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Short Communication

Effect of Infestation Size on Rush Skeletonweeds (*Chondrilla juncea* L.) Dispersal Distance

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Abstract

When an infestation of rush skeleton weed (*Chondrilla juncea* L.) is found, land managers need to determine how long a search radius should be in order to locate other patches that may be linked by seed dispersal processes. It is expected that small patches likely derive from larger patches. To test this idea, we examined the potential influence of infestation size on rush skeleton weed dispersal using an area located across the Salmon River Canyon, Idaho. Assuming larger infestations to be older infestation sources, infestations larger than 40 ha were buffered from 1 km to 20 km. Based on the distribution of rush skeleton weed infestation sizes and previous observations of the authors , infestations under 40 ha were classified into two size classes (Small: less than 1.6 ha and Large: more than 1.6 ha). The number of infestations within each category was counted and the respective proportions calculated. The proportions of infestation were then modeled separately for each size class as a function of distance using nonlinear regression models. For small infestations, the proportion of infestation increased with increasing distance up to 12 km. A similar increasing pattern was seen for large infestations with a maximum distance estimated at 17.5 km, suggesting that large infestations require a longer search radius. Land managers need to prioritize in searching for small satellite rush skeleton weed infestations within 12 km while large infestations will require a radius of 17.5 km from the source population. Long-tailed dispersal curves suggest both the smaller and larger infestations should receive similar importance when setting priorities to manage for preventing additional dispersal.

INTRODUCTION

Due to several dispersal mechanisms, many invasive species show heterogeneous spatial distributions [1]. According to Marco et al. [2] invasive species distributions are often composed of a few large and many small satellite foci, a pattern probably generated by long dispersal kernels. Some individual plants disperse, survive, and produce new satellite populations that are located away from their source populations [3]. It is possible that such satellite populations push the range of an invading species rapidly [4,5]. Plants with frequent but random long distance dispersal events may spread in unpredictable ways [6] and be more difficult to contain while plants with mostly local dispersal may spread in more predictable patterns and have easily identifiable bottlenecks where spread may be contained.

Following Moody and Mack's [7] landmark paper on the spatial allocation of effort to manage plant invasions, considerable effort has been devoted to the question whether and when to target source and satellite populations. Targeting both source and satellite populations appear to depend upon their respective growth rates and strengths as source of dispersal, as well as the costs associated with search and control [8]. Whittle et al. [9] and Blackwood et al. [10] indicated that control should be applied to both source and satellite populations. According to Fletcher and Westcott [11] dispersal of propagules makes invasions a fundamentally spatial phenomenon and that effective management action to control or eradicate invasive species must take this spatial structure into account. This spatial extent should be related to the ecology of dispersal and spread of the focal species. Spatial considerations such as distance from source

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populations are important in determining where control efforts should be carried out.

Movement of invasive plant species is mediated by a range of dispersal factors. A series of studies have examined how dispersal drives invasion [12-14] and how understanding factors of dispersal can help structure successful management [15]. Many invasion models have highlighted the importance of rare, long-distance dispersal events [12,16]. Generalized empirically based studies, particularly at a strategic level that can inform on-ground management, are crucial because invasive species management is frequently urgent and often must be started before detailed studies can be completed.

Rush skeleton weed (*Chondrilla juncea* L.) is a perennial invasive forb in the *Asteraceae* family found in mountain foothills and canyon grasslands of the Pacific Northwest United States. Rush skeleton weed seeds have a parachute-like "pappus" that enables long distance dispersal via wind.

Its ability for wind dispersal and its ability to establish within grass and shrub lands enable the plant to spread rapidly over long distances, contributing to long distance movement. In the canyon grasslands of Central Idaho, rush skeleton weed patches have been shown to be spatially dependent up to 12 km [16]. In this paper, we will examine the potential influence of infestation size on rush skeleton weed dispersal across the Salmon River Canyon, Idaho, and address the question of where to focus plant survey efforts.

METHODS

Infestation data

Here, an infested area of land is defined as the actual perimeter of the infestation as determined by the plant canopy, excluding areas that are not infested. Rush skeleton weed infestations were recorded from annual, ground-based surveys taken by crews tasked with identifying locations of invasive plant species. These data were recorded on hand-held global positioning systems or on topographic paper which were later digitized to include plant location, aerial size of populations and an estimate of the foliar cover occupied by the invasive plant species. Infestation data were collected over multiple years spanning 1998 to 2011 and different sites were visited each year; the entire area was not surveyed each year

Study area

To examine the influence of infestation size on rush skeleton weed dispersal, a study area including the Salmon River Canyon, Idaho was used (Figure 1) [17]. In general, the area of land containing one weed species is referred to as infestation size (patch size). Rush skeleton weed infestations were classified into two classes based on their infestation size: small (less than 1.6 ha) and large (more than 1.6 ha) size class (Figure 3). Infestations larger than 40 ha were assumed to be older infestation sources. Twenty nine polygons/infestations (source patch) were greater than 40 ha. Using these 29 source patches, buffers ranging from 1 km to 20 km were created for each patch (Figure 2c). Infestations of each size category at each distance for each patch were clipped and numbers of infestations which fall in patches were counted. Figure 2b shows the cumulative number of infestations at each distance.

