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Trillium grandiflorum height is an indicator of white-tailed deer density at local and regional scales

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ABSTRACT

High densities of white-tailed deer (*Odocoileus virginianus*) in the U.S.A. and Canada are reducing or preventing forest regeneration, and as a result, deer function as a keystone species in some sites. Management decisions about deer require reliable population density data, which are challenging to obtain at both regional and local scales. We tested the broad-scale applicability of the indicator species approach in which forage plant height was used to estimate deer density. The maximum heights of marked and unmarked plants of the widely distributed, spring-flowering polycarpic herb, white trillium (*Trillium grandiflorum*) were measured across southern Ontario, Canada, over a 15-year period. A significant negative relationship was found at 10 sites between maximum plant height and estimates of deer population densities, which were derived from counts of live or culled animals and varied from 7 to 40 deers km^{-2}. Maximum plant height could be reliably measured within a 4-week period. The underlying mechanism driving the negative relationship between plant height and deer density was attributed to deer preferentially selecting taller plants that grew less than ungrazed plants in the subsequent year. In 16 additional sites with locally high deer populations, the mean maximum height of *T. grandiflorum* appeared to be a more reliable indicator of deer density than estimates based on hunter returns across the broader regional scale of the Wildlife Management Unit. The ability to assess local scale white-tailed deer densities based on measuring heights of an easily identifiable, widespread plant, provides local residents and landowners with a tool for estimating the potential impacts of deer browsing and grazing in local woodlots and forests, improving local knowledge about herbivory pressure.

1. Introduction

High deer populations and their impacts on forest regeneration and dynamics are a global phenomenon (Gill, 1992; Coomes et al., 2003; Côté et al., 2004; Dolman and Wäber, 2008; Takatsuki, 2009). In the past 100 years, white-tailed deer (*Odocoileus virginianus*) populations in Canada and northeastern U.S.A. have increased greatly (Russell et al., 2001; Côté et al., 2004). High levels of deer browsing reduce woody plant regeneration (Tilghman, 1989; Anderson and Katz, 1993; Côté et al., 2004), alter the structure and composition of non-woody plant communities (Russell et al., 2001; Augustine and de Calesta, 2003), and influence the diversity of native wildlife (de Graaf et al., 1991; de Calesta, 1994; McShea and Rappole, 1992).

Obtaining accurate estimates of deer population sizes in forests is challenging, but required for herd management. Traditional means of estimating population size include using harvest data, which provide a non-representative sample of the true population structure (Mladenoff and Stearns, 1993; Anderson, 2001). The assumption of detection probability being consistent across space and time (Anderson, 2001) does not hold for local deer distribution, which is a function of local forage and cover availability (Harlow, 1984). However, harvest data are often the only information readily available to managers, and population estimates tend to be derived from regionally-collected data by state and provincial wildlife organizations. In small, fragmented forests where deer hunting is prohibited, large-scale estimates from harvest data may provide a poor reflection of local deer density and be of limited value in supporting site-level management decisions. Other methods for estimating deer densities are also limited by being highly labour intensive (Broadfoot and Voigt, 1996) or subject to observer error (e.g. fecal pellet sampling) (Smart et al., 2004).

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The use of indicator plant species may provide a more tractable alternative for estimating local deer densities. The height of the widely distributed forest ephemeral *Trillium grandiflorum*, a preferred spring forage species of white-tailed deer, has been used as an indicator of deer herbivory levels and local ecosystem-level effects in the last 15 years (Anderson, 1994; Augustine and Frelich, 1998; Augustine and Jordan, 1998; Augustine and de Calesta, 2003). *T. grandiflorum*, are long-lived, exceeding 32 years of age (Hanzawa and Kalisz, 1993), and provide an integrated measure of deer grazing pressure over several years (Webster et al., 2001). However, the extent to which this represents an indicator of deer grazing pressure across broad spatial and temporal gradients remains unclear (Kirschbaum and Anacker, 2005; Vellend, 2005). Our research aimed to assess whether deer population size and grazing pressure could be linked to *T. grandiflorum* height at local scales in sites spanning a regional scale. Specifically, we examined:

1. The effect of deer grazing on the size (measured as height) and growth of individual plants to clarify the underlying mechanism through which plants become shorter in forest sites with higher deer densities.
2. The relationship between plant height and deer density at the local-site level within a 700 km region from Windsor to Ottawa, a distance greater than the longest axis of any state in the northeastern U.S.A.

We tested the robustness of using height as a quantitative indicator of deer numbers in sites with reliable local deer counts. We predicted that deer would preferentially select taller plants, and consequently generate the smaller plants observed elsewhere in northeastern North American (Anderson, 1994; Augustine and Frelich, 1998; Augustine and de Calesta, 2003). We then asked whether this derived relationship between *T. grandiflorum* height and site-level deer numbers would hold in estimating local deer densities at other sites across the broader landscape.

