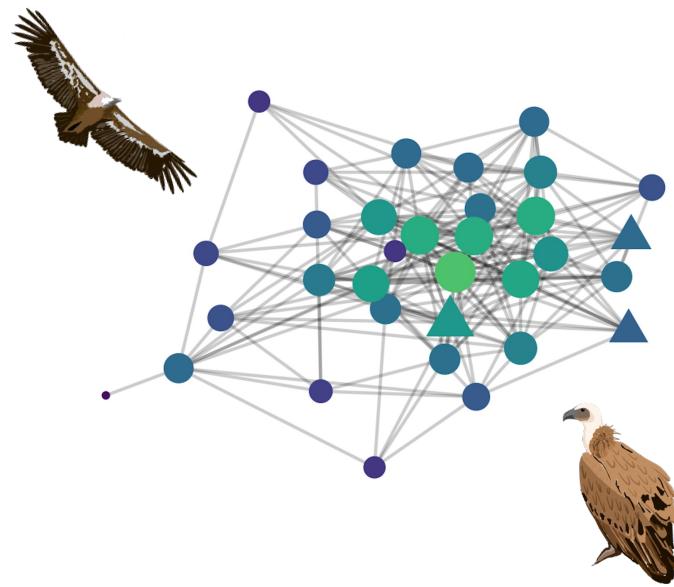
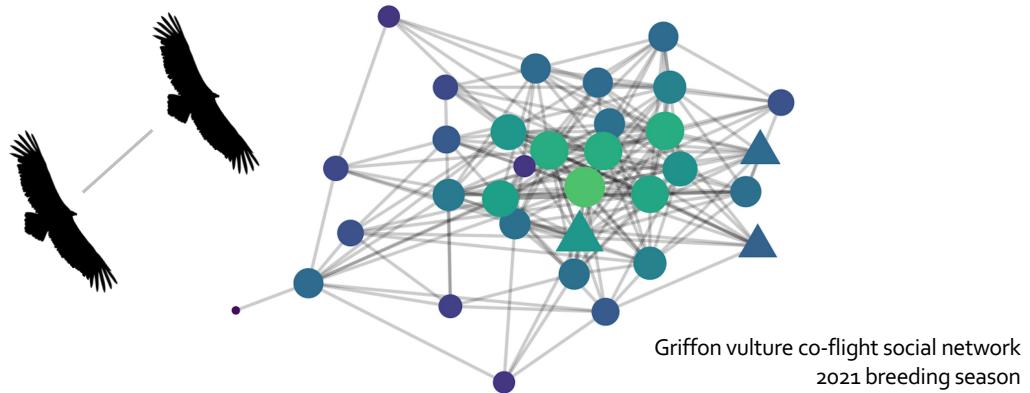


Effect of spatial phenotype on social centrality across seasons and social situations in an avian scavenger

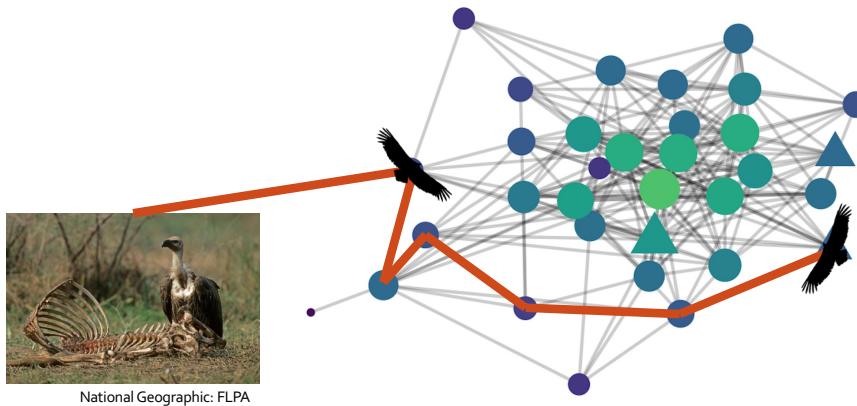
Kaija Gahm
Pinter-Wollman Lab, UCLA
SoCAB, 2024-02-25



Social networks illustrate the connections between individuals in a population

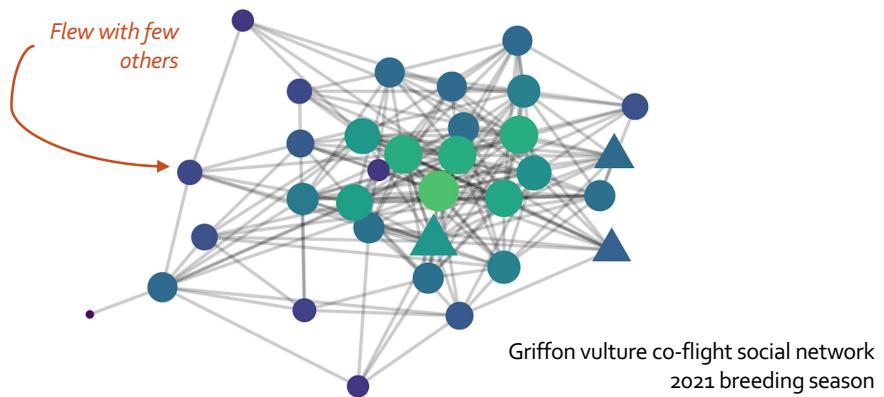


Network connections can promote disease or information spread

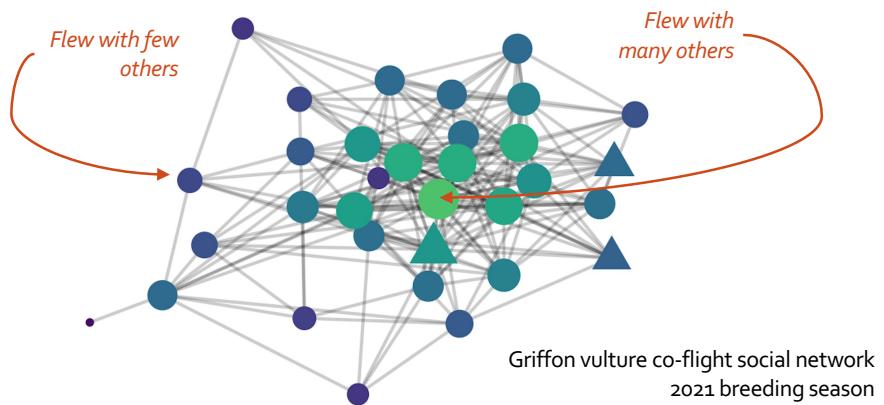


And therefore, an individual's centrality in a social network can affect their likelihood of receiving information or contracting disease.

What determines social centrality?



What determines social centrality?



What determines social centrality? > Individual traits

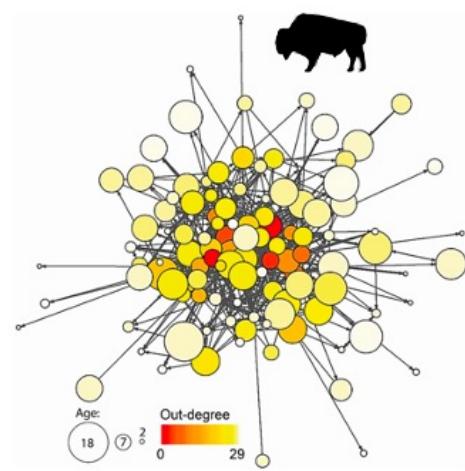


Fig. 2. Wyman et al. 2021. *J. Mammal.*

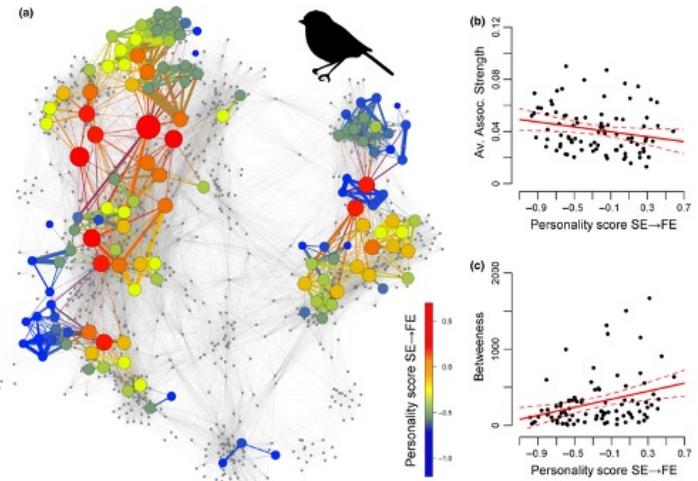


Fig. 1. Aplin et al. 2013. *Ecology Letters* 6

Movement behavior is another individual trait that can shape social interactions.



