Effects of Dung Beetle Functional Group Diversity on Dung Removal and Community Assembly

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Abstract

Dung beetles (family *Scarabaeidae*) are primarily coprophagous beetles that are found worldwide. These beetles have important roles within an ecosystem that often translate to substantial ecosystem services, particularly within the agriculture industry. Through dung removal and restructuring of the dung, they alter physical characteristics and influence the arthropod community that utilizes dung as a resource. There are three recognized functional groups of dung beetles: rollers (telecoprids), who roll dung into balls and bury them vertically and horizontally, dwellers (endocoprids), who live within the dung, and tunnelers (paracoprids), who bury brood balls in tunnels below the pat .To test how functional group diversity affected arthropod diversity and dung removal, exclosures were built to prevent removal by certain groups and dung weight was measured over four time periods: 1, 2, 7, and 14 days. Arthropod presence was characterized into three groups: non-coleopteran, coleopterans, and larvae, and abundance, richness, and diversity were accounted for all dung pats. Weight between groups was nearly significant, with time having a significant effect on weight as well as all arthropod groups. However, only adult non-coleopterans diversity and richness were affected by functional group diversity. Absence of rollers significantly increased non-coleopteran diversity and richness, and substantially lowered dung removal rates. As many non-coleopteran species are considered pest species, a maintenance of diversity in important for livestock. Dung removal is also important for effective nutrient cycling, important for fertilization of agriculture and ecosystem functioning.

Introduction

Dung beetles (family *Scarabaeidae*) are primarily coprophagous beetles that are found worldwide (Nichols et al., 2008). These beetles have important roles within an ecosystem that often translate to substantial ecosystem services, particularly within the agriculture industry (Nichols et al., 2008). Dung beetles are crucial to the microhabitat of a dung pat as they modify multiple aspects of the dung, including inner structure and amount of dung in a pat. These physical alterations can then influence the community of organisms that inhabit the dung. For example, tunnels made by some beetles aerate the dung, which can be beneficial for many living within, but also create passageways for predatory arthropods to access their prey (Hanski and Cambefort, 2014). Furthermore, dung removal itself removes habitat space for other species to occupy (Yoshihara and Sato, 2015). However, we do not know how dung beetle functional composition affects community composition and diversity within a dung pat.

Besides bacteria, organisms that are known to inhabit piles of dung include collembolans, acarines, dipterans, parasitic hymenopterans, and coleopterans, both predatory and herbivorous (Beynon et al., 2012). Which insects live on the dung as well as when and where depends on size and shape of the dung, how much time has passed, and which insects have colonized the dung previously (Nichols et al., 2008). Larvae of the community living on the dung largely occupy different niches than adults and often feed on different materials or organisms (Hanski and Cambefort, 2014), leading to a complex and constantly shifting food web as they mature. Adult dung beetles feed on the liquid flora from the digestive tract of the animal that produced the dung, and feed the larger pieces of undigested plant material to their larvae (Nichols et al., 2008). In the process of feeding themselves and their larvae as well as inhabiting the dung, beetles manipulate many characteristics of the dung, which can have considerable impacts on other organisms that may also inhabit the dung.

Dung beetles who live in the dung utilize it in multiple ways. There are three recognized functional groups of dung beetles: rollers (telecoprids), who roll dung into balls and bury them vertically and horizontally, dwellers (endocoprids), who live within the dung, and tunnelers (paracoprids), who bury brood balls in tunnels below the pat (Bertone et al., 2006). These functional groups each alter physical aspects of the dung differently, and therefore play different roles in how the dung is used by other arthropods, whether by creating tunnels, mechanically damaging larvae and eggs of other species, and resource competition (Nichols et al., 2008). These three functional groups, when acting together, have been shown to enhance dung removal and seed dispersion (Slade et al., 2007). It follows that when all three functional groups are able to remove dung, other insects are also able to exploit all potential niches. Using field manipulations, I hypothesized that increased functional group diversity would result in increased dung removal and increased community diversity over time.

Methods

Study Site:

All trials were conducted during the summer of 2015 on the National Bison Range (NBR), located in Dixon, MT. The NBR is characterized by rolling hills and Palouse prairie grasses. It is grazed by pronghorn antelope (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), bighorn sheep (*Ovis canadensis*), and the American Bison. There are about 400 bison currently living on the range, which are managed by the USFWS (USFWS, 2013). The field experiment was conducted in Lower Pauline pasture, where bison were present as part of their summer grazing rotation.

