Indirect Competitors in a Spatial Landscape: Mutualist Hosts

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Collaborators

 

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Thanks

- NSERC Discovery Grant Program
- UBC Okanagan Institute for Biodiversity, Resilience, and Ecosystem Services
- Unceded territory of the Sylix (Okanagan) Peoples

NSERC CRSNG

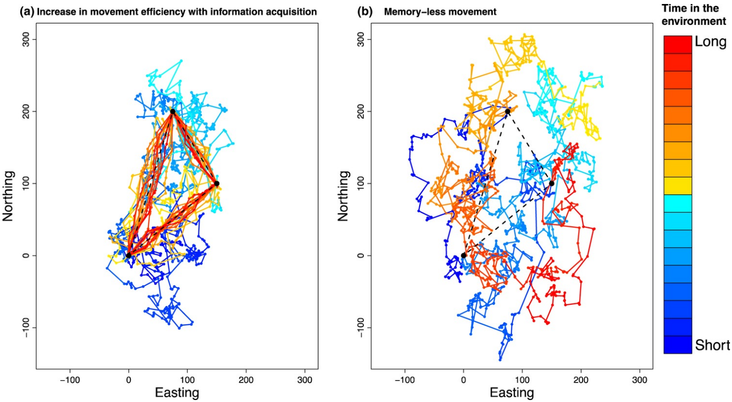
UBC THE UNIVERSITY OF BRITISH COLUMBIA
Okanagan Institute for Biodiversity, Resilience, and Ecosystem Services (BRAES)

sylix Okanagan Nation Alliance

Crop Pollination Services

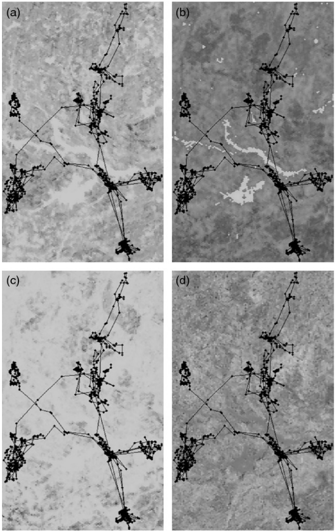
Pollen and Nectar Resources

Foraging With and Without Memory



Fagan et al (2013)

Memory-Guided Foraging



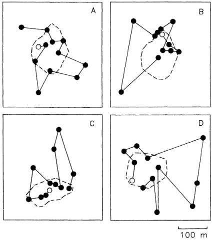
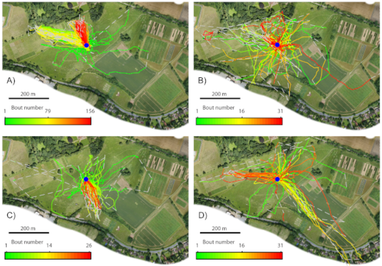


FIG. 3. Samples of the forays made by radio-collared red squirrel offspring. Each individual was located approximately



Avgar et al (2015), Larsen & Boutin (1994), Woodgate et al (2016)

Memory Movement Types

Movement behaviour	Typical movement pattern
Central place foraging	Foray loops with regular return to a central location
Migration; Philopatry	Seasonal or longer movement between two distant habitats
Trapline nectaring	Regular routes; visiting flowers in a precise repeated order

Fagan et al (2013)

When to Invest in Memory?

$$\text{Memory Map} = \text{Long Term Memory} - \psi_M \text{Short Term Memory}$$

- Long Term Memory: $L(z,t)$
  - decays slowly
  - attracts forager to high quality habitat
- Short Term Memory: $S(z,t)$
  - decays quickly
  - repels forager from recently depleted habitat

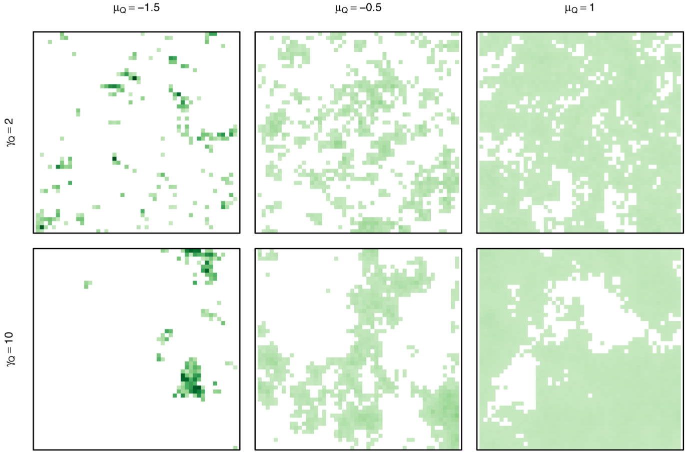
$$\frac{\partial L}{\partial t} = \beta_L f_L(|z-Z|)(Q_0 - L) - \phi_L L$$
$$\frac{\partial S}{\partial t} = \beta_S f_S(|z-Z|)(Q_0 - L) - \phi_S L$$

