Predictability of Long-term, but not Short-term Phenotypic Evolution in *Drosophila*

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cE3c
centre for ecology, evolution
and environmental changes

The importance of repeatability and predictability in evolution

- Long-standing question in evolutionary biology (Gould's question of 'replaying the tape of life').

- Interconnected with understanding the mechanisms underlying the adaptive process.

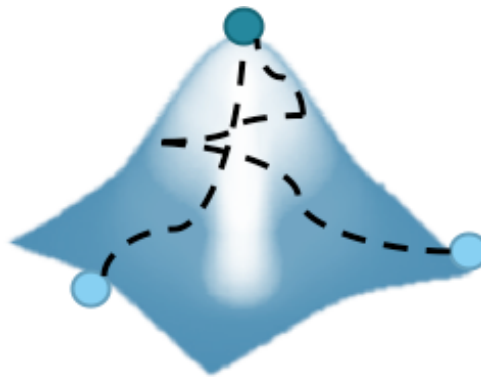- However there are still a lot of incognitos

Predictable vs. Repeatable Evolution
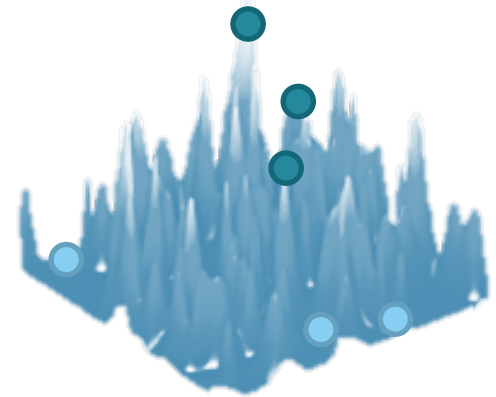## Two sides of the same coin?

Analogy of the fitness landscape
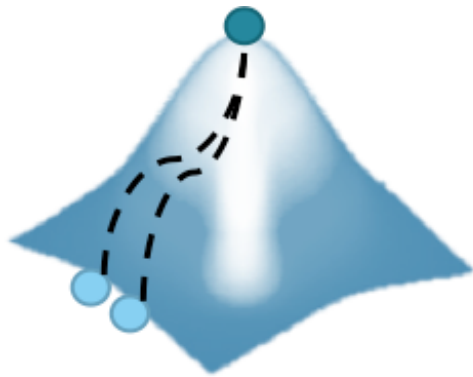
Predictable and Repeatable

Predictable and Non-repeatable

Non-Predictable

- **Predictability** – Outcome
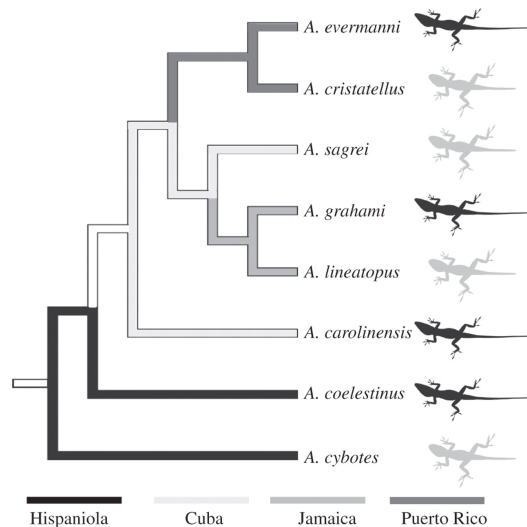- **Repeatability** – Evolutionary path taken

What to expect?

Presence of similar phenotypic traits across species; repeated adaptive radiations

Parallel evolution in nature and laboratory

Independent evolution of habitat specialists (Sanger *et al*, Proc. R. Soc. B, 2012)

A. evermanni
A. cristatellus
A. sagrei
A. grahami
A. lineatopus
A. carolinensis
A. coelestinus
A. cybotes

Hispaniola   Cuba   Jamaica   Puerto Rico

Four bird groups with similar bill shape (Futuyma, *Evolution* 3r Ed, 2005)

Losos, Evolution, 2011; Ord and Summers, BMC Evol Biol, 2015; Lind *et al*, eLife, 2015

What to expect?

Evidence for Predictability/ Repeatability	Works against Predictability/ Repeatability
Presence of similar phenotypic traits across species; repeated adaptive radiations	Random sampling
Parallel evolution in nature and laboratory	Effect of Drift

Losos, Evolution, 2011; Ord and Summers, BMC Evol Biol, 2015; Lind *et al*, eLife, 2015

Theory and Empirical data meet…

Coupling theoretical framework and experimental data allows us to create and test expectations on the repeatability and predictability of evolution
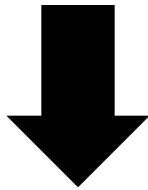
1- How repeatable is evolution in the laboratory environment?

2 – Can initial adaptive patterns inform about long-term evolutionary patterns?

3 –What do we need to predict evolution in the laboratory environment?

4 – Can we describe the fitness landscape underlying the laboratory environment?
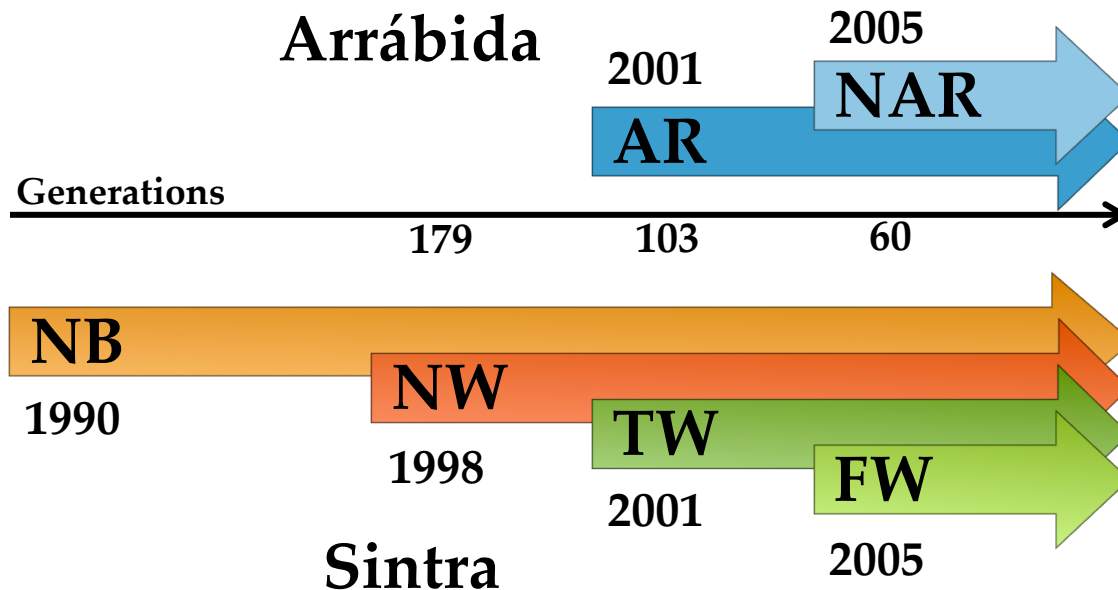
Experimental Design

