

Toadflax Stem Miners and Gallers: The Original Weed Whackers

THE TROUBLE WITH TOADFLAX

A field of flowering toadflax might seem picturesque to the casual observer. The aesthetic appeal of Dalmatian and yellow toadflax's showy, snapdragon-like blossoms might help explain why these species have spread across thousands of acres of rangelands and meadows in the United States. These toadflax species are affectionately referred to as butter and eggs, Jacob's ladder, or wild snapdragon, and share the visual appeal of closely related ornamentals such as foxglove, snapdragon, and penstemon.

However, ask rangeland managers and researchers throughout the Intermountain West, and they will tell you that there is nothing beautiful about a field of toadflax. Significant problems lurk below the superficial beauty. Sharlene E. Sing, a USDA Forest Service Rocky Mountain Research Station (RMRS) research entomologist located in Bozeman, Montana, where much of RMRS's biocontrol research is located, concurs: "Dalmatian and yellow toadflax number among the most challenging invasive weeds to manage in the Intermountain West."



Don't be fooled by the visual appeal of toadflax—yellow toadflax and Dalmatian toadflax are exotic weeds that evict native plants from rangelands and meadows. Dalmatian toadflax patches in the Elkhorn Mountains, Helena National Forest (southwest Montana) (image credit: Sharlene E. Sing).

SUMMARY

Dalmatian and yellow toadflax are aesthetically pleasing weeds wreaking havoc in rangelands across the western United States. These non-native forbs spread rapidly into fields following fire, tilling, construction, or other disturbances. They are successful and stubborn invaders, producing massive quantities of seeds each year and rapidly re-sprouting from root fragments. Eight non-native toadflax feeding insect species have been intentionally released or accidentally introduced in North America. Stem mining weevils, *Mecinus* spp., serve as particularly powerful "weed whackers" against toadflax. Biological control of toadflax is complicated by the existence of two *Mecinus* species—each of which performs better on different toadflax species—and the appearance of competitively superior hybrids of yellow and Dalmatian toadflax. Cooperation between researchers and managers continues to improve the effectiveness of biocontrol and make headway against weedy invaders.

Research entomologist Sharlene Sing categorizes Dalmatian and yellow toadflax as “among the most challenging invasive weeds to manage in the Intermountain West.”

Yellow toadflax (*Linaria vulgaris*) and Dalmatian toadflax (*L. dalmatica*) originate from Eurasia. It is thought that both species were intentionally introduced to the United States predominantly for ornamental purposes. Yellow toadflax appeared in colonial North America sometime before 1670, but Dalmatian toadflax waited until the mid-1800s for its trek across the Atlantic.

Yellow and Dalmatian toadflax species are short-lived, perennial forbs that are reproductively self-incompatible. This means that toadflax requires the service of bumble bees and other large bee

species to transfer pollen from flower to flower of unrelated plants. Toadflaxes were formerly classified as figworts (Scrophulariaceae), primarily based on morphological characters. Results of more recent molecular analyses indicate that toadflaxes and snapdragons are more appropriately assigned to the plantain family (Plantaginaceae)—not to be confused with the completely unrelated banana-like plantain.

Dalmatian and yellow toadflax are similar in appearance, but have obvious distinguishing characteristics if you know what to look for. Dalmatian

