



Forest Health Technology Enterprise Team

TECHNOLOGY TRANSFER

Invasive Species

FHTET–2009–03
September 2009

RUSH SKELETONWEED *(CHONDRILLA JUNCEA)* MANAGEMENT PLAN FOR THE WESTERN UNITED STATES

Rush Skeletonweed Task Force
2009
First Edition

Rachel Winston, Mark Schwarzländer
John Gaskin, Carl Crabtree, Editors

USDA US DEPARTMENT OF AGRICULTURE

US FOREST SERVICE

FOREST HEALTH TECHNOLOGY ENTERPRISE TEAM

University of Idaho Extension

The Forest Health Technology Enterprise Team (FHTET) was created in 1995 by the Deputy Chief for State and Private Forestry, USDA Forest Service, to develop and deliver technologies to protect and improve the health of American forests. This book was published by FHTET as part of the technology transfer series.

http://www.fs.fed.us/foresthealth/technology/

For additional copies of this publication, contact:

Mark Schwarzländer
University of Idaho Campus
Agriculture Science 237
Moscow, Idaho
(208)-885-9319
markschw@uidaho.edu

Richard Reardon
USDA Forest Service, FHTET
Morgantown
West Virginia
(304) 285-1566
rreardon@fs.fed.us

RUSH SKELETONWEED *(CHONDRILLA JUNCEA)* MANAGEMENT PLAN FOR THE WESTERN UNITED STATES

EDITORS:

Rachel Winston, MIA Consulting, Shelley, ID
rachel@getmia.net

Mark Schwarzländer, Center for Research on Invasive Species and Small Populations, University of Idaho, Moscow, ID
markschw@uidaho.edu

John Gaskin, United States Department of Agriculture Agriculture Research Service, Sidney, MT
jgaskin@sidney.ars.usda.gov

Carl Crabtree, Idaho County Weed Control
Grangeville, ID
ccrabtree@idahocounty.org

A report on behalf of the rush skeletonweed task force

2009 First Edition

This management plan aims to provide a compendium of the most up-to-date information for the biology, ecology, and integrated management of the highly invasive rush skeletonweed infesting natural areas throughout the western U.S. Management of this species is still in the early to mid-stages of development of a landscape approach to control the plant, both on public conservation and private lands. This report will be updated every five years to reflect changes in research progress and/or management strategies.

Cover photos and plan design: Rachel Winston, MIA Consulting; Chuck Benedict, FHTET.

Table of Contents

Acknowledgements

The Rush Skeletonweed Task Force and the editors of this Plan wish to thank Brad Harmon (PSES Department, University of Idaho) for help with the literature gathering process, George Markin (USDA Forest Service, retired) for contributions to the section on foreign exploration of biocontrol agents, and Amy Ferriter (Idaho State Department of Agriculture) for the initial idea to produce a comprehensive management plan and compendium of information for rush skeletonweed. We also would like to thank Richard Reardon of the USDA Forest Health Technology Enterprise Team (FHTET), Morgantown, WV, for providing the funds to prepare and publish this Management Plan, and Chuck Benedict (FHTET), Madison, WI, for help with editing and layout.

Executive Summary

Rush skeletonweed (RSW) is one of the West's most troublesome invaders.

- RSW infests more than 6.2 million acres in 15 US states, two Canadian provinces.
- RSW spreads at a rate of 99,000 acres/year in 1980s, and is likely spreading faster now.
- RSW has three geographically isolated genotypes, each with distinct biological traits.
- South and central Idaho are the "heart" of the most aggressive western infestations.
- RSW causes millions of dollars of damage annually to agriculture and wildlife.
- Controlling RSW is one of the highest priorities of Western land managers.

Current management practices are mostly ineffective.

- Herbicides were the original tool, but their low efficacy did not control RSW outbreaks.
- More-recent herbicides, e.g. picloram/2,4-D combination, are more effective.
  - These herbicides are expensive and require continual use.
  - Many herbicides are not registered for all areas and can result in environmental damage if used at rates high enough to kill RSW.
  - Additional herbicide trials underway to develop novel compounds more selective to each RSW genotype and more cost effective for large infestations.
- Burning RSW is not effective and might actually exacerbate the problem.
- Livestock feed on young RSW, but prolonged grazing is not good for the animals (inferior forage to most grasses) or the land; RSW quickly recovers when grazers removed.
- Physical control may be effective but requires continual upkeep, is not useful in most RSW-invaded areas, and may increase the problem by spreading regenerative root fragments.
- There are three RSW biological control agents (a rust fungus, gall mite and gall midge) established in the western U.S.
  - Each agent provides only limited control.
  - Releases of a fourth agent (a root-feeding moth) are underway.

Current focus of the RSW management (plan):

- Primary emphasis is prevention.
  - Preventing RSW is far more cost effective than treating it.
  - The keys to preventing the spread and establishment of new infestations are to increase awareness of RSW issues and educate stakeholders on the importance of altering land-use practices.
- Integrating multiple control methods leads to greatest success.
  - There is no single, stand-alone control method for RSW.

  - The proper combination/timing of different methods varies by site and genotype.
  - Size, location, land usage, other vegetation/wildlife, etc, are factors in determining the proper means to treat each infestation.

- Inventory, data management and prioritizing are crucial for treating existing infestations efficiently and effectively.
  - Inventory allows land managers to determine scope of problem on larger scale and subsequently allocate resources more effectively.
  - New, small or satellite populations should be eradicated immediately.
  - Infestations along transportation routes (e.g. roads and waterways) should be given high priority for rapid treatment, ensuring the cease of further spread.
  - Small, well-established infestations should be treated in a manner to reduce the population over time, resulting in smaller, fragmented infestations easier to manage; expensive, rapid treatments are not applicable to these infestations.
  - Large, well-established infestations should be treated with emphasis on the leading edge of the populations; expensive, rapid treatments are not applicable to these infestations.
- Coordination among landholders essential component to successful RSW management.

Requirements for future effective RSW management:

- Increase prevention.
  - Increased efforts in promoting awareness and education are necessary to prevent spread of RSW into uninfested areas; prevention is most cost-effective action.
- Increase coordination among all stakeholders.
  - Sharing data and techniques saves time and resources and promotes consistency.
  - Stakeholders working jointly more effectively treats RSW than fragmented efforts.
- Determine proper rates and timing of physical, chemical, livestock control.
  - Rates and timing vary by site and according to other control methods used.
- Increase foreign exploration for new biocontrol agents.
  - Biocontrol is the tool relied on most heavily for large, established infestations.
  - Additional agents are needed to augment efforts of those established.
- Test biological and chemical control options against all U.S. RSW genotypes.
  - Several different RSW genotypes occur in the West.
  - Each genotype responds differently to similar treatments.
- Determine how best to integrate each available control method.
- Educate land managers on proper inventory and prioritization of RSW infestations.

Introduction

The introduction of non-indigenous species to new habitats is an increasing concern for biodiversity and global environmental change (Walker and Steffen 1997, Mack et al. 2000). Exotic plants invade approximately 700,000 hectares (1.8 million acres) of wildlife habitat every year in the United States (Babbitt 1998). Their establishment and spread severely impact agriculture and other human activities (Pimental et al. 2001), displace native plant communities (Morse et al. 1995), and disrupt existing ecosystems (D'Antonio and Vitousek 1992, Walker and Steffan 1997). Exotic plant species cause more than $34 billion of damage per year to farming and ranching sectors, and well over $148 million per year in environmental losses (Pimental et al. 2000).

In the western U.S., the majority of land is publicly owned and managed by government agencies, such as the USDI Bureau of Land Management, the USDA Forest Service, and the National Park Service, and several state and regional land managers. Thousands of hectares within the western U.S. are invaded by exotic plants each year. Rush skeletonweed (RSW) (*Chondrilla juncea*), often referred to in the literature as CHOJU, is among the worst of them. Others include spotted knapweed (*Centaurea maculosa*), Russian knapweed (*Acroptilon repens*), tansy ragwort (*Senecio jacobaea*), St. Johnswort (*Hypericum perforatum*), yellow starthistle (*Centaurea solstitialis*), Canada thistle (*Cirsium arvense*), and musk thistle (*Carduus nutans*). Due to increasing concern for the vast parcels of forests and rangeland being invaded by exotics, Cooperative Weed Management Areas (CWMAs) were created. A CWMA is a distinguishable hydrologic, vegetative, or geographic zone, delimited by geography, weed infestations, and climatic or human-use patterns. Participants in CWMAs are federal, state and regional land managers, as well as concerned private landowners. Through collective efforts across jurisdictional borders, CWMAs can combine and stretch limited resources and manpower to better manage invasive species and protect and restore habitat. The Rush Skeletonweed Task Force (RSWTF) is such a CWMA. It is an interagency group of professionals who have either direct experience in managing RSW, or the technical knowledge required for an integrated management approach.

The Rush Skeletonweed Management Plan is intended to guide and direct the management of RSW within the western United States. It identifies the program goals and objectives, and management options and recommendations, developed by the RSWTF. The plan will be updated every five years as new management information is collected.

Problem statement

Rush skeletonweed (*Chondrilla juncea* L., Asteraceae) is a perennial herb indigenous to the Mediterranean and Central Asia (Cullen and Groves 1977). It was inadvertently introduced into the eastern U.S. during the 1870s (Piper and Coombs 1996). The flowers of RSW are apomictic (produce fertile seeds without pollination), plentiful (Wells 1971), and have a long reproductive period, all of which favor the spread of the plant by seed. Its rhizomatous root system enables the species to reproduce and spread vegetatively, as well.

Rush skeletonweed (RSW) is one of Australia's most problematic, exotic weeds. Since its introduction in 1918, RSW has negatively impacted many sectors of the country's agricultural industry, and devastated wheat and cereal production. Though this weed has not yet had as large an impact on U.S. agriculture, its populations continue to expand, and the lessons learned from Australia's RSW experience make the threat of RSW a top priority among U.S. land managers. RSW is distributed on both coasts and in some Midwestern states in the U.S. (USDA NRCS 2008), but is not yet considered an important weed in the East. In the West, RSW is a major pest of rangelands, pastures, transportation rights-of-way, croplands, and forests in Idaho, California, Montana, Oregon, and Washington (Old 1981). This weed colonizes deer and elk winter range, reduces crop yields, and decreaes the productive capacity of rangeland for domestic livestock (Sheley et al. 1999).

Western U.S. infestations originated from RSW-contaminated orchard and vineyard rootstocks introduced from the Mediterranean around 1900 (Piper and Coombs 1996). Although herbicides were widely used to manage this species in the 1960s-70s, it quickly spread beyond control: currently RSW infests an estimated 1,290,000 ha (3,187,590) in Washington, Oregon and California (Sheley et al. 1999). During the last two decades, RSW has been reported in Colorado, Montana, and British Columbia, Canada. South and central Idaho currently serve as the "heart" of the western infestations, with RSW continuously spreading outward from heavily-invaded regions. During the late 1970s, a biological control program initially developed to manage RSW in Australia was implemented in the western U.S. Three biocontrol agents, a gall midge, a gall mite, and a rust fungus, have since become established in the U.S. (Rees et al. 1996 as cited in Zouhar 2003), but they have provided only limited control of RSW within the western U.S. (Prather 1993, Milan et al. 2006).

The Rush Skeletonweed Task Force, with support from the USDA Forest Service, the University of Idaho, and Boise State University, sponsored a day-long summit on February 21, 2007 to exchange management information and experiences and to outline an action plan to address the threat posed by RSW. Nearly 30 participants, including ranchers, county weed superintendents, CWMA board members, federal and state researchers, and land managers from the USDI Bureau of Land Management and the USDA Forest Service attended. The attendees exchanged information, identified knowledge gaps, discussed priorities for future research, monitoring, control, and communication, and formalized the following goal, objectives, and recommendations below.

Goal

To work as a region-wide Cooperative Weed Management Area to protect the integrity of the West's natural and agricultural systems from the biological degradation caused by rush skeletonweed (*Chondrilla juncea*).

Objectives

The goal of the Rush Skeletonweed Task Force can be achieved through the following objectives:

1. An overall reduction of RSW on federal, state, tribal, and private lands throughout the western U.S.

2. A sustainable, economically feasible method preventing the spread of RSW into the West's RSW-free natural and agricultural systems.

3. An effective public information program that encourages public participation in and support for RSW management.

Recommendations

The participants of the Summit agreed on the following recommendations to guide the immediate work and future direction of the Rush Skeletonweed Task Force:

1. Develop an integrated approach for controlling this invasive species. The consensus of the 2007 Rush Skeletonweed Summit was that biocontrol agents, grazing techniques, and more-effective herbicide treatments are needed to reduce or stop the spread of RSW in the western U.S.

2. Increase biological control implementation through a) increased releases of the RSW root moth and b) improved coordination of overseas development of new biological control agents, with top priority given to those insects that feed inside the plant (stem or root-boring agents).

3. Continue herbicide evaluations. Specifically, quantitative studies are needed to a) determine the efficacy of single herbicide and mixed herbicide applications for both single and multiple treatments b) evaluate herbicide efficacy, i.e., the percentage active ingredient(s), translocation success, optimal season of treatment, length of control, effects on non-target vegetation, habitat type, initial versus follow-up treatment, and post-treatment monitoring requirements.

4. Use a regional approach. A regional approach should be used to manage RSW by creating RSW-quarantine areas in the affected western states.

5. Mobilize rapid response efforts. An early detection system must be developed for localized infestations allowing land managers to treat small, isolated patches of RSW before the populations become unmanageable. Early detection methods will save resources, both in terms of treatment and manpower costs. Currently, limited staff and the isolated nature of RSW infestations in many areas make complete ground surveys impossible.

6. Learn more about the role and consequences of wildfires on RSW invasions in the western U.S. The questions that need to be addressed include:

    - Can fire be used as part of a management strategy?
    - Does the plant rapidly invade recently burned habitat?
    - What is the best time to treat re-growth of the plant after a fire?
    - Does fire in RSW-infested areas change the structure and composition of native plant communities?

7. Develop fire Best Management Practices (BMPs). Fire, either prescribed or lightning-ignited, is an integral part of the landscape and land management activities. Development of BMPs for RSW in frequently burned areas is a necessary part of an overall management strategy for this invasive plant.

8. Encourage and increase RSW control efforts on private lands.
Strategies must be developed to control the plant on private lands. Ultimately, education and incentives for private landowners may be the best tools to improve control of infestations on private lands. Innovative ideas are needed to develop ways and means to more effectively reach private landowners.

9. Increase awareness and cooperation among land managers. All
natural-area managers need to be keenly aware of RSW infestations on properties

they manage. Those working in the field of natural resource management should be able to readily identify and the plant treat it with the most up-to-date method. New infestations should be treated immediately, with monitoring and re-treatments made top priorities. All land managers should be trained to follow monitoring protocols consistent across all agencies, and should submit all data to an established, central data clearinghouse.

For a listing of RSWTF members and an outline of the priorities and recommendations from the 2007 RSW Summit, please refer to Appendices 1 and 2, respectively.

Technical Background

Biology

Taxonomy and Classification

Rush skeletonweed (RSW)
Chondrilla juncea L.

Common Names

Native Range chondrilla, skeletonweed, chondrille, *chondrille à tige de jonc*, *chondrille effilée*, Binsen-Knorpellattich, Grosser Knorpellattich

North America rush skeletonweed, skeletonweed, hogbite, nakedweed, gum succory, rush-like gum-succory, devil's-grass

Australia skeleton weed, gum succory, nakedweed

South America condrila, gum succory (yuyo esqueleto)

Synonyms

There are no botanical nomenclature synonyms for this species (USDA PLANTS Database 2009).

Classification

Kingdom	Plantae (Plants)
Subkingdom	Tracheobionta (Vascular plants)
Superdivision	Spermatophyta (Seed plants)
Division	Magnoliophyta (Flowering plants)
Class	Magnoliopsida (Dicotyledons)
Subclass	Asteridae
Order	Asterales
Family	Asteraceae
Genus	*Chondrilla*
Species	*Chondrilla juncea* L.

Asteraceae is the largest plant family (number of species) in North America north of Mexico, with 418 genera and 2,413 species (Flora of North America, 2009). Because of its large size and great diversity worldwide, the Asteraceae family has been divided into numerous tribes, a classification level below family and above genus. Recent phylogenetic data contradict traditional tribal classifications, making it impossible to state the exact number of tribes in this family; however, the genus *Chondrilla* is undisputedly a member of the tribe Cichorieae. This tribe is most easily identified by the milky sap exuded from damaged foliage (Fig. 1). Cichorieae is represented by approximately 100 genera and 1,600 species worldwide and 49 genera and 229 species in North America (Flora of North America, 2009). There are approximately 25 species within *Chondrilla*, out of which only RSW occurs in North America (USDA NRCS 2009).

Figure 1. Milky latex in rush skeletonweed (Rachel Winston, MIA Consulting).

The name "*Chondrilla*" is derived from the Greek word *chondrile,* from *chondros*, meaning "gristle," and likely refers to this species' wiry stems (Parsons and Cuthbertson 2001). The specific epithet of RSW, *juncea*, is from *juncus* (the Latin name for rushes) and refers to the plant's rush-like stems (Old 1981).

Morphology

Much of the following information was obtained from Hitchcock and Cronquist 1973.

Rush skeletonweed (RSW) (Fig. 2) is a herbaceous perennial that can reach heights of 1.2m (4 ft). Rosettes consist of numerous hairless leaves, each wider at the tip than the base.

Figure 2. Morphology of rush skeletionweed (USDA NRCS PLANTS Database).

Each leaf is 4–13 cm (2 to 5 in) long and 15–45 mm (0.6 to 1.8 in) wide (Fig. 3a). Lobes of rosette leaves are irregular, opposite each other, and point backwards. Leaves are often tinged with purple or reddish-brown, especially along margins and near leaf tips. Plants have one or more flowering stems with multiple spreading and ascending branches (Fig. 3b). Stems often lack leaves. When present, stem leaves are small, linear, 2–10 cm (0.8 to 4 in) long and 1–8 mm (0.04 to 0.3 in) wide. As flowering stems bolt and mature, basal and stem leaves often whither; upper leaves are at times no more than scale-like bracts (McVean 1966). Upper portions of stems are not hairy, but there are many stiff, downward pointing hairs at the base of flowering stems (Fig. 3c).

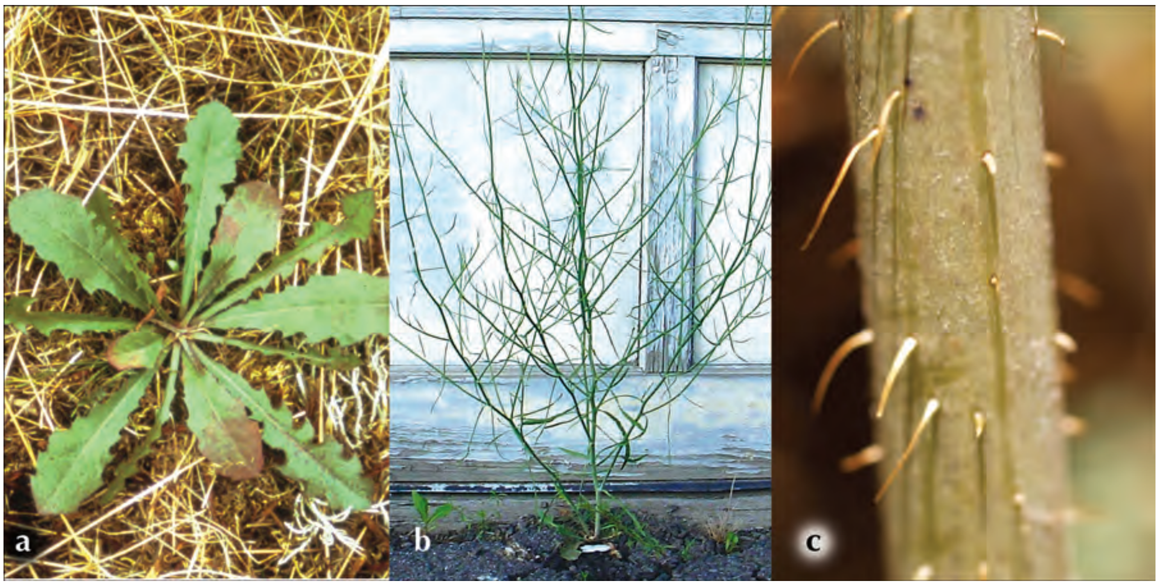


Figure 3. **a)** Rush skeletonweed rosette (Utah State University Archive, Utah State University, UGA1459571): **b)** RSW stems (Richard Old, XID Services Inc., UGA 5230050); **c)** downward pointing hairs (Rachel Winston, MIA Consulting).

Flower heads are produced along and at tips of branches, either solitary or in clumps of two to five. Each flower head consists of nine to twelve bright yellow flowers (Fig. 4a). Flowers themselves (each resembling one single petal) consist of five fused petals, their individual tips separate at the ends of flowers. The involucre (base of the flower head) is small, only 9–12 mm (0.4 to 0.5 in) tall, and attached directly to a branch or via a short stem. Bracts are cylindrical as a unit and occur in two unequal rows at the base of the involucre, the outer row being much smaller than the inner. Fruits of RSW are achenes (hereafter referred to as seeds). They are oblong, hairless, tapered at both ends, pale to dark brown, 3–4 mm (0.1 in) long, with many lengthwise ribs. At the distal end of each seed is a large amount of pappus consisting of numerous, fine, white bristles 5 mm (0.2 in) long, similar to the pappus of dandelion seeds (Fig. 4b). Characteristic of all species in the Cichorieae tribe is the milky latex that exudes from cut or broken RSW leaves, stems, and roots (Fig. 4c).

Figure 4. **a)** Rush skeletonweed flower; **b)** pappus; **c)** milky latex exuding from cut leaf, Schirman and Robocker, 1967. All Photos, Rachel Winston, MIA Consulting.

Taproots of RSW are slender, deep (2 m or 6.5 ft long), persistent, and have short lateral branches along their length. Taproots can become somewhat woody with age. Most lateral roots are short-lived, non-woody, and less than 8 cm (3 in) long, but some near the surface can become rhizome-like and grow laterally, most often in very sandy, gravelly, or waterlogged soils (Old 1981).

Variation

There are hundreds of morphological forms or biotypes of RSW (Chaboudez 1994). These are sometimes differentiated by leaf morphology, height, branching patterns, or flowering times. Likewise, many of the morphological differences between variants correspond to true genetic differences between biotypes (see "Distribution and Impacts," page 18).

Similar Species

Numerous species present in the western U.S. are similar in appearance to RSW, especially those in the same family and tribe (Fig. 5). For greater ease of identification, some of these species are discussed, utilizing characteristics found in Hitchcock and Cronquist (1973).

Rosette leaves of RSW are very similar in appearance to dandelion (*Taraxacum officinale*), chicory (*Cichorium intybus*), and yellow starthistle (*Centaurea solstitialis*). Both dandelion

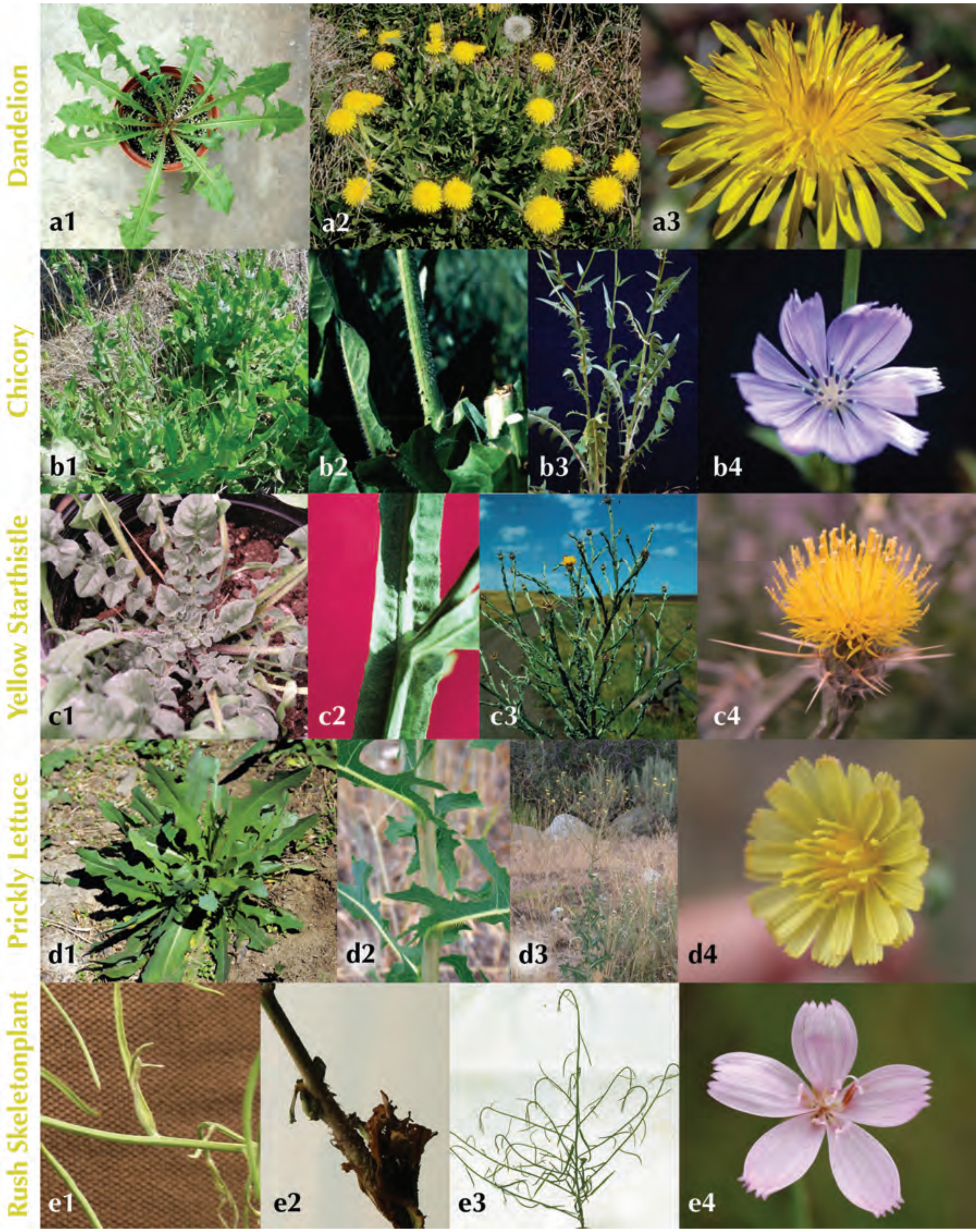


Figure 5. **a1)** Lynn Sosnoskie, Univ. of Georgia, UGA 5140008; **a2)** Howard F. Schwartz, Colo. State Univ., UGA 5364473; **a3)** Chris Evans, River to River CWMA, UGA 1380079; **b1)** Richard Old, XID Services, Inc., UGA5230070; **b2** and **b3**) Ohio State Weed Lab Archive, Ohio State Univ., UGA 1551015 and UGA 1553154; **b4)** John Cardina, Ohio State Univ., UGA 1553157; **c1)** Rachel Winston, MIA Consulting; **c2** and **c3** Steve Dewey, Utah State Univ., UGA 1459660 and UGA 1459656; **c4)** Rachel Winston, MIA Consulting; **d1)** Ohio State Weed Lab Archive, Ohio State Univ., UGA 1553223; **d2**, **d3** and **d4,** Mary Ellen Harte, UGA 5097017, UGA 5097019, UGA 5097021; **e1**, **e2** & **e3** Rachel Winston, MIA Consulting; **e4)** Glen Regina.

and RSW have leaves without hairs, leaf lobes pointing backwards and opposite each other, and exude a milky latex when cut or torn. Unlike RSW, dandelion has hollow, unbranched, leafless, fleshy flowering stems, and its flower heads are much larger than RSW. Chicory and yellow starthistle differ from RSW in that their rosette leaf lobes point outwards or forwards and are not always opposite. Chicory basal leaves often have scattered, coarse hairs, and flowers are blue. Yellow starthistle plants are grayish-green, covered in fine hair, and produce flower heads with very long, spiny bracts.

Prickly lettuce (*Lactuca serriola*) is similar to RSW in that it has stiff hairs at the base of the plant, comparable flowers, and foliage that exudes a milky latex when cut or torn. However, the stiff hairs of prickly lettuce extend along the entire stem of the plant and along the undersides of leaf margins. Furthermore, prickly lettuce usually has just one main flowering stem, with several ascending branches growing from the top half of the stem. Rush skeletonplant (*Lygodesmia juncea*), native to many parts of North America, is also similar to RSW. Rush skeletonplant exudes latex when stems or leaves are broken, but lacks a winter rosette, has pink flowers, and grows only 10–40 cm (4 to 16 in) tall.

Growth and Reproduction

Rush skeletonweed is an obligate apomict: it always produces seeds without fertilization (Wells 1971). This breeding system is often beneficial to an invasive species in an area where environmental factors, other RSW plants, or pollinators may limit growth. Pollinators have been observed visiting the plant in both native and introduced ranges (McVean 1966). Though many of these visits serve no function for RSW (McVean 1966), some diploid sexual plants have been discovered in Turkey (Hasan et al. 1995).

