

Temperature and male traits outweigh female traits in driving dung beetle reproductive behavior

Introduction

Tunneling dung beetles influence critical soil processes such as water infiltration and nutrient cycling. However, dung beetle behavior varies with abiotic and biotic conditions^{1,2}, which can subsequently alter the ecosystem services they provide.

For example, warming can cause dung beetles to produce more numerous but lighter brood balls and to bury them more deeply³. Smaller brood balls may result in lower survivorship and smaller offspring^{4,5}. Increased temperatures and temperature fluctuation will also negatively impact offspring size⁶. However, data on how the combination of warming and traits that influence dung beetle behavior and reproduction come from few species and typically only with females, which limits predictions at broader scales.

Phanaeus difformis is a common tunnelling species in sandy soils of Texas. Preliminary work suggests both sexes are needed for brood ball construction and provisioning⁷, but how sex-specific traits and warming influence reproductive behavior is unclear.

Experimental Design



Fig. 1: Experimental setup, Brackenridge Field Laboratory

7-gallon buckets ($n=60$) were filled to a total depth of 40cm, leaving 8cm from the surface of the soil to the brim of the bucket. We used ceramic heat lamps to create gradients in soil temperature according to May 2023 data from the Texas Soil Observation Network. Half the buckets were additionally warmed to be 1 degree C higher than control buckets at 20cm depth.



Fig. 2: *Phanaeus difformis* pair, male (left) & female (right)

One pair of *P. difformis* (fig. 2) per bucket were given 400g of fresh-frozen cow dung every 5 days, for a duration of 15 days with a total of 5 trials. Beetle pre-treatment weight and number, depth and weight of brood balls were recorded (fig. 5).

Data Analysis

Depth \leftarrow lmer(brood ball depth ~ male weight + female weight + temperature + (1 | trial number) + (1 | pair ID))

Weight \leftarrow lmer(brood ball weight ~ male weight + female weight + temperature + (1 | trial number) + (1 | pair ID))

Results

A total of 13 beetle pairs produced 24 brood balls

Brood ball depth

- Warming caused dung beetles to bury brood balls deeper ($p=0.0261$)
- Male weight had a marginally significant positive effect on brood ball depth ($p=0.0599$)(fig.3); brood balls were buried 1.3cm deeper for every 100mg increase in male weight

Brood ball weight

- Heavier males had a marginal positive effect ($p=0.0578$) on brood ball weight (fig. 4); for every 1mg increase in male weight, brood ball weight increased by 31.8mg
- Female weight was not significantly associated with brood ball weight or brood ball burial depth.