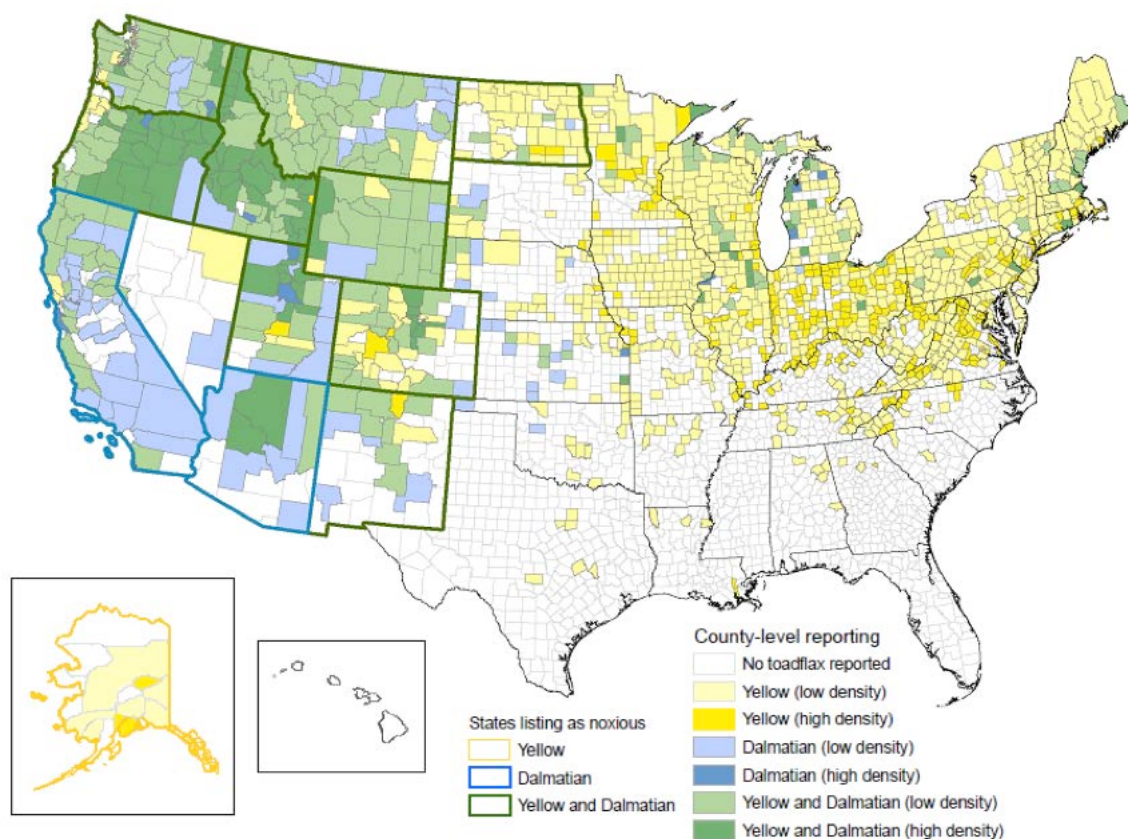
toadflax has dark green, broad, somewhat waxy or fleshy heart-shaped leaves. In contrast, the leaves of yellow toadflax are narrower and often have a light-green tinge. Dalmatian toadflax is usually taller than yellow toadflax, with stem heights ranging from 2-5 ft., compared to 1-3 ft. for yellow toadflax. Morphological differences are illustrated and described in the helpful guide, *Biology and Biological Control of Dalmatian and Yellow Toadflax*, published by the USDA Forest Service (Wilson and others 2005).

Populations of yellow and Dalmatian toadflax can stay at low, background levels until released by favorable environmental conditions, such as those created through disturbance. Both species can readily invade and rapidly dominate rangelands following grazing, tillage, erosion, prescribed burning, or wildfire. Dalmatian toadflax has invaded a minimum of 400,000 acres in the western United States, with a minor presence in some eastern states; Yellow toadflax has spread to all 49 continental states. These flowering forbs have successfully established in sensitive and rare classified ecosystems, including sagebrush steppe. Yellow and Dalmatian toadflax are such troublesome invaders that 13 western states and 4 Canadian provinces have listed one or both as noxious weeds.

Toadflax can suppress native and other desirable plants, reducing floral diversity. Researchers have noted substantial reductions in the abundance of desirable plants, such as Flagstaff pennyroyal (*Hedeoma diffusum*), following fire and subsequent invasion by toadflax. Soil tillage can release toadflax populations, to the detriment of crops. Invaded fields have experienced 20-70% reductions in yields of barley, canola, and wheat due to competition from yellow toadflax. Even though toadflax is not toxic to



Dalmatian toadflax (left) has dark green, broad, waxy ‘heart-shaped’ leaves, and yellow toadflax (far right) has narrow, pale green leaves. The snapdragon-like blossoms of yellow toadflax have a distinct, bright orange ‘throat’, unlike the larger, more uniformly yellow flowers of Dalmatian toadflax. Dalmatian x yellow toadflax hybrids (middle) have characteristics similar to both parental species (image credit: Sarah Ward, Colorado State University).



