

Hollie Pufal¹, Ben Rowland¹, Stephen Rushton¹, Marin Kovačić², Giles Budge¹

¹School of Natural and Environmental Sciences, Newcastle University, Newcastle upon Tyne, Tyne and Wear, NE1 7RU, UK.

²J.J. Strossmayer University of Osijek, Faculty of Agriculture, 31000, Osijek, Croatia

Varroa destructor continues to erode the resilience of global beekeeping, with infestation leading to an increase in the level of viruses that can ultimately lead to colony collapse. Many beekeepers utilise different interventions to maintain Varroa populations below damage thresholds. Chemical treatments, queen caging and drone brood removal are all routinely deployed by beekeepers to manage Varroa mites. Field data on treatment efficacy and long-term honey bee colony survival are difficult to obtain and highly variable. It is also not clear how Varroa build-up and treatment efficacy might alter under climate change.

Individual based models (IBMs) attempt to capture the underlying processes of animal behaviour and can be a useful tool to monitor population build-up in a changing environment. Here we report the development of a two-population IBM that includes Varroa mites and their honey bee hosts under the Horizon Europe project BeeGuards (see www.beeguards.eu). We incorporate weather as a major driver of honey bee colony development, and monitor Varroa build up over time. We also developed functions that allow management practices to be incorporated into the model, to allow us to monitor the likely impacts interventions have on Varroa populations under different climate scenarios.

Resilient beekeeping and breeding to safeguard
natural genetic resources and pollination services



Predicting the impact of *Varroa* under climate change: An individual based modelling approach

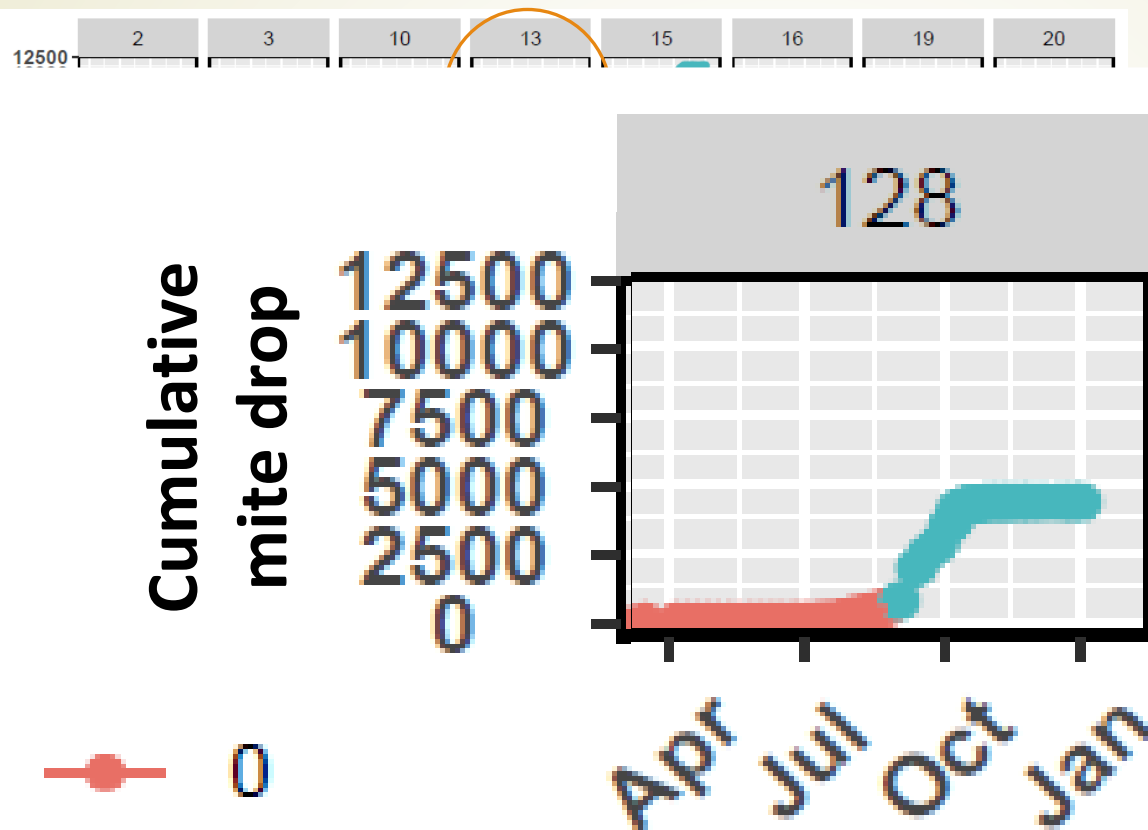
Hollie Pufal, Steve P. Rushton and Giles E. Budge

Newcastle University



Varroa populations vary

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- Mite levels vary even at the same site
- Some didn't meet treatment threshold
- Post treatment mite drop so different

Marin Kovačić et al. 2020

Apidologie
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DOI: 10.1007/s13592-020-00783-0

Original article



Effects of selection and local adaptation on resilience and economic suitability in *Apis mellifera carnica*