Autumn rains stimulate seedling germination with seedlings or rosettes overwintering (Panetta and Dodd 1987). Increasing day length (usually a photoperiod of 8 to 14 hours) in spring induces flowering stems to bolt and branch (Caso and Kefford 1968). Rosette and stem leaves wither during this stage; photosynthesis takes place in the green stems (Martin 1996). While RSW has no absolute requirement for vernalization (cold temperature exposure as in a winter setting), bolting and flowering accelerate with this process (Panetta and Dodd 1987). RSW plants less than one year old are capable of producing seeds (Panetta 1989). Temperatures must reach at least 15 °C before flowers will be produced; flower production is also dependent on moisture availability (McVean 1966). First-year plants typically produce 50 to 150 flower heads, which equates to 500 to 1,500 seeds per plant. Longer-lived individuals are capable of producing much more—20,000 seeds per plant on average (McVean 1966).

Seeds are readily dispersed by wind and carried long distances via their bristly pappus (Panetta and Dodd 1987). Animals can transport the seeds as well, because the rough seed coat readily attaches to fur. Seed viability is relatively high, with 60% to 100% of seeds germinating in most greenhouse and field experiments (Liao et al. 2000). Germination is dependent on moisture availability and temperature, but independent of light availability (Cuthbertson 1970). Seeds germinate at between 7 and 40°C (45 and 104°F), but rates are increased under the optimal temperature of 25°C (77°F) (Liao et al. 2000). Seeds on the soil surface (where water is not stored) and in clay soil (where water is difficult to access) germinate with less success than seeds slightly buried in loamy or sandy soil (McVean 1966). Seedlings require a continuous supply of water for 3 to 6 weeks following germination (Cullen and Groves 1977). Consequently, seedlings that germinate in the summer following a single rain event often die of desiccation shortly thereafter, whereas seedlings that germinate in the fall often receive water from subsequent rainfalls and survive (Panetta 1988). Disturbance of the soil is a very important contributor to RSW seedling establishment (McVean 1966). High levels of calcium, phosphorus, and nitrogen also support greater germination rates of RSW than do soils with low levels (McVean 1966). Seedlings are also sensitive to shading from other plants, surviving better in areas with little competition for light (Schirman and Robocker 1967). The vast majority of seeds germinate within one year, but the soil seed bank can produce RSW seedlings several years after seed drop (Liao et al. 2000).

Seed dispersal is most often responsible for the distant spread of this species. However, the majority of local-population increase is due to vegetative regeneration (Panetta and Dodd 1987). In undisturbed plants, adventitious buds near the top of the taproot and on major lateral roots can produce several new rosettes sharing a common root system (Rosenthal et al. 1968, Old 1981). When the original lateral root connection with the parent plant breaks down, these rosettes can form their own roots to become satellite plants. Infestations of RSW may spread by as much as 0.6 m (2 ft) per year through satellite plants formed along lateral roots (Old 1981, Fig. 6). Lateral roots occur more commonly on RSW growing in sandy soils and in sparse stands than in dense stands of RSW or in loam or clay soil (Zouhar 2003). The majority of RSW roots, especially deeper parts, are brittle and easily fragmented. Pieces as small as 1–2 cm (0.4 to 0.8 in) can produce new rosettes from depths to 1 m (3.2 ft), though success often depends on plant biotype and age, and soil and climatic conditions (Cuthbertson 1972). Roots of older plants are thicker and store more carbohydrates than roots of young seedlings; therefore, fragments of older plants have higher regenerative capacities as well as an increased probability of avoiding desiccation (Cuthbertson 1972).

Figure 6. Rush skeletonweed root system, Utah State University Archive, UGA 1459568.

Distribution and Impacts

Native Range Distribution

The genus *Chondrilla* is most diverse in the submontane region surrounding the Caspian Sea, so this area is thought to be the origin of RSW (Panetta and Dodd 1987). The species is considered native to the Mediterranean region and from Western Europe to Central Asia and southern Russia to Northern Africa (McVean 1966, Fig. 7). Typically, it can be found growing between 35°N and 55°N latitude and at elevations between sea level and 1,800 m (5,900 ft) (McVean 1966). Dense infestations of RSW require a particular combination of climate, soil and disturbance. This combination is not as common in the native range of Western Europe and the Mediterranean as it is in some invaded regions. Consequently, RSW growing in the native range is often found in scattered, localized populations rather than dense infestations (Wapshere et al. 1974).

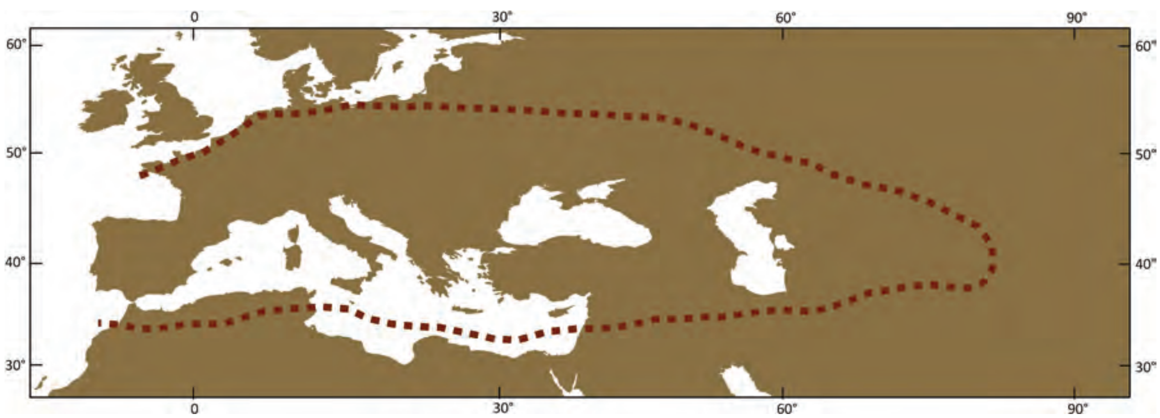


Figure 7. Native (European) distribution of rush skeletonweed is enclosed within the broken line. Redrawn from McVean (1966).

Native Range Ecology

Throughout its native range, RSW grows best in Mediterranean and steppe climates characterized by cool winters and hot, dry summers (Wapshere et al. 1974). Typical annual rainfall in RSW native regions is between 384 and 700 mm (15 to 28 in) (Wapshere et al. 1974, Wapshere et al. 1976). Rush skeletonweed does not occur in the cool, maritime climates of extreme Western Europe; increased moisture may inhibit RSW by promoting the growth of competitive species (Wapshere et al. 1974). Timing of precipitation is important for the establishment and spread of RSW. In areas where infrequent summer showers are followed by severe drying, the RSW seed bank is often depleted as seedlings die of desiccation following germination; thus spread by seed is limited (McVean 1966, Cuthbertson 1970, Panetta 1988). Consequently, RSW does not occur in the desert climates of central Algeria or southern Iraq.

In its native region, RSW is most often found in coarse-textured, well-drained soils such as sand dunes and granitic outcrops (McVean 1966, Wapshere et al. 1974). Coarse textured soils, among other things, facilitate lateral root growth and horizontal spread (Old 1981). Favored soils contain calcium carbonate and are mildly acidic and low in nutrients (Wapshere et al. 1974, Wapshere et al. 1976). Establishment and persistence of RSW are highest in soils that support mesic-xeric to xeric plant communities that naturally display very low density plant cover, a trait conducive to RSW seedling establishment (Schirman and Robocker 1967).

Rush skeletonweed is an early succession species, capitalizing on disturbance of the soil for establishment and spread. Disturbance by cultivation, soil erosion, road grading and overgrazing weaken existing plant communities and decrease plant cover, all of which favor RSW establishment and persistence (Wells 1971). Throughout its native region, RSW is found in highly disturbed sites, including roadsides, river banks, dry river beds, degraded coastal dunes, eroded ground and in fallow and abandoned fields (Wapshere et al., 1974, Wapshere et al. 1976). It can be found as a constituent of several different plant communities, including needlegrass-sagebrush (*Achnatherum/Stipa-Artemisia*) steppe in Russia, Iraq, Anatolia and Eastern Europe; open, semi-natural communities in the Mediterranean region; upper oak scrubs of Kurdistan and Khalifan in Iraq; thin pine forests on sandy soils in part of Russia; and degraded, weedy coastal dune sites in southern France (Wapshere et al. 1974, Wapshere et al. 1976).

Economic Uses

Rush skeletonweed has little recorded economic value in its native range. Sheep graze the rosette and early flowering plant (Cuthbertson 1967, Fig. 8). Cattle and horses will graze the tips of flowering stems early in the season, before the stems become lignified (see Cultural

[**Figure 8**. Sheep grazing. Howard F. Schwartz, Colorado State University, UGA 5359505.

Control, page 43). When rainfall is sufficient to support the production of numerous flowers, RSW can be a major source of pollen, and golden colored honey can be produced from its nectar (Clemson 1985 as cited in Panetta and Dodd 1995).

Numerous sources cite this species as a food source and for its medicinal properties. The leaves, both cooked or raw in salads, have a mild and pleasant taste, and were historically consumed by Europeans (Flora Europaea 1964–1980, Hedrick 1972, Kunkel 1984). The plant was also used as a stomachic (Hedrick 1972), a medicine that tones the stomach, improving its function and increasing appetite. (Note: The RSWTF does not vouch for nor promote the historical uses of this species.)

Distribution and Ecology in the United States

Rush skeletonweed was inadvertently introduced into the eastern United States during the 1870s (Schirman and Robocker 1967), and is now most often found between 35°N and 50°N latitude and at elevations between 300 and 950 m (900 to 3,000 ft) (Old 1981, Hickman 1992). It is currently established on both coasts and in some interior states and Canadian provinces. However, because RSW is difficult to find along the eastern seaboard, it is not considered an important weed in that region (L. Kinter, Idaho Department of Fish and Game, pers. comm.). Western U.S. infestations began with RSW-contaminated orchard and vineyard rootstocks introduced from the Mediterranean around 1900. The plant was first reported in Washington State in 1938 (Old 1981). It appeared in Idaho in 1960, in California in 1965, in Oregon in 1971, and in Montana in 1991 (Old 1981, Sheley et al. 1999). In Idaho, the infested area increased from 20 hectares (ha) (49.4 acres) in the 1960s to 1.4 million ha (6 million acres) in the mid 1980s (Piper and Andres 1995). Throughout the 1970's, this weed infested an estimated 809,000 ha (2 million acres) in eastern Washington, 73,000 ha (180,000 acres) in western Oregon and 408,000 ha (1 million acres) in northern California (Cheney et al. 1981, Coleman-Harrell et al. 1979). Since the 1980s, RSW has been reported in Montana and the Canadian province of British Columbia. The extent of RSW infestation in North America now exceeds 2.5 million ha (6.2 million acres) (Sheley et al. 1999). South and central Idaho currently serve as the "heart" of the western infestations, with RSW continuously spreading outward from these heavily-invaded regions (Fig. 9).

Throughout its introduced range in the western U.S., RSW grows best in Mediterranean- and steppe-like climates, characterized by cool winters and hot, dry summers (Old 1981, Wapshere et al. 1974). Typical annual rainfall in U.S. RSW-infested regions is between 250 and 1,000 mm (10 to 40 in) (Liao 1996). Generally, the soil at infestations is coarse-textured, deep, and well-drained, but in some instances it is shallow over bedrock or of glacial origin (Old 1981).

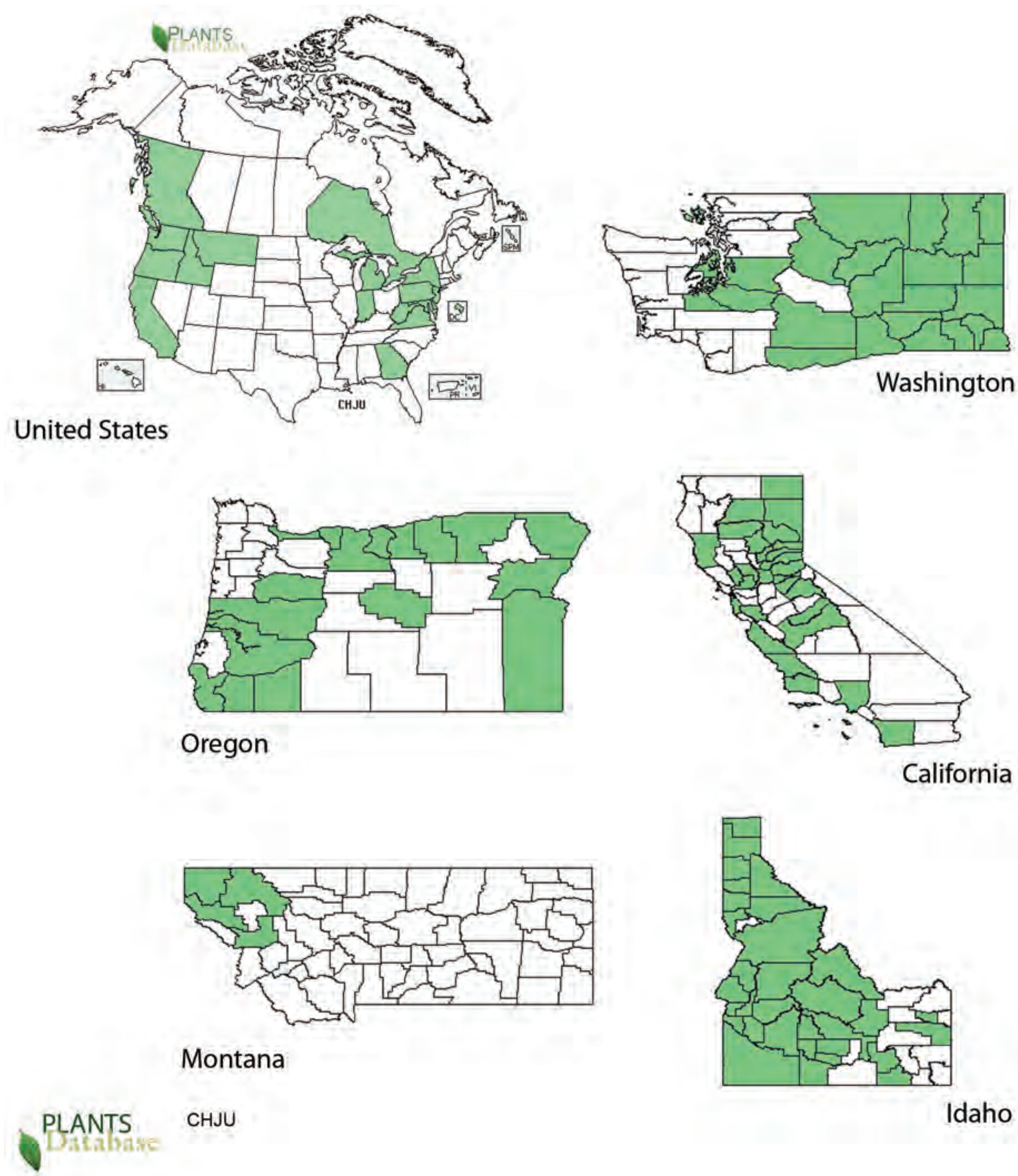


Figure 9. Distribution of rush skeletonweed in North America and the western United States.

In western North America, RSW is commonly found in heavily disturbed areas including railroads, roadsides, overgrazed rangeland, river banks, fallow fields and abandoned lots (Hitchcock and Cronquist 1973, Old 1981). Habitat types and plant associations include a variety of native communities that have been heavily altered by grazing, trampling, cultivation, logging, and burning (Old 1981, Zouhar 2003). Some examples of typical communities of the channeled scablands and much of the open rangeland of the West are: bluebunch wheatgrass-Sandberg bluegrass (*Pseudoroegneria spicata-Poa secunda*); stiff sagebrush-Sandberg bluegrass (*Artemisia rigida-P. secunda*). Examples of increasing-elevation and open-forest communities are: ponderosa pine (*Pinus ponderosa*); common snowberry (*Symphoricarpos albus*); and Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*). In many of these environments, non-native plants are often better indicators of site potential than are native plants. Areas with significant numbers of exotic plant species are indicative of the large-scale disturbance regime favored by RSW (Old 1981, Zouhar 2003).

Variation

There are three morphological variants or biotypes of RSW currently recognized as established in the U.S. (Rosenthal et al. 1968, Old 1981, Harris 2003): 1) Banks, 2) Washington early-flowering, and 3) Washington late-flowering. Characteristic descriptions of each type vary tremendously in the literature. Rosenthal et al. (1968) cite Type 2 as flowering from mid-June to July, being bushy and compact in appearance, and growing to a maximum height of 60 cm (24 inches). The authors cite Type 3 as flowering 15 to 30 days later than Type 2, having thick stems and growing upright to a maximum height of 120 cm (47 inches) (Rosenthal et al. 1968). Harris (2003) states both Type 2 and 3 grow to a maximum height of 120 cm and differ only in the timing of flowering (Type 2 in July and Type 3 in August). Type 1 is reputed to be similar to Type 3 in its later flowering period from late July to early August, but differs in its maximum height of 90 cm (Harris 2003).

Each RSW biotype reacts in a unique way to environmental conditions and differs from other RSW biotypes in its susceptibility to control methods. Therefore, understanding the biotype of target infestations aids land managers in optimizing control strategies. Consequently, numerous studies have been conducted to find a genetic basis, rather than purely morphological, for separating biotypes of RSW. Some of the original studies conducted utilized isozymes to determine that the three variants of RSW described above demonstrated three distinct isozyme patterns (Hasan et al. 1995). However, studies are utilizing AFLPs (Amplified Fragment Length Polymorphisms) which allow for more precise fingerprinting than isozymes to determine the number of genotypes present in North America. Although these studies are ongoing, preliminary results indicate the presence of not three but five genotypes of RSW in western North America (genotypes 1, 1a, 2, 3, 3a, Fig. 10) and two other distinct genotypes found on the East coast (genotypes 8, 9, Fig. 10) (J. Gaskin, USDA-ARS,

Figure 10. Genotype distribution of rush skeletonweed in US based on analyses of 72 RSW plants. J. Gaskin, USDA-ARS, M. Schwarzländer, University of Idaho, L. Kinter, Idaho Department of Fish and Game, G. Markin, USDA Forest Service, unpublished data.

M. Schwarzländer, University of Idaho, L. Kinter, Idaho Department of Fish and Game, G. Markin, USDA Forest Service, unpublished data).

Distribution and Ecology in Australia

Rush skeletonweed was first reported in Wagga Wagga, Australia around 1918 (McVean 1966, Panetta and Dodd 1987). By the 1930s it had spread through much of Victoria, likely via fodder from New South Wales (Parsons and Cuthbertson 2001). The heaviest infestations were initially in the cereal growing area of New South Wales and Victoria, and later spread into Western Australia and throughout the Australian wheat belt (Panetta and Dodd 1987). Bioclimatic prediction techniques indicate virtually all of the western Australian wheat belt is climatically suitable for RSW (Panetta and Dodd 1987 and references therein). To date in Australia, RSW is most often found between 26°S and 38°S latitude (Fig. 11) and at elevations between sea level and 1,650 m (5,400 ft) (McVean 1966).

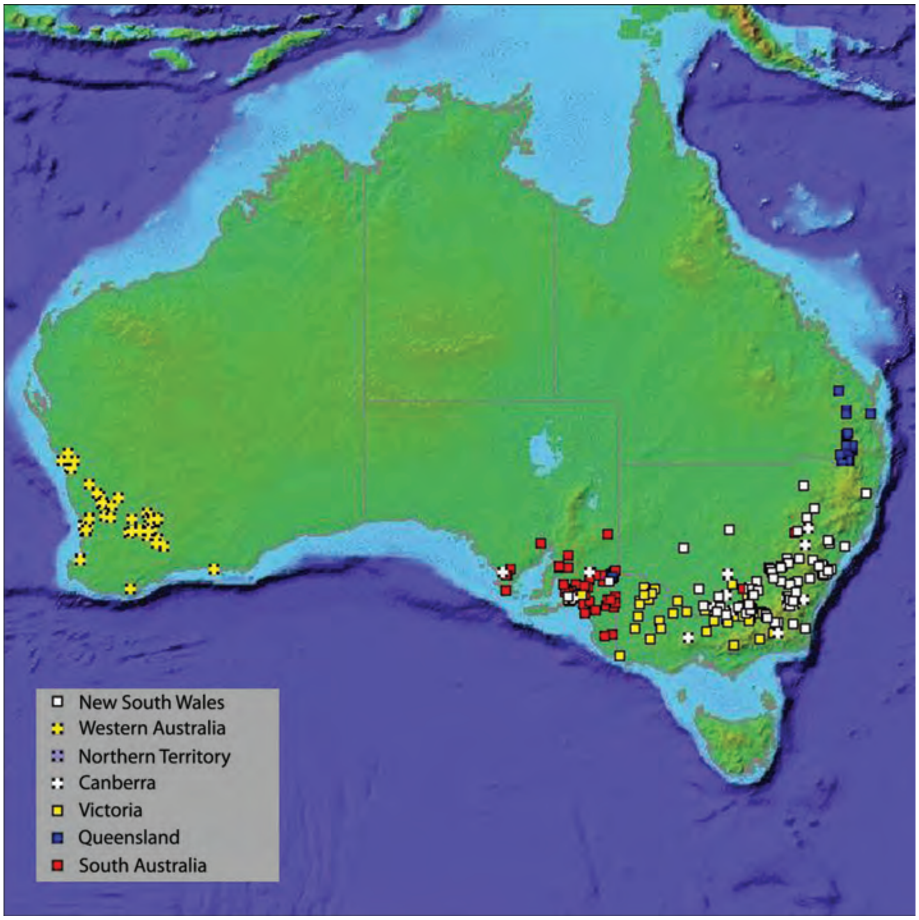


Figure 11. Invasive distribution of rush skeletonweed in Australia. Australia's Virtual Herbarium. http://www.rbg.vic.gov.au/cgi-bin/avhpublic/avh.cgi

Throughout its introduced range in Australia, RSW grows best in Mediterranean and steppe climates characterized by cool winters and hot, dry summers (McVean 1966). Typical rainfall in Australian RSW-infested regions is between 230 and 1,520 mm (9 to 60 in) annually (Wells 1971). Infestations of RSW in Australia have been observed on most soil types though most frequently on deep sands, sandy loams, and sandy-clay loams and not at all on heavy clay soils (Cullen 1977, Panetta and Dodd 1987).

In Australia, RSW occurs at highest densities in annual pastures that follow crops such as those under a wheat/fallow system. In fact, the extent of wheat cropping often coincides with the inland distribution of RSW (McVean 1966). This weed species forms tall and very dense infestations along roadsides and other places subjected to repeated disturbance. Throughout Australia, RSW typically does not invade native or improved pasture, though it may establish dense stands in native pastures weakened by drought and/or overgrazing (McVean 1966, Panetta and Dodd 1995 and references therein). Habitat types and plant associations with which RSW is associated in Australia include eucalyptus (*Eucalyptus* spp.), savanna woodland, and needlegrass (*Stipa* spp.) grasslands (McVean 1966).

VARIATION

There are three morphologically distinct forms or biotypes of RSW currently recognized as established in Australia: A, B and C (Hull and Groves 1973, Fig. 12). These can be distin-

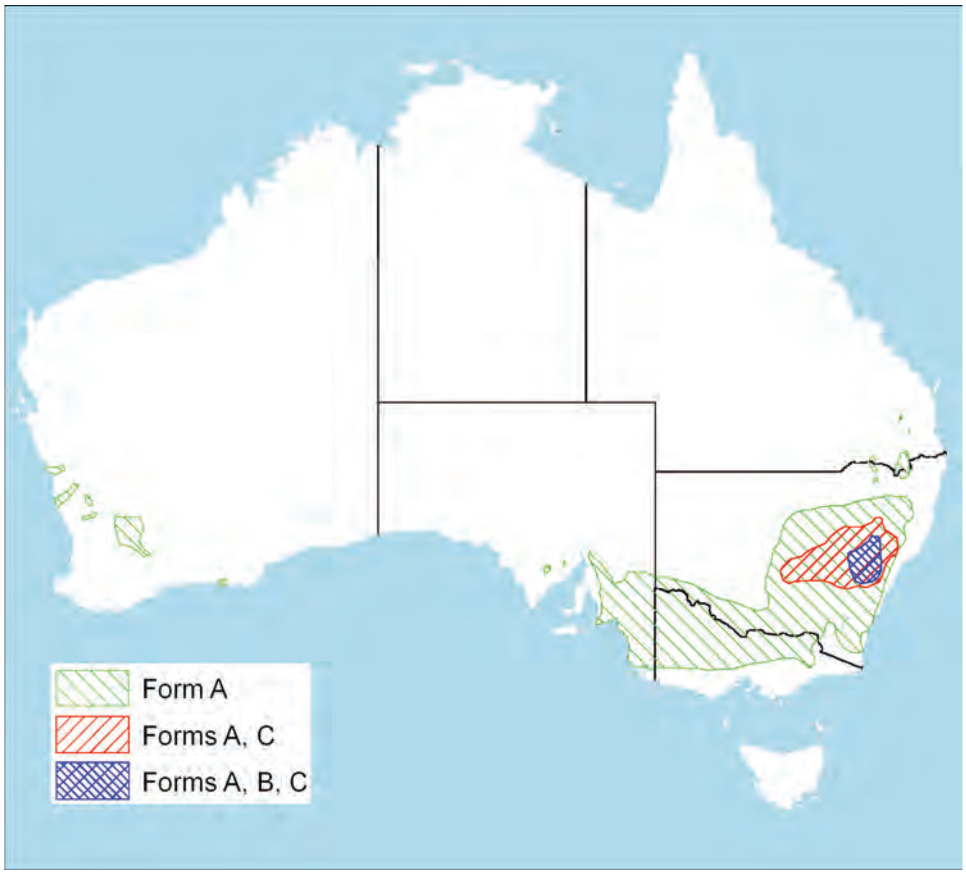


Figure 12. Morphological biotype distribution in Australia in the 1960s and 1970s. Redrawn from Hull and Groves (1973) and Cullen and Graves (1977).

guished by the shape of rosette leaves, inflorescence morphology, fruit characteristics, and regenerative potential from root fragments (Fig. 13). Form A has narrow-shaped rosette leaves and branching usually occurring at close to a 90° angle from the main flowering stem. Both Form B and C have more tertiary branching than has Form A. In comparing Forms B and C, they can be distinguished from one another as follows: rosette leaf shapes are intermediate in Form B and broad in Form C; branching is more acute in Form B than in Form C; stem leaves show a greater degree of development in Form C than in Form B (Hull and Groves 1973).

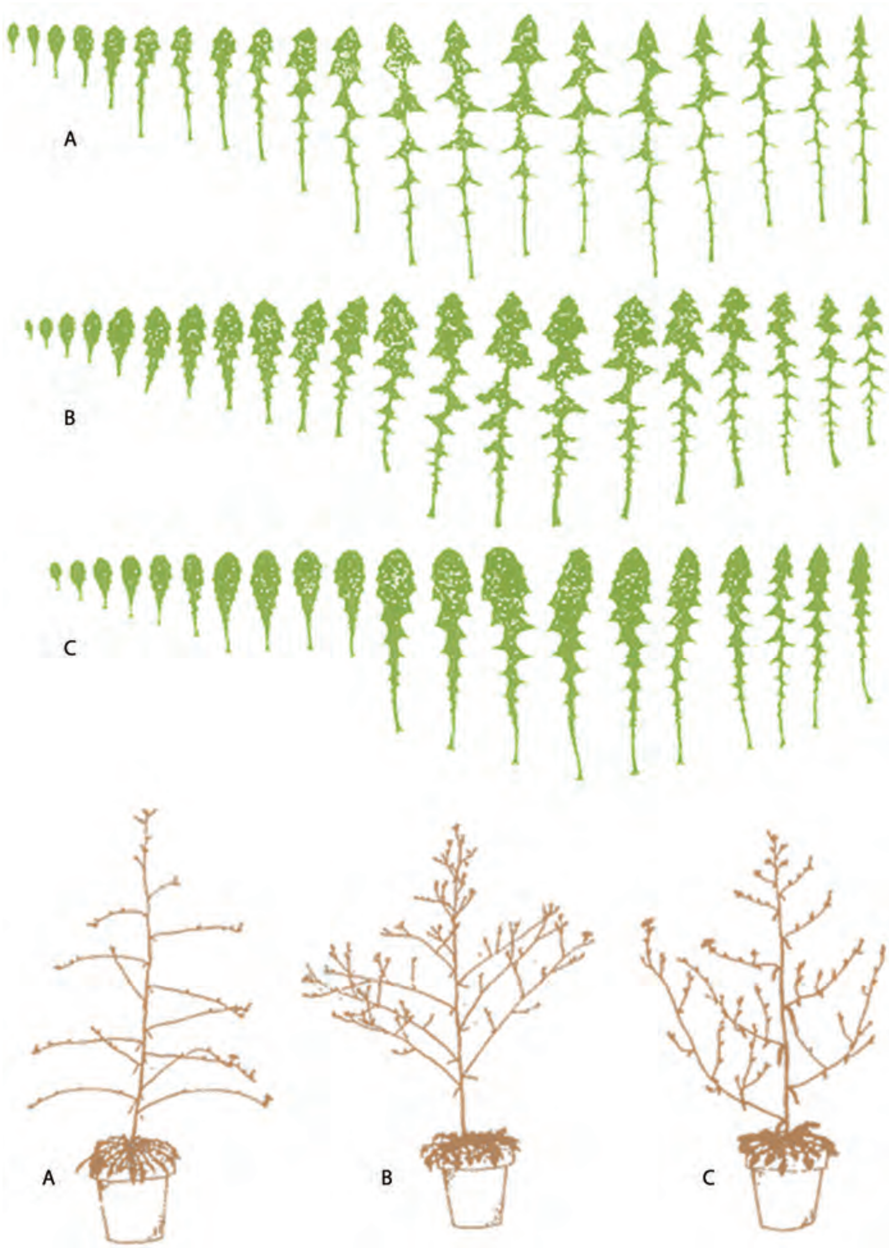


Figure 13. Morphological variation of the three recognized forms of rush skeletonweed established in Australia. Redrawn from Hull and Groves 1973.

