimated area of *C. pepo* plants sampled across both sample months (derived from plant height vs. width measurements). In our study system, urban cover is often correlated with the percent of natural and open cover, and only (n=4) garden sites are surrounded by agricultural cover; therefore, we only consider urban cover within 2 km in our models. Once we had selected a suite of variables, we ran one final check to prevent multicollinearity in our models. We tested the variable inflation factor (VIF) using the ‘car’ package in R (Fox and Weisberg 2018) and removed any predictor variables with VIF scores higher than 3. Thus, the final list of predictor variables included in the models were garden size, garden age, ground cover from mulch, ground cover from grass, number of flowers (LN), number of herb species in flower, height of herbaceous vegetation, urban cover within 2 km (square root) and the total area of *C. pepo* plants sampled in each garden (Table 1.1).

Following this, we categorized all insect specimens collected by feeding group, considering herbivores, predators, and parasitoids, the latter two of which were combined as the natural enemies group. We calculated each site's overall abundance and richness of herbivores and natural enemies across both sampling dates. Also, we calculated the abundance and richness of the most common taxonomic groups in each feeding group. Specifically, we looked at the abundance and richness of all herbivores and natural enemies found for at least 50 individuals. For herbivores, we examined the abundance of aphids, whiteflies, other hemipteran herbivores, and leaf beetles (Chrysomelidae) and species richness of other hemipteran herbivores and leaf beetles. We also considered abundance for all herbivores and other herbivores. For natural enemies, we examined the abundance of ants, spiders, predatory Hemiptera*,* and ladybeetles (Coccinellidae) and the species richness of spiders, predatory Hemiptera, and ladybeetles. For all groups for which we examined species richness, we also calculated estimated species richness (Chao1) and diversity (Shannon's Index, H') using the Vegan package in R (Oksanen 2018). We only included adults, larvae, and nymphs for all calculations, as those are the feeding life stages.

We then used generalized linear models (GLM) to check for relationships between the predictor variables and abundance, species richness, estimated species richness (Chao1), and diversity (H') of herbivores, natural enemies, and selected herbivores and natural enemies groups. In addition to checking for covariance in our predictor variables and ensuring that the residuals of our response variables fit the normal condition, we log-transformed most of our response variables. We used a Gaussian family distribution in all GLM models. We used the 'MuMin' package in R (Barton 2012) to assist with model selection and used a conditional averaging approach to average top models within 2 AIC scores of the best models. We interpreted associations between our predictor variables and response variables as limited to the parameters of our GLM model.

Results

We identified 17,586 insect and spider individuals across all sites sampled, including a total of 17 herbivore families from 37 species or morphospecies and 36 natural enemy families from 118 species or morphospecies (Table S1.2). The most common herbivores that we found were aphids (13,495 individuals), whiteflies (476 individuals), leaf beetles (Chrysomelidae, 108 individuals), and leaf hoppers

(Cicadellidae, 49 individuals). The most common natural enemies encountered were ants (2,473 individuals), spiders (252 individuals), flower bugs (Anthocoridae, 72 individuals), and ladybeetles (60 individuals).

In our models, no variable could significantly explain the overall variation in other herbivore abundance or herbivore diversity (H'), but we did find estimated species richness of other herbivores (Chao1). Additionally, unique combinations of predictor variables were associated with taxa-specific herbivore groups (Fig. 1.1, Table S1.3). More specifically, the estimated species richness of all herbivores dropped with garden age p=0.004, Fig. 1.1e) and with a higher number of herb species in flower (p=0.043, Fig 1.1h). Chrysomelidae abundance was lower in gardens with more plant species in flower (p=0.042, Fig. 1.1c) and decreased in bigger gardens (p=0.048, Fig. 1.1d). No predictor variables explained variance in the abundance of aphids, whiteflies, or other herbivore Hemiptera. The estimated species richness of other hemipteran herbivores increased with the area of *C. pepo* sampled (p=0.037, Fig. 1.1e) and percentage mulch cover (p=0.016, Fig. 1.1f), but decreased with garden age (p=0.007, Fig. 1.1g), and the number of plant species in flower (p=0.03), Fig. 1.1h). The diversity of other hemipteran herbivores increased with the area of *C. pepo* (p=0.034, Fig. 1.1i), mulch cover (p=0.001, Fig. 1.1j) and garden size (p=0.029, Fig.1.1k), but decreased with garden age (p=0.005, Fig. 1.1l) and the number of plant species in flower (p=0.026, Fig. 1.1m).

For natural enemies, no variable could significantly explain the variation of abundance and diversity (H'), but specific variables explain estimated species richness (Chao1) (Fig. 1.2, Table S1.4). Natural enemy estimated species richness increased with both the number of flowers (p=0.015, Fig. 1.2a) and more area of *C. pepo* sampled (p=0.003, Fig 1.2b), but decreased with the number of herb species in flower (p=0.024, Fig 1.2c). Natural enemy taxa-specific groups varied with specific combinations of garden or landscape features. Predatory Hemiptera abundance increased with increasing urban cover within 2 km of the garden (p=0.03, Fig. 1.2d) and more area of *C. pepo (*p=0.026, Fig. 1.2e). The estimated richness of predatory Hemiptera was higher with increasing garden size (p=0.039, Fig. 1.2f). Estimated species richness of spiders increased with increased area of *C. pepo* (p=0.041, Fig. 1.2g). Finally, predatory Hemiptera's diversity increased with landscape urban cover (p=0.001, Fig. 1.2h). No variables could significantly explain the abundance of spiders, ladybeetles, or ants.

Discussion

This study suggests that local garden age and size and local habitat management decisions by gardeners, as well as the surrounding landscape cover, can influence the abundance, species richness, estimated species richness, and diversity of specific herbivores and natural enemy groups, but no one variable is indicative of changes to all herbivores or all natural enemies. At the local scale, garden size and age, floral characteristics, and the area of *C. pepo* were significant for herbivores and natural enemies. In contrast, the one landscape factor, urban cover within 2 km, was a significant predictor only of one natural enemy group. We do not find evidence that the abundance of all herbivores increases with the area of *C. pepo,* but estimated richness of all other herbivores and herbivore Hemiptera, as well as herbivore diversity (H'), increased with more areas of *C. pepo.* We also found conditional support for our hypothesis that parasitoid and predator richness would respond to floral resources. The estimated richness (Chao1) of all natural enemies increased with the number of flowers but decreased with the increasing number of herb species in flower. Parasitoids did not respond to any variable, and only predatory Hemiptera increased with urban cover in the landscape. Further, our results corroborate the findings of Egerer et al. (2017a) and Philpott et al. (2014), who found that individual insect groups respond to unique environmental variables in urban gardens. In the following sections, we discuss possible relationships between specific variables that were predictive of particular herbivores or natural enemy groups.

First, we found that garden demographics like garden age and size can shape herbivores and natural enemy communities. Older gardens in this study were associated with a decrease in the estimated species richness of all other herbivores and other Hemiptera herbivores. Shifts in plant diversity in older gardens may drive the drop in the richness of other herbivore species. For instance, Philpott et al. (2023a) identified a higher species richness of weeds in older urban gardens, suggesting that garden age can impact vegetation management and potential host plants for cucurbit herbivores. Older gardens reflect secure land access or tenure. This may result in the development of local ecological patterns or management practices sustained by gardeners, which may act as a filter for herbivore species traits, thus lowering estimated species richness and diversity of herbivore Hemiptera. A local ecological pattern has been identified to impact bumble bee abundance and richness. Male worker bees with limited dispersal abilities benefit from spurious vegetation within vacant lots at the local scale despite high levels of impervious surface cover in the landscape (Glaum et al. 2017). Garden size negatively correlated with Chrysomelidae abundances but increased herbivore Hemiptera diversity (H’). The drop in chrysomelid abundance in more extensive gardens could be due to higher plant diversity in larger gardens that could interrupt their ability to locate preferred host plants (Letourneau 1990; 2009). The absence or preference of preferred plant hosts may be higher in small patches, as observed in a study of polyphagous leaf beetles (i.e., *Acalymmna vittatum)* in a survey of plant-to-plant movement (Andow 2023). Increased garden size may lead to increased cultivation of plants that can be used as a landing space by herbivore Hemiptera, whose movements include jumping and flying in response to disturbance (Lu et al. 2023). This positive effect may translate to increased diversity (H’) if herbivore Hemiptera experience resource partitioning facilitated by increased garden size. This population boost may sustain predator Hemiptera, whose estimated richness is positively associated with garden size. We identified the following herbivore Hemiptera families: Cicadellidae (n= 49), Coreidae (n=27), Miridae (n=19). Host plant range has been previously identified as equally crucial for predicting the effects of plant diversity on herbivore densities (Letorneau et al. 1990). Turning towards natural enemy responses to garden-based and landscape factors may help us identify additional factors that can support the regulation of herbivores.

Of the ground cover features examined, we found that mulch boosted herbivorous Hemiptera's estimated species richness, diversity, and the estimated species richness of other herbivores but had no effect on natural enemies. At least for some species of cucurbit herbivores, different kinds of mulch may protect from their natural enemies (Boyle et al. 2002), which could have boosted populations and thus the richness of herbivore Hemiptera. Mulch may increase plant quality for different species of herbivorous Hemiptera that feed off various plant structures (Wheeler et al. 2015) and increase their diversity (H’). We do not find support that natural enemies respond to mulch but note that (Otoshi et al. 2015, Egerer et al. 2017b, Philpott et al. 2023b) have identified the richness and abundance of natural enemies, such as spiders and Carabidae ground beetles can benefit. Mulch may increase prey availability or offer hiding places to escape intra-guild predation, but none of these studies examined predatory Hemiptera. As an example, Snyder et al. (2022) found that intra-guild predation between predatory Hemiptera (*Nabis* sp. feeding on *Geocoris* sp.) was more pronounced in areas with higher prey abundance and richness (such as mulched areas of gardens), which may have prompted more predatory Hemiptera foraging on the ground.

We found that the number of herb species in flower was negatively correlated with chrysomelid abundance, the estimated species richness and diversity of herbivorous Hemiptera, and a lower estimated species richness of natural enemies. In our sampling effort, we identified the following common Chrysomelidae – *Epitrix* sp. 1 (n=32)*, Diabrotica undecimpunctata* (n=32)*, Acalymna trivittatum* (n=23)*, and Systena* sp. 1 (n=14). A higher diversity of garden flowering plants may confuse chrysomelids when locating host plants. Flowering plants can be a positive effect on the regulation of chrysomelids, given that the pest complex that includes *D. undecimpunctata* and *A. trivvittatum* express a plant-host preference for cucurbits caused by attraction cucurbitacin content found in *C. pepo* (Metcalf et al. 1979, Haber et al. 2023; 2021). Gardeners' decisions to add flowers may serve as a selective mechanism for herbivore species. For example, mirid population dynamics are strongly tied to plant identity and follow plant flowering closely (Lu et al. 2024); thus, a decrease in herbivore Hemiptera estimated species richness and diversity may occur if preferred hosts are unavailable in the garden. Generalist predators may also locate herbivore Hemiptera more quickly in the garden due to their high dispersal abilities and movement when switching host crops (Lu et al. 2024). The lower estimated richness of natural enemies with an increasing number of herb species in flower but increased estimated species richness of natural enemies with the number of flowers can reflect the decreased abundance of prey species like Chrysomelidae and the utility of floral resources as foraging sites or as supplementary food resources. Floral abundance and richness have previously been linked to natural enemy abundance, diversity, and longevity (e.g. Andow 1991, Bennett and Gratton 2012, Burks and Philpott 2017, He et al. 2021), all of which could increase predation on herbivores, and potentially reduce herbivore richness in gardens.

The last garden-based (local variable) – *C. pepo* area sampled – was positively associated with increased species richness and diversity of herbivore Hemiptera, of all herbivores, and with spider abundance of predatory Hemiptera, and estimated richness of spiders. We expected that *C. pepo* area sampled might positively influence herbivore abundance of species richness following Root‘s (1973) resource concentration hypothesis, which states that a single-crop structure should be selected by herbivores that prefer a single-host crop. However, we did not see the impacts of *C. pepo* area on herbivore abundance, but we observed other Hemiptera herbivores are strongly associated with increased *C. pepo* area. The most abundant species that we observed in this group were Coreidae (n=27), Miridae (n=19), Psyllidae (n=11), and Cercopidea (n=6). *C. pepo* area may facilitate the partitioning of feeding areas among Hemiptera herbivores; species may find the complex plant structure advantageous to exploit all different parts of plant tissue like trichomes (Wheeler and Krimmel 2015). The high abundance of Herbivore Hemiptera associated with *C. pepo* may be explained by plant-host preference among species like *Anasa tristis* which use the bottom of plant leaves for oviposition and feeding (Doughty et al. 2016, Cornelius et al. 2019). Not surprisingly, herbivore Hemiptera's preference for *C. pepo* may attract generalist Hemipteran predators. The most abundant predatory Hemiptera species observed were Anthocoridae species (n=72), *Nesidiocoris tenuis* (n=39), *Geocoris puncticeps* (n=14), and *Nabis americoferus* (n=6). The abundance of predatory Hemiptera may be explained by overlap with Hemiptera herbivores (Fair et al. 2018), and be particularly supportive for *Geocoris punctipes* and spiders who can utilize plant structure as undisturbed sites for prey capture or hunting substrate for protection (Decker et al. 2008). The estimated richness of spiders might be expected to increase with *C. pepo* area as some spiders prefer hunting or building webs in plant leaves that offer concealed locations (Nyffeller et al. 1988, Scheidler 1990). Predatory Hemiptera, like anthocorids, feed on thrips that may be common in *C. pepo* flowers (Letourneau et al. 1990), which could have bolstered this predatory Hemiptera's abundance. Additionally, omnivory is a life-history strategy known among predatory Hemiptera, like anthocorids, and these predatory Hemiptera species may supplement their diets with plant flowers in the absence of prey (Salas-Aguilar and Ehler 1977, Coll et al. 1998). *C. pepo* is a host of complex predator-prey interactions shaped by local and landscape factors.

At the landscape scale, we observed urban cover associated with higher abundance and diversity of predatory Hemiptera only. Urbanization (i.e. percent of impervious surface cover and buildings) has been identified as disruptive to biodiversity processes and the ecologies of ‘matrix intolerant’ insects (McIntyre 2000, Bennett and Gratton 2012). Generalist predators can disperse various kilometers across landscapes (Bianchi et al. 2006, Gardiner et al. 2009), and thus, vegetation patches in the surrounding landscape may provide critical habitat, especially in higher urban cover areas (Bang and Faath 2011). Although it may seem counterintuitive, urban cover (and lower natural habitat or landscape diversity) sometimes corresponds to increases in diversity and abundance of insects in urban landscapes (e.g. Philpott and Bichier 2014, Egerer et al. 2018b), potentially due to context-dependent environmental features, history of the region and species natural histories. Thus, identifying how green spaces (i.e lawns, home gardens, native vegetation, and landscaping) that surround urban garden sites may be able to provide better resources is highly important (Burkman and Gardiner 2014).

Conclusion

Our study identified that no single local or landscape factor predicts the abundance, species richness, estimated species richness or diversity of all herbivores or predators, or even of all herbivores or predator groups. Instead, we document several local management features (garden size, age, floral abundance diversity, and ground cover). The landscape surroundings (urban cover) shape the communities of herbivores and natural enemies found on *C. pepo* in urban gardens. Although herbivores and natural enemy groups responded to local factors, only predators responded to landscape change, which had significant implications for garden management. It may be helpful to consider trait-based connections between predator and prey in the same order, like herbivore and predatory Hemiptera, to parse out who is eating who and how effective they may be. Moreover, considering how specific natural enemy taxa interact with specific flowering plant species may lead to a better understanding of potential herbivore pest problems within urban gardens. Finally, exploring indirect effects among insect communities in urban gardens can add to our understanding of possible interactions.

Author’s contributions

Edith M. Gonzales supported fieldwork, labwork, data analysis, and focal crop selection and prepared a manuscript draft. Stacy M. Philpott contributed to the design of field research, logistics, data analysis, and manuscript editing. Marily Muñoz-Serrano supported insect identification.

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Table 1.1 Local and landscape variables included in generalized linear models (GLMs).

Variable Scale	**Variable Type**	**Variable**
Local	Crop density	*Cucurbita pepo* area sampled in 20 m x 20 m plot
Local	Ground cover	Grass ground cover (%) in 1 m x 1 m quadrat
Local	Ground cover	Mulch ground cover (%) in 1 m x 1 m quadrat
Local	Vegetation	Herbaceous vegetation height (cm)
Local	Vegetation	Number of herb species in flower
Local	Vegetation	Number of flowers
Local	Garden feature	Garden size
Local	Garden feature	Garden age
Landscape	Land cover class	Urban cover (%) within 2 km of the garden

Table 1.2 GLM results for abundance, Chao1, diversity (H`) of herbivore and natural enemy groups.

A. GLM results feature negative or positive associations between the abundance, estimated richness, and diversity of herbivore taxa-specific groups and local and landscape factors.

Taxon-specific group	*C. pepo* area	Number of flowers	Number of herb species in flower	Mulch	Garden size	Garden age	urban cover (%) in 2 km
All herbivores Chao1	(+)			(+)		(-)	
Chrysomelidae abundance			(-)		(-)		
Herbivore Hemiptera Chao1	(+)		(-)	(+)		(-)	
Herbivore Hemiptera (`H)	(+)		(-)	(+)	(+)	(-)	

B. GLM results feature negative or positive associations between the abundance, estimated richness and diversity of natural enemy taxa specific groups and local and landscape factors.

Taxon-specific group	*C. pepo* area	Number of flowers	Number of herb species in flower	Mulch	Garden size	Garden age	% of urban cover at 2km
Natural Enemies Chao 1	(+)	(+)	(-)				
Predator Hemiptera abundance	(+)						(+)
Predator Hemiptera Chao 1					(+)		
Predator Hemiptera (`H)							(+)
Spiders Chao 1	(+)						

Figure 1.1 Associations between herbivore taxa-specific groups and local and landscape factors.

