BUL 782

Collection and Redistribution of *Biological Control Agents* of

Rush Skeletonweed

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Rush skeletonweed, *Chondrilla juncea* L. (Asteraceae), a native of central Asia and the Mediterranean Basin area of Europe, has spread into several countries around the world, including the United States. Small infestations of this weed were first discovered in Washington in 1938, Idaho in 1960, and Oregon in 1971. It now infests more than 3 1/2 million acres in 12 northern and southwestern Idaho counties, 2 million acres in 18 Washington counties, and scattered areas in 14 Oregon counties (Fig. 1).

Rush skeletonweed infests rangelands, semiarid pasturelands, croplands, transportation rights-of-way, residential properties, and other areas subjected to repeated soil disturbance. It forms dense stands that crowd out other desirable vegetation. Most infestations in the Pacific Northwest occur on rangelands and roadside sites, although some invasion of cropland has occurred. Rush skeletonweed can be effectively controlled with registered herbicides[1]. However, chemical control is often impractical because of the low economic value, inaccessiblity, or environmental sensitivity of the areas infested. In order to maintain rush skeletonweed below economically damaging levels, an aggressive vegetation management program that incorporates biological control must be implemented.

Many noxious weeds of the Pacific Northwest, including rush skeletonweed, are exotic plants intentionally or accidentally introduced into the region. Also, they are introduced without their natural enemies. This fact, coupled with the abundance of susceptible habitats such as degraded rangeland and disturbed rights-of-way and movement of seed by wildlife and people, leads to increased weed population growth and spread. With this in mind, a biological control program aimed at introducing host-specific natural enemies of rush skeletonweed was initiated in the Pacific Northwest during the early to mid-1970's. Currently, a gall midge (small fly), *Cystiphora schmidti*, a gall mite, *Eriophyes chondrillae* (also known as *Aceria chondrillae*) and a rust fungus, *Puccinia chondrillina*, are well established in Idaho, Oregon, and Washington (Table 1). Grasshoppers and blister beetles are common native insects that often feed on rush skeletonweed, but are not suitable as biological control agents because they also feed on many crops and other desirable plant species.

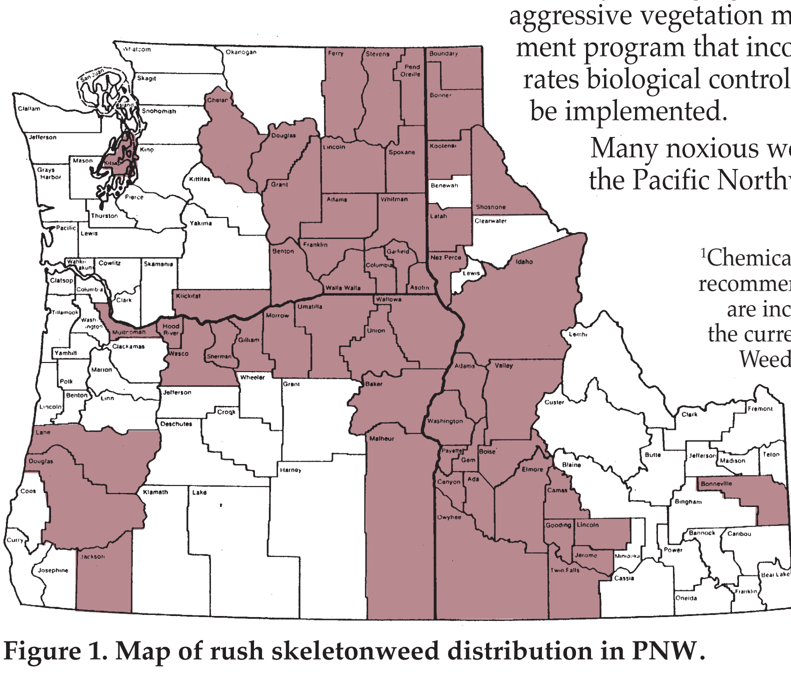

Figure 1. Map of rush skeletonweed distribution in PNW.

[1]Chemical control recommendations are included in the current PNW Weed Control

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Table 1. Biological control agents of rush skeletonweed: Status in the Pacific Northwest.

