

# Supplementary file: Are ants good organisms to teach elementary students about invasive species? (Zollota et al., Insects)

Quentin D. Read

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## Summary

## Description of methods

In this document, I fit two separate logistic regressions to answer the research questions described below. One model is for changes in knowledge about ants and invasive species, and the other is for changes in attitude about ants and about care for the environment resulting from the education program. The models also allow us to ask whether the changes were different between different categories of question, or between the two schools where the program was done. Estimated marginal means were calculated from the model, contrasts and interaction contrasts were taken, and the results are presented in graphs and tables.

## Research questions

- Was there any change in knowledge about ants or about invasive species in general as a result of the education program? (Within each school separately and averaged across schools)
- Was there any change in attitude about ants or about care for the environment as a result of the education program? (Within each school separately and averaged across schools)
- Was the knowledge/attitude about ants both before and after the program different between the two schools?
- Was the effect of the program different between the two schools?

# Abstracted results

There is a very strong trend in increasing knowledge of ants and invasive species as a result of the program. Knowledge about invasive species increased more than knowledge about ants. These trends were similar between the two schools.

There is also a strong trend in increasing positive attitude about ants and care for the environment as a result of the program. Positive attitudes about care for the environment increased slightly more than positive attitudes about ants. These trends were similar between the two schools.

Before the program, ME students had significantly higher knowledge about ants than LE students. This difference was smaller after the program. Both before and after the program, ME students had significantly more positive attitude about ants and caring for the environment.

## Setup

```
library(tidyverse)
library(emmeans)
library(gt)
library(glue)
library(performance)
```

Load the data.

```
survey_data <- read_csv('data/ascunce/ant_survey_clean.csv') %>%
  mutate(survey = factor(survey, levels = c('pre', 'post'), labels = c('before', 'after')))
```

For questions in the knowledge categories that have a right or wrong answer, combine the wrong and “do not know” answers together.

```
knowledge <- survey_data %>%
  filter(category %in% c('ant knowledge', 'general impact knowledge', 'invasive species knowledge')) %>%
  mutate(right = if_else(correct_answer == 'yes', yes, no),
         wrong = if_else(correct_answer == 'yes', no + do_not_know, yes + do_not_know))
```

Subset the attitude questions as well. All the attitude questions are “positive” so we can model change in the frequency of “yes” answers. Sum up the no and “do not know” answers.

```
attitude <- survey_data %>%
  filter(category %in% c('general care for environment', 'general feelings about ants')) %>%
  mutate(not_yes = no + do_not_know)
```

## Statistical analysis

### Fit models

Fit a generalized linear model (logistic regression or binomial GLM) using survey (before or after), category of questions, and school as effects. Also include all two-way and three-way interactions. Do a separate model for the knowledge questions and the attitude questions.

```
glm_knowledge <- glm(cbind(right, wrong) ~ survey * category * school, data = knowledge, family = binomial)
glm_attitude <- glm(cbind(yes, not_yes) ~ survey * category * school, data = attitude, family = binomial)
```

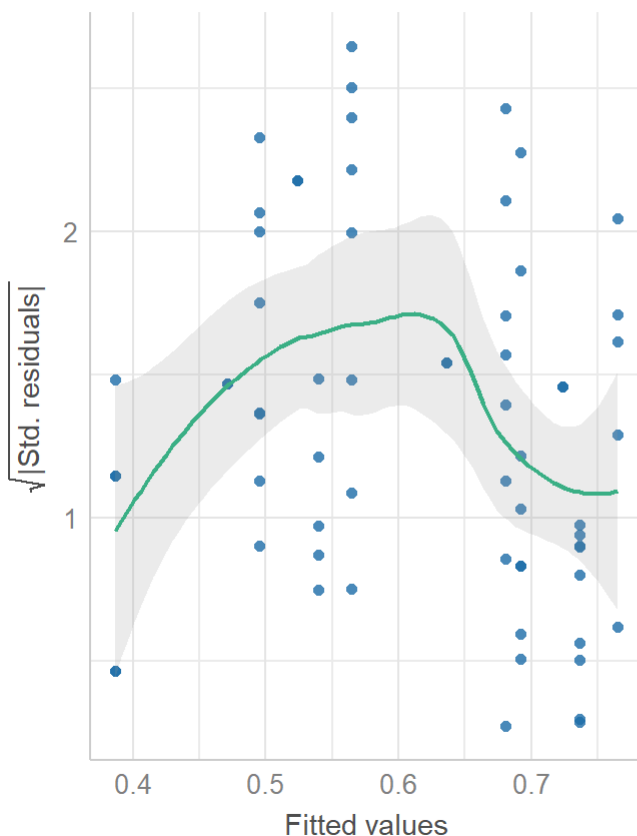
## Check model diagnostics

To ensure that the residuals meet the assumptions of normal distribution and homogeneous variance, make diagnostic plots. Inspecting the plots shows that the model assumptions are met (no overall trend in square root of standardized residuals versus fitted values and no major deviations from straight line for normal Q-Q plot).