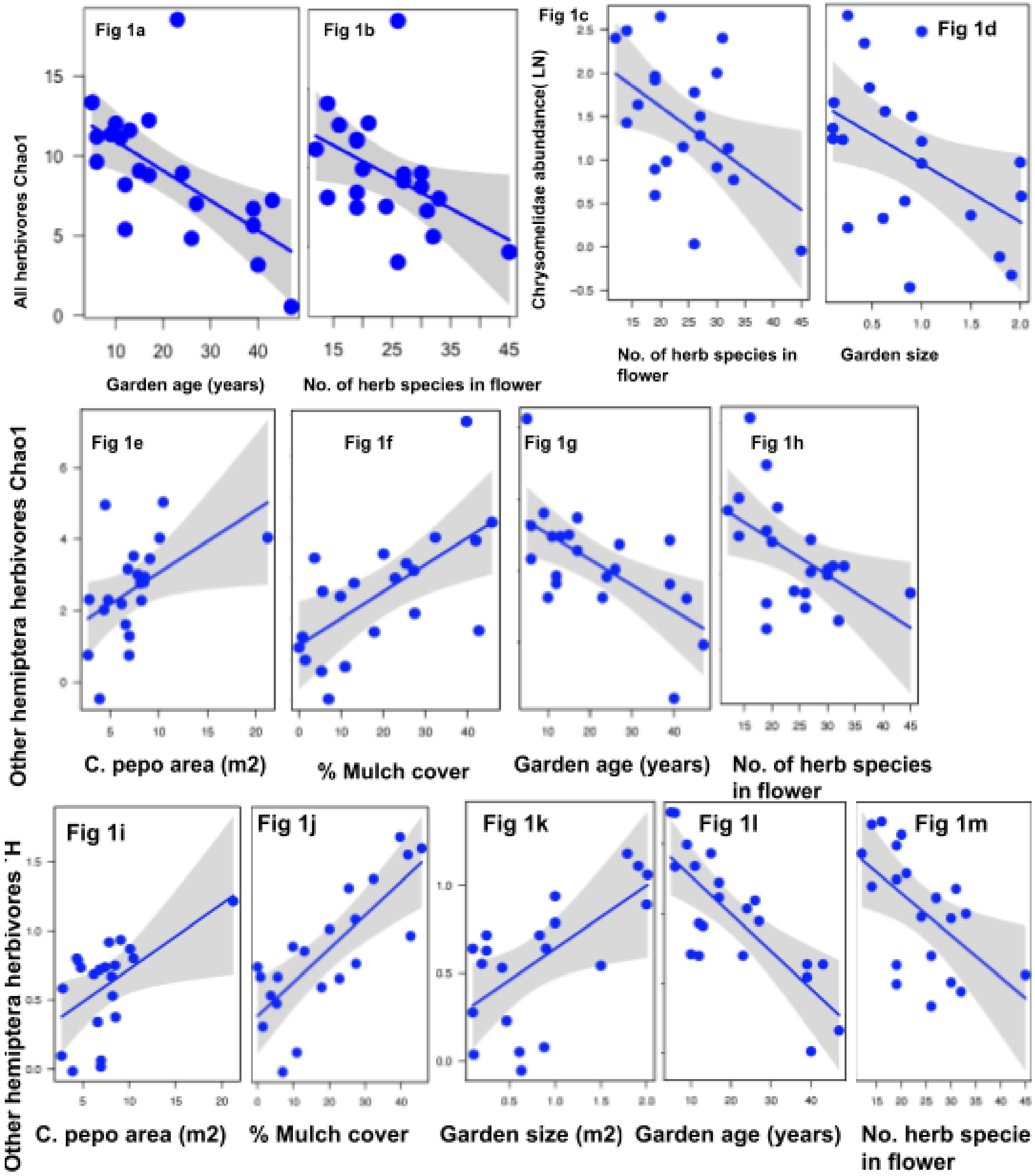
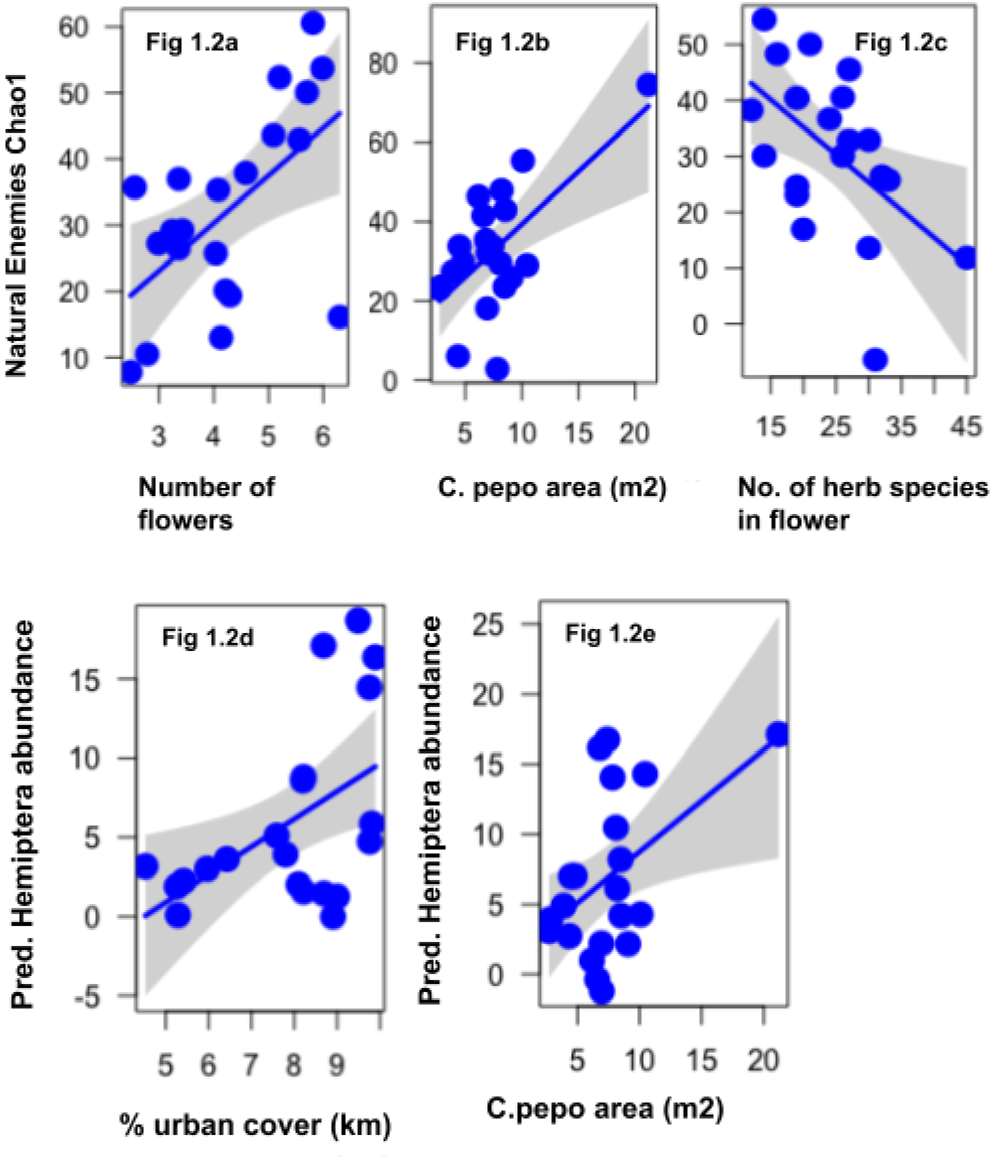


Figure 1.2 Associations between natural enemy taxa-specific groups and local and landscape factors.



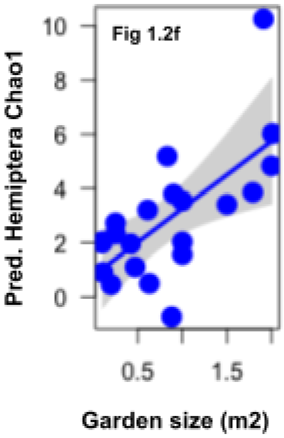


Fig 1.2f
Pred. Hemiptera Chao1
10
8
6
4
2
0
0.5
1.5
Garden size (m2)

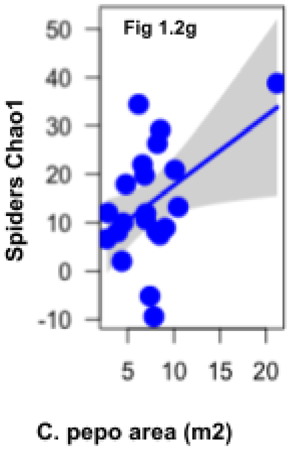


Fig 1.2g
Spiders Chao1
50
40
30
20
10
0
-10
5
10
15
20
C. pepo area (m2)

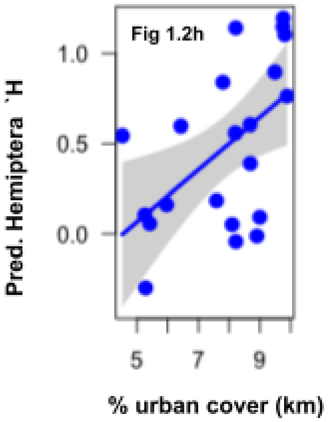
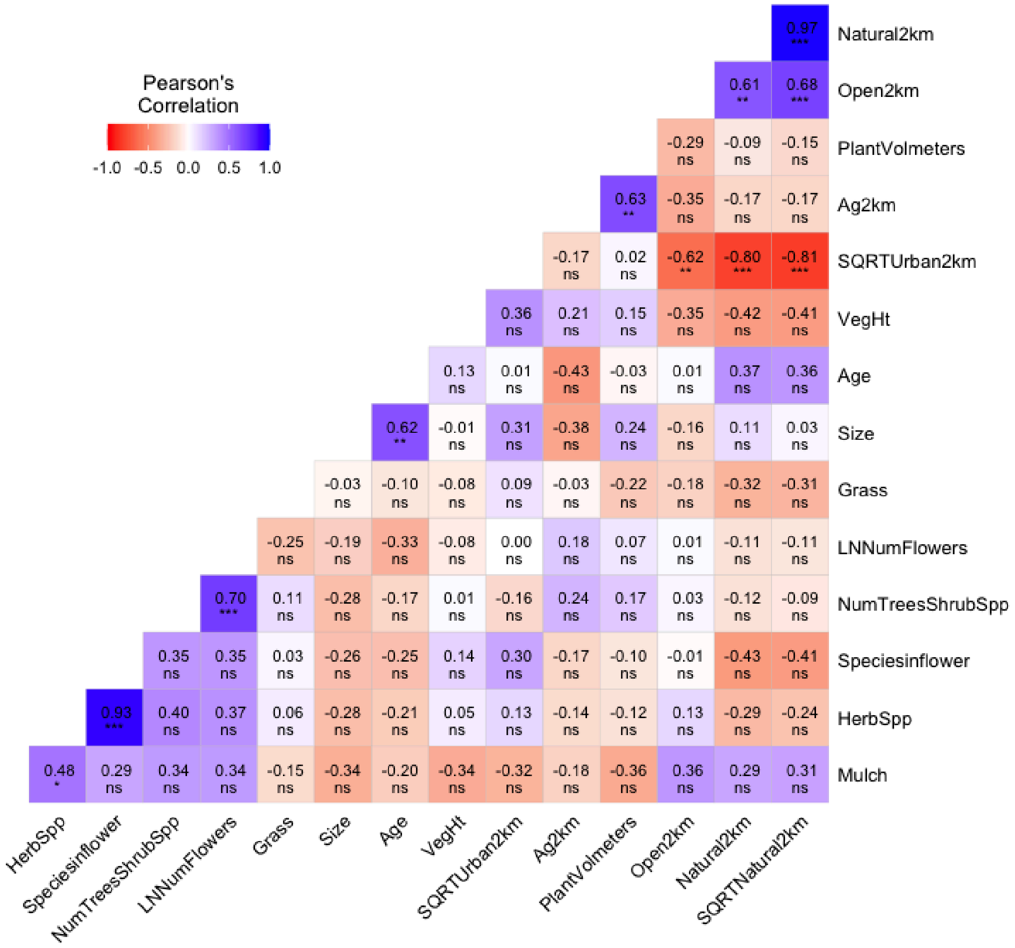


Fig 1.2h
Pred. Hemiptera `H
1.0
0.5
0.0
5
7
9
% urban cover (km)

Suuplementary Material

Figure S1.1 Pearson's Correlation plot of all local and landscape factors measured in and around urban gardens in the California central coast.



	HerbSpp	Speciesinflower	NumTreesShrubSpp	LNNumFlowers	Grass	Size	Age	VegHt	SQRTUrban2km	Ag2km	PlantVolmeters	Open2km	Natural2km	SQRTNatural2km
Natural2km														0.97 ***
Open2km													0.61 **	0.68 ***
PlantVolmeters												-0.29 ns	-0.09 ns	-0.15 ns
Ag2km											0.63 **	-0.35 ns	-0.17 ns	-0.17 ns
SQRTUrban2km										-0.17 ns	0.02 ns	-0.62 **	-0.80 ***	-0.81 ***
VegHt									0.36 ns	0.21 ns	0.15 ns	-0.35 ns	-0.42 ns	-0.41 ns
Age								0.13 ns	0.01 ns	-0.43 ns	-0.03 ns	0.01 ns	0.37 ns	0.36 ns
Size							0.62 **	-0.01 ns	0.31 ns	-0.38 ns	0.24 ns	-0.16 ns	0.11 ns	0.03 ns
Grass						-0.03 ns	-0.10 ns	-0.08 ns	0.09 ns	-0.03 ns	-0.22 ns	-0.18 ns	-0.32 ns	-0.31 ns
LNNumFlowers					-0.25 ns	-0.19 ns	-0.33 ns	-0.08 ns	0.00 ns	0.18 ns	0.07 ns	0.01 ns	-0.11 ns	-0.11 ns
NumTreesShrubSpp				0.70 ***	0.11 ns	-0.28 ns	-0.17 ns	0.01 ns	-0.16 ns	0.24 ns	0.17 ns	0.03 ns	-0.12 ns	-0.09 ns
Speciesinflower			0.35 ns	0.35 ns	0.03 ns	-0.26 ns	-0.25 ns	0.14 ns	0.30 ns	-0.17 ns	-0.10 ns	-0.01 ns	-0.43 ns	-0.41 ns
HerbSpp		0.93 ***	0.40 ns	0.37 ns	0.06 ns	-0.28 ns	-0.21 ns	0.05 ns	0.13 ns	-0.14 ns	-0.12 ns	0.13 ns	-0.29 ns	-0.24 ns
Mulch	0.48 *	0.29 ns	0.34 ns	0.34 ns	-0.15 ns	-0.34 ns	-0.20 ns	-0.34 ns	-0.32 ns	-0.18 ns	-0.36 ns	0.36 ns	0.29 ns	0.31 ns

ns p >= 0.05; * p < 0.05; ** p < 0.01; and *** p < 0.001

Table S1.1: Garden sites and descriptive variables for each site.

Site	County	Garden age (years)	Eco-Region	Garden size (acres)	Urban cover (%) within 2 km
Aptos	Santa Cruz	11	Coast	0.42	27.60
Beach Flats	Santa Cruz	26	Coast	0.25	67.23
Berryessa	Santa Clara	17	Inland	1.91	95.27
Charles Street	Santa Clara	15	Inland	1.00	97.8
Coyote Creek	Santa Clara	27	Inland	0.83	90.06
Grange	Santa Cruz	23	Coast	0.47	80.94
Guadalupe	Santa Clara	13	Inland	1.50	96.27
La Colina	Santa Clara	43	Inland	1.79	75.50
Laguna Seca	Santa Clara	40	Inland	0.61	29.31
MEarth	Monterey	17	Coast	0.90	20.45
MIIS	Monterey	12	Coast	0.11	57.57
Natividad	Monterey	5	Coast	0.10	67.47
Pacific Grove	Monterey	9	Coast	0.20	35.55
Pajaro	Monterey	6	Coast	0.10	41.29
Prusch	Santa Clara	39	Inland	2.01	95.10
Salinas	Monterey	12	Coast	0.88	79.27

Table S1.2. List of all herbivore, predator, and parasitoid species categorized by order (or class for Araneae or sub-class for Acari) and family and their total abundances across all sites sampled for adult (A), larvae (L) and nymph (N) life stages.

Order or Class	**Family**	**Species or Morphospecies**	**A**	**L**	**N**	**Total**
A. HERBIVORES						
Acari	Tetranychidae	*Tetranychus pacificus*	327	0	0	327
Coleoptera	Chrysomelidae	*Acalymma trivittatum*	23	0	0	23
		Bruchinae sp. 1	2	0	0	2
		Chrysomelidae sp. 1	3	0	0	3
		Diabrotica undecimpunctata undecimpunctata	32	0	0	32
		Epitrix sp. 1	32	0	0	32
		Systena sp. 1	14	0	0	14
		Trirhabda confusa	2	0	0	2
	Elateridae	Elateridae sp. 1	1	0	0	1
Hemiptera	Aleyrodidae	Aleryrodidae sp. 1	135	0	341	476
	Aphididae	*Aphis gossypii*	13495	0	0	13495
	Cercopidae	Cercopidae sp. 1	1	0	0	1
		Cercopidae sp. 2	1	0	0	1
		Cercopidae sp. 3	1	0	0	1
		Cercopidae sp. 4	1	0	0	1
		Cercopidae sp. 5	2	0	0	2
	Cicadellidae	Cicadellidae sp. 1	1	0	0	1
		Cicadellidae sp. 2	1	0	0	1

		Cicadellidae sp. 3	1	0	0	1
		Empoasca sp. 1	41	0	5	46
	Coreidae	*Anasa tristis*	22	0	4	26
		Leptoglossus occidentalis	0	0	1	1
	Issidae	Issidae sp. 1	1	0	0	1
	Lygaeidae	*Nysius raphanus*	3	0	0	3
	Miridae	Miridae sp. 1	4	0	0	4
		Miridae sp. 2	5	0	0	5
		Miridae sp. 3	7	0	0	7
		Miridae sp. 4	1	0	0	1
		Miridae sp. 5	2	0	0	2
	Psyllidae	Psyllidae sp. 1	11	0	0	11
Lepidoptera	Noctuidae	*Spodoptera exigua*	0	2	0	2
		Trichoplusia ni	0	7	0	7
	unknown	Lepidoptera sp. 1	0	1	0	1
Orthoptera	Gryllidae	Gryllidae sp. 1	1	0	0	1
	Melanoplinae	Melanoplinae sp. 1	1	0	0	1
	Oedipodinae	Oedipodinae sp. 1	1	0	0	1
Thysanoptera	Thripidae	*Frankliniella occidentalis*	28	0	0	28
B. PARASITOIDS						
Hymenoptera	Aphelinidae	Aphelinidae sp. 2	1	0	0	1
		Aphelinidae sp. 3	1	0	0	1
	Braconidae	Braconidae sp. 1	6	0	0	6
		Braconidae sp. 2	2	0	0	2
		Braconidae sp. 3	2	0	0	2
		Diaeretiella rapae	6	0	0	6
	Ceraphronidae	Ceraphronid sp. 1	1	0	0	1
	Cynipidae	Cynipidae sp. 1	1	0	0	1
		Cynipidae sp. 2	3	0	0	3
	Eulophidae	Eulophidae sp. 1	5	0	0	5

	Ichneumonidae	Ichneumonid sp. 1	2	0	0	2
		Ichneumonid sp. 2	1	0	0	1
		Ichneumonid sp. 3	5	0	0	5
		Ichneumonid sp. 4	1	0	0	1
	Megaspiliidae	Megaspiliid sp. 1	4	0	0	4
	Pteromelidae	Pteromelidae sp. 1	1	0	0	1
	Torymidae	Torymidae sp. 1	1	0	0	1
C. PREDATORS						
Acari	Phytoseiidae	*Phytoseiulus persimilis*	2	0	0	2
Araneae	Agelenidae	Agelenidae sp. 1	1	0	0	1
		Agelenopsis sp. 1	2	0	0	2
		Agelenopsis sp. 2	2	0	0	2
	Anyphaenidae	*Anyphaena californica*	5	0	0	5
		Anyphaena sp. 1	21	0	0	21
		Anyphaena sp. 2	1	0	0	1
	Araneidae	Araneidae sp. 1	1	0	0	1
		Cyclosa turbinata	2	0	0	2
	Cheiracanthiidae	Cheiracanthium sp. 1	6	0	0	6
		Cheiracanthium sp. 2	1	0	0	1
		Cheiracanthium sp. 3	4	0	0	4
		Cheiracanthium sp. 4	1	0	0	1
	Dictynidae	Dictynidae sp. 1	4	0	0	4
		Dictynidae sp. 2	2	0	0	2
		Dictynidae sp. 3	7	0	0	7
	Hahniidae	Hahniidae sp. 1	1	0	0	1