Isozyme patterns of five enzyme systems also differentiate these three forms (Chaboudez 1994). Shepherd (1991) genetic differences among the three biotypes. Using her own enzyme analyses, Shepherd (1991) confirmed that each of the three biotypes is genetically different from the others. Using her own enzyme analyses in the 1980s, Shepherd found that Forms A and C were the most common and Form B was only found in low numbers and limited distribution.

Ongoing studies utilizing the more precise AFLP method confirm there are three genotypes currently established in Australia (genotypes 5, 6, 7, Fig. 14), and that they are distinct from genotypes found in North America and Argentina (J. Gaskin, USDA-ARS, M. Schwarzländer, University of Idaho, L. Kinter, Idaho Department of Fish and Game, and G. Markin, USDA Forest Service, unpublished data).

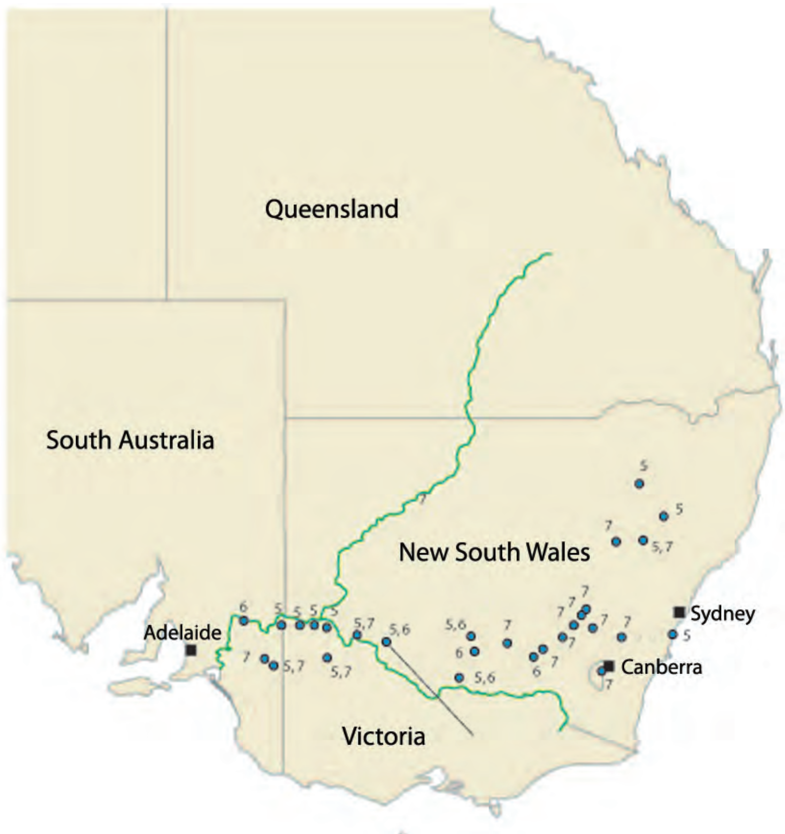


Figure 14. Distribution of rush skeletonweed genotypic variation in Australia based on analyses of 260 RSW plants. J. Gaskin, USDA-ARS, M. Schwarzländer, University of Idaho, L. Kinter, Idaho Department of Fish and Game, G. Markin, USDA Forest Service, unpublished data.

Distribution and Ecology in South America

Rush skeletonweed was introduced to Argentina inadvertently with seed for cereal crops in 1977. It is now well-established in over 100,000 ha (247,000 acres) in the administrative regions of Guamini, Alsina, Coronel Suárez, Saavedra and Tomquinst within the province of Buenos Aires (de Crouzel et al. 1983, Fig. 15). Because of its rapid spread since introduction, it was declared a national plague of agriculture in Disposition 52/77 of the State Department of Agriculture. RSW invades sandy fields, mainly in fine crop stubble, throughout the agricultural regions of Argentina (Tortosa and Medan 1978).

Figure 15. Distribution of rush skeletonweed in administrative areas of the province Buenos Aires in Argentina ca 1983.

Variation

A single AFLP genotype (genotype 4) has been found in Argentina; it is distinct from genotypes found in Australia and North America (J. Gaskin, USDA-ARS, M. Schwarzländer, University of Idaho, L. Kinter, Idaho Department of Fish and Game, G. Markin, USDA Forest Service, unpublished data).

Worlwide Genotypic Variation of RSW

Rush skeletonweed is an apomictic species; therefore, particular gene combinations would be expected to remain unchanged in the short term (Panetta and Dodd 1995). However, over time new variants may arise through auto segregation or random mutation. The different biotypes of RSW currently observed in the U.S., Australia and South America could be the result of auto segregation and mutation; however, this is unlikely given the level of genetic difference between most genotypes. It is much more likely that multiple introductions of different biotypes of RSW from its native range are responsible for the different RSW biotypes observed throughout the world.

Distinct biotypes have unique reactions to environmental conditions and differ from one another in their susceptibility to control methods; therefore, understanding the biotypes of target infestations and how they compare to biotypes of RSW in other regions will help land managers identify optimal control options for each biotype. AFLP studies currently underway will not only help identify genotypic variation in the different regions where RSW has established, but also help determine relationships among any genotypes identified. Matching morphotypes or biotypes between invasions and the native range is not possible due to the large amount of variation found in Eurasia. Hasan et al. (1995) found relatively close matches between U.S. and Eurasian genotypes, but the ongoing AFLP study should find more precise matches and could lead to the discovery of effective biological control agents specific to each invading genotype. (J. Gaskin, USDA-ARS, M. Schwarzländer, University of Idaho, L. Kinter, Idaho Department of Fish and Game, and G. Markin, USDA Forest Service, unpublished data).

Impacts in the United States, Australia and South America

United States

Rush skeletonweed is one of the most problematic nonnative plant species threatening rangeland, forests, agriculture, and conservation areas in the West. (Quinney 2000). This species is extremely adaptable and resilient, and as such threatens diverse habitats under a myriad of conditions. Rush skeletonweed forms dense monocultures on the wintering range of elk and deer, displacing native vegetation and decreasing forage production and/or biodiversity (Sheley et al. 1999). Although young rosettes are nutritious and often eaten by livestock (J. Little, Rancher, Emmett ID, pers. comm.), cattle still prefer grasses to RSW. Consequently, grazing RSW-infested pastures or rangeland often favors the expansion of RSW. Because lignified flowering stems of RSW are not palatable to most domestic cattle and sheep (Cuthbertson 1967), when these animals graze infested regions during the RSW flowering stage, RSW populations increase even more. It has yet to be quantified, but it is believed that the U.S. ranching industry is impacted heavily by RSW infestations because meat production decreases appreciably as suitable food becomes scarce (Sheley et al. 1999).

In the West., RSW is spreading most rapidly on rangelands (Liao et al. 2000). However, its propensity to compete aggressively for light, water, and nutrients (especially nitrogen) makes this species a major concern for agricultural crops (Schirman and Robocker 1967). Though not well documented, in some portions of Idaho and Oregon, RSW has reduced annual wheat yields by 26 to 42% (Cheney et al. 1981, Fig. 16).

Figure 16. Rush skeletonweed infestation in grain crop. Gary Piper, Washington State University, UGA 0022089.

Australia

Rush skeletonweed is the most serious weed of Australian wheat-growing regions (Cuthbertson 1967, Groves and Cullen 1981). The impact of this species on cereal crops is two-fold:

1. Rush skeletonweed individuals utilize limited moisture and nutrients (especially nitrogen) during and between growing seasons, thus out-competing crop species (Cuthbertson 1967).
2. The wiry stems and milky latex of RSW flowering branches interfere with harvesting processes by clogging machinery (Wells 1971).

Competition for moisture becomes especially problematic late in the growing season as grain heads are filling and water demand is high. RSW moisture competition has been shown to decrease cereal yields by 78% (Wells 1970, Cullen 1978). Competition for nitrogen and other nutrients is responsible for cereal yield losses as high as 50% in wet years when water is not limiting (Groves and Cullen 1981). During the 1930s, RSW competition with grain crops was responsible for low yields, difficulties of harvesting, and depressed prices, all of which led to cereal farms being abandoned or converted to pastures (Panetta and Dodd 1995). In one wheat-producing area alone, between 1946 and 1955, over 15,000 ha (37,000 acres) of cropland were converted to pasture (19,000 ha (46,000 acres) in 1946 to 61,000 ha (150,000 acres) (Old 1990 and references therein). The threat RSW posed to the Australian wheat industry was so great during this time that the New South Wales Government offered a prize of £5,000 for the development of a successful eradication method (Old 1981). The reward went unclaimed (Panetta and Dodd 1995).

Sheep, goats, horses, and cattle readily feed on RSW while in the rosette and early-flowering stages, before flowering stems become lignified (Cuthbertson 1967). Continuous grazing keeps the plant from bolting at all when other green feed is scarce (Panetta and Dodd 1995). However, this heavy feeding is considered by many to be overgrazing. When livestock are moved as part of rotational grazing, RSW quickly recovers, bolting and spreading rapidly (Panetta and Dodd 1987).

Heavy infestations of RSW in pastures deplete nitrogen and other nutrients, interfering with the growth of sown fodder plants (Currie 1936). There are claims that the best fat lambs in the Riverina come from pastures heavily infested with RSW (Cuthbertson 1967); however, it should be noted that the deliberate sowing of RSW is undocumented (Parsons 1973). The importance of RSW in comparison to native and/or noninvasive pastoral vegetation should not be overemphasized (Panetta and Dodd 1995). Furthermore, the flowering stem of RSW has been known to cause choking and sometimes even poisoning when consumed by dairy cattle (Currie 1936).

South America

Argentina

Though the impacts of RSW in Argentina have not yet been documented, it is likely that the agricultural and ranching sectors invaded by this weed will be negatively impacted in manners similar to those observed in the U.S. and Australia (Tortosa and Medan 1978).

Proposed and Enacted Laws (US)

Federal

Rush skeletonweed is not currently listed by the Federal government as a noxious weed per Part 360- Noxious Weed Regulations: 7 U.S.C. 2803 and 2809; 7 CFR 2.17, 2.51, and 371.2(c).

State

Rush skeletonweed is listed as noxious in nine states of the U.S. (USDA NRCS 2009). The implications of the designation "noxious" vary from state to state.

Arizona

Rush skeletonweed is not currently established in the state of Arizona. To prevent its introduction, RSW is listed as a prohibited noxious weed. As such, RSW plants, rhizomes, cuttings, and seed are prohibited from entry into the state. The following commodities are hosts or carriers of the prohibited plants and are targeted for search:

- All plants other than those categorized as a regulated or restricted pest
- Forage, straw and feed grains
- Live and dead flower arrangements
- Ornamental displays
- Any appliance, construction or dredging equipment, boat, boat trailer or related equipment, or any other vehicle with soil attached or carrying plant debris

California

Rush skeletonweed is currently established in 28 counties (Fig. 9, page 21). It is categorized as an A-list noxious weed. A-list weeds are targeted for eradication, containment, rejection, or other holding action at the state-county level. Quarantine interceptions are to be rejected or treated at any point in the state.

Colorado

Rush skeletonweed is not currently established in the state of Colorado. To prevent its introduction, RSW is categorized as an A-list noxious weed. Noxious weeds on the Colorado A list are designated by the commissioner for eradication once any population is discovered within the state.

Idaho

Rush skeletonweed has been identified in 32 counties in Idaho (Fig. 9, page 21). It is currently listed on the statewide noxious-weeds containment list. Species on this list are known to exist in various populations throughout the state. Weed control efforts may be directed at reducing or eliminating new or expanding weed populations, while known and established weed populations may be managed by any approved weed control methodology, as determined by the weed control authority. No article containing RSW propagules may be sold or furnished to any person within the state, until it has been treated in a manner sufficient to eliminate all RSW propagating capability, except when sold or furnished to a person for the purpose of destroying the viability of the RSW propagules.

Montana

Rush skeletonweed is currently established in four counties in Montana (Fig.9. page 21) where it is listed as a Category 2 noxious weed. Category 2 weeds have recently been introduced to the state or are quickly spreading from their current infestation sites. These weeds are capable of rapid spread, rendering lands unfit for beneficial uses. Management criteria include awareness and education, monitoring and containment of known infestations, and eradication where possible. The Montana County Noxious Weed Control Law makes it unlawful for any person to permit RSW to propagate or produce seeds on his or her land. The only exceptions to this are to follow the district's noxious weed management plan or to develop and implement a noxious weed management agreement approved by the district weed board. Under the noxious weed law, county embargo programs may be implemented to reduce the spread of noxious weeds such as RSW within the county or to prevent the introduction of RSW into the county. The county weed board can establish a voluntary embargo program for the movement of any material into or out of the county--forage, sand and gravel, timber, etc. which may contain RSW seeds, or for forage that is sold as noxious weed seed free but has not been so certified by the state.

Nevada

Rush skeletonweed is not currently established in the state of Nevada where it is listed as a Category-A noxious weed. Category-A weeds are those generally not found or that are limited in distribution throughout the state. Such weeds are subject to:

- Active exclusion from the state and active eradication wherever found
- Active eradication from the premises of a dealer of nursery stock

Oregon

Rush skeletonweed is currently established in 17 counties in the state of Oregon (Fig. 9, page 21) where it is listed as a Category-B noxious weed. Category-B weeds are of economic importance and regionally abundant, but may have limited distribution in some counties. By fitting this category, RSW is:

- Prohibited entry into the State of Oregon
- Prohibited from transport, purchase, sale or offering for sale in the State of Oregon
- Prohibited from being propagated in the State of Oregon
- Permitted to be collected from the wild in areas that are already infested with the specific species that is collected, provided that the plants, plant parts, or seed are not used for propagation or sale within the State of Oregon.

All plants on the Category-B list that are held or possessed in violation of this quarantine will be returned immediately to point of origin (if from out of state) by the Oregon receiver, or at the owner's option will be destroyed under the supervision of the department. Exceptions: The director may issue a permit allowing entry into this state, propagation, or selling of plants covered by this rule, upon request, and upon investigation and finding that unusual circumstances exist justifying such action, and that the benefits of granting the permit outweigh the potential harm that may result. The director may impose specific conditions on any permit issued, and the permit may be canceled for failure to meet the conditions of the permit. Such permits expire in less than one year.

South Dakota

Rush skeletonweed is not currently established in the state of South Dakota. To prevent its introduction, all RSW plants, plant parts, and seed capable of propagation are listed as regulated non-native plant species. Quarantines and embargoes are authorized for regulated non-native plant species. The secretary of agriculture is authorized to quarantine the state or any portion thereof when it is determined that such action is necessary to prevent or retard the spread of RSW within or from the state, and to place an embargo on any in-bound (from any other state) articles containing RSW. Movements contrary to quarantine rules are prohibited. No person may move RSW or any regulated article described in the quarantine within, from, into, or through the state. Violating the quarantine is a misdemeanor.

Washington

Rush sletonweed is established in 23 counties in the state of Washington (Fig. 9, page 21). It is currently listed as a Class-B noxious weed. Class-B weeds are non-native species that are either absent from or limited in distribution in some portions of the state but very abundant in other areas. The goal is to contain Class-B weeds where they are and prevent their spread into new areas. As such, it is prohibited to transport, buy, sell, offer for sale, or to distribute RSW or RSW parts into or within the state of Washington or to sell, offer for sale, or distribute the seed, flower seed blends, or wildflower mixes of RSW into or within the state of Washington.

Management Techniques

Rush skeletonweed offers significant management challenges, principally because it can be rapidly and widely distributed via windblown seeds. The appropriate management approach for controlling RSW depends on several factors, including: population size, location, plant genotype, non-target vegetation and life cycles, access, treatment costs, and available resources. Successful management programs must first determine the scope of the problem and then define a systematic action plan for thorough management. The following list defines terms and courses of action as they pertain to different RSW populations. Each management technique is described in detail beginning with "Prevention" on page 40.

Inventory and Mapping documenting the location and extent of RSW infestations and infestation characteristics such as RSW density, native plant species and density, current land use, etc

Prevention education, land-use activities, and management practices put into place before RSW arrives in an area

Treatment strategies for existing populations attempting to kill, or reduce the spread or extent of, RSW. Established populations of RSW should be treated differently depending on the infestation conditions and available resources. Treatment should not take place until inventory and mapping have been done. Inventory results will help land managers classify each RSW infestation into one of three categories, each of which should be treated differently from each other:

1. Eradication of Satellites: Eradication is the complete kill or permanent removal of a plant or plant population such that the population cannot recover and re-grow. Satellite populations are small infestations occurring away from a main infestation body. These could be either recent introductions or older infestations that are smaller in size. Eradicating satellites is an extremely important step. If the satellite

population is small, relatively recent, and away from the larger RSW infestation body, eradication will prevent that population from growing into its own massive infestation or merging with the original large infestation. Eradication of satellites can be accomplished through physical removal and/or chemical applications. Biological control and/or cultural methods ARE NOT APPROPRIATE for the eradication of satellite populations, because they are often slow acting and, by definition, control but do not kill the entire plant or population.

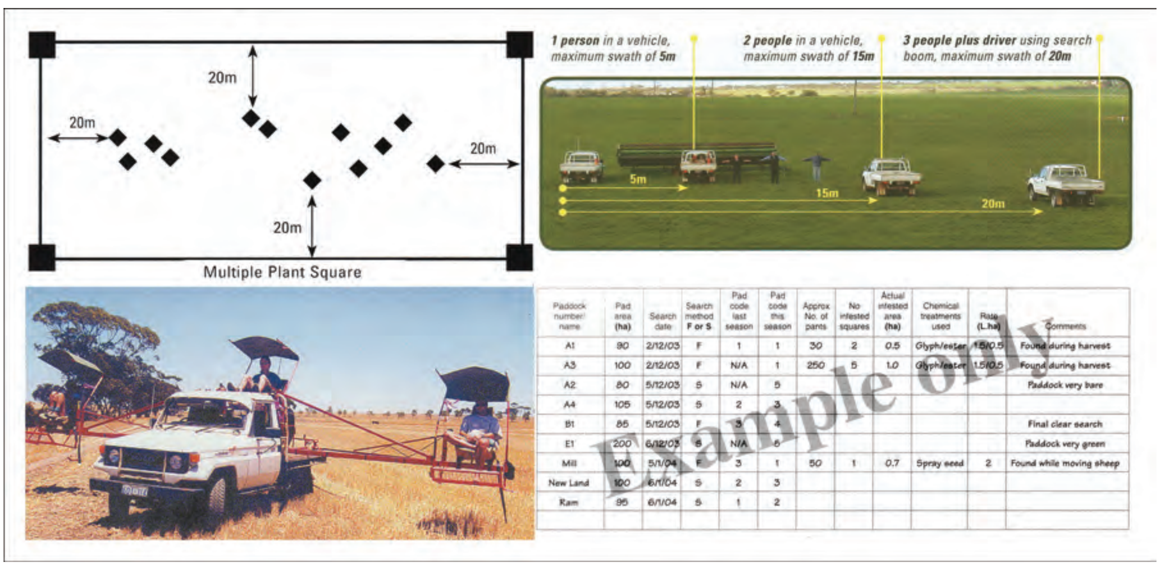
2. Reduction of a Population: this management goal seeks to reduce the overall size of the RSW populations (often much larger than satellite populations) by managing its reproduction. Any infestation along a transportation corridor should be reduced. For this management goal to be most effective, it is best to utilize a natural geographical barrier or boundary to weed spread (e.g. a deep canyon), and work from there into the infestation. Reduction of a population can be achieved with a variety of control methods. Mechanical and chemical control efforts that do not successfully kill the entire population allow RSW to recover and re-grow, but RSW populations are often diminished in the process. Usually, neither cultural nor biological control eradicate a population, but over time they may significantly decrease population density and spread.
3. Containment of a population: to contain a population, reproduction must decrease, such that the population can retain its original size, but does not spread beyond its current perimeters. Containment management goals are appropriate for very large RSW infestations. Mechanical control is usually not feasible in large infestations spanning thousands of rugged acres. The high cost of chemical treatment of RSW makes this method uneconomical for very large RSW infestations. Because it is rarely possible to fully treat the entire area, surrounding RSW easily fill in any gaps left from chemical treatment, essentially rendering the original chemical applications ineffective. Cultural control efforts may serve to decease RSW density within the main infestation, but alone often will not reduce reproduction and perimeter spread. Biological control can also effectively reduce RSW density within the main population; however, if used extensively on the leading edges of large RSW infestations, biological control may reduce and contain its spread. A combination of cultural and biological control is often most effective for containing the largest of RSW infestations.

Individual management techniques stated briefly above are described in greater detail, below. In the section, "Resource Management Approach," management techniques are revisited as they pertain to the management goals of eradication, reduction and containment, and in the context of integrated management. (Note: most control methods discussed herein are more effective in combination than when employed alone.)

Inventory and Mapping

Inventory and mapping are some of the most important elements of a successful weed management program. It is imperative that the extent of a population is understood before control activities are implemented; optimal treatment methods are often determined by the size of the infestation. Land managers should take immediate steps to eliminate all new and small infestations of RSW they discover. When dealing with an older infestation, it is usually most economical and efficient to treat it in the manner best suited for its size, location, and level of establishment.

Inventorying RSW infestations is often a tedious task. In Western Australia, inventories of new RSW populations are taken very seriously. Western land managers were well versed on the destruction RSW had caused in the agricultural communities of eastern Australia; when it first appeared in Western Australia in 1963, they were well aware that it could devastate their entire wheat industry. In response, the Skeleton Weed (Eradication Fund) Act was passed in 1974, and large resources have since been spent in searching for and attempting to eradicate RSW (Parsons and Cuthbertson 2001). Whereas in Western Australia, RSW is surveyed on foot, by farm machinery, and ultralight aircraft, the majority of new infestations discovered each year are reported by header drivers. Very strict farm search protocols have been developed by the Western Australia Department of Agriculture and Food (Atkins and Peirce 2007, Fig. 17 and Table 1).



Paddock number/ name	Pad area (ha)	Search date	Search method F or S	Pad code last season	Pad code this season	Approx No. of pants	No infested squares	Actual infested area (ha)	Chemical treatments used	Rate (L.ha)	Comments
A1	90	2/12/03	F	1	1	30	2	0.5	Glyph/ester	1.5/0.5	Found during harvest
A3	100	2/12/03	F	N/A	1	250	5	1.0	Glyph/ester	1.5/0.5	Found during harvest
A2	80	5/12/03	S	N/A	5						Paddock very bare
A4	105	5/12/03	S	2	3						
B1	85	5/12/03	F	3	4						Final clear search
E1	200	6/12/03	S	N/A	6						Paddock very green
Mill	100	5/1/04	F	3	1	50	1	0.7	Spray seed	2	Found while moving sheep
New Land	100	6/1/04	S	2	3						
Ram	95	6/1/04	S	1	2						

Figure 17. Rush skeletonweed monitoring protocol in Western Australia. Reproduced with permission from Atkins and Peirce (2007).

Table 1. Western Australia rush skeletonweed search protocol. Reproduced with permission from Atkins and Peirce 2007.

	Single Plant Find	Multiple Plant Find
1	Mark the plant(s) using flagging tape, a star picket or a drum.	Where the site contains multiple plants, search thoroughly to locate the extremity of the infestation using flagging tape, star pickets or drums. Step out a 20m buffer from the outermost plants to form a large rectangle.
2	Search thoroughly to ensure there are no other plants, and step out a 20m buffer in all directions, forming a square. Where adjoining squares with single plants are within 50m of each other, combine the squares into a larger one.	Place star pickets or drums in each corner of the rectangle.
3	Place star pickets or drums in each corner of the square.	Mark the find(s) on a farm map and submit a Record Sheet from your Infested Property Paddock Record book to your local DAFWA office by February 15.
4	Mark the find on a farm map and submit with a Record Sheet from your Infested Property Paddock Record book to your local DAFWA office by 15 February.	

Unlike in Australia, in the U.S. there is no standard monitoring protocol for RSW and no single agency managing RSW infestation data. Because numerous groups and individuals are currently working on RSW inventory, multiple monitoring methods are used. Past and current inventory efforts of RSW have been conducted on foot and on horseback and by ATV and helicopter (Fig. 18).

Figure 18. Mapping rush skeletonweed infestations. Credits from left to right: Leon Slichter, Idaho County Weed Control (2 photos); Rachel Winston, MIA Consulting; Jason Karl, The Nature Conservancy.

Just as the physical characteristics of RSW infestations differ greatly from one to another, so too must the techniques to monitor them. For example, the skeletal nature of RSW stems makes the plants difficult to distinguish from neighboring vegetation. This can make it very difficult to spot small infestations, especially early in the season (Fig. 19a). Thus, small infestations are often best spotted through small-scale search operations either on foot or on horseback. Larger infestations are more easily spotted by their gray-green appearance, monoculture tendencies and (during late summer) the presence of numerous scattered and yellow flowers (Fig. 19b). Large infestations can often be seen from aircraft; however, depending on the color of the surrounding vegetation, identification might require ground truthing. Monitoring late in the season when most other vegetation has dried up makes surveying for

Figure 19. **a)** Rush skeletonweed in a rangeland setting, Steve Dewey, Utah State University, UGA 1459573; **b)** rush skeletonweed infestation, Rachel Winston, MIA Consulting.

the still-green RSW easier and is recommended for all sizes of RSW infestations. Regardless of the monitoring method used or the terrain, a 20-m (65-ft) buffer, emanating outward from the outermost RSW plants, should always be searched. (A similar monitoring method is employed in Western Australia.) Given the rhizomatous nature of this species, a 20-m buffer is required in order to ensure the entire population is mapped and all daughter plants are contained within the inventoried area (Atkins and Peirce 2007).

Documenting inventory and mapping efforts enables land managers to determine if all known infestations have been treated, and makes post-treatment monitoring possible. In turn, this allows land managers to judge the efficacy of various treatment methods. Maintaining treatment records and inventory maps of RSW infestations also proves invaluable in the event there is a turnover in personnel, new personnel can continue treatment and monitoring efforts of documented sites. When documenting inventory and mapping efforts, it is crucial that inventory data be collected and assembled in a usable format so that it may be used by numerous RSW management partners. Data should be submitted to any land management agency or group affiliated with the inventoried land parcel following the discovery of new infestations, or the updating of old infestation coverage. This will bring land managers working with RSW closer to the goal of consolidated monitoring, research and control efforts and will help make the most of limited RSW management resources. Land management groups to be contacted include CWMAs, county weed control offices, land grant universities, and state and federal agencies.

Follow-up monitoring should take place two weeks after the treatment (Carl Crabtree, Idaho County Weed Control, pers. comm.). When the management goal is the eradication (complete kill) of satellites, the treated population should be monitored at least three times within a one-year period (Fig. 20). A monitoring and treatment schedule for eradicating satellites would include:

1. Initial inventory efforts in spring when plants begin growing.
2. First treatment efforts for satellite populations immediately following population identification.
3. Second, post-treatment monitoring two weeks following first treatment to ensure the effectiveness of the treatment.
4. After the second monitoring (step three), second treatment application applied to populations not completely eradicated by initial treatments.
5. Final, third, post-treatment monitoring conducted on populations that required second treatment.
6. Final, post-treatment monitoring conducted in late fall or early spring on populations that required only one treatment.

Figure 20. Post-treatment monitoring, Marianna Szucs, University of Idaho.

Prevention

A key to successful invasive plant management is to prevent the initial introduction or spread of the species. The inadvertent spread of RSW via human interactions can only be prevented if resource users (farmers, ranchers, land management personnel and the general public) are aware of RSW, understand the damage it causes, can identify it, and know how to prevent its spread.

The unintentional transport of RSW seeds and root fragments into RSW-free areas must be stopped. Seeds are easily dispersed by wind and water (Panetta and Dodd 1987), but they also readily adhere to animal fur, trains, machinery and vehicles (especially ATV's) (Sheley et al. 1999). During the seed formation stage, livestock should be kept off weed-infested land. If livestock has been in RSW-infested areas, they should be held in a containment area for 10 to 14 days prior to transport to a RSW-free region (Sheley et al. 1999). If it is not possible to avoid driving vehicles and machinery through RSW infestations, it is crucial that a thorough cleaning take place before leaving the contaminated area (Atkins and Pierce 2007). All RSW infestations neighboring the RSW-free area should be contained, especially along transport corridors such as roads, railways and waterways.

Proper land management is key to maintaining competitive plant stands that help limit RSW encroachment. Cultivation, soil erosion, road grading, recreational driving (e.g. dirt bikes and four wheelers) and overgrazing weaken existing plant communities and decrease plant cover, conditions that favor RSW establishment and persistence (Wells 1971). Such activities should be avoided in RSW-prone areas. Where grazing is inevitable, proper livestock management, such as alternating the season of use, changing stocking numbers, and rotating livestock, will allow grazed vegetation to recover and litter to accumulate, which in turn will help prevent the establishment of RSW (Sheley et al. 1999).

Physical Control

Rush skeletonweed can be physically or mechanically controlled with hand-pulling, mowing and cultivation (Zouhar 2003). However, extreme care must be taken when employing physical control methods, because this species can regenerate from severed root fragments, and populations can actually *increase*, if they are not removed properly (Rosenthal et al. 1968). Regardless of the physical method employed, to prevent the spread of RSW it is imperative that all equipment used be thoroughly cleaned following use.

