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Is there a critical density at which Canada thistle (*Cirsium arvense*) displaces native plant species on the South Boulder Creek floodplain?

Submitted to:

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A draft report submitted to Open Space Department by Rebecca Rawlinson,
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Abstract

Many researchers have described the need to understand how invasive plants modify natural areas at both community/population and ecosystem levels (Cronk and Fuller, 1995; Luken and Thieret, 1997). In general, experimental studies assessing the community level impact of invasive plants are rare (McCarthy, 1997). This study assessed the relationship between Canada thistle (*Cirsium arvense*) density and the diversity of the plant community in a South Boulder Creek floodplain area. The researcher measured species richness, relative abundance, and Canada thistle height and phenology in $1m^2$ vegetation plots with low, medium, or high densities of Canada thistle. Overall, the results suggest a "critical" density (16 stems of Canada thistle/m^2 or greater) where Canada thistle may negatively affect native community richness in this area. This study complements the on-going monitoring of Canada thistle by Open Space staff in the South Boulder Creek area. Understanding the effect of invasive plants in these biologically diverse areas is important to constantly keep fine-tuning management techniques.

Introduction

The invasion of natural communities by introduced plants constitutes one of the most serious threats to the integrity and health of ecosystems. Invasive plants spread aggressively, cause rapid, often irreversible changes to the landscape, and represent a significant problem to the conservation of natural communities (Luken and Thieret, 1997). Estimates suggest that between 5-25 percent of the vascular plants in United States reserves are non-native species (Vitousek, 1990). In fact, exotic plant species are the cause of endangerment for 46% of threatened plant species in the US (Wilcove et al., 1996). Specifically, numerous studies suggest that biological invasion by exotic species alters the population dynamics and community composition of native ecosystems by reducing native plant diversity, changing plant phenology, introducing new disturbance patterns, and altering the nutrient status of the soil, among others (Cronk and Fuller, 1995; Luken and Thieret, 1997, Vitousek, 1990). This invasion by exotic species requires increased use of pesticides, reduces the value of lands for agriculture and recreation, and compromises the integrity of natural resources on these lands. Understanding the causes and consequences of plant invasions is crucial to the maintenance and restoration of healthy grassland ecosystems: "If invasive plants are competitive enough to invade and alter the habitat, they are likely to modify structure, composition, and habitat quality of the native plant community." (Gordon, 1998).

Colorado currently lists Canada thistle as one of top ten most troublesome non-native weeds in the state (Colorado Dept. of Agriculture, 1996), and further research is needed to understand how this invader modifies ecosystem dynamics in natural areas.

Canada thistle was inadvertently introduced to North America in the early 1600's and has now spread throughout the northern United States and Canada. It is considered one of the most economically detrimental agricultural weeds, resulting in tens of millions of dollars in crop loss and herbicide control each year (Evans, 1984). This perennial is an aggressive invader because it has a rapid growth rate, forms dense patches from horizontally growing rootstocks, produces many mobile seeds, and dominates above- and below-ground resources (McLendon, 1993; Morishita, 1999). The Open Space department has targeted Canada thistle for priority control and management in the South Boulder Creek area because it covers a large percentage of the land and threatens the persistence of a rare orchid, *Spiranthes diluvialis*. Open Space is currently assessing the historical management techniques of Canada thistle on the South Boulder Creek floodplain areas because the thistle has continued to spread despite control efforts (Riedel, 1999). No single control method is effective for the control of Canada thistle and a combination of techniques is necessary to reduce its spread on natural lands (Evans, 1984). Thus, this study assessing the community-level effects of Canada thistle on Boulder's grasslands is a an important step in designing effective weed management techniques for this area and complements ongoing monitoring efforts.

Objective and Hypotheses

The objective of this study is to conduct vegetation sampling to address the following question:

At what density does Canada thistle alter plant community composition?

At high densities of Canada thistle, the diversity of the native plant community (both species richness and relative abundance) is hypothesized to be less than that of the plant community associated with low densities of thistle. If Canada thistle does not alter community composition, all communities will be equally diverse, regardless of density. If Canada thistle does indeed alter community diversity, I expect to find one of two potential patterns: 1) the diversity of the community will remain relatively constant until a "critical" density of Canada thistle is reached, at which point native plant diversity will decline, or 2) there may be constant linear decrease in plant community diversity as thistle density increases.

