

The Good, the Bad and the Ugly: Insights and trends from a 20-year natural selection experiment on disease resistance in Gotland, Sweden

Barbara Locke Grandér

Honey Bee Research Centre, Department of Ecology, Swedish University of Agricultural Sciences

Background and Purpose

Disease susceptibility has caused a significant decline in honeybee populations thriving outside of human management, as honeybees rely on disease interventions for their health and survival. This is especially true in the context of Varroa destructor mites and their associated viruses. Chemical-based treatments are effective, but can harm bees, leave residues in products, and are increasingly ineffective as mites develop resistance. New approaches are required to ensure the sustainability of beekeeping.

A long-term natural selection experiment on the island of Gotland Sweden consists of a honeybee population that has survived without mite control, showing evidence of adapted resistance to Varroa and tolerance to viral infections. This population is a valuable model for understanding how these species interact and exploit each other and could inform more refined and effective mite control strategies but does not advocate for removing control strategies in beekeeping. The growing trend of "natural" or treatment-free beekeeping, which advocates minimal intervention to reduce stress and improve bee health, relies on adaptations of resistance to Varroa mites but is based on an oversimplification of natural selection processes, at the cost of high mortality rates. This highlights the need for clearer definitions of "stress" and "better health" in the context of honey bee management.

Results and CONCLUSION: This presentation will provide an overview of the key insights gained from studying the Gotland population, highlighting the positive outcomes (the good), assessing its current health and productivity status (the bad), and examining the trends it has sparked in "natural" beekeeping (the ugly).

Practical Implications for Beekeepers

The promising results of the long-term treatment-free study on Gotland do not suggest that treatment should be removed within the beekeeping industry. For adaptations and evolutionary rescue to succeed, a sufficiently large population with adequate genetic diversity is essential. Moreover, evolution through natural selection does not always guarantee improved prospects for long-term survival. While treatment-free beekeeping is feasible, it requires careful management and is not a low-intervention alternative if the goal is a healthy honey bee climate. Success in this approach demands thoughtful consideration of ethical values and responsible practices.



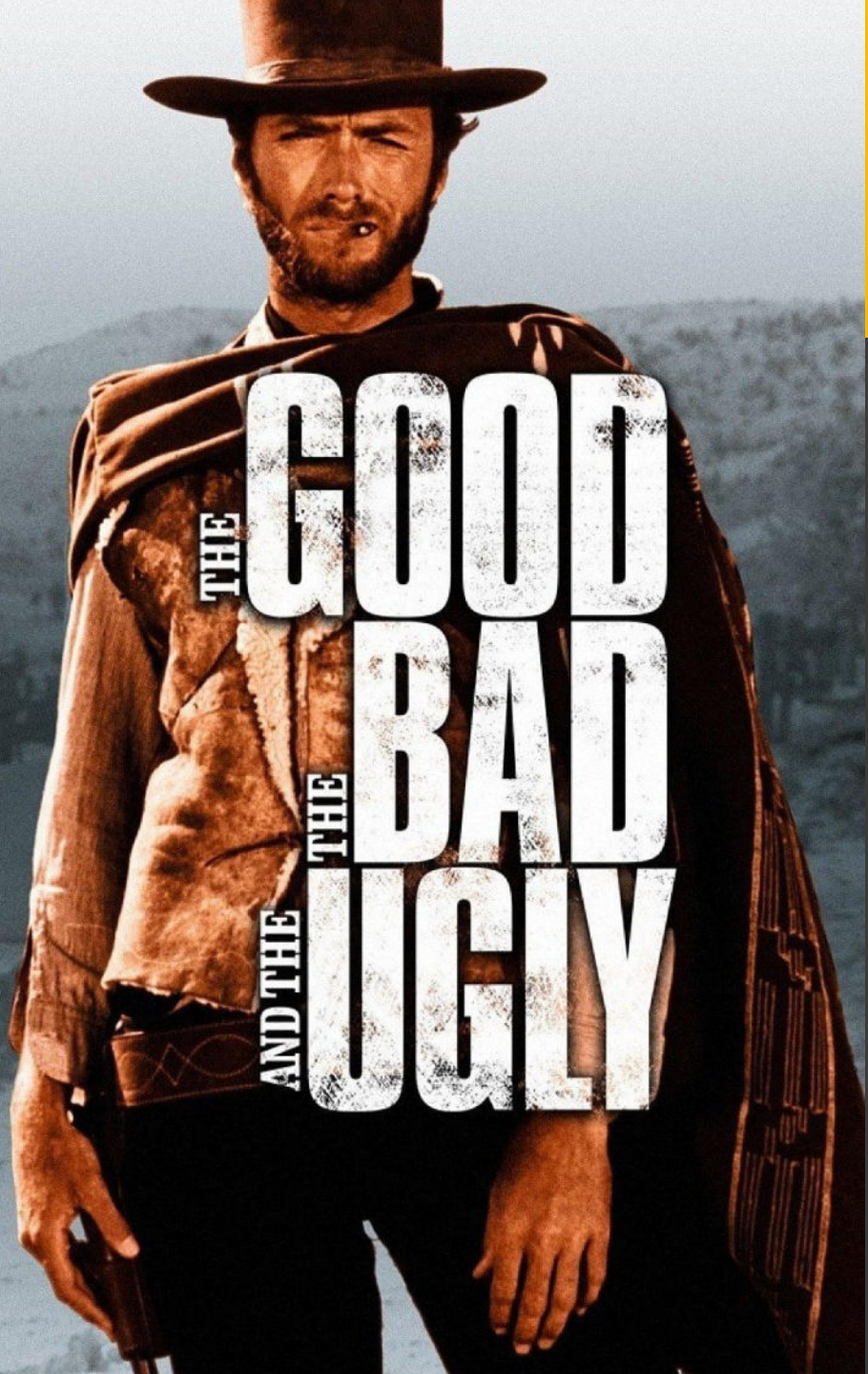
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Insights and trends from a 20-year natural selection experiment on disease resistance in Gotland, Sweden

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Apimondia 2025
23-27 September 2025, Copenhagen

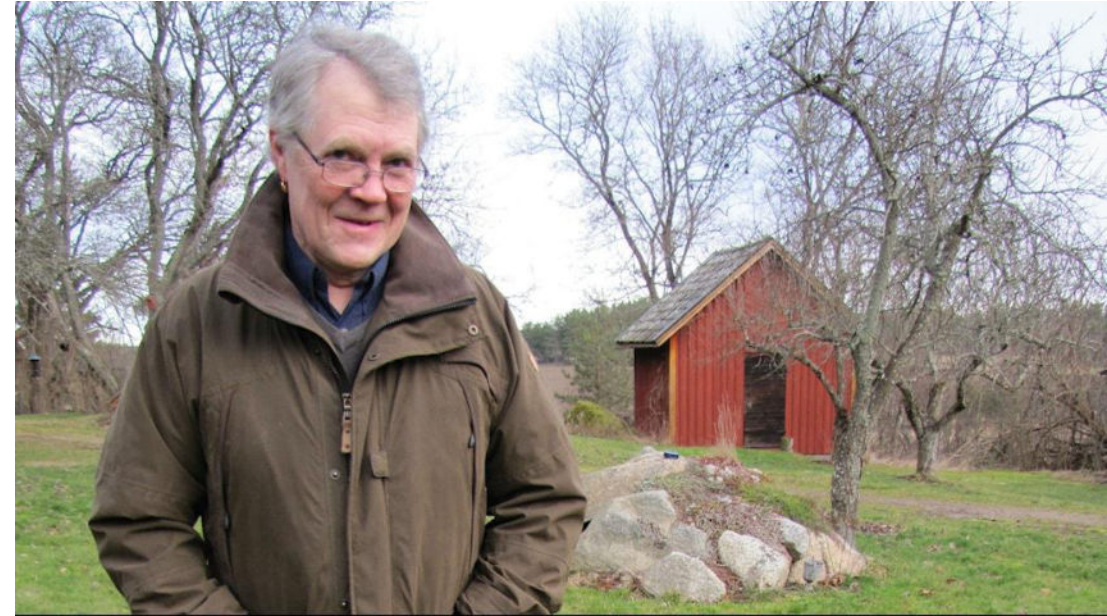


A natural selection experiment since 1999

Aim: to use concepts in evolutionary ecology to better understand bee health.

- - 150 colonies
 - Evenly infested with varroa

Hypothesis: varroa would become less virulent in a bee population that swarmed freely.
(Evolution of virulence theory)



