Project Notes:

Project Title: Simulating Pollinators to Find How Habitat Loss Affects Biodiversity
Name: Edward Goodwin

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
How can ABMS be used	Intro to simulation	Article #5	9/13
How do pesticides affect the bees?	Thiacloprid impairs honeybee worker learning and memory	Article #8	9/18
How does the impact of habitat loss and fragmentation affect bees?	The diverse effects of habitat fragmentation on plant–pollinator interactions	Article #4	9/24
How are native bees effected by agriculture?	Crop pollination from native bees at risk from agricultural intensification	Article #11	11/13
How are Agent-based models set up?	Often using a flow chart to show the interactions.	Article #13	12/11
Are native bees better at pollination of crops	Native specialist bees are often more efficient pollinators.	Article #15	12/11
How can I implement habitat fragmentation onto Netlogo?	Uploading a map as the background	Article #17	12/11

Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Google Scholar	Bees, Agent-based modeling	Found articles on how a beehive was modeled
Google Scholar	Decline of Bees	Found general knowledge on the decline of bees
Scopus	Neonicotinoids AND bees	Found how pesticides affect bees
Google Scholar	Bees and habitat fragmentation	Found how habitat fragmentation affects plant-pollinator interactions
Google Scholar	Will honey bees go extinct?	Honeybees are unlikely to do die out
Google	Do individual bees tend to focus on one flower?	Generalist bees will focus on one flower type at a time.
Google Scholar	Agent based modeling habitat fragmentation	
Google	Guide to netlogo	Instructions for all code in netlogo
Google Scholar	"habitat fragmentation" effects on native pollinators	

Tags:

Tag Name	
#Biology	#Agriculture
#Evolution	#Ecology

#ABMS	

Article #1 Notes: From A Single Domestication, Donkeys Helped Build Empires

Article notes should be on separate sheets

Source Title	From A Single Domestication, Donkeys Helped Build Empires Around the World
Source citation (APA Format)	Becher, M. A., Grimm, V., Thorbek, P., Horn, J., Kennedy, P. J., & Osborne, J. L. (2014). BEEHAVE: A systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure. *Journal of Applied Ecology*, *51*(2), 470–482. https://doi.org/10.1111/1365-2664.12222
Original URL	https://www.science.org/content/article/single-domestication-donkeys-helped-build-empires-around-world
Source type	Online Article
Keywords	Domestication, Genetics
#Tags	#Biology #Evolution #Agriculture
Summary of key points + notes (include methodology)	It was previously thought that donkeys were domesticated twice, once in Africa and once in Asia, however new genetic data shows that donkey's were domesticated only once in east Africa. As donkeys spread throughout Africa and Eurasia, they formed distinctive populations that became more specialized to their locations.
Research Question/Problem/ Need	How did donkey's domestication and genetic specialization to areas affect early civilizations?
Important Figures	Donkeys sequenced from up to 4000 years ago

VOCAB: (w/definition)	Paleogenetics - the study of the past through the examination of preserved genetic material from the remains of ancient organisms.
Cited references to follow up on	Siberia may be long-sought site of dog domestication | science. (n.d.). https://www.science.org/doi/10.1126/science.371.6528.451
Follow up Questions	In what ways did the specialization of donkeys affect civilization? What was the original ancestor of the donkey? What new breeds have occurred from the mixing of donkeys as these areas became more globalized?

Article #2 Notes: Alien-Looking Viruses Discovered in Massachusetts Forest

Article notes should be on separate sheets

Source Title	Alien-Looking Viruses Discovered in Massachusetts Forest
Source citation (APA Format)	Wilcox, C. (2023). *Alien-looking viruses discovered in Massachusetts forest* [dataset]. https://doi.org/10.1126/science.adj9542
Original URL	https://www.science.org/content/article/alien-looking-viruses-discovered-massachusetts-forest
Source type	Online Article
Keywords	Viruses, Biodiversity
#Tags	#Biology
Summary of key points + notes (include methodology)	While most research on giant viruses is conducted from freshwater samples, undiscovered genetic diversity could lie in forests. In the soils of theHarvard Forest west of Boston, scientists found novel giant viruses using electron microscopy with features like many hairlike structures, channeled structures, and tails.
Research Question/Problem/ Need	Do forests contain undiscovered ecological diversity in soil?
Important Figures	Sediments and soil host 97% of all the viral particles on Earth

VOCAB: (w/definition)	Morphology - the branch of biology that deals with the form of living organisms, and with relationships between their structures.
Cited references to follow up on	Giant virus genomes discovered lurking in DNA of common algae. (n.d.-a). https://www.science.org/content/article/giant-virus-genomes-discovered-lurking-dna-common-algae
Follow up Questions	What could be found from other forests? How do these novel giant viruses interact with different organisms? What genetic similarities and differences do they share with other viruses?

Article #3 Notes: Agent-Based Modeling and Simulation of Biological Systems

Article notes should be on separate sheets

Source Title	Agent-Based Modeling and Simulation of Biological Systems
Source citation (APA Format)	Bora, Ş., & Emek, S. (2018, December 5). *Agent-based modeling and simulation of Biological Systems*. IntechOpen. https://www.intechopen.com/chapters/64642
Original URL	https://www.intechopen.com/chapters/64642
Source type	Peer-reviewed chapter
Keywords	Agent-Based Modeling and Simulation, Biological systems
#Tags	#ABMS
Summary of key points + notes (include methodology)	This article explained some of how ecological models worked with interactions between species. It explained how many ecosystems form cyclical patterns of competition as each species impacts its environment and also just competes with the other species. It also showed how different methods of decision making whether instinctual or learned can benefit more as the environment they are in changes or stays more stable. ● Shows how to develop a simulation for biological systems on Repast Simphony ● ABMS can model biological systems like human physiology, ecosystems, and organisms that live in colonies like bees or ants ● Repast Simphony is free and open sourced, integrated with eclipse

	• Agents created in continuous space and based on classes interact with each other • Different attributes like size or energy, actions to take in response to the environment like move, grow, or reproduce, and rules that govern how the model works that affect how the agents can interact. • Predator prey relationships, bacterial interactions with immune cells and antibiotics, how biological systems maintain homeostasis with negative feedback loops like thermoregulation. Uses shivers, vasoconstriction to increase temp, sweat and vasodilation to decrease temp. • Thermoregulation: receptor agent senses temperature, controller agent knows the optimal body temperature, effector agents are the blood vessels that have different blood flow, • Sunn pest-wheat: predator-prey relationship, pests stage of life modeled by size with dying after reproduction, how much they grow restricted by wheat in the cell, parasitoid moves around to find a pest embryo to kill • Antibiotics: Immune cells repressing bacterial flora in a balance; immune cells observe neighboring cells and reacting by killing bacteria, signaling to other immune cells, or disappearing; bacteria reproduce, antibiotics kill the bacteria although some are resistant and reproduce more
Research Question/Problem/ Need	How can computer simulations be used for Agent-Based modeling? Are all repast simphony models just using dots? How does the 3-d model work or is displayed? Does it make it harder to make good models with more factors?
Important Figures	Graph made by the Agent based model of the regulation of body temperature.

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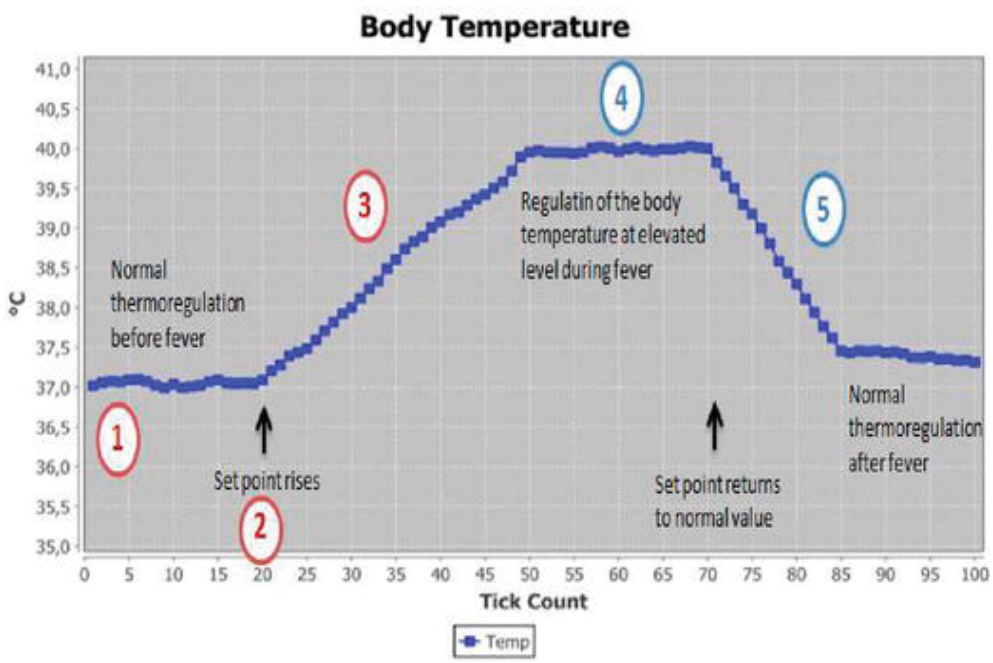

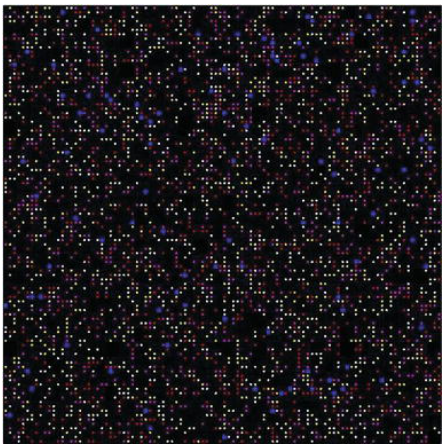
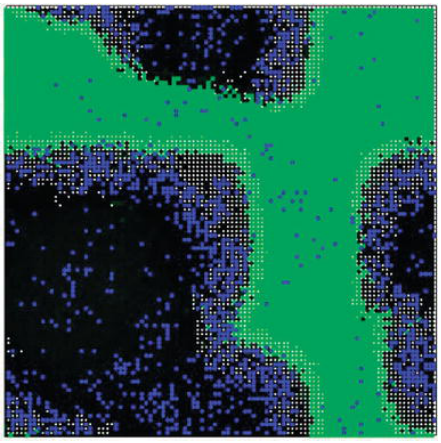
White, Yellow, red, purple- different bacteria, blue -immune cells in model of immuno cells and bacteria
Before and after simulation running</td>
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<td>VOCAB: (w/definition)</td>
<td>Agent-based modeling and simulation (ABMS): a computational model implemented as computer simulation in which there are individual entities and their behaviors and interactions

Repast Simphony: an agent-based modeling and simulation framework based on object-oriented programming using Java language.

Classes: ways to describe attributes and roles of agents in a model

Vasodilation: dilation of blood vessels to help body lose heat</td>
</tr>
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	Vasoconstriction: constriction of blood vessels to help body retain heat
Cited references to follow up on	Salehie, M., & Tahvildari, L. (2009). Self-adaptive software: Landscape and research challenges. *ACM Transactions on Autonomous and Adaptive Systems*, *4*(2), 14:1-14:42. https://doi.org/10.1145/1516533.1516538 (more useful for later on technical research)
Follow up Questions	How do I apply agent based modeling to solve my research question?

Article #4 Notes: Towards a Complete Agent-Based Model of a Honeybee Colony

Article notes should be on separate sheets

Source Title	Towards a Complete Agent-Based Model of a Honeybee Colony
Source citation (APA Format)	Rivière, J., Alaux, C., Le Conte, Y., Layec, Y., Lozac'h, A., Rodin, V., & Singhoff, F. (2018). Toward a Complete Agent-Based Model of a Honeybee Colony. In J. Bajo, J. M. Corchado, E. M. Navarro Martínez, E. Osaba Icedo, P. Mathieu, P. Hoffa-Dąbrowska, E. del Val, S. Giroux, A. J. M. Castro, N. Sánchez-Pi, V. Julián, R. A. Silveira, A. Fernández, R. Unland, & R. Fuentes-Fernández (Eds.), *Highlights of Practical Applications of Agents, Multi-Agent Systems, and Complexity: The PAAMS Collection* (pp. 493–505). Springer International Publishing. https://doi.org/10.1007/978-3-319-94779-2_42
Original URL	https://link.springer.com/chapter/10.1007/978-3-319-94779-2_42
Source type	Article

Keywords	Agent-based Modeling, Honeybees
#Tags	#Biology #Ecology #ABMS
Summary of key points + notes (include methodology)	Agent-based can be used to model the interaction of thousands of honeybees in a hive. By simulating the outside environment and the scouting behavior of bees, foraging for nectar and honey can be modeled. ● Bees can change roles, ventilate hive, select best nectar, resource allocation ● Ecosystem Module - outside conditions affecting agents- weather, climate, temp ● Scouts look for flowers and communicate to hive using waggle dances to communicate the info of the source ● Source module represents surrounding pollen and nectar resources, source factors about source, how profitable it is to access source based on distance ● Use different states for what bees are doing, adding some level of random to model imperfection
Research Question/Problem/ Need	How can a honeybee colony be simulated using agent-based modeling?
Important Figures	Foraging bees go outside the hive to bring back resources (nectar, pollen, water), within a range of approximately 10 km, for an area of 314 km^2
VOCAB: (w/definition)	Dadant hive - Type of artificial beehive Eusocial - showing an advanced level of social organization, in which a single female or caste produces the offspring and nonreproductive individuals cooperate in caring for the young.
Cited references to follow up on	Becher, M. A., Grimm, V., Thorbek, P., Horn, J., Kennedy, P. J., & Osborne, J. L. (2014). BEEHAVE: A systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure. *Journal of Applied Ecology*, *51*(2), 470–482. https://doi.org/10.1111/1365-2664.12222
Follow up Questions	How could the simulation be used with the queen bee and a life-death cycle included? How could this model be applied to different ecological problems?

