Buffelgrass dispersal pattern: invasion front or satellite?

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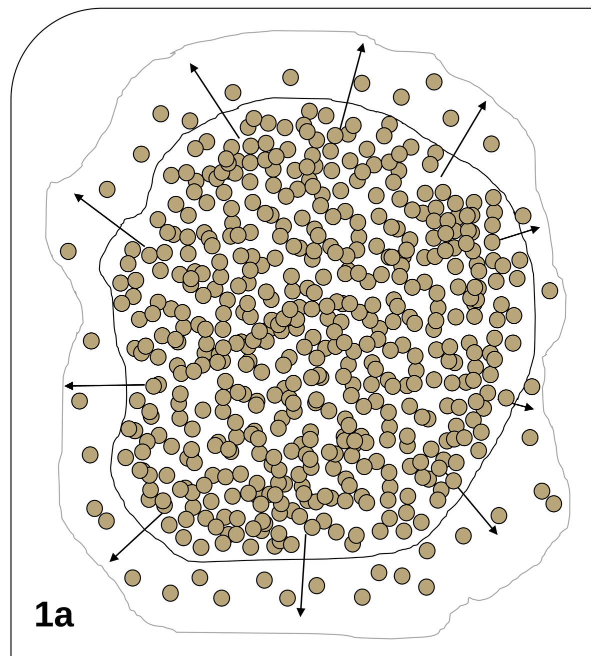
Introduction

Impact from invasive species has become a force of global land change. This is especially true in arid and semi-arid lands, where recovery from land change is long-term and more difficult (D'Antonio and Vitousek, 1992). Buffelgrass, a C4 perennial grass from Africa, causes significant landscape change in the southwestern United States and northern Mexico. Buffelgrass outcompetes native vegetation through strategies such as propagule pressure and fire (Rogstad, 2008).

While many control methods for buffelgrass can be successful (Jernigan et al., in press), land managers struggle to prioritize control efforts (Rogstad, 2008). One reason it is difficult to plan a strategy is that buffelgrass dispersal pattern during invasion remains unknown. There are two readily detectible dispersal patterns: (1) invasion along the edge of existing patches (i.e. an "invasion front", whereby new plants spawn mostly along the edges of the source population) and (2) invasion by satellite populations (i.e. new plants spawn near and far from the source population, resulting in satellite populations that become new source populations). If an invasion front occurs, then a control strategy of encircling invaded patches would be efficient. If invasion by satellite happens, then targeted removal of colonies (e.g. Moody and Mack, 1988) will best slow or stop the invasion. Because of a lack of literature, we tested buffelgrass dispersion pattern.

Hypotheses

H0: Buffelgrass invasion pattern is random – neighbor distances will show little pattern.
H1: Buffelgrass invasion pattern is a front along the edges of the existing patches – neighbor distances will be dominated by the size of the patch or less.
H2: Buffelgrass invasion pattern is heavily influenced by dispersal far away from existing patches – the neighbor distances will show peaks which represent (1) the plants within the colony and (2) the plants from other colonies.