Hand-pulling

According to Sheley and others (1999), hand-pulling can provide effective control for very small RSW infestations. Cuthbertson (1972) showed that seedlings and rosettes growing for fewer than five weeks are not capable of full regeneration from severed roots. Consequently, small populations of RSW can be controlled if all individuals are pulled shortly after germination. As plants age, hand pulling can result in increased populations due to regeneration from the severed roots. To account for this plant response, small populations of older RSW individuals must be hand-pulled several times a year and often for multiple years (Sheley et al. 1999). Multiple hand-pulling sessions will also control new RSW individuals sprouting later in the growing season from seeds lying dormant in the short-lived seed bank. To ensure total seed and root destruction, pulled mature plants should be destroyed in a very hot fire (Sheley et al. 1999).

Mowing

Mowing RSW infestations sometimes results in a compensatory reaction, whereby shoot production is stimulated and increases markedly to compensate for the original stem removal (McLellan 1991). However, this response is costly to the plant in terms of root carbohydrates. Regular mowing throughout the growing season utilizes much of the stored root reserves, and over time decreases the root's regenerative capacity and above-ground biomass, which in turn decreases rosette and seed production (McLellan 1991). It is important that mowing events occur before seed production, because mowing can increase seed dispersal. Frequent mowing of RSW is not feasible in either the crop or rangeland setting, where RSW is so problematic in the U.S. However, it may help control RSW along roadsides and rights-of-way, providing plants do not compensate by growing along the ground in a sprawl that is too short for mowers to cut but still capable of producing prolific seeds.

Cultivation

One of the most common physical weed control methods in grain crops is cultivation prior to sowing cereal seed (Moore 1971). This method was one of the earliest recommendations for controlling RSW infestations in eastern U.S. grain crops (Georgia 1914). However, because of RSW's ability to regenerate from severed roots, cultivation as part of a crop-and-fallow system actually led to a dramatic increase, not a decrease, in RSW infestations throughout Australia (Groves and Cullen 1981). It has since been determined that, with proper timing and frequency, and providing the soil is turned deeply enough, cultivation can be used successfully against RSW.

Root regeneration of RSW depends on soil moisture and the energy reserves in the roots (Cuthbertson 1972). Root-fragment growth and development can occur only when there is sufficient moisture available in the soil (Rosenthal et al. 1968). When fragmentation occurs in dry soil, the probability is increased that fragments will succumb to desiccation rather than sprout new shoots (Cullen and Groves 1981). The deeper in the soil the root or root fragment is, the more energy the plant needs to produce a shoot (Cuthbertson 1972). If the root is severed again before the energy from shoot production is regained, its reserves are further depleted, and the plant is weakened and often killed. Consequently, deep and frequent cultivation of dry soil can help decrease RSW populations (Fig. 21). These factors are thought to be responsible for the successful limitation of RSW in European vineyards and cropping systems (Wapshere 1971), where cultivation occurs at depths of 25 cm (10 in) compared to the shallow 10-cm (4-in) cultivation depth practiced in Australia, where RSW has been so problematic. Frequent and deep cultivation is not feasible in a wheat-fallow rotation or in the extensive rangeland system in the western U.S.

Figure 21. Cultivation equipment, Howard R. Schwartz, Colorado State University, UGA 5358338.

Cultural Control

Competition

Seedlings of RSW are very sensitive to the light they receive upon germination (Schirman and Robocker 1967). When cool-season, annual crop or pastoral plants emerge first, their dense shade restricts the growth of RSW seedlings and adult plant rosettes (Moore 1964). Moore and Robertson (1964) demonstrated that shading of this sort can reduce RSW populations by as much as 63% in four years. A reduction to below 1% of full daylight at the soil surface completely prevents seedling establishment (McVean 1966). In addition to competition for light, certain species hinder the growth of RSW through other mechanisms. Deep-rooted perennials (e.g., alfalfa, *Medicago sativa*, Fig. 22), compete with RSW for much-needed soil moisture (Panetta and Dodd 1987). Alfalfa and other legumes (e.g., sub-clover, *Trifolium subterraneum*) fix their own nitrogen, which effectively increases the amount of nitrogen in the soil, which in turn leads to an increase in growth to, and competition from, other pastoral species (Panetta and Dodd 1995). Artificially adding up to 170kg/ha (150 lbs/acre) of nitrogen and/or superphosphates has a similar effect, and reduces RSW rosette densities by around 80% (Kohn and Cuthbertson 1975). Note: It is often difficult to maintain dense stands of shading and/or nitrogen-fixing species necessary to achieve the level of management required to control RSW(Wells 1971), especially in the vast rangeland habitat RSW has invaded in the western U.S.

Figure 22. Alfalfa, Richard Old, XID Services, Inc., UGA 5239071.

GRAZING

Domestic livestock, including goats, sheep, horses and cattle, and some species of wildlife feed on RSW (McVean 1966, Cuthbertson 1967, Harris 2003). Most of these herbivores will feed on RSW in the young rosette stage, but goats are the only species documented to feed on lignified stems of flowering plants (Cuthbertson 1967). The most appreciable amounts of damage are caused by sheep; grazing domestic sheep can reduce or even prevent RSW seed production (Cuthbertson 1967, Fig. 23). Experiments conducted on the efficacy of grazing for RSW control show that the lowest densities of RSW were obtained under continuous, not rotational, grazing (Kohn and Cuthbertson 1975). Continuous grazing prevents the plant from bolting when other green feed is scarce (Panetta and Dodd 1995). However, this heavy feeding is considered by some to be overgrazing. As well, when livestock is moved as part of rotational grazing, RSW quickly recovers, bolts and spreads (Panetta and Dodd 1987). Increasing the stocking rate from five to 15 sheep/ha (two to six sheep/acre) had no effect on final weed numbers (Kohn and Cuthbertson 1975). Ultimately, heavy grazing due to greater numbers of animals present is no more effective against RSW than is moderate grazing, because heavy grazing decreases the competitive ability of desired plant species (Sheley et al. 1999). In the western U.S., some ranchers found that, whereas dense populations of RSW often required intensive control efforts, RSW plants scattered across well-managed pastures posed no serious decrease in livestock carrying capacity and even supplied late season forage. However, care should be taken when running cattle on RSW infested land because flowering stems have been known to choke and poison dairy cattle (Currie 1936).

Figure 23. Sheep, USDA ARS, UGA 1320070.

Fire

Although the effects of fire on RSW have not been studied extensively, it is not recommended for controlling RSW. Researchers and land managers have observed that fire promotes rather than hinders the spread of RSW (Asher et al. 2001, Kinter et al. 2007). On a large tract of public land in southern Idaho, RSW was once found only intermittently. Following a severe wildfire, RSW was observed as hearty and established throughout the entire burned area (J. Milan, Bureau of Land Management, pers. comm.). Whereas the aboveground biomass of RSW burns readily in very hot fires, the deep rhizomatous root system is unlikely to be damaged and will recover (Zouhar 2003). Furthermore, this species is capable of producing numerous windblown seeds whose establishment success is aided markedly by disturbance of the soil (McVean 1966). The disturbance caused by fire often provides excellent infestation potential for RSW seed establishment (Zouhar 2003, Kinter et al. 2007, Fig. 24).

Figure 24. Prescribed fire, David Cappaert, Michigan State University, UGA 5187041.

Herbicidal Control

Although they can be effective in gaining initial control of an infestation of invasive plants, herbicides are not economically feasible for treating many RSW infestations, especially those covering vast tracts of remote rangeland. Herbicides are often very effective when incorporated into management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations (Bussan and Dyer 1999). The history of herbicide use against RSW is long and involved (Groves and Cullen 1981). Beginning in 1935, early methods were non-selective, involving spot applications of common salt, arsenicals and chlorates (Cashmore and Carn 1938, Greenham et al. 1940). If used in quantities sufficient to kill RSW, these chemicals left the soil sterile (Old 1981). After more-selective herbicides were developed, chemical control of RSW became more economical and had fewer non-target effects (Groves and Cullen 1981). However, even with the more selective herbicides, efficacy of chemical treatments remained low (Table 2).

Rosette leaves are the preferred sites for herbicide applications. Although 2,4-D (2,4-dichlorophenoxy acetic acid) and dicamba (3,6-dicholor-2-methoxybenzoic acid) will kill aboveground portions of established RSW plants, these chemicals do not kill the extensive root system, and new rosettes can regenerate within one year (Groves and Cullen 1981). The initial destruction of aboveground biomass is often sufficient to minimize interference with harvesting, even at low application rates (Moore and Robertson 1963, Heap 1993). If the goal is to temporarily remove RSW, 2,4-D destroys aboveground biomass. It should be applied to actively bolting plants in the spring and early summer, when target leaf area is at a maximum, at rates of 850 g ai/ha to 1.12 kg ai/ha (0.75lb ai/acre to 1 lb ai/acre) (Cheney et al. 1980, Heap 1993).

Table 2. Published herbicide efficacy results taken from Cheney et al. 1980 and Heap 1993. For suggested rates and procedures in your area, ALWAYS refer to the label.

Herbicide	RSW damage	Time	Annual rate
2,4-D	Aboveground only	spring bolting	850 - 1120 g ai/ha
Metsulfuron	Above and belowground	spring rosette	9 g ai/ha
Clopyralid	Aboveground only	spring rosette	150 g ai/ha
Clopyralid	Above and belowground	spring rosette	300 g ai/ha
Clopyralid + dicamba	Above and belowground	spring rosette	220 g ai/ha + 1.12 kg ai/ha
Picloram	Above and belowground	fall rosette	2.24 kg ai/ha
Picloram + 2,4-D	Above and belowground	fall rosette	1.12 kg ai/ha + 1.12 kg ai/ha

For more complete control and a decrease of RSW individuals, the active chemical must reach deep into the extensive root system. Unfortunately, the poor ability of RSW to translocate compounds from the site of application to the roots prevents toxic levels of many herbicides from ever reaching the root system (Moore and Robertson 1963, McVean 1966). At the proper application rates, metsulfuron (methyl 2-(4-methoxy-6-methyl-1,3,5-triazin-2-ylcarbamoylsulfamoyl)benzoate), clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) and picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) can control RSW biomass above *and* belowground . Metsulfuron was most effective in Australian herbicide trials when applied at 9 g ai/ha (0.008 lb ai/acre) every year for multiple years (Heap 1993). Clopyralid had the best success against Australian populations of RSW, with 60% decreases in plant density three years after an initial application of 300 g ai/ha (0.26 lb ai/acre) (Heap 1993). Clopyralid was most effective when used in conjunction with 2,4-D, MCPA (4-chloro-2-methylphenoxy acetic acid) and dicamba. Mixing clopyralid with dicamba at 220 g ai/ha (0.2 lb ai/acre) and 1.12 kg ai/ha (1 lb ai/acre), respectively, reduced the number of shoots by 75% three years after application. Annual applications of this mixture decrease stand density by 95% (Heap 1993). In Idaho, picloram controls RSW rosettes in the fall when applied at rates of 2.24 kg ai/ha (2 lb ai/ha) (Cheney et al. 1980). The best control of RSW in the western U.S. has been achieved using a combination of picloram at 1.12 kg ai/ha (1 lb ai/acre) and 2,4-D at 1.12 kg ai/ha (1 lb ai/acre) applied to fall rosettes (Cheney et al. 1980). It is not recommended that picloram, clopyralid or metsulfuron be used in a cropping or pasture system where other broadleaf species are expected to grow for a period of up to three years following application. All of these chemicals have residual effects within soil and are especially damaging to legume species (Groves and Cullen 1981, Heap 1993).

The various forms of RSW react to herbicides differently. In Australia, Form A (narrow-leaf rosettes) is more susceptible to metsulfuron and 2,4-D than are Forms B and C (Black et al. 1998). Clopyralid was the most effective herbicide on all forms, though forms A and B were more susceptible than Form C (Black et al. 1998). Susceptibility studies for North American forms of RSW are still needed.

When chemical control is used against RSW, it is important that all label instructions be followed thoroughly to ensure the usage, rate, and location of herbicide application are correct. Not all herbicides are registered for use in agricultural and rangeland settings, nor are all herbicides registered for use in each state of the U.S. and in Canada. Many herbicides are restricted use and can only be applied by a certified and licensed applicator, and then only under specific conditions (Table 3).

(Note: The Rush Skeletonweed Task Force (RSTF) does not endorse one brand or one type of herbicide over another. Please see Appendix 3, Pesticide Precautionary Statement, page 117.)

Table 3. Selected herbicides registered for rush skeletonweed control in the U.S. Taken from Pesticide Action Network 2008. **Note**: Results for many of the registered products have not been published, so rates and efficacy are not included here.

Registered Product Name Name as it appears on the package	U.S. EPA Reg. No.	U.S Restricted Use Status	Manufacturer Name Distributor Name	Active Ingredient
Arsenal herbicide Arsenal herbicide	241-273	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Arsenal herbicide Polaris rr herbicide	241-273	No	Basf corporation Nufarm americas inc.	Imazapyr, isopropylamine salt
Arsenal herbicide Arsenal herbicide	241-299	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Arsenal herbicide Polaris ac hebicide	241-299	No	Basf corporation Nufarm americas inc.	Imazapyr, isopropylamine salt
Arsenal herbicide Arsenal herbicide	241-346	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Arsenal herbicide Polaris herbicide	241-346	No	Basf corporation Nufarm americas inc.	Imazapyr, isopropylamine salt
Chop herbicide Chop herbicide	34704-905	No	Loveland products, inc. Loveland products, inc.	Imazapyr, isopropylamine salt
Chopper herbicide Chopper herbicide	241-296	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Chopper herbicide Polaris sp herbicide	241-296	No	Basf corporation Nufarm americas inc.	Imazapyr, isopropylamine salt
Distinct herbicide Distinct herbicide	7969-150	No	Basf corporation Basf corporation	Diglufenzopyr-sodium and Dicamba
Dupont cimarron herbicide Dupont cimarron herbicide	352-616	No	E. i. du pont de nemours and co., inc. E. i. du pont de nemours and co., inc.	Metsulfuron-methyl
Dupont cimarron max herbicide Dupont cimarron max herbicide	352-615	No	E. i. du pont de nemours and co., inc. E. i. du pont de nemours and co., inc.	Metsulfuron-methyl
Dupont cimarron max part b Dupont cimarron max part b	352-614	No	E. i. du pont de nemours and co., inc. E. i. du pont de nemours and co., inc.	Metsulfuron-methyl
Dupont cimarron plus herbicide Dupont cimarron max part b	352-670	No	E. i. du pont de nemours and co., inc. E. i. du pont de nemours and co., inc.	Metsulfuron-methyl
Dupont cimarron x-tra (mp) herbicide Dupont cimarron x-tra (mp) herbicide	352-630	No	E. i. du pont de nemours and co., inc. E. i. du pont de nemours and co., inc.	Metsulfuron-methyl
Dupont cimarron x-tra herbicide Dupont cimarron x-tra herbicide	352-669	No	E. i. du pont de nemours and co., inc. E. i. du pont de nemours and co., inc.	Metsulfuron-methyl
Dupont escort xp Dupont escort xp	352-439	No	E. i. du pont de nemours and co., inc. E. i. du pont de nemours and co., inc.	Metsulfuron-methyl
Ecomazapyr 2 sl Ecomazapyr 2 sl	74477-6	No	Vegetation management, llc Vegetation management, llc	Metsulfuron-methyl

Table 3, *continued*. Selected herbicides registered for rush skeletonweed control in the U.S. Taken from Pesticide Action Network 2008. **Note**: Results for many of the registered products have not been published, so rates and efficacy are not included here.

Registered Product Name Name as it appears on the package	U.S. EPA Reg. No.	U.S Restricted Use Status	Manufacturer Name Distributor Name	Active Ingredient
Eh-1384 Eh-1384	2217-841	No	Pbi/gordon corp Pbi/gordon corp	Glyphosate, isopropylamine salt
Eh-1384 Ornery systematic weed an d grass killer	2217-841	No	Pbi/gordon corp Drummond american corporation	Glyphosate, isopropylamine salt
Et-008 Et-008	81959-14	No	Etigra llc Etigra llc	Metsulfuron-methyl
Gf-1249 Gf-1249	62719-528	No	Dow agrosciences llc Dow agrosciences llc	Picloram and Triclopyr
Habitat herbicide Habitat herbicide	241-426	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Habitat release 75sg herbicide Habitat release 75sg herbicide	241-402	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Habitat release herbicide Habitat release herbicide	241-401	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Imazapyr 2sl Imazapyr 2sl	74477-4	No	Vegetation management, llc Vegetation management, llc	Imazapyr, isopropylamine salt
Imazapyr 4 sl Imazapyr 4 sl	74477-5	No	Vegetation management, llc Vegetation management, llc	Imazapyr, isopropylamine salt
Imazapyr right-of-way herbicide Imazapyr right-of-way herbicide	34704-908	No	Loveland products, inc. Loveland products, inc.	Imazapyr, isopropylamine salt
Lpi imazapyr herbicide Lpi imazapyr herbicide	34704-896	No	Loveland products, inc. Loveland products, inc.	Imazapyr, isopropylamine salt
Milestone VM Plus herbicide Milestone VM Plus herbicide	62719-572	No	Dow agrosciences llc Dow agrosciences llc	Aminopyralid
Picloram + 2,4-d ivm Picloram + 2,4-d ivm	42750-82	No	Albaugh inc Albaugh inc	Picloram and 2,4-D, triisopropanol-amine salt
Polaris herbicide Polaris herbicide	228-480	No	Nufarm americas inc. Nufarm americas inc.	Imazapyr, isopropylamine salt
Redeem r & p Redeem r & p	62719-337	No	Dow agrosciences llc Dow agrosciences llc	Triclopyr, triethylamine salt and Clopyralid
Sahara dg herbicide Sahara dg herbicide	241-372	No	Basf corporation Basf corporation	Diuron and Imazapyr
Stalker herbicide Stalker herbicide	241-398	No	Basf corporation Basf corporation	Imazapyr, isopropylamine salt
Toram 101 Toram 101	48273-15	Yes	Marman usa inc Marman usa inc	Picloram and 2,4-D (triisopropanol-amine salt both)

Table 3, *continued*. Selected herbicides registered for rush skeletonweed control in the U.S. Taken from Pesticide Action Network 2008. **Note**: Results for many of the registered products have not been published, so rates and efficacy are not included here.

Registered Product Name Name as it appears on the package	U.S. EPA Reg. No.	U.S Restricted Use Status	Manufacturer Name Distributor Name	Active Ingredient
Tordon 101 mixture Tordon 101 mixture	62719-5	Yes	Dow agrosciences llc Dow agrosciences llc	Picloram and 2,4-D (triisopropanol-amine salt both)
Tordon 22k_weed killer Tordon 22k_weed killer	62719-6	Yes	Dow agrosciences llc Dow agrosciences llc	Picloram and 2,4-D (triisopropanol-amine salt both)
Tordon k Tordon k	62719-17	Yes	Dow agrosciences llc Dow agrosciences llc	Picloram and 2,4-D (triisopropanol-amine salt both)
Triclopyr tea + clopyralid tea r&p Triclopyr tea + clopyralid tea r&p	42750-125	No	Albaugh inc Albaugh inc	Triclopyr, triethylamine salt and Clopyralid, triethanolamine

Biological Control

Classical biological control of exotic plants seeks to expose exotic, invasive plants found outside their native range, to herbivorous arthropods or fungi collected from the plant's native range (DeBach 1964, Myers 1985, Delfosse 2004). There are numerous examples of biological control agents successfully controlling invasive populations of their host species (Julien 1998 and references therein). The call for biological control of RSW began in Australia in 1936 (Currie 1936), but the first RSW biocontrol agent was not released until 1971 (Cullen et al. 1973). To date, a total of one rust fungus, two insects, and one mite species have been released in Australia and the U.S. to control RSW (Table 4), and the search continues for additional agents (Panetta and Dodd 1987).

Table 4. Biocontrol agents approved for release in the U.S.

Type	Scientific name	U.S. field efficacy	Availability
Rust	*Puccinia chondrillina*	Moderate	Readily available
Mite	*Aceria chondrillae*	Moderate	Readily available
Fly	*Cystiphora schmidti*	Low alone	Readily available
Moth	*Bradyrrhoa gilveolella*	Unknown	Not established in North America

Puccinia chondrillina The rush skeletonweed rust fungus, *Puccinia chondrillina* Bubak and Sydenham, was the first biological control agent released against RSW. This autoecious macrocyclic fungus, with numerous strains, is native to Eurasia and the Mediterranean (Hasan 1972). It has a very wide, climatic, native range that extends from cold, continental Siberia to the hot Mediterranean climate of North Africa and Portugal (Hasan 1972). During fall and spring, RSW rosettes are infected with urediospores from the previous year's stems (Hasan and Wapshere 1973). Urediospores are round, dark brown, dry and powdery (Fig. 25). They are easily dispersed by both wind and rain, spreading rapidly from plant to plant in fall and spring, and more slowly in winter (Blanchette and Lee 1981). Although spores in other stages

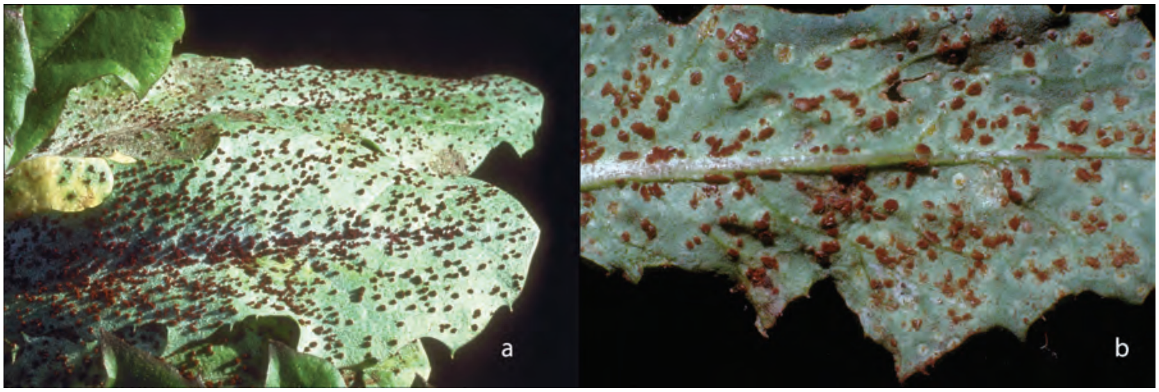


Figure 25. **a)** Uridiospores *of P. chondrilla Bubák*, Eric Coombs, Oregon State Department of Agriculture, UGA 0022097; **b)** symptoms of *P. chondrilla Bubák,* Gary Piper, Washington State University, UGA 0022096.

of the rust's life cycle have been observed, this species mainly multiplies from year to year with its urediospores alone (Hasan and Wapshere 1973). Though *P. chondrillina* is adapted to diverse conditions, sufficient overnight humidity is required for spore germination and penetration (Hasan and Wapshere 1973). Urediospores cover the surface of leaves and flowering stems and produce pustules. This reduces plant photosynthetic capabilities and depletes root nutrient storage, leading to plant weakening and even death (Grove and Cullen 1981). Small rosettes and seedlings are often destroyed by heavy rust infestations. If larger plants are infected early enough in the season, flowering stems are stunted and deformed and produce few viable seeds (Hasan and Wapshere 1973).

The first strain of *P. chondrillina* originated in Vieste, Italy and was introduced to southern Australia in 1971 where it quickly spread (Cullen et al. 1973). This strain heavily attacks the once most common form of RSW, narrow-leaved Form A; experimental stand densities decreased by 50% due to *P. chondrillina* alone (Hasan 1972, Hasan and Wapshere 1973, Hanley and Groves 2002). Plants that survive the rust's attack are weakened and often succumb to drought, intra- and inter-specific competition, and secondary attack by other organisms (Hasan and Wapshere 1973). High attack rates to Form A RSW resulted in a decrease of this biotype throughout Australia and an increase in forms B and C (Hanley and Groves 2002). A new strain (*P. chondrillina* TU 788) has since been released and proven effective against the intermediate-leaved biotype, Form B (Hanley and Groves 2002).

The strain of *P. chondrillina* initially introduced to Australia was released against biotypes 2 and 3 (Washington early-flowering and Washington late-flowering) in the U.S., but it failed to establish on either (Lee 1986). A new strain was then obtained from Eboli, Italy, and released in California in 1976 (Supkoff et al. 1988). This strain spread throughout the West, successfully establishing on biotypes 2 and 3, but not on biotype 1 (Banks) (Adams and Line 1984). A second strain from Eboli was collected and released in the U.S.. It aggressively attacked biotype 1 but did not establishing on biotypes 2 and 3 (Lee 1986). Rust efficacy studies conducted on biotypes 2 and 3 demonstrate that *P. chondrillina* is capable of reducing RSW flower production by 50% and stand densities by up to 90% (Cheney et al. 1981, Supkoff et al. 1988). Studies on the effects of *P. chondrillina* on Banks biotype 1 showed a decrease of flower production on one of two field sites, but no effect on aboveground biomass (Milan 2005), despite the proven virulence of the rust strain currently established on that biotype. Although not covered in published literature, it has been observed that, whereas the rust strain currently established on the Banks biotype 1 of RSW is itself parasitized by the fungus (Fig. 26), *Eudarluca caricis* (Fr.) O.E. Erikss, the rust strains established on biotypes 2 and 3 are not parasitized, and therefore have potentially greater efficacy (M. Schwarzländer, University of Idaho, unpublished data).

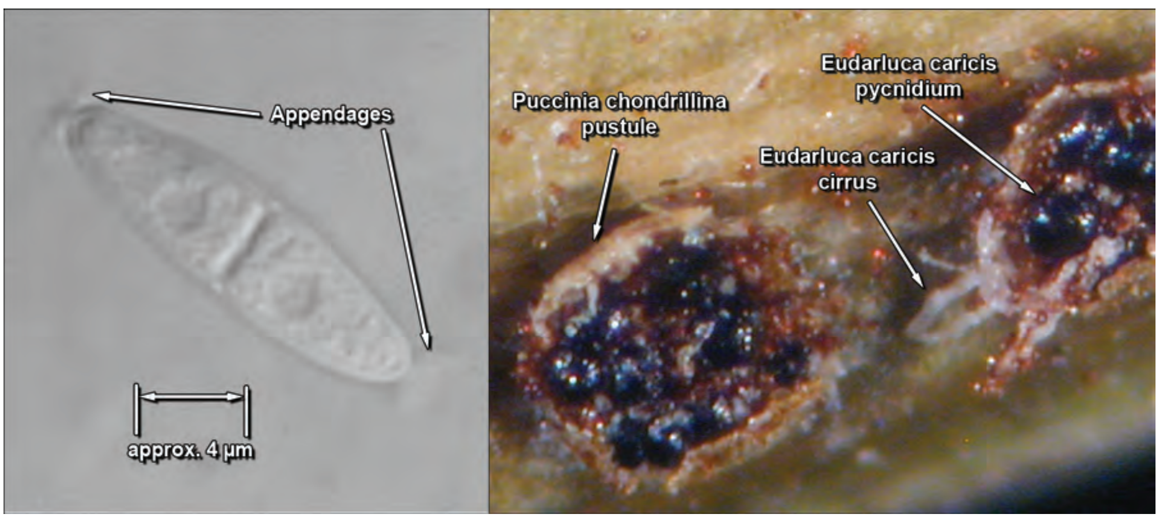


Figure 26. *E. caricis*, a parasitic fungus on the biocontrol agent P. chondrillina. Lisa Collison, University of Idaho.

Aceria chondrillae

The rush skeletonweed gall mite, *Aceria chondrillae* Canestrini [= *Eriophyes chondrillae* Canestrini] was the second biological control agent released against RSW in Australia. This tiny, gall-forming eriophyid mite is native to Eurasia and the Mediterranean. During the spring, mites attack RSW by piercing vegetative and flower buds, inducing the formation of numerous galls consisting of enlarged plant tissue (Caresche and Wapshere 1974). Gall formation stunts plant growth, decreases stand density and reduces seed production of RSW

(Caresche and Wapshere 1974, Groves and Cullen 1981, Cullen et al. 1982, Spollen 1986, Fig. 27). Females oviposit between 60 and 100 eggs within galls; new mites exit as galls dry and

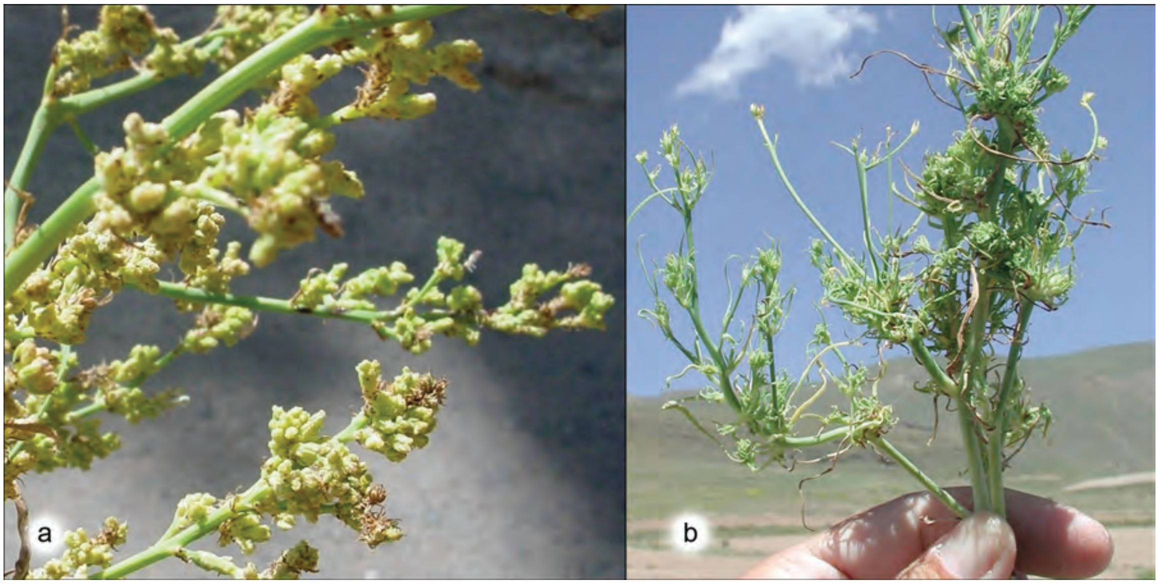


Figure 27. **a)** *Chondrillae* gall damage, Richard Old, XID Services Inc., UGA 5230052; **b)** Biotechnology and Biological Control Agency.

either crawl to adjacent host plants or are blown by the wind to distant patches (Caresche and Wapshere 1974). New generations are produced every 10 days throughout the course of the growing season. All stages and all generations attack new bud growth and form galls (Caresche and Wapshere 1974). In the fall, *A. chondrillae* move down to newly regenerated rosettes. They overwinter in plant crevices or in the soil and are inactive until the following spring (Caresche and Wapshere 1974).