Natural enemy	States[1]	Release[2] date(s)	Status[3]	Plant stages attacked	Comments
Cystiphora schmidti	ID, WA OR	1976 1977	E,R E,R	Rosettes, leaves and stems	Gall midge; widespread in ID and WA. Reduces photosynthesis—stresses plant.
Eriophyes chondrillae	ID, OR WA	1977 1979	E,R E,R	Rosettes, leaves and stems	Gall mite; widespread in ID and WA. May kill seedlings, young plants, reduces flower production.
Puccinia chondrillina	ID, OR WA	1977 1978	E,R E,R	Rosettes, leaves and stems	Rust fungus; may kill young plants, stresses older, some biotypes are resistant to the fungus.

1 ID=Idaho, WA=Washington; OR=Oregon

2 Dates first released

3 E=Established; R=Ready for redistribution.

Table 2. Comparison of rush skeletonweed biotypes in the PNW.

Geographic Region	Biotype	Characteristics	Comments
Eastern Washington, Northern Idaho	Spokane	Taller, later flowering, little branching	Susceptible to rust
Northern Idaho, Eastern Washington	Post Falls	Shorter, earlier flowering, more branching	Resistant to rust
Southwestern Idaho, Eastern Oregon	Banks	Similar to Spokane biotype	Susceptible to rust
Western Oregon	Canyonville	Similar to Spokane and Banks biotypes	Resistant to rust

Biological control of rush skeletonweed: expectations

Introducing biological control agents does not guarantee short-term weed control. The newly established natural enemies serve as colonizers; several years are required for them to multiply to population levels that effectively suppress the weed. Rush skeletonweed natural enemies (bioagents) will not eradicate or even control rush skeletonweed. However, by reducing seed production or stunting the plants, they impair the weed's competitive ability to a point where it may be replaced by other competitive plant species. Because biological control will not eradicate rush skeletonweed, it should be part of a total integrated vegetation management effort that includes the use of herbicides, fertilizers, competitive plantings, and grazing management techniques.

It is important to eradicate small new invasions of rush skeletonweed into previously unifested areas. The use of herbicides, or other techniques is preferable. Natural enemies can reduce seed spread and suppress plants, but do not completely stop their spread. Therefore, in the long run, it is better to eliminate small infestations using spot treatments of herbicides or other suitable eradication techniques.

Figure 2. Mature rush skeletonweed plant.

Life cycle of rush skeletonweed

Rush skeletonweed is a taprooted, herbaceous perennial with milky white sap, ranging from 1 to 4 feet in height at maturity. There are several rush skeletonweed forms or biotypes. Plant biotypes differ from one another in their physical, chemical, or physiological attributes. Rush skeletonweed biotypes differ from one another in stem length, branching pattern, flowering period, and susceptibility to biological control agents. Also, they are generally located in specific geographic areas in the region. Not all populations of rush skeletonweed in the western United States have been identified or classified into specific biotypes. Table 2 summarizes the information on known biotypes in the region.

The weed's seasonal growth cycle usually begins in the fall when rains promote germination of seeds and the development of one or more rosettes from buds on established perennial roots. The rosettes resemble nonflowering dandelion plants. The lance-shaped, deeply-lobed rosette leaves are 1/2 to 1 1/4 inches wide and 2 to 5 inches long, and often develop a reddish tinge near the tips during the winter.

Longer days and higher temperatures in the spring stimulate the growth of multibranched, upright stems from the root crown. The slender, pale-green stems are generally smooth except for a dense covering of erect, downward-directed hairs on the lower 2 to 3 inches of most biotypes. Flowering begins in midsummer and continues until lack of moisture halts flower production or fall frosts kill the stems. The rosette leaves of the Banks and Spokane biotypes die off during the flowering period; the Post Falls biotype retains its rosette leaves.

Flower buds develop on and at the ends of the stems, either individually or in groups of as many as five. A single large plant may produce more than 1,500 flower heads. The number of flowers varies depending upon plant biotype, size, and environmental conditions. There are 7 to 15 bright yellow, strap-shaped florets in a head, and each can form a seed. An individual plant can produce 20,000 seeds a year; 90 percent are capable of germinating. Each seed has a tuft of fine hairs that facilitates wind dispersal, much like dandelion seeds. Most seeds fall close to the parent plants, but some may be transported long distances. Seeds are carried from place to place in the fur or hair of animals, on the clothing of people or by vehicles traveling through infested areas. Seeds have little dormancy and survive no more than 18 months under normal conditions.