Marin Kovačić¹, Zlatko Puškadija¹, Marica Maja Dražić², Aleksandar Uzunov^{3,4}, Marina D. Meixner⁴, Ralph Büchler⁴

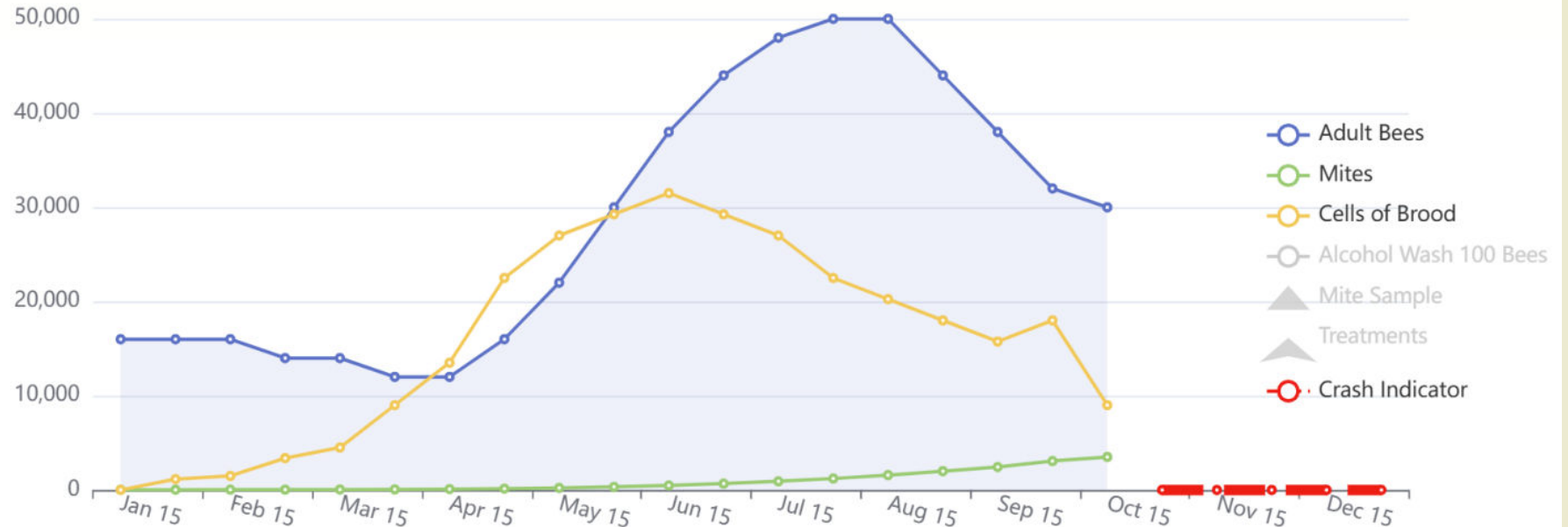


Current *Varroa* models

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Colony Status

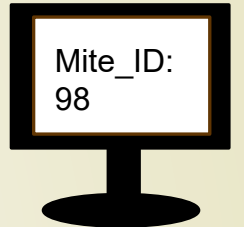
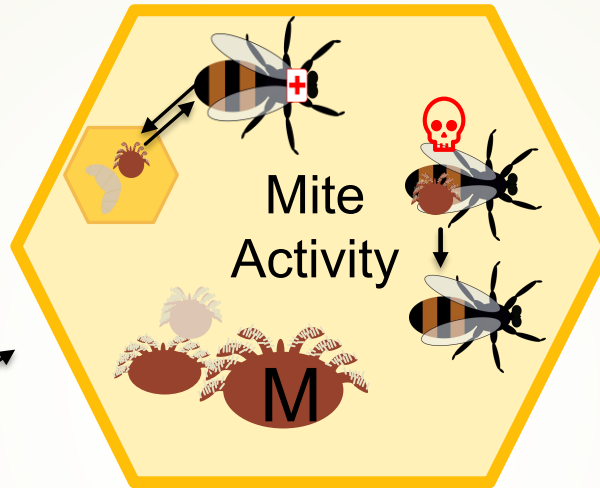
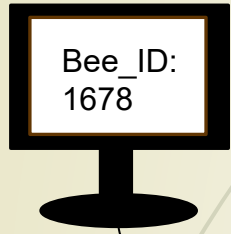
Varroa Situation in the Colony