Karsten Heuer



Simon Ripperger



Vivek Khanzode

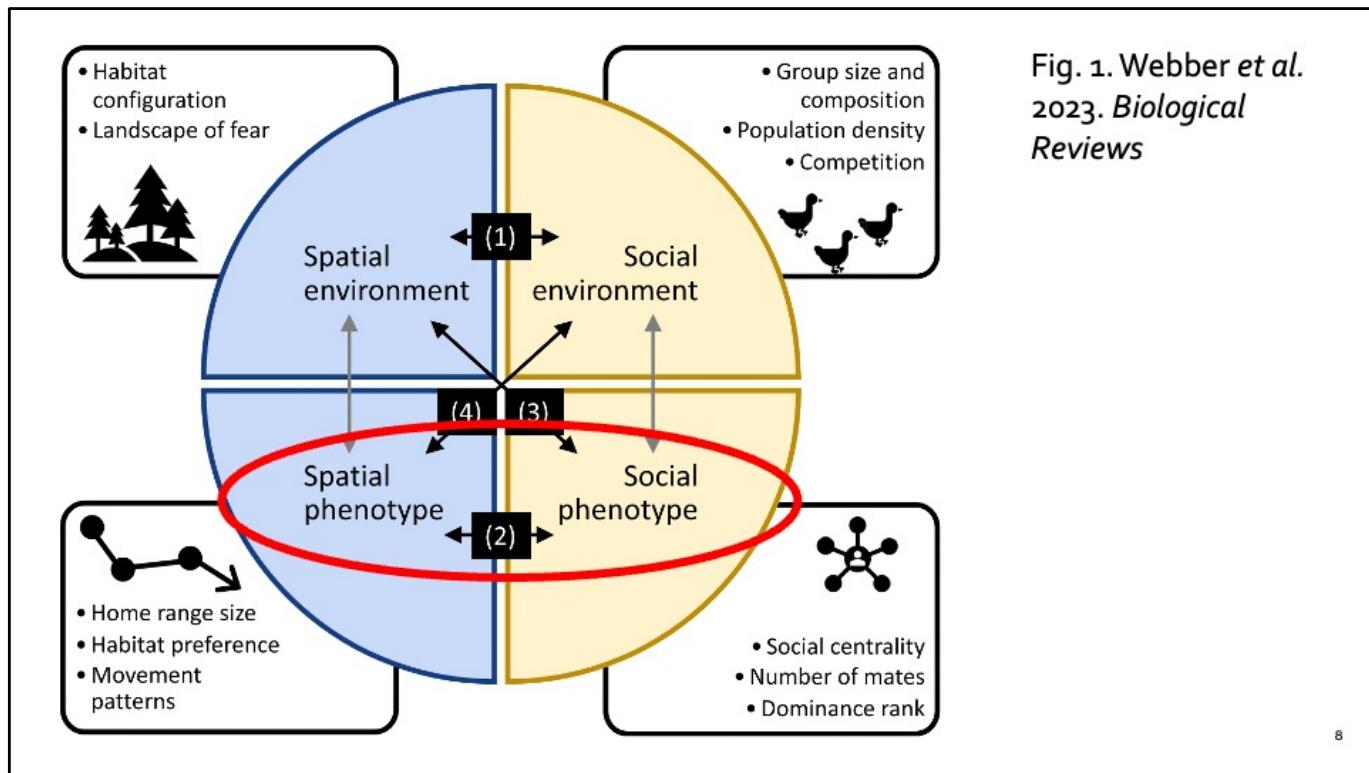


Fig. 1. Webber et al.
2023. *Biological
Reviews*

8

In a review on this topic, Webber et al introduce the concepts of **spatial phenotype** (which describes how an individual moves and uses space); and **social phenotype**, which describes an individual's social centrality and how it relates to its conspecifics.

Study system

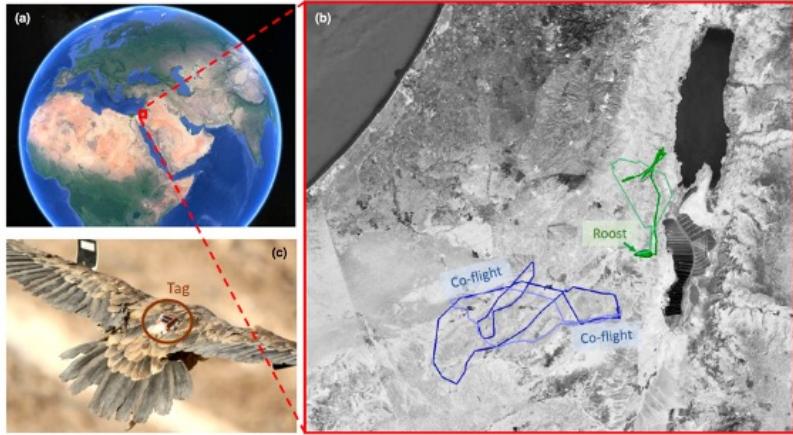


Fig. 2. Sharma et al. 2023. *Ecology and Evolution*



Photos by Noa Pinter-Wollman

9

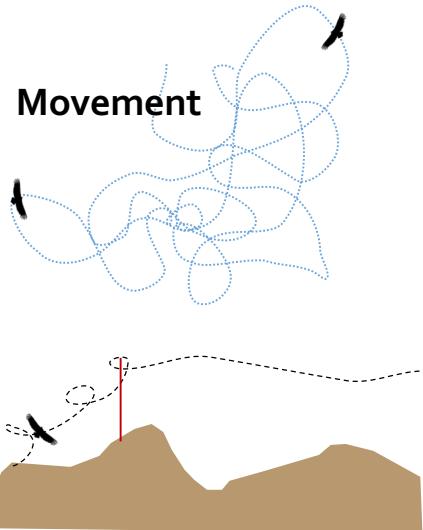
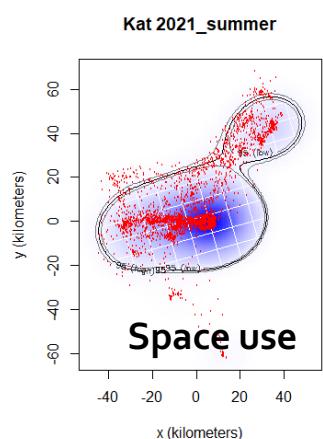
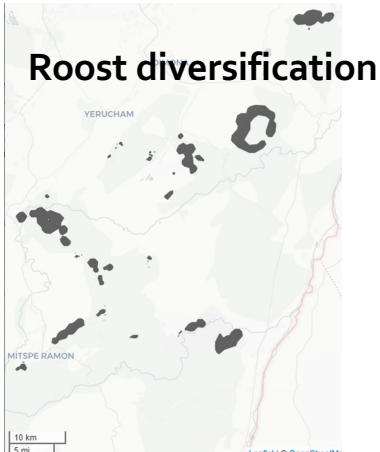
"Like most other vulture species, griffons are large obligate scavengers (2.4-2.7 m wing span, 6-10 kg mass), that scan large areas through soaring flight ²⁹. Once food is detected, individuals converge from vast areas, attracted by other vultures gliding to a carcass ³⁰. Multiple individuals land and feed simultaneously in a scrambling feast, facilitating poisonings as mass events. Griffons roost and nest in communal roosts, which can serve as information centers for locating resources ³¹, but may also contribute to disease spread among individuals. Roosts are also breeding colonies where pairs will incubate their single egg for 55 days, and rear the chick for at least 100 days until fledging. The chick will take 4-6 years to mature and start breeding." (Nili Anglister, PhD Progress Report)

A majority of the vultures are tagged with GPS transmitters



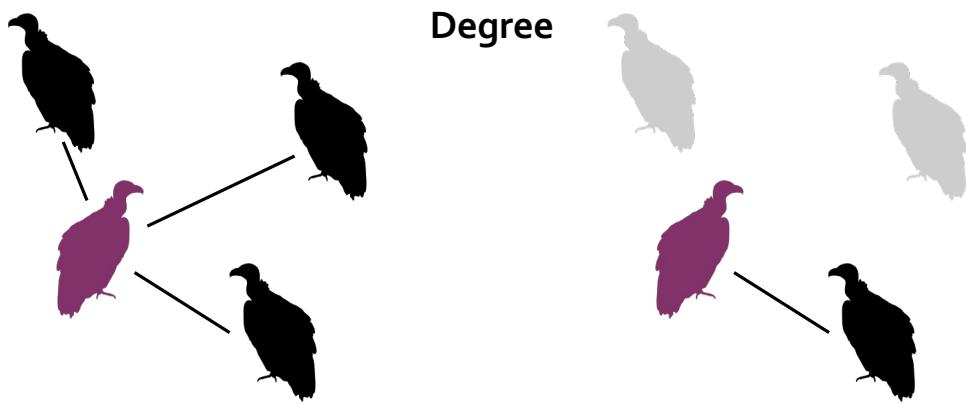
- INPA and the Spiegel lab have done so much work to fit a very large percentage of the population with solar-powered GPS tags.
- 50 grams
- Teflon harness
- Solar powered. Communicates via cellular networks, for real-time tracking. Can store a large amount of data on board.
- 2020-2021 about 100 tags deployed. More have been deployed since. Can theoretically last for up to 3 years. 80-90% of the population. Give fixes every 10 minutes, but can be set to give fixes more frequently.