	Linyphiidae	*Erigone atra*	26	0	0	26
		Erigone autumnalis	20	0	0	20
		Erigone sp. 1	3	0	0	3
		Erigone sp. 2	1	0	0	1
		Erigone sp. 3	9	0	0	9
		Erigone sp. 4	1	0	0	1
		Erigoninae sp. 1	7	0	0	7
		Erigoninae sp. 2	4	0	0	4
		Linyphiidae sp. 1	3	0	0	3
		Linyphiinae sp. 1	4	0	0	4
		Linyphiinae sp. 2	2	0	0	2
		Microlinyphia mandibulata	1	0	0	1
		Spirembolus dispar	1	0	0	1
	Pholcidae	*Physocyclus enaulus*	1	0	0	1
	Salticidae	*Phiddipus audax*	2	0	0	2
		Phiddipus sp. 1	1	0	0	1
		Phiddipus sp. 2	1	0	0	1
		Phiddipus sp. 3	7	0	0	7
		Phiddipus sp. 4	1	0	0	1
		Phiddipus sp. 5	1	0	0	1
		Saltidicae sp. 1	1	0	0	1
		Sassacus sp. 1	2	0	0	2
		Sassacus sp. 2	2	0	0	2
		Sassacus vitis	1	0	0	1
	Tetragnathidae	*Tetragnatha caudata*	1	0	0	1
		Tetragnatha laboriosa	2	0	0	2
		Tetragnatha sp. 1	1	0	0	1
		Tetragnatha sp. 2	1	0	0	1
		Tetragnatha sp. 3	2	0	0	2

	Theridiidae	*Cryptachaea blattea*	1	0	0	1
		Enoplognatha ovata	1	0	0	1
		Laterodectus hesperus	3	0	0	3
		Latrodectus sp. 1	1	0	0	1
		Parasteatoda tepidariorum	12	0	0	12
		Steatoda grandis	1	0	0	1
		Steatoda nobilis	24	0	0	24
		Steatoda sp. 1	2	0	0	2
		Theridiidae sp. 1	13	0	0	13
		Theridiidae sp. 2	1	0	0	1
		Theridion goodnightorum	5	0	0	5
		Theridion kawea	1	0	0	1
		Theridion neomexicanum	1	0	0	1
		Theridion punctipes	2	0	0	2
		Theridion sp. 1	2	0	0	2
		Theridion sp. 2	2	0	0	2
		Theridion sp. 3	4	0	0	4
		Theridion sp. 4	3	0	0	3
	Thomisidae	*Ozyptilla pacifica*	1	0	0	1
	Titanoecidae	Titanoecidae sp. 1	2	0	0	2
Coleoptera	Coccinellidae	*Coccinella septempunctata*	2	0	0	2
		Coccinellidae sp. 1	0	1	0	1
		Cycloneda polita	2	1	0	3
		Cycloneda sanguinea	1	3	0	4
		Delphastus pusillus	2	0	0	2
		Halmus chalybeus	1	0	0	1

		Harmonia axyridis	2	1	0	3
		Hippodamia convergens	15	4	0	19
		Hyperaspis quadrioculata	4	0	0	4
		Olla v nigrum	1	0	0	1
		Scymnus coniferarum	1	0	0	1
		Scymnus marginicollis	4	0	0	4
		Scymnus socer	1	0	0	1
		Stethrous punctum	13	1	0	14
	Staphylinidae	Staphylinidae sp. 1	3	0	0	3
		Staphylinidae sp. 2	1	0	0	1
Dermaptera	Forficulidae	*Forficula auricularia*	12	0	0	12
Diptera	Syrphidae	Syrphidae sp. 1	0	28	0	28
Hemiptera	Anthocoridae	Anthocoridae sp. 1	1	0	2	3
		Anthocoridae sp. 2	6	0	0	6
		Orius tristicolor	63	0	0	63
	Geocoridae	*Geocoris puncticeps*	13	0	1	14
	Miridae	*Nesidiocoris tenuis*	38	0	1	39
	Nabidae	*Nabis americoferus*	5	0	1	6
Hymenoptera	Formicidae	*Cardiocondyla mauritanica*	180	0	0	180
		Linepithema humile	1467	0	0	1467

		Monomorium ergatogyna	507	0	0	507
		Nylandera vividula	116	0	0	116
		Tapinoma sessile	203	0	0	203
	Vespidae	Vespidae sp. 1	3	0	0	3
Neuroptera	Chrysopidae	*Chrysoperla carnea*	5	3	0	8
		Crysopidae sp. 1	0	1	0	1
	Hemerobiidae	*Hemerobius pacificus*	4	0	0	4
Opiliones	unknown	Opiliones sp. 1	1	0	0	1

Table S1.3: Conditional general linear model (GLM) output showing which factors were included in each model and which factors were significant predictors of each dependent variable for herbivores. All models are averaged for individual models within 2 AICS points of the top model.

Dependent variable	**Predictor variable**	**No. models**	**Estimate**	**Std. Error**	**Adjusted SE**	**Z-value**	**P**
All herbivore abundance	(Intercept)	8	5.46	1.187	1.23	4.45	<0.001
	Size	8	0.78	0.428	0.46	1.7	0.089
	Age	8	0.04	0.02	0.02	1.7	0.089
	Species in flower	8	-0.05	0.035	0.04	1.45	0.147
	No. flowers (LN)	8	-0.3	0.238	0.26	1.19	0.234
Other herbivore abundance (excluding aphids and whiteflies)	(Intercept)	2	2.288	0.489	0.51	4.497	<0.001
	C. pepo area	2	0.084	0.063	0.07	1.256	0.209
All herbivore species richness	(Intercept)	3	10.713	2.252	2.383	4.495	<0.001
	Age	3	-0.083	0.034	0.036	2.278	0.023
	Species in flower	3	-0.148	0.058	0.062	2.372	0.018
	C. pepo area	3	0.227	0.117	0.126	1.799	0.072
	Mulch	3	0.404	0.032	0.034	1.279	0.201
All herbivores estimated species richness (Chao1)	(Intercept)	5	13.975	4.619	4.81	2.901	0.004
	Age	5	-0.185	0.060	0.064	2.880	0.004
	Species in flower	5	-0.223	0.103	0.110	2.019	0.043

	C. pepo area	5	0.385	0.197	0.212	1.817	0.069
	Urban 2 km (SQRT)	5	0.668	0.458	0.494	1.351	0.177
All herbivores diversity (H’)	(Intercept)	3	0.805	0.182	0.191	4.205	<0.001
	Age	3	-0.009	0.008	0.008	1.02	0.307
	Size	3	-0.189	0.173	0.186	1.02	0.308
Aphid abundance	(Intercept)	6	4.97	1.23	1.334	3.714	<0.000
	Size	6	0.889	0.52	0.55	1.62	0.106
	Age	6	0.04	0.25	0.03	1.59	0.113
	Species in flower	6	-0.06	0.042	0.05	1.37	0.169
Whitefly abundance	(Intercept)	3	1.63	0.634	0.66	12.47	0.013
	Age	3	0.04	0.023	0.02	1.63	0.104
Chrysomelidae abundance	(Intercept)	11	2.09	1.054	1.09	1.91	0.056
	Size	11	-0.56	0.261	0.28	1.98	0.048
	Species in flower	11	-0.05	0.022	0.02	2.04	0.042
	C. pepo area	11	0.09	0.045	0.05	1.92	0.054
	No. flowers (LN)	11	0.26	0.152	0.16	1.56	0.118
	Urban 2 km (SQRT)	11	-0.19	0.102	0.11	1.72	0.086
	Age	11	-0.02	0.013	0.01	1.75	0.081
	Grass	11	-0.06	0.039	0.04	1.45	0.146
Chrysomelidae species richness	(Intercept)	9	2.52	1.144	1.18	2.13	0.033
	Species in flower	9	-0.06	0.032	0.04	1.59	0.112
	C. pepo area	9	0.09	0.067	0.07	1.31	0.19
	Grass	9	-0.08	0.059	0.06	1.22	0.224
	Age	9	-0.02	0.019	0.02	1.12	0.265

	Urban 2 km (SQRT)	9	-0.17	0.157	0.17	1.01	0.312
	Veg Ht	9	0.01	0.005	0.01	1.02	0.307
Chrysomelidae estimated species richness (Chao1)	(Intercept)	6	2.22	1.202	1.25	1.78	0.075
	Species in flower	6	-0.07	0.046	0.05	1.31	0.189
	Veg Ht	6	0.01	0.008	0.01	1.26	0.209
	Grass	6	-0.1	0.086	0.09	1.07	0.286
	C. pepo area	6	0.1	0.098	0.1	0.91	0.362
Chyrsomelidae diversity (H')	(Intercept)	6	0.44	0.342	0.36	1.24	0.214
	Species in flower	6	-0.02	0.13	0.01	1.35	0.177
	C. pepo area	6	0.03	0.027	0.03	1.11	0.265
	Veg Ht	6	0	0.002	0	1.11	0.266
	Grass	6	-0.03	0.024	0.03	0.97	0.331
Other Herbivorous Hemiptera abundance (excluding aphids and whiteflies)	(Intercept)	7	0.67	0.883	0.92	0.73	0.468
	C. pepo area	7	0.08	0.05	0.05	1.45	0.147
	Urban 2 km (SQRT)	7	0.16	0.114	0.12	1.32	0.188
	Veg Ht	7	0	0.004	0	1.01	0.312
	Species in flower	7	0.03	0.025	0.03	1.05	0.292
Other Herbivorous Hemiptera species richness (excluding aphids and whiteflies)	(Intercept)	11	2.05	1.513	1.57	1.31	0.191
	Age	11	-0.06	0.024	0.03	2.18	0.029
	Mulch	11	0.05	0.019	0.02	2.17	0.030
	Species in flower	11	-0.07	0.033	0.04	1.89	0.058
	C. pepo area	11	0.14	0.067	0.07	1.96	0.049
	Urban 2 km (SQRT)	11	0.27	0.146	0.16	1.72	0.085
	Size	11	0.89	0.506	0.55	1.63	0.103

Other Herbivorous Hemiptera estimated species richness (Chao1) (excluding aphids and whiteflies)	Intercept)	4	3.33	2.264	2.36	1.41	0.158
	Age	4	-0.08	0.027	0.03	2.68	0.007
	Mulch	4	0.07	0.026	0.03	2.42	0.016
	Species in flower	4	-0.1	0.044	0.05	2.17	0.030
	C. pepo area	4	0.18	0.081	0.09	2.08	0.037
	Urban 2 km (SQRT)	4	0.36	0.192	0.21	1.72	0.086
	Size	4	1.09	0.638	0.69	1.58	0.115
Other Herbivorous Hemiptera diversity (H`) (excluding aphids and whiteflies)	(Intercept)	3	0.7	0.405	0.43	1.61	0.107
	Size	3	0.39	0.163	0.18	2.19	0.029
	Age	3	-0.03	0.008	0.01	2.78	0.005
	Mulch	3	0.02	0.005	0.01	3.47	0.001
	Species in flower	3	-0.02	0.01	0.01	2.22	0.026
	C. pepo area	3	0.05	0.022	0.02	2.12	0.034

Table S1.4 Conditional general linear model (GLM) output showing which factors were included in each model and which factors were significant predictors of each dependent variable for natural enemies and predators. There were no significant predictors of any parasitoid variables. All models are averaged for individual models within 2 AICS points of the top model.

Dependent variable	**Predictor variable**	**No. models**	**Estimate**	**Std. Error**	**Adjusted SE**	**Z-value**	**P**
Natural enemy abundance	(Intercept)	8	3.88	0.760	0.79	4.92	<0.001
	Size	8	0.58	0.299	0.32	1.84	0.066
	Species in flower	8	0.03	0.022	0.02	1.4	0.163
	Urban 2km (SQRT)	8	0.15	0.108	0.12	1.26	0.207
	Age	8	-0.02	0.016	0.17	1.17	0.241
	Grass	8	-0.05	0.039	0.04	1.25	0.260
	No. flowers (LN)	8	0.17	0.147	0.16	1.09	0.275
Natural Enemy Species Richness	(Intercept)	5	9.294	5.436	5.705	1.63	0.103
	C. pepo area	5	0.840	0.346	0.370	2.27	0.023
	No. flowers (LN)	5	1.832	1.146	1.223	1.5	0.134
	Species in flower	5	-0.250	0.174	0.186	1.35	0.177
	Mulch	5	0.106	0.093	0.099	1.07	0.284
Natural enemy estimated richness (Chao1)	(Intercept)	1	6.659	13.55			0.629
	No. flowers (LN)	1	7.201	2.671			0.015
	Species in flower	1	-0.987	0.400			0.024
	C. pepo area	1	2.663	0.776			0.003

Natural enemy diversity (`H)	(Intercept)	5	1.994	0.634	0.658	3.031	0.002
	Species in flower	5	-0.035	0.021	0.022	1.587	0.112
	Size	5	-0.287	0.261	0.278	1.033	0.301
	No. flowers (LN)	5	0.186	0.142	0.152	1.227	0.219
Ant abundance	(Intercept)	8	3.21	0.98	1.01	3.17	0.002
	Size	8	0.84	0.40	0.43	1.95	0.051
	Species in flower	8	0.05	0.28	0.03	1.57	0.116
	Age	8	-0.03	0.02	0.02	1.13	0.259
	Grass	8	-0.06	0.05	0.05	1.14	0.253
	Urban 2km (SQRT)	8	0.19	0.14	0.15	1.27	0.204
Spider abundance	(Intercept)	7	10.31	9.72	10.1	1.02	0.307
	No. flowers (LN)	7	3	1.745	1.86	1.61	0.107
	Species in flower	7	-0.38	0.269	0.29	1.32	0.187
	Urban 2km (SQRT)	7	-1.4	1.168	1.25	1.12	0.264
	C. pepo area	7	0.58	0.529	0.57	1.02	0.307
Spider species richness	(Intercept)	5	5.49	4.878	5.04	1.09	0.276
	Plant area	5	0.43	0.291	0.31	1.38	0.167
	No. flowers (LN)	5	1.14	0.952	1.02	1.12	0.264
	Urban 2km (SQRT)	5	-0.6	0.681	0.73	0.82	0.412
Spider estimated species richness (Chao1)	(Intercept)	3	-11.98	11.98	12.49	0.65	0.512
	No. flowers (LN)	3	4.84	2.17	2.32	1.92	0.056
	C. pepo area	3	1.47	0.672	0.72	2.05	0.041
Spider diversity (H’)	(Intercept)	4	1.83	0.671	0.7	2.62	0.009
	Species in flower	4	-0.03	0.022	0.02	1.07	0.287
	Plant area	4	0.05	0.046	0.05	1.04	0.3

	Urban 2km (SQRT)	4	-0.11	0.105	0.11	0.99	0.321
Ladybeetle abundance	(Intercept)	4	2.87	1.082	1.12	2.56	0.104
	Mulch	4	-0.05	0.034	0.04	1.46	0.144
	Size	4	1.47	0.982	0.04	1.41	0.156
	Age	4	-0.07	0.049	0.05	1.25	0.211
Ladybeetle species richness	(Intercept)	4	1.9	0.734	0.76	2.49	0.013
	Size	4	1	0.588	0.62	1.62	0.105
	Age	4	-0.05	0.027	0.03	1.61	0.107
	Species in flower	4	-0.04	0.038	0.04	1.01	0.312
Ladybeetle estimated species richness (Chao 1)	(Intercept)	7	4.27	2.294	2.38	1.8	0.073
	Species in flower	7	-0.14	0.075	0.08	1.69	0.091
	No. flowers (LN)	7	0.67	0.504	0.54	1.24	0.214
	Size	7	1.12	0.928	0.99	1.13	0.26
	Grass	7	-0.16	0.133	0.14	1.14	0.255
Ladybeetle diversity (H`)	(Intercept)	7	0.4	0.436	0.45	0.88	0.377
	Size	7	0.34	0.214	0.23	1.51	0.131
	Age	7	-0.02	0.01	0.01	1.4	0.16
	Grass	7	-0.03	0.027	0.03	1.12	0.261
	No. flowers (LN)	7	0.12	0.1	0.11	1.14	0.255
	Species in flower	7	-0.01	0.151	0.02	0.89	0.372
Predatory Hemiptera abundance	(Intercept)	3	-14.8	6.62	7.07	2.09	0.037
	Urban 2km (SQRT)	3	1.67	0.71	0.76	2.18	0.03
	C. pepo area	3	0.74	0.31	.33	2.23	0.026
	Species in flower	3	0.22	0.15	0.17	1.31	0.191
	No. flowers (LN)	3	1.15	0.1	1.07	1.1	0.282
Predatory Hemiptera	(Intercept)	4	-2.61	1.358	1.45	1.8	0.07

species richness	Urban 2km (SQRT)	4	0.49	0.163	0.17	2.85	0.004
	Plant area	4	0.11	0.069	0.07	1.62	0.105
	Size	4	0.7	0.431	0.46	1.51	0.13
Predatory Hemiptera Estimated species richness (Chao 1)	(Intercept)	5	-1.88	3.065	3.16	0.6	0.552
	Size	5	2.39	1.11	1.158	2.1	0.039
	Age	5	-0.09	0.04	0.05	1.92	0.054
	Urban 2km (SQRT)	5	0.623	0.30	0.32	1.95	0.051
	C. pepo area	5	0.171	0.12	0.13	1.31	0.19
Predatory Hemiptera diversity (H’)	(Intercept)	2	-0.882	0.44	0.47	1.88	0.06
	Size	2	0.257	0.15	0.16	1.62	0.103
	Urban 2km (SQRT)	2	0.16	0.06	0.062	2.59	0.001

CHAPTER 2: Latinx and Indigenous Latinx urban gardeners in the central coast of California

Abstract

Latinx and Indigenous Latinx community members approach gardening as practice in relation to structural, historical, and lived experiences they navigate in the central coast of California. In this chapter, I describe how I learn about land, food, and agriculture with gardeners through semi-structured interviews, participant observations, and agrobiodiversity data. I highlight three food groups cultivated by community members: the milpa, tomatoes, and quelites to illustrate the connections, values, and benefits that gardening sustains. Gardening as practice reflects ecological knowledge processes, is political, and expresses self-provisioning strategies. I describe how Latinx and Indigenous Latinx community members who tend to urban gardens continue a practice of being in a relationship with the land through food and agriculture.

Keywords

Land, ecological knowledge, agrobiodiversity

Introduction

It is around 3 pm on a hot August day in San Jose, California. I am standing underneath a tall milpa in a community garden. This milpa is shading us, and the intense heat of the sun's rays starts to feel less intense. The leaves of *maiz* begin to rub against each other, creating a whooshing sound, and for a second, I am transported back to my grandmother's milpa in southern Mexico. If I close my eyes I can visualize the hills in the distance of *el pueblo* and see wood smoke in a kitchen nearby. I hear the clucking of chickens walking near me in the garden. I am afraid of chickens! So, I open my eyes to this bountiful garden in the fifth largest city of California. Daniela, a undergraduate student researcher, accompanies me. This moment of rest allows us to return to our bodies after a long drive from Santa Cruz. We have spent the summer of 2023 traveling up and down the central coast, to connect with Latinx and Indigenous Latinx community members. This work is energy intensive– lots of talking, movement, and introductions, yet our bodies always feel nourished at the end of a conversation with gardeners.

Daniela and I are daughters of Mexican immigrants, and our backgrounds shape our experiences with language, agriculture, food, and the cultural expressions of the diverse communities that make up a vast place called Mexico. As she and I have repeatedly discussed, the embodied experience of carrying out this research work has taught us and transformed us in ways that need more time to digest beyond the timeline of this research. We are incredibly thankful for the people who welcomed a conversation with us–all our learning is relational. This learning or *aprendizaje* could not have occurred without our engagement with gardeners and their stories and the plants that create the conditions for learning that are mediated through the land. Community members' stories and experiences about their ongoing education, tending, and care for their garden plots and plants have provoked us to think more deeply about agroecology. The following writing describes my interpretations of gardeners' words expressed with us.

