








Information Document for Invasive and Noxious Weed Control Project on Utah's Waterfowl Management Areas 2006-2018

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Photos on front cover
by Randy Berger

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About This Document

I created this information document for the Invasive and Noxious Weed Control Project the Utah Division of Wildlife Resources (DWR) implemented on the agency's wetlands. The purpose of this document is to identify weed species in Utah's waterfowl management area wetlands and associated uplands, to outline treatment plans and objectives for managing these species, and to explain weed life histories and control methods. I compiled information for this document from the internet, university libraries, personal communications with land managers and weed specialists, and personal experience. My intention was not to write a comprehensive resource but to provide valuable information about the DWR's weed management efforts. During the next twelve years or more, as weed control treatments change and the DWR adds new weed species to the project, this document will require updates.

To make this document more readable, I did not follow a strict scientific format; however, I included research citations when I refer to information from other authors. Although I tried to avoid plagiarism by acknowledging secondary research, I found it difficult to express my own ideas about a topic that other authors have written about so extensively.

Because I do not recommend the products identified in this document, I suggest contacting the Utah State University Extension Service, an herbicide representative, or another qualified source for help choosing and using herbicides.

A special thanks to Val Bachman, David Rich, Jason Jones, Rich Hansen, Tom Aldrich, Dean Mitchell, and Dr. Steve Dewey for helping review and edit this document. I also want to thank Christopher Schulze and James Christensen for doing the literature search and editing the document. Special thanks to Nikole Eyre for final revisions to the document before public release.

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April 24, 2009

Introduction

The purpose of this document is to address the control and containment of identified invasive and noxious weeds on waterfowl management areas (WMAs) managed by the Utah Division of Wildlife Resources (DWR). In addition to information the DWR used to plan and implement the Invasive and Noxious Weed Control Project, this document outlines project goals, objectives, and strategies.

The DWR submitted the *Invasive and Noxious Weed Control Project Proposal* to secure funding for the Invasive and Noxious Weed Control Project initially in 2006. The agency updates and resubmits this proposal annually for funding approval.

The weed species included in this project are common reed (*Phragmites australis*); hoary cress (*Lepidium draba*, previously *Cardaria draba*); two hemlock species, poison hemlock (*Conium maculatum*) and western water hemlock (*Cicuta douglasii*); perennial pepperweed (*Lepidium latifolium*); saltcedar (*Tamarix spp.*); dyers woad (*Isatis tinctoria*); and four thistle species, Canada thistle (*Cirsium arvense*), bull thistle (*C. vulgare*), musk thistle (*Carduss nutans*), and Scotch thistle *(Onpordum acanthium)*.

A list of other weed species the DWR monitors for control and containment is provided in Appendix 1, "Weed Watch List." As conditions warrant, the agency will add weed species to this list.

The following WMAs are participating in the Invasive and Noxious Weed Control Project: Desert Lake WMA, Clear Lake WMA, Farmington Bay WMA, Howard Slough WMA, Ogden Bay WMA, Harold Crane WMA, Salt Creek WMA, Public Shooting Grounds WMA, and Locomotive Springs WMA. These WMAs account for 85,737 acres of wetland and associated upland habitat environments and are critical to Utah's wildlife: over 212 bird species, ten mammal species, five reptile species, and three amphibian species use these lands. The WMAs also provide the majority of public waterfowl hunting and significant recreational opportunities for watching and photographing wetland wildlife species in Utah.

Weed Control History and Future

Weed control on the WMAs has been an integral part of DWR management activities since the WMAs were established, many in the early 1900s. The agency determined weed control efforts by considering the cost of control methods and available equipment and personnel. Although the DWR used these resources to maximize control efforts, the high cost of control methods and additional demands on available equipment and personnel prevented area managers from containing invasive and noxious weed species.

As a result of sportsmen's concerns about the invasion and rapid expansion of common reed and other weed species during the last fifteen years, the DWR created the Invasive and Noxious Weed Control Project. The agency will continue to use project funding to maintain and increase weed control efforts.

Plan Development and Current Conditions

Due to public support, primarily from sportsmen, the DWR secures and dedicates $200,000 annually to the Invasive and Noxious Weed Control Project. These funds come from a DWR licensing fee restructuring proposal supported by sportsmen and passed by the Utah Legislature in 2007.

Based on previous experience controlling common reed and other weed species, the DWR estimated in the *Invasive and Noxious Weed Control Project Proposal* that the common reed control portion would take fifteen years. After acquiring more specialized equipment, the agency modified this estimate, reducing the common reed control portion by 20% to twelve years. However, because weed control has been and always will be an issue in managing habitat—and each year the DWR works to reduce weeds in one area, weeds expand in another area—the common reed control portion will undoubtedly continue beyond this twelve-year time frame. The massive scope of the Invasive and Noxious Weed Control Project, over 10,000 acres of common reed and hundreds of acres of other weed species, does not allow for complete coverage of all affected areas. Also, as new invasive and noxious weeds expand to unacceptable levels, the DWR will add these species to the project.

The DWR chose a three-year, four-step strategy for treating common reed.

> *Year one, step one:* in the fall of the first year, the agency aerially treats selected sites with herbicide.
>
> *Year two, step two:* the following spring, the agency burns the sites.
>
> *Year two, step three:* in the fall, the agency spot treats the sites with herbicide for surviving common reed. Depending on the conditions and distribution and survival rates, the agency performs spot treatments from the air and/or ground.
>
> *Year three, step four:* in the fall, the agency treats the sites again from the ground with herbicide for surviving common reed.

Using this three-year, four-step strategy for treating common reed, the DWR bases the number of new acres aerially treated each year on the ability to re-treat the previous two years' acres from the ground, which limits new acres the agency aerially treats. Other limiting factors include available funds, equipment, and personnel and the time frame for effective treatments.

By the third year of the Invasive and Noxious Weed Control Project (2008) and the final year of the original (2006) sites' treatment cycle, the DWR is treating or re-treating the maximum acreage. New aerial treatment acres in 2006 were 1,860; in 2007 were 1,400; and in 2008 were 1,300. These numbers total 4,560 treatment and re-treatment acres in 2008. The agency plans to stabilize new aerial treatments to 1,300 acres per year; in 2009 the treatment and re-treatment acres will be 4,000, and from 2010 on treatment and re-treatment acres will stabilize to 3,900 acres annually. If unforeseen obstacles occur, the agency will modify these plans.

The DWR also identified ten other weed species as part of the Invasive and Noxious Weed Control Project. The agency treats these species, which cover hundreds of acres—an estimated 600-1,000 acres in 2006—in the spring and summer months. For these weed species, treatment is an ongoing effort. By monitoring the species, the DWR identifies new infestations that require treatment, and, by evaluating previously treated sites, the agency determines follow-up treatment needs annually.

In 2006 the DWR treated 769 acres of the ten weed species. In 2007 and 2008, the agency treated 840 acres and 909 acres of the weed species.

Project Goals

The primary goal of the Invasive and Noxious Weed Control Project is to control and contain invasive and noxious weeds on DWR wetlands in order to reestablish diverse plant communities that benefit wildlife and to increase recreational opportunities for public users.

The project's second goal is to encourage individuals, other agencies, organizations, and government entities to evaluate the need for weed control, and to initiate control efforts in areas considered to be in the best interest of wildlife and public users.

A third goal, which may become an important part of the project in future years, is to reduce the risk of fire spreading from DWR wetlands to adjacent private lands.

Project Objectives

The Invasive and Noxious Weed Control Project's primary objective is to restore the high values of wetland and associated upland habitats for wildlife by increasing the functions of plant communities. These functions include food production; resting, molting, and loafing areas; and plant and habitat characteristics used for nesting and brood-rearing activities that increase reproductive opportunities. (Specific control and containment objectives for each weed species are outlined in the seven sections of this document.)

The project's second objective is to improve opportunities, and quality of experience, for public users, including sportsmen, wildlife viewers, educators, and students.

A third objective is to encourage participation in weed control activities that benefit wildlife and improve habitats by demonstrating positive results to individuals, other agencies, organizations, and government entities.

A fourth objective, which may become an important part of the project in time, is to alter habitats containing high biomass-producing plants that may create a fire hazard. When rural development or agricultural production expands to WMAs' boundaries, the DWR will need to evaluate each site on a case-by-case basis.

Project Strategies

The DWR developed strategies for the Invasive and Noxious Weed Control Project from a literature review, communication with land managers and weed specialists, and personal experience.

In general, the agency's strategy is to treat invasive and noxious weeds with appropriate and approved herbicides and then to monitor sites, both pre- and post-treatment, for herbicide effects on weed species. When necessary, the agency will perform follow-up treatments on the sites, which will require another two years minimum for each site depending on the weed species being treated; herbicide effectiveness; and desired outcome for the site, such as eradication, reduction, or change in growth form.

After sufficient reduction, or when conditions warrant, the DWR will integrate additional control and containment methods into the weed management effort. These methods include the use of livestock grazing, burning, water level management, mechanical manipulation, cultural practices, and biological control agents.

Part I: Common Reed
Phragmites australis
Species-Specific Control and Containment Strategies

Common Reed Treatment Plan Objectives

By following a three-year treatment process, the DWR plans to achieve an acceptable level of common reed in selected sites. Avoiding total eradication of common reed will help the agency restore a diverse plant community, of which common reed (native *Phragmites australis* subsp. *americanus)*, is an integral part.

The agency defines acceptable level as when common reed constitutes less than 2% of the vegetation component of a distinguishable marsh unit (marsh unit). A marsh unit has three definitions: 1) an area above or below an impoundment and under the control of the impoundment's water level management (water level management unit), 2) any area affected by a single water source or multiple sources within a topographically confined area (basin or delta), and 3) an area under an irrigation system developed to spread water over a defined area (wet meadow or ephemeral emergent marsh).

When the DWR identifies populations of native *Phragmites australis* subsp. *americanus* and verifies pure stands that do not contain invasive common reed, the agency may increase the percentage of the weed in a marsh unit.

Common Reed Treatment Plan

The DWR's plan to control and contain common reed involves a three-year, four-step process, followed by monitoring and some form of integrated management strategy to prevent spread and reinvasion (Strategy AA, BB, CC, DD, and EE). Each year new sites will begin this process and previous years' treatment sites will fall along the process spectrum.

Ten-Foot Common Reed at Ogden Bay WMA
Photo by Randy Berger

First-Year Treatment Plan

For the first-year treatment plan, the agency will carry out the following steps:

- identify the annual aerial treatment sites;
- generate an ARCGIS map;
- calculate acreages;
- identify the sites for archeological survey and take the appropriate actions;
- create specifications for aerial application;
- request bids and award contracts;

- initiate pre-monitoring activities;
- accomplish aerial application of aquatic-approved glyphosate herbicide;
- confirm and coordinate burn plans with the Division of Forestry, Fire and State Lands (FFSL);
- prepare to assist FFSL with burns by requiring DWR personnel to complete wildland fire training;
- initiate burning when prescriptions are met;
- complete re-flooding where applicable; and
- assess follow-up needs.

