Fire ecology and management of spotted knapweed, diffuse knapweed, and yellow starthistle

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Spotted knapweed (*Centaurea stoebe* subsp. *micranthos*), diffuse knapweed (*C. diffusa*), and yellow starthistle (*C. solstitialis*) are nonnative, invasive forbs that can displace native plants, reduce native plant diversity, reduce native wildlife habitat and forage, and alter soil physical and chemical properties. They are also a threat to rangelands, causing substantial economic losses due to reductions in livestock forage and production. All three *Centaurea* species can establish and spread after fire, but fire is sometimes used to control them. To better understand the species' relationships with fire, writers for the Fire Effects Information System (FEIS, www.feis-crs.org/feis/) reviewed thousands of publications and synthesized their findings into Species Reviews published in FEIS. This research brief summarizes the fire effects information from the FEIS Species Reviews regarding the biology and ecology of these species, how fire affects them, and how they respond to fire.

Key Management Findings

- **These species are especially invasive after disturbance.**
- **Successful control requires preventing seed production, depleting the soil seed bank, and establishing and maintaining desired vegetation.**
- **Prescribed fire can reduce seed production and deplete the soil seed bank in the short term, but frequent fires (or other follow-up treatments) are needed to reduce seed production and seedling establishment in the long term.**
- **If prescribed fire is used to reduce *Centaurea* spp. populations, it may be most effective when used in combination with other control methods, such as herbicide or hand pulling.**
- **Seeding may be necessary after fire in areas where desirable plant populations are depleted.**
- **Fire effects vary by plant community, site characteristics, and fire characteristics, so site-specific management is recommended.**
- **Data are lacking on many aspects of the fire ecology of these species, especially for diffuse knapweed. Long-term studies are needed.**

Fire Ecology and Management Summary

The three *Centaurea* species differ in life expectancy and regeneration characteristics. Spotted knapweed is typically perennial or biennial, diffuse knapweed is typically biennial, and yellow starthistle is typically annual. All three *Centaurea* spp. produce abundant seeds, and regenerate almost entirely from seeds. All can resprout after top-kill, and spotted knapweed plants are also able to extend lateral shoots below the soil surface that form rosettes adjacent to parent plants. Seedlings of all three *Centaurea* spp. establish after disturbances that reduce vegetation, increase sunlight to the soil surface, and increase bare soil, such as fire. After fire, they can establish either from undamaged seeds in the soil, from seeds dispersed from off-site sources, or from resprouting plants. Postfire abundance varies depending on plant community, site characteristics, and fire severity, frequency, and timing.

Wildfire

Seedlings of spotted knapweed, diffuse knapweed, and yellow starthistle can establish quickly after wildfire. Postfire establishment may be limited by:

- Minimizing the use of fire retardants.
- Minimizing soil disturbance and vegetation removal during fire suppression and rehabilitation activities.
- Minimizing seed dispersal onto burned areas by vehicles and livestock.
- Detecting plants early and eradicating them before seed dispersal.
- Reestablishing desired vegetation on bare ground as soon as possible.

Prescribed Fire

All three *Centaurea* species regenerate primarily from seed, so their control requires preventing seed production and depleting the soil seed bank. Prescribed fire can accomplish this in the short term, but frequent fires (or other follow-up treatments) are needed to reduce seed production and seedling establishment in the long term. Seeding with natives may be necessary after fire in areas where desirable plant populations are depleted. Prescribed fire may be most effective at reducing *Centaurea* species populations when used in combination with other control methods, such as herbicides or hand pulling.

Spotted Knapweed

Fire has mixed effects on spotted knapweed, depending on fire characteristics, life stage at the time of burning, and plant community. High-severity fire can kill spotted knapweed plants by damaging the root crown, but plants are likely to survive low- and moderate-severity fire. Seedlings tend to be most sensitive to fire during spring, whereas adult plants are less sensitive to season of fire. If fire occurs prior to bolting, spotted knapweed plants are likely to resprout and produce flowering stems in the same growing season.

Spotted knapweed has a persistent soil seed bank and seeds are viable in soil for at least 8 years. Fire can damage spotted knapweed seeds in the soil seed bank, reducing germination and seedling emergence. But, fire is likely to create conditions that are favorable for spotted knapweed seedling establishment, and even a small percentage of seeds surviving can be sufficient to reestablish a site.

Douglas-fir and ponderosa pine forests

Wildfire: Spotted knapweed in Douglas-fir and ponderosa pine forests burned by wildfire tends to increase in cover with time-since-fire.

Prescribed Fire: Data are insufficient for drawing firm conclusions regarding prescribed fire effects on spotted knapweed in Douglas-fir and ponderosa pine forests. Data suggest that spotted knapweed abundance may increase after prescribed fire, and may increase more after low- than high-severity spring prescribed fire. One study reported no spotted knapweed present after fire despite nearby seed sources.

Flowering spotted knapweed. Photo by Rob Routledge, Sault College, and courtesy of Budwood.org.

A firefighter uses a drip torch to ignite a prescribed burn in a steppe community at the Big Hole National Battlefield, Montana. Photo courtesy of the National Park Service.

Bunchgrass steppes

Few published studies examined spotted knapweed's response to fire in bunchgrass steppes and available information is conflicting. Limited information suggests that spotted knapweed is likely to increase after low-intensity prescribed fire in bunchgrass steppes but more research is needed.

