10-15-1999

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GEOGRAPHY OF EXOTIC PLANTS ADJACENT TO CAMPGROUNDS, YELLOWSTONE NATIONAL PARK, USA

Karen Allen¹ and Katherine Hansen²

ABSTRACT.—Eleven campgrounds in Yellowstone National Park were studied to determine the geography of 10 specific exotic plant species adjacent to campgrounds. Exotics were found in only 6 campgrounds. Six species were found at Mammoth campground, a low-elevation, dry site with year-round use. Only 2 species were found in the other 5 campgrounds. Exotics decreased with distance from Mammoth campground out to 6 m and then increased, suggesting a spread in their distribution. Significant associations were found between exotic presence and both open and closed canopies and low levels of disturbance. Generally, exotics decreased with an increase in cover of other vegetation forms. Five species were found most frequently in big sagebrush habitat types.

Key words: exotic plants, campgrounds, disturbance, canopy cover, Yellowstone National Park.


In 1994, 140 exotic species were found in Yellowstone National Park, while in 1986 only 85 were known to occur there (Yellowstone National Park 1986; J. Whipple, Yellowstone National Park botanist, personal communication 1996). It was hypothesized that some of this increase might be related to activities within campgrounds. More exotics were expected to be found close to campgrounds where a source of seeds may have been introduced by humans, cars, and maintenance equipment; whereas ground disturbance had created areas that could serve as seedling establishment sites; and where the overstory canopy may have been opened for campsites. With that in mind, the objectives of this study were to determine whether exotics were distributed according to (1) distance from campgrounds, (2) amount of canopy (overstory) cover, (3) amount of disturbance, and (4) amount of ground cover.

STUDY AREA AND METHODS

We studied all 11 vehicle-accessible campgrounds of Yellowstone National Park, USA. The campgrounds (1820–2425 m elevation) occur within habitats ranging from big sagebrush/bluebunch wheatgrass (Artemisia tridentata/Agropyron spicatum) at lower elevations to subalpine fir/grouse whortleberry (Abies lasiocarpa/Vaccinium scoparium) at higher elevations (Table 1). Average annual precipitation near the 11 campgrounds ranges from 37 to 105 cm, and frost-free days range from 21 to 125 (Natural Resources Conservation Service 1994). Campgrounds range in age from approximately 30 to 78 yr. Overnight use today consists primarily of campers with automobiles and, secondarily, of hikers and bicyclists. While the type of use within campgrounds is relatively homogeneous, the number of campers varies substantially and is

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<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Elevation range (m)</th>
<th>Campground(s)</th>
<th>Number of transects</th>
<th>Number of transects with exotics</th>
<th>Transect frequency (%)</th>
<th>Exotic species found</th>
<th>Mean canopy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big sagebrush/blue bunch wheatgrass</td>
<td>1820</td>
<td>Mammoth</td>
<td>8</td>
<td>8</td>
<td>100</td>
<td>SK, YSC, HT, MULL, CT, DT</td>
<td>14</td>
</tr>
<tr>
<td>Big sagebrush/Idaho fescue</td>
<td>1895–2090</td>
<td>Slough Creek, Pebble Creek</td>
<td>8</td>
<td>2</td>
<td>25</td>
<td>CT</td>
<td>0</td>
</tr>
<tr>
<td>Douglas-fir/common snowberry</td>
<td>1895–2000</td>
<td>Slough Creek, Tower Fall</td>
<td>6</td>
<td>1</td>
<td>17</td>
<td>CT</td>
<td>0</td>
</tr>
<tr>
<td>Engelmann spruce/sweetscented bedstraw or horsetail</td>
<td>1895–2090</td>
<td>Slough Creek, Pebble Creek</td>
<td>7</td>
<td>1</td>
<td>14</td>
<td>CT</td>
<td>27</td>
</tr>
<tr>
<td>Subalpine fir/twinflower</td>
<td>2000</td>
<td>Tower Fall</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>none</td>
<td>n/a</td>
</tr>
<tr>
<td>Subalpine fir/pinegrass</td>
<td>2060–2275</td>
<td>Norris, Indian Creek, Madison</td>
<td>21</td>
<td>2</td>
<td>14</td>
<td>OD, CT</td>
<td>6</td>
</tr>
<tr>
<td>Subalpine fir/grouse whortleberry</td>
<td>2075–2425</td>
<td>Canyon, Grant Village, Norris, Bridge Bay, Lewis Lake</td>
<td>35</td>
<td>1</td>
<td>9</td>
<td>CT</td>
<td>21</td>
</tr>
</tbody>
</table>