For a more detailed outline of the first-year treatment plan, see Appendix 2, "Schedule of Tasks."

Second-Year Treatment Plan
The second-year treatment plan repeats the first-year steps for new sites. The DWR also assesses the previous year's sites and determines that second-year treatment will consist of one of these methods:

- When common reed is widespread and evenly distributed (defined as ≥1 stem/3 sq. feet & continuous in an area ≥5 acres) or is in relatively unaffected large patches (defined as ≥2 acres & ≤80% kill), the agency will use a helicopter to aerially apply herbicide for follow-up spot treatments.
- When the two conditions described in the first method do not exist, the agency will use ground vehicles to apply follow-up spot treatments.

Third-Year Treatment Plan
The third-year treatment plan repeats the first-year steps for new sites and the second-year methods for the previous year's aerial treatment sites. To perform follow-up spot treatments on the initial sites, the DWR will use ground vehicles to apply aquatic-approved glyphosate or another aquatic-approved herbicide, such as imazapyr or triclopyr, on surviving common reed. If the initial sites are still infested with sufficient common reed to meet the conditions of the second-year aerial treatment method, the agency will determine treatments on a site-by-site basis.

Ground Treatments Using Aquatic-Approved Glyphosate. Continuous aerial applications of aquatic-approved glyphosate, a nonselective contact plant killer, will not achieve the Invasive and Noxious Weed Control Project's desired results because the herbicide kills or severely limits desirable plants. By using both aerial and ground treatment methods, the DWR will expedite reinvasion by preferred plants while controlling and containing common reed.

Due to the limited window of opportunity for applying glyphosate most effectively to common reed, efficiency is critical in large ground operations. Limited equipment and personnel and poor weather compound the importance of efficiency because these factors interfere with herbicide application. To maximize the efficiency of ground treating sites with glyphosate, the agency matches equipment to treatment zones and assigns team leaders.

Because the conditions of a treatment zone within the wetland complex can hinder equipment use, the agency matches equipment to appropriate treatment zones. These zones include open water (Zone 1, boat or airboat); shallow water emergent marsh and saturated emergent marsh (Zone 2, wide rubber-track, low-ground-pressure machines); high ground water emergent marsh (Zone 3, rubber-track, medium-ground-pressure machines); and dry emergent marsh sites (Zone 4, ATVs or OHVs). For example, equipment capable of working in Zone 2 can work in Zone 3 and Zone 4; conversely, Zone 3 and Zone 4 equipment should not work in Zone 2 and Zone 3.

The project leader assigns team leaders who are responsible for organizing and directing ground operations team memebers. Team memeber assignments include maintaining the resepective equipment they operate. Having a team memeber responsible for each piece of equipment reduces downtime and equipment failure associated with multiple operators. The agency also ensures that teams have no more than four equipment operators and, although multiple teams can work in a treatment zone, assigns each team to a specific area within the zone.

Strategy AA

Year One: Aerial herbicide treatment and prescribed burning

Year Two: Air and ground herbicide spot treatment

Year Three: Air and ground herbicide spot treatment

Helicopter Aerial Application of Herbicide
Photo by Christopher Schulze

Aerial Herbicide Treatment. For strategy AA, the DWR will aerially apply aquatic-approved glyphosate to initially treat common reed. Currently, the agency applies six gallons of mixture per acre. The mixture contains three quarts glyphosate, one quart non-ionic surfactant, and five gallons water. Another aerially applied solution used in northern Utah is a ten-gallon mixture per acre containing three quarts glyphosate, one quart non-ionic surfactant, and nine gallons water. If the six-gallon mixture per acre results in less of a kill than expected, the agency will assess plant survival and application rate and adjust the solution.

The DWR will apply glyphosate with either fixed-wing or rotary-wing aircrafts when plants are at full-flower stage, prior to the first frost of the growing season. Even though only about half the stands in well-developed common reed flower annually, to target healthy, vigorously growing plants that are not under stress, the agency will aerially apply the herbicide between August 15 and October 1. However, because the DWR plans to apply the glyphosate during translocations of sugars by the plant to the roots and rhizome tissues, and evidence suggests this process may occur in common reed as early as late June, prior to full-flower stage, the agency may use ground treatment equipment to apply the herbicide to a small area in order to investigate the success rate of earlier application on common reed survival.

The agency anticipates an 80% or greater kill rate for first-year aerially treated common reed. If the kill rate is lower than this target, the agency will adjust the application volume to increase plant surface contact with the herbicide.

Prescribed Burning. Prescribed burning is DWR's preferred method for removing residual plant material. Following the aerial application of glyphosate, the agency will burn initial treatment sites. These sites should not need follow-up burn treatments. If the aerial applications occur early enough to allow for translocation of herbicide to the root material, and are prior to area openings for public use, the agency will conduct fall burns. Spring burns will take place between February 1 and May 1. Because late spring burns can be detrimental to nesting wildlife, the agency will try to avoid burning during this time.

Prescribed Burn after Initial Herbicide Treatment
Photo by Randy Berger

Burns must meet air quality standards and the conditions of the burn plan prescription. These multi-variable conditions may prevent the DWR from carrying out desired burns some years on some treatment sites. A second factor that may interfere with burning is limited personnel, who may be unavailable to carry out burns safely on scheduled days.

The burning process requires a weather conditions check within eighteen to twenty-four hours of the planned burn. If the weather conditions are satisfactory, the agency arranges equipment and personnel for the following morning. The protocol for a planned burn involves sending an email to the pre-burn notification list, which includes the media, other agency personnel, DWR administrators, and people who may be in the area, such as mosquito abatement employees, researchers, and surveyors. Protocol also involves securing the burn site to restrict public entry and placing signs to identify the site is in the process of a planned burn. On the morning of the planned burn, the agency checks the weather conditions again, stages equipment and personnel on the burn site, and contacts the Division of Air Quality for the clearing index. If the index is not within acceptable limits, the planned burn does not take place; if the index is within acceptable limits, the burning process continues.

When the Division of Air Quality clears a planned burn, the Incident Commander follows these steps:

- distributes burn maps,
- helps personnel flag or post the burn site,
- identifies any hazards or structures that need to be protected,
- identifies safety zones and escape routes,
- defines equipment and personnel assignments,
- discusses communication protocol and checks radio frequency,
- contacts the burn-plan call list,
- performs a test burn, and
- confirms with the ignition team to initiate the burn.

After the planned burn, the DWR sends a follow-up email to the pre-burn notification list with completion information and general observations.

Flooding. When possible, the agency floods the site after a planned burn. If done soon after a burn, flooding reduces the amount of ash the wind blows off the site and, by settling the ash, starts the biological breakdown of residual material and the process of mineral infiltration back into the soil profile. Flooding also inhibits common reed seed from germinating and reduces common reed seed viability.

Dewatering a burn site after flooding or delaying flooding can allow some native wetland species that germinate early, before April 15, and withstand partial submersion to gain a limited competitive advantage over common reed, which may increase the colonization speed of desirable plants.

Track Machine Ground Spot Treatment
Photo by James Christensen

Air and Ground Herbicide Spot Treatment. During the second year, the DWR will spot treat surviving common reed between August 15 and October 1 using air and ground herbicide applications. Second-year sites should not need follow-up burn treatments. The agency will conduct pre- and post-treatment assessment and monitoring around July 1 for the previous year's treatment sites and the current year's planned treatment sites.

The third, and hopefully final, year will repeat second-year treatment methods. After the third year, the agency plans to monitor the treatment sites for common reed reinvasion or expansion beyond acceptable levels.

Strategy BB

Year One: Aerial herbicide treatment

Year Two: Air and ground herbicide spot treatment and prescribed burning

Year Three: Air and ground herbicide spot treatment

Strategy BB is for when the DWR cannot implement prescribed burning on a treatment site after initial aerial application but expects to burn the site the following year (delayed burn site). Under these conditions, the agency will assess the site's surviving common reed and choose a follow-up treatment method.

If the treatment site is inaccessible or if barriers create safety issues, the agency will solicit a helicopter on bid to spot treat visible remnants of common reed within the site. Due to biomass, standing stems, flowers, and litter, the agency does not expect excellent results; however, this effort may reduce the expansion of aerially observed common reed patches. Also, the agency will schedule the site as a high priority for prescribed burning in the fall or following spring. If this burn does not take place after the second aerial spot treatment and monitoring suggests value in re-treating the site, the agency will consider aerially spot treating the site in the third year.

Delayed Burn 2006 (Gray Area by Water)
Delayed Burn 2007 (Brown Area at Bottom of Picture)
Photo by Tom Aldrich

Delayed Burn 2008
Photo by Tom Aldrich

Common reed decomposes slowly: standing canes can persist for up to five years, and stems can take two or more years to deteriorate in damp, oxygenated, and warm areas. Under these same conditions, leaves can take eight to nine months to break down and, in unfavorable conditions, may extend to eighteen months. Accumulation of dead plant material can reach a depth of three to four feet within stands, making herbicide penetration and contact with live plant material problematic and accessing the stand for evaluation difficult or impossible.

Unfortunately, most single glyphosate treatment sites return to pre-treatment conditions within two to five years. However, a single glyphosate treatment regime on common

reed followed by some method of residual material removal has produced short-term positive results. Without residual material removal on single treatment sites, stand density will likely reestablish before decomposition, which will prevent the DWR from gaining any real value from the treatment.

Strategy CC

Year One: Aerial herbicide treatment and mowing or rolling

Year Two: Ground herbicide spot treatment

Year Three: Mowing or rolling, if necessary

In the future, air quality standards, political and public pressure, and encroaching human development may prohibit burning. When burning is not an option (no burn site), or when aerially spot treating common reed is impossible or ineffective, Strategy CC will provide a treatment method.

Mowing. Using specialized equipment, the DWR will mow areas to open common reed sites for ground treatment. In the past, the agency penetrated common reed patches to a depth of twenty feet from the patches' edge with medium-pressure spray application equipment mounted on ground vehicles. Although this method may not achieve adequate coverage, mowing makes much of a site accessible and treatable.

Two other advantages of mowing include 1) facilitating travel by wildlife, sportsmen, and DWR personnel, which increases the agency's ability to monitor results effectively; and 2) encouraging other plant growth by opening the canopy. The optimal grid pattern of mowed paths is seven to fourteen feet wide and forty feet apart, but, ultimately, equipment, personnel, time constraints, and site conditions will dictate grid dimensions.