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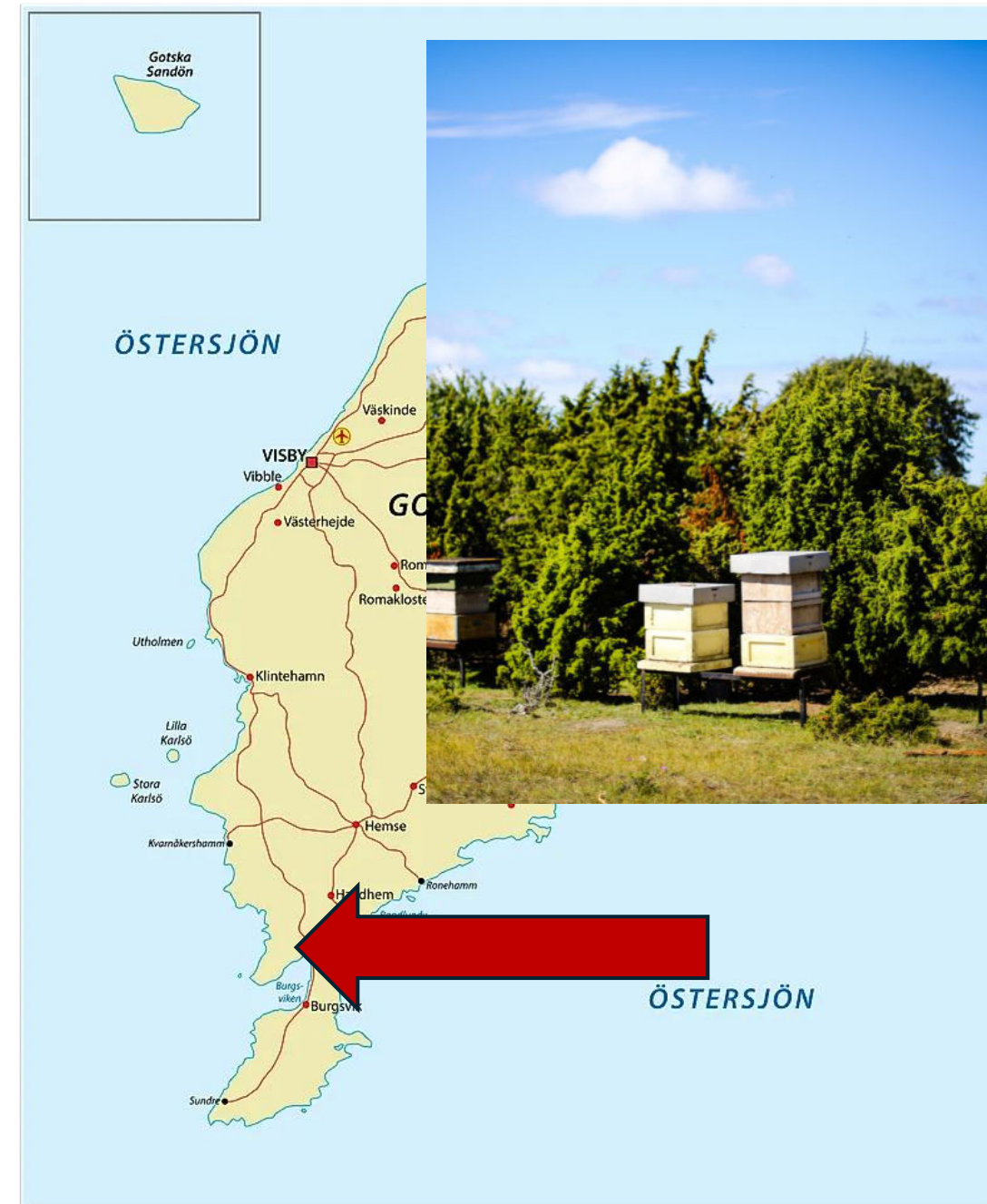
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The “Bond” Project

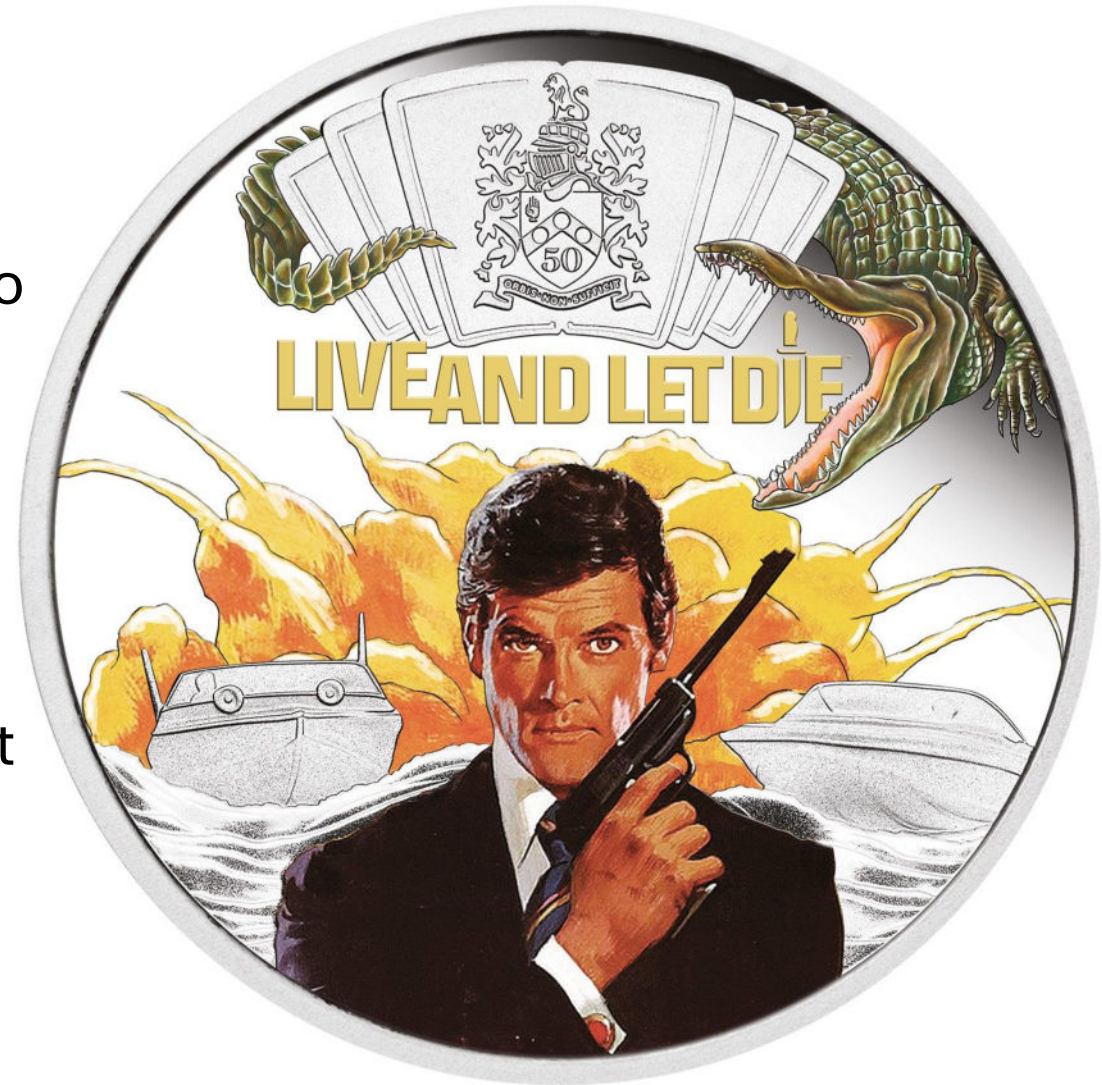
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“Live and Let Die”



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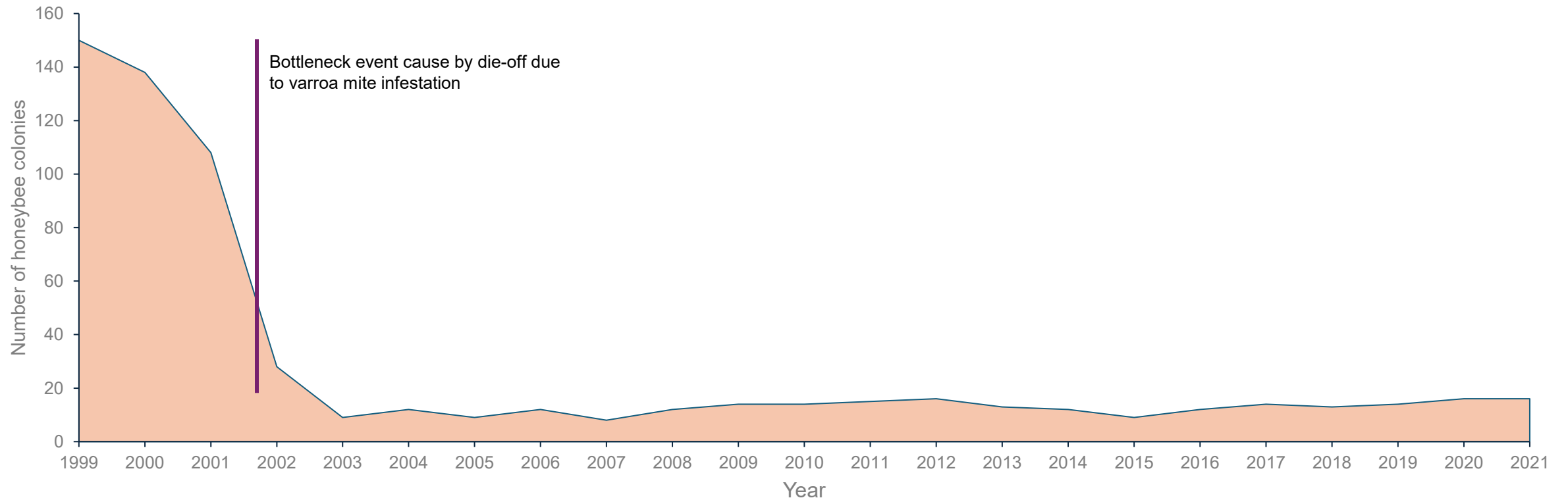
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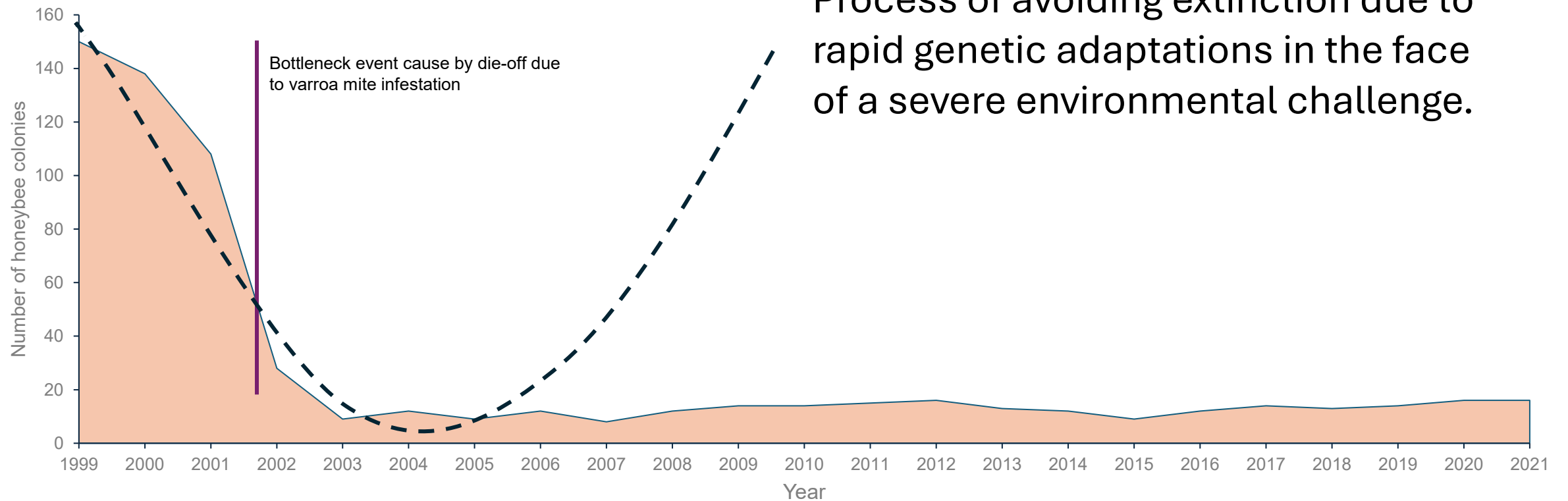
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Population demography