Yellow and/or Dalmatian toadflax are listed as noxious weeds in 13 states. Yellow toadflax occurs in about 1,330 counties across the United States and Dalmatian in 370, with the species co-occurring in at least 275 counties. Counties with high toadflax densities are those in the upper 25th percentile for reported occurrences of toadflax, standardized by county land area. Data provided by the Early Detection & Distribution Mapping System, a program compiling site and county-level reports made by experts, herbaria, and literature regarding the distribution of weedy species (EDDMapS 2014; <http://www.eddmaps.org/>).

cattle, forage quality and quantity are significantly reduced in infested rangelands. Grazing allotments invaded by toadflax put additional strain on Western cattle producers, many of whom already struggle with low rangeland productivity from chronic drought and wildfire risk.

STUBBORN TOADFLAXES ARE HERE TO STAY

What makes Dalmatian and yellow toadflax such successful invaders? One reason is that Dalmatian and yellow toadflax are exceptionally fecund. A mature Dalmatian toadflax plant can produce up to 500,000 seeds per year. Slightly less prolific, mature yellow toadflax plants can generate 15,000 – 20,000 seeds each year. In addition, both species readily re-sprout from abundant root buds. These two traits allow toadflax to quickly establish dense colonies that monopolize water and nutrients and

push out native and other desirable plant species.

Making matters worse, these super-invaders are incredibly stubborn. Hand pulling is ineffective since toadflax can vigorously re-sprout from roots and root fragments. Several herbicides dramatically reduce above-ground cover of Dalmatian and yellow toadflax, but effectiveness largely depends on the precise timing of application, rate of application, and the proper combination of chemicals. Toadflax control with herbicide also comes with undesirable side-effects. Researchers have noted declines in species richness and biomass of native forbs following application of herbicides targeted at toadflax.

Wildfire and prescribed burning are useless for evicting toadflax from rangelands. In fact, fires facilitate the expansion and dominance of

toadflax infestations. Mature yellow and Dalmatian toadflax plants grow deep root systems that can survive fires. Surviving root tissues often re-sprout, which positions toadflax to take advantage of reduced competition from other vegetation, especially following high intensity burns. Seed production of Dalmatian toadflax is also stimulated post-fire, potentially due to reduced competition and increased nutrient availability. In fact, researchers observed 100-5000% greater seed production following fire in sagebrush ecosystems near Boulder, Montana.

If a manager's toolbox for controlling toadflax should not include prescribed fire, and given the vast scale of infestations (therefore high cost of management), and limited success of mechanical or chemical control methods, what tactics are left for managers to use against toadflax?



Yellow and Dalmatian toadflax are deep-rooted, allowing for rapid and vigorous regrowth following high-severity wildfires (image credit: Robert K.D. Peterson, Montana State University).

Weed-whacking weevils to the rescue! Plants and insects have dueled for thousands of years. Herbivorous insects must co-evolve with their host plant species in order to exploit them for food or reproductive purposes. Plants have a number of natural defenses for fending off insect species and other herbivores. Many plant species deter insects by producing toxic or foul-tasting chemicals in their leaves, stems, or roots. In turn, insect species experience selective pressure to develop a tolerance to these natural chemicals, or they are forced to find different host plants.

Some plants find significant relief from herbivory when they travel beyond their native range. Intercontinental dispersal due to intentional or accidental introductions by humans or incidental transport by animals, wind, or water,

frees non-native plants from their natural enemies. Some non-native plants celebrate this new found freedom by thriving and spreading across new territories.

Humans insert themselves into the saga of complex plant-insect interactions through the implementation of biological control. This approach involves intentionally deploying arthropods (insects or mites) or pathogens (fungi, bacteria, or viruses) that co-evolved with the target weed and selectively utilize it as a host plant. Over the long term, biological control can be more cost-effective, sustainable, and ecologically safe than mechanical or chemical control; however, it occasionally fails to meet control expectations. For example, insects might die out after a release, and biocontrol agents that establish sizable populations can still be

wiped out by pathogens, parasitic wasps, grazing livestock and wildlife, adverse weather events, or human intervention, such as construction or herbicide treatments.

North America currently hosts eight non-native insect species that primarily feed or breed on toadflaxes. These tiny weed-whackers include:

- two flower or seed feeding beetle species accidentally introduced to North America, probably as stowaways on European plant material;
- a defoliating moth rigorously tested for host specificity before being approved for its first North American release in 1968;
- four approved, intentionally released insects that made their U.S. debut in 1996, including one root galling weevil, two root-feeding moths, and a stem mining weevil; and
- a recently discovered second species of stem mining weevil.

