Pollination and Food Production in a Changing World

Lecturer: Dr. Danny Minahan

3-weekly hours, 3-academic credits

Course description

For 200 million years flowering plants and pollinators have co-evolved together. This interaction has led to most of the biodiversity we see today, with 80% of flowering plants requiring pollinator visits for reproduction. Pollinators are necessary to produce 35% of the total food humans consume, and most of the nutrients necessary for a healthy diet. However, plant-pollinator interactions are being disrupted by rapid global change. In this course you will master ecological concepts through the lens of plant-pollinator interactions. By bridging ecological theory with practical application, you will design a sustainable food system that protects biodiversity and promotes food production.

Course Requirements and Class Structure

Each class is 3 hours, meeting once per week. Weekly classes are interactive, consisting of integrated lectures and activities. Over the course of the semester there will be a mid-term exam, two guest lectures, and one field trip. In addition, students will maintain a *plant-pollinator* journal, and for their final project develop and present an action plan for a sustainable food production system.

Grading components

Attendance and punctuality	15%
In-class activities and reading assignments	20%
Pollination reflections x2: (2 submitted reflections)	10%
Field trip report	10%
Mid-term exam	20%
Final project: Presentation and written report	25%
Total	100%

Books used in this course

- Ollerton, J. (2021). *Pollinators and pollination: nature and society*. Pelagic Publishing Ltd.
- Purdy, J. (2023) The foraging ecology of the honey bee. Elsevier.

Lesson 1 – Course introduction

Topics:

- Part 1: Syllabus lecture and activity
- Part 2: Ecology and pollination

Learning objectives:

- Articulate the topics and assignments for the semester with their peers
- Define ecology using pollination as an example

Readings:

- No mandatory readings

Lesson 2 – Biodiversity and ecosystem services

Topics:

- Part 1: Ecology unit 1: Populations and communities
- Part 2: Ecology unit 2: Pollination as an ecosystem service
- Part 3: Discuss the final project

Learning objectives:

- Define ecology in terms of populations, communities, and biodiversity.
- Explain why pollination is considered an ecosystem service
- Review the objectives and timeline for the final project

Readings:

- Ollerton, J. (2021). *Pollinators and pollination: nature and society*. Pelagic Publishing Ltd. **Chapter 1 only**
- Rehman, A., Farooq, M., Lee, D. J., & Siddique, K. H. (2022). Sustainable agricultural practices for food security and ecosystem services. *Environmental Science and Pollution Research*, *29*(56), 84076-84095. https://doi.org/10.1007/s11356-022-23635-z.

Lesson 3 – Behavioral ecology of pollination

Topics

- Part 1: Plant-pollinator interactions in food production ecosystems
- Part 2: Outdoor activity: Plant-pollinator journal #1

Learning objectives

- Describe the different types of ecological interactions and their outcomes
- Describe 3 plant-pollinator interactions, and explain why the flower visitor was or was not a pollinator
- Construct a story for a pollinator based on behavioral observations.

Readings

- Anselmo, P. A., Cardoso, J. C. F., Siqueira, P. R., & Maruyama, P. K. (2023). Non-native plants and illegitimate interactions are highly relevant for supporting hummingbird pollinators in the urban environment. *Urban Forestry & Urban Greening*, *86*, 128025. https://doi.org/10.1016/j.ufug.2023.128025.
- Sapir, G., Baras, Z., Azmon, G., Goldway, M., Shafir, S., Allouche, A., ... & Stern, R. A. (2017). Synergistic effects between bumblebees and honey bees in apple orchards increase cross pollination, seed number and fruit size. *Scientia Horticulturae*, *219*, 107-117. https://doi.org/10.1016/j.scienta.2017.03.010.