2. Methods

2.1. Study species

T. grandiflorum (Michx.) Salisb., is a polycarpic, spring-flowering herb (Britton and Brown, 1913) with limited clonal growth (Sobey and Barkhouse, 1977) and widespread distribution (Griffin and Barrett, 2004). Within season growth of individual plants is determinate, with young plants producing one leaf until they reach a threshold size, when a whorl of three leaves and possibly, a flower is produced (Hanzawa and Kalisz, 1993; Knight, 2003).

2.2. Study Region 1, southwestern Ontario

Populations of *T. grandiflorum* were studied at 10 forest locations in southern Ontario, in the deciduous forest and the Great Lakes-St. Lawrence forest regions (Hosie, 1990) (Fig. 1 and Table 1). Study sites varied from several hectares to several square kilometers in area (Table S1). Typical canopy vegetation included *Acer saccharum*, *Fraxinus* spp., and *Fagus grandifolia*. Understorey vegetation was a mixture of spring ephemerals, e.g. *Claytonia virginica*, *Maianthemum canadense*, ferns, and sedges (e.g. *Carex pensylvanica*). Palaeozoic rocks underlay all study locations (Chapman and Putnam, 1966). There was frequently as much

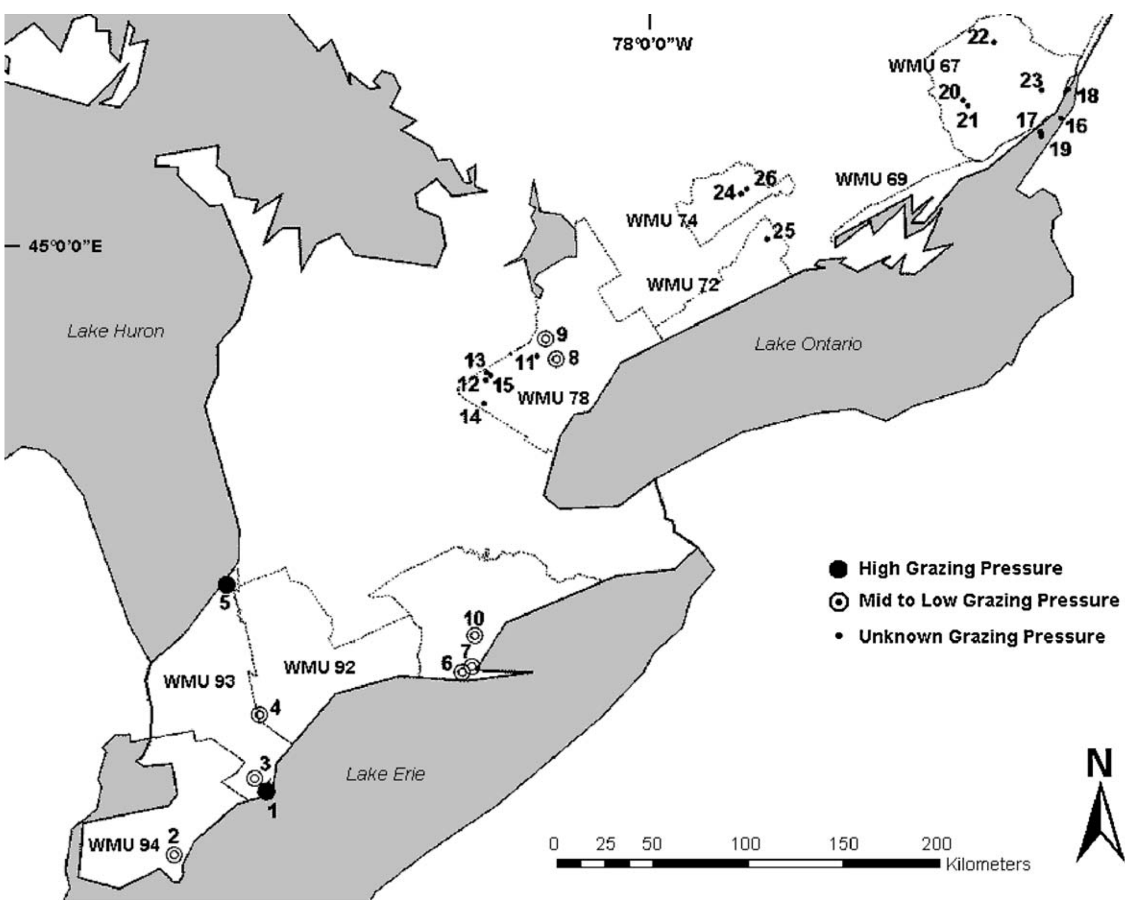

Fig. 1. Study locations in southern Ontario, Canada. Location numbers correspond to those in Table 1. Numbers and boundaries of relevant Wildlife Management Unit (WMU) areas are shown. Grazing pressures are denoted as either high or mid to low for Study Region 1 sites, and unknown for Study Region 2.