Tallgrass prairies and other warm-season grasslands

Many studies examined spotted knapweed abundance after fire in tallgrass prairies and other warm-season grasslands, and most found reduced spotted knapweed abundance following frequent fire. Results depended on prefire spotted knapweed abundance and phenology, fire intensity and severity, weather, and fire season. Spotted knapweed abundance is likely to increase after cessation of frequent burning if on- or off-site seed sources are available.

- Spring fires can be effective at reducing spotted knapweed abundance if they are of high enough intensity and severity.
- Summer fires, prior to seed production, may be most effective at reducing spotted knapweed populations. However, summer fires may be less beneficial to native warm-season grasses than spring fires.
- Low-intensity fires do not reach temperatures necessary to kill spotted knapweed seeds in the seed bank. If soil moisture is adequate, spotted knapweed is likely to establish after fires of low intensity and severity.
- Consecutive annual prescribed fires (or other follow-up treatments) are needed to prevent subsequent seed production and reduce spotted knapweed populations in the long term.

Diffuse Knapweed

Information regarding diffuse knapweed response to fire is very limited and almost entirely anecdotal. Diffuse knapweed may resprout after fire, assuming the root crown survives and sufficient moisture is available. Diffuse knapweed produces large quantities of seeds that may survive fire, and has at least a short-term persistent soil seed bank, but it is unclear how long seeds remain viable in the soil. Seedlings may establish after fire from surviving seeds in the soil or from off-site sources, but no observations of postfire seedling establishment were described in published literature.

Diffuse knapweed plant in Kamloops, British Columbia. Photo by Franz Xaver and courtesy of Wikimedia Commons.

There is limited information and mixed opinions on the potential effects of prescribed fire on diffuse knapweed. After a single fire, reduced diffuse knapweed abundance is likely to be only temporary because plants may resprout and flower after top-kill, seeds may survive in the soil seed bank or unburned seedheads, and seeds may be dispersed to burned sites from off-site sources. Burning is most likely to control diffuse knapweed in areas where native plants increase in abundance after fire.

Prescribed fire to control diffuse knapweed, south of Shoshone, Idaho. Photo by Steve Dewey, Utah State University, Bugwood.org

Yellow Starthistle

Most studies about yellow starthistle's response to fire were conducted in California annual grasslands. Only two studies examined fire effects on yellow starthistle in perennial grasslands in the Northern Rocky Mountains, and these studies found no change in yellow starthistle abundance after fire in the short term.

Yellow starthistle plant in California. Photo by J. Smith and courtesy of Wikimedia Commons.

Fire usually consumes or top-kills yellow starthistle plants, although plants may resprout after low-severity fire. Sufficient heat is required to scorch the foliage, stem-girdle, and kill the plants. Fuels may be too moist in spring to carry fire such that burning is incomplete and yellow starthistle mortality is low. Yellow starthistle has a persistent soil seed bank and fires are not usually severe enough to kill seeds in the soil. Estimates of yellow starthistle seed longevity in the seed bank range from about 4 to 10 years and plants can reestablish from any remaining viable seeds.

Prescribed fire in annual grasslands

Most information about controlling yellow starthistle with prescribed fire comes from field studies in California annual grasslands. The effectiveness of fire for killing yellow starthistle or reducing its population growth depends on fire characteristics (pattern, severity, timing, and frequency), as well as the species present in the prefire plant community and soil seed bank. Observations of increased germination and high seedling densities in burned areas suggest that burning may "stimulate germination" of surviving seeds, and thus reduce the density of germinable seeds in the soil seed bank. Therefore, consecutive annual prescribed fires (or other follow-up treatments) may be effective in preventing subsequent seed production and thus reduce yellow starthistle populations in the long term.

Prescribed fire management considerations for yellow starthistle include:

- Fires are most effective for controlling yellow starthistle populations when they are spatially continuous (i.e., consuming or scorching and stem-girdling all plants) and timed to kill yellow starthistle plants before they produce seeds. Patchy fires leave surviving plants that can produce seeds and replenish the soil seed bank.
- Burning yellow starthistle in summer—during the early flowering stage and prior to seed set—can reduce yellow starthistle seed bank density that fall.
- Consecutive annual burning can further reduce seed bank density if fuels are sufficient to carry fires that kill all reproductive yellow starthistle plants before seeds mature.
- Sufficient fuels may not be available to carry consecutive annual fires, and fires of this frequency may have severe impacts on desired plants.
- Follow-up monitoring and treatment may be needed for several years to prevent reestablishment.

Field in Bitterwater, California, after prescribed fire to control yellow starthistle in early June, when yellow starthistle first began to flower. Most yellow starthistle survived because burning was incomplete due to high soil moisture, high humidity on the day of the fire, and a substantial number of still-green shortpod mustard plants. Photo by Devii Rao, University of California Cooperative Extension, Hollister, California.

Conclusion

While fire has the potential to exacerbate the establishment and spread of spotted knapweed, diffuse knapweed, and yellow starthistle, there is potential to use prescribed fire as a management tool to control populations of these species in the short term under specific conditions. However, caution is warranted because long-term studies are lacking. Land managers must carefully consider factors including fire timing, intensity, severity, and frequency, as well as the plant community and site characteristics, when utilizing prescribed fire or anticipating the impacts of a wildfire on these invasive species. Research is limited and sometimes inconsistent, so managers must also be prepared to monitor long-term fire effects and adapt accordingly with follow-up burns and/or alternative control methods.

Citations and Additional Information

Innes, Robin J. 2021. Centaurea stoebe subsp. micranthos, spotted knapweed. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/plants/forb/censtom/all.html

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For more information on the Fire Effects Information System, visit: www.feis-crs.org/feis/

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