Article #5 Notes: Introduction to simulation

Article notes should be on separate sheets

Source Title	Introduction to simulation
Source citation (APA Format)	*Introduction to Simulation*. Chapter 1: Introduction to Simulation. (n.d.). https://intro.bio.umb.edu/SLNbook/introduction.html
Original URL	https://intro.bio.umb.edu/SLNbook/introduction.html
Source type	Lesson plan
Keywords	StarLogo Nova, NetLogo
#Tags	#ABMS
Summary of key points + notes (include methodology)	Agent-based models are very useful for trying to find something about the behavior of a group of agents individually, that you already know how each individual acts. These simulations are always wrong because they are extremely simplified, but their findings can be useful to estimate behavior. ● "All models are wrong; some models are useful" ● Useful because cheap and easier, and what if experiments ● Need to understand how agents in real world would act ● Numerical simulation - equations like N = e^kT ● Uses randomness on a set probability to determine some behaviors ● There is no god that can upkeep a model, so have a method to limit agents, don't just say that stuff gets deleted once reaching a certain number ● Timing is important
Research Question/Problem/ Need	What are the basics of Agent-based modeling?
Important Figures	Video of fish school model
VOCAB: (w/definition)	NetLogo - a Agent based modeling software
Cited references to follow up on	N/A
Follow up Questions	How do I know if it's accurate enough?

Article #6 Notes: Decline of Bees, a Major Pollinator - A Review

Source Title	Decline of Bees, a Major Pollinator - A Review
Source citation (APA Format)	Rong, C., & Sadhukhan, S. (2021). *Decline of Bees, a Major Pollinator – A Review*. *2*(2), 9. https://bkgc.in/ejournal/paper_list/35-43.pdf
Original URL	https://bkgc.in/ejournal/paper_list/35-43.pdf
Source type	Journal Article
Keywords	Bees, Pesticides, Mites
#Tags	#Biology
Summary of key points + notes (include methodology)	Bees are a keystone species and about ⅓ of our agriculture relies on them as pollinators. Bees have been in decline due to pesticides killing them, fragmentation and loss of habitat, diseases and parasites, and climate change. We can help the bee populations by having more wildflowers near farms, more urban green spaces, and to use less pesticides or have more organic farming. ● Decline of bees will affect crops ● "There are several factors that are the foundation for bee declining includes habitat loss, climate change, use of insecticide and pesticide, environmental stressor disease." ● Pollinators- "Butterflies, Bees, Moths, wasps and other insects, vertebrate mammals like bats, monkeys, rodent, squirrels, Birds like hummingbirds,

	sunbirds, honeycreepers. Hymenopteran are the most important groups of pollinating insects." ● Pollinators essential for sexual reproduction of plants ● Essential for maintaining ecosystems including " including natural areas, pasture fields, meadows, roadsides, many agricultural crops, fruits, orchards, backyard vegetables and flower gardens" ● "For many crops, wild bees are better pollinators than honeybees. " ● Loss of foragers cause younger bees to start foraging too early and leads to the collapse of the hive ● Fragmentation of habitat, pesticides, diseases, parasites, and climate change causing decline ● Parasites and mites killing bees ● Steps to control decline ○ Flower rich fields near farms ○ Reduced pesticides usage and organic food ○ Urban greenspaces
Research Question/Problem/ Need	What has caused the decline of bees?
Important Figures	Approximately 35% of the food and fibre crops depend upon pollinator for reproduction (Kelin etal.2007) - losing more bees will cause a major negative effect on agricultural production that people rely on.
VOCAB: (w/definition)	Neonicotinoids-a systemic agricultural insecticide resembling nicotine that harms bees Anther - the part of a stamen that contains the pollen. Hymenopteran - an insect of the order , such as a bee, wasp, or ant. Habitat fragmentation - The breaking up of habitat areas by roads and concrete.
Cited references to follow up on	Kearns, C. A., & Oliveras, D. M. (2009). Environmental factors affecting bee diversity in urban and remote grassland plots in Boulder, Colorado. *Journal of Insect Conservation*, *13*(6), 655–665. https://doi.org/10.1007/s10841-009-9215-4 Le Conte, Y., & Navajas, M. (2008). Climate change: Impact on honey bee populations and diseases. *Revue Scientifique Et Technique (International*

	Office of Epizootics), *27*(2), 485–497, 499–510.
Follow up Questions	What wildflowers can best help bees? Are there ways to prevent mites and other parasites from preying on bees?

Article #7 Notes: Thiacloprid impairs honeybee worker learning and memory

Source Title	Thiacloprid impairs honeybee worker learning and memory with inducing neuronal apoptosis and downregulating memory-related genes
Source citation (APA Format)	Li, A., Yin, L., Ke, L., Diao, Q.-Y., Wu, Y., Dai, P., & Liu, Y.-J. (2023). Thiacloprid impairs honeybee worker learning and memory with inducing neuronal apoptosis and downregulating memory-related genes. *Science of The Total Environment*, *885*, 163820. https://doi.org/10.1016/j.scitotenv.2023.163820
Original URL	https://www-sciencedirect-com.ezpv7-web-p-u01.wpi.edu/science/article/pii/S0048969723024415?via%3Dihub
Source type	Journal Article
Keywords	Insecticide
#Tags	#Biology #Agriculture
Summary of key points + notes (include methodology)	Agriculture greatly depends on the pollination from bees, but much of agriculture uses insecticides like neonicotinoids that harm bees. In this study they found that neonicotinoids negatively affect foraging, navigating, immune function, and fertility of bees. ● Bees are very important in agriculture ● Neonicotinoids most commonly used insecticides ● "Chronic sublethal concentrations of neonicotinoids are a major cause of colony and population decline in honeybees (Woodcock et al., 2017), bumble bees (Minnameyer et al., 2021; Rundlof et al., 2015, Whitehorn et al., 2012), and wild bees (Chan and Raine, 2021; Rundlof et al., 2015; Woodcock et al., 2016)."

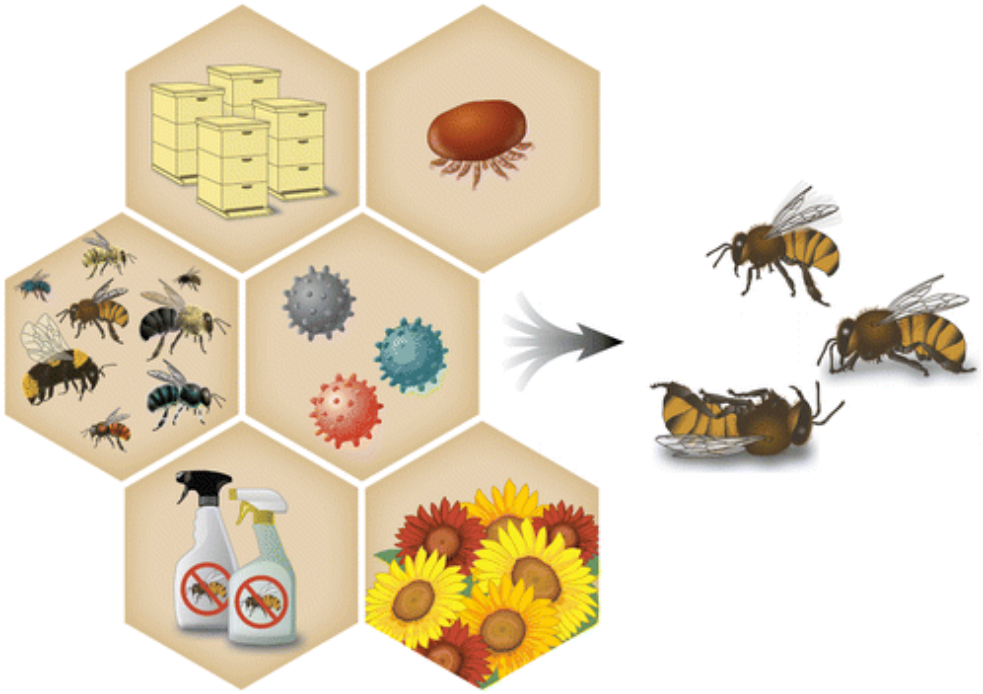
	● Negatively affect bee fertility, immune function, foraging and navigating, ○ Impairs recruitment patterns ○ Inhibits cell growth ○ Mitochondrial damage ○ Thiacloprid neonicotinoid generally more safe for bees ● Methodology ○ Isolated bee hives fed neonicotinoids measuring dead bees, food consumed, and weight of bees ○ Preformed sensitivity tests ○ Gene expression analysis ○ Tested sucrose sensitivity ○ Immunal imagery ● Results ○ High concentration of Thiacloprids reduced survival ○ Bodyweight of bees decreased as exposed to pesticides in greater concentration ○ Affected sucrose sensitivity ○ "Thiacloprid not only impairs honeybees' ability to learn, but also their memory, especially their long-term memory, thus effectively reducing their ability to forage or return to the hive." ○ Brain nerve damage ○ Increased chemicals associated with cell apoptosis in the brain ○ These changes allows more mites and parasites ○ Negative impact on expression of genes for memory formation ○ Can shorten lifespan of bees
Research Question/Problem/ Need	What are the effects of Thiacloprid Neonictinoids on honey bees?
Important Figures	"Evidence suggests that pollinating insects (such as moths, flies, bees and butterflies) are responsible for 30 % of the world's major economic crops, including fruits, vegetables, and seeds."
VOCAB: (w/definition)	Thiacloprid: type of neonicotinoid
Cited references to follow up on	Castle, D., Alkassab, A. T., Bischoff, G., Steffan-Dewenter, I., & Pistorius, J. (2022). High nutritional status promotes vitality of honey bees and mitigates negative effects of pesticides. *Science of The Total Environment*, *806*, 151280. https://doi.org/10.1016/j.scitotenv.2021.151280

	Grozinger, C. M., & Flenniken, M. L. (2019). Bee viruses: Ecology, pathogenicity, and impacts. *Annual Review of Entomology*, *64*(1), 205–226. https://doi.org/10.1146/annurev-ento-011118-111942
Follow up Questions	Ways to mitigate the effects?

Article #8 Notes: Bee Viruses: Ecology, Pathogenicity, and Impacts

Source Title	Bee Viruses: Ecology, Pathogenicity, and Impacts
Source citation (APA Format)	Grozinger, C. M., & Flenniken, M. L. (2019). Bee Viruses: Ecology, Pathogenicity, and Impacts. *Annual Review of Entomology*, *64*(1), 205–226. https://doi.org/10.1146/annurev-ento-011118-111942
Original URL	https://www.annualreviews.org/doi/10.1146/annurev-ento-011118-111942
Source type	Journal article
Keywords	Viruses, parasites, insecticides
#Tags	#Ecology #Biology
Summary of key points + notes (include methodology)	Viruses like deformed wing viruses can give us insights into how bees respond to viruses and how parasites like varroa can impact transmission. Insecticides are very negative for bees as they interfere with key pathways and weaken them to viruses. ● Ecological and agricultural importance of bees ● DWV transmuted from queen/drone to offspring or from shared resources like flowers or being in the same hive ○ Varroa benefits from feeding of DWV infected hive ○ DWV infected bees cannot heal mite feeding sites as fast because of weakened immune systems ○ Varroa transmits certain strains of DWV more than others ○ Exposure to neonicotinoids and poor quality diet can decrease immune system function and allow even more DWV

- DWV transmission shows complex relationships that affect bees
- Many other viruses with diverse methods
  - Some not active in bees but are plant viruses taken from pollen
- DWV has accumulated numerous mutations as spread over continents
  - Different transmission methods can influence different mutations or recombinants
- Transmission
  - Leaving viruses on flowers
  - Going to wrong colony, robbing weak colony, or switching colonies
  - Honey bees are source for many viruses because of large populations but there are many cross species infections
- Some viruses are asymptomatic, while others cause deformity and paralysis of bees
- Precocious foragers have shorter lifespans and are less productive
  - DWV or other environmental stressors can cause precocious foragers
  - Can lead to colony collapse
- Defense against viruses
  - Apoptosis, autophagy, eicosanoid biosynthesis, endocytosis, melanization, JAK/STAT, Toll, NRkB, JNK, and MAPK, and RNA interference
  - Viral RNA is recognized than destroyed, targets complementary RNA of viruses using siRNA
  - General antivirus responses triggered by non specific sequences of dsRNA likely to help colonies with thousands of bees not to spread more viruses
  - RNA interference pathways consistently induced with different specific viral infections
- Metabolic pathways
  - Bees that consume more protein have lower viral loads
  - Link between metabolic changes in cells and immune system
  - Biomarkers important for recognizing harmful viruses
- Chemicals
  - Bees often come into contact with the insecticides used in agriculture as well as in-hive chemicals to control parasites
  - Phytochemicals can be positive and negative, may increase the immune system
  - Insecticides interfere with specific pathways in bees
  - Herbicides limit variance in bees diet and nutritional status
  - Chemicals weaken bees, causing increased viruses
    - Neonicotinoids have direct correspondence to DWV levels

	○ Beekeepers also use pesticides to manage mites in their hives like acaricides ○ Acaricides cause greater mortality in already virus-infected bees ○ However by reducing varroa they overall help the bees ○ Minimizing chemical use can help to not make pesticide resistant pests
Research Question/Problem/ Need	What do we know about viral bee ecology?
Important Figures	 Grozinger CM, Flenniken ML. 2019. *Annu. Rev. Entomol.* 64:205–26 Example causes of bee decline
VOCAB: (w/definition)	Deformed Wing Virus (DWV): a well studied bee virus Varroa: a honey bee mite Precocious foragers: when underaged bees are needed to take up foraging duties. Autophagy: your body reusing old or damaged cell parts Eicosanoid biosynthesis: production of lipids in the membranes as part of immune signaling Melanization: production of melanin around wounds to trap pathogens JAK/STAT (Janus kinase/signal transducer and activator of transcription): signaling pathway essential for immune response JNK (c-Jun N-terminal kinase):a transcription factor that is needed for inflammation, immunity, cell proliferation, differentiation, and survival.