The “Bond” Project

Population demography

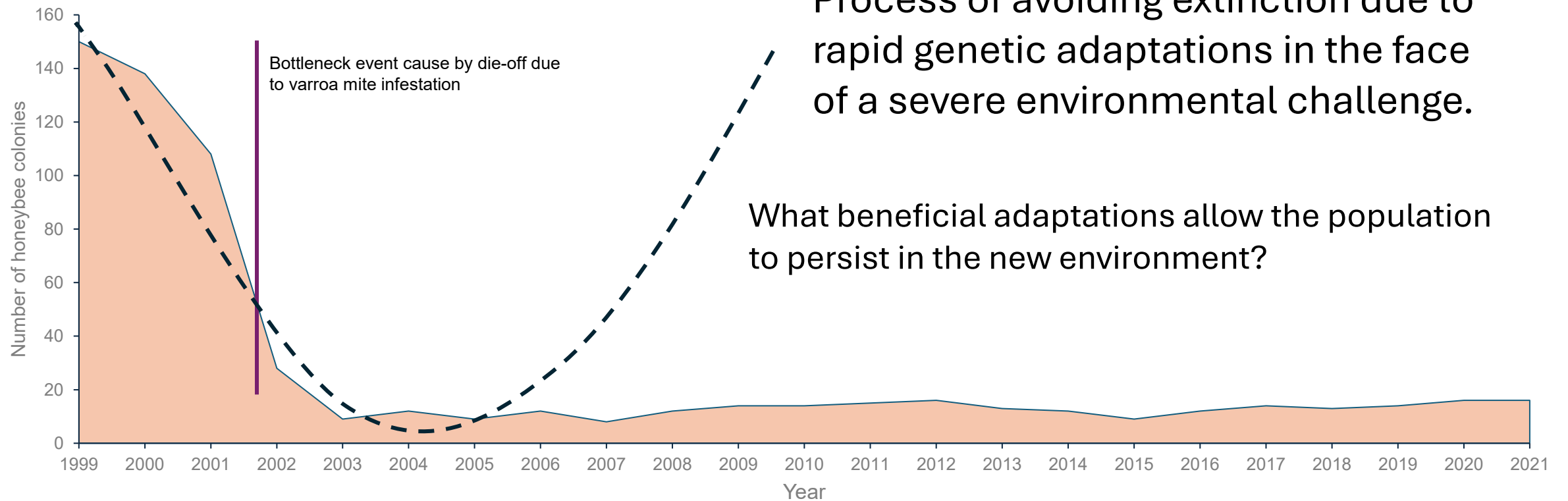


Evolutionary Rescue

Process of avoiding extinction due to rapid genetic adaptations in the face of a severe environmental challenge.

The “Bond” Project

Population demography



Evolutionary Rescue

Process of avoiding extinction due to rapid genetic adaptations in the face of a severe environmental challenge.

What beneficial adaptations allow the population to persist in the new environment?

The “Bond” Project on Gotland

- Mite reproduction is reduced

Locke & Fries 2011

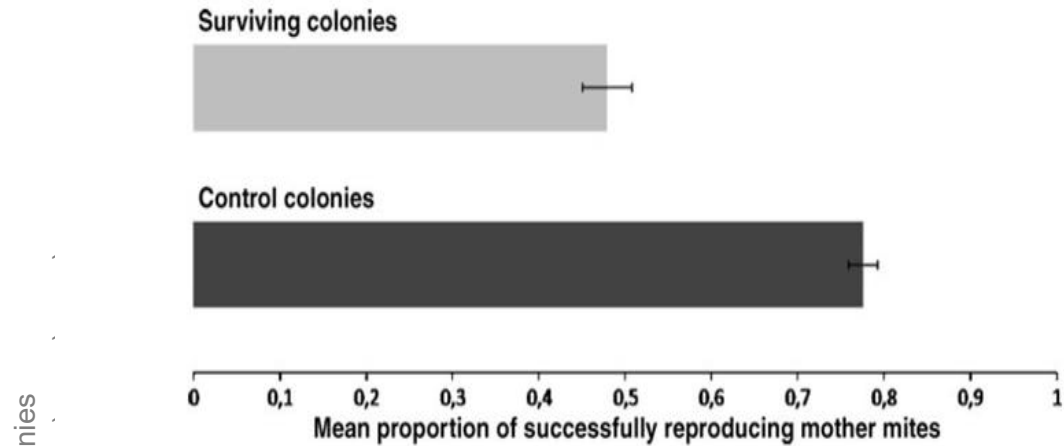
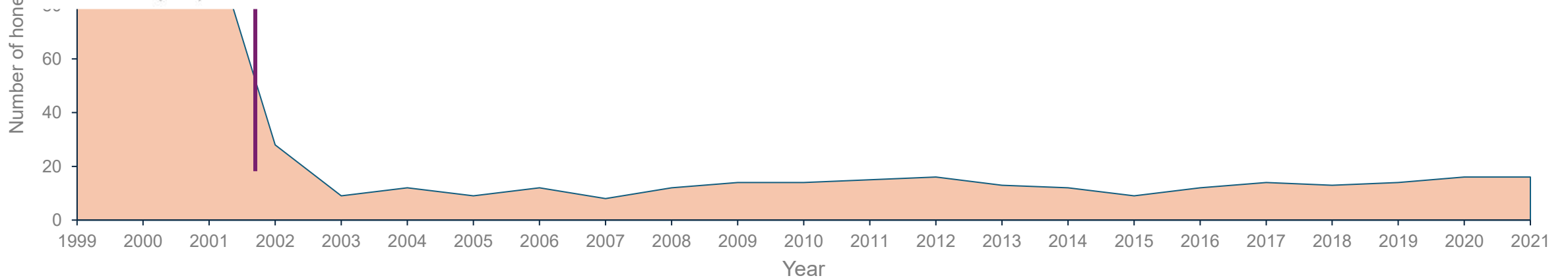


Figure 3. Mean proportions of mother mites producing viable mated female offspring in surviving ($n=23$) and control colonies ($n=21$) with standard error bars.