Rush skeletonweed has a slender, vertical taproot that may penetrate to a depth of 8 or more feet. One or more rhizomatous lateral roots develop, primarily in the upper 2 feet of soil. Plants spread vegetatively by roots. Daughter rosettes arise near the roots of the parent plant. The proliferation of lateral roots enables a single plant to become a colony that increases in size and

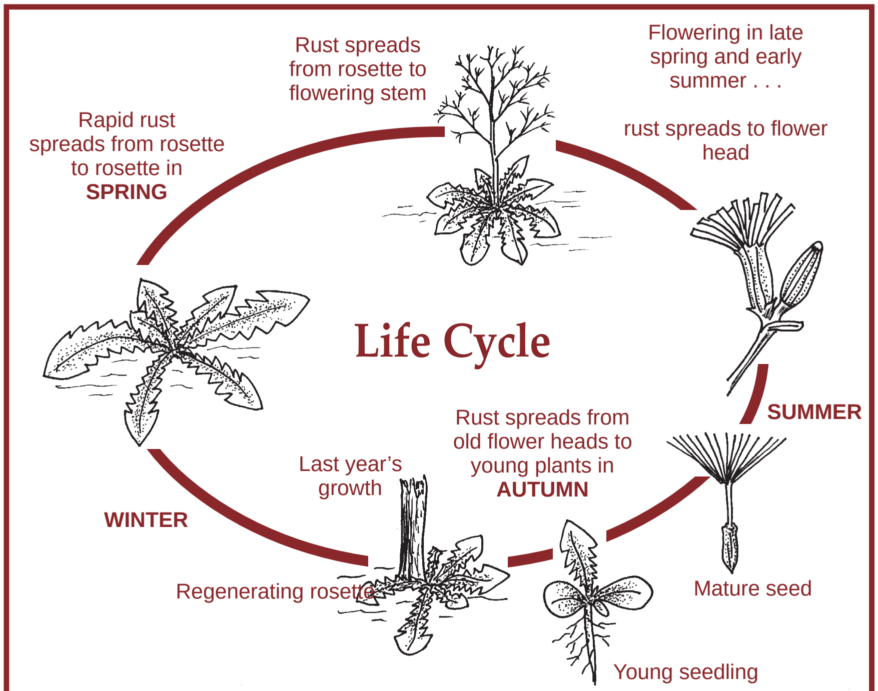

Figure 3. Life cycle of Rush Skeletonweed

density and may merge with other colonies, resulting in total infestation of an area. New rush skeletonweed plants can arise from buds on the taproot and lateral roots. In agricultural lands, roots severed by cultivation implements are frequently spread throughout a field and into uninfested fields by contaminated equipment. Along highway rights-of-way, vehicles, roadgraders and other maintenance equipment spread root fragments that grow and develop into mature plants.

Biological control agents

Rust fungus

(*Puccinia chondrillina*):

This rust fungus remains active throughout the year (Fig. 3) and may infect all aboveground plant parts. From spring to fall, cinnamon-brown colored, round or "bull's-eye," eruptive pustules (blisters) called "uredia" develop on rosette leaves (Fig. 4), stems, and flower buds. Uredia can proliferate to partially or entirely cover the leaves and stems. They produce red-brown spores called "uredospores" that propagate the fungus during the growing season, but do not overwinter. Elongate lesions or telia are produced at the base of flowering stems (Fig. 5). Telia produce dark brown teliospores which remain dormant and overwinter until the following spring. Rust development is slowed or stopped during the winter but resumes rapid growth in the spring. In March, the teliospores produce basidiospores, the pathogen's sexual stage. These germinate on the rosette leaves and form clusters of yellowish spermogonia which eventually yield spermata. Thesse produce aecia and aeciospores in April. Aeciospores germinate to produce uredia and uredospores, thus completing the lifecycle. The uredospore infection spreads rapidly on and between plants, the spores readily being disseminated by wind, water, and animals. A new generation of uredospores can be produced every 2 weeks during the summer on the floral shoots.