### Diagnostic plots: knowledge model

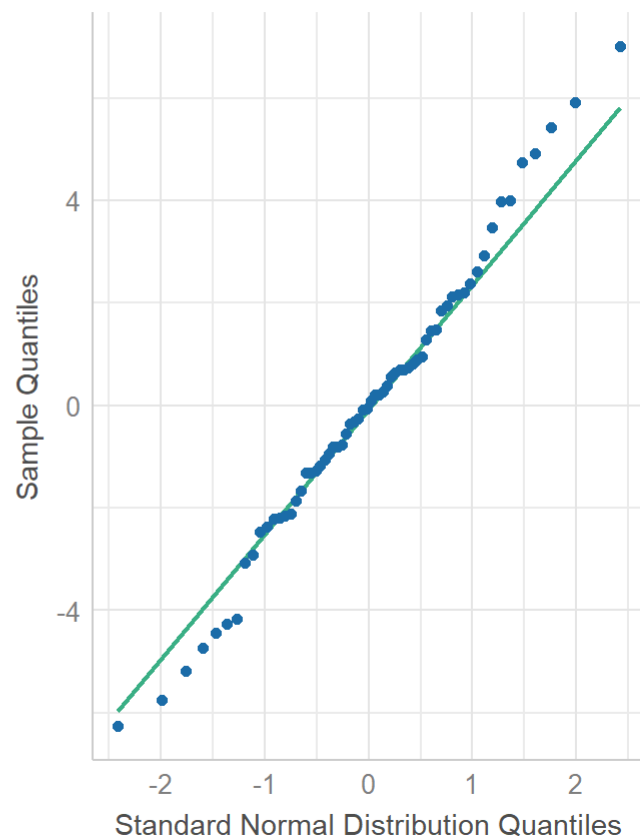
#### Homogeneity of Variance

Reference line should be flat and horizontal



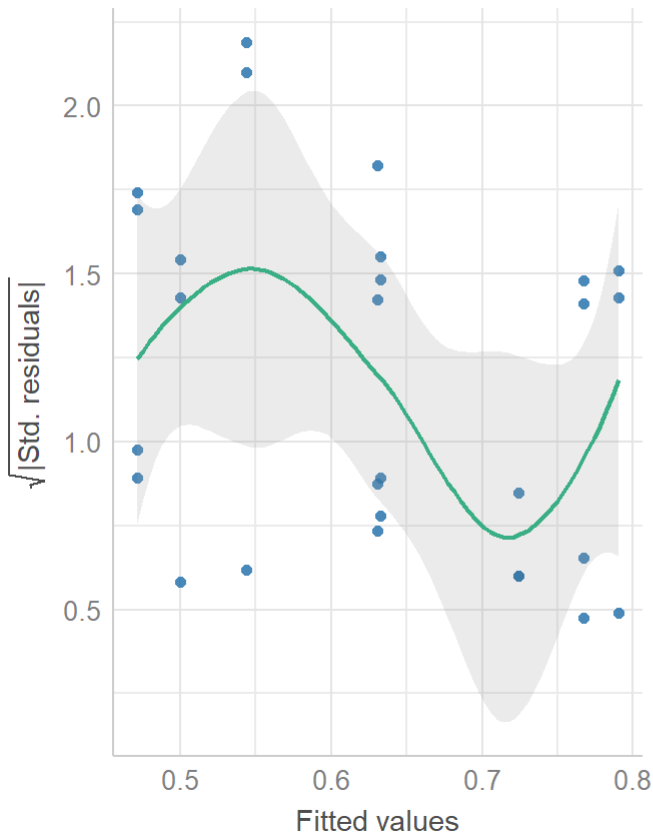
#### Normality of Residuals

Dots should fall along the line

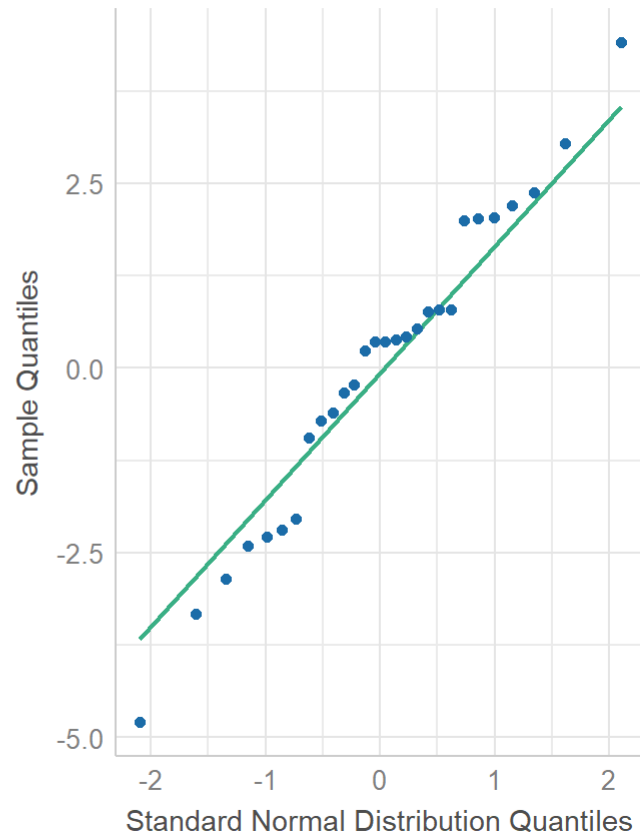


### Diagnostic plots: attitude model

**Homogeneity of Variance**  
Reference line should be flat and horizontal



**Normality of Residuals**  
Dots should fall along the line



## Estimate marginal means

For each GLM, estimate the marginal means of predicted percent correct (for knowledge questions) or percent positive attitude (for attitude questions) for the following:

- Before and after, averaged across both schools and all question categories
- Before and after for each category, averaged across both schools
- Before and after for each school, averaged across all question categories
- Before and after for each category separately within each school