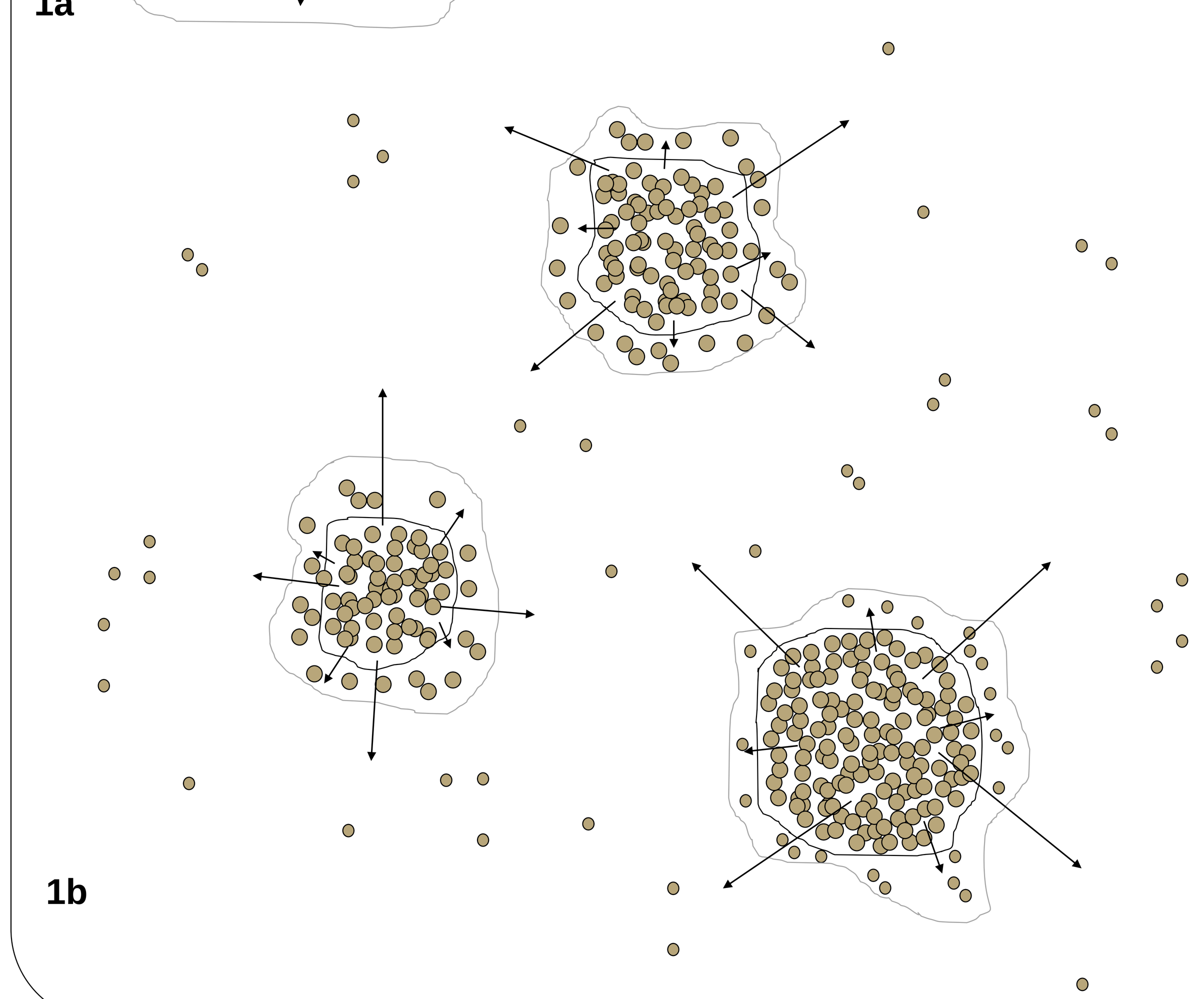


1a

Fig. 1 Each brown circle represents and individual plant. The black polygon inscribes the source population. The area between the black and grey polygon is the area of expansion via an invasion front dispersal.

1a Example of an invasion front. The seeds fall next to the source and new spawns are at the outer edges of the source population.

1b Example of invasion by dispersal. The seeds fall next to the source, just as in invasion front dispersal. However, many new plants also spawn great distances from the source population, leading to new colonies. There are three source populations to demonstrate that invasion by dispersal has multiple source colonies.



1b

Study Site and Methods

Study Area
Data was collected from the west side of a 9 mile stretch of highway 85 on the Barry M. Goldwater Range (BMGR) in Southwest Arizona. This area was chosen because buffelgrass invasion on BMGR is new and can be assumed to come from the relatively few existing colonies of plants. The initial invasion was likely started by seeds carried on vehicles or in road maintenance equipment.

Data Collection
GPS coordinates were taken in April 2015 for all buffelgrass within 6m of the highway, with one exception. Individuals shorter than 30 centimeters were excluded because it is unclear if they will survive. Density was estimated for Buffelgrass stands in which density was uniform with a $1m^2$ quadrat and a sampling quadrat design (Etzinga, Salzer, and Willoughby, 1998). GPS boundary points were then recorded for these stands for translation to a GIS software.