Bracis et al (2015)

ABM Foragers with Memory

Movement: autocorrelated, directed, continuous

Landscape: fixed



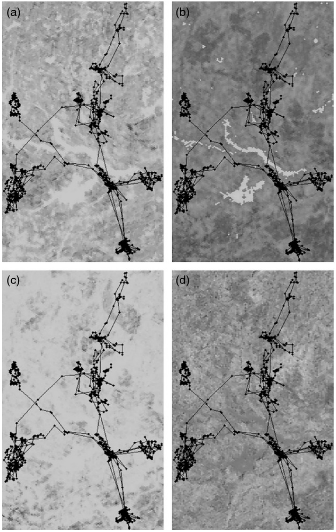
Bracis et al (2015)

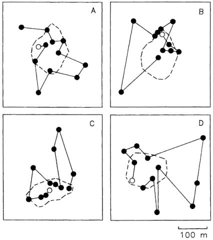
Memory is Advantageous When ...

- almost always
- especially when patches are
  - sparse & contiguous
  - high value
  - regenerate quickly
  - within a zero-value matrix

Bracis et al (2015)
https://s.abcnews.com/images/Video/bee-migration-08-abc-jrl-180111$_1$6x9$_9$92.*jpg*

Memory-Guided Landscape Use





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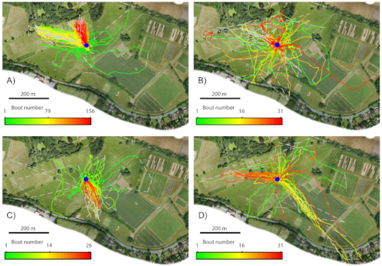

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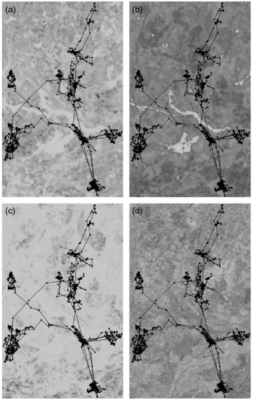

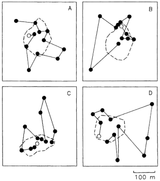

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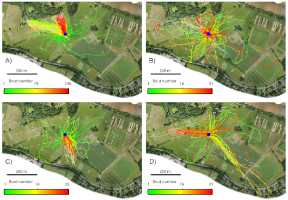
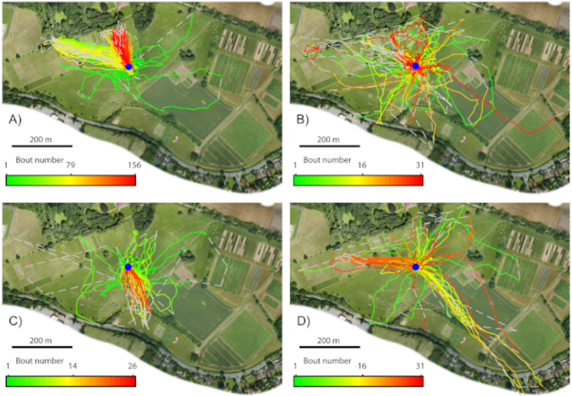


How can we take advantage of a forager's movement pattern to maximize ecosystem services?

Avgar et al (2015), Larsen & Boutin (1994), Woodgate et al (2016)

Pollination Services



How can we take advantage of a forager's movement pattern to maximize crop pollination services?

