RNA viruses and Varroa mites: How does temporal variation influence patterns of co-infection?

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Acknowledgments

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Bees are Important

- 30% of the world's food is derived from pollination

Aizen et al., 2009

- Pollinators are responsible for between $235-577 billion

Gallai et al., 2009

- Honeybees are responsible for $14 Billion in the USA

Morse and Calderone, 2000

Honey Bee Pathogens:

- VIRUSES:
  - *Deformed Wing Virus (DWV)*
  - *Black Queen Cell Virus (BQCV)*
  - *Israeli Acute Paralysis Virus (IAPV)*

Deformed wing Virus
University of Florida,
Entomology Dept.

- PARASITES:
  - *Nosema (ceranae, bombi & apis)*
  - *Varroa Mite*

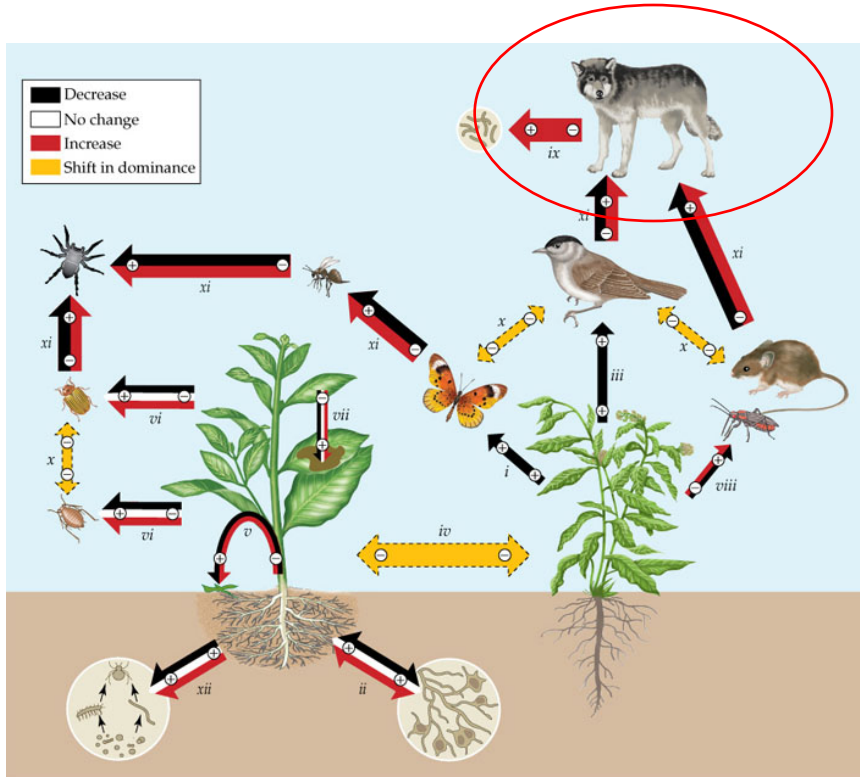
Varroa destructor
North Carolina State University,
Cooperative Extension

- OTHER PATHOGENS & Pests:
  - *American Foulbrood (AFB)*
  - *European Foulbrood (EFB)*
  - *Chalk Brood*
  - *Small Hive Beetle*

American Foulbrood
Bee Informed Partnership

Disease Ecology:

- **Ecology:** the study of organisms interacting with each other and their environment



Sinaur, Ecology 3rd Ed.

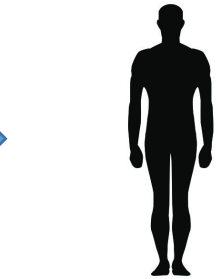
- **Negative Interactions:**
  - Competition
  - Predation
  - Parasitism
- **Positive Interactions:**
  - Mutualism
  - Commensalism

Bees and Epidemiology:

Time Magazine

West Meadow Bees

Bees and Epidemiology:



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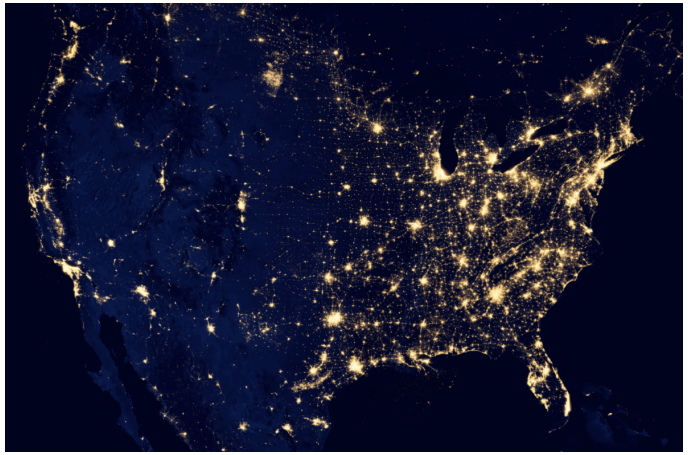

NASA

My main questions:

How do these pathogens disseminate throughout the environment?

What are the drivers behind co-infection?

How do pathogens interact with each other (organismal interactions) and their host (environment)?

Why does this matter?

- This community ecology approach to disease research is under-utilized (Johnson et al., 2016)
- Co-infection is understudied in many disease systems (Rigaud et al., 2010)
- Co-infection has been shown to lead to unhealthy bees (Cox-Foster et al., 2007)

My Dissertation:

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Chapter I – Survey of *Nosema* in Vermont Bumble bees to parameterize a time-based model

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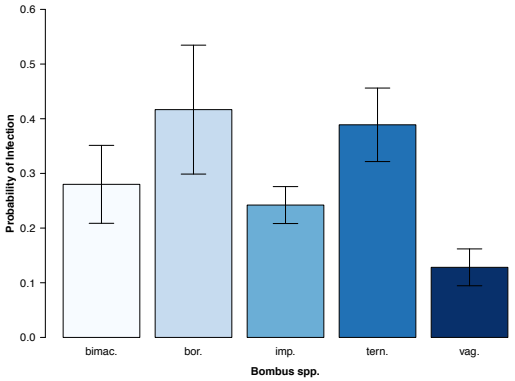
Chapter I – Survey of *Nosema* in Vermont Bumble bees - parameterize a epidemiological model