Fall and spring infection of rosettes, especially those of seedlings, often kills plants prior to bolting. Open wounds or lesions, produced by uredia (Fig. 4) and telia (Fig. 5) cause desiccation, reduced photosynthetic surface area, increased plant susceptibility to other pathogens, and suppressed plant growth. Heavily rust-infected floral stems are stunted, deformed, and produce few branches. The fungus reduces production, weight, and viability of seeds. The weed's ability to regenerate from root buds is also reduced. The early-flowering "Post Falls" biotype found in northern Idaho and eastern Washington, and the late-flowering "Canyonville" biotype found in southwest Oregon are not susceptible to the fungus. Researchers in eastern Europe, in cooperation with Australian scientists, are attempting to locate a more virulent strain of the rust fungus to control these biotypes.

Gall midge

(*Cystiphora schmidti*):

Midge adults are light brown in color and are about 1/8 inch long (Fig. 6). They resemble tiny mosquitoes and are not readily seen. Males live l to 2 days and females 3 to 4 days. Females of the first generation lay eggs in rosette leaves. Eggs are inserted through the lower epidermis, with individual eggs separated from one another by 1/8 inch or more. Succeeding generations (up to 4) develop on the flower stems until fall senescence in the fall. A female produces about 100 eggs during her lifetime. All rush skeletonweed biotypes are attacked by the midge, but the late-flowering biotypes are the most heavily damaged. Upon hatching, the pink to orange larvae feed on the tissues beneath the surface of the leaf or stem where they hatch. Feeding stimulates the plant to form galls which are characterized by swelling and yellowish to reddish-purple discoloration of

Figure 4. Uredia of rust fungus on rosette leaf.

Figure 5. Telia of rust fungus on stem.

Figure 6 . Adult gall midge on stem.

Figure 7. Reddish-purple galls formed by midge larvae on leaf.

affected tissues. Galls become noticeable l0 to l2 days after egg deposition. Leaf galls are circular (Fig. 7), approximately 1/8 inch in diameter, and slightly raised, whereas stem galls are elongate and distinctly raised (Fig. 8).

Larvae usually develop in 4 to 7 days. Mature larvae cease to feed and become prepupae which spin silken cocoons about themselves within the gall prior to pupating. Some larvae may exit the galls, drop to the ground, and pupate in the soil. During the growing season, the pupal period lasts 4 to 6 days. Pupae rupture the gall epidermis and form holes through which the adults escape. The life cycle, from egg to adult, can be completed in 24 to 44 days. In the Pacific Northwest the midge is active from late April until October. Midge populations reach peak densities from August to early October. Galls are produced on floral stems until the stems begin to dry and die following autumn frosts. When this occurs, midges then oviposit in regenerating rosette leaves. Mature larvae, prepupae or pupae overwinter within galls on dead stems or rosette leaves, or as pupae in the soil.

The midge injures rush skeletonweed both in the rosette and flowering stem stages. When galls become abundant on rosette leaves, photosynthesis is reduced, and the production of gall tissue, along with the feeding of the larvae, decreases the amount of photosynthate available for plant growth and maintenance functions. The mesophyll tissue of attacked leaves is destroyed and the epidermis is injured, causing the leaves to dry, turn yellow, and die prematurely. Both spring and fall rosettes, especially seedling rosettes, may die. Midges are most damaging to fall rosettes, destroying over 50 percent of the leaves formed. The competitive ability of these damaged rosettes is reduced and some plants die during the winter. Midge-infested stems do not usually die, but small seedlings often do. Stems can become so heavily galled that they appear purple instead of green. When this happens, the photosynthetic and reproductive capabilities of affected plants are reduced. Infested plants have fewer branches and may produce 60 percent fewer flower heads than uninfested plants. Viability of seeds from heavily infested plants is reduced.

Effectiveness of the midge is decreased due to a high incidence of parasitism by several native wasps. Grasshoppers feeding on stem galls and death of overwintering pupae in waterlogged soils also reduce the impact of the midge. Despite these mortality factors, the midge is still an important bioagent of rush skeletonweed.