Methodology

To test my hypothesis, I established a study site in a riparian wet meadow community along the east side of South Boulder Creek between the town of Marshall and Baseline Road on land managed by the City of Boulder Open Space Department (Figure 1 and 2). The study site is dominated by *C. arvense* (Canada thistle),*Spartina pectinata* (cord grass),*Carex sp.* (sedges), and a variety of other tallgrass and herbaceous species (D'Amico, 1996). The distribution of Canada thistle at this site is patchy, and the patches contain thistle in varying densities. I measured vegetation characteristics of plots (1 m^2) located in high, medium, and low density plots of Canada thistle, as well as plots uncolonized by Canada thistle (5 replicates each, 20 plots total) using a point-frame (Figure 3). I established plots randomly and categorized the density of the plots as follows: high density plots had 31-45 stems of Canada thistle per 1 m^2; moderate density plots had 16-30 stems of Canada thistle per 1 m^2; low density plots had 1-15 stems of Canada thistle per 1 m^2; and uninvaded plots had 0 stems of Canada thistle per 1 m^2. Vegetation measurements within the 1 m^2 plot included: percent cover of all species, the number and height of Canada thistle stems, and phenology (number of stems in vegetative, budding, and flowering stages) of Canada thistle.

I used the species percent cover data at each density to calculate the richness, evenness, and a species diversity index (Shannon-Wiener index of diversity) for each plot (Magurran, 1988). In addition, I calculated the percent of thistle individuals that were in a reproductive phase (flowering or budding) and the average height of thistle individuals for each plot. I statistically analyzed all data with analyses of variance (ANOVA) to compare the results among density levels.

Results

The results indicate a statistically significant correlation between Canada thistle density and community richness at this site. The average species richness is highest in low density plots (5.6 species/m2) and plots without Canada thistle invasion (5.0 species/m2), and lowest in plots with moderate density (2.5 species/m2) and high density plots (4.0 species/m2) (one-way ANOVA, $F_{3,17}=3.6$, $p<0.05$) (Figure 4). The single degree of freedom linear contrast test indicates that the difference between richness in low density vs. medium density plots is statistically significant (SAS Institute Inc., 1995).

The results also indicate that a higher proportion of Canada thistle individuals are in reproductive stages (flowering or budding) at higher densities (high density, .73; moderate density, .71; low density, .22) (one-way ANOVA, $F_{2,13}=9.9$, $p<0.05$) (Figure 5). In addition, the average height of Canada thistle is significantly higher for the higher densities (high density, .98m; moderate density, .94m; low density, .52m) (one-way ANOVA, $F_{2,13}=8.3$, $p<0.05$) (Figure 6).

Note: full species list and further analyses forthcoming

Discussion

Overall, species richness is low in this riparian area of South Boulder Creek. The area is dominated by cord grass, *Carex* species, Canada thistle and other tall grasses which may exclude a high diversity of understory herbs. Despite overall low diversity, the presence of Canada thistle in densities greater than 16 stems/m^2 is correlated with a sharp decrease in species richness (Figure 4). Thus, these results reject the null hypothesis and indicate a "critical" density of Canada thistle at a moderate number of stems/m^2 which is correlated with lower species richness.

Overall, the Canada thistle seemed to be less competitive at lower densities. The thistle in low density plots were significantly shorter and were less reproductively developed at the time of the study (Figures 5 and 6). Potential mechanisms exist to explain these observations. The higher levels of diversity, shorter height, and slower reproductive development in low diversity plots may be related to differences in soil conditions, time since invasion, and/or provide support for the "intermediate disturbance hypothesis" (Connell, 1978). For instance, plots with lower densities of Canada thistle may have been invaded more recently than plots with higher densities of Canada thistle. In this case, it is only a matter of time before Canada thistle competitively excludes other species, and reduces the species richness of these areas. Also, while all samples were taken from one site to reduce heterogeneity in community characteristics, the plots may have differed in soil characteristics, such as soil moisture or nutrient levels. As a result, some of the low density plots may have been located in areas with much drier or more nutrient poor conditions. In general, Canada thistle seedlings are much less competitive than established thistle and will only survive if environmental conditions are suitable, competition is limited, and they receive adequate sunlight (McLendon, 1993; Morishita, 1999). Thus, in areas with higher levels of species richness, such as areas with relatively lower cord grass cover, Canada thistle may be competing with a greater variety of species. Finally, at low levels of Canada thistle invasion, the disturbance by the thistle may provide intermediate disturbance levels where species both tolerant and intolerant to disturbances may coexist (Collins et al., 1995).