Organism: *Drosophila subobscura*

Control Populations: NB

Collection Locations: Arrábida and Sintra

Collection Years: 1998, 2001, 2005

Three-fold Replicated Populations
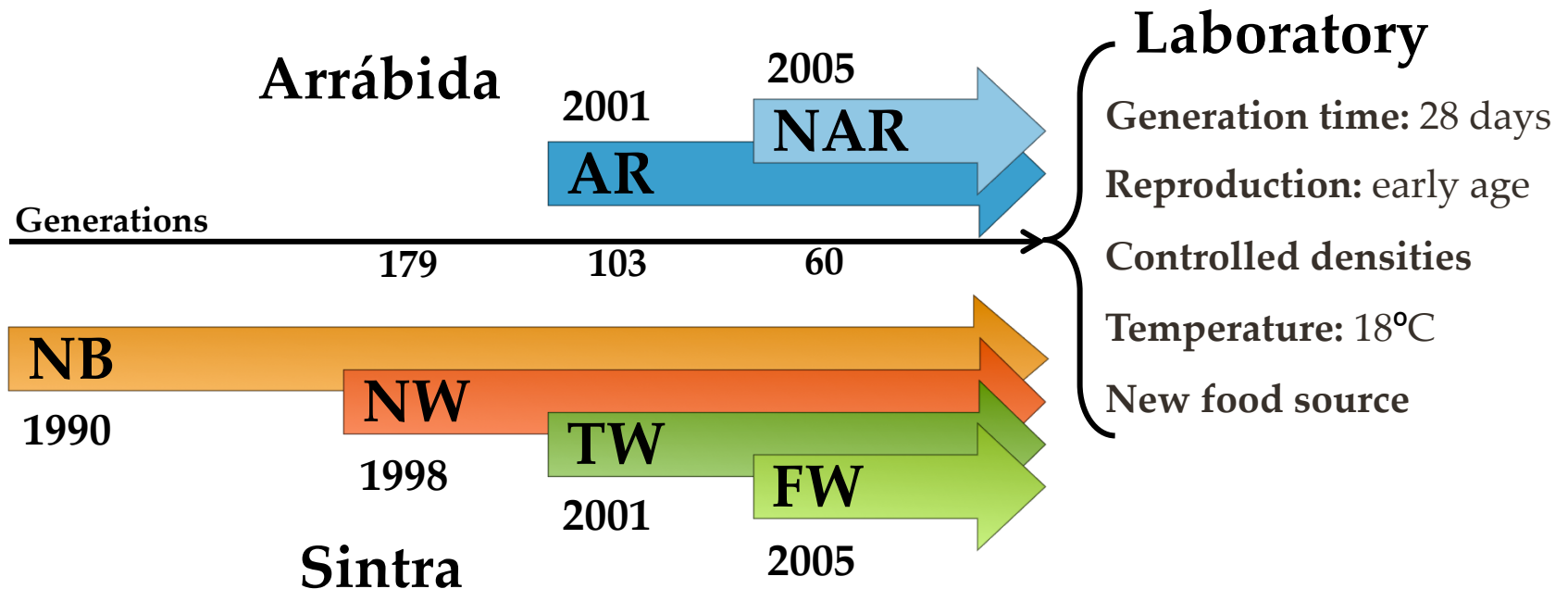
Experimental Design

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Three-fold Replicated Populations

Arrábida

2001
2005

AR
NAR

Laboratory

Generation time: 28 days

Reproduction: early age

Generations

179   103   60

Controlled densities

Temperature: 18°C

NB

NW

TW

FW

New food source

1990

1998

2001

2005

**Sintra**

Experimental Design

Traits: Age of First Reproduction **(A1R)**

     Early Fecundity **(F1-7)**

     Peak Fecundity **(F8-12**)

     Female Starvation Resistance **(RF)**

     Male Starvation Resistance **(RM)**

More closely related to fitness

More loosely related to fitness

Experimental Design

Traits: Age of First Reproduction **(A1R)**

Early Fecundity **(F1-7)** ⬅

Peak Fecundity **(F8-12**)

Female Starvation Resistance **(RF)** ⬅

Male Starvation Resistance **(RM)**

Experimental Design

Traits: Age of First Reproduction **(A1R)**

Early Fecundity **(F1-7)**

Peak Fecundity **(F8-12**)