*Transact frequency: percentage of transects in a given habitat type that contain exotics.

*Key to exotic species found: SK = spotted knapweed, HT = hound's-tongue, CT = Canada thistle, OD = cowye-daisy, DT = dallatian toadflax, YSC = yellow sweetclover, MULL = common muletine.

*Mean canopy refers to quadrats in which exotics were found.
dependent on the number of sites within a campground and the length of time a campground is open (Wert 1994). Mammoth campground, located near the park's headquarters, is the only one open all year.

Ten exotic species were selected for study based on their designation by park staff as high priority for control (Yellowstone National Park 1986). These included spotted knapweed (Centaurea maculosa), hound's-tongue (Cynoglossum officinale), Canada thistle (Cirsium arvense), oxeye-daisy (Chrysanthemum leucanthemum), yellow sweetclover (Melilotus officinalis), Russian knapweed (Centaurea repens), musk thistle (Carduus nutans), tansy aster (Tanacetum vulgare), and common mullein (Verbascum thapsus). Species nomenclature and verification of alien status follow Hitchcock and Cronquist (1973). All species, except yellow sweetclover, are also considered noxious weeds by the states of Wyoming, Montana, or both. A noxious weed as defined by federal law is a plant of foreign origin that can directly or indirectly injure agriculture, navigation, fish and wildlife, or public health (Yellowstone National Park 1986, Bedunah 1992).

We systematically established 8 transects, with a random starting point, outward from and perpendicular to the edge of each campground. The edge was located where ≤10% vegetative cover existed adjacent to the campground road's outer border. To identify the distance at which exotic occurrence changed, we sampled contiguous quadrats (4 × 1 m) along each transect from just inside the campground edge (quadrat 0) to 15 m outside the edge (quadrat 15). Additionally, quadrats were sampled at 20, 25, 30, 40, and 50 m from the campground edge to determine the extent of occurrence at greater distances. Eight quadrats inside each campground and 8 control quadrats outside each campground were also sampled for comparisons. Data collected within each quadrat during summer 1994 included percent cover and density of exotics, percent canopy cover of trees and shrubs (using a spherical densiometer), percent cover of disturbance (disturbed bare ground, trampled grass, footprints, and social trails), and percent cover of bare ground and other vegetation. Additional data were collected and analyzed as reported by Allen (1996).

Distribution of exotic plant cover and density relative to distances from campground edges were displayed with side-by-side boxplots and scatterplots for campgrounds in which exotics were found. A Cox-Stuart test for trend (Daniel 1990) was used to determine the general trend in occurrence of exotics with increasing distance from the edge of Mammoth campground. Chi-square tests were used to determine whether significant associations existed between canopy cover and presence of exotics and between disturbance and presence of exotics (α = 0.05 for all analyses).

RESULTS AND DISCUSSION

Species Distributions

Exotic plants were found in only 6 of 11 campgrounds (Mammoth, Slough Creek, Madison, Norris, Grant Village, and Bridge Bay). Six species were found at Mammoth (spotted knapweed, hound's-tongue, Canada thistle, dalmatian toadflax, yellow sweetclover, and common mullein). Canada thistle was found in all 6 campgrounds, while oxeye-daisy was found in just 1 quadrat at Norris campground. We observed no other exotics within the quadrats; however, we saw others in the vicinity.