Gall mite
(*Eriophyes chondrillae*):

This minute yellowish-orange mite, barely visible to the naked eye, attacks all biotypes of rush skeltonweed in the Pacific Northwest, but is most damaging to the late-flowering forms. It is the most effective biological control agent against rush skeletonweed in the Pacific Northwest.

Adult females overwinter in the central bud area of rosettes, but do not feed or otherwise damage the plant during this stage. In the spring, the mites ascend and attack the growing shoot produced from the rosette. Females progressively colonize young axillary buds produced along the shoot as it lengthens and eventually infest the terminal bud. Chemicals released by mites during feeding cause the formation of galls which appear as swollen, contorted, masses of tiny, leafy buds. The first hint of gall development is a slight swelling of the bud and hooking of its tip or a flattening of the stem (Fig. 9). Within 2 months of initiation, a gall may develop to nearly 3/4 inch in diameter (Fig. 10) and may

Figure 8. Extensive bud gall caused by midge infestation.

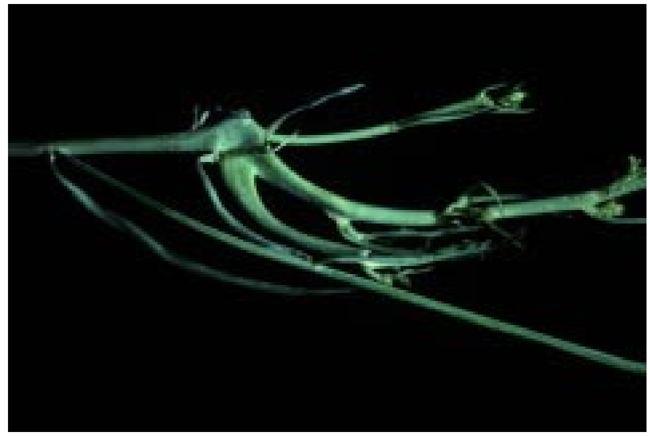

Figure 9. Distorted and flattened stem: early symptoms of gall mite infestation.

continue to grow to become nearly 2 inches in diameter under favorable conditions. Frequently, all flower buds and growing points on a plant are galled.

The female mite generally lives 3 to 4 weeks, and during this time deposits between 60 and 100 eggs. Maturation of mites is rapid and a generation can be completed in l0 days during the summer. Several hundred adults and nymphs may feed within the gall.

Eventually, the green, leafy gall stops growing, becomes yellow as it begins to desiccate and eventually turns brown when completely dried out. Mites escape from these deteriorating galls. Exiting females may infest buds on the same plant, be transported by wind, or crawl to other plants. Mite multiplication and dissemination continues until flower shoot growth is stopped by lack of moisture or fall frosts. New releases may be difficult to establish where there is heavy grazing on the plants (including the galls) by wildlife.

A heavy mite gall load decreases plant vigor by reducing root reserves, hindering rosette formation from established roots, stunting the plant and decreasing the number of vegetative shoots produced, decreasing or completely preventing. Seedlings and young satellite plants (produced by vegetative reproduction) are often killed when they are heavily damaged by the mite.

Collection and redistribution of natural enemies

There are several ways to redistribute the natural enemies. The easiest way, particularly for sites that are heavily infested with the weed, is to collect rush skeletonweed stems that are infested with the mite, midge, fungus, or any combination of the three from infested sites. Trim seedheads and flowers off the infested plants and tie the stems into bundles as shown in Fig. 11 to form "teepees." Place several teepees among the rush skeletonweed at the release sites during mid-to late summer. The natural enemies will complete their development within the old stems and leaves, emerge, and disperse to the other plants. Large numbers of teepees or inoculated plant stems are not necessary to insure establishment of bioagents. Four or five bundles at a site should suffice. Early season collections may require more bundles since there are fewer natural enemies available at these times.

At release sites where plants are scattered, it is better to place a 12-inch section of infested stem against an unifested plant. If it is windy, the infested stem section should be tied to the unifested plant. This ensures that the biological control agents can easily disperse from the cut stems to new plant hosts. Where the weed populations are low and plants scattered, inoculate several hundred plants in a square mile using this technique.

