

CASE STUDIES ON CONSERVATION OF POLLINATION SERVICES AS A COMPONENT OF AGRICULTURAL BIOLOGICAL DIVERSITY

TITLE: Pollination Services to Crops in Yolo Co., California: working towards restoration
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Overview

We studied the contributions of wild bee pollinators to pollination of four crops, watermelon, sunflower, almond and tomato, in the Central Valley of California, one of the most important agricultural regions in North America. Our studies were conducted along a gradient of agricultural intensification, from intensively managed farms in a primarily agricultural landscape, to less intensively managed farms in a primarily natural landscape. The main objectives of these studies were to: 1. define the role of wild bee populations in crop pollination and identify the most important contributing species; 2. investigate the influence of agricultural intensification on the crop pollinating species and on the pollination services they provide; 3. identify floral and nesting resources across the landscape to develop protocols for restoring/promoting the wild bee populations and their services; and 4. establish an outreach program to inform growers of techniques to improve pollinator habitat in this heavily agricultural landscape.

Key results:

- We found over 60 wild, unmanaged bee species visit crops in this area.
- Wild bee diversity, abundance and services declined significantly with agricultural intensification.
- The most important pollinating species were also most sensitive to agricultural intensification. Other species did not compensate by increasing in abundance.
- In watermelon, a plant species with large pollination requirements, the wild bee community can provide sufficient pollination services, but only on low intensity farms.
- In tomato, wild bee species increased the set and size of fruits through cross pollination.
- In hybrid sunflower seed production, wild bees were found to have important indirect effects on honey bees that doubled the value of honey bees, on average, as pollinators of this crop. Both sunflower and almond are crops that are often under-pollinated. Our preliminary work found 7 wild bee species visiting almond.
- We have identified a phenological suite of wild plants that can provide resources for the most important crop pollinators throughout their adult flight periods. This plant list is useful for establishing restoration protocols to improve the farming landscape for wild pollinators.
- A few wild bee species were found nesting in the ground on farms. We found that nesting bees were more abundant on farms close to natural habitat, suggesting that natural habitat provides the source of these nesting females

With the Xerces Society, we developed information sheets for farmers describing these results in accessible terms, and detailed guidelines on management actions that farmers can take to improve habitat for wild bees on their farms. The Xerces Society is actively engaged in outreach to farmers through conferences and workshops.

We are currently bringing all of this data together into a common framework, in order to model alternative land management scenarios that could augment and restore pollination services across this landscape. We hope that this work will lead to an array of potential land management plans that could help to guide land-use decisions in our study area.

I. Background/Problem statement:

We studied the contributions of wild bee pollinators to pollination of four crops, watermelon, sunflower, almond and tomato, in the Central Valley of California, one of the most important agricultural regions in North America. We focus on watermelon here, since sunflower and tomato are described in more detail in separate case studies. We compare the benefits provided by wild, unmanaged populations of bees with honey bees that are imported to fields to provide pollination services to crops.

We investigated the influence of agricultural intensification on the bee communities and the pollination services they provided. In this study area, farms with low agricultural intensity were organic farms situated in a matrix including a large proportion (> 30%) of natural habitat (oak woodland; chaparral) within 2 km of the farm; while at the other end of the spectrum, farms with high agricultural intensity were conventional farms situated in a largely agricultural matrix (< 1% natural habitat). Organic farms grew multiple crops and used no pesticides; conventional farms were monocultures utilizing pesticides and artificial fertilizers.

We assessed use of other floral resources found in farm or natural areas by the key wild crop pollinators. We investigated nesting of wild bees on farms along the gradient of agricultural intensification. We assessed how the gradient of agricultural intensification influenced productivity of bumble bees (*Bombus vosnesenskii*) that we placed in different sites along the gradient, including sites where they do not (no longer?) occur.

II. Objectives/Purpose of the Activities:

The main objectives of these studies were to: 1. define the role of wild bee populations in crop pollination and identify the most important contributing species; 2. investigate the influence of agricultural intensification on the crop pollinating species and on the pollination services they provide; 3. identify floral and nesting resources across the landscape to develop protocols for restoring/promoting the wild bee populations and their services; 4. establish an outreach program to inform growers of techniques to improve pollinator habitat in this heavily agricultural landscape.

III. Details of the case study and the approach taken:

Main Actors

Princeton University: team led by Dr. Claire Kremen, including Dr. Neal Williams (Bryn Mawr) and Dr. Sarah Greenleaf;

University of California at Davis: team led by Dr. Robbin Thorp (with Dr. Robert Bugg and Nikki Nicola);

Xerces Society: team lead by Mace Vaughan, including Matthew Shepherd and Scott Black.