	MAPK (mitogen-activated protein kinase): an important kinase important in cell proliferation, cell differentiation, and cell death RNA interference (siRNA): small pieces of RNA that can shut down protein translation by binding to the mRNA of those proteins dsRNA - double stranded RNA viruses Phytochemicals - chemicals produced by plants Acaracides - pesticides used to kill ticks and mites
Cited references to follow up on	Brosi, B. J., Delaplane, K. S., Boots, M., & de Roode, J. C. (2017). Ecological and evolutionary approaches to managing honeybee disease. *Nature ecology & evolution*, *1*(9), 1250-1262.
Follow up Questions	Are there ways to defend beehives against DWV?

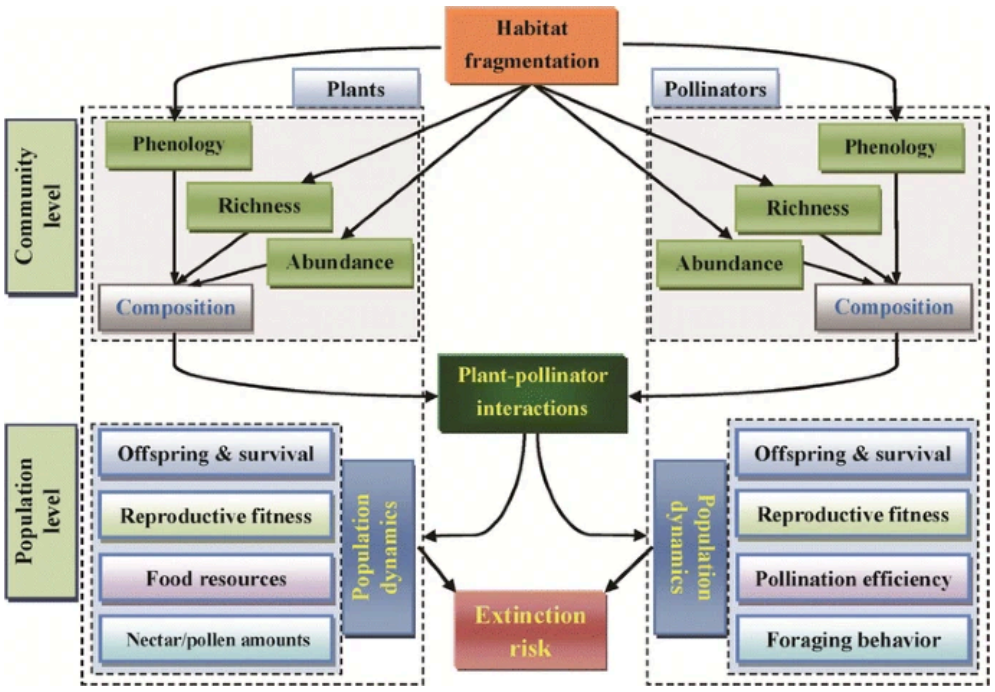
Article #9 Notes: The effects of habitat fragmentation on plant–pollinator interactions

Article notes should be on separate sheets

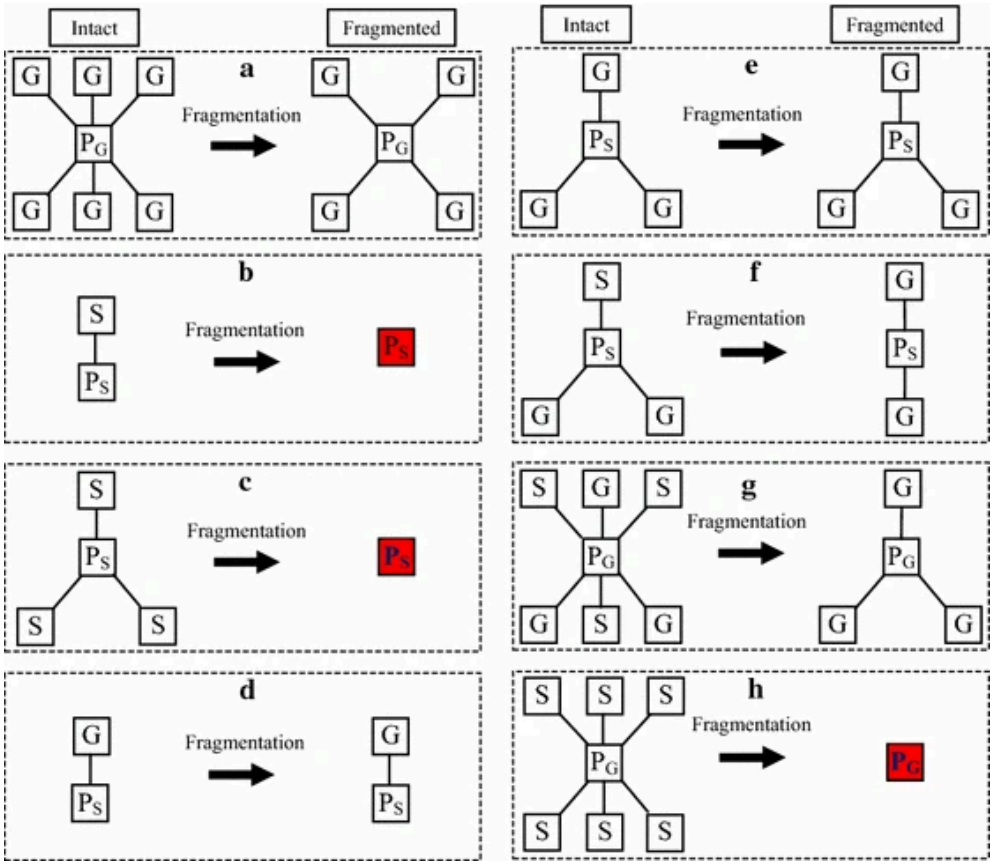
Source Title	The diverse effects of habitat fragmentation on plant–pollinator interactions
Source citation (APA Format)	Xiao, Y., Li, X., Cao, Y., & Dong, M. (2016). The diverse effects of habitat fragmentation on plant–pollinator interactions. *Plant Ecology*, *217*(7), 857–868. https://doi.org/10.1007/s11258-016-0608-7
Original URL	https://link.springer.com/article/10.1007/s11258-016-0608-7
Source type	Journal article
Keywords	“Habitat Fragmentation”
#Tags	#Ecology #Biology
Summary of key points + notes (include methodology)	Habitat fragmentation can be very negative for both bee and flower populations because it can cause discrepancies in the amount of pollen created or the time frame of blooming flowers. These have greater effects on pollinators that are more specialized in their plant-pollinator interactions, although not having as much of an effect on specialist plants.

	● habitat fragmentation can reduce abundance of plants and bees ○ Decreased reproduction ● Fragmentation a leading factor of biodiversity loss ○ Extinction as a result of reduced interactions ● Larger areas near agricultural areas → high pollinator diversity ● Smaller habitats → less diversity ● Fragmentation → more edges that have different environments ● Flowers closer to habitat centers had longer flowering periods ○ Echinacea ● Some with inverse relationship ○ Syagrus Romanzoffiana increases flowering duration with fragmented habitat ● Fragmentation delays flowering and amount of flowering in many populations ● Pollinators are affected directly through fragmentation or indirectly through plants ● Size and distance between patches matter ● Little is known about how fragmentation affects phenology of bees ● Phenological shifts of plant and pollinators may cause mismatching, causing both to not do as well ○ Decreased reproduction ● Some bat pollinators can cause fragmentation to not affect plants because of mobility ● "Isolated habitats may select for increased autogamy in plants" ● Plants with pollination specialization are more vulnerable to mutualistic relationship disruption from fragmentation ○ It seems more plants are becoming generalist but while pollinators are becoming more generalized, plants are not ○ Specialist pollinators are often in more patchy populations so are greatly affected when they are further fragmented ● Further study needed on interactions
Research Question/Problem/ Need	How does habitat fragmentation impact plant-pollinator interactions?

Important Figures



Different factors that impact the risk of extinction caused by habitat fragmentation



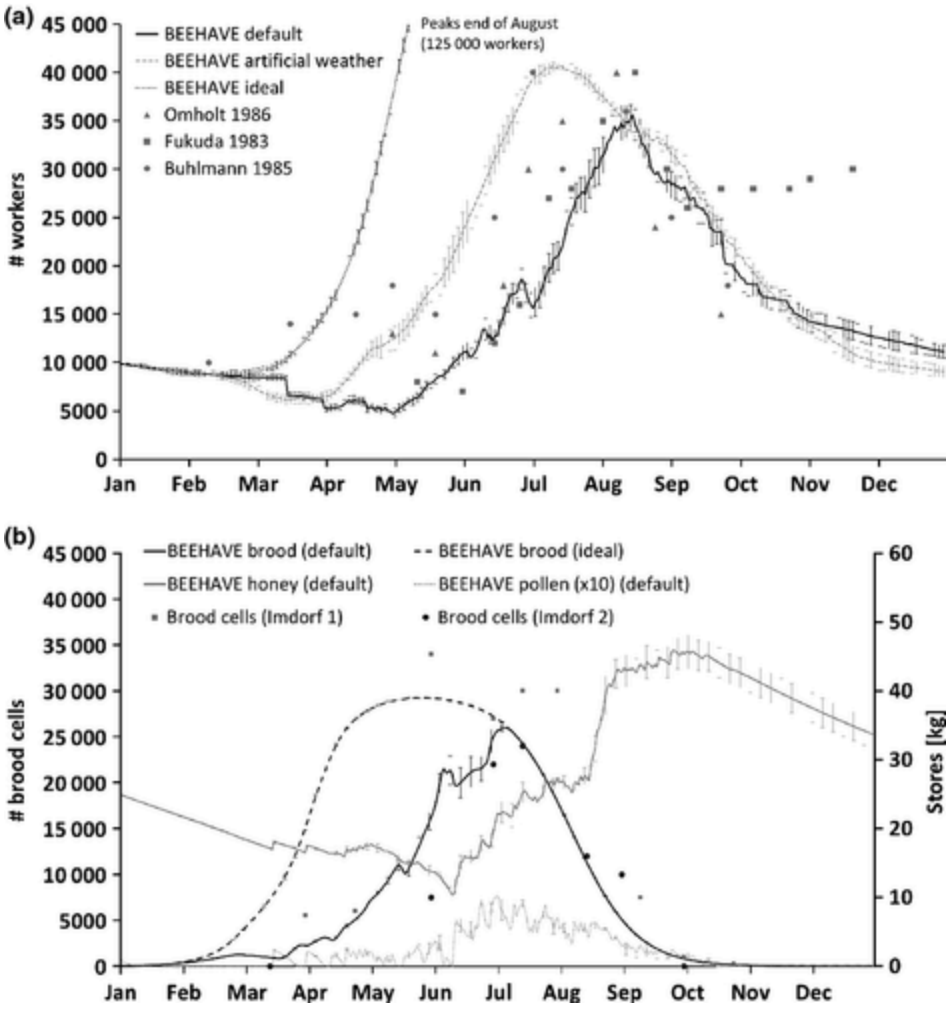
	How fragmentation can affect different types of plant pollinator interactions. S-specialized pollinators; G- generalist pollinators, P_G-generalist plants, P_S-specialist plants
VOCAB: (w/definition)	Phenology: study of cyclic or seasonal phenomena in plant and animal life Autogamy: self-fertilization of plant Specialization plant-pollinator networks: when plants are pollinated by a couple pollinators Asymmetrical plant-pollinator relationships: when plants rely on certain pollinators that don't only rely on that plant
Cited references to follow up on	Aguilar, R., Ashworth, L., Galetto, L., & Aizen, M. A. (2006). Plant reproductive susceptibility to habitat fragmentation: review and synthesis through a meta-analysis. *Ecology letters*, *9*(8), 968-980.
Follow up Questions	What species are at most risk? Is there a way we can connect fragments in strips to mitigate the effects?