Female Starvation Resistance **(RF)**

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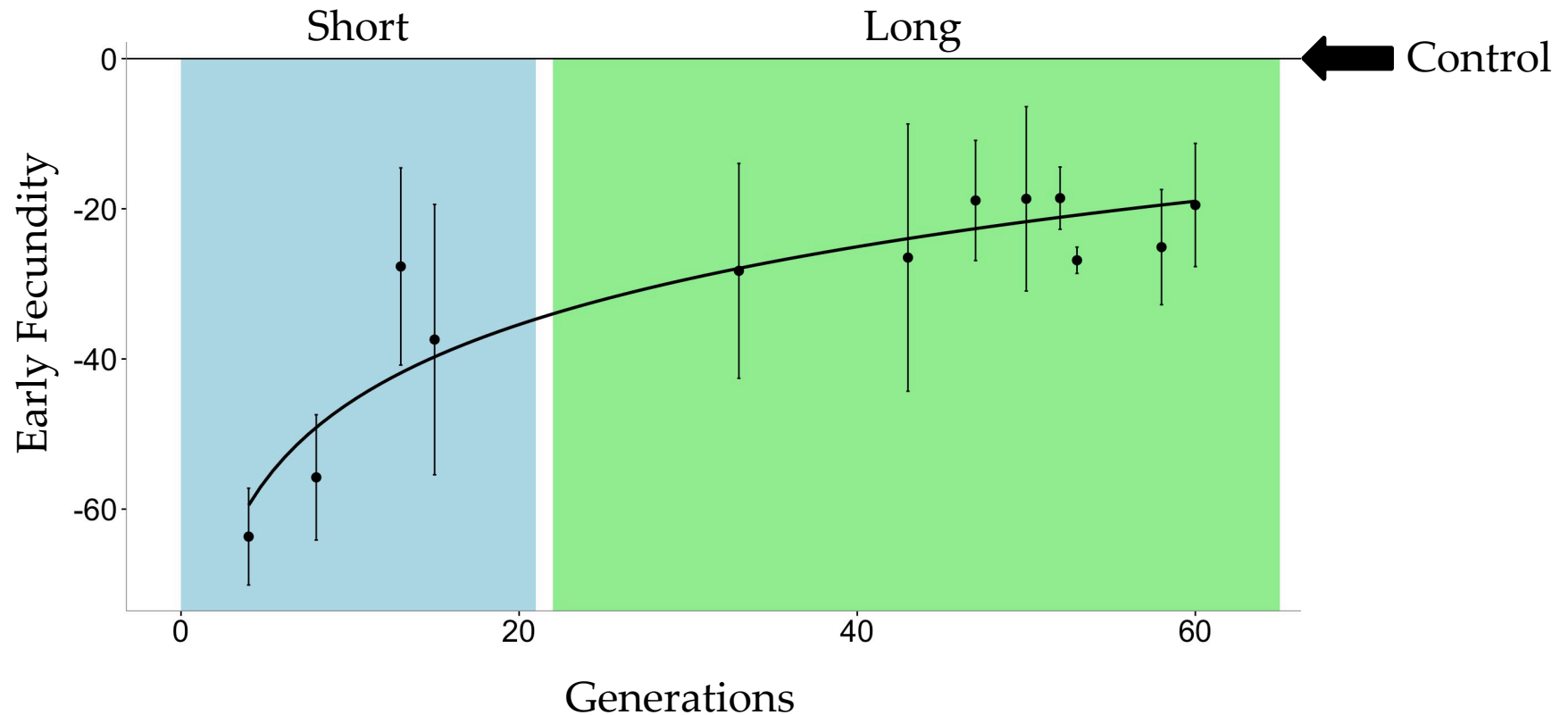
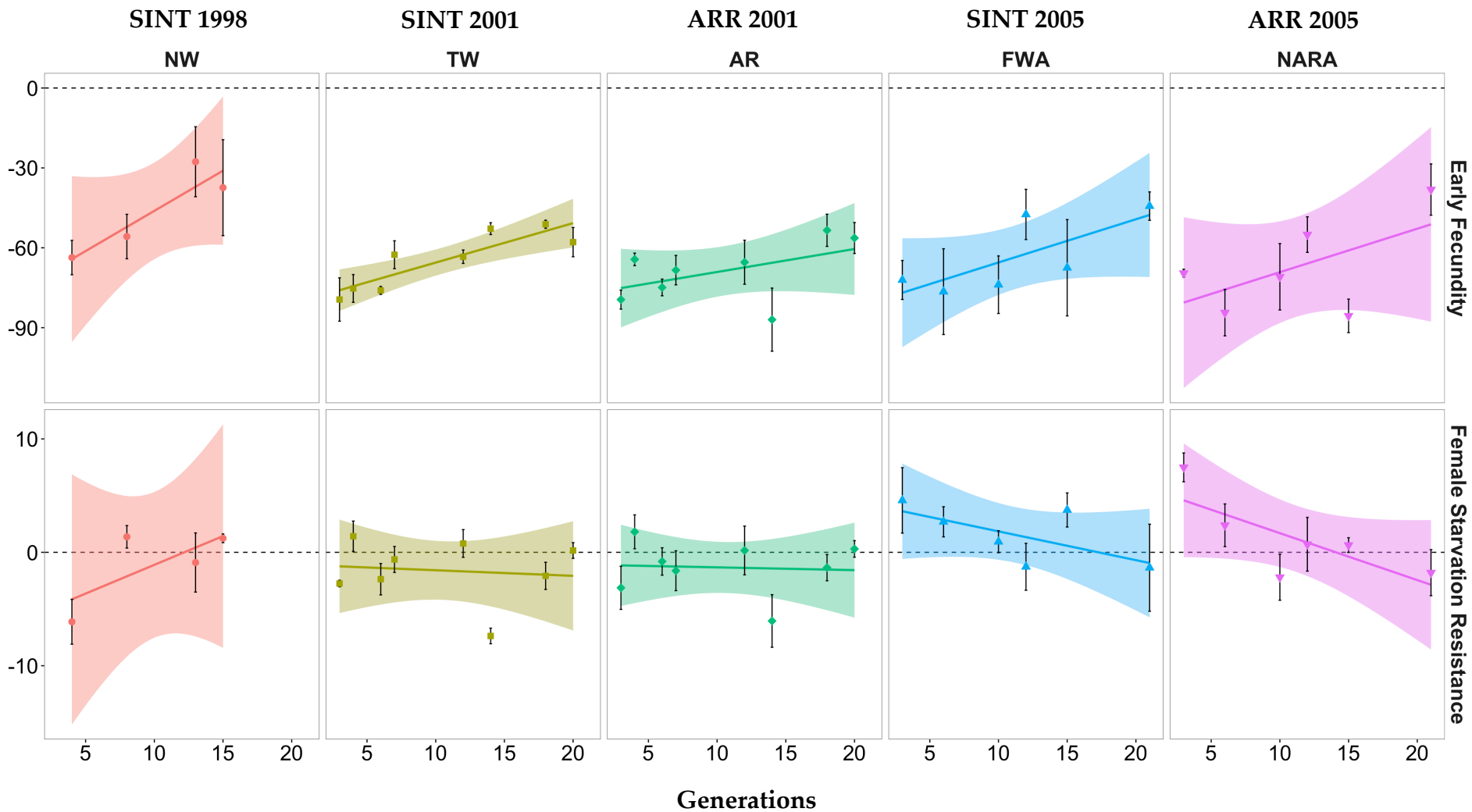1- How repeatable is evolution in the laboratory environment?