Measuring spatial phenotype

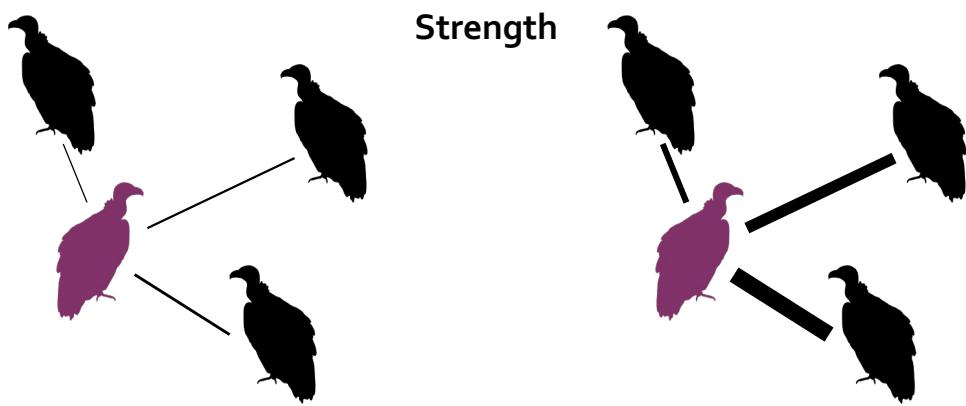


Measuring social centrality

Degree



Measuring social centrality



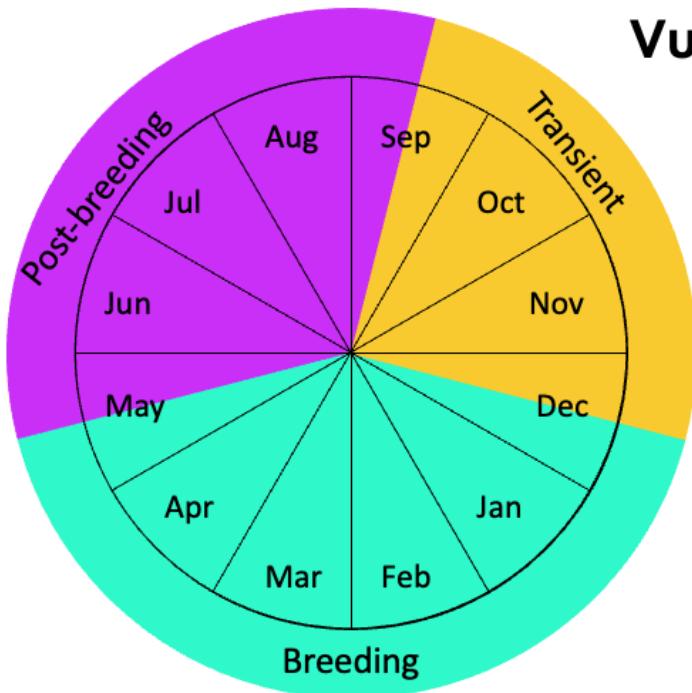


Griffon vultures interact in several behavioral situations

14

Griffon vultures interact socially with conspecifics in several behavioral situations.

They interact in flight when they fly close to each other, such as these two individuals here. Sometimes they coordinate their flight and move through the landscape together for longer periods, such as these individuals moving through a thermal together.



Vulture behavior changes with the seasons

Breeding

- Incubation shifts
- Nest failures
- Cooler weather

Post-breeding and Transient seasons

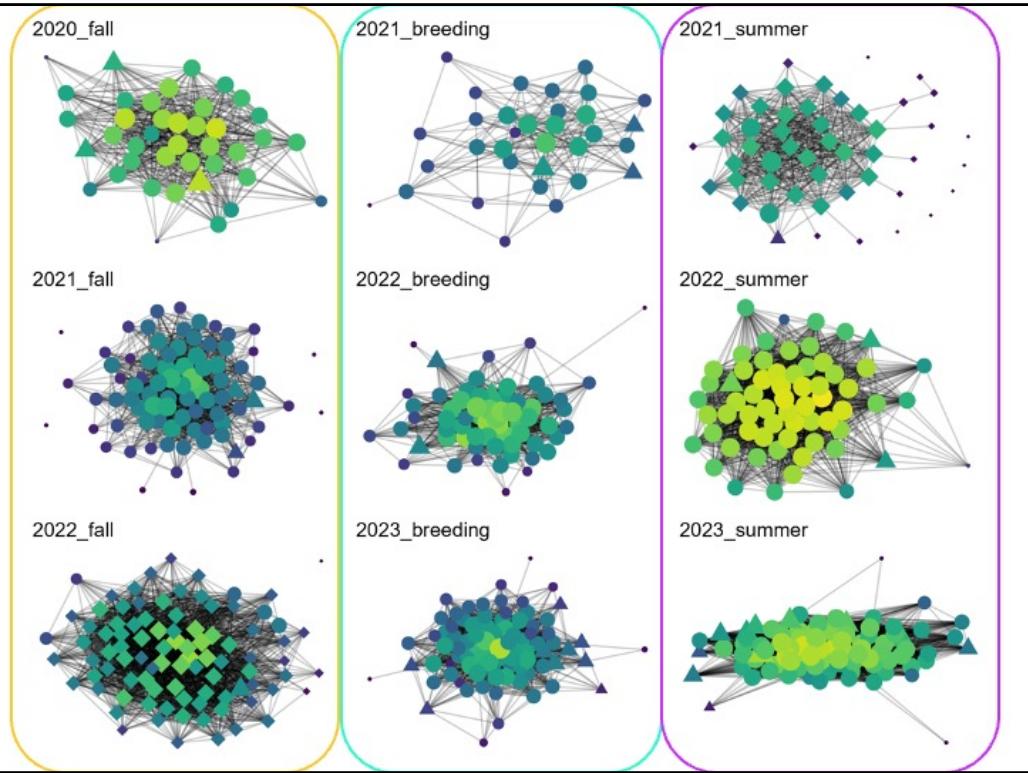
- Warmer weather
- Juveniles out of nest, some long-range dispersal

15

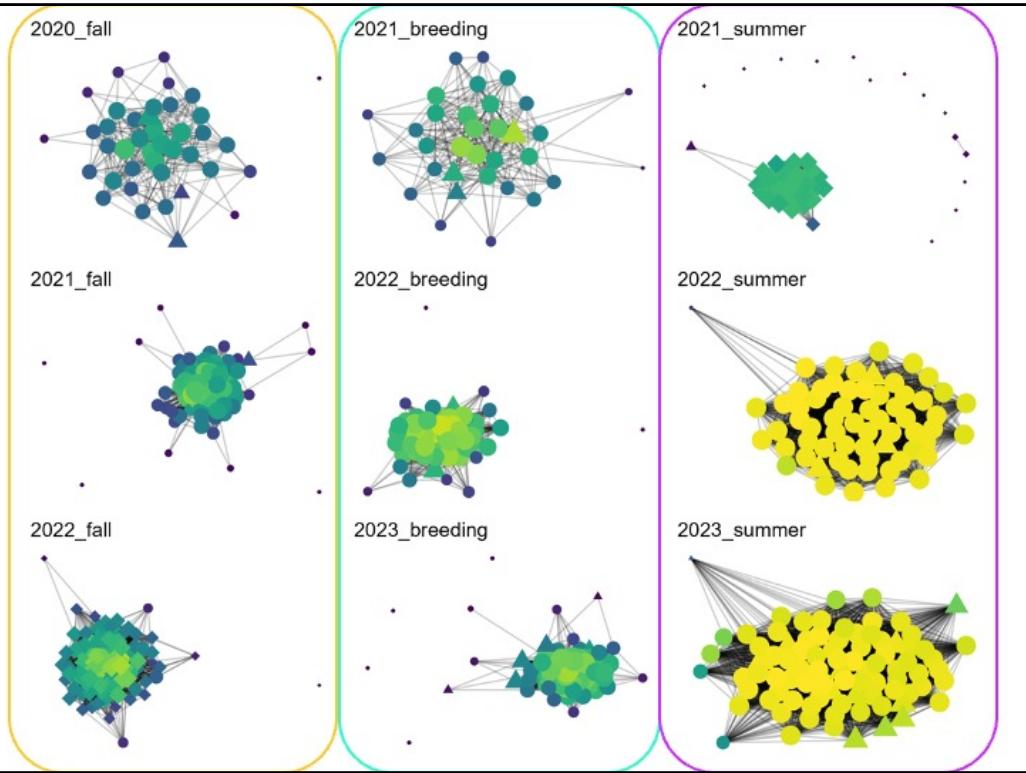
Make this just a single slide for all three seasons. Very brief overview.

"During the non-breeding period (September-November) cages are baited with large mammal carcasses, resulting in captures of ~150 Griffons yearly (including many recaptured and non-residents). They are inspected externally for body condition and any signs of new injury or disease. Samples for pathogens (bacteriology and virology) are collected from pharyngeal and blood is checked for hemoparasites, lead and pesticide poisoning (e.g., measuring Cholinesterase activity). Age is determined from molting stage (for bird <4 y old), or from known history (e.g., captive raised or capture history). Feather samples are collected for genetic classification of sex, and birds are weighed and marked with wing tags and color rings (for field identification)." (Nili Anglister PhD Progress Report)

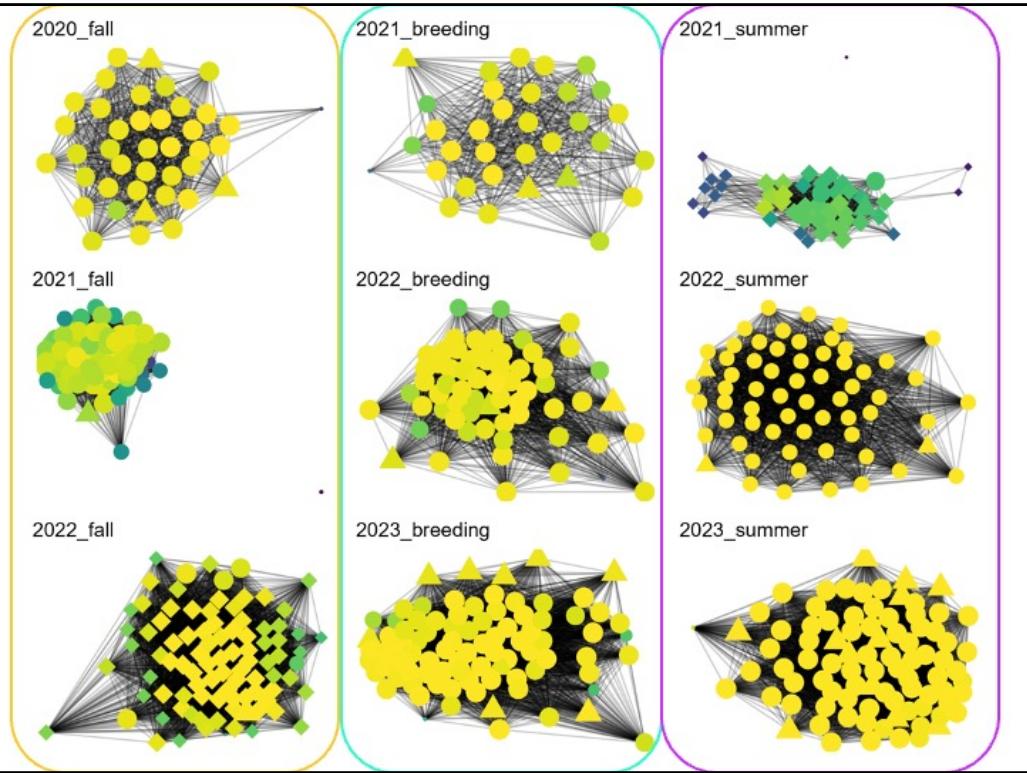
Co-flight



Co-feeding

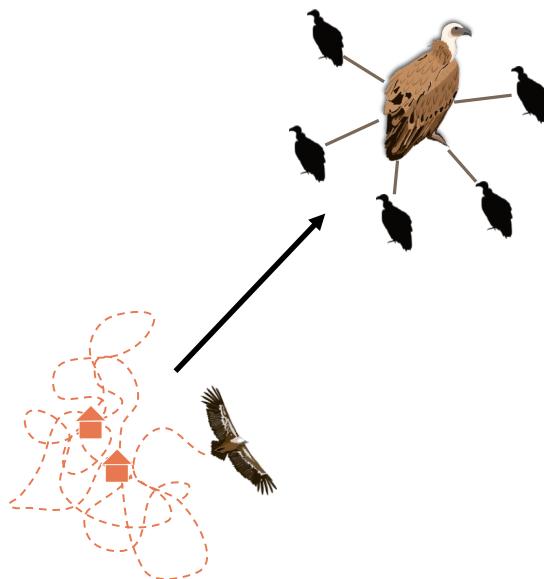


Co-roosting



Questions

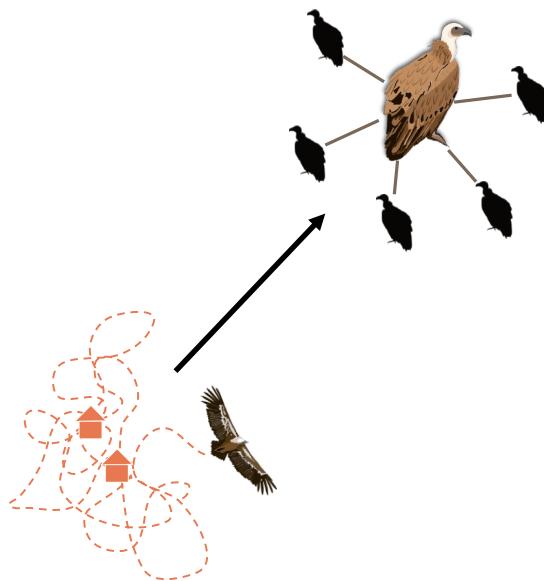
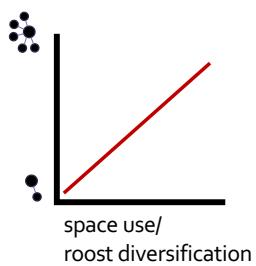
1. Does spatial phenotype predict social centrality?



- Individuals that explore more (use more space and more diverse roosts) will encounter more unique others and therefore have a higher degree centrality in the social network.
- Individuals that move more will have more social interactions and therefore have a higher strength centrality in the social network.

Questions

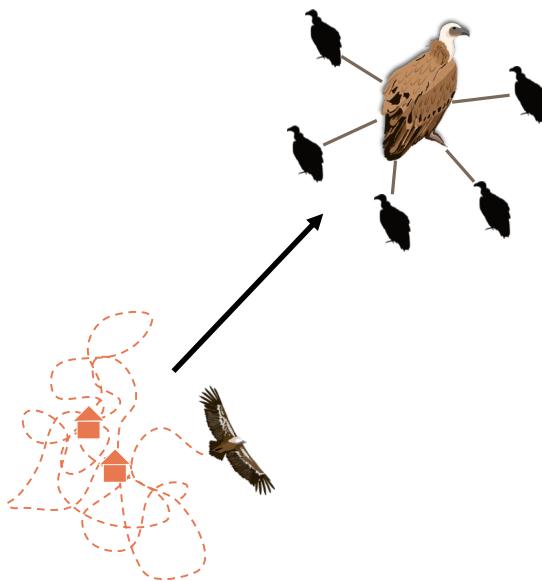
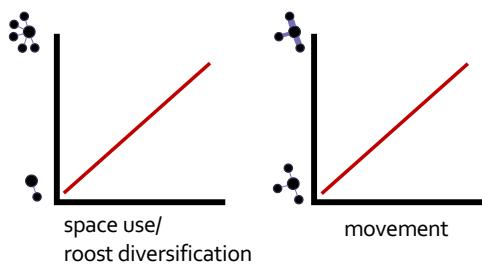
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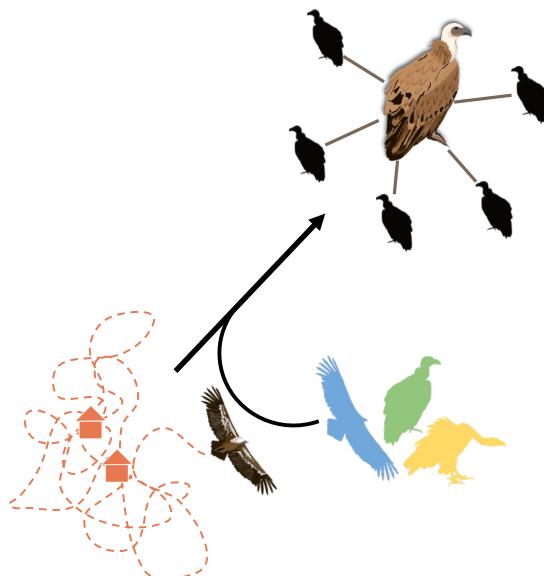
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Questions

1. Does spatial phenotype predict social centrality?
2. Does spatial phenotype predict social centrality differently in different **social situations**?

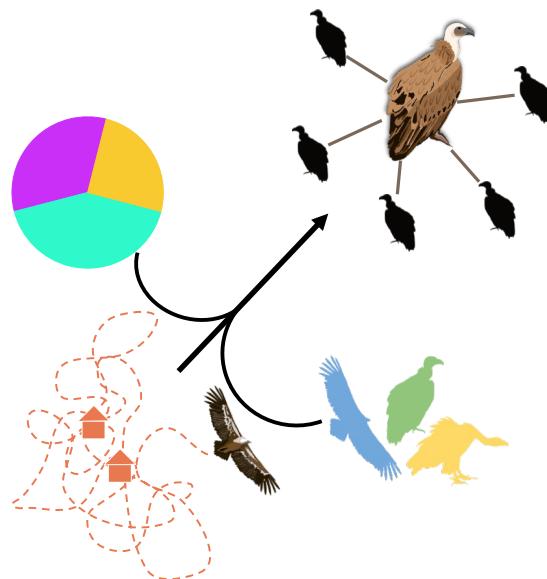


And, in addition to looking at the relationship between spatial phenotype and social centrality overall, I wanted to know whether the relationships will differ in different social situations.

Different components of spatial phenotype will be most strongly predictive in different social situations

Questions

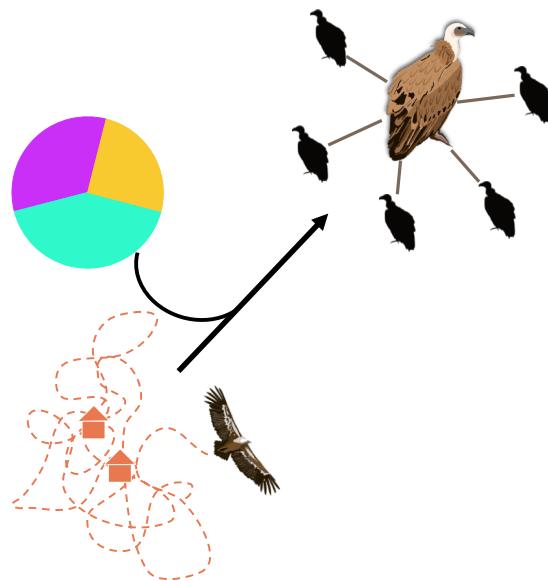
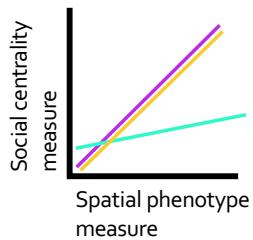
3. Does spatial phenotype predict social centrality differently in different **seasons**?



- Spatial phenotype will be more strongly predictive of social centrality in the non-breeding seasons (versus the breeding season)
 - summer and fall, more movement, more exploration
- Alternatively, spatial phenotype will be more strongly predictive of social centrality in the breeding season, when there is more differentiation between breeding and non-breeding vultures.

Questions

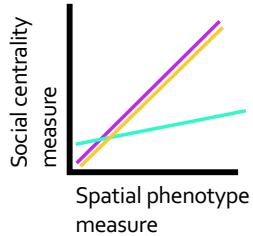
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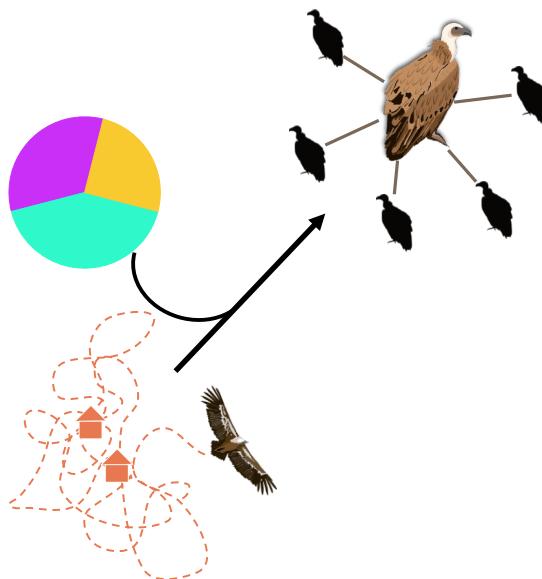
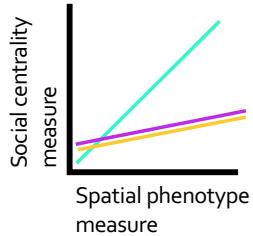
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Questions

3. Does spatial phenotype predict social centrality differently in different **seasons**?

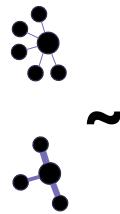


OR



- Spatial phenotype will be more strongly predictive of social centrality in the non-breeding seasons (versus the breeding season)
 - summer and fall, more movement, more exploration
- Alternatively, spatial phenotype will be more strongly predictive of social centrality in the breeding season, when there is more differentiation between breeding and non-breeding vultures.

Generalized linear mixed models



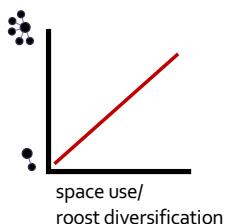
Generalized linear mixed models

$$\sim \text{movement} + \text{space} + \text{roost}$$
$$+ \text{age} + (1 | \text{ID}) + (1 | \text{season})$$

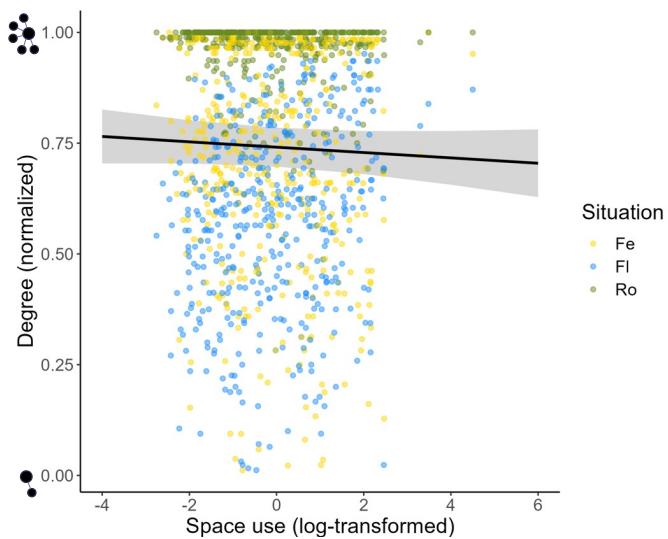
**1. Does spatial
phenotype predict
social centrality?**

So for the first question, does spatial phenotype predict social centrality

1. Does spatial phenotype predict social centrality?



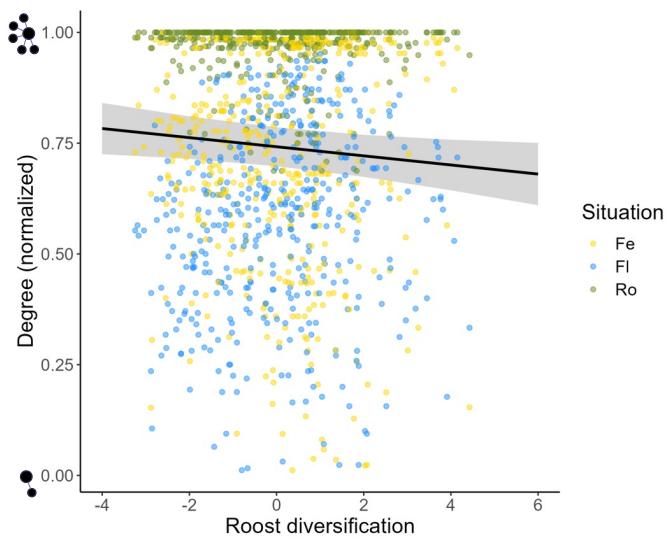
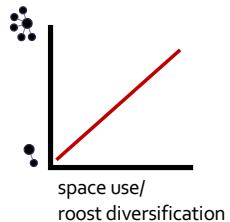
space use/
roost diversification



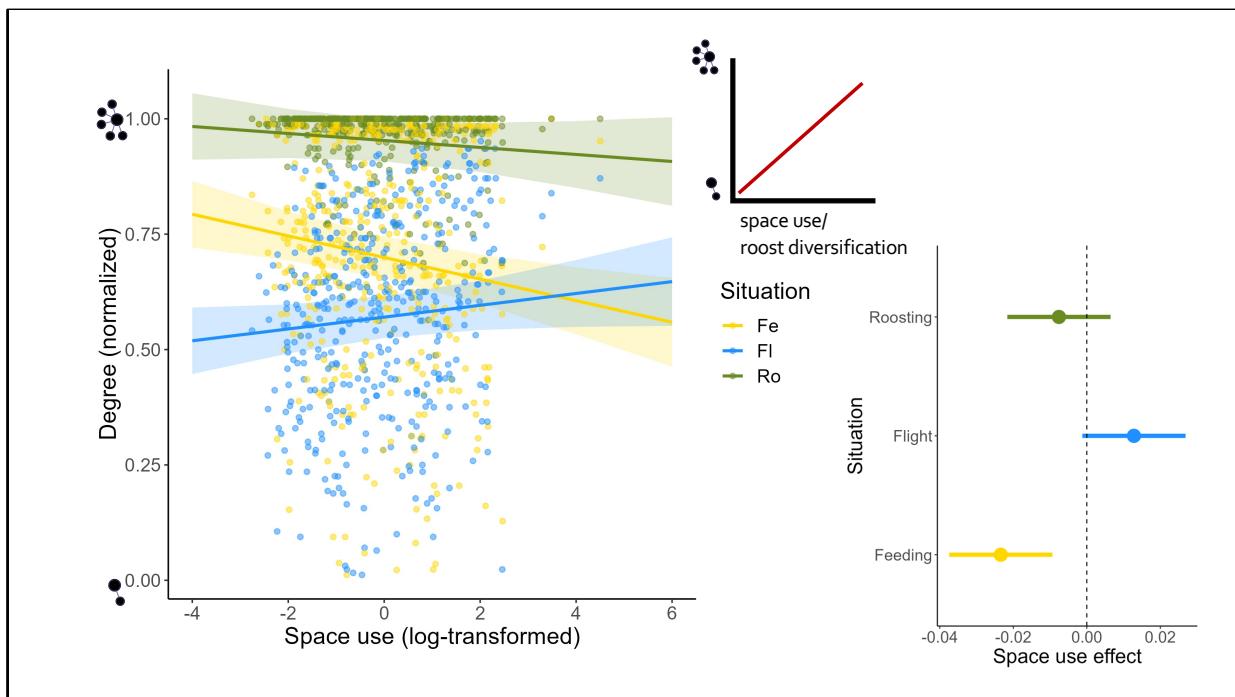
We predicted that more exploratory individuals (those that used more diverse roosts and had larger ranges) would have a higher degree, because they would encounter more unique others.

Overall in the model, that did not end up being the case; if anything there was a slight negative effect (across all the social situations). This is for space use.

1. Does spatial phenotype predict social centrality?



...and we find the same thing for roost diversification.



However, we do see a significant interaction with social situation here (only for space use, not for roost diversification).

So if we break it down by social situation, we see that different social situations are behaving differently when it comes to space use.

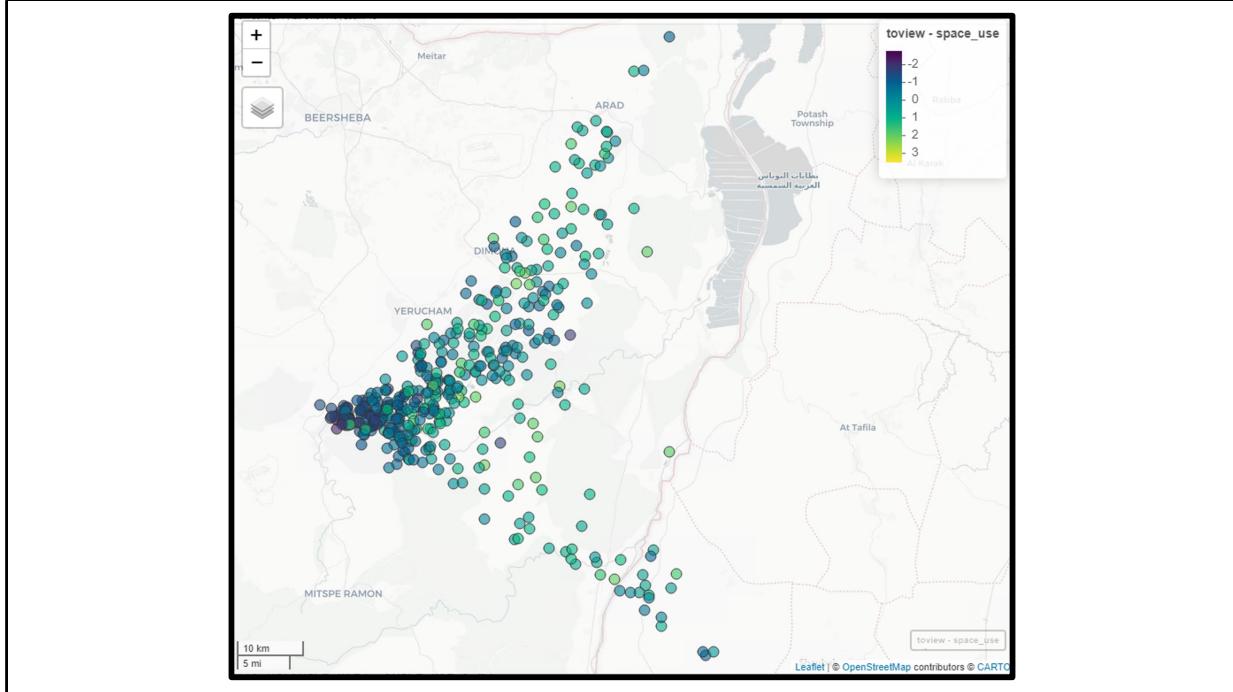
For co-flight networks only, space use is positively related to degree, as predicted, though the effect is only marginally significant.

By contrast, in the co-feeding networks, vultures that use more space actually end up encountering **fewer** unique other vultures, which is contrary to what we predicted.

One reason for this is that the vultures that used more space tended to feed outside the population center.

- Most individuals are tagged, but there could be some outside of our study population that these are encountering
- Not actually fewer, just untagged birds

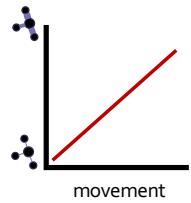
- One way to check this is to look at the centers of activity of the birds with higher space use.



We do see something of a pattern to this effect.

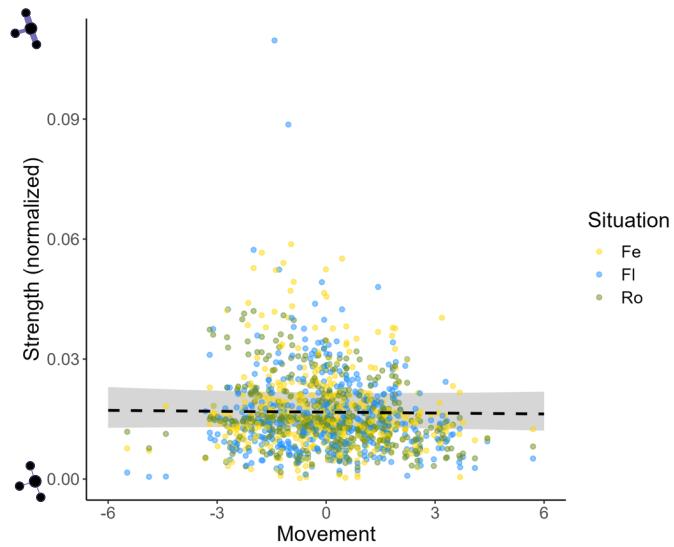
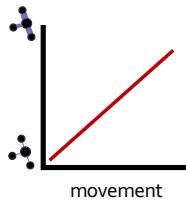
To be seen whether this pattern holds up after accounting for the latitude/longitude effect. In that case, it might just be that individuals that range farther are more likely to find carcasses on their own and therefore end up feeding alone rather than at big crowded feeding stations.

1. Does spatial phenotype predict social centrality?



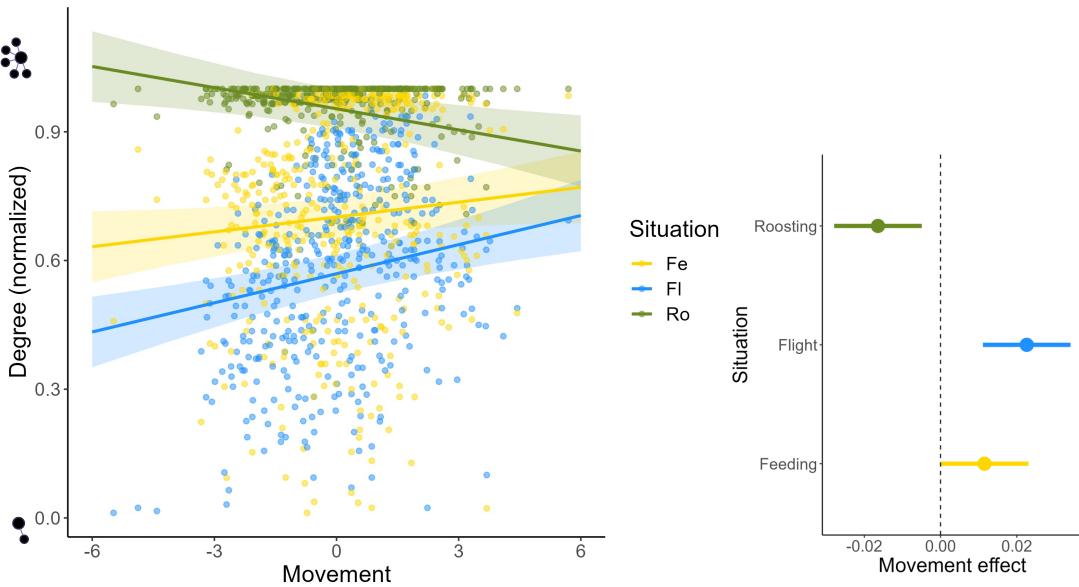
We also expected that individuals that moved more would have higher strength (would meet more others)

1. Does spatial phenotype predict social centrality?



We also expected that individuals that moved more would have higher strength (would meet more others)

And this is not what we found. There was no relationship between movement and strength either overall or in any of the individual social situations.



However, we actually did see significant effects of movement on *degree*, the number of other individuals encountered, and those effects also differed by social situation.

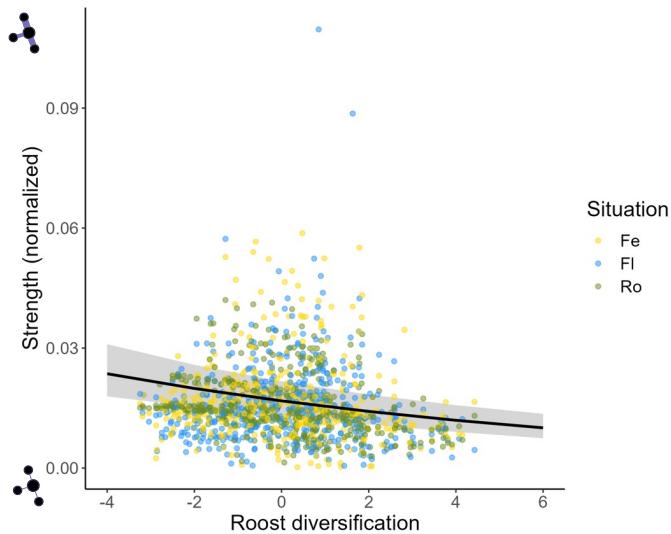
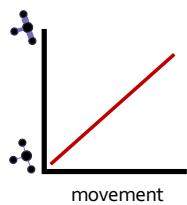
Vultures that flew more interacted with significantly more unique individuals in the co-flight network. This makes sense, since if you're spending more time in flight, you would have more of an opportunity to run into others and have those co-flight interactions.

But interestingly, there is also a slight positive effect in the co-feeding situation. Those that moved more also fed with more unique others.

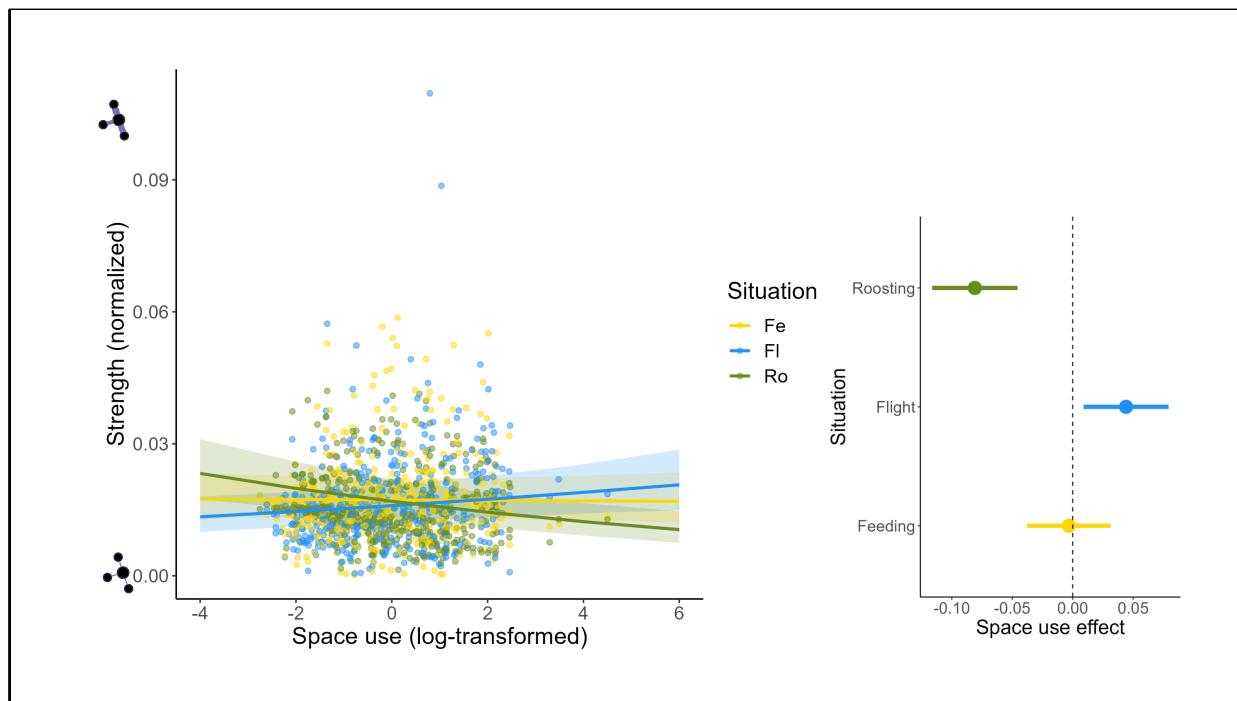
- it's not clear why. This could have to do with them being more active, maybe more inclined to interact at the carcass instead of staying by themselves
- Also interesting is that vultures that moved more roosted with significantly *fewer* others. Maybe these actually are the more exploratory birds, and they spend more time on isolated cliffs rather than in the more central group roosts. In my predictions, I used space use and roost diversification as the main indices for exploratory tendencies in vultures, but movement could be

another measure—they are correlated with each other, and we did see a marginally significant negative effect of space use on degree.

1. Does spatial phenotype predict social centrality?



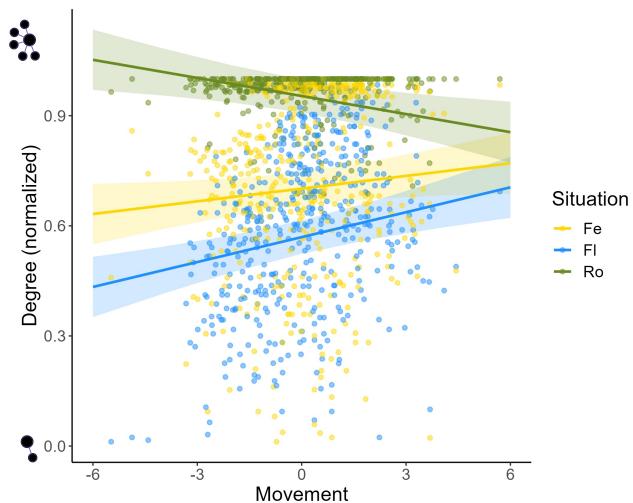
Meanwhile what did actually predict strength was roost diversification and space use, not movement! Vultures with more diverse roosts had lower, not higher strength across the board (no significant interaction with social situation). This is probably because the most central roosts are also the largest so having greater roost diversification probably means you are generally more peripheral in the population, which could be either a cause or a consequence of you being less social in flight, at carcasses, and at roosts.



This is also consistent with our finding that wider-ranging vultures had significantly lower co-roosting strength, specifically, than vultures with smaller home ranges.

2. Does spatial phenotype predict social centrality differently in different social situations?

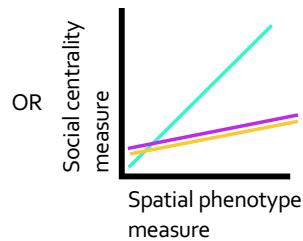
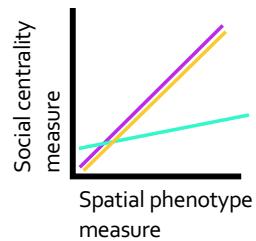
> Yes! But not straightforwardly so.



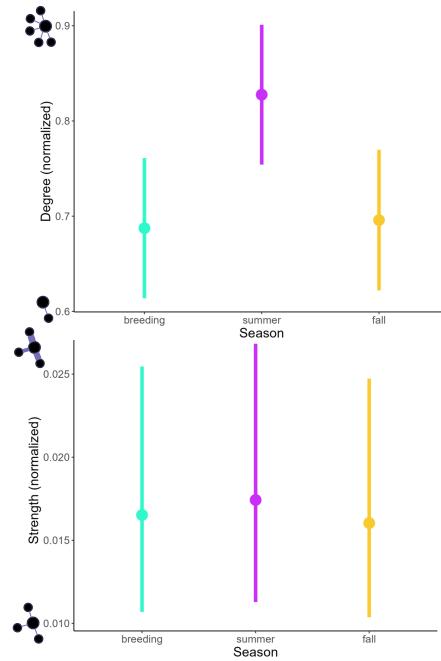
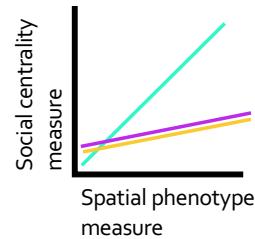
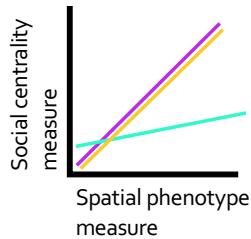
There were definitely different relationships in different social situations.

We might have expected the roost-focused components of movement phenotype to be the best predictors of the position in the co-roosting network, but that wasn't the case (no significant interaction between roost diversification and co-roosting centrality for either strength or degree). Instead, co-roosting centrality ended up being negatively related to individuals' movement and space use behavior.

3. Does spatial phenotype predict social centrality differently in different seasons?



3. Does spatial phenotype predict social centrality differently in different seasons?



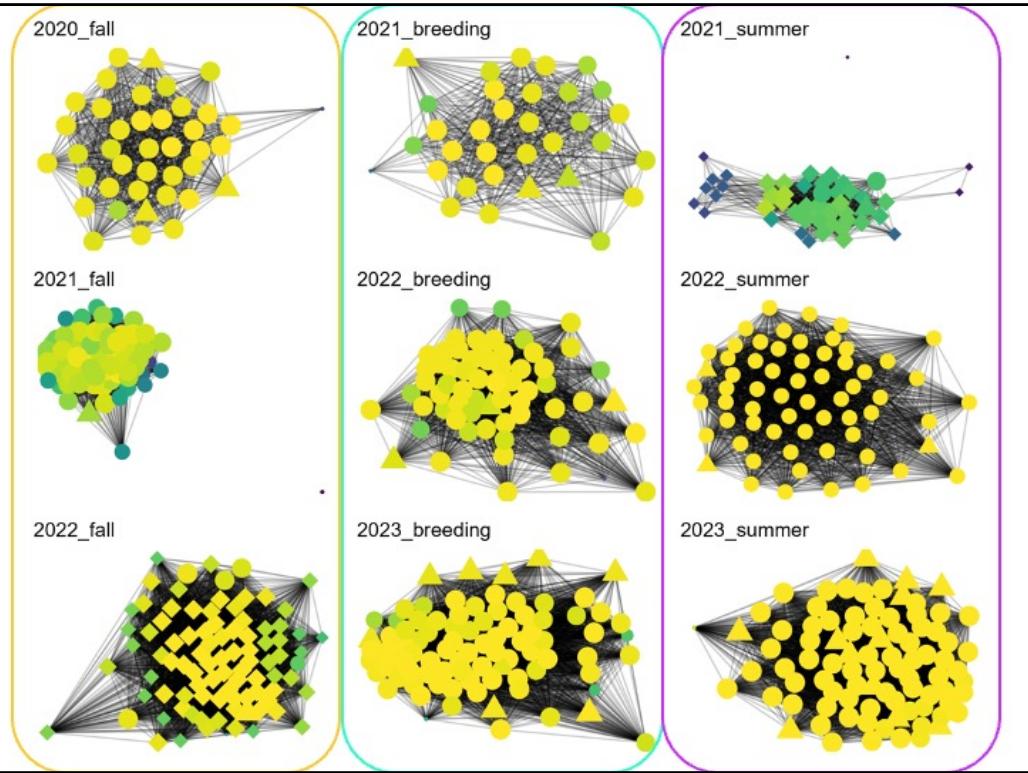
We see an overall increase in degree in the summer, which is consistent with individuals doing more flying in that season

But there was no significant interaction with season on any of the relationships. That is, the relationship between spatial phenotype and social centrality did not vary by season.

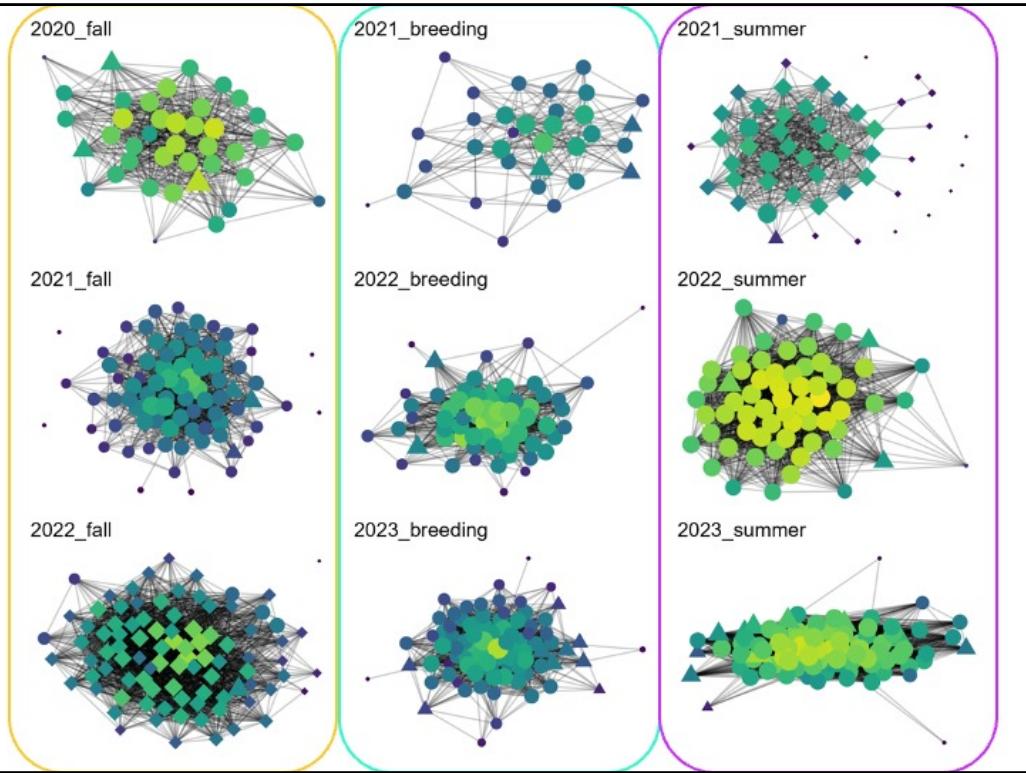
If everyone's more active or uses more space, the same relationship could still be maintained with the social centrality measures; maybe everyone just has more encounters generally.

Differentiation between breeding and non-breeding birds could come out in the wash because breeders have more consistent interactions and are located more centrally, while non-breeders would be freer to range wider and to potentially less used areas.

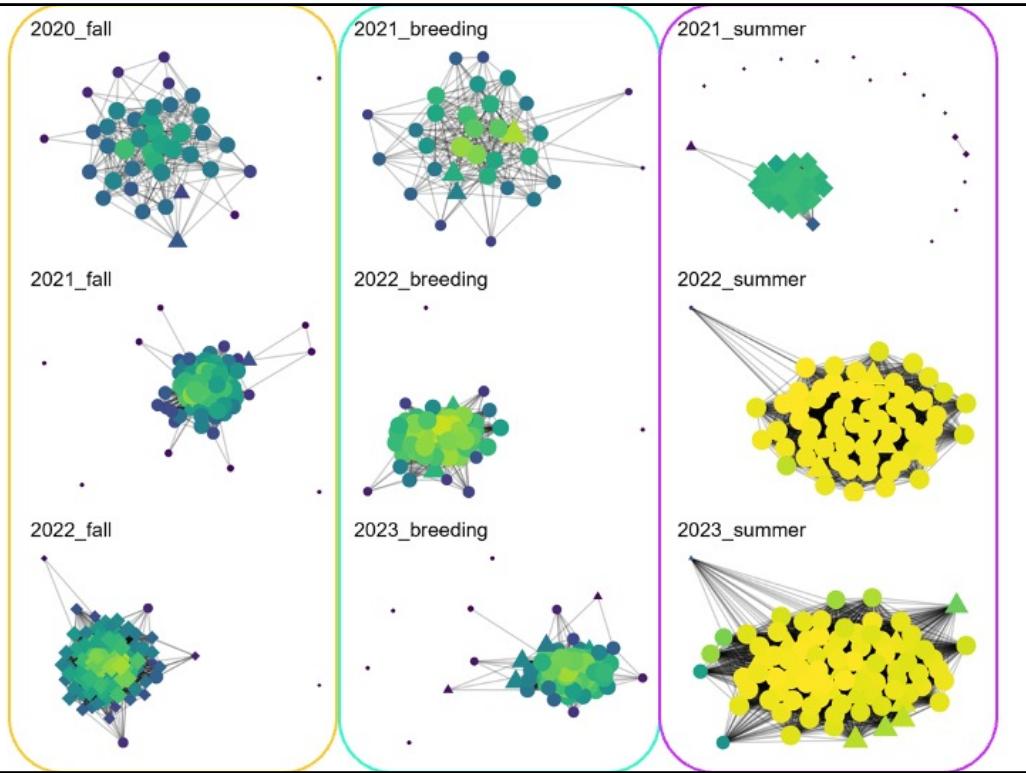
Co-roosting

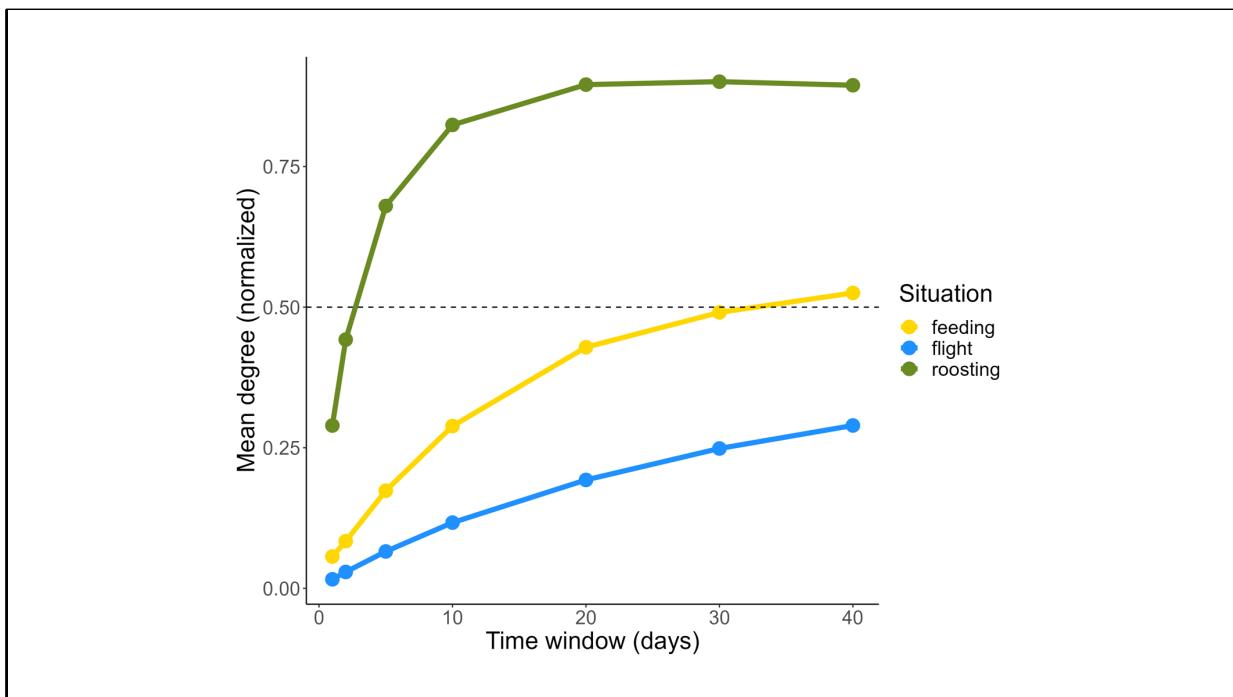


Co-flight



Co-feeding





Conclusions

- Vultures' social centrality is related to their spatial phenotype (movement, use of space, use of different roosts).

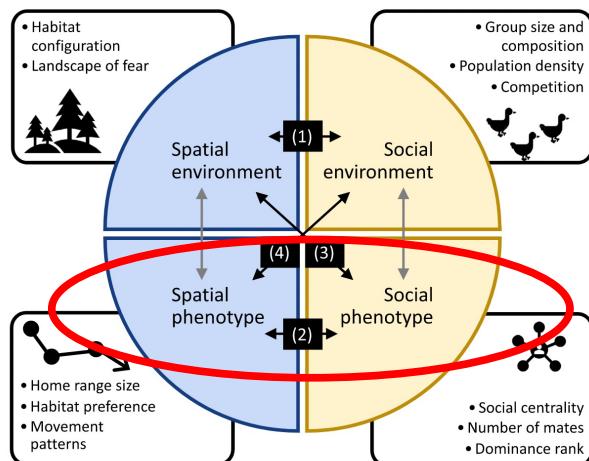


Fig. 1. Webber et al. 2023. *Biological Reviews*

Conclusions

- Vultures' social centrality is related to their spatial phenotype (movement, use of space, use of different roosts).
- Mechanisms determining social structure differ for different social situations.

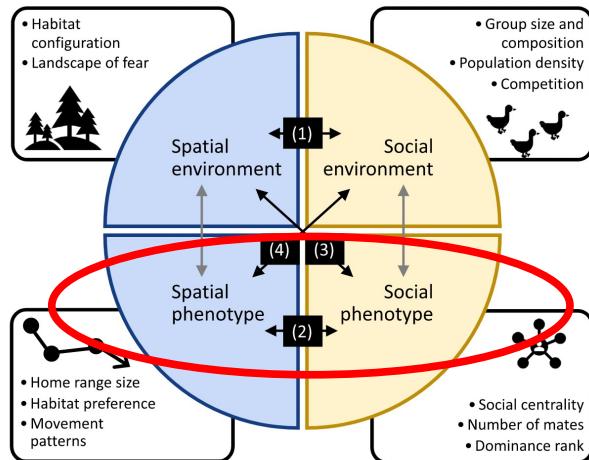


Fig. 1. Webber et al. 2023. *Biological Reviews*

Conclusions

- Vultures' social centrality is related to their spatial phenotype (movement, use of space, use of different roosts).
- Mechanisms determining social structure differ for different social situations.
- Emergent social patterns depend on the explicit spatial context and the temporal scale of analysis.

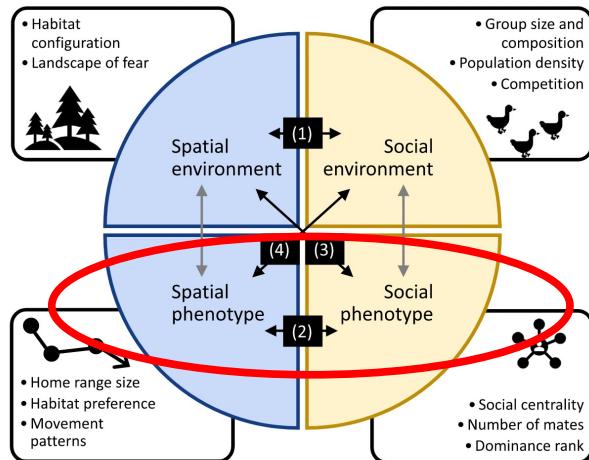
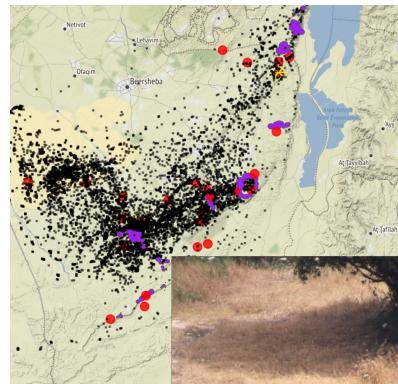


Fig. 1. Webber et al. 2023. *Biological Reviews*

Future directions

- Temporal change
- Spatial vs. social influences on interaction patterns on the landscape
- Effect of social position in this population



Thank you!



Pinter-Wollman lab: Elvira
D'Bastiani, Alejandra Gamboa,
Sean O'Fallon, Ryan Nguyen