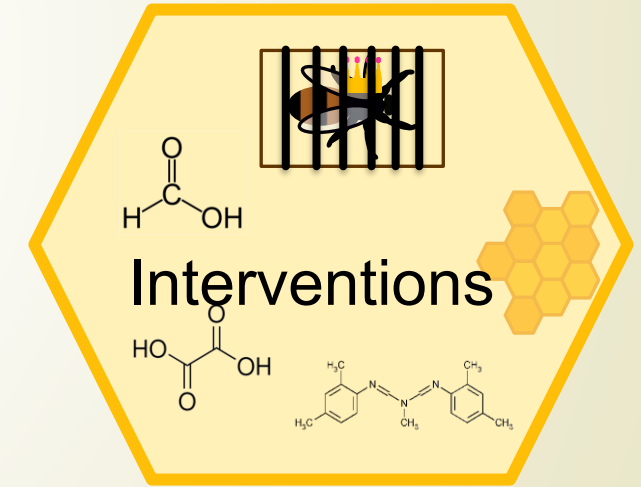
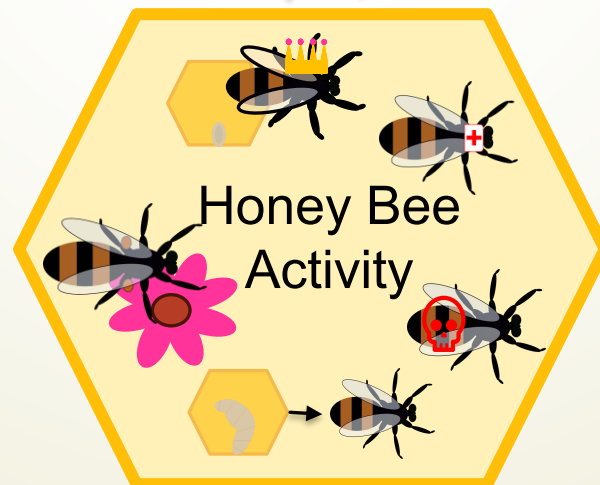
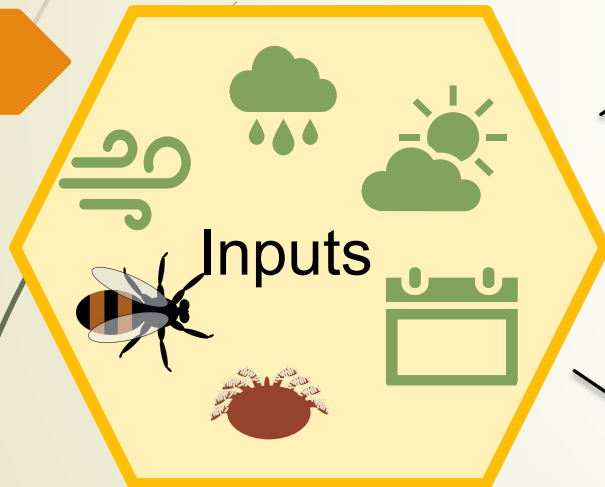
- Great example of a model (www.varroamodel.dk)
- Same result every time
- Do not always account for weather
- Do not account for host variation



Two species individual based model (IBM)



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Rowland, 2025 (unpublished)



Benefits of IBMs: Emergent properties

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TABLE 6. Comparison of the average number of adult female offspring produced per mother mite in this and other studies. In this study only infested cells containing bee pupa older than 322 hpc in drone cells or 230 hpc (grey pads) in worker cells were used. It assumes no further mortality of offspring after the observation was made and excludes the effect of early male death. The data in brackets show the mean number of viable adult female offspring produced when infertile mites due to the premature death of the male are excluded.

Cell type & species	Mother mites/cell				Author or hive ID
	1	2	3	4	
DRONE					
<i>A. cerana</i>	2.3	1.7	1.2		Rath, 1991
<i>A. mellifera</i>	2.21	1.90	1.52	1.51	Fuchs & Langenbach, 1989
<i>A. mellifera</i>	2.1 (1.9)	1.9 (1.9)	1.6 (1.6)	1.4 (1.4)	Martin, 1995 ¹
WORKER					
<i>A. mellifera</i>	1.5	1.4	1.2	0.96	Moosbeckhofer <i>et al.</i> , 1988
<i>A. mellifera</i>	1.5	1.58	1.13	0.83	Blum, 1989
<i>A. mellifera</i>	1.4	1.09	1.16	0.91	Fuchs & Langenbach, 1989
<i>A. mellifera</i>	1.3 (1.2)	1.3 (1.2)	1.2 (1.2)	0.5 (0.5)	Hive 22
<i>A. mellifera</i>	1.0 (0.8)	1.4 (1.3)	1.1 (1.1)	0.8 (0.8)	Hive 7
<i>A. mellifera</i>	1.6 (1.3)	1.5 (1.5)	1.7 (1.7)		Martin, 1994 ¹
<i>A. mellifera</i>	1.1 (1.0)	0.6 (0.6)	0.6 (0.6)		Hive 14
<i>A. mellifera</i>	1.3 (1.3)	0.9 (0.9)			Hive 21

¹Values calculated from the data collected during these studies

Martin, 1995

Numbers of female offspring per brood cell and per mite increased continuously from February until July (C: 0.35 to 1.33, L: 0.30 to 1.41, M: 0.50 (March) to 1.63) and decreased again from August to November (C: 1.37 to 0.81, L: 1.49 to 0.95, M: 1.55 to 1.08).

Otten and Fuchs, 1990

Population modelling of *Varroa jacobsoni* Oud.