Field Experiments:

Four treatments were created so as to prevent dung removal by different functional groups of dung beetles: tunnelers, rollers, both, and neither. It has been previously demonstrated that when prevented from moving their brood ball, dung beetles abandon it (Slade et al., 2007, Peck and Forsyth, 1982). To prevent tunnelers from removing dung below ground, 40 cm x 40 cm squares were cut from 1 mm aluminum insect screening. To prevent rollers from rolling dung horizontally, 33 cm diameter cylinders were constructed from the same screening. To exclude dung removal by both tunnelers and rollers, cylinders were sewn onto squares with aluminum wire. All dung was placed on 20 cm x 20 cm 1 cm wire netting (Slade et al., 2007).

A randomized block design was designed of 4 blocks by 4 blocks spaced 10 feet apart with each treatment replicated once within each block (Slade et al., 2007). Exclosures were fixed to the ground using a combination of earth staples and wooden stakes, ensuring no beetles would be able to crawl underneath or through any spaces to remove dung.

Fresh bison dung was collected from around the NBR. Only the insides of the dung pats were collected to ensure even moisture amongst pats. Dung was homogenized, formed into 600 g patties, and frozen for 24 hours to kill any organisms living within the dung (Slade et al., 2007). 600 grams was a suitable enough size to prevent drying and is comparable in thickness to naturally occurring bison dung.

Four replicates of dung were removed at four time intervals following deployment: 24 hours, 48 hours, 1 week, and 2 weeks. All dung inside the exclosure was collected as this represented dung that failed to be removed by beetles. Dung was immediately weighed to measure amount removed by beetles. Each dung pat was dissected for 20 minutes, and all organisms found were accounted for and differentiated to morpho-species.

Analyses:

Organisms were divided into three categories: adult non-coleopterans, larvae, and coleopterans. This avoided double-counting of species between larval and adult forms.

Abundance, species richness, and Shannon-Wiener diversity indices were calculated for each sample. ANOVA and repeated measures ANOVA were conducted in SYSTAT.

Results

There was a nearly significant effect of treatment (p=0.0695), and significant effect of time (p=0.0001, Figure 1) on weight of dung. However, there was no significant effect based on arthropod grouping as opposed to pooled (df=3, F=2.144, p=0.148). For 1, 2, and 7 days, exclosures that prevented rollers from removing dung, either by themselves or in combination with tunnelers, had higher weights of dung. However, these effects were dampened by the 14 day mark.

For adult non-coleopteran diversity, there was a significance difference between treatments (df=3, F=4.273, p=0.029, figure 2), and over time (df=3, F=19.426, p=0.000), but no significant interaction (df=9, F=1.147, p=0.357) between the two. For non-coleopteran richness, there was a significant effect of treatment on species richness (df=3, F=3.535, p=0.048, figure 3) as well as time (df=3, F=11.811, p=0.000) and the interaction between the two (9=12, F=2.257, p=0.040). For both of these measures, pats that excluded rollers (in either method) had higher diversity and richness. For adult non-coleopteran abundance, there was no significant effect of treatment on abundance (df=3, F=0.662, p=0.591, figure 4), but time did have a significant effect (df=3, F=47.897, p=0.000). The interaction between the two is not significant (df=9, F=0.522, p=0.849).

For larval diversity, there was no significant difference between treatments (df=3, F=0.130, p=0.940, figure 5), but time had a significant effect (df=3, F=16.885, p=0.0001), while there was no interaction between treatments and time (df=9, F=1.632, p=0.143). For larval species richness, treatments did not have a significant effect on larval species richness (df=3, F=2.059, p=0.159, figure 6), but time (df=3, F=40.310, p=0.0001) and the interaction term (df=9, F=2.609, p=0.020) were both significant. For larval abundance, there was no significant effect of treatment (df=3, F=1.466, p=0.273, figure 7), but time did have a significant effect (df=3, F=27.456, p=0.0001). The interaction was not significant (df=9, F=1.361, p=0.242).

For coleopteran diversity, there was no significant effect of treatment (df=3, F=0.716, p=0.561, figure 8), but time did have a significant effect (df=3, F=16.237, p=0.0001). There was a significant interaction (df=9, F=2.247, p=0.041) between the two variables. For coleopteran species richness, there was no significant effect of treatment (df=3, F=1.233, p=0.341), but time did have a significant effect (df=3, F=9.021, p=0.0001), as did the interaction (df=9, F=1.986, p=0.070). For coleopteran abundance, there was no significant effect of treatment (df=3, F=1.409, p=0.288), time (df=3, F=0.801, p=0.501), or interaction between the two (df=9, F=1.935, p=0.078) on coleopteran abundance.