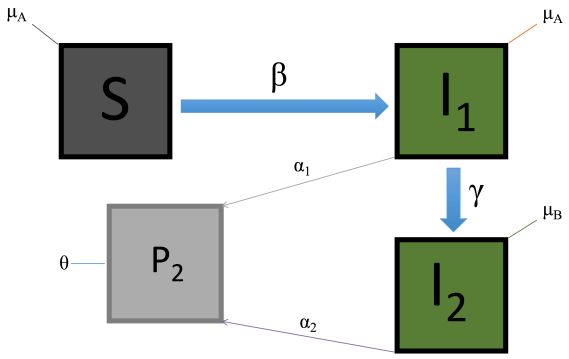


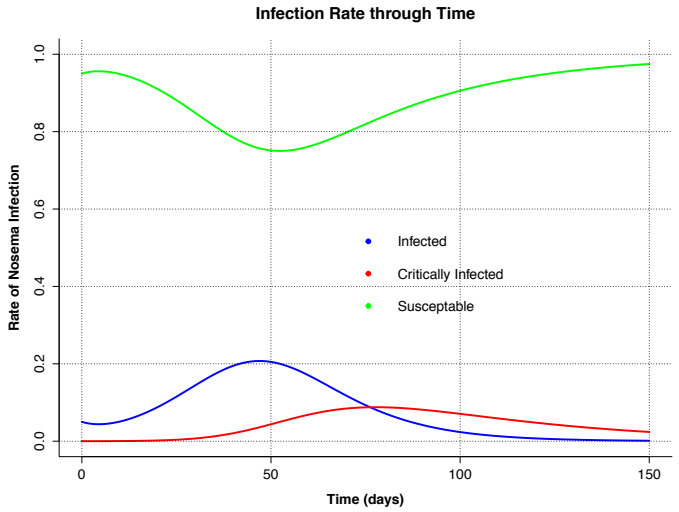
$$\frac{dS}{dt} = -SP\beta - S\mu_A$$

$$\frac{dI_1}{dt} = SP\beta - I_1\mu_A - I_1\gamma$$

$$\frac{dI_2}{dt} = I_1P\gamma - I_2\mu_B$$

$$\frac{dP_1}{dt} = I_1\alpha_1 + I_2\alpha_2 - P\theta$$





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Chapter III – Lab inoculation experiments for RNA viruses and *Nosema spp*. in Bumble bees.

My Dissertation:

Chapter II – Survey of *Apis* and *Bombus* pathogens through time to model patterns of co-infection

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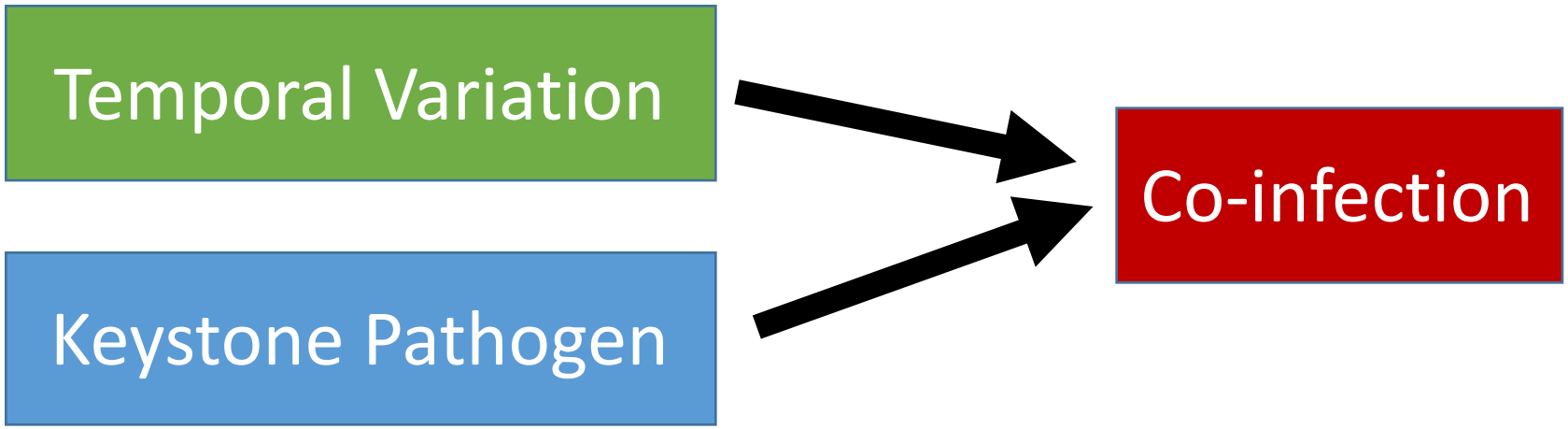
The questions of this study:

- How does temporal variation affect co-infection?

- Is their evidence for keystone pathogens that help drive co-infection?



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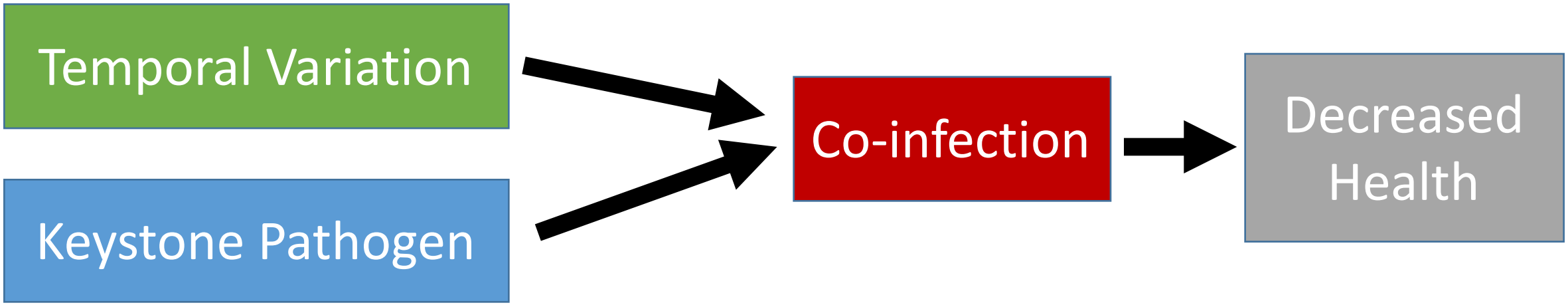


Methods

Experimental Design:

