

ABSTRACT

All species in genus *Formica*, or only some species in the genus?

Size-task association has been studied in many different animals. ^{This} this paper specifically looks at the relationship between head width and task association in *Formica* ants. This genus of ants lacks discrete morphological subcastes and therefore do not follow a strict pattern for task specialization. Some considerations ~~that need to be~~ acknowledged ^{is} is that ~~these species may~~ ^{There} experience task switching, which could make the data more difficult to interpret, ^{There} there were not equal sample sizes collected for each species, and ~~that there are~~ ^{were} both mound-building and subterranean species ~~being~~ ^{were} studied. Overall, it was found that in the mound-building groups ants with smaller head widths were more likely to be assigned to the honeydew collecting task rather than nest building or protein foraging. Subterranean groups did not seem to have a strong association with head width to any of the tasks. This could indicate that in mound-building groups, selection favors species with task specialization, ^{These} so these species have a stronger size-task association leading them to have a stronger colony overall.

INTRODUCTION

Task association based on body size has been studied in multiple different animal societies. Some species have discrete morphological worker subcastes which are used to help divide labor in order to protect the colony. Social insects ^{such as} ~~like~~ thrips, aphids, termites, stingless bees, and some ants break into size-based morphs (Richards 2020). This allows smaller workers to be tasked with the less intense jobs, while the bigger workers take on tasks with more physical requirements. By having task specialization distinguished it allows workers to learn their specific task and avoid the cost of task switching, which is thought to increase efficiency of the colony (Chittka and Muller 2009; West 2022). Some insects do not have discrete subcastes, which many people would assume meant that their colony would run less efficiently; however, in ~~some~~ cases

they avoid task switching even though it increases efficiency?

Potentially rewrite this sentence to read better. → Some may assume that insects without discrete subcastes would have less efficient colonies;

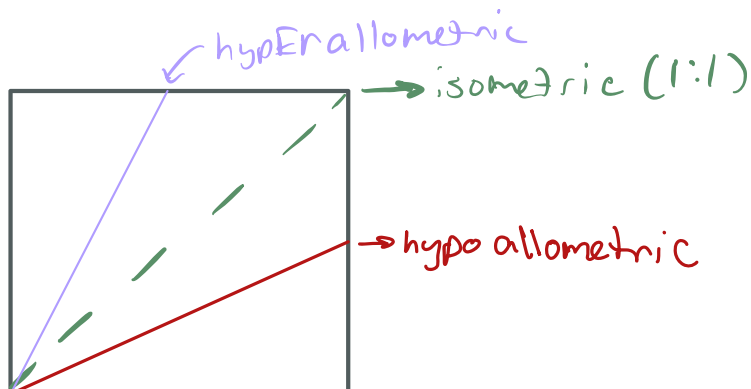
where there is a high variance in worker size, it has been shown that there is still an association between worker size and task specialization (Grüter et al. 2011). This suggests that even if there are not specific subcastes, that some species still determine tasks assignments based on size.

There are over 15,100 species of ants (Hymenoptera: Formicidae) in the world (Wong and Guenard 2017). Looking at ants specifically, the genus *Formica* have a high level of natural worker size variation while lacking discrete morphological worker subcastes. This genus is found in North America, Europe, and Asia and are usually found in sparse to medium-dense mature forests, along the edges of the forest, or in ephemeral open patches (Sundström et al. 2005). Within this genus there are two groups: mound-building and subterranean. Mound-building species are facultative social parasites that build mounds on top of their underground nests. Subterranean species are not socially parasitic and they can sometimes build loose dirt mounds above their nests, but are usually entirely underground (Goryunov 2015).

Using a genus of ants with a high level of variation allows us to test whether there is an association between task specialization and worker size whenever there is not discrete subcastes assigned. A study showed that there is linear allometric and some isometric scaling relationships between body size and task assignment (Tawdros et al. 2020). Taking this a step further, we are testing whether head width measurements specifically have an impact on task assignment, rather than looking at body size as a whole. The main goal of this paper is to determine whether there is an association between head width size and task across species of *Formica* ants.