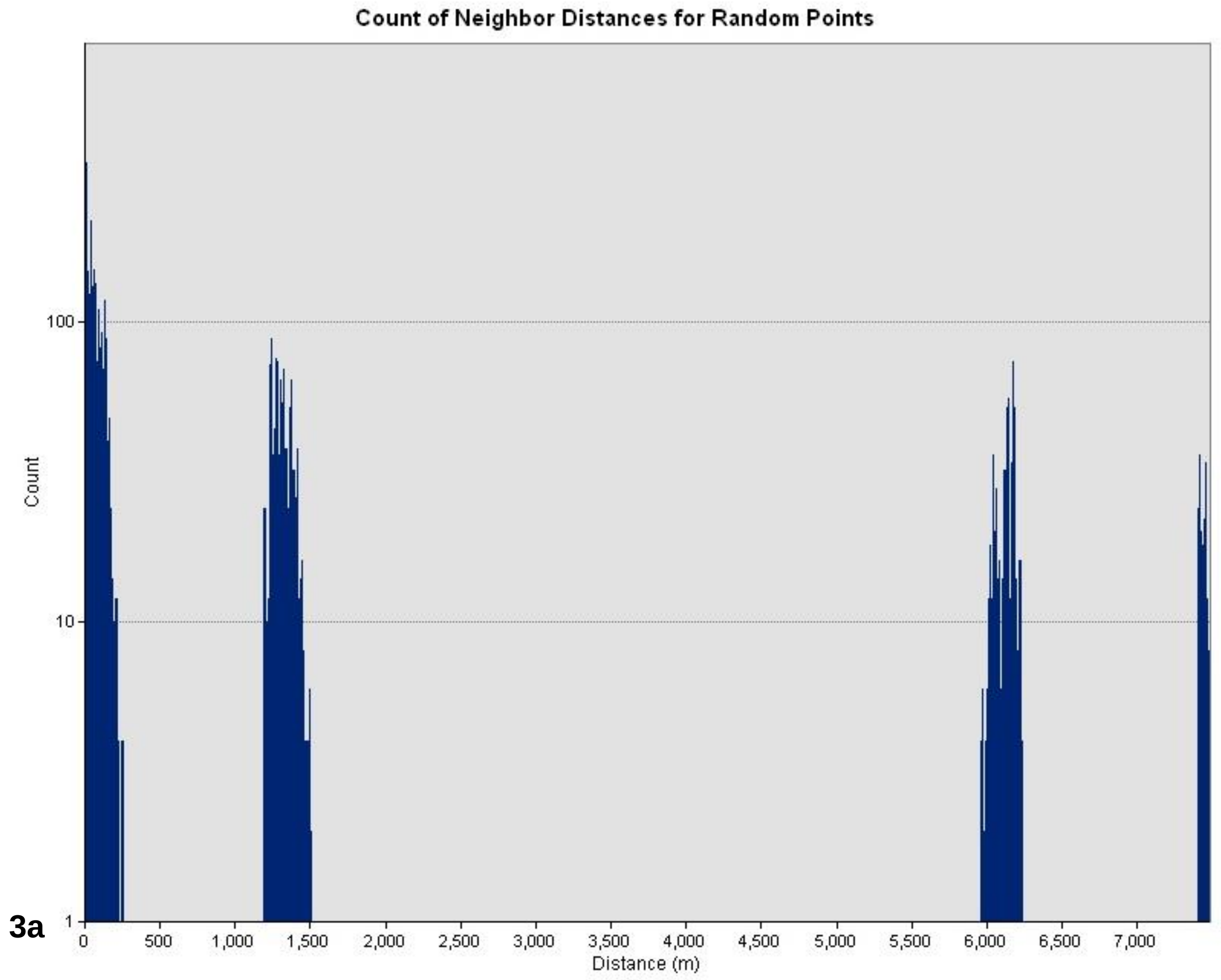
Data Processing
GPS points and stand density were mapped into ArcGIS version 10.2.2. To determine dispersal pattern, statistical tests were run on the distance between buffelgrass individuals. Specifically, a Nearest Neighbor analysis was conducted via the native ArcGIS Nearest Neighbor tool. Nearest Neighbor uses the distance of the closest buffelgrass individual for statistical calculations.

We also calculated the distance between one buffelgrass and all other buffelgrass individuals, for each buffelgrass individual. This information provided us with a list of distances between buffelgrass individuals we could use for further analysis.

Fig. 2 Buffelgrass was found in three major clusters along a 9-mile stretch of the west side of highway 85 on BMGR.

Results

The nearest neighbor analysis resulted in a z-score of -34.5, $p < 0.01$. Based on this test, we reject the null hypothesis and accept H2.