Exotics and Distance from Campgrounds

Exotic plants at Mammoth campground were fairly numerous and occurred at all measured distances beyond the campground edge (Fig. 1). Few to no exotics were found within the quadrats placed immediately inside the campground edge (quadrats 0), due primarily to frequent and severe campground-associated disturbance. Exotic cover and density were higher immediately outside the campground edge (quadrats 1 and 2). Median exotic density and cover decreased from 2 m out to 4 m and 6 m, respectively, suggesting the campground may be a source of inoculation or introduction. This decrease in exotics with distance from disturbance is similar to results found by Dale and Weaver (1974), Benninger-Truax et al. (1992), and Tyser and Worley (1992). Beyond about 6 m, density and cover increased out to 9 m, and then became more variable. We found a general trend of higher density (P = 0.001) and cover (P = 0.011) at distances of 11-50 m (versus 0–10 m) from Mammoth campground edge. Canada thistle presence was
highest between 11 m and 15 m, and between 30 m and 50 m, from campground edges, based on the cumulative relative frequency of Canada thistle relative to distance for all quadrats in which the plant was found. No decreasing trend in Canada thistle presence with distance was found.

Exotics and Canopy Cover

At Mammoth campground a significant association was found between canopy cover (at the 20% and 30% open/closed threshold divisions) and presence of hound’s-tongue, spotted knapweed, and yellow sweetclover (Table 2). Hound’s-tongue was significantly associated with closed canopies, suggesting the plant prefers or tolerates some degree of shade. It was more consistently found under higher canopy covers than any other exotic species (Fig. 2). This condition is similar to that reported by Lacey and Lacey (1986), where hound’s-tongue was found in areas of...
thick litter accumulation (as might be found under a forest with high canopy cover). Presence of spotted knapweed and yellow sweetclover was significantly associated with open canopy conditions (at the 20% and 30% open/closed threshold divisions). Spotted knapweed was always found under <20% canopy, and 75% of its occurrence fell below ≤3% canopy cover (Fig. 2). Previous studies have also found spotted knapweed to be more abundant under open canopies (Watson and Renney 1974, Losensky 1987, Milner 1995). Seventy-five percent of yellow sweetclover occurrences were beneath ≤10% canopy cover.

Dalmatian toadflax, found growing under a wide range of canopy covers, from 0% to 85%, was predominantly found under lower canopy cover values. While it is known to establish drier, open areas (Lajeunesse et al. 1993), results indicate its tolerance for moderate amounts of shade. Mullein was always found under a canopy cover of <30%, and 75% of its occurrences were under ≤5% canopy cover (Fig. 2). No significant association was found between canopy cover and mullein, nor between all exotics (when combined at Mammoth; Table 2), reflecting differences in canopy cover tolerance of individual species. In 84% of quadrats within which exotics were found, however, canopy cover was ≤30% (Fig. 2).

Eighty-seven percent of Canada thistle occurrences were under a canopy cover of ≤20%. Haderlie et al. (1989) found that warmth and long days favored Canada thistle growth. This condition is present in open canopy conditions during the Yellowstone National Park growing season. Although Canada thistle grows most often under open canopies, its occasional presence under more closed canopy covers (up to 95%) suggests it is somewhat tolerant of shade.

### Table 2. Results of chi-square tests used to determine the association between canopy cover and exotic plant presence at Mammoth campground (*denotes significance at 0.05 level).

