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Integrating Ecological and Economic Considerations for Pollinator Habitat Policy

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Over the last year, the public, politicians, and industry executives have proclaimed their support for pollinators. In June of 2014, President Barack Obama published a presidential memorandum calling for pollinator health protection. The memorandum calls for a variety of actions across federal government agencies to increase the availability and vitality of pollinator habitat (Executive Office of the President, 2014). This memo is complementary to the pollinator-related policy set forth in the 2014 Farm Bill. This legislation calls on the Department of Agriculture for greater pollinator habitat support through the Conservation Reserve Program (CRP) and increased pollinator education and extension programs (Senate and House of Representatives of the United States of America, 2014).

These policies and investments have gained traction despite scientific uncertainty about the best strategies to improve pollinator health and productivity. The natural science remains cloudy given there are multiple factors at play. Confounding factors which may affect pollinators include monoculture cropping practices, natural pollinator habitat decline and fragmentation, neonicotinoid pesticide seed treatments, increased herbicide use, diseases and pests, and migratory beekeeping practices (Fairbrother et al., 2014; Garibaldi et al., 2014; Gordon, Bresolin-Schott, and East, 2014; Wade, 2014). It is unclear which exact factor has triggered the historically high rates of managed honeybee deaths since 2007 and the decreasing availability of wild pollinators such as monarch butterflies.

As a result of the political movement to promote pollinator health in the presence of scientific uncertainly, industry has also taken serious interest in policy. For instance, Bayer CropScience's North American Operations has invested millions of dollars in bee research and health to stave off criticism of their neonicotinoid seed treatments which some believe kill pollinators, especially honey bees (Bernick, 2014).

The scientific evidence is not yet conclusive about whether or not all the potential factors negatively affect pollinator health or just a subset. Assigning cause and effect in pollinator health is challenged by a culmination of multiple stressors since no single factor exists in a vacuum and may interact with other stressors that create synergies causing pollinator mortality (Potts et al., 2010). Many stressors originate from economic motives and feedbacks between the natural and economic systems. Understanding the entire ecological system, drivers, and economic system linkages is needed to fully uncover the root causes of pollinator declines and define successful policies to promote pollinator health.

Most pollinator health research and policies focus on the ecological system in which pollinators are embedded. There is less focus on the economic factors affecting that ecological system, and the links and feedback loops between the two systems. Moreover, economic research has been limited in focus to agricultural productivity rather than ecological systems related to wild and native pollinators. The ecological and economic systems are treated as if they act in isolation from one another instead of with the interconnectedness that exists between them. Figure 1 illustrates the interconnected economic and ecological relationships affecting pollinator health and productivity. Across agro-ecological landscapes, human demands,

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Figure 1: Ecological and Economic Elements of Pollinator Habitat, Health, and Productivity

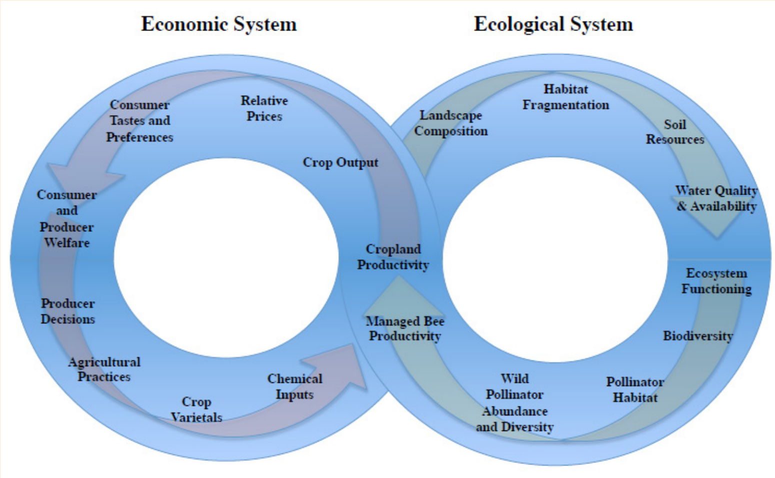


Table 1: Recommend Best Practices to Enhance Agro-Ecological Context for Pollinators

