

Distribution and Amount of Four Knapweed (*Centaurea* L.) Species in Eastern Washington¹

Abstract

Since their introduction in the early 1900's, four knapweed (*Centaurea* L.) species have become prominent weeds of pastures, rangeland, and nonirrigated hay in the Northern Intermountain Region. The reduction in forage following invasion by these weeds threatens the stability of the ranching industry. Planning an effective integrated control program requires information on the distribution and amount of each species. An eastern Washington knapweed survey was completed in 1987.

Diffuse knapweed (*Centaurea diffusa* Lam.) was reported in all 20 eastern Washington counties, for a total of 173, 151 ha of infested area. Ninety percent of the infestation was in the six counties that border the Columbia River Basin to the north and west: Stevens, Ferry, Okanogan, Chelan, Kittitas, and Yakima. Of the 16 counties reporting yellow starthistle (*C. solstitialis* L.), those 5 in southeastern Washington had 93 percent of the 54,172 ha. A total of 10,777 ha of spotted knapweed (*C. maculosa* Lam.) was reported from 19 counties. Ninety-two percent was reported from the northeastern counties of Spokane, Pend Oreille, and Stevens. Russian knapweed (*C. repens* L.), reported from 19 counties, was estimated at 3,259 ha.

The annual loss in forage production on pasture and rangeland was estimated to be 59,190,540 kg, a value of \$951,000 in Animal Unit Months or \$2.9 million in hay.

Introduction

During the past quarter century, populations of several *Centaurea* species expanded on rangelands of the Northern Intermountain Region of North America. They pose a serious threat to the stability of the ranching industry. Forage production on rangeland was reduced as perennial bunchgrasses were replaced by downy brome (*Bromus tectorum* L.²). Although undesirable for various reasons (e.g., extreme production cycles, short grazing period, and fire hazard at maturity), downy brome is highly palatable to livestock in its flush of early growth. The low palatability of the knapweeds creates a much more serious type of range deterioration (Roché *et al.* 1986).

Although 14 species of *Centaurea* have been collected in Washington (Roché and Talbott 1986), the important species in eastern Washington are yellow starthistle and diffuse, spotted, and Russian knapweed. The rosettes of yellow starthistle (*C. solstitialis* L.) and spotted and diffuse knapweeds (*C. maculosa* Lam. and *C. diffusa* Lam., respectively) are not readily grazed. Popova (1960) noted that although the rosettes

of the first year's growth of diffuse knapweed are nutritious and edible, "they are strongly appressed to the ground, as if fastened to it, and are difficult for cattle to get at, even for sheep in snow-free winters." Mature knapweeds are fibrous; yellow starthistle has sharp spines on the seed heads. Coarse dense stems and spines limit access by grazing animals to associated forage species. In addition, yellow starthistle and Russian knapweed (*C. repens* L.) are poisonous to horses (Kingsbury 1964, Young *et al.* 1970).

Because they are unpalatable, knapweeds greatly reduce dryland forage production, whether hay, range, or pasture. In British Columbia, the loss in forage production due to diffuse and spotted knapweed is estimated at \$320,000 annually which equates to a theoretical loss in beef output value of over \$1.5 million (Cranston 1985). Spotted knapweed causes an estimated \$4.5 million forage loss annually to the Montana range livestock industry (Lacey *et al.* 1986).

Other losses include soil erosion, and reductions in wildlife populations, recreation and property values (Cranston 1985). In Montana, it was estimated that the rate of soil erosion doubled when spotted knapweed replaced perennial bunchgrass on rangeland (French and Lacey 1983).

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²Scientific names follow Hitchcock and Cronquist 1976.

The need for a survey of knapweed distribution in Washington has been evident for at least two decades. In 1958 the westward movement of spotted knapweed from Montana along railroad and highway rights-of-way was recognized, and a survey of acreages by county was suggested to assist in gaining program support (Roché 1985). In December 1984, an interagency meeting held at Washington State University led to the formation of a Knapweed Steering Committee. This committee was assigned to "evaluate alternatives and recommend an integrated knapweed control program" (Roché 1986). This paper reports the results of the first, and essential, step in such a program, a survey of the four major species by amount, location, and relative dominance (Talbot 1987).

Methods and Materials

The location and amount of each species of knapweed was estimated by soliciting data from professionals interested in weed control in the 20 counties east of the Cascade Mountains in Washington. In 1984, survey cards, an explanation of the survey, and a discussion of the knapweed problem were sent to personnel in Cooperative Extension, County and District Weed programs, Soil Conservation Service, and public land management agency personnel (e.g., Forest Service, Bureau of Land Management, Bureau of Indian Affairs, and Washington State Departments of Natural Resources and Wildlife). We requested the following information for each of the four species: area infested, dominance rating of the

weed, current land use, and location. Estimates of area and dominance rating of the weed were the only quantitative factors. The cooperators were instructed to estimate infestation size as the area that would require treatment. The dominance scale of 1 to 5 (Table 1) is slightly modified from Poulton (1962). Density, which requires time-consuming counting of individuals in a definite space, was not used: it is often impossible to count individuals for plants which reproduce vegetatively and the size of mature individuals may vary a thousand fold under different growing conditions (Daubenmire 1968). Dominance based on occupancy of space indicates the relative influence that a species exerts on the other components. In addition to the ease in recording the relative amount of the weed, relative forage reduction can be estimated from the dominance rating.

Participation in the survey was voluntary; thus some infestations were missed because the individuals chose not to participate in the survey. Other infestations were missed because there was not sufficient time or personnel to cover the entire area. The completeness of the survey as a percentage of the land area in each county is estimated for each species in the results section. Survey cooperators are listed by county in the Acknowledgments.

The survey was done in varying intensities. In some counties it was a systematic search for knapweed (Adams, Ferry, Franklin, Klickitat, and Stevens); in other counties it was the best recollections of individuals familiar with the area

Table 1. Dominance rating definitions¹

Dominance	Definition	Estimated Forage Reduction (%)
1	It can be found by searching in and around other species. A "1" is not obvious.	5
2	It can be seen only by moving through the vegetation or by searching for it while standing in one place. A patchy pattern observed by moving through the vegetation rates a "2."	10
3	It is easily seen by standing in one place and glancing around, but it is not an obvious dominant. In a mixed stand several species may fall into this category.	40
4	It is at least a codominant. It shares dominance relative to cover or is considered slightly subordinate to other species, native or introduced; for example: cheatgrass, Kentucky bluegrass (<i>Poa pratensis</i> L.), bunchgrass range or a mixture of weeds on abandoned farmland.	60
5	It dominates the site. It is dominant in the sense that it provides essentially total cover when viewed casually.	95

¹Modified from Poulton 1962

combined with some systematic search and noting of weed locations while doing county weed inspection or other work (Asotin, Chelan, Columbia, Douglas, Garfield, Grant, Kittitas, Lincoln, Okanogan, Pend Oreille, Spokane, Walla Walla, Whitman and Yakima). In Benton County, there was no county-wide coordination of the survey. The Hanford Reservation, U and I Group, Chateau Ste. Michelle, and U.S. Fish and Wildlife Service lands were surveyed. Other locations were infestations the cooperators happened to notice.

Survey cards were completed only when weeds were found. The minimum amount for a card was one plant. There was no maximum limitation although the surveyors were encouraged to report by dominance rating for each site, thereby discouraging a county lump sum approach. Surveyors were not limited to a set number of cards. Additional cards were sent as requested. In some instances, a less detailed survey was accepted because it was the only information available. The number of survey cards returned were 4,142 for diffuse knapweed, 838 for yellow starthistle, 700 for Russian knapweed, and 425 for spotted knapweed.

Weed locations were plotted on U.S. Geological Survey 1:100,000 topographic maps. Map locations were numbered to correspond with the site number on the survey card. Duplicate reports were avoided by comparing new reports with previously recorded sites on the base maps. Base maps were digitized to produce computer-plotted maps. These maps along with summaries of amount, dominance rating, and land use by species were sent to each county at the beginning of the second field season. This progress report facilitated the addition of new sites and the completion of the survey with a minimum of duplication of effort.

Survey work continued through the 1986 field season. A report was sent to each county coordinator (weed supervisor and/or Cooperative Extension agent) in early 1987 for approval or corrections.

Results and Discussion

This is the most thorough survey attempted to date on a set of weed species in eastern Washington. Lower amounts of knapweed were reported in this survey, which required precise locations, than in previous surveys which were

subjective broad estimates. Two previous weed surveys in Washington by Roché (1967) and Penhalegon (1983) included knapweed species. Results of the three surveys follow: for diffuse knapweed, 150,674 ha (1967), 274,062 ha (1983), and 173,151 ha (1987); for yellow starthistle, 10,288 ha (1967), 62,057 ha (1983), and 54,172 ha (1987); for spotted knapweed, 28,900 ha (1967), 79,882 ha (1983), and 10,777 ha (1987); and for Russian knapweed, 41,252 ha (1967), 15,962 ha (1983), and 3,259 ha (1987).

Diffuse Knapweed

Diffuse knapweed grows in every eastern Washington county (Table 2, Figure 1). It was by far the most abundant species, occupying 72 percent of the total area reported for the four species. The total of 173,151 ha is an underestimate because the survey was not completed in Adams (80%), Benton (20%), Grant (80%), Okanogan (50%), and Yakima (60%) counties. Five counties (Okanogan, Ferry, Yakima, Kittitas, and Stevens) each reported more than 12,000 ha. Including Chelan, the six counties which border the Columbia River Basin to the north and west had 90% of the diffuse knapweed reported for eastern Washington (Figure 1, Table 2).

Table 2. Infested area in each county by species, in hectares.¹

	Yellow				Total
	Diffuse knapweed	star-thistle	Spotted knapweed	Russian knapweed	
Adams	264	24	56	333	677
Asotin	270	2,223	trace	28	2,521
Benton	1,232	12	trace	43	1,287
Chelan	5,779	2	1	85	5,867
Columbia	12	17,956	1	2	17,971
Douglas	3,104	0	0	86	3,190
Ferry	23,696	336	69	278	24,379
Franklin	103	19	4	160	286
Garfield	179	858	127	12	1,176
Grant	553	0	6	281	840
Kittitas	13,483	trace	59	175	13,717
Klickitat	2,936	2,512	3	38	5,489
Lincoln	683	0	362	106	1,151
Okanogan	79,402	527	80	1,081	81,090
Pend Oreille	98	0	518	0	616
Spokane	1,468	4	9,061	8	10,541
Stevens	12,534	153	378	47	13,112
Walla Walla	233	25,422	4	33	25,692
Whitman	5,308	3,852	29	20	9,209
Yakima	21,814	272	19	443	22,548
TOTALS	173,151	54,172	10,777	3,259	241,359

¹Multiply by 2.47 to convert to acres.

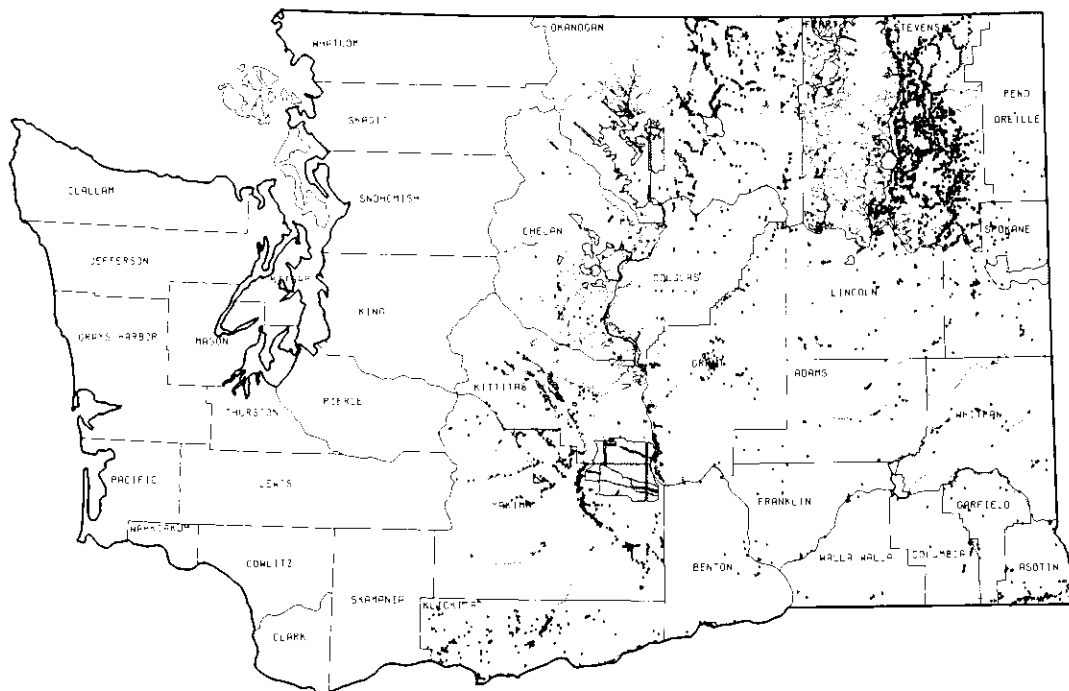


Figure 1. Distribution of diffuse knapweed in eastern Washington. Sites were plotted as points, lines or areas. Each indicate only presence of the weed. A point may indicate one plant up to 65 ha. Lines indicate stringers along roads, rivers, power lines, or railroads. Area is indicated when detailed mapping of individual sites was not done.

Every county reported diffuse knapweed along roadsides and railroads, for a total of 13,096 ha, or 7.6 percent of the total. This "tumble knapweed" has spread along roadsides, gaining wide distribution. Plants carried or blown by vehicles lose seeds gradually from the urn-shaped heads (Watson and Renney 1974). Transportation routes through pasture, rangeland, and timbered range have served as a source of infestation for entire areas.

Rivers and streams also transport diffuse knapweed, often into areas not accessible by vehicle. We have observed the bushy stalks floating in rivers and plants growing on gravel bars and sandy shores. Diffuse knapweed was found along the Okanogan, Methow, Yakima, Snake, Grande Ronde, Columbia, and other rivers.

From rivers and rights-of-way, diffuse knapweed has moved onto rangeland. Eighty percent (138,297 ha) of the diffuse knapweed in eastern Washington was reported on pasture, range, and timbered range (Table 3). Of this total, 7 percent was pasture, 35 percent was timbered range, and

58 percent was rangeland. Infested rangeland represents about 5 percent of the total rangeland in eastern Washington (Washington Rangeland Committee and Washington Conservation Commission 1984). The percentage of rangeland in each county infested by diffuse knapweed varied, but Ferry County reported the highest level (31%), followed by Okanogan and Stevens counties.

Dominance rating of the weed generally increased with site disturbance. Abandoned cropland and industrial sites were commonly dominated by diffuse knapweed (rating 5). Overall, 38 percent of the diffuse knapweed was reported as dominance ratings 1 and 2, while dominance ratings 3, 4, and 5 were estimated at 23, 25, and 14 percent, respectively (Table 4).

Yellow Starthistle

The 54,172 ha of yellow starthistle was 22 percent of the total area reported for the four species. Four counties (Douglas, Grant, Lincoln, and Pend Oreille) reported no yellow starthistle.

TABLE 3. Infested area by current land use by species, in hectares.

Current Land Use	Yellow			
	Diffuse Knapweed	Starthistle	Spotted Knapweed	Russian Knapweed
cropland	1,601	29	28	510
edge of cropland	1,307	6,217	177	162
abandoned cropland	2,506	314	32	323
pasture	9,732	935	1,217	333
rangeland	80,359	44,663	398	1,206
timbered range	48,206	81	185	1
clearcut	213	0	0	0
recreational area	1,176	204	171	75
urban/residences	1,158	186	2,403	46
industrial sites	2,472	125	4,253	24
roadside/railroad	13,096	307	724	339
skid road	4,974	0	6	0
parking area	253	49	6	3
speculation	1,728	22	1,052	35
idle land	3,801	1,033	119	162
other	43	0	6	3
irrigation r/w, river	526	7	4	38

TABLE 4. Infested area by species and dominance rating category, in hectares.

	Dominance Rating				
	1	2	3	4	5
Diffuse knapweed	38,923	26,874	39,825	43,288	24,241
Yellow starthistle	2,292	11,880	15,506	22,211	2,283
Spotted knapweed	29	269	3,407	6,554	519
Russian knapweed	16	50	490	1,136	1,567

The yellow starthistle survey is estimated to be 90 percent to 100 percent complete for all counties. Better records were available for this species because a cost-share control program has been available since the early 1970's. Locations of weed control projects funded one third each by the state, county and landowner were documented by county weed supervisors.

Yellow starthistle was concentrated in the southeastern corner of the state: 80 percent occurred in Columbia and Walla Walla counties (Table 2, Figure 2). These two counties, along with Asotin, Garfield, and the southern part of

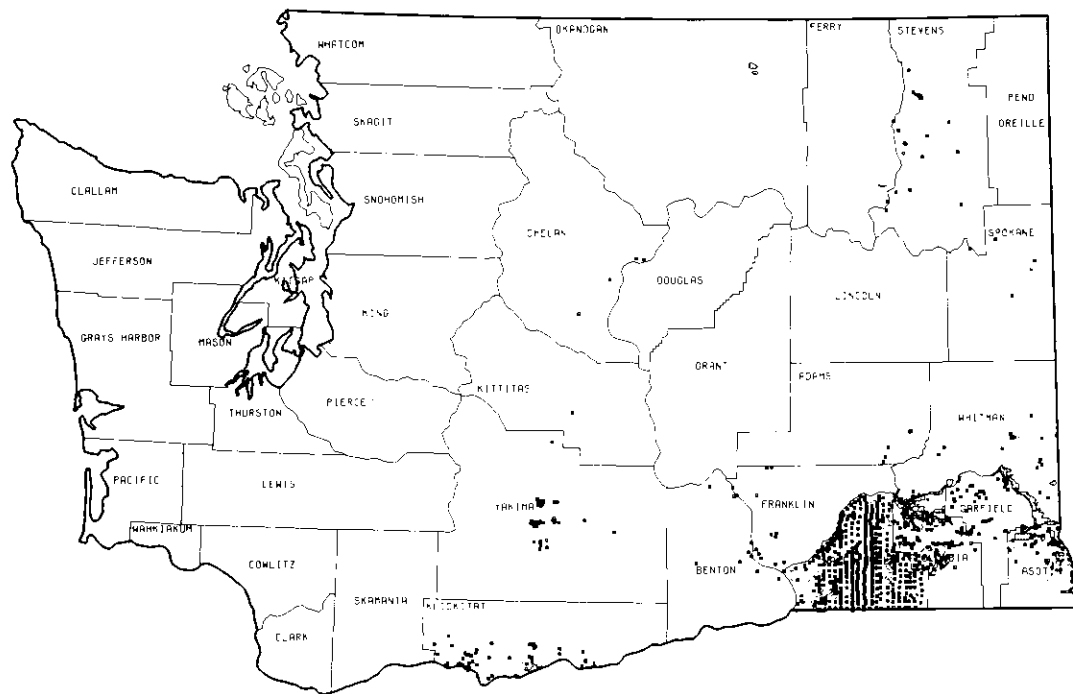


Figure 2. Distribution of yellow starthistle in eastern Washington. Symbols as in Figure 1.

Whitman County, had 93 percent of the yellow starthistle in eastern Washington. The remaining sites fit one or more of five categories: (1) sunny, warm south-facing slopes along the Columbia River, (2) seeded along with alfalfa or clover, (3) along irrigation ditches, (4) in overgrazed pastures, or (5) a ranch with branch operations in southeastern Washington. A small population persisted on both sides of the Columbia River at the old Hanford townsite ferry crossing. In Klickitat, Ferry, and Stevens counties, the yellow starthistle was found on natural grasslands along the Columbia River or in dryland alfalfa. The approximately 500 ha in Okanogan County was seeded in 1985 with contaminated crimson clover broadcast over a wildfire area. The yellow starthistle in Adams County occurred where the landowners have moved equipment or livestock in from Columbia County.

Yellow starthistle is primarily a rangeland weed. Eighty-four percent of the infested area was pasture, range, or timbered range (456,679 ha), with 98 percent of that on rangeland (Table 3). This constituted about 2 percent of the total rangeland in eastern Washington (Washington Rangeland Committee and Washington Conservation Commission 1984). The percentage of rangeland infested in Walla Walla and Columbia counties was much higher, 41 and 25 percent, respectively.

The movement of yellow starthistle along roadsides, railroads, and rivers has been more limited than diffuse knapweed. Fourteen counties reported some yellow starthistle along roadsides or railroads, but the amount (307 ha), 5 percent of the total, was the lowest of the four knapweeds. Seed of yellow starthistle growing in gravel pits has been distributed along roadsides and at new construction sites (dams, parking lots, substations, powerlines, roads).

Contaminated seed and feed have been the most important means of spread of yellow starthistle. The seed industry considered the *Centaurea* species in the West as the most difficult type of seeds (i.e., weight, size, shape, etc.) to remove from alfalfa seed (Roché 1965). Most of the infested 30 ha reported on cropland was in alfalfa. Most of the "edge of cropland" area (215 ha in Columbia County and 5,951 ha in Walla Walla County) was adjacent to grain crops. These were the eyebrows or "outground," some of which was previously farmed.

Yellow starthistle occurred as a codominant (rating 4) on 41 percent of the total infested area. Dominance ratings 1 and 5 were each reported as 4 percent, while dominance ratings 2 and 3 comprised 22 and 29 percent, respectively (Table 4). In Columbia and Walla Walla counties, dominance ratings increased with elevation: ratings 4 and 5 were more common in the foothills of the Blue Mountains, with ratings 1 through 3 prevalent near the Snake River, except in disturbed areas such as abandoned cropland or industrial sites.

Spotted Knapweed

Spotted knapweed was reported from 19 eastern Washington counties for a total of 10,777 ha (Table 2). None was found in Douglas County. The survey information is estimated to be 90 percent complete except for Benton (10%), Grant (80%), and Yakima (50%) counties.

Spotted knapweed ranked third of the four species with only 4 percent of the total area infested by the four species. Ninety-two percent of the spotted knapweed was found in Spokane, Stevens, and Pend Oreille counties (Figure 3).

Seventeen percent of the spotted knapweed was reported on pasture, range, and timbered range (Table 3). Sixty-eight percent of the pasture-range-timbered range total was pasture. Spotted knapweed was a common pasture weed in Spokane and Pend Oreille counties and occurred in dryland alfalfa in Stevens, Pend Oreille, Kittitas, and Spokane counties. Approximately 2 percent of the spotted knapweed was reported on abandoned cropland. This figure includes areas that are listed in Table 3 under other land uses such as pasture, idle land, or edge of crop, for which the surveyors indicated on the card were also abandoned cropland.

All counties reporting spotted knapweed found it along roadsides and railroads, 724 ha or 7 percent of the total. Counties with low levels of spotted knapweed found it almost exclusively on roadsides and in urban areas. For example, it was reported in Chelan County only along Highway 2 near Stevens Pass, along a powerline access road south of Wenatchee, and in Leavenworth.

Thirty-nine percent (4,253 ha) grew on industrial sites. The single largest infested industrial area was in the Spokane Valley. The acreage

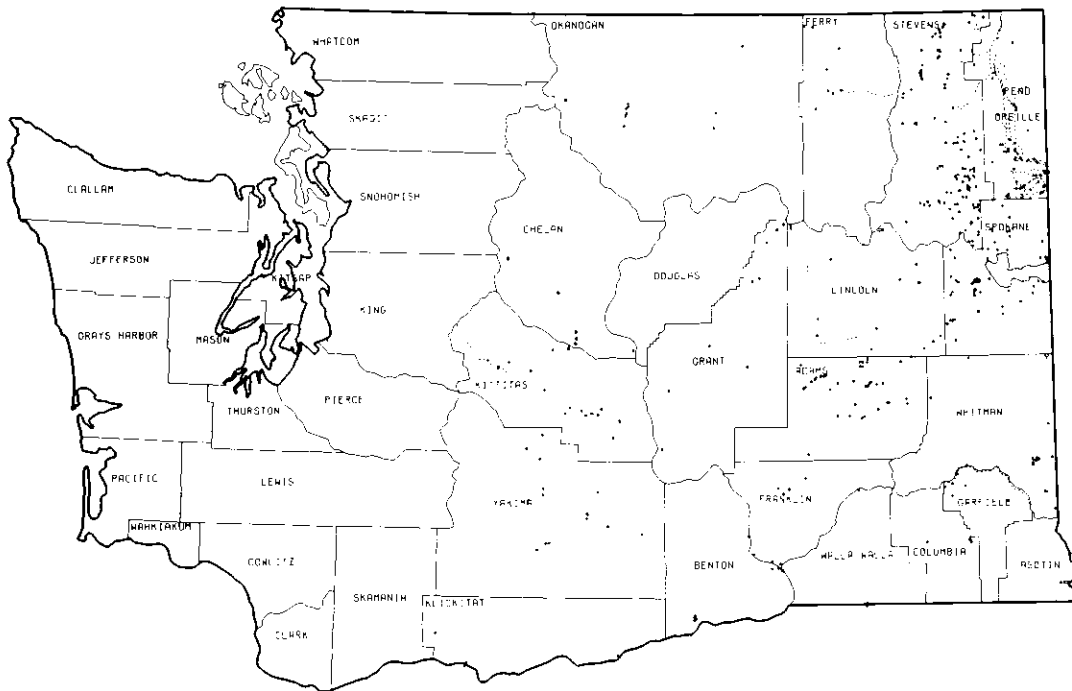


Figure 3. Distribution of spotted knapweed in eastern Washington. Symbols as in Figure 1.

listed as industrial sites included gravel pits and stockpiles, power lines, grain elevators, railroad, and equipment yards. These are strategic seed distribution points because of the volume of traffic and movement of materials which can carry seeds to new locations.

Ninety-three percent of the spotted knapweed was reported as dominance ratings 3 and 4 (Table 4). Many of the spotted knapweed sites were reported as scattered plants (dominance ratings 1 and 2). Although low in dominance as well as total acreage, their relative importance should not be underestimated. The potential rate of expansion of many widely scattered small infestations is greater than for the same size infestation in a single location.

Russian Knapweed

The total area reported for Russian knapweed was 3,259 ha (Table 2). Only Pend Oreille County had no Russian knapweed. The survey was incomplete for Adams (80%), Benton (20%), Grant (60%), Okanogan (50%), and Yakima (60%) counties. Because Russian knapweed generally

grows as small dense patches and does not spread rapidly, it has often been overlooked, especially on non-cropland. Russian knapweed was widely scattered, but most was found in the Columbia Basin and in the Okanogan and Yakima valleys (Figure 4). Fifty-seven percent of the area reported was in Okanogan, Yakima, and Adams counties (Table 2).

Russian knapweed has spread along railroads and, less commonly, roadsides. Thirteen counties reported this weed on rights-of-way for a combined 339 ha, 1 percent of the total. Movement along roadsides has been less important for Russian knapweed than for the other knapweeds because of lower production of viable seed and because the seeds are held in a cup-shaped head and lose their plume upon maturity (Watson 1980). Fewer seeds are caught on passing vehicles, either as individuals like spotted knapweed and yellow starthistle or as intact stalks like diffuse knapweed. Larger quantities of seed are needed to establish a new infestation when seed viability rates are low.

The amount reported on cropland (510 ha) was 16 percent of the total. Many infestations

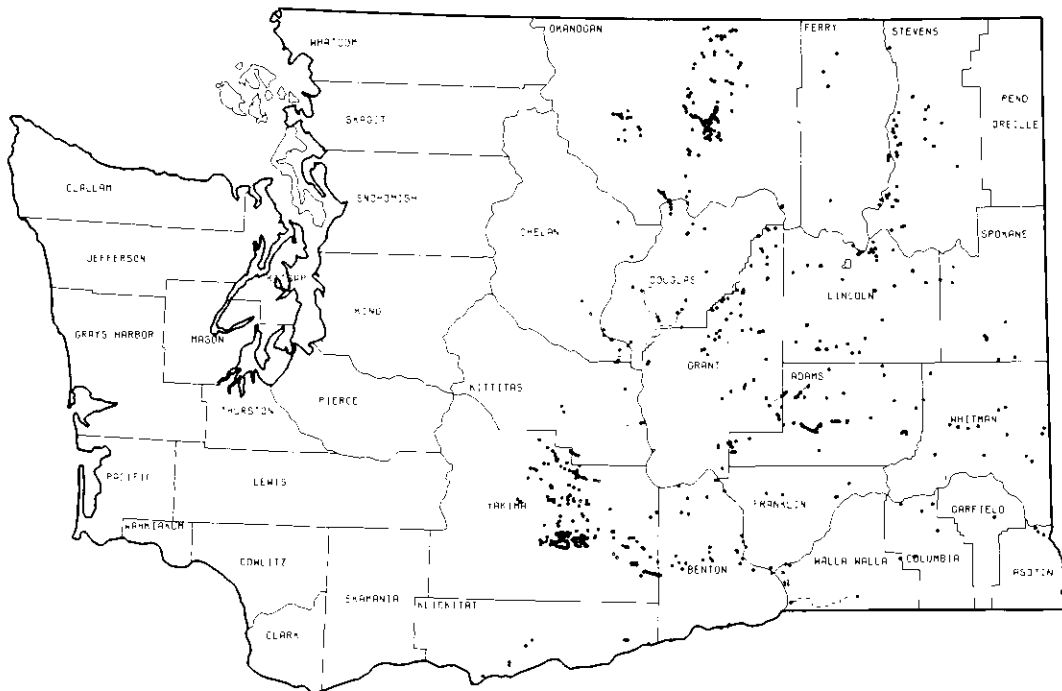


Figure 4. Distribution of Russian knapweed in eastern Washington. Symbols as in Figure 1.

were caused by contaminated crop seed, usually alfalfa or sugar beet seed (Noxious Weed Control Task Force 1952, Robbins *et al.* 1951).

Forty-seven percent of the Russian knapweed was reported on range and pasture (Table 3). Much of the pasture was irrigated or bottomland. Russian knapweed tolerates poor drainage, heavy soils, and saline/alkaline conditions (Watson 1980).

Russian knapweed shoots, except seedlings, develop from stem buds on horizontal roots. Under favorable conditions Russian knapweed forms dense stands that crowd out other vegetation. It is not surprising then, that 83 percent was reported as dominance ratings 4 and 5 (Table 4).

Conclusions

Attempts to control knapweed species have led to large expenditures of private and public funds. At times, these costs have exceeded the productive potential of the land. Money spent in control programs should be offset by reductions in losses or potential losses.

Losses in forage production in eastern Washington are estimated here by multiplying the infested area (Table 5) by production per unit area, a utilization factor, and a forage reduction factor based on dominance rating of the weed (Table 1). In the computation we assumed 50 percent utilization and average annual forage production for good condition pasture at 5,625 kg/ha (5,000 lb/ac), for good condition rangeland at 1,125 kg/ha (1,000 lb/ac), and for good condition timbered range at 1,462 kg/ha (1,300 lb/ac). This average annual forage production was estimated for representative range sites, habitat types and soil series where the weeds were found (Talbot 1987) by consulting tables and descriptions in soil survey reports (Beieler 1975, 1981; Donaldson 1980; Donaldson *et al.* 1982; Donaldson and Giese 1968; Harrison *et al.* 1964; Lenfesty 1980; Zulauf and Star 1979) and productivity estimates for plant associations in Steppe Vegetation of Washington (Daubenmire 1970). The knapweed species were uncommon on coarse textured, excessively drained range sites and shallow range sites (Talbot 1987), so the estimates are based on normal production for loamy range sites.

TABLE 5. Species by dominance rating on pasture and rangeland, in hectares.

	1	2	3	4	5
Pasture					
Diffuse knapweed	948	335	2,821	3,107	2,519
Yellow starthistle	40	19	521	370	8
Spotted knapweed	0	50	107	937	119
Russian knapweed	1	5	42	105	194
Pasture total	989	409	3,491	4,519	2,840
Range					
Diffuse knapweed	21,160	15,877	11,863	18,895	12,480
Yellow starthistle	1,710	10,689	10,006	19,930	2,272
Spotted knapweed	22	88	43	112	133
Russian knapweed	2	15	221	508	458
Range total	22,894	26,669	22,133	39,445	15,343
Timbered Range					
Diffuse knapweed	13,540	7,950	14,280	10,306	2,130
Yellow starthistle	0	19	56	4	0
Spotted knapweed	0	4	55	117	8
Russian knapweed	0	0	0	0	1
Timbered range total	13,540	7,973	14,391	10,427	2,139

On pasture, the annual loss in forage production due to the four knapweeds species is 19,288,523 kg (42,434,750 lbs), the equivalent of 21,217 tons of hay or 42,435 AUMs.³ Comparable values for rangeland are 28,577,591 kg (62,870,700 lbs); 31,435 tons of hay or 62,870 AUMs and for timbered range, 11,324,426 kg (24,913,737 lbs); 12,457 tons of hay or 24,914 AUMs. Using a value of \$45 per ton for hay fed as replacement forage (Doug Warnock, Kittitas County Extension Chairman, pers. comm.), the estimated annual additional cost due to knapweed is \$2.9 million. Using a value of \$10 per AUM on pasture (Doug Warnock, pers. comm.) and \$6 per AUM on rangeland (Eric Anderson, Range Conservationist, Yakima Firing Center, pers. comm.), the estimated annual loss is \$951,000.

The results of the survey and subsequent mapping can be used to design weed control strategies. Distribution and relative dominance suggests practical levels of effort ranging from

³Animal Unit Month, the forage requirements of one cow or five sheep, for one month, here defined as 1,000 lbs of air dry forage.

containment to eradication. Data of the type reported can provide the basis for understanding and cooperation among the several interest groups.

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Survey cooperators in each county are listed as follows:

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- Grant County
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 Edd Bracken and Ken Kilgore, Wash. State Dept. of Wildlife
 Larry Charlton and Gary Berndt, Wash. State Dept. of Natural Resources
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