

## SECTION 4 Weed Management Concepts

ECOLOGICAL AND ECONOMIC IMPACTS OF NOXIOUS WEEDS

INTEGRATED WEED MANAGEMENT STRATEGIES

**T**his section provides an overview of general concepts in weed management methods and issues. Impacts of exotic species on species diversity, wildlife habitat, natural resources, and economics are discussed.

Weed management strategies are outlined beginning with planning, inventory, and monitoring methods, and followed by integrated management strategies including prevention, mechanical, biological, chemical, and cultural control methods. This section only provides an introduction to these concepts. More information can be found in other sections of this handbook or separate documents and publications.

## 4.1 Ecological and Economic Impacts of Noxious Weeds

Celestine Duncan, Weed Management Services

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*Summary*

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### Exotic Plant Impacts on Species Diversity and Native Plant Habitat

- The introduction and spread of non-native plants threaten biological diversity of native plant communities and can alter ecosystem processes such as intensity and frequency of fire, hydrologic cycles, and soil erosion rates.
- Invasion of cheat grass (downy brome) in the Intermountain West has increased the frequency of fires from once every 60 to 110 years to once every 3 to 5 years. This has changed plant diversity by reducing native shrub communities.
- Native species have been displaced by invasions of spotted knapweed and leafy spurge. As weed infestations increase, the abundance and diversity of native species decline.
- Native plant communities in Glacier National Park, Theodore Roosevelt National Park, the Bob Marshall Wilderness, and Rocky Mountain National Park are threatened by weed invasion.
- Altamont Prairie Preserve in South Dakota is no longer managed as native prairie by The Nature Conservancy because of invasion by leafy spurge. The site is now used to study the effectiveness of grazing animals (goats and sheep) for controlling leafy spurge and prairie restoration.
- Wetland vegetation is endangered by purple loosestrife invasions. The displacement of native vegetation by this weed has caused serious reductions in waterfowl and aquatic furbearer productivity as breeding habitats are degraded.
- The status of rare and threatened plants such as bulrush, dwarf spikerush, bog turtle, Sacramento thistle, sapphire rockcress, and Colorado butterfly plant are further imperiled by weed invasions.

### Noxious Weed Impacts on Wildlife Habitat Quality

- The introduction of exotic plants impacts wildlife by reducing forage, modifying habitat (i.e. replacing a grass community with forbs), or changing how a species interacts within the environment.

- Bison and deer use of habitat infested with leafy spurge was 82% and 70% lower respectively than for non-infested habitat. This causes animals to use non-infested areas more heavily intensifying stress on these sites and increasing their susceptibility to invasion by non-native species.
- The use of herbicides to remove spotted knapweed from an elk winter range in Montana changed elk distribution patterns resulting in a 266% increase in elk use. This change in elk distribution reduced grazing pressure on adjoining private lands.
- Spotted knapweed invasion of bunchgrass sites in western Montana reduces available winter forage for elk by as much as 50% to 90%. Since a highly productive foothills site in western Montana can produce an average of 1,800 pounds per acre, forage (grass) loss from spotted knapweed can be as high as 1,620 pounds per acre.
- Purple loosestrife invasion of wetland sites degrades habitat for aquatic furbearing animals and waterfowl species. Degradation to these habitats from exotic species is of special concern because of the additional loss of wetland from urban, agricultural, and industrial uses.
- Displacement of native vegetation by exotic species significantly changes bird species composition and small mammal populations.

## Noxious Weed Impacts on Soil and Water Resources

- Salt cedar invasion can lower water tables influencing native plant habitat, and can alter stream flow cycles.
- The displacement of native bunchgrasses by spotted knapweed substantially increases surface water run-off and sediment yield (soil loss). For example, an additional 18 tons of soil would be lost from a 500 acre spotted knapweed infested rangeland in western Montana during an average 30 minute rainfall event, compared to a similar site with native bunchgrass.

## Economic Impacts of Noxious Weeds

- Noxious weeds have a substantial economic impact on state economies and may cause potential job losses. However, the economic impact of most noxious weeds is not well documented.
- Economic impacts of leafy spurge in Montana, North Dakota, South Dakota, and Wyoming total \$129.5 million annually, and represent the potential loss of 1,433 jobs.
- Economic impacts of knapweed infestations on grazing land and wildland in Montana are about \$42 million annually, which could support 518 full-time jobs.

- If knapweed infested all lands highly susceptible to invasion in Montana (34 million acres), the economic loss to the state would be \$155 million.

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*Introduction*

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Invasions by non-native plants degrade biological communities and threaten survival of native species world wide. These plants, commonly known as “weeds” or “exotic species”, use water, nutrients, and sunlight that would normally be utilized by native species, thus altering communities and ecosystems (Herbold and Moyle, 1986; Randall, 1995). Dewey and Torell (1991) defined a weed as any plant that interferes with the management objectives for a given area of land (or body of water) at a given point in time. Once a plant has been classified as a weed, it attains a “noxious” status only by legislation. Noxious weeds, as defined by Montana state law, are, “...exotic plant species established or that may be introduced in the state which may render land unfit for agriculture, forestry, livestock, wildlife, or other beneficial uses or that may harm native plant communities and that is designated”. More than 500 weeds are designated as noxious by either weed or seed laws in the United States and Canada (Lorenz and Dewey, 1988).