For each mean, a 95% confidence interval is estimated based on the z-statistic.

```
comparisons <- list(survey = ~ survey,
                    survey_by_category = ~ survey + category,
                    survey_by_school = ~ survey + school,
                    three_way = ~ survey + category + school)

emm_knowledge <- emmeans(glm_knowledge, comparisons, type = 'response')
emm_attitude <- emmeans(glm_attitude, comparisons, type = 'response')
```

## Contrasts and interaction contrasts

Do a statistical test (z-test) testing whether the odds ratio is significantly different from 1 for the following comparisons. The before-after contrasts are odds ratios because we are looking at the difference between two different probabilities: probability of a correct or positive answer before the program and after the program. The interaction contrasts are a ratio of two odds ratios. This is done for both the knowledge questions and the attitude questions. When comparing more than two means, a Sidak adjustment is made for multiple comparisons. In all cases, 1 is the null value representing no change (equal ratio).

- Is the odds of correct answer/positive attitude greater after the test than before, averaged across both schools and question categories?
- Is the odds of correct answer/positive attitude different between schools, averaged across categories, in the before and after surveys separately?
- Is the trend of increase in correct answer/positive attitude different between question category, averaged across schools?
- Is the trend of increase in correct answer/positive attitude different between schools, averaged across question categories?
- Is the trend of increase in correct answer/positive attitude different between schools within each question category separately?

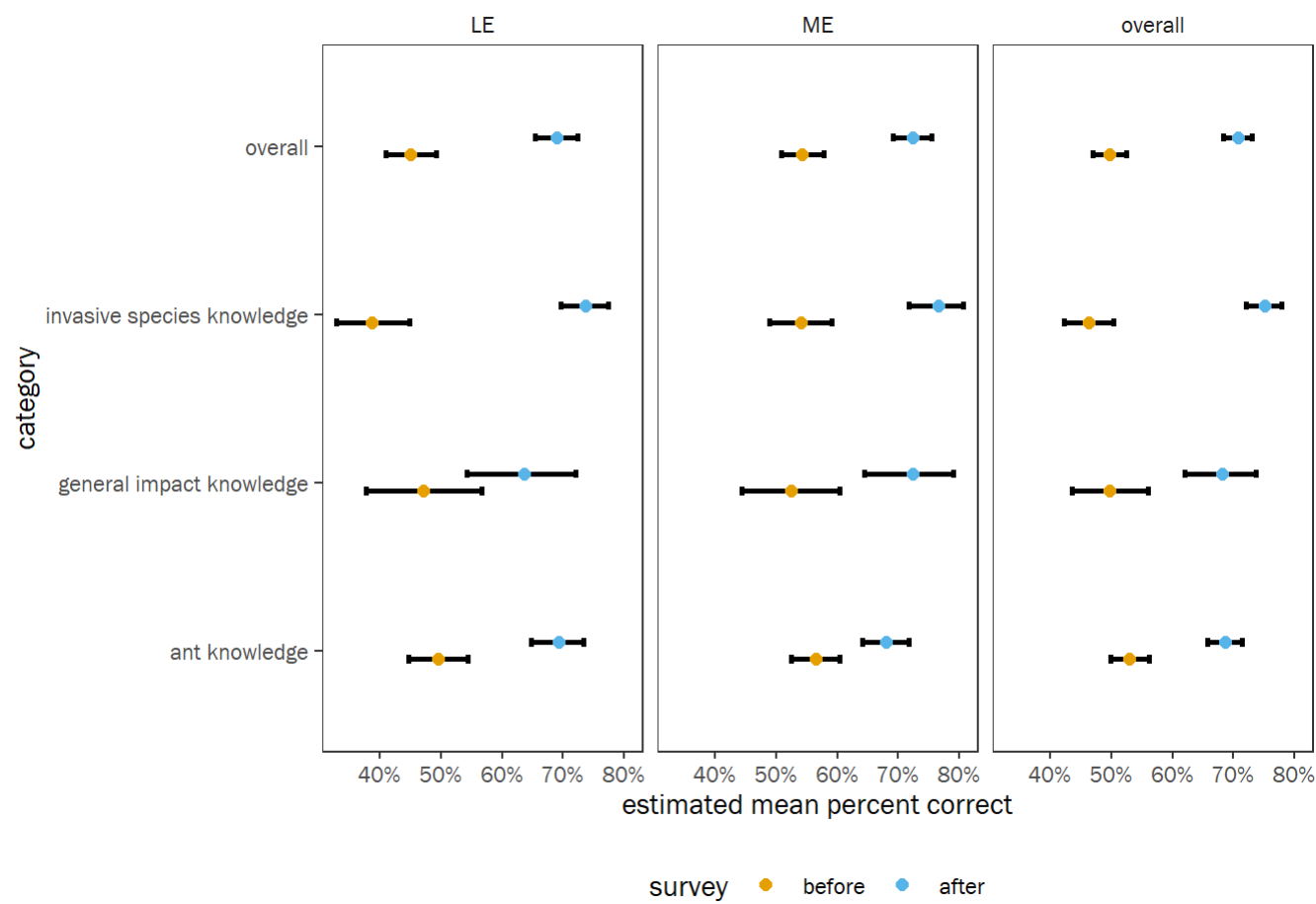
```
contr_knowledge <- list(
  survey = emmeans(glm_knowledge, ~ survey, type = 'response') |> contrast('revpairwise'),
  school_within_survey = emmeans(glm_knowledge, ~ school | survey, type = 'response') |> contrast('revpairwise'),
  survey_by_category = emmeans(glm_knowledge, ~ survey + category, type = 'response') |> contrast(interaction = 'revpairwise', adjust = 'sidak'),
  survey_within_category_ME = emmeans(glm_knowledge, ~ survey | category, type = 'response', at = list(school = 'ME')) |> contrast(interaction = 'revpairwise') |> rbind(adjust = 'sidak'),
  survey_within_category_LE = emmeans(glm_knowledge, ~ survey | category, type = 'response', at = list(school = 'LE')) |> contrast(interaction = 'revpairwise') |> rbind(adjust = 'sidak'),
  survey_by_school = emmeans(glm_knowledge, ~ survey + school, type = 'response') |> contrast(interaction = 'revpairwise'),
  three_way = emmeans(glm_knowledge, ~ survey + school | category, type = 'response') |> contrast(interaction = 'revpairwise') |> rbind(adjust = 'sidak')
)

contr_attitude <- list(
  survey = emmeans(glm_attitude, ~ survey, type = 'response') |> contrast('revpairwise'),
  school_within_survey = emmeans(glm_attitude, ~ school | survey, type = 'response') |> contrast('revpairwise'),
  survey_by_category = emmeans(glm_attitude, ~ survey + category, type = 'response') |> contrast(interaction = 'revpairwise', adjust = 'sidak'),
  survey_within_category_ME = emmeans(glm_attitude, ~ survey | category, type = 'response', at = list(school = 'ME')) |> contrast(interaction = 'revpairwise') |> rbind(adjust = 'sidak'),
  survey_within_category_LE = emmeans(glm_attitude, ~ survey | category, type = 'response', at = list(school = 'LE')) |> contrast(interaction = 'revpairwise') |> rbind(adjust = 'sidak'),
  survey_by_school = emmeans(glm_attitude, ~ survey + school, type = 'response') |> contrast(interaction = 'revpairwise'),
  three_way = emmeans(glm_attitude, ~ survey + school | category, type = 'response') |> contrast(interaction = 'revpairwise') |> rbind(adjust = 'sidak')
)
```