Rolling. If other treatment options are unavailable, the DWR will roll or crush common reed stands using specialized ground equipment that pulls or pushes a roller, which will knock over and compact stands closer to the soil surface. By creating a dense vegetative mat that reduces light penetration, this method will decrease reinvasion of the treatment site by desirable plants. A microenvironment will also develop in rolled common reed patches where elevated humidity and moisture increase the decomposition rate of dead plant material. However, soil contact and warm, moist conditions may stimulate shoot development from surviving common reed stems, rhizomes, and root material. Also, common reed seed can germinate in darkness and may survive long enough to reach light for photosynthesis.
Because ground operations using equipment can induce the growth of new common reed from stem, rhizome, and stolon fragments and from seed, the agency will monitor treatment sites and adjust the timing for rolling common reed patches, possibly waiting until winter when frost will reduce above-ground plant material viability. Years of observation prove that vegetation response varies between the track imprint area and adjacent areas. These microenvironments increase the survival of chemically treated common reed where standing water is present, which reduces chemical effectiveness

and chemical adherence with the plant. In some cases, these areas are the first sites to recolonize with other plant species.

The DWR will evaluate third-year treatment sites to determine follow-up treatment methods.

Strategy DD: Marketing products from harvested common reed

Common reed is a commodity in Europe, Asia, and Africa. These countries use the plant in structural applications, including fences, privacy panels, and roofs; as livestock feed; and in the production of textiles and pulp for paper. North America could use common reed in the cellulosic production of biofuel comparable to other high cellulous products at a 1:2 energy input: output ratio. If and when the opportunity arises and is feasible, Strategy DD proposes exploring markets for products using harvested common reed.

Currently, a viable market for common reed does not exist in North America, and labor, freight costs, and other export/import requirements most likely prohibit exporting common reed to worldwide commercial markets. If viable markets develop, however, the DWR will consider setting aside areas for the commercial management of common reed and use the profits from these operations to help pay for control and containment efforts on the greater wetland areas. The United Kingdom, Asia, and Africa have already developed strategies for managing common reed beds to produce structurally uniform stem material. Ironically, these countries are diligently working on ways to prevent deteriorating and disappearing common reed stands.

The agency may investigate emerging local markets for products harvested from common reed. These markets may include livestock forage, blinds, privacy panels, fencing panels, and biofuels.

Harvesting common reed for commercial products will require a cut and removal system. These systems are available in the United Kingdom and most likely in other countries in Europe and Africa. In Africa harvesting by hand is still a major harvest technique.

Strategy EE: Managing containment after three-year treatment effort

Strategy EE provides methods for containing common reed after the three-year treatment effort. Most containment methods will combine several treatment options. Site conditions and management objectives will dictate the method or combination of methods the DWR uses, and these methods will probably change over time for each site.

Most likely, the agency will use some combination of these methods:

- herbicide application

- livestock grazing
- disking
- mowing
- burning
- water level management

Because biological controls with bugs are in the testing phase and may be years away from actual application and because mechanical manipulation is difficult, even with specialized equipment, the agency will delay use of these containment methods.

Herbicide Application. The DWR will apply herbicide to contain expansion and control new invasions of common reed.

Experimental Grazing 2007 at Ogden Bay WMA
Photo by Randy Berger

Livestock Grazing. The agency plans to initiate grazing when livestock will consume early new growth and gain weight. Early in the growing season, livestock should consume total above-ground common reed then apical tissue material. This treatment method may not be the most practical, however, because, later in the season, overall consumption will decrease, causing livestock to lose weight and require supplemental feeding. Also, most livestock owners will expect compensation for reduced weight gain.

Achieving the desired trampling effect on open stands and damaging shoots, rhizome, stolons, and dormant shoot material will require the DWR to extend grazing periods or increase stocking rates. In addition, maintaining livestock on common reed patches for extended periods will require fencing and some supplemental feeding because animals will consume less palatable plant material. As a result, the agency will confirm this measure with livestock owners prior to implementation.

Currently, the Bear River Refuge, Ogden Bay WMA, and Farmington Bay WMA use experimental grazing to control and contain common reed. The agency is evaluating this method, including stocking rates, grazing intensity, grazing timing, and short- and long-term grazing results, for use in other northern Utah WMAs.

Disking. Burning followed by disking with standard agricultural equipment is a treatment option in dry areas. Because desiccation and frost kill viable common reed buds, the agency will disk treatment sites when conditions are dry throughout the growing season then expose disked plants to frost the following winter. Deeply buried plants may not reach the surface and die. Any flooding of the treatment sites can create propagation fields that increase expansion.

To reduce the risk of spreading common reed plant parts and seed, the agency will clean all equipment thoroughly before leaving a treatment site.

Disked Common Reed Spring 2006
Photo by Randy Berger

Mowing. Repeated mowing up to six times a year can reduce common reed stand density and plant vigor. Single mowing in the summer, usually July, can increase stress, potentially reducing stand height and density. Cutting at the wrong time in the spring can increase production of common reed. Fall cutting may have no positive or negative effects on stands.

The DWR will not use extensive mowing as a containment method on most treatment sites, with the exception of Salt Creek WMA, Public Shooting Grounds WMA, and Locomotive Springs WMA where burning common reed is problematic. In these areas, burning small, scattered common reed patches requires burning large expanses of healthy, diverse marsh; therefore, the agency will use mowing on these WMAs for the residual removal of treated common reed stands that are outside prescribed burn sites designated for other management purposes.

Softrak Machine with Mower
Photo by Marcus Franpitt,
Loglogic United Kingdom

The agency will mow extensively to develop firebreaks during the winter months following aerial herbicide treatments. Because the DWR has already initially treated and burned most sites with natural and manmade barriers, such as dikes, roads, and channels, firebreak development will focus on new treatment sites without adequate firebreak protection. In areas where the agency cannot mobilize fire-fighting equipment, firebreaks, which are at least two times the flame length, will have to be forty to eighty feet wide, and hand crews will need safety zones, which are at least four times the flame length, estimated at 150-300 feet wide and 150-300 feet long.

Currently, the agency needs firebreaks to protect no-burn zones and reduce the acreage of some planned burns. To develop these firebreaks, the agency will mow areas at or near ground level and remove residual plant material or incorporate this material into burn zones (cut and removal). Some firebreaks will be miles long to prevent carrying ground fires to protected zones. For example, a 640-acre burn can require four or more miles of firebreak; at forty-two feet wide (six passes), this area equals mowing twenty acres in rough terrain. The agency will plan mowing treatments and subsequent burns carefully to reduce the length of cut and removal firebreaks. These operations will be labor-intensive and require expensive, high-maintenance specialized equipment.

Burning. Due to the amount of smoke produced from fires that are 1,000+ acres, the DWR will likely subdivide large burns. In the future, the agency anticipates facing burning restrictions, including size and frequency of burns. Because of these anticipated restrictions, by 2011 the agency plans to purchase three complete operational units, a rubber track machine with a seven-foot mower and a rubber track loader with removal attachments, to maintain current firebreaks and develop new firebreaks.

Burning can stimulate growth in wetland plants, including common reed, so the agency will not use this option alone as a containment method but will carry out burning as part of another method, such as pre-disking or post-herbicide application.

Water Level Management. Water level management is a useful tool for controlling and containing common reed. Deep, prolonged flooding, three feet for four months, can reduce or kill plants, although none of Utah's marshes has this capacity. Mowing and flooding can reduce growth and density and may kill common reed. Literature does not clarify the depth of flooding over cut stems, but in Utah approximately six to ten inches of water, three inches over cut stems, will kill cattail. The DWR will adjust mowing and flooding, possibly mowing in the summer and/or fall then flooding in the winter, to evaluate the effects of timing on survival rates.

Drawdown and Mowing 2006 at Farmington Bay WMA
Photo by Flying Sensor, Bountiful Utah

Water depths of twenty-four inches have successfully contained common reed expansion at Ogden Bay WMA. The agency observed plants spreading into open water areas, but at a depth of twenty-four inches the plants did not root in the substrate. Flooding common reed seeds with at least five centimeters of water will reduce germination.

The DWR currently uses drawdowns to create a stunted growth form and reduce the seed production of common reed. The stands open with a smaller stem diameter and lower growth form, allowing some growth and short-term development of other plants adapted to drier sites. Drawdowns also produce common reed stands that are more accessible for hunters and some wildlife, particularly pheasants and deer. The agency can burn drawdown areas in the summer or fall and flood these areas to create short-term hunting opportunities. However, because burning may stimulate growth, the agency does not consider this method effective for controlling or containing common reed.

Drawdown 2006 at Ogden Bay WMA
Photo by Randy Berger

At Farmington Bay WMA, drought stressing and late summer mowing opened common reed stands the following growing season. Combined with flooding, this strategy increased bird use but failed to accomplish long-term containment of common reed.

Managing Common Reed Stubble
When burned or mowed, residual common reed stubble creates significant management issues. Burning common reed sharpens and somewhat tempers the stem ends. Mowing produces stubble four to six inches high with a more flattened end and a stem density of eighteen to thirty stems per square foot, which makes walking on treatment sites difficult. This stubble persists for many years and presents a potential hazard to hunting dogs' feet and hunters' wading boots.

Because stem material takes two to five years or more to decompose, the DWR will work to identify and implement techniques for lessening the negative impacts of common reed stubble. For example, the agency will experiment with rolling stubble, varying site conditions and timing to determine the most satisfactory results. At a minimum, the agency will educate public users, with signs and during personal visits, about the safety issues associated with common reed stubble and address safety issues in presentations and public discussions.

Assessment and Monitoring
In 2006, the DWR assessed common reed distribution on the WMAs to estimate acreages and determine the Invasive and Noxious Weed Control Project's time frame. This initial assessment concluded that common reed dominated more than 10,000 wetland acres, which was a conservative estimate and did not include all vegetated areas below water control structures (dikes) or all adjacent private lands. Ducks Unlimited conducted another assessment during a mapping project and determined that 36% (15,902 acres) of the 44,130 acres of emergent marsh around the Great Salt Lake, including private and state lands, was dominated by common reed. The agency considered areas dominated where common reed comprised more than 50% of an existing plant community. For a map of Ducks Unlimited's common reed assessment, see Appendix 3, "Map of Ducks Unlimited Analysis of Common Reed Dominance on Great Salt Lake."

The DWR performs ground assessments of previously treated and burned areas for ocular estimates of common reed survival. By surveying plant distribution, the agency identifies either aerial or ground herbicide treatment as a follow-up treatment method.

To photographically document changes to treatment sites, the agency establishes photo points near common reed clonal stands and advancing walls of common reed and in mixed plant communities. Placing a post between 4' 7" and 5' 3" to act as a camera stand for photographing all cardinal directions and using the same camera, lens, and camera settings help ensure consistency for each site. In each site's file, the agency includes a photograph of a directional marker post placed directly north twenty to thirty feet hung with a sign that records the date and the site's ID number. Once fully initiated in 2008, the agency will use this monitoring approach for four years: pre- and post-

treatment for each site at the same time of year for the three-year treatment process. The agency will also map these sites using GPS technology and ARCGIS software.

Because a fixed-wing aircraft typically covers entire designated areas with herbicide during initial aerial treatments, the agency is concerned about the effects of glyphosate on non-target plant species within treatment zones. Although a fixed-wing aircraft can be more precise when large gaps exist between common reed stands, most treatment sites are heavily infested with common reed, and this spatial distribution complicates spot treating select stands within mixed plant communities from the air. Using a rotary-wing aircraft may reduce some unnecessary spraying of non-target species because helicopters can spot treat confined and widely separated common reed stands more effectively. Ground treatments also provide a more refined application on small sites with small common reed patches.