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Contingencies on short term evolution

Populations seem to be **adapting** in the **same direction** but **using different routes.**

Simões *et al* Evolution 2008
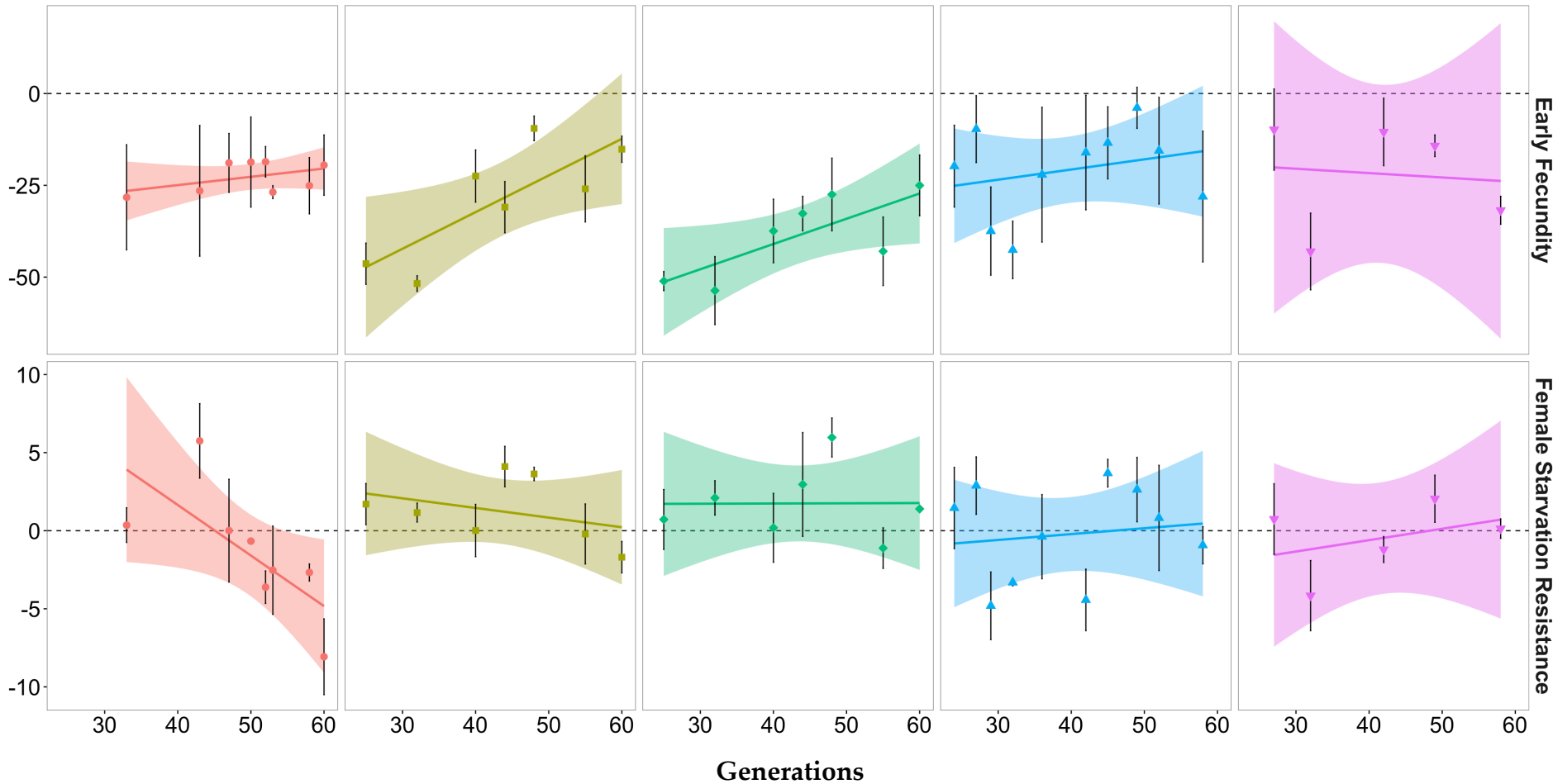
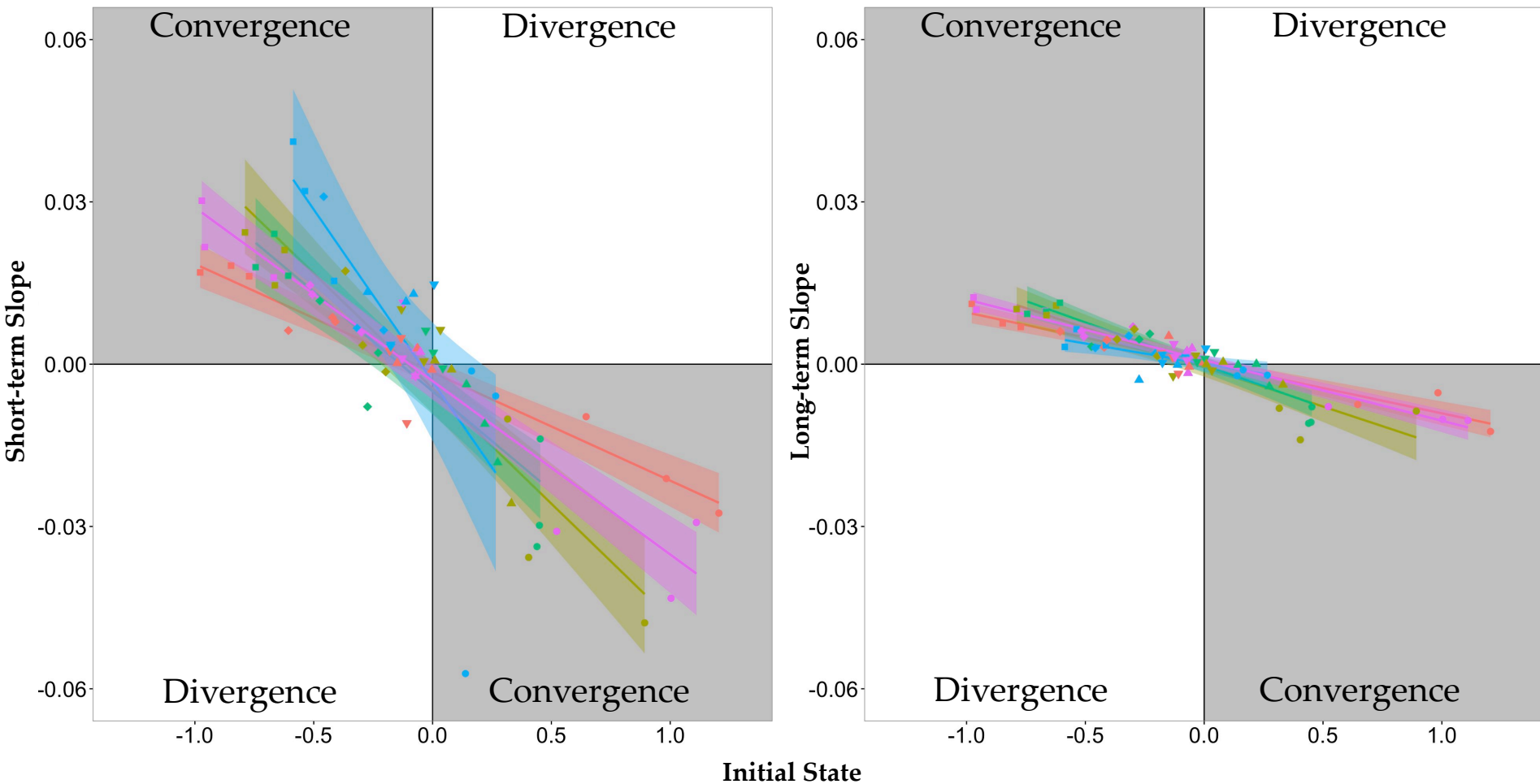**Even more pronounced contingencies in the long term!**