- Tremlett, C. J., Moore, M., Chapman, M. A., Zamora-Gutierrez, V., & Peh, K. S. H. (2020). Pollination by bats enhances both quality and yield of a major cash crop in Mexico. *Journal of Applied Ecology*, *57*(3), 450-459. https://doi.org/10.1111/1365-2664.13545.
- Haran, R. (2026). Mutualism across Biogeographic Regions between Lesser Whitethroat Curruca curruca and Maerua crassifolia Trees. *Ardea*, *113*(2), 1-9. https://doi.org/10.5253/arde.2025.a5.

Lesson 4 – Honey bees and beekeeping

Topics

- **Guest lecture:** Honey bees and society, from past to present

Learning objectives

- Examine the role of beekeeping in society and culture
- Understand honey bees as a model system for studying behavior, cognition, and social organization

Readings

- Egerer, M., & Kowarik, I. (2020). Confronting the modern gordian knot of urban beekeeping. *Trends in Ecology & Evolution*, *35*(11), 956-959. https://doi.org/10.1016/j.tree.2020.07.012.
- Brunet, J., & Minahan, D. (2024). Honey bee pollination ecology. In *The Foraging Behavior of the Honey Bee (Apis mellifera, L.)* (pp. 121-150). Academic Press.
- Page, M. L., & Williams, N. M. (2023). Evidence of exploitative competition between honey bees and native bees in two California landscapes. *Journal of Animal Ecology*, *92*(9), 1802-1814. https://doi.org/10.1111/1365-2656.13973.

Lesson 5 – Global challenges threatening food security.

Topics

- Part 1: Food production, conservation, and ecological systems
- Part 2: Work on final projects

Learning objectives

- Interpret graphs to describe the distribution of food production around the world and its relationship to human well-being
- Identify the location for developing the Action Plan and which crops are grown there

Readings

- Ollerton, J. (2021). *Pollinators and pollination: nature and society*. Pelagic Publishing Ltd. *Chapter 7 pages 108-123*
- *Senapathi, D., Biesmeijer, J. C., Breeze, T. D., Kleijn, D., Potts, S. G., & Carvalheiro, L. G. (2015).* Pollinator conservation—the difference between managing for pollination services and preserving pollinator diversity*. Current opinion in insect science, 12, 93-101.* https://doi.org/10.1016/j.cois.2015.11.002.

Lesson 6 – Field trip: Walking tour of Ketura agriculture

Topic:

- Observing ecological interactions in desert food production

Learning objectives:

- Complete a reflection worksheet that connects the ecology and pollination concepts learned in class to the field trip observations
- Identify 2-3 questions from the field trip that will help in the design of a sustainable food production landscape

Readings:

- Eeraerts, M., Borremans, L., Smagghe, G., & Meeus, I. (2020). A growers' perspective on crop pollination and measures to manage the pollination service of wild pollinators in sweet cherry cultivation. *Insects*, *11*(6), 372. https://doi.org/10.3390/insects11060372.
- Khalifa, S. A., Elshafiey, E. H., Shetaia, A. A., El-Wahed, A. A. A., Algethami, A. F., Musharraf, S. G., ... & El-Seedi, H. R. (2021). Overview of bee pollination and its economic value for crop production. *Insects*, *12*(8), 688. https://doi.org/10.3390/insects12080688.
- Proesmans, W., Bonte, D., Smagghe, G., Meeus, I., Decocq, G., Spicher, F., ... & Verheyen, K. (2019). Small forest patches as pollinator habitat: oases in an agricultural desert?. *Landscape Ecology*, *34*(3), 487-501. DOI:10.1007/s10980-019-00782-2.
- Schackermann, J., Pufal, G., Mandelik, Y. and Klein, A.-M. (2015). Agro-ecosystem services and dis-services in almond orchards are differentially influenced by the surrounding landscape. *Ecol Entomol*, 40: 12-21. https://doi.org/10.1111/een.12244.