MATERIALS AND METHODS

Collection



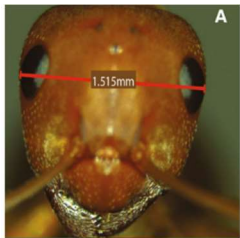
"A study showed..."
is ambiguous.
What study?
How did they show this?

↓
What do you mean by linear allometric?

Data was collected in June-August of 2017 throughout Alberta, Canada. Ten species of *Formica* ants were observed and collected at ten different locations. There were three tasks that were focused on while collecting: honeydew collectors (HC), nest builders (NB), and protein foragers (PF). Honeydew collectors tend to aphids or other plants and they were selected while performing this task. Nest builders carry the materials to build the nests (pine needles, wood chips, dirt, pebbles) and then were selected while building the nest. Protein foragers search for prey and can be found carrying other insects or spiders (Tawdros et al. 2020).

Head Measurements

A Leica S8AP0 microscope with Leica DMC2900 camera attached to imaging software was used to photograph the head in 25x magnification. Measurements of each specimen were taken to one-thousandth of a millimeter measuring the widest point across the eyes with the Leica Application Suite version 4.6.2.



↙ nice!

Figure 1: Example of head width

Identifying Species

Genetic sequencing (RADseq) was used to identify the species that had been captured. Two species in *F. Rufa* group were unable to be identified so they are referred to as, '*F. rufa* sp. #1' and '*F. rufa* sp. #2'. These species were separated into mound-building and subterranean groups. Mound-building groups included: *F. Aserva*, *F. Dakotensis*, *F. Neorufibarbes*, *F.*

Obscuricentris, *F. Ulkei*, and *F. Rufa Sp. #2*. The subterranean groups consisted of *F. Glacialis*, *F. Neoclara*, *F. Podzolica*, *F. Rufa Sp. #1*.

Statistical Tests

A boxplot was made to demonstrate the relationship between head width and task for each species, as well as one with the total head widths and task assignments. A chi squared test was performed to determine whether the relationship between head width and task was significant. To

further understand the relationship between head width and task association, a multinomial logistic regression was used. This test was performed under the assumptions that the model was specified correctly with no extraneous variables, the cases were independent of each other, and that there is no multicollinearity between the individual variables. The *lme4* package in R was used to

perform the multinomial function. We specify that task be modeled as a function of head width. A logit model was made to demonstrate the ratio of the probability, or relative risk. Another multinomial logistic regression was performed testing the effects of both head width and species as a function of task.

This was performed to determine the impact that species has on size-task allocation.

RESULTS $\chi^2 = \sum \frac{(o_i - e_i)^2}{e_i}$ Chi square formula: Chi square tests compare observed results with expected results to examine whether variables are independent or not. What value(s) did you use for e_i (the expected)? Average head width?

Formica Aserva, *F. Obscuriventris*, *F. F. Ulkei*, *F. Rufa Sp. #1*, and *F. Rufa Sp. #2*, all show a statistically clear difference a significant difference between ant head width of those selected for the honeydew collecting task when compared to the nest builders and protein foragers. *F. Dakotensis* and *F. Neorufibarbes* also demonstrate that there is a significant difference between honeydew collector head width and the other tasks. This difference is not as significant as *F. Aserva*, but it follows the same trend. *F. Glacialis*, *F. Neoclara*, and *F. Podzolica* do not show any indications that head width is a determinant of task association. The chi-squared test showed a p-value of

0.0025. Overall, there is a relationship between head width and task association in seven of the ten species that were tested (Figures 1-12).

— also reference these when you first mention them.