Conclusion

Open Space is currently involved in extensive monitoring to determine the best management options for controlling Canada thistle on the South Boulder Creek floodplain areas. This study complements these monitoring efforts, by further assessing the community level effects of Canada thistle on riparian areas of South Boulder Creek. As Walker and Smith (1997) point out, successful management of an invasive species includes: 1) assessing whether invaders have significantly altered the ecosystem and community processes from its pre-invasion condition, 2) recognizing and measuring specific community and ecosystem properties potentially being altered by the invader, and 3) developing strategies that return communities and associated ecosystem properties to pre-invasion state. While this study only provides correlations and not causation related to Canada thistle's effects on native species, it does provide preliminary evidence that native species richness is reduced under higher densities of Canada thistle. In order to conserve species diversity in this area, control is mandatory. In addition, the study also indicates that native species seem to coexist with Canada thistle at low levels of invasion. As a result, control techniques which reduce and/or maintain Canada thistle populations at low densities may be effective in maintaining overall species richness in this area. However, these suggestions are very guarded, as the study was limited to one study site and one snapshot in time. In general, site conditions are likely to play a large role in Canada thistle's competitive ability (Beck, 1999). Further studies are recommended to determine the overall viability and reproductive potential of native species in invaded areas over time, and to assess the effect of Canada thistle on ecosystem processes, such as nutrient cycling and hydrology, in this area.

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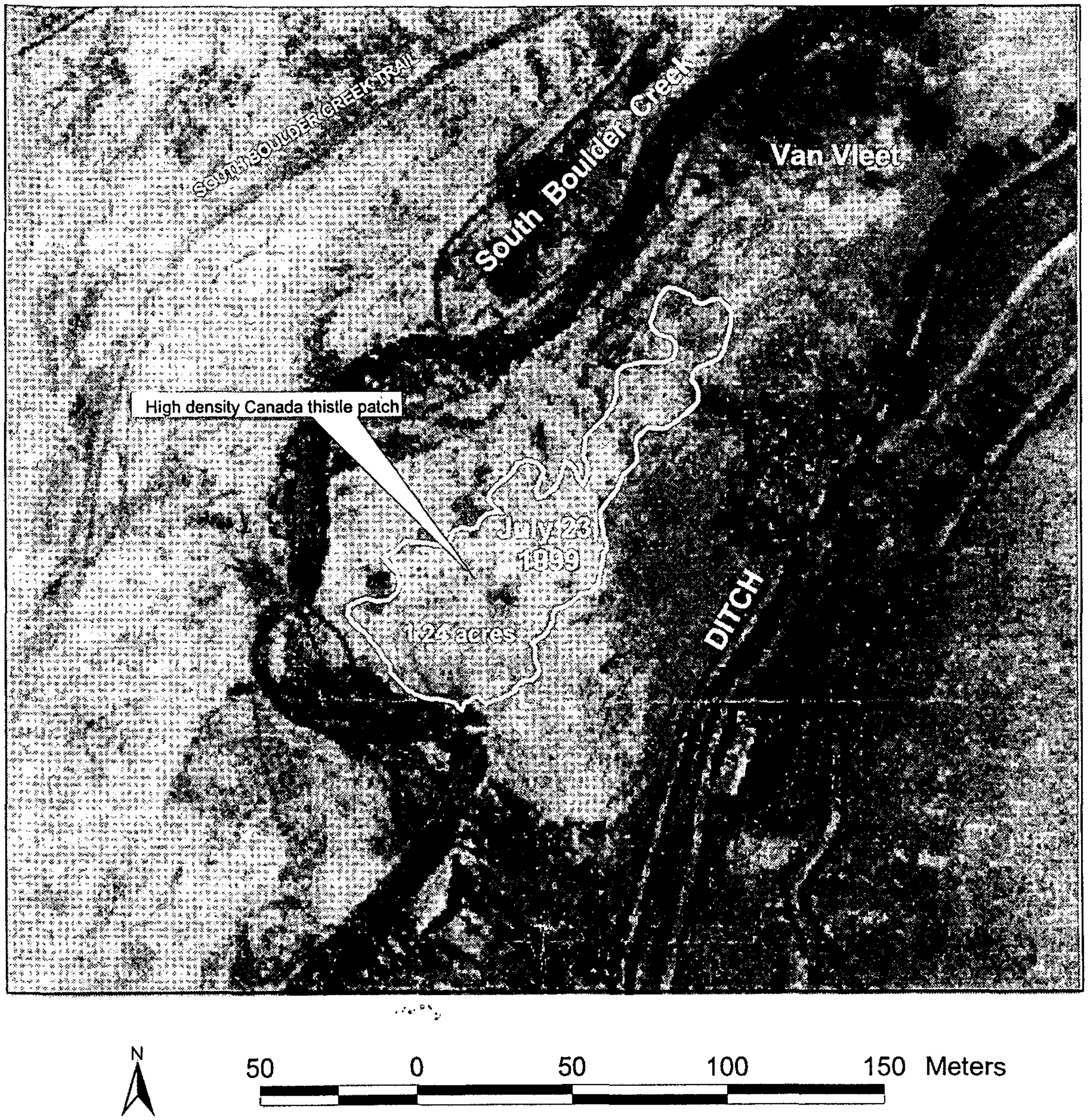
Figure 1. Digital orthograph depicting study site location and size. The site is approximately 1.2 acres located on the east side of South Boulder Creek, between Highway 36 and the town of Marshall. (Map source: City of Boulder Open Space, 1999).



