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Individual- and population-level effects of *Odocoileus virginianus* herbivory on the rare forest herb *Scutellaria montana*

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ABSTRACT

Odocoileus virginianus (white-tailed deer) grazing can impact rare plant species dramatically given their risk for local extirpation and extinction. To determine if *O. virginianus* management could aid conservation of federally threatened *Scutellaria montana* (large-flowered skullcap), we conducted an exclosure experiment across a large occurrence of this rare species in Catoosa County, Georgia, USA. We aimed to: (1) quantify the effects of *O. virginianus* grazing on *S. montana* individuals, and (2) evaluate the potential of *O. virginianus* to influence *S. montana* populations. A lesser percentage of *S. montana* individuals protected from *O. virginianus* were grazed than plants accessible to grazers and additional protection from smaller grazers did not reduce grazing, suggesting that *O. virginianus* primarily do graze *S. montana*. But grazing did not significantly influence *S. montana* individuals as evidenced by changes in stem height or the number of leaves per plant assessed during two single growing seasons or across those growing seasons. At the population-level, grazing impacts were buffered by a lack of grazer preferences for specific plant life stages. Although mostly not significant, our findings are biologically interesting given the numerous ecological concerns associated with *O. virginianus* abundance, including their demonstrated and proposed impact on rare plants.

1. Introduction

White-tailed deer (*Odocoileus virginianus* Zimmermann) are one of the most widely distributed large mammals in the Western Hemisphere, occurring from southern Canada to northern Colombia and Venezuela (Demarais et al., 2000; Smith, 1991). In North America in particular, both the distribution and density of *O. virginianus* have increased markedly since the time of European settlement (Rooney, 2001). A combination of historical, anthropological, and archeological data (see McCabe and McCabe, 1997), as well as ecological modeling (see Alverson et al., 1988), has been used to estimate the pre-settlement density of *O. virginianus* in North America as approximately 2–4 individuals km^2. In contrast, *O. virginianus* population densities currently are approximately three times greater in many parts of the eastern United States (McCabe and McCabe, 1997; Russell et al., 2001). Various factors have been cited as directly or indirectly influential to the relatively recent increase in *O. virginianus* in eastern North America, including a decrease in the severity of winters (McCaffery, 1976; Solberg et al., 1999), the local extirpation of many large predators (Brown et al., 1999; McCullough, 1997; Rooney, 2001), a transition from old-growth to young forest stands (McCaffery, 1976; Fuller and Gill, 2001; Rooney, 2001), and a decrease in hunting pressure, which culled the *O. virginianus* population to near-extinction by the late 1800s (Brown et al., 1999).

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The increased presence of *O. virginianus* has been associated with numerous ecological and land management concerns, including the impact that their grazing may have on forest ecosystems and the plant species that they contain (McShea et al., 1997). In particular, grazing by *O. virginianus* has been associated with declines in tree species recruitment and losses of understory shrubs and herbaceous species (Alverson et al., 1988; Rooney, 2001; Rooney and Waller, 2003; Rooney and Dress, 1997; Rooney et al., 2000). Relative to all other activities, *O. virginianus* allot more time to feeding (Smith, 1991). Food selection varies from season to season depending on the availability (Crawford, 1982; Smith, 1991). During the winter, woody plants dominate the diet, but once herbaceous vegetation emerge in the spring and summer months, *O. virginianus* will feed preferentially on these plants (Balgooyen and Waller, 1995; Crawford, 1982). It has been estimated that forbs, in particular, comprise nearly 75% of the *O. virginianus* diet in late spring (Crawford, 1982). Foraging by *O. virginianus* has been described as selective for preferred species (Crawford, 1982) and plant parts that are relatively high in caloric value (Short, 1975) and easily digestible (Demarais et al., 2000; Short, 1975).