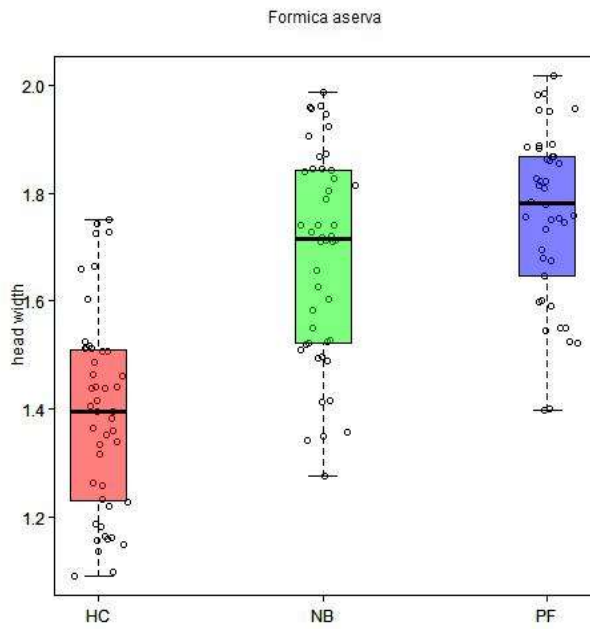


Figure 2: Boxplot depicting relationship between head width and task in *F. Aserva*.

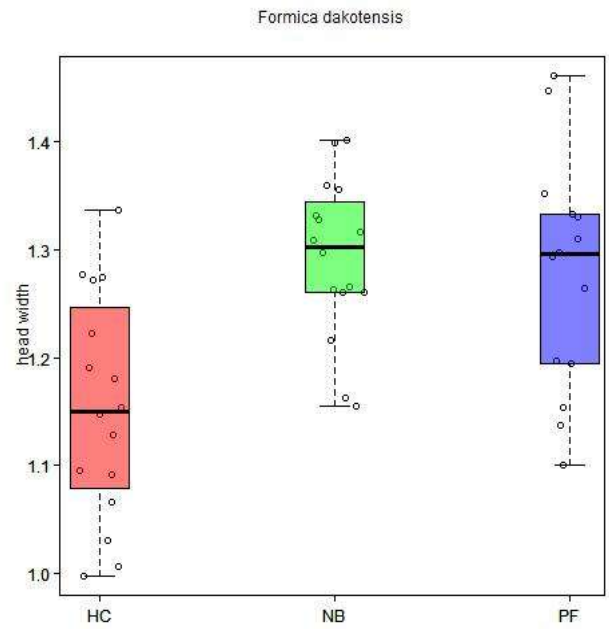


Figure 3: Boxplot depicting relationship between head width and task in *F. Dakotensis*.

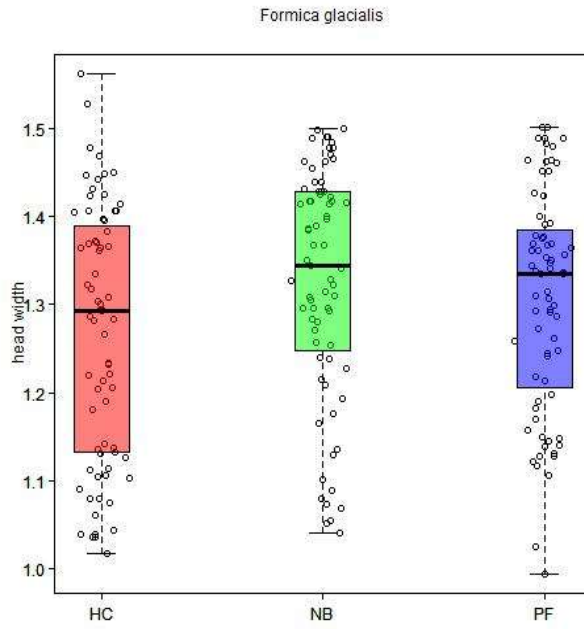


Figure 4: Boxplot depicting relationship between head width and task in *F. Glacialis*.