CANADA THISTLE MONITORING PROJECT: VAN VLEET PROPERTY

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Figure 2. Photograph depicting site conditions during study, August 1999. Photo is taken from east side of site, looking west towards South Boulder Creek.

Figure 3. Photograph depicting typical high-density plot of Canada thistle (*Cirsium arvense*), 31-45 stems/m^2.

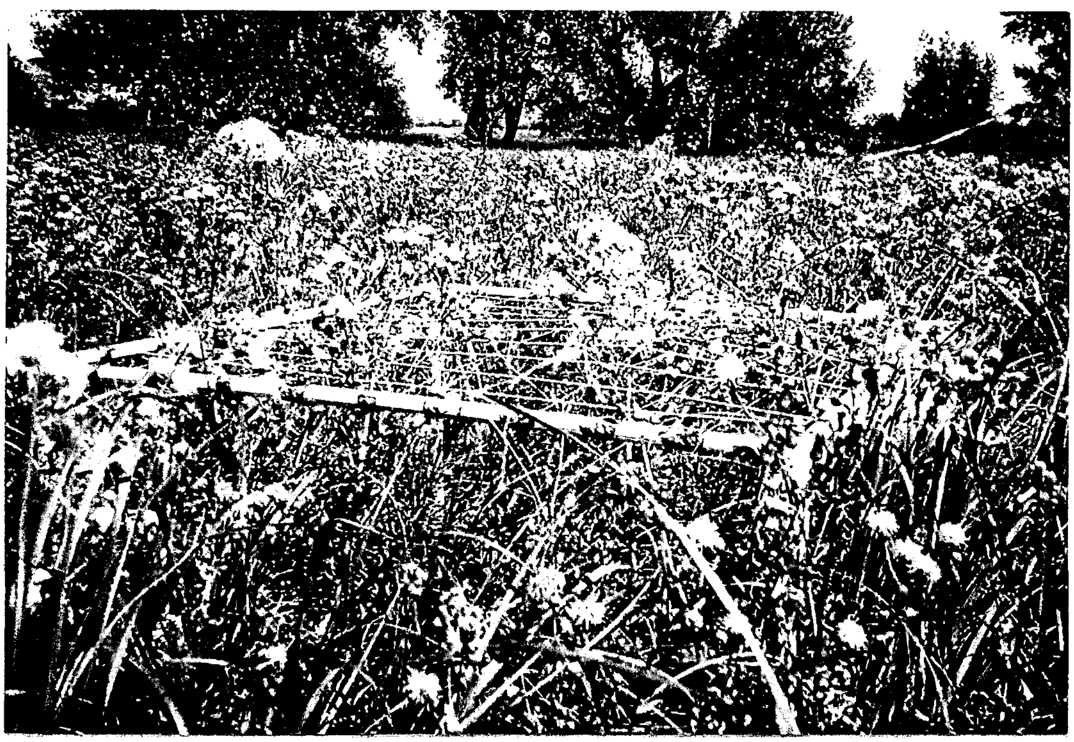

Figure 4. Species richness in plots of high, medium, low, and no Canada thistle (*Cirsium arvense*) density on South Boulder Creek, August 1999. Species richness totals exclude Canada thistle.