Discussion

Most of the loss of weight of dung could be accounted for by drying. Future methods of testing dung removal should measure dry weight in order to measure only how much dung was lost from dung beetle removal. However, despite this setback, rollers did appear to have a nearly significant effect on dung removal. Perhaps with greater replication or different measures of weighing, this number would be close to significance.

Further explanation can be found in the size of the beetles found in the dung. These were nearly all less than 1 cm in length. Slade et al. (2007) found that larger (> 1cm) dung beetles had a greater effect on dung removal. It is possible that the overall smaller size of the dung beetles found here dampened the effects of dung removal.

Time was significant in all tests except for adult coleopteran abundance. As previously stated, as physical aspects of dung change, different patterns in colonization can occur. As dung gets removed, there is less physical space to colonize. As tunnels are created, so are passageways which provide a microhabitat to live in, but dung also dries faster, reducing other occupiable space. This will shift community composition to "better" competitors and potentially organisms better adapted to a comparably dryer habitat.

Rollers were responsible for the primary increases in non-coleopteran diversity and richness. Rollers do minimal damage to the internal structure of the dung, and instead only remove dung from the pat. This likely has minimal effects on aeration and moisture content of the dung, as well as leaves more space for non-coleopterans to occupy.

This study has important implications for agricultural and ecosystem functional reasons. The majority of non-coleopterans were dipterans, which are considered a pest species to livestock. If the greatest diversity of functional groups reduced diversity of these pest species, it is in the best interest of livestock farmers that a diversity of dung beetles is maintained. Furthermore, it has been shown that dung in large pats "poisons" the grass surrounding it. With more effective dung removal, pats break down faster and allow livestock to graze in a greater area. With bison becoming more popular as a livestock species, this is relevant in a specific manner and can likely be extrapolated to other types of livestock.

Dung removal relates to the important ecosystem function of nutrient cycling. Dung beetles, in taking small pieces of dung and distributing locally around the pat, ensure that nutrients do not get trapped in a singular location. The mechanical damage and processing of the dung both aid in decomposition. This is useful to agriculturalists who depend on decomposition of manure to fertilize their plants, as well as ecosystems in general that require nutrients to be distributed and cycled throughout. Diversity of functional groups is significantly beneficial in this process.