Most weeds are not native to the areas in which they are a problem. In a survey conducted on Nature Conservancy managed lands, 237 plants were listed as problem species. Of these, 197 were not native to the area in which they were troublesome (Randall, 1995). Most weeds were either introduced for their perceived value to man, or unintentionally as contaminants in feed and seed products. The invasiveness of weeds is due to their genetic make-up which enables them to exploit a resource “niche”, and the lack of natural enemies such as insects, diseases, and pathogens (Story, 1992).

The spread of noxious weeds has been considered analogous with a biological wildfire. As with wildfire management, a variety of treatments or techniques are available for management of weeds. These include prevention, early detection, timely control (biological, physical, chemical, or cultural), and site rehabilitation (Dewey et.al., 1995). The selection of respective control methods is influenced by land management objectives; effectiveness of the control technique on the target species; environmental factors; land use; economics; and the size of weed infestations (Lacey, C. 1991). An integrated weed management (IWM) approach that gives equal consideration of all management tools, including herbicides, is critical for managing extensive weed infestations.

Land managers involved with controlling weeds on public lands must be able to discuss weed management issues and concerns with the public. This includes information on the importance of managing non-native species, management techniques, and an assessment of health and environmental information associated with various methods. The purpose of this section of the guide is to review current literature on: (1) impacts of exotic plants; (2) response of plant communities to weed invasion and herbicide treatments; and (3) case histories of successful weed control programs. Although invasions of exotic plant species occur worldwide, this review is limited to problem species in the western United States.

### 4.1.1 Impact of Exotic Plant Species on the Ecosystem

#### SPECIES DIVERSITY AND NATIVE PLANT HABITATS

The introduction and spread of non-native plants threaten biological diversity of native plant communities and can alter ecosystem processes. For example, annual plants introduced into California grasslands have replaced native bunchgrasses, and downy brome (*Bromus tectorum* L.) has altered ecosystem process and changed structure and function of plant communities in the Intermountain West (Mack, 1981; Randall, 1996). Downy brome invasion has increased the frequency of fires from once every 60 to 110 years to once every 3 to 5 years on millions of acres of rangeland in the Great Basin (Whisenant, S.G. 1990). The high frequency of fire has eliminated native shrub communities (Randall, 1996).

Many weeds out-compete native species, change community structure, degrade or eliminate habitat for native animals, or provide food and cover for undesirable non-native animals (Kurz, 1995; Randall, 1996). Spotted knapweed (*Centaurea maculosa* Lam.) and diffuse knapweed (*Centaurea diffusa*) are recognized as serious invaders in the western U.S., infesting over 10 million acres in nine western states and two Canadian provinces (Lacey, C. 1989). Invasion of spotted and diffuse knapweed into undisturbed native bunchgrass communities is well documented (Myers and Berube, 1983; Tyser and Key, 1988; Bedunah and Carpenter, 1989; Lacey, et.al., 1990). As spotted knapweed increases, cover of more desirable but less competitive grasses and forbs is significantly reduced, sometimes as much as 60 to 90 percent (Harris and Cranston, 1979; Bucher, 1984). In Glacier National Park, spotted knapweed reduced species richness (Figure 1) and the frequency of six native species during a three year period. In addition, seven species classified as “rare” and “uncommon” at the beginning of the study were not present three years later. These results suggested that spotted knapweed was capable of spreading into natural fescue grasslands and altering plant community composition (Tyser and Key, 1988).

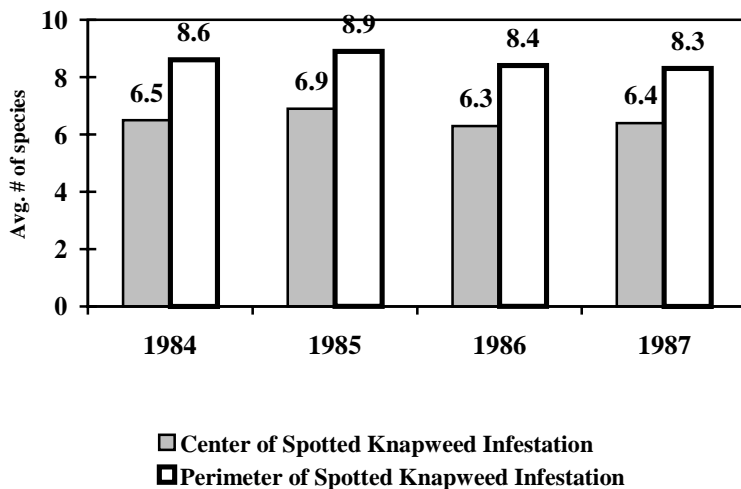


Figure 1: Average number of species, excluding spotted knapweed and *Carex* spp., per square foot within, and adjacent to, a knapweed infestation in Glacier National Park.