Woodgate et al (2016)

Wildflower Patches & Crop Pollination

https://www.rothamsted.ac.uk/sites/default/files/_DSC0253.jpg

Effects of Wildflowers

- Positive:
  - increase wild bee densities in crop fields

    (Haaland (2011) Insect Conservation Diversity)
  - increase crop pollination services

    (Blaauw (2014) J. Applied Ecology; Klein (2012) J. Applied Ecology; Feltham (2015) Ecology and Evolution; Morandin (2013) Ecological Applications)
  - may attract bees from nearby natural areas

    (Sidhu (2016) Frontiers in Plant Sciences; Haaland (2011) Insection Conservation Diversity)
- Negative:
  - distraction

    (Nicholson (2019) J. Applied Ecology; Lander (2011) Current Biology)

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So: **Where to put the wildflower patch, and how big should it be?**

Where and How Big: Context

Nest-Crop-Patch Geometry

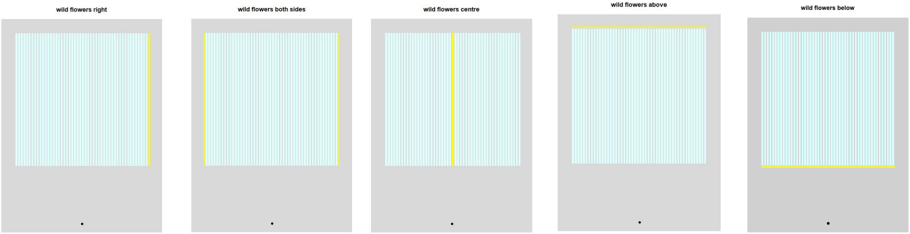
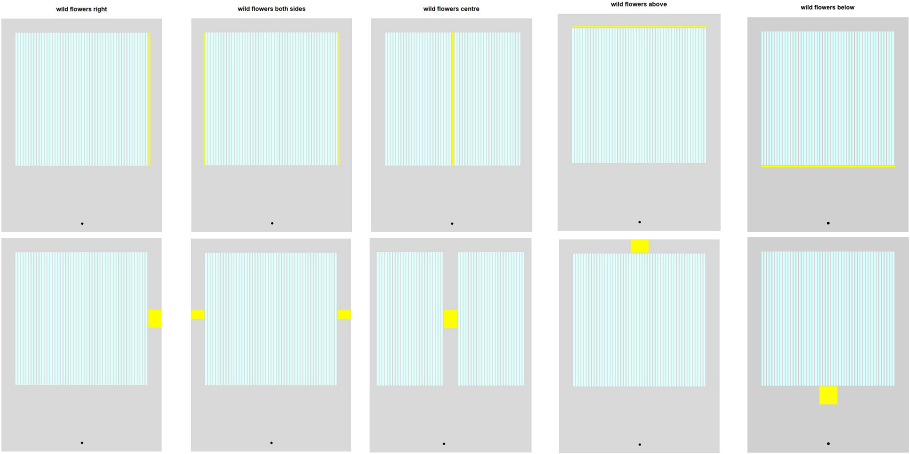


Figure Legend

pale blue:	blueberry bushes	yellow:	wildflower patches
grey:	grass	black dot:	nest

MacQueen, Braun, & Tyson (2021) JTB

Nest-Crop-Patch Geometry



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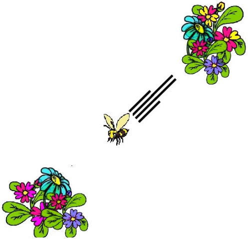
Movement: Harvesting & Scouting

Foraging Movement Patterns	
Harvesting: Diffusion	Scouting: Advection



Note: Opposite assumption made by Fagan et al (2020) Theoretical Ecology: Advection inside a resource patch, Diffusion outside.

Harvester-Scout Model

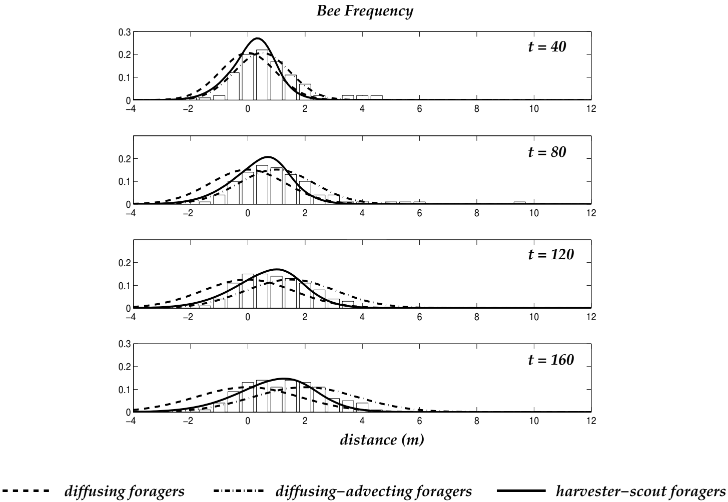
$$\frac{\partial H(\vec{x},t)}{\partial t} = \overbrace{D\nabla^2 H}^{\text{diffusion}} - \overbrace{(\gamma_1 H - \gamma_2 S)}^{\text{movement mode switching}}, \tag{1a}$$