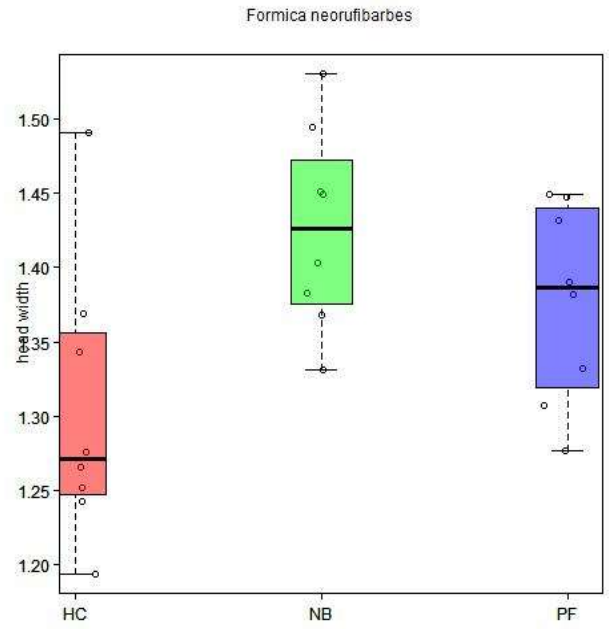


Figure 6: Boxplot depicting relationship between head width and task in *F. Neorufibarbes*.

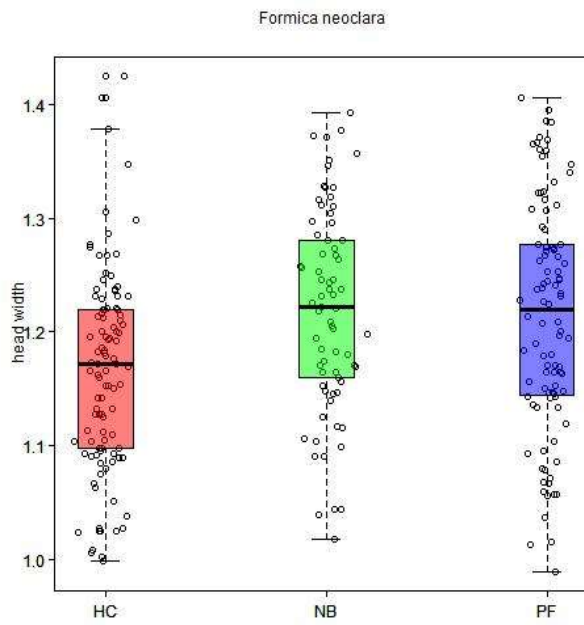


Figure 5: Boxplot depicting relationship between head width and task in *F. Neoclara*.

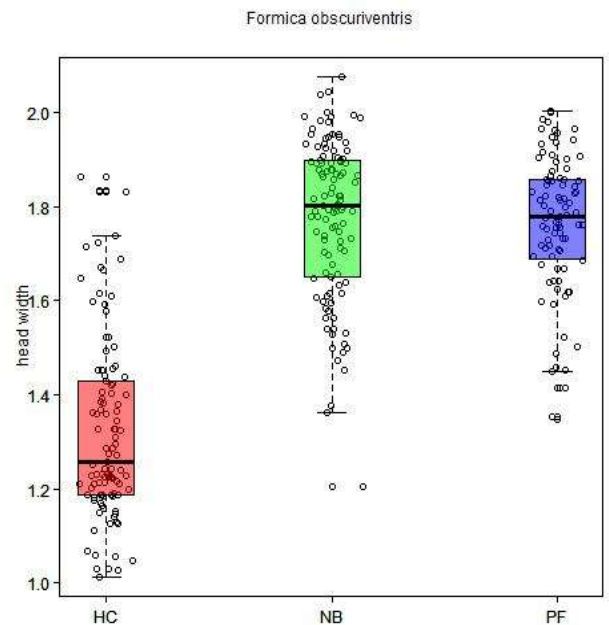


Figure 7: Boxplot depicting relationship between head width and task in *F. Obscuriventris*.