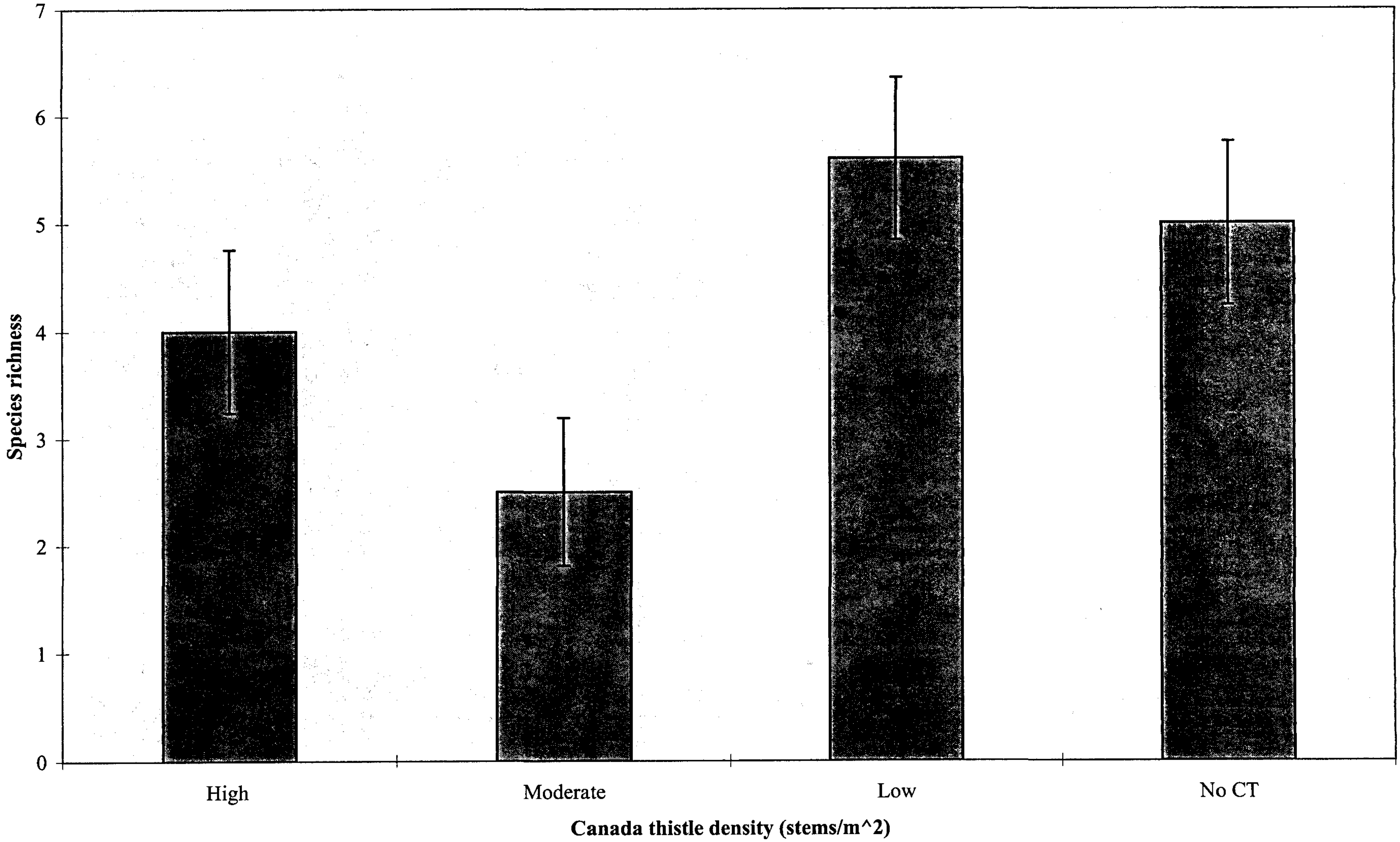

Figure 5. Proportion of Canada thistle (*Cirsium arvense*) individuals within plots of high, moderate, or low densities of Canada thistle that were budding or flowering, South Boulder Creek, August 1999.