The rush skeletonweed gall mite was collected from Greece and released in Australia in 1971 and 1972 (Panetta and Dodd 1987). The efficacy of this biological control agent was studied in glasshouse experiments in Australia. It was found to reduce regeneration and aboveground biomass and to decrease flowering (and thus subsequent seed production) by up to 96% (Cullen et al. 1982). Unfortunately, the majority of mite damage is inflicted on Form A, with Form B receiving very little damage and Form C virtually unaffected (Caresche and Wapshere 1974). Later attempts to increase the susceptibility of Form B, by selecting from mite populations that had reproduced on Form B, proved unsuccessful (Cullen and Moore 1983).

The same strain of *A. chondrillae* that was successful against Form A RSW in Australia was tested on the RSW biotypes present in the U.S. (Sobhian and Andres 1978). It did not establish on any type. However, *A. chondrillae* mites collected from Vieste, Italy, reproduced and formed varying amounts of gall tissue on all U.S. biotypes (Sobhian and Andres 1978).

This strain was introduced to the western U.S. in 1977 (Andres 1982). Multiple greenhouse studies found that *A chondrillae* reduces U.S. RSW aboveground biomass, root biomass, and flower production (Spollen 1986, Prather 1993). However, a field study conducted on the Banks (type 1) biotype found that, although *A. chondrillae* reduced flower production at one of two field sites, mite damage had no impact on aboveground biomass (Milan 2005). The lower-than-expected field efficacy of the rush skeletonweed gall mite may be partially explained by the extensive winter mortality of this species (>90%) and its dependence for survival on sometimes-absent winter rosettes (Milan et al. 2006). However, even without high kill rates in the U.S., large infestations by the gall mite have been shown to weaken RSW and decrease its ability to compete with associated vegetation (Cheney et al. 1981).

Cystiphora schmidti

The rush skeletonweed gall midge, *Cystiphora schmidti* Rübsaamen, was the third biological control agent released against RSW in Australia. This gall-forming fly is native to Eurasia and the Mediterranean. Adults are brown and small, usually 1 to 1.5 mm (0.04 to 0.06 in) long (Fig. 28). Larvae are flattened, 1 to 2.5 mm (0.04 to 0.10 in) long, and pink or orange. Adults emerge and mate in spring. Females deposit 60 to180 eggs under the epidermis of RSW leaves

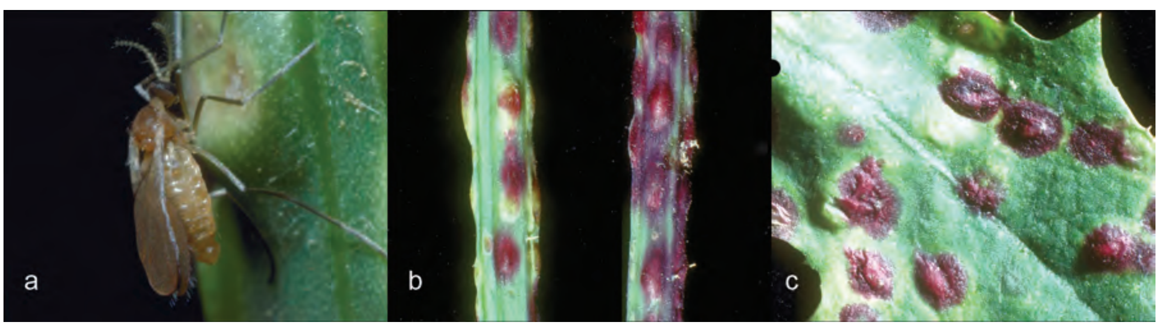


Figure 28. **a)** Adult rush skeletonweed gall midge, *C. schmidti*, Charles Turner, USDA ARS, UGA0022093; **b** and **c)** rush skeletonweed damage due to gall midge, Gary Piper, Washington State University, UGA 0022091, UGA 0022092.

and stems (Caresche and Wapshere 1975a). Emerging larvae feed on stem and leaf tissue, inducing the formation of purplish galls. Leaf galls are circular, 3 mm (0.12 in) in diameter, and slightly raised. Stem galls are elongated and usually more elevated than leaf galls (Figs. 38b and c). Pupation occurs within galls with each larva spinning a silky cocoon around itself prior to pupation (Caresche and Wapshere 1975a). Adults emerge from the cocoons and galls with the aid of pupal head spines. The act of exiting destroys leaf and stem tissue leading to chlorosis and leaf desiccation. At dense levels, midge infestations reduce photosynthesis and reproductive capabilities and may lead to the death of smaller plants (Lee 1986). There are up to five generations per year; overwintering occurs in both the larval and pupal stages either in galls or just beneath the surface of the soil (Caresche and Wapshere 1975a).

The skeletonweed gall midge was collected from Greece and, together with the skeletonweed gall mite, released in Australia in 1971 and 1972 (Cullen 1974). This midge is the only established biocontrol agent that attacks all three forms of RSW in Australia, equally (Moore 1991); however, this insect's impact is lower than that of the other established biocontrol agents (Panetta and Dodd 1987). This is likely due to climatic constraints (Cullen 1974) and heavy parasitization by a native wasp, *Tetrastichus* spp (Panetta and Dodd 1995).

The skeletonweed gall midge was introduced to the U.S. in 1976 from populations established in Australia that had originated in Greece (Littlefield and Barr 1980). As it does in Australia, the skeletonweed gall midge attacks all biotypes of North American RSW (Sobhian and Andres 1978). It is currently established throughout the western U.S. (Lee 1986). Efficacy experiments demonstrate that *C. schmidti* can reduce flower production by 60% to 100%, depending on infestation density (Mendes 1982). Plants infested for more than two years yielded stem lengths half their normal lengths (Littlefield and Barr 1980). Despite these effects, the skeletonweed gall midge is the least effective of the three established biocontrol agents (Piper and Andres 1995). This is likely due to extensive gall predation by grasshoppers (*Melanoplus sanguinipes*) and a pteromalid wasp (*Zatropis* spp.) (Littlefield and Barr 1980, Lee 1986).

BRADYRRHOA GILVEOLELLA

The rush skeletonweed root moth, *Bradyrrhoa gilveolella* Treitschke, was the fourth agent released for control of RSW in Australia and North America (Delfosse and Cullen 1982). This moth is native to Europe and the Mediterranean (Caresche and Wapshere 1975b). Adults are 11 to 13 mm (0.43 to 0.53 in) long, creamy buff colored, and have three brown bands that traverse their anterior wings (Fig. 29). Their wingspan is approximately 25 mm (1 in) across. Adults emerge in spring and oviposit up to 250 eggs onto stems or the soil surface near the bases of plants (Caresche and Wapshere 1975b). Newly hatched larvae are pink with brown heads, changing to an ivory color as they age. Once in contact with the plant, larvae feed into the stem base and move downward to attach themselves to the root, feeding on root cortex and spin-

Figure 29. *B. gilveolella* adult, Laura Parsons, University of Idaho.

ning silk feeding tubes as they travel (Caresche and Wapshere 1975b). Sandy and loose soil is essential for this species' survival. Mature larvae are up to 25 mm (1 in) long. Larvae overwinter in feeding tubes (Caresche and Wapshere 1975b). Pupation occurs beneath the soil inside the feeding tubes; once pupation is complete, the emerging adults exit the root through the feeding tubes (Caresche and Wapshere 1975b). Second-generation adults emerge in late summer and lay eggs.

The root system of RSW is key to its perennial survival and asexual spread, so it would seem the direct attack of *B. gilveolella* on RSW would give this insect great impact potential (Groves 1984). However, this insect failed to establish after its initial release in Australia (Cullen 1980). Though a later Australian introduction was more successful, population levels have never been high enough to have a significant impact on RSW reproduction and spread (Delfosse and Cullen 1982). Even in North America, where multiple release events have occurred (Fig. 30), field establishment has yet to be documented (J. Littlefield, Montana State University, unpublished data; M. Schwarzländer, University of Idaho, unpublished data). Coordinated efforts to establish this root moth in North America are currently underway.

Figure 30. Field cage for *B. gilveolella*, Carl Crabtree, Idaho County Weed Control.

Additional Agents

(This section written in large part by George Markin, USDA Forest Service, retired.)

Previous foreign exploration studies targeting the coast of the Mediterranean and the southern parts of the native range of RSW yielded the biocontrol agents presently released against RSW in Australia and the U.S. Additional surveys to find new biocontrol agents possibly better suited to the cold, dry climate of portions of the U.S. Pacific Northwest began in 1995. They were undertaken by Mark Volkovitsh (Russian Academy of Sciences, St. Petersburg, Russia), George Markin (USDA Forest Service, retired, Bozeman, Montana), Javid Kashefi (USDA EBCL, Thessaloniki, Greece), Massimo Cristofaro (BBCA, Rome, Italy) and their cooperators, and were conducted over the drier parts of the native RSW range, including: northern Greece, interior Bulgaria, the Ukraine, the Anatolia Plateau of Turkey, Armenia, the Republic of Georgia, and southwest Russia. In these regions, the most suitable populations of plants were in southwestern Russia, Bulgaria, and Greece; to date, most follow-up studies have been concentrated in these areas. A list of more than 100 species known to feed on RSW has been compiled from these surveys. Seven of the most promising species were selected:

Brachycoleus decolor

Immature and adults of this small mirid were found throughout the Balkans feeding on the growing green stems of bolting RSW plants (Fig. 31). Their feeding destroys a 2 to 5-mm oval patch of the epidermis below the cuticle, bleaching it and leaving distinctive shrunken, white feeding scars that discolor the stems. While the feeding has never been observed to kill a bolting stem, extensive loss of photosynthetic tissue can stunt RSW stems and reduce flower production. The insect was considered for further study even though the literature claimed it might feed on many plant species. Earlier observations in the field indicated that it would not feed on the closely related species *Cichorium endivia* when found adjacent to RSW, even though the plants are very similar in morphological structure with a leafless green, latex-filled shoot. Its restricted host range was also indicated by preliminary laboratory studies in which the adults could not be forced to feed on either *C. endivia* or several species of *Lactuca*, another genus closely related to *Chondrilla*.

Figure 31. *B. decolor* adult. George Markin, USDA FS.

Cycloderes canescens

Weevils have frequently been used as biological control agents and usually have a fairly restricted host range. Therefore, when this root-attacking weevil was observed in central and eastern Turkey, it was added to the list of top ten priority insects for further study. However, to date neither a large enough population nor a suitable cooperator in this area have been located to begin studies.

Enea wertheimsteini (=Oporopsamma wetheimsteini)

This root-feeding moth was originally identified by Australian researchers in the early 1980s. The caterpillars of this small moth feed on the root crowns of RSW plants. This feeding pattern would complement that of either *Bradyrrhoa* or *Sphenoptera* which feed deeper in the soil on the root proper, so it appeared at that time to be very promising as a potential biological control agent for RSW. However, investigations were terminated due to lack of funding.

Ensina sonchi

Seedhead-feeding insects are often dismissed as suitable biological control agents because their feeding usually does not have a significant impact on flowering plants. Well-established stands of weeds attacked by seedhead insects often show no visible impact, and usually enough seed survives to replace the attacked plant. However, targeted populations of RSW in the Pacific Northwest are rapidly expanding and have probably reached only a fraction of their potential distribution. Therefore, any insect that would destroy a significant portion of the seed production might at least help slow the spread of RSW. The large tephritid fly, *Ensina sonchi*, was found destroying up to 15% of RSW seedheads in northern Greece and has been selected for further study. Similar tephritid flies have an extensive history of use as biological control agents and are usually very restricted in their host range. Further studies on this fly are dependent on the development of a protocol for artificially rearing laboratory colonies.

Sawfly

This presently unidentified tenthredinid sawfly is common in Greece and Bulgaria in early spring when its large (2-cm long) white larvae, which closely resemble caterpillars, cause extensive feeding damage to bolting RSW plants (Fig. 32). Larvae were never found on the adjacent related plant species *C. endivia* and *Lactuca* spp. During preliminary tests in the laboratory, this insect selected and fed only on RSW leaves. There are plans to continue stud-

Figure 32. Tenthredinid sawfly larva, Biotechnology and Biological Control Agency.

ies of this insect, but it must first be determined how to eliminate a viral disease that almost always spreads through laboratory colonies.

Schinia cognata

Larvae of this small moth (Fig. 33) feed on the developing flower buds of RSW. A cooperator in Bulgaria (I. B. Lecheva) identified and studied the field biology of this moth, showing in preliminary lab feeding tests that its feeding and development appeared restricted to RSW. At present, attempts are being made to establish a colony in the Montana State University quarantine at Bozeman, Montana, for further host-specificity testing.

Figure 33. *S. cognata* adult, J. Kashefi.

Sphenoptera spp.

Three root-feeding species of beetles, *Sphenoptera foveola, S. signata* and *S. aeneomicans*, were found feeding on *Chondrilla* (Fig. 34). These three species were found only in the eastern-most region of RSW's native range. Studies of the biology and field host range of these insects are underway in southwestern Russia, Armenia and eastern Turkey, and species within this complex will be studied at the Montana State University quarantine, Bozeman, Montana.

Figure 34. *Sphenoptera* adult, George Markin, USDA FS.

In sum, at least seven species show potential to be developed as biological control agents for RSW. A network of cooperators and laboratories has been established throughout the northwestern U.S. and the eastern portion of the native RSW range in eastern Europe and Asia Minor to support the development of these biological control agents. It is believed that a complex of insects could be introduced into North America to manage RSW, but financial support is critical for the development of these biocontrol agents.

Redistribution of Established Biocontrol Agents

Established biological control agents can be collected and redistributed to new RSW infestations, but there are species-specific guidelines for doing so (Table 5). Before releasing biological control agents into an area, you should monitor the target infestation to ensure that biocontrol agents are not already established (Table 6). Keep in mind that, even if a biocontrol release is warranted, transporting biological control agents is regulated by state and federal agencies. A summary of regulations pertaining to the redistribution of RSW biocontrol agents in the Uniteds States and Canada appears on page 61.

Table 5. Redistribution of rush skeletonweed biological control agents approved for release in the United States.

Scientific name	Agent stage	Plant stage	Timing	Method	Favorable sites	Unfavorable sites
Puccinia chondrillina	Urediospore	All stages	Spring (Apr-Jun); Fall (Sep-Nov)	Move infected plant material to uninfected site	Significant period of dew (4+ hours) during darkness	Lack of humidity and dew, even during darkness
Aceria chondrillae	All stages	Bolting, flowering	Summer (Jun-Sep)	Move whole plants infected with mites to uninfected sites	RSW rosettes produced in fall and winter	Extreme winter temperatures with no fall and winter rosettes
Cystiphora schmidti	Any stage inside gall	Bolting, flowering	Spring (Apr-Jun)	Move galled plants to uninfected sites prior to adult emergence	Low amounts grasshoppers and other parasites	High amounts grasshoppers and other parasites
Bradyrrhoa gilveolella	Not established in North America					

Table 6. Suggestions for detecting biocontrol agent establishment.

Scientific name	Agent stage	Where to look	When to look	Damage
Puccinia chondrillina	Urediospore	Foliage	All year	Numerous brown spores and pustules
Aceria chondrillae	All stages	Shoot tips and buds	Growing season	Growing tips and buds covered with tiny galls of enlarged plant tissue; stems stunted and deformed
Cystiphora schmidti	All stages	Foliage	Summer (Jun-Sep); Fall (Sep-Nov)	Leaves and stems covered with purplish colored galls
Bradyrrhoa gilveolella	Not established in North America			

Summary of regulations governing the redistribution of rush skeletonweed biological control agents in North America.

United States, intrastate Generally, there are few if any restrictions governing collection and shipment of biological control within the same state; however, you should check with your state's department of agriculture or agriculture extension service about regulations governing the release and intrastate transport of your specific biological control agent.

United States, interstate The interstate transportation of biological control agents is regulated by the US Department of Agriculture (USDA), and an approved permit is required to transport living biological control agents across state lines. You should apply for an APHIS Plant Protection Quarantine (PPQ) permit as early as possible, ideally at least six months before actual delivery date of your biological control agent. You can check the current status of regulations governing intrastate shipment of weed biological control agents and obtain the permit application form PPQ Form 526 from the USDA-APHIS-PPQ website at http://www.aphis.usda.gov/ppq/permits. A recently initiated ePermit process can be accessed at this website; this allows the complete online processing of biological control agent permit requests

Canada Canada requires an import permit for any new or previously released biological control agents. Permits are issued by the Plant Health Division of the Canadian Food Inspection Agency. Redistribution of biological control agents within a province is generally not an issue; however, you should consult with provincial authorities and specialists prior to moving biological control agents across provincial boundaries. More information on biological control agents is available online at http://res2.agr.ca/lethbridge/weedbio/index_ehtm#oc.

Integrated Resource Management - putting it all together

It is unlikely that one single treatment method will provide long-term control of rush skeletonweed (RSW) in any part of its introduced range (Groves and Cullen 1981, Sheley et al. 1999). Consequently, the key to RSW management is the integration of multiple control methods. The following information highlights key elements of various control approaches as they pertain to an integrated management program. For more detail on each individual control method, refer to Management Techniques, pages 35–61.

Prevention

The first line of defense is to prevent the introduction and establishment of RSW in an un-infested region. This can only be accomplished through a multi-faceted approach:

1. **Public Education and Awareness** Seeds and/or regenerative root fragments are easily spread via many means, including: wind, water, animals, personal vehicles or machinery (Panetta and Dodd 1987). The inadvertent spread of RSW via human interactions can only be prevented if resource users (ranchers, land management personnel, the general public, etc.) are aware of RSW, appreciate the damage it causes, can identify the species, and know how to prevent its spread.

2. **Land Use Alterations** In some regions not infested by RSW, land use practices already in place actually might be conducive to the introduction and spread of RSW. Such practices include: large-scale disturbance of the soil due to construction activity, excessive motorized vehicle usage, fire, and overgrazing livestock. Such activities weaken the capability of native plant communities to resist foreign species infestations (Wells 1971), and either should be avoided completely, or carried out so as to make the smallest possible ecological impact. Activities to consider include environmentally-conscientious construction practices or alternative grazing methods. Even if the land management practices do not overly disturb the soil, they still provide vectors for RSW plant spread (on vehicles, machinery and livestock). Steps should be taken to remove all potential RSW plant propagules (seed and root fragments) from vectors prior to entering an un-infested region (Sheley et al. 1999).

Early Detection and Rapid Response to Eradicate Satellite Populations

Rush skeletonweed is a difficult species to eradicate once it is well established. Therefore, management emphasis should be placed more on detecting and removing new or satellite populations than on eradication.

1. **Inventory** It is imperative that the extent of a population is understood before control activities are implemented, because optimal treatment methods are determined by the size, location and level of establishment of the infestation. To that end, land managers trained in detecting RSW should conduct a thorough inventory of the targeted land parcel prior to treatment.

2. **Rapid Response** Land managers should act immediately to eradicate any new RSW populations or satellites they encounter. There are many control options (Table 7). The location of the infestation will help determine which method is most appropriate.

Table 7. Options for rapid response treatment of new populations.

Method	Applicability	Advantages	Disadvantages
Hand-pulling	Ideally, infestations with plants <5 weeks old; all new infestations	Inexpensive and can eliminate young infestations quickly	Time consuming for well established RSW; requires repeat visits
Mowing	Established infestations on flat terrain	Easy to do on the right terrain	Requires multiple visits, and only prior to seed production
Cultivation	Ideally infestations with plants <5 weeks old; all infestations in agricultural fields	Can eliminate young infestations in single visit	Established RSW can spread via root cuttings and require multiple visits ; disturbs soil
Grazing	Pasture infestations	Inexpensive and provides fodder for livestock	Requires continuous grazing to eliminate RSW; continuous grazing may damage soil and competitive ability of neighboring vegetation
Herbicides	Infestations without interspersed forbs that are susceptible to herbicides	Can eliminate young infestations in single visit; has residual control effects	Expensive; established RSW often require repeat visits; can have non-target effects for multiple years

Control of Established Populations

A thorough inventory of RSW will help land managers categorize the RSW population in terms of its treatment: eradication, reduction , or containment. Once the treatment has been determined the managers should consider:

1. **Economic factors** How much will initial controls and long-term follow up treatments cost? What sources of funding are available? Will treatments be carried out by staff or contractors?

2. **Work schedule** Determine a reasonable time schedule for initial treatment and routine maintenance control.

The economies and efficiencies of treating older, established RSW populations differ, depending on the size of the infestations, locations, and levels of establishment. The following is a summary of treatments for controlling such RSW populations.

Agricultural Management

In situations where cropland currently under production is infested with rush skeletonweed, mechanical control with cultivation is feasible. If cultivation occurs when RSW populations are young (less than five weeks old) and is done repeatedly, RSW plants can be eradicated completely (Cuthbertson 1972). Cultivation should be done at a depth of 25 cm (10 in) to ensure sufficient damage to the deep root system, and should be done when soil is dry to promote desiccation of the root fragments. Multiple cultivation events are required if RSW plants are well established, but this is often not possible for many of the crop species growing in the Western U.S. Consequently, other methods are needed to supplement mechanical controls. In the wheat belt of Australia, RSW populations were reduced through a combination of biological and herbicidal controls (Groves and Cullen 1981). High densities of skeletonweed rust decrease the vigor and density of RSW, coupled with the application of 2,4-D destroys RSW's aboveground biomass, increases crop yield, and minimizes harvesting interference (Heap 1993). Use of clopyralid, metsulfuron or picloram in conjunction with dicamba or 2,4-D may kill RSW completely, especially if applied on fall or winter rosettes. Unfortunately, the residual action of these herbicides makes them unsuitable for use in crop settings under rotational farming with legumes and other broadleaf species (Groves and Cullen 1981). Further, a complete kill of RSW aboveground biomass adversely impacts rust populations, because it removes the rust's required host, i.e., RSW. As a result, following the aboveground chemical treatment, re-growth of RSW will no longer be impacted by the rust (Cheney 1981). Burning fields following harvest should be avoided as a means of control because it simply does not reduce RSW populations (Zouhar 2003).

A summary of integrated control methods available for use in an agricultural setting is listed in Table 8. Refer to local land management personnel for acquisition of the skeletonweed rust and for suggestions on applicable herbicides.

Table 8. Control options for rush skeletonweed infestations in an agricultural setting.

Method	Technique	Advantages	Disadvantages	Integration
Cultivation	Immediately on plants <5 weeks old; multiple times throughout growing season if possible; on dry soil at depths of 25 cm	Inexpensive; can eliminate young infestations quickly	Established RSW can spread via root cuttings and require multiple visits	Supplement with *P. chondrillina* and herbicides
Herbicides	On fall and winter rosettes if possible; spring rosettes in addition or as alternative; 2,4-D to decrease aboveground biomass; picloram/2,4-D or clopyralid/dicamba combo for complete kill	Reduces harvesting interference; can completely kill RSW; has residual control effects	Expensive; established RSW often require repeat visits; can interfere with broadleaf crop species for multiple years	Supplement with *P. chondrillina* releases
Biocontrol	*P. chondrillina* released in spring or fall; released every year if augmentation needed	Decreases vigor, reproduction and biomass of RSW; inexpensive; perpetuating	Slow initially; multiple introductions may be needed	Supplement with herbicides that damage but do not destroy aboveground biomass of RSW if belowground is not killed as well

Pastoral Management

Pastoral infestations of RSW can be treated a number of ways, most of which reduce, rather than eradicate, RSW populations (Table 9). The most obvious first choice for RSW control in pastures is to graze the domestic livestock. Cattle, sheep, goats and sometimes horses readily feed on young RSW (Cuthbertson 1967). Care should be taken when running cattle on RSW-infested pastures as the flowering stem of RSW can choke and sometimes poison the animals (Currie 1936). (Refer to the section on cultural control of RSW for management guidelines regarding livestock on RSW.) Without continuous grazing that prevents bolting and reproduction, RSW will quickly recover, bolt, flower and set seed (Panetta and Dodd 1987). Because continuous grazing is considered by some to be overgrazing and have a negative impact on more desirable pasture species, grazing of RSW should be augmented by other forms of control. Little has been published regarding the combination of grazing and biological control, though infestations of the mite and gall midge are unlikely to impede livestock feeding on RSW.

Cultivation is not suitable in a pastoral setting because it disturbs the root systems of important pasture species and provides continuous disturbances that actually promote RSW establishment (McVean 1966). However, other mechanical methods of control are suitable for pastures. Hand-pulling can be effective when infestations are young and small. Multiple mowing events of pasture vegetation can weaken RSW and promote the growth of competitive pasture species (McLellan 1991); however, mowing should only be done prior to RSW seed maturation lest the problem be made worse by distributing seeds. The addition of nitrogen to the soil will increase the density of perennial pasture species (Kohn and Cuthbertson 1975). This can be accomplished by applying nitrogen fertilizer or by planting nitrogen-fixing legume plants such as clover or alfalfa. Planting competitive leguminous species has the additional advantage of increasing shade, which has a direct negative impact on RSW survival (Moore 1964).

Biological control agents can be successfully integrated with mowing of RSW and the planting of competitive pasture species. Spores of the rust (*P. chondrillina*) can be spread by mowing, as can various stages of the mite *A. chondrillae*. However, mowing of RSW heavily infested with galls of *A. chondrillae* and the gall midge *C. schmidti* can be counterproductive to control, because it can destroy the galls and reduce agent populations. RSW plants simultaneously infected by the rust and growing in the presence of competitive leguminous species experience significant reductions in density and biomass (Groves and Williams 1975). The synergistic action of these two control methods may be limited, though. A greenhouse study demonstrated that very dense shading by a competitive legume species reduced the level of rust infection in RSW, presumably due to reduced spore transfer (Groves and Williams 1975). In a field setting, it is often very difficult to reach the densities of competitive legume species achieved in the greenhouse experiment. Under conditions present in typical pastures, competitive plant canopy is somewhat decreased, and the infection levels and effects of the rust continuously increase. The successful control of RSW in South Australia is believed to be caused by the combination of the rust and competitive leguminous species (Groves and Cullen 1981). The efficacy of biological control agents combined has not been studied extensively. Preliminary data collected in an Idaho field study demonstrate that a mite/rust combination does not negatively or positively impact the effects each has on its own (Milan 2005).

Herbicides can be used in a pasture setting, providing certain precautions are taken. Broadcast applications of chemicals are not recommended because many of the herbicides registered for use within pastures are effective against several broadleaf species of great importance in healthy pasture communities. The spot treatment of herbicides is preferred because it is much more selective. Aboveground kill can be achieved with herbicides such as 2,4-D and dicamba; however, complete aboveground destruction adversely impacts biocontrol populations because it removes their required host (Cheney et al. 1981). Lower levels of RSW aboveground herbicide damage allow biocontrol populations to endure; however, the phytotoxic effect of some chemical compounds prevents mite populations from intensifying (Dimock 1987 as cited in Lee 1986). Picloram, clopyralid, and metsulfuron can be used to completely kill RSW. These herbicides are not ideal for pasture use because they can kill important clovers and alfalfa and have residual effects that can last for many years (Heap 1993). Herbicides used in conjunction with mowing continuously weaken the root reserves of RSW, leading to eventual plant death (Cheney et al. 1981).

Table 9. Control options for rush skeletonweed infestations in a pastoral setting.

Method	Technique	Advantages	Disadvantages	Integration
Hand-pulling	Immediately on plants <5 weeks old; multiple times throughout growing season if needed	Inexpensive; can eliminate young infestations quickly	Time consuming for well established RSW that requires repeat visits	Supplement with mowing, grazing and biocontrols which all weaken RSW
Mowing	Multiple times throughout growing season prior to seed production	Easy to do on the right terrain	Requires multiple visits, especially prior to seed production	Supplement with herbicide spot treatments, grazing and biocontrol agents (rust and mite)
Grazing	Intensive grazing by cattle, goats or sheep early in the season, goats later as well; all before seed production so as not to spread seed	Inexpensive; similar to mowing except more selective	RSW often recovers; level of grazing intensity needed to kill plant often has nontarget effects on pasture ecology	Supplement with mowing and biocontrol agents (midge and mite)
Herbicides	Spot treatments on fall and winter rosettes if possible; spring rosettes in addition or as alternative; 2,4-D to decrease aboveground biomass; picloram/2,4-D or clopyralid/ dicamba combo for complete kill	Can significantly hinder if not completely kill RSW; can have residual control effects	Expensive; established RSW often require repeat visits; can interfere with broadleaf pasture species for multiple years	Supplement with mowing and biocontrol releases
Biocontrol	Rust released in spring or fall; mite released in summer; gall midge released in spring	Decreases vigor, reproduction and biomass of RSW; inexpensive; perpetuating	Slow initially; multiple introductions may be needed	Supplement with mowing, grazing and herbicides that damage but do not destroy aboveground biomass of RSW if belowground is not killed as well

Roadside Management

Figure 45. Roadside weed control. Tom Heutte, USDA FS, UGA 1196064.

