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Spotted knapweed distribution in stock camps and trails of the Selway-Bitterroot Wilderness

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This article documents spotted knapweed (Centaurea maculosa Lam.) in 30 campsites and along 5 trails in the Selway-Bitterroot Wilderness and assesses the role of disturbance and environmental factors in controlling infestation. Spotted knapweed was present in only 6 of 30 surveyed campsites and limited portions of all 5 trails that were sampled. All spotted knapweed in camps was below 1700 m elevation, in open canopy, and in areas with an opportunity class disturbance ranking of 3 or 4. Overall disturbance levels measured using U.S. Forest Service Site Impact Work­sheets (SIWs) did not help predict occurrence of spotted knapweed, although bare mineral soil, vegetation loss, and development variables of SIWs provide some explanation of spotted knapweed presence or absence. There was no significant difference in knapweed frequency between areas used predominantly by horses and those used by humans within camps. Over 95% of spotted knapweed along trails was found within 0.5 km of the trailhead, occurred within 4.6 m of the trail, and had low reproductive potential. If the Bitterroot portion of the Selway-Bitterroot Wilderness is representative of forested wilderness areas in the Northern Rockies, then the perceived threat of spotted knapweed to wilderness areas may substantially exceed the actual danger in many instances. Study findings indicate that managers should conduct surveys before initiating costly control measures in wilderness areas, that eradication may be a viable alternative when spotted knapweed numbers are this low, and that regulations promoting minimum-impact camping should reduce spotted knapweed infestation.

**Key words:** spotted knapweed, wilderness, management, disturbance, camp, trail.

Exotic plants pose a threat to wilderness areas where they displace native species and alter natural conditions that wilderness areas are intended to preserve (Kummerow 1992). Management policies on these public lands now call for control of nonnative species to preserve native plant communities (Westman 1990). Despite these policies, recent studies have shown ever-increasing numbers of nonnative species in public lands of the Northern Rocky Mountain region (Losensky 1987, Lolo National Forest 1991, Whipple 1991, Tyser and Worley 1992, Flathead National Forest 1993, Lesica et al. 1993).

One of the most pernicious exotic species is spotted knapweed (Centaurea maculosa Lam.), which covers vast areas of the American West. This species is thought to be actively invading the Selway-Bitterroot Wilderness Area of Montana and Idaho (Losensky 1987). Understanding the mechanisms that allow invasion of spotted knapweed into this large wilderness area provides insights to the problem and guidance on means of controlling this species in a variety of wilderness settings. This article documents the extent of spotted knapweed along trails and in stock camps in the Bitterroot portion of the Selway-Bitterroot Wilderness and evaluates the role of disturbance and environmental factors in controlling its extension in this area.

**Spotted Knapweed Habitat and Study Area**

Spotted knapweed is native to the steppes of Europe. Introduced to North America in the early 20th century as a contaminant in Turkestan alfalfa (Medicago sativa L.) seed (Groh 1940), it has, since that time, expanded its range to cover almost 3 million ha in the northwest United States (Lacey et al. 1992).

Spotted knapweed in Montana has been found in areas where average annual precipitation is as low as 200 mm/yr and as high as 2030 mm/yr (Lacey et al. 1992), although Chicoine et al. (1985) found most spotted knapweed in areas with average annual precipitation between 310 and 760 mm/yr. Survival and reproduction are enhanced if precipitation coincides with seedling emergence (Schirman
and germination increases with increased soil moisture content (Spears et al. 1980). Soil type, however, does not appear to play a major role in determining spotted knapweed distribution (Schirman 1984).

Optimum temperatures for germination are between 10°C and 28°C (Chicoine 1984), and the plant seems best adapted to areas with 90–120 frost-free days (Chicoine et al. 1985). Spotted knapweed in Montana has been documented at elevations from 579 m to 3048 m, with 90% of infested rangeland sites occurring between 610 m and 1829 m (Lacey et al. 1992). Spotted knapweed occupies every major habitat type west of the Continental Divide in Montana (Mooers and Willard 1989), although on forested lands it is believed to pose the greatest threat in the relatively low-lying ponderosa pine (Pinus ponderosa Doug.) and Douglas-fir (Pseudotsuga menziesii [Mirbel] Franco) habitats (Forcella and Harvey 1983, Losenky 1987).

Disturbed habitat is a key factor facilitating spotted knapweed invasion. Exposed soil, reduced canopy, irrigation, selective grazing of native species, and contaminated hay all have been cited as causative factors in the spread of spotted knapweed (Watson and Renney 1974, Morris and Bedunah 1984, Mooers 1986, Losenky 1987).

Dispersion of Spotted Knapweed

Spotted knapweed reproduces only by seed (Story 1992) and disperses naturally through peripheral enlargement (Watson and Renney 1974). Seeds are dispersed up to 1 m by a flicking motion when the plant is disturbed. In Montana seed production of spotted knapweed averages 1000 seeds per plant (Chicoine 1984). French and Lacy (1983) found that seeds may remain viable for up to 5 yr, while Davis et al. (1993) continued to find viable seeds into the 8th yr of their study.

Spotted knapweed rapidly expands along roadways and in fields as plants are caught up in the undercarriage of farm machinery and motor vehicles (Montana Department of Agriculture 1986, Lacey et al. 1992). In preserves and grasslands, primary roads and motor vehicles help facilitate seed dispersal into adjacent grasslands and trailheads (Tyser and Worley 1992). Within wilderness stock camps, where use of motorized vehicles is prohibited, spotted knapweed can be introduced from seeds in pack stock hay (Cole 1983, Marion et al. 1986) or within manure from animals that have consumed weed-infested feed (Dale and Weaver 1974, Marion et al. 1986, Montana Department of Agriculture 1986). Seeds can also adhere to damp tarp or tent bottoms or become attached to humans or pack stock as they move along trails (Watson and Renney 1974, Marion et al. 1986). Stock camps are occupied by both humans and animals, but usually pack and saddle stock are kept separate from the portion of the camp where humans eat, sleep, and socialize. Thus, one might expect more spotted knapweed to be present in stock portions of the camp.

Early work suggested that spotted knapweed is allelopathic (Chicoine 1984), but later research by Kelsey and Bedunah (1989) found that allelopathy is not a significant factor contributing to the spread of spotted knapweed. Harvey and Nowierski (1989), however, documented the possibility of spotted knapweed displacing other species by depleting the soil of phosphorus and other nutrients.

Objectives and Hypotheses

This study documents spotted knapweed distributions in camp sites and along trails to determine the role of disturbance and select environmental variables in controlling the presence and abundance of spotted knapweed in the Selway-Bitterroot Wilderness. Specifically, we evaluate the hypotheses that spotted knapweed abundance will (1) decrease at higher elevations, (2) increase in areas with open canopy cover, (3) be greater in areas with higher Forest Service disturbance rankings and (4) be higher in stock than in human portions of camp sites. The number of viable spotted knapweed seeds within 3 km of trailheads is also documented to assess the reproductive potential of plants.

The primary objective of this work was to provide resource managers with an improved understanding of (1) the extent of spotted knapweed infestations in the Selway-Bitterroot Wilderness Area, (2) controls on spotted knapweed distribution in Northern Rocky wilderness settings, and (3) possible management approaches for dealing with this problem.

Study Area

We chose the Bitterroot segment of the Selway-Bitterroot Wilderness (Fig. 1) as a study...
Fig. 1. Spotted knapweed study locations in the Selway-Bitterroot Wilderness Area. Solid circles indicate campsites without spotted knapweed in 1993. Solid triangles are campsites with spotted knapweed. Trails surveyed for spotted knapweed in 1994 parallel Big, Bear, Mill, Sawtooth, and Chaffin creeks. Trailheads of surveyed trails range from 0.0 km to 0.3 km upstream of the wilderness boundary with the exception of Chaffin Creek trailhead, which is 3 km upstream of the wilderness boundary.

area because it receives regular use by hikers and pack stock and because spotted knapweed in non-wilderness portions of the Bitterroot National Forest is common and considered out of control (Losensky 1987). As of 1987 there were 109,600 ha within the forest infested by the plant and another 284,524 ha at risk. Long-distance spotted knapweed dispersal has been associated with contaminated hay (Forcella and Harvey 1983); stock camps in the wilderness therefore may serve as points of weed colonization. There are thus ample seed sources, mechanisms of seed dispersal, and a suitable environment for spotted knapweed to invade the wilderness area.

We surveyed 30 camp sites and 5 trails (Fig. 1), which have elevations ranging from approximately 1400 m to 2400 m. Precipitation in the wilderness area ranges from 1800 mm at 2700 m elevation in higher portions of the northern Bitterroot Mountains to 625 mm in the lower southeastern wilderness at approximately 1200 m.
m elevation (Finklin 1983). Mean monthly temperatures range from -5°C in January to 15°C in July at high elevations and from -2°C in January to 21°C in July at lower sites. Elevations, temperatures, and precipitation in the study area are all well within environmental tolerance levels reported elsewhere for spotted knapweed.

METHODS

We gathered data within stock camps and along trails on spotted knapweed distribution and on environmental and disturbance factors that might affect the species. Environmental information included data on elevations and canopy and vegetation cover. Disturbance data focused on level of disturbance, use by stock or humans, and distances from trailhead and trails. “Stock” camps are used by both hikers and packers. There are no designated backpacker-only camps or trails within the wilderness area.

Thirty camps were surveyed between early June and late August 1993. Four of the camps with spotted knapweed that were along surveyed trails were revisited in 1994. Percent cover of spotted knapweed, bare ground, rocks, litter, moss, grass, forbs, shrubs, and trees was surveyed using a modification of Cole’s (1983) method for determining wilderness impact levels. Measurements were taken along 8 equally spaced 24-m transects radiating from the center point of the “human” and “horse” portions of the camp. We differentiated human and horse areas to determine if use type alters spotted knapweed distribution and density. Horse areas were defined on the basis of manure, exposed roots, tree damage from tenters, bare mineral soil, and observations by wilderness rangers. Fire rings, fire scars, and excavated tent pads identified human areas of camps. We used a 2-sample t test to test the null hypothesis that there is no significant difference between the number of spotted knapweed plants in human and horse areas of camps. One camp with weeds was eliminated from analysis because horse and human areas could not be clearly separated.

Along each 24-m transect, we located 2 x 2-m quadrats 2 m apart; within each quadrat we counted the number of spotted knapweed plants. To characterize vertical structure of the canopy, we visually estimated vegetation cover variables at 3 heights: ground level to 50 cm, 51 cm to 3 m, and above 3 m. Scatterplot analysis was used to determine the relationship of spotted knapweed to vegetation variables within camp sites where spotted knapweed was present.

Spotted knapweed distribution along 5 trails was surveyed in August and September 1994 (Fig. 1). Starting at the trailhead and recording the distance to trail-side infestations up to 20 m from the trail, we recorded all occurrences of spotted knapweed along each trail. At randomly selected points of infestation along each trail, a transect was established perpendicular to the trail and 1-m² quadrats were placed at trail center, 0.5, 1.2, 2.4, 4.6, and 20 m from the trail. In each quadrat the percent canopy cover of spotted knapweed and other species groups (bare ground, moss, grass, herbs, shrubs, and trees) was visually estimated and recorded. Because all sampled trails paralleled streams, we recorded distances from the trail as negative (toward the stream) or positive (away from the stream).

Degree of disturbance in each camp and along trails was initially determined based on “opportunity classes” as defined on existing Forest Service maps. The Selway-Bitterroot is divided into 4 opportunity classes (Selway-Bitterroot Wilderness 1992), which are based on degree of modification of the natural setting and sites, degree of isolation, and frequency of use. A ranking of 1 indicates a pristine, unvisited region, while a ranking of 4 indicates a largely unmodified region but with frequent visitation and locally significant alteration of many of the destination sites.

We also determined disturbance at individual campsites using Selway-Bitterroot Wilderness Site Impacts Worksheets (SIWs), forms used by all wilderness rangers working in the Selway-Bitterroot and by managers throughout the United States. SIWs are modified from worksheets developed by Cole (1989) for documenting wilderness impacts in campsites. The second author of this article (GM) attended the wilderness ranger training session on assessing disturbance with the SIW form and was the only individual to collect SIW data used in this study.

Degree of disturbance at a campsite is assessed based on measures of 8 variables (Table 1). Each variable receives a rating ranging from 1, which is least disturbed, to 3, most
disturbed. The rating for each variable is multiplied by a weighting factor. Types of impacts that are easily remedied receive a weighting of 1. Impacts that are contained or could recover with less use receive a 2. The heaviest weighting of 3 applies to impacts that are difficult to restore or are long lasting. Weighted rankings are then summed to determine overall campsite impact level, which can fall into 1 of 4 classes: light (18-27), moderate (28-36), heavy (37-45), and extreme (46-54). SIW forms also require noting whether the camp area has a predominantly closed or open canopy. A closed canopy is defined as branches from different trees overlapping over the central campsite. A complete copy of the 4-page SIW is contained in Milner (1995).

Opportunity class and SIW measures generate classes of disturbance ranging from 1 to 3 or 4, depending on the variable in question. Because of the small range of disturbance rank values, a chi-square test was used to statistically evaluate the disturbance hypotheses.

Seed heads were collected from spotted knapweed plants within 3 km of the trailheads along Mill Creek, Big Creek, and Bear Creek trails (Fig. 1). Seed was removed from the seed heads and divided into plump, shriveled, and damaged seeds. Germination of the seed was tested using a standard spotted knapweed protocol (Davis et al. 1993).

**RESULTS AND DISCUSSION**

Spotted knapweed occurred in 6 of 30 surveyed campsites (Fig. 1, Table 2). Knapweed occurred along very limited portions of all 5 trails, but never beyond 4.6 m from the trail or 7.6 km from the trailhead, with over 95% observed within 0.5 km of the trailhead (Fig. 2, Table 3). More complete summaries of the vegetation transect and SIW disturbance data for each campsite are contained in Milner (1995).

**Elevation**

All 6 camps containing spotted knapweed are located at <1700 m, which is consistent with Chicoine et al.’s (1985) work in Montana showing 90% of infestation sites occurring at <1829 m (6000 ft; Table 2). There was no spotted knapweed in any camps or along any trails above 1700 m, nor in 10 of the 16 camps below 1700 m.

### Table 1. Variables, ratings, and weighting factors on the Selway-Bitterroot Wilderness Site Impacts Worksheets. Coverage classes for vegetation and mineral soil are class 1: 0–5%; class 2: 6–25%; class 3: 26–50%; class 4: 51–75%; and class 5: 76–100%.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Rating 1</th>
<th>Rating 2</th>
<th>Rating 3</th>
<th>Weighting factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation loss</td>
<td>Estimated difference between on-site and off-site coverage</td>
<td>no difference</td>
<td>difference = 1</td>
<td>difference &gt;1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in coverage</td>
<td>coverage class</td>
<td>coverage class</td>
<td></td>
</tr>
<tr>
<td>Mineral soil increase</td>
<td>Estimated difference between on-site and off-site coverage</td>
<td>no difference</td>
<td>difference = 1</td>
<td>difference &gt;1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in coverage</td>
<td>coverage class</td>
<td>coverage class</td>
<td></td>
</tr>
<tr>
<td>Tree damage</td>
<td>Total number of damaged trees in the camp site</td>
<td>no more than</td>
<td>1-25 damaged</td>
<td>&gt;25 damaged</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>broken lower</td>
<td>trees or &gt;25%</td>
<td>trees damaged</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>branches</td>
<td>trees</td>
<td>trees damaged</td>
<td></td>
</tr>
<tr>
<td>Root exposure</td>
<td>Total number of trees with exposed roots caused by erosion or trampling</td>
<td>none</td>
<td>1-15 exposed</td>
<td>&gt;15 exposed</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>roots or &gt;25%</td>
<td>trees exposed</td>
<td>trees exposed</td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td>Number and type of facilities found within the camp</td>
<td>no facilities</td>
<td>primitive log</td>
<td>facilities other</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or rock seat</td>
<td>or rock seat</td>
<td>than seat</td>
<td></td>
</tr>
<tr>
<td>Cleanliness</td>
<td>Amount of trash, fire scars, or manure at the site</td>
<td>no fire scars</td>
<td>1 fire scar/</td>
<td>&gt;1 fire scar;</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or rings</td>
<td>some trash/</td>
<td>much trash/</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>manure</td>
<td>manure or human</td>
<td></td>
</tr>
<tr>
<td>Social trails</td>
<td>Number of trails leading in and out of the camp</td>
<td>no more than 1</td>
<td>2-3 trails, max.</td>
<td>&gt;3 trails,</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 well worn</td>
<td>&gt;1 well worn</td>
<td></td>
</tr>
<tr>
<td>Barren area estimate</td>
<td>Total barren area within the site; considered barren if &gt;90% of the vegetation is absent</td>
<td>&lt;50 ft²</td>
<td>50-1500 ft²</td>
<td>&gt;1500 ft²</td>
<td>3</td>
</tr>
</tbody>
</table>
### Table 2. Summary characteristics of campsites surveyed for spotted knapweed in the Selway-Bitterroot Wilderness Area. SIW variables and rating scale are described in Table 1.

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Distance from trailhead (km)</th>
<th>Forest cover</th>
<th>Overall impact</th>
<th>Development</th>
<th>Elevation</th>
<th>Forest cover</th>
<th>Opportunity class</th>
<th>Average knapweed density (plants/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg: 1519</td>
<td>Avg: 9.0</td>
<td>6 open</td>
<td>extreme</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5.4</td>
</tr>
<tr>
<td>Min: 1536</td>
<td>Min: 4.8</td>
<td>0 closed</td>
<td>heavy</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Max: 1658</td>
<td>Max: 13.3</td>
<td></td>
<td>moderate</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg: 1858</td>
<td>Avg: 11.5</td>
<td>10 open</td>
<td>extreme</td>
<td>15</td>
<td>3</td>
<td>10</td>
<td>3</td>
<td>5.4</td>
</tr>
<tr>
<td>Min: 1402</td>
<td>Min: 4.4</td>
<td>14 closed</td>
<td>heavy</td>
<td>7</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>7.2</td>
</tr>
<tr>
<td>Max: 2304</td>
<td>Max: 21.3</td>
<td></td>
<td>moderate</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>3.1</td>
</tr>
</tbody>
</table>

#### Table 3. Occurrence of spotted knapweed along trails in the Bitterroot portion of the Selway-Bitterroot Wilderness Area.

<table>
<thead>
<tr>
<th>Trail name</th>
<th>Opportunity class ranking</th>
<th>Distance to final knapweed location (km)</th>
<th>Spotted knapweed per infested trail distance (knapweed/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill Creek</td>
<td>3 or 4</td>
<td>6.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Big Creek</td>
<td>4</td>
<td>7.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Chaffin Creek</td>
<td>3</td>
<td>5.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Bear Creek (North Fork)</td>
<td>4</td>
<td>1.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Sawtooth Creek</td>
<td>2</td>
<td>6.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Canopy

Spotted knapweed was present in 6 of 10 open canopy camps below 1700 m, but not in any of the 14 closed canopy sites, which included 10 sites below 1700 m (Table 2). A chi-square test indicated a significant relationship at the 0.10 level between open canopy and presence of spotted knapweed in camps (Table 4). Visual observations along trails also suggested that spotted knapweed was more associated with open areas and talus slopes in particular.

Open canopy can result from natural variability in forest cover but can also reflect disturbance such as trampling and cutting down of trees for firewood, ease of movement, and facilities (e.g., hitches). Association of spotted knapweed with open canopy is consistent with work by Watson and Renney (1974), who found it to be more commonly associated with open areas and rarely in shade. Losensky (1987) noted that spotted knapweed germinates equally well under a 0–100% canopy, but shade severely limits growth.

Disturbance and Spotted Knapweed

Opportunity class and campsite infestation.—Five of 10 opportunity class 4 camps and 1 of 8 class 3 campsites contained spotted knapweed (Table 2). No infestations occurred in 12 camps with ratings of opportunity class 1 or 2, which designate areas receiving less use. A chi-square test indicated a significant positive relationship between opportunity class rank and spotted knapweed presence in campsites at the 0.10 level (Table 4). The positive association of opportunity class and spotted knapweed fits with previous research showing that disturbance plays a key role in facilitating spotted knapweed infestation (Watson and Renney 1974, Morris and Bedunah 1984, Mooers 1986, Losensky 1987).

Site impact rating and campsite infestation.—Unlike the clear association of opportunity class and spotted knapweed, the overall SIW rating for campsites (moderate, heavy, extreme) did not have a significant relationship to presence or absence of spotted knapweed in the Selway-Bitterroot Wilderness (Table 4). This is probably because the overall SIW rating gives significant weighting to a number of variables such as cleanliness, root exposure, and tree damage which, based on existing literature, would not be expected to have a direct connection to spotted knapweed presence or absence. In contrast, opportunity classes are largely defined based on frequency of use and probably provide a better indicator of total numbers of users and the resultant disturbance and potential for seed introduction.

Some components of disturbance that are measured to determine the overall SIW rating do, however, appear to be associated with
spotted knapweed. Although not significant at the 0.10 level, vegetation loss and mineral soil variables both show weak associations with the presence of spotted knapweed in camps (Table 4). This suggested link between vegetation loss, mineral soil, and presence of spotted knapweed is consistent with previous research indicating that exposed mineral soil provides a fertile area for spotted knapweed germination (Morris and Bedunah 1984, Mooers 1986).

The apparent association of the development variable with spotted knapweed (Table 4) is perplexing. Development as defined on the SIW is the number and type of facilities (e.g., tent poles, log seats, hitch rails, etc.). Four of 19 camps with a development rating of 3 (the most developed) and 2 of 4 that rated a 2 contained spotted knapweed (Table 2). None of the 7 camps with a development rating of 1 contained the weed.

The apparent preference of spotted knapweed for development rating 2 sites may simply reflect the elevations of camps with open canopy rather than a preference for sites with intermediate levels of development. Three of 4 development rating 2 camps are situated below the 1700 m maximum elevation at which spotted knapweed was found in this study, while only 5 of 19 development rating 3 sites are located below 1700 m. Approximately equal proportions of development rating 2 and 3 camps below 1700 m thus contain spotted knapweed. None of the development rating 1 camps contain spotted knapweed, but all are located above 1700 m. Greater development is also associated with open canopy because trees are felled to make hitches, tent poles, seats, and other facilities.

**DISTURBANCE AND INFESTATION ALONG TRAILS.**—Spotted knapweed occurrence along trails is limited in extent, generally occurring in low-elevation, most frequently visited portions of trails within 0.5 km of trailheads (Fig. 2). Disturbance as indicated by opportunity class ranking also is associated with infestation, with the large majority of weeds growing along the opportunity class 3 and 4 trail sites (Table 3). Spotted knapweed occurred at only 3 open scree sites along the opportunity class 2 Sawtooth Creek trail.

In general, spotted knapweed is most commonly observed along all trails on scree slopes where soil is shallow and rock is often moving over and disturbing the surface. Spotted knapweed cover decreases with distance from the trail (Fig. 2), which may be the result of decreased disturbance associated with activity on the trail or increased distance from sources (people and animals) traveling along the trail. There is also a decrease in knapweed frequency and cover with increased distance from trailheads (Fig. 2). These results are similar to those described by Dale and Weaver (1974).

**Stock and Human Use Areas in Camps**

In the horse areas of the remaining 5 camps, 16 of 1355 quadrats contained a total of 84 spotted knapweed. In human areas, 13 of 1264 quadrats contained 51 total plants. At the scale of individual campsites, our data indicate no significant difference in spotted knapweed frequency between horse and human areas.

**Vegetation in Camps**

A Pearson correlation of vegetation cover and spotted knapweed abundance was conducted to determine if local scale variations in ground cover affect the ability of spotted knapweed to colonize. We limited our analysis to the 16 camps below 1700 m where spotted knapweed was known to be viable. The correlation supports the general observation that canopy is key in controlling spotted knapweed (Table 5). The only correlation that was significant at the 0.05 level was the negative correlation ($r = 0.08$) between tree cover above 3 m in height and spotted knapweed density.

### Table 4. Chi-square test of the relationship between number of spotted knapweed at each campsite ($n = 30$) and possible driving variables. Relationships significant at the 0.10 level are in boldface.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Chi-square</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opportunity class</td>
<td>8.90</td>
<td>0.019</td>
</tr>
<tr>
<td>Variables on SIW sheet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation loss</td>
<td>4.36</td>
<td>0.113</td>
</tr>
<tr>
<td>Mineral soil</td>
<td>3.96</td>
<td>0.138</td>
</tr>
<tr>
<td>Tree damage</td>
<td>0.17</td>
<td>0.690</td>
</tr>
<tr>
<td>Root exposure</td>
<td>1.29</td>
<td>0.256</td>
</tr>
<tr>
<td>Development</td>
<td>5.83</td>
<td>0.054</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>3.40</td>
<td>0.183</td>
</tr>
<tr>
<td>Social trails</td>
<td>1.96</td>
<td>0.575</td>
</tr>
<tr>
<td>Barren core area</td>
<td>1.09</td>
<td>0.581</td>
</tr>
<tr>
<td>Closed/open forest canopy</td>
<td>5.64</td>
<td>0.010</td>
</tr>
<tr>
<td>Overall SIW impact rating</td>
<td>1.47</td>
<td>0.537</td>
</tr>
</tbody>
</table>
In 6 camps where spotted knapweed was present and where cover could influence the within-camp distribution, scatterplot analysis indicated that spotted knapweed does best in areas with <25% cover of rock, which simply reflects the inability of the plant to grow without soil. In general, spotted knapweed was present only in quadrats where percent cover of litter, moss, grass, and trees was each <25%, or the total canopy cover was <100% (canopy cover often exceeded 100% because it was measured in 3 different levels and then summed). This is consistent with Morris and Bedunah's (1984) and Mooers' (1986) findings that bare soil enhances the ability of spotted knapweed to invade a site. Percent cover of forbs showed no clear relationship to spotted knapweed. Spotted knapweed, however, was usually present only in quadrats with <25% bare ground. This partially results because spotted knapweed covers the soil and reduces the percent cover of bare ground. In addition, many areas with significant bare ground in campsites are locations where fire rings, tent sites, and horse hitches are concentrated. While some bare ground is beneficial to spotted knapweed, areas that receive repeated disturbance and soil compaction can make it difficult for any new plant, including spotted knapweed, to become established.

**Seed and Plant Viability**

In 1994 no knapweed was observed in 3 of 4 camps that were infested in 1993. This suggests that spotted knapweed may be ephemeral in the wilderness and present only under ideal growing conditions.

In plants sampled along Mill, Big, and Bear Creek trails, there was a mean of 16 (±12) seeds per head. This is substantially lower than the 1000 seeds per head generally reported. The proportion of plump seeds ranged from 2% to 100% of seeds in individual heads. No shriveled or damaged seeds germinated, but 100% of plump seeds did. Thus, one may conclude that viable seed is produced in the wilderness but reproductive potential is low.

**Management Implications**

It is notable that only 6 of 30 wilderness campsites and very small portions of 5 wilderness trails contained spotted knapweed in an area perceived to be at great risk from infestation. Furthermore, spotted knapweed occurred in only 1 of 4 camps infested in 1993 that were revisited the following summer, and seed production was low for specimens collected along the trail during the summer of 1994. If the Bitterroot portion of the Selway-Bitterroot Wilderness is representative of forested wilderness areas in the Northern Rockies, then the perceived threat may substantially exceed the actual danger in many instances. The results from this study suggest 4 general avenues of management responses.

1. Managers should conduct surveys before initiating costly control measures in any wilderness area. Surveys in forested regions similar to the Selway-Bitterroot should initially focus on areas most prone to infestation, that is, areas with open canopy adjacent to trails where opportunity class ratings are 3 or greater and in elevations that are optimal for spotted knapweed.

2. Wilderness workers can be trained to remove weeds as part of their normal backcountry duties. Likewise, volunteers can be educated and recruited to remove weeds via existing weed awareness programs, signing of trails, and information packets given to backcountry users.

3. The association of spotted knapweed at campsites with loss of vegetation, exposed mineral soil, open canopy, and development of facilities emphasizes the need for already existing regulations promoting minimum-impact camping in wilderness areas. In particular, backcountry permits should stress packing in camp chairs and using aluminum poles for tent poles and hitches rather than tearing down dead wood or cutting live trees, both of which open up the canopy.
(4) The tendency for spotted knapweed to grow only on scree slopes along trails suggests that infestation could be avoided by routing trails to avoid these open disturbed areas.

This research leaves open the question of how serious the spotted knapweed problem is in surrounding forested, non-wilderness portions of the Bitterroot National Forest and whether the same variables of elevation, open canopy, and opportunity class can be used to predict potential for infestation on those lands. There is clearly a vast gulf between the perception of infestation and the reality in some areas. This uncertainty suggests that, at a minimum, further surveys should be conducted in different use areas to determine where the threat is serious, what variables control that threat, and how to best allocate resources to control spotted knapweed.

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LITERATURE CITED


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