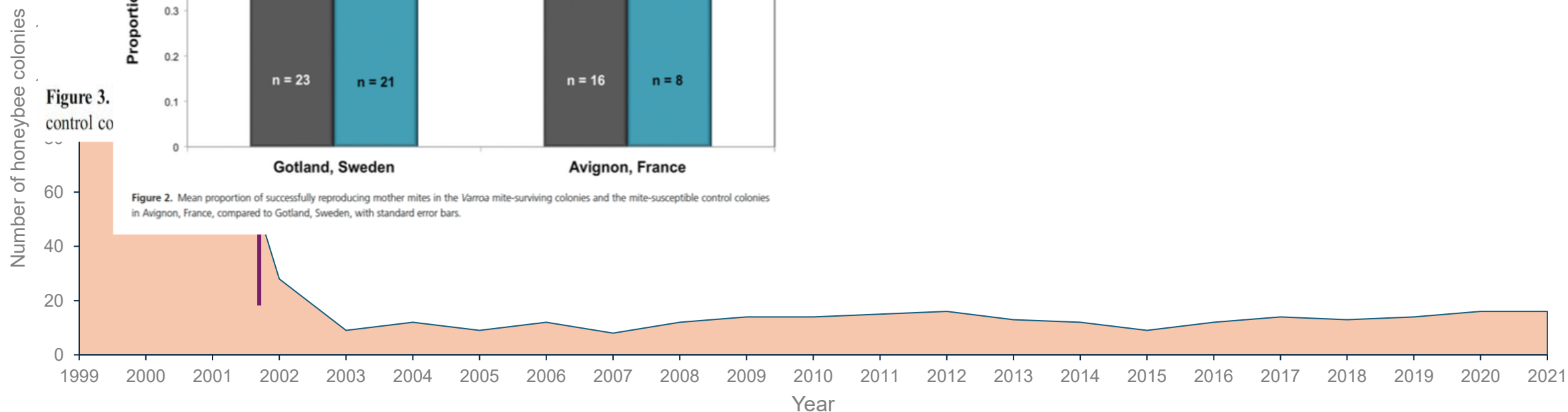
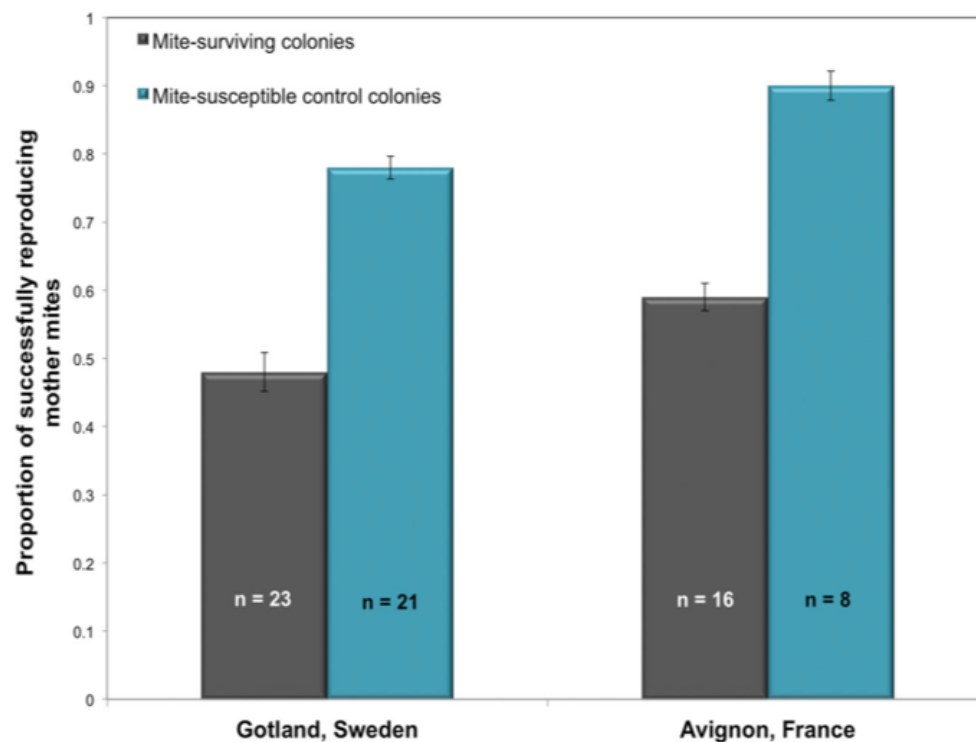
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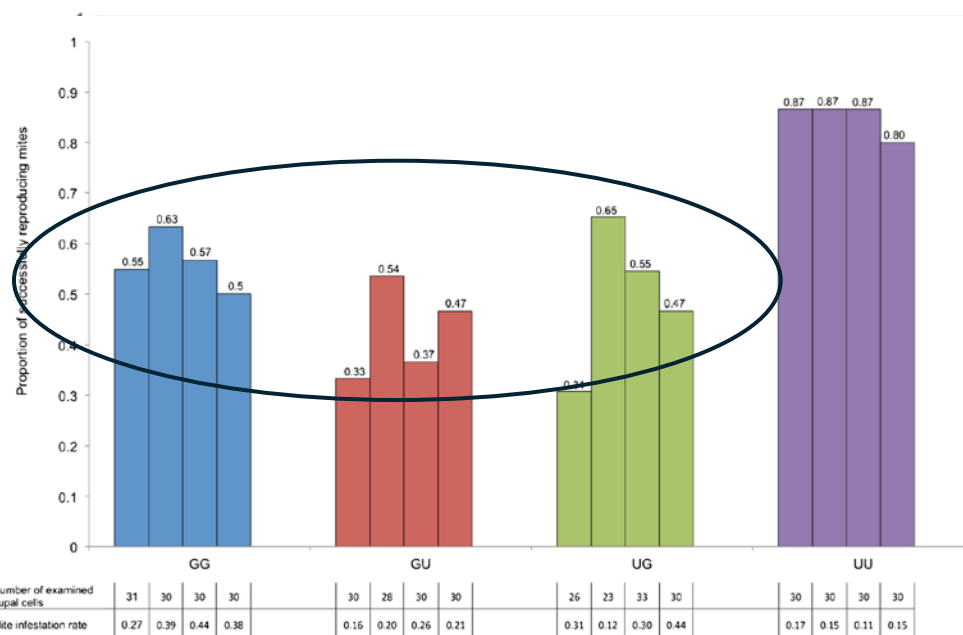
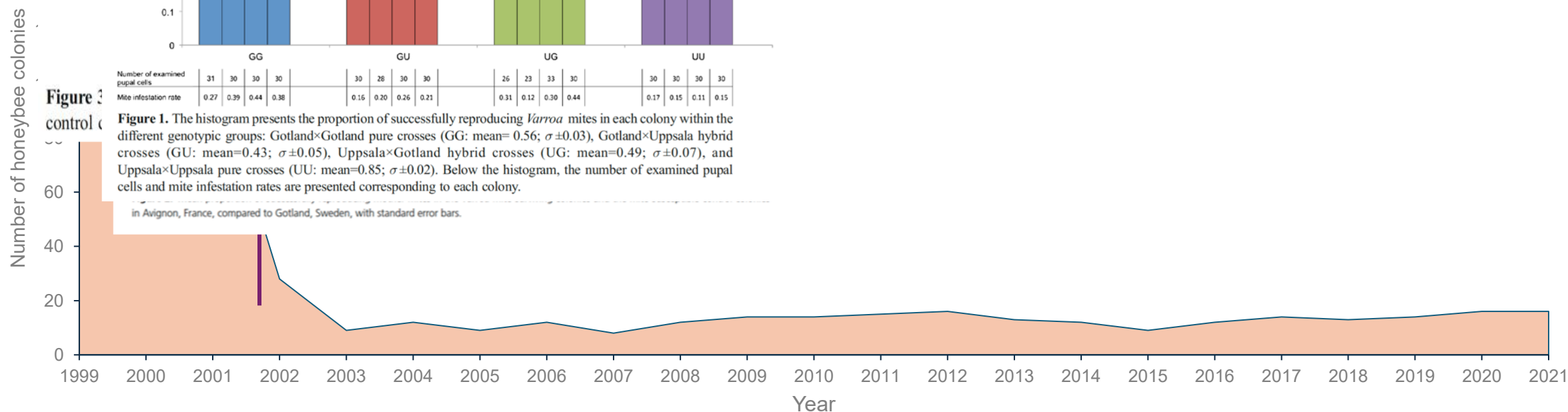


Figure 1

The histogram presents the proportion of successfully reproducing *Varroa* mites in each colony within the different genotypic groups: Gotland×Gotland pure crosses (GG: mean=0.56; $\sigma \pm 0.03$), Gotland×Uppsala hybrid crosses (GU: mean=0.43; $\sigma \pm 0.05$), Uppsala×Gotland hybrid crosses (UG: mean=0.49; $\sigma \pm 0.07$), and Uppsala×Uppsala pure crosses (UU: mean=0.85; $\sigma \pm 0.02$). Below the histogram, the number of examined pupal cells and mite infestation rates are presented corresponding to each colony.

in Avignon, France, compared to Gotland, Sweden, with standard error bars.



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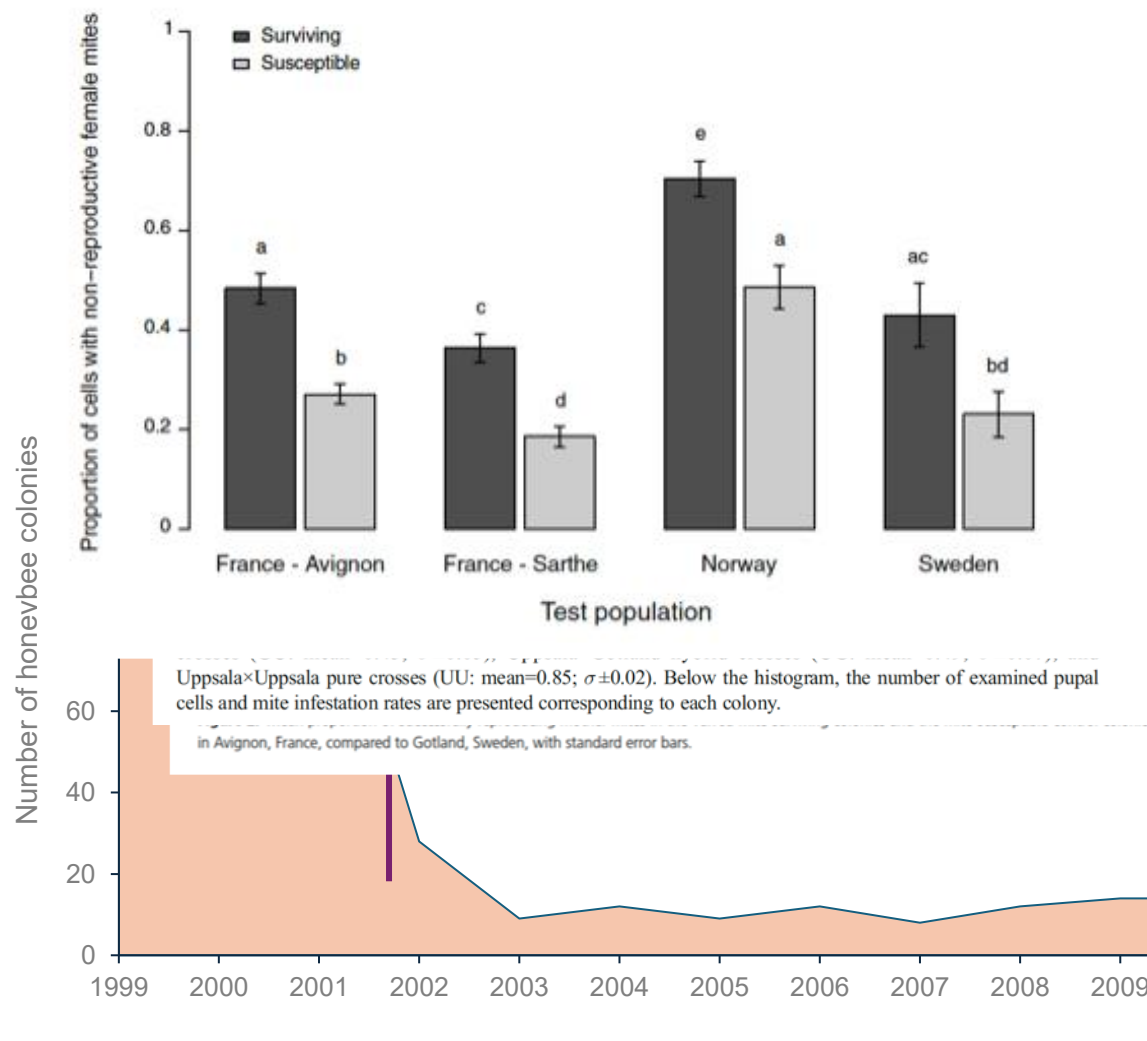
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- This trait is expressed in even more populations