To determine survivability after aerial herbicide application and burning, the agency will monitor some non-target plant species in select sites. The agency will estimate the stand size, density, and plant condition (healthy or stressed) of species on these sites, which will have GPS points for relocation, and will note site conditions, such as wet or dry and water depth, if present. Then, the agency will revisit the sites post-treatment to compare pre-treatment data.

The DWR observed that the timing of glyphosate application may not affect the survival of plant species that are phenologically near dormant or in dormancy. For example, alkali bulrush (*Scirpus paludosus*), a valuable wetland species, matures early, sets seed, and can begin dormancy, depending on location and environmental conditions, around September 1 in northern Utah. After this time, glyphosate may prove less detrimental to alkali bulrush. The agency will investigate the effects of application timing on non-target plant species, including alkali bulrush, cattail (*Typha* spp.), olney threesqaure bulrush (*Scirpus olneyi*), inland salt grass (*Diatichlis stricta*), and hardstem bulrush (*Scirpus acutus*). This sampling and analysis will be rudimentary but may provide some direction for timing herbicide applications.

The agency can use ocular estimates to determine common reed treatment methods adequately; however, to estimate survival percentage based on stem counts more precisely, the agency will sample plots that are one-meter square.

Literature Review of Common Reed Information Sources

Weed Species: Common Reed, *Phragmites australis* (Cav.) Trin ex. Steud; Phragmites (frag-mī-tēz) comes from the Greek word *phragma* meaning “fence” (5).

Taxonomy (2, 6)

Kingdom *Plantae:* Plants
Subkingdom *Tracheobionta:* Vascular plants
Superdivision *Spermatophyta:* Seed plants
Division *Magnoliophyta:* Flowering plants
Class *Liliopsida:* Monocotyledons
Subclass *Commelinidae:* Plants with no septal nectaries
Order *Cyperales:* Commelinidae plant with reduced, mostly wind-pollinated or self-pollinated flowers that have a unilocular, two- or three-carpellate ovary bearing a single ovule
Family *Poaceae:* Grass family
Tribe *Arundineae:* Tall weeds or tussock grasses
Genus *Phragmites* Adans.: Reed
Species *Phragmites australis* (Cav.) Trin. ex Steud.: Common reed

World Species and Distribution (55)

***Phragmites mauritianus* Kunth:** Tropical Africa and islands of Indian Ocean
***Phragmites karka* (Retz.) Trin. ex Steud:** Tropical Africa, Southeast Asia, and northern Australia
***Phragmites japonicus* Steud:** Japan, China, and eastern areas of Russia
***Phragmites australis* (Cav.) Trin. ex Steud:** Worldwide distribution

Common Reed, *Phragmites australis* (1, 2, 9)

Common Name: Common reed, giant reed, phragmites, giant reedgrass, Roseau, Roseau cane, yellow cane, or cane.
Scientific Name: *Phragmites australis*
North American lineages: *P. australis var. berlandieri* (E. Fourn) C. F. Reed, haplotype I, Gulf Coast type, southern USA, Asia, southern Pacific Islands, and South and Central America; *P. australis subsp. americanus* Saltonstall, P. M. Peterson & Soreng, haplotype A, B, C, D, E, F, G, H, S, Z, AA, Native lineage, USA and Canada; and *P. australis* (Cav.) Trin. Ex Steud, haplotype M, Introduced lineage, Europe, Africa and Asian

Distribution

Common reed is found practically worldwide from North and South America to Europe, Asia, Africa, and Australia. Common reed is not found in Antarctica, the Amazon Basin, and Central Africa. This wetland plant can be found in every U.S. state, except Alaska and Hawaii (5). Common reed has a wide climatic tolerance from tropical to cold temperate areas and is found from sea level to 1,980 meters in elevation (9). Common reed has a cosmopolitan distribution and is abundant in marsh communities, along roadsides, ditches, ponds, and road and rail right-of-ways. It can grow where

ground water is within 1½ meters below the ground surface or in shallow water less than ½ meters in depth (7).

Over the past 150 years, common reed distribution and abundance has dramatically increased, especially along the Atlantic coast. Botanical records typically described common reed as rare or not common in the 1800s. In the 1900s, the plant was considered and described as more abundant and spreading (8).

In Utah the DWR saw a dramatic increase in the abundance and distribution of common reed between 1995 and 2007. There is some speculation the flooding of the Great Salt Lake (GSL) in the mid 1980s was one of the primary disturbance factors that stimulated invasion and expansion by common reed along the shoreline. It is also speculated the rapid expansion of common reed can be attributed to the existence of the invasive form of common reed (Personal communiqué, Val Bachman and Rich Hansen).

Rebuilding the dikes, roads, and water delivery systems affected by the flooding event of the GSL may have been a contributing factor for establishing new colonies of common reed around the lake. Disturbance through construction and maintenance activities can play some role in the establishment of new colonies (Personal observations).

Common reed has been invading and expanding in other areas not affected by the flooding event. Bear Lake in northern Utah has experienced an increase in common reed, independent of any recorded disturbance around the same time period (Personal communiqué, Steve Dewey).

History in North America

The earliest traces of common reed in North America come from the 40,000-year-old dung of a ground sloth (extinct for 10,000 years) that was found in the Southwest containing 65% common reed. Core samples from east coast marshes show 3,000-year-old remnants of common reed. Mats woven from common reed by Anasazi Indians approximately 1,000 years ago were found in Colorado caves (5).

Common Reed, *Phragmites australis*
Photo by Randy Berger

Description

Common reed is a warm-season perennial, sod-forming grass that annually can grow from two to four meters high (three to 15 feet) (3, 9, 10, 11).

The hollow, unbranched, jointed stem (culm) usually measures 1.0 to 1.5 centimeters (¼ to ¾ inches) in diameter but can reach 2.5 centimeters (one inch) in diameter. Stem density can be 200 stems per square meter (3) or eight to 20 stems per square foot (22).

Alternate leaves are one to five centimeters (½ to 1 ½ inches) wide and up to 50 centimeters (two to 24 inches) long. The leaf surface is described as glabrous (hairless) and prominently veined above with a smooth, sparsely-haired underside and scabrous leaf margins. Leaves are elongated and taper to a point at the end (9, 10, 11). They can be stiff and sharp due to high contents of cellulose and silica (10). The foliage is gray-green during the growing season and turns tan in the fall. Most leaves drop off while the stems and florescence persist and remain conspicuous in the winter (11).

The terminal flower is a plume-like panicle 15 to 50 centimeters (five to16 inches) long. Flowers form in late July and August and are usually purple or golden in color (9, 10). Seeds are brown, thin, delicate, and numerous. Research indicates few seeds are viable and germination is difficult (10). However, some reports indicate the viability of seed can vary among populations, or even individual plants, and by over-wintering conditions (12, 29). Although seed production is plentiful and contributes to the seed bank, most reproduction is vegetative. Seed and transport of root material, rhizome, and stolon fragments are the means of initial establishment (5).

It is reported that young plants may persist for two years in a small rather inconspicuous stage resembling other grasses (24). Plants initiate flowering in the third or fourth year. About half of the shoots will bear flower clusters in the most mature stand. The common reed shoots die after flowering and will usually remain standing for an extended period (22).

Above-ground plant material, stems, and leaf material will persist for extended periods. Decomposition rates for leaf material are reported at 74% to 80% within eight to 30 months, depending on conditions. Decomposition of stem material is reported as 60% to 80% in 24 to 30 months (14, 15). Standing dead-stem material may persist for at least four years (47).

The root structure of common reed is complex and has many advantages. Mud-tap roots one meter (three feet) in depth and stolons capable of growing 15 meters (ten to 50 feet) in a growing season with rhizomes that can spread ten meters (30 feet) annually are characteristic of common reed (9, 10, 13, 16, 22). Rhizomes create a dense underground mat of root material close to the soil surface and can grow to a reported depth of three to six feet (3, 10, 24). Roots and stems develop at the nodes on the rhizomes and stolons (10).

Chemistry (directly copied and quoted from 68, *Phragmites australis* (Cav.) Trin. Ex Steud Syn.: Phragmites communes Trin. Phragmites vulgaris B.S.P. Poaceae, Common Reed, James A. Duke, Source: Handbook of Energy Corps, unpublished, 1983):

> Per 100 g, the reed is reported to contain (ZMB): 415 calories, 10.6 g protein, 2.1 g fat, 72.7 g total carbohydrate, 31.9 g fiber, 14.6 g ash, 480 mg Ca, 60 mg P, and 130 mg Mg. Leaves are reported to contain 17.1 g protein, 3.5 g fat, 63.7 g total carbohydrate, 27.4 g fiber, and 15.7 g ash. Stems are reported to contain 4.8 g protein, 0.8 g fat, 90.0 g total carbohydrate, 41.2 g fiber, and 4.4 g ash. According to Hagers Handbook (List and Horhammer, 1969–1979), the fresh herb contains 5.15 mg Vit. A/100 g, and 91.1 mg Vit. C as well as Vit. B_1, and B_2,

the triterpene b-amyrin, taraxerol, and taraxeron ($C_{30}H_{48}O$). The rhizomes contain: moisture, 5.3; nitrogenous substances, 5.2; fat, 0.9; NFE, 50.8; CF, 32.0; sucrose, 5.2; reducing sugars, 1.1; and ash (rich in silica), 5.8%. Asparagine (0.1%) is also present. P. communes is rich in pentosans and may be used for the production of furfural; nodes and sheaths yield 6.6% and the underground parts over 13% of furfural. The pentosan content increases throughout the growing period and is maximum in the mature reed. The reed can be used also for the preparation of absolute alcohol, feed yeast and lactic acid. Analysis of the young grass gave: protein, 11.4; EE, 2.3; carbohydrates, 43.1; CF, 31.05; mineral matter (with high silica content), 10.8; calcium (CaO), 0.94; and phosphorus (P_2O_5) 0.39%. The reed is reported to contain a wax and a saponin. Leaves have a high ascorbic acid content (200 mg/100g). (68)

Habitat and Environmental Conditions

Common reed grows in a variety of environmental conditions, from full sun to half shade (21). It grows in wetlands and drier border areas as well as disturbed sites where ground water is present. Common reed can grow where ground water is within 1½ meters below the ground surface or in shallow water less than ½ meter deep (7). Common reed grows in fresh water, brackish water areas, and at the edges of saltwater marshes (11, 20). Common reed tolerates acidic and alkaline conditions and can tolerate salt water; however, growth may be stunted (20, 21). Disturbed and polluted sites provide an environment for common reed establishment (20). However, common reed can establish in pristine sites (23). Common reed was reported growing among Ponderosa Pines in Bryce Canyon National Park in Utah along a forest trail, which demonstrates the versatility of this plant (Personal communiqué, Steve Dewey).

