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Elk nutritional resources: Herbicides, herbivory and forest succession at Mount St. Helens

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ABSTRACT

Concern exists about the effects that silvicultural herbicides, past herbivory, and forest succession may have on the carrying capacity for ungulates in the vicinity of Mount St. Helens in southwest Washington. We independently evaluated the effects of both operational herbicides and ungulate herbivory on biomass and available digestible energy of forages in a chronosequence of early-succession (ES) forest stands using a retrospective, paired-site design. We distinguished between trends in biomass by classifying species as avoided (used less than available) or accepted (used equal or more than available) forages for elk based on recent research involving foraging trials of hand-raised, tractable elk in western Oregon and Washington. Herbicide application reduced biomass of accepted forages (kg/ha) for only two years, whereas the initial reduction in avoided biomass persisted throughout the 13-year ES period that we evaluated. The reduction in avoided species was not associated with an increase in accepted species, which may be related to herbivory. We observed that forest canopy closure even at 10–13 years was similar in stands treated and untreated with herbicides, suggesting herbicides did not shorten the seral window when palatable forages were abundant. Because dry matter digestibility of accepted species was generally higher than avoided species, digestible energy (DE, kcal/ha) available to elk was similar to trends in accepted and avoided biomass. An initial 2-year increase in modelled estimates of dietary DE in herbicide-treated stands in years 1–2 resulted from a rapid recovery of plants with high digestibility. In contrast to herbicide treatments, effects of ungulate herbivory on ES communities increased with stand age with a reduction of deciduous shrub height but not densities, reduced biomass of accepted but not avoided species, and reduced standing DE of accepted species outside exclosures. Despite the influence of herbicide applications, herbivory, or their interactions, nutritional resources for elk were equal or more available in ES stands than in mid- and late-succession stands, highlighting the importance of maintaining ES stands for elk in this region.

1. Introduction

Early-succession (ES) forests are essential habitats for ungulate species in many parts of North America because available forage declines as the forest canopy closes (Witmer et al., 1985). This is particularly true in forests of the Pacific Northwest where understory biomass can exceed 4000 kg/ha during the first 10 years of stand establishment, but then decline to <100 kg/ha as the canopy closes (Alaback, 1982; Hanley, 1984; Harper, 1987; Jenkins and Starkey, 1996; Witmer et al., 1985; Cook et al., 2016). Wildfires and wind storms historically created the majority of ES forests in the Pacific Northwest (Agee, 1993), but since the early 1950s, timber harvest has been the major disturbance creating ES stands in this region (Weisberg and Swanson, 2003). Over the last several decades, the increased use of wood aggregate products, competition with foreign markets, and protection of old growth forests for spotted owls (*Strix occidentalis* Xantus de Vesey) has led to declines in timber harvest and the loss of ES stands in western Washington and Oregon, particularly on federal lands (Franklin and Spies, 1991; Perez-Garcia and Barr, 2005; Washington Department of Natural Resources, 2012). Thus, the majority of ES stands in western Washington now exist primarily on private industrial timberlands (Washington Department of Natural Resources, 2012) where silvicultural herbicides are routinely used to enhance fiber production (Wagner et al., 2004). A suite of silvicultural herbicides is used operationally 1–2 times during the

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early-successional window to reduce competing grass and broadleaf woody plants (Blake et al., 1987; Brodie and Walstad, 1987; Freedman et al., 1993). Although the understory recovers post application (Blake et al., 1987; Brodie and Walstad, 1987; Stein, 1999), herbicide application may alter plant community composition and the long-term forage value of the understory community to ungulates (Strong and Gates, 2006).

Information on the effects of herbicides on understory plant communities in the Pacific Northwest is accumulating (Clark et al., 2009). For example, sword fern (*Polystichum munitum* C. Presl), a highly competitive evergreen species that is unpalatable to most ungulates, may be reduced for more than 5 years following herbicide application (Stein, 1995), whereas high-value forage species for elk (*Cervus elaphus* Erxleben), such as wooly catsear (*Hypocharis radicata* L.) and *Crepis* spp., may increase with the frequency of herbicide application because their short life cycle permits them to establish between treatments (Peter and Harrington, 2009). On the other hand, 50–70% reductions in cover of palatable woody plant species with herbicide application have been documented, which may directly reduce browse availability (Freedman et al., 1993; Stein, 1999), but also may indirectly alter the abundance of forbs and grasses due to reduced shading.