Lesson 7 – Midterm exam

Topics

- The midterm exam will be during the class period and handwritten

Learning objectives

- Demonstrate an understanding of pollination as an ecosystem service in food production and biodiversity conservation

Readings

- There will be no readings for this class

Lesson 8 – Sub-lethal stressors and pollinator health

Topics

- Part 1: Effects of pesticides, pathogens, and unbalanced nutrition on pollinators
- Part 2: Work on SMART goals for the Action Plan

Learning objectives

- Interpret graphs from primary research articles in small groups, share conclusions, and revise
- Read example SMART goals in small groups, share, and revise

Readings

- Stuligross, C., Melone, G. G., Wang, L., & Williams, N. M. (2023). Sublethal behavioral impacts of resource limitation and insecticide exposure reinforce negative fitness outcomes for a solitary bee. *Science of the Total Environment*, *867*, 161392. https://doi.org/10.1016/j.scitotenv.2023.161392.
- Requier, F., Jowanowitsch, K. K., Kallnik, K., & Steffan-Dewenter, I. (2020). Limitation of complementary resources affects colony growth, foraging behavior, and reproduction in bumble bees. *Ecology*, *101*(3), e02946. https://doi.org/10.1002/ecy.2946.

Lesson 9 – Global initiatives to protect pollinators.

Topics

- Part 1: How do scientists study pollinators and pollination around the world
- Part 2: Successful approaches to pollinator conservation and protection
- Part 3: Outdoor activity: Plant-pollinator journal #2

Learning objectives

- Describe and diagram a food production ecosystem in relation to landscape elements that impact pollinators, and the associated ecosystem services

- Describe how you would study the pollinator community in an agricultural system in relation to floral traits and pollinator behavior.
- Describe 3 plant-animal interactions (could be pollinator, pest, or other) that you observe and incorporate their function into the story from class 3.

Readings

- Bruninga-Socolar, B., Winfree, R., & Crone, E. E. (2022). The contribution of plant spatial arrangement to bumble bee flower constancy. *Oecologia*, *198*(2), 471-481. DOI: 10.1007/s00442-022-05114-x.
- González-Varo, J. P., Biesmeijer, J. C., Bommarco, R., Potts, S. G., Schweiger, O., Smith, H. G., ... & Vilà, M. (2013). Combined effects of global change pressures on animal-mediated pollination. *Trends in ecology & evolution*, *28*(9), 524-530. 10.1016/j.tree.2013.05.008
- Nath, R., Singh, H., & Mukherjee, S. (2023). Insect pollinators decline: an emerging concern of Anthropocene epoch. *Journal of Apicultural Research*, *62*(1), 23-38. https://doi.org/10.1080/00218839.2022.2088931.

Lesson 10 – Habitat management across the landscape

Topics:

- Part 1: **Guest lecture**: Flower strips and other floral resource interventions to protect pollinators
- Part 2: Work on final projects

Learning objectives

- Understand the importance of floral diversity and semi-natural habitats to beneficial insects in food production ecosystems

Readings

- Fijen, T. P., Bishop, G. A., Ganuza, C., Scheper, J., & Kleijn, D. (2025). Analyzing the relative importance of habitat quantity and quality for boosting

pollinator populations in agricultural landscapes. *Conservation Biology*, 39(1), e14317. https://doi.org/10.1111/cobi.14317.

- Eeraerts, M., Van Den Berge, S., Proesmans, W., Verheyen, K., Smagghe, G., & Meeus, I. (2021). Fruit orchards and woody semi-natural habitat provide complementary resources for pollinators in agricultural landscapes. *Landscape Ecology*, 36(5), 1377-1390. https://doi.org/10.1007/s10980-021-01220-y.
- Minahan, D., & Brunet, J. (2025). Pollen collection by the western honeybee and common eastern bumble bee foraging in a common landscape and applications for agri-environment schemes. *Royal Society Open Science*, *12*(3). https://doi.org/10.1098/rsos.240675.
- Priyadarshana, T. S., Martin, E. A., Sirami, C., Woodcock, B. A., Goodale, E., Martínez-Núñez, C., ... & Slade, E. M. (2024). Crop and landscape heterogeneity increase biodiversity in agricultural landscapes: A global review and meta-analysis. *Ecology Letters*, 27(3), e14412. https://doi.org/10.1111/ele.14412.