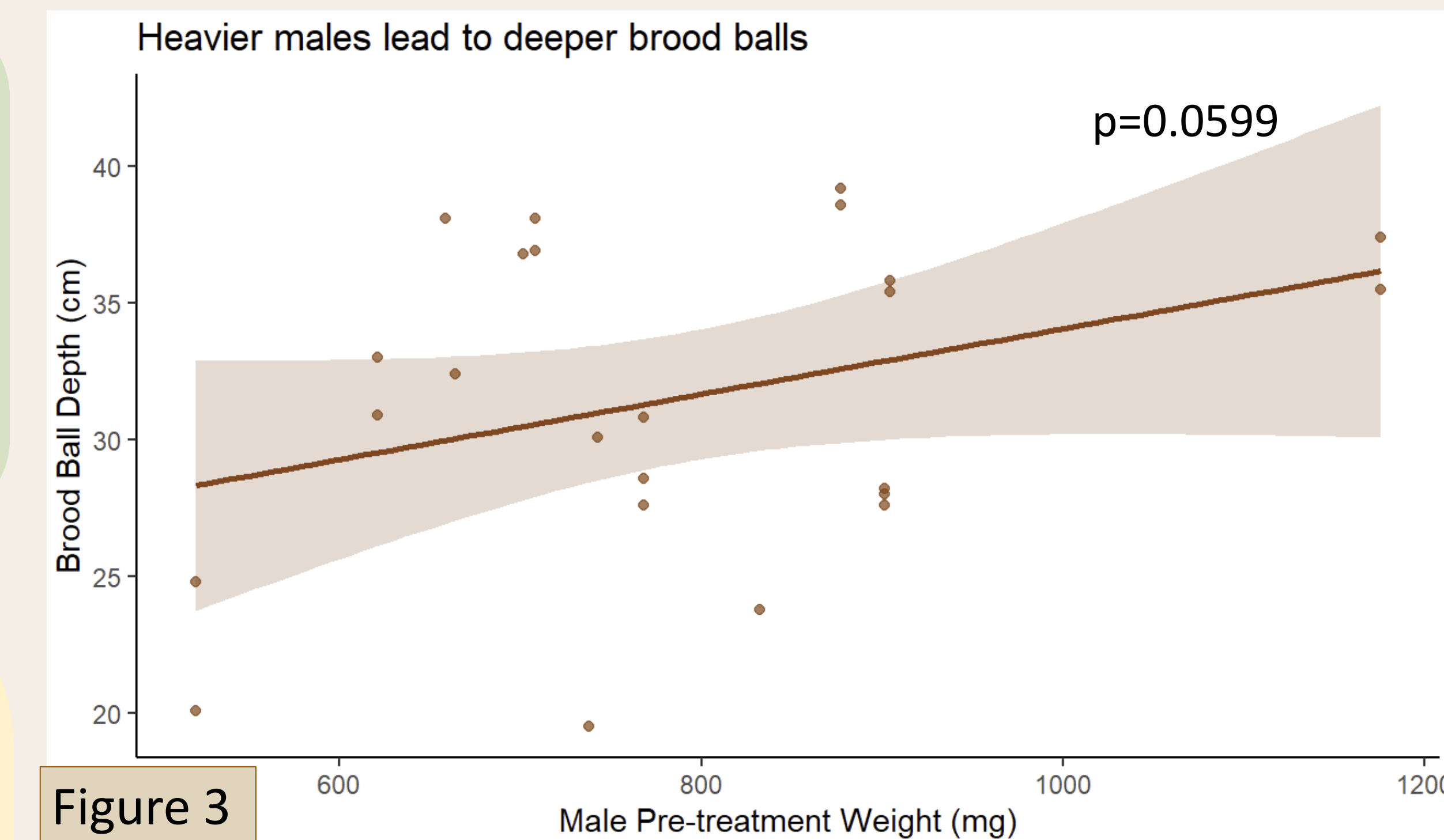


Figure 3

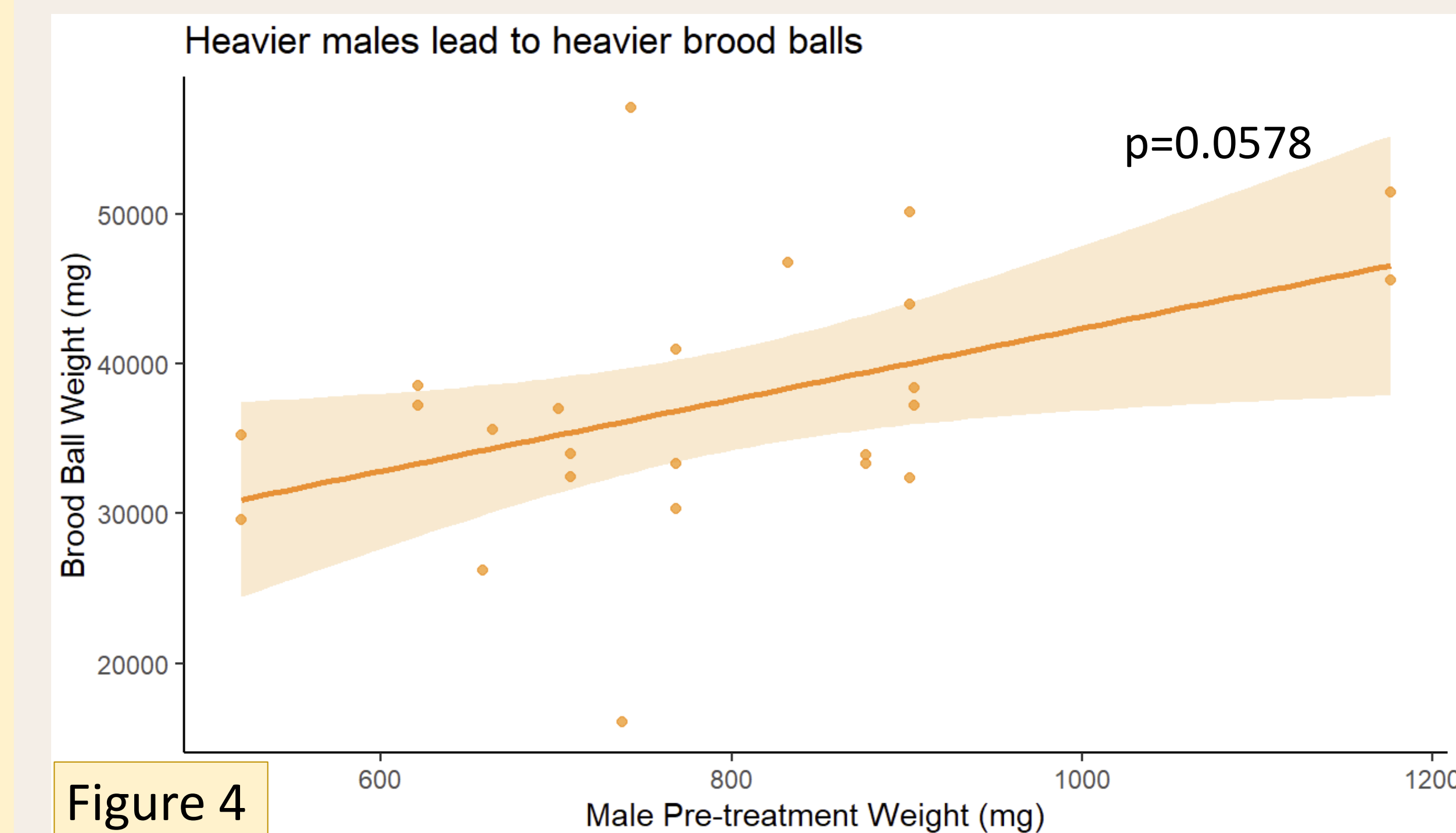


Figure 4



Fig. 5: Constructed Brood Ball

Future Work

This research is part of a larger study investigating how parasitism and warming affect dung beetle ecosystem services.

****Please get in touch if you're interested in collaborating!****

Discussion

Warming caused dung beetle pairs to bury brood balls deeper, consistent with findings from other species³. Deeper burial should help mitigate negative effects of climate warming on dung beetle reproduction, given that warmer incubation temperatures lead to reduced fitness and smaller offspring⁶.

Unexpectedly, we found female body weight was not associated with brood ball size or burial depth, which contrasts with current literature⁸. Male weight was marginally associated with brood ball metrics, which aligns with research conducted on other tunneling species where beetle size was a significant factor^{1,8}.

Our preliminary results suggest there may be sex-specific impacts on critical brood ball metrics that could influence offspring survival or fitness and associated ecosystem services. Additional research may be needed to address whether warming influences these sex-specific effects.

Works Cited

- Gregory, N., Gomez, A., de S. Oliveira, T.M.F., & Nichols, E. (2015). "Big dung beetles dig deeper: trait-based consequences for faecal parasite transmission". *Intl. Journal for Parasitology*, **45**, 101-105.