1- How repeatable is evolution in the laboratory environment?

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Convergence to the same peak!
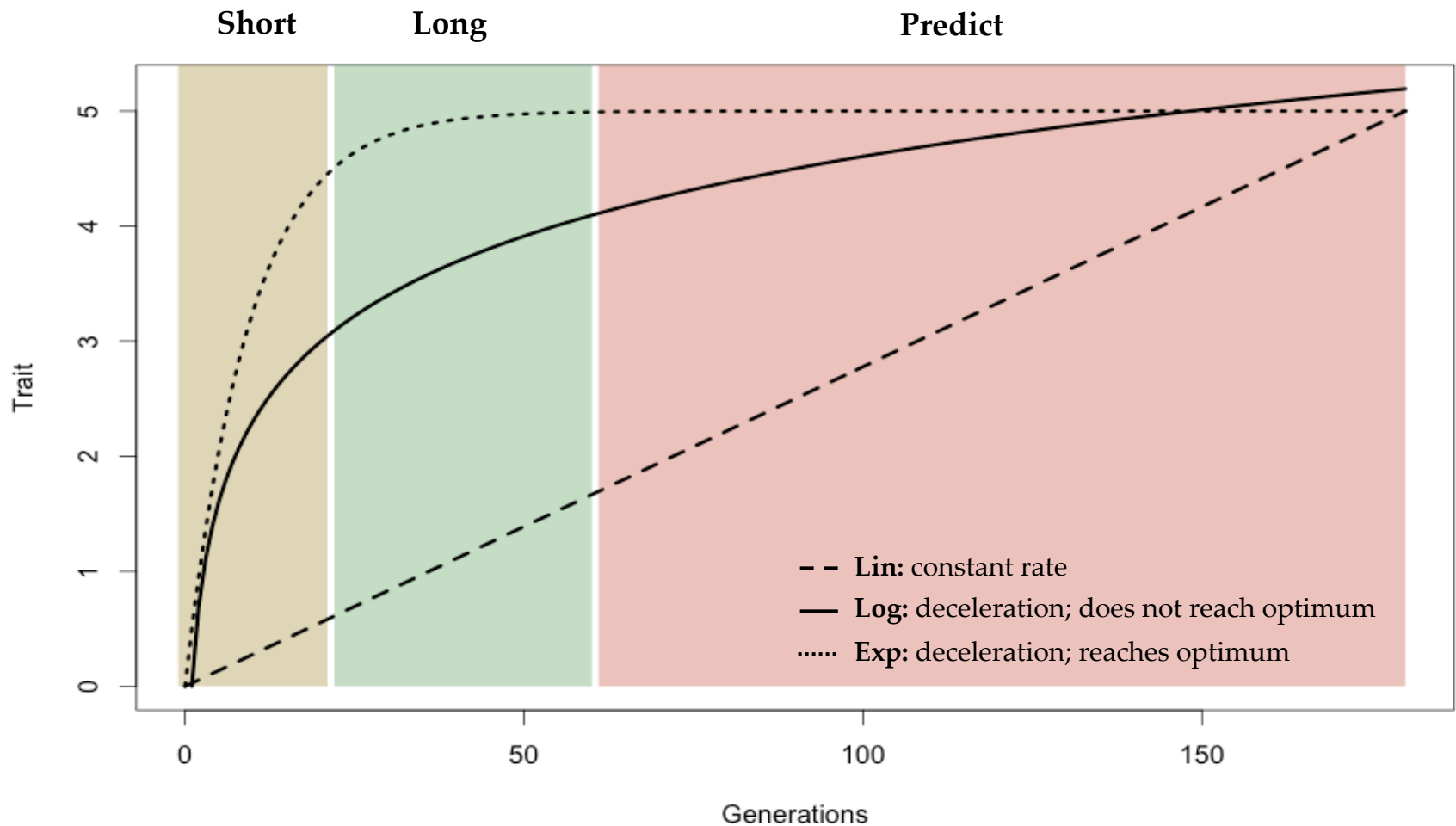**Similar dependency of the evolutionary rate on the initial fitness**

1- How repeatable is evolution in the laboratory environment?