Article #10 Notes: BEEHAVE

Article notes should be on separate sheets

Source Title	BEEHAVE: a systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure
Source citation (APA Format)	Becher, M. A., Grimm, V., Thorbek, P., Horn, J., Kennedy, P. J., & Osborne, J. L. (2014). BEEHAVE: A systems model of honeybee colony dynamics and foraging to explore multifactorial causes of colony failure. *Journal of Applied Ecology*, *51*(2), 470–482. https://doi.org/10.1111/1365-2664.12222
Original URL	https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.12222
Source type	Journal Article
Keywords	BEEHAVE, simulation, Varroa mites,
#Tags	#Biology #ABMS
Summary of key points + notes (include methodology)	To make a model of a beehive, a variety of factors such as food levels, virus levels, and the weather. The amount that bees could forage played a big role on the health of the hive, with them doing worse in worse weather, and when mortality of foragers were higher (to model pesticides). Tests found that this model was similar to tests of actual beehives. ● Several stressors together causing failure of colonies ● Most frequently Varroa mites, viruses from the mites, and *Nosema Ceranae* ● Hard to study colonies of bees ○ Simulations are fast and cost effective ● Full model called BEEHAVE built to test these dynamics ○ One virus at time with virus levels instead of individual entities ○ Foraging model is agent-based, factors such as quality of nectar and pollen sources, weather conditions, and the size, stores, and demand for food of the colony ○ “The structure of the model is a compromise between structural realism (i.e. the ability to represent heterogeneity where it is likely to matter) and computational efficiency and parsimony regarding parameterization and model analysis”

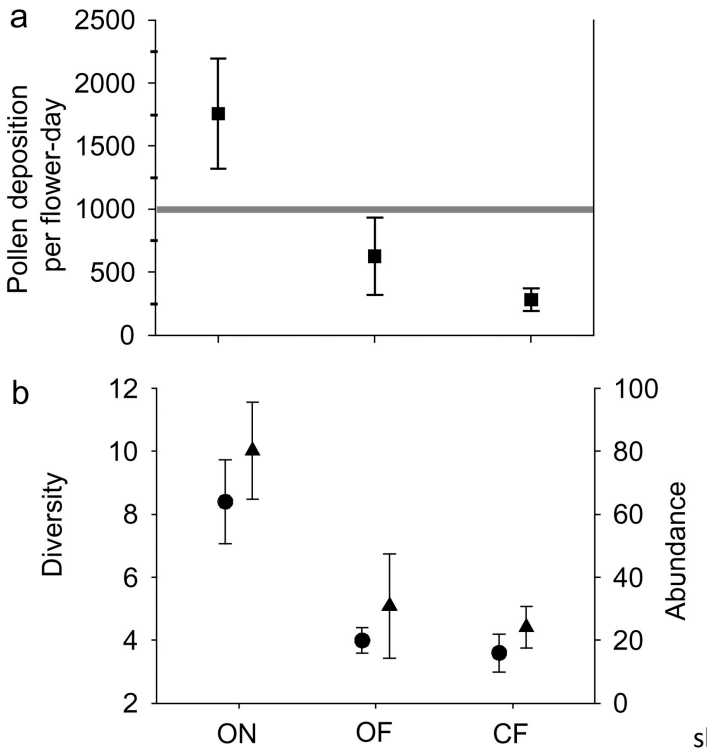
	○ Age cohorts for different stages of bee life ○ Added level of complexity for pollen and nectar dynamics ○ Entities for colony- age classes, the hive, the queen ○ Mite model - phoretic mites go into cells before capped; randomly distributed ○ Foraging Model - agents are foragers(represents many bees) and flower patches, foragers from adult cohort, ○ Consumption rates by bees decrease stores, increased by successful foraging ○ Real weather data ○ Mostly used to test impacts of varroa mites with different circumstances like treatment and without varroa mites , forager mortality because of pesticides, ○ Model wasn't sensitive to many of the changes, mortality of bees caused the biggest change ○ Models were tested to make sure they followed empirical data ○ Bees showed preferences for sources of food ● Potential applications ○ Shows model with DWV virus with or without varroa ○ Hives driven by pollen and nectar levels nearby ○ "BEEHAVE captured the switch of foragers between feeders very well. ○ Increasing foraging distance caused more failure ○ "We conclude that BEEHAVE is ready to be used to tackle basic and applied questions regarding honeybees, their functioning and their decline."
Research Question/Problem/ Need	Need: a simulation that can model a beehive to be pretty accurate.

Important Figures	 Hive dynamics of the simulation under different conditions.
VOCAB: (w/definition)	Nosema Ceranae - a type of fungus that mainly affects the asiatic honey bee
Cited references to follow up on	Chen, Y. P., Pettis, J. S., Collins, A., & Feldlaufer, M. F. (2006). Prevalence and transmission of honeybee viruses. *Applied and environmental microbiology*, *72*(1), 606-611. Sumpter, D., & Pratt, S. (2003). A modelling framework for understanding social insect foraging. *Behavioral Ecology and Sociobiology*, *53*, 131-144. Schmickl, T., Thenius, R., & Khoury, D. S., Myerscough, M. R., & Barron, A. B. (2011). A quantitative model of honey bee colony population dynamics. *PloS one*, *6*(4), e18491. Crailsheim, K. (2012). Swarm-intelligent foraging in honeybees: benefits and costs of task-partitioning and environmental fluctuations. *Neural Computing and Applications*, *21*, 251-268.
Follow up Questions	How could the model be potentially improved?

Article #11 Notes: Crop pollination from native bees at risk from agricultural intensification

Article notes should be on separate sheets

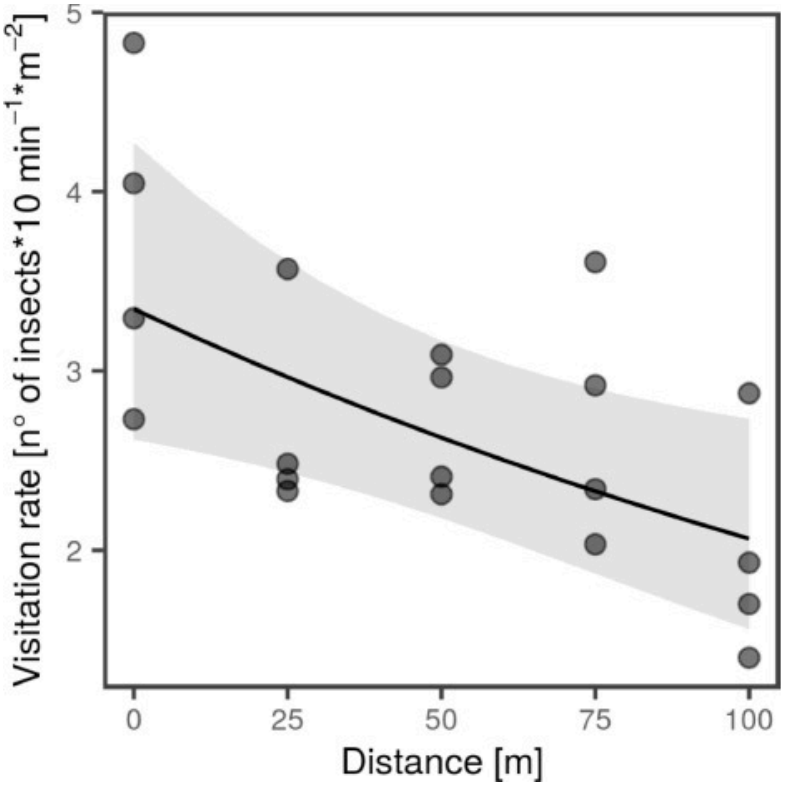
Source Title	Crop pollination from native bees at risk from agricultural intensification
Source citation (APA Format)	Kremen, C., Williams, N. M., & Thorp, R. W. (2002). Crop pollination from native bees at risk from agricultural intensification. *Proceedings of the National Academy of Sciences*, *99*(26), 16812–16816. https://doi.org/10.1073/pnas.262413599
Original URL	https://doi.org/10.1073/pnas.26241359
Source type	Journal Article
Keywords	Native Bees
#Tags	#Biology #Agriculture #Ecology
Summary of key points + notes (include methodology)	The article emphasizes the critical role of ecosystem services, particularly pollination provided by native bee communities, for crop production. The study reveals that on organic farms near natural habitat, native bees can adequately fulfill pollination services for crops like watermelon without the need for managed honey bees. However, on other farms with reduced native bee diversity and abundance, there is a reliance on managed honey bees, highlighting the importance of conserving and restoring bee habitat to sustain this essential service for agriculture. - chatGPT ● Pollinators very important to crops we currently rely on the honeybee which is declining ○ New africanized bee becoming more aggressive ○ Native bees needed in case honeybees not used ● Measure visitation of native bees to certain plants(organic v conventional) ● Measured pollen deposition on watermelons ● Results: native bees are sufficient alone to provide pollination to organic farms ● more diversity of bee species seen within organic farms as well as increased pollination especially when near habitats

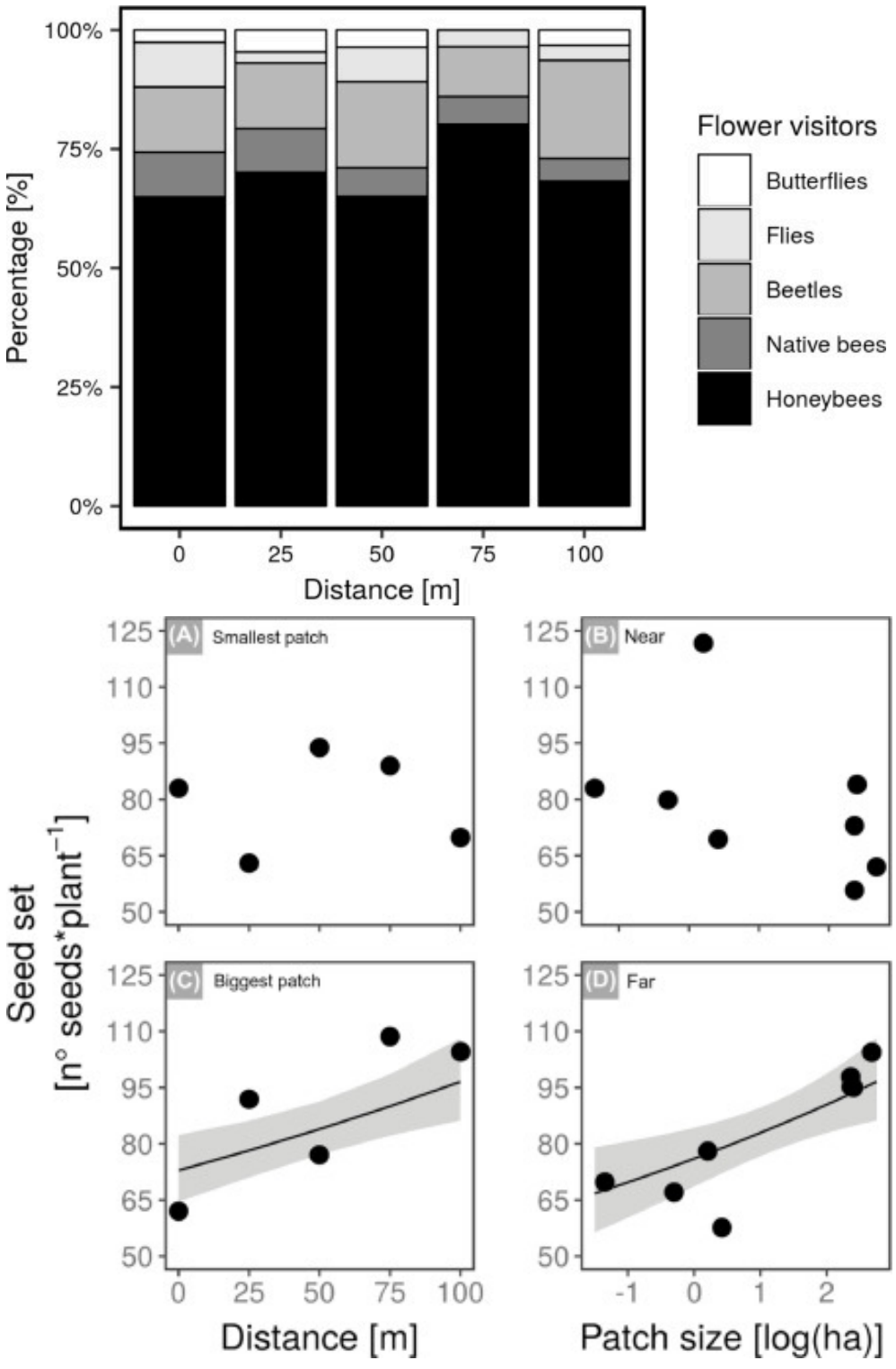
	• Organic farms have increased native bee pollination • Agricultural intensification reduces bee diversity
Research Question/Problem/ Need	What agricultural contributions do native bees have?
Important Figures	 shows the diversity of the bee species and the pollination in organic farms near bee habitats (ON), organic farms that are far from bee habitat(OF) and conventional farms (OF) which are all far from bee habitats.
VOCAB: (w/definition)	Citrullus lanatus - the watermelon
Cited references to follow up on	Free, J. B. (1970). *Insect pollination of crops*. Academic Press, London and New York..
Follow up Questions	Did the africanized bees hybrids continue to spread through the US.