# Results

## Knowledge

This figure shows the knowledge GLM model's estimates of percent correct scores for each category and each school separately, as well as averaged across categories overall and averaged across schools overall. Points show the estimated marginal means, colored by survey (before or after), and error bars show the 95% confidence intervals of the means.



This table is the same information as contained in the figure above (estimated marginal means and 95% confidence intervals).

| survey  | category      | estimated proportion correct | 95% confidence interval |
|---------|---------------|------------------------------|-------------------------|
| overall |               |                              |                         |
| before  | overall       | 0.497                        | (0.47, 0.524)           |
| after   | overall       | 0.707                        | (0.683, 0.73)           |
| before  | ant knowledge | 0.530                        | (0.498, 0.562)          |
| after   | ant knowledge | 0.686                        | (0.657, 0.714)          |

| survey    | category                   | estimated proportion correct | 95% confidence interval |
|-----------|----------------------------|------------------------------|-------------------------|
| before    | general impact knowledge   | 0.498                        | (0.435, 0.56)           |
| after     | general impact knowledge   | 0.681                        | (0.621, 0.737)          |
| before    | invasive species knowledge | 0.462                        | (0.422, 0.503)          |
| after     | invasive species knowledge | 0.751                        | (0.72, 0.78)            |
| <b>LE</b> |                            |                              |                         |
| before    | overall                    | 0.450                        | (0.41, 0.492)           |
| after     | overall                    | 0.690                        | (0.655, 0.723)          |
| before    | ant knowledge              | 0.495                        | (0.447, 0.543)          |
| after     | ant knowledge              | 0.692                        | (0.648, 0.733)          |
| before    | general impact knowledge   | 0.471                        | (0.377, 0.567)          |
| after     | general impact knowledge   | 0.636                        | (0.543, 0.721)          |
| before    | invasive species knowledge | 0.387                        | (0.329, 0.448)          |
| after     | invasive species knowledge | 0.737                        | (0.696, 0.773)          |
| <b>ME</b> |                            |                              |                         |
| before    | overall                    | 0.543                        | (0.508, 0.577)          |
| after     | overall                    | 0.724                        | (0.691, 0.755)          |
| before    | ant knowledge              | 0.565                        | (0.524, 0.605)          |
| after     | ant knowledge              | 0.680                        | (0.641, 0.718)          |
| before    | general impact knowledge   | 0.524                        | (0.443, 0.604)          |
| after     | general impact knowledge   | 0.723                        | (0.644, 0.791)          |
| before    | invasive species knowledge | 0.540                        | (0.488, 0.591)          |
| after     | invasive species knowledge | 0.765                        | (0.718, 0.807)          |

This table presents the statistical test results for the odds ratio contrasts and z-tests. Again, an odds ratio of 1 indicates no change. We see significantly greater proportion correct scores after the program versus before, averaged across all categories and schools (OR = 2.45 times greater odds of correct scores,  $p < 0.0001$ ). In the pre-test, ME had significantly higher knowledge than LE (OR = 1.45,  $p = 0.0008$ ), but the difference was less and not significantly different in the post-test (OR = 1.18,  $p = 0.15$ ). When comparing the trend between question categories, we see that invasive species knowledge increased more than ant knowledge (OR = 1.81,  $p = 0.0002$ ). All trends were significantly positive when looking at each category and school individually. The trend was similar between the two schools ( $p > 0.05$  indicating OR is not significantly different from 1), and the trend within each question category was similar between the two schools ( $p > 0.05$  in all cases indicating OR is not significantly different from 1).