#### 4.1.1 | SECTION 4 WEED MANAGEMENT CONCEPTS

Cryptogamic ground crust may also be impacted by spotted knapweed. This crust, which is composed of small lichens and mosses and commonly covers undisturbed soil surfaces, is important for soil stabilization, moisture retention, and nitrogen fixation (Rychert and Skujins, 1974, Anderson et. al., 1982). Tyser (1992) compared a native fescue grassland site to one invaded by spotted knapweed in Glacier National Park. Results of the study indicated that the cryptogam ground cover within the spotted knapweed infested site was 96% less than the native fescue grassland site.

Leafy spurge (*Euphorbia esula* L.) infests about 2.7 million acres, mainly in the Northern Great Plains and prairie provinces of Canada (Lajeunesse et. al., 1995). The relationship between leafy spurge and the species composition of mixed-grass prairie was studied near Manitoba, Canada. Within a single infestation of leafy spurge, the frequency of 5 common native species decreased significantly. Most native species were absent where leafy spurge was most abundant, and species richness declined from 11 species outside the infestation to 3 species at the center. Leafy spurge poses a considerable threat to the conservation of native plant communities and to the economic use of prairie for rangeland (Lajeunesse et. al. 1995, Belcher and Wilson, 1989; Lym and Messersmith, 1985).

Other noxious weeds such as yellow starthistle (*Centaurea solstitialis*), sulfur cinquefoil (*Potentilla recta*), and Dyers woad (*Isatis tinctoria* L.) have been found to reduce establishment and growth of more desirable species (Evans and Chase, 1981; Rice et.al., 1994; Callihan et al, 1989). Yellow starthistle is especially troublesome because it aggressively colonizes a variety of sites, and is responsible for a neurological disorder called “chewing disease” in horses (Kingsbury, J.M. 1964). In California, acreage infested by the weed increased from 1.2 million acres in 1958 to 7.9 million acres in 1985 (Maddox et. al. 1986). Yellow starthistle is also a serious problem in Oregon, Washington, and Idaho where 1.2 million acres were reported infested in 1988 (Lacey C., 1989).

Noxious weeds are recognized as serious problems on lands managed for wilderness or wildland values by federal, state, and private entities. When weeds invade and expand into a wilderness environment, the “naturalness” of the area is degraded and scientific values of once biologically diverse landscapes are impaired (Asher and Harmon, 1995). Examples of weed invasion in natural areas are found in most states. The Nature Conservancy (TNC) reported weed problems on preserves in 46 states, and 13% of managers surveyed listed weeds as their number one management problem (Randall, 1995). Leafy spurge infestations occur at Pine Butte Swamp Preserve along the Rocky Mountain front in Montana, and in other preserves of the Plains of western Minnesota and eastern Dakotas. TNC’s Altamont Prairie in South Dakota is so badly infested with leafy spurge that it is no longer regarded worth managing as native prairie and cannot be sold as cropland. Instead, the site is now being used to test the efficacy of sheep and goats for leafy spurge control and prairie restoration (Randall, 1996). Leafy spurge has also successfully established and is increasing its range in rough fescue communities of Glacier National Park and has invaded the remote Danaher Creek area of the Bob Marshall Wilderness (Bedunah, 1992). Infestations of leafy spurge are also present in Theodore Roosevelt National Park in North Dakota (Andrascik, R.J. 1994) and spotted knapweed and Dalmatian toadflax (*Linaria dalmatica*) infest Yellowstone National Park. In Rocky Mountain National park, Canada thistle (*Cirsium*

*arvense*) has spread from horse and foot trails into native plant communities (Beck, pers. comm.).

Wetland sites are also susceptible to invasion by noxious weeds. Purple loosestrife (*Lythrum salicaria*) was introduced in northeastern North America by the early 1800's. By 1940 it was established in the Pacific Northwest and had spread into the Great Plains (Thompson et. al, 1987), and now infests all states north of the 35th parallel, except Alaska. The weed forms dense infestations which displace native species including those that provide food and cover for many waterfowl and other wildlife (Thompson et. al., 1987).

Limited information is available on the impact of weeds on rare and threatened plants and animals. Dense infestations of purple loosestrife imperil endangered species, such as bulrush (*Scirpus longii*) in Massachusetts (Coddington and Field, 1978), dwarf spikerush (*Eleocharis parvula*) in New York (Rawinski, 1982), and the bog turtle (*Clemmys muhlenbergii*) in the northeastern U.S. (Thompson, 1987). Teazel (*Dipsacus sylvestris*) is interfering with growth and germination of the Sacramento thistle (*Cirsium vinaceum*), a federally-listed threatened species endemic to the Sacramento Mountains in New Mexico (Huenneke, Laura F., 1996). Sapphire rockcress (*Arabis fecunda*) is a candidate for listing as a threatened or endangered species by the U.S. Fish and Wildlife Service, and is listed as a threatened species in Montana (Lesica and Shelly, 1991). The plant is at risk because of livestock trampling and encroachment of habitat by spotted knapweed (Lesica, 1991). Sapphire rockcress is subjected to an increased risk of extinction since spotted knapweed reduces space available for seedling establishment (Lesica, 1991). The Colorado butterfly plant (*Gaura neomexicana*) is another candidate for listing as a threatened or endangered species. As a result of competition from Canada thistle, *Gaura* populations declined 40 to 50% from the mid-1980's to 1992 (Cheater 1992). Although populations of *Gaura* are currently increasing, it is suspected that establishment and survival of seedlings of this plant may be hindered by competition for light, water, and nutrients from noxious weeds (Fertig, 1996).