Article #12 Notes: Forest fragments influence pollination and yield of soybean crops in Chaco landscapes

Article notes should be on separate sheets

Source Title	Forest fragments influence pollination and yield of soybean crops in Chaco landscapes
Source citation (APA Format)	Huais, P. Y., Grilli, G., Amarilla, L. D., Torres, C., Fernández, L., & Galetto, L. (2020). Forest fragments influence pollination and yield of soybean crops in Chaco landscapes. *Basic and Applied Ecology*, *48*, 61–72. https://doi.org/10.1016/j.baae.2020.09.003
Original URL	https://www-sciencedirect-com.ezpv7-web-p-u01.wpi.edu/science/article/pii/S1439179120300943?via%3Dihub
Source type	Article
Keywords	Crop Pollination, Habitat Fragmentation
#Tags	#Biology #Ecology
Summary of key points + notes (include methodology)	This study in central Argentina examined the impact of habitat loss on pollinators and soybean crop yield. It found that bees, including honeybees and native species, were the primary pollinators of soybean flowers. The study concluded that small forest patches (around 1 hectare) near soybean fields played a crucial role in ensuring effective pollination and crop yields, particularly at shorter distances, while larger forest patches had a positive impact on crop pollination at greater distances from the forest edge. However, the study also highlighted the need for further research to understand other factors influencing soybean pollination and production. - chatGPT ● Forests can help pollinators access soybean crops ● Habitat loss causing biodiversity crisis ● Small patches of forest surrounded by crops ● Not much specific research with conclusive results ● Hypothesize that the remnants of forest give soybeans pollinators ● Tested on farms using chemicals, no close domesticated honeybee hives, ○ Measured visitation rate of insects and pollen deposition

	○ Used tags in soybean flowers, and some blocked from pollination ■ 40 of both ● Results ○ Open soybeans ad double seeds ● Preliminary testing ○ Bagged and not bagged plants ○ "Of a total of 320 initially bagged plants, only 153 (48%) survived exclusion system, compared to 287 (90%) open plants; the rest (52%) of the bagged plants were found dead during the harvesting." ○ Soybeans also had more seeds without bags ○ However plants were also undeveloped, showing that bags harmed plants in other ways unrelated to pollinators ○ New experiment with mesh instead of bags ● Variables measured ○ Flower Visitors ○ Pollen Deposition on stigmas ○ Plant Yield
Research Question/Problem/ Need	How does habitat loss affect pollinators, effective pollination, and soybean crop yield in central Argentina, specifically considering the distance to the forest edge and the size of forest patches in the landscape? - ChatGPT
Important Figures	


100%
75%
50%
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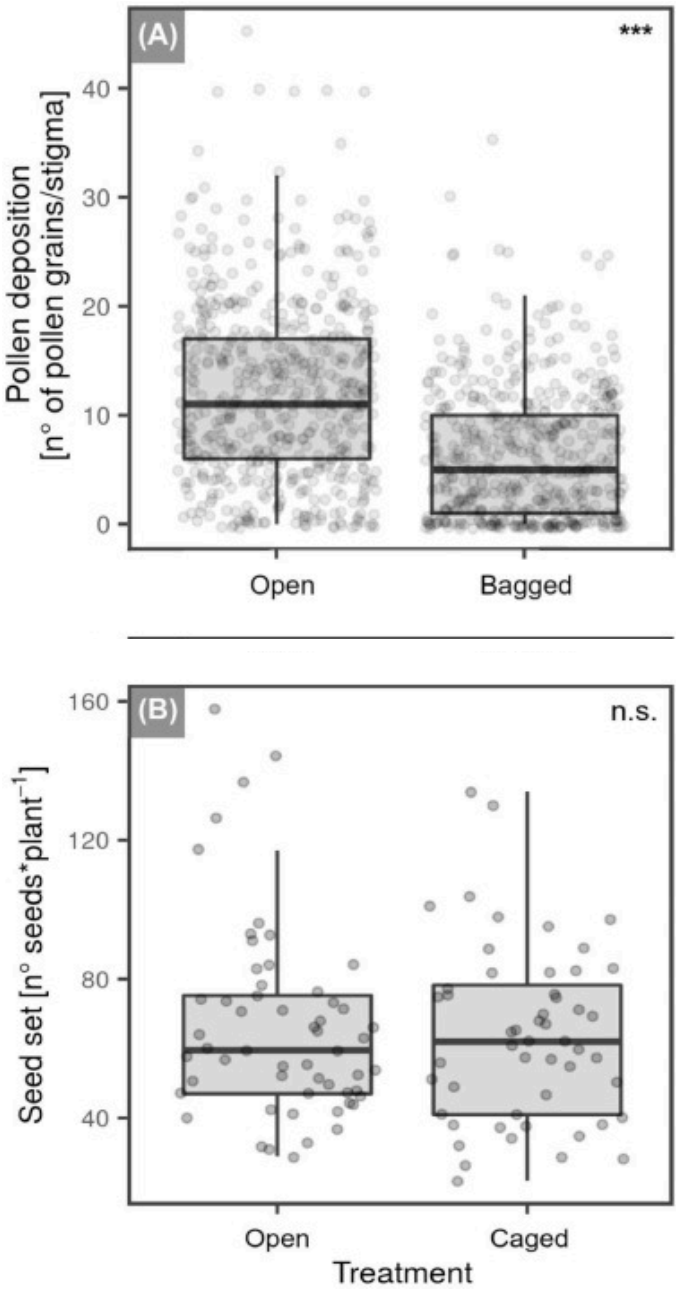
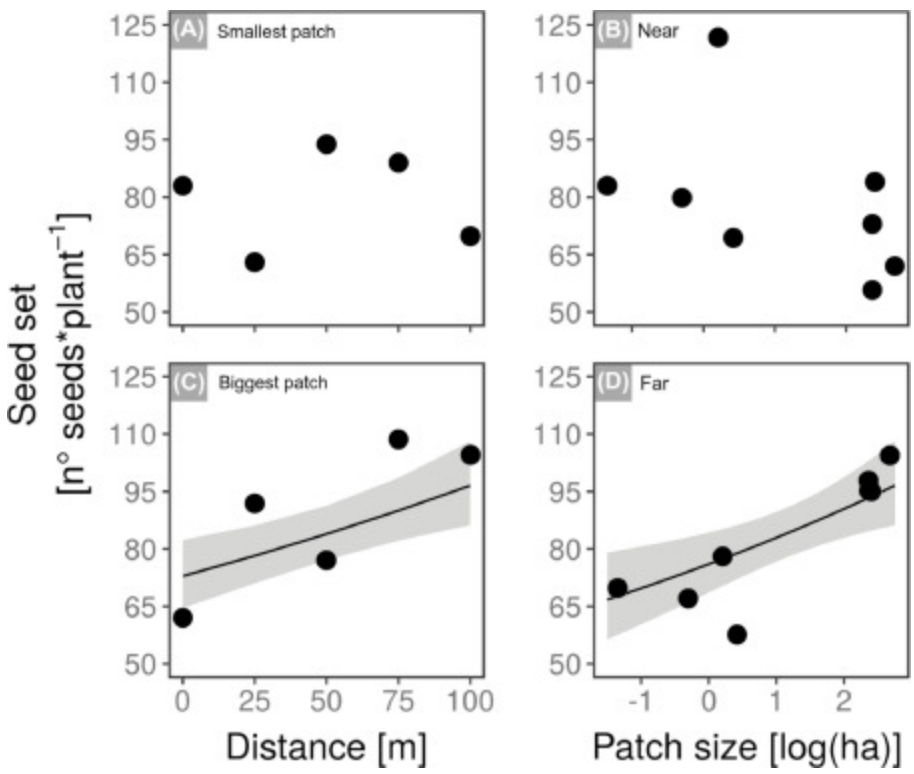
0%
Percentage [%]
0
25
50
75
100
Distance [m]
Flower visitors
Butterflies
Flies
Beetles
Native bees
Honeybees
(A) Smallest patch
(B) Near
(C) Biggest patch
(D) Far
Seed set
[n° seeds*plant^{-1}]
125
110
95
80
65
50
0
25
50
75
100
Distance [m]
-1
0
1
2
Patch size [log(ha)]


(A)
***
Pollen deposition
[n° of pollen grains/stigma]
40
30
20
10
0
Open
Bagged
(B)
n.s.
Seed set [n° seeds*plant^{-1}]
160
120
80
40
Open
Caged
Treatment

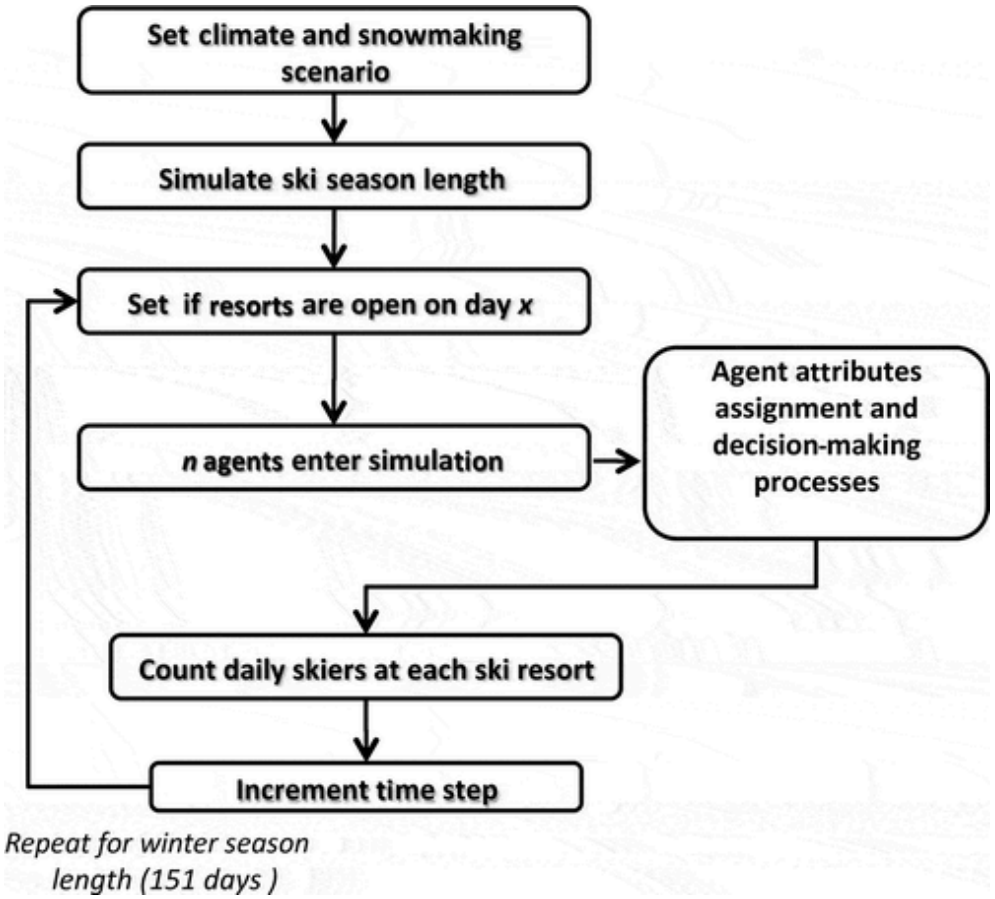
	
VOCAB: (w/definition)	conventional agriculture intensification: "larger fields of monoculture crops that rely on external inputs"
Cited references to follow up on	Dicks, L. V., Viana, B., Bommarco, R., Brosi, B., Arizmendi, M. D. C., Cunningham, S. A., Galetto, L., Hill, R., Lopes, A. V., Pires, C., Taki, H., & Potts, S. G. (2016). Ten policies for pollinators. Science, 354(6315), 975–976. https://doi.org/10.1126/science.aai9226 Garibaldi, L. A., Carvalheiro, L. G., Vaissière, B. E., Gemmill-Herren, B., Hipólito, J., Freitas, B. M., Ngo, H. T., Azzu, N., Sáez, A., Åström, J., An, J., Blochtein, B., Buchori, D., García, F. J. C., Oliveira Da Silva, F., Devkota, K., Ribeiro, M. D. F., Freitas, L., Gaglianone, M. C., … Zhang, H. (2016). Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. Science, 351(6271), 388–391. https://doi.org/10.1126/science.aac7287

Follow up Questions	What further research could be done to remove much of the ambiguity? In different areas would the native bee population change the results of these experiments?

Article #13 Notes: A georeferenced agent-based model to analyze the climate change impacts on ski tourism at a regional scale

Article notes should be on separate sheets

Source Title	A georeferenced agent-based model to analyze the climate change impacts on ski tourism at a regional scale
Source citation (APA Format)	Pons, M., Johnson, P. A., Rosas, M., & Jover, E. (2014). A georeferenced agent-based model to analyze the climate change impacts on ski tourism at a regional scale. *International Journal of Geographical Information Science*, *28*(12), 2474–2494. https://doi.org/10.1080/13658816.2014.933481
Original URL	https://www.tandfonline.com/doi/full/10.1080/13658816.2014.933481
Source type	Article
Keywords	Agent-based modeling
#Tags	#ABMS
Summary of key points + notes (include methodology)	The article utilizes a regional-scale coupled gravity and georeferenced agent-based model to examine the impact of climate change on ski resorts and skier behavior. Through four scenarios considering temperature increases and snowmaking, the study classifies resorts into highly vulnerable, low vulnerability, and resilient groups based on their response to climate change. The agent-based model helps highlight how individual behavioral adaptations contribute to the redistribution of skiers, challenging previous predictions of an overall decline in the ski industry. -chatGPT ● Agent based models can be used to model human and environmental factors interactions ○ Study population dynamics ○ Visualizing movement patterns

	○ Agent-based model useful for taking in many factors ○ Flow charts can be used to explain and plan for a simulation ● Skiing model ○ Uses the actual length of the winter ○ Takes into account actual data from weather ○ Mathematical model of the amount of tourism taken into account ○ Gravity model to show redistribution of skiers on the mountain ○ Validation process by comparing to real data ○ Model then can be applied to future years
Research Question/Problem/ Need	The research question of this article is how climate change affects ski resorts and skier distribution, examining the role of snow conditions and individual behavior through a coupled gravity and agent-based model. -chatGPT
Important Figures	 Shows the process of making an agent-based model
VOCAB: (w/definition)	stochastic process - a process that operates with chance

Cited references to follow up on	Crooks, A. T. (2010). Constructing and implementing an agent-based model of residential segregation through vector GIS. International Journal of Geographical Information Science, 24(5), 661–675. https://doi.org/10.1080/13658810903569572
Follow up Questions	How were the amount of variables and what variables were necessary determined?