We now focus on the hero of our story, the stem mining weevil *Mecinus* spp. that researchers found feeding and breeding on European toadflax. The weevil's initial North American release occurred in Canada in 1991, and it became a U.S. resident in 1996 with its first official release in Montana. Prior to the release of *Mecinus* weevils, researchers conducted tests overseas and in greenhouses in North America to verify their preference for toadflax hosts, and to ensure they would not harm crops, ornamentals and plants native to North America, especially threatened or endangered species. The weevil showed no preference for yellow or Dalmatian toadflax in research studies, so it was released against both weed species.

Mecinus stem mining weevils utilize their host toadflax in multiple ways.



Toadflax stems attacked by *Mecinus janthinus* are easily identified by calloused holes along the stem, which the weevil creates before inserting its eggs. Tunneling and feeding by weevil larvae can also cause thin stems to swell and develop a purple cast (image credit: Sharlene E. Sing).

Entomologists categorize them as both miners and gallers; they spend part of their life cycle “mining” (boring) through toadflax stems, and their activities can create galls, mostly limited to abnormal stem swellings, on host plants. From early April to early July, large groups of adult weevils voraciously munch on succulent shoots and leaves, stunting stem height and substantially reducing mature toadflax flower and seed production. Female weevils chew shallow holes in toadflax stems before inserting a single white egg. Females are busy during their first and only reproductive (oviposition) period, producing an average of 45 eggs each. Larvae hatch 6-7 days later and begin ravaging their toadflax host, tunneling and chomping away inside the host stem for 4-5 weeks. Weevils complete metamorphosis into adulthood by late August or early September, but remain in the natal stem until the

following spring, when they emerge by chewing their way out.

Sing and her collaborators have spent the last decade closely monitoring the impact of *Mecinus* weevils on toadflax infestations. They observed up to 70% reduction in average stem height of Dalmatian toadflax following the deployment of *Mecinus* weevils into invaded fields. Infested stems of Dalmatian toadflax also have less energy available to invest in producing flowers and seeds, which could significantly slow the spread of Dalmatian toadflax. A welcomed finding indeed!

Managers have released *Mecinus* weevils in Washington, Idaho, Montana, British Columbia, and Alberta. The weevil is doing substantial damage to Dalmatian toadflax populations, but it rarely eliminates the weed. Unfortunately, the weevil is making less headway with yellow

toadflax. Why the mixed and occasionally underwhelming results?

EVER-EVOLVING SOAP OPERA OF TOADFLAX BIOCONTROL

For more than two decades, researchers assumed that the toadflax-weevil story involved two target weed species, yellow and Dalmatian toadflax, and one biological control agent, (*Mecinus janthinus*). Following anomalous field observations and molecular diagnostics, researchers recently determined that this story has two additional ‘stealth’ players: fertile hybrids of Dalmatian and yellow toadflax, and a cryptic weevil species. These discoveries have added an unexpected twist to the toadflax drama.

In 2005, Sing and her collaborator, Colorado State University plant geneticist Sarah Ward, first observed and collected putative Dalmatian-yellow toadflax hybrids. “Yellow toadflax and Dalmatian toadflax are not reported to hybridize within their native European ranges,” reports Ward, “however, invasive populations of these species in the Rocky Mountains are growing in sufficient proximity at some locations to allow cross-pollination between them.” The researchers were visiting two such locations within the Beaverhead-Deerlodge and Helena National Forests in Montana when they noticed something unusual: several toadflax plants had leaves and flowers that looked sort of like yellow toadflax, but also a bit like Dalmatian.

Further research by Sing, Ward, and Colorado State University graduate students Marie Turner and Andrew Boswell confirmed that Dalmatian and yellow toadflax are spontaneously hybridizing on multiple sites in the western United States. But that’s not all!

Turner determined that their offspring are frequently taller, produce a higher percentage of viable seeds, and emerge earlier in the season than their parents. These super-invaders are producing even more powerful and competitive offspring. This spells bad news for managers already challenged by infestations of yellow and Dalmatian toadflax.