Common reed can become established by seed transport and germination and by plant fragmentation and propagation. Seed production is prolific, but viability is considered low due to the level of self-incompatibility (9, 17, 22). Common reed initiates growth once the greatest threat of frost passes. Growth rates of stems up to 1½ inches per day have been reported (5). Warm, moist, disturbed or bare soil environments in late spring (May and June) are conducive to common reed seed germination. Establishment requires that a site maintain adequate moisture for plant survival and reduce porewater salinity for development of sufficient root material for nutrient and water transport. Rapid drying or prolonged flooding reduces seed germination opportunities (17, 22, 28). Common reed has been germinated in total darkness and is able to germinate under heavy litter (26).

It is reported that common reed has shown a preference for growing in pH levels of 6.4 to 8.1; however, it has shown tolerance to pH 2.9 (7, 22).

Reproduction and Adaptive Strategies

Once common reed is established, expansion is primarily by vegetative growth through development of rhizomes and stolons (3, 9, 10, 13, 22). Most of the nutrient reserves and hormones are stored in the plant rhizome. Rhizome growth is most rapid in late summer to early winter. Buds are formed in fall and normally remain dormant through winter and emerge in late spring. All common reed stands will have vertical and

horizontal rhizomes creating a root mat and surface stolons for rapid expansion. Nodes on the rhizomes and stolons can develop into an erect stem; a stolon (prostate stem); or root material: rhizome, taproot, or mud root (22).

Propagation of new stands of common reed is enhanced by anthropogenic (human-caused) activities (12, 28). Burials of fragments containing at least one axillary bud have a high establishment and survival rate in well-drained soils. Oxygen is required for establishment of common reed. Once established, translocation through clonal integration and pressure ventilation through the aerenchyma tissue in stems, rhizomes, and roots facilitate spread into less oxygenated environments via clonal expansion (12, 28).

One of the competitive advantages common reed has is in gas exchange ability. The aerenchyma tissue provides gaseous exchange from root, rhizome, and stems and is capable of carrying a greater volume of gas. Larger and denser stomata located on the upper (adaxial) and lower (abaxial) leaf surfaces improve gas exchange. Growing in water allows common reed to keep the stomata open to effect gas exchange virtually all of the time (12).

Another adaptive strategy of common reed is apical dominance of horizontal stems (rhizomes and stolons). Growth can be directed to these stems rather than aerial vertical stems. When these stems encounter unfavorable conditions where apical dominance is prohibited or the apical bud is damaged, axillary buds are released and new photosynthetic stems are produced, which can lead to explosive growth and expansion of the colony (12).

Common reed possesses three mechanical adaptations, height, stem density, and litter production, to reduce growth of other wetland plants. The growth form of the plant, tall and dense, reduces light availability and physically crowds out understory plant species. Common reed is a rapid-growing, high biomass-producing plant, which creates a lot of thatch. This thatch is slow to decay, and between dead standing stems, live stems, and thatch, sunlight is blocked from reaching the soil surface, reducing the chance of germination of plants present in the soil seed bank (12, 53).

It has been recently reported by the University of Delaware that a toxin has been found in the soil associated with common reed. It is stated that this toxin, 3,4,5-trihydroxybenzoic acid, is suspected of causing adjacent plant root material to rot, which provides common reed with a competitive advantage to expand (33).

Limitations

Common reed does not tolerate strong wave action or rapidly moving water (19). The plants are less competitive with variation in water levels among wet and dry years and seasons (7, 53). It is reported that small increases in water table may influence sediment-oxygen equilibrium and create anoxia in root and horizontal rhizome apices, thereby stressing common reed plants (27).

Low or high soil fertility can stunt plant growth (22). Sulfides, anoxia, and salinity are identified stressors to common reed growth (28).

High levels of iron (Fe) can restrict growth in common reed. This is attributed to the formation of iron hydroxide deposits on the root, which in turn may reduce the uptake of phosphate. However, the study suggested phosphates might be absorbed by submerged hydropotes on the above-ground stem material. High iron concentrations were characterized by a deep orange color on the root material (31).

High temperature and high salinity have a detrimental effect on seed germination of common reed. Lower temperatures increase salinity tolerance of common reed. Low mean temperature and mid-range salinity (five to ten ppt.) can increase germination. It was suggested that restoration activities be initiated in fall or early winter after rains have reduced salinity levels or when salinity levels are lowered (26).

Phytotoxins, mainly sulfides, have been identified as a cause of reed bed diebacks. Plants were found to have callus-blocking internal pathways in the aerenchyma, rhizome nodes and the base of buds and culms. Blockage in xylem and phloem in roots and rhizomes was common. It was suggested that phytotoxins, which induce blockage in aeration pathways and cause stunting of roots and abnormal development of root wall lignifications and suberization, cause interference with water and mineral absorption, and phytotoxins that create internal blockage with vascular transport could bring about common reed dieback. Causes of callus formation, abnormal lignifications and blockages found in the phloem (tyloses), are not clearly defined. Increase in decay of dead plant or other organic material may increase phytotoxins, such as reduced iron, manganese sulphide and volatile organic acids (acetic acid) production. Lignification is a defense response in plants against damage caused by microorganism attacks and harmful quantities of phytotoxins and in response to waterlogging conditions in flood tolerant species. This thickening of the root and rhizome material is thought to reduce absorption of phytotoxins, reduce mineral nutrients intake, and conserve root oxygen reserves. This report also provides an illustration of a tentative scheme for possible pathways for common reed diebacks based on information found in dieing stands in Hungary and the United Kingdom. It demonstrates a cyclic loop of increased organic matter and an increase in phytotoxins and plant dieback (27).

It has been reported that some repression factors may exist to reduce common reed expansion in some mixed plant communities. Taller species may shade out common reed, reducing plant growth. Tall species may lodge, causing common reed to fall, and shoots incorporated in the litter mat can be shaded so high humidity hinders maturation. Litter decreases and germination and seedling survival increase to create more competition for available resources. Competition for nutrients and damage to buds create smaller buds with less robust growth. In mixed stands, litter accumulation may actually depress common reed (53).

Other causes suspected of creating common reed diebacks in the United Kingdom and Hungary were from acute, above-ground damage to buds and culms caused by mowing, grazing, and covering by rotting algal mats (27).

Uses and Values
Common reed has a number of historic and current uses reported in the literature. It is structurally useful for a number of projects. Common reed has growth characteristics and adaptive advantages, which can be exploited for other purposes. Wildlife use is usually considered as negatively impacted in large monotypic stand of common reed. Mixed stands can provide some structure and other functional values for wildlife species. Common reed as a wildlife food resource is considered limited; however, stands can harbor numerous insect species.

Human Use. Native Americans used the stems for arrow shafts, animal calls, cigarettes, musical instruments, pipe stems, matting, shelter construction, canoe, personal adornment pieces, toys, and game pieces. Common reed can also be used as a food resource where the seeds and young shoots are consumed, rhizomes are ground into a starchy product, and plant materials are converted to sugars (9, 36, 37, 48, 62). Native people of Tasmania used the stems for making jewelry, baskets, spears, and rafts (9).

Common reed has also been used as a medicine by Native Americans to treat phlegm, lung pain, stomach problems, boils, pneumonia, and diarrhea (9, 37). It is reported to be used as a folk medicine to treat condylomata, indurated breast, mammary carcinomata, leukemia, abscesses, arthritis, bronchitis, cancer, cholera, cough, diabetes, dropsy, dysuria, fever, flux, gout, hematuria, hemorrhage, hiccup, jaundice, leukemia, lung, nausea, rheumatism, sores, stomach, thirst, and typhoid. Common reed is claimed to be alexeteric, diaphoretic, diuretic, emetic, refrigerant, sialogogue, stomachic, and sudorific (68).

Common reed can be used as a food source. Shoots, when young, are eaten as a vegetable. In Russia it is harvested and processed into starch. Common reed can produce a manna-like-gum that can be eaten (68). Common reed has been harvested for fuel where other fuel sources were unavailable (9). In South Africa, common reed is used extensively for hut building, fencing, craftwork, and thatching (39).

Common reed stems are processed into pulp, paper, and fiberboards. Stems are composed of over 50 percent cellulose with fibers 0.8 to 3.0 millimeters long by 5.0 to 30.5 micrometers in diameter (9, 68).

With the current interest in biofuels production, perhaps someday common reed will be considered a source for cellulosic biofuel production.

Commercial Use. Common reed is a commercial product in Britain, used for roof thatch. Of the 5,000 remaining hectares of common reed in Britain, 65% is managed to provide a biannual or annual crop of stems for the thatch industry (35, 80). Another study reported 6,500 hectares of reed beds in the United Kingdom. Thatched properties exceeded 60,000 primarily small parcels. Roofs thatched with reed lasted for 80 years in eastern Britain and 50 years in the wetter southwest. It was estimated that one bundle of reed was required for one foot of roof, and approximately 2,000 to 3,000 bundles were used. It is estimated that 623 to 824 bundles can be harvested from a

hectare of common reed. Mechanical harvest has mostly replaced hand harvest. In the United Kingdom, it was estimated 336,555 bundles were harvested per year. Eighty percent of reeds are imported for use in the United Kingdom. Estimate value of the bundles of reed in 2000 was 653,950 to 753,950 English pounds (in US dollars 2007, $1,300,000). Employment in the thatch business was considered to be 1,000 persons with 800 being thatchers. Fencing and screen panels were also identified for commercial use in this report (82). In the Muzi Swamp in Africa, reed harvest has changed from a subsistence practice for use in craftwork, construction of huts, and thatch and fence material to commercialization and marketing. Quotas are now in place to reduce the pressure on reed beds (39). Management plans and strategies have been developed to protect and improve reed beds in the United Kingdom (80).

Wildlife Use. Common reed provides some benefit for avian wildlife species. It is reported seven nationally rare or threatened birds use common reed stands in England, including bittern (*Botaurus stellaris)*, marsh harrier (*Circus aeruginosus)*, crane (*Grus grus)*, Cetti`s warbler (*Cettia cetti)*, Savi`s warbler (*Locustella luscinioides),* bearded tit (*Panurus biarmicus),* and aquatic warbler (*Acrocephalus paludicola*) (34). Black-crowned night-heron (*Nycticorax nycticorax)*, snowy egrets (*Egretta thula)*, yellow-headed blackbirds (*Xanthocephalus xanthocephalus)*, marsh wren (*Cistothorus palustris),* and red-winged blackbirds (*Agelaius phoeniceus)* are reported to use interior part of common reed stands for nesting (9, 21).

In Utah marshes, snowy egret, black-crowned night heron, and yellow-headed blackbird nest in the interior of common reed stands (40). White-faced Ibis (*Plegadis chihi)* have a nesting colony established in a reed stand at Bear River Migratory Refuge (Personal communiqué, Bridget Olson).

Ruby-throated hummingbird (*Archilochus colobris)*, Black-capped chickadees (*Poecil atricapillus),* and downy woodpeckers (*Picoides pubescens)* have been identified feeding on insects within common reed stands (21).