Article #14 Notes: Mitigating the Effects of Habitat Loss on Solitary Bees in Agricultural Ecosystems

Article notes should be on separate sheets

Source Title	Mitigating the Effects of Habitat Loss on Solitary Bees in Agricultural Ecosystems
Source citation (APA Format)	Kline, O., & Joshi, N. K. (2020). Mitigating the effects of habitat loss on solitary bees in agricultural ecosystems. *Agriculture*, *10*(4), 115. https://doi.org/10.3390/agriculture10040115
Original URL	https://www.mdpi.com/2077-0472/10/4/115
Source type	Journal Article
Keywords	Solitary Bees, Agriculture
#Tags	#Ecology #Biology #Agriculture
Summary of key points + notes (include methodology)	The article emphasizes the crucial role of solitary bees and wild pollinators in sustaining ecosystems and agricultural economies. It highlights the decline in their populations due to factors like pesticide use, climate change, and pathogens, with habitat loss being a primary driver. The review suggests that mitigating habitat loss through strategies such as incorporating wildflower plantings and preserving natural habitats can enhance bee diversity and abundance, ultimately benefiting pollination in agricultural landscapes. - chatGPT ● Solitary bees and other wild bees are important to both wild ecosystems and agriculture. ● Species richness is decreasing (from pesticide use, climate change, pathogens, habitat loss) ● Large monocultures (agricultural intensification) cannot support the bees that pollinate ● 11% of GDP comes from animal pollinated plants ● Other types than solitary bees have been studied more ● Wild bees can have beneficial effect on crop yield ○ Some plants need sonication that honey bees don't have ● Habitat loss with increase in farmland ○ Grazing causing grassland decay

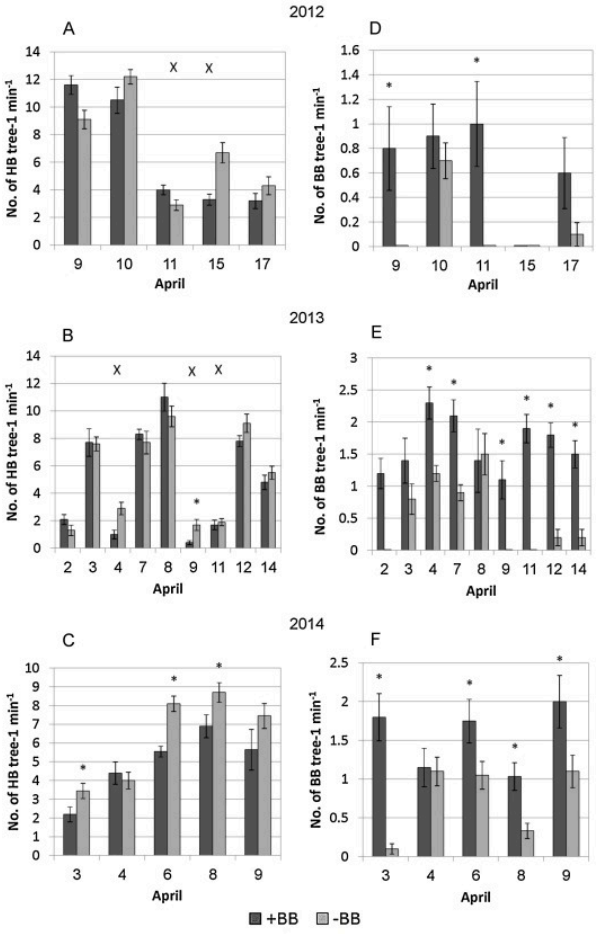
	● Bees need nesting sites such as suitable ground trees that are near sources of nectar ● Lack of floral diversity has negative impact on bee health ● Higher diversity of flowers tends to cause higher diversity of bees ● Solutions ○ Preservation of remaining natural areas (prairies and fields) ○ Provide nesting sites ○ Giving more diverse flowers for bee nutrition ● Balance needs to be found between agriculture and wilderness ○ " to establish hedgerows of native trees, shrubs, grasses, sedges, and rushes, have been shown to improve several ecosystem services, including soil erosion control, enhanced water filtration and water quality, and increased species richness of beneficial arthropods" ● Planting along margins of crop fields help pollination best
Research Question/Problem/ Need	The research question revolves around understanding the effects of habitat loss on solitary bees and exploring potential mitigation strategies to conserve bee diversity and populations in agricultural landscapes. - chatGPT

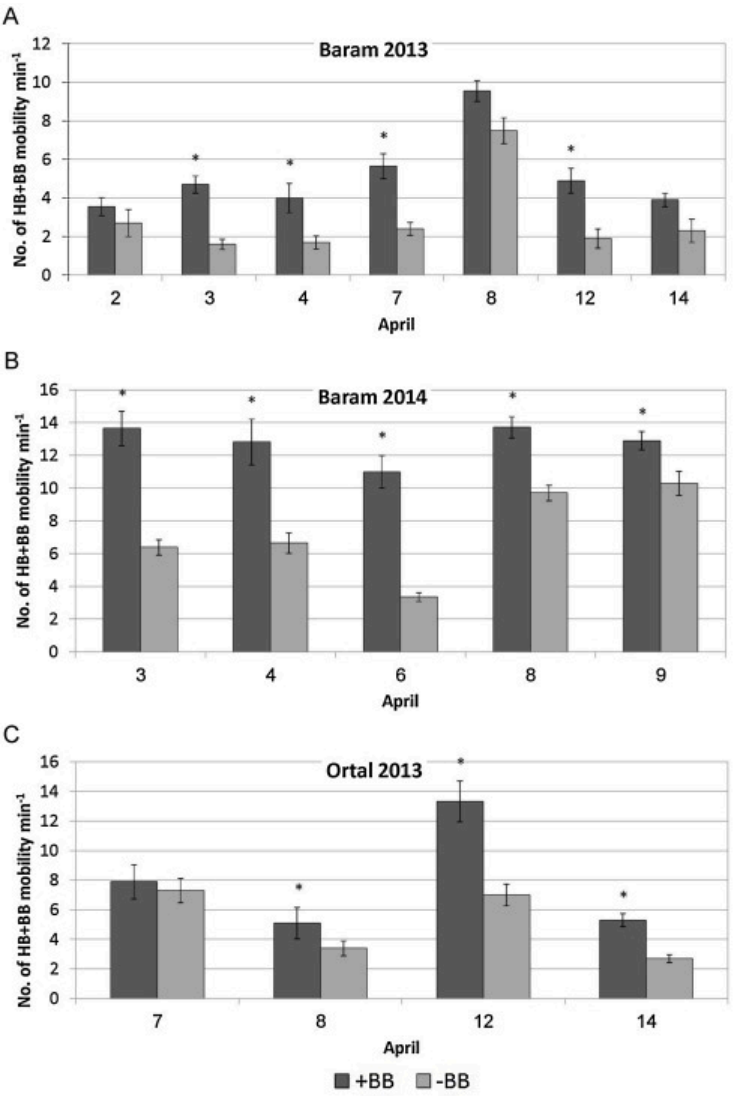
Important Figures	  Shows what the proposed solution might look like.
VOCAB: (w/definition)	Sonication - involuntary vibrations formed by some native bees
Cited references to follow up on	Winfree, R., Aguilar, R., Vázquez, D. P., LeBuhn, G., & Aizen, M. A. (2009). A meta-analysis of bees' responses to anthropogenic disturbance. *Ecology*, *90*(8), 2068–2076. https://doi.org/10.1890/08-1245.1
Follow up Questions	How could increasing these populations be beneficial in non-agricultural areas, and what would be the best strategy for those?

Article #15 Notes: Synergistic effects between bumblebees and honey bees in apple orchards increase cross pollination, seed number and fruit size

Article notes should be on separate sheets

Source Title	Synergistic effects between bumblebees and honey bees in apple orchards increase cross pollination, seed number and fruit size
Source citation (APA Format)	Sapir, G., Baras, Z., Azmon, G., Goldway, M., Shafir, S., Allouche, A., Stern, E., & 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
Original URL	https://doi.org/10.1016/j.scienta.2017.03.010
Source type	Journal Article
Keywords	Pollinatino
#Tags	#Agriculture #Ecology
Summary of key points + notes (include methodology)	Most apple cultivars rely on cross-pollination, mainly facilitated by honey bees (HB), but their inefficient pollination often leads to small and commercially undesirable fruits. This study experimented with introducing bumblebees (BB) into apple orchards, discovering that the addition of BBs not only increased the overall number of pollinators but also altered honey bees' foraging behavior. This change resulted in improved cross-pollination, higher efficiency, and larger fruits, particularly benefiting the 'Gala' cultivar, which typically produces fruit with few seeds. - ChatGPT ● Most apples depend on cross-pollination for fruit ● The honeybee is efficient in pollinating apple blossoms ○ They often take nectar without pollination (sideworking)

	○ Honeybees often switch from apples to other flowers and don't pollinate them for very long ○ This stunts crop yield ● Bumblebees are shown to be better for pears and result in more and larger fruit ● More bee diversity the more ecosystem services like crop pollination ● Competition in pollination can cause honeybees to move to more flowers and pollinate more ● Some bumble bees a lot bigger and can carry more pollen, as well as more temperature resistant ● Bee mobility increases with more diversity ● More bees are topworkers with bumblebees ● Data showed greater fruit yield with bumblbees
Research Question/Problem/ Need	Will the addition of bumblebees cause increased cross-pollination in orchards?
Important Figures	 Shows the amount of Honeybees and Bumblebees in the trees with or without bumble bee hives (+BB, -BB)



Shows how much bees move around with or without bumble bees

<table>
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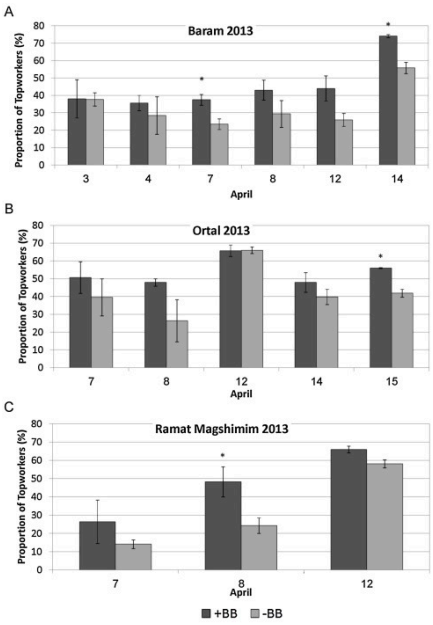
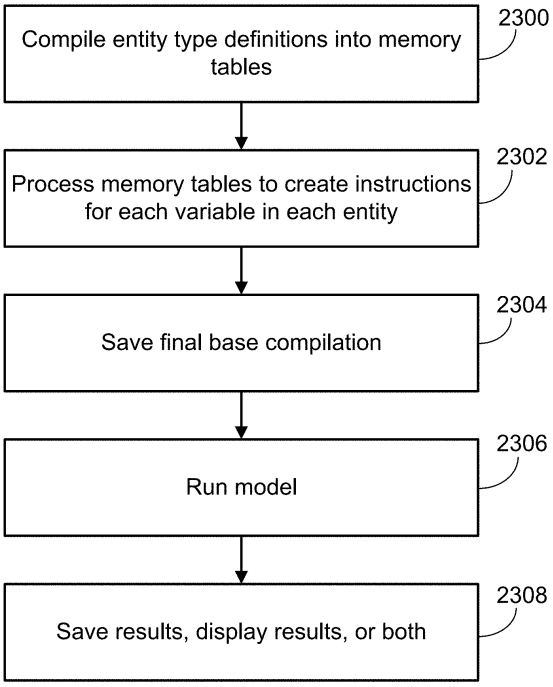


shows that with bumble bees, more are topworkers
<table>
<tr><th>Orchard site</th><th>Cultivar</th><th colspan="2">Seed no.[1]</th><th colspan="2">Fruit size (mm)[1]</th></tr>
<tr><th></th><th></th><th>+BB</th><th>−BB</th><th>+BB</th><th>−BB</th></tr>
<tr><td>Baram</td><td>Gala</td><td>6.3 a</td><td>6.2 a</td><td>68 a</td><td>68 a</td></tr>
<tr><td></td><td>Golden Delicious</td><td>9.1 a</td><td>8.4 b</td><td>70 a</td><td>69 a</td></tr>
<tr><td>Elrom</td><td>Gala</td><td>7.2 a</td><td>4.0 b</td><td>72 a</td><td>69 b</td></tr>
<tr><td></td><td>Pink Lady</td><td>8.2 a</td><td>7.6 b</td><td>74 a</td><td>71 b</td></tr>
<tr><td>Ortal</td><td>Gala</td><td>7.9 a</td><td>6.1 b</td><td>73 a</td><td>69 b</td></tr>
<tr><td></td><td>Red Delicious</td><td>8.1 a</td><td>6.3 b</td><td>74 a</td><td>72 b</td></tr>
</table>
shows that the addition of BB caused increased fruit yield
</td>
</tr>
<tr>
<td>VOCAB: (w/definition)</td>
<td>Sideworking: when a bee bypasses the stamen and pollen spreading to get to just the nectar
Topworking: when a bee goes through the top of the flower, coming into contact with the pollen organs and pollinating the flower.</td>
</tr>
<tr>
<td>Cited references to follow up on</td>
<td>Goulson, D. (2010). Bumblebees: behaviour, ecology, and conservation. Oxford University Press.</td>
</tr>
<tr>
<td>Follow up Questions</td>
<td>How can this apply to places that are not agricultural? How can these bumblebees be best encouraged to pollinate?</td>
</tr>
</table>

Patent #1 Notes: Modeling and simulation

Article notes should be on separate sheets

Source Title	Modeling and simulation
Source citation (APA Format)	Yeager, L. F., Fiddaman, T. S., Peterson, D. W., & Graham, A. K. (2021). *Modeling and simulation* (United States Patent US11093668B2). https://patents.google.com/patent/US11093668B2
Original URL	https://patents.google.com/patent/US11093668B2
Source type	Patent
Keywords	Agent-based modeling
#Tags	#ABMS
Summary of key points + notes (include methodology)	The method involves creating and storing model elements based on user-provided information through a graphical user interface. These elements define a computer-simulated model of a real-world system, incorporating collections of software entities that mirror real-world features, and subsequently running the model utilizing these software entities. - chatGPT ● Creates software entities ● Sometimes uses statistical distributions ● Can be used for economic, energy, environmental, and societal models ● Accuracy depends on level of empirical data available ● Can be linked to spreadsheets ● Can model stocks ● Flows depicted as lines or pipes ● Inputs equations to dictate rules of simulation ● Various implementations
Research Question/Problem/ Need	A system for using various entities that interact with each other.