Lesson 11 – The future of pollination and food production in a changing world

Topics

- Part 1: Responses by pollinators to a changing climate and planning for the future
- Part 2: Final project presentations session 1

Learning objectives

- Describe 2 global change factors that impact pollinators and how you will mitigate their effects in your Action Plan.
- Practice presenting, providing feedback, and discussing your projects.

Readings

- Martén-Rodríguez, S., Cristobal-Pérez, E. J., de Santiago-Hernández, M. H., Huerta-Ramos, G., Clemente-Martínez, L., Krupnick, G., ... & Quesada, M. (2025). Untangling the complexity of climate change effects on plant reproductive traits and pollinators: A systematic global synthesis. *Global Change Biology*, 31(2), e70081. https://doi.org/10.1111/gcb.70081.

Lesson 12 – Practicing science as a field ecologist

Topics

- Part 1: Embracing and managing uncertainty in food production
- Part 2: Final project presentations session 2

Learning objectives

- Discuss the ways in which you are managing contrasting demands in your Action Plan

Readings

- Bascompte, J., & Scheffer, M. (2023). The resilience of plant–pollinator networks. *Annual Review of Entomology*, *68*(1), 363-380. https://doi.org/10.1146/annurev-ento-120120-102424.

Final project submission

- The Action Plan will be submitted 1 week after Lesson 12.

Literature

- Anselmo, P. A., Cardoso, J. C. F., Siqueira, P. R., & Maruyama, P. K. (2023). Non-native plants and illegitimate interactions are highly relevant for supporting hummingbird pollinators in the urban environment. *Urban Forestry & Urban Greening*, 86, 128025. https://doi.org/10.1016/j.ufug.2023.128025.

- Bascompte, J., & Scheffer, M. (2023). The resilience of plant–pollinator networks. *Annual Review of Entomology*, *68*(1), 363-380. https://doi.org/10.1146/annurev-ento-120120-102424.
- Bruninga-Socolar, B., Winfree, R., & Crone, E. E. (2022). The contribution of plant spatial arrangement to bumble bee flower constancy. *Oecologia*, *198*(2), 471-481. DOI: 10.1007/s00442-022-05114-x.
- Brunet, J., & Minahan, D. (2024). Honey bee pollination ecology. In *The Foraging Behavior of the Honey Bee (Apis mellifera, L.)* (pp. 121-150). Academic Press.
- Eeraerts, M., Van Den Berge, S., Proesmans, W., Verheyen, K., Smagghe, G., & Meeus, I. (2021). Fruit orchards and woody semi-natural habitat provide complementary resources for pollinators in agricultural landscapes. *Landscape Ecology*, 36(5), 1377-1390. https://doi.org/10.1007/s10980-021-01220-y.
- Eeraerts, M., Borremans, L., Smagghe, G., & Meeus, I. (2020). A growers' perspective on crop pollination and measures to manage the pollination service of wild pollinators in sweet cherry cultivation. *Insects*, *11*(6), 372. https://doi.org/10.3390/insects11060372.
- Egerer, M., & Kowarik, I. (2020). Confronting the modern gordian knot of urban beekeeping. *Trends in Ecology & Evolution*, 35(11), 956-959. https://doi.org/10.1016/j.tree.2020.07.012.
- Fijen, T. P., Bishop, G. A., Ganuza, C., Scheper, J., & Kleijn, D. (2025). Analyzing the relative importance of habitat quantity and quality for boosting pollinator populations in agricultural landscapes. *Conservation Biology*, 39(1), e14317. https://doi.org/10.1111/cobi.14317.
- Haran, R. (2026). Mutualism across Biogeographic Regions between Lesser Whitethroat Curruca curruca and Maerua crassifolia Trees. *Ardea*, *113*(2), 1-9. https://doi.org/10.5253/arde.2025.a5.
- Khalifa, S. A., Elshafiey, E. H., Shetaia, A. A., El-Wahed, A. A. A., Algethami, A. F., Musharraf, S. G., ... & El-Seedi, H. R. (2021). Overview of bee

pollination and its economic value for crop production. *Insects*, *12*(8), 688. https://doi.org/10.3390/insects12080688.