Oddie et al., 2018



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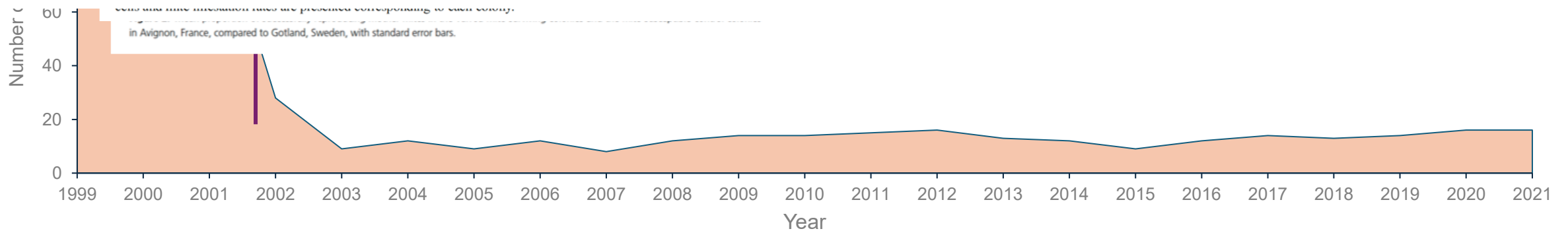
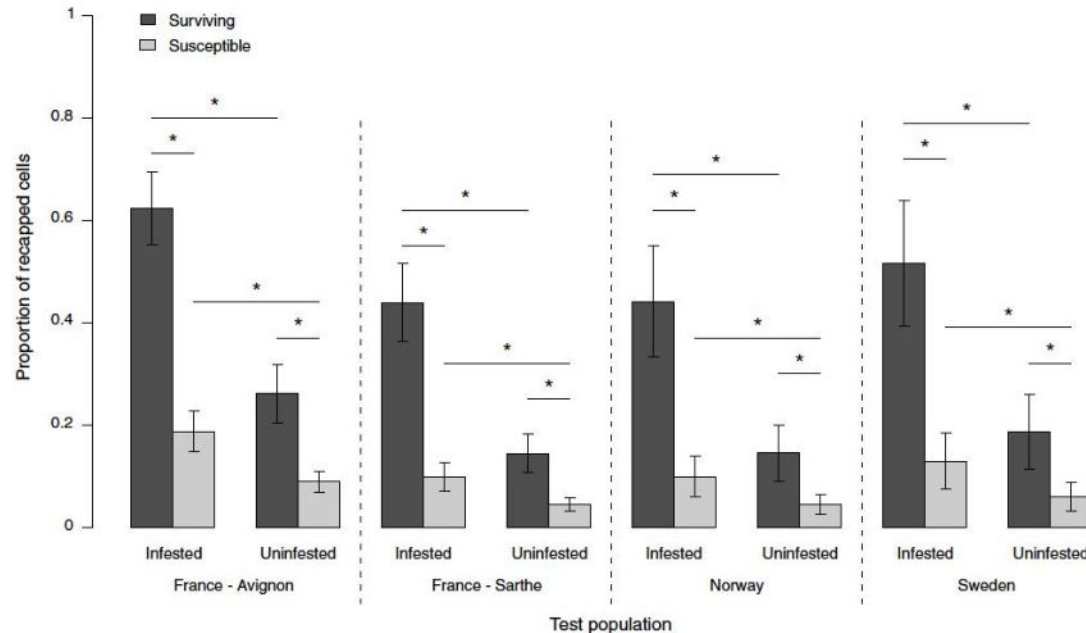
Locke 2016

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- These populations also express high rates of recapping behaviour

Oddie et al., 2021



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- Mites are reciprocating in an arms race

Beaurepaire et al., 2019

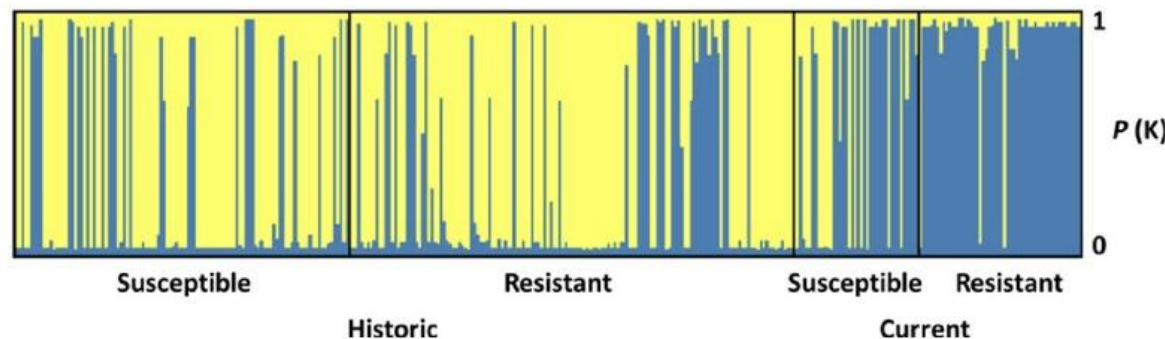
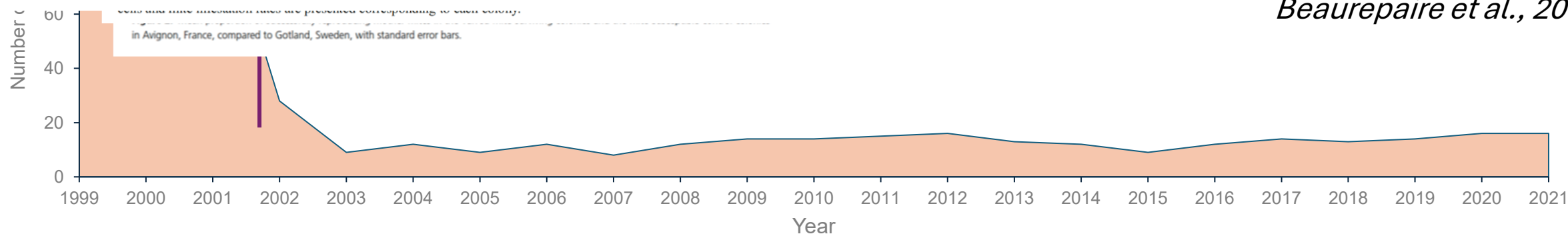
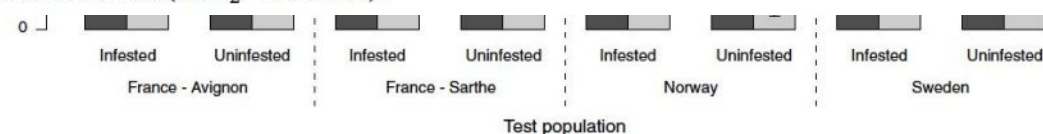


Figure 3. Genetic Structure of the Gotland mite populations. The blue and yellow colours in the figure represent different genetic clusters, the X-axis represents individuals and the Y-axis represents the probability to belong to a different cluster ($\Delta K_2 = 269.46$).



The “Bond” Project on Gotland

N. Scaramella, A. Burke, M. Oddie et al.

International Journal for Parasitology 53 (2023) 565–571

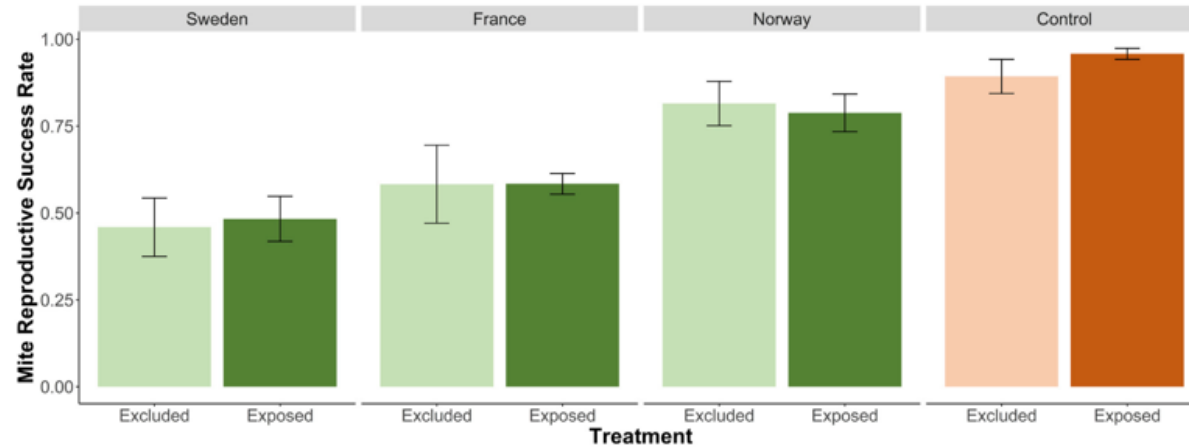
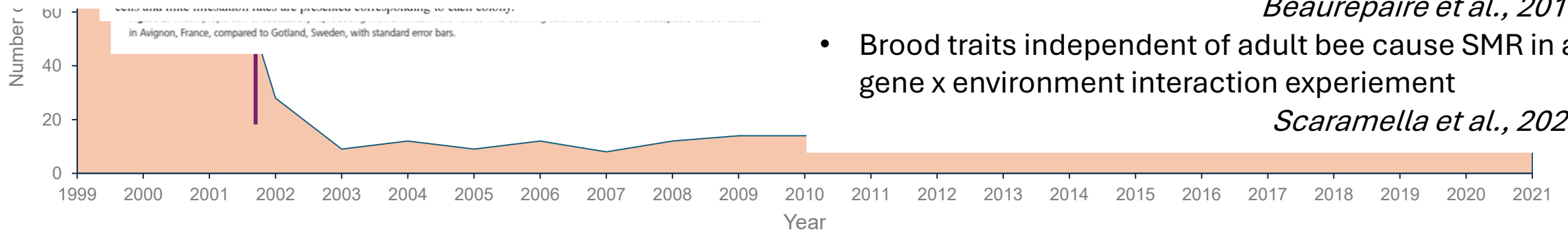


Fig. 2. The average rates of *Varroa destructor* mite reproductive success (means $\pm$ SE) examined in four honey bee (*Apis mellifera*) populations (n indicates number of colonies) with error bars indicating standard error. Bars represent the three mite-resistant populations examined from: Sweden ($n = 6$), France ($n = 5$), and Norway ($n = 3$), and the mite-susceptible control group ($n = 4$). Within each population, treatment groups were differentiated between caged brood excluded from adult bees (light color) and brood exposed to adult bees (dark color).