- Thotagamuwala, A., Noriega, J.A., Webb, S., Weston, P., Doube, B.M., Caron, V., Gleeson, P., Forgie, S.A., Favila, M.E., Burgess, G. & Gurr, G.M. (2023). "Rearing dung beetles (Coleoptera: Scarabaeidae): Identifying knowledge gaps and future challenges". *Entomologia Generalis*, 1-19.
- Kirkpatrick, W.H. & Sheldon, K. (2022). "Experimental increases in temperature mean and variance alter reproductive behaviors in the dung beetle *Phanaeus vindex*". *Biology Letters*, **18**, 1-6.
- Pettersen, A.K., White, C.R., Bryson-Richardson, R.J. & Marshall, D.J. (2020). "Linking life-history theory and metabolic theory explains the offspring size-temperature relationship". *22(3)*: 518-526.
- Mamantov, M.A. & Sheldon, K.S. (2020). "Behavioural responses to warming differentially impact survival in introduced and native dung beetles". *Journal of Animal Ecology*, **90**, 273-281.
- Fleming, M.J., Carter, A.W., Sheldon, K.S. (2021). "Dung beetles show metabolic plasticity as pupae and smaller adult body size in response to increased temperature mean and variance". *Journal of Insect Physiology*, **131**, 1-6.
- Price, D.L., May, M.L. (2009). "Behavioral ecology of *Phanaeus* dung beetles (Coleoptera: Scarabaeidae): Review and new observations". *Acta Zoologica Mexicana*, **25(1)**: 211-238.
- Lee, J.M. & Peng, Y.S. (1981). "Influence of adult size of *Onthophagus gazella* on manure pat degradation, nest construction, and progeny size. *Environmental Entomology*, **10**, 626-630.