Statistical analysis

The proportion of infestations for each size class that were covered at a specified distance from an identified source infestation was calculated as follows

$$\Pr oportion = \frac{Number\ of\ polygons\ at\ a\ distance}{Total\ number\ of\ polygons} \qquad (1)$$

The proportion of infestations for each size class was then modeled as a function of distance to investigate how the proportions of each size class changed with distance from the source patch. We examined several possible nonlinear regression model forms including exponential, logistic, quadratic, and Gompertz as potential candidates for modeling the dispersal distance [18]. The best fit model was selected based on the AIC, BIC, and RMSE respectively. The logistic form best described the data and is given by:

Figure 1 Black ellipse (on inset of Idaho county map) indicates study area along the Salmon River Canyon (left) and the expanded view has black polygons representing rush skeletonweed infestations (right).

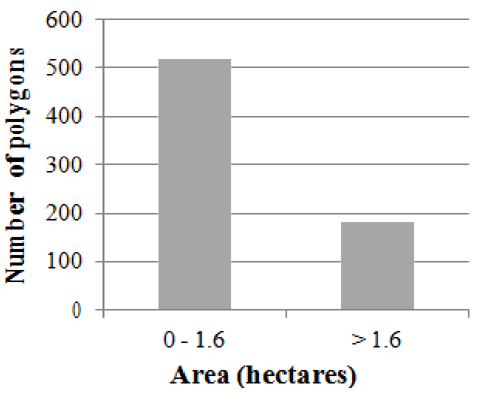

Figure 2a Number of rush skeleton weed polygons within two size classes (small: <1.6, large: > 1.6 ha).

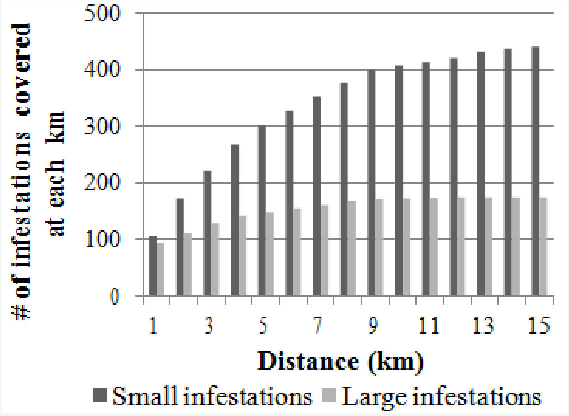

Figure 2b Number of rush skeleton weed infestations (cumulative) encompassed by the model at a range of distances from the source polygon.

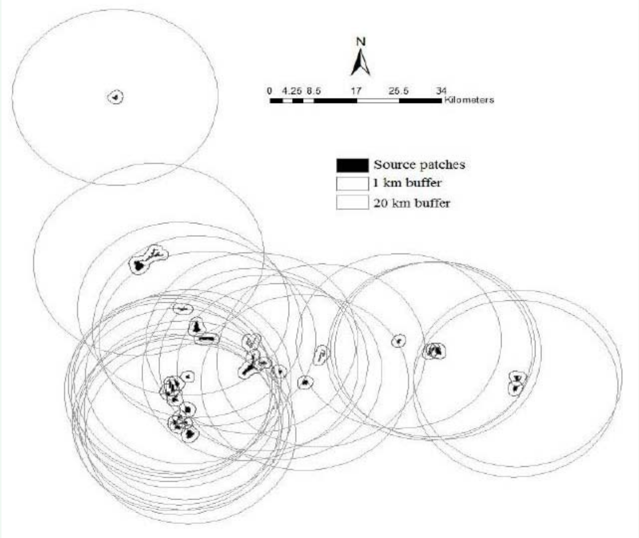

Figure 3 Example of buffers at 1 and 20 km used around the source patches.

$$Proportion = \frac{c}{\left[1 + Exp\left[-a * \left[Distance(km) - b\right]\right]\right]} \quad (2)$$

Where as

a = Rate of change parameter

b = Inflection point

c = Asymptote, indicating the maximum possible infestation proportion.

RESULTS

We found that the proportions of infestation increased significantly with increase in distance up to 12 km and thereafter became constant for the small size class (Figure 4), while for the large size class, the proportion of infestations leveled out at a distance of 17.5 km (Figure 5). Table 1 and 2 show the logistic regression model that resulted from each size classes. Examination of the logistic model discovered that large infestations require a longer search radius compared to small infestations.