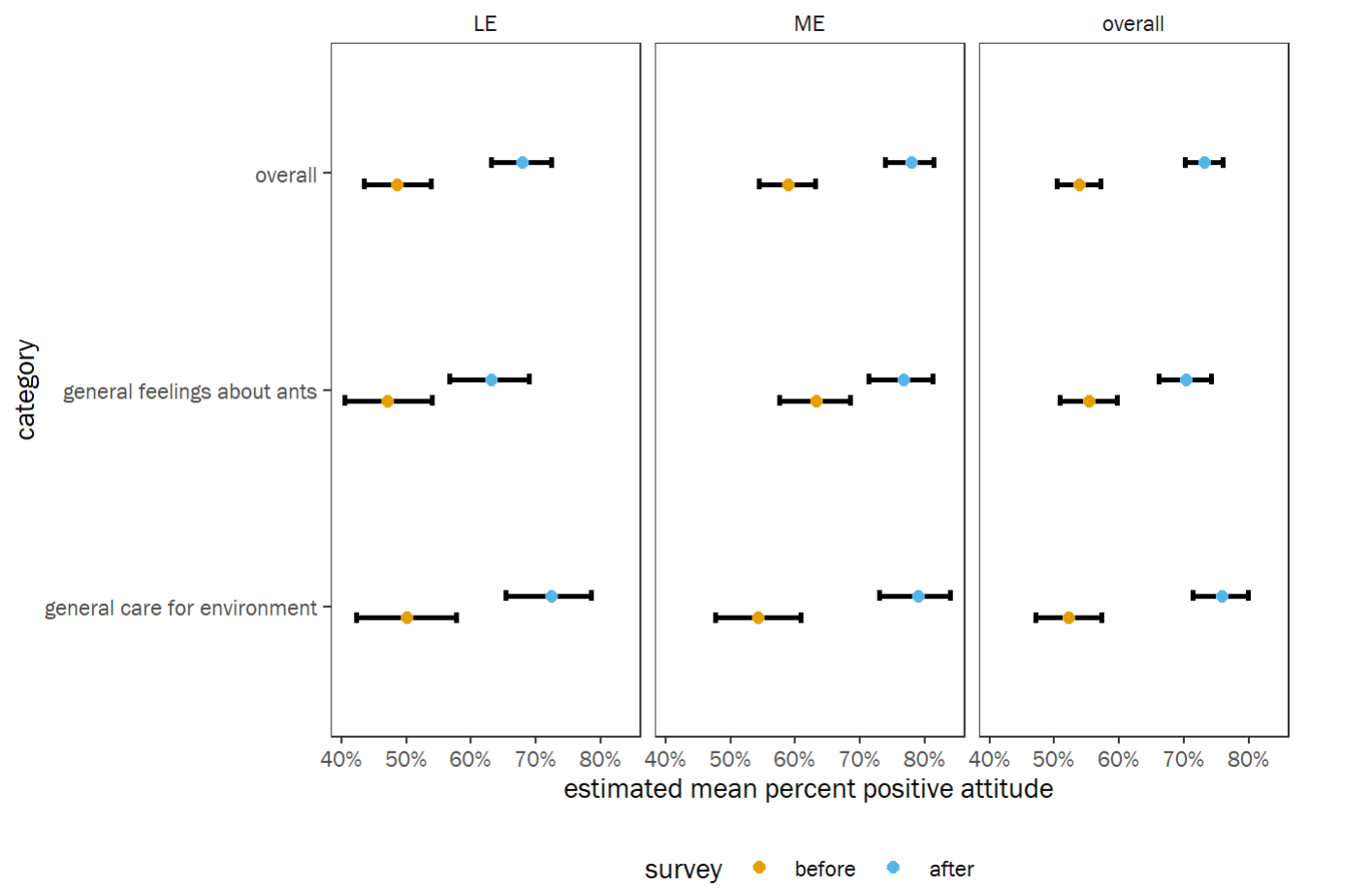
| comparison  | odds ratio | standard error | z ratio | p-value               |
|---|------------|----------------|---------|-----------------------|
| after/before ratio, averaged across all categories and schools                                    | 2.450      | 0.196          | 11.209  | $3.7 \times 10^{-29}$ |
| ME/LE ratio, pre-test   | 1.449      | 0.161          | 3.348   | 0.000813              |
| ME/LE ratio, post-test  | 1.181      | 0.136          | 1.442   | 0.149                 |
| trend comparison general impact knowledge vs. ant knowledge, averaged across schools              | 1.113      | 0.234          | 0.511   | 0.94                  |
| trend comparison invasive species knowledge vs. ant knowledge, averaged across schools            | 1.808      | 0.270          | 3.971   | 0.000215              |
| trend comparison invasive species knowledge vs. general impact knowledge, averaged across schools | 1.624      | 0.358          | 2.199   | 0.0814                |
| after/before ratio, ant knowledge, ME only  | 1.640      | 0.202          | 4.009   | 0.000183              |
| after/before ratio, general impact knowledge, ME only   | 2.374      | 0.596          | 3.443   | 0.00173               |
| after/before ratio, invasive species knowledge, ME only   | 2.774      | 0.456          | 6.207   | $1.63 \times 10^{-9}$ |
| after/before ratio, ant knowledge, LE only  | 2.294      | 0.325          | 5.861   | $1.38 \times 10^{-8}$ |
| after/before ratio, general impact knowledge, LE only   | 1.964      | 0.548          | 2.419   | 0.0459                |
| after/before ratio, invasive species knowledge, LE only   | 4.436      | 0.724          | 9.120   | 0                     |
| trend comparison ME vs. LE, averaged across all categories  | 0.815      | 0.130          | -1.283  | 0.2                   |
| trend comparison ME vs. LE, ant knowledge category  | 0.715      | 0.134          | -1.786  | 0.206                 |



| comparison  | odds ratio | standard error | z ratio | p-value |
|---|------------|----------------|---------|---------|
| trend comparison ME vs. LE, general impact knowledge category   | 1.209      | 0.454          | 0.505   | 0.942   |
| trend comparison ME vs. LE, invasive species knowledge category | 0.625      | 0.145          | -2.025  | 0.123   |