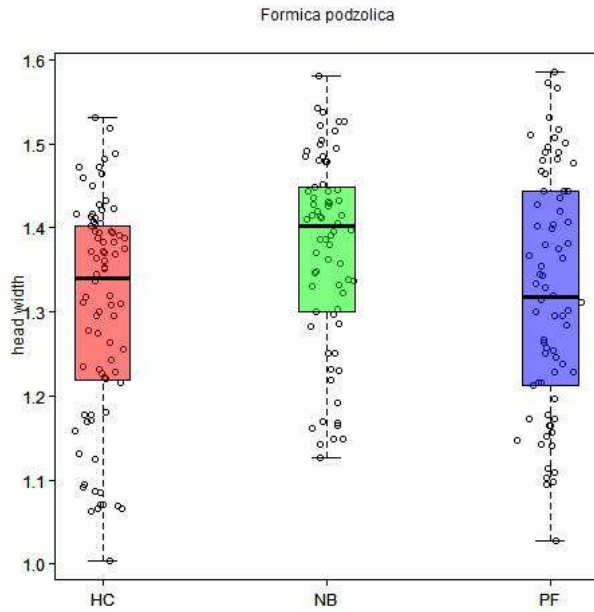


Figure 8: Boxplot depicting relationship between head width and task in *F. Podzolica*.

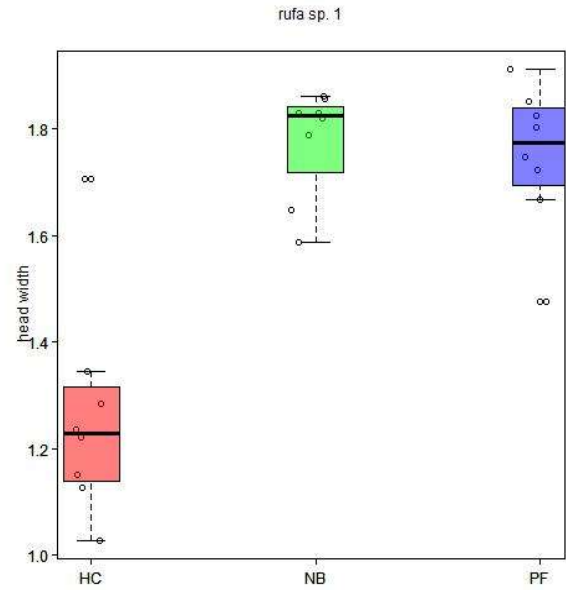


Figure 10: Boxplot depicting relationship between head width and task in *F. Rufa Sp. #1*.

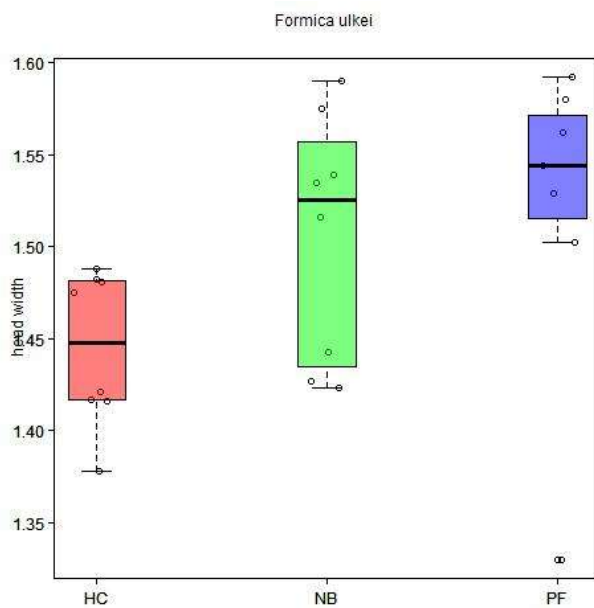


Figure 9: Boxplot depicting relationship between head width and task in *F. Ulkei*.