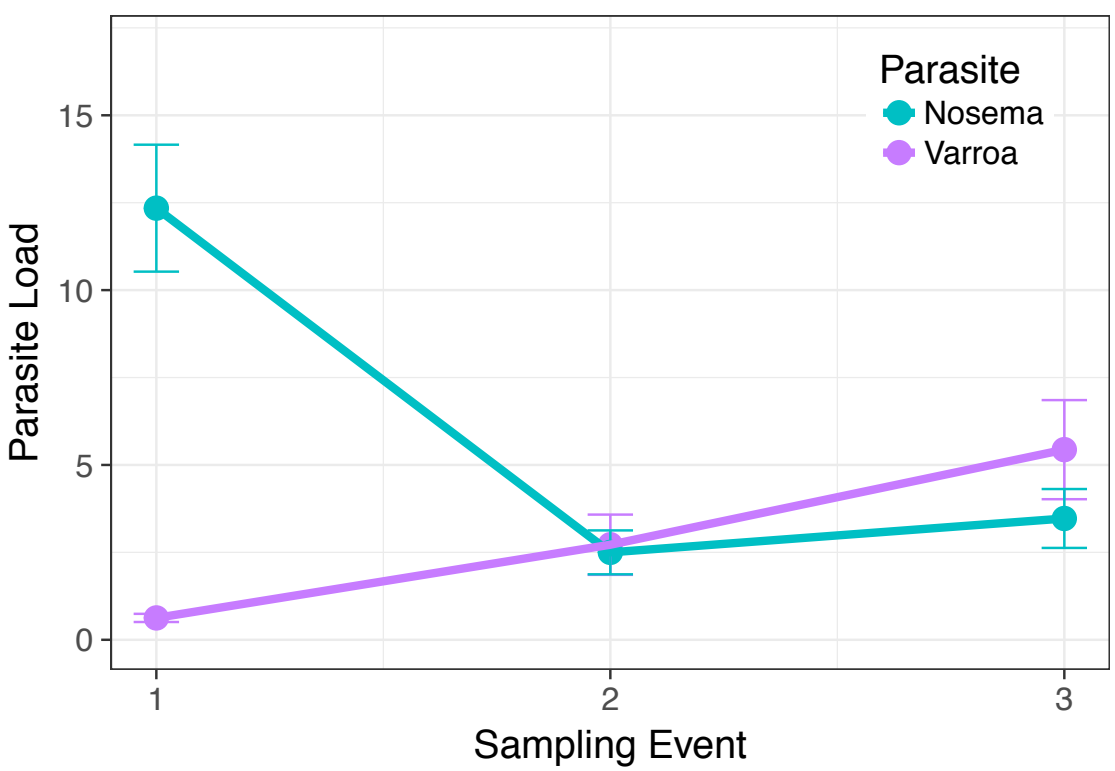
- 3 yards in North Carolina
- Samples taken at 3 time point every 4 weeks
- Sample size: N1=32, N2=32, N3=16

We sampled for:

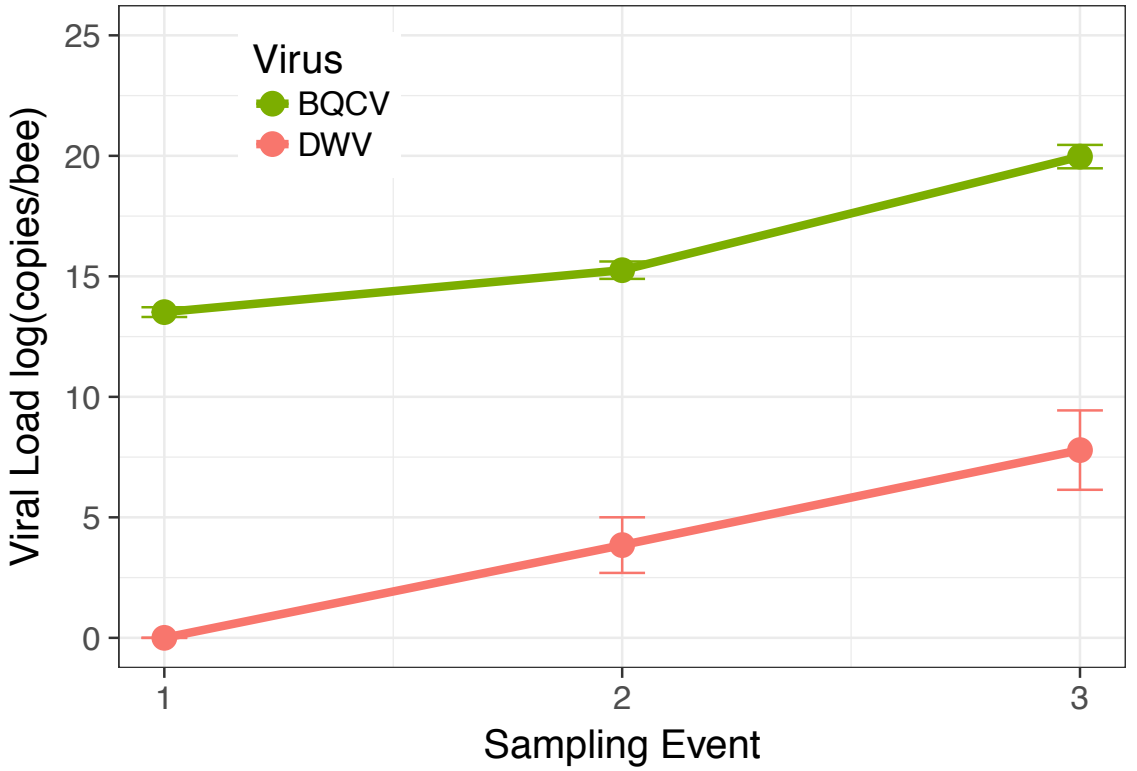
- Growth:
  - Brood Pattern (queen quality)
  - Frames of Bees (colony size)
- Pathogens:
  - Varroa Mites
  - *Nosema spp.*
  - DWV (Deformed Wing Virus)
  - BQCV (Black Queen Cell Virus)