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Scaramella et al., 2023

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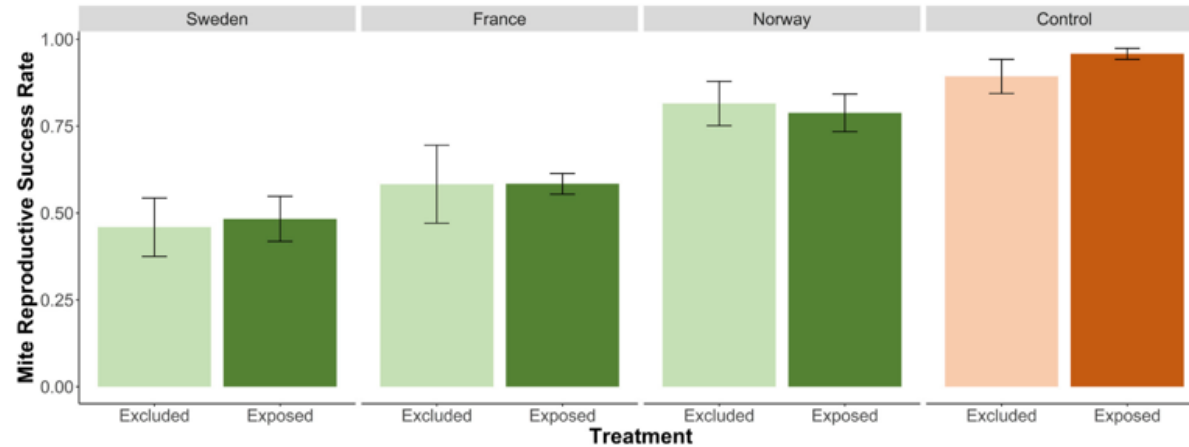
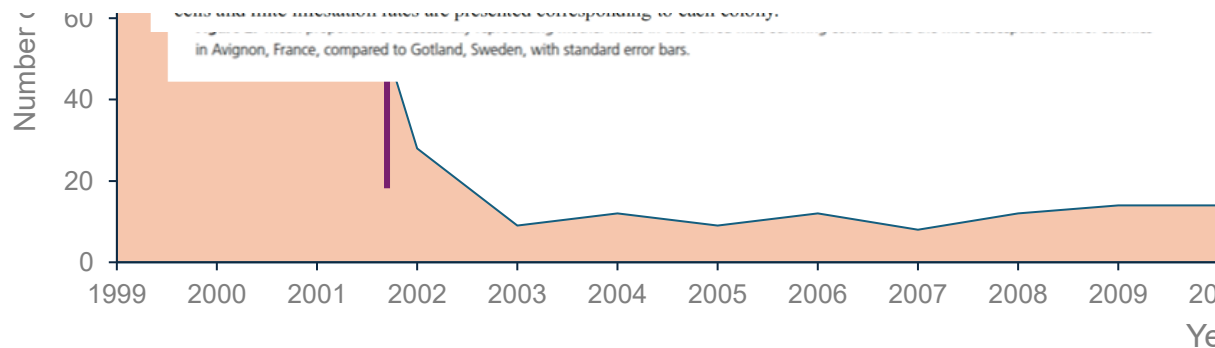


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Scaramella et al., 2024

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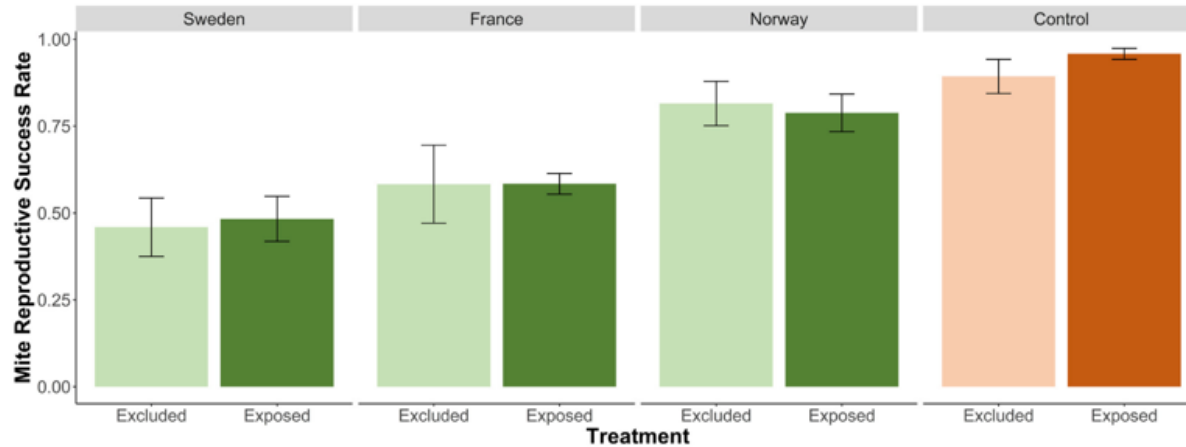


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- QTL mapping on reduced mite reproduction