Around the time that Ward and Sing found their toadflax hybrids, another toadflax-weevil mystery started to unfold. A rancher in Powell County, Montana, noticed small black bugs feeding on yellow toadflax in his pasture. He asked researchers at Montana State University to investigate. Three entomologists, Sharlene Sing (Rocky Mountain Research Station), David Weaver (Montana State University), and Dr. Patrice Bouchard (Canadian National Collection of Insects, Arachnids and Nematodes) worked together to confirm the identity of the small weevil as *Mecinus janthinus*.

The researchers were surprised by their finding. The stem mining weevil was thought to prefer Dalmatian toadflax, but here it was, camped in a field of yellow toadflax. As Weaver explained to reporters for the Montana State University News Service, “They [the weevils] have been established on the related weed, but this is one of the first discoveries of a sustained population on yellow toadflax in the United States and North America.”

The toadflax-weevil story was becoming more complicated. In search of answers, the researchers contacted Dr. Ivo Toševski and Dr. Andre Gassmann, entomologists with CABI-Switzerland, who study *Mecinus janthinus* across its native range in Eurasia. These Serbian and Swiss collaborators compared the genetic makeup of *Mecinus janthinus*

found on yellow toadflax in Europe to the specimens collected from yellow toadflax in Powell County, Montana. Toševski and Gassmann determined that the Montana and European weevils on yellow toadflax were the same species. They were also able to conclude that weevils collected from Dalmatian toadflax in Europe and in Missoula, Montana, were an entirely

different species, *Mecinus janthiniformis*. Further research confirms that each weevil species has a very strong and consistent preference for one of the two toadflaxes: *Mecinus janthinus* for yellow toadflax and *Mecinus janthiniformis* for Dalmatian toadflax.

So how do these discoveries change the outlook for toadflax biocontrol?



Which weevil is which? Although similar in appearance, *Mecinus janthinus* (top) is better at damaging yellow toadflax, and its slightly larger sister species, *M. janthiniformis* (bottom), prefers Dalmatian toadflax. *M. janthiniformis* is suspected of hitch-hiking to North America in shipments of *M. janthinus* (image credits: Jay Cole, USDA APHIS and Sharlene E. Sing, USDA Forest Service).

Sing explains that “hybridization between Dalmatian and yellow toadflax undoubtedly played a role in biocontrol shortfalls.”

Sing explains that “hybridization between Dalmatian and yellow toadflax undoubtedly played a role in biocontrol shortfalls. Strategic implementation of biological control for forests and rangelands affected by widespread, trenchant infestations of both toadflax species now seems less straight-forward.”

In other words, managers could be inadvertently releasing less-effective insects onto less-susceptible plants. This might explain why stem mining weevils leave toadflax unfazed in some areas but totally devastated in others. Sing and her colleagues stress that matching the correct weevil to the target toadflax species is crucial. The general rule is that *Mecinus janthinus* does more damage to yellow toadflax and *Mecinus janthiniformis* to Dalmatian toadflax.

Sing and her collaborators, including entomologist Carl Jorgensen (USDA Forest Service, Forest Health Protection), research entomologist Robert Progar (USDA Forest Service, Pacific Northwest Research Station), and weed biocontrol specialist Joseph Milan (Bureau of Land Management / Idaho State Department of Agriculture), are conducting additional research with implications for managers by using *Mecinus* weevils for biocontrol. Recent field-based research indicates that managers can counteract high overwintering mortality of *Mecinus* by making “rescue” releases, especially in post-burn areas. They suggest serial

releases (2 years in a row) at multiple locations within the same drainage. These releases should deploy more weevils—about 800 adult weevils—instead of the typical release of 500 adults.

SOLID STRIDES HAVE BEEN MADE, BUT THE JOURNEY IS FAR FROM OVER

Researchers made substantial headway in understanding toadflax biocontrol by discovering yellow x Dalmatian hybrids and the additional stem mining weevil, *Mecinus janthiniformis*. However, their work is not done. Collaborators in Switzerland are assessing the potential of several additional insects for toadflax biocontrol. North American researchers and managers alike are anxious to begin releasing one of the most promising candidate species, a yellow toadflax stem galling weevil, *Rhinusa pilosa*.