Johan N.M. Calis^{a*}, Ingemar Fries^b, Stephen C. Ryrie^c

^a Department of Entomology, Wageningen Agricultural University, POB 8031, 6700 EH Wageningen, the Netherlands

^b Swedish University of Agricultural Sciences, Bee Division, Box 7044, S-570 07 Uppsala, Sweden

^c Department of Mathematical Sciences, University of the West of England, Frenchay, Bristol BS16 1QY, UK

(Received 20 August 1998; accepted 22 February 1999)

- Current models use one offspring average all year
- 1.45 average offspring in worker
- This figure is a product of underlying processes



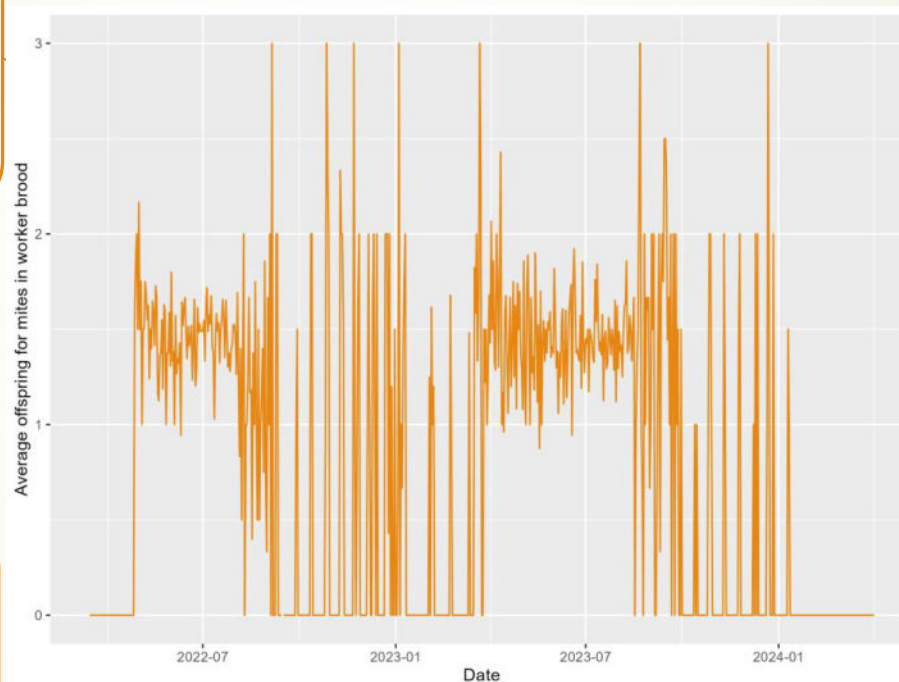
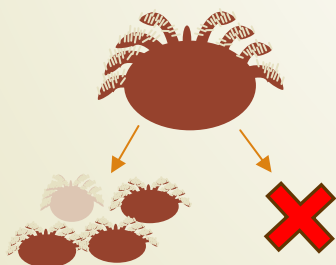
Benefits of IBMs: Emergent properties

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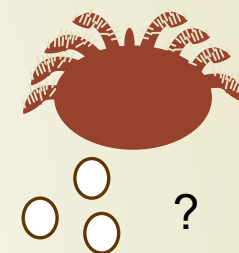
Mother mite reproductive capability