Numerous waterfowl species have been reported nesting in the edges of common reed stands, and some use the edge area as escape cover from avian predators (40). In Manitoba, one study found 31 % and another found only 6% of duck nests were found near stand edges of common reed. In Manitoba, mallards (*Anas platyrhynchos)*, lesser scaup (*Aythya affinis)*, canvasback (*Aythya valisineria)*, ruddy duck (*Oxyura jamaicensis),* and redheads (*Aythya Americana)* have been located nesting in the edge of common reed stands (40). In Utah, at Fish Springs National Wildlife Refuge, only 4% of duck nests were found in common reed near stand edges (40).
Tree swallow (*Tachycineta bicolor)*, bank swallow (*Riparia riparia)*, eastern kingbird (*Tyrannus tyrannus)*, red-winged blackbird, bobolink (*Dolichonyx oryzivorus)*, brown-headed cowbird (*Molothrus ater)*, common grackle (*Quiscalus quiscula)*, rusty blackbird (*Euphagus carolinus),* and European starling (*Sturnus vulgaris)* are reported non-breeders that roost in common reed stands (21).

Common reed provides habitat to numerous invertebrates, which can provide a food resource for birds, reptiles, and amphibians. Spiders (*Araneida)*; beetles (*Coleoptera)*;

aphids (*Aphidina);* isopods (*Isopoda);* moths (*Lepidoptera);* mite and ticks (*Acarina);* flies (*Brachycera);* springtails (*Collembola);* bugs and water striders (*Heteroptera);* sawflies, ants and bees (*Hymenoptera);* crane flies (*Nematocera);* book lice and bark lice (*Psocoptera);* and thrips (*Thysanoptera)* have been found in common reed stands in France (21, 34, 38). Aphids are increasingly common in common reed in Utah marshes (Personal communiqué, Val Bachman).

Decomposition of common reed is a food resource for tiny animals used by estuary finfish, grass shrimp, and fiddler crabs (21, 36).

Mammals also use reed beds for different functions. Muskrat (*Ondatra zibethicus)* feed on young stems and root material and use the stems as building material. White-tailed deer *(Odecoileus virginianus)* use it for shelter and sleeping. Meadow vole (*Microtus pennsylvanicus)*, white-footed mouse (*Peromyscus leucopus),* and mink (*Mustela vison)* use reed beds at times (21). In Utah, beaver (*Castor Canadensis)* use common reed in the construction of lodges, and raccoon (*Procyon lotor)* use reed beds as shelter (Personal communiqué, Val Bachman and Rich Hansen).

Livestock Use. Common reed can be grazed and used for livestock forage as freestanding or as harvested hay. Early spring growth is good forage for cattle and horses. Common reed contains 11.4% protein, 2.3% fat, 42.1% carbohydrates, 31.1% crude fiber, and 10.8% ash (35). If common reed is to be winter grazed, it is suggested that a protein supplement be supplied to the livestock (40).

Other Uses. Common reed has been used for soil stabilization for restoration projects and for water treatment to remove nutrients and metals. Common reed has a high tolerance for Zinc (Zn), Lead (Pb), and Cadmium (Cd) and has been used for water treatment and restoration efforts (29, 40). Marshes dominated by common reed in coastal areas may help offset rapid sea-level rise effects due to increased sedimentation, high productivity, and slow decomposition rate (18). The mat-like root structures of rhizomes and adventitious roots create an effective erosion barrier to stabilize disturbed sites (24, 40).

Risks and Impacts

Common reed can produce numerous negative effects and undesirable conditions. Thick stands of common reed present a fire hazard when close to human habitation and developed areas (67, 69, 74). Reed beds can diminish aesthetics, property values, and views, and wildlife viewing opportunities can be lost (18; Personal communiqué, Val Bachman and Rich Hansen; Personal observation).

Waterfowl hunters have become lost in dense stands of common reed and required assistance from search and rescue teams at Farmington Bay Waterfowl Management Area (Personal communiqué, Rich Hansen).

Sediment trapping by common reed stands in coastal areas can increase the marsh surface and reduce the frequency of tidal inundation, altering the ecosystem (16, 67).

Common reed patches can present a barrier to movement of animals, fish, and invertebrates (5, 9, 18).

Dense monotypic stands of common reed displace other marsh plants and the fauna they support. Common reed provides few food resources and provides little shelter for wildlife (9, 11, 42). Wetlands composed of native plant mixes provide greater diversity for a greater diversity of wildlife than do marshes dominated by common reed (16).

Common reed is considered a noxious weed in Alabama, South Carolina, Vermont, and Washington (70).

Common Reed Haplotype Identification

Since the late 1980s, it has been suspected that an invasive form of common reed had been introduced to North America. This form was thought to be more aggressive and was a major contributor to the expansion of common reed in North America (64).

In 2002, Kristin Saltonstall successfully identified 13 haplotypes (lineages) of common reed in North America. The native haplotypes are identified with the label of haplotype A through the letter H, S, Z, and AA. Another haplotype found in North America, haplotype I, is also found in Asia, the southern Pacific Islands, and South and Central America. The identified Eurasian haplotype M has a worldwide distribution, including North America (1, 2, 4, 32, 63, 64). In North America, the native haplotypes are spread over various geographic locations (64).

Recent research has further defined common reed in North America as the 11 native haplotypes being a subspecies, *Phragmites australis* subsp. *americanus* and the Gulf Coast haplotype I as a variety, *Phragmites australis* var. *berlandieri.* There is a "Key to the Lineages of *Phragmites australis* in North America" developed for the identification of these species (2). Recent research by Saltonstall and others has elevated the variety *Phragmites australis* var. *berlandieri* to a subspecies level taxonomically (83).

There have been a number of physical traits and environmental elements used in an effort to be able to identify the difference between the introduced haplotype M and the native haplotypes. Leaf sheath adherence, stem color, stem texture, stem flexibility, stem toughness, stem density, time of flowering, inflorescence characteristics, time of senescence, leaf color, rhizome density, rhizome color, rhizome diameter, clonal expansion rate, habitat required, ligule width, upper glume length, and stem spots have all been suggested and used in the identification process (3, 64). Some have provided more consistent diagnostic capabilities, others have not, and other characteristics are still being investigated (Personal communiqué, Kristin Saltonstall and Bernd Blossey). It is important to realize that morphological characteristics change over the growing season and throughout the winter (63).

Another method used was satellite images and ground truthing done at Utah Lake, Utah (65).

Genetic sampling has been offered at Cornell University, and numerous samples have been submitted and analyzed (66).

Invasion and Expansion

Common reed invasion has been postulated as being caused by disturbances in hydrologic patterns, mechanical disturbance, increased sedimentation, and pollution. Increases in salinity from fresh to brackish, road salts, storm water discharge and nutrient shifts, and habitat disturbances also may contribute to invasion and expansion (7, 8, 24, 69). The introduction of an invasive form of common reed, haplotype M, is believed to be the main reason for rapid expansion. This haplotype is thought to have been transported to North America from Europe in the early 19th century. Common reed was documented where ship ballasts were dumped in the early 1800s. Human dispersal is thought to have facilitated the spread across the continent (8). Replacement of native common reed populations has been documented in New England, and a southeastern expansion into areas not known to have common reed has occurred (64).

Once established from seed or root material, most of the expansion is facilitated by vegetative growth. Eighty-eight percent of the common reed clonal expansion in the St. Lawrence River study was attributed to vegetative processes (7).

Expansion of common reed is reported to be affected by three variables: distance to nearest colony, north south aspect, and average water depth. Expansion is greater to the southern exposure, which is believed to be an effect of exposure to more sunlight (7).

Silt collection leads to terrestrialisation of waterlogged areas and natural loss of reed beds in Africa. This is thought to be precipitated by increased production of aerial parts, leading to increased litter and a slow decomposition of the stem material. The moribund material accumulates and collects silt, creating drier sites for other terrestrial plants to establish and compete with common reed (52, 47). Silt collections in estuary environments have actually facilitated the expansion of common reed by reducing tidal effects and reducing salt intrusions (67). Silt collection in Utah marshes has blocked or reduced flows in water delivery systems and reduced water control ability, which has lead to expansion of common reed stands (Personal communiqué, Val Bachman).

Preventative Actions

Preventative actions have been suggested for the reduction of establishment and expansion. Plant fragments should be removed along with mud and debris on equipment and wading gear. Boats should be washed and drained of any water before leaving a launch site. Don’t plant any reed species for erosion control or as livestock forage. When common reed is first observed, initiate a plan for control and containment (5).

Control Methods

Numerous tools, techniques, and methods have been used to control common reed. The invasive nature of the non-native haplotype M and the rapid expansion in wetlands have displaced valuable plant species. Monotypic stands of common reed provide fewer

benefits to wildlife and can reduce valuable food resources, eliminate nesting cover, and restrict movement. The competitive advantages and characteristics of common reed make it difficult to control and contain. A combination of control methods may be required to meet objectives.

Chemical. Chemical control has proven to be successful in control and containment of common reed. Numerous herbicides have been used with varying degrees of effectiveness. Typically, systemic herbicides applied to actively growing plants during the time of sugar translocation to the roots and rhizomes are the most effective. This time period is when the common reed has flowered and is setting fruit prior to the first frost in the fall (22, 24). Chemicals that have been used for control are glyphosate, amitrol, dalapon, imazapyr, and triclopyr (22, 69). Imazapyr has been used along with glyphosate in early summer applications with limited success (46). Amitrol was reported better than glyphosate or dalapon on flooded sites. Glyphosate and dalapon have been reported to be effective on moist and dry sites. Glyphosate is effective on senescing shoots in late fall (22). Dalapon and amitrol are no longer registered for use in the United States (Personal communiqué, Steve Dewey).

Glyphosate is probably the most commonly used herbicide for control of common reed. It biodegrades quickly into organic elements and has been tested extensively (74, 75, 76, 77, 78). Glyphosate and surfactants have been evaluated for use on common reed in wetlands and its effects on terrestrial wildlife, soil organisms, amphibians, and fish (44). Many researchers suggest a split treatment using ½ the dosage with a 15- to 30-day period between treatments (22). Treatment should be planned for successive years and include follow-up treatment of surviving plants (24, 43, 44, 62, 48). Burning to remove residual common reed and accumulated litter will reduce the level of difficulty in the re-treatment effort. It will improve seed germination conditions for desirable plants and improve visual assessment (49; Personal observation). Monitoring must be planned in any treatment project to assess potential for reinvasion of common reed (20, 22, 43, 44, 45). Glyphosate is applied by many methods, such as aerial spraying, backpack sprayers, ground motorized application equipment, mist blowers, bloody glove method, dripping, small hand-spray or squirt bottles, mowing or cutting, and wipe-on applicators (22, 24, 43, 44, 45, 62).

Repeated herbicide treatment has been discussed in the literature, and burning following initial treatment is recommended (49, 61). Short-term gains are quickly lost in one-time only treatments, and some treatments have been repeated for up to six consecutive years (44, 62, 49).