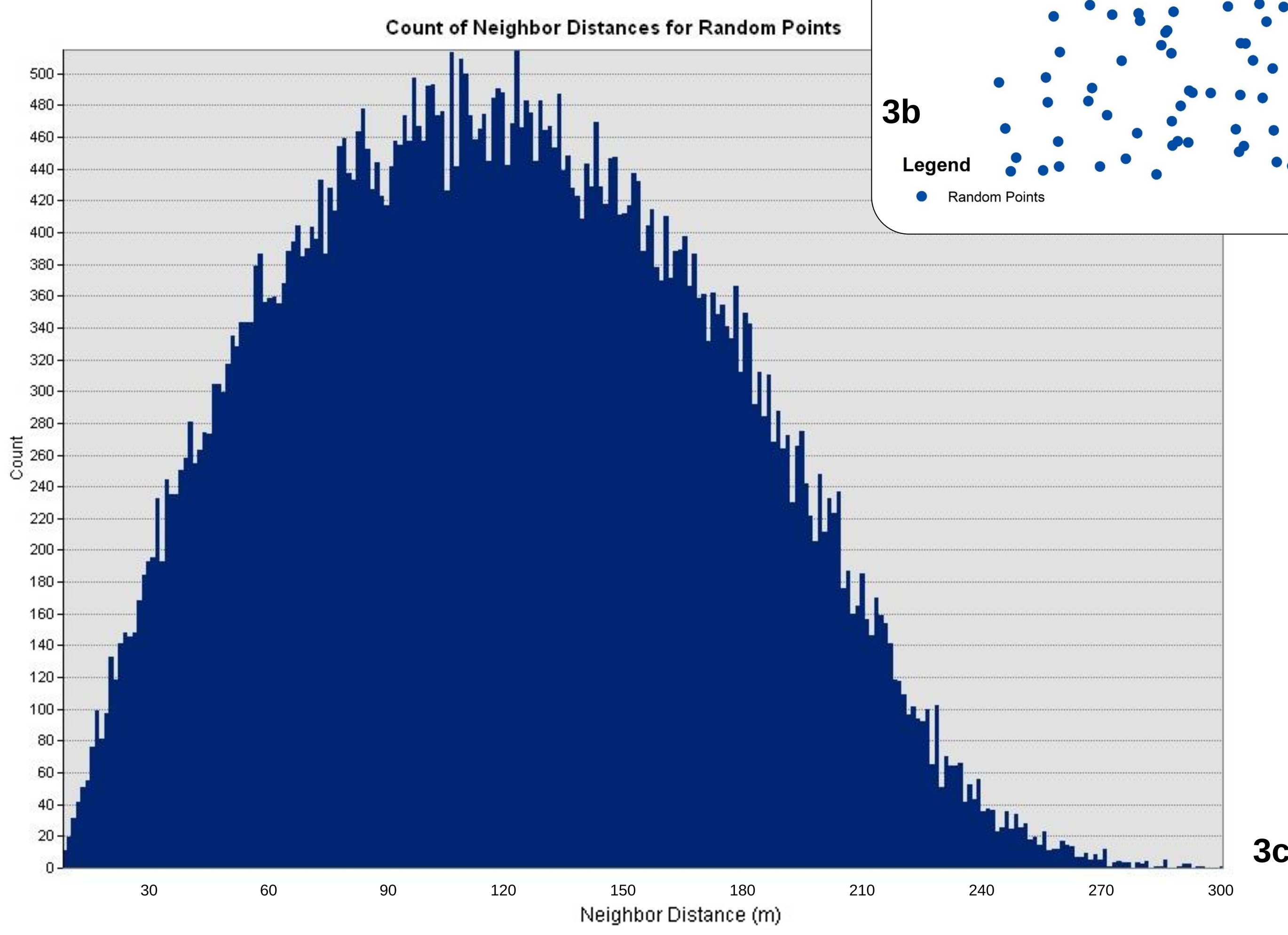
3a

Fig. 3 Histograms visualize buffelgrass clustering on BMGR. Histograms were created from datasets of distances from one buffelgrass individual to all buffelgrass individuals, for each individual.

