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Ecological Sustainability in Rangelands: The Contribution of Dung Beetles in Secondary Seed Dispersal (Case study: Chaharmahal and Bakhtiari province, Iran)

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Abstract:
Ecological sustainability has been recognized as one of the main aspects of sustainable development of rangelands, at which different kinds of animal including insects, make substantial contributions. Dung beetles, known as dung-visiting insects, play several key roles in many ecological functions from which benefit both terrestrial ecosystems and human population. Specifically, they benefit rangelands through reducing greenhouse gas emission, nutrient cycling, plant growth enhancement, trophic regulation and pollination and secondary seed dispersal. This study examined secondary seed dispersal as one of the ecological functions of dung beetles, in Chaharmahal and Bakhtiari province, Iran. We applied an experimental approach to measure ecological function (i.e. seed removal) by functional groups of dung beetles. We tested whether functional dung beetle groups influence secondary seed dispersal differently. Through repeated standardized samples of sheep dung, data obtained regularly during two different months August and November in 2013. The results show that dung beetles play a role in secondary seed dispersal. However, it is affected by seed size, so that seed removal increased in the order of, large, medium and small size, respectively. The significant differences between treatments were found for small seeds in the both months. More seeds were dispersed from treatment t02 (all combinations of functional groups except large rollers) in August, while in November more seeds from treatments t01 (dwellers plus large and small tunnelers plus large and small rollers) and t03 (the combinations of dwellers plus small tunnelers, and small rollers) were removed. As a conclusion, it is suggested that if it is to guarantee the ecological sustainability of rangelands, paying attention to the ecological functions of dung beetles is crucial.

Keywords: Ecological sustainability, functional groups, secondary seed dispersal, dung beetles, Chaharmahal and Bakhtiari province, Iran.

1. Introduction

The term "sustainability" has been originated from ecological science and developed to express the conditions that must be available for the ecosystem to sustain

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itself over the long-term (Holden *et al.* 2014). Recently, criteria and indicators for monitoring and assessing the economic, social, and ecological sustainability of rangelands have been developed. Amongst them, ecological sustainability has been recognized as a capacity of ecosystems to retain their essential functions and processes and conserve their biodiversity in the full measure over the long-term. Among the indicators considered, "presence and density of wildlife functional groups on rangeland" have acknowledged as excellent indicators of ecological sustainability (Mitchell 2010). Thus, ecological sustainability can be introduced as one of the main aspects of sustainable development of rangelands, at which different kinds of wildlife including insects, make substantial contributions.

Insects, as one of the most important branches of animal, have effective roles in relation to their ecological performance due to their mobility. Dung beetles, known as dung-visiting insects, play several important roles in several ecological functions, from which benefit both terrestrial ecosystems and human population. They are extensive in almost all ecosystems, including deserts, farmlands, forests, and grasslands that can be used bioindicator index to effectively design and evaluate ecologically sustainable management plans (Maleque *et al.* 2009). In line with this, due to their sensitive to disturbance and respond to habitat alterations, they are suggested to be used as indicators of habitat (Estrada and Coates-Estrada 2002; Andresen 2005; Feer 2008; Nichols *et al.* 2007). Further, since they have a good relationship with all types of vertebrate fauna dung and play a role as decomposers and dispersers, can be useful to understand ecosystem structure and function on the landscape scale (Aguilar-Amuchastegui and Henebry 2007; Davis *et al.* 2001; Halffter and Arellano 2002). Moreover, most of the ecosystem services provided by dung beetles are related to the decomposition and removal of dung (Yamada *et al.* 2007; Wu and Sun 2010), and effects on reducing greenhouse gases (Atte *et al.* 2013) nutrient cycling (Liberal *et al.* 2011), plant growth (Bang *et al.* 2005), seed dispersal (Slade *et al.* 2007), through which benefit rangelands. If some of their functions are measured, they can be considered as an effective indicator of their habitat.