Figures

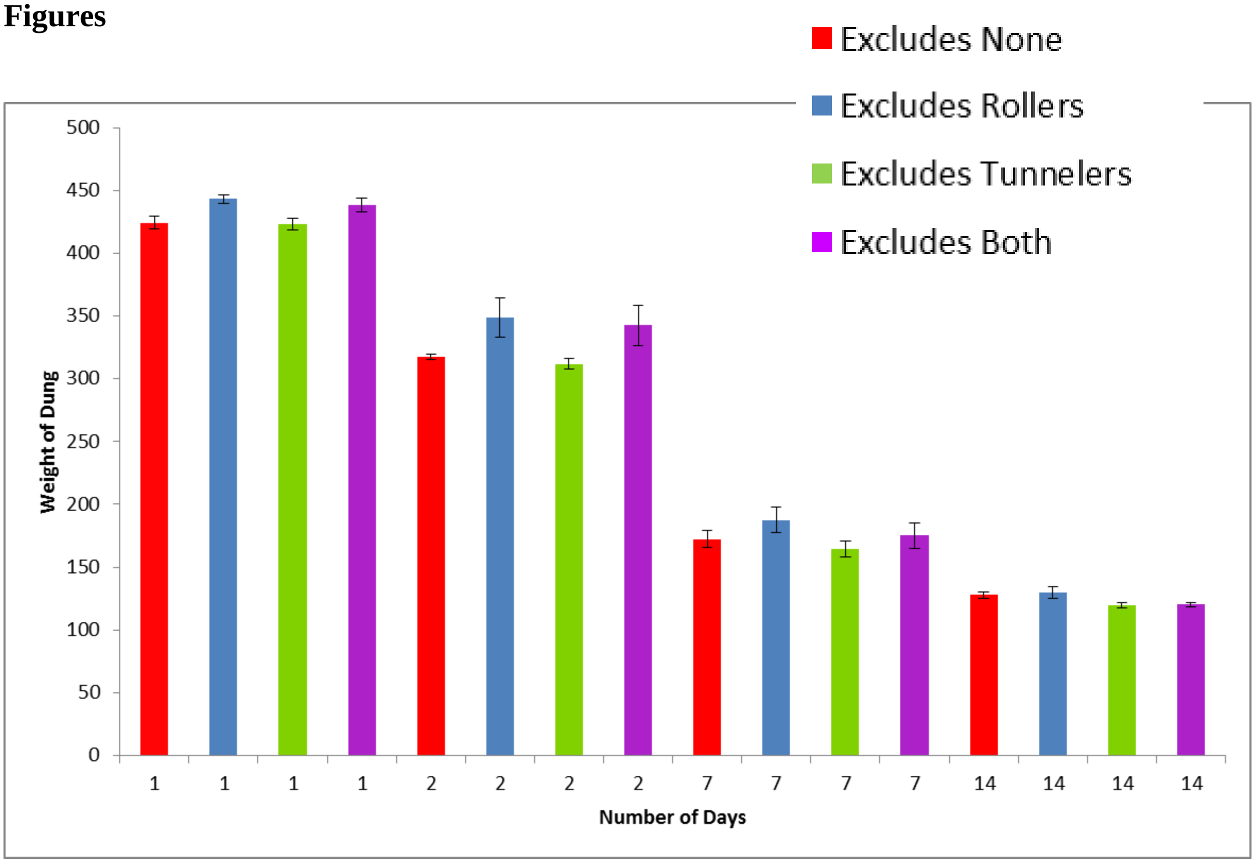


Figure 1: Weight of dung over time based on functional group exclusion (mean ± 1 se) Nearly significant effect of treatment (p=0.0695), and significant effect of time (p=0.0001). No significant effect based on arthropod grouping as opposed to pooled (p=0.148).

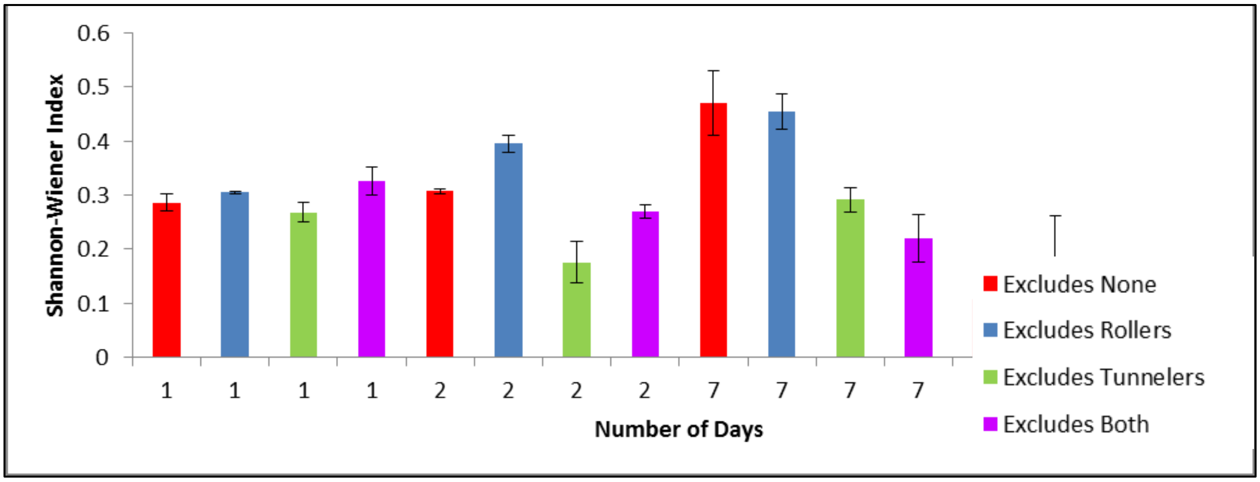


Figure 2: Shannon-Wiener diversity of adult non-coleopterans based on functional group exclusion (mean ± 1 se) There was a significance difference between treatments (p=0.029), and over time (p=0.0001), but no significant interaction (p=0.357) between the two.

