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## The Ecology and Evolution of Plant–Pollinator Interactions

A conference organized by Jeffrey D. Karron, Randall J. Mitchell, and Rebecca E. Irwin prior to the 2008 ESA Annual Meeting in Milwaukee, Wisconsin, with support from the Ecological Society of America and the Annals of Botany Corporation.

For over two centuries, pollination biology has enjoyed a rich history of study by both ecologists and evolutionary biologists, and has fascinated natural historians, gardeners, and environmental enthusiasts. Studies in pollination biology have provided insight into animal cognition and behavior, mutualism, exploitation, mating biology, and some of the best-known examples of evolution and co-evolution by natural selection (reviewed in Thompson 1994, Chittka and Thomson 2001, Harder and Barrett 2006). Like many disciplines in biology, innovation in the study of pollination has often involved specialization in a particular subdiscipline (McPeck 2006), such as botanical vs. zoological aspects (Waser and Price 1998) or plant-mating system vs. pollination ecology focus areas (Lloyd and Barrett 1996). However, this specialization may cause fragmentation of understanding and conceptual frameworks, which can hamper progress if unaddressed. The study of pollination biology has experienced a recent surge of growth in two related fields. On the one hand, studies in community pollination ecology are breaking new ground in research addressing webs of species interactions and the repercussions of disturbance, land-use change, and invasion to community dynamics (Waser and Ollerton 2006). On the other hand, evolutionary pollination biologists are now armed with advanced molecular and genomic tools that enable them to delve into the processes and consequences underlying the dynamics of pollen transport, the evolution of obligate mutualisms and plant mating patterns, and the genetics of floral evolution (Harder and Barrett 2006).

The goal of this conference was to highlight exciting recent advances in community and evolutionary pollination biology, and to foster interaction among pollination biologists. We aimed to encourage a unified framework for the study of community and evolutionary approaches, and draw attention to largely unexplored questions at the intersection of community and evolutionary pollination biology to inspire future research. The two-day conference featured 23 speakers from eight countries, as well as a poster session with 85 participants. The conference drew more than 200 attendees from 17 nations.

Oral presentations were organized into four half-day sessions, two each on evolutionary and community approaches in pollination biology. The conference opened with six talks on evolutionary approaches. Three talks focused on the adaptive nature of floral traits, including how close traits are to their adaptive optimum and why populations depart from their adaptive optimum (S. Armbruster), the roles of integration and constraint on anther-position evolution within the context of a diverse pollinator assemblage (J. Conner), and the effect of flower color and correlated traits on pollinator visitation preferences (D. Campbell). Three additional talks explored theoretical, molecular, and experimental approaches (L. Harder, J. Brunet, and J. Karron) to investigating plant mating patterns and the causes and consequences of pollen dispersal by diverse pollinator assemblages. One common thread through all of the talks was the importance of community composition (both of the plants and the pollinators)

to mating and fitness outcomes, providing a direct link between the ecology of the plant–pollinator community and evolutionary implications in terms of mating patterns, gene flow, and selection on floral traits. These talks also emphasized the need for more research quantifying male components of reproductive success.

The next set of talks highlighted the importance of nonpollinating species to the ecology and evolution of plant–pollinator interactions. A surprising number of organisms interact with flowers but do not act as pollinators; these nonpollinating floral visitors may have powerful effects on the ecology and evolution of plant–pollinator interactions via both direct and indirect mechanisms. C. Herrera highlighted the patterns and mechanisms driving microbial communities in floral nectar. Yeasts are common in floral nectar across a diversity of habitats and may shape (and be shaped by) pollinator visitation, with implications for plant fitness and floral evolution. J. Bronstein and R. Irwin offered empirical insight into how multispecies interactions shape plant fitness and natural selection on floral traits, including plant interactions with ants, nectar robbers, and other co-flowering plants. One common theme running through these studies is that these nonpollinating floral visitors may impose selection on floral traits that may conflict with or strengthen pollinator-mediated selection.