The overall ecosystem services provided by dung beetles have stated much by researchers (Nichols *et al.* 2008; Braga *et al.* 2013). However, the secondary seed dispersal by dung beetles has been much attention paid as one of the most important of their functions. By definition, the system of dispersal and post-dispersal by the dung beetles, known as secondary seed dispersal or diplochory, is a process of removing seeds by a secondary disperser (e.g., rain, ants, rodents, birds and dung beetles) once they have been deposited by their primary disperser (e.g., wind, water, gravitation or animals) (D'hondt *et al.* 2008). The seeds of various species are transported by different dung beetles; for example, tunnelers transfer through the deposited food in burrows and rollers by means of rolling a ball to the nest. In a specific type of secondary seed dispersal, dung beetles remove the seeds deposited in dung after endozoochorous dispersal and therefore affect plant reproductive success (Andresen and Levey 2004; Feer *et al.* 2013). Diplochory has been studied in the forest through dung beetles that disperse small seeds (Estrada and Coates-Estrada 1991; Huerta *et al.* 2013). Burying the seeds by the dung beetles reduces the risk of predation of seeds by rodents (Vander Wall & Longland 2004), but very little is known regarding the diplochory or secondary dispersal in terms of ecological sustainability.

This study sought to the realization and understanding of secondary seed dispersal that is crucial for nature conservation, human population, and terrestrial ecosystems. It examines secondary seed dispersal as one of the ecological functions of dung beetles, in Chaharmahal and Bakhtiari province, Iran. We applied an experimental approach to measure ecological function (i.e. seed removal) by functional groups of dung beetles. We tested whether or not, different functional groups influence secondary seed dispersal. Through repeated standardized samples of sheep dung, data obtained regularly during two different months August and November in 2013.

2. Method & material

The study sites are located in semi-arid rangelands in the Chaharmahal and Bakhtiari province, geographically Southwestern part of Iran (50° 49' 52" E, 32° 21' 43" N). The climate of the region is classified as cold and arid (in terms of Köppen classification) with an annual temperature of 2 °C to 20°C and an annual average precipitation of 285 mm. The average height of the area is 2385 meter above sea surface level. We tested whether functional groups influence secondary seed dispersal differently. Through repeated standardized samples of sheep dung, data obtained regularly during two different months August and November in 2013 at Tangesayad site.
Dung beetles were classified into three functional groups including dwellers, tunnelers, and rollers by combinations, six exclosures as treatments were used in the seed removal experiment. They included t01 ($D^+T^+t^+R^+r^+$), t02 ($D^+T^+t^+R\text{-}r^+$), t03 ($D^+T\text{-}t^+R\text{-}r^+$), t04 ($D^+T\text{-}t\text{-}R\text{-}r^+$), t05 ($D^+T\text{-}t\text{-}R\text{-}r\text{-}$) and t06 ($D\text{-}T\text{-}t\text{-}R\text{-}r\text{-}$). Abbreviations are dwellers (D), large tunnelers (T), large rollers (R), small tunnelers (t), small rollers (r) and + and - signs represent the access or non-access of the respective functional groups. In exclosure t06, all dung beetles were admitted to represent that dung beetles were the great agents of seed removal and were not contained in subsequent analyses. Seed dispersal was calculated through formula percent of seed dispersal= $(N_{initial} - N_{regained}) \times \frac{100}{N_{initial}}$ where $N_{initial}$ are a number of seeds initially placed inside the dung sample and $N_{regained}$ is the number of seeds regained from the sample at the end of the experiment. For the assessment of effects of functional group composition on seed removal for all seed sizes, one-way ANOVA was performed with functional group composition and dung type as independent or fixed factors and seed dispersal data as measured variable. Post hoc comparisons for selected variables (seed removal in different seed sizes) were tested using Tukey HSD. Analyses were carried out using SPSS 16 Software.

3. Results

The results of the One-way ANOVA in August at Tange Sayyad site indicated that treatments differed significantly for removal of small seeds and significant difference between treatments were not found for variables including medium and large seed. Furthermore, in November, there is also a significant difference between treatments for small seeds removal (Table 2).

Table2. Results of the One-way ANOVA analysis for evaluating the influence of the treatments on seed removal for Tangesayad site.

Month	August			November		
variables	% small seed	% medium seed	% large seed	% small seed	% medium seed	% large seed
F	3.718	1.102	1.239	7.083	2.250	1.053
P	0.017	0.377	0.320	<0.001	0.092	0.400

Significant differences between treatments were found for small seeds in the both months. In August more seeds were dispersed with the treatments in which the most of the dung beetle groups could enter including t02 (all combinations of functional groups except large rollers) and in November t01 (dwellers plus large and small tunnelers plus large and small rollers) and t03 (the combinations of dwellers plus small tunnelers, and small rollers), while seeds were less dispersed in the most of the cases with the treatments such as t04 (the presence of dwellers plus small rollers) and t05 (only the presence of dwellers). Moreover, the seed dispersal in both months (August and November) had a difference significantly (Figure1).