2 – Can initial adaptive patterns inform about long-term evolutionary patterns?

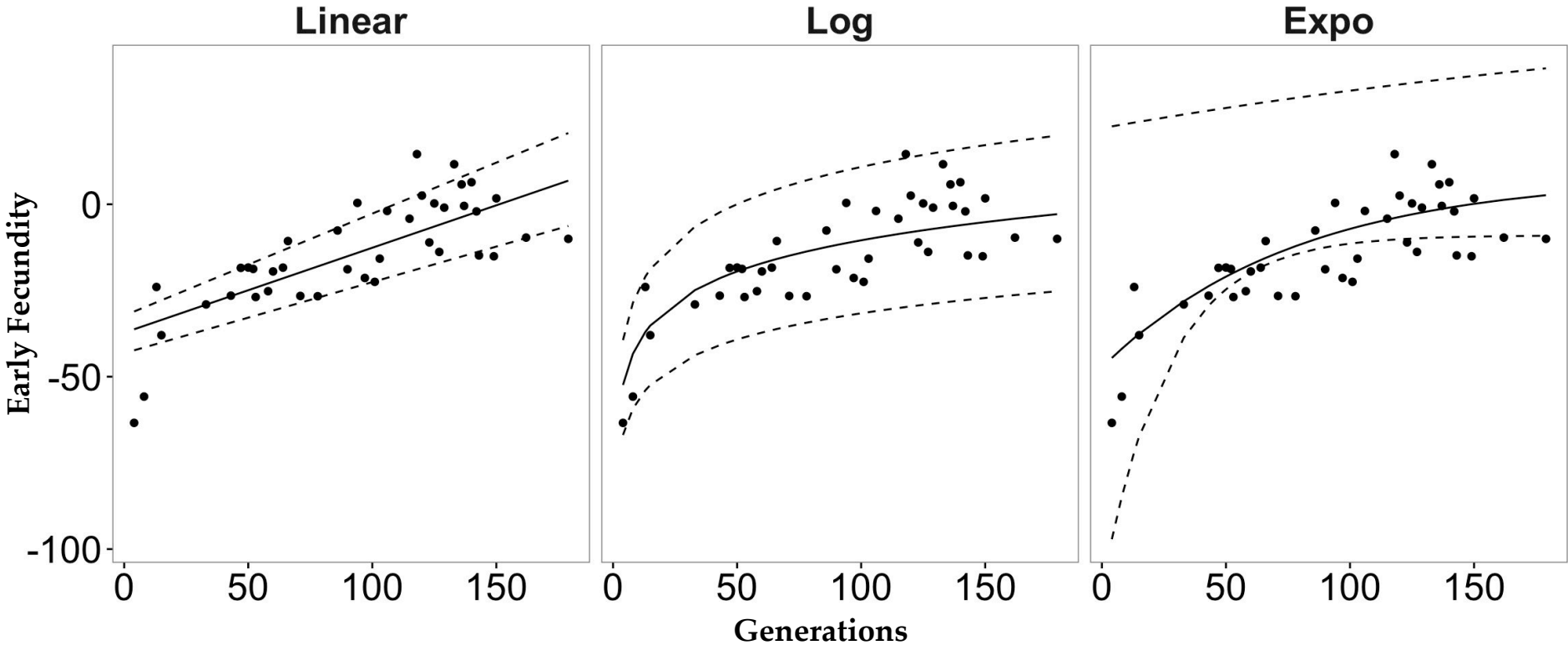3 –What do we need to predict evolution in the laboratory environment?

4 – Can we describe the fitness landscape underlying the laboratory environment?

**Three models with different expectations on the adaptive process**

Preliminary analyses suggest deceleration without reaching an optimum

Parameter estimation through MCMC – NW population

Dashed lines correspond to Confidence Intervals

→ But only for this trait and population – what about other traits and populations?