Behrens et al., 2011

Conlon et al., 2018

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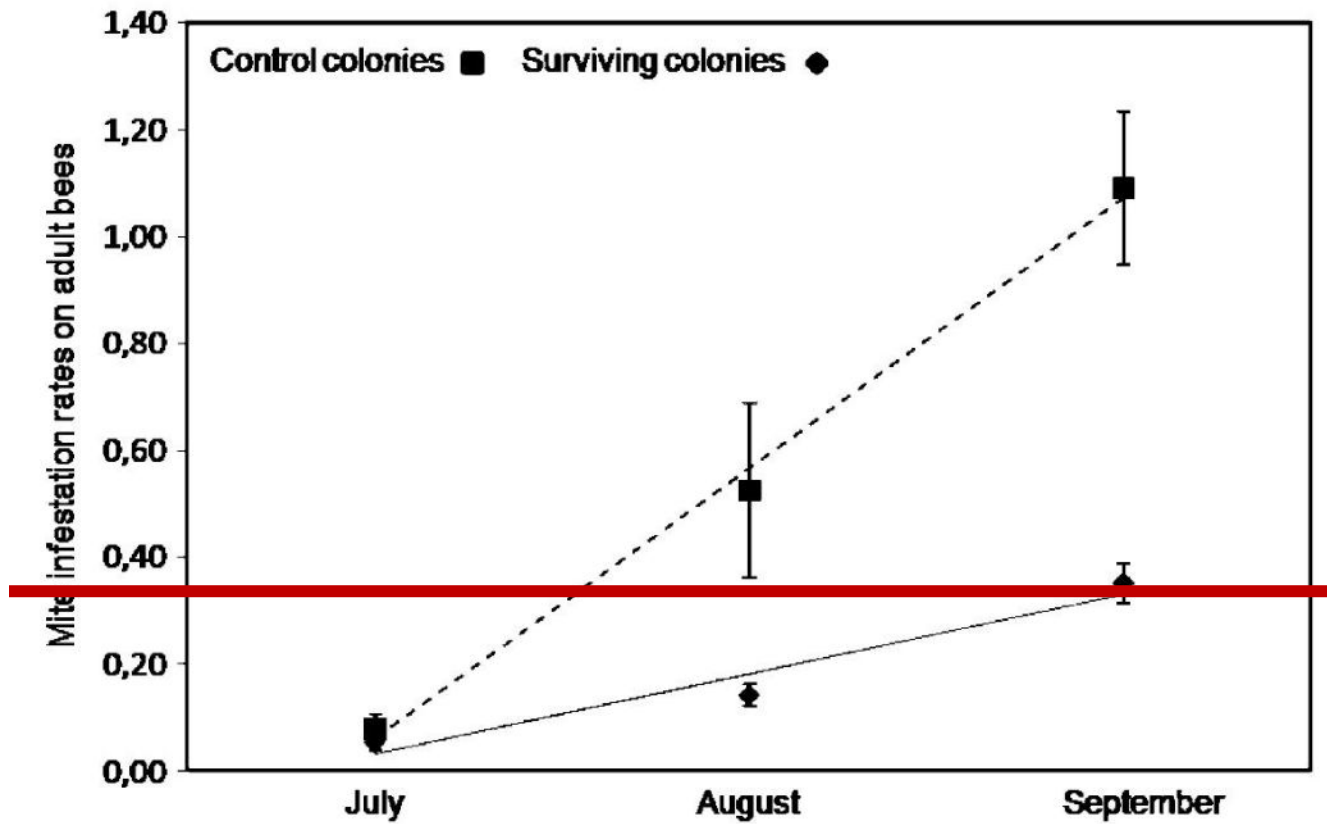
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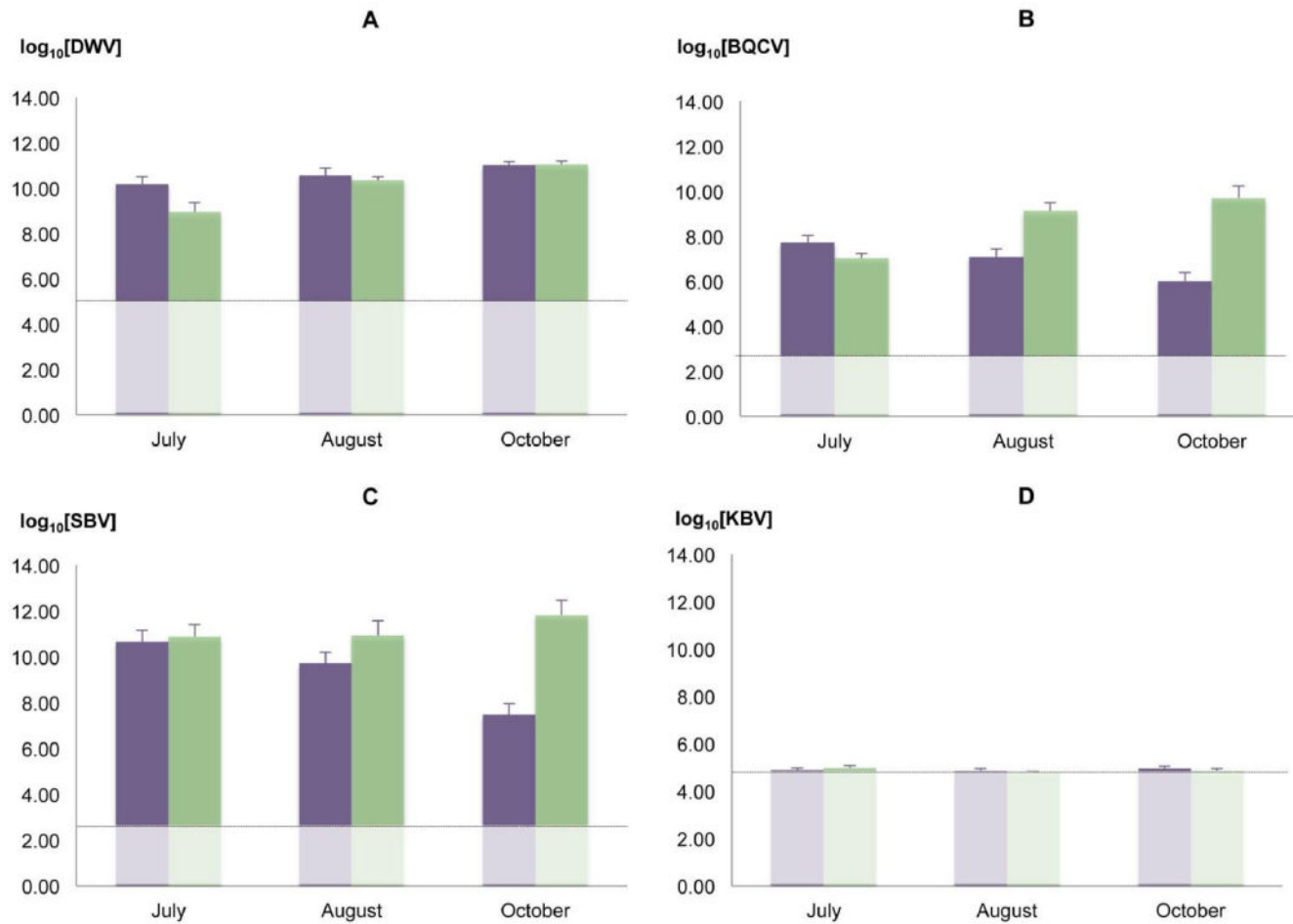
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The “Bond” Project on Gotland



The “Bond” Project on Gotland

Virus Infection Tolerance and Resistance in Honey Bees



Colonies tolerate DWV infection and reduce BQCV and SBV infections over the season

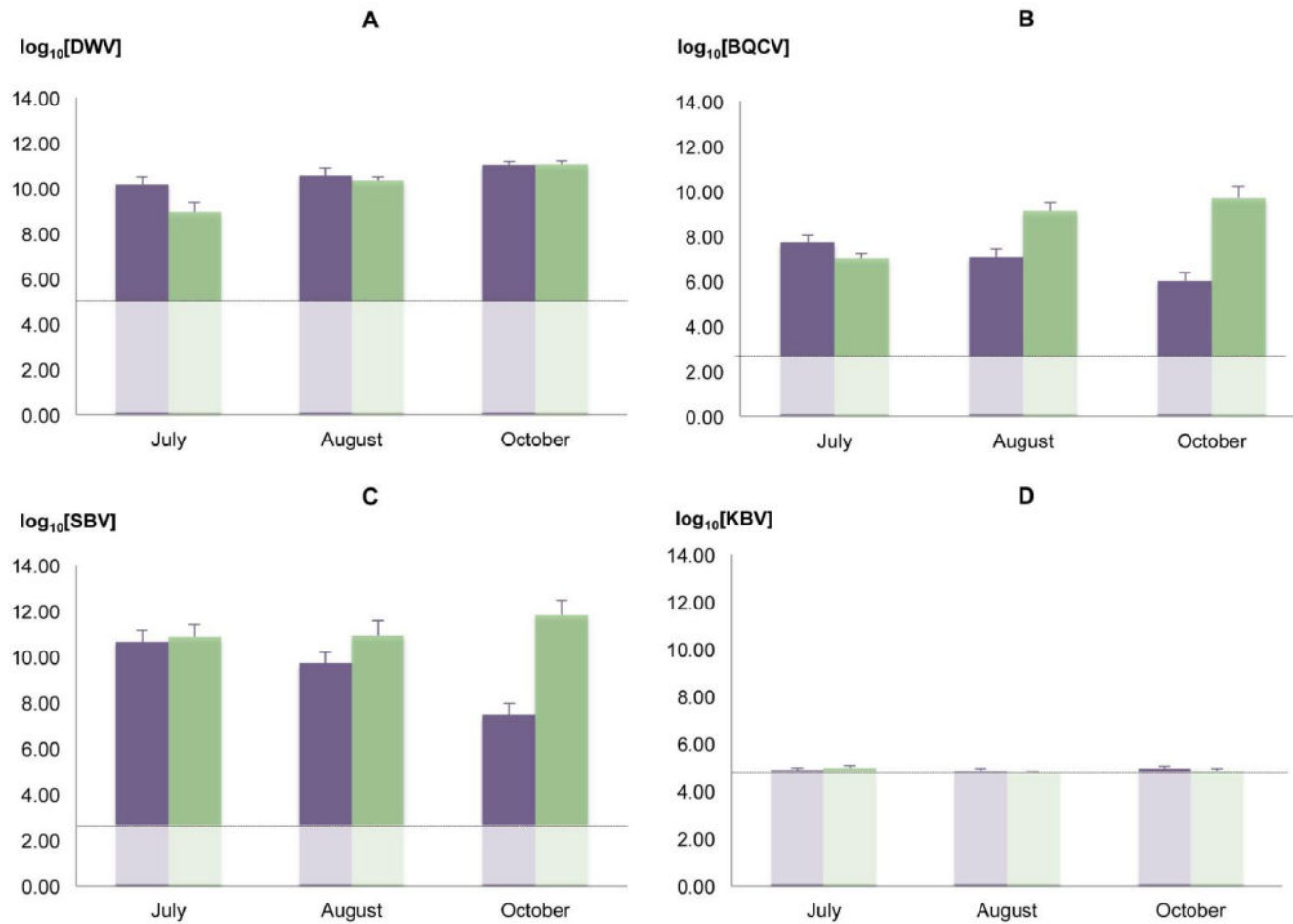
Locke et al., 2014

Figure 2. Virus infection dynamics. Virus titres in adult bees (mean values with standard error bars) of (A) deformed wing virus (DWV), (B) black queen cell virus (BQCV), (C) Sacbrood virus (SBV) and (D) Kashmir bee virus (KBV) in mite-resistant (MR) colonies (purple bars) and mite-susceptible (MS) colonies (green bars) from late summer to autumn of 2009 on Gotland, Sweden. The broken line and opaque in each graph area represent the RT-qPCR detection threshold.