Gardens as a place are more than physical spaces (Nazarea and Gagnon 2021). A garden is a mosaic of expressions created by community members who come together to shape diverse learning experiences. As a member of the diaspora and a person who is not a gardener but is attuned to social relations with land, I can see how agrobiodiversity in garden plots recreates a landscape away from the local context of the environment. In some cases, Latinx and Indigenous Latinx community members' ecological knowledge reflected expressions of Traditional Ecological Knowledge (TEK). At times, they expressed place-based ecological knowledge emerging from learning with the community. TEK holds that through embodied knowledge, Indigenous communities can transform a physical location into a place they know through memory, remembering, and relationships (Cajete 2000). Latinx and Indigenous Latinx community members are actively tending and rebuilding a connection with the land through gardening.

In some cases, identifying as *campesino* or as a person with agrarian lineage shapes what Rosalinda Guillen called an “unbroken relationship with land” (Guillen and C2C 2017). Speaking Spanish or Indigenous languages sometimes draws from place-based knowledge of plants and their uses–knowing the name of a *quelite* in

Mixteco and how to use these plants' transverse geographical space. And yet, at other times, it is knowledge and experiences with food taste and flavors that shape connections with the land. In this chapter, I argue that immigrant and diasporic communities that use urban gardens continue to practice being in relationship with land through food and agriculture.

Background

Considering these engagements in garden plots requires me to contextualize communities within a larger historical context that shapes gardeners' individual and collective experiences in the places where they live now. Most Latinx and Indigenous Latinx are immigrants or descendants of immigrants who have experienced displacement; many have been pushed out by political-economic policies such as the North American Free Trade Agreement (NAFTA) and Central-American Republican Free-Trade Agreement (CAFTA) (Galvez 2018). Over 500 years, settler-colonial relationships in their homelands and the United States have altered relationships with the land, and these transformations have led to rural-out migration, increasing urbanization, and transnational livelihoods (Najera et al. 2012). Migration experiences increasingly shape communities, and are becoming diasporic with increased movement across political borders, dependence on wage labor, and experiences with racialization processes across space (Lynn 2005, Castellanos 2015). The experience of immigrants employed in industrialized agriculture and the types of structural violence (e.g. health risks due to labor practices and environmental conditions) amplified by the inequality of immigration policies and discrimination is one example of a persistent sociopolitical issue (Mendez et al. 2020, Holmes 2013). Historical and present-day environmental and social conditions shape the everyday experiences of immigrants. Immigrants in the United States (U.S.) navigate structural conditions in their locality that impact their wages and experiences with the cost of living. Estimates suggest that about 80% of agriculture and meat industry workers are immigrants (Fitch et al. 2017). Immigration status has been linked to workers' earnings, with immigrants often earning less than minimum wage and being less likely to earn above the poverty line (Jarayaman and Food Labor Research Center 2014). As of June 2024, the US's inflation rate is above 3%, with food most highly impacted by higher prices (Bureau of Labor Statistics July 2024). Inflation impacts other fundamental human rights like access to affordable housing. The city of San Jose estimates that individuals must earn 59 dollars an hour to afford a 2-bedroom apartment (City of San Jose Quarter 4, 2023). Similarly, in the Santa Cruz-Watsonville area, the average cost of a 2-bedroom apartment is estimated to start at $4,054 (National Low Income Housing Coalition 2024). This, compared with the minimum wage for large-scale agriculture at $15.50 an hour and the California state minimum wage at $16 an hour, highlights a significant discrepancy in the capacity of low-income workers to support their livelihoods (California Department of Industrial Relations 2024). Latinx and Indigenous Latinx gardeners who I spoke with are embedded within these more extensive social relations and the historical processes described above.

At the group level, Latinx and Indigenous Latinx gardeners can also encounter structural inequities connected to land management and power dynamics in the U.S. Land tenure has implications for the place-based connections and experiences that gardeners develop with land and the long-term sustainability of ecological processes that occur in urban agriculture (Ela et al. 2017, Philpott et al. 2023). Many community gardens enter into contract-based agreements with private and local city governments to secure access to land (Arnold and Altieri 2016, Horst et al. 2024). Land tenure insecurity in urban gardens can impact cultivation practices and embodied experiences. For immigrant communities who tend to urban gardens, a potential “double displacement” has been documented in the case of the Beach Flats Community Garden in downtown Santa Cruz, CA, which lost a significant portion of its land under cultivation to the private property owner (Glowa et al. 2018). Glowa et al. (2018) attributed this phenomenon to capitalism; this increases community gardeners’ vulnerability to displacement from local rental housing markets and the garden space itself. Legal tenure and land transfer to underserved farmers and farming collectives are perceived by geographers, political ecologists, and community organizations as most relevant to supporting urban agriculture’s long-term sustainability (McClintock et al. 2018, Hammelman et al. 2022). Yet Indigenous sovereignty and more-than-human understandings of land are increasingly supported and called for as pathways for challenging the reproduction of capital-based relationships with land (Tuck and Yang 2012, Cadieux and Slocum 2015).

Literature Review

So, while historical and political economic processes shape Latinx and Indigenous Latinx daily lived experiences and collective experiences with environments in the U.S., urban gardens can sometimes create opportunities for developing other types of relationships with food and agriculture. Foodways or relationships with foods that hold cultural, historical, or community value are actively recreated by immigrants to sustain connections with their homelands and identities (Abarca 2006, Mares 2012). Foodways can shape garden agrobiodiversity and facilitate access to culturally relevant food crops unavailable in the market (Saldivar-Tanaka et al. 2004, Minkoff-Zern 2014, Philpott et al. 2020). Autonomy over food production and a delinking from the industrialized food system is increasingly observed in urban gardens tended by immigrant communities. This reflects visions of food sovereignty articulated by La Via Campesina in the global south (Mares and Peña 2010).

Scholars in anthropology, critical food studies, and Latinx and Indigenous Studies have learned from communities and documented how immigrant communities sustain the ecological knowledge they carry from their homelands to build connections across space (Hondagneu-Sotelo 2014, 2017, Minkoff-Zern 2019, Valle 2021; 2022). Mares and Pena (2011) call the process of recreating the homeland in a garden space “autotopography,” the process of writing one’s story onto a garden space through material components such as agrobiodiversity and culture. In this framing, garden plots can be read as an expression of individual and community-held knowledge. I hear and I see Mares and Pena’s concept of autotopography as rooted in a historical practice that other displaced communities carry out to build relationships with land. Relational thinking and reading is, in the words of Jones (2023), a way of seeing and highlighting “points of connection and disjuncture across “othered” subjugated epistemologies.” Thus, thinking relationally with Native and Black scholars allows me to see that land-based connections persist across space and are rooted in ways of knowing. Native scholars often see land as an ancestor and relate to land as stewards and students of the land (Simpson 2017, Calderon 2014). Black Geographies scholars highlight how present-day engagements with land are rooted in embodied ways of knowing, self-reliance, and liberatory practices (White 2018, Reese 2019, Carney 2019, Jones 2019). In the global south, frameworks such as sentir-pensar and cuerpo-territorio from collectives of Indigenous women share understandings about how the body and the land are experienced as one, such that resisting the destruction of the environment and the privatization of land-based resources is akin to challenging violence against the body itself (Escobar 2020, Cabnal 2010). Gardening as practice describes my interpretation of this activity carried out by Latinx and Indigenous Latinx gardeners; it emerges from a way of thinking relationally with other communities who persist and recreate connections with land. I do not attempt to recreate a false binary between theory and practice–because practice emerges from theory and vice-versa, but rather, I use the word practice to refer to the constantly transforming, recreated, and changing nature of this activity with gardeners' needs, goals, and learning with each other and land.

Methodology

Data Collection

I conducted 20 semi-structured interviews and participant observations between June and September 2023 (see Table S2.1). I interviewed gardeners who tend to garden plots in San Jose, Watsonville, Santa Cruz, and Salinas. I connected with gardeners by volunteering with a collective of community gardeners in Watsonville, CA. I also contacted gardeners who tend to plots in garden sites visited for ecology research (see Chapter 1). Most semi-structured interviews were approximately 1.5 hours in length and were conducted on the same day that agrobiodiversity data was collected. Agrobiodiversity data was collected from each gardener, who identified each plant by its common name (see Fig S2.1). When possible, I identified spurious vegetation as a measure of non-planned agrobiodiversity, but this was not possible for all garden plots. Semi-structured interviews took place in the garden space while I assisted gardeners with watering, weeding, or harvesting if they extended this opportunity. Other times, per gardeners’ preference, we sat in chairs under a shaded area of the garden space. I was accompanied by Daniela, an undergraduate student researcher at UCSC, for most of this data collection.

Five of the gardeners I connected with identified as female, and fifteen as male. Most gardeners were born outside of the United States, but two of the gardeners are diaspora and were born in the United States. The age of these gardeners ranged from the late 30s to over 60. On average, gardeners have been cultivating a garden for six years. All gardeners spoke Spanish, but two gardeners also spoke Mixteco, an indigenous language spoken in southern Mexico.

Data Analysis

I am guided by Dolores Calderon's (2016) concept of “unsettling reflexivity.” This framework refers to the practice of describing how one arrived at the methodology and reflecting on how settler colonialism makes its way into our research process. Before I held conversations with gardeners, I proposed a research project to learn and document how 1) gardening practices in urban gardens could reflect or differ from rural farming approaches and 2) gardeners' practices expressed alternatives to the food system. Through an iterative process of meaning-making with data, scholarship, and self-inquiry, the writing-up of this research has shifted in a different direction.

My approach to data analysis developed in the following way: first, all audio-recorded semi-structured interviews were transcribed using Descript Inc. software. Second, I used Atlas.ti software to analyze semi-structured interview transcripts and participant observation notes. I coded transcripts for direct responses to the five semi-structured questions (see Table S2.1). Sample codes that guided interview data include “soil”, “watering”, “family”, and “milpa”. Third, I matched common plant names from each gardener's agrobiodiversity data to genus and species using enciclovida.mx and the PictureThis identifier application (Conabio 2024). I also corroborated plant identification across semi-structured interviews and participant observation notes. Fourth, I aggregated data from all 20 gardeners to identify plant species abundance. Analysis of transcript and participant observation codes paired with agrobiodiversity data analysis highlighted a set of common food crops cultivated by gardeners: the milpa, tomatoes, and quelites. I asked myself: What are the uses, values, or connections gardeners describe with these plants? Finally, I returned to search for direct quotations from gardeners for each food group described above.

Following Peterson (2023), I identify food groups cultivated by gardeners to illustrate how I interpret gardening as a practice among Latinx and Indigenous Latinx community members. This is also a way of honoring the orientation of gardeners and aligning with a long tradition among Native and diasporic scholars in the United States and Mexico who lead with food crops as a way of expressing stories of healing, philosophies, and knowledge of the community and the self (Smith 2021, pg. 192-193, Peña et al. 2017). More broadly, foods or plants have been used to interpret and describe broader political-economic relations, histories of oppression, and resistance (Mintz 1985, Carney 2009, Guthman 2019). Traveling with crops in this writing and learning alongside gardeners is how I attempt to re-embed these crops' cultural and historically grounded significance. This chapter asks the following question: How do Latinx and Indigenous Latinx gardeners in the central coast of California express their relationships to land in the contexts where they live now?

Cumulative Agrobiodiversity

Cumulatively, gardeners cultivated a wide variety of plants, fruit trees, and herbs with and without corn (Fig. 2.5). Corn in gardener's plots is most often accompanied by tomatoes, *chile*, *tomatillo*, squash, *nopal*, beans, and strawberries (Table 2.1). In the absence of corn, gardeners cultivate other plants equally as often or more than corn, including *quelite cenizo*, oregano, geranium, purslane, *ruda*, aloe vera, *epazote,* and *hierba mora* (Table 2.2). Corn and tomatoes are produced under highly industrialized conditions in the U.S. and in Mexico with significant consequences for livelihoods (Wise 2008, Browning 2013). Whereas quelites commonly known as "noncultivated but edible plants" or popularly called "edible weeds" in the U.S. are more delicate and perishable, their availability is still limited across standard markets in the United States (Ebel et al., 2024). The agrobiodiversity of garden plots expresses volumes about gardeners' cultural connections and ecological knowledge about these plants. I selected milpa, tomatoes, and quelites to illustrate how I understood gardening as practice.

Milpa

The more time one spends visiting gardens, the more we can see that no two gardens are the same. Thus, we may also see that no two milpas are the same. This is affirmatively stated by a gardener in Watsonville who said, “Everyone here gardens differently.” (ID 16). 15 out of 20 of the gardeners I spoke with cultivated diverse expressions of the traditional milpa system (Fig. 2.2). Additional companion plants grown in the milpa included tomatillo, quelites, and squash (Table 3.1). Milpa, cultivated by Latinx and Indigenous Latinx gardeners, illustrates how gardening involves cultivating relational and place-based knowledge production.

Milpa in tropical systems is built on shifting practices (e.g., slash and burn, swidden, nomadic) and integrates a high diversity of plants, including–corn with squash, beans, fruit trees, and quelites and more (Toledo et al. 2003, see Table 2.1). For example, in tropical environments, communities integrate papaya, coffee or other local trees with the milpa system (Linares and Bye 2011). Milpas across many rural communities in Mexico are a primary land-use cultivation strategy that historically has been used to structure time, common-pool resources, social relations, and strengthen identity ties for Indigenous and Campesino people (ibid).

The milpa I witnessed in urban gardens sometimes included corn, beans, squash, and quelites, reflecting a historical farming practice in Mesoamerica. Yet, I also observed corn growing along a garden plot as a vegetation fence with tomatillo, or corn allocated a couple of rows in the garden plot. The swapping out of companion plants in the milpa is historically understood as an expression of communities' ecological knowledge and regional environmental conditions (Toledo et al. 2003).

Gardeners' knowledge of caring for and tending to the milpa varied depending on their background or lived experiences. For example, a female gardener expressed that her understanding of milpa emerged from learning with and from other gardeners. First, she reminded us that in Chile, the name for corn is *choclo* and not *maiz* as it is known among the Mexican community. As we walked by a tall milpa she said this milpa was *"territorio comunal"* and *e*veryone was welcomed to care for the plant and harvest fruits. As we continued walking around the garden space, she pointed out which plots were tended by Salvadorean and Mexican gardeners that also featured their own milpa and other plants. She said that her own Mapuche friends in Chile are "true agriculturalists." This gardener expressed that gardeners from diverse Latin American countries held knowledge about the milpa both individually and collectively. For her, developing ecological knowledge about the milpa was a process that integrated transnational and community-based knowledge networks. This gardener expressed that she knew who to learn with to get the information needed to cultivate food crops like milpa. This gardener expressed that sharing space and sustaining relationships with other gardeners allowed her to feel connected to foods from land she knows in her way. Gardeners who did not cultivate a milpa at a young age expressed learning how to care for this system through observations and dialogue with others.

A second female gardener shared details about what she has learned about growing a milpa in her garden space through experiential learning. This gardener is self-taught with no background in agriculture or family farming. She expressed that trial and error motivated her to move from frustration to action as she navigated limited resources that helped people learn how to grow food in her community.

During our time together, we learned that she structured her time in the garden as she balanced a full-time job, being a mother, and working with the community. We helped her with weeding as we held a conversation. Part of her ongoing learning process about the milpa was self-reflecting on what type of care best supports the success of milpa. She said:

> "Our sad corn. So everybody's always like, corn is so easy! And I am just not the best corn grower. We planted it in like a Tres Hermanas, you know, with the beans and squash, and I don't know, I'm gonna get better at it. It's a lot of water. And…it needs consistent watering. So I mean, with drip irrigation now, you know, the sky's the limit. I'm only going to get better." (ID 29)

This gardener expressed that her ongoing learning about the milpa has highlighted how knowledge- and time-intensive the milpa is. Reflecting on the knowledge intensiveness of the milpa, she has shifted her way of seeing things and looking towards community-held knowledge to support gardening as practice. She added:

> "And as a community, we are very intelligent people. And especially when it comes to growing food, we have a lot of information and knowledge that is innovative and could be revolutionary. And so that's what I love about our region and space." (ID 29)

Like the female gardener quoted before, this gardener also sees that ecological knowledge of how to grow food is widely distributed at a community level. However, support for caring for the milpa can benefit from interdependence with others who can help care for it, given its time requirement and knowledge-intensive system. This gardener's words also point out that one feature of the continuity of ecological knowledge is dependent on exchanges between those who hold knowledge and those new to developing this knowledge.

Specialized knowledge about the phases of the milpa, or the names for different stages of plant development, were articulated more confidently by gardeners connected with agrarian histories and family farming backgrounds. For example, specific words in Spanish expressed *campesino* knowledge. Gardeners who were older and had experience cultivating a milpa shared specific names for parts of the corn plant and the milpa growing process. These words speak to a way of knowing agriculture specific to their trajectories and learning from community and family knowledge. It also highlights that learning about milpa for some gardeners is relational–meaning that the plant and the land are a source of their knowledge. In one instance, a gardener shared details about his agrarian background:

> "In Mexico, I dedicated myself to farming. But I farmed with animals, by hectares. With animals say horses or a *yunta* composed of *bueyes*. Do you know what *bueyes* are? I farmed over there before coming and then I kept going [to Mexico] and coming back." (ID 16)

The words used by gardeners invoked a way of knowing agriculture more broadly based on a farming background. As a member of the diaspora, I learned some words like *temporal, yunta* and *jiloteando* when I visited my grandmother's milpa in Mexico, but I learned new words from gardeners. Ecological knowledge of the milpa for this gardener occurred with plants, animals, and land in different contexts and conditions. Yet, gardening allowed him to continue expressing his embodied knowledge through language and care for the milpa. Language births entire worldviews, and this gardener's use of specific language in our conversation highlighted that ecological knowledge in gardens is transnational and local.

I experienced a cross-generation knowledge exchange in gardens with community members who saw Daniela and me as students of farming and agriculture. A gardener explained to me, in-depth, his soil preparation approach:

> “But we have to say something to people like you who are learning, you are developing experience and have it forever. The *terreno* is not prepared only one time, how will it give you a beautiful *cultivo*? I turn it two times so that grass does not grow, so why is grass useful, and at the same time it is not useful. Why is it not useful?Well these are *tomatillos*, but everything that is born over there in the middle, the *hierba* and all of that takes away strength from the milpa. It steals nutrients from the soil, although we already added compost and so forth to not add chemicals.” (ID 2).

This gardener shared with us through a nuanced ecological understanding that weeding is an art form as much as a part of the milpa cycle. I grew up hearing weeding being called *deshierbar* in Oaxaca. As I understand it, this is one of the most laborious parts of cultivating milpa. In smallholder communities, weeding has often relied on collective community labor, also called *tequio* where community members come to help each other remove weeds in exchange for mutual support with their milpa. This gardener expressed that milpa is a time-intensive system that relies on previous knowledge and observations to support building and nourishing the soil. Similar to the gardener I quoted before, embodied knowledge of the milpa is relational; this gardener also positioned himself as a learner of the milpa and land-based processes. Our engagement with this gardener allowed me to understand that ecological knowledge processes reflect accumulated knowledge facilitated through practice, experimentation, and repetition as a way of coming to know how best to cultivate a milpa.