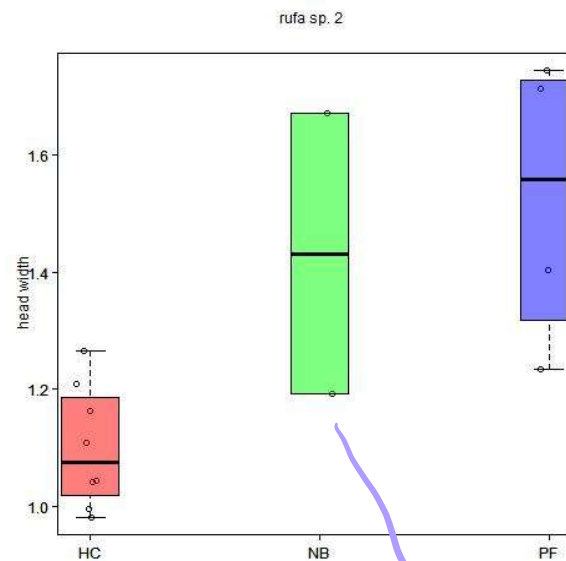


Figure 11: Boxplot depicting relationship between head width and task in *F. Rufa Sp. #2*.

why no
error
bars
(address this?)
maybe

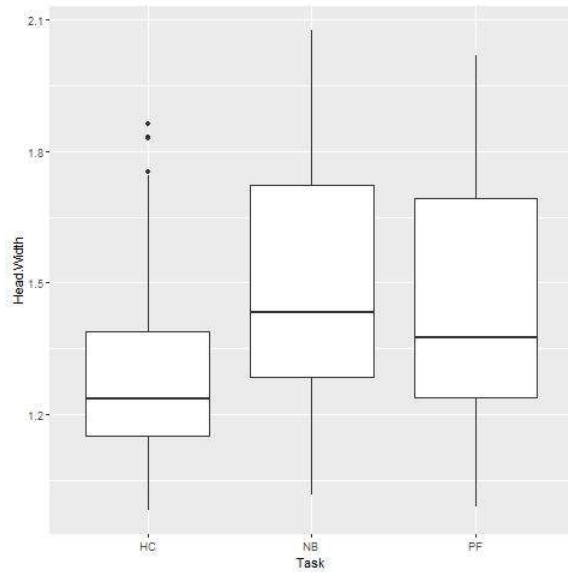


Figure 12: Boxplot depicting the relationship between all head widths and task assignment.

The multinomial logistic regression using task as a function of head width found that the coefficient ^{of} NB to HC to be 4.26 with a standard error of 0.35. The coefficient ^{of} PF to HC was 3.62 with a standard error of 0.35. The confidence intervals for NB was (3.57, 4.95), while PF was (2.94, 4.31). There was a total of 454 collections for HC, 515 for NB, and 515 for PF. The response level of each task was predicted using the ggeffects function in R. Figure 13 was created to depict the predicted probability of each task with the ribbons showing the lower and upper confidence limits.

task	coefficient	stand error	confidence interval
NB-HC	4.26	0.35	...
...
...