3a There are four different sets of distances that register on this histogram. These sets visualize the distances from individuals in one cluster of buffelgrass to another. The fact that four different sets registered indicates clustering. A logarhytmic function was applied to the y-axis to account for extremely high values for low distance (x-axis). There four sets of distances instead of three because one of the patches was very long. The buffelgrass at each end of the long patch registered a fourth distance set range.

3b A set of random points were created in GIS. There is no detectable pattern among the points (H0).

3c A neighbor distance histogram of random points visualizes random dispersal. There are no sets of distances, showing the difference from 3a.



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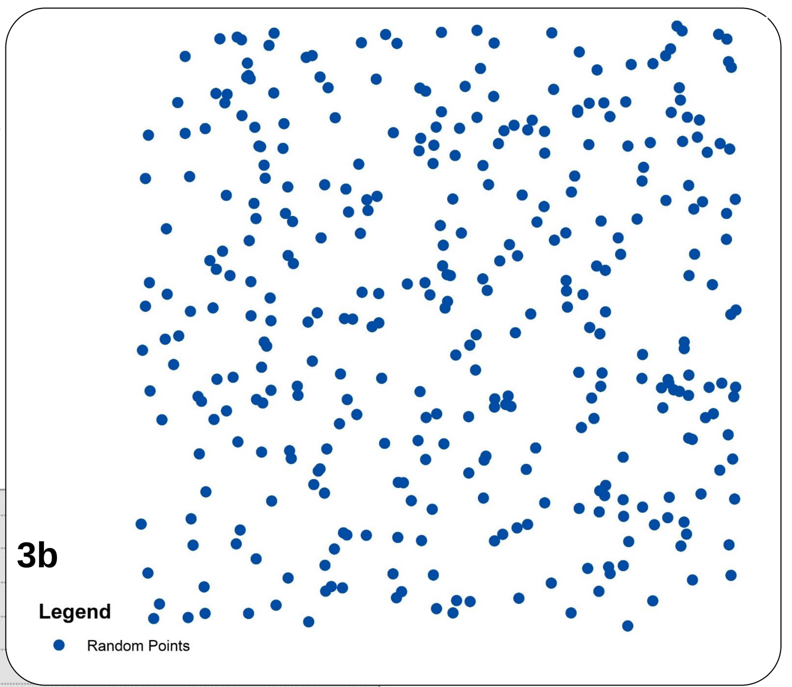

Discussion

The results of this study showed that buffelgrass invades by satellite dispersal. A land management method that targets buffelgrass clusters may be an effective strategy of controlling buffelgrass, as opposed to attempting to control the main source population (Moody and Mack, 1998). Removing clusters removes a new source of buffelgrass seed, reducing propagule pressure and the rate of buffelgrass spread. Conversely, if the main source is targeted and clusters are allowed to grow, it is unlikely that the source will be significantly affected, meaning that both the source will remain and staellites will become new sources. If satellite clusters are left untreated, then multiple populations will be growing at the same rate as a single source populations. Thus, a satellite dispersal pattern results in orders of magnitude of higher growth than an invasion front, if untreated (Moody and Mack, 1998). In response to this study, other studies could investigate buffelgrass dispersion (1) at a larger scale to characterize how buffelgrass spreads at larger, "land-management-scale" (2) over time to characterize how buffelgrass moves and which clusters might be most dangerous and (3) test land management strategies that target buffelgrass clusters to bring practical knowledge to this strategy.

Literature Cited

D'Antonio, C. and Vitousek, P. (1992). Biological Invasions by Exotic Grasses, The Grass/Fire Cycle, and Global Change. Annual Review of Ecology and Systematics, 23, 63-87.
Elzinga, C., Salzer, D., and Willoughby, J. (1998) Measuring and Monitoring Plant Populations. Bureau of Land Management.
Jernigan, M.B., M.P. McClaran, S.H. Biedenbender, and J.S. Fehmi. In Press. Uprooted Buffelgrass Thatch Reduces Buffelgrass Seedling Establishment. Arid Land Research and Management. DOI: 10.1080/15324982.2015.1107152.
Moody, M. and Mack, R. (1988). Controlling the Spread of Plant Invasions: The Importance of Nascent Foci. Journal of Applied Ecology, 25, 1009-1021
Rogstad, A. (2008) The buffelgrass strategic plan. Arizona-Sonora Desert Museum, Tucson, AZ.

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