Additionally, the exchange of seeds was also part of the flow of ecological knowledge in the garden space, facilitating learning and support for growing milpa. A male gardener pointed to a neighbor's plot as we walked towards his garden plot and said:

> Gardener: "Look at this milpa, this gardener was disillusioned with his milpa. Look, it is very tall but it did not produce. He told me, "Senor Tomas (pseudoname), I am going to ask you to please save a few of your corn for me to plant." (ID 3)

Underlying this, the gardener emphasizes the importance of relationships with other gardeners to learn and support a better harvest. Ecological knowledge, as illustrated by this gardener, reflects gardening as a process of constantly adapting and drawing from other gardener's knowledge to develop a synthesis of the best approaches. The gardener I talked with shared additional details about how he cares for his plants. He shared that he speaks to his plants to show them appreciation, and the principle of space guides how he structures and designs his garden plot. He mentioned learning from people who share their knowledge about gardening via YouTube, and, through this medium, absorbed the idea that sugar levels in plants fall and rise with changing phases of the moon. This conversation with this gardener helped me to understand further that place-based knowledge was increasingly adaptive, responded directly to the local conditions of the environment, and could reflect learning processes among gardeners and broader networks of practitioners.

Overall, gardeners' experiences with milpa illustrate that ecological knowledge reflects learning from the ecology of plants and learning with the community. Ecological and cultural knowledge embodied by individuals and held by the community supports the cultural and historical significance that milpa holds in urban gardens. Thus, the cultivation of the milpa also reflects a refusal to forget connections to places and land beyond the local environment. Milpa, cultivated by gardeners, showcases that gardening as practice is flexible and adaptive and requires deep observation that emerges from positioning of the self as a learner of the land and the community.

Tomatoes

Not surprisingly, the second-most cultivated food in urban gardens included tomato varieties, which serve as a primary ingredient for dishes across diverse Latin American food cultures and around the world (Fig. 2.1). Taste, smell, flavor profiles, and the experience of cultivating that gardening as a practice is also inherently political. It is about food sovereignty and the ability to control the means through which food is produced and experienced.

In the cumulative agrobiodiversity data collected with gardeners, 19 gardeners cultivated the red tomato variety (*Lycopersicum spp.*), and 14 gardeners cultivated tomatillo or green tomato (*Physalllis spp.*) (Table 2.1). The tomato plant has experienced a complex and nuanced history of what ethnobotanists and biologists call “domestication”. Records trace the origin of the red tomato to a wild relative *S. pimpinellifolium* in Ecuador and Peru; the fact that it traveled up to Mexico suggests that communities shaped the adaptation of this crop (Klee et al. 2020). In contrast, the tomatillo or green tomato in Mexico is a species that dispersed without human intervention, probably via bird dispersal, and adapted to parts of Mexico, where it joined as the understory of milpa (Long 2022). Like corn, the red tomato is highly cultivated under an industrialized agriculture model in the United States and Mexico. The red tomato is the ultimate example of homogenization regarding taste, flavor, or, some argue, the lack of flavor (Ekelund et al. 2011). Mexico is one of the top exporters of red tomatoes for the U.S. market (USDA 2024). Capitalist expansion tied to tomato production in Mexico has created a farm labor network that underpays seasonal migrant labor across both sides of the border and this reproduces racial hierarchies and poverty (Barron 2000). So, what can thinking about tomatoes grown in gardens tell us about ecological knowledge in the garden, primarily as we pay attention to the experiences gardeners describe having with these food crops?

Latinx and Indigenous Latinx gardeners who cultivate their food in urban gardens refuse to be limited to a wage-labor connection with food. Their decision to grow their food is a political act. Cultivating tomatoes in urban gardens is a signifier of a different type of nourishment and working with land that farm labor employment limits. Guthman (2017) articulates, “farm labor processes do not so much transform nature as encourage, manage, and eventually harvest it” (Benton 1989). The difference is that in urban gardens, community members can express agency over the conditions of food production. A Oaxaqueño gardener described his labor history in Mexico:

> “We always worked over there in the city of Sinaloa only harvesting tomatoes. Cherry tomato, the apple tomato… but since we came to Ensenada we worked in cilantro, beets, onions, and garlic. That’s how we worked in Maneadero. [We worked] more on the onion because it was too hot for garlic.

> That's what we worked on over there. But in San Quintin we worked…same… on tomatoes as well." (ID 23)

This gardener further described that as a youth in the off-seasons of farm labor, he would return to Oaxaca to tend to the milpa in their community. Gardeners employed in industrial agriculture and who have histories of smallholder farming can put into practice their ecological knowledge in the garden in a way that is limited in the employment space. This gardener has experienced two different visions of working with land to grow food, and his decision to grow food on his terms articulates agency and a commitment to being in relation with land as a producer and not only as a consumer of food. This is aligned with claims of food sovereignty movements, which articulate a right to food and the right to define the conditions under which food is produced. Ecological knowledge held by this gardener is put into practice through gardening and by passing on knowledge to his children. This gardener was accompanied by his son around 6-7 years old. When his son came over and laid his weight on his father's legs and pointed at a bee flying around the garden, the gardener replied:

> "She is helping, so that it [the plant] produces many tomatoes. She is visiting every flower. Everything we give [is] life so that she can eat and that we can eat, right?" (ID 23).

The experiences shared by this gardener express that structural inequities in the food system shape the livelihoods of Latinx and Indigenous Latinx gardeners. Yet it also speaks about how gardening as the practice allows gardeners to teach future generations about ways of knowing land beyond a consumer or worker-only based experience.

Gardeners expressed their politics in various ways–some were more direct and explicit in their communication. A gardener expressed himself confidently:

> Gardener: "I garden because I am against the system."
> Me: "Do you mean the food system?"
> Gardener: nods his head. (ID 31)

This gardener was very direct in guiding my interpretation of his garden. He described that the tomato vines hanging over a wooden fence would not produce anymore. He said I was looking at the second phase of this tomato plant's production cycle and that the plant had already produced many fruits in July. Further, he explained his irrigation strategies, like limiting the watering of his tomatoes so they are richer in sugars and hanging a tail of dog hair to fend off pests like the mole rat. Regarding the ability to harvest his tomatoes when they are ripe, unlike those sold by the market, he added:

> "The taste of a tomato here is something that is very different from the store." (ID 31).

In addition to growing red tomatoes, he grew a variety of chilis, including Dragon's breath chili, *cuerno de chivo* chili and Thai chili (Fig. 2.3). Ecological knowledge expressed by this gardener is experiential and motivated in large part by foodways that reinforces a further sense of connection with land through gardening as practice. This gardener is very attuned to the cycles and rhythms of the garden. His philosophical understandings are guided by his garden. He added, "We are de-ecologizing ourselves." (ID 31). This gardener did not have a background in farming and agriculture; he was trained as a chemical engineer in Mexico, but I heard him express that he was rebuilding his ecological knowledge through gardening. He shared that gardening helped him be in sync with life in a way that differentiated him from only being a consumer in society. Caring for tomatoes, as expressed by this gardener, was about the food itself and the politics of caring for the land as nourishment.

A female gardener and mother of one shared details about her decision to cultivate a wide variety of heirloom tomatoes to self-provision. Her rationale was based on analyzing food prices in the market and her role as the person in charge of food production for her household. She explained:

> Gardener: "If you look for heirlooms in a store like Safeway. How much are you going to pay? Or Whole Foods?
> Me: Maybe 5 dollars a tomato?
> Gardener: 6 dollars a pound!
> (ID 30)

She counted 46 heirloom tomato plants and 60 chili plants in one garden area. This gardener recognized that the market made it unfeasible for her to purchase what she perceived as tastier tomatoes. She expressed concerns about the flavor of tomatoes in food dishes:

> "What did I do with that pack of red tomatoes on the table? Well, I think, half I gifted to others. The other, a quarter I used in the kitchen for *entomatadas* and rice. I only cook *entomatadas* when the red tomatoes are in season, because if you prepare them with roma tomatoes you don't get that taste. Red tomatoes give you a good flavor because they are heirloom…So a quarter I used for foods a quarter I stored. My freezer is filled with tomatoes. They are all unblended, they aren't that big, not like the green zebra or yellow ones over there." (ID 30)

Like other gardeners, this gardener more explicitly expressed economic reasons for growing these crops. When asked about how she learned to garden, she said she learned to garden from gardeners who shared their knowledge via YouTube and this motivated her to garden and to create her own gardening blog. She is the daughter of Oaxaqueno immigrants who came to California for a livelihood. My time with this gardener emphasized that food sovereignty was important for this gardener, and this meant having access to food on her terms. Other gardeners mentioned emphasis on growing tomatoes and chiles as a way of "*ayudarnos*" (ID 24) or helping yourself out by saving money by not purchasing food at the store.

The taste of the tomatillo was also highlighted by another Oaxaqueno gardener who planted this food crop with milpa, various types of quelites, and beans. Tomatillo can be purchased in Latino grocery stores, but this gardener did not express interest in depending on that option. Instead, he and his wife both tended to their garden plot where they could plant seeds of corn and beans they sourced from his home state. The flavor of the milpero tomato variety is distinct from the red tomato as a different variety, and it can give food a unique taste. When asked about what work was pending for the remainder of his season, this gardener said:

> "What's pending is for it to ripen and then you will see there will be a lot of tomatillo. Those tomatillos are of the *milpero* variety. They also come from Oaxaca." (ID 17)

Figuratively speaking and literally, these seeds helped him weave a connection with a place that is far away from the central coast of California. Sourcing culturally appropriate foods directly connected to cultural identity is essential to immigrants' foodways in the United States. This gardener asked his employer to be able to work the land in the back of their home. Cultivating these food crops reflected the significance of foodways and contributions to his livelihood, yet it also allowed him to experience the joy of growing food on his terms. In previous conversations, this gardener shared that his main source of income was employment in the strawberry industry. When asked if he plans to continue gardening the following season, this gardener said: “We’ll see if the señora lets us continue gardening here. We’ll see.” (ID 17) While industrialized agriculture on the central coast does not nourish food sovereignty and gardeners experience land tenure insecurity– communities will practice self-provisioning strategies and find ways to stay connected with land. Gardening as practice, in the case of this gardener, expresses a politics of refusal to stop practicing his ecological knowledge and to allow the industrialized food system to interrupt his understanding of food and relationships with land.

Ecological knowledge processes in gardens respond to industrialized food system and expresses other visions of food production. A politicized experience among Latinx and Indigenous Latinx gardeners emerges from their roles and experiences as workers and consumers. In this context, taste and flavor become inherently political, and these ways of knowing food illustrate how gardening can resist the prices, quality, and food options the food system offers. Collectively, the politics shared by Latinx and Indigenous Latinx gardeners also conveys the possibility of transforming the food system through land access and land tenure to enact food sovereignty.

Quelites

Quelite from the Nahuatl *kilitl* have been known by Indigenous communities in Mexico for a long time, and each plant is given different names (Castro et al. 2011, Ávila 2011). Often known to accompany the milpa in Mesoamerica, the quelites I saw growing in urban garden plots grow with or without milpa (Fig. 2.4, Fig. 2.5, Table 2.2). This aligns with ethnobotanical studies of quelites that observe these plants as spurious in milpas or intentionally planted and protected (Casas et al. 2007). Quelites cultivated by Latinx and Indigenous Latinx gardeners illustrate how gardening as practice expresses a way of being resourceful and self-sufficient.

Drawing from the collective agrobiodiversity of all 20 gardeners interviewed, I learned of several species of quelites cultivated in garden plots: *papaloquelite, quelite cenizo, verdolagas, alache, quintonil, yerbamora, hierba santa, epazote,* and *lengua de vaca.* Quelites are considered nutrient-dense plants that complement the starchy composition of corn-based foods in Mexico (Bye 1981).

In a conversation with a female gardener, I learned about how quelites and other herbs contribute to plant diversity in her garden space throughout the seasons. Transportation paired with seasonal employment in the strawberry industry limits her time in the garden. When asked about what her garden looks like with the changing seasons, she explained that she only gardens during the summertime. She fallows her plot during the wintertime. In the wintertime is when *hierba buena* an aromatic medicinal herb, and *hierba santa,* a nutrient-dense quelite grows and remains in her garden plot (ID 35). Allowing quelites like *hierba santa* to grow in this gardeners' plot reflects the strategic use of time in between seasons to derive benefits from the garden. From other interactions with this gardener, I know that she is a steward of many food recipes from her homeland, and her knowledge of food and flavor is much appreciated and contributes to community food exchanges. Quelites and specific bean varieties that she cultivates express a way of being self-sufficient and resourceful. Although I did not follow up to ask about particular food dishes prepared with *hierba santa*, other gardeners provided more details about how they are integrated into diets.

A Oaxaqueno gardener I quoted above, speaking about tomatillos, welcomed me to visit his garden several times. On one occasion, when I helped him and his wife place strings for holding the bean plants, I was invited to have breakfast with them. Our food plate included *quintonil* and beef. He mentioned that he saw *quintonil* growing in his workplace, and he brought the seed back to his garden plot. In addition to growing *quintonil*, this gardener also grew other quelites like *alache* and *hierba mora*. *Hierba mora* (*Solanum nigrens*) is a *quelite* that produces black and purple berries. It grows in the U.S. through Chile in South America (Fig 2.4b) (Torres-Garcia et al. 2023). Whereas *alache (Anoda crsistata (L.) Schl.*, Malvaceae) is a plant distinguished by a beautiful flower featuring white, lavender, or blue colors and it can grow in land types between the U.S. to Bolivia (Fig 2.4a). Yet alache is most commonly known in Mexico, where it is both a cultivated and a roadside plant across various states (Rendon et al. 2001). This gardener shared that his daughter shipped him seeds of *alache* from Oaxaca. He dedicated an entire row to *alache* reflecting a protected approach to growing quelites. He described his way of cooking with this *quelite*:

> “ I can cook *alache* with squash or you can take some today and we can go look for a squash and you cook it yourself…. And it’s good, a lot of people from Oaxaca like to eat *alache*, yes. (ID 17)

Similarly, the protection of quelites as a primary food crop was very apparent in a different gardener’s plot who cultivated *papaloquelite* in pots (Fig 2.4d). This gardener said that in his experience, the milpa required too much space, which he was not willing to give to the milpa alone. He explained how he did not know about milpa because he grew up in an urban center in Mexico. But when he migrated to the U.S. and was searching for employment, he came to help an older resident gardener, and there he learned about the milpa. Later, he joined an Aztec group dance, through which he learned about GMO corn and how it was changing genetic diversity and health in Mexico. He felt motivated to grow his corn, but after years of experimentation, he decided not to cultivate milpa to create more space for other plants, including *papaloquelite*. His garden is covered by a viney chayote plant, hanging baskets of flowers, and approximately 20 pots of *papaloquelite*. This gardener reported he primarily consumed *papaloquelite* on the side with food, and he compared it to cilantro. He also shared he exchanges *papaloquelite* with other gardeners for other food items.

Gardeners' cultivation or welcoming of quelites express self-provisioning as a connection or acknowledgment of ancestral and Indigenous knowledge that supports the ability to harness and utilize plant diversity. In some cases, the cultivation or welcoming of quelites in the garden plot reflected a taste preference and place-based knowledge of these plant names in Indigenous languages. Quelites also connect community members to a place outside of their local environment, but more specifically, they reflect a way of knowing how to reshape agrobiodiversity on land. Quelites reflect the principle of using all resources as much as possible, and resourcefulness and self-provisioning nourishes gardeners' ways of being in the world.

Discussion

This chapter asked: How do Latinx and Indigenous Latinx gardeners in the central coast of California express their relationships to land in the contexts where they live now? I have learned that gardening supports Latinx and Indigenous Latinx community members' relationship with land through food and agriculture. Gardening as practice is embedded within ecological knowledge processes, is political, and expresses strategies of self-provisioning. The milpa, tomatoes, and *quelites* reflect values, uses, and connections essential to community members. By centering food, we can see that claims to food sovereignty and foodways remain ever present among Latinx and Indigenous Latinx community members who garden. Experiences shared by community members suggest that gardening is vital for expressing ways of knowing and being in the world.

To return to Calderon’s (2016) “unsettling reflexivity” framework that guides this chapter, I will share teachings that have emerged from my learning with gardeners. I have learned that centering the philosophies of the communities in which we work requires us to engage in a deep process of learning, unlearning, and relearning. In this sense, our language and translation, analytical frameworks, and how we articulate this with community-based and Indigenous ways of knowing is a learning process. In the words of Patricia Gonzales (2020) I have come to understand that "knowledge and knowing are two different things. Deep knowing carries the implicit order of our ancestors, of values that are more than thought about but are a living imprint." Learning how to honor and hold our worldviews while at the same time holding and learning about the worldviews of the communities we work with is another essential teaching I take with me. The words of Simpson (2017, pg. 49) resonate with my educational trajectory:

> "If you do not know what it means to be an intelligent within Nisshnaabeg realities, then you can't see the epistemology, the pedagogy, the conceptual meaning, or the metaphor, or how this story has references to other parts of our oral tradition, or how this story is fundamentally, like all of our stories, communicating different interpretations and realizations of an Nisshnaabeg worldview."

Learning to work with diverse ways of knowing has been a lesson in listening, taking steps back, looking inward, and adapting. For example, learning with and from the collective of urban gardens in Watsonville was formative for my scholarly and personal growth. I experienced a community education with them, encouraging me to rethink research work. I attribute credit to the organization for helping me rephrase how to ask about land preparation methods. I take away lessons for reweaving the ways in which I may be able to be in solidarity with land-based organizations and farming communities.

Table 2.1 List of plants grown more often in the same plots as corn. This table shows all the plants cultivated by at least one gardener.

Plant name	No. gardeners cultivating
tomato	19
chile	15
tomatillo	14
squash	13
nopal	12
beans, black	11
strawberry	11
cucumber	10
cilantro	9
mint	9
onion	7
chilacayote	7
sunflower	7
potato	6
kale	6
garlic	5
amaranth	5
bunching onions	5
chayote	5
peach	5
hierba santa	5
sage	5
zucchini	5
agave	4
beans, green	4
celery	4
guava	4
lemon balm	4
sugarcane	4
artichoke	3
bearded iris	3
fig	3
parsley	3
radish	3
apple	3

avocado	3
blackberry	3
borage	3
chamomile	3
dahlia	3
lemongrass	3
pomegranate	3
watermelon	3
artemisia	2
beets	2
cabbage	2
carrot	2
edible weed	2
fava	2
hollyhock	2
Jerusalem artichoke	2
lavender	2
loquat	2
olives	2
regal pergonium	2
sweet potato	2
thyme	2
wild radish	2
yarrow	2
aceitilla	1
agave, foxtail	1
alyssum	1
arnica	1
bean, white	1
belladona lily	1
bindweed	1
bitter orange	1
blue blossom	1
blueberry	1
Brassicae sp.	1
California brittle bush	1
California fuchsia willowherbs	1
California poppy	1
Cane cactus	1
cauliflower	1

Cherimoya	1
cherry	1
cherry, black	1
chickpea	1
chives	1
coyote melon	1
crying tree	1
cucurbita maxima	1
dill	1
elderberry	1
elephant garlic	1
fennel	1
hairy crabgrass	1
hardy fuchsia	1
hedge nettle	1
Huizachi	1
margorum	1
marigold	1
melon cucumber	1
Mexican wild pistachio	1
milkweed	1
mugwort	1
mullein	1
nance	1
nettleleaf goosefoot (*quelite*)	1
passion fruit	1
peanuts	1
peas	1
pirul	1
plum, cherry	1
plum, Chinese	1
poppy	1
pot marigold	1
prickley lettuce	1
quelite	1
quina	1
raspberry	1
red valerian	1
redroot pigweed	1
rhubarb	1

rose, china	1
rose, hybrid tea	1
scarlet pimpernel	1
sleepy morning	1
sorghum	1
speedwell	1
spinach	1
strawberry tree	1
succulent	1
sullus spurge	1
sullw spurge	1
sweet alyssum	1
sweet cherry	1
tomato	1
tree stonecrop	1
Tropical Pokeweed	1
trueno	1
unbrellaworts (mirabillis)	1
white sage	1
willow tree	1
winter squash	1

Table 2.2 List of plants grown equally as often or more often in plots without corn.