→ Maybe more generations would give different results!
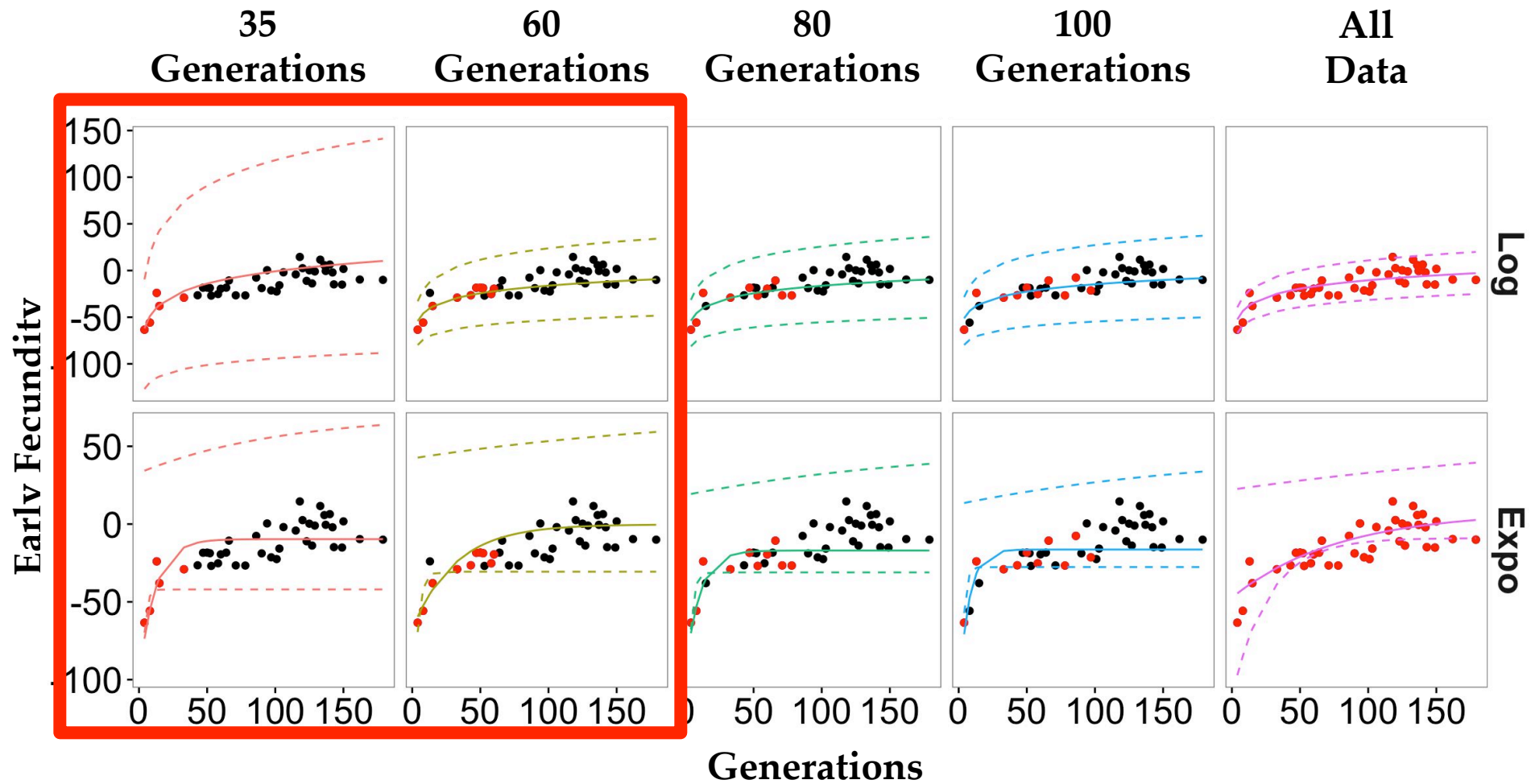
How many generations do we need?

Parameter estimation through MCMC – NW population

Dashed lines correspond to Confidence Intervals

Red dots correspond to the generations used to estimate parameters in each interval

Summary so far…

1 – How repeatable is evolution in the laboratory environment?

→ No repeatability in both short and long-term

2 – Can initial adaptive patterns inform about long-term evolutionary patterns?

→ High dependency on the initial state

→ Convergence to the same peak ➡ Predictability

Work in Progress

3 – What do we need to predict evolution in the laboratory environment?

→ Intermediate experimental duration, not many data points needed

4 – Can we describe the fitness landscape underlying the laboratory environment?

→ Suggestion of smooth fitness landscape, without reaching an optimum

Summary so far…

1 – How repeatable is evolution in the laboratory environment?

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(Somewhat) Predictable but not repeatable patterns

Next steps…

? Introduce error and drift in the already tested models

? How to best describe and predict evolutionary patterns: One trait analyses vs. multivariate trait analyses?
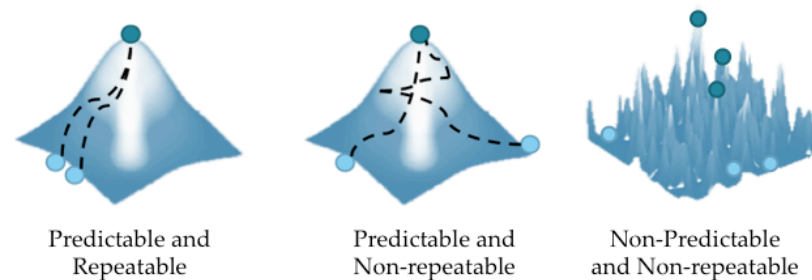
   ? Can the weight of traits change across evolution?

? One optimum, several optima?

   ? Fitness landscape models – smooth *vs.* rugged, epistatic effects

? Apply model to populations with different genetic background

? Suggestions? ☺

Analogy of the fitness landscape

Predictable and Repeatable   Predictable and Non-repeatable   Non-Predictable and Non-repeatable