Early focus of research on the impacts of *O. virginianus* herbivory to woody vegetation (see Côté et al., 2004) has given way to a more recent focus of research on the impacts to herbaceous vegetation (see Knight, 2007). Such research has evidenced mainly that *O. virginianus* negatively impact herbs at the levels of plant individuals, populations, and communities (Anderson, 1994; Augustine and Frelich, 1998; Balgooyen and Waller, 1995; Fletcher et al., 2001a; Frankland and Nelson, 2003; Garcia and Ehrlén, 2002; Knight, 2007; Rooney and Waller, 2003; Ruhren and Handel, 2000). At the individual-level, these impacts include partial to complete removal of leaf and stem tissues and reproductive structures, as well as decreased overall plant height due to tissue removal (Anderson, 1994; Augustine and Frelich, 1998; Balgooyen and Waller, 1995; Frankland and Nelson, 2003; Garcia and Ehrlén, 2002). At the population-level, preferences of *O. virginianus* for tall flowering individuals (Anderson, 1994; Frankland and Nelson, 2003) could have negative implications for future growth (Garcia and Ehrlén, 2002). At the community-level, the decline or extirpation of plant populations that are preferentially grazed by *O. virginianus* could reduce overall plant species diversity (Balgooyen and Waller, 1995; Fletcher et al., 2001a; Rooney and Waller, 2003), which could have cascading impacts on the populations of pollinators and other herbivores (Anderson, 1994). Waller and Alverson (1997) proposed that the direct and indirect effects of *O. virginianus* herbivory on co-existing species and community structure and the cascading impacts of such effects on multiple trophic levels warrant its classification as a keystone species in eastern North American forests.

Because *O. virginianus* grazing has the potential to greatly impact and possibly extirpate common plant species (Anderson, 1994; Augustine and Frelich, 1998; Balgooyen and Waller, 1995; Frankland and Nelson, 2003; Knight et al., 2009), it is intuitive that there are even greater implications for impacts on rare plant species. Preferential feeding by *O. virginianus* has been shown to negatively impact plant species that are already rare (Fletcher et al., 2001b; Kettering et al., 2009; Vitt et al., 2009; Webster et al., 2005). Additionally, *O. virginianus* grazing has been implicated in causing common species to become rare in specific locations (Augustine and Frelich, 1998; Webster et al., 2005). For example, in the Cades Cove area of Great Smoky Mountains National Park, Tennessee, USA, long-term exposure to *O. virginianus* caused *Trillium* spp. to become rare while remaining common at a reference site that had comparatively lower *O. virginianus* densities (Webster et al., 2005). This localized rarity was likely influenced by persistent grazing that reduced mean plant height and reproduction since *Trillium* spp. reproduction is dependent on the plant height (Webster et al., 2005). Similarly, a study of the common understory species *Trillium grandiflorum* (white trillium) determined that levels of *O. virginianus* herbivory common to forest understory perennials were sufficient to cause its loss (Knight et al., 2009).

Scutellaria montana Chapm. (large-flowered skullcap) is an endemic perennial forb of the mint (Lamiaceae) family (Beck and Van Horn, 2007; Cruzan, 2001) found only in the Cumberland Plateau and Ridge and Valley physiographic provinces of the southeastern United States (Bridges as cited in USFWS, 1996; Patrick et al., 1995). Specifically, known populations occur in four counties (Bledsoe, Hamilton, Marion, and Sequatchie) in southeastern Tennessee, USA, and nine counties (Bartow, Catoosa, Chattooga, Dade, Floyd, Gordon, Murray, Walker, and Whitfield) in northwestern Georgia, USA (USFWS, 2012). Additionally, although *S. montana* has not been officially recorded from Alabama, USA, it has been reported anecdotally that populations also may occur there (Bridges as cited in USFWS, 1996; Patrick et al., 1995).

In 1986, the United States Fish and Wildlife Service (USFWS, 1986) listed *S. montana* as federally endangered due to habitat loss/alteration, possible exploitation for commercial use, inadequate regulatory protection, and the potential of population elimination due to natural fluctuations in numbers or human-induced habitat modifications. At that time, there were less than 7000 known *S. montana* individuals occurring within ten populations. Following its federal listing, a recovery plan was implemented for this species. The overall goal of the plan was to recover and/or protect *S. montana*; specific actions toward meeting this goal included habitat studies, additional population searches, land management, and translocations to be performed or funded by various government entities (USFWS, 2000). One of the main objectives outlined in the recovery plan was to downlist and then eventually delist *S. montana* based on evidencing a number of adequately protected and self-sustaining populations. In 2000, it was proposed that *S. montana* be downlisted from endangered to threatened because 32 distinct and 11 protected, self-sustaining populations had been determined to exist (USFWS, 2000). The official downlisting of *S. montana* to its current threatened status occurred two years later (USFWS, 2002). Recovery and protection actions continue for this species with the ultimate goal of delisting it.

Threats posed to the continued persistence of *S. montana* include inherently low reproductive rates (USFWS, 2002); habitat destruction due to development, logging, wildfire, and grazing (USFWS, 1996, 2002); competition from invasive plant species (GADNR, 2008), and a lack of management information (USFWS, 1996). Although the USFWS (2002) report on the reclassification of *S. montana* from endangered to threatened did not list *O. virginianus* as a specific threat to this species,