Results

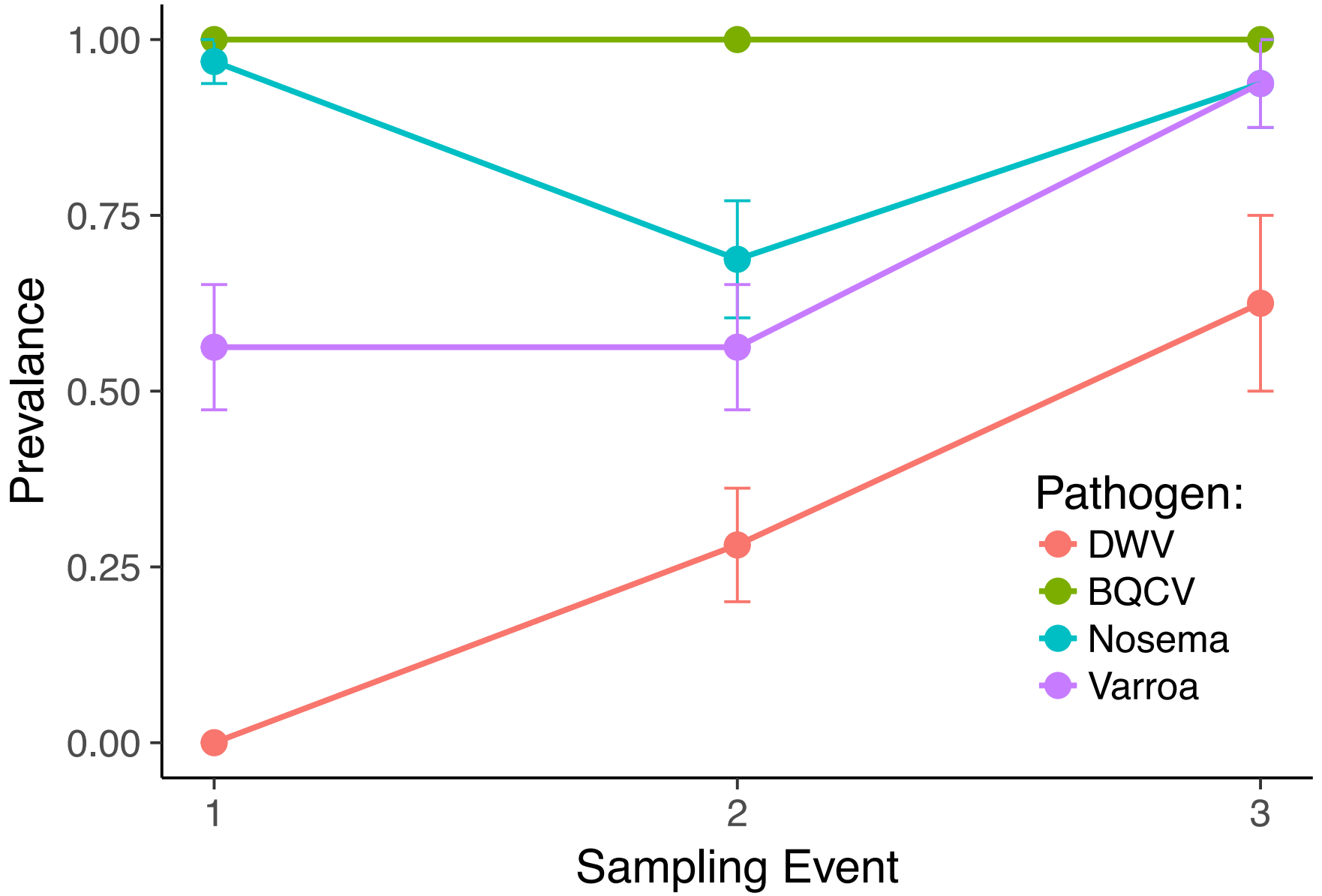
Varroa & Nosema Load



DWV & BQCV Load



Pathogen Prevalence Through Time