- **Predictability** – Outcome
- **Repeatability** – Evolutionary path taken

Evolutionary Dynamics - IGC

Local Adaptation in _Drosophila_ – cE3c

Acknowledgments
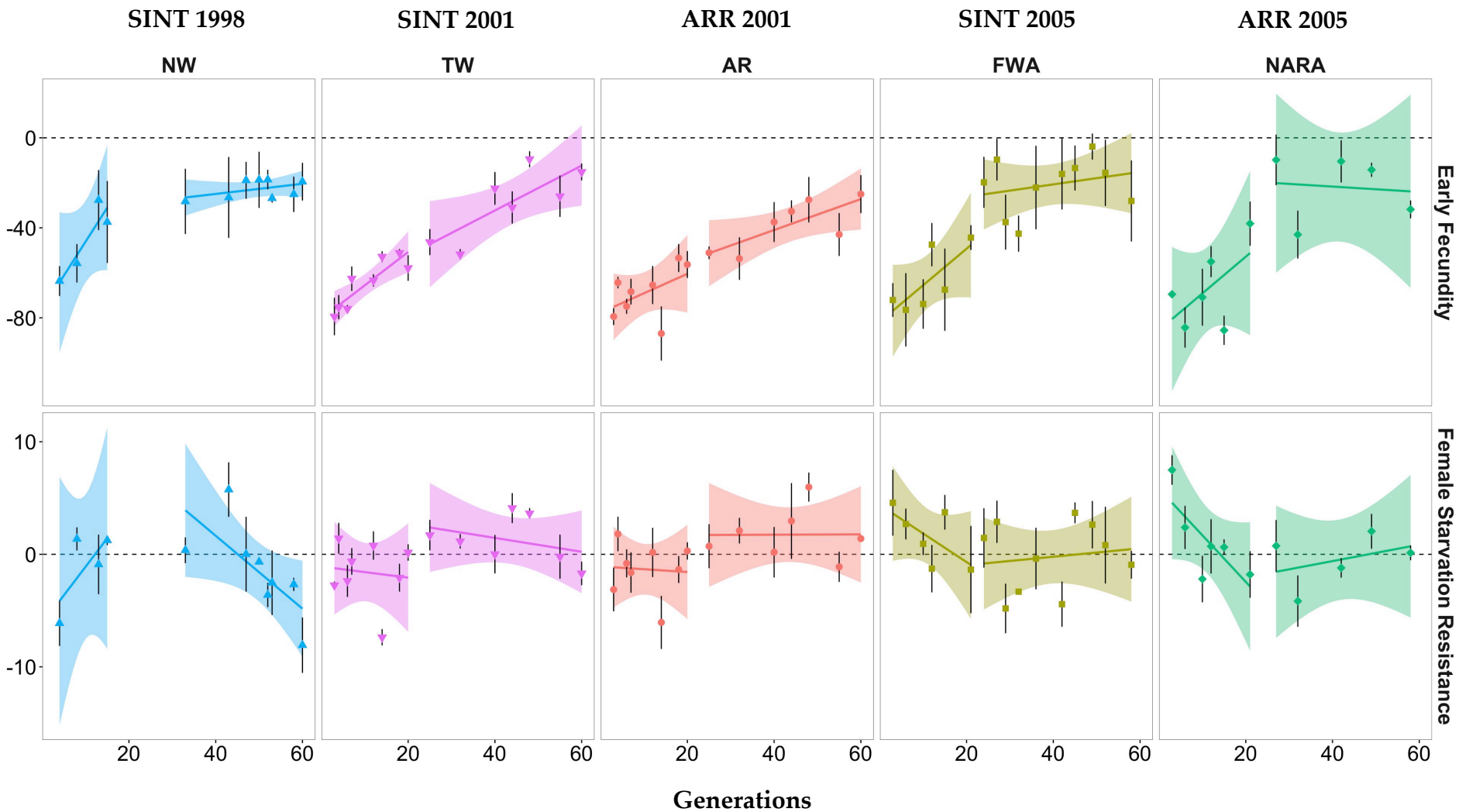
No dependency between periods

→ No correlation between long and short-term slopes
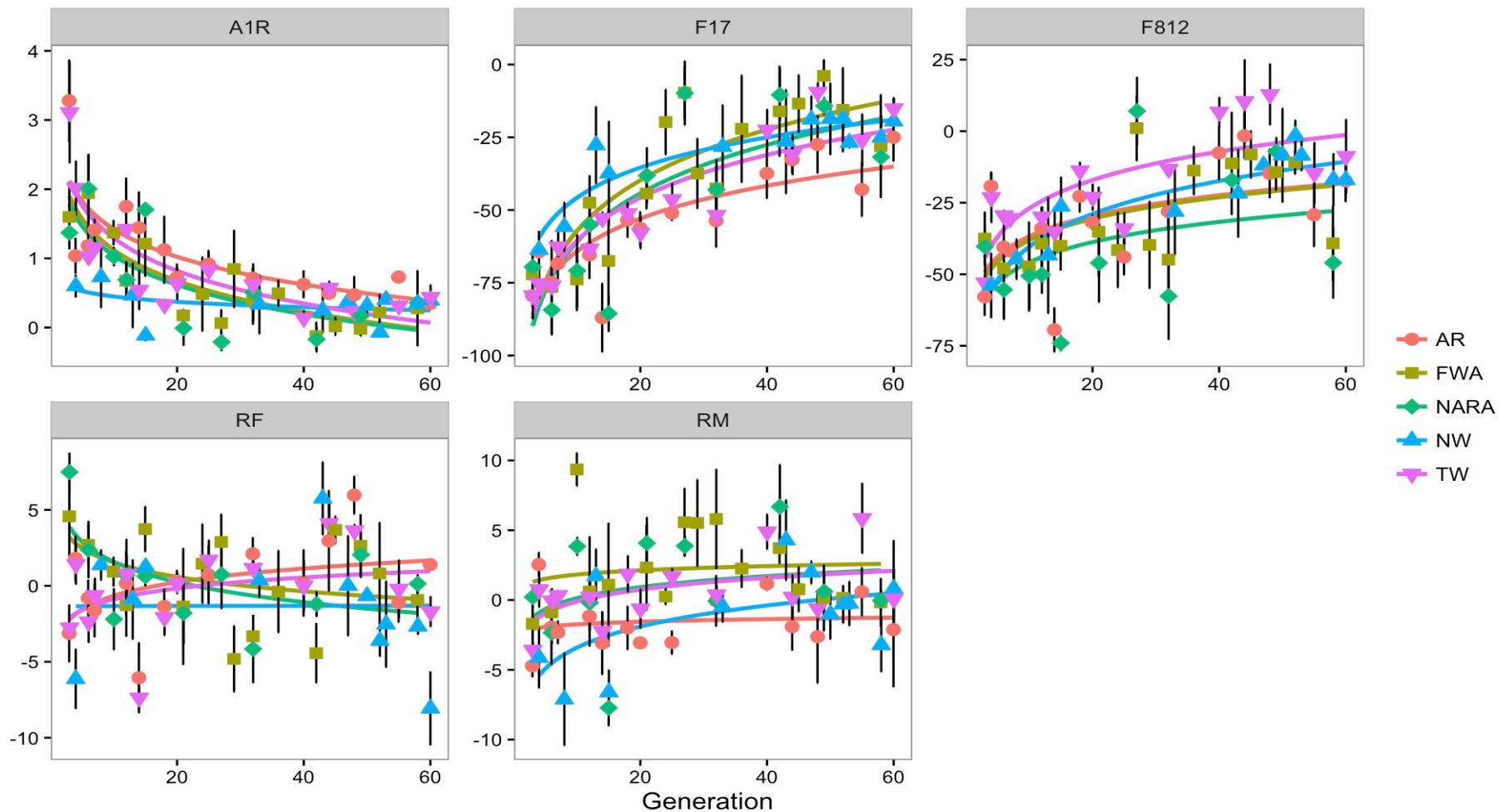
No repeatability on either short or long-term evolution