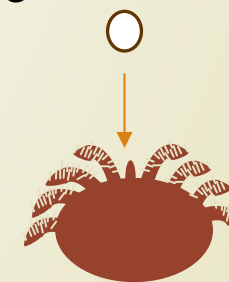
Probability of reproduction



How many eggs laid



Survivorship of each egg

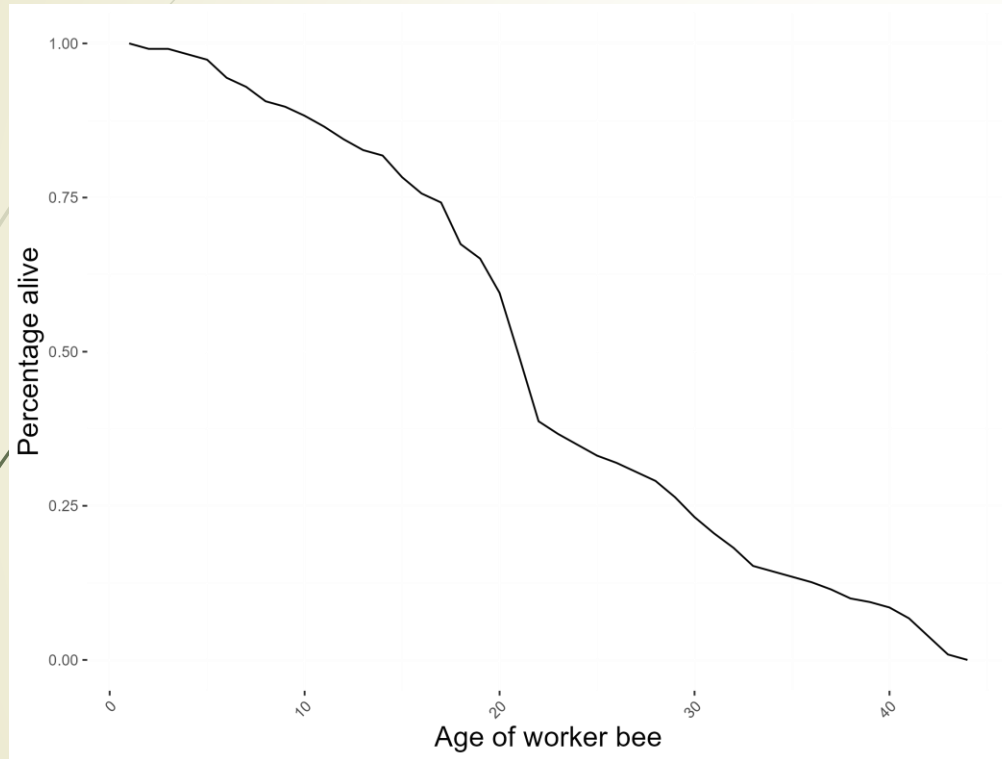


Martin, 1994, 1995 & 1997



Benefits of IBMs: Probabilistic outcomes

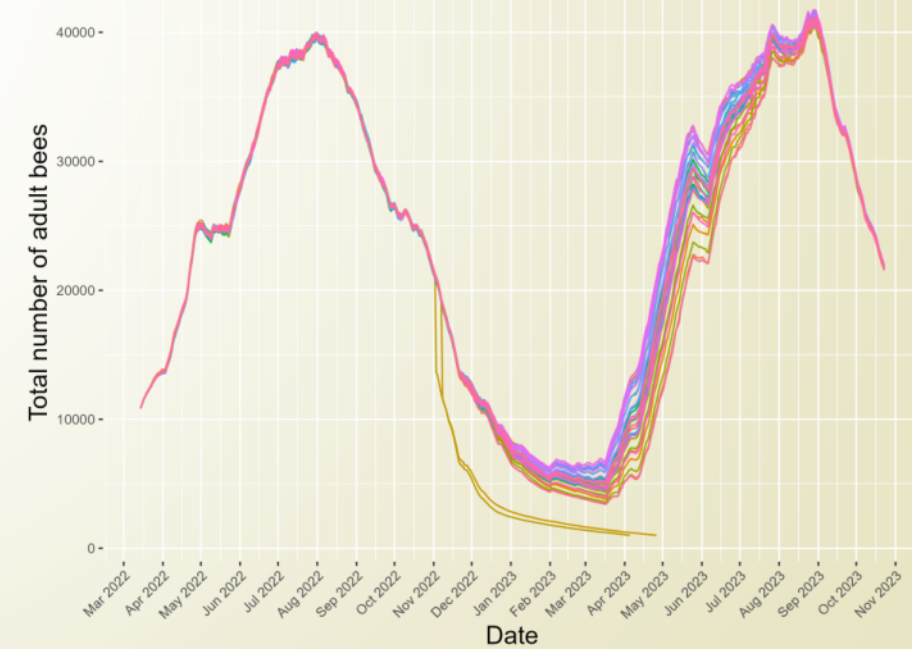
7



- Different result every time due to probabilistic factors.

Minaud et al, 2025

- Mortality the same for every bee in current models
- 31 days in *Calis et al*
- Each bee is individual and has a probability of survival each day