Total nonstructural carbohydrate, TNC, summer depletion, and replacement cycle was measured in the Delta Marsh in Manitoba, Canada. From the first of May to mid-June, depletion was occurring in the root material. Replacement began around mid-June and continued up to the frost when common reed senesced (60). This might suggest glyphosate chemical could be applied as early as the end of June and functionally kill common reed, with translocation of material taking place in below-ground material.

Dalpon was used 48 days following a mid-summer burn and was effective on common reed control in Utah (40).

Mechanical. Mechanical methods for controlling common reed are seldom recommended due to the difficulty of operating machinery in wet soil environments where common reed grows. Upland dry sites are more conducive to mechanical control methods. The methods mentioned are mowing, cutting, disking, dredging, plowing, rotary ditch digger, brush cutters, rototiller, mulchers, crushers, and bulldozers (22, 24). It is suggested, if disking or root cutting or any other method that cuts up the plant material in lengths with two or more nodes and the plant material is left in contact with the soil surface, that the area not be re-flooded until after the winter season to allow for frost-killing or desiccation of possible live buds or propagate material (22).

An excavation project at Locomotive Springs WMA in Utah completely removed two meters of soil from an area containing common reed. The area of removal was 2.5 meters above the impounded water. The remaining undisturbed material still contained root material, and the following season re-sprouting had occurred (Personal observation).

Cutting or mowing is a control tool used to reduce common reed patches. Cutting is unlikely to completely eliminate common reed. Timing of the cutting may increase production or may reduce production. Multiple cuttings up to six times per season are suggested for the removal of photosynthetic material to reduce plant vigor, below-ground reserves, and patch density (24, 44, 50, 51, 62). A single-cut strategy is recommended in the month of July to remove plant growth prior to translocation of sugars to the root system for storage and increase stress (24), although measurements of total nonstructural carbohydrate, TNC, indicated translocation of sugar as early as mid June in a Manitoba study (60). Removal of stem material was recommended to remove potential for stolon formation and sprouting of cut stems (24). Winter cutting and removal is used to reduce litter build-up and likely increase spring seed germination by opening the canopy. Stunted growth in the following year can occur. It is reported that summer cutting followed by flooding (drowning) may kill common reed (50). However, no mention was made of flooding depth or duration. Utah wetland managers have not observed any drowning events on established common reed stands in shallow water flooding events, one to 18 inches. Flooding has been successful when three feet of water has been held over the rhizomes for four months (24).

Harvesting and removal of the stems for the thatch industry is common throughout much of Europe and Africa. A study in Sweden showed harvesting increased biomass production the following year by increasing shoot density (30). In Africa, harvesting and burning combined reduced the quality of stems in reed bed stands by reducing height and stem diameter. In continuously uncontrolled harvest areas, common reed has nearly disappeared. It was suggested that harvesting be followed by three years of rest to maintain reed bed quality (39, 52). Harvesting increases stem density if done during the growing season by removing the apical dominance and increasing production of side shoots (12, 50).

Water Level. Water level can influence common reed growth characteristics, survival and, expansion. Stabilization of water levels and increased agricultural water in the Delta Marsh in Manitoba was considered a prime reason for expansion of common reed (59). Common reed seed requires moist soil conditions to germinate and does not germinate if covered by greater than five centimeters of water (24). Expansion by rooting stems, stolons, has been observed to cease in water levels 12 to 20 inches deep due to lack of ability to anchor to the substrate (22, 40; Personal communiqué, Val Bachman). However, stolons have been observed crossing open, deeper stagnant water channels 20 feet wide and establishing rooted plants on the opposite shore (Personal observation).

Drawdowns, which dry out common reed stands, can stunt growth and reduce seed production. Drawdowns are typically initiated in the spring (May 1 through 15) prior to alkali bulrush starting to set seed. The area is maintained dry until late summer (mid-September) and then re-flooded for public use (Personal communiqué, Val Bachman and Rich Hansen).

Flooding stems that have been cut in June can almost totally inhibit growth of common reed plants the following summer. It was suggested that flooding with brackish water provided better results. Flooding to a depth of three feet for the duration of four months during the growing season has been reported effective at controlling common reed (24). Common reed typically grows where ground water is within 1½ meter below the ground surface or in shallow water less than ½ meters in depth (7).

No consistent water level over cut stems was reported for common reed control. Flooding over cut stems of cattail in Utah was reported most successful when cut stems were covered by three inches of water for an extended period (81).

A long term analysis of common reed expansion in the Long Point Marshes (22,229 hectares) of Lake Erie in Ontario provided the following information: in 1945, there was 54.1 ha.; in 1964, there was 69.5 ha.; in 1985, there was 4 ha.; in 1995, there was 18 ha.; and in 1999, this expanded to 142 ha. There was evidence of a negative correlation to increased water depth of Lake Erie and common reed expansion. A positive correlation to increased temperature and increased common reed expansion was reported (85).
Increasing salinity and tidal action has been used as a control method for common reed in coastal areas (22, 24). In many cases, competing plants or desirable plants are not as salt tolerant as common reed (22).

Fire. Fire reduced stand height and density in harvested reed beds in an Africa study (52). Timing of burning has an effect on aerial and below-ground biomass production. Spring (May) burns increase biomass of aerial and below-ground plant material, and fall burns (October) increase or produce no change in the following year's biomass production (22, 59, 60). Summer (August) burns produced less biomass than spring or fall burns. One study monitoring second-year growth following a summer burn found production of biomass had returned to pre-burn levels (59). Biomass production has been reported from 625 grams per square meter in an 86% dominated stand to 984

grams per square meter in a 91% dominant stand. Other reports indicate production at 1,110 grams per square meter or 2,711 to 5,567 pounds per acre (59, 60, 61). Dead standing canes and litter often can constitute twice the biomass as live aerial plant material (40). Summer burns increased plant diversity, and it is thought to be a function of reduced shading, increased sunlight penetration, and increasing seed germination.

Removal of above-ground biomass with fire during the fall can expose rhizomes and fall elongated buds to frost and possible death (60). Early development in the spring of large fall buds can be damaged by late frost. If killed, three side shoots will develop from the side of the damaged shoot. Spring-formed buds are small, remaining dormant below ground until replacement is necessary due to damage (40).

Burning does not damage buried root material unless a peat fire occurs. Ground temperatures measured in a Utah burn were recorded at 118 degrees Fahrenheit (48 degrees Celsius) (40). Unless the area has completely dried, wicking of moisture will occur in the stems and stubble will be left unburned (40; Personal observation).

Burning is also used to stimulate growth of common reed. Spring burning will encourage a more uniform and dense stand of even-aged stems for the thatching industry (60). Burning is thought to be responsible for subsequent flush marsh plant growth through the release of nutrients stored within the standing biomass, opening of the canopy, and increased sunlight and heat penetrating the soil surface (Personal observation).

Prescribed burn plans have numerous elements that should be taken into consideration. Smoke management, fire intensity, fire spread, fuel load, firebreaks, equipment capability and availability, and personnel availability and safety are all important considerations and affect the ability to meet the burn objectives. It is thought that many burns are never evaluated for the expressed objective due to poor or no pre- and post-monitoring (73).

Grazing. Grazing common reed can provide a food resource for livestock and may be used to increase or reduce stand vigor. Common reed can be grazed and used for livestock forage as freestanding or as harvested hay. Early spring growth is good forage for cattle and horses. Common reed contains 11.4% protein, 2.3% fat, 42.1% carbohydrates, 31.1% crude fiber, and 10.8% ash (35). Grazing has been documented to remove 67% to 98% of above-ground biomass, and after four years common reed may reach equilibria with grazing regimes (24). Trampling has an effect on rhizomes and new shoot growth buds and can influence common reed production (22, 24). Continuous and long-term grazing strategies, two years at least, have shown positive effects on reducing common reed stand vigor, and, in one case, reduced stand size (54). Cattle used common reed during the summer, and horses used it for a longer period and also consumed rhizomes in the winter. Trampling allowed for openings in the reed bed stands and enabled establishment of other plants. Heavy stocking rates and confinement in common reed stands encouraged heavier grazing and allowed grasses to replace common reed. Common reed is less tolerant to grazing in drier sites (54). Nutria (*Myocastor coypus),* muskrat (*Ondontra zibethicus),* and American coot (*Fulica*

Americana) are also known to consume aerial material of common reed but have no significant impact on stand vigor or stand density (22).

Insects. Over 156 specialized insects are known to utilize common reed. This counts for 151 species outside North America and five native species in North America. Twenty-one species from outside North America have already been accidentally introduced.

The five native species include the Yuma skipper (*Ochlodes yuma),* a dolichopdid fly in the genus (*Thrypticus),* a gall midge (*Calamomyia phragmites),* and a native broad-winged skipper (*Poanes viator)*.

The introduced species include a European moth species (*Apamea unanimis),* (*Apamea ophiogramma),* (*Archanara geminipuncta),* (*Chilo phragmitella),* (*Schoenobius gigantella), and* (*Phragmataecia castaneae)*; several shoot flies in the genus (*Lipara)*, (*Dolichopodidae*), (*Lipara rufitarsis), (L. pullitarsis), (L. lucens), and (L. similes)*; a rhizome-feeding noctuid moth (*Rhizedra lutosa)*; the gall midge (*Lasioptera hungarica)* and (*Platycephala planifron*s); the aphid (*Hyalopterus pruni)*; a mite (*Steneotarsonemus phragmitidis)*; a rice grain gall midge (*Giraudiella inclusa)*; a legless reed mealybug (*Chaetococcus phragmitis)*; a the wasp (*Tetremesa phragmitis)*; species of *Tetramesa*, *Trypticus,* and *Giraudiella*; and a *Phragmites* Mite.

Europe has 140 species of insects utilizing common reed, and 50% are common reed specialist while 40% are monophagous. Lepidoptera and Diptera are the most important orders on common reed specialists in Europe. Seventy percent attack leaves and stems while five attack rhizomes. In Europe, significant damage to reed beds has been reported from insect attacks (55, 72).

Insect use was reported as being affected by patch size, plant characteristics, and health. Species utilization is also determined by these characteristics, and some resource partitioning does occur. Flush and crash cycles, ending in local population extinction, wasn't considered important if proximity of common reed patches were close enough ("Minimum Dynamic Area") for reinvasion of insect populations to occur. The moth *Archanara geminpuncta* was considered a keystone species enabling other species, *Lasioptera arundinis* (a gall midge) and *Giraudiella inclus*a (a gall midge) to exist in damaged common reed plants. The moth damages apical dominate stems causing side shoot development, which are the plant parts utilized by the gall midge (56).

Four sympatric stem-boring noctuid moths have been investigated in Europe for consideration as biological control agents for common reed: *Archanara geminipuncta*, *Archanara dissolute*, *Archanara neurica,* and *Arenostola phragmitidis*. Larva of all species created premature tip death and lack of reproduction in attacked stems. Mowing, fire, and predation by parasites and birds all influence reproduction potential, survival, and population size (57).