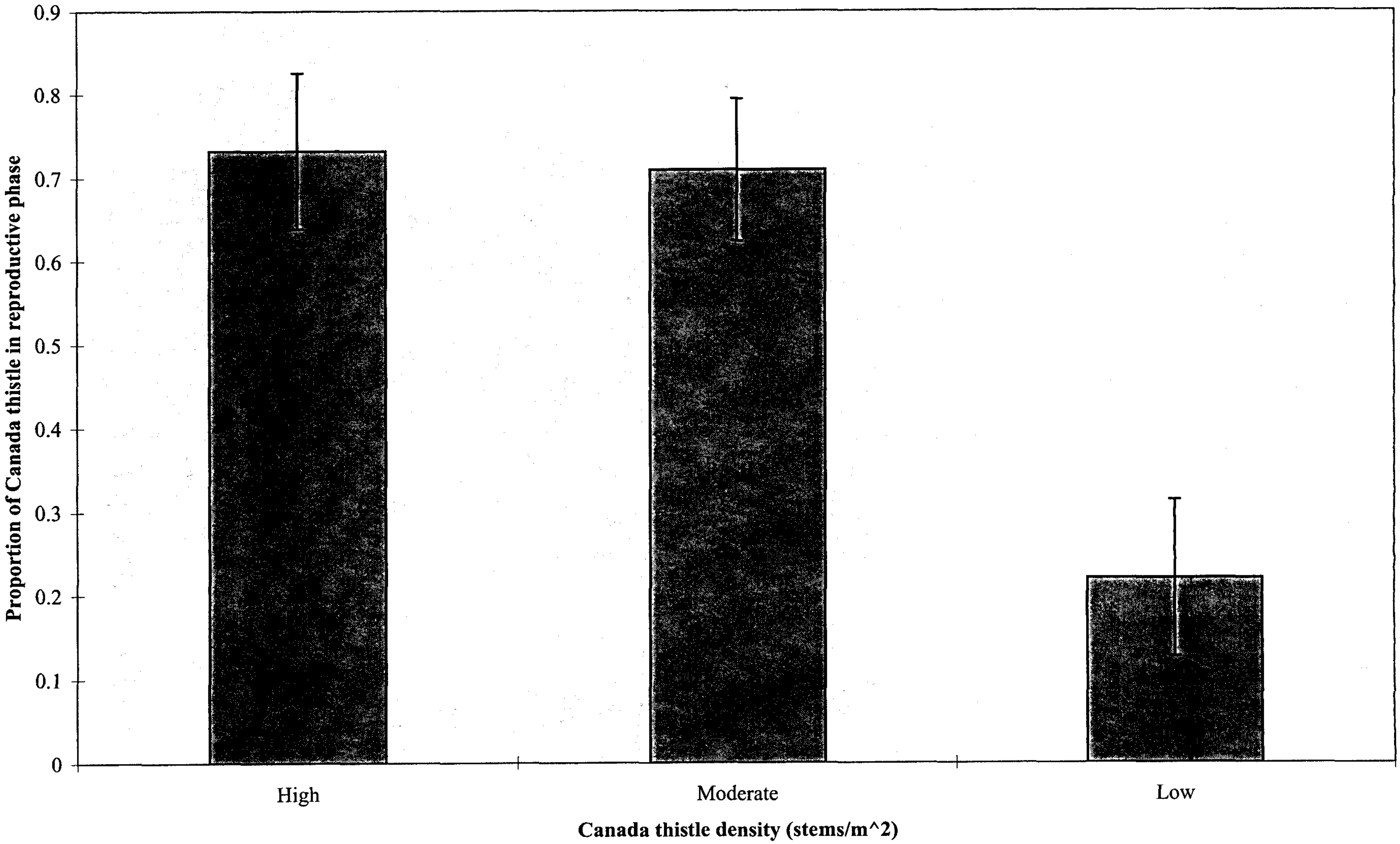

Figure 6. Average height of Canada thistle (*Cirsium arvense*) individuals within plots of high, moderate, and low densities of Canada thistle, South Boulder Creek, August 1999.