#### IMPACT ON WILDLIFE HABITAT QUALITY

The introduction of exotic plants influences wildlife by displacing forage species, modifying habitat structure- such as changing grassland to a forb-dominated community-, or changing species interactions within the ecosystem (Belcher and Wilson, 1989; Bedunah, 1992; Trammell and Butler, 1996). Use of leafy spurge infested and non-infested habitats by deer (*Odocoileus* spp.), elk (*Cervus elaphus*), and bison (*Bos bison*) were studied in Theodore Roosevelt National Park, ND during 1992 and 1993. Fecal pellet-group densities indicated that bison use of leafy spurge infested grassland habitats averaged 83% less than for noninfested sites. Deer pellet-group densities, normally highest within creeping juniper-little bluestem habitat, were reduced 70% by infestations of leafy spurge. Use of browse in green ash and chokecherry habitat during summer and winter was reduced an average of 32% by infestations of leafy spurge. Trammell and Butler (1996) concluded that the reduction in native ungulate use of leafy spurge-infested sites may be attributed to lower forage production in infested sites as well as simple avoidance.

Spotted knapweed also influences elk and deer foraging behavior and population distribution (Hakim, 1979). In western Montana, herbicides were used to remove spotted

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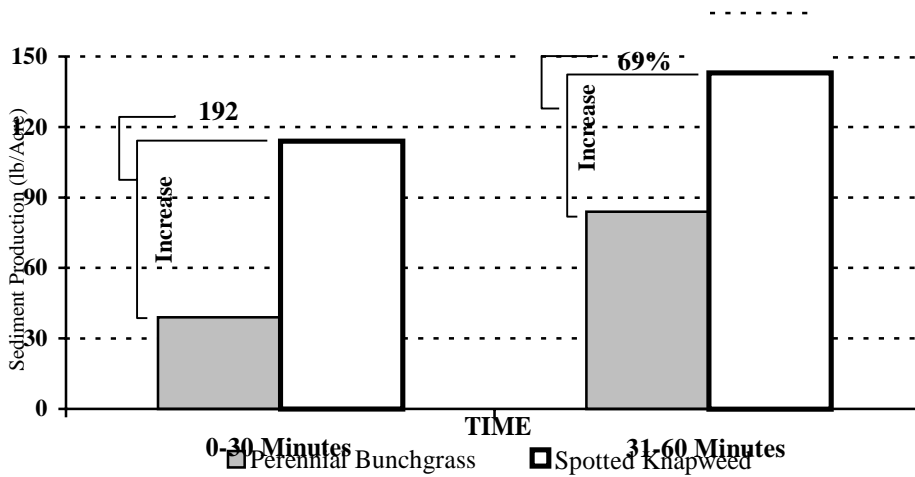
knapweed from a 272 acre winter range site on Three Mile Game Range. Subsequent elk foraging behavior (trend counts and feeding craters) on spotted knapweed infested and non-infested winter range was compared for 4 years (Thompson, 1996). Elk walked indiscriminately within knapweed infested and non-infested sites, but foraged almost exclusively in the grass stand where knapweed was removed. In addition, elk use increased an average of 266% after knapweed was removed from the site. Redistribution of a portion of the area elk population to the treated site may have benefited the entire herd by reducing competition for limited resources in other areas (Thompson, 1996). Spotted knapweed invasion of bunchgrass sites in western Montana results in a 200% to 300% decline in elk winter forage (Bedunah and Carpenter, 1989). Guenther (1989) found that although knapweed was common on a mule deer (*Odocoileus hemionus*) winter range in Montana, the plant was not detected in the deer's diet.

Small birds and mammals are also impacted by noxious weeds. Purple loosestrife reduces desirable waterfowl plants such as cattails (*Typha latifolia*) that are preferred habitats for muskrats and long-billed marsh wrens (Rawinski and Malecki, 1984). Waterfowl broods are also more susceptible to predation because dense stands of purple loosestrife reduce access from water to nesting sites. Wilson and Belcher (1989) reported that the introduction of Eurasian plants not only replaced the native plant community; it also significantly changed bird species composition. Small mammal populations have been reduced as Russian knapweed (*Centaurea repens* L.) displaces native species (Kurz, 1995).

