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Original Research Article

Arthropod diversity and assemblage structure response to deforestation and desertification in the Sahel of western Senegal

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ABSTRACT

Drylands are highly vulnerable to desertification and among the most endangered ecosystems. To understand how biodiversity responds to environmental degradation in these fragile ecosystems, we examined whether arthropod, beetle, spider and ant diversity and assemblage structure differed (1) between seasons, (2) among locations (3) between protected areas of tropical dry forest and adjacent communal lands suffering from desertification, as well as (4) how vegetation impacts assemblage structures. We established 12 plots spaced homogenously throughout each protected area and the adjacent communal land at three locations: Beersheba, Bandia and Ngazobil. Within each plot, we measured canopy closure, vegetation height, percent cover of bare ground, leaf litter, grasses and forbs and collected arthropods using pitfall traps during the 2014 dry (May) and rainy (September) seasons. We collected 123,705 arthropods representing 733 morphospecies, 10,849 beetles representing 216 morphospecies, 4969 spiders representing 91 morphospecies and 59,183 ants representing 45 morphospecies. Results showed greater arthropod and beetle diversities ($P = 0.002–0.040$) in the rainy season, no difference in diversity among locations for any taxonomic group and a difference ($P \leq 0.001$) in diversity for all taxa between protected areas and communal lands. Assemblage structures of all taxa responded ($P = 0.001$) to vegetation characteristics, differed ($P = 0.015–0.045$) between seasons and, with a few exceptions, locations and fragments. Our results illustrate the importance of a multi-taxa approach in understanding biodiversity response to anthropogenic disturbances as well as the value of protected areas in preserving biodiversity of the Sahel.

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1. Introduction

Biodiversity is a multidimensional concept that covers all aspects of biological variation (Wilson, 1988). It includes the genetic variability within (individual level) and among (population level) individuals, the composition and abundance of species within a particular environment (community level) and the variety of ecological roles species play in nutrient cycling and energy flow (ecosystem level). The impact of anthropogenic disturbances on earth's biota has led to a global biodiversity crisis (Ceballos et al., 2015). A key strategy to combat biodiversity loss is to create and expand protected areas throughout ecoregionally representative areas (Venter et al., 2014). Despite increases in the extent of protected areas across the globe, biodiversity continues to decline (Butchart et al., 2010).

Drylands are one of the least understood, monitored and protected biomes in the world where human demand for farmland, pasture and fuelwood pose serious threats to biodiversity (Brito et al., 2014; Duncan et al., 2014). These biomes have attracted less scientific attention than other environments because of the perception of drylands as bare regions containing low diversity (Durant et al., 2012). Drylands receive low amounts of precipitation and have an aridity index value < 0.65, a measure of the ratio between average annual precipitation and total annual potential evapotranspiration (UN Environment Management Group, 2011). Overexploitation and mismanagement of drylands leave them vulnerable to desertification, defined as the loss of ecosystem services essential to sustaining life resulting from changes in soil and vegetation due to anthropogenic disturbances and/or climatic variations (D'Odorico et al., 2013). Desertification of dryland ecosystems is worsened by deforestation because the reduction in tree cover exposes the ground to wind and water erosion (Anjum et al., 2010). This process removes soil fertility, alters the water cycle and prevents vegetation regrowth, making life more difficult for the two billion people who depend on dryland ecosystem services for their livelihoods. High demand for water, farmland, grazing land, fuelwood and construction material further contributes to desertification (Millennium Ecosystem Assessment, 2005).

The decline in woody vegetation throughout the Sahel has exposed this dryland to desertification and resulted in biodiversity loss (Walther, 2016). The Sahel is located south of the Sahara Desert, north of the Guinean zone and runs latitudinally across the African continent from the Atlantic to the Indian Ocean. It is characterized by cyclic droughts, long dry seasons and an annual precipitation between 250 and 1100 mm. Despite growing human population and increased demand on natural resources, it remains one of the most vulnerable drylands with only 5% partially and 1% fully protected. Protected areas are vital to vertebrate conservation in the Sahel, with most large mammals unable to exist outside of them. Senegal once contained vast tropical dry forests; today, few protected areas remain in its Sahel, which is characterized by desertified communal lands used as pasture and farmland.

While deforestation and desertification have negatively impacted plants and vertebrates in the Sahel (Walther, 2016), little is known about how arthropods have been affected. Despite comprising over 90% of terrestrial species, arthropods are often overlooked in biodiversity studies (Briggs, 2016). Arthropods are excellent indicators of ecosystem health because they play an integral part in maintaining ecosystem processes and are abundant, widely distributed, phylogenetically and functionally diverse, ecologically important, sensitive to environmental disturbance and easy to sample (Kremen et al., 1993; McGeoch, 1998). In order to gain a more complete understanding of the biodiversity loss occurring in the Sahel and the role protected areas play in arthropod conservation, we examined general arthropod as well as beetle, spider and ant diversity and assemblage structure in western Senegal. We included multiple taxonomic groups since arthropod taxa can respond to environmental disturbances differently (Cabra-García et al., 2012; Fattorini et al., 2012; Beck et al., 2013; Leach et al., 2013) and a dry and rainy season sample to account for seasonal changes in their abundance and assemblage structure (Bourliere and Hadley, 1970).

The objectives of this study were to determine whether arthropod, beetle, spider and ant diversity and assemblage structure differ (1) between dry and rainy seasons, (2) among locations nested within season and (3) between protected areas of tropical dry forests and adjacent communal lands suffering from deforestation and desertification. We also wanted to (4) identify if environmental characteristics (canopy, leaf litter, grass, forb and bare ground cover as well as vegetation height) relate to assemblage structures for all taxa. We hypothesize that biodiversity, regardless of taxonomic grouping, will be greater in the rainy season compared to the dry season and in the protected areas compared to adjacent communal lands during both seasons. We hypothesize biodiversity will increase with fragment size and that assemblage structure for all taxonomic groupings will differ between seasons, among locations and between protected areas and communal lands. We further hypothesize that: canopy closure will be associated with assemblage structures in protected areas; bare ground and grass cover will be associated with communal land assemblage structures in the dry and rainy season, respectively; leaf litter cover will be associated with protected area assemblage structures in the dry season; and forb cover and vegetation height will be associated with protected area assemblage structures in the rainy season.

2. Materials and methods

2.1. Study locations

We studied arthropod diversity within a human-modified landscape suffering from deforestation and desertification in the Thiès region of western Senegal near the city of Mbour. The climate is semi-arid with 36 °C average maximum and 22 °C average minimum temperatures (Climate Zone, 2004). Rainfall in the Sahel is erratic; annual rainfall in Mbour ranges from