- González-Varo, J. P., Biesmeijer, J. C., Bommarco, R., Potts, S. G., Schweiger, O., Smith, H. G., ... & Vilà, M. (2013). Combined effects of global change pressures on animal-mediated pollination. *Trends in ecology & evolution*, 28(9), 524-530. DOI: 10.1016/j.tree.2013.05.008
- Martén-Rodríguez, S., Cristobal-Pérez, E. J., de Santiago-Hernández, M. H., Huerta-Ramos, G., Clemente-Martínez, L., Krupnick, G., ... & Quesada, M. (2025). Untangling the complexity of climate change effects on plant reproductive traits and pollinators: A systematic global synthesis. *Global Change Biology*, 31(2), e70081. https://doi.org/10.1111/gcb.70081.
- Minahan, D., & Brunet, J. (2025). Pollen collection by the western honeybee and common eastern bumble bee foraging in a common landscape and applications for agri-environment schemes. *Royal Society Open Science*, 12(3). https://doi.org/10.1098/rsos.240675.
- Ollerton, J. (2021). Pollinators and pollination: nature and society. Pelagic Publishing Ltd.
- Priyadarshana, T. S., Martin, E. A., Sirami, C., Woodcock, B. A., Goodale, E., Martínez-Núñez, C., ... & Slade, E. M. (2024). Crop and landscape heterogeneity increase biodiversity in agricultural landscapes: A global review and meta-analysis. *Ecology Letters*, 27(3), e14412. https://doi.org/10.1111/ele.14412.
- Proesmans, W., Bonte, D., Smagghe, G., Meeus, I., Decocq, G., Spicher, F., ... & Verheyen, K. (2019). Small forest patches as pollinator habitat: oases in an agricultural desert?. *Landscape Ecology*, *34*(3), 487-501. DOI:10.1007/s10980-019-00782-2.
- Nath, R., Singh, H., & Mukherjee, S. (2023). Insect pollinators decline: an emerging concern of Anthropocene epoch. *Journal of Apicultural Research*, *62*(1), 23-38. https://doi.org/10.1080/00218839.2022.2088931.

- Page, M. L., & Williams, N. M. (2023). Evidence of exploitative competition between honey bees and native bees in two California landscapes. *Journal of Animal Ecology*, *92*(9), 1802-1814. https://doi.org/10.1111/1365-2656.13973.
- Rehman, A., Farooq, M., Lee, D. J., & Siddique, K. H. (2022). Sustainable agricultural practices for food security and ecosystem services. *Environmental Science and Pollution Research*, 29(56), 84076-84095. https://doi.org/10.1007/s11356-022-23635-z.
- Requier, F., Jowanowitsch, K. K., Kallnik, K., & Steffan-Dewenter, I. (2020). Limitation of complementary resources affects colony growth, foraging behavior, and reproduction in bumble bees. *Ecology*, *101*(3), e02946. https://doi.org/10.1002/ecy.2946.
- Sapir, G., Baras, Z., Azmon, G., Goldway, M., Shafir, S., Allouche, A., ... & Stern, R. A. (2017). Synergistic effects between bumblebees and honey bees in apple orchards increase cross pollination, seed number and fruit size. *Scientia Horticulturae*, *219*, 107-117. https://doi.org/10.1016/j.scienta.2017.03.010.
- Schackermann, J., Pufal, G., Mandelik, Y. and Klein, A.-M. (2015). Agro-ecosystem services and dis-services in almond orchards are differentially influenced by the surrounding landscape. *Ecol Entomol*, 40: 12-21. https://doi.org/10.1111/een.12244.
- Senapathi, D., Biesmeijer, J. C., Breeze, T. D., Kleijn, D., Potts, S. G., & Carvalheiro, L. G. (2015). Pollinator conservation—the difference between managing for pollination services and preserving pollinator diversity. *Current opinion in insect science*, 12, 93-101. https://doi.org/10.1016/j.cois.2015.11.002.
- Stuligross, C., Melone, G. G., Wang, L., & Williams, N. M. (2023). Sublethal behavioral impacts of resource limitation and insecticide exposure reinforce negative fitness outcomes for a solitary bee. *Science of the Total Environment*, 867, 161392. https://doi.org/10.1016/j.scitotenv.2023.161392.
- Tremlett, C. J., Moore, M., Chapman, M. A., Zamora-Gutierrez, V., & Peh, K. S. H. (2020). Pollination by bats enhances both quality and yield of a major