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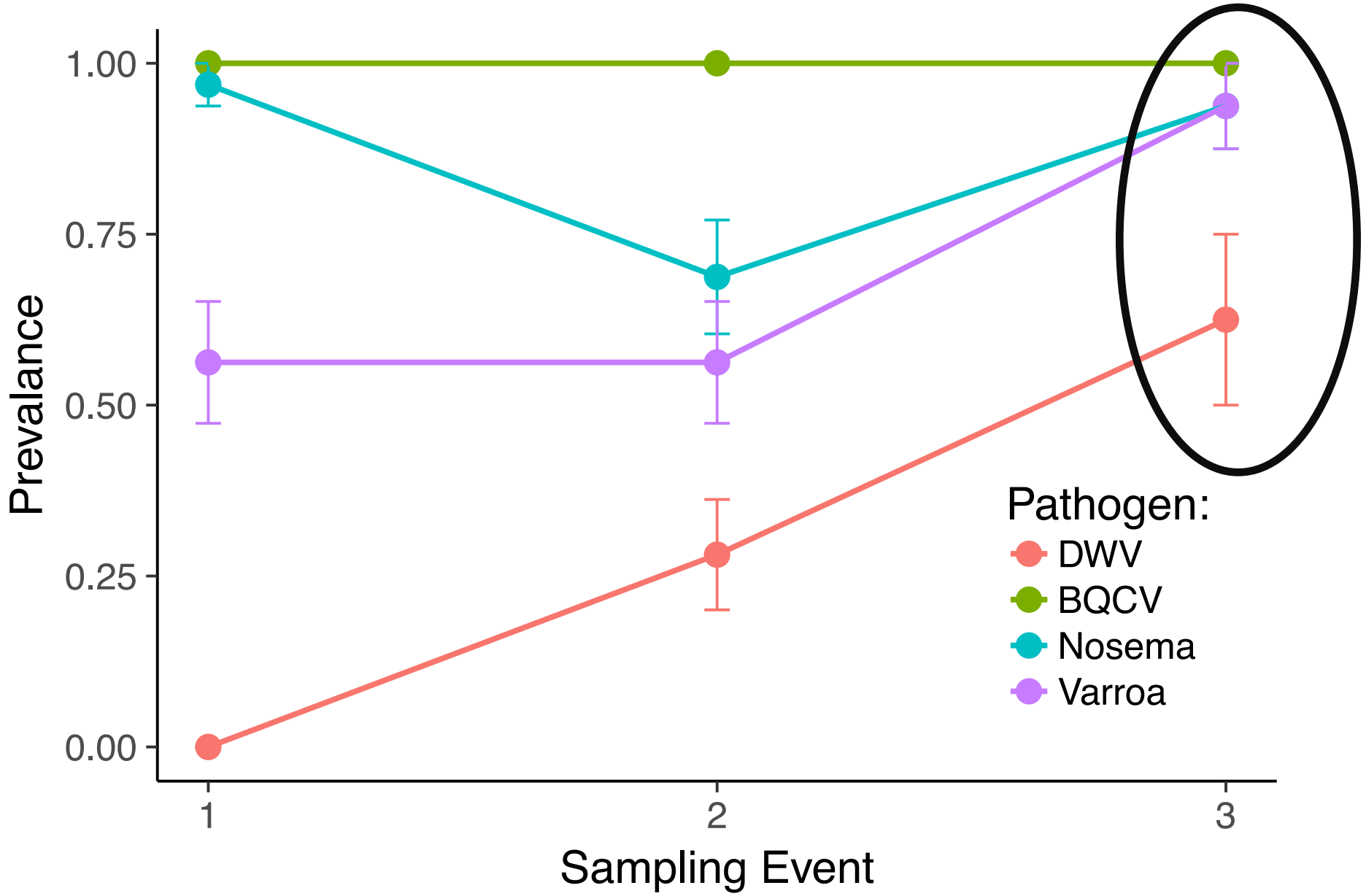
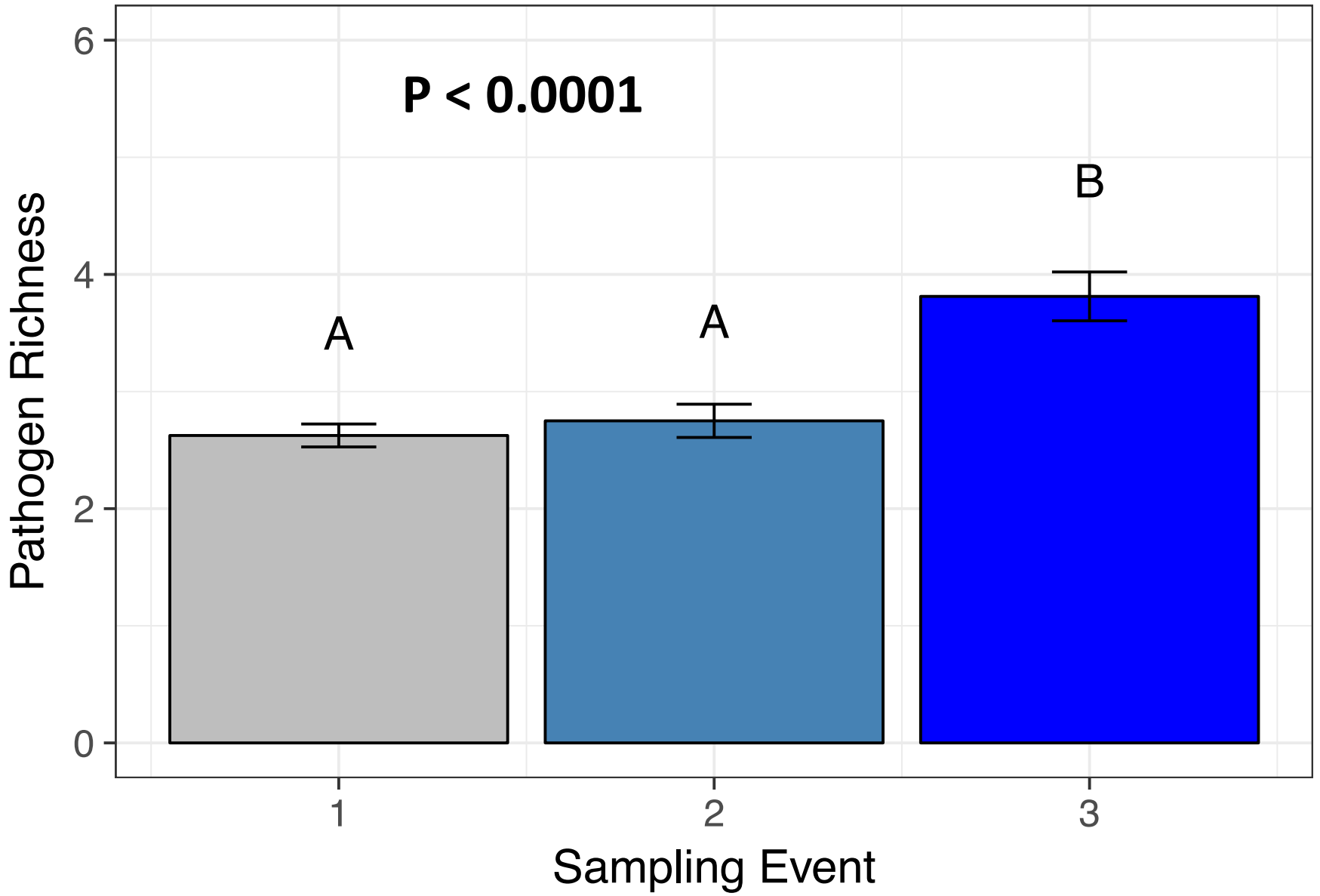
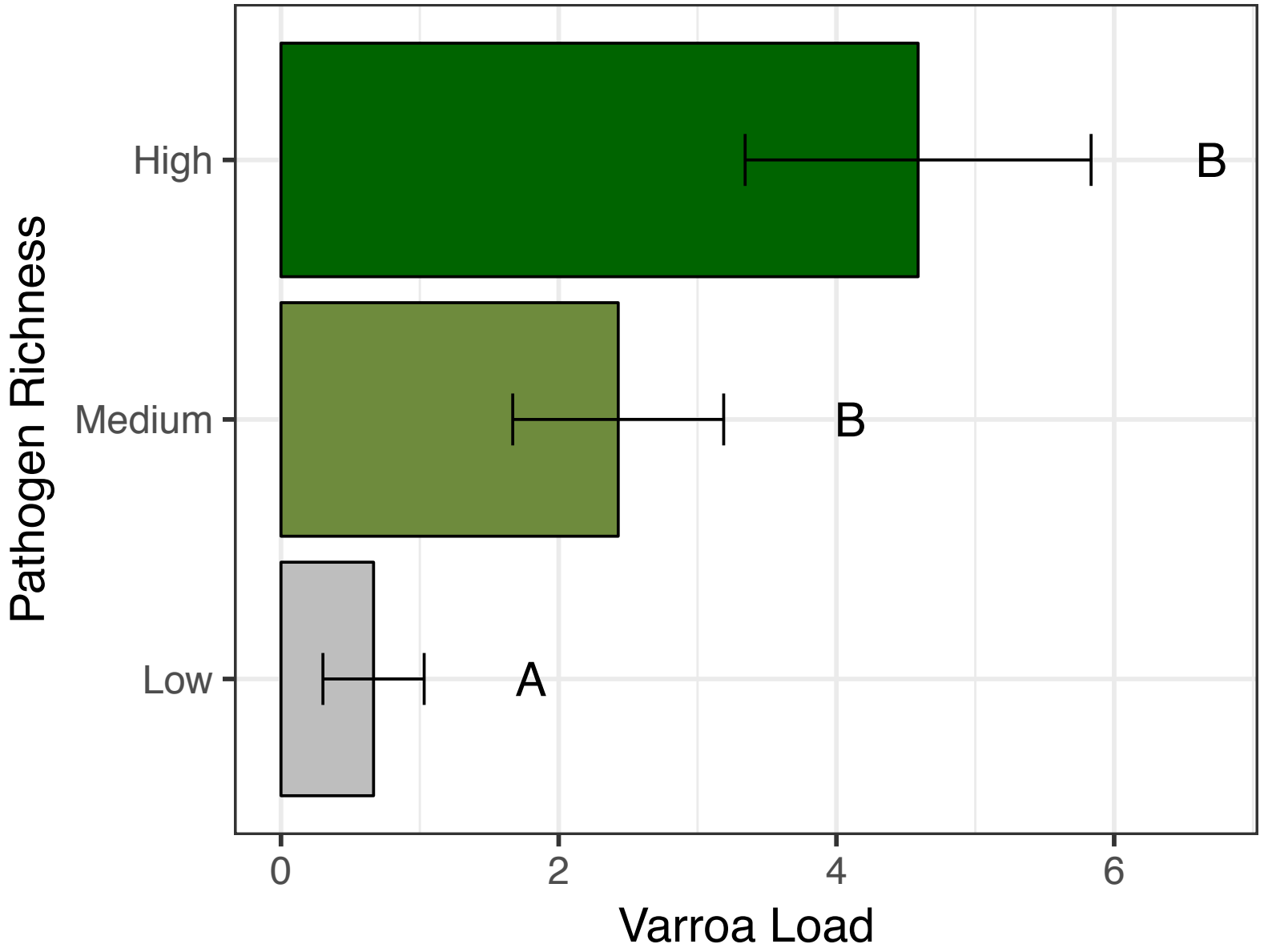