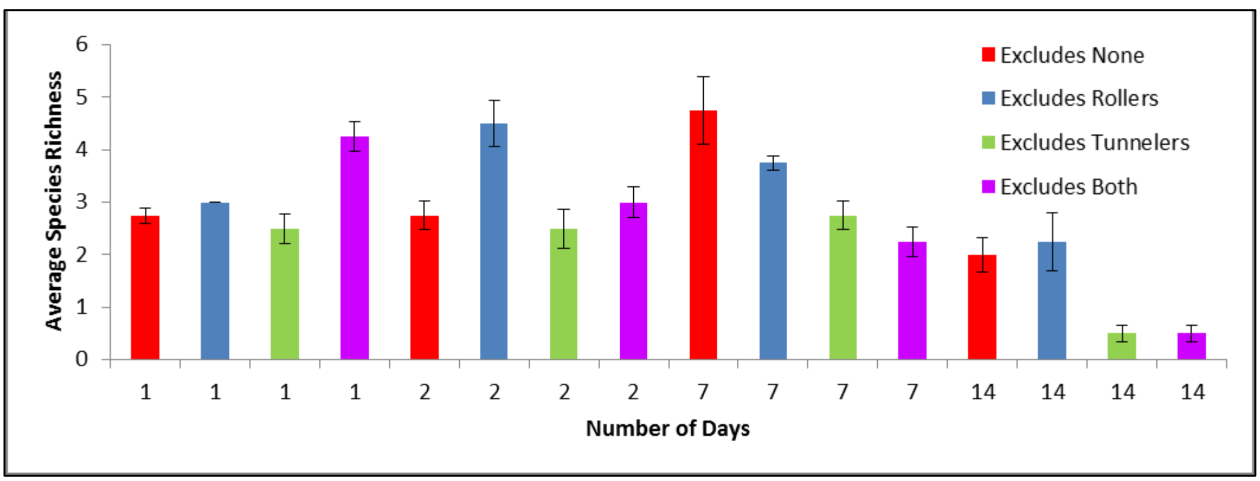


Figure 3: Species richness of adult non-coleopterans based on functional group exclusion (mean ± 1 se) There was a significant effect of treatment on species richness (p=0.048) as well as time (p=0.0001) and the interaction between the two (p=0.040).

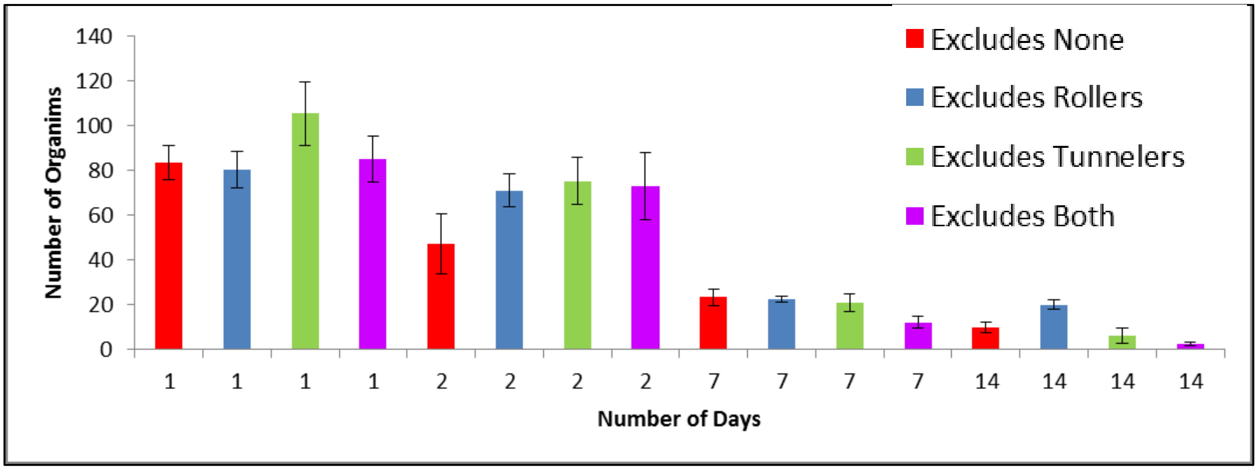


Figure 4: Abundance of adult non-coleopterans based on functional group exclusion (mean ± 1 se) There is no significant effect of treatment on abundance (p=0.591), but time did have a significant effect (p=0.0001). The interaction between the two is not significant (p=0.849).