$$\frac{\partial S_\theta(\vec{x},\theta,t)}{\partial t} = -\overbrace{v(\cos(\theta),\sin(\theta)) \cdot \left(\frac{\partial S_\theta}{\partial x}, \frac{\partial S_\theta}{\partial y}\right)}^{\text{scout mode movement in direction } \theta} + \overbrace{\left(\gamma_1 \frac{H}{2\pi} - \gamma_2 S_\theta\right)}^{\text{movement mode switching}}, \tag{1b}$$

$$\frac{\partial S(\vec{x},t)}{\partial t} = \overbrace{\int_0^{2\pi} \frac{\partial S_\theta(\vec{x},\theta,t)}{\partial t} d\theta}^{\text{scouts in all directions } \theta}, \tag{1c}$$

Tyson, Wilson, & Lane (2011) TPB

Model Validation - Honeybee Movement

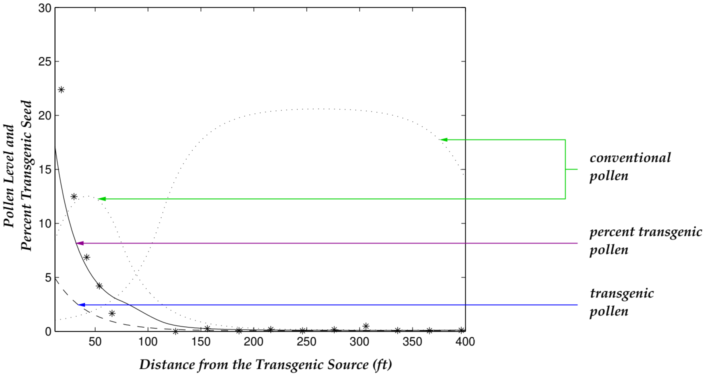


Data Source: Morris, W.F. (1993) Ecology 74(2):493–500

Tyson, Wilson, & Lane (2011) TPB

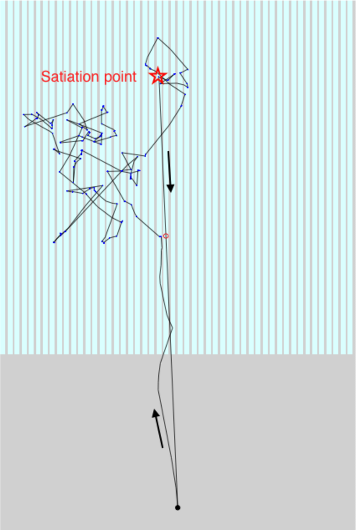
Model Validation - Transgene Spread

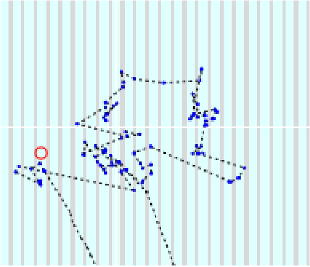
- Percent transgene presence in seeds versus distance from the nearest Transgenic tree:



