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Arthropod communities in a selenium-contaminated habitat with a focus on ant species☆

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ABSTRACT

The selenium contamination event that occurred at Kesterson Reservoir (Merced Co., CA) during the 1970–80s is a frequently cited example for the negative effects of contamination on wildlife. Despite the importance of arthropods for ecosystem services and functioning, relatively little information is available as to the impacts of pollution on arthropod community dynamics. We conducted surveys of the arthropod community present at Kesterson Reservoir to assess the impacts of selenium contamination on arthropod diversity, with a focus on ant species richness, composition and density. Trophic groups were compared to determine which arthropods were potentially receiving the greatest selenium exposure. Plant samples were analyzed to determine the selenium content by site and by location within plant. Soil concentrations varied across the study sites, but not across habitat types. Topsoil contained higher levels of selenium compared to core samples. Plants contained similar concentrations of selenium in their leaves, stems and flowers, but flowers contained the greatest range of concentrations. Individuals within the detritivores/decomposers and predators accumulated the greatest concentrations of selenium, whereas nectarivores contained the lowest concentrations. Species composition differed across the sites: *Dorymyrmex bicolor* was located only at the site containing the greatest soil selenium concentration, but *Solenopsis xyloni* was found at most sites and was predominant at six of the sites. Selenium concentrations in ants varied by species and collection sites. Nest density was also found to differ across sites, but was not related to soil selenium or any of the habitat variables measured in our study. Selenium was not found to impact species richness, but was a significant variable for the occurrence of two out of the eight native species identified.

1. Introduction

Understanding of the responses exhibited by arthropods to habitat variation or stress can be important for predicting changes that may occur within arthropod communities following disturbance. In particular, changes that occur among ant populations may reveal potentially negative consequences for ecosystem functioning due to the critical roles ants play in various ecological processes (Folgarait, 1998; Del Toro et al., 2012). In Australia, ants serve as useful biological indicators of ecosystem changes following such disturbances as fires, mining, deforestation, urbanization and pollution (Hoffmann and Andersen, 2003; Andersen and Majer, 2004). The impacts of heavy metal pollution on ant populations have also been extensively investigated in Europe (Grześ, 2010). Such investigations have reported pollution-induced effects on abundance (Bengtsson and Rundgren, 1984; Eeva et al., 2004), colony size (Eeva et al., 2004), species diversity (Bengtsson and Rundgren, 1984; Grześ, 2009), behavior (Sorvari and Eeva, 2010), and health (Sorvari et al., 2007). However, there is a lack of similar studies available for ant populations in North America, despite the existence of both natural and anthropogenic sources of environmental contamination.

Selenium is a naturally occurring element that enters the environment through the weathering of Cretaceous sedimentary rock, but can be concentrated and mobilized following human activities such as mining, smelting, coal burning and irrigation (Haygarth, 1994). Selenium is globally widespread, but present in varying concentrations across regions within a given country (Oldfield,

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2002). In the United States, selenium is particularly abundant in soils of several western states (Brown et al., 1999), where about 414,400 km^2 of land are considered susceptible to rain or irrigation-induced selenium contamination (Seiler et al., 1999). Selenium is an essential dietary requirement for animals (including insects), and several reports have linked regions with high incidences of dystrophy, cardiovascular disease, and certain cancers to selenium deficiencies (NRC, 1983; Oldfield, 2002). Previous studies suggest selenium may also play a similar important role for some insects (Martin-Romero et al., 2001; Popham et al., 2005). However, exposure to excess amounts of Se can also cause negative effects, such as vomiting, hair loss and yellowing of nails in humans and blind staggers and hoof deformations in animals (NRC, 1983). In insects, selenium exposure can increase mortality, decrease reproduction, and modify behaviors (Hladun et al., 2013; De La Riva and Trumble, 2016; Burden et al., 2016).

The potential for selenium toxicity in wildlife became evident in the 1980s when high concentrations of selenium at Kesterson Reservoir were found responsible for the deaths and deformities exhibited by birds breeding in the reservoir's evaporation ponds (Ohlendorf et al., 1986). The holding ponds of Kesterson Reservoir, located in Merced Co., CA, were originally meant to act as both a wetland habitat for migrating birds and a location to divert excess agricultural drainage water from the San Joaquin Valley's irrigated fields. However, damage to avian and fish populations occurred when subsurface drainage waters carrying selenium from the valley's selenium-abundant soils concentrated at the reservoir (Garone, 1998). The use of the reservoir as a repository for drainage water was then terminated and the ponds were filled in and the vegetation plowed in an effort to prevent further exposure to wildlife. Scientists have continued to monitor wildlife in the area, with most studies focusing on birds and small mammals (Ohlendorf et al., 1988; Santolo, 2009, 2007). A few publications have reported on the accumulation of selenium by invertebrates at Kesterson (Ohlendorf, 2002; Ohlendorf et al., 1988; Santolo and Yamamoto, 1999; Santolo, 2007), but no published information is available as to the impact on ants, pollinators, or terrestrial insects at the population or community level.