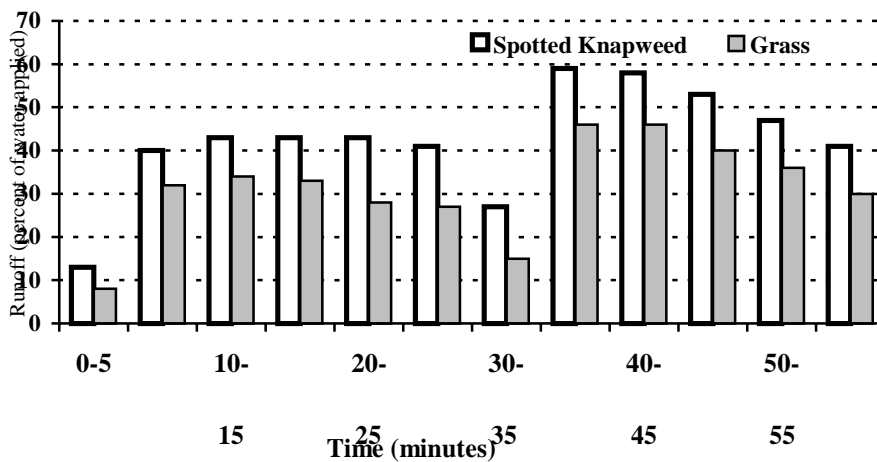
#### SOIL AND WATER RESOURCES

Exotic species that alter hydrologic cycles, sediment deposition, erosion, and other ecosystem processes can cause serious ecological damage (Vitousek, 1986). Salt cedars (*Tamarix chinensis* L.) which invade wetland and riparian areas in the Southwest U.S. are responsible for lowering water tables at some sites (Horton, 1977). This reduces or eliminates surface water habitats required by native plants. Salt cedar infestations also trap more sediments than stands of native vegetation, thus altering the shape, carrying capacity and flooding cycle of water courses (Blackburn, 1982).

Tap-rooted weed species can also increase erosion rates as they invade grasslands. The influence of spotted knapweed on surface runoff and sediment yield was determined under simulated rainfall conditions near Garrison, MT (Lacey et al, 1989). Surface water runoff and sediment yield (soil erosion) were measured during a 30 minute simulated rainfall event on 12 paired plots. One plot of each pair was in a bunchgrass community whereas the other was dominated by spotted knapweed. Runoff was 56% higher and sediment yield was 192% higher on spotted knapweed plots compared to bunchgrass plots during the initial 30 minute simulated rainfall period (Figure 2 and 3). The study concluded that spotted knapweed invasion onto bunchgrass rangelands of western Montana was detrimental to the protection of soil and water resources (Lacey et. al., 1989).



**Figure 2.** Sediment yield on grass-dominated and spotted knapweed dominated plots subjected to two consecutive simulated rainfall periods. The initial 30-minute period was on the unaltered site to measure the effect of vegetative cover plus soil surface characteristics. Vegetative cover was removed before the second 30-minute period to measure the effects of surface characteristics alone. (Lacey et. al. 1989)



**Figure 3.** Surface runoff from 12 grass-dominated and 12 spotted knapweed-dominated plots at various time intervals during two consecutive 30-minute simulated rainfall periods. Vegetation was clipped and removed from the plot after the first 30-minute rainfall period.

### 4.1.2 Economic Impact of Noxious Weeds

There is limited information on economic impacts of noxious weeds on range, pasture, and wildland sites. The most thorough study was conducted by economists at North Dakota State University (Leitch et. al., 1994). They reviewed economic losses caused by leafy spurge in the upper Great Plains including states of Montana, North and South Dakota, and Wyoming. Economic impacts caused by leafy spurge to ranchers and landowners include reduced income from lower grazing capacity, lost livestock sales, and reduced grazing land values as a result of infestations. In 1993, grazing capacity lost to leafy spurge infestations in the four state area would have supported a herd of about 90,000 cows, which could generate about \$37.1 million in annual livestock sales. The direct loss of \$37.1 million generated about \$82.6 million in secondary impacts to the regions economy. Total direct and secondary impacts were about \$119.7 million or about \$163 per lost animal unit month (AUM). In addition to impacts to grazing lands, the study also estimated impacts of leafy spurge on wildlands from changes in wildlife habitat and soil and water conservation benefits.

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Degradation of habitat was assumed to reduce wildlife related expenditures in each state (Figure 4). Nearly \$3.4 million in direct economic impacts result from slightly less than 1% infestation level of leafy spurge. Eliminating leafy spurge on wildlands could add 174 jobs and \$9.8 million in business activity in the four state area. The study concluded that direct and secondary economic impacts of leafy spurge infestations on grazing land and wildland in the four-state area are about \$129.5 million and represent the potential loss of 1,433 jobs.