Tyson, Wilson, & Lane (2011) Ecological Modelling

ABM: Harvester-Scout

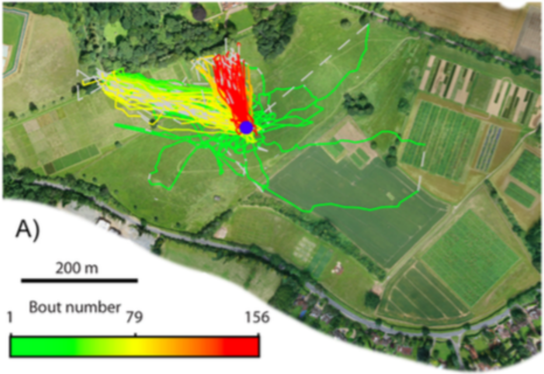




- red circle: memory point
- nest: black dot
- scouting: gray
- harvesting: blue

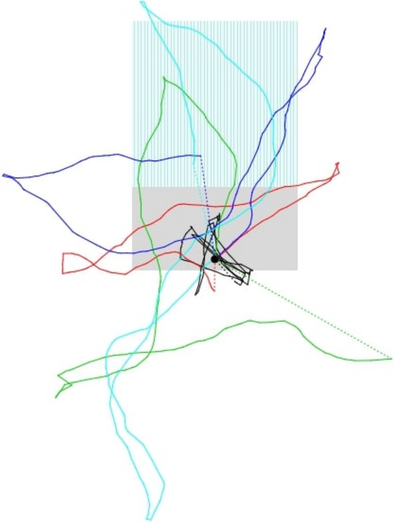
MacQueen, Braun, & Tyson (2021) JTB

Exploring & Exploiting



Woodgate et al (2016)

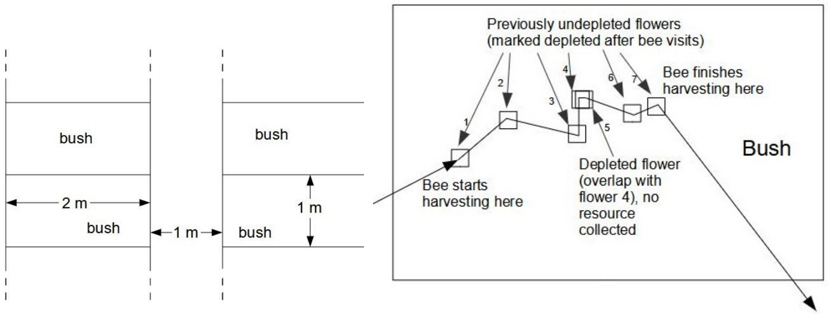
Finding the Memory Point



- 1st trip: black
- 2nd trip: red
- 3rd trip: green
- 4th trip: indigo
- 5th trip: cyan

MacQueen, Braun, & Tyson (2021) JTB

Flowers & Depletion



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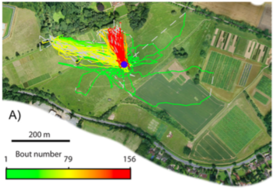
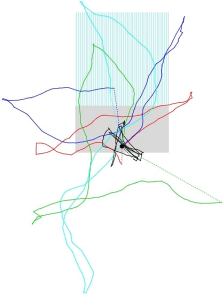
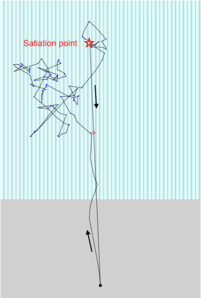
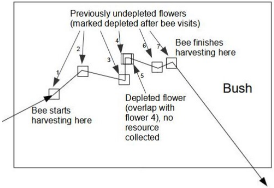
Full Model

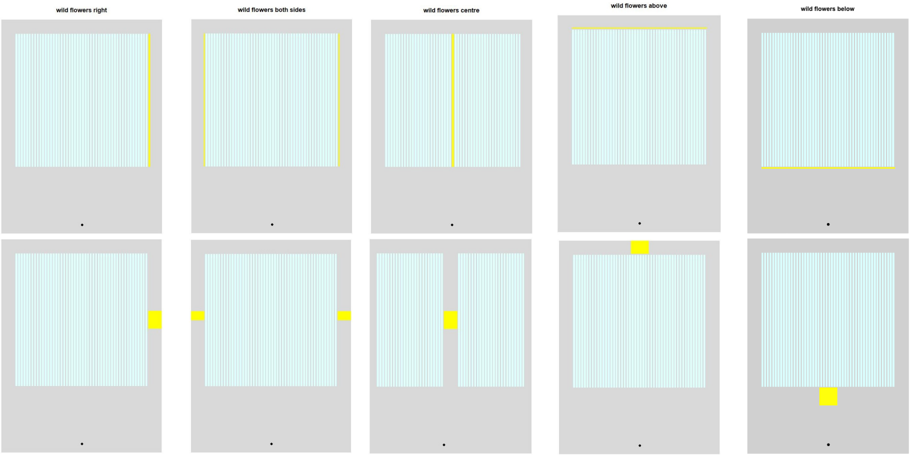

A)
200 m
Bout number
1
79
156




Satiation point


Previously undepleted flowers
(marked depleted after bee visits)
Bee finishes
harvesting here
Bush
Bee starts
harvesting here
Depleted flower
(overlap with
flower 4), no
resource
collected
1
2
3
4
5
6
7

Desired Resource: Crop or Wildflower?