In Field Practices	Beside Field Practices
1. Reduce synthetic pesticide use	1. Provide nesting resources
2. Reduce tillage	2. Plant hedgerows and flowering strips
3. Employ drip irrigation	3. Conserve or restore semi-natural area
4. Enhance within field floral richness	4. Enhance farmland heterogeneity
5. Organic farming	5. Small crop fields
6. Sow flowering crops	6. Increase crop diversity across landscape
7. Inter-temporally stagger crop floral activity	
Sources: Table summarized from Blaauw and Isaacs, 2012; Donkersley et al., 2014; Garibaldi et al., 2014; Isaacs and Kirk, 2010; Petersen and Nault, 2014.	

and cropping production practices both influence and affect the ecological systems supporting pollinators. Ecological factors are fundamental to human choices regarding agricultural production and food consumption, and vice versa (Polasky and Segerson, 2009).

Landscape disturbance and habitat fragmentation are the primary threats to many pollinator species' well-being (Ricketts et al., 2008). Agricultural development and production outcomes act in combination with underlying soil and water endowments to inhibit or support ecosystem functions. The ecosystem underlies flora and fauna biodiversity, feeding the health and well-being of pollinators, especially wild pollinators. Managed pollinators provide one of the most direct connections between systems. While modern beekeepers are responsible for honeybees' landscape presence and quantity, the bees' productivity and health depend on both surrounding crops and the natural ecosystem.

The good news is that economic tools and information may be used to inform and improve existing pollinator policy, especially given scientific uncertainty. While federal policies aim to increase pollinator habitat, they do not define either the ecological or economic means to achieve this end. Both economic and ecological systems need to be considered for national, state, and local policy development and analysis. Regardless of whether honey bees and natural pollinators are most affected by diseases, transportation or chemical exposure, the substantial gap in policy needs to be addressed—researchers need to better integrate the ecological and economic functions underpinning pollinator health and productivity.

Ecological Relationships and Policy Recommendations

Pollinator needs vary by pollinator and region. For example, monarch butterflies rely on transcontinental supplies of milkweed for their migration and reproduction. In contrast, many bumble bees rarely venture more than a few hundred yards from their nest (Wade, 2014). Further, pollinator effectiveness varies by insect type and agro-ecological conditions including soil type, natural land cover, and cropping practices. Given the complex ecological and biodiversity relationships involved, it is impossible to evaluate all potential policy options for each species. Following organization in Garibaldi et al., (2014) Table 1 summarizes the suggested best practices to promote pollinator health through in-field and beside-the-field practices.

The trend toward large, monoculture crop landscapes is a major trend threatening pollinator habitat in North America. Possible approaches to improve pollinator habitat under these conditions include: (a) increasing crop heterogeneity, including flowering crops across the landscape, and (b) reducing field sizes (Garibaldi et al., 2014; Isaacs and Kirk, 2010). A challenge of using these practices is to ensure they are implemented at spatially appropriate intervals across the landscape. Pollinator forage needs vary by species and plant complementarity. Wild pollinators and managed honeybees often have different habitat ranges. For example, honey bee colonies have a greater habitat need as well as foraging needs, which easily encompass a three mile radius of their hive during normal conditions (Visscher and Seeley, 1982). In contrast, wild bumblebees' ranges tend to be smaller—within 50 to 100 meters.