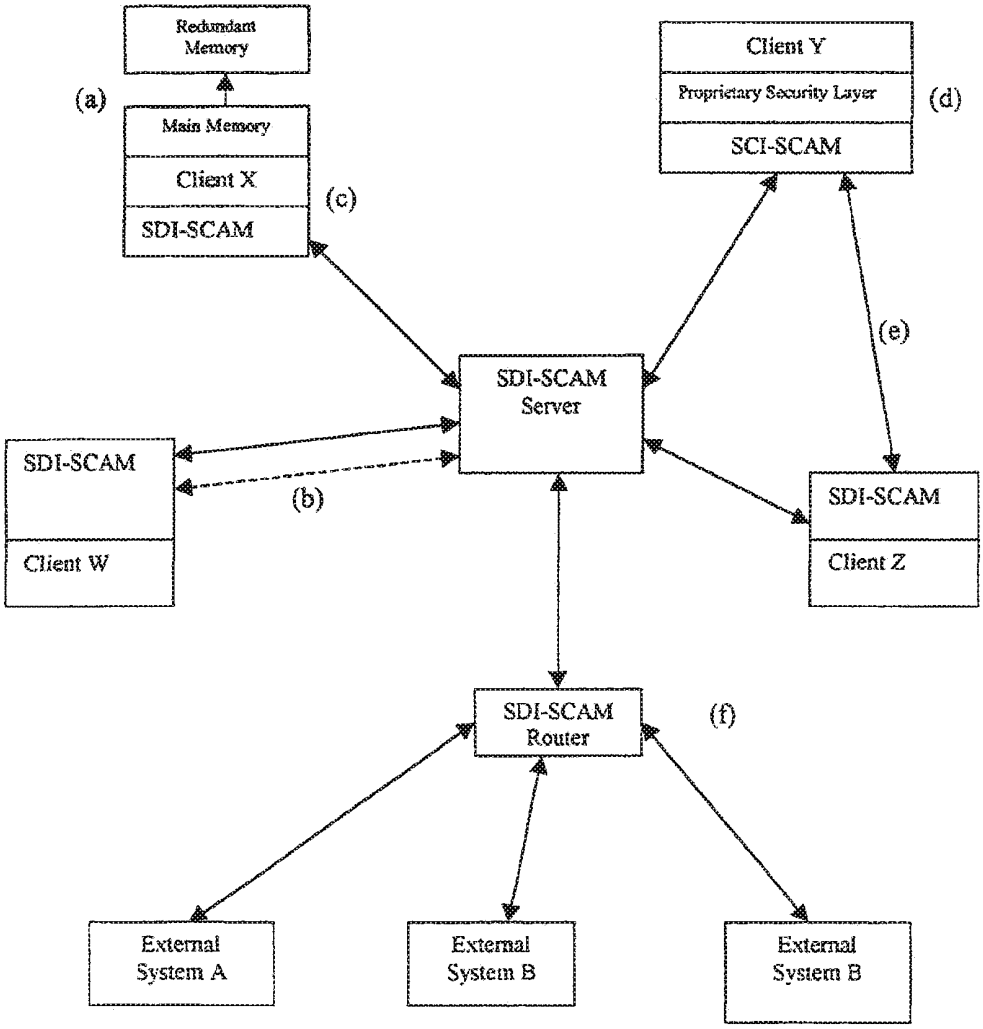
Important Figures	 Shows an overview of the model
VOCAB: (w/definition)	Integrated development environments: A system that facilitates software development with tools for developing and debuggers.
Cited references to follow up on	Peterson, D. W., & Eberlein, R. L. (1995). *Constraint knowledge in simulation modeling* (United States Patent US5446652A). https://patents.google.com/patent/US5446652A/en
Follow up Questions	How could I apply this to my model?

Patent #2 Notes: Distributed agent based model for security monitoring and response

Article notes should be on separate sheets

Source Title	Distributed agent based model for security monitoring and response
Source citation (APA Format)	Gertner, Y., Herz, F. S. M., & Labys, W. P. (2021). *Distributed agent based model for security monitoring and response* (United States

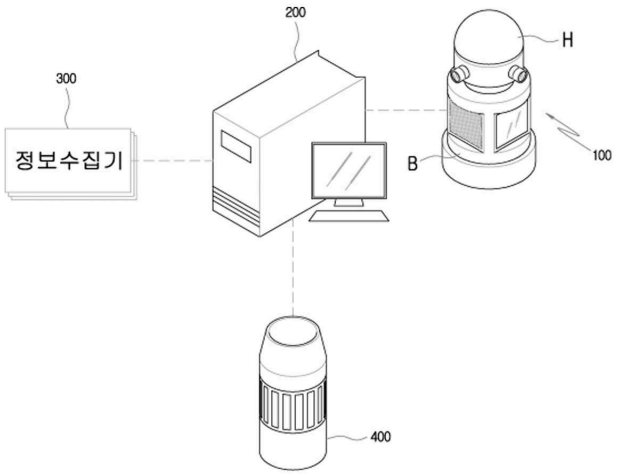
	Patent US11171974B2). https://patents.google.com/patent/US11171974B2/en
Original URL	https://patents.google.com/patent/US11171974B2
Source type	Patent
Keywords	Agent-based model
#Tags	#ABMS
Summary of key points + notes (include methodology)	SDI-SCAM is a widely distributed security system that continuously analyzes network data to detect novel methods of intrusion or attack. It distributes warnings, probability-based intrusion characteristics, and tailored countermeasures to individual machines, fostering a collaborative, adaptive response to potential threats while also sharing repair methods network-wide in the event of adverse effects. - ChatGPT ● Pools together data from many computers to detect patterns of attacks ● Computers can be reset from backup data when detected ● Actions taken when files are access unauthorized ● Nodes in each computer installed part of a computer network ● Can detect tampered with files
Research Question/Problem/ Need	To create a system that can detect security breaches.

Important Figures	
VOCAB: (w/definition)	SDI-SCAM: a widely distributed security system
Cited references to follow up on	Sung, A. H., Mukkamala, S., & Lassez, J.-L. (2011). *Computationally intelligent agents for distributed intrusion detection system and method of practicing same* (United States Patent US7941855B2). https://patents.google.com/patent/US7941855B2/en
Follow up Questions	How do you make the computer data into the agent-based model?

Patent #3 Notes: Modeling system and method by analyzing indoor environment based on digital-twin

Article notes should be on separate sheets

Source Title	Modeling system and method by analyzing indoor environment based on digital-twin
Source citation (APA Format)	이봉규 & 이원상. (2019). *Modeling system and method by analyzing indoor environment based on digital-twin* (Patent KR101989982B1). https://patents.google.com/patent/KR101989982B1/en
Original URL	https://patents.google.com/patent/KR101989982B1/en
Source type	Patent
Keywords	Agent-based Modeling
#Tags	#ABMS
Summary of key points + notes (include methodology)	The invention pertains to a modeling system utilizing digital twin technology to analyze indoor spaces. By employing simulation analysis based on a digital twin, the system can anticipate changes in indoor floating population and occupancy, facilitating proactive planning of indoor structures and management of environmental states. The components include an information collector, a main server, and terminals for comprehensive implementation. - ChatGpt ● Predicts that flow of air for temperatures ● Map created that agent interact on ● Records the temperatures in various areas and then simulates the environment to regulate temperature ● Takes into account flow direction of air to more accurately simulate ● Takes into account the flow of people from cameras.
Research Question/Problem/ Need	To create a more accurate temperature control based on a simulation

Important Figures	 Temperature detecting system shown
VOCAB: (w/definition)	digital twin: a virtual simulation of real situation
Cited references to follow up on	王亚洲. (2020). *Digital twin five-dimensional model based 3D printer modeling method and model system* (China Patent CN111159793A). https://patents.google.com/patent/CN111159793A/en
Follow up Questions	How could this system of measuring people be repurposed into bees?

Article #16 Notes: Ten policies for pollinators

Article notes should be on separate sheets

Source Title	Ten policies for pollinators
Source citation (APA Format)	Dicks, L. V., Viana, B., Bommarco, R., Brosi, B., Arizmendi, M. D. C., Cunningham, S. A., Galetto, L., Hill, R., Lopes, A. V., Pires, C., Taki, H., & Potts, S. G. (2016). Ten policies for pollinators. *Science*, *354*(6315), 975–976. https://doi.org/10.1126/science.aai9226
Original URL	https://www.science.org/doi/10.1126/science.aai9226
Source type	Journal Article

Keywords	Ecology Agriculture
#Tags	#Ecology #Agriculture
Summary of key points + notes (include methodology)	The first global thematic assessment from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlights widespread declines in wild pollinators, particularly in northwest Europe and North America, emphasizing the urgent need for monitoring and policy action globally. The authors propose ten policies to protect pollinators, including international pressure to raise pesticide regulatory standards, improving risk assessments for genetically modified crops, better managing the movement of pollinators, promoting ecological intensification and diversified farming systems, recognizing local knowledge and rights, adopting green infrastructure approaches for habitat conservation, and addressing knowledge gaps through long-term monitoring and research on agricultural practices that support pollinators. They emphasize the potential for global-scale policy change, independent of their involvement with IPBES. - ChatGPT ● Pesticides are a major problem for pollinators worldwide ● GM crops could be risky to pollinators as they are not well understood ● Bumblebees have become invasive ● Agricultural intensification major issue for pollinators ● Incentives for farmers that promote pollinators in face of uncertainty about ecological effects ● Increasing organic farming that are less harmful to ecosystems need ● Diversifying farming such as organic, home gardens, livestock, mixed cropping with patches of habitat for pollinators ● “Green infrastructure”
Research Question/Problem/ Need	The problem addressed is the global decline of pollinators, prompting the need for urgent policy interventions and proposing specific measures to mitigate risks associated with factors such as pesticides, genetically modified crops, and unsustainable farming practices. - ChatGPT

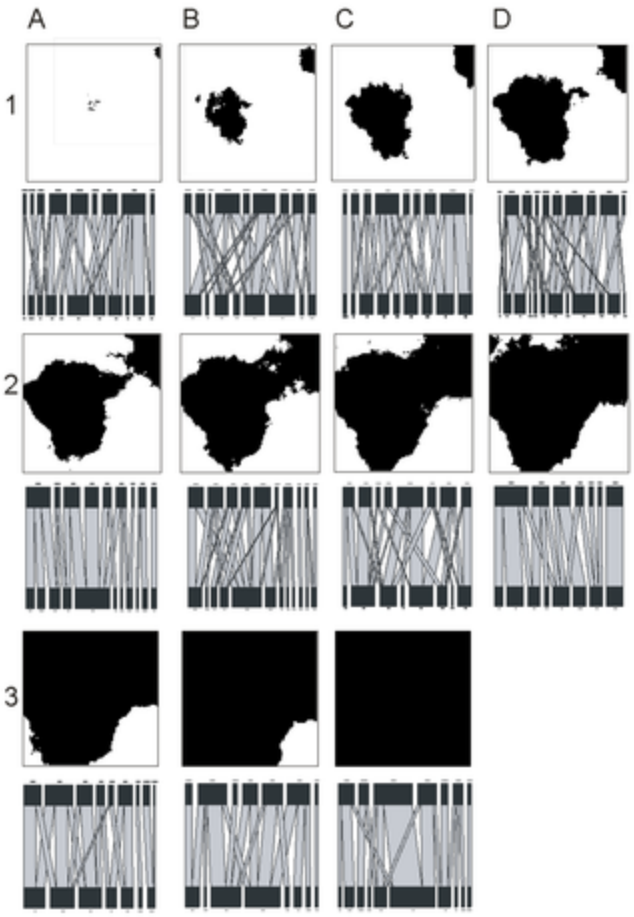
Important Figures	**Ten pollinator policies** 1. Raise pesticide regulatory standards. 2. Promote integrated pest management (IPM). 3. Include indirect and sublethal effects in GM crop risk assessments. 4. Regulate movement of managed pollinators. 5. Develop incentives, such as insurance schemes, to help farmers benefit from ecosystem services instead of agrochemicals. 6. Recognize pollination as an agricultural input in extension services. 7. Support diversified farming systems. 8. Conserve and restore "green infrastructure" (a network of habitats that pollinators can move between) in agricultural and urban landscapes. 9. Develop long-term monitoring of pollinators and pollination. 10. Fund participatory research on improving yields in organic, diversified, and ecologically intensified farming.
VOCAB: (w/definition)	Green Infrastructure: network of habitats that pollinators can move between
Cited references to follow up on	Defra. (2014). The National Pollinator Strategy: for bees and other pollinators in England. Department for Environment, Food and Rural Affairs.
Follow up Questions	How could the most efficient green infrastructure be studied?