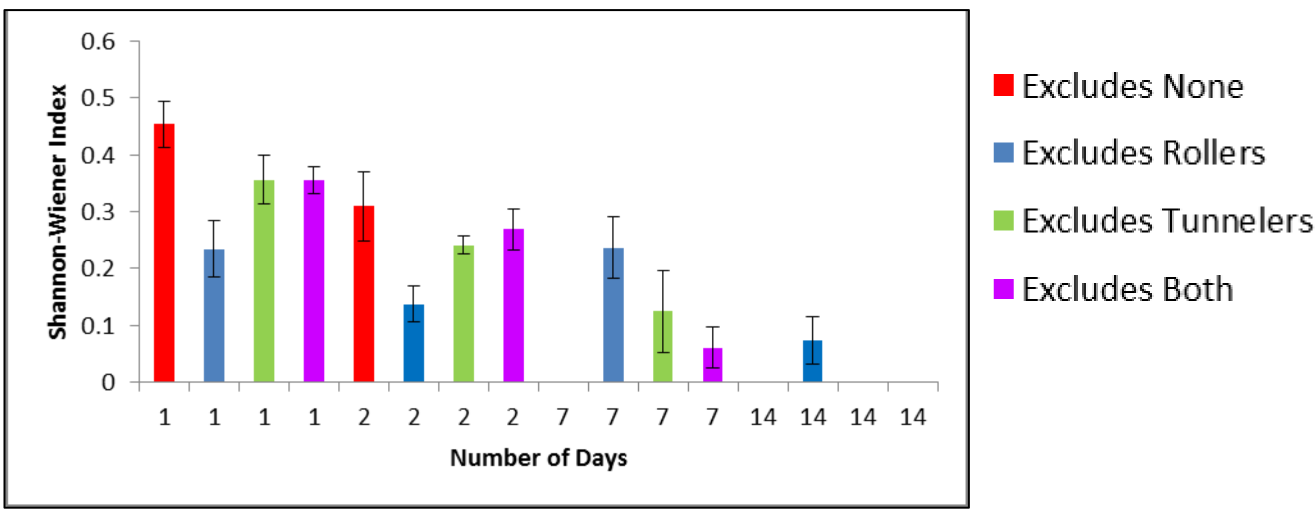


Figure 5: Shannon-Wiener diversity of larvae based on functional group exclusion (mean ± 1 se) No significant difference between treatments (p=0.940), but time had a significant effect (p=0.0001), while there was no interaction between treatments and time (p=0.143).

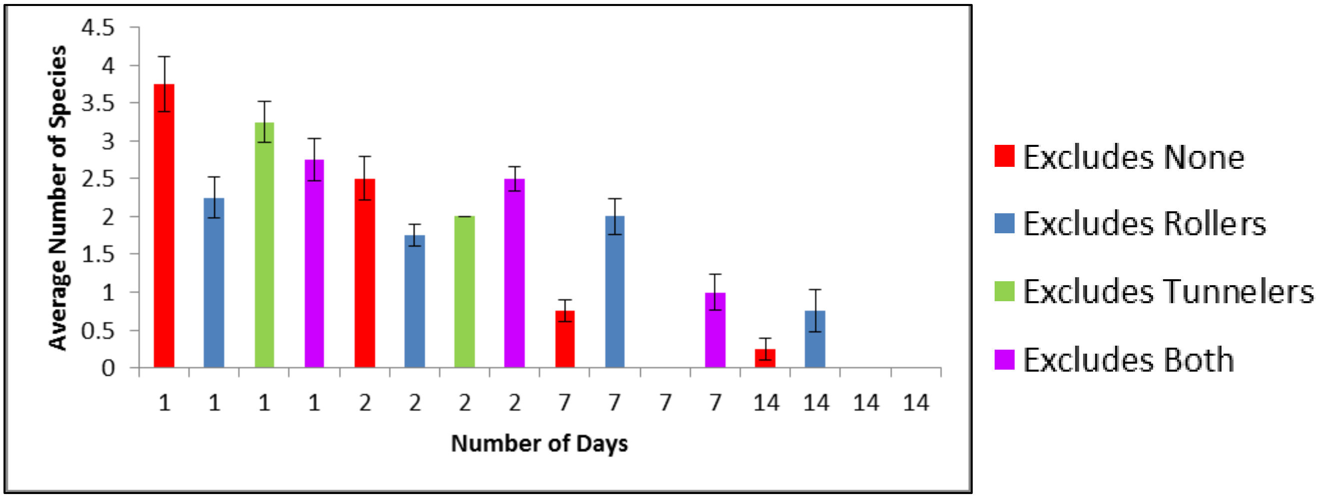


Figure 6: Species richness of larvae based on functional group exclusion (mean ± 1 se)

Treatments did not have a significant effect on larval species richness (p=0.940), but time (p=0.0001) and the interaction term (p=0.020) were both significant.