- preferred resource (wildflower) is scarce, but required
- target is 40:60 (bl:wf) (Toshack (2019) Apidologie; Bobiwash (2018) J. Economic Entomology)

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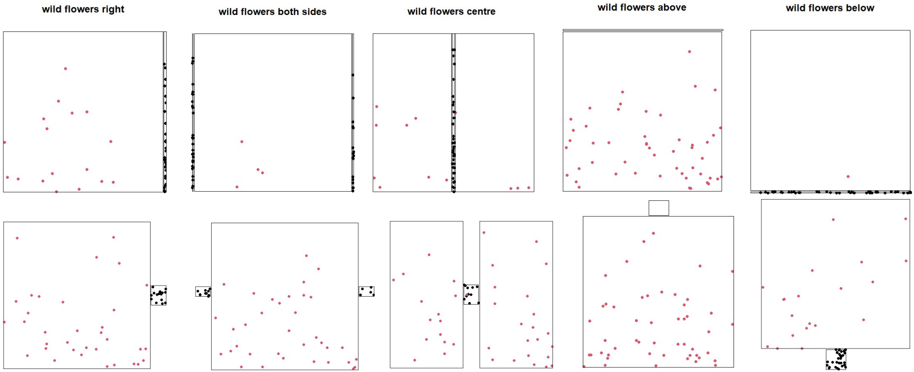
Results: Memory Points



- wildflower memory points: black
- blueberry memory points: red

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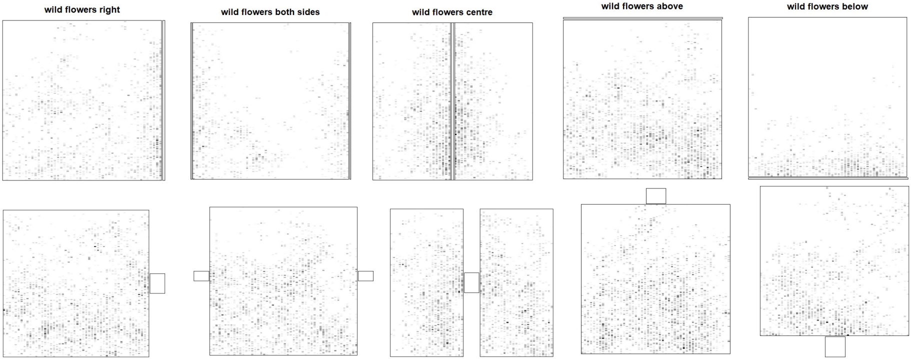
Results: Blueberry Flower Visit Intensity



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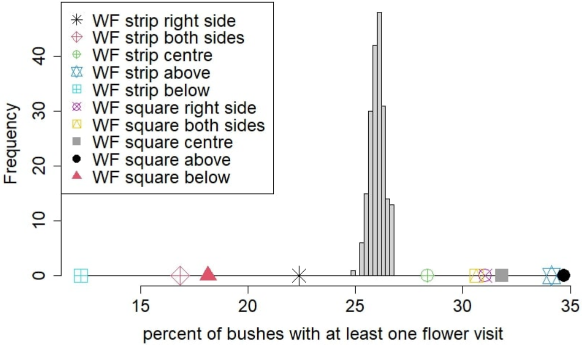
Results: Percent Bushes Visited



GANOVA plots: Mean values on each farm (points on the x-axis) and scaled residuals across all farms (histogram). Mean values that are farther apart from each other than the width of the histogram are significantly different.

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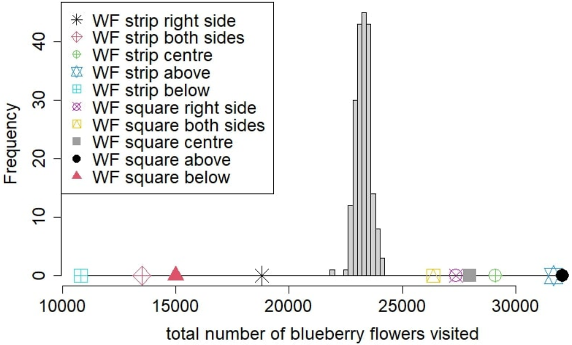
Results: Blueberry Flowers Visited



GANOVA plots: Mean values on each farm (points on the x-axis) and scaled residuals across all farms (histogram). Mean values that are farther apart from each other than the width of the histogram are significantly different.