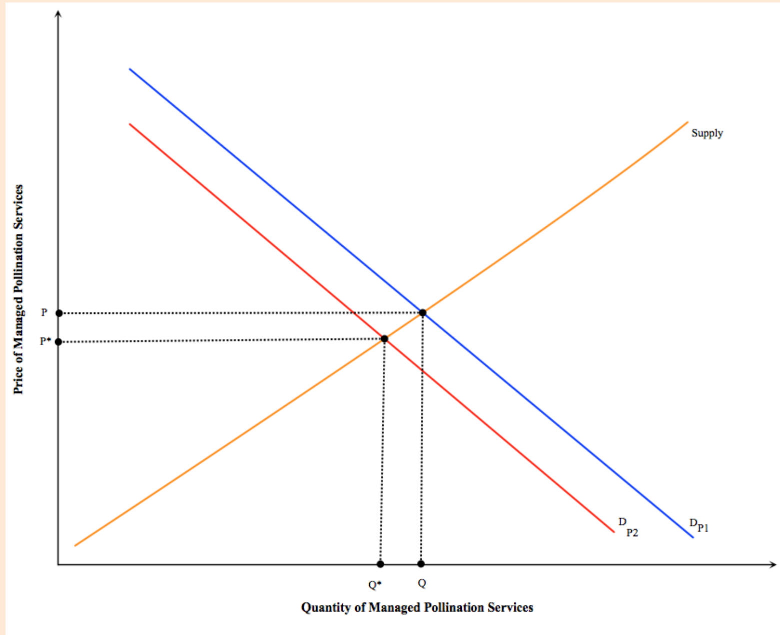
Uncertainty remains about which recommended best practice should be pursued first and in what priority. For some recommendations, scientific uncertainty may hinder adoption. Feeding this inertia is economic uncertainty regarding the production-level profitability, market demand, and non-market benefits of different pollinator conservation practices. For instance, planting flowers among existing crops may boost pollinator health and productivity of some of those crops, but it is not clear what the costs and benefits to farmers will be. Both economic and ecological science dimensions need further investigation to develop both efficient and effective pollinator policies.

Economics in Pollinator Policy Development

Economists bring several useful tools and frameworks to the policy workbench including supply and demand analysis for pollinator services; crop production function estimation; pollination market analysis; and non-market pollinator valuation. Each tool requires data and information for implementation.

The supply and demand relationships for managed pollination services are a starting point to estimate the pollinators' value across agricultural crops. Figure 2 shows the relationship between price of pollinator services and the quantity pollinators are willing to provide at that price (supply) and the price of pollinator services and the quantity that purchasers of the service are willing to buy at that price (demand). Today, only a few crop farmers own their own bees, and most pollination services are provided by migratory beekeepers (Daberkow, Korb, and Hoff, 2009). Markets for pollination services exist for specific crops in different areas of the country (Rucker, Thurman, and Burgett, 2012). In Figure 2, the total demand for pollination services is represented by D_P. When wild pollinators are not present, the price of pollination services is P and the quantity demanded is Q. In the short-run, the quantity of managed pollinators available is Q. When wild pollinators are available in the agro-ecosystem, they effectively subsidize growers' demand for pollinators from the private, managed pollinator market. Grower pollination demand decreases from D_{P1} to D_{P2}. This decreased market demand leads to a lower market price, P^*, and pollination service demand, Q^*. The difference between P^* and P, if measurable, can help estimate the value of wild pollinators.

Figure 2: Managed Pollination Services Supply and Demand



While held constant in Figure 2, in reality, the supply curve is in a nearly constant state of flux, expanding and contracting, due to economic and environmental forces. The supply of managed pollinators depends on their care, the environment, and disease and pest threats. The degree to which P and P^* vary, depends on a complex set of linked ecological and economic relationships, including both consumer and producer decision processes. Accurately understanding these relationships is critical for effective pollinator conservation policies.

Unfortunately, missing information creates challenges to implementing this market approach to measuring pollination values. First, bio-economic relations are not known to properly estimate the necessary supply and demand relationships across crop types. Second, most pollination contracts are privately negotiated and the market-clearing price for those services is unknown in the current season or at all (Rucker, Thurman, and Burgett, 2012). Such information is vital for supply and demand modeling. Finally, full information regarding the substitutability between pollinator species is needed to understand the relationship between *P* and *P**.