Roadways infested with RSW pose a unique control problem. Due to continuous disturbance from traffic and construction machinery, conditions are nearly always optimal for constant RSW establishment and spread (Fig. 45). Consequently, it is more practical and efficient to reduce, rather than attempt to eradicate, these populations. To that end, varied and repeated treatments are likely to be required (Table 10). Biological control efforts may not

Table 10. Control options for ush skeletonweed infestations in a roadside setting.

Method	Technique	Advantages	Disadvantages	Integration
Mowing	Multiple times throughout growing season prior to seed production	Easy to do on the right terrain	Requires multiple visits, especially prior to seed production	Supplement with herbicide treatments and biocontrol agents (rust and mite)
Herbicides	Treatments on fall and winter rosettes if possible; spring rosettes in addition or as alternative; 2,4-D to decrease aboveground biomass; picloram/2,4-D or clopyralid/dicamba combo for complete kill	Can significantly hinder if not completely kill RSW; can have residual control effects	Expensive; established RSW often require repeat visits; can interfere with colonization of more desirable roadside species for multiple years	Supplement with biocontrol agents and multiple mowings
Biocontrol	Rust released in spring or fall; mite released in summer; gall midge released in spring	Decreases vigor, reproduction and biomass of RSW; inexpensive; self-perpetuating	Slow initially; multiple introductions may be needed	Supplement with mowing and herbicides that damage but do not destroy aboveground biomass of RSW if belowground is not killed as well

be as effective in this setting as in other infestation environments, but releases are still warranted, especially of the skeletonweed rust. The biocontrol agents may weaken and suppress established populations (Cheney et al. 1981). Mowing is applicable because, by design, most major roads are accessible by mowing machinery. Multiple mowings can weaken RSW and encourage the growth of more-competitive species (McLellan 1991). Mowing should only be done prior to RSW seed maturation lest the problem be made worse by distributing seeds. Biological control agents can be successfully integrated with mowing of RSW. Spores of the rust can be spread by mowing, as can various stages of the mite; however, mowing RSW heavily infested with galls of the mite and gall midge can destroy the galls and reduce agent populations.

Roadside infestations of RSW can be controlled with herbicides, especially if chemical is applied to the susceptible rosettes in fall and winter (Cheney et al. 1981). Aboveground kill can be achieved with herbicides such as 2,4-D and dicamba, while Picloram, clopyralid and metsulfuron can be used to completely kill RSW. However, complete aboveground destruction adversely impacts biocontrol populations because it removes their required host, i.e., their food source (Cheney 1981). Eventually the roots will recover and re-shoot, but by then the biocontrol populations (if still present, at all) will have declined and by default will be less effective as control agents. The residual action of these herbicides makes them unsuitable for colonization by legumes and other competitive broadleaf species (Groves and Cullen 1981). Herbicides used in conjunction with mowing continuously weaken the root reserves of RSW, leading to eventual plant death (Cheney et al. 1981). Burning roadsides is ineffective as a means of control and should be avoided (Zouhar 2003, Kinter et al. 2007).

Rangeland Management

The vast majority of RSW infestations in the Western U.S. occur on rangeland where many control options are not feasible or economical (Sheley et al. 1999). Most western rangeland is too rugged for mechanical forms of control or planting/maintaining high densities of competitive species. While other methods of control are applicable in a rangeland setting, the category of the RSW population will determine which control method is most appropriate.

Eradication of Satellite Populations

Satellite populations of RSW are new, small, and distant from a larger RSW infestation and should be eradicated immediately via chemical control.

Reduction of a Population

When rangeland RSW infestations are well established but do not cover a vast acreage of land, a reduction of the population may be feasible. This can be accomplished with well-timed and well-placed herbicides, biological control agents, and grazing,.

Herbicidal control can be somewhat successful at containing RSW, especially if the chemical is applied to the susceptible rosettes of fall and winter and along the perimeters of infestations (Cheney et al. 1981). Aboveground kill can be achieved with herbicides such as 2,4-D and dicamba; Picloram, clopyralid and metsulfuron can be used to completely kill RSW. Few herbicides are registered for use on RSW in a rangeland setting, and though some options are available, there are many inherent difficulties with rangeland herbicide application. Rugged terrain is not conducive to most equipment needed to spray herbicides, and it is inefficient to use backpack sprayers to treat vast infestations. Aerial applications are possible, but this method can be very expensive and produce many unwanted effects, such as damage to desirable rangeland species (Heap 1993). Furthermore, aerial applications are very difficult, especially in early spring because the herbicide-susceptible new growth is very difficult to spot from the air (Carl Crabtree, Idaho County Weed Control).

Cattle, sheep, goats, horses and some wildlife readily feed on young RSW (Cuthbertson 1967). (See Cultural Control, page 44, for management guidelines regarding livestock grazing on RSW.) Without continuous grazing to prevent bolting and reproduction, RSW will quickly recover, bolt, flower and set seed (Panetta and Dodd 1987). Some consider "continuous grazing" to be "overgrazing," which implies that it will have a negative impact on more desirable pasture species; therefore, grazing should be augmented by other forms of control.

Biological control agents can help reduce the density and spread of established RSW populations by weakening and suppressing RSW (Cheney et al. 1981). Biocontrol agents are inexpensive, self-perpetuating and capable of reaching RSW infestations in all types of terrain. The field efficacy of biological control agents combined has not been studied extensively. Preliminary data collected in an Idaho field study demonstrate that the effects of the mite and rust in conjunction do not negatively or positively impact the effect each has alone (Milan 2005). High levels of herbicides have a phytotoxic effect on biocontrol populations which does not kill the agents, but prevents them from proliferating (Dimock 1987 as cited in Lee 1986). Herbicides can be used in conjunction with biological control agents most easily by spraying RSW rosettes in fall; biocontrol agents contribute by infecting the aboveground portion of any RSW individuals that escape herbicidal control in fall, spring and summer (Cheney et al. 1981). Little has been published regarding the combination of grazing and biological control, though infestations of the mite and gall midge are unlikely to impede livestock feeding on RSW. Table 10 (page 69) lists the control options available for control of RSW infestations in a rangeland setting.

Containment of a Population

When infestations of RSW are well established and extremely widespread, the appropriate approach is to attempt to contain the populations, prevent them from spreading, but not significantly reduce their size. Over time and as other, smaller RSW populations are reduced and eradicated, the management goal will turn from containment to reduction, and then perhaps to eradication. Chemical control is not appropriate for containment. To begin with, the method is uneconomical for very large RSW infestations. Even if it were economical, very rarely would it be possible to treat a vast area effectively. Surrounding RSW would immediately fill in any gaps left from chemical treatment.

Cattle, sheep, goats, horses, and some wildlife readily feed on young RSW (Cuthbertson 1967). (See Cultural Control, page 44, for management guidelines regarding livestock grazing on RSW.) Without continuous grazing to prevent bolting and reproduction, RSW will quickly recover, bolt, flower, set seed, and spread (Panetta and Dodd 1987) (Fig. 36). Continuous grazing can lead to overgrazing and have a negative impact on more desirable pasture species; therefore, grazing should be augmented by other forms of control.

Figure 36. Rangeland infestation near Banks, ID. Laura Parsons, University of Idaho.

Biological control is the only other appropriate containment treatment for RSW populations. Even though current biological control agent population levels are not sufficient to curtail the spread of RSW in the Western U.S., the prognoses are good that they will continue to rise naturally and through on-going applications, and eventually contain RSW. Biological control agents are inexpensive, self-perpetuating, and capable of reaching RSW infestations over all types of terrain. They have been shown to weaken and suppress populations of RSW (Cheney et al. 1981). The field efficacy of combined biological control agents has not been studied extensively; however, preliminary data from an Idaho field study show that mite and rust treatments have no effect on the individual impacts of each (Milan 2005). Little has been published regarding the combination of grazing and biological control; however, it is unlikely applications of the mite and gall midge will impede livestock feeding on RSW. Table 11 lists all control options available for control of RSW infestations in a rangeland setting.

Table 11. Control options for rush skeletonweed infestation in a rangeland setting.

Method	Technique	Advantages	Disadvantages	Integration
Grazing	Intensive grazing by cattle, goats or sheep early in the season, goats later as well; all before seed production so as not to spread seed	Inexpensive and efficient	RSW often recovers; level of grazing intensity needed to kill plant often has nontarget effects on rangeland ecology	Supplement with biocontrol agents (midge and mite) and fall application of herbicides
Herbicides	Spot treatments on fall and winter rosettes if possible; spring rosettes in addition or as alternative; 2,4-D to decrease aboveground biomass; picloram/2,4-D or clopyralid/dicamba combo for complete kill	Can significantly hinder if not completely kill RSW; can have residual control effects	Expensive; established RSW often require repeat visits; can interfere with broadleaf pasture species for multiple years	Supplement with biocontrol agents and spring/summer grazing
Biocontrol	Rust released in spring or fall; mite released in summer; gall midge released in spring	Decreases vigor, reproduction and biomass of RSW; inexpensive; self-perpetuating; reaches otherwise inaccessible infestations	Slow initially; multiple introductions may be needed	Supplement with grazing and herbicides that damage but do not destroy aboveground biomass of RSW if belowground is not killed as well

Following Control

Inadvertently, the suppression or control of RSW creates new challenges for land managers. Once the targeted weed is controlled, the area is immediately susceptible to invasion by other weeds. Unless several precautions are taken to fill the niche left by RSW, non-desirable invasive species, such as cheatgrass (*Bromus tectorum*), medusahead (*Taeniatherum caput-medusae*) and knapweeds (*Centuarea* spp.), may move in. One precaution includes changing the management of the resource so that it no longer subjects the land to continuous disturbance. Activities responsible for the introduction and spread of RSW and other weeds include construction activities, excessive motorized vehicle usage, fire, and livestock overgrazing. These activities weaken the capability of native plant communities to resist foreign species infestations (Wells 1971). Such activities should either be stopped or carried out in such a manner as to make the smallest ecological impact possible, whether through environmentally-conscientious construction practices or alternative grazing methodology. Even if the land management practices do not overly disturb the soil, they still provide vectors for RSW and other invasive species spread (on vehicles, machinery and livestock); therefore, steps should be taken to remove all invasive species seeds and vegetative root fragments from machinery, vehicles, and other vectors prior to entering the region newly cleared of RSW (Sheley et al. 1999).

In many regions infested with RSW, the soil seed bank is already filled with seeds of exotic species. If only exotic seeds are in the seed bank, only exotic species will fill the gap left by a disturbance or the removal of RSW. This can be avoided with the re-seeding of native or more-desirable plant species. Re-seeding is not applicable for an agricultural setting (Groves and Cullen 1981), but it is a recommended control practice for pastoral infestations of RSW, roadsides and rangelands, though it can be logistically very difficult to accomplish. Re-seeding roadsides may be futile if they are mowed or treated with herbicides continuously, because these activities do not promote the healthy growth of many desirable plant species. The difficulty with re-seeding rangelands is they are generally remote and very rugged, making them difficult to reach and treat with machinery. (Refer to the pamphlet Revegetation Guidelines for Western Montana: Considering Invasive Weeds (Goodwin et al. 2006) for suggested techniques and seed mixes.)

Coordination and Cooperation

Effective control of RSW cannot be achieved without multiple public and private partnerships. The vast acreage of land currently and/or susceptible to RSW infestation greatly outnumbers the manpower and funding available to combat this species. Efforts must be pooled to stretch limited resources further, and to create comparability and consistency in the ways landowners assess species distributions, program priorities and success, implement control actions, and track progress of programs. The Western U.S. is already rich in cooperative working groups (CWMAs), comprised of federal, state and regional land managers, as well as concerned private landowners, working to control and eradicate invasive exotic plants. These working groups should be the main regional conduits for RSW education/awareness, surveillance and treatment (and funding for all three program components). All research and action results pertaining to RSW should be shared extensively among partners of each CWMA, and archived and organized by the Rush Skeletonweed Task Force (RSWTF). Continuously updating and sharing knowledge will keep this RSW Management Plan up-to-date and provide all land managers with the most recent and complete RSW management information.

Future Needs

Much is known about RSW and RSW management, but gaps remain. Likewise, stepped up efforts are being made to fill those gaps, and this Plan will be updated as new data is compiled. To that end, efforts must continue to:

1. Increase biological control implementation through a) increasing the number and size of releases of the RSW root moth, b) continued development of new biological control agents and, c) continued study of the integrative potential of RSW biological control agents.

2. Continue herbicide evaluations. Specifically, quantitative studies are needed to a) determine the efficacy of single and mixed herbicide applications, b) evaluate herbicide efficacy in regards to the concentration (%) of active ingredient(s), translocation success, optimal season and length of treatment, effects on different RSW genotypes, non-target vegetation and habitat type and c) determine the integrated management potential and techniques for herbicide usage.

3. Expand understanding of proper integrated management for all methods of RSW control.

Salmon River Weed Management Area

Carl Crabtree, Idaho County, ID, Weed Superintendent

Background

The Salmon River Weed Management Area (SRWMA) is located on the western border of Idaho. It was created in 1994 to bring together those responsible for weed management within the Salmon River drainage; develop common management objectives; facilitate effective treatment; integrate weed programs; and, within logical geographic boundaries, coordinate the various management efforts being applied to similar lands, use patterns, and problem weeds. Cooperating partners include private landowners, county government, state agencies, the Nez Perce Biocontrol Center, and federal land management agencies.

Management Efforts

Rush skeletonweed was first reported on SRWMA land in 1989. Based on early inventories, populations in the SRWMA were thought to exist largely in the Allison Creek area. It was believed that SRWMA infestations were the result of seed spread from rusk skeletionweed (RSW) populations upriver in the Frank Church Wilderness Area.

Currently, upriver (southern) populations are large, while downriver (northern) populations consist of numerous, smaller, leading-edge satellite populations. Currently, RSW is present across approximately 141,000 acres (Fig. 47). Because this weed is one of the fastest-spreading weeds in the SRWMA, all known infestations within this area have been assigned to management categories and treated aggressively.

Figure 37. Targeted rush skeletonweed management area (red box) within the SRWMA.

Larger, upriver infestations of RSW have been classified for "Containment of a Population," the management goal of which is to prevent them from spreading beyond their current boundaries. These infestations are in very steep and rugged terrain along the Salmon River. Aerial application for chemical treatment might be effective for this region; however, limited funds and higher cost/benefit ratios make such a treatment a low priority. Consequently, the upriver infestations are being treated with a combination of grazing and biological control.

Downriver RSW populations are scattered and smaller than the upriver infestation. These outbreaks have been classified for "Eradication of Satellite Populations," the management goal of which is to treat the populations, so that no viable seed is produced and all plants are eliminated during the current growing season. The Rapid River area near Riggins currently serves as a geographical and management boundary for RSW work in the SRWMA. All RSW populations north of Rapid River are under an eradication objective.

During the growing season of 2007, an aggressive treatment/post-treatment monitoring approach led to the detection and successful treatment of numerous RSW satellite populations. The protocol followed was the same for any program seeking to eradicate satellite populations: all detected RSW populations were treated and subsequently monitored at least three times within a one-year period. To map and inventory RSW, interagency crews were trained in and utilized HP-IPAQs with Windows CE® and ArcMap® software. Several satellite RSW infestations were identified in late spring and early summer. Their locations were recorded in the US Forest Services Natural Resources Information System (NRIS TERRA). The data was used in mid-June to treat the infestations aerially (helicopter) with Tordon 22K® (1 quart/acre) and with M90® nonionic surfactant (0.32 oz/acre) and Placement® antidrift agent (1.2 oz/acre). Two weeks after the initial treatment, high school students from southeastern Idaho began post-treatment inspections (Fig. 38). Students hiked to each treated area and determined whether treatments were effective (efficacy), where RSW had survived treatment, and where RSW populations had originally escaped notice (Fig.39). Where necessary, retreatment was conducted immediately following an area's second inspection. The third and final inspections occurred in fall 2007 and early spring of 2008. Again, where necessary, retreatment was conducted immediately. In total, 127 RSW infestations were treated over 2,889 acres (Fig. 40).

Figure 38. High school students and Idaho County employee Cris Baker monitoring rush skeletonweed post-treatment. Leon Sichter, Idaho County Weed Control.

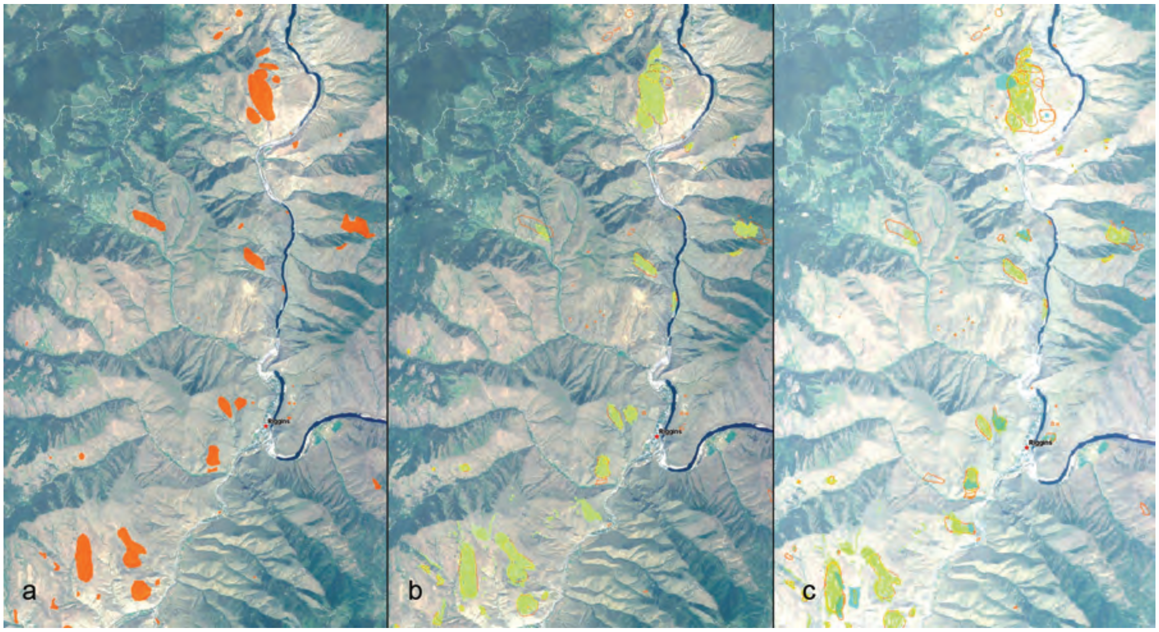


Figure 39. a) Original inventory of rush skeletonweed (red); b) Original inventory of skeletonweed with overlay of aerial treatments (green); c.) Original inventory of skeletonweed and aerial treatments with overlay of post-treatment monitoring of surviving/escaping rush skeletonweed patches (aqua).

Figure 40. Joe Slichter overlooking pristine and invaded SRWMA land. Leon Slichter, Idaho County Weed Control.

One key to the success of this method is the use of *separate* crews to treat and monitor RSW populations. Crewmembers, whose task is to treat weed infestations, search on the ground for individual weeds and small "patches" or satellite populations of RSW. Crewmembers, whose task is to survey for the presence of the target weed, search the broader landscape for infestations. In this way, each crew develops a different search pattern. In the SRWMA, utilizing multiple crews for each task has proven to be the most economical and efficient way to operate.

Another key to the success of this program is to immediately re-treat after monitoring. Only through a very aggressive monitoring and treatment program can satellite populations of RSW be completely eradicated. Populations are monitored most effectively during spring or summer. RSW rosettes are small and hard to identify; however, in late spring, more-extensive aboveground growth makes this plant much easier to distinguish from its surroundings.

Conclusion

Traditional approaches that do not follow the strategic methods of categorizing and prioritizing infestations, coupled with extensive inventory and data management, will lead to a continual increase of RSW and waste of precious resources. The strategic manner in which the SRWMA treats RSW is essential for managing this species on a landscape scale. Focusing limited resources on treating infestations on the leading edges of RSW populations and along transportation corridors prevents the weed from expanding its coverage. Simultaneously working to contain large infestations of RSW with self-sustaining biocontrol agents and grazing efforts helps to decrease RSW density and vigor, leading to possible future fragmentation of the main infestation into smaller, more easily managed populations.

Hell's Canyon-Southern Border

Michael Atchison, The Nature Conservancy, ID

Background

Hell's Canyon is one of the most biologically significant landscapes in the Western U.S. Measuring 7,500 ft deep from mountain peaks to the Snake River and up to 10 miles wide, Hell's Canyon forms the deepest river canyon in North America (Fig. 41). There are several rare species present among hundreds of native plants and animals. Bunchgrasses once covered major portions of the inland Northwest, though much of this area has since been converted to agriculture and weedy annual grasslands. Hells Canyon grasslands represent some of the best examples of the once extensive bunchgrass system.

Figure 41. Drainage near southern border of Hell's Canyon. Michael Atchison TNC, Idaho office.

One of the greatest threats to biodiversity in the Hell's Canyon Ecosystem is invasive weeds such as rush skeletonweed (RSW). When invasive species infest areas upriver (to the south) of Hell's Canyon, river current and wind patterns carry those species throughout the Canyon system, threatening the balance and integrity of the entire Hell's Canyon biotic community. Ox Ranch, Cuddy Mountain and Cecil Andrus Wildlife Management Area all border the 1.15 million-acre Hell's Canyon Priority Landscape on its southeastern border. Ox Ranch is a large working cattle ranch, Cuddy Mountain is a ranching and recreational area, and the Cecil Andrus WMA is operated by the Idaho Department of Fish and Game. One of the largest conservation projects of The Nature Conservancy (TNC) of Idaho is the protection, conservation and restoration of Hell's Canyon. Consequently, TNC has a vested interest in protecting and managing the canyon's southern entrance. As such, TNC is active in invasive species management on neighboring, southern parcels.

Management Efforts

Though the rush skeletonweed mite and rust are present at control sites, they don't appear to be having an appreciable impact on RSW populations. Cultural control techniques, such as the planting of native or more desirable competitive species, is not feasible in the rugged, difficult-to-access terrain RSW currently infests. Consequently, most TNC control efforts have involved herbicides (Fig. 42). Herbicides have been applied for the past four to five years, with most applications being spot-treatments via backpack sprayers. During the growth seasons of 2005 and 2006, RSW was targeted especially hard with the intent to eradicate RSW populations for good. Tank mixes included Tordon® and Milestone® and were applied in late spring through early fall, when TNC spray crews—mostly college students—were available for work. Application methods focused on one drainage at a time, starting at the top and working downward. Following the intense herbicide applications of 2005 and 2006, approximately 200 combined acres of treated RSW populations were effectively controlled; however, an extensive influx of windblown seed from large RSW infestations on surrounding public and private land immediately reintroduced the weed to the treated areas.

Figure 42. mapping and spraying rush skeletonweed. TNC, Idaho Office.

Conclusion

The difficulties encountered while treating RSW on Cecil Andrus WMA, Ox Ranch and Cuddy Mountain demonstrate just how serious a problem RSW can be on a very large landscape scale. The most important lesson learned from experience of treating the weed at these locations is that it futile to treat infestations of this species when larger, surrounding populations exist. This plant reproduces too successfully, through its mass production of seeds and its ability to spread via its very breakable and transportable rhizomatous root system, to be controlled through such treatments. Furthermore, there are simply not enough resources in the entire West to completely eradicate the main population of RSW. Attempting to treat infestations on a small scale, when surrounded by the larger RSW population, will never produce the desired results. Resources would be better spent on true satellite infestations and on containing the leading edges of the main RSW body.

Early Control of Rush Skeletonweed in a Barrier Zone

Kim Goodwin, Montana State University, Bozeman, MT; Dave Burch, Montana Department of Agriculture, Helena, MT; Daniel Bertram, Lemhi County Weed Control, Salmon, ID

Introduction

Even though some states are nearly free of rush skeletonweed (RSW), it continues to spread to new sites in the western region. Effective early detection and rapid response is fundamental to preventing invasion and slowing the spread. An inter-county planning network tasked to reduce logistical difficulties and identify or create strategic barrier zones can help restrict the spread of RSW at the landscape level.

Goals and Objectives

Barrier-zone networks slow the spread of RSW and other new plant invaders to un-infested areas. Our first goal is to establish the Continental Divide Barrier Zone, across 13 million acres, along the Continental Divide, on the border between southwestern Montana and northeastern Idaho (Fig. 43). This zone will provide opportunity and land on which to develop local-level methods to protect north central Idaho, southwestern Montana, and western Wyoming, from the rapid spread of RSW (99,000 ac/yr; Cheney et al. 1981) and other new weeds. The objectives of this project are to: 1) build stakeholder support and design early detection strategies with a landscape focus, 2) develop an early warning system and interactive GIS mapping website to track new weed distribution and movement, and 3) evaluate the efficacy of the project and use this information to identify best practices and corrective actions. The purpose of this case study is to document the early control constraints of RSW and describe potential solutions to slow spread across landscapes. Our intent will be to formulate a comprehensive approach to coordinate efforts, improve collaboration among multiple-level stakeholders, and increase opportunities for long-term funding.

Methods

Barrier zones protect particular areas and habitats from the spread of invasive species through early control (Sharov and Liebhold 1998). Successful invasive-plant barrier zones at landscape scales should include provisions to interrupt/interdict long-distance dispersal and maintain intensive monitoring so new populations can be removed very soon after they are detected. To date, our methods have included strategic assessments of the project area to identify factors that impact early control and long-term barrier-zone monitoring. Information was gathered in 2007–08 through a regional symposium and a series of 32 strategic planning meetings and presentations. County, state, and federal stakeholders from the following counties attended the meetings: Lemhi, Custer, Butte, Clark, Jefferson, Fremont, Madison, and Teton (ID); Beaverhead, Madison, Gallatin, and Ravalli (MT); Park and Teton (WY). A local-level RSW committee was developed in 2007 to identify needs to slow spread in the barrier zone. Committee recommendations are presented below.

<u>Status of the RSW Problem</u>

Rush skeletonweed can be found over 3.5 million acres in Idaho (Cox 2007), but over less than 700 acres in Montana (Moon 2008), predominately in the northwestern portion of the state. In 2006 and 2007, RSW invaded southwestern and eastern Montana near a logging road and along a highway in Ravalli and Treasure counties, respectively. The plant was first detected in Wyoming in 2003 near Jackson. These introductions were associated with roads and have been eradicated. Most of north central Idaho is susceptible to invasion but still remains largely RSW-free (Fig. 43). For instance, RSW can be found on less than 300 acres in Custer

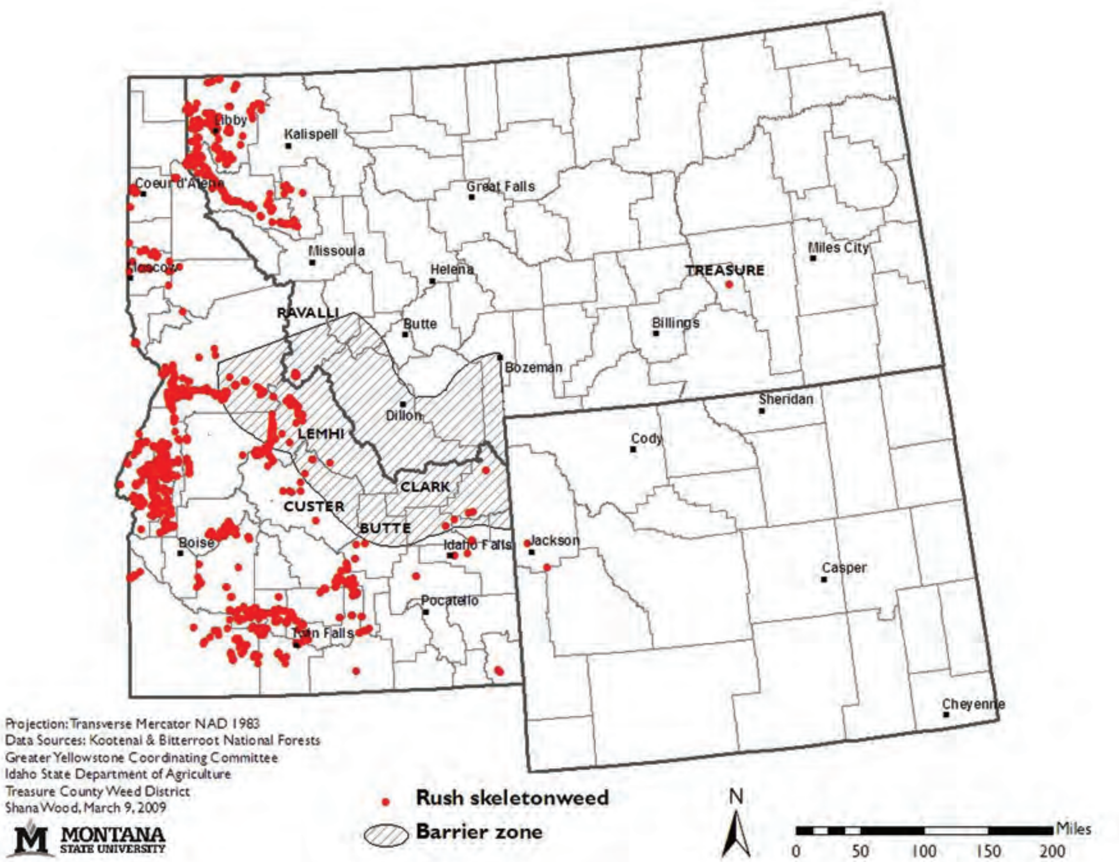


Figure 43. Known locations of Rush skeletonweed in the Intermountain West in 2007.