## Attitude

This figure shows the attitude GLM model's estimates of percent positive attitude scores for each category and each school separately, as well as averaged across categories overall and averaged across schools overall.



This table is the same information as contained in the figure above (estimated marginal means and 95% confidence intervals).

| survey  | category | estimated proportion positive | 95% confidence interval |
|---------|----------|-------------------------------|-------------------------|
| overall |          |                               |                         |
| before  | overall  | 0.538                         | (0.503, 0.571)          |

| survey    | category                     | estimated proportion positive | 95% confidence interval |
|-----------|------------------------------|-------------------------------|-------------------------|
| after     | overall                      | 0.732                         | (0.701, 0.761)          |
| before    | general care for environment | 0.522                         | (0.47, 0.573)           |
| after     | general care for environment | 0.759                         | (0.713, 0.799)          |
| before    | general feelings about ants  | 0.553                         | (0.508, 0.597)          |
| after     | general feelings about ants  | 0.703                         | (0.662, 0.742)          |
| <b>LE</b> |                              |                               |                         |
| before    | overall                      | 0.486                         | (0.434, 0.537)          |
| after     | overall                      | 0.679                         | (0.631, 0.724)          |
| before    | general care for environment | 0.500                         | (0.422, 0.578)          |
| after     | general care for environment | 0.724                         | (0.653, 0.785)          |
| before    | general feelings about ants  | 0.471                         | (0.405, 0.539)          |
| after     | general feelings about ants  | 0.630                         | (0.566, 0.69)           |
| <b>ME</b> |                              |                               |                         |
| before    | overall                      | 0.589                         | (0.545, 0.631)          |
| after     | overall                      | 0.779                         | (0.739, 0.814)          |
| before    | general care for environment | 0.543                         | (0.477, 0.608)          |
| after     | general care for environment | 0.790                         | (0.73, 0.84)            |
| before    | general feelings about ants  | 0.632                         | (0.575, 0.686)          |
| after     | general feelings about ants  | 0.767                         | (0.714, 0.813)          |

This table presents the statistical test results for the odds ratio contrasts and z-tests. Again, an odds ratio of 1 indicates no change. We see significantly greater proportion positive attitude scores after the program versus before, averaged across all categories and schools (OR = 2.35 times greater odds of positive attitude scores,  $p < 0.0001$ ). ME had significantly more positive attitude than LE in the pre-test (OR = 1.52,  $p = 0.003$ ) as well as the post-test (OR = 1.67,  $p = 0.001$ ). When comparing the trend between question categories, we see weak evidence that positive feelings about care for the environment increased more than positive feelings about ants (OR =  $1/0.663 = 1.51$  times greater increase in positive feelings about environment relative to ants,  $p = 0.049$ ). However all trends were significantly positive when looking at each category and school individually. The trend was similar

between the two schools ( $p > 0.05$  indicating OR is not significantly different from 1), and the trend within each question category was similar between the two schools ( $p > 0.05$  in both cases indicating OR is not significantly different from 1).

| comparison  | odds ratio | standard error | z ratio | p-value                |
|---|------------|----------------|---------|------------------------|
| after/before ratio, averaged across all categories and schools  | 2.350      | 0.245          | 8.187   | $2.67 \times 10^{-16}$ |
| ME/LE ratio, pre-test   | 1.515      | 0.211          | 2.975   | 0.00293                |
| ME/LE ratio, post-test  | 1.665      | 0.258          | 3.289   | 0.00101                |
| trend comparison feelings about ants vs. feelings about care for environment, averaged across schools | 0.663      | 0.138          | -1.967  | 0.0492                 |
| after/before ratio, feelings about ants, ME only  | 3.170      | 0.688          | 5.314   | $2.15 \times 10^{-7}$  |
| after/before ratio, feelings about care for environment, ME only                                      | 1.915      | 0.357          | 3.480   | 0.001                  |
| after/before ratio, feelings about ants, LE only  | 2.625      | 0.612          | 4.137   | $7.03 \times 10^{-5}$  |
| after/before ratio, feelings about care for environment, LE only                                      | 1.913      | 0.372          | 3.337   | 0.00169                |
| trend comparison ME vs. LE, averaged across all categories  | 1.100      | 0.229          | 0.455   | 0.649                  |
| trend comparison ME vs. LE, feelings about ants category  | 1.208      | 0.385          | 0.592   | 0.801                  |
| trend comparison ME vs. LE, feelings about care for environment category                              | 1.001      | 0.270          | 0.004   | 1                      |