<table>
<thead>
<tr>
<th>Exotic plant(s)</th>
<th>Canopy cover (%)</th>
<th>Chi-square</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>20</td>
<td>0.940</td>
<td>0.3323</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1.334</td>
<td>0.2481</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>2.047</td>
<td>0.1525</td>
</tr>
<tr>
<td>Hound’s-tongue</td>
<td>20</td>
<td>18.475</td>
<td>0.0000*</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>5.483</td>
<td>0.0192*</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>2.853</td>
<td>0.0912</td>
</tr>
<tr>
<td>Spotted knapweed</td>
<td>20</td>
<td>7.920</td>
<td>0.0049*</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>3.859</td>
<td>0.0495*</td>
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<tr>
<td></td>
<td>40</td>
<td>3.047</td>
<td>0.0809</td>
</tr>
<tr>
<td>Dalmatian toadflax</td>
<td>20</td>
<td>0.036</td>
<td>0.8485</td>
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<tr>
<td></td>
<td>30</td>
<td>0.025</td>
<td>0.8744</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0.017</td>
<td>0.8963</td>
</tr>
<tr>
<td>Yellow sweetclover</td>
<td>20</td>
<td>19.313</td>
<td>0.0000*</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>5.797</td>
<td>0.0161*</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>3.085</td>
<td>0.0806</td>
</tr>
<tr>
<td>Mullein</td>
<td>20</td>
<td>2.088</td>
<td>0.1475</td>
</tr>
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<td></td>
<td>30</td>
<td>2.206</td>
<td>0.1373</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>1.743</td>
<td>0.1868</td>
</tr>
<tr>
<td>Canada thistle</td>
<td>20</td>
<td>0.355</td>
<td>0.5513</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.173</td>
<td>0.6775</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0.137</td>
<td>0.7113</td>
</tr>
</tbody>
</table>

Disturbance cover at Mammoth decreased from the campground edge out to a distance of 6 m. A general trend of decreasing exotic plant cover with increasing disturbance was found. In other studies it was often predetermined or assumed that disturbance decreased with distance from the road or trail, and that exotic presence decreased along this gradient (Weaver et al. 1989, Benninger-Truax et al. 1992). In this study the cover of disturbed ground was highest between 25 m and 40 m from Mammoth campground edge; however, highest exotic covers did not occur at comparable distances.

We found Canada thistle growing in all amounts of disturbance, although 20% of quadrats in which it was present had no evidence of disturbance. Canada thistle abundance increased as disturbance cover increased from 5% to 40%. No relationship was found between disturbance and Canada thistle when disturbance covers exceeded 60%. Where both Canada thistle and disturbance occurred, the...
plant was consistently rooted within the disturbance. The ability of Canada thistle to reproduce by lateral roots (Haderlie et al. 1989) may contribute to its presence in undisturbed and in both low and high levels of disturbed ground.

Patterns in exotic cover were explained, in part, by both canopy and disturbance. The highest exotic plant cover at Mammoth, in most transects, occurred where canopy and disturbance covers were both low. An exception to this occurred along 2 transects where a high percentage of hound’s-tongue was found under canopies >25% (again indicating its tolerance of higher canopy covers).

Exotics and Other Vegetation

Exotic species were usually found growing with other plants, but overall the exotic plant cover at Mammoth decreased with an increase in individual covers of grasses, forbs, shrubs, and the combined cover of these vegetation forms. In contrast, 77% of Canada thistle occurrences were with at least 45% cover of other vegetation, and 33% of occurrences of Canada thistle were with ≥75% cover, suggesting Canada thistle can compete well for available resources. Overall, exotic cover was greatest where bare soil cover was ≤10%. When Canada thistle was present, bare soil always covered <40% of the quadrant. This result (more exotics where less bare soil is found) supports other results (reported above) for disturbance, as disturbance often produces bare soil. A slight decrease in exotic cover occurred with an increase in litter, and no relationship was found between exotic cover and that of moss/lichen, sedges, or trees.

Exotics and Habitat Type

Six exotic species were found in the big sagebrush/bluebunch wheatgrass habitat type, a lower-elevation, drier habitat type than others in Yellowstone (Table 1). Forcella and Harvey (1983) also found exotics to be common in low-elevation, dry habitats.

The abundance of exotics at Mammoth may be related to climate. Of all Yellowstone campgrounds, this site has the longest frost-free period (125 d) and the highest average temperatures (15.3°C) for the summer growing season (June–August; Natural Resources Conservation Service 1994). Spotted knapweed has been found to be more common at relatively low elevations (610–1829 m), and it requires 50–120 frost-free days (Chicoine et al. 1988, Milner 1995). Mammoth was the only campground that met these conditions.