doi:10.1371/journal.pone.0099998.g002

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Locke et al., 2014

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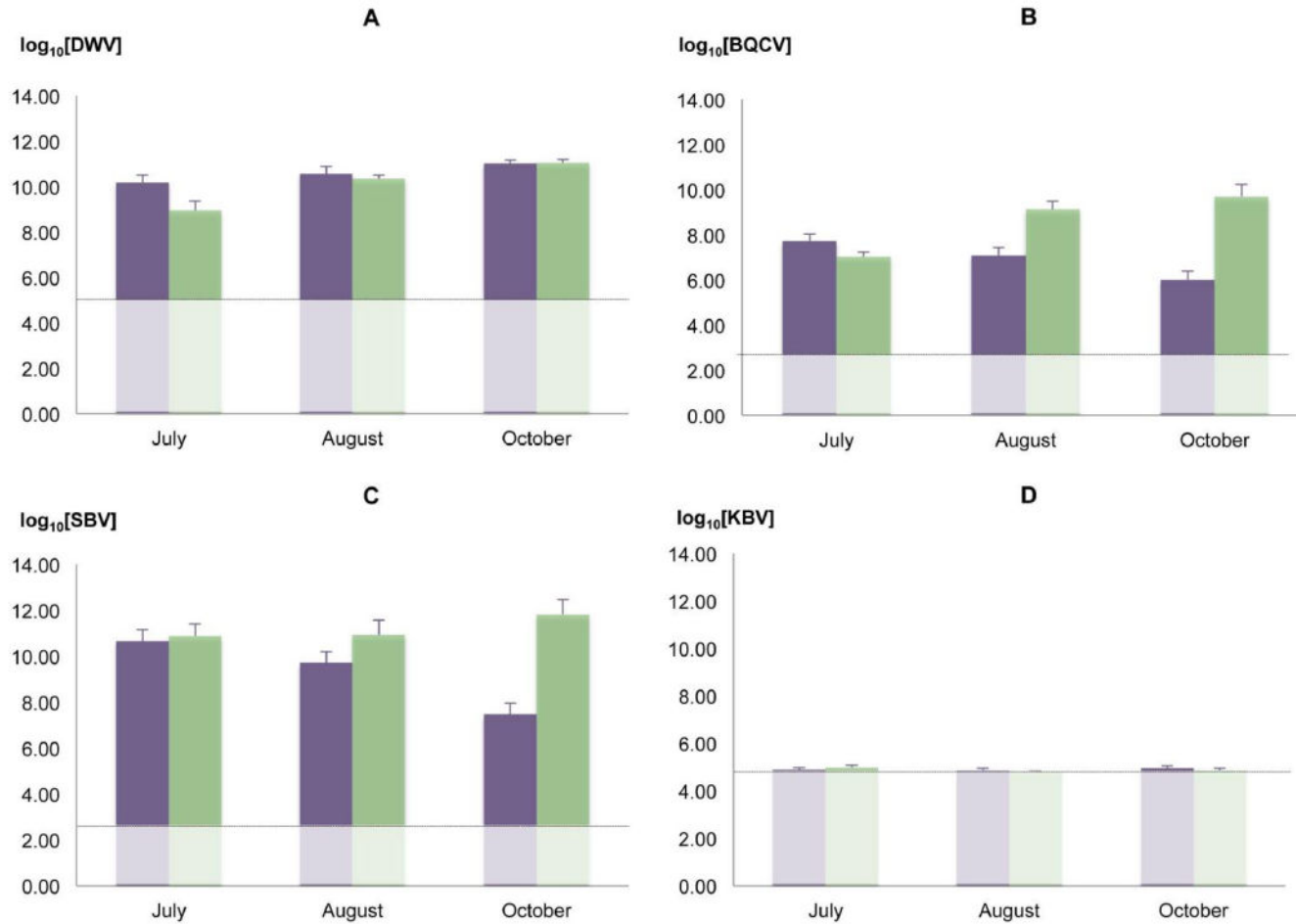
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The “Bond” Project on Gotland

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Locke et al., 2014

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Thaduri et al., 2019

- Other similar populations also show some virus tolerance

Locke et al., 2021

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Honey bee resistance to varroa mites: insight into the complex nature of the SMR trait

Amélie Noël & Barbara Locke

Honey Bee Research Centre, Swedish University of Agricultural Sciences, Uppsala, Sweden



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Varroa destructor Alters the Brood Ester Pheromone Profile of European Honey Bee Larvae

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SEPTEMBER 26th, 2025 - Friday

**HALL A2
17:00 - 18:30**

**SYMPOSIUM / BEE HEALTH
Honey Bee Viruses**

17:45 – 18:00 Joachim de Miranda
Bond bee dynamics and trait plasticity

18:15 – 18:30 Amélie Noël
viruses & recapping

***Varroa destructor* Alters the Brood Ester Pheromone Profile of European Honey Bee Larvae**

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**Gotland Honey Bees Exhibit Sustained Innate Immune Activation
in Response to Acute Bee Paralysis Virus (ABPV) Infection**

Xinyan Ruan, Joachim de Miranda, Barbara Locke

Honey Bee Research Centre, Department of Ecology, Swedish University of Agricultural Sciences

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The good, the bad and the ugly



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The good, the bad and the ugly

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The good, the bad and the ugly

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- It has inspired the establishment of new populations for research purposes.
- We have gained an incredible amount of insight and understanding of the interactions and adaptations
- Demonstrated the independent role of virus infections and virus resistance.
- Has inspired beekeepers to adapt towards removing chemical treatments from their beekeeping.



The good, the bad and the ugly

- Success with natural selection comes at a high cost.



The good, the bad and the ugly

- Success with natural selection comes at a high cost.
- Trade-offs might make colonies more susceptible to other pathogens or to slight environmental change.



The good, the bad and the ugly

- The growing trend of “natural” or treatment-free beekeeping, when advocating for minimal intervention to improve bee health, is an oversimplification of natural selection processes, at the cost of high mortality rates.



The good, the bad and the ugly

- The growing trend of “natural” or treatment-free beekeeping, when advocating for minimal intervention to improve bee health, is an oversimplification of natural selection processes, at the cost of high mortality rates.
- Evolution through natural selection does not always guarantee improved prospects for long-term survival.



RESEARCH ARTICLE

A pan-European epidemiological study reveals honey bee colony survival depends on beekeeper education and disease control

Antoine Jacques^{1,2}, Marion Laurent², EPILOBEE Consortium^{1†}, Magali Ribière-Chabert², Mathilde Saussac¹, Stéphanie Bougeard³, Giles E. Budge^{4,5}, Pascal Hendrikx¹, Marie-Pierre Chauzat^{1,2*}



Responsibilities?
Decisions?
Value?

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SEPTEMBER 26th, 2025 - Friday

HALL A1

MAIN SYMPOSIUM / Animal Welfare from a Beekeeping Perspective

11:00 - 13:00

Bee Health & Bee Biology

12:00 – 12:15 Lisa Dickel

Honey bee welfare





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Successful treatment-free beekeeping is possible but requires diligent and well-educated beekeepers.



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Successful treatment-free beekeeping is possible but requires diligent and well-educated beekeepers.

8. **Minimize disturbances of nest organisation.** When working a colony, replace each frame in its original position and orientation. Also, avoid inserting empty frames in the broodnest to inhibit swarming.
9. **Minimize relocations of hives.** Move colonies as rarely as possible. If you must do so, then do so when there is little forage available.
10. **Refrain from treating colonies for *Varroa*.**

WARNING: This last suggestion should only be adopted if you can do so carefully, as part of a program of extremely diligent beekeeping. If you pursue treatment-free beekeeping without close attention to your colonies, then you will create a situation in your apiary in which natural selection is favouring virulent *Varroa* mites, not *Varroa*-resistant bees. To help natural selection favour *Varroa*-resistant bees, you will need to monitor closely the mite levels in all your colonies and kill those whose mite populations are high. If you do not, your colonies can collapse.

Darwinian beekeeping

An evolutionary approach to apiculture

Professor Tom Seeley, Cornell University, USA



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Successful treatment-free beekeeping is possible but requires diligent and well-educated beekeepers.

We should consider a more holistic view, perhaps IPM management.

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It should not come at the cost of healthy bees and a healthy ecosystems.

8. **Minimize disturbances of nest organisation.** When working a colony, replace each frame in its original position and orientation. Also, avoid inserting empty frames in the broodnest to inhibit swarming.
9. **Minimize relocations of hives.** Move colonies as rarely as possible. If you must do so, then do so when there is little forage available.
10. **Refrain from treating colonies for *Varroa*.**

WARNING: This last suggestion should only be adopted if you can do so carefully, as part of a program of extremely diligent beekeeping. If you pursue treatment-free beekeeping without close attention to your colonies, then you will create a situation in your apiary in which natural selection is favouring virulent *Varroa* mites, not *Varroa*-resistant bees. To help natural selection favour *Varroa*-resistant bees, you will need to monitor closely the mite levels in all your colonies and kill those whose mite populations are high. If you do not, your colonies can collapse.

Darwinian beekeeping

An evolutionary approach to apiculture

Professor Tom Seeley, Cornell University, USA



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Special thanks to Åke Lyberg
& the entire Honey Bee Research Centre in Uppsala



Don't miss talks today by:

Lisa Dickel, Hall A1, 12:00 - 12:15, Considering honey bee welfare to support sustainable beekeeping and honey bee protection

Joachim de Miranda, Hall A2, 17:45 - 18:00, High plasticity for many of the Bond bee population's varroa, colony development, foraging, and virus traits, in relation to year, season and varroa treatment

Amélie Noël, Hall A2, 18:15 - 18:30, Impact of viruses on recapping behaviour



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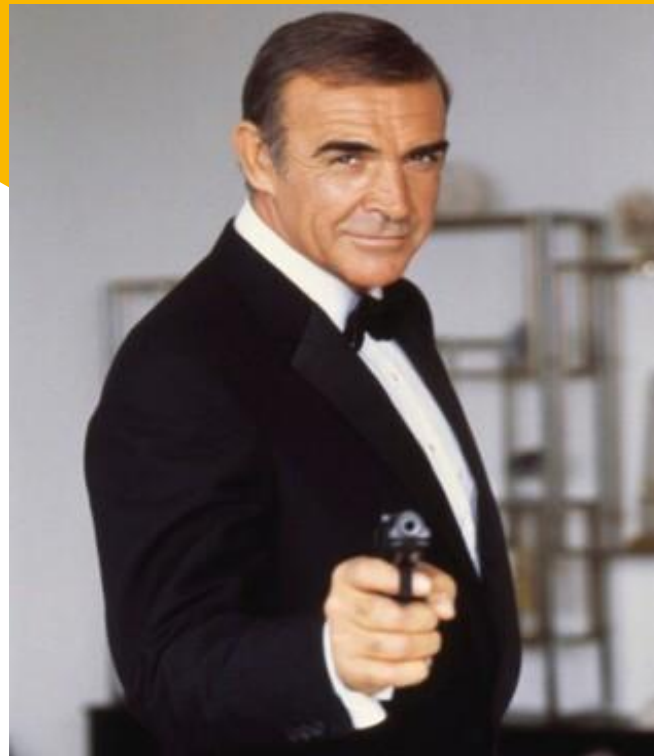
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Thank you for listening!

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