Pathogen Richness for Each Sampling Event

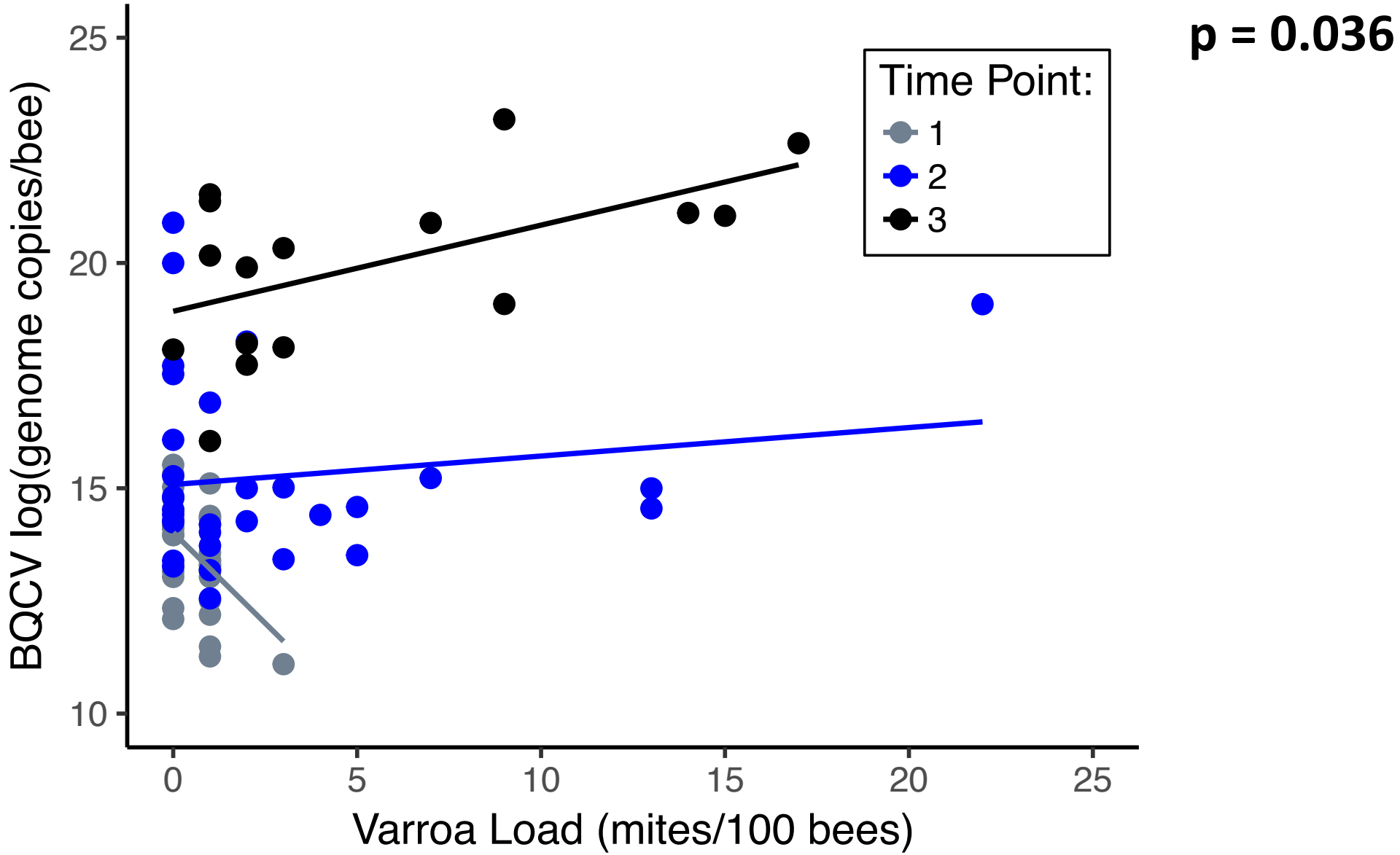


Varroa Load Predicts Pathogen Richness



p < 0.0001

Varroa Load by BQCV for Each Sampling Event



In Summary

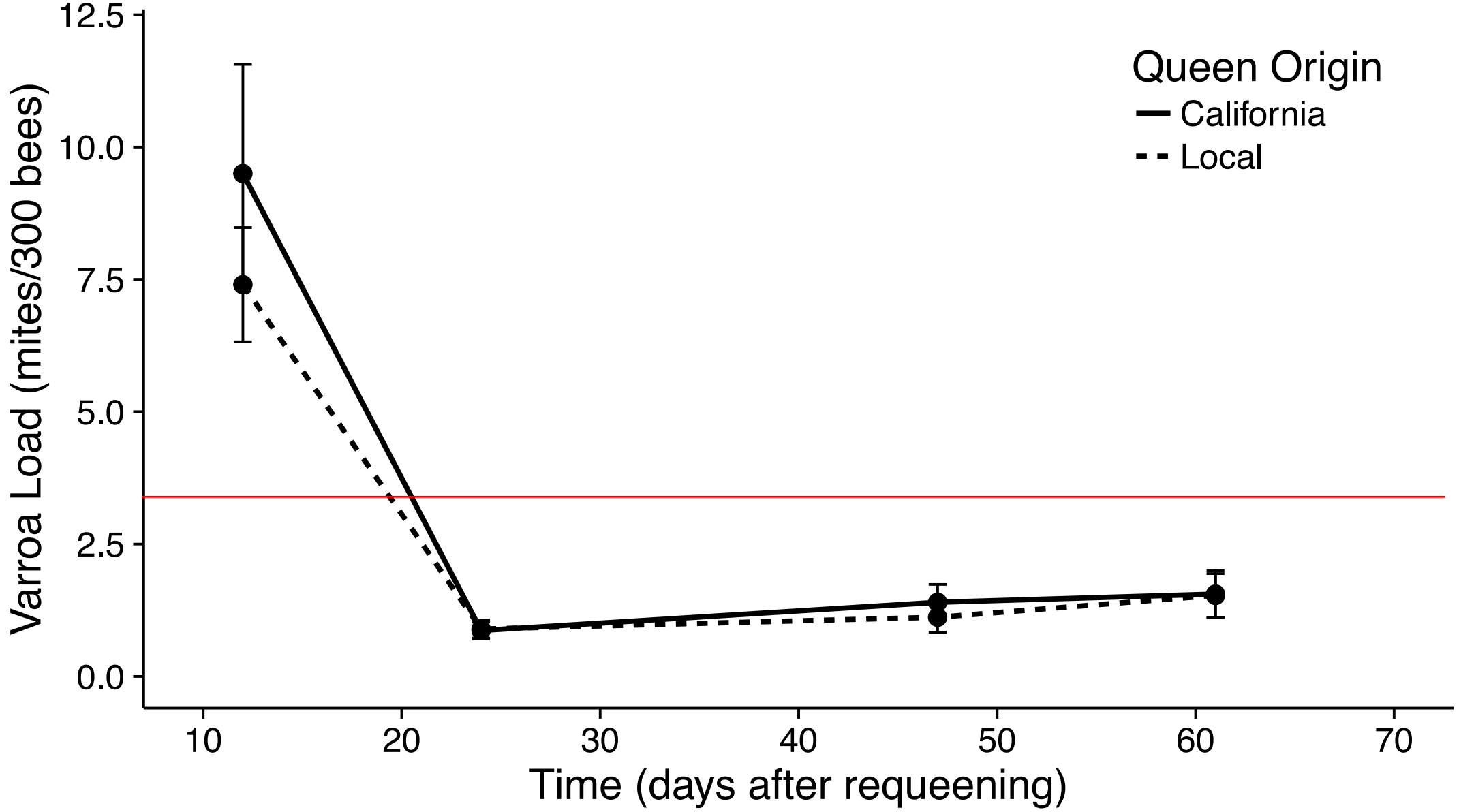
- Pathogens can change drastically in prevalence and load through time (Temporal Variation)
- Pathogens like **Varroa** (Keystone Pathogens) have some influence over the entire pathogen community as a whole
- Monitoring and Managing these treatable pathogens can help lower overall pathogen load and species richness