Approach taken

Depending on the study, 12 to 30 sites were selected. Studies were conducted on crops; at flowers naturally occurring on farm and natural sites (bee-plant interaction studies); at colonies of *Bombus vosnesenskii* reared in the lab and placed out on different farm and natural sites; or on farm fields (solitary bee nesting study). For crop studies, we measured the abundances of different bee species visiting the crop across the landscape gradient. In separate studies, we measured the pollination efficiency of each species on each crop. From these two measurements, we could then estimate the total pollination services provided by the wild bee community (and by honey bees) to each crop at each site. For bee-plant interaction studies, we conducted standard surveys on natural and farm sites and collected wild bees on each flowering plant. We identified the bees and constructed interaction webs. For the *Bombus* study, we weighed colonies weekly and counted total numbers of workers and queens at the end of the study to assess how different environments influenced colony productivity (production of individuals providing pollination services). For the nesting study, we trapped solitary female bees

emerging from nests in the ground on farms located across the gradient of agricultural intensification.

As a direct follow on from these studies, we prepared lists of key native plants that support native bee populations and developed guidelines for identifying, protecting, and enhancing bee habitat within the productive agricultural landscape. We also made presentations at several conferences and led training workshops, both for farmers and for natural resources agency staff.

Key Results

Crops, general:

- Over 60 wild, unmanaged bee species visit crops in this area.

Watermelon

- The wild bee community can provide sufficient pollination services for watermelon, which is a plant species with large pollination requirements (requiring deposition of 1000 grains of pollination to set a marketable fruit; therefore needing multiple bee visits), but only on organic farms near wild habitat (low intensity).
- Wild bee community also provided some pollination services on other farms at higher intensity along the gradient; roughly 20% of needs at the high end of the gradient of agricultural intensity, and 50% in the middle of the gradient.
- These functional differences along the gradient of agricultural intensification were related to underlying changes in diversity and abundance of the bee community: at low intensity sites, bee communities were much more diverse and more abundant than at high intensity sites.
- The species that were most sensitive to agricultural intensification (lost first) were also the largest and most efficient pollinators. Their loss had a disproportionate impact on function. Other species did not compensate by increasing in abundance.

Tomato:

- Two wild bee species were found to increase the set and size of cherry tomatoes through cross pollination. Honey bees did not visit cherry tomato. One of the wild species was sensitive to agricultural intensification, while the other was not.

Sunflower:

- Wild bee species contributed directly to sunflower pollination and were generally as or more efficient than honey bees. It was found, however, that they had a far greater effect on pollination services indirectly: by improving the pollination efficiency of honey bees. In this hybrid seed production system, it is necessary to move pollen from male-fertile hybrids to male-sterile (female) hybrids. Wild bees improved honey bee pollination efficiency by causing them to move much more frequently than they normally would between the two cultivars. Wild bee diversity and abundance declined with agricultural intensification in this system, as for watermelon.

Almond:

- We have identified 7 wild bee species that visit almond in this area. This is important because almond growers frequently cannot obtain enough honey bees to pollinate this crop, which flowers in winter (February). We are in the process of analyzing this dataset, but it appears to demonstrate similar trends of declining abundance/diversity with increasing agricultural intensification.

Bee-plant interactions:

- We have identified a phenological suite of wild plants that can provide resources for the most important crop pollinators throughout their adult flight periods. This plant list can be used by farmers who wish to establish small-scale restoration plots (e.g. hedgerows, tail-water plantings) on their farm sites to provide habitat for pollinators when their crops are not in bloom. It can also be used by land managers conducting restoration on partially or fully degraded lands.
- We are also analyzing this data set to determine what native plants may benefit from promoting the important crop pollinators in this region. Most crop pollinators are generalists visiting a wide array of both native and weedy species.

Nesting:

- A few wild bee species were found nesting in the ground on farms. We found that nesting bees were more abundant on farms close to natural habitat, suggesting that natural habitat provides the source of these nesting females.

Bombus colonies:

- All colonies survived for 6 or more weeks, and the majority grew and produced queens, regardless of their local site or surrounding environment. This shows that this species can potentially be re-introduced into the landscape.
- Colonies were more productive when there was a larger proportion of natural habitat within foraging range of the colony (2 km).

Outreach, general:

- We have produced information materials, given talks at conferences, and presented workshops. Our outreach has been directed at farmers, natural resource specialists working with farmers, and natural area managers.