This table shows all the plants cultivated by at least one gardener.

Plant name	No. gardeners cultivating
Lambs Quarters (*quelite cenizo*)	8
oregano	8
geranium	6
purslane	6
ruda	6
aloe vera	5
epazote	5
hierba mora	5
melon	4
rose	4
lemon	3
morning glory	3
rosemary	3
African marigold	2
asparagus	2
basil	2
common comfrey	2
dandelion	2
dandelion root	2
feverfew tansies	2
gladiolus	2
grapes	2
mandarin	2
nasturtium	2
papalo	2
quintonil	2
achitaba	1
alfalfa	1
anise	1
black cumin	1
blue agave	1
bogaumville	1
fern	1
guaje	1
guamuchilillo	1

lemon verbana	1
longetivity spinach	1
loofah plant	1
Mexican petunia	1
montbretia (palmira)	1
pine tree	1
pineapple guava	1
pitiona	1
plum	1
san pedro cactus	1
smooth rattlebox	1
watercress	1

Figure 2.1: Image of fruits and vegetables gifted from gardeners in San Jose. A variety of chilis, *calabacitas* and tomato varieties cultivated by different gardeners.

Figure 2.2. Expressions of the milpa system in urban gardens. The gardens are located (a) in a San Jose, CA community garden, (b) in the Royal Oaks community in Watsonville, CA, (c) a milpa located in Watsonville, CA, and (d) in Santa Cruz, CA.

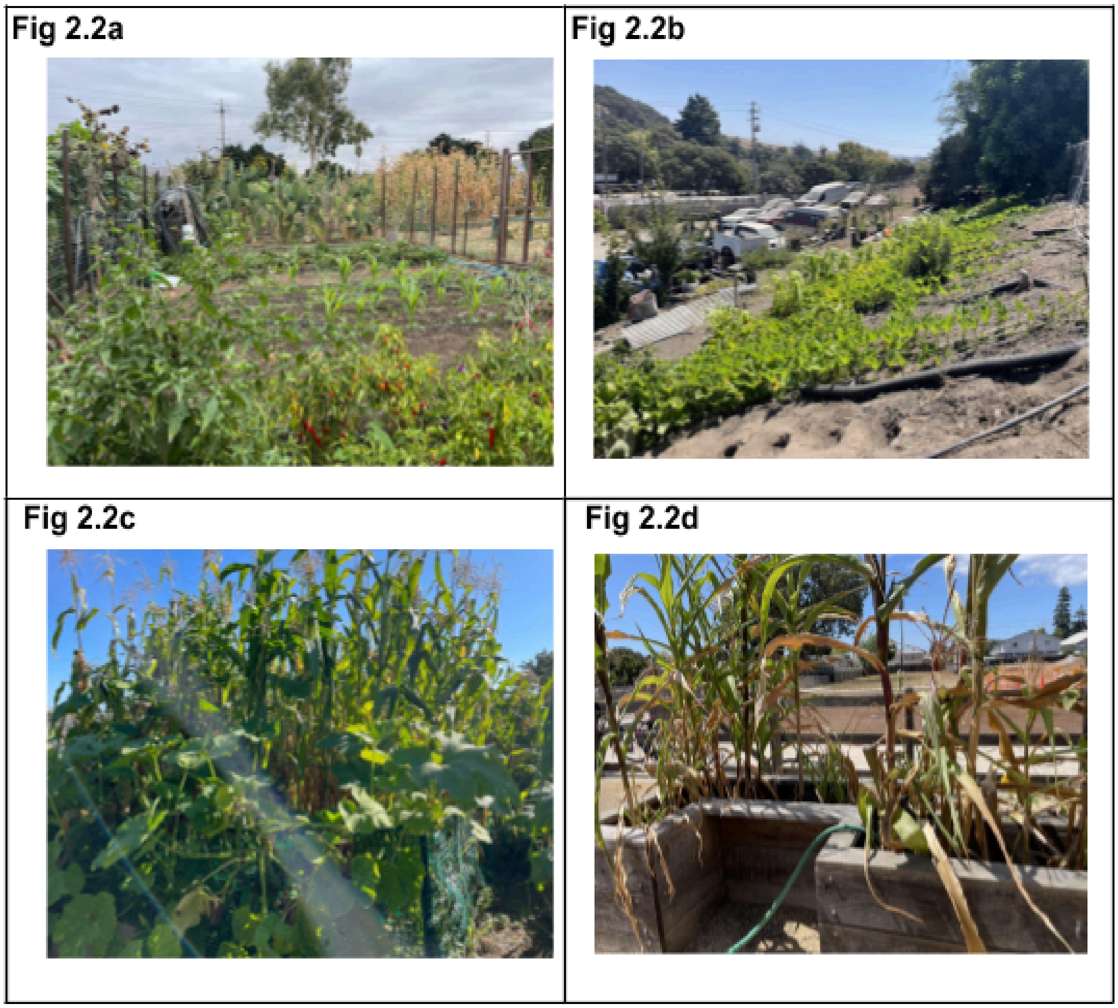


Fig 2.2a

Fig 2.2b

Fig 2.2c

Fig 2.2d

Figure 2.3 Expressions of the tomato varieties in urban gardens. The panels depict (a) a raised-bed of heirloom tomato varieties in a community garden in San Jose, CA, (b) a raised-bed of tomato and chili plants in a community garden in San Jose, CA, (c) a direct-planting of tomato and potted chili varieties lined with chayote in a community garden in San Jose, CA, and (d) a direct-planting of tomato and chili plants intercropped with other plants in Watsonville, CA.

Fig 2.3a

Fig 2.3

Fig 2.3c

Fig 2.3d

Figure 2.4 Expressions of quelites cultivated in urban gardens. The panels show (a) a picture of alache cultivated in a row in the back of a home in Salinas, CA, (b) yerbamora cultivated in a garden in Watsonville, CA, (c) purslane growing in between rows of strawberry intercropped with cilantro in Watsonville, CA, and (d) papaloquelite grown in pots in San Jose, CA.

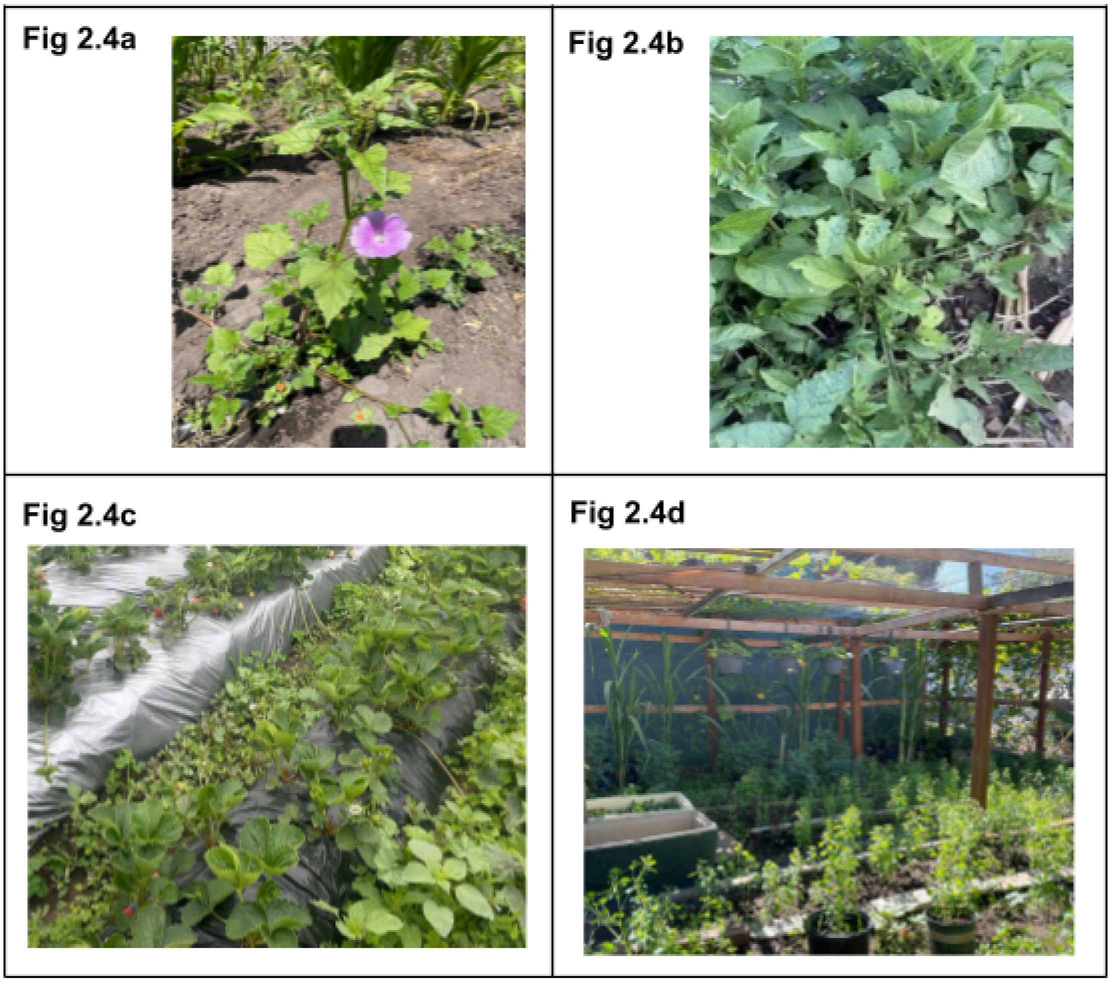
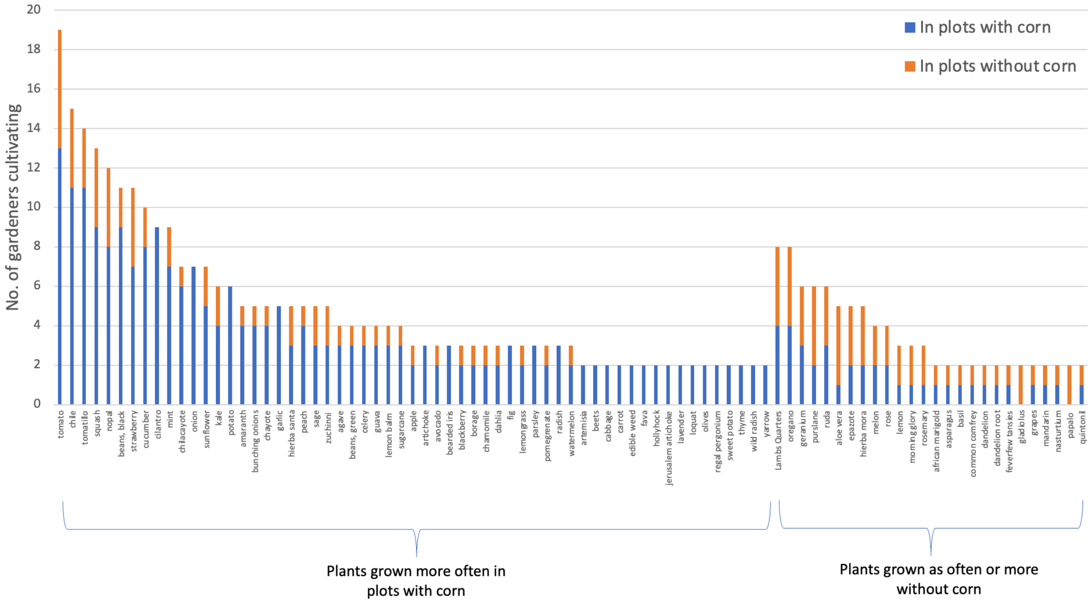


Figure 2.5 Garden plants cultivated in plots with corn and without corn in garden plots. This graph identifies which plants grown by at least two gardeners are more likely to co-occur in plots with corn or at least 50% of the time or more in plots without corn.

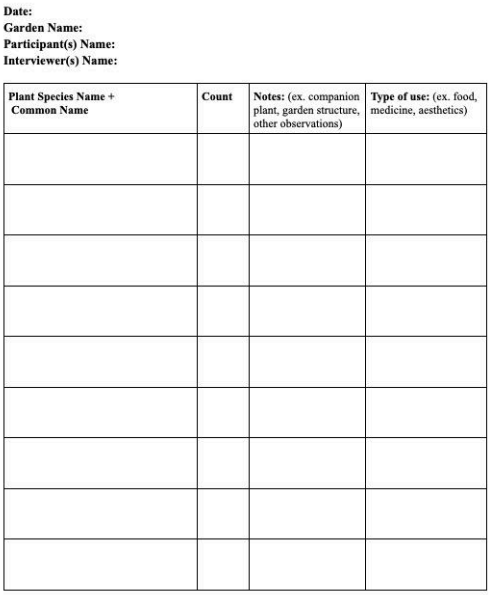


Supplemental Information

Table S2.1 Semi-structured interview questions that guided conversations with community members.

1) What are you growing in your garden?
2) How did you learn about agriculture?
3) How do you prepare your soil?
4) What ecological challenges do you confront in your garden space?
5) What work is pending in your garden for the remainder of the season?

Figure S2.1 Agrobiodiversity data collection sheet.



Date:
Garden Name:
Participant(s) Name:
Interviewer(s) Name:

Plant Species Name + **Common Name**	**Count**	**Notes:** (ex. companion plant, garden structure, other observations)	**Type of use:** (ex. food, medicine, aesthetics)

CHAPTER 3: Ecological knowledge of insects an emergent feature of urban gardening

Abstract

Community gardeners’ ecological knowledge of insect communities can support gardening goals and insect conservation. This chapter considers how the lived and learning experiences of community gardeners contribute to their ecological knowledge of insect roles in urban agriculture. We used an online survey that included both an insect identification activity (featuring pollinators, herbivores, and natural enemies) and questions about gardener lived experience and various knowledge sources used by gardeners to learn about what ecological roles gardeners attribute to insects (and spiders) and which factors are associated with more detailed insect knowledge. We learned that overall, gardeners are highly knowledgeable about insect roles in gardens, correctly identifying between 71-83% of the time, on average. Female gardeners are more likely to identify pollinators. Participating in the UC ANR Master Gardener (MG) program is strongly associated with a higher likelihood of identifying herbivores and natural enemy functional groups. We reflect on knowledge of how gender interacts with ecosystem management and consider the specific features of MG's program-based training that may explain our findings. Finally, we self-reflect on how identifying and categorizing functional insect groups may not be necessary if gardeners already adopt ecological approaches that attract diverse insect groups (and spiders), which can create autonomous ecological systems in community

gardens.

Key Words

Functional insect groups, ecology, urban agriculture

Introduction

Community gardeners can come to know insects in diverse ways, including cultural, spiritual, and historical connections. However, identifying insect functional groups as allies and beneficial partners in the garden can enhance ecological knowledge processes that support insect conservation (Lavoipierre 2021). Insects contribute to pollination and herbivore regulation, supporting fruit production and food crop health (Kremen et al. 2007). Estimates suggest that insects and other animals facilitate the pollination of approximately 90% of wild flowering plant species and globally important crops (Ollerton 2012, Potts 2016). Natural enemy insect species are estimated to contribute to up to 50% of non-chemical biological control in crop fields (Pimentel et al. 2005). Yet, insect habitat is susceptible to human land-use transformations associated with agricultural intensification and urbanization processes (Sanchez-Bayo et al. 2019). To support insect conservation, various management approaches that are ‘pollinator-friendly’ or ‘biodiversity-friendly’ have been identified for application across rural and urban landscapes (Tschanrtke et al. 2021). Urban spaces like community gardens are a type of agricultural space with high potential to support habitat for different insect functional groups (e.g., Lin et al. 2015, Hall et al. 2016). Gardening approaches that create insect habitat (i.e. high plant diversity, soil conservation strategies, and or cultural practices) are prominently observed in community gardens (Surls et al. 2022). Gardeners may be consciously or unconsciously gardening with insects in mind. Yet, a differential ability to recognize insects that provide ecosystem services in gardens, such as pollination or pest control, may impact how aggressively gardeners work to conserve insect diversity.

Insect behavior, including buzzing, flying, or stillness, can be observed by gardeners through their everyday interactions with plants and the environment. Still, some insect species that provide ecosystem services are generally more known than others. Studies about ecological knowledge of insects and their associated ecosystem services reveal that pollination is more commonly known among farmers than natural biological control processes (Quinn et al. 2015, Date et al. 2024). This is especially the case among farmers where biological control services provided by natural enemies have been "under-estimated" or less known compared to pollination (Martinez-Sastre et al. 2020). Even so, the diversity of animal species contributing to pollination services is generally underrecognized among the public and biased toward specific insect groups (Wilson et al. 2017, Iwasaki et al. 2021). Bees and butterflies are perceived to be more charismatic than flies and wasps (Sumner et al. 2018). Managed species like the honey bee (*Apis mellifera)* are well-known among the public. Yet, scientists have emphasized knowing native bee species and non-bee pollinators that also contribute to crop pollination (Oberhauser et al. 2009, Klein et al.

2018). These non-bee pollinators (i.e., flies and wasps) visit significant crops more frequently than bee pollinators (Requier et al. 2024). For example, non-bees visit global crops (i.e. coffee, tomato, almonds, pumpkin) approximately 23-50% more than bee-only pollinators (Rader et al. 2015).

Moreover, lesser-known pollinators like hoverflies and other flies carry up to 84% of the flower pollen across farmlands (Orford et al. 2015). Still, the diversity of certain natural enemies such as parasitoids is vast, with about 74,000 known species of parasitoids just from three insect groups: wasps (Hymenoptera), phorid flies (Diptera), and tachinid flies (Diptera) (Heraty 2017). However, knowing parasitoids and seeing them in the garden space can be challenging given their small size (e.g., between 0.5 - 2.4 mm) layered with their cryptic or “out of sight” life cycles often not visible to the human eye. Other generalist predators, like spiders, prey on soft-bodied insects and eggs, but their body movement and appearance often induce fear among the public (Lindner et al. 2017, Zvarikova 2021). On the other hand, more well-known and charismatic predators like ladybeetles benefit from positive cultural associations (Vanderstock et al. 2022). Overall, insects' unique anatomy, life strategies, and lives may draw observations and curiosity from gardeners, yet differential knowledge of insect groups may reflect broader social and cultural processes.

Learning experiences

Group-based learning experiences can contribute to gardeners' ecological knowledge of insects. The primary motivations for gardening are food access, health and well-being, community-building, and cultural expression (Gray et al. 2014). Yet, gardening as a social practice can develop robust and deep ecological knowledge by integrating observations, experimentation, and learning with and from other gardeners (Andersson 2017). Collectively managed gardens can create “communities of practice” whereby knowledge is held above the individual and held in a material form or embodied by gardeners to support the management of land-based resources in the garden, food crops, and insects (Wenger 1999, Barthel 2014). Specifically, group-based learning experiences in workshops, cooperative member training, or farmer field schools have increased participants' knowledge of beneficial insects (Segura et al. 2024, Mariyono et al. 2013). Thus, accounting for group-based or training program experiences can shape gardeners’ knowledge of insect ecological roles.

