Larger workers outperform smaller workers across resource environments: an evaluation of demographic data using functional linear models

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Abstract

1. Behavior and organization of social groups is thought to be vital to the functioning of societies, yet the contributions of various roles within social groups towards population growth and dynamics have been difficult to quantify. A common approach to quantifying these role-based contributions is evaluating the number of individuals conducting certain roles, which ignores how behavior might scale up to effects at the population-level. Manipulative experiments are another common approach to determine population-level effects, but they often ignore potential feedbacks associated with these various roles. 2. Here, we evaluate the effects of worker size distribution in bumblebee colonies on worker production in 24 observational colonies across three environments, using functional linear models. Functional linear models are an underused correlative technique that has been used to assess lag effects of environmental drivers on plant performance. We demonstrate potential applications of this technique for exploring high-dimensional ecological systems, such as the contributions of individuals with different traits to colony dynamics. 3. We found that more larger workers had mostly positive effects and more smaller workers had negative effects on worker production. Most of these effects were only detected under low or fluctuating resource environments suggesting that the advantage of colonies with larger-bodied workers becomes more apparent under stressful conditions. 4. We also demonstrate the wider ecological application of functional linear models. We highlight the advantages and limitations when considering these models, and how they are a valuable complement to many of these performance-based and manipulative experiments.

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1

2

No size-based effects

(a)

Slope of *Y* vs. # of workers of size *x*

Y increases with more workers,
but size is unimportant

0

No effect

Y decreases with more workers,
but size is unimportant

Positive size-based effects

(b)

Y increases with more
workers, and intermediate
workers contribute the most

Y increases with more
workers, and larger
workers contribute the most

0

No effect

Negative size-based effects

(c)

Slope of *Y* vs. # of workers of size *x*

No effect

0

Y decreases with more workers,
and smaller workers have
the greater negative effect

Y decreases with more workers,
and intermediate workers have
the greatest negative effect

Worker size, *x*

Mixed size-based effects

(d)

Y decreases with more
smaller workers, but increases
with more larger workers

0

No effect

Y increases with more smaller or
larger workers, and intermediate
workers have a negative effect

Worker size, *x*

3

Low (2016)   **High-low (2016)**   **High (2015)**