Researchers also continue to develop, implement, and teach methods for evaluate the impact of biocontrol treatments. Long-term monitoring is especially important. Substantial damage to toadflax might not materialize until 3-5 years after the release of weevils or other toadflax-targeting agents. Tips for monitoring are provided in the guide *Biology and Biological Control of Dalmatian and Yellow Toadflax*, and through a highly recommended website on weed biocontrol administered by the Bureau of Land Management and Idaho State Department of Agriculture: <http://www.agri.state.id.us/Categories/PlantsInsects/NoxiousWeeds/BioControl.php>.

Researchers and managers need to work together to identify success stories and to detect negative outcomes, such as treatment failures and damage to species



Students measure damage to Dalmatian toadflax following the release of stem mining weevils in a burned area on the Helena National Forest (image credit: Sharlene E. Sing).

other than the target weed. According to Sing, “post-release monitoring is critical to ensuring accountable management of public lands and resources. Monitoring is truly the only way to document the full range of beneficial and detrimental ecological responses that may result from the release of weed biocontrol agents, to demonstrate if stakeholder needs are being met, and to ultimately increase biocontrol implementation.” Cooperation between researchers and managers might also lead to insights about rangeland restoration and other ways to improve the resilience of ecosystems to toadflax and other weed invasions.

***Entomologist
Sharlene Sing with
the Rocky Mountain
Research Station finds
that “post-release
monitoring is critical to
ensuring accountable
management of public
lands and resources.”***

FURTHER READING

Krick, N.J. 2011. Examining the unpredictable nature of yellow toadflax. M.S. Thesis. Fort Collins, CO: Colorado State University.

Nowierski, R.N. 2004. Toadflax. Pg 379-395 in E.M. Coombs, J.K. Clark, G.L. Piper, and A.F. Confrancesco, Jr. (eds). Biological control of invasive plants in the United States. Corvallis, OR: Oregon State University Press.

Sing, S.E. and R.K.D. Peterson. 2011. Assessing risks for established invasive weeds: Dalmatian (*Linaria dalmatica*) and yellow (*L. vulgaris*) toadflax in North America. International Journal of Environmental Research and Public Health 8: 2828-2853.

Toševski, I., R. Caldara, J. Jović, G. Hernández-Vera, C. Baviera, A. Gassmann, and B.C. Emerson. 2011. Morphological, molecular and biological evidence reveal two cryptic species in *Mecinus janthinus* Germar (Coleoptera, Curculionidae), a successful biological control agent of Dalmatian toadflax, *Linaria dalmatica* (Lamiales, Plantaginaceae). Systematic Entomology 36: 741-753.

Ward, S.M., C.E. Fleischmann, M.F. Turner, and S.E. Sing. 2009. Hybridization between invasive populations of Dalmatian toadflax (*Linaria dalmatica*) and yellow toadflax (*Linaria vulgaris*). Invasive Plant Science and Management 2(4): 369-378.

Wilson, L. M., S. E. Sing, G. L. Piper, R. W. Hansen, R. De Clerck- Floate, D. K. MacKinnon, and C. Randall. 2005. Biology and biological control of Dalmatian and yellow toadflax. FHTET-05-13. Washington, DC: U.S. Department of Agriculture, Forest Service.

Zouhar, K. 2003. *Linaria* spp. Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Fire Effects Information System. Online: <http://www.fs.fed.us/database/feis/plants/forb/linspp/all.html>.

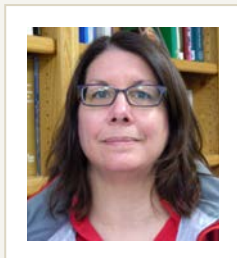


WRITER'S PROFILE

Megan Matonis is a PhD student with the Graduate Degree Program in Ecology at Colorado State University (CSU), and a graduate student cooperator with the RMRS Science Integration and Application Staff. She earned a BS degree in Natural Resource Management from CSU and a MS degree in Forestry from Michigan State University. Megan can be reached at megan.matonis@colostate.edu.