Lived experiences

At the individual level, social and cultural diversity - such as experience, farming background, and cultural notions- may influence gardeners' ecological knowledge. Among the general public, the values, goals, and thresholds of risk or emotions (e.g., fear and distrust) towards insects are connected to the individual perceptions of biological control approaches (Catton 2021). Rural farmers express divergent perspectives in appreciation for insect diversity or identification of insects as ecosystem providers (Busse et al. 2021). Farmers’ perspectives emerge from diverse values and worldviews that reflect how their livelihoods are situated within structural and political-economic conditions that shape production-oriented goals and intrinsic values for biodiversity (ibid). In the global south, gender and cultural knowledge are linked to emotional connections and care for pollinators. For example, stingless bees (i.e. *Meupona Beecheiiamong)* have been historically managed by Mayan communities, with female beekeepers taking the lead (Bratman et al. 2020, Muñoz 2018). Nonetheless, all individuals can experience a sense of 'commoning' with nature through gardening, leading to an appreciation for insect diversity (Bergame 2023). For example, gardeners with more experience gardening are more likely to experience biophilia and appreciation for wildlife, including insects (Lin et al. 2018). Time spent in the garden, which reflects individuals' backgrounds and capacities, has been linked to a higher likelihood of reporting pests among individual gardeners in California urban gardens, reflecting ecological knowledge (Liere et al. 2020). Still, not all insect species are equally appreciated. For example gardeners have expressed negative emotions towards wasps because of a perceived risk of being stung, leading to this insect species being overlooked as ecosystem providers (Schmack et al. 2024). Studies of farmers, public, or gardener's ecological knowledge of insects have usually highlighted specific insect species, yet the emphasis on the knowledge of multiple functional groups (i.e. pollinators, herbivores, and natural enemies) has received less attention in the global north (Tatiana et al. 2022, Rawluk et al. 2019). Gardens, like other ecosystems, involve complex ecological interactions. Therefore, considering the knowledge that gardeners develop can help us understand how ecological knowledge in urban gardens may support insect conservation.

In this study, we add to research considering how ecological knowledge of insects can emerge in agricultural systems by centering urban community gardens. To conduct a snapshot analysis of gardeners' ecological knowledge of insects, which can be multidimensional and expressed in ways not captured by a survey, we drew associations between insect identifications and gardeners' lived and learning experiences. Specifically, we were interested in learning about which insects gardeners associate with specific feeding strategies and ecological roles in gardens (e.g., pollination, predation, and herbivory) and the lived and learned experiences of gardeners that shape this knowledge. We specifically asked: (1) How well can gardeners recognize insects that are members of particular functional groups (e.g., pollinators, natural enemies of pests, and herbivore insects) and (2) What gardener demographics and learning experiences are associated with the likelihood of identifying insects that are members of particular functional groups (e.g., pollinators, natural enemies of pests, and herbivore insects) groups? We expected that knowledge of functional groups would increase with their years of gardening experience and formal education in environmental or biological sciences.

Methods

Online gardener surveys

We distributed an electronic survey using Qualtrics to garden managers of 21 community gardens in Monterrey, Santa Clara, and Santa Cruz Counties (Appendix A). These gardens have hosted ecological research on beneficial insect research since 2016 (e.g. Egerer et al. 2017a). We also asked a regional Urban Agriculture and Food Systems Advisor employed by the University of California Natural Resources (UCANR) to distribute this online survey to members of the UCANR Master Gardener certificate-based program. Survey-based tools are helpful under specific circumstances to capture rapid knowledge of broad and geographically distributed populations such as the communities represented across urban community gardens (Khanal et al. 2020). This electronic survey was designed to simulate the individual experience of categorizing and identifying the ecological roles of three insect (and spider) groups in real-time. Following the study design of Wilson et al. 2017, which centered on bees as a model system, we selected species from three insect groups (i.e. pollinators, herbivores, and natural enemies) that may be visitors in community gardens on the central coast of California. We prompted gardeners with three multiple-choice questions, each featuring eight images of insects (or spiders).

The first question asked, “Which of these organisms are pollinators?”. The second question asked, “Which of these organisms eat plants and may cause crop damage?”. The third question asked, “Which of these organisms protect crops from pests?”. The survey questions were designed to decenter technical and ecological scientific language to describe insects (e.g., herbivores, natural enemies). The concept of pollinators was assumed to be common knowledge based on the high visibility of this ecological interaction in gardens and widespread knowledge about the role of bees in the environment (Hall 2020). We do not refer to herbivores as pests in the surveys presented to gardeners because the concept of “pests” can carry a value judgment that assumes a bias toward production-oriented agriculture (Morales et al. 2000). We also asked gardeners to share information about their backgrounds including lived experiences and garden learning experiences to gather information about sources of knowledge and unique social processes that can shape gardener ecological knowledge of insects (see Appendix A). We collected data about gardeners self-identified gender, age, whether they had a formal degree in biology, natural resources, environmental studies, or related field, whether they are a Master Gardener, whether they’ve learned about biology, ecology, or how plants and insects interact from other sources such as spending time outdoors and observing, from family and friends, classes, or from other activities, and whether they have a background in agriculture, farming, or farm work. We coded responses as social connections if gardeners’ responses expressed direct learning from other gardeners and family or friends supporting their knowledge of insects and plant interactions. We expected this survey to take approximately 10-15 minutes to complete, but there was no time limitation, and this survey remained open during June - August 2023.

Limitations to this online survey include language and online or email access only. This survey was only made available in English; therefore, it was likely inaccessible to non-English speakers and gardeners who do not subscribe to email communications. The recruitment approach and format of this survey design could have yielded different results with alternative recruitment efforts in-person and accessibility featuring language translation or the collection of group responses. Alternative communication methods can help connect with diverse populations of different socioeconomic and cultural backgrounds (Stocklin-Marois et al. 2011, Peterson et al. 2024). The Human Subjects Research office at the University of California, Santa Cruz, reviewed and approved this survey in April 2023.

Data analysis

Survey data responses included categorical (e.g., gender, formal degree), numerical responses (e.g., age), and open-ended responses (e.g., other sources of insect-plant knowledge). We removed survey responses left blank for any demographic variables included in our general linear model only. We coded open-ended responses to this question: Have you learned about biology, ecology, or how plants and insects interact from other sources? If so, how have you learned? We identified the following codes: education, experiential, family, other gardeners, program training, public media, and social connections. To determine which insect organisms were correctly and incorrectly categorized as part of each functional group (i.e. pollinators, herbivores, and natural enemies) by survey participants, we calculated the frequency of correct multiple-choice responses for each insect functional group. To learn about any potential association between the frequency of correct responses for each functional group and gardener background, lived and learning experiences, we used General Linear Models (GLM) with a link function in R to transform proportions into probability responses between 0 and 1 (R Core Team, 2021). Using the ‘cbind’ function in R we calculated the proportion of correct and incorrect responses for each insect identification question and used a ‘binomial’ family distribution for analysis. We included the following as predictor variables: gender, number of years gardening, Master Gardener (yes/ no), formal degree in ecology, biology, environmental studies or related field (yes/ no), and agricultural background (yes/ no). We used two sets of response variables, including the overall number of correct (and incorrect) answers and the number of correct (and incorrect) answers for “difficult to ID insects” (see results).

Results

A total of 153 gardeners responded to our online survey. However, some submitted responses were left incomplete for one or more predictor variables. Thus, we included 146 survey responses in our analysis. If any coded responses for open-ended questions were left unanswered, we classify these as “na.”

Backgrounds of community gardeners

In the survey responses, 108 gardeners identified as female, and 39 identified as male. The total number of years spent gardening spanned from 1-70 years. In terms of agricultural background, 24 gardeners reported having an agricultural background and 123 gardeners did not report any agricultural background. About 40% (or 58) of gardeners are enrolled in the Master Gardener program, and 89 gardeners are not associated with this type of program training. Only 28 gardeners reported a formal degree in ecology, biology, or environmental studies, and 119 did not have a formal education degree in these sciences.

Gardeners reported multiple sources of knowledge that they engage with to learn about gardening continuously (Fig. 3.1). Public media (23%), program training (24%), and experiential learning (23%) are relatively equally reported by gardeners as continual sources of garden learning. Education (11%) and social connections (15%) were reported less but were not exclusive to other learning.

General trends from survey data

Overall, gardeners correctly identified most insects into functional groups. Most gardeners correctly identified 5-7 pollinators, herbivores, and natural enemies out of the eight photos provided for each group (Fig. S3.1). On average, gardeners correctly identified 6.7 out of 8 pollinator species (or 83.75%), 6.7 out of 8 herbivore species (or 83.75%), and 5.7 out of 8 natural enemy species (71.25%) (Fig. 3.2).

The specific species of insects that gardeners correctly classified varied considerably (Table 3.1). First, in the pollinator category, there were two bee species nearly all gardeners correctly identified (Fig. S3.2). Bumble bees were identified by 97% of gardeners, and honey bees were identified by 95% of gardeners. The three other pollinator species presented to gardeners were less often correctly identified. These included *Agapostemon texanus* (sweat bee), which was correctly identified by 68% of gardeners, *Syrphus* sp. (hoverfly) correctly identified by 77% of gardeners, and *Osmia* sp. (mason bee) correctly identified by 79% of gardeners. Similarly, two highly recognized species were in the natural enemy species category (Fig. S3.3). This included *Hippodamia convergens* adult (convergent lady beetle), correctly identified by 92% of gardeners, and the *Pardosa* sp. (wolf spider), identified by 84% of gardeners. Two species were less often correctly identified as natural enemies, including the Ichneumonidae parasitoid (62% correct) and the *Hippodamia convergens* larva (convergent lady beetle) (57% correct). The *Geocoris* sp. (big-eyed bug) was infrequently correctly identified (only 12% correct). In the herbivore category, two species that gardeners highly identified included the *Tricoplusia ni* (cabbage looper larva) (95% correct responses) and the *Brevicoryne brassicae* (cabbage aphids) (94% correct responses)(Fig S3.4). The other three herbivores were less often correctly identified, and these included the *Anasa tristis* (squash bug) (71% correct), *Diabrotica undecimpunctata* (cucumber beetles) (64% correct), and *Murgantia histrionica* (harlequin bugs) (58% correct). Two trends emerged from this data: first, there was a set of insects that were most commonly or highly identifiable by survey participants (correctly identified by > 80% of gardeners), and there was a set of "difficult to ID" insects correctly identified by 40-80% of gardeners. To explore the possibility that variance between the two observed trends could be explained by unique or combinations of predictor variables, we ran two analyses.

Two factors were overwhelmingly important for gardeners' ability to identify insects correctly: gender and participation in the Master Gardener Program (Fig. 3.2, Table S3.1). Female gardeners were more likely to correctly identify all pollinators (p=0.008), as well as the "difficult to ID" pollinators (p=0.003). Gardeners enrolled in the Master Gardener program were more likely to identify herbivores across all multiple-choice options (p=0.002) and the “difficult to ID” herbivores in this category (p=0.01). An agricultural background among gardeners was marginally associated (p=0.07) with the likelihood of identifying all herbivores and the “difficult to ID” herbivore species (p=0.057). Gardeners enrolled in a Master Gardener program were also more likely to identify all natural enemy species (p=0.026) and the “difficult to ID insects” in this category (p=0.006). A higher number of years spent gardening was marginally associated with the likelihood of identifying a higher proportion of all-natural enemy insects (p=0.059). The number of years spent gardening (p=0.098) and a formal degree in ecology, biology, environmental studies, or a related field (p=0.066) were also marginally significant for the “difficult to ID insects” in the natural enemy group.

Discussion

Gardeners correctly identified many insects according to their functional roles as insects (and spiders). Gardeners correctly identified between 73-85% of insects on average. Gender was most strongly associated with the likelihood of identifying pollinator species, and participation in the Master Gardener program was strongly related to the probability of identifying herbivores and natural enemies. Agricultural background was marginally associated with the probability of identifying all herbivore species, and the number of years spent gardening was marginally related to the probability of identifying all natural enemies. A formal education in biology or related fields was marginally significant only for identifying the “difficult to ID" natural enemies. In our study, we single out unique aspects of community gardeners’ backgrounds (i.e. gender, agricultural background, number of years spent gardening); each of these lived or learning experiences is linked to social processes of learning and knowledge development. Our interest in drawing associations is to identify broad patterns that can be pursued with further study.

Discussion

Pollinators and gender

We prompted gardeners to identify pollinators beyond bee species and less-recognized pollinator species with different life strategies. We presented images of two social bees (honey bee and bumblebee) and two solitary bees (sweat and mason bee). Social species are bigger, and they may be observed in more significant numbers visiting flower resources inside and outside community gardens. In contrast, sweet bees are soil nesters, and mason bees nest in logs or other wooden cavities (UCANRc). We included an image of a syrphid fly, but we did not prompt gardeners with images of wasps, a less-known pollinator species that has been reported as a less-preferred or liked pollinator (Schmack et al. 2024).

The positive connection between female gardeners and identifying these pollinator species in our survey can lead us to consider many possible historical and social processes that could explain this association. Gendered relations between people and animals and plants are documented across feminist political ecology work, mainly in the global south (Rocheleau et al 1995, Bezner-Kerr et al. 2019). Feminist epistemological approaches to studies in the global north suggest that gender as an axis of lived experiences can move women to express care and identify agency in pollinators through the relational self (Lloro-Bidart 2018). In this sense, female-identified individuals may express affect towards bees and other pollinators because of their knowledge of labor histories or a struggle for women's rights in a dominantly patriarchal world (ibid). In the United States, hobbyist beekeepers, including females, articulate their work as an expression of environmentalism that directly addresses a perceived pollinator crisis and a deep awareness of anthropogenic impacts on biodiversity (Didonato et al. 2020).

It could also be that the ability to recognize and identify pollinator insects in this survey may also require deep observation and embodied engagement with these pollinator species in gardener's plots. Embodied relationships with gardens that reflect environmental concerns and care work may allow female-identified gardeners to develop specialized knowledge about the diversity of pollinators providing ecosystem services in garden spaces (Beisel et al. 2013). This possibility is supported by Philpott et al. (2020), who learned that female gardeners in California cultivate a higher proportion of ornamental plants potentially because they see themselves as "lifestyle" gardeners (Taylor et al. 2017). Planting decisions motivated by gender dynamics then, whether consciously or unconsciously, maybe create pollinator habitats that attract and consequently increase pollinator visitation to gardens, thereby creating opportunities to know diverse pollinator species more closely or continuously. In Colombia, Kolze et al. (2023) learned that Indigenous and campesina women harbor habitat for pollinators by planting flowers in home gardens, yet functional knowledge of pollinators differed with gardener identity. The difference in ecological knowledge is attributed to time spent in the garden, leisure time, and the availability of economic resources. Ethnographic work to learn about women's livelihoods and the social processes they navigate may be able to further highlight how ecological knowledge processes develop.

Gardening program learning and knowledge of insects

We presented gardeners with images of herbivore insect species with different life-strategies and feeding preferences that could cause plant damage and non-herbivorous insects. Aphids are piercing-sucking insects that express aggregation behavior and create a white, patchy look on plant leaves (UCANRa). Cucumber beetles are generalist-feeding insects with great flight abilities, and they are particularly identifiable by their spotted wings and yellow-green color (Haber et al. 2021). We also presented an image of a squash bug, which is known to feed primarily on Cucurbitaceae plants, and the Harlequin bug is known to feed on Brassicaceae plants (UCANRb).

A higher likelihood of identifying both herbivores and natural enemies among Master Gardener participants suggests that program structure and content may be a factor shaping this result. We recognize that many collective organizations specifically BIPOC groups, are emerging as collective knowledge hubs for farming and gardening knowledge exchange. Unfortunately, we did not explicitly ask gardeners to identify other program training besides the Master Gardener program. We suspect that this association reflects the time-intensive and specialized knowledge design and structure of the Master Gardener program. Participants who enroll in this program agree to complete 50 hours of online training over 16 weeks and 25 hours of continuing education course units (UCANR). Participants in this program benefit from specialized courses and knowledge shared by guest speakers, including entomologists, agriculture specialists, and other urban and integrated pest management (IPM) specialists. For example, archived recorded training is accessible via the campus.extension repository displays two recordings titled "Vertebrate Pest Management" and "Entomology" (UCANR Master Gardener recorded training). The first course highlights the life stages of insects like the Harlequin beetle and associates specific plant symptoms or damage (i.e. chewing, spots, waxy or cottony appearance) with the images of potential herbivore pests. Two chapters in the 2nd edition of the California Master Gardener book are titled Insects and sustainable pest management, and most natural enemies we presented in their survey are featured in this book with images except the big-eyed bug, which is merely in text as a beneficial insect (Pittenger 2015). This specialized level of information may be experienced or interpreted by community gardeners participating in the Master Gardener program as a type of extension or technical information training. In a 2009 survey with various urban agriculture groups, including community gardeners in Alameda County, half of community gardener respondents reported not needing extension support. This was attributed to the possibility that respondents access publicly available resources (i.e. Facebook, books) and participate in the Master Gardener program (Reynolds 2011).

The Master Gardener program content and program design facilitated access to ecological knowledge for new gardeners who may have limited experience or no agricultural background or experience. In an evaluation study with Master Gardener in the north-central U.S., more years of experience of participation in the Master Gardener program was positively associated with a likeliness of integrating IPM strategies and recommending strategies to other gardeners (Meyer et al. 2010). Master Gardener participants and other volunteers with an agriculture and gardening background have also been identified as key contributors to the success of long-term educational efforts promoted by “train-the-trainer” workshops in Oregon and Washington (Corp et al. 2013). The willingness to volunteer and devote time to cultivating specialized knowledge of herbivores and natural enemies, among other gardening topics, may reflect specific social characteristics and demographics. A review of Missouri State Master Gardener program participants found that most respondents were married women with children and with some college education who valued experiential learning, with interest in horticulture and gardening and who valued being of service to others (Schrock et al. 2000). The willingness to take an active role in robust learning of ecological concepts for practical applications in gardens has both motivated scientists to recruit Master Gardeners to support citizen-science projects for projects about pollinators like the first ever Georgia pollinator census and the monitoring of squash bees a wild pollinator of Cucurbit crops (Griffin et al. 2022, Apenfeller et al. 2020).

Agricultural background

Our survey identified that gardeners with an agricultural background were marginally better at identifying herbivores, but this factor did not influence the identification of pollinators or natural enemies. Possible reasons that could explain this association include the possibility that participants with an agricultural background may work in production agriculture, field scale, or commercial agriculture that utilizes organic farming practices where herbivore pest monitoring or spotting may be useful (Baker et al. 2020). In commercial agriculture, a focus on general natural enemies or pollinators might be less of a job skill. Still, herbivore monitoring may help assess plant damage thresholds to evaluate pest management approaches. Gardeners with an herbivore monitoring capacity could develop more specialized knowledge of herbivorous insects (Barzman et al. 2015). Some specific herbivores shown should be very common to agricultural workers in this region (e.g. cabbage aphids and cabbage loopers are common on Brassicas - an economically important crop in the study region). Our survey only captured a few gardeners with an agricultural background (only 16% of respondents). The online format of this survey and its availability only in English further limited our ability to reach this demographic.

Number of years spent gardening

When all natural enemy species and the “difficult to ID" natural enemy species were considered in our study, the number of years spent gardening was a marginally significant factor for identifying this functional group. Gardening for long periods may develop an environmental gardening identity that can motivate gardeners to increase their observation of the ecological process that occurs in the garden (Kliesling et al. 2010). This attunement to the ecology of the garden space may facilitate a higher ability to distinguish natural enemies. The number of years spent gardening has been linked with more knowledge and time-intensive gardening practices that express higher resilience in drought or water scarcity (Egerer et al. 2020). Accumulated experience in the garden facilitated by the number of years spent gardening may allow gardeners to identify the role of natural enemies in the garden.

Formal education in ecology, biology or other science

The “difficult to ID” natural enemies were also marginally associated with gardeners who reported having a formal education in ecology, biology, or another science. Gardeners in our survey reported a degree in chemistry, civil engineering, landscape architecture, and biological sciences. It could be that a formal education in a field relevant or not relevant to agriculture and gardening can support the ability to find information about natural enemies and their roles in the garden space. Likewise, formal education may increase access to networks of people who could support knowledge of insects in the garden space.