Concerns have risen regarding the combined effects of declining ES stands and routine herbicide application on elk and black-tailed deer (*Odocoileus hemionus columbianus* Richardson) populations in the Pacific Northwest (Washington Department of Fish and Wildlife, 2006; Oregon Department of Fish and Wildlife, 2008). Black-tailed deer populations have been regionally declining (Oregon Department of Fish and Wildlife, 2008), and low pregnancy rates and body fat levels have been reported for elk in western Oregon and Washington (Cook et al., 2013). However, only Ulappa (2015) has directly assessed the effects of operational herbicide treatments on nutritional resources available to ungulates in detail, and their study was directed at black-tailed deer. Because black-tailed deer and elk have different requirements and may select for different plant species (Leslie et al., 1984; Kirchhoff and Larsen, 1998), we focused on evaluating effects of operational herbicide application on nutritional resources for elk in ES stands ranging in age from 1 to 13 years and of ungulate herbivory on stands ranging in age from 1 to 6 years on commercial timberlands around Mount St. Helens, Washington. We used a nutritional approach modified from Cook et al. (2016), who classified plant species as accepted (used equal or more than available) or avoided (used less than available) by elk based on foraging trials with hand-raised, tractable elk (henceforth, tractable elk) in western hemlock forests of western Oregon and Washington. We focused on differences in understory biomass (kg/ha), standing digestible energy (DE, kg/ha), and modelled dietary DE (kcal/g) of these plant classes in summer because elk reproduction and survival has been related to summer and autumn nutrition (Cook et al., 2004, 2013). Because of the high productivity of vegetation in the Pacific Northwest, we predicted that (1) herbicide applications would initially reduce forage availability but a reduction in residual forest dominants, such as swordfern, salal (*Gaultheria shallon* Persh) and Oregon grape (*Mahonia nervosa* Nutt.), would promote rapid growth of shade-intolerant herbs and shrubs to improve nutritional resources for elk, and (2) that the early-successional window of abundant forage would decline more quickly in areas treated with herbicides than in untreated sites because of the increased growth rates of crop trees and associated forest canopy closure. Because elk populations have been high in this area since the Mount St. Helens eruption in 1980 (Washington Department of Fish and Wildlife, 2006), and ungulates may themselves alter the plant community via selective foraging, we also evaluated the influence of ungulate herbivory on the forage resource where herbicides were applied. We predicted that herbivory might substantially reduce abundance of accepted forage due to focused foraging on these species. Although our sampling design did not permit direct comparison of the impacts of herbivory to herbicides, we present results of both treatments to qualitatively compare their relative influences on nutritional resources for elk in this area.

2. Methods

2.1. Study area

The study was conducted near Mount St. Helens in southwest Washington in an area bordered by Swift Reservoir in the south and Rife Lake in the north (Fig. 1). The climate is Pacific maritime with wet, mild winters and dry, cool summers (Franklin and Dyrness, 1988). Topography of the area is rolling to mountainous with elevations ranging from 240 m to 1200 m. The area supports 3 major forest zones (Franklin and Dyrness, 1988) including the western hemlock series (75% of study area), Pacific silver fir (*Abies amabilis* Parl.) series (20%), and mountain hemlock (*Tsuga mertensiana* (Bong.) Sarg.) series (<1%), but we limited stand selection to the western hemlock-swordfern series because of the difficulty of finding untreated sites in these other forest zones.

The area includes private industrial timberlands of the St. Helens Tree Farm operated by Weyerhaeuser Company (70%) and public lands under the jurisdiction of the Department of Natural Resources (10%), Mount St. Helens National Monument managed by the United States Forest Service (12%), a state wildlife area managed by Washington Department of Fish and Wildlife (WDFW), and a small percentage of non-industrial private landowners. The dominant land use in the area is forestry with the majority of the study area managed for mid-successional Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands harvested on 40-year cycles.

The area is inhabited by a portion of the Mount St. Helens elk herd, which remains one of the largest herds in Washington (McCorquodale et al., 2014). After the volcanic eruption, the elk population in the Mount St. Helens blast zone recovered quickly, which was attributed to rapid recovery of natural forage, broadcast seeding of grass-legume mixes, and restrictions on human access and elk harvest (Merrill, 1987; Merrill et al., 1995; Raedeke et al., 1986). The estimated elk population across the 5 WDFW Game Management Units (520, 524, 522, 550, 556; total 2754 km^2) in the Mount St. Helens area ranged from approximately 2700 to 5000 elk during 2009–2013 (McCorquodale et al., 2014). Additionally, the black-tailed deer population in the Mount St. Helens region was estimated at approximately 500 (Davis et al., 2010).

2.2. Silvicultural management and herbicide treatments

Silvicultural management by the Weyerhaeuser Company in this area typically consists of high-density planting of rapidly growing conifer seedlings within one year after harvesting. The company also typically applies herbicides aerially prior to conifer planting as a chemical site preparation treatment and sprays a second application during the second growing season to release conifer seedlings from competing graminoids and woody shrubs. Herbicide mixtures across the sites varied, but site preparation mixtures typically included combinations of glyphosate (1.12–2.80 kg/ha), sufometuron methyl (0.06–0.16 kg/ha), metsulfuron methyl (0.04–0.84 kg/ha) and imazapyr (0.14–0.63 kg/ha), whereas release treatments included combinations of clopyralid (0.16–0.47 kg/ha), atrazine (2.24–4.48 kg/ha), hexazinone (0.28–1.68 kg/ha), 2-4D (1.57–2.35 kg/ha), glyphosate (1.12–2.80 kg/ha), and sufometuron methyl (0.06–0.16 kg/ha).