SCIENTIST PROFILES

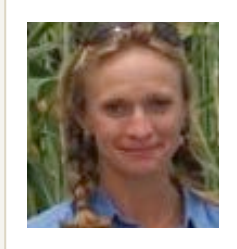
The following scientists were instrumental in the creation of this Bulletin:



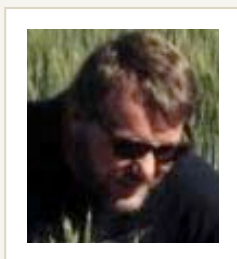
SHARLENE E. SING is a Research Entomologist with the USDA Forest Service, Rocky Mountain Research Station, Bozeman, MT. Her research investigates ways to assess and improve the efficacy and safety of classical weed biological control, with a focus on yellow, Dalmatian, and hybrid toadflax; Tamarisk; Russian olive; and oxeye daisy. Sharlene received an MS degree in Natural Resource Sciences (entomology) from McGill University and a PhD in Land Resources and Environmental Sciences (agroecology) from Montana State University.



SARAH WARD is an associate professor of plant genetics at Colorado State University, where she assesses how genetic processes drive rapid evolutionary change in weedy and invasive plants. Sarah is investigating the molecular and population genetics of herbicide-resistant weeds, as well as the invasive potential of yellow-Dalmatian hybrids. She received her PhD in plant breeding from Colorado State University.



MARIE F.S. TURNER is a recent graduate of Colorado State University, where she is currently serving as a plant genetics postdoctoral fellow. Her doctoral research compared the invasive potential and fitness of hybrid toadflax to parental species. She also developed a model to predict Intermountain West locations where hybrid toadflax is likely to occur, based on known Dalmatian and yellow toadflax distributions. Marie's current research includes influences of drought stress on bioenergy crops.



DAVID WEAVER is a professor of entomology at Montana State University. He uses insect chemical ecology and behavioral responses to develop solutions for the bio-rational management of storage and cropland pests and to optimize biological control of insect and weed pests. David holds a PhD in entomology from McGill University.



IVO TOŠEVSKI is a research scientist affiliated with CABI-Switzerland who specializes in classical biological control of weeds. His primary research interests are in integrated pest management (IPM) of insects and weeds; weed control, including biological control of toadflaxes; taxonomy of insect pests; and interactions among vectors, pathogens, and plants. Ivo's home base is the Institute for Plant Protection and Environment, Department of Plant Pests in Zemun, Serbia.

Sharlene Sing can be reached at:

USDA Forest Service
Rocky Mountain Research Station
Forestry Sciences Laboratory
1648 South 7th Ave, MSU Campus
Bozeman, MT 59717-2780

SCIENTIST PROFILES (*cont.*)

ANDRÉ GASSMANN is CABI-Switzerland's Assistant Centre Director and Principal Research Scientist. He specializes in research on non-native invasive plants and evaluating candidate biological control agents of weeds. André's recent projects include biological control of toadflaxes, European buckthorns, common tansy, and swallow-worts.



PATRICE BOUCHARD is a research scientist and curator for the Canadian National Collection of Insects, Arachnids, and Nematodes. He researches interactions among non-native invasive plants, agricultural practices, and insect biodiversity, and is helping develop a national arthropod information system for pests, beneficial insects, and environmentally sensitive insects. Patrice earned his PhD in entomology from the University of Queensland.

PURPOSE OF THE SCIENCE YOU CAN USE BULLETIN

To provide scientific information to people who make and influence decisions about managing land. The US Forest Service RMRS Science You Can Use Bulletin is published regularly by:

Rocky Mountain Research Station (RMRS)

US Forest Service
240 W Prospect Rd
Fort Collins, CO 80526

Forest Service researchers work at the forefront of science to improve the health and use of our Nation's forests and grasslands. RMRS is one of seven Forest Service R&D Stations located throughout the US. For more information about a particular research station, please visit their website:

[Northern Research Station \(NRS\)](#)

[Southern Research Station \(SRS\)](#)

[Rocky Mountain Research Station \(RMRS\)](#)

[Pacific Northwest Research Station \(PNW\)](#)

[Pacific Southwest Research Station \(PSW\)](#)

[International Institute of Tropical Forestry \(IITF\)](#)

[Forest Products Lab \(FPL\)](#)

PNW and SRS produce regular science delivery bulletins similar to the Science You Can Use Bulletin:

[PNW Science Findings](#)

[SRS Compass Live](#)

To receive this bulletin via email, scan the QR code below or use this link:

<http://tinyurl.com/RMRSsciencebulletin>

Sarah Hines, Bulletin editor; shines@fs.fed.us

Jan Engert, Assistant Station Director,
Science Application & Integration;
jengert@fs.fed.us



The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