Plant–pollinator interactions occur within the context of a changing world. The next three talks highlighted how anthropogenic factors may affect the ecology of plant–pollinator interactions, with implications for seed production in wild and agricultural plants. T. Knight focused on pollen limitation in invasive vs. native flowering species, using both empirical studies and a meta-analysis. M. Aizen and C. Kremen investigated plant–pollinator interactions in agricultural landscapes. Approximately 35% of crops worldwide require pollinators for production (Kremen et al. 2002). At a global scale, M. Aizen investigated the evidence concerning pollinator shortages in agricultural systems, and how increasing reliance on crops that require pollinators may affect future crop yield. At a local scale, C. Kremen used empirical studies to assess pollen limitation in agricultural systems and discussed the development of a model of pollination services to generate a pollinator source map.

The first day of oral presentations was followed by an evening mixer and poster session. The mixer and poster session provided many opportunities for participants to share diverse research perspectives and view some of the most exciting new work in pollination biology. Many of these posters may also be viewed online at the conference web site <<http://www3.uakron.edu/biology/pollination/>>

The opening talks on the second day addressed pollinator communities and their host plants. There is growing recognition that plant–pollinator interactions are generalized in nature (Waser et al. 1996) and web-like in structure (Memmott 1999). The Pollination Syndrome Concept, which has drawn much controversy in recent years (Waser et al. 1996, Johnson and Steiner 2000, Fenster et al. 2004), describes convergent sets of floral characters that are presumed to be adaptations to specific types of pollinators. N. Waser developed the framework for a quantitative test of the Pollination Syndrome Concept, and provided an empirical test of the model from six plant–pollinator communities on three continents. J. Ollerton used a biogeographic and phylogenetic approach to the study of plant–pollinator interactions, focusing on a diverse plant genus (*Ceropegia*, Apocynaceae) and the diversity of flies that pollinate them. Continuing with the exploration of generalization and specialization in pollination systems, T. Roulston and T.-L. Ashman investigated pollinator redundancy across space and time and across studies

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with implications for pollinator efficiency and pollen limitation of seed production. The next series of talks focused on webs of plant–pollinator interactions and the factors that may determine the structure of the webs, including floral and insect morphology (M. Stang) as well as plant and insect abundance, phenology, and space (D. Vazquez).

The conference closed with a series of talks on evolutionary pollination biology with a focus on spatial structure and community composition. While many studies in ecology focus on small spatial scales, pollination biologists must incorporate the spatial structure at which pollinators forage. This spatial structure was convincingly incorporated in studies on trap-lining bees (J. Thomson and K. Ohashi), flowering phenology and pollination success at the landscape scale (G. Kudo), the effects of habitat fragmentation on pollination and outcrossing (R. Whelan), and the ecological and evolutionary implications of competition for pollinators in mixed-species plant stands (R. Mitchell). S. Barrett took a different approach to the study of pollination than many talks in the conference by focusing on the ecology and evolution of wind pollination, shattering many of the conventional wisdoms typically associated with wind pollination. Finally, R. Mitchell tied the conference together by synthesizing the diversity of ecological and evolutionary approaches used and questions addressed, demonstrating the fundamental importance of plant–pollinator interactions to ecology and evolution and the link between ecological and evolutionary disciplines from both the plant’s and the pollinator’s perspective.

The goal of the conference was to unite themes from evolutionary and community disciplines in pollination biology. While the talks themselves were organized into thematic sections, calls for action did emerge that will continue to unite evolutionary and community approaches to the study of pollination biology. We note the following three topic areas, although many others were also discussed: (1) the implications of diverse pollinator communities and behaviors to plant mating patterns and selection on traits; (2) the evolutionary consequences of global environmental change via changes in plant–pollinator interactions; and (3) the importance of temporally and spatially varying interaction webs for (co)evolution among partners. A separate vein of agreement was the recognition of the growing international nature of modern pollination biology. The many excellent international speakers and participants at this meeting highlighted the rapidly growing strength of the science. We encourage readers who would like to read more about this conference to view a forthcoming special issue of *Annals of Botany* on the Ecology and Evolution of Plant–Pollinator Interactions.

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