cash crop in Mexico. *Journal of Applied Ecology*, *57*(3), 450-459. https://doi.org/10.1111/1365-2664.13545.

Expectations for students

Attendance and punctuality

It is mandatory to arrive in class on time, and you will lose points from your attendance grade if you are late (per AIES policy). It is expected that you will arrive prepared, having completed any required readings, and ready to engage in the discussions and activities for the day. Laptops are to remain put away until they are needed for an activity. If you take notes using a laptop let us know in advance.

In-class activities and reading assignments

All classes will include small group activities integrated into the lectures. Often you will work on these activities with 2-3 of your peers to answer questions and solve problems related to the content of the lecture. It is expected that you will actively participate during class. In addition, for classes which have a pre-class reading assignment there will be a short quiz at the start.

Plant-pollinator journal (2 submitted reflections)

These will be individual nature observation and reflection activities designed to help you understand the process of pollination, and how this knowledge can be applied in sustainable food production. You will work through guiding questions covering material from the course but also incorporate reflections on your personal relationship with the natural world. The first reflection will occur early in the semester (class 3) and the second later in the semester (class 9).

Field trip report

There will be 1 field trip on class 6 to the Ketura agricultural area, where you will hike through a desert food production system. On this hike you will take a step back from examining the direct plant-pollinator interaction and examine the broader ecosystem in which pollination occurs. The field trip report will be completed by answering guiding questions that connect material from the first half of the course (ecology and

pollination) to the upcoming material in the second half (applied food production and biodiversity conservation).

Midterm exam

The midterm exam separates the first half of the course where you learn about pollination and fundamental ecological concepts, from the second half where you will learn about landscape management for establishing and maintaining resilient food production systems. The midterm will be in class and handwritten, while consisting of short-answer and multiple-choice questions.

Final project: Presentation and written report

Each student will be required to submit a written final project and present it to the class **instead of** a final exam. The presentation should be no more than 8 minutes + 2 minutes for questions. Some students will present during class 11, and others during class 12, you will sign up for these dates during class 2. The written portion will be due during the final's week (class 13).

The final project will be introduced in class 2, and you will have formal class time to work on it during the last hour of classes 5 and 10. For the final project you will create an action plan to establish a sustainable food production system in a location of your choice. As part of the action plan, you will need to do background research regarding the area you are interested in. You will need to figure out what crops are grown there, which crops you would like to add, take away, or replace. In addition, you will need to identify ongoing challenges in that locale or region, any possible future challenges, and describe how you will address them.

You will articulate SMART (Specific, Measurable, Achievable, Relevant, Time bound) goals to ensure that your food production system supports pollinators and pollination, relies upon, and provides ecosystem services, is resilient, and addresses food security challenges in the chosen region.

This is a class about pollination, so you will need to include at least 3 crops that require pollinators and identify the best pollinator for each crop based on what you have learned about the characteristics of pollinators and flowers. In addition, you will need to discuss how you will manage environmental stressors such as unbalanced nutrition, exposure to agrochemicals and other pollutants, and parasites and

disease. If you are planning to continue working in food production systems, this final project could very well be used as a jumping off point for action.