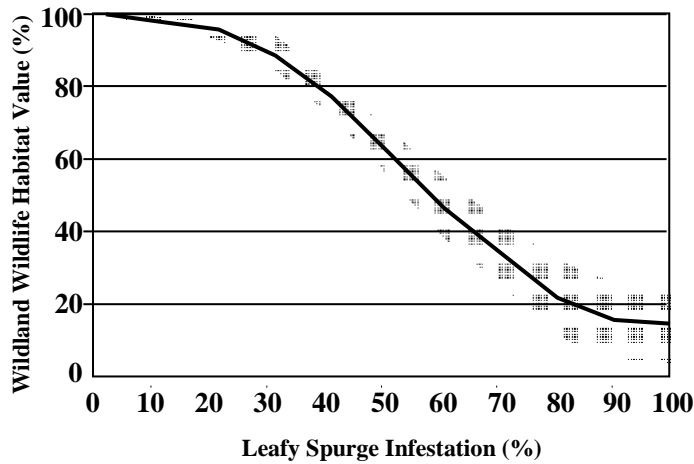


Figure 4. Estimates of reduced wildland wildlife habitat value caused by various leafy spurge infestations rates (Leitch et al., 1994). Shading along the function indicates uncertainty associated with the relationship.

A similar economic study was conducted on the impact of knapweed on Montana's economy (Hirsch and Leitch, 1996). Because cattle avoid grazing knapweed, the weed affects Montana's grazing industry, specifically ranchers, landowners, businesses supplying livestock products, and communities that rely on ranching as an economic base. Economic impact of the weed in Montana was estimated for an infestation level of 2 million acres for all knapweed species. Direct impact to the state's economy was calculated by adding the value of lost forage production (\$3.221 million) and reduced sales of livestock production inputs associated with herd reductions (\$7.804 million). Total direct impacts were \$11.025 million annually or \$10.73 per infested grazing land acre. The study also estimated impacts of knapweed on wildlands based on changes in wildlife habitat which would affect wildlife-associated recreation expenditures, and soil and water conservation benefits (Figure 5). Total direct impacts on Montana's economy from infested wildland are about \$3.093 million annually or \$3.95 per infested acre. The study concluded that direct and secondary economic impacts of knapweed infestations on grazing land and wildland in Montana are about \$42 million, which could support 518 full time jobs in the state's economy.

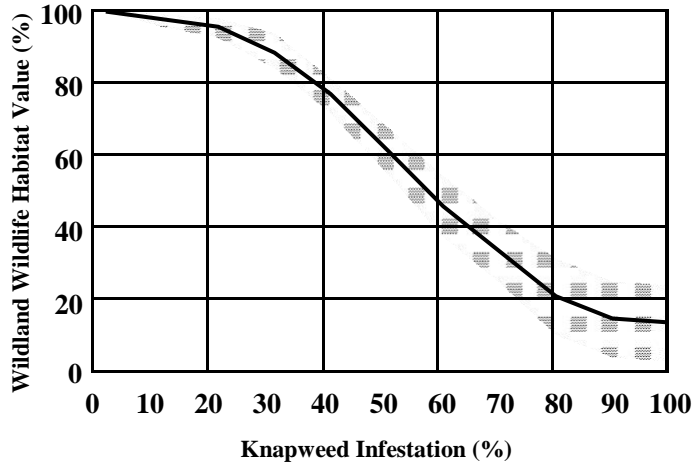


Figure 5. Estimates of reduced wildland wildlife habitat value caused by various knapweed infestations rates (Leitch et al., 1994). Shading along the function indicates uncertainty associated with the relationship

Another economic report in 1984 reviewed loss of range livestock income in Montana if all vulnerable lands in the state were infested with spotted knapweed. The report (Bucher, 1984) concluded that if spotted knapweed invaded 34 million acres of highly vulnerable lands (Chicoine, 1988), annual gross revenue of Montana's livestock industry would be reduced by \$155 million. Additional information and research is needed to understand the economic impact of noxious weed invasion in the western United States.

### 4.1.3 Summary

Noxious weeds are having a major impact on the ecology and economy of Western States. These weeds are a form of "biological pollution" because they can degrade native ecosystems by displacing native plant species, increase soil runoff and sediment yield, degrade wildlife habitat, and decrease forage for wildlife and livestock. A viable Integrated Weed Management Program is necessary to manage non-native plants, using available methods, including education, prevention, physical or mechanical practices, biological control agents, herbicides, and cultural practices for sustainable land management.

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## 4.2 Integrated Weed Management Strategies

Modified from Principles of Integrated Weed Management, by Barbara Mullin.

The goal of an effective weed management program is to replace undesirable plants that are causing loss—resource, economic, habitat, or aesthetic—with a plant or plants that are beneficial to the environment.

An integrated and coordinated approach to weed management should have two primary goals. First, development of a long-term plan that encompasses all land in a designated area, with all landowners and managers working together toward effective management. Second, implementation of the most economical and effective weed control methods for the target weed.

Integrated weed management (IWM) is a systems approach to management of undesirable plants. IWM is defined in the Federal Noxious Weed Act as “a system for the planning and implementation of a program, using an interdisciplinary approach, to select a method for containing or controlling an undesirable plant species or group of species using all available methods, including—education, prevention, physical or mechanical methods, biological control agents, herbicide methods, cultural methods, and a general land management practices.” It is a multidisciplinary, ecological approach to managing unwanted plant species—weeds.