| school | survey | category                     | question   | correct_answer | no | yes | do_not_know |
|--------|--------|------------------------------|--|----------------|----|-----|-------------|
| LE     | pre    | ant knowledge                | Ants bodies have three parts                                   | yes            | 11 | 32  | 9           |
| LE     | post   | ant knowledge                | Ants bodies have three parts                                   | yes            | 14 | 41  | 3           |
| ME     | pre    | ant knowledge                | Ants bodies have three parts                                   | yes            | 2  | 57  | 14          |
| ME     | post   | ant knowledge                | Ants bodies have three parts                                   | yes            | 19 | 51  | 1           |
| LE     | pre    | ant knowledge                | Ants use chemical signals to communicate with each other       | yes            | 14 | 23  | 15          |
| LE     | post   | ant knowledge                | Ants use chemical signals to communicate with each other       | yes            | 8  | 45  | 5           |
| ME     | pre    | ant knowledge                | Ants use chemical signals to communicate with each other       | yes            | 6  | 36  | 30          |
| ME     | post   | ant knowledge                | Ants use chemical signals to communicate with each other       | yes            | 10 | 37  | 23          |
| LE     | pre    | ant knowledge                | Fire ant stings are dangerous                                  | yes            | 24 | 15  | 12          |
| LE     | post   | ant knowledge                | Fire ant stings are dangerous                                  | yes            | 13 | 39  | 6           |
| ME     | pre    | ant knowledge                | Fire ant stings are dangerous                                  | yes            | 21 | 32  | 19          |
| ME     | post   | ant knowledge                | Fire ant stings are dangerous                                  | yes            | 21 | 38  | 10          |
| LE     | pre    | ant knowledge                | Fire ants are a problem  | yes            | 17 | 19  | 15          |
| LE     | post   | ant knowledge                | Fire ants are a problem  | yes            | 8  | 41  | 7           |
| ME     | pre    | ant knowledge                | Fire ants are a problem  | yes            | 15 | 39  | 19          |
| ME     | post   | ant knowledge                | Fire ants are a problem  | yes            | 10 | 46  | 12          |
| LE     | pre    | ant knowledge                | Fire ants are an invasive species                              | yes            | 11 | 21  | 19          |
| LE     | post   | ant knowledge                | Fire ants are an invasive species                              | yes            | 14 | 36  | 7           |
| ME     | pre    | ant knowledge                | Fire ants are an invasive species                              | yes            | 14 | 18  | 40          |
| ME     | post   | ant knowledge                | Fire ants are an invasive species                              | yes            | 10 | 53  | 8           |
| LE     | pre    | ant knowledge                | Fire Ants love sugar   | yes            | 24 | 11  | 16          |
| LE     | post   | ant knowledge                | Fire Ants love sugar   | yes            | 24 | 22  | 10          |
| ME     | pre    | ant knowledge                | Fire Ants love sugar   | yes            | 28 | 16  | 28          |
| ME     | post   | ant knowledge                | Fire Ants love sugar   | yes            | 22 | 32  | 17          |
| LE     | pre    | ant knowledge                | I think it is ok to touch a fire ant pile                      | no             | 38 | 6   | 6           |
| LE     | post   | ant knowledge                | I think it is ok to touch a fire ant pile                      | no             | 41 | 12  | 3           |
| ME     | pre    | ant knowledge                | I think it is ok to touch a fire ant pile                      | no             | 60 | 11  | 1           |
| ME     | post   | ant knowledge                | I think it is ok to touch a fire ant pile                      | no             | 54 | 11  | 4           |
| LE     | pre    | ant knowledge                | There is only one type of ant                                  | no             | 44 | 5   | 3           |
| LE     | post   | ant knowledge                | There is only one type of ant                                  | no             | 50 | 5   | 1           |
| ME     | pre    | ant knowledge                | There is only one type of ant                                  | no             | 69 | 2   | 2           |
| ME     | post   | ant knowledge                | There is only one type of ant                                  | no             | 70 | 1   | 0           |
| LE     | pre    | general care for environment | I help the environment on a daily basis                        |                | 13 | 25  | 14          |
| LE     | post   | general care for environment | I help the environment on a daily basis                        |                | 9  | 40  | 9           |
| ME     | pre    | general care for environment | I help the environment on a daily basis                        |                | 22 | 23  | 28          |
| ME     | post   | general care for environment | I help the environment on a daily basis                        |                | 7  | 49  | 14          |
| LE     | pre    | general care for environment | I put effort into taking care of native species                |                | 12 | 20  | 20          |
| LE     | post   | general care for environment | I put effort into taking care of native species                |                | 6  | 43  | 9           |
| ME     | pre    | general care for environment | I put effort into taking care of native species                |                | 18 | 41  | 14          |
| ME     | post   | general care for environment | I put effort into taking care of native species                |                | 9  | 56  | 5           |
| LE     | pre    | general care for environment | I try to protect the environment and ecosystems around me      |                | 8  | 33  | 11          |
| LE     | post   | general care for environment | I try to protect the environment and ecosystems around me      |                | 6  | 43  | 9           |
| ME     | pre    | general care for environment | I try to protect the environment and ecosystems around me      |                | 6  | 55  | 12          |
| ME     | post   | general care for environment | I try to protect the environment and ecosystems around me      |                | 4  | 61  | 5           |
| LE     | pre    | general feelings about ants  | Are ants fun to learn about?                                   |                | 15 | 22  | 16          |
| LE     | post   | general feelings about ants  | Are ants fun to learn about?                                   |                | 12 | 39  | 7           |
| ME     | pre    | general feelings about ants  | Are ants fun to learn about?                                   |                | 7  | 44  | 22          |
| ME     | post   | general feelings about ants  | Are ants fun to learn about?                                   |                | 4  | 59  | 6           |
| LE     | pre    | general feelings about ants  | Are ants important?  |                | 10 | 34  | 8           |
| LE     | post   | general feelings about ants  | Are ants important?  |                | 6  | 43  | 9           |
| ME     | pre    | general feelings about ants  | Are ants important?  |                | 6  | 49  | 18          |
| ME     | post   | general feelings about ants  | Are ants important?  |                | 7  | 55  | 8           |
| LE     | pre    | general feelings about ants  | Do you like ANTS?  |                | 29 | 16  | 8           |
| LE     | post   | general feelings about ants  | Do you like ANTS?  |                | 27 | 26  | 5           |
| ME     | pre    | general feelings about ants  | Do you like ANTS?  |                | 26 | 37  | 9           |
| ME     | post   | general feelings about ants  | Do you like ANTS?  |                | 14 | 47  | 9           |
| LE     | pre    | general feelings about ants  | Do you want to learn more about Ants?                          |                | 14 | 27  | 11          |
| LE     | post   | general feelings about ants  | Do you want to learn more about Ants?                          |                | 13 | 37  | 6           |
| ME     | pre    | general feelings about ants  | Do you want to learn more about Ants?                          |                | 6  | 54  | 13          |
| ME     | post   | general feelings about ants  | Do you want to learn more about Ants?                          |                | 7  | 53  | 10          |
| LE     | pre    | general impact knowledge     | Invasive species cost our government a lot of money in damages | yes            | 8  | 19  | 25          |
| LE     | post   | general impact knowledge     | Invasive species cost our government a lot of money in damages | yes            | 10 | 29  | 16          |
| ME     | pre    | general impact knowledge     | Invasive species cost our government a lot of money in damages | yes            | 16 | 24  | 33          |
| ME     | post   | general impact knowledge     | Invasive species cost our government a lot of money in damages | yes            | 8  | 45  | 17          |
| LE     | pre    | general impact knowledge     | The balance of the species in our ecosystem is important       | yes            | 9  | 30  | 13          |
| LE     | post   | general impact knowledge     | The balance of the species in our ecosystem is important       | yes            | 6  | 41  | 8           |
| ME     | pre    | general impact knowledge     | The balance of the species in our ecosystem is important       | yes            | 10 | 52  | 10          |