Reframing knowledge of insects

Although knowing the identity of insect species can support insect conservation, it is also possible that community gardeners who practice ecological farming are already creating habitats for diverse insect groups (Morales 2000). Several garden features and vegetation management approaches shaped by gardeners (i.e. mulch, floral richness, tree cover, herbaceous plant richness) support ecosystem services in urban gardens, with some synergies and tradeoffs that interact with the landscape context (Jha et al. 2023). Additionally, knowledge of insect functional roles may not be necessary if gardeners develop tacit and embodied ways of knowing about insect-plant interactions through their observations and experience (Maderson et al. 2023). Moreover, the horizontal exchange of knowledge and expertise among gardeners can create opportunities to learn about insects in other ways (e.g. food, medicinal, cultural). These ways of knowing may also support insect conservation (Lima et al. 2016).

Conclusion

Community gardeners express robust knowledge of insect functional roles, yet specific species of insects are more highly recognized than others. The social diversity of gardeners, including their lived and learning experiences, is differentially associated with knowledge of insect functional groups. In our study, female gardeners are likelier to identify pollinator groups, suggesting that planting preferences and embodied experiences can impact the ecological knowledge of insects. We also learn that gardener participation in the Master Gardener program is associated with a higher likelihood of identifying herbivores and natural enemies. This suggests that access to agriculture professionals and curriculum-based knowledge also shape ecological knowledge of insects. Overall knowledge of multiple insect functional groups expressed by gardeners can support their goals and ecologically based processes in urban agriculture.

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Author Contributions

Stacy M. Philpott, Brenda B. Lin, Shalene Jha, and Heidi Liere developed ideas for this research and provided editing support. Stacy M. Philpott and Brenda B. Lin designed the online survey. Edith M. Gonzales carried out data analysis and wrote up data results.

Table 3.1 Proportions of correct and incorrect identification of functional insect groups, listed by insect (or spider) species.

Functional group	**Insect species**	**Common name**	**% correct**	**% incorrect**
Pollinators	*Agapostemon texanus*	Sweat bee*	68%	32%
	Syrphus sp.	Hoverfly*	77%	23%
	Osmia sp.	Mason Bee*	79%	21%
	Hippodamia convergens	Convergent lady beetle (larva)	90%	10%
	Bombus sp.	Bumble bee*	97%	3%
	Orius tristicolor	Minute pirate bug	88%	12%
	Apis mellifera	Honey bee*	95%	5%
	Linepithema humile	Argentine ant	79%	21%
Herbivores	*Diabrotica undecimpunctata*	Cucumber beetle*	64%	36%
	Trichoplusia ni	Cabbage looper (larva)*	95%	5%
	Hippodamia convergens	Convergent ladybeetle	95%	5%
	Anasa tristis	Squash bug*	71%	29%
	Murgantia histrionica	Harlequin bug*	58%	42%
	Brevicoryne brassicae	Cabbage aphids*	94%	6%
	Osmia sp.	Mason bee	98%	2%
	Bombus sp.	Bumble bee	99%	1%
Natural Enemies	*Hippodamia convergens*	Convergent* lady beetle	92%	8%
	Pardosa sp.	Wolf spider*	84%	16%
	Plutella xylostella	Diamondback moth (larva)	94%	6%
	Apis mellifera	Honey bee	86%	14%

	Hippodamia convergens	Convergent ladybeetle (larva)*	57%	43%
	Geocoris sp.	Big-eyed bug*	12%	88%
	Ichneumonidae sp.	Parasitoid wasp*	62%	38%
	Acyrthosiphon pisum	Pea aphid	90%	10%

All species that correspond to each functional group are indicated by an asterisk (*) next to the common name.

Table 3.2 Results of GLM models for identification of pollinators, herbivores, and natural enemies. This table displays positive or negative associations with associated predictor variables for each functional insect groups for all species and “difficult to ID insects”

Functional Group	**All multiple choice**	**Difficult to ID insects (and spiders)**
Pollinators	Female gardeners (+)	Female gardeners (+)
Herbivores	Master gardener program (+) *Agricultural background (+)	Master gardener program (+) *Agricultural background (+)
Natural Enemies	Master gardener program (+) *Number of years spent gardening (+)	Master gardener program (+) *Number of years spent gardening (+) *Formal education (+)

* This asterisk refers to marginally significant factors associated the likelihood of identifying each functional group

Figure 3.1 Sources of continual garden learning reported by gardeners.

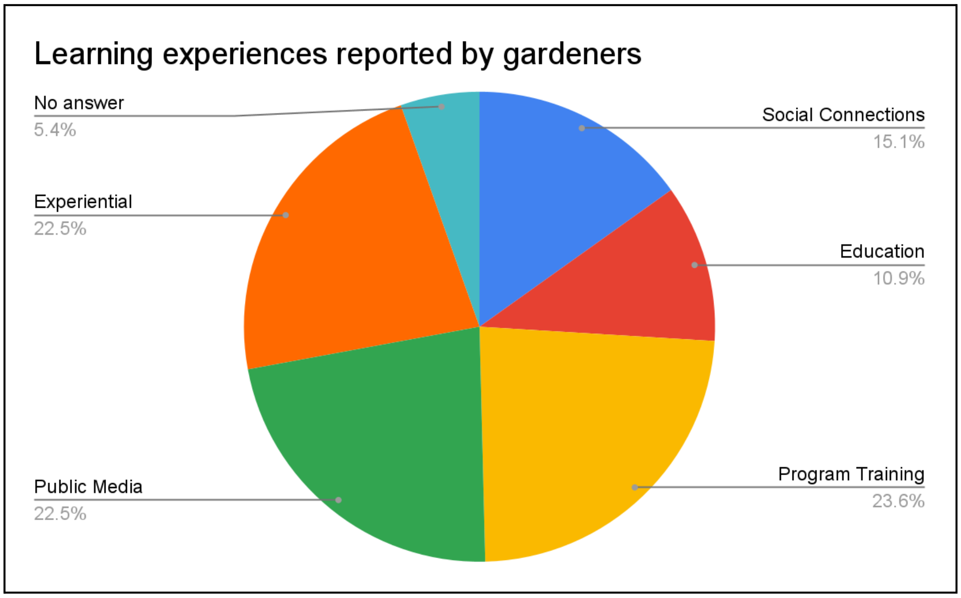
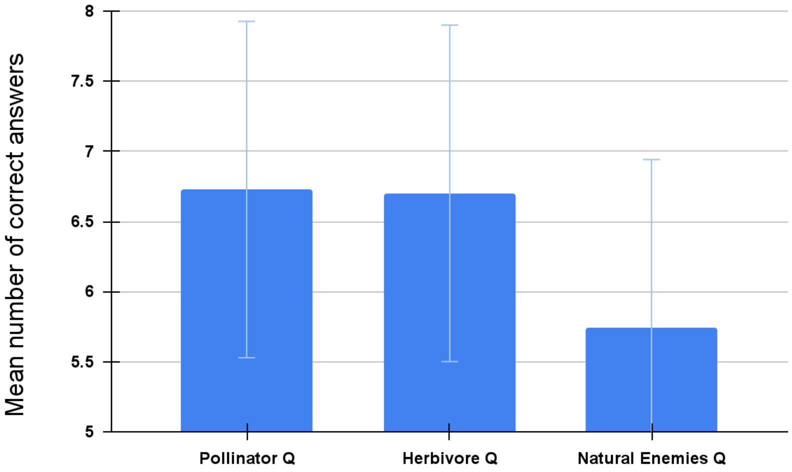


Figure 3.2. Mean (± SE**)** number of correct answers provided by gardeners identifying insects into one of three functional groups (e.g., pollinators, herbivores, and natural enemies).



Supplementary Material

Figure S3.1 A histogram showing the number of gardeners providing a range of correct answers to questions asking them to identify insects to functional groups (e.g., pollinators, herbivores, and natural enemies).

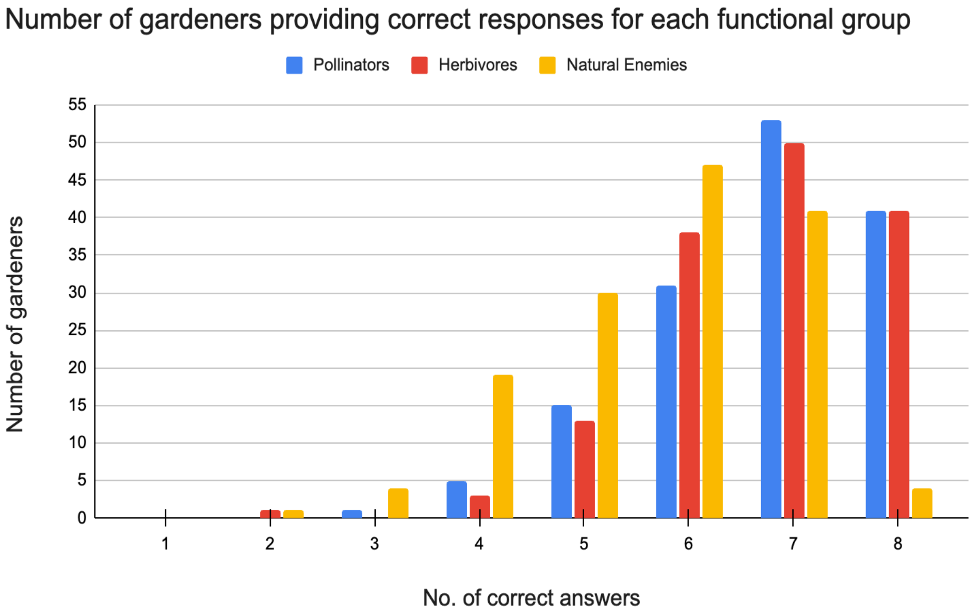


Figure S3.2 The percentage of correct responses from community gardeners in question 1 (pollinators).

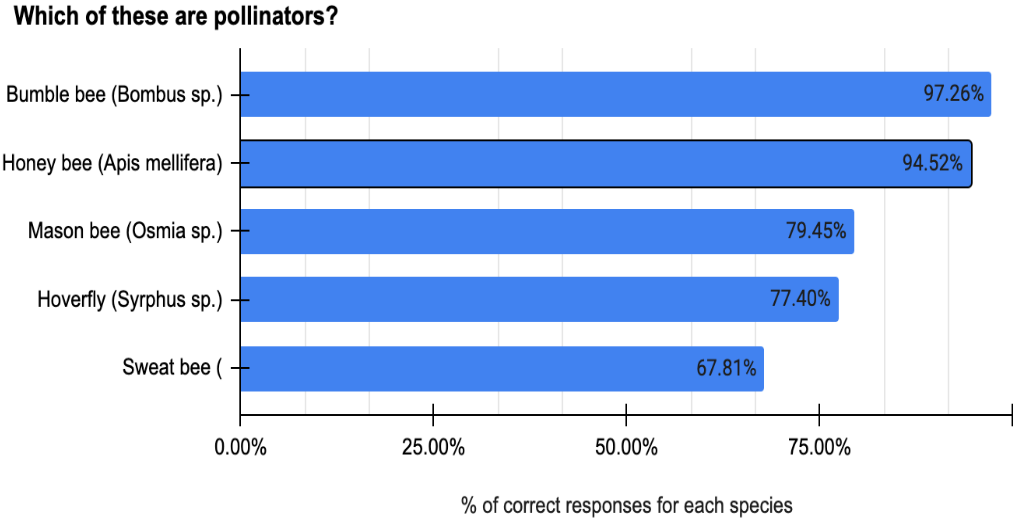


Figure S3.3 The percentage of correct responses from community gardeners in question 2 (herbivores).

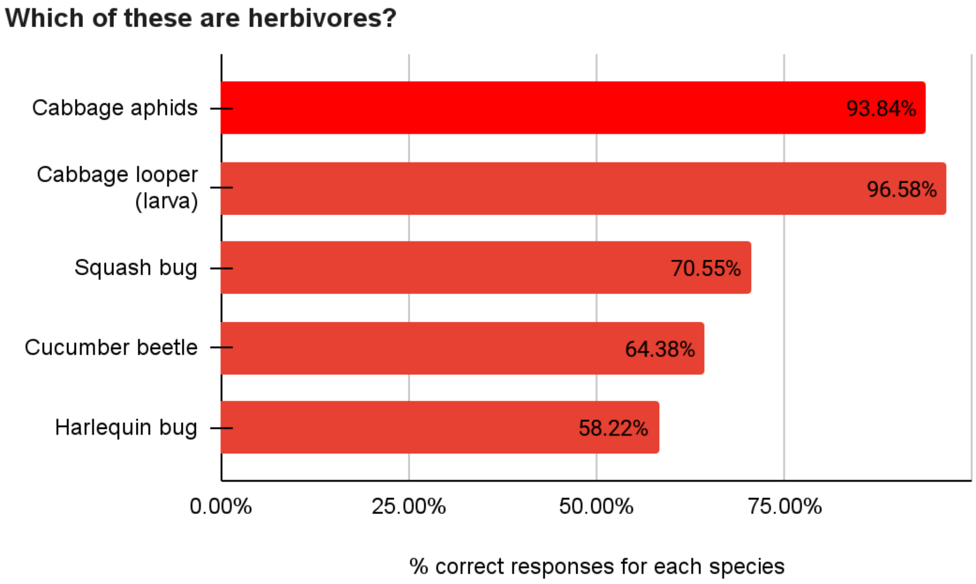


Figure S3.4. The percentage of correct responses from community gardeners in question 3 (natural enemies).

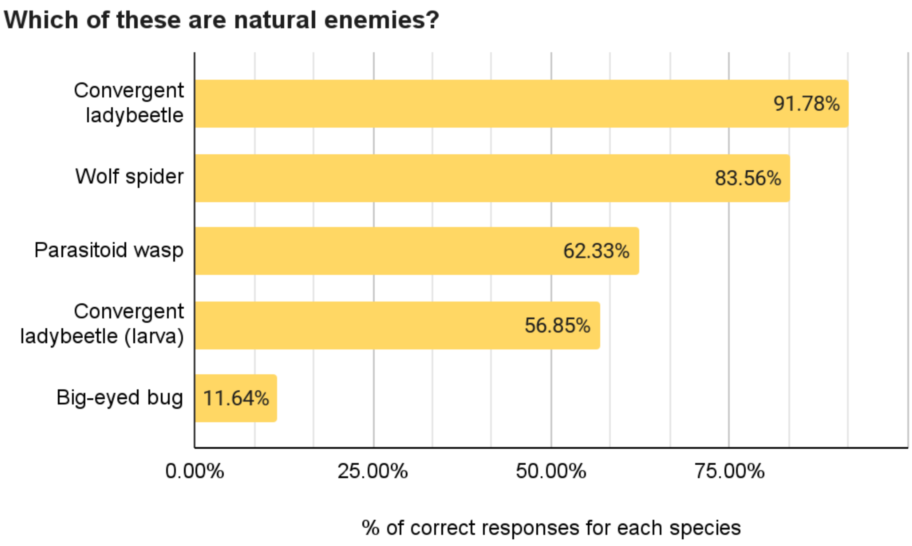
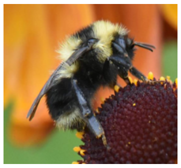
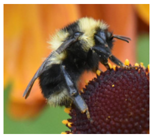


Table S3.1 Summary statistics for all GLM models using a binomial distribution for all multiple choice responses (a) and the difficult to identify or "mid-range" insects (b).

Functional group	**Predictor variables**	**Odds Ratios**	**Std. Error**	**Confidence Interval**	**Statistic**	**p-value**
A. Models including all insects						
Pollinators	(Intercept)	4.93	0.79	3.62 – 6.79	9.95	<0.001
	gender [male]	0.63	0.11	0.44 – 0.89	-2.65	**0.008**
	formal degree [y]	1.22	0.28	0.79 – 1.96	0.87	0.382
	ag background [y]	1.21	0.29	0.77 – 1.97	0.82	0.414
	years gardening	1	0	1.00 – 1.01	1.08	0.281
	master gardener [y]	1.03	0.19	0.72 – 1.48	0.18	0.855
Herbivores	(Intercept)	4.35	0.69	3.21 – 5.98	9.28	<0.001
	gender [male]	0.91	0.17	0.63 – 1.31	-0.53	0.593
	formal degree [y]	0.86	0.19	0.57 – 1.34	-0.68	0.497
	ag background [y]	1.58	0.4	0.98 – 2.66	1.81	**0.07**
	years gardening	1	0	0.99 – 1.01	0.01	0.991
	master gardener [y]	1.79	0.34	1.23 – 2.62	3.02	**0.002**
Natural Enemies	(Intercept)	0.596	0.129	1.41 – 2.34	4.63	<0.001
	gender [male]	-0.112	0.150	0.67 – 1.20	-0.74	0.457
	formal degree [y]	0.277	0.183	0.93 – 1.90	1.51	0.131
	ag background [y]	0.035	0.188	0.72 – 1.51	0.18	0.854
	years gardening	0.006	0.003	1.00 – 1.01	1.89	**0.059**
	master gardener [y]	0.332	0.149	1.04 – 1.87	2.23	**0.026**
B. Models including only difficult to identify or "midrange" insects						
Pollinators	(Intercept)	1.041	0.222	1.85 – 4.42	4.69	<0.001
	gender [male]	-0.719	0.245	0.30 – 0.79	-2.93	**0.003**

	formal degree [y]	-0.014	0.310	0.54 – 1.85	-0.05	0.963
	ag background [y]	0.479	0.340	0.85 – 3.25	1.41	0.159
	years gardening	0.002	0.006	0.99 – 1.01	0.28	0.782
	master gardener [y]	0.376	0.257	0.88 – 2.43	1.46	0.144
Herbivores	(Intercept)	0.355	0.201	0.96 – 2.12	1.77	0.077
	gender [male]	0.0356	0.235	0.66 – 1.65	0.15	0.88
	formal degree [y]	-0.277	0.270	0.45 – 1.29	-1.03	0.305
	ag background [y]	0.579	0.3045	1.00 – 3.31	1.91	**0.057**
	years gardening	-0.001	0.005	0.99 – 1.01	-0.18	0.857
	master gardener [y]	0.595	0.232	1.16 – 2.87	2.57	**0.01**
Natural Enemies	(Intercept)	-0.764	0.203	0.31 – 0.69	-3.77	**<0.001**
	gender [male]	-0.317	0.236	0.46 – 1.15	-1.35	0.178
	formal degree [y]	0.480	0.261	0.97 – 2.71	1.84	**0.066**
	ag background [y]	-0.104	0.280	0.52 – 1.56	-0.37	0.711
	years gardening	0.008	0.005	1.00 – 1.02	1.65	**0.098**
	master gardener [y]	0.593	0.217	1.18 – 2.77	2.74	**0.006**

Figure S3.5. List of all survey questions including identification of insect images for all functional insect categories: pollinators, herbivores and natural enemies and demographic questions.

Question	**Question**
Q1	Which of these organisms are pollinators? (Choose all that you believe fall into that category)        
Q2	Which of these organisms eat plants and may cause crop damage? (Choose all that you believe fall into that category)    .     

Q3	Which of these organisms protect crops from pests? (Choose all that you believe fall into that category)  
Q4	What gender do you identify with?
Q5	What is your age?
Q6	What is the zip code of where you live?
Q7	Do you speak a language other than English at home?
Q8	If so, what language(s)?
Q9	Do you have a formal degree in biology, natural resources, environmental studies or related field?
Q10	If so, what degree do you have?
Q11	Have you learned about biology, ecology, or how plants and insects interact from other sources? (For example, this could be from spending time outdoors and observing, from family and friends, classes, or from other activities).
Q12	If so, how have you learned?
Q13	Do you have a background in agriculture, farming, or farm work?
Q14	For how many years have you been gardening?
Q15	Are you a “Master Gardener”?
Q16	If so, for how many years have you been a "Master Gardener"?

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