Potential of this *Varroa* model



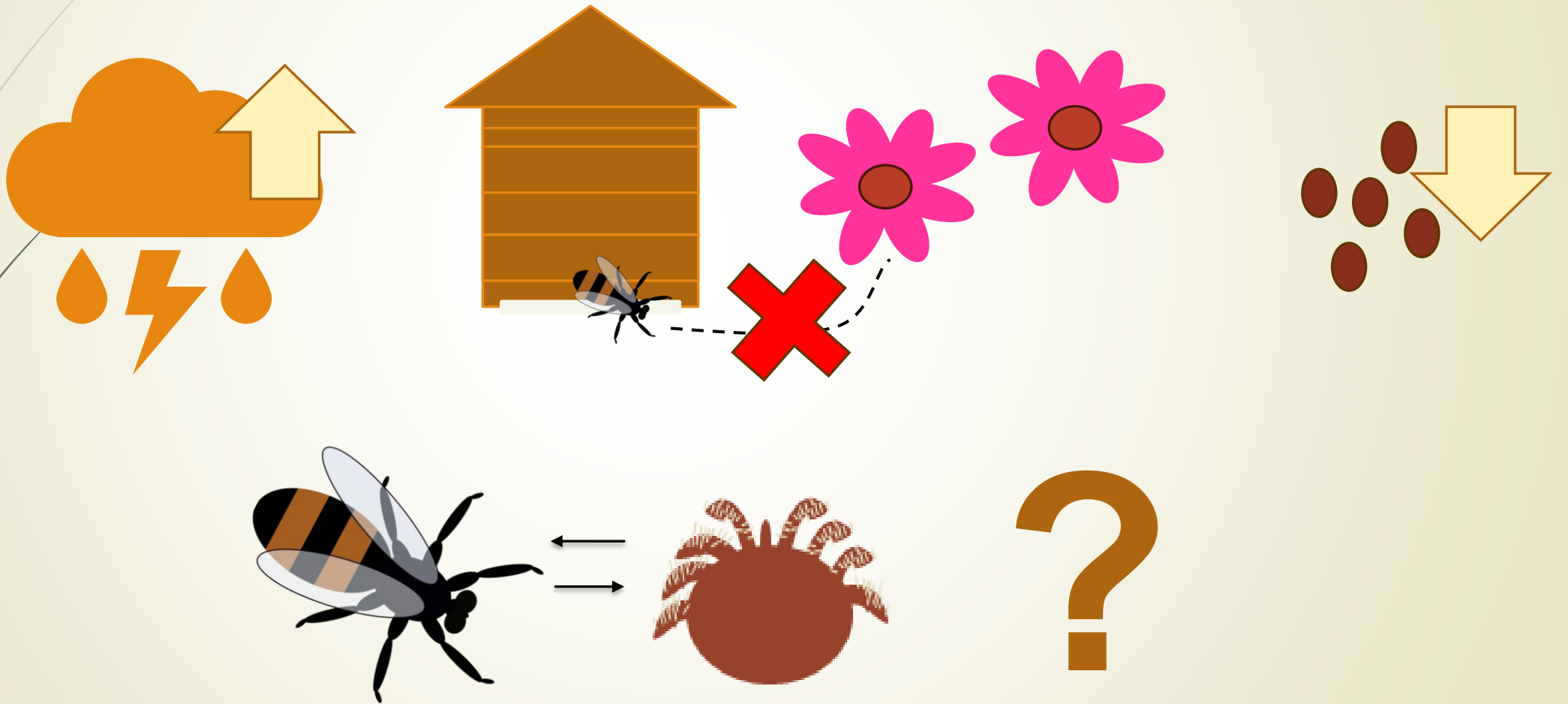
Account for
future
climate change

2035



How we predict *Varroa* populations in a changing climate?