Fewer exotic plants were found at higher elevations, perhaps due to shorter growing seasons, habitat types, and related higher canopy covers. Low temperatures have been shown to inhibit total germination and rate of germination in yellow sweetclover (McElgunn 1973). Oxeye-daisy is adapted to a more northern climate (Lindsay 1953) than that of Yellowstone National Park, perhaps explaining its presence at a higher elevation (2275 m) than most other exotics, in the subalpine fir/pinegrass habitat. Canada thistle was found in a
wide range of habitats (big sagebrush/Idaho fescue, Douglas-fir/common snowberry, Engelmann spruce/sweetscented bedstraw, Engelmann spruce/horsetail, subalpine fir/grouse whortleberry, and subalpine fir/pinegrass habitats), a range of elevations (1820–2365 m), and on slopes ≤10%. No exotics were found in the subalpine fir/twinflower habitat.

Random and Control Quadrats
All 8 random quadrats sampled within Mammoth campground contained hound’s-tongue, spotted knapweed, dalmatian toadflax, and yellow sweetclover. Canada thistle was found in 2 quadrats within Slough Creek campground. Control quadrats near Mammoth were the only ones that contained exotic plants. Five of these 8 contained dalmatian toadflax.

CONCLUSIONS
Results of this study provide new information about the (1) geography of exotics within Yellowstone National Park and (2) canopy conditions under which some exotics may grow. Exotic occurrence was limited adjacent to most of the park’s campgrounds, but it was relatively high adjacent to Mammoth campground. Exotics decreased with distance from the campground edge, up to 6 m, and then increased. The large number of exotics found colonizing between 11 m and 50 m from Mammoth campground edge disturbance may be a result of several factors: availability of viable seed, habitat type, canopy cover, year-round use, and proximity to roads and trails. Distribution of exotics at Mammoth suggests that plants may spread outward from the campground area or from other nearby roads and trails. Canada thistle was the most prevalent species in all other campgrounds, covering a wide range of habitats.

Canopy cover and exotic occurrence were inversely related for most species; however, hound’s-tongue, Canada thistle, and dalmatian toadflax were also found under more closed canopy conditions. Fewer exotics occurred as disturbance increased, and exotics were frequently encountered in areas of no disturbance. Because undisturbed or slightly disturbed ground is common under natural conditions, exotics can be expected to colonize these areas given a seed source and sufficient light and nutrients. Canada thistle was found, however, in all amounts of disturbance, suggesting that many areas are suitable for its establishment. Generally, exotics decreased with an increase in cover of other vegetation, perhaps due to increased competition for available nutrients, water, and light. Canada thistle appears to compete well, as indicated by its occurrence with high percentages of other vegetation.

Resource management activities in Yellowstone may have contributed to the geography of exotics as found in this study. Some spraying and pulling of exotics in campgrounds has occurred, but most control efforts have been concentrated along roadsides (J. Sweeney, North District Resource Management coordinator, Yellowstone National Park, personal communication 1996). Canopy cover within forested campgrounds of the park is being reduced as necessary to prevent “hazard trees” from falling. Although exotics were found adjacent to few campgrounds, and a relatively small number of species was found, there are indications that exotics are spreading. The results of this study may be applied to ecosystems similar to this national park and can serve as a baseline for evaluating human-induced changes elsewhere.

ACKNOWLEDGMENTS
We thank John Borkowski, Andrew Marcus, Jennifer Whipple, Jim Sweeney, and Roy Renkin for guidance and expertise. This study was supported, in part, by the Department of Earth Sciences and the Mountain Research Center at Montana State University, the Business and Professional Women’s Foundation, and Yellowstone National Park.

LITERATURE CITED


Received 16 December 1997
Accepted 7 December 1998