Inspect natural enemy collection sites prior to gathering any stems to confirm the presence of the bioagents. Collect bioagent-infested plant material from the same plant biotype as that which it will be released against. This reduces the chance of spreading the plant biotypes to different regions if seed is produced from cuttings. Collect infested stems prior to seed-set to minimize this problem.

The best time to collect and redistribute all the natural enemies is from early July to late September. During that time there should be enough bioagents on the stems collected for redistribution. Plants are actively growing at this time and are still susceptible to the transferred bioagents, thus allowing for successful establishment.

When transporting bioagent-infested plant materials, maintain temperatures between 50 and 80°F. Avoid exposure to severe high or low temperatures. Pack the material in ice if possible. Do not use dry ice; it will kill the organisms. If you use ice to keep the bioagents cool, protect them from the melting ice during transport. If you do not have an ice chest or cooler, store the material in a burlap or plastic bag and keep it cool and dry. Do not put wet plant material into plastic bags without ventilation. You may drown the midges and mites or cause the plant material to rot. Keep bioagents and infested plant material out of direct sunlight during transport. Release the bioagents as soon as possible after collection. Successful introductions have been made 5 days after harvesting infested plant material, but such long intervals between harvest and release are not recommended.

Selection of release sites

In some areas, rush skeletonweed is still being targeted for eradication. Contact weed control supervisors (usually located at your county Cooperative Extension office) to determine the status of the weed in your county and specific location of interest.

The midge, mite, and rust fungus can survive in most areas that support rush skeletonweed. When establishing local "field nurseries" from which natural enemies can later be collected for further redistribution, select large, open stands of the weed that are free from livestock disturbances and applications of herbicides or insecticides.

Figure 10. Teepee of rush skeletonweed stems used for redistribution of bioagents.

Sources of natural enemies for redistribution

The natural enemies of rush skeletonweed can be found in many areas of eastern Washington (especially Spokane and Spokane counties), northern Idaho (particularly Kootenai and Bonner counties), and southwestern Idaho (especially Banks and Garden Valley). Transporting the bioagents and infested plant material across state borders requires federal and/or state permits. Contact the appropriate state department of agriculture if you anticipate collecting or purchasing bioagents from another state.

"In-state" sources of bioagents should be utilized as much as possible. Because these bioagents are already adapted to conditions in the specific geographic region, they are more likely to establish at the new sites. Use of in-state insects and mites lessens the likelihood of introducing parasites of the natural enemies or new biotypes of the weed (from plant material that might accompany the bioagents).

Monitoring natural enemy populations

Prior to relocating natural enemies to new rush skeletonweed-infested areas, survey the target weed populations to see if the agents are already present. The general sources of the bioagents noted above does not represent a complete picture of the bioagents' current distribution. All three bioagents are capable of substantial dispersal on their own.

Because all the natural enemies are small, look for the symptoms of their attack rather than the organisms themselves. In the case of the rust fungus, the spore-forming structures (uredia and telia) are easily recognized (Figs. 4 and 5) on leaves and stems. Early-season surveys (April-June) should focus upon inspection of the rosette leaves, while late season surveys (July-October) should be restricted to the stems. Early surveys for the midge should emphasize the detection of galls (Fig. 7) on the rosette leaves, while later surveys should emphasize the stems (Fig. 8). Midge populations early in the season are often low; thus, late season surveys are usually easier and more productive. Early season symptoms of the gall mite can be recognized as flattened crooks in the stems of plants (Fig. 9), but substantial gall production occurs later (Fig. 10). As with the midge, late season surveys for mites are considerably easier and more reliable.

Records of survey results and redistribution efforts are extremely useful for mapping purposes. Such maps describe both weed and biological control agent distributions. This information is important in planning future weed and bioagent management activities. Survey and redistribution report forms can be obtained from your county Cooperative Extension Educator, weed control board, or state department of agriculture, and should be returned to those same offices. If survey report forms are not available, record date, location, weed species and density, bioagent species and source, the observer's name, and any other notes that help describe the situation. Send this information to the above-mentioned offices. Anyone can participate in natural enemy survey and redistribution.

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