Article #17 Notes: Impacts of deforestation on plant-pollinator networks assessed using an agent based model

Article notes should be on separate sheets

Source Title	Impacts of deforestation on plant-pollinator networks assessed using an agent based model

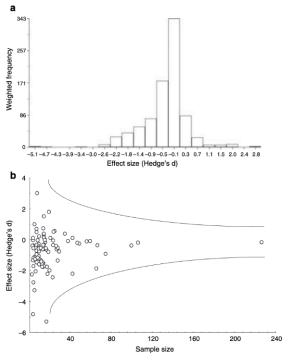
Source citation (APA Format)	Newton, A. C., Boscolo, D., Ferreira, P. A., Lopes, L. E., & Evans, P. (2018). Impacts of deforestation on plant-pollinator networks assessed using an agent based model. *PLOS ONE*, *13*(12), e0209406. https://doi.org/10.1371/journal.pone.0209406
Original URL	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0209406
Source type	Journal Article
Keywords	Deforestation
#Tags	#ABMS #Ecology
Summary of key points + notes (include methodology)	The study introduces an agent-based model (ABM) to simulate bee movement and pollination events in diverse landscapes, providing insights into the poorly understood mechanisms shaping plant-pollinator networks. The experiments, conducted with virtual landscapes representing varying degrees of forest loss and fragmentation, reveal that increasing forest loss leads to a shift from specialist to generalist pollinators, resulting in an increase in complementary specialization and a decline in network connectance. Additionally, the study highlights the potential of ABMs in exploring and understanding the structure and dynamics of plant-pollinator networks. ChatGPT ● The model simulates the movement of bees over a heterogeneous landscape ● Sees a shift from specialist to generalist pollinators ● Lack of wild pollinators leading to reduced crop yields ● Other software has shown the movement of bees using netlogo ● Landscape maps can be imported with binary classification of land cover ● Each bee type had a different flowers that they could visit ● The software GradientLand generated the land cover maps
Research Question/Problem/ Need	What are the mechanisms underlying the structure of plant-pollinator networks in heterogeneous landscapes, particularly in relation to forest loss and fragmentation, and how do these mechanisms influence network characteristics such as complementary specialization, network connectance, and nestedness? -ChatGPT

Important Figures	 shows the habitat fragmentation in percentages
VOCAB: (w/definition)	Network nestedness - connections between multiple agents
Cited references to follow up on	Becher, M. A., Grimm, V., Knapp, J., Horn, J., Twiston-Davies, G., & Osborne, J. L. (2016). BEESCOUT: A model of bee scouting behaviour and a software tool for characterizing nectar/pollen landscapes for BEEHAVE. *Ecological Modelling*, *340*, 126–133. https://doi.org/10.1016/j.ecolmodel.2016.09.013
Follow up Questions	How do I make the bee agent's sense what kind of patch they are on?

Article #18 Notes: Plant reproductive susceptibility to habitat fragmentation: review and synthesis through a meta-analysis

Article notes should be on separate sheets

Source Title	Plant reproductive susceptibility to habitat fragmentation: review and synthesis through a meta-analysis
Source citation (APA Format)	Aguilar, R., Ashworth, L., Galetto, L., & Aizen, M. A. (2006). Plant reproductive susceptibility to habitat fragmentation: Review and synthesis through a meta-analysis. *Ecology Letters*, *9*(8), 968–980. https://doi.org/10.1111/j.1461-0248.2006.00927.x
Original URL	https://pubmed.ncbi.nlm.nih.gov/16913941/
Source type	Journal Article
Keywords	Plant Reproductive
#Tags	#Ecology #Biology
Summary of key points + notes (include methodology)	The study conducts a meta-analysis to assess the impact of habitat loss and fragmentation on animal-mediated pollination and plant reproduction. The findings reveal an overall large and negative effect of fragmentation on both processes, with the compatibility system of plants being a key factor explaining differences among species' responses. The study suggests that pollination limitation may be a significant factor contributing to reproductive impairment in fragmented habitats, emphasizing the importance of considering these dynamics in conservation efforts. - ChatGPT ● Pollinators are necessary for sexual reproduction among plants ● Breeding systems used to determine dependence on pollinators ● Self-incompatible plants are more vulnerable to habitat fragmentation due to reliance on bees ● Data tests conducted on data to find significance found that this was statistically true ● Sexual reproduction and seed dispersal is extremely important

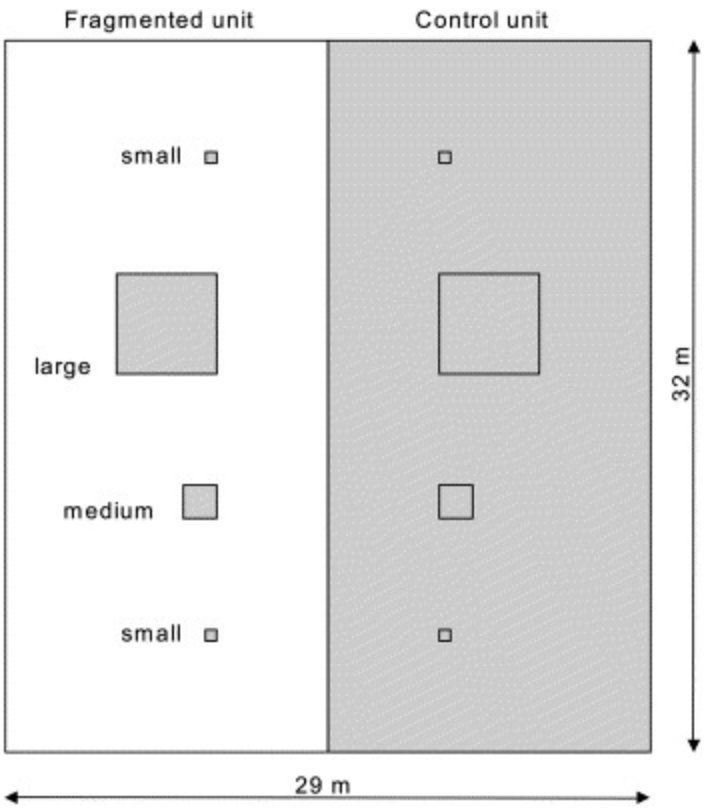
Research Question/Problem/ Need	How does habitat loss and fragmentation, resulting from human activities, affect animal-mediated pollination and plant reproduction, and what are the underlying mechanisms and implications for biodiversity conservation? - ChatGPT
Important Figures	 **Figure 5** Histogram of effect size values of plant reproductive success weighted by 1/variance (a), and Funnel plot of sample size vs. effect size values of plant reproductive success (b) based on 93 data points from 89 plant species. Shows the reproductive success based on the size of the plot.
VOCAB: (w/definition)	Self-incompatible - can pollinate itself and produce viable seeds
Cited references to follow up on	Aguilar, R., Quesada, M., Ashworth, L., Herrerias-Diego, Y., & Lobo, J. (2008). Genetic consequences of habitat fragmentation in plant populations: Susceptible signals in plant traits and methodological approaches. *Molecular Ecology*, *17*(24), 5177–5188. https://doi.org/10.1111/j.1365-294X.2008.03971.x
Follow up Questions	What ways could this be mitigated?

Article #19 Notes: Small-scale habitat fragmentation effects on pollinator behaviour: experimental evidence from the bumblebee Bombus veteranus on calcareous grasslands

Article notes should be on separate sheets

Source Title	Small-scale habitat fragmentation effects on pollinator behaviour: experimental

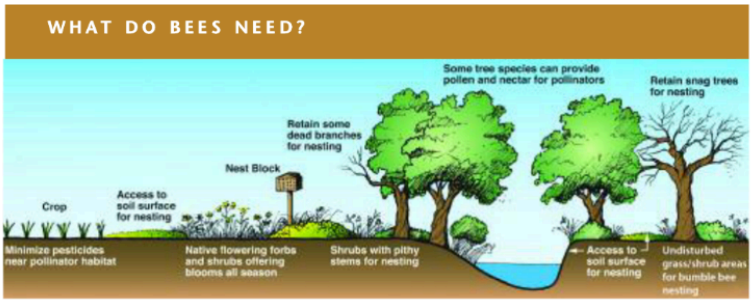
	evidence from the bumblebee Bombus veteranus on calcareous grasslands
Source citation (APA Format)	Goverde, M., Schweizer, K., Baur, B., & Erhardt, A. (2002). Small-scale habitat fragmentation effects on pollinator behaviour: Experimental evidence from the bumblebee Bombus veteranus on calcareous grasslands. *Biological Conservation*, *104*(3), 293–299. https://doi.org/10.1016/S0006-3207(01)00194-X
Original URL	https://www.sciencedirect.com/science/article/pii/S000632070100194X
Source type	Journal Article
Keywords	Bumblebee
#Tags	#Ecology
Summary of key points + notes (include methodology)	The study investigated the impact of experimental fragmentation on the visiting patterns of pollinators, particularly the bumblebee Bombus veteranus, in Betonica officinalis L. (Lamiaceae) in calcareous grasslands in the north-western Swiss Jura mountains. Results showed that the most common pollinator, Bombus veteranus, visited fragmented areas significantly less frequently compared to control plots, and exhibited altered foraging behavior, potentially influenced by decreased floral rewards. The study highlights that small-scale habitat fragmentation can lead to both reduced visitation rates, affecting seed set, and changes in pollinator behavior, potentially impacting pollen dispersal and genetic variability in plant populations. - ChatGPT ● Bumble bees visited fragmented plots less often ● Bees are a keystone species ● If distance between plants is too large pollination is limited ● Studied a layout of fragmented and control area ● Time of taking sample was random ● Fragmentation can lead to more inbreeding ● Fragmentation changed the behavior of the common pollinator
Research Question/Problem/ Need	How does small-scale habitat fragmentation impact the visiting patterns and foraging behavior of pollinators, particularly the bumblebee Bombus veteranus, in Betonica officinalis L. (Lamiaceae), and what are the implications for plant fitness, seed set, and genetic variability in populations of this bumblebee-pollinated plant. - ChatGPT

Important Figures	 shows the layout of the experiment
VOCAB: (w/definition)	calcareous grasslands: grasslands with soil composed of chalk or limestone
Cited references to follow up on	Allen-Wardell, G., Bernhardt, P., Bitner, R., Burquez, A., Buchmann, S., Cane, J., Cox, P. A., Dalton, V., Feinsinger, P., Ingram, M., Inouye, D., Jones, C. E., Kennedy, K., Kevan, P., Koopowitz, H., Medellin, R., Medellin-Morales, S., Nabhan, G. P., Pavlik, B., … Walker, S. (1998). The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology*, *12*(1), 8–17. https://www.jstor.org/stable/2387457
Follow up Questions	What ways could the patches be connected to reduce them being avoided?

Article #20 Notes: Native Pollinators: How To Protect and Enhance Habitat For Native Bees

Article notes should be on separate sheets

Source Title	Native Pollinators: How To Protect and Enhance Habitat For Native Bees
Source citation (APA Format)	Vaughan, M., & Black, S. H. (2008). Native pollinators: How to protect and enhance habitat for native bees. *Native Plants Journal*, *9*(2), 80–91. https://doi.org/10.2979/NPJ.2008.9.2.80
Original URL	https://npj.uwpress.org/content/9/2/80.short
Source type	Journal Article
Keywords	Nesting,
#Tags	#Ecology #Agriculture
Summary of key points + notes (include methodology)	The key to successful ecological restoration and overall biodiversity relies on maintaining a robust population of native pollinators, particularly bees, which play a crucial role in seed production for both native plants and food crops. To support native bee populations, it is essential to provide a continuous supply of diverse plants with overlapping blooming times, create suitable nesting sites such as underground burrows or dead trees, and protect them from harmful pesticides by minimizing herbicide use and adopting bee-friendly practices. Conservation efforts should focus on observing, safeguarding, and enhancing both nesting sites and year-round sources of pollen and nectar. - ChatGPT ● Many farms begin to rely on honeybees for pollination ○ From intensive agriculture ● Ways to support native bees ○ Diverse plants ○ Leads to diverse pollinators making plants more fertile ○ Ensure flowers are always present in the season of bees ○ Incorporate things for bees to forage ○ Best plants ○ Native bees have a very different nest such as ground or wood/twigs ○ Bumbles make nest in holes often old rodent nests ○ Leaving untilled soil supports these nests

	○ Putting wood blocks with hole or bamboo are examples of nest helpers ○
Research Question/Problem/ Need	What are the essential habitat requirements for supporting native bee populations, and how can nursery managers, seed producers, and field restorationists contribute to the conservation of native bees by providing suitable food sources, nesting sites, and protection from pesticides? - ChatGPT
Important Figures	 Shows an example placement of plants to promote native pollinators
VOCAB: (w/definition)	Solitary Ground nesting bees - bees that live in narrow tunnels in the ground Solitary Wood nesting bees - bees that live in narrow tunnels in the twigs
Cited references to follow up on	Kremen, C., Williams, N. M., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., Packer, L., Potts, S. G., Roulston, T., Steffan-Dewenter, I., Vázquez, D. P., Winfree, R., Adams, L., Crone, E. E., Greenleaf, S. S., Keitt, T. H., Klein, A., Regetz, J., & Ricketts, T. H. (2007). Pollination and other ecosystem services produced by mobile organisms: A conceptual framework for the effects of land-use change. *Ecology Letters*, *10*(4), 299–314. https://doi.org/10.1111/j.1461-0248.2007.01018.x
Follow up Questions	How much would the placement of these matter?