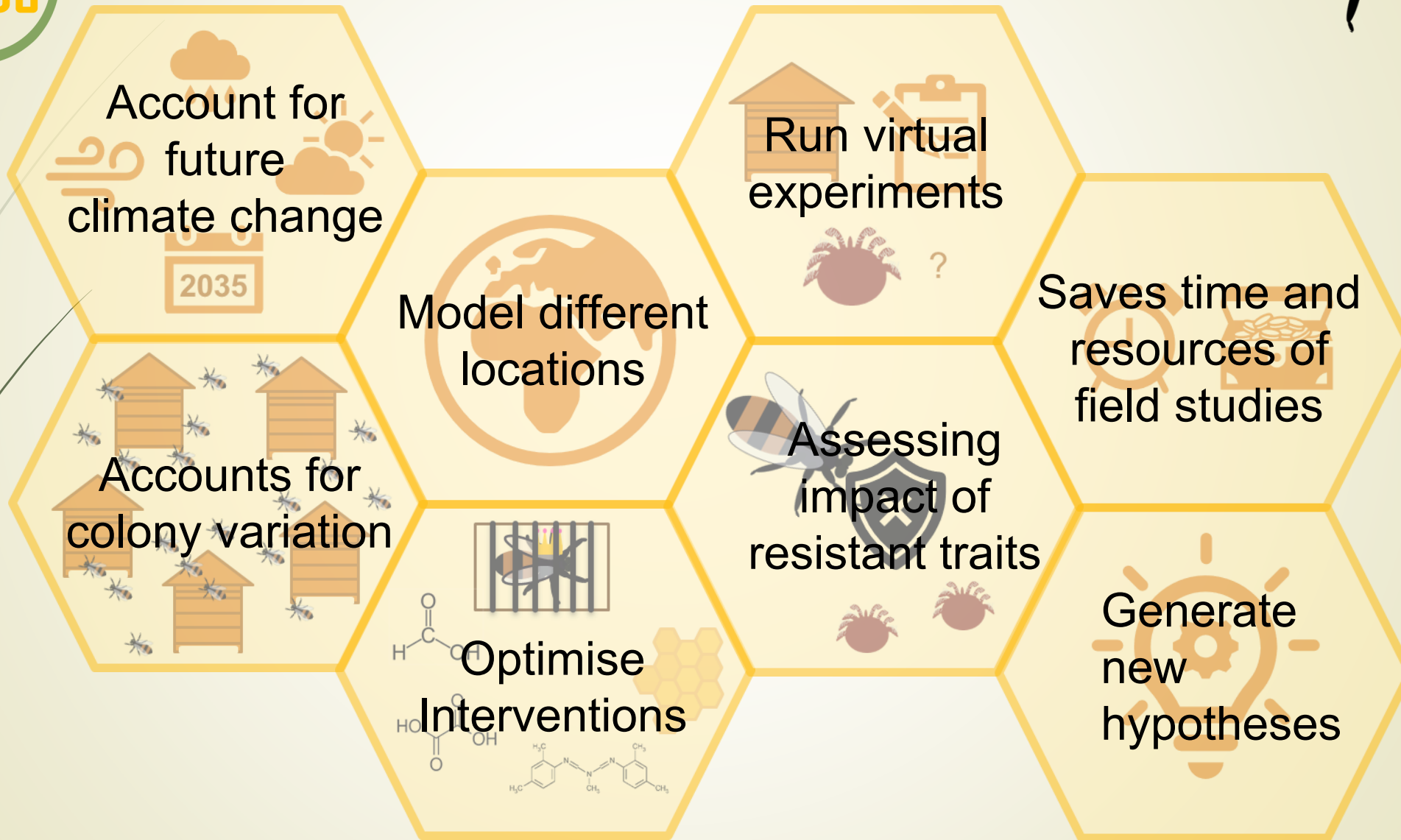
9



Potential of this *Varroa* model



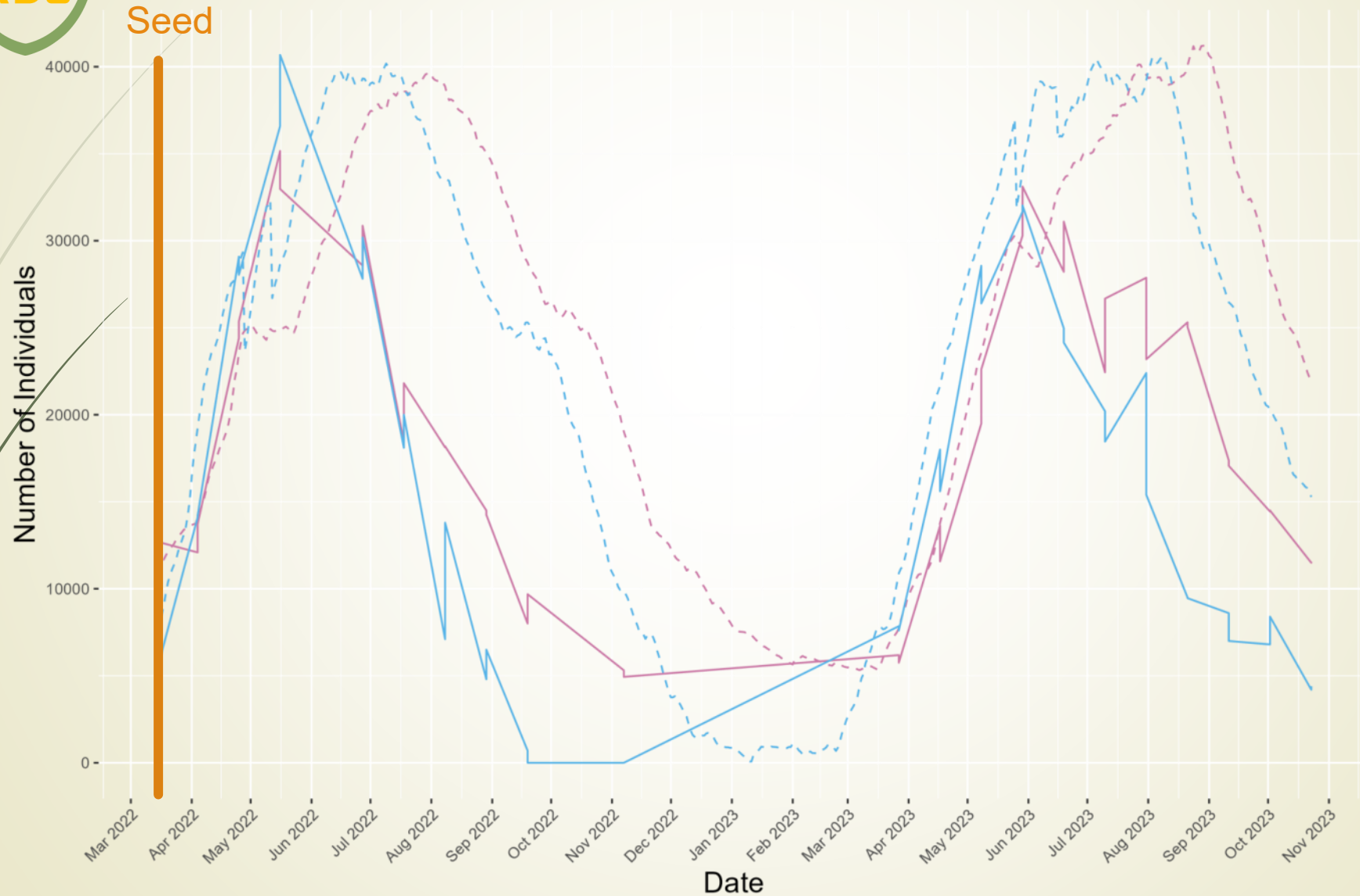
10





Preliminary results- Bee population

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Bee Type

- Adult Number
- Brood Number

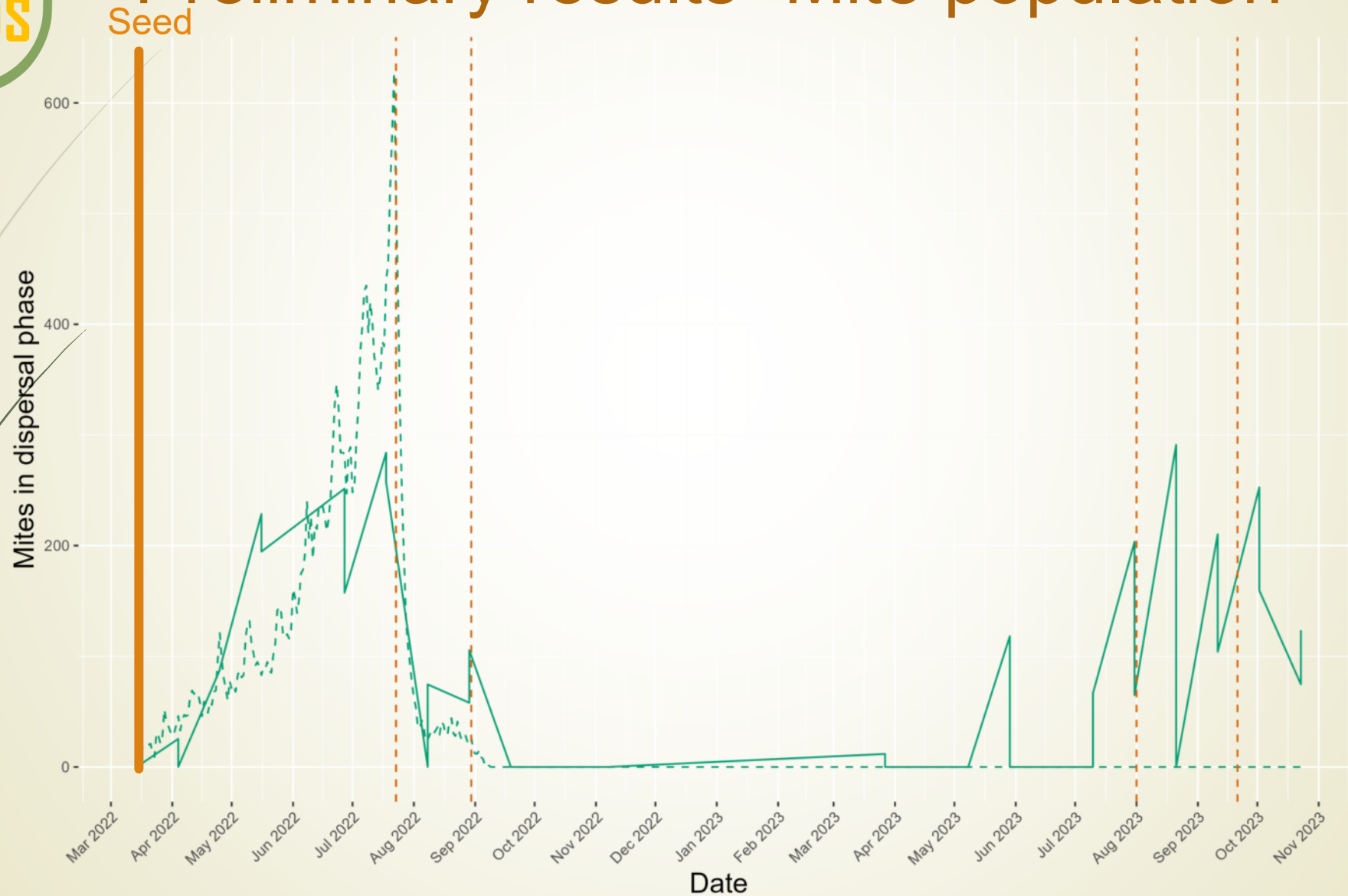
Data Type

- Observed
- Predicted



Preliminary results- Mite population

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Summary



In the final stages of developing a two species IBM



Probabilistic approach reflect real world observations



The model accounts for variable climate



Model development has highlighted research gaps

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Next Steps

Iron out
some
processes



Validation



Sensitivity
analysis



Test
hypotheses



Acknowledgements



Thank you for listening.

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UK Research
and Innovation



Funded by the
European Union

Funded by the European Union under GA No 101082073. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them."



Ben Rowland



Steve Rushton



Mark Shirley



Giles Budge



Marin Kovačić



Sveučilište Josipa Jurja
Strossmayera u Osijeku
Fakultet
agrobiotehničkih
znanosti Osijek



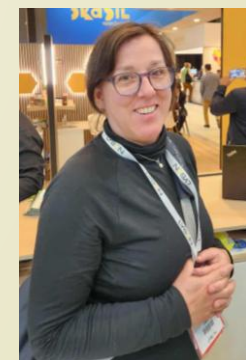
Janez Prešern



Lena Frank



Kmetijski inštitut Slovenije



Annely Brandt