DISCUSSION

Our main finding is that infestation size influenced the distance among spatially related patches. Smaller patches had fewer years to produce seed that dispersed via wind and therefore should have shorter distances (12 km) within which patches are spatially related. Congruently, larger patches likely are older than smaller patches, allowing for more years of dispersal with spatially related patches more distant (17.5 km). Surprisingly, we found only a difference of 5.5 km dispersal distance between small and large patches. According to Krasny et al [19] guiding management of invasive species has to do with distribution patterns. Our long-distance dispersal curves (Figure 3 and 4) suggest both the smaller and larger infestations should receive similar importance when setting priorities to manage for preventing additional dispersal. Small size classes may be responsible for rush skeleton weed long-distance dispersal up to

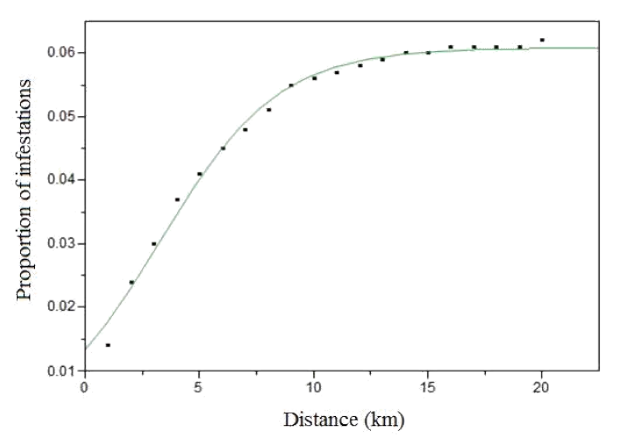

Figure 4 Estimated small size class logistic model (green line) fit to the cumulative proportion of infestations covered (black dots) as a function of distance from source patches.

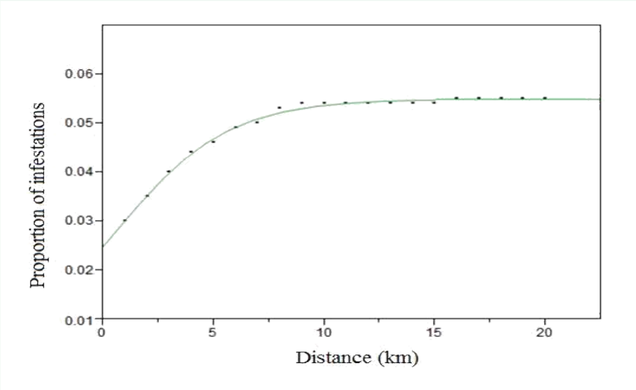

Figure 5 Estimated large size class logistic model (green line) fit to the cumulative proportion of infestations covered (black dots) as a function of distance from source patches.

Table 1: Logistic regression model (sigmoid curve) results for the small size class (less than 1.6 ha).

Parameter	Estimate	SE	Lower 95%	Upper 95%
Expansion rate	0.3867	0.0198	0.3479	0.4255
Inflection point	3.2703	0.1125	3.0497	3.4909
Asymptote	0.0608	0.0005	0.0598	0.0618

Table 2: Logistic regression model (sigmoid curve) results for the large size class (greater than 1.6 ha).

Parameter	Estimate	SE	Lower 95%	Upper 95%
Expansion rate	0.3915	0.0143	0.3634	0.4195
Inflection point	0.5313	0.0869	0.3610	0.7015
Asymptote	0.0549	0.0002	0.0545	0.0552

12 km [16, 17]. One key to preventing new infestations is early detection of these small size class infestations that have a high probability of expanding into large infestations [7]. Moody and Mack [7] argued that smaller patches have more seeds that fall outside the patch and so smaller patches increase in size more quickly than large patch. It has been noted that eradication may be more effective to focus first on satellite populations [20]. The satellite populations of shorter dispersing species expand more rapidly and potentially cover greater area than the invasion front of source populations leading to prioritization of satellite patch eradication prior to source patch eradication [21, 7]. However, for longer dispersing species like rush skeleton weed, the invasion front appears less important given the 12 km and 17.5 km distances for small and large infestations. Small and large infestations need to have similar prioritization for long-distance dispersing species [9, 10]. Depending on the potential impacts of individual species, even infestations larger than 1000 hectares should be targeted for eradication, or, at least, substantial reduction and containment [22]. A notable example of an ongoing eradication program for is eradication of the parasitic weed *Striga asiatica* in parts of North and South Carolina [23]. In the 45 years of the eradication program, the initial gross infestation of 20 000 km2 was reduced to 2800 ha of very light occurrences [22].

Eradication in areas of previously rush skeletonweed free areas will rely on extensive plant survey of potential habitat within at least 12 km of a source population. In addition, examination of up-wind areas within 17.5 km should help to identify where seed may have originated and include those areas within plans for eradication that may rely on biological control or control with herbicides [24].

CONCLUSION

Of note in this study, large infestations of rush skeleton weed require a longer search radius (17.5 km) while small infestations require a shorter search radius of 12 km from source populations. Management efforts need to be focused on both satellite and large infestations [9, 10]. A strategy for species with long-distance dispersal is different from a strategy for a species with short-distance dispersal making management to reduce ecological impacts from long-distance dispersing species more challenging.

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