| school | survey | category                   | question   | correct_answer | no | yes | do_not_know |
|--------|--------|----------------------------|--|----------------|----|-----|-------------|
| ME     | post   | general impact knowledge   | The balance of the species in our ecosystem is important                       | yes            | 6  | 57  | 8           |
| LE     | post   | invasive species knowledge | Affecting one area of our ecosystem can have a rippling effects on other parts | yes            | 4  | 39  | 11          |
| LE     | pre    | invasive species knowledge | Ants interact with the ecosystem as much as any other animal                   | yes            | 7  | 20  | 23          |
| LE     | post   | invasive species knowledge | Ants interact with the ecosystem as much as any other animal                   | yes            | 8  | 39  | 10          |
| ME     | pre    | invasive species knowledge | Ants interact with the ecosystem as much as any other animal                   | yes            | 8  | 41  | 23          |
| ME     | post   | invasive species knowledge | Ants interact with the ecosystem as much as any other animal                   | yes            | 13 | 41  | 17          |
| LE     | post   | invasive species knowledge | Can you explain to your friend what native and invasive species are?           | yes            | 10 | 41  | 5           |
| LE     | post   | invasive species knowledge | I know how some invasive species are introduced                                | yes            | 10 | 38  | 7           |
| LE     | post   | invasive species knowledge | I know how some invasive species can harm the environment                      | yes            | 8  | 43  | 4           |
| LE     | pre    | invasive species knowledge | I know what a native species is  | yes            | 26 | 16  | 10          |
| LE     | post   | invasive species knowledge | I know what a native species is  | yes            | 8  | 44  | 4           |
| ME     | pre    | invasive species knowledge | I know what a native species is  | yes            | 21 | 43  | 9           |
| ME     | post   | invasive species knowledge | I know what a native species is  | yes            | 6  | 62  | 1           |
| LE     | pre    | invasive species knowledge | I know what an Invasive species is   | yes            | 27 | 16  | 9           |
| LE     | post   | invasive species knowledge | I know what an Invasive species is   | yes            | 8  | 44  | 5           |
| ME     | pre    | invasive species knowledge | I know what an Invasive species is   | yes            | 26 | 31  | 16          |
| ME     | post   | invasive species knowledge | I know what an Invasive species is   | yes            | 7  | 61  | 1           |
| LE     | pre    | invasive species knowledge | Invasive ants compete with native ants for food and resources                  | yes            | 9  | 20  | 21          |
| LE     | post   | invasive species knowledge | Invasive ants compete with native ants for food and resources                  | yes            | 5  | 41  | 11          |
| ME     | pre    | invasive species knowledge | Invasive ants compete with native ants for food and resources                  | yes            | 9  | 36  | 27          |
| ME     | post   | invasive species knowledge | Invasive ants compete with native ants for food and resources                  | yes            | 8  | 49  | 14          |
| LE     | pre    | invasive species knowledge | Protecting native ants is important for the environment                        | yes            | 4  | 27  | 21          |
| LE     | post   | invasive species knowledge | Protecting native ants is important for the environment                        | yes            | 8  | 43  | 7           |
| ME     | pre    | invasive species knowledge | Protecting native ants is important for the environment                        | yes            | 9  | 45  | 19          |
| ME     | post   | invasive species knowledge | Protecting native ants is important for the environment                        | yes            | 5  | 54  | 10          |