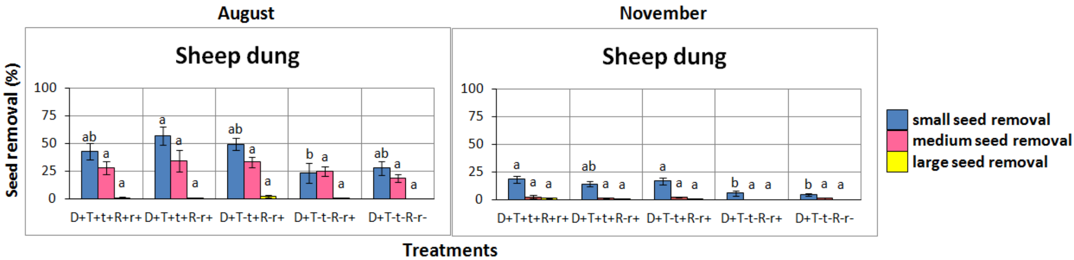

Figure1. Mean percentages for the dispersion of small, medium and large beads by treatments at Tangesayad site in August & November. Error bars represent the standard errors, and different letters indicate significant differences between groups after applying a Tukey HSD test on the One-way ANOVA results using small, medium and large seed removal consecutively as measurement variables (significance level: 0.05).

4. Discussion

The first result showed that seed dispersal affected by the presence of dung beetles. In line with this, some studies asserted, dung beetles play a role on burying seeds and their activity should be taken into consideration (Andresen 2001; Andresen and Levey 2004). The second result of this study showed that seed dispersal affected by different functional groups. In most cases, the significant differences between treatments were found for small seeds in the both months. In August most seeds were dispersed from treatment t02 which allows the activity of all functional groups except large rollers, but in November, most seeds in the treatments t01 and t03 get dispersed. The treatments t01 include the activity of dwellers plus large and small tunnelers plus large and small rollers and treatments t03 involve the combinations of dwellers plus small tunnelers, and small rollers. The treatments t04 (assemblages of dwellers plus small rollers) and t05 (the only assemblage of dwellers) were represented the least amount in both months. Our result agreed with Slade *et al.* (2007) and O'Hea *et al.* (2010) that in their studies concluded that increasing the combination of functional groups has increasingly an effective role in seed removal and conversely. Seed removal increased in the order of, large, medium and small size, respectively, it probably depends on the composition of the beetle community and seed size. In their studies; Scholtz *et al.* (2009) and Andresen (2002) stated that the probability and distance of a seed's horizontal dispersal by dung beetles is influenced the size of the seed. Moreover, Dangles (2012) demonstrated that burial rates, a key ecosystem process influenced by changes in functional groups, and temporal patterns in community composition.

The third conclusion is that seed dispersal transferred by dung beetles change in terms of environmental and seasonal conditions. In our study, most seeds were removed in August than November. Another explanation could be found in the fact that November was a rather wet month, in addition to colder temperatures, while the weather in August become drier and warmer which resulted in higher beetle activity. This result is consistent with Davis' work (Davis 1996), he concluded that seed removal differs during the different seasons so that it was more on warm and wet conditions than warm, dry, cool and cloudy conditions. However, the gap is more detailed evaluations that should be taken to assess the effect of the species type or different functional groups. Further, our result accordance with Quidé *et al.* (2015) that indicated the activity of groups of dung beetles (e.g., large tunnelers) was higher in drier and warmer weather than colder weather. In contrast with these result, in a study of Andresen (2002) showed that during the rainy season, seeds more buried than dry season. She attributed it, to the soil type so that soft soil facilitates dung and seed removal in the rainy season. Errouissi *et al.* (2009) found that the seasonal differences and opposite patterns based on the temporal distribution of species are related to the composition and diversity of dung beetles assemblage, i.e., dwellers and tunnelers so that dwellers were more active from autumn to spring. In contrast, tunnelers were more active in the spring-summer period and less in winter. However, in another study, Labidi *et al.* (2012) indicated that there were no spatial-temporal patterns according to bioclimatic, but the influence of local and regional factors on the dung beetle assemblages' distribution. As a conclusion, regarding the study area, we can argue that the distribution and composition of dung beetles' assemblages are influenced by seasonal patterns followed by affect secondary seed dispersal and seed survival. Finally, we can conclude, dung beetles contribute to ecological sustainability through the secondary seed dispersal as one of the most important ecological functions that was examined within this study in two different seasons.

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