Existing economic analyses is mostly limited to the value managed pollinators add to commercial agricultural production. Economic estimates show pollinators added approximately $197 billion to global crop production (Gallai et al., 2009). In the United States, there has been an increase in the production of direct pollinator dependent crops from $14.29 billion to $15.12 billion since 1996 (Calderone, 2012). Yet, the precision of these macroeconomic estimates is unclear as the pollinator crop production function—a relationship between production inputs and output—and ecosystem health relationships remain foggy (see Winfree, Gross, and Kremen, 2011; Muth and Thurman, 1995 for further discussion).

Consumer or food retail food prices can also reflect pollinator worth. In theory, pollination increases crop supply to the commodity markets, leading to decreased food prices and increased consumer welfare via those lower prices (Hanley et al., in press). Over the last 50 years, consumer demand for pollinated crops has doubled (Aizen and Harder, 2009). This demand affects both crop prices and the demand for managed and wild pollinator production factor inputs. But, the availability and productivity of pollinators depends on ecological systems.

The most explicit relationships between agriculture crop production and ecosystem functioning may be observed at the farm level. Economic relationships such as crop productivity and input choices are directly related to ecosystem functioning and pollinator abundance as illustrated in Figure 1. At a basic research level, we know relatively little about the exact productivity relationships among wild and managed pollinators and the broad range of crops they help produce. Researchers have modeled and examined the productivity of crops such as almonds, alfalfa, watermelons, and blueberries from managed pollinators (Champetier, Sumner, and Wilen, 2015; Isaacs and Kirk, 2010). Whilst this crop list is not comprehensive, economic relationships between crop production and wild pollinators is nearly non-existent.

Due to the lack of knowledge between economic and pollinator processes, policy would greatly benefit from increased understanding of farm level bio-economic relationships. Ecological models alone will not accurately predict agro-ecosystem responses to new pollinator policies. However, economic and ecological models may be linked through bio-economic modeling processes.

In order to accomplish these ends, economic analysis would benefit from more generalizable crop production data incorporating pollinators, especially wild pollinators. The supply price of pollinated crops depends on alternative production opportunities, producer skill, target pollinator levels, land productivity, and habitat resources (Hanley et al., 2012). It is also essential to understand the complementarity and substitutability across pollinator species for different crops to estimate economic impacts of policy adoption at the farm level. With this information, economists would more precisely gauge the costs, benefits, and risks of different policy options for farmers.

The total value of pollinators to society is the net present value of both the market and non-market benefits they offer (Hanley et al., in press). Market benefits may be summarized as the contribution pollinators make to agricultural and horticultural crop production we just discussed. Yet, pollinators' total value exceeds market-based estimates and encompasses non-market pollinator benefits including societal values of sighting pollinators, knowing they exist, and experience the beautification they add through flowers and trees. Disregarding pollinators' non-market values may lead to inefficient pollinator conservation investments.

In most cases, it is more challenging to obtain non-market than market values. Economists may measure non-market values using stated preference and willingness-to-pay measures of direct and indirect societal values of pollinator benefits. Benefits may be measured procuring individuals' willingness-to-pay for pollinator benefits via surveys and economic experiments. Such tools may refine policies to achieve desirable pollinator population targets and determine which policy attributes people find most desirable.

Behavioral and Institutional Dimensions of Effective Pollinator Policy

On both sides of the bio-economic system, external factors may disrupt policy effectiveness and implementation. On the ecological side, external pressures such as climate variability and invasive species can disrupt ecosystem functioning and thwart policy implementation. Similarly, on the economic side, institutional operations and individuals' cooperation, risk and time preferences can influence policy effectiveness. We need to consider such environmental, institutional, and behavioral factors to develop effective and sustainable pollinator conservation policies. Institutional factors include the laws and regulatory structure, government, and market organizations shaping producer and consumer choices. Behavioral factors include individual and group psychology, perceptions, and beliefs shaping decision processes. Here, we discuss ways in which policies should consider principal-agent relationships—that is to ensure conservation policies are designed so that producers efficiently adopt effective practices and created intended outcomes—policy mechanism implementation, and community public good problems.