The objectives of this survey were as follows: 1) document the ant populations present; 2) determine whether selenium concentrations present in the environment are impacting ant species composition and abundance; 3) compare bioaccumulation levels of selenium across ant species and ant functional groups; 4) identify other insect taxa residing at Kesterson Reservoir; 5) compare selenium levels across different insect trophic groups.

2. Materials and methods

2.1. Study sites

Surveys were conducted during the spring of 2013 and 2014 at Kesterson National Wildlife Refuge, at the site of the former Kesterson Reservoir (37° 13′ 53″ N, 120° 53′ 26″ W, ~8 km east of Gustine, CA). The original 12 holding ponds no longer remain after the drying and filling or disking of the habitat; monitoring in the area has since been conducted based on three trisections of the entire 2100-ha land (Ohlendorf and Santolo, 1994). Our surveys were conducted on the southern end of the reservoir (Fig. 1) in sites at TriSection 1 (previously ponds 1–4) and the southern end of TriSection 2 (previously ponds 5–7, 9) in the three main habitat types (filled, open and grassland). Filled habitats were previously lower elevation areas that were filled in with soil, open habitats were the lands that formerly contained cattails that were disked, and grassland habitats were the upland areas that existed before the reservoir ponds were filled (Ohlendorf and Santolo, 1994). Collections were conducted in habitats at the southern end of Kesterson because we expected soil selenium concentrations to be greatest in the south (TriSection 1) and decrease northward,

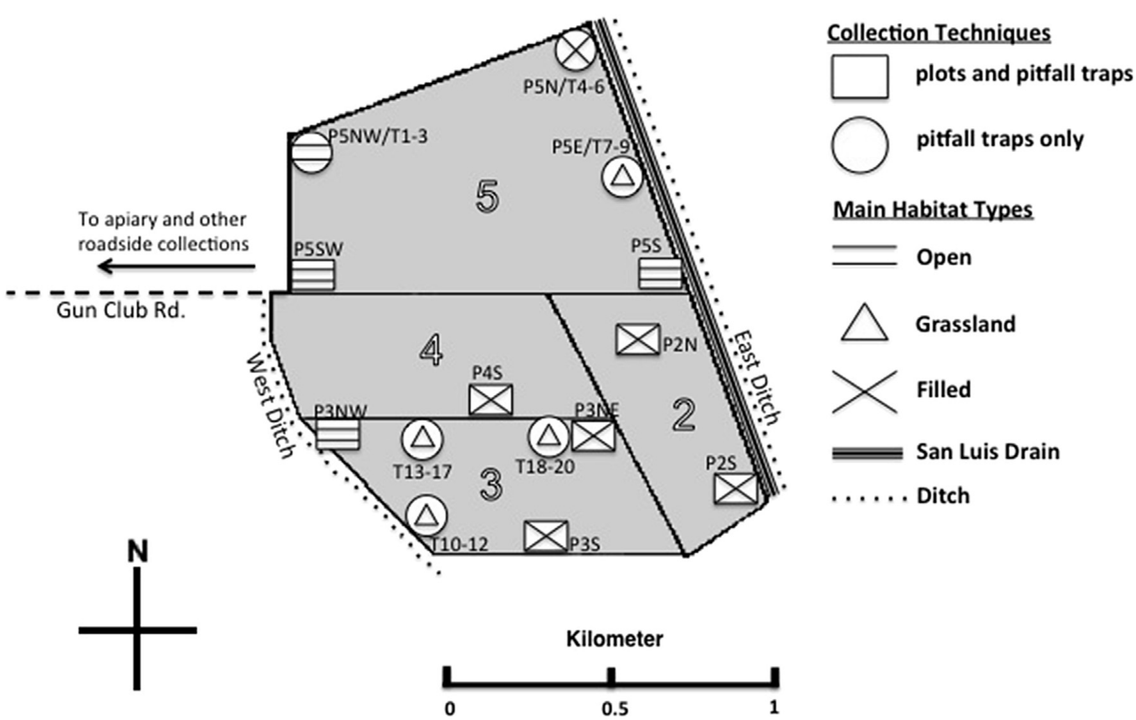

Fig. 1. Collection site locations within Kesterson Reservoir that were previously ponds 2, 3, 4 and 5. Rectangles represent sites that contained six replicate 4-m x 4-m plots containing pitfall traps. Circles only are those sites that only contained additional pitfall traps. Main habitat types were determined using previously established maps of Kesterson (Ohlendorf and Santolo, 1994).

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