### 4.2.1 Planning, Inventory, & Monitoring

Integrated weed management involves the use of the best control techniques described for the target weed species in a planned, coordinated program, to limit the impact and spread of the weed. The control methods selected should be determined by the control objectives for the land, the effectiveness of the control techniques in the target species, environmental factors, land use, economic, and the extent and nature of the weed infestation.

Factors that must be assessed prior to making a management decision include:

- Inventory and assessment to identify the target weed species and determine the size of infestation.
- Assessment of non-target vegetation in the management area.
- Determination of soil types, climatic conditions, and important water resources.
- Determination of the limitation of the control method chosen.

An accurate assessment of the target infestation will help determine the most appropriate control method or methods for the weed species. A small patch of leafy spurge could be

economically and easily controlled with a residual herbicide application and continued vigilance of the landowner. A large, dense infestation of leafy spurge may require establishment of a grazing program or biocontrol agent, combined with a herbicide containment program. All control options have some limitations. If complete eradication of a weed is necessary, biocontrol agents would not be a good choice. If soils preclude use of a herbicide, mechanical or biological may be the next choice.

In order to appraise the performance and progress of your weed management activities, systematic monitoring and evaluation should be incorporated into your weed management plan.

More detailed guidelines on planning, inventory and monitoring are provided in Section 5 (Weed Inventory Techniques), and 10 (Planning).

#### 4.2.2 Prevention & Education

Preventing the spread of the weed by seed or vegetative propagules should be the first line of defense in developing a weed management program. There are many potential weed threats to lands and land managers need to be aware of the threat, identify unknown species and implement effective controls immediately.

Quarantines and embargoes can be effective in isolating and preventing the spread of weeds into new areas. Weed-seed-free forage programs and certification programs for agronomic crops are designed to stop movement of new species into areas where they are not currently found. A program of this type is especially well suited for protection of wilderness areas, where other control methods may be difficult to initiate if the weed becomes established.

State seed laws are enacted to insure the purity of seed for planting, thus preventing the spread of weeds. State of Montana seed laws prohibit the sale and use of purple loosestrife (purple lythrum) a commonly used ornamental that has escaped into many wetland areas.

Preventing the introduction of weed seed and plant parts into non-infested sites is an important part of any weed plan. Prevention is always recognized as the most practical and cost-effective method of weed control at tours and during other educational programs. Preventive measures include minimizing soil disturbance, restricting off-road vehicles, warning against the transport of weed-contaminated seed and feed, advising that machinery and equipment be cleaned before they are moved from weed-contaminated areas, and not allowing newly established weeds to set seed.

Early detection and treatment of weeds, and an overall effective preventive weed management program is dependent on education. Public education programs, such as tours, workshops, meetings, radio and television announcements, youth programs, etc., are useful for preventing the spread of noxious weeds. Publications and computer programs are available that give excellent information and color plates of important weed species in the West.

On going education of weed district and federal agency personnel and private landowners on weed identification, new weed management techniques and proper use of control techniques available is an important part of a weed program. This includes yearly training seminars for land managers and support of the state pesticide applicator certification programs.

Educational efforts targeting the general public emphasize what weeds are of concern and why they are a threat. These programs have included development of brochures to show hunters what spotted knapweed looks like in the fall, so they can report new infestations; a Ned an Nellie Knapweed coloring book highlights the damage knapweed can do; bumper stickers, radio announcements and tours of areas with serious weed problems all emphasize the importance of noxious weeds to the land.

### 4.2.3 Physical or Mechanical Weed Management

The use of physical methods to eliminate weeds can be effective on small infestations. Handpulling, hoeing, tilling, mulches, burning and mowing are all commonly used methods. Physical/mechanical methods are labor intensive for perennial, deep-rooted noxious weeds, making them expensive treatments that are often not effective.

Handpulling and hoeing are most effective in areas where there is a limited weed infestation and soil types allow for complete removal of plant material. Spotted knapweed has been effectively pulled in areas of loose soil near water, where other methods were unacceptable and the infestation was small. It is not recommended in high-density infestation where there is not native vegetation to replace the pulled plants.

Tilling is generally limited to cropland situations. Canada thistle has been effectively controlled when tilled every 21 days over several growing seasons. Some rhizomatous noxious weeds, such as leafy spurge, are not effectively controlled by tillage and in fact may be spread.

Mulches block sunlight to germinating seedlings, and can be effective against many annual weeds. However, mulches only allow better competition when the target weed is a perennial plant.

Burning has been shown to be an effective set-up treatment for herbicide applications by removing old stand vegetation that would tie-up herbicides as they are applied. Burning should be timed properly to minimize damage to non-target species.

Mowing reduces seed production in some plants. It is most effective on annual and biennial plants. Timing and frequency of mowing varies with each species. It has been shown that mowing can increase seed production in diffuse knapweed, while spotted knapweed can show a seed decrease when mowed in the flowering stage.