Currently, a host specificity test is planned for four stem mining noctuid moth species. This is being overseen by Lisa Tewksbury, Plant Sciences Department, University of Rhode Island, Kingston, RI 02881. The project is being submitted to the Technical Advisory Group for Biological Control of Weeds in North America (TAG). The criteria of the proposed plant species to be tested are as follows:

1. Species in the same family as *Phragmites australis* (Poaceae). At present, the list contains at least one representative species of six subfamilies of the family Poaceae.

2. Species with similar morphology or chemistry.

3. Species in the same habitat.

4. Species that are hosts of close relatives of the control agents.

5. Species of ecological importance (rare, wildlife food).

6. Economically important species.

7. Other (58).

There is a good reference for biological control protocol, definitions, and current agents available used to control various plant species (79).

Mulch. Plastic mulch has been used on small isolated areas for control of common reed. High temperatures have caused mortality in three to four days in some cases. Clear plastic was used and in full sunlight had a complete kill in ten days while one in partial shade failed to attain a complete kill. Black plastic is considered to be more effective than other plastic due to higher heat retention (22, 24, 41, 70).

Case Studies

Most of the reported common reed control cases reviewed have been on relatively small acreages and of limited duration in commitment of years of continuous treatment (Personal observation).

Cutting methods are typically small in size (10 x10 feet up to ten acres) due to costs ($150,000 in 1991 for Quincy, Massachusetts, to cut ten acres three times in the summer), and equipment available (hand-held clippers and weed whackers to bobcat loaders with mowing equipment attached) (24).

Controlled burn treatments by themselves are typically small due to the extreme fire behavior common reed can exhibit (73). Acreages are reported from less than one acre (Wallops Island, Virginia) to 30 acres (Wertheim National Wildlife Refuge, New York) (24).

Chemical treatments are usually followed up with some sort of removal of the dead stems. This is either by cutting or burning in most cases. Acreages for annual chemical treatments are reported from less than one acre (in Connecticut a 5 meter x 23 meter patch) to 500 acres (Prime Hook Wildlife Refuge, Delaware) (24). Numerous refuges and states have initiated chemical control activities on common reed in the past: Bombay Hook Wildlife Refuge (20 to 60 acres); Chincoteague National Wildlife Refuge (an 18-mile freshwater impoundment, estimated treatment of 100 to150 acres); Tinicum Environmental Center (18-acre site); Parker National Wildlife Refuge (50 acres of a 100-acre freshwater impoundment); Cape May Meadows (20-acre area); and Constitution Marsh in New York (25 feet x 25 feet to waist height) with one drop of Roundup and hedge clippers to cut stem (24).

Numerous programs may be available for assistance in restoration activities and common reed control, such as the Partners for Fish and Wildlife Program in New Jersey (84). A workshop held in Wisconsin provides some other potential funding sites (86). Those exploring noxious weed control projects should investigate possible avenues for financial and technical assistance.

Bibliography for Common Reed Information Sources

#1 Microsatellite variation within and among North American lineages of *Phragmites australis*
K. Saltonstall
Molecular Ecology (2003) 12, 1689-1702

#2 Recognition of Phragmites *Australis SubSP. Americanus* (Poaceae: Arundinnoideae) in North America: Evidence from Morphological and Genetic Analysis
Kristin Saltonstall, Paul M. Peterson & Robert J. Soreng

#3 PCA Fact Sheet, Giant Reed Common Reed
Kristin Saltonstall
Plant Conservation Alliance's Alien Plant Working Group, May 20, 2005, pages 6

#4 A Rapid Method for Identifying the Origin of North American Phragmites Populations using RFLP Analysis
Kristin Saltonstall
Wetlands, Vol 23, No. 4, December 2003, pp. 1043-1047

#5 Common Reed/Giant Reed
Indiana document? 9-2005
Unknown Author, pages 2

#6 NRCS Plant Profile: *Phragmites australis* (Cav.) Trin ex. Steud, common reed
USDA Plants Database, undated
Unknown author, pages 4

#7 Hydrological factors controlling the spread of common reed (*Phragmites australis*) in the St. Lawrence River (Quebec, Canada)
Christiane Hudon, Pierre Gagnon & Martin Jean
Ecoscience 12 (3): 347-357 (2005)

#8 Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*,
into North America
Kristin Saltonstall
PNAS office, February 19, 2002 vol. 99, no. 4 2445-2449

#9 *Phragmites australis* (Cav.) Trin. Ex. Steud, Poaceae
John K. Francis
U.S. Department of Agriculture, Forest Service, undated, pages 3

#10 Invasive Species Fact Sheet: Common Reed
Ann F. Rhoads & Timothy A. Block
Morris Arboretum of the University of Pennsylvania, April 2002, pages 3

#11 Invasive Alien Plant Species of Virginia, Common Reed
Unknown author, undated
Virginia Native Plant Society, pages 1

#12 Adaptive Strategies of Common Reed *Phragmites australis*
M. Stephen Ailstock
Environmental Center, Anne Arundel Community College, pages 7

#13 *Phragmites australis*, (Cav.) Trin. Ex. Phragmites communis
Wisconsin? Publication
Unknown author, unknown date

#14 Decomposition of Phragmites australis Litter in Seasonally Flooded and Exposed Areas of a Managed Reedbed
Alan P. Bedford
Wetlands, Vol. 25, No. 3, September 2005, pp 713-720

#15 Breakdown and nutrient dynamics of submerged Phragmites shoots in the littoral zone of a temperate hardwater lake
Mark O. Gessner
Aquatic Botany 66 (2000) 9-20

#16 Maine Invasive Plants, Common Reed
University of Maine Cooperative Extension, Bulletin 2532
Virginia Howe Theisin, undated

#17 Sexual versus Asexual colonization by *Phragmites australis*: 25-year reed dynamics in a Mediterranean marsh, southern France
Maria G. Alvarez, Francois Tron & Andre Mauchamp
Wetlands Vol. 25, No. 3, September 2005, pp. 639-647

#18 Habitat Formed by Human Activity, Invasive Plant Habitats
Unknown author and date
Gulf of Maine Marine Habitat Primer, Chapter 11, pages 3

#19 Invasive Plant Fact Sheet, Common Reed, *Phragmites australis,* Grass Family (Gramineae Poaceae)
The Nature Conservancy, Connecticut,
Undated, pages 2

#20 Common Reed (*Phragmites*)
Unknown author
University of Maine Cooperative Extension, Bulletin #2532

#21 What Reed (Phragmites) Ecology Tells US about Reed Management
News from Hudsonia, Vol 20, No. 1, Spring 2005

#22 Control of Phragmites or Common Reed
Diana H. Cross & Karen Fleming
U.S. Fish and Wildlife Service Leaflet 13.4.12, 1989, (Waterfowl Management Handbook, 7 pages)

#23 Genetic diversity of fungi closely associated with common reed
Stefan G. R. Wirsel, Wolfgang Leibinger, Michael Ernst & Kurt Mendgen
New Phytologist (2001) 149: 589-598

#24 Elements Stewardship Abstract for *Phragmites australis*, Common Reed
Beth Lapin & John Randall
The Nature Conservancy, last citation 1993, 27 pages

#25 Effects of Road Salt and *Phragmites australis* Invasion on the Vegetation of Western Massachusetts Calcareous Lake-Basin Fen
Julie A. Richburg, William A. Patterson III & Frank Lowenstein
Wetlands, Vol. 21, No. 2, June 2001, pp. 247-255

#26 Effects of Salinity and Temperature on the Germination of *Phragmites australis*, *Juncus kraussii* and *Juncus acutus*: Implications for Estuarine Restoration Initiatives
Mary E. Greenwood & Geoff R. MacFarlane
Wetlands, Vol. 26, No. 3, September 2006, pp. 854-861

#27 Phragmites die-back: bud and root death, blockages within the aeration and vascular systems and the possible role of phytotoxins
J. Armstrong, W. Armstrong & W. H. Van Der Putten
New Phytol. (1996) 133, 399-414

#28 Environmental Constraints on Early Establishment of *Phragmites australis* in Salt Marshes
David Bart & Jean Marie Hartman
Wetlands, Vol. 22, No. 2, June 2002, pp. 201-213

#29 Zinc, Lead and Cadmium tolerance, Uptake and Accumulation by the Common Reed, *Phragmites australis* (Cav.) Trin. Ex Steudel
Z. H. Ye, A. J. M. Baker, M. H. Wong & A. J. Willis
Annals of Botany 80: 363-370, 1997

#30 Effects of winter harvest on water and sediment chemistry in a stand of reed (*Phragmites australis*)
Lars-Anders Hansson & Wilhelm Graneli
Hydrobiologia 112, 131-136 (1984)

#31 Effects of External Iron Concentration upon Seedling Growth and Uptake of Fe and Phosphate by the Common Reed, *Phragmites australis* (Cav.) Trin Ex. Steudel
L.C. Batty & P. L. Younger
Annals of Botany 92: 801-806, 2003

#32 Genetic Variation among North American Populations of *Phragmites australis*: Implications for Management
Kristin Saltonstall
Estuaries Vol. 26, No. 2B, p. 444-451, April 2003

#33 Killer Reed Lethal Weapon
Molly Murray, October 17, 2007
Delaware Online, Copyright © 2007, The News Journal.
Harsh Bais, a plant biologist at UD's Biotechnology Institute. "It's a horticultural disaster".

#34 Habitat Action Plan: Reedbeds
UK Biodiversity Action Plan, 2002
Roger Meade & Rebecca Longfield, *Lead Partners*

#35 Variation in the quality of the thatching reed Phragmites australis from wetland in Anglia, England
R. R. Boar, J. J. H. Kirby & D. J. Leeming
Geological Society of England, 1999

#36 Phragmites: A tale of two strains
Ann Faulds & Kristin Wakefield
Pennsylvania Sea Grant and Coastal Zone Management Program, undated, page 4

#37 Phragmites use by Native North Americans
Erik Kiviat & Elizabeth Hamilton
Aquatic Botany 69 (2001) 341-357

#38 Reed cutting affects arthropod communities, potentially reducing food for passerine birds
Martin H. Schmidt, Gaetan Lefebvre, Brigitte Poulin & Teja Tscharntke
Biological Conservation 121 (2005) 157-166

#39 Impact of Harvesting and Fire on *Phragmites australis* Reed Quality in Tembe Elephant Park, Maputaland
Rooyen, M. W. van, Matthews, W. S., Tosh, C. A., Rooyen, N. van, Kellerman, M. J. S.
Koedoe, 2004, (vol. 47) (No. 1) 31-40, CAB Abstract, Article also attached

#40 *Phragmites australis*:
Uchytil, Ronald J. 1992. Phragmites australis. In: Fire Effects Information System, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer)

#41 Summary of Common Questions Concerning Phragmites Control
M. Stephen Ailstock, Environmental Center Anne Arundel Community College Arnold MD,

#42 Common Reed-Exotic Aquatics on the Move
Common Reed (Phragmites australis)
Unknown author
www.iisgcp.org, undated, pages 6
www.iisgