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Foraging behavior of parasitized and non-parasitized voles during new moon and full
moon events

ABSTRACT:

According to trade-off theory, animals weigh the benefits of obtaining resources against the risks of being preyed upon during these activities. One major factor that can influence an animal's risk assessment is its current body condition, for example animals that are of lower body condition may be more desperate for food and thus more willing to take risks in searching for food. Body condition can be influenced by a variety of factors, including parasite burden, which can reduce it considerably. It has commonly been assumed that besides large epidemics mostly due to micro parasites (e.g. viruses, bacteria), macro parasites (e.g. cestodes, ecto-parasites) do not have much impact on their hosts, which allows them to reproduce and be transmitted to other hosts. However, while parasites might not directly manipulate their hosts' foraging behavior, they may have indirect effects on hosts' behavior by influencing their risk assessment during foraging by impacting their hosts' physiology or condition. In our study we trapped montane voles, *Microtus montanus*, and collected data and fecal samples from them to analyze for parasites. We trapped voles for five consecutive days during one full moon event and two new moon events to see if there was a significant difference in the parasite burden of the voles we trapped during new moon and riskier full moon conditions when voles are more exposed to predators. Our study is important because it will examine how parasites may indirectly impact host behavior, and has important implications since parasites are common and may influence prey-predator dynamics in other animals.

KEY WORDS:

Montane voles, parasites, parasitism, host, foraging

INTRODUCTION:

According to trade-off theory, animals weigh the benefits of obtaining resources against the risks of being preyed upon during these activities. Lima et al. (1989) proposed that an animal's assessment of risks plays a big role in its decision-making process about when to search for food. One major factor that can influence an animal's risk assessment is its current body condition, as was demonstrated in a study on snowshoe hares by Murray

(2002), because animals of lower body condition may have higher nutritional demands and are thus more willing to take risks in searching for food.

Body condition can be influenced by a variety of factors, including parasite burden. Hakkaraineh et al. (2007) found that voles infected with *Eimeria* had significantly lower body mass. In another study Ezenwa (2003) found that especially under adverse conditions like droughts animals that could not maintain adequate nutrition were less resistant to parasites. Parasite burden can also differ between the sexes, as males produce testosterone in developing secondary sex characteristics, which can suppress their immune systems and decrease their resistance to parasites, according to Zuk et al. (1996). Clearly parasites can play an important role in reducing their host's body condition.

While parasites may not directly manipulate their hosts' foraging behavior, they may have an indirect influence on behavior by impacting their hosts' condition. More specifically, parasitized animals of poorer body condition might be more likely engage in risk-taking behavior, like foraging under full moons where they are more exposed to predators, or during temperature conditions where predators are more prevalent. I did not know if there was a correlation between temperature and predation or what that would be but I wanted to compare the two variables to see if they were related. Daly et al. (1992) did find that the desert rodent, *Dipodomys merriami*, was more likely to be found in its hole during full moons and ventured closer to home when it did emerge, which minimized its vulnerability to nocturnal predators. Additionally, Seppala et al. (2008) found that parasitized rainbow trout, *Oncorhynchus mykiss*, were less likely to participate in shoaling behavior, an adaptation that reduces vulnerability to predators, and thus were more likely to be preyed upon by birds. Evidence that in support of parasite influence on host foraging behavior this would corroborate the findings of these previous studies and have implications for predator-prey dynamics in other animals since parasites are ubiquitous in the wild.

For my project I sought to determine if parasites did in fact decrease vole body condition, and if infected voles were more likely to engage in risk-taking behavior to compensate for their reduced condition. To do this I analyzed capture numbers of parasitized and non-parasitized montane voles, *Microtus montanus*, during new moon and

more risky full moon events. Montane voles and their parasites provide a good study system because they are abundant at Gothic, many of the voles are infected with parasites, and they can be representative of behavioral traits in other small rodents. I hypothesized that voles that are infected with parasites are more likely to forage during riskier conditions like full moon phases when they are more exposed to predators or temperature conditions associated with higher predation rates.

METHODS:

I selected Research Meadow as my study site because of its abundant vole population, and I set up a grid of 63 traps spaced 10 meters apart there. We trapped for 5 consecutive days for the first new moon period and 4 consecutive days for the first full moon period and the second new moon period (the last trapping period). To avoid pseudo-replication we only trapped rodents and took samples at Research Meadow and we set traps in the same locations every time. We also marked each animal with unique ear-tags so we could identify recaptured individuals. We obtained data from individuals like weight, length, reproductive status, and sex, scanned the animals for ecto-parasites (e.g. ticks and mites), and collected fecal samples from the traps to use in endo-parasite analysis. At the lab we used fecal flotation methods to analyze the slides for cestodes and *Eimeria*, two prevalent endo-parasites in vole populations, and recorded the number of parasite species and intensities for each sample.

Over the trapping sessions we captured a total of 199 voles including recaptures, but I only used results from 170 of the captured voles because some of the data was missing for certain individuals. Because many of the recaptured animals varied greatly in body condition and parasite burden over the days we caught them, I decided to treat each data point as an individual vole even if it was a recaptured vole. I used a variety of statistical methods to analyze my results to determine whether parasites had detrimental impacts on body condition. I first used a regression of weight against log length as an indicator of body condition then saved the residuals for each individual. Jakob et al. (1996) found that this method was the most reliable in estimating body condition in behavioral studies. I then ran t-tests on the data to analyze the effects of *eimeria*, cestodes, ecto-parasites, and total endo-parasite presence on body condition. I used four categories of grouping variables in this analysis: *eimeria* presence, cestode presence,

ecto-parasite presence, and the presence of one or both endo-parasites, and I indicated their presence using a 1 and absence using a 0. I also ran separate regressions on condition for males and females, and juveniles, sub-adults, and adults, to analyze whether parasites would have an impact on condition specific to sex or age, and I analyzed these residuals using the same t-tests and grouping variables as before. Age was determined using the weight of the individual, if the vole weight was under 16 grams it was considered a juvenile, if it was between 16 and 24 grams it was a sub-adult, and if it was greater than 24 grams it was considered an adult. I also ran linear regressions on total parasite species burden using the residual for all animals, as well as regressions on total parasite species burden using the residuals for sex and age groups separately. I also used chi-square tests to analyze how species presence differed by age and sex, and a t-test using sex as the grouping variable for the presence of each parasite species and all endo-parasites. Finally I ran regressions on condition by moon phase and temperature to see if there was a relationship between these variables and condition.

To analyze whether parasitized voles engaged in significantly more risk-taking behavior, I first ran an ANOVA to compare the variation in total species richness between each lunar phase and within each lunar phase. Then I ran t-tests on the data comparing the data on total species richness from the full moon trapping session, to which I assigned a 2, and I grouped together the data from both new moon trapping sessions, to which I assigned a 1. I also ran t-tests comparing each lunar phase assigning the first lunar phase and trapping session a 1, the full moon phase a 2, and the last lunar phase and trapping session a 3. I also ran linear regressions on the data for capture numbers of parasitized animals, total capture numbers, and the ratio of parasitized animals to non-parasitized animals for moon event and date of trapping day. I also used linear regressions to analyze how capture numbers for animals differed by sex and age for each moon phase and I ran linear regressions on total species burden for different age and sex groups. Finally I ran regressions on temperature using parasitized animal and total capture numbers, total species richness, and the ratio of infected animals to non-infected animals. I also graphed the number of newly captured animals found during each trapping day as this is an indication of changes in population density over time.

RESULTS:

There was no significant relationship between the presence of each parasite species and total species richness with the overall condition of the animals captured. Parasite species and total species richness did not significantly impact condition by age groups. Parasite species and total species richness did not impact female condition either but there was a relationship between *Eimeria* presence and lower male body condition, as well as between *Eimeria* presence and lower adult male body condition. Females were of significantly lower condition than males as can be seen in Fig. 1, and adults were of significantly higher body condition of sub-adults who were of significantly higher body condition than juveniles. When I compared parasite prevalence between males and females I found that there were significantly more cestodes and ecto-parasites in males and that there were significantly more *Eimeria* in females. Adult voles had significantly higher total parasite species richness as well as numbers of cestodes, ecto-parasites, and total-endo parasites present than sub-adults and juveniles as is evident in Fig. 3.

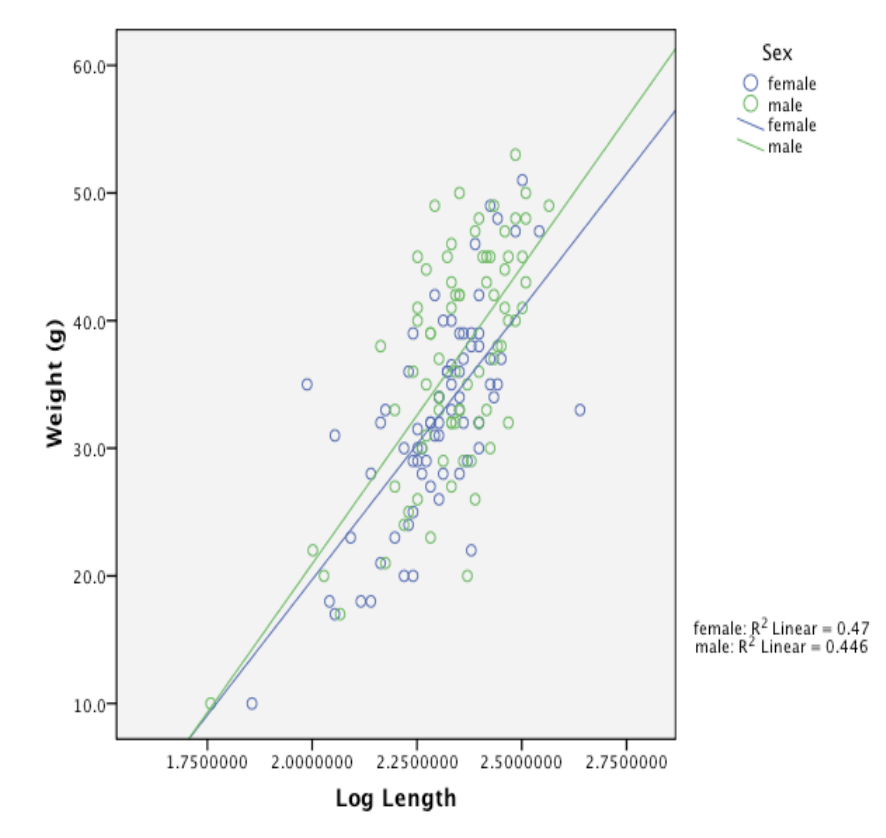


Fig. 1: Body condition for males and females.

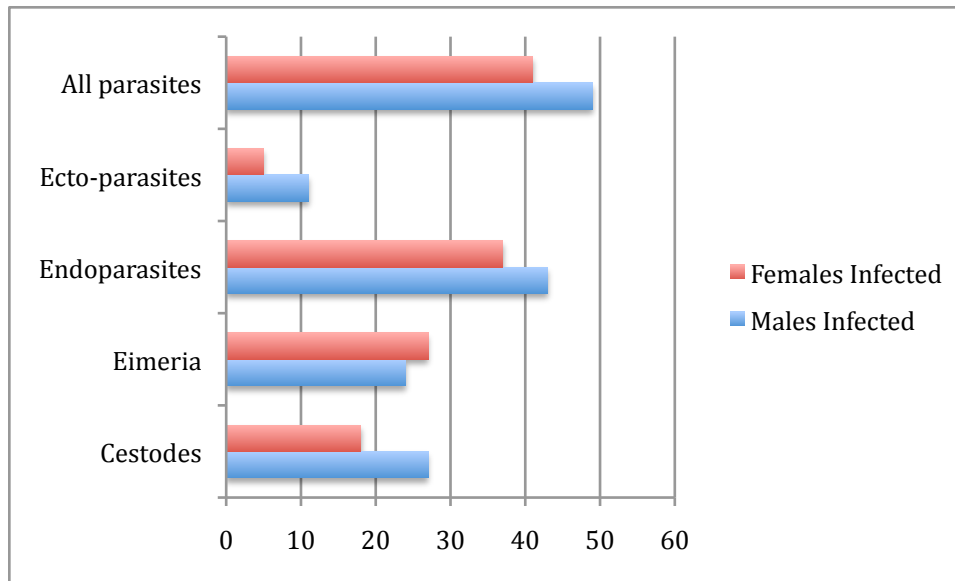


Fig. 2: Parasite prevalence in males and females.

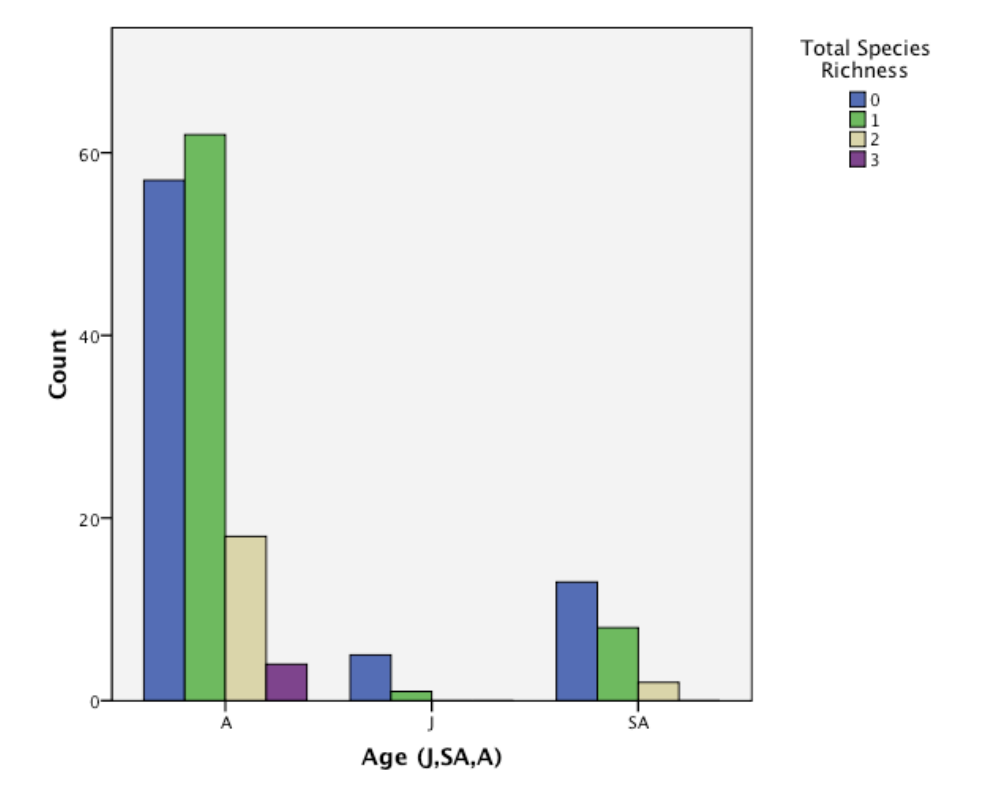


Fig. 3: Total parasite species richness per individual by age. Each bar color represents a different number of species present, J stands for juveniles, SA stands for sub-adults, and A stands for adults.

There was a strong linear relationship between the total number of animals captured over time and the number of parasitized captured animals over time with R-

squared values of 0.792 and 0.755, respectively, and the latter relationship is shown in Fig. 4. There was no significant relationship between the ratio of parasitized to non-parasitized animals captured over time and in moon phase (r square value). There were significantly more cestodes and ecto-parasites present in the second new moon phase than in the first new moon phase and the full moon phase. There was also more variation in total parasite species richness between moon phases than within the moon phases, and total species richness was very significantly higher in the second new moon phase than in the first two phases, as is evident in Fig. 5. I also found that the total number newly captured animals increased over time as is shown in Fig. 6.

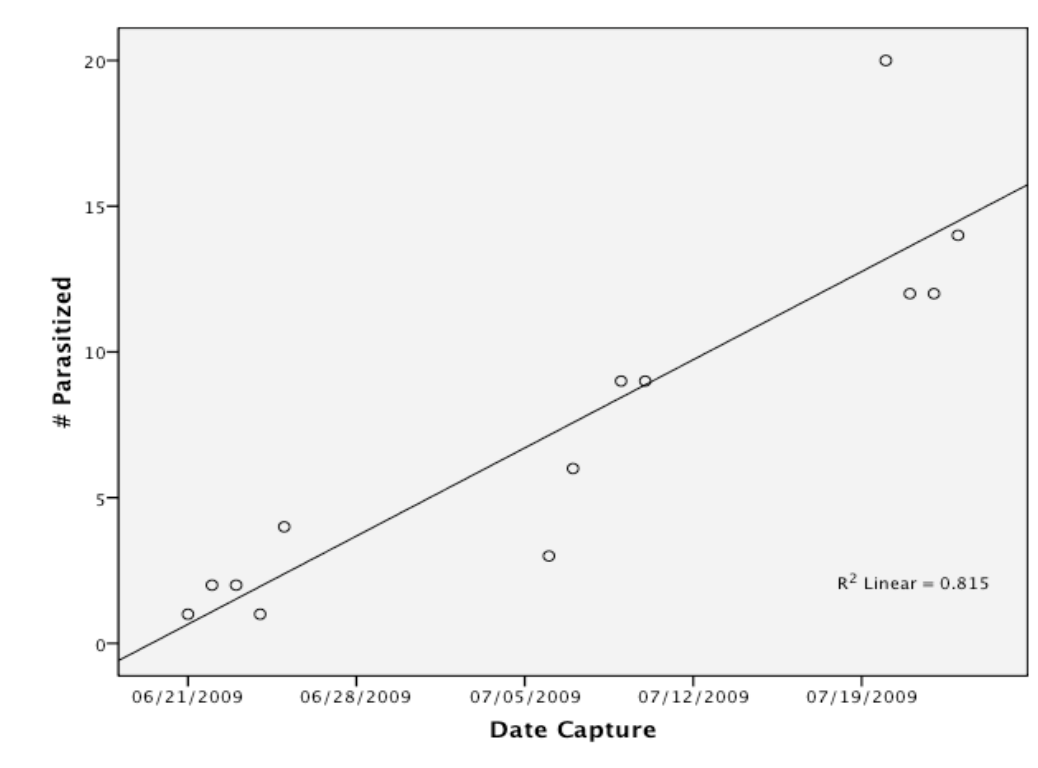


Fig. 4: Capture numbers of parasitized voles over all trapping sessions.

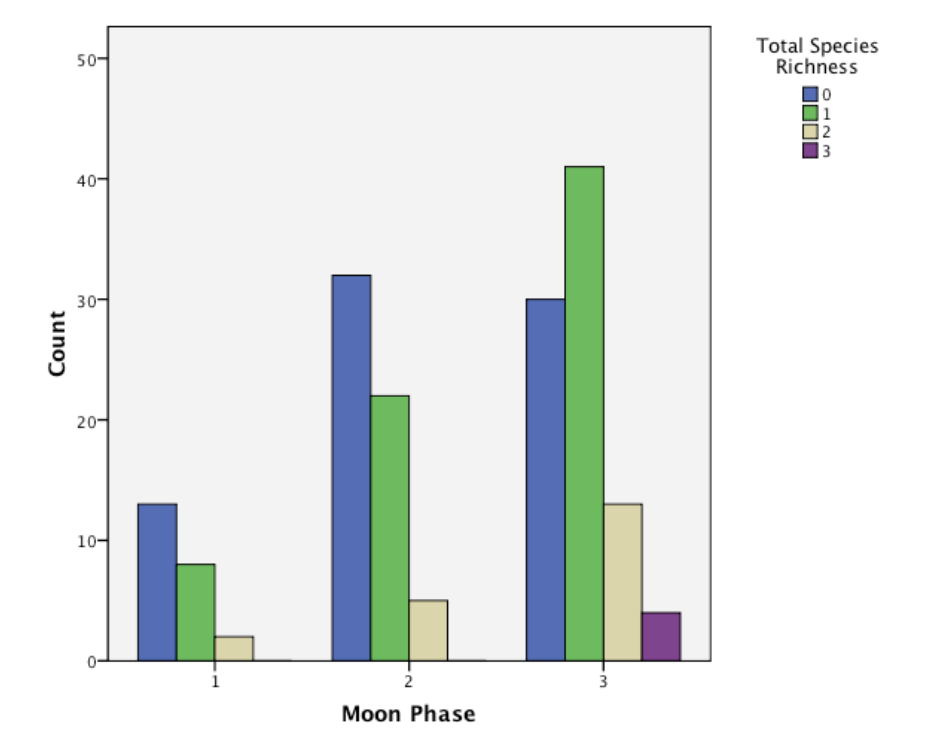


Fig. 5: Total parasite species richness per individual by moon phase. Each bar color represents a different number of species present and the numbers at the bottom indicate the moon phase: 1 stands for the first trapping session and the first new moon phase, 2 stands for the second trapping phase and the full moon phase, and 3 stands for the last trapping session and second full moon phase.

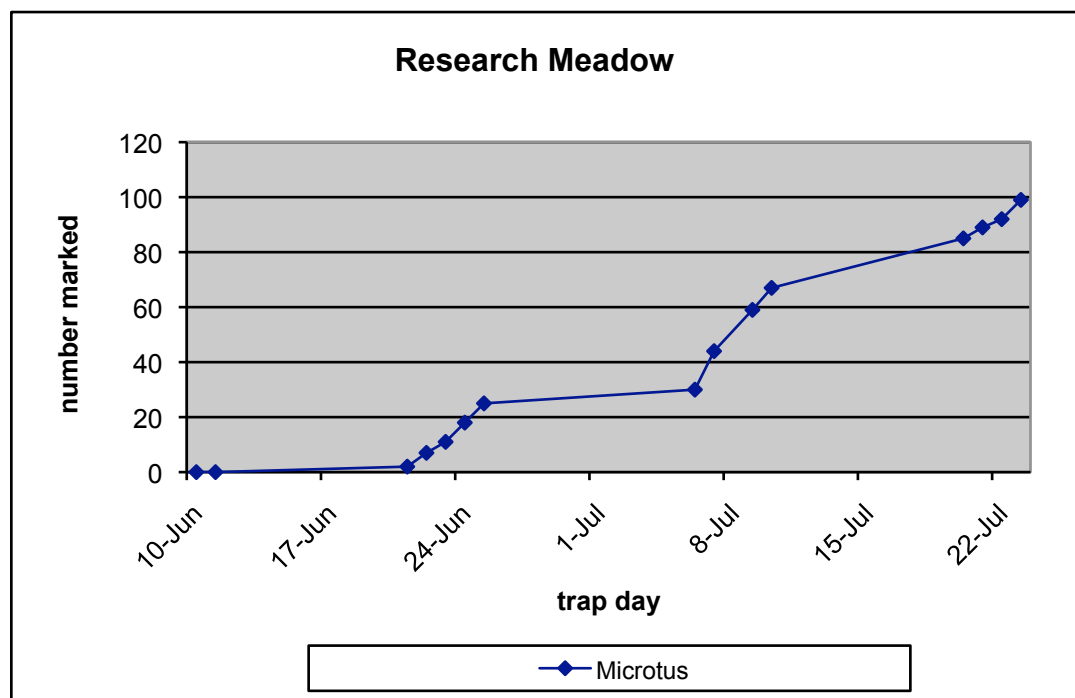


Fig. 6: Changes in population density over time, as represented by the number of new individuals caught per trapping session.

DISCUSSION:

For my first research question I predicted that parasites would have a significant impact on body condition in animals and that impact might differ between animals of different sex and age. I did not find that parasites significantly decreased body condition in animals except for a relationship between *Eimeria* presence and lower condition in males and adult males. Females were in significantly lower condition than males but *Eimeria* did not significantly impact their condition despite the fact that more of them were infected with *Eimeria*. These differences may be due to the fact that it is breeding season and many of the females are highly stressed because they are lactating or pregnant, and parasites may not significantly impact animals that are already of lower body condition. These differences could also be attributed to testosterone production in males, as males have circulatory testosterone levels during mating season and testosterone is known to reduce immune resistance to infections, so males may be more vulnerable to infection.

For my second research question I predicted that the ratio of parasitized to non-parasitized animals would increase during the full moon event, that capture numbers would decrease during the full moon event, and that there would be higher parasite prevalence and total species richness during the full moon event. I also predicted that temperature would be correlated with some of these variables, which could indicate that certain temperatures were associated with predation risk. However, I did not find strong evidence in support of parasite influence on foraging patterns during different moon phases and temperature conditions. Firstly, I found that capture numbers of total animals and parasitized individuals increased linearly over time rather instead of decreasing during the full moon trapping period as I predicted, so moon phase appeared to have no impact on foraging rates. I also found no relationship between the ratio of captured infected individuals to non-infected individuals over time and moon phases, however this may be because capture numbers were much smaller at the beginning of trapping so the results may be skewed. I also found that total parasite species richness was actually higher during the last new moon phase than the first two phases, the opposite of my prediction. Lastly, I found that temperature was not correlated with condition or parasite

species found or date and moon phase, so it is likely that temperature is not a factor in predation rates.

I think that two main factors behind the trends in capture numbers over time and total parasite species richness per moon event may be age differences in foraging rates and population density. Adults had much higher rates of total parasite species richness than juveniles and sub-adults in spite of being in higher body condition, and the number of captured adults also increased over time; all the animals caught in the last trapping session were adults. This may indicate that animals are more likely to pick up parasites when they spend more time foraging but may not point to a relationship between parasite load and condition. Additionally, population density increased over time and higher population densities are associated with higher rates of infection transmission between individuals.

Although I did not find conclusive evidence to support my hypothesis, I believe that deviations from my predictions in the results were mostly due to confounding variables related to the observational design of my study. Population density, time, and age and sex differences in foraging rates and immunocompetence may be responsible for masking impacts of parasites on condition and the role they may play in influencing behavior and risk-taking. Since this was not a direct randomized-controlled experiment, I could not control for these variables. Furthermore, I could not directly analyze the effects of parasites on animals as I could in an experiment where I would directly manipulate the voles' infection status. I believe that future research into this topic should include an experimental study design and use data from a larger sample size and multiple populations to draw more conclusive evidence.

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