Although mechanical treatments are commonly used to control some weeds on cropland, success varies with the timing and frequency of the treatment, and the species of weed. It is

practically impossible to eliminate leafy spurge, or similar species that have an extensive root system and the capability of sprouting new shoots from numerous buds on lateral roots.

#### 4.2.4 Biological Weed Management

Biological control attempts to recreate a balance of plant species with predators. Since many noxious weeds that are of the most serious concern in rangeland are exotic species, they have few established natural predators. Research focuses on introduction of natural predators from the weed's area of origin on to local plant populations. Biological control involves the use of living organisms, such as insects, mites, nematodes, pathogens or grazing animals, to control a weed infestation.

Leafy spurge currently has several insect species cleared for release in the United States. A number of other species are currently undergoing host specificity testing and additional research. Flea beetles (*Aphthona spp.*) seem to be showing the most promise at this time.

Two gallflies, a root moth, and a root weevil have established effectively on spotted knapweed in western Montana and show some stand reduction. Several additional insects are in the experimental stages and researchers expect that it will take a number of different insects, attacking various parts of the plant before stand reductions will take place.

Research on plant pathogens includes limiting the host range of a commonly found *Sclerotinia* fungus to attack close relatives to the knapweed species; determining the pathogenicity of soil borne fungi that have shown some impact on leafy spurge in the field, and screening of weeds in their native areas for potential pathogens.

Grazing animals have been used to decrease the density of leafy spurge and limit spread by reducing seed production. Grazing must be timed to have the greatest impact on the weed. Sheep and cattle have been managed under intensive grazing systems to utilize spotted knapweed. In Stillwater County, goats have been used in fishing access sites to stop seed production of leafy spurge and were effective in reducing infestations of certain biennial weeds, such as houndstongue. Predators may limit the use of grazing animals in some areas.

Section 9 (Biological Weed Management) provides more detailed information in biocontrol agents, methods for obtaining and releasing agents, and monitoring biocontrol sites.

#### 4.2.5 Chemical Weed Management

Herbicides are important tools for controlling noxious weeds. It is important to understand the affects and limitations of those used for control of noxious weeds. Herbicides are categorized as selective or non-selective. Selective herbicides kill a specific type of plant; for example, 2,4-D kills only broadleaf plants. Herbicides are also selective based on the rate used. Spotted knapweed generally is controlled using lower rates than leafy spurge, thus causing less potential impact on non-target broadleaf species.

The most commonly used herbicides on noxious weeds are 2,4-D (various brands), picloram (Tordon), dicamba (Banvel), clopyralid (Transline, Stinger), and glyphosate (Roundup, Rodeo). With the exception of glyphosate, they are all auxin-type compounds that are selective for broadleaf plants, making them effective tools for controlling noxious weeds while maintaining valuable grass species.

Herbicides are applied several ways depending on the objectives and economic and environmental constraints. Truck or ATV-mounted spray equipment (with a boom, single broadjet, or hand-held pressure nozzles), or backpack sprayers are usually used. Aerial application is also used on large scale infestations where environmental concerns are less of a risk.

Application rates, measured in pounds of active ingredient (AI) per acre, vary for each herbicide or combination of herbicides depending on the target species, management objective, and environmental conditions. To assure proper application, all guidelines and label restrictions must be carefully followed. Use of many herbicides is restricted near surface water, areas with coarse textured soils and high water tables, under certain wind, temperature, and soil moisture conditions, and during some stages of plant growth.

Additional information regarding these herbicides is included in Section 7 (Herbicides in the Environment / Safety and Handling) and 8 (Chemical Weed Management).

#### 4.2.6 Cultural Weed Management

Cultural methods of weed control that enhance the growth of desired vegetation may help slow invasion onto a site. The use of plant competition, smother crops, crop rotation and allelopathy are methods often most suited to cropland agriculture. When dealing with noxious weeds, it is important to maintain the native or desirable vegetation in a healthy condition to allow adequate competition once the weeds have been controlled.

In some forest sites, improving brush and tree canopy cover can reduce spotted knapweed density and slow invasion. Fertilization and reseeding with competitive, adapted species may be necessary in some areas.

#### 4.2.7 Land Management

Follow-up management is especially important on range and pasture lands. It determines the longevity of control obtained by the methods used. Because noxious weeds have persistent growth characteristics and seeds can remain viable in the soil for years, long-term control programs must be implemented.

Long-term management includes retreatment with herbicides or continued cultural, mechanical or biological control practices to maintain low weed populations. Range improvements, such as grazing systems, cross fencing, and water development, will help retard reinvasion of many weed species. Sites with no desirable species should be reseeded to a competitive plant species as a part of the total management program.

## 4.2.8 Conclusion

Integrated weed management practices will work when land managers understand all of the methods available for use; evaluate the site and choices for restrictions; implement the management plan and then implement follow-up management in the area to prevent reinvasion.

A systems approach to weed management, with increased emphasis on managing the land for beneficial species and specific controls targeting unwanted vegetation, is the ultimate goal of an integrated weed management plan.