Publications - *Farming for Bees. Guidelines for Providing Native Bee Habitat on Farms:*

- These guidelines promote a three-step approach to pollinator conservation on farms: 1) recognize the existing nesting and foraging habitat on the farm; 2) adapt current farming practices to minimize disturbance to these areas; and 3) expand the area of habitat by creating new nesting and foraging areas. They also emphasize the importance of recognizing and protecting native bee habitat in the area surrounding the farm.
- The guidelines are currently only available in English and are generally geared towards farming systems in the United States. However, with help from other partners, we intend to translate them into French and Spanish, and adapt them to the needs of farmers in other regions.

Publications - Information sheets:

- We have produced general information sheets: one on crop pollination by native bees and another on addressing the habitat needs of native bees when managing natural areas. Crop-specific sheets on watermelon, hybrid sunflower seed, and cherry tomato pollination are in draft form. In addition, we are developing a tool for watermelon and tomato growers to assess the contribution native bees make to the pollination of their crops.

Conferences and workshops:

- We gave presentations at the EcoFarm conference in 2004 and 2005, and at the 2004 California Society for Ecological Restoration conference.
- On-farm workshops for farmers have been held in partnership with other non-profits that support sustainable agriculture, including the Wild Farm Alliance, Community Alliance for Family Farms and the Center for Land-Based Learning.
- Four seminars have been given to Natural Resources Conservation District staff.

State wildlife preserve managers:

- We have held on-site meetings with managers of California Department of Fish and Game wildlife preserves to encourage support for native pollinators occurring outside of farms, but still in the agricultural landscape.

Partnerships:

- We have developed partnerships with other non-profits and state agencies that have been critical for effective outreach. We have been able to provide useful information that has helped partner organizations demonstrate the benefits of protecting natural areas in the agricultural landscape for wildlife, as well as sustainable agricultural practices that may decrease grower's reliance on a single pollinator (i.e. the honey bee). In return, we have received logistical support in setting up workshops and seminars, and in making connections with growers.

IV. Analysis

This study provides information for the following items in the appendix:

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- 2a. identified services provided by pollinators and functional relationships
- 2b. identified beneficiaries; immediate beneficiaries are farmers, but longer term beneficiaries could be food consumers, since the presence of wild bees provides an insurance policy that lessens our single reliance on the honey bee, a species that has been decline in the US for the past 50 years. Loss of honey bees will undoubtedly lead to decreased diversity and diet-breadth of human food products; protection/maintenance of other pollinators will lessen the blow.
- 2d. the scale of pollination services is on the order of 1 – 2 km. We identified a relationship between the proportion of natural habitat at this scale and the level of services provided.
- 2d. Barriers to management at this scale are that multiple private land-owners must cooperate to restore habitat or improve farming management practices with benefits for all. If one farmer uses pesticides while his neighbor restores pollinator habitat, results are likely to be unsatisfactory.
- 3a. This study shows that diversity and abundance of pollinators are at risk from increasing agricultural intensification, with important effects on pollination services.
- 3b. We identified management practices that we think will promote wild bee existence and persistence on farms; ideally, before and after monitoring is needed to assess the impact of these techniques.
- 3c. Farming communities naturally form interactive social units that depend upon one another for various kinds of assistance (sharing equipment, transport, techniques). Therefore, although implementing positive practices for pollinators across an entire landscape is a challenge (see 2d), working with farming communities means working with individuals who may already see the benefits of a communal approach.
- 5. The diversity of pollinators and the services provided are highly related; thus one serves as an indicator of the other.
- 8. Taxonomy was an impediment in this study. Without the participation of Dr. Robbin Thorp, this study could never have been accomplished. More taxonomists like him are desperately needed.
- 11. An extensive outreach program has developed targeted information materials and provided learning opportunities for farmers and agency staff. Although prepared for California's Central Valley, these materials and techniques can be transferred to other regions.

Many of the research results that we have found may be generally applicable; however it is important to compare among studies to determine if this is true. Thus the statements made in this section are only intended to refer to our own study area and crops. Please see Bibliography for more detailed information about these studies.

V. Conclusions.

Outcomes:

We are currently bringing all of this data together into a common framework, in order to model alternative land management scenarios that could augment and restore pollination services across this landscape. One scenario would focus on conserving and restoring natural habitat – what pattern of natural habitat patches would be required to restore sufficient services? Another scenario would focus on improving habitat quality on farms. A third scenario would do both. We hope that this work will lead to an array of potential land management plans that could help to guide land-use decisions in our study area.

In addition, thanks to partnerships with other farm related non-profits working in California, we currently have an outreach infrastructure in place that would allow for the efficient dissemination of this framework and landscape management models to state agency (i.e. Natural Resource Conservation Districts) biologists working with farmers throughout the state of California.

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