County and on only 30 acres in Butte County. Occasionally, RSW is found on the foothills of the Pioneer Mountain Range and basaltic lava fields in Craters of the Moon National Monument (CMNM) in southern Butte County. These landforms have potential to act as natural barriers by interrupting north and eastward movement through Custer and Butte Counties. But transportation corridors violate these barriers, and it would be risky to rely on the depauperate habitat in CMNM to restrict RSW's spread. Originally, land managers speculated the substrate might largely hinder RSW establishment. But surveys in 2007 found over 400 new sites ranging in size from one plant to larger infestations spread over 100 acres (Wolken 2007). Rush skeletonweed has not been detected in Clark County, but effective early control in Butte County is critical to slowing its spread to Clark and Jefferson Counties.

Rush skeletonweed can be found over 9,000 acres along t he Middle Fork of the Salmon River, located in northwest Lemhi County. This site is located in the Frank Church Wilderness Area and managed by the Salmon-Challis National Forest. The wilderness designation limits motorized access and grazing management. Other management difficulties include site inaccessibility and largely ineffective biological control agents (Puccinia and Cystiphora). Also, sites tend to have poor soil conditions (e.g., dry, coarse and low organic content), which might reduce herbicide translocation and persistence. The morphology of RSW, specifically the lack of leaf area, might hinder absorption, which could reduce translocation to the extensive root system. Translocation is improved with silicone surfactants and water conditioning agents.

Dispersal Ability and Early Control Constraints

The rapid expansion of RSW might be due to its high dispersal rate, the survival rate of its dispersed propagules (up to 80% viability; Liao et al. 2000), and/or its ability to tolerate large variation in precipitation (ca. 10 to 60 in/yr) and elevation (sea level to ca. 6,000 ft). Rush skeletonweed disperses well, due to high production of small seeds (up to 27,000 seeds/plant; Kinter et al. 2007 and references therein) over a relatively long period, and dispersion capabilities related to distance and spatial pattern, which are not hindered by landscape structure (With 2002). Wind-dispersed plants have diverse spread patterns and access distant, open-canopy habitats as scattered individuals. Plants can establish on high quality sites (Fig. 44) and quickly develop dense stands from vegetative growth (Kinter et al. 2007). The high dispersal rate and complex spread of RSW makes it difficult to narrow search areas. In Lemhi County, vast expanses of rugged wildland must be surveyed regularly in order to locate satellite populations that originate from the Middle Fork. Similar conditions exist in other areas of north central Idaho, where hundreds of sample units must be systematically surveyed to detect new populations.

Figure 44. Rush skeletonweed can invade high quality areas like this sagebrush-bluebunch wheatgrass community in Lemhi County, ID. New invasions are usually found on warm, south-facing, open-canopy sites on gentle slopes with granitic, sandy soil. Flags mark RSW. D. Bertram Spring 2007.

Ground surveys have been conducted across approximately 100,000 acres in Lemhi County over the past decade. About 200 new sites, ranging from one to 100 plants, have been recorded. High-risk sites are surveyed, including shrub-steppe communities on gentle slopes with south-facing aspects. Plants are frequently found on toe-slopes, continuing upslope to the first ridgeline. Low-risk areas include closed-canopy forest and rough fescue (*Festuca campestris*) sites in good range condition. From June to September, 15 ground surveyors typically search about 18,000 acres in Lemhi County. A typical crew of four surveyors, following 30 to 40 ft transect intervals, can search about 1,000 acres/week at a cost of about $6,000. A three-person crew in difficult terrain can survey about 400 acres/week at a cost of about $5,000. Areas confirmed as RSW-free have not been resurveyed, and the optimal frequency of surveillance has not been determined. Land managers need methods to quickly and regularly search high-risk landscapes for new invasions.

Undiscovered populations might exist in the project area, the result of having been overlooked during, or having been established after, the last survey. Such populations escape control, thereby contributing to rapid rates of spread (Panetta 2004). Likewise, invasions known to exist in areas difficult to access may escape control. Partnerships between outfitters and licensed commercial herbicide applicators could improve the delivery of treatment to such areas. To promote discovery, “bounties,” including public recognition, could be awarded for each new invasion reported. Passive monitoring networks of hunters and other user groups are planned to monitor invasions in remote areas (Fig. 45). An internal campaign to encourage public land management personnel to identify and report invasions as a component of their field activities would be helpful, as well. Finally, additional improvements to ground-based detection surveys could be improved by including habitat characteristics and plant-occurrence models that include topographic variables and remote sensing data (Shafii et al. 2003 and 2006). Adapting RSW to current susceptibility models might need to include proximity-to-seed sources, solar-angle differences, and wind-dispersal parameters (T. Prather, pers. comm., 2008).

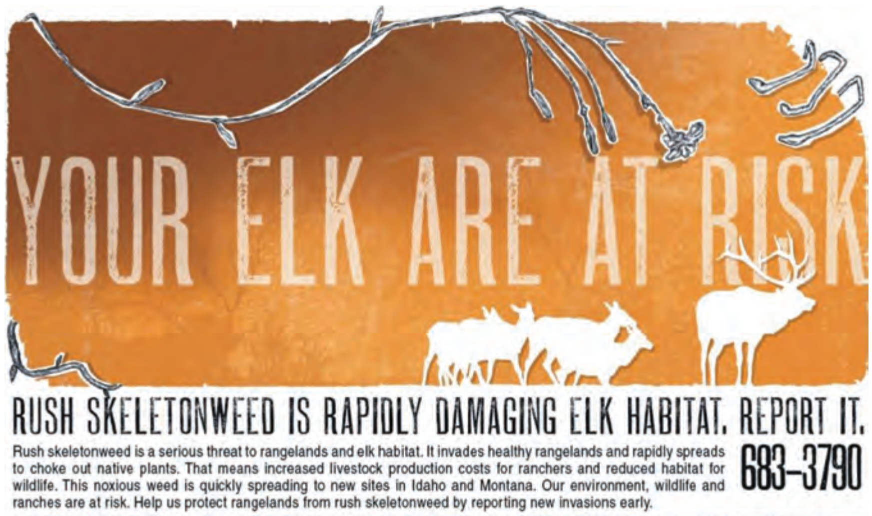


Figure 45. This draft awareness message personalizes the problem of rush skeletonweed spread and makes a call to action for hunters to report new invasions to local weed departments.

Source Management and Approaches to Address Dispersal

Slowing the spread of RSW in the barrier zone requires early control. The most effective management approach to slowing the spread of invasive species, including RSW, is to treat new populations (Moody and Mack 1988; Kinter et al. 2007). This approach is challenging at best, especially when seeds are transported long distances along wind currents and new populations go undetected (Wadsworth et al. 2000).

Better source management with grazing and more effective biological control will be important to offset monitoring difficulties, because they reduce seed production and interfere with long-distance dispersal. Cattle will graze early flowering plants, horses will graze plants in the vegetative stage, and sheep will graze plants in the rosette-to- flowering stage (Davidson et al. 2006). Improved source management should include containment. Containing RSW and other weeds with long-distance dispersal methods will be difficult. For such weeds, lines should be located relatively far from the population front. Dispersal distance can be a function of the inflorescence position (Harper 1977), terminal velocity of the seed (Sheldon and Burrows 1973), wind speed and duration (Stallings et al. 1995), and topography and thermal updrafts (Tackenberg 2003). Anecdotal reports and non-refereed literature indicate winds are capable of dispersing RSW seeds up to 20 miles. An extensive review of peer-reviewed literature did not corroborate this, *per se*; however, in Australia infestations have been observed spreading at rates of "15 to 20 mi annually" (McVean 1966).

Rapid surveys performed at regular intervals are needed for early detection in high-risk landscapes, especially those near source populations. Remote sensing techniques might meet this need. Johnson et al. (1997) and Mundt et al. (2006) found that, due to its morphology, RSW was difficult to detect accurately using aerial photos; however, small, maneuverable helicopters can travel slowly and close enough to the ground for spotters to scan plant communities in real time and map new infestations using digital aerial sketch mapping (DASM) (Karl and Porter 2006). Also, sometimes helicopters can access sites too difficult to reach on foot or observe from fixed-wing aircraft (Fig. 46). The landscape is usually sampled at treetop level (ca. 50 ft) and at speeds less than 10 knots (ca. 12 mph). DASM operational costs vary ($0.10 to $0.70/ac; Karl and Porter 2006) depending on survey pattern, which is a function of

Figure 46. Jet ranger (shown) and Hughes-500 helicopters are used to quickly survey landscapes for new populations of rush skeletonweed and other invasive plants. Photo: M. Porter.

physical terrain features, vegetation, accuracy needs, and target-survey unit. In many areas, around 2,400 acres can be surveyed per day using a tight grid pattern, and about 40,000 acres of suspected infestation can be sampled (M. Atchison [Leading Edge Aviation, Lewiston, ID], pers. comm., 2009). Drones and power parachutes are sometimes used for remote sensing; they work close to the ground, but compared to DASM, have a slower turnaround time for data collection and processing, and also some delivery constraints.

Ground surveys remain the most accurate method to detect new invasions (Radosevich et al. 2003), but they are labor intensive and time consuming. In some situations, digital aerial sketch mapping can improve ground-survey efficiency by (1) scanning suspect areas and thus reducing the number of ground units to be sampled and (2) helping ground surveyors target sites known to contain plants that otherwise would be more difficult to detect. In the future, it might help develop comprehensive distribution maps, define baseline conditions for future comparisons, and quantify spatial and temporal patterns of invasion. It is not known just how reliable DASM is for spotting RSW infestations; what is known is that the spotter's accuracy will vary with his/her experience, site and weather conditions, target species and survey unit, grid spacing, and aircraft speed and altitude. During optimal conditions, such as in the fall when RSW remains green and understory grasses are yellow and dormant, experienced spotters have detected large, robust individuals (M. Porter [Wallowa Resources, Enterprise, OR], pers. comm., 2007). In August, 2008, field trials near Salmon, Idaho, were made to quantify the accuracy of DASM in detecting eradicable RSW populations with patch sizes smaller than 0.1 acre. Unfortunately, sampling conditions were not optimal, and results were inconclusive. We plan to conduct additional field trials in fall 2009.

Eradication

Improvements in survey accuracy will lead to an increase in eradication and other treatment costs, because additional funding will be needed to treat newly-discovered populations. Most invasions in Lemhi County, Idaho, have not been declared eradicated even after 10 years of treatment. Eradication difficulties could be due to a number of things, including herbicide tolerance, inconsistent control resulting from site inaccessibility, and 'reproductive escape' (Panetta 2004) resulting from low detection rates. Studies have shown that RSW has short-lived seeds, so eradication is probably not impacted by seed bank persistence (Panetta and Timmins 2004). As well, RSW seeds display little or no dormancy (Liao et al. 2000, Kinter et al. 2007) and only remain viable in the soil for 6 to 18 months (Cullen and Groves 1977, Lee 1986). In contrast, vegetative reproduction of RSW can be prolific (Kinter et al. 2007), and deep, extensive roots may constrain eradication in ways functionally similar to those of long-lived seed banks.

Successful eradication depends on many years of consistent treatments and near-perfect control to prevent reproduction. But the morphology of RSW—individuals lack leaves and large, distinct flowers—makes plants difficult to detect and ultimately treat (Fig. 47). Detection rates might be improved with light-wavelength viewers (under investigation) and by deploying detector dogs. A recent study found that canines trained to sniff out rare spotted knapweed (Centaurea stoebe) significantly outperformed surveyors:; 87% of the time the dogs found more plants than the surveyors found. The dogs' acute sense of smell enabled them to detect weak odor signals from juvenile targets and small adult plants, which frequently went unseen by surveyors (Goodwin et al. 2009). We are now considering training dogs to detect RSW.

Figure 47. The structure of rush skeletonweed might decrease visual conspicuousness and probability of detection by surveyors.

Prevention

Successful RSW prevention may rely largely on reducing ongoing dispersal from source populations and interrupting non-natural movement resulting from human activity. Reducing seed production might be an important preventative measure, given this plant's high dispersal rate. Many effective programs, such as weed-free forage and gravel pit certification programs and washing protocols for roadside maintenance equipment, are already in place. Monitoring programs for new plants along roads are in place, as well. These efforts may be augmented with formal roadside monitoring by vegetation-maintenance technicians. Roadside monitoring is important because new invaders frequently appear along roads that pass by or through infestations (Brooks and Lair 2005), or along off-highway vehicle routes and hiking trails.

Ecosystem management is critical to controlling RSW establishment. Avoiding large-scale disturbance, such as wildfire and heavy grazing, and maintaining competitive, native-plant communities in good condition might help curtail invasion. Rush skeletonweed is associated with another invasive plant, cheatgrass (Bromus tectorum). Primary invasions of cheatgrass might promote secondary invasions of RSW and what is known as the cheatgrass-wildfire cycle, which may then promote additional expansion of RSW. Vegetative reproduction will not be severely hindered, if at all, because RSW's roots are generally too deep to be destroyed by topical fires (Kinter et al. 2007). Plus, fires will free the land of vegetation and seed pathogens that would otherwise compete with or hinder the expansion of RSW. Rush skeletonweed might be somewhat tolerant of shade but is seldom found on closed forest canopy sites (McVean 1966); therefore, maintaining closed canopy habitat might hinder RSW expansion.

Education

The protection of RSW-free habitats yields benefits to the public. Safeguarding native plant resources ensures healthy environments and contributes to the economy through improved agriculture (National Plant Board 1999). But legislation and public concern for environmental and economic harm caused by invasives is lacking (U.S. Congress, Office of Technology Assessment 1993). Prevention is a viable option, but we need public marketing campaigns to promote the value of RSW-free habitats and the urgency for early control . Regional marketing campaigns could include such things as rally slogans, social networking, on-line updates, public relations and recognition, signs designating RSW-free zones, editorial coverage, monitoring networks, and bounties for reporting new sites. Educational field tours, complete with structured assignments, should be held for the general public, but should include the media, county commissioners, and federal supervisors. Additional target marketing should personalize the problem posed by RSW, and aim to influence public opinion and stimulate policy makers to introduce legislation or request funding.

Conclusion

Rush skeletonweed is rapidly expanding its distribution. Entire states and geographic regions still remain largely RSW-free, but they are susceptible to invasion. Control efforts within the Continental Divide Barrier Zone will aid with early control and suppress the rapid spread of RSW in north central Idaho, Montana, and Wyoming. Early control of RSW is difficult because it has a high dispersal rate, is difficult to detect, and has a high tolerance for herbicides. Successful prevention will require improved source management, including grazing and better biological control to reduce seed production and disrupt complex spread patterns, and ecosystem management to prevent new sites from becoming established. Long-term funding support to county weed departments is needed for continuous monitoring utilizing the most accurate landscape-scale sampling approaches. An example of a comprehensive, landscape-scale sampling protocol would begin with susceptibility models, followed by aerial surveys, followed in turn by narrowly focused, highly accurate ground surveys. Eradication costs will increase as we detect new populations, because the discovery of new infestations will require the treatment of more sites. Successful eradication depends on consistency and might require several different monitoring techniques to improve. Communication and education are critical to increase public concern and influence policy to gain support and prevention.

ACKNOWLEDGMENTS

This project is funded by the Montana Noxious Weed Trust Fund and Cooperative Forestry Assistance Program. We thank the Idaho State Department of Agriculture for its support of early control in north central Idaho. Special thanks to Warren Ririe and Jim Olivarez and the members of the local RSW committee who shared their time and ideas: Gil Gale, Brad Gamett, Tom Gionet, Jim Hawkins, Andy Klimek, Mike Overacker, Diane Schuldt, Chris Tambe, and Elias Williams. Committee advisory members include Joe Milan and Amy Ferriter. Special appreciation goes out to Shana Wood for GIS mapping support and suggestions for improvement to the draft manuscript.

The Ranching Perspective

Jim Little, Rancher, Emmett, ID

Background

Jim Little is a third generation rancher in southern Idaho. His family has been part of the Idaho ranching community since the late 1800s. The 27,000-acre Van Deusen Ranch near Emmett, Idaho, was purchased by the Little family in the 1920s. It had been overgrazed by sheep prior to the purchase. An intensive effort to manage livestock grazing (subsequently switched to cattle) began in the 1960s with the implementation of rest-rotation grazing. As part of this process, pastures are utilized in the early part of the growing season of the first year, late in the season of the second year following seed production, and are completely free of livestock during the third "resting" year. Though progress has been slow, this approach has led to a marked improvement of the watershed and general health and productivity of the range.

Management Efforts

Rush skeletonweed (RSW) was first observed infesting the South Fork of the Payette River during the 1970s and has since spread extensively. The nearby Van Deusen Ranch was still RSW-free in the 1980s. Land managers advised the Littles not to change their land management practices; his efforts appeared to be keeping RSW away. Never the less, RSW invaded the ranch in the 1990s.

Rush skeletonweed populations have increased on the Van Deusen Ranch, though not exponentially as they have elsewhere in the RSW-invaded range. The plant can be found in scattered patches throughout various pastures. Cattle seem to feed well enough on it; however, given the nature of proper grazing management they do not have a permanent impact on the plant's survival. If cattle are left on RSW-invaded land long enough to significantly impact the RSW population, adverse effects on other vegetation are likely. Furthermore, despite its beneficial effects on desired pasture species, the resting stage of the rotational grazing method allows RSW to recover and re-sprout from its extensive root system. Consequently, other means of control are necessary.

The bulk of the RSW infestation occurs in a series of alluvial fans at the base of BLM-owned hills to the west of the ranch. Here, the south-facing, moisture-holding soils create ideal conditions for RSW growth (Fig. 48). Since 2001, numerous herbicide trials have been conducted on these alluvial fans with the cooperation of the Littles, Gem County Weed Control, and Wilbur-Ellis, Inc. Preliminary results suggest that Tordon 22K® (1 quart /acre) is the most effective of the chemicals used. While spot treatment in spring and summer is partially effective on RSW aboveground biomass, a near complete kill of RSW occurred after an aerial application (airplane) in December.

Figure 48. Healthy rush skeletonweed. Rachel Winston, MIA Consulting.

Conclusion

Effectiveness aside, there is a downside for utilizing Tordon 22K®, namely its relatively high cost. The current high cost of controlling RSW cannot be justified when there are more pressing weed and other rangeland issues at hand. Heavy deer and elk movements as well as regular wind patterns serve to spread RSW seed onto the Little property, making routine or on-going herbicidal treatments necessary. In addition, there are other invasive and undesirable species on and entering the Van Deusen Ranch. Cattle find these invasives even less palatable than RSW, making them difficult to control through grazing. Whitetop and western water hemlock both require annual treatments. Scotch thistle is considered the toughest, most labor-intensive, and most expensive weed species for ranch workers to stay ahead of; assistance from Gem County Weed Control is needed to keep this weed at bay.

New herbicide trials (some of which include novel compounds new to weed control) and biological control feeding trials are underway. It is the hope of Jim Little and other ranchers that a more cost-effective solution to the RSW problem will be discovered.

Boise County, ID

Mike Bottoms, Boise County Weed Superintendent, Idaho City, ID

Background

Boise County encompasses 1.2 million acres (Fig. 59), the majority of it in rugged National Forest land. The exact origin of rush skeletonweed (RSW) within Boise County is debatable but it is believed to have been introduced in the 1960s either via the tipping of a grain truck contaminated with weed seed, or from contaminated elk feed.

Management Efforts

Records can't be found, but it is speculated that Gem and Boise counties, working together at that time, petitioned the State Department of Agriculture for funds to treat the population when the first RSW population reached 40 acres in size. The petition was denied because the potential of RSW to spread quickly throughout the region was not yet known, and the concept of Early Detection and Rapid Response had not yet been formulated. Rush skeletonweed spread rapidly and now infests more than 400,000 acres in Boise County, alone (Fig. 49). One can scarcely find a south-facing slope below 5,000 ft in elevation that is not overrun by RSW.

Figure 49. Boise County, ID.

Chemical control of RSW has been underway for years but has encountered many obstacles and setbacks. For example, the rugged terrain and inaccessibility of much of Boise County land make it difficult to apply herbicides to the bulk of the RSW population. The majority of Boise County land is under the management of the Forest Service, but up until three years ago the Forest Service did not work extensively with Boise County Weed Control, so they did not combine their efforts to control RSW.

Owing to the vast acreage this species has invaded, complete coverage by chemical application is not possible (Fig. 60). Due to limited resources and manpower, only select areas of the RSW population are targeted for control. These include roadsides, trails, and campgrounds–essentially, all areas capable of spreading seeds to human vectors, thus raising the potential of


Figure 50. Rangeland infestation near Banks, ID. Laura Parsons, University of Idaho.

making the problem worse. In these regions, a number of different herbicides have been used over the years. Tordon 22K® applied at 1 quart/acre in early May has had some of the best impacts against RSW. However, the application of this herbicide is very limited by location and soil type . Weedmaster® is more versatile than Tordon 22K®, and produced good results along rights-of-way when applied in early May at rates of 1 quart/acre.

During 2005 and 2006, representatives from the University of Idaho and workers from the Boise Country weed control division conducted field trials in Horseshoe Bend, using Milestone® to treat RSW. The tests were favorable: RSW is now on the Milestone® label/registered for use against RSW. In the short amount of time Milestone® has been available for use, applications at rates of 6-7 oz/acre in early May have resulted in good control of RSW with a helpful residual effect in the soil. The amount of chemical needed to treat roads, trails and campgrounds has already decreased markedly because of the effects of Milestone®. However, because the bulk of the RSW infestation is inaccessible, seeds from these regions continuously re-invade treated sites, making regular upkeep necessary. To combat the RSW in more inaccessible sites, efforts have been focused on biological control.

The first biological control agent releases against RSW in Boise County took place in 1978. Biocontrol agents can currently be found throughout the county, though their establishment varies from site to site for reasons unknown. In some regions, RSW plants can be observed to be infested with the fly, mite and rust. A few miles away, RSW plants might only be infested with one agent. Despite the variation of biocontrol agent densities, plants that are heavily infested are observed to produce far fewer (if any) seeds compared to un-infested plants. While biological control efforts have not reduced the population of RSW, they have reduced its rate of spread. Biocontrol efforts against other weeds, e.g. Dalmatian toadflax, in the area have produced marked reductions in plant populations. It is hoped that continual introductions of new agents will increase their efficacy. Along these lines, releases of the new agent *B. gilveolella* were made in Boise County in the summer of 2008.

Conclusion

The RSW issue has served as a major lesson to land managers on the importance of Early Detection and Rapid Response. The Idaho State Department of Agriculture now has a special fund set aside for treatment of new invading species so that a situation similar to that for RSW will not happen again. For the RSW problem, it is hoped that chemical treatments will continue to be effective in transportation corridors. Hopefully, biological control agents will reduce RSW populations to sizes more economically feasible to treat with herbicides.

Literature Cited

Adams, E. and R. Lone. 1984. Biology of Puccinia chondrillina in Washington. Phytopathology. 74: 742-745.

Andres, L. 1982. Considerations in the use of phytophagous mites for the biological control of weeds. In: Biological Control of Pests by Mites. [eds.] M. Hoy, G. Cunningham and L. Knutson. Berkeley: University of California division of Agriculture and Natural Resources. Special Publication 3304. pp. 53-56.

Asher, J., S. Dewey, C. Johnson and J. Olivarez. 2001. Protecting relatively uninfested lands: reducing weed spread following fire. Resource Note No. 52, [Online]. In: Resources notes. Denver, CO: U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center (Producer). Available: http://www.blm.gov/nstc/resourcenotes/rn52.html [2008, June 16]

Atkins, D. and J. Peirce. 2007. Skeletonweed in Western Australia. Bulletin No: 4717. Department of Agriculture and Food WA. ISSN: 1833-7236.

Babbitt, B. 1998. Statement by Secretary of the Interior on invasive alien species. In: Proceedings of the National Weed Symposium, BLM Weed Page, 8-10. April 1998.

Black, I., R. Pederson and D. Stephenson. 1998. The three forms of skeleton weed (Chondrilla juncea L.) in Australia differ in their susceptibility to herbicides. Plant Protection Quarterly. 13(1): 29-32.

Blanchette, B. and G. Lee. 1981. The influence of environmental factors on infestation of rush skeletonweed Chondrilla juncea by Puccinia chondrilllina. Weed Science. 29: 364-367.

Brooks, M., and B. Lair. 2005. Ecological effects of vehicular routes in a desert ecosystem. USDI – USGS, Western Ecological Research Center, Las Vegas (NV).

Bussan, Alvin J.; Dyer, William E. 1999. Herbicides and rangeland. In: Sheley, R. and J. Petroff [eds.] Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 116-132.

Caresche, L. and A. Wapshere. 1974. Biology and host specificity of the Chondrilla gall mites, Aceria chondrillae (G. Can.)(Acarina: Eriophyidae). Bulletin of Entomological Research. 64: 183-192.

Caresche, L. and A. Wapshere. 1975a. The Chondrilla gall midge, Cystiphora schmidti (Ruebsaamen) (Diptera, Cecidomyiidae). Biology and host specificity. Bulletin of Entomological Research. 65: 55-64.

Caresche, L. and A. Wapshere 1975b. Biology and host specificity of the Chondrilla root moth Bradyrrhoa gilveolella (Treitschke) (Lepidoptera, Phycitidae). Bulletin of Entomological Research. 65: 171-185.

Cashmore, A. and K. Carn. 1938. Skeleton weed, Chondrilla juncea L. Experiments with weed-killers. Journal of the Council of Scientific and Industrial Research 11: 21-29.

Caso, O. H. and N. P. Kefford. 1968. The bolting and flowering of Chondrilla juncea L. as influenced by temperature and photoperiod. Australian Journal of Biological Science. 21: 883-894.

Chaboudez, P. 1994. Patterns of clonal variation in skeleton weed (Chondrilla juncea), an apomictic species. Australian Journal of Botany. 42(3): 283-295.

Cheney, T., W. Belles and G. Lee. 1980. Herbicidal control of rush skeletonweed (Chondrilla juncea L.). Proceedings of the Western Society of Weed Science. 33: 52-56.

Cheney, T., G. Piper, G. Lee, W. Barr, D. Thill, R. Hawkes, R. Line, R. Old, L. Craft Jr., and E. Adams. 1981. Rush skeleton weed biology and control in the Pacific Northwest. University of Idaho, College of Agriculture, Cooperative Extension Service. Current Information Service. 585. Moscow, ID.

Clemson, A. 1985. Honey and pollen flora. P 209-210. Inkata Press, Melbourne, Australia.

Coleman-Harrell, M., D. Ehrensing, G. Lee, W. Belles, D. Isaacson and R. Schirman. 1979. Rush skeletonweed. Idaho Current Information Service No. 468. 4pp.

Cox, S. (Idaho State Dept. of Agriculture, scox@agri.idaho.gov. Rush skeletonweed estimate [Internet]. Message to: Kim Goodwin (kgoodwin@montana.edu). 2007 Sept 20, 8:13 am [cited 2007 Oct 10].

de Crouzel, I.S., H.A. Cordo and E.D. Saini. 1983. Sobre el control biologico del “Yuyo esqueleto” Chondrilla juncea L. en la Republica Argentina. Malezas. 11(1): 216-232.

Cullen, J. 1978. Evaluating the success of the programme for the biological control of Chondrilla juncea L. Proceedings IV International Symposium Biological Control Weeds. Gainesvillle, Florida. 1976. p. 117-121.

Cullen, J. and R. Groves. 1977. The population ecology of Chondrilla juncea L. in Australia. Proceedings of the Ecological Society of Australia. 10: 121-134.

Cullen, J. and A. Moore. 1983. The influence of three populations of Aceria chondrillae on three forms of Chondrilla juncea. Journal of Applied Ecology. 20: 235-243.

Cullen, J., R. Groves, J. Alex. 1982. The influence of Aceria chondrillae on the growth and reproductive capacity of Chondrilla juncea. Journal of Applied Ecology. 19: 529-537.

Cullen, J., P. Kable and M. Catt. 1973. Epidemic spread of a rust imported for biological control. Nature 244: 462-464.

Currie, G. 1936. A report on a survey of weed problems in Australia. CSIRO pamphlet No. 60.

Cuthbertson, E. 1967. Skeleton weed. Distribution and control. New South Wales Department of Agriculture. Bulletin No. 68.

Cuthbertson, E. 1970. Chondrilla juncea in Australia. Seed maturity and other factors affecting germination and establishment. Australian Journal of Experimental Agriculture and Animal Husbandry. 10: 62-66.

Cuthbertson, E. 1972. Chondrilla juncea in Australia. Root morphology and regeneration from root fragments. Australian Journal of Experimental Agriculture and Animal Husbandry. 12: 528-534.

D'Antonio, C. and P. Vitousek. 1992. Biological invasions b exotic grasses, the grass/fire cycle, and global changes. Annual Review of Ecological Systems 23: 63-87.

Davidson, J.C., E. Smith, and L.M. Wilson. 2006. Livestock grazing guidelines for controlling noxious weeds in the western United States. Ext. Serv. Bull. EB-06-05. Univ. of Nevada.

DeBach P. 1964. Biological Control of Insect Pests and Weeds. Chapman & Hall. London, U.K. 844 pp.

Delfosse, E.S. 2004. In: Biological Control of Invasive Plants in the United States. [eds.] Coombs, E.M., J.K. Clark, G.L. Piper and A.F. Cofrancesco, Jr., pp 1-11. Oregon State University Press. Corvallis, OR.