Future Work

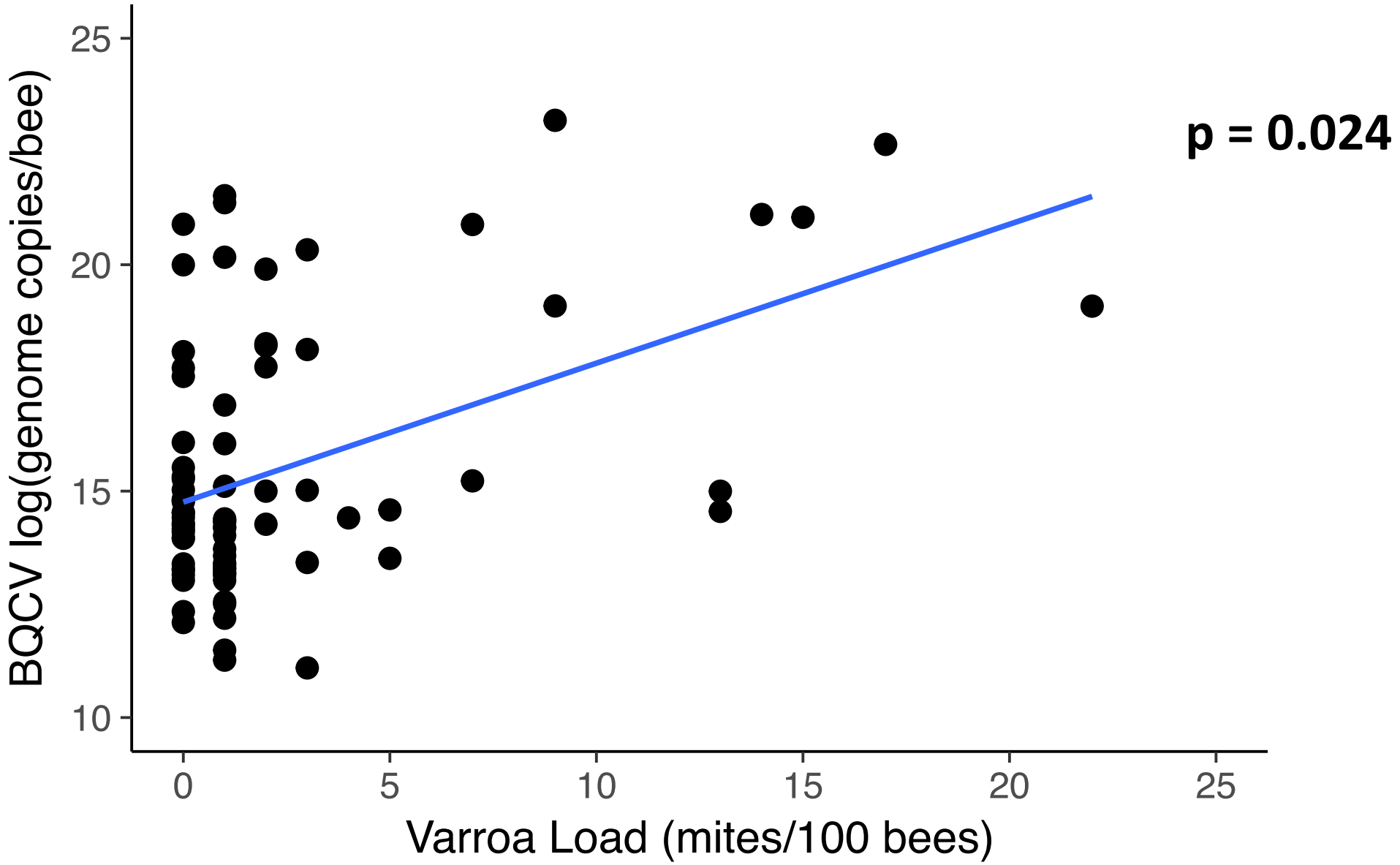

Thank You!


Questions?