First and foremost, a dichotomy exists between regulatory and landowner interest. Landowners incur both direct and indirect opportunity costs for conservation actions. Yet, they only receive a part of the full benefits of their actions. For example, they may see improved crop production, but are also providing external benefits for pollinator and wildflower viewing to society. Regulatory agencies are challenged to achieve conservation outcomes with their own limited resources. An important source of principal-agent problems for pollinator conservation is hidden information regarding the biodiversity production function. The agent (farmer) has more information about this than the principal (regulator). There is uncertainty about how much pollinator outcomes rely on land manager actions when the surrounding ecosystem, soil and water resources, temperature, and general landscape use factors are also influential on pollinator health. Given the uncertainty surrounding outcome achievements, most conservation policy is targeted at farmer actions, rather than outcomes (Hanley et al., 2012).

Second, farmer participation can be affected by payment levels, transaction costs, time horizon, and externality effects. Past research suggests conservation contract prices need to be higher than farmers' true supply costs. Farmer participation is deterred by transaction costs. Their program transaction costs include search, negotiation, and administration costs. There is a trade-off between contract length and landowner participation. However, landowners are less likely to enroll in long or infinite term contracts even though the habitat benefits generally increase with longer contracts. Pollinator conservation has externality effects. Farmers may not enroll if they are enjoying pollination benefits from surrounding farms without having to conserve their own land (Hanley et al., 2012).

Finally, overcoming one of the primary challenges to pollinators, fragmented landscapes requires overcoming public good and spatial coordination challenges. Spatial coordination is challenging because each landowner has a unique opportunity cost associated with pollinator conservation. Tools from game theory and behavioral economics may help facilitate landscape level coordination. Regarding CRP for pollinator conservation, it is important to consider how to incentivize CRP enrollment for separate farmers with contiguous acreage to enroll and create spatially adequate amounts of pollinator habitat. One proposed policy tool to reunite fragmented habitat is an agglomeration bonus (Smith and Shogren, 2002). This bonus is designed to enhance uniform payment schemes by enhancing individual landowner payments when adjacent property—including that owned by another party—is enrolled in the conservation program (Hanley et al., 2012; Parkhurst and Shogren, 2007; Smith and Shogren, 2002). Researchers have used experimental methods to explore if the agglomeration bonus could be an effective policy tool to coordinate landowner formed wildlife corridors and continuous reserves for biodiversity conservation across privately held land (Banerjee et al., 2014; Drechsler et al., 2010; Parkhurst and Shogren, 2007; Parkhurst et al., 2002). Agglomeration bonus research may also guide how pollinator conservation policy may be implemented at the landscape level.

Policy and Research Directions

Lasting, long-term pollinator conservation policy needs to consider both economic and ecological system influences and outcomes for managed and wild pollinators. Economists and ecologists may make more valuable contributions to policy by developing improved bio-economic models with clearly defined production function relationships across crops and pollinator species. Accurate policy benefit and cost analysis must account for both market and non-market benefits of pollinator species. Finally, all stakeholders need to keep the big picture in mind, both literally and figuratively. Pollinators need landscape-level policies, requiring cooperation among farmers, farmers, and regulators, and both parties and the public. Behavioral and institutional economic principles may facilitate such cooperation.

How must policy makers proceed with pollinator policy? Our overview suggests an integrated approach, incorporating both economic and ecological considerations and feedback. As the U.S. Congress and executive agencies support scientific research to improve pollinator health and well-being, they need to promote well-rounded, objective research that accounts for both economic and ecological data and information needs. Such an integrated approach will improve our understanding of the forces and feedbacks that influence pollinator wellbeing. Integrating both economic and ecological factors into research and policy design will improve the chances future pollinator policy is successful.

For More Information

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