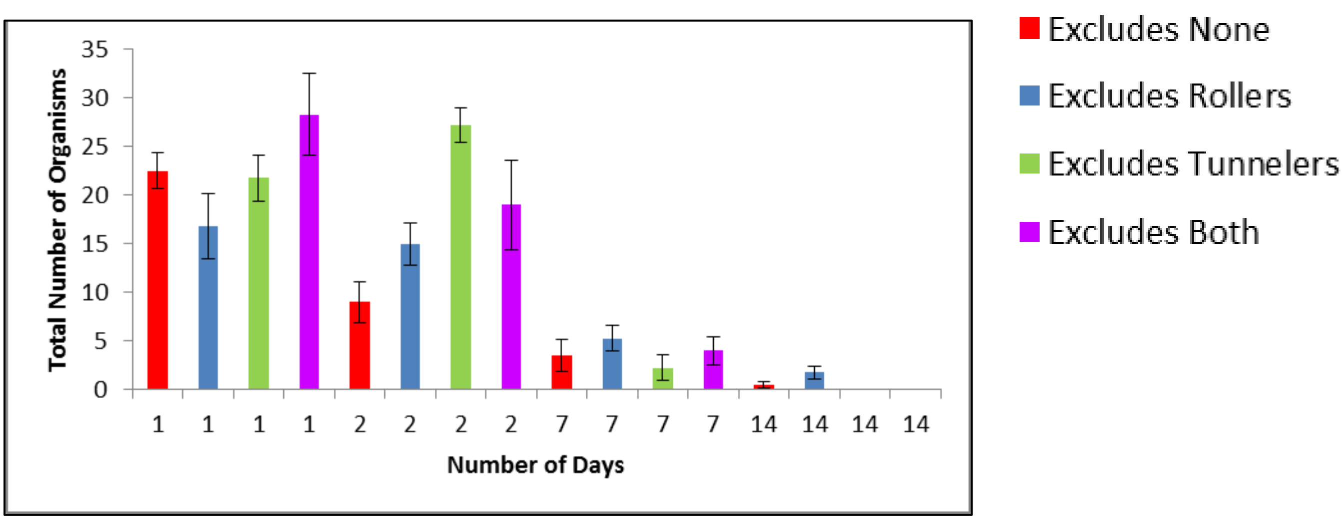


Figure 7: Abundance of larvae based on functional group exclusion (mean ± 1 se) There was no significant effect of treatment (p=0.273), but time did have a significant effect (p=0.0001). The interaction was not significant (p=0.242).

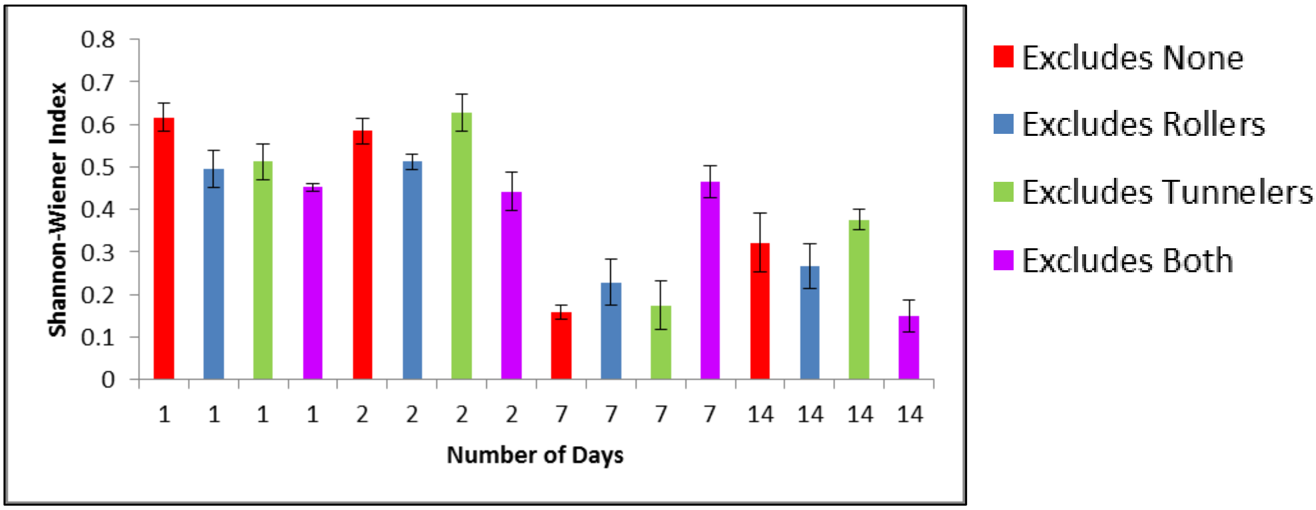


Figure 8: Shannon-Wiener diversity of adult coleopterans based on functional group exclusion (mean ± 1 se) There was no significant effect of treatment (p=0.561), but time did have a significant effect (p=0.0001). There was a significant interaction (p=0.041) between the two variables.