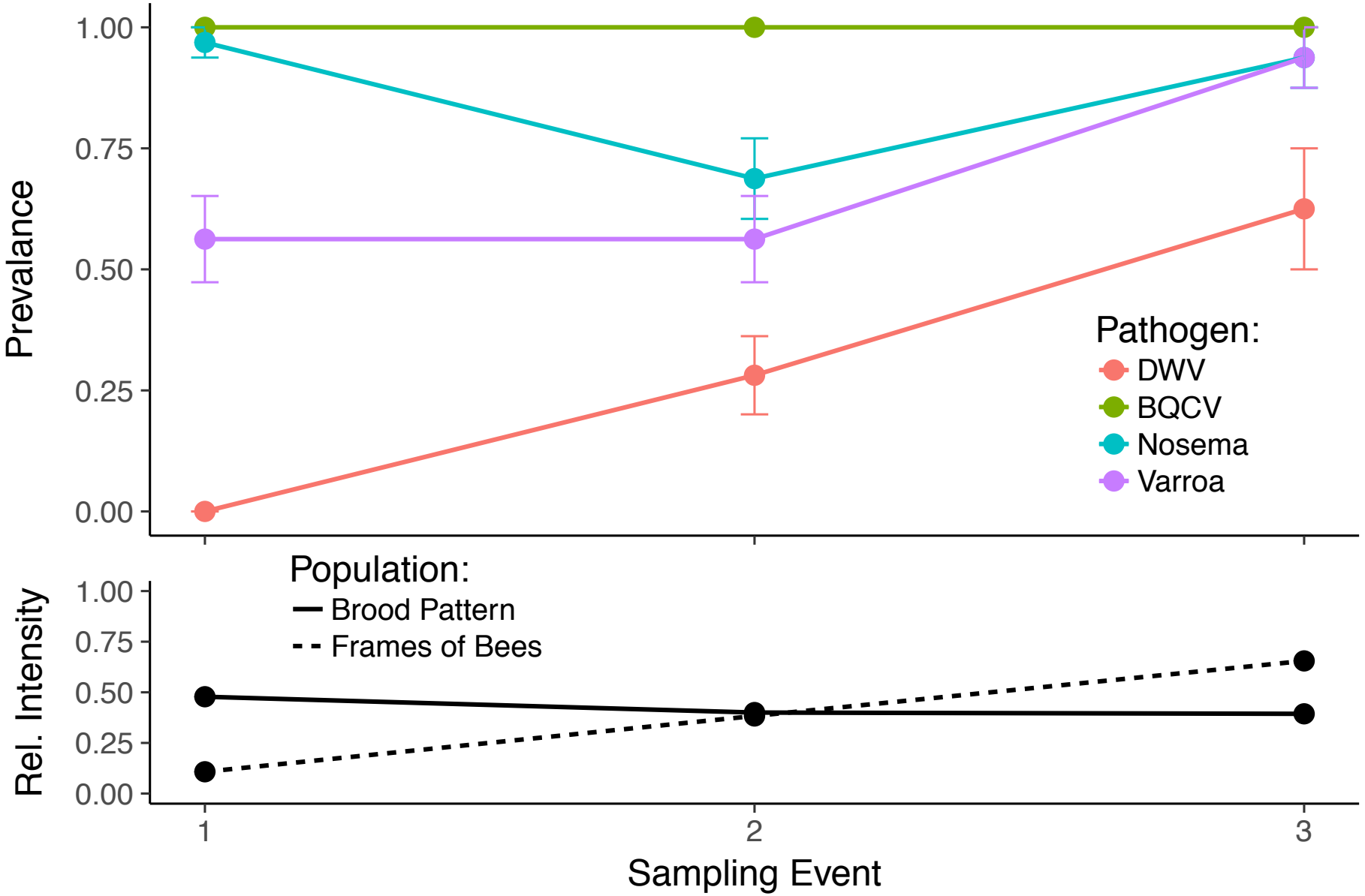
Varroa Load (before and after formic acid)



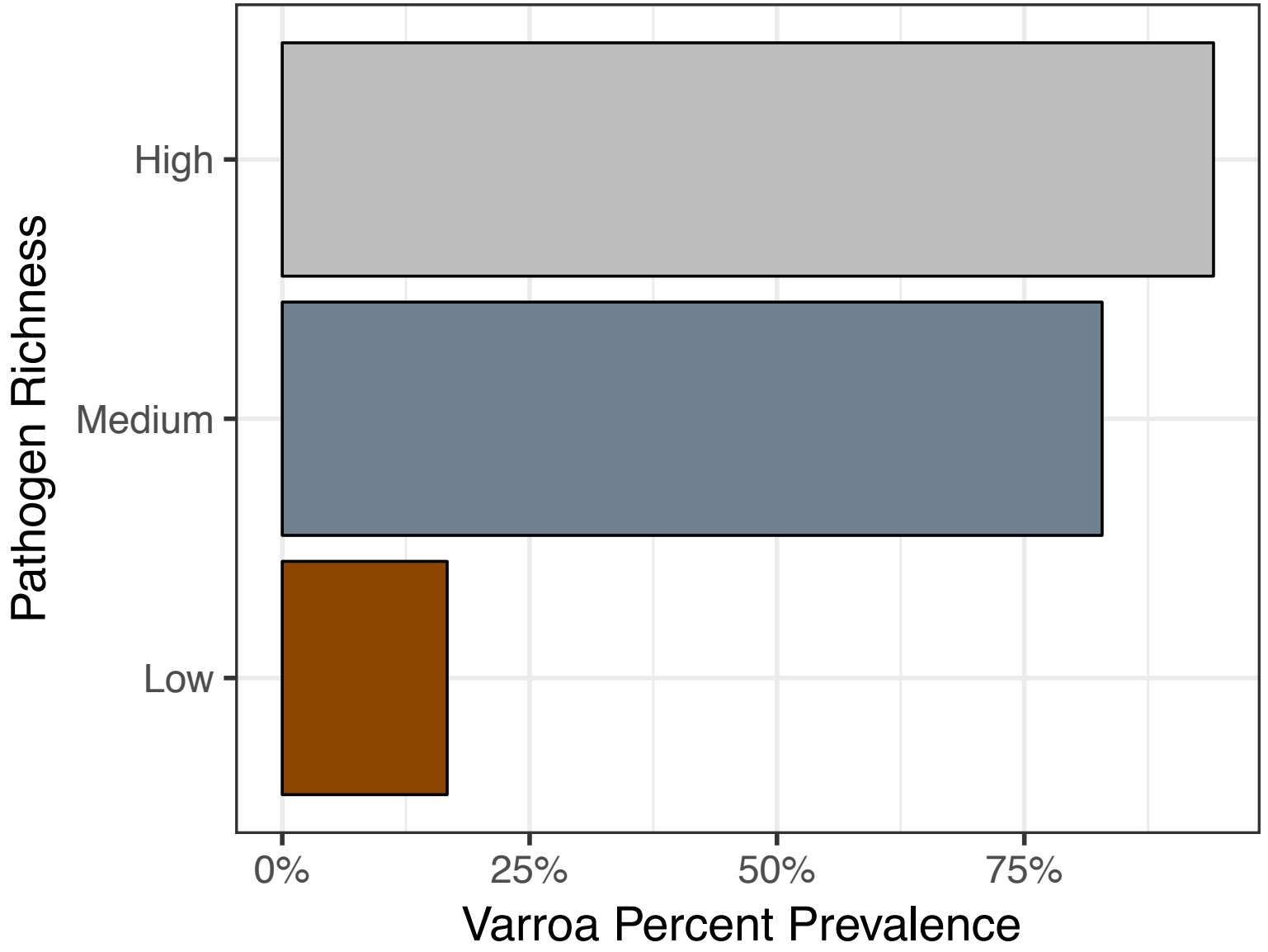
Varroa Load by BQCV



Disease Prevalence & Population Metrics through Time



Varroa Prevalence Predicts Pathogen Richness



p < 0.0001

What am I interested in:

Temporal Variation – how pathogens fluctuate in prevalence or load through time

Keystone Pathogen – pathogen or parasite who's presence has a significant effect on the community composition as a whole

Co-infection – multiple infections (pathogens) occurring simultaneously in the host

Population Measures for Each Sampling Event