may be easier to read as a table

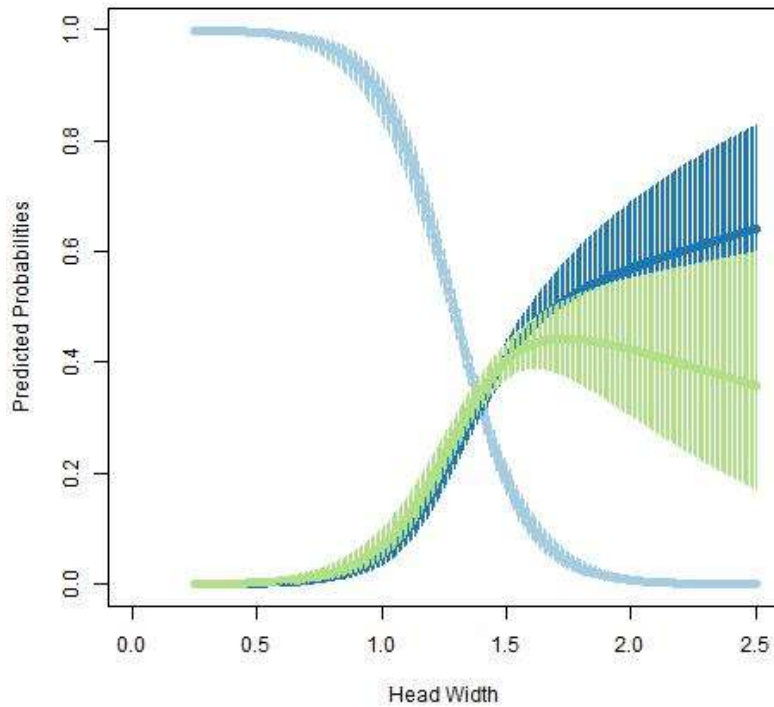


Figure 13: Graph showing the predicted values of which task will be selected depending on head width with ribbons showing the lower and upper confidence limits.

also a maybe table?

The AIC of the multinomial logistic regression that only used head width and task was 2621.004 with a residual deviance of 2613.004. The AIC of the regression that included species was 2522.92 with a residual deviance of 2478.92. In the regression that included species the coefficients for head width for NB was 7.16 with a standard error of 0.53. The coefficients for head width for PF was 6.59 with a standard error of 0.51. The following species had a slightly lower coefficient for PF than NB and a lower standard error: *F. Glacialis*, *F. Neorufibarbes*, and *F. Podzolica*. The *F. Dakotensis*, *F. Obscurieventris*, and *F. Ulkei* species all had lower coefficients, but had a higher standard error than PF. *F. Neoclara*, *F. Rufa Sp. #1*, and *F. Rufa Sp. #2* all had higher coefficients and lower standards of error than NB.

DISCUSSION

The outliers in the head widths within each task makes it difficult to accurately assess the size-task association of the *Formica* ants on the boxplots, but by looking at the interquartile range it is easier to see the differences in size-task association. A p-value of 0.0025 was found which means that there is a statistically clear significant difference when comparing head width to task assignments. Despite the error bars making the values seem less significant, the values depicted in the boxplots seem to follow the trend that mound-building species have a stronger association between the ants with smaller head widths being assigned to the honeydew collecting task. When

thinking about assigning tasks, it would make sense that the smaller ants get the least physically demanding job. In groups where there are more taxing jobs which requires larger heads, such as MB, it would make more sense that 'x' occurs because of 'x'. In groups that are mound-building where there are taxing jobs that often require ants with larger heads, then it makes sense that these species would assign tasks based on head width more frequently than the subterranean groups. The association in *F. Dakotensis* and *F. Neorufibarbes* were not as strong as the relationship found in the other mound-building species.

This could be due to the variance in sampling size. There was not an even collection of data from each species, so that could have an impact on providing sufficient data to draw conclusions.

Another possibility would be that these species did not build as big of mounds as the other species, so ants with smaller heads could still complete the task. The likely the most possible explanation would be that head width specifically may not be the determinate of task assignment in those species. This could be the case in any of the subterranean groups as well. why?

The coefficients for the relative risk of task and head width found that PF to HC was more accurate than NB to HC. Since they both have a standard error of 0.35, the smaller coefficient in the PF makes it the more precise measurement. This means that each additional increase in head width the log odds of choosing NB is 3.62 chances higher, while the log odds of

Yes, I agree but you assessed head size. does bigger heads = stronger ant? does ant strength come from the head or are we assuming an isometric relation b/w head size & body size w/in this genus?