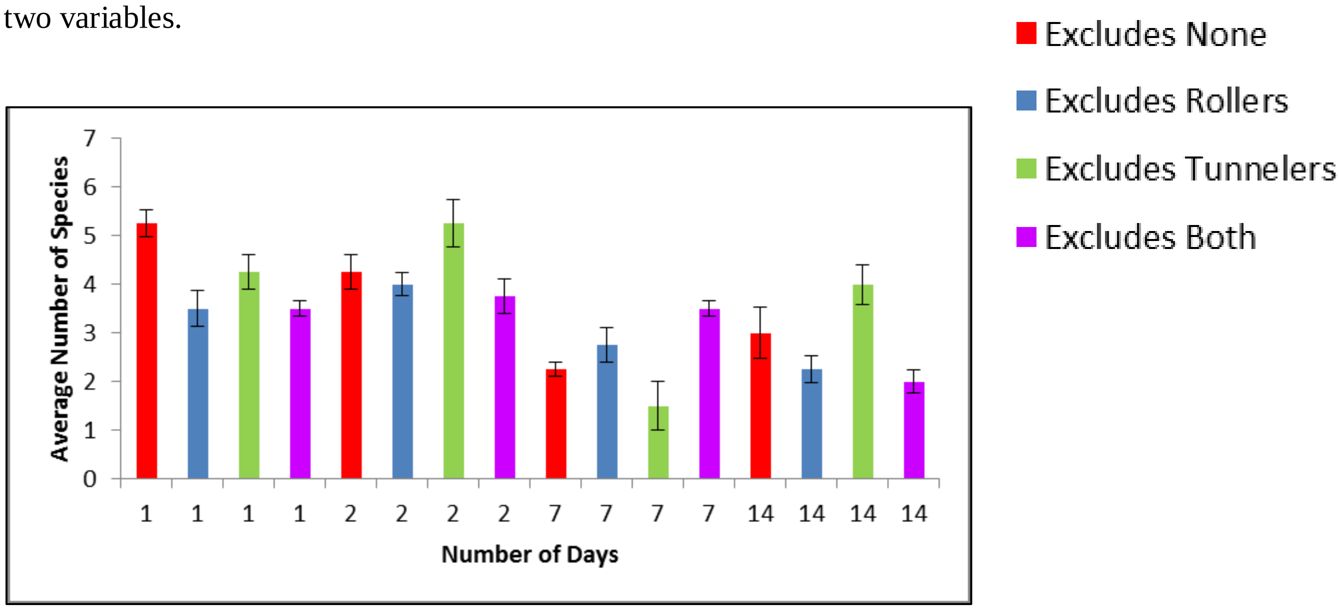
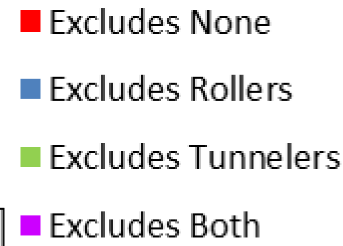


Figure 9: Species richness of adult coleopterans based on functional group exclusion (mean ± 1 se) There was no significant effect of treatment (p=0.341), but time did have a significant effect (p=0.0001), as did the interaction (p=0.070).



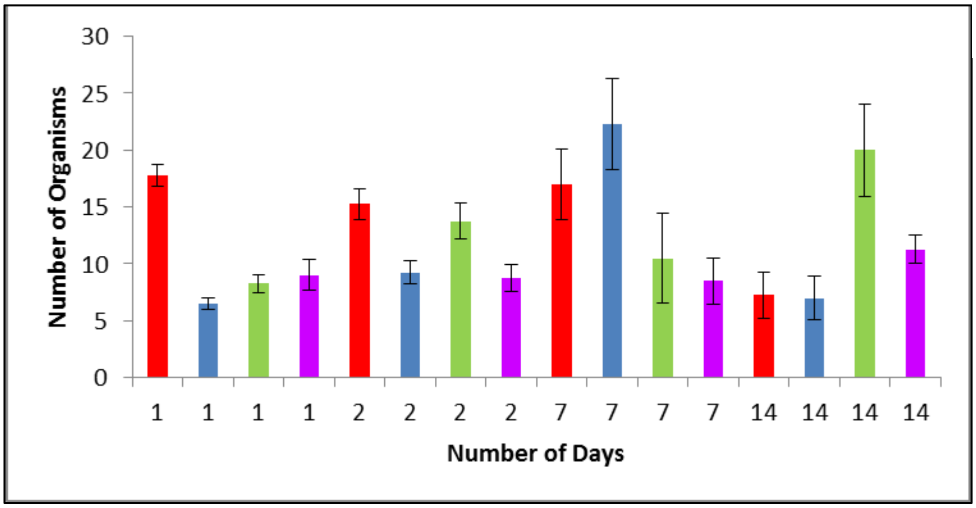


Figure 10: Abundance of adult coleopterans based on functional group exclusion (mean ± 1 se) There was no significant effect of treatment (p=0.417), time (p=0.159), or interaction between the two (p=0.135) on coleopteran abundance.

References

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