MacQueen, Braun, & Tyson (2021) JTB

Conclusions

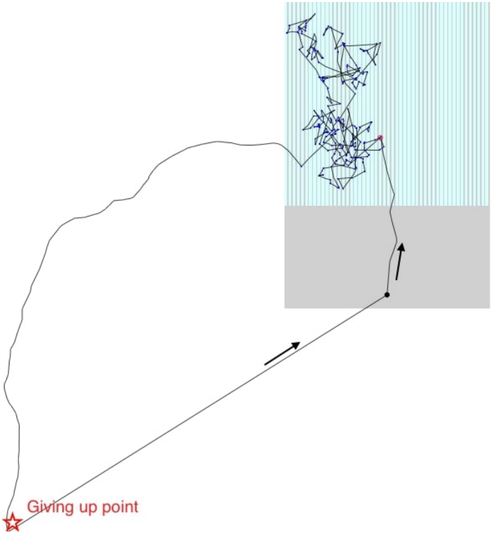
For a **central-place forager** with **memory** and **repeated visits** to a **specific foraging location**:

- when ecosystem services are desired in an abundant but lower-quality habitat
- supporting habitat can be added:
  - position and shape of both matter
  - best if foragers drawn across the lower-quality habitat

MacQueen, Braun, & Tyson (2021) JTB

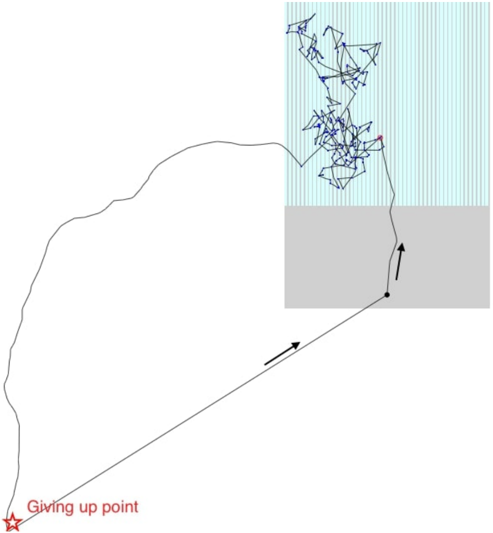
Future Work

- Assumptions
  - spillover
  - edge behaviour
  - memory point selection

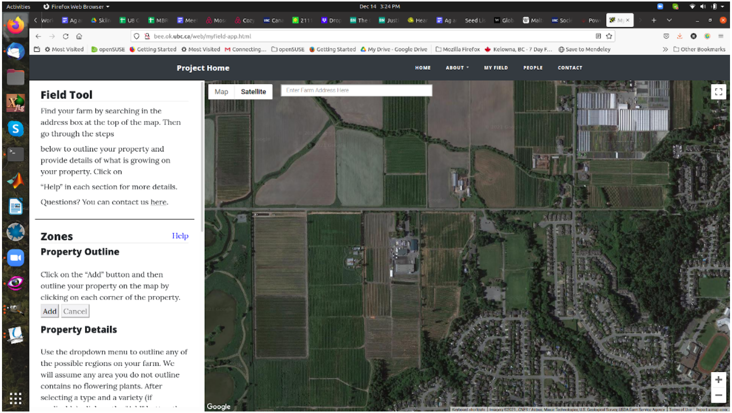


Future Work

- Assumptions
  - spillover
  - edge behaviour
  - memory point selection
- Theory
  - ecosystem services from other memory-guided foraging types