Delfosse, E.S. and J. Cullen. 1982. Biological control of weeds of Mediterranean origin, a progress report. Australian Weeds. 1: 25-30.

Flora Europaea. 1964-1980. 5 vols. T. G. Tutin, V. H. Heywood, N. A. Burges, D. H. Valentine, S. M. Walters, and D. A. Webb, Eds. Cambridge University Press, NY. 2,245 pp.

Flora of North America. 2009. Published on the Internet http://www.efloras.org, Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA. [Accessed 2009, March 8]

Georgia, A. E. 1914. A Manual of Weeds. Macmillan. New York, NY, USA. 593 pp.

Goodwin, K., G. Marks, and R. Sheley. 2006. Revegetation guidelines for Western Montana: considering invasive weeds. Extension Service Bulletin. Montana State University. EB 170.

Goodwin, K., R. Engel and D. Weaver. 2009. A new method to locate rare spotted knapweed, unpublished manuscript, Montana State Univ., Bozeman, MT.

Greenham, C. and T. Wilkinson. 1942. Studies on chemical weed-killers with special reference to skeleton weed. IV. Further spray trials and toxicity investigations with a note on translocation. Journal of the Council of Scientific and Industrial Research 15: 154-161.

Groves, R. 1984. Ecological control of skeleton weed in south-eastern Australia- past, present and future research. Proceedings 7th Australian Weeds Conference, Perth. 1: 125-128.

Groves, R. and J. Cullen. 1981. Chondrilla juncea, the ecological control of a weed. In: The ecology of pests- some Australian case histories. [eds.] R. Kitching and R. Jones. p. 7-17. CSIRO, Australia.

Groves, R. and J. Williams. 1970. Growth of skeleton weed (Chondrilla juncea L.) as affected by growth of subterranean clover (Trifolium subterraneum L.) and infection by Puccinia chondrillina Bubak and Syd. Australian Journal of Agricultural Research. 26: 975-983.

Hanley, M. and R. Groves. 2002. Effect of the rust fungus Puccinia chondrillina TU 788 on plant size variability in Chondrilla juncea. Weed Research. 42: 370-376.

Harper, J.L. 1977. Population Biology of Plants. London, U.K.: Academic Press.

Harris, P. 2003. Biology of target weeds: Rush skeletonweed Chondrilla juncea L., In: Classical biological control of weeds. Lethbridge, AB: Agriculture and Agri-Food Canada, Lethbridge Research Centre (Producer). Available: http://res2.agr.ca/lethbridge/weedbio/plant/brshskel_e.htm [2007, June 13]

Hasan. S. 1972. Specificity and host specialization of Puccinia chondrillina. Annals of Applied Biology. 72: 257-263.

Hasan, S. and A. Wapshere. 1973. The biology of Puccinia chondrillina- a potential control agent of rush skeletonweed. Annals of Applied Biology. 74: 325-332.

Hasan, S., P. Chaboudez, C. Espiau. 1995. Isozyme patterns and susceptibility of North American forms of Chondrilla juncea to European strains of the rust fungus Puccinia chondrillina. In: Delfosse, E. S.; Scott, R. R., eds. Proceedings of the 8th international symposium on biological control of weeds; 1992 February 2-7; Canterbury, New Zealand. Melbourne, Australia: DSIR/CSIRO: 367-373.

Heap, J. 1993. Control of rush skeleton weed (Chondrilla juncea) with herbicides. Weed Technology. 7(4): 954-959.

Hedrick. U. 1972. Sturtevant's Edible Plants of the World. Dover Publications, Mineola, NY. 686 pp.

Hickman, J. [ed.]. 1993. The Jepson Manual: Higher plants of California. Berkeley, CA: University of California Press. 1400 p.

Hitchcock C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Hull, V. and R. Groves. 1973. Variation in Chondrilla juncea L. in south-eastern Australia. Australian Journal of Botany 21: 113-135.

Johnson, V., Hl Lachowski, L. Lake, and B. Anderson. 1997. Mapping and monitoring noxious weeds using remote sensing. USDA - FS Remote Sensing Applications Center Report RSAC-2-RPT1. Salt Lake City, UT.

Julien, M. [ed.] 1998. Biological Control of Weeds: A World Catalogue of Agents and Their Target Weeds, 4th ed., CAB International, Wallingford, Oxford, U.K.

Karl, J., and M. Porter. 2006. Digital aerial sketch-mapping for early detection and mapping. Pgs 33-41 in L.J. Rew and M.L. Pokorny, eds. Inventory and survey methods for nonindigenous plant species. Ext. Serv. Bull. EB 171. Montana State Univ., Bozeman, MT.

Kinter, C.L., B.A. Mealor, N.L. Shaw and A.L. Hild. 2007. Postfire invasion potential of rush skeletonweed (Chondrilla juncea). Rangeland Ecology and Management 60:386-394.

Kohn, G.D. and E.G. Cuthbertson. 1975. Response of skeleton weed (Chondrilla juncea) to applied superphosphate and grazing management. Australian Journal of Experimental Agriculture and Animal Husbandry. 15: 102-104.

Kunkel G. 1984. Plants for Human Consumption, an annotated checklist of the edible phanerograms and ferns. Koeltz Scientific Books, Koenigstein, Germany. 393 pp.

Lee, G. 1986. Integrated control of rush skeletonweed (Chondrilla juncea) in the Western US. Weed Science. 34: 2-6.

Liao, J. 1996. Phenological development and seed germination characteristics of rush skeletonweed in southwestern Idaho. Provo, UT: Brigham Young University. 57 pp. Thesis.

Liao, J. D., S. B. Monsen, V. J. Anderson, N. L. Shaw. 2000. Seed biology of rush skeletonweed in sagebrush steppe. Journal of Range Management. 53(5): 544-549.

Littlefield, J. and W. Barr. 1980. Impact of grasshoppers on the rush skeletonweed gall midge in southwestern Idaho. Proceedings of the V International Symposium on the Biological Control of Weeds. Brisbane, Australia. 649 pp.

Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout and F.A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications. 10: 689-710.

Martin, M. E. 1996. Rush skeletonweed (Chondrilla juncea) and Parasitic Associates: A Synopsis of Selected Information. Web site: http://infoweb.magi.com/~ehaber/skeleton.html. [23 Dec 2003]

McLellan, P. W. 1991. Effects of mowing on the efficacy of the gall mite, Eriophyes chondrillae, on rush skeletonweed, Chondrilla juncea. Pullman, WA: Washington State University. 59 pp. M.S. Thesis.

McVean, D. N. 1966. Ecology of Chondrilla juncea L. in south-eastern Australia. Journal of Ecology. 54(2): 345-365.Morse, L.E., J.T. Cartes and L. Center. 1995. Native vascular plants. In: Gibbs, A., R. Meischke (Eds.), Pests and Parasites as Migrants. Cambridge University Press, Cambridge. 28-39.

Mendes, R. 1982. Effectiveness of Cystiphora schmidti (Ruebsaamen) (Diptera, Cecidomyiidae) as a biological control agent of rush skeletonweed, Chondrilla juncea L. in Eastern Washington. Pullman, WA, Washington State University. 78 pp. M.S. Thesis.

Milan, J.D. 2005. Impact of the gall mite Erophyes chondrillae and the rust Puccinia chondrillina on their shared host plant rush skeletonweed, Chondrilla juncea L. Moscow, ID, University of Idaho. Master thesis. 89 pp.

Milan, J.D., B. L. Harmon, T. S. Prather and M. Schwarzländer. 2006. Winter mortality of Aceria chondrillae, a biological control agent released to control rush skeletonweed (Chondrilla juncea) in the western United States. Journal of Applied Entomology. 130(9-10): 473–479.

Moon, T. (Montana Dept. of Agriculture, tmoon@mt.gov). Rush skeletonweed distribution in Montana [Internet]. Message to: Kim Goodwin (kgoodwin@montana.edu). 2008 Aug 4, 10:54 am [cited 2008 Aug 4].

Moody, M.E. and R.N. Mack. 1988. Controlling the spread of plant invasions: the importance of nascent foci. The Journal of Applied Ecology 25:1009-1021.

Moore, A. D. 1991. Gall formation on the different forms of skeleton weed by Cystiphora schmidti Rübsaamen (Diptera: Cecidomyiidae). Journal of the Australian Entomological Society. 30: 237-238.

Moore, R. M. 1964. Chondrilla juncea L. (skeleton weed) in Australia. Proceedings of the 7th British Weed Control Conference. p 563-568.

Moore, R. M. 1971. Weeds and weed control in Australia. Journal of the Australian Institute of Agricultural Science. 37: 181-191.

Moore, R. M. and J. Robertson. 1963. Studies on skeleton weed–chemical control. Field Station Records Division of Plant Industry. CSIRO. 2: 1-8.

Moore, R. M. and J. Robertson. 1964. Studies on skeleton weed- competition from pasture plants. Field Station Records Division of Plant Industry. CSIRO. 3: 69-72.

Mundt, J.T., N.F. Glenn, K.T. Weber, and J.A. Pettingill. 2006. Determining target detection limits and accuracy delineation using an incremental technique. Remote Sensing of Environment 105: 34-40.
Myers, J.H. 1985. How many insect species are necessary for successful biocontrol of weeds? In Proc. VI Internat. Symp. on Biol. Contr. Weeds, ed. E.S. Delfosse, pp 77-82. 19-25 August 1984. Vancouver, Canada. Agriculture Canada, Ottawa, Canada.

National Plant Board. 1999. Safeguarding American plant resources: a stakeholder review of the APHIS-PPQ safeguarding system. National Plant Board.

Old, R. 1981. Rush skeletonweed (Chondrilla juncea L.): Its biology, ecology and agronomic history. Pullman, WA: Washington State University. 92 p. Thesis.

Old, R. 1990. Rush skeletonweed (Chondrilla juncea L.) in Washington: Identification, biology, ecology and distribution. In: Roche, Ben F.; Roche, Cindy Talbott, eds. Range weeds revisited: Proceedings of a symposium: A 1989 Pacific Northwest range management short course; 1989 January 24-26; Spokane, WA. Pullman, WA: Washington State University, Department of Natural Resource Sciences, Cooperative Extension: 71-76.

Panetta, F. D. 1988. Factors determining seed persistence of Chondrilla juncea L. (skeleton weed) in southern western Australia. Australian Journal of Ecology. 13(2): 211-224.

Panetta, F.D. 1989. Reproduction and perennation of Chondrilla juncea L. (skeleton weed) in the Western Australian Wheatbelt. Australian Journal of Ecology. 14:123-129.

Panetta, F.D. and J. Dodd. 1987. Bioclimatic prediction of the potential distribution of skeleton weed Chondrilla juncea L. in Western Australia. Journal of the Australian Institute of Agricultural Science. 53:11-16.

Panetta, F.D. and J. Dodd. 1995. Chondrilla juncea L. In: R. Groves, R. Shepherd and R. Richardson [eds.]. The Biology of Australian Weeds. R. and F. Richardson. Frankston, Australia. 67-86.

Panetta, F.D. 2004. Seed banks: the bane of the weed eradicator. Pgs 523-526 in B.M. Sindel and S.B. Johnson, eds. Proceedings of the 14th Australian weeds conference. Weed Society of New South Wales, Wagga Wagga, New South Wales, Australia.

Panetta, F.D., and S.M. Timmins. 2004. Evaluating the feasibility of eradication for terrestrial weed incursions. Plant Protection Quarterly 19:5-11.

Parsons, W. 1973. Noxious weeds of Victoria. p.93-98. Inkata Press, Melbourne, Australia.

Parsons, W. and E. Cuthbertson. 2001. Skeleton weed, p. 264-270. Noxious Weeds of Australia. CSIRO Publishing.

Pesticide Action Network North America. 2008. [Online]. Available at: http://pesticideinfo.org/ . [2008, 23 June].

Pimental, D., L. Lach, R. Zuniga and R. Morrison. 2000. Environmental and economic costs associated with non-indigenous species in the United States. BioScience. 50 (1): 53-65.

Pimental, D., S. McNair, J. Janecka, J. Wightman, C. Simmonds, C. O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino, T. Tsomondo. 2001. Economic and environmental threats of alien plant, animal and microbe invasions. Agriculture, Ecosystems and Environment. 84: 1-20.

Piper, G. and L. Andres. 1995. Rush skeletonweed. In: Biological Control in the Western United States: Accomplishments and Benefits of Regional Research Project W-84 1964-1989. [Eds.] J. Nechols, L. Andres, J. Beardsley, R. Goeden and C. Jackson. University of California, Oakland, CA. Publication 3361.

Piper, G. and E. Coombs. 1996. Rush skeletonweed--Chondrilla juncea. In: Rees, Norman E.; Quimby, Paul C., Jr.; Piper, Gary L.; [and others], eds. Biological control of weeds in the West. Bozeman, MT: Western Society of Weed Science. In cooperation with: U.S. Department of Agriculture, Agricultural Research Service; Montana Department of Agriculture; Montana State University: Section II.

Prather, T.S. 1993. Combined Effects of Biological Control and Plant Competition on Rush Skeletonweed. Moscow, ID, University of Idaho. PhD dissertation. 63 pp.

Quinney, D. 2000. Then and now: changes in vegetation and land use practices in southwestern Idaho sagebrush lands of the Snake River Birds of Prey National Conservation Area north of the Snake River. In: Entwistle, P. G.; DeBolt, A. M.; Kaltenecker, J. H.; Steenhof, K., compilers. Sagebrush steppe ecosystems symposium: Proceedings; 1999 June 21-23; Boise, ID. Publ. No. BLM/ID/PT-001001+1150. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office. p. 91-97.

Radosevich, S. R., M. M. Stubbs and C. M. Ghersa. 2003. Plant invasions – process and patterns. Weed Science 51:254-9.

Rees, N. and P. Quimby, G. Piper, E. Coombs, C. Turner, N. Spencer and L. Knutson (eds.), 1996. Rush skeletonweed; Cystiphora schmidti; Eriophyes chondrillae; Puccinia chondrillina. Biological Control of Weeds in the West. Western Society of Weed Science in cooperation with USDA Agricultural Research Service, Montana Department of Agriculture and Montana State University.

Rosenthal, R., R. Schirman and W. Robocker. 1968. Root development of rush skeletonweed. Weed Science. 16: 213-217.

Shafii, B., W.J. Price, T.S. Prather, L.W. Lass, and D.C. Thill. 2003. Predicting the likelihood of yellow starthistle (Centaurea solstitialis) occurrence using landscape characteristics. Weed Science. 51(5):748-751.

Shafii, B., W.J. Price, T.S. Prather, L.W. Lass, and D. Howard. 2006. Modeling dispersal of yellow starthistle in the canyon grasslands of north central Idaho. Applied Statistics in Agriculture. G. A. Milliken (Ed.). Kansas State Univ., Manhattan, KS.

Sharov, A. and A. Liebhold. 1998. Model of slowing the spread of gypsy moth (Lepidoptera: Lymantriidae) with a barrier zone. Ecological Applications 8(4): 1170-1179.

Schirman, R. and W. C. Robocker. 1967. Rush skeletonweed--threat to dryland agriculture. Weeds. 15: 310-312.

Sheldon, J. C. and F. M. Burrows. 1973. The dispersal effectiveness of the achene-pappus units of selected Compositae in steady winds with convection. New Phytologist 72:665-75.

Sheley, R., J. Hudak, R. Grubb. 1999. Rush skeletonweed. In: Sheley, R and J. Petroff [eds.] Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 308-314.

Spollen, K. 1986. Effectiveness of Eriophyes chondrillae (G. Can.)(Acarina: Eriophyidae) as a biological control agent of rush skeletonweed, Chonrilla juncea L. (Compositae: Chicoriaceae) seedlings in eastern Washington. Pullman, WA, Washington State University. Master thesis.

Sobhian, R. and L. Andres. 1978. The response of the skeletonweed gall midge, Cystiphora schmidti (Diptera: Cecidomyiidae), and gall mite, Aceria chondrillae (Eriophyidae) to North American strains of rush skeletonweed (Chondrilla juncea). Environmental Entomology. 7: 506-508.

Stallings, G. P., D. C. Thill, C. A. Mallory-Smith and L. W. Lass. 1995. Plant movement and seed dispersal of Russian thistle (Salsola iberica). Weed Science 43:63-69.

Supkoff, D., D. Joley and J. Marois. 1988. Effect of introduced biological control organisms on the density of Chondrilla juncea in California. Journal of Applied Ecology. 25: 1089-1095.

Tackenberg, O. 2003. Modeling long-distance dispersal of plant diaspores by wind. Ecological Monographs 73:173-89.

Tortosa, F. and D. Medan. 1978. Chondrilla L. (Compositae), Nuevo genero para la Argentina. Darwiniana 21: 115-119.

U.S. Congress, Office of Technology Assessment. 1993. Harmful non-indigenous species in the United States. Washington (DC): U.S. Government Printing Office. Report OTA-F-565.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2009. PLANTS Database, [Online]. Available: http://plants.usda.gov/ [2009, March 8].

Wadsworth, R.A., Y.C. Collingham, S.G. Willis, B. Huntley, and P.E. Hulme. 2000. Simulating the spread and management of alien riparian weeds: are they out of control? Journal of Applied Ecology 37:28-38.

Walker, B.H. and W. Steffan. 1997. An overview of the implications of global change for natural and managed terrestrial ecosystem. Conservation Ecology 1 (2): 2-17.

Wapshere, A.J. 1971. The effect of human intervention on the distribution and abundance of Chondrilla juncea L. Proceedings of the Advanced Study Institution. Dynamics Numbers Populations. Oosterbeek, 1970. p. 469-477.

Wapshere, A. J.; Caresche, L.; Hasan, S. 1976. The ecology of Chondrilla in the eastern Mediterranean. Journal of Applied Ecology. 13(2): 545-553.

Wapshere, A. J.; Hasan, S.; Wahba, W. K.; Caresche, L. 1974. The ecology of Chondrilla juncea in the western Mediterranean. Journal of Applied Ecology. 11(2): 783-799.

Wells, G. 1970. Skeleton weed (Chondrilla juncea) in the Victorian Mallee. Effects of legumes on soil fertility and subsequent wheat crop, and the resultant effect on weed population. Australian Journal of Experimental Agriculture and Animal Husbandry. 10: 622-629.

Wells, G. 1971. The ecology and control of skeleton weed (Chondrilla juncea) in Australia. The Journal of the Australian Institute of Agricultural Science. 37: 122-137.

With, K.A. 2002. The landscape ecology of invasive spread. Cons. Biology 16(5):1192-1203.

Wolken, P. (Craters of the Moon NM, National Park Service, Paige_Wolken@nps.gov). Rush skeletonweed [Internet]. Message to: Tess O'Sullivan (tess@lavalake.net). 2007 Sept 12, 2:04 pm [cited 2008 July 15].

Zouhar, K. 2003. Chondrilla juncea. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2008, May 29].

APPENDIX 1: RUSH SKELETONWEED TASK FORCE MEMBERS

Rick Belnap
Idaho Dept. of Lands
McCall, ID
Phone 208.634.7125
rbelnap@idl.idaho.gov

Daniel Bertram
Superintendent, Lemhi Co.
Salmon, ID
Phone 208.756.2824
weeds@salmoninternet.com

Mike Bottoms*
Superintendent, Boise Co.
Idaho City, ID
Phone 208.793.2447
mbottoms@co.boise.id.us

Paul Brusven
Nez Perce BC
Lapwai, ID
Phone 208.843.9374
pbrusven@nezperce.org

Dave Cottle
US Forest Service
Stanley, ID
Phone 208.774.3014
dcottle@fs.fed.us

Carl Crabtree*
Superintendent, Idaho Co.
Grangeville, Idaho 83530
Phone 208.983.2667
ccrabtree@idahocounty.org

Liese Dean
US Forest Service
Stanley, ID
Phone 208.774.3017
ldean@fs.fed.us

Michael Diem
US Forest Service
Cascade, ID
Phone 208.382.7400
mdiem@fs.fed.us

Amy Ferriter*
BSU/ISDA
Boise, ID
Phone 208.332.8686
aferriter@agri.idaho.gov

John Gaskin*
USDA-ARS
Sidney, MT
Phone 406.433.9444
jgaskin@sidney.ars.usda.gov

Kevin Gaither
Superintendent, Valley Co.
Cascade, ID
Phone 208.382.7199
kgaither@co.valley.id.us

Kim Goodwin
LRES Dept., MSU
Bozeman, MT
Phone 406.580.9704
kgoodwin@montana.edu

Ray Holes*
Weed grazing
Grangeville, ID
Phone 208.740.9264
rayholes@yahoo.com

Dean Johnson
Idaho Dept. of Lands
Boise, ID
Phone 208.334.3488
djohnson@idl.idaho.gov

Carl Jorgensen
US Forest Service
Boise, ID
Phone 208.373.4225
cljorgensen@fs.fed.us

Dave Klaw
Superintendent, Adams Co.
Council
Phone 208.253.4669
weeds@co.adams.id.us

Terry Lee
Superintendent, Camas Co.
Fairfield
Phone 208.764.3512
camascreekweeds@rtci.net

Jim Little
Rancher
Emmett, ID
Phone 208.365.2220
littleja@bigskytel.com

Howard Lyman
US Forest Service
Whitebird, ID
Phone 208. 839.2111
hlyman@fs.fed.us

Joseph Milan*
BLM/ISDA
Boise, ID
Phone 208.384.3487
joseph_milan@blm.gov

Jim Olivarez
US Forest Service
Misoula, MT
Phone: 406.329.3621
jolivarez@fs.fed.us

*Summit attendee. See page 4.

Warren Ririe*
US Forest Service
Boise, ID
Phone 208.373.4151
wririe@fs.fed.us

Dan Safford
ISDA
Boise, ID
Phone 208.332.8592
dsafford@agri.idaho.gov

Mark Schwarzländer*
PSES Dept, U of I
Moscow, ID
Phone 208.885.9319
markschw@uidaho.edu

Daniel B. Sharratt*
Oregon Dept of Agriculture
Union, Oregon
Phone 541.562.5109
dsharrat@oda.state.or.us

Lynne Silva
BLM
Vale, OR
Phone 541.473.6271
lynne_f_silva@or.blm.gov

Brian Wilbur*
Superintendent, Ada Co.
Garden City, ID
Phone 208.577.4646
wpwilbbk@adaweb.net

Rachel Winston*
BSU/U of I
Boise, ID
Phone 509.339.3143
wins9529@uidaho.edu

Mike Woods
BLM
Baker City, OR
Phone 541.523.1302
mike_woods@blm.gov

Jake Wyant
Superintendent, Gem Co.
Emmett, ID
Phone 208.365.4201
gcwc@bigskytel.com

*Summit attendee. See page 4.

Appendix 2: Priority Needs and Recommendations- 2007 RSW Summit

Identifying Information Gaps in a Group Discussion

Summit participants were first tasked with identifying gaps in RSW management in the western US. After identifying a broad range of gaps, participants prioritized and determined the best course of action for bridging those gaps. Ultimately, summit participants were successful in developing specific goals and objectives necessary for combating the increasingly problematic issues associated with RSW.

What we know about RSW

- Spreads up to 20 miles by wind
- Transportation corridors are vectors
- Occurs at elevations greater than 6800 ft, but there aren't as many populations
- Soil factors play a role in occurrence of RSW
- Competition, grazing, biocontrol, and chemical methods all affect RSW
- There is no effective control for large populations
- We know RSW produces viable seeds even if flowers are not pollinated
- There are three major different RSW genotypes in the western U.S.
- Some herbicides are effective
- More than one rust strain are introduced and all act differently on RSW
- Established biocontrol agents are not known to have non-target effects
- Fire invigorates RSW
- Four biocontrol agents released thus far (three widely established, one recently released)
- RSW individual plant lifespan is 6-10 years
- Idaho CWMA priorities not always RSW (region dependent)
- Late chemical spray (fall/winter) effective against RSW

What we don't know about RSW

- Optimal time to spray, and location-dependant differences of optimal application time
- Need more information/details regarding control options
- Role of climate on chemical efficacy is unclear

- Role of weather (and other factors) on biocontrol efficacy is unclear
- Most important vectors for spreading this plant are unclear
- Role of elevation in population establishment is unclear
- How control efforts can best be integrated
- Suitable colonization traits so that we might better target areas of future spread
- Conditions suitable for clonal growth
- Best timing of grazing
- Restrictions on certain chemical usage (federal agencies)
- Preventative measures for areas currently RSW-free
- Best chemical formulations
- Resistance/efficacy on different biotypes
- If the rust travels with RSW seed
- Current RSW infestations (areas now covered by this plant – where are outlier populations?)
- How do we define an "outlier population?"
- Long-term studies on control methods
- Revegetation options on large scale infestations
- More state level consolidation of information and funding
- Management practices in regard to patch size
- How to manage multiple genotypes
- Weaknesses of RSW to better guarantee control effort efficacy
- Funding for RSW research and control

Summarizing Information Gaps in Group Discussions

Group A

A. Expand search for biocontrol agents
    i. Multiple avenues to have a chance at finding successful agents
    ii. Different landscape types
        a. More in pipeline
        b. More researchers, foreign cooperators
            1. Foreign collaborators
            2. Univ./EBCL/ARS/CA

B. Determine how control efforts can be best integrated (landscape, grazing, revegetation, chemical, biocontrol)
    i. Well established that this is still needed
    ii. Research on healthy product/revegetation/resotoration species recommendations
        a. Universities
            1. Land managers (private/public) and county weed agents
            2. ARS

C. Preventative measures for clean areas ….detection…eradication small-scale remote sensing/aerial sketch mapping
    i. Efficiency
    ii. Cost effectiveness
        a. Mapping: Identify clean areas, develop strategy for protection
        b. Make statewide plans
        c. Identify leading edge of invasion and lost cause areas
            1. Land managers (private/public) and county weed agents
            2. Universities

D. Short term timing/rate issues with Milestone or other chemicals
    i. Reduce the immediate spread
    ii. Satisfaction
        a. See what research is out there, talk to chemical reps
        b. University research
            1. Chemical reps
            2. University researchers
            3. Weed Supervisors

E. Grazing research
    i. Another tool that is underutililzed
        a. See what is out there
        b. Make universities start working/fund them
        c. Integrate grazing into RSW task force
            1. Universities, existing grazers redirected with lower cost
            2. Ray Holes (prescriptive livestock management)
            3. Sheep researchers out of area

F. Other suggestions from group:
    i. Dubois sheep experimental station
    ii. Karen Launchbaugh (U of I)
    iii. Grazing book by U of I
    iv. Grazing where interaction with bighorn sheep will not happen

Group B

A. Revegetation/restoration options
    i. We don't know how to do this on a landscape basis
        a. Find suitable species/mixes that will reduce RSW
        b. Prevention angle: if we don't have complete weed plan, what prevention methods can we take to protect plant community?
        c. Determine livestock options on landscape basis
            1. Universities
            2. State, federal, local land managers
            3. Private landowners

B. Clearly define genotypes
    i. This knowledge will increase the efficacy of our control efforts
        a. Determine which biocontrol agents will be most effective against present genotypes
        b. Determine which chemicals and formulations will be most effective against present genotypes
        c. Elucidate why this weed isn't that much of a problem in California
        d. Discover weaknesses of RSW (genotypes that are already present) that we can explore to better manage it
            1. USDA
            2. Universities

C. Strategic view of this weed in Idaho
    i. Have a large need to determine statewide perspective
        a. Perform statewide inventories
        b. Need to determine working definitions
            1. What is "satellite infestation"- a plant, an acre?
            2. What is control?
            3. What is eradication?
        c. Need statewide priorities for RSW to know leading edge and the infestations to target
            1. ISDA
            2. RSW Task Force

D. Integrated management techniques
    i. Chemical research data assembled for everyone's use so that methods are consistent across the board
        a. Efficacy of various chemicals
        b. Timing of application during season and at what locations
        c. Rates of application
    ii. Grazing research because cattle will eat early but then recovers fine, so additional work must be done
        a. Learn whether goats/sheep be utilized later in the season
        b. Determine best timing for various grazing efforts
            1. Universities

E. Communication
    i. Need to get on same page for the information that we do have
        a. CWMA network should be utilized for channeling information
        b. Inventory data needs to be centralized and then given open access for all interested parties
            1. RSW Task Force

<u>Group C</u>

A. Prevention measures for clean areas
    i. Create with prevention guide
        a. State weed guy (Tim Prather, Matt Voile)
        b. Education

B. Biocontrol efficacy of different biotypes
    i. Pursue this action via research
        a. University of Idaho

C. More state level consolidation of information and funding
    i. Need state strategic plan with priorities and actions
        a. RSW task force

B. Management practices in regard to patch size
    i. Discuss and develop management practices and define the patch size
        a. Include in Integrated Strategy
            1. RSW Task Force

C. Determine how control efforts can best be integrated, with emphasis on grazing
    i. Determine prescriptions for integrating chemical, grazing, and biocontrol management techniques in different circumstances
        a. University of Idaho

Where Do We Go From Here?

The entire group of summit attendants discussed the small group discussion outcomes and combined findings into one unified list of priority RSW management knowledge gaps. Although some discussion was given to the idea of further prioritizing the final prioritization list, it was concluded that the seven items stated on this list are of equal importance.

- Integrated RSW management techniques
- Clearly define genotypes of existing RSW populations
- Grazing

- Biocontrol
- Chemical
- Revegetation
- Preventative Measures
- Communication

Appendix 3: Pesticide Precautionary Statement

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels. Below are some general guidelines to follow.

- Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.
- Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.
- Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.
- If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.
- Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.
- Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States in the U.S. have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Rush Skeletonweed Management Plan for the Western United States **Winston, Schwarzländer, Gaskin, Crabtree** FHTET 2009-03