"When thinking about it it makes sense" What do you think about that makes it make sense?

choosing PF is 4.26 chances higher. Figure 13 shows the predicted values of a certain task being selected based on head width with upper and lower confidence levels. This shows that HC has a much higher chance of being assigned if the head width is small compared to NB or PF. As the head width increases, the chances of getting assigned either NB or PF increases, while the likelihood of HC decreases. This shows that in most cases there is an association between head width and task assignments and that it is demonstrated across different taxa suggesting that this could be an evolutionary change that has evolved to help the ants protect their colonies.

To further consider the impact that species may have on this relationship we performed a multinomial logistic regression using both head width and species as a function of task. By looking at the AIC values between this multinomial logistic regression and the one that only uses task and head width, it shows that this model is a better fit for the data. The AIC of this model is 2522.92 with residual deviance of 2478.92 which is lower and therefore more accurate than the previous model which had an AIC of 2621.004 with residual deviance of 2613.004. *F. Glacialis*, *F. Neorufibarbes*, and *F. Podzolica* had the lowest coefficient as well as the lowest standard error suggesting that they were the most precise. *F. Glacialis* and *F. Podzolica* are both subterranean species, but *F. Neorufibarbes* is a mound-building species. These are all species that had smaller sampling sizes, which could be why the results are ~~showing that they are the most~~ ^{more} precise. One thing that would need to be considered is to test larger sample sizes of these species to see if the results match on larger populations.

Further research would warrant larger sample sizes to see...

There is some variation in the results, but most of them followed the trend that subterranean groups did not have as strong of a relationship between head width and task association. In all of the mound-building groups it was found that ants with smaller head widths were more commonly assigned to the honeydew collecting task rather than nest building or

Why could this be

protein foraging. There are some cases where ants with smaller head widths are assigned to other tasks, but it seems that there are relatively few with larger heads that are assigned to honeydew collecting. This suggests that smaller ants may be able to step up to larger tasks, but most of the larger headed ants are needed for the physically demanding tasks and would not be assigned to the honeydew collecting task.

Comments

- is sexual dimorphism a thing w/ ants
✗ would it change the results if taken into account?
- all data was collected from Canada, so
would the results be different or the same
if data was collected somewhere w/ a dif. climate?
- perhaps bigger head width in subterranean groups
also has to do w/ more than task association
or strength. They are underground ✗ will need strong
heads to dig tunnels

REFERENCES

- Chittka, L., and H. Muller. 2009. Learning, specialization, efficiency and task allocation in social insects.
- Goryunov, D. N. 2015. Nest-building in ants *Formica exsecta* (Hymenoptera, Formicidae). *Entmol. Rev.* 95:953–958.
- Grüter, C., C. Menezes, V. Imperatriz-Fonseca, and F. Ratnieks. 2011. A morphologically specialized soldier caste improves colony defense in a neotropical eusocial bee.
- Richards, M. H. 2020. Size and shape in *Formica* ant workers. *Insect. Soc.* 67:457–458.
- Sundström, L., P. Seppä, and P. Pamilo. 2005. Genetic population structure and dispersal patterns in *Formica* ants — a review. *Annales Zoologici Fennici* 42:163–177. Finnish Zoological and Botanical Publishing Board.
- Tawdros, S., M. West, and J. Purcell. 2020. Scaling relationships in *Formica* ants with continuous worker size variation. *Insect. Soc.* 67:463–472.
- West, M. 2022. A Cross-Species Comparison of Task Partitioning in Ants Lacking Discrete Morphological Worker Subcastes. UC Riverside.
- Wong, M. K. L., and B. Guenard. 2017. Subterranean ants: summary and perspectives on field sampling methods, with notes on diversity and ecology (Hymenoptera: Formicidae).