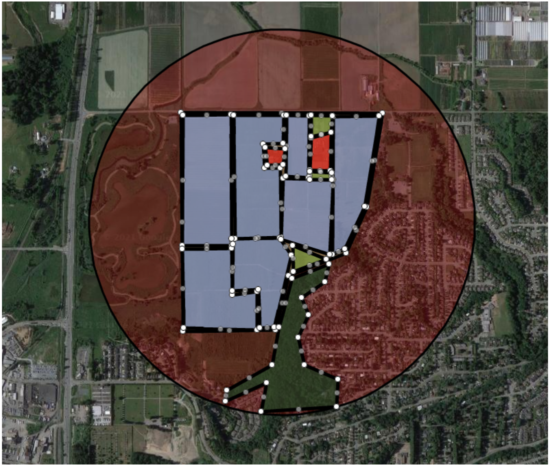


Predicting Pollination Services



https://bee.ok.ubc.ca

Predicting Pollination Services



https://bee.ok.ubc.ca

Predicting Pollination Services

Bumble Bee Pollination Services

Report prepared for *farm/name* on *date*

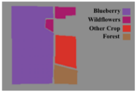
We have simulated bumble bee populations and foraging on your farm for a period of several years to produce these results. The model uses the farm map you provided and information about flower densities and bee behaviour from field studies to simulate realistic bee behaviour and track flower visits to the blueberry fields. For the added wildflower patches, we assume a mix of wildflowers that produce both pollen and nectar, and will be blooming for the entire spring and summer. For more information about the research and web simulation tool, visit http://bee.ok.ubc.ca.

Planting Option: 1 (Best)

Number of blueberry flower visits: (16000-17600)

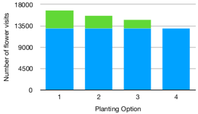
Increase in blueberry flower visits: (23-35)%

Total number of hibernating queens at the end of the year: (30-35)



This wildflower planting option shows the greatest increase in blueberry flower visits relative to having no additional wildflower plantings. We report the total number of blueberry flower visits, the increase in blueberry flower visits relative to the map with no wildflowers, and the total number of hibernating queens, which is an indicator of the bumble bee population.

Summary Results:



This plot shows the number of flower visits with no wildflower plantings in blue, and the additional flower visits with each wildflower planting option on top in green. The planting options are ranked according to the number of flower visits. The best option is displayed above, and the remaining options on the next page(s).

Planting Option: 2

Number of blueberry flower visits: (15000-16200)

Increase in blueberry flower visits: (15-25)%

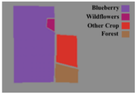
Total number of hibernating queens at the end of the year: (19-24)

Planting Option: 3

Number of blueberry flower visits: (14300-15200)

Increase in blueberry flower visits: (10-17)%

Total number of hibernating queens at the end of the year: (15-20)



Planting Option: 4 (No Wildflowers patches)

Number of blueberry flower visits: (12000-14000)

Increase in blueberry flower visits: (0-0)%

Total number of hibernating queens at the end of the year: (10-16)

Prepared by researchers from the University of British Coulumbia, Okanagan Campus, and University of Calgary.
Funded and supported by NSERC Strategic Project Grant and the British Columbia Blueberry Council.
Contact information: ***http://bee.ok.ubc.ca/web/contact.html***

https://bee.ok.ubc.ca

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Environment and Sustainability Institute > Research & Impact > Projects > BEE-STEWARD: A tool for supporting resilient pollinator populations

An integrated model for predicting bumblebee population success and pollination services in agro-ecosystems

Pollination is an ecosystem service which underpins agricultural production. There are serious concerns that populations of key pollinators, such as bees and other insects,

- Research Opportunities
- Projects

Principal researchers

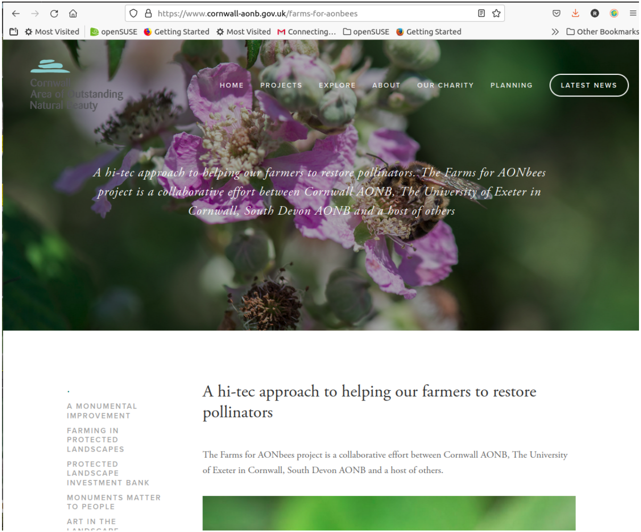
Professor Juliet Osborne, Dr Grace Twiston-Davies

Find more information on our current suite of bee colony and foraging bee models.

Related publications

BEESCOUT: A model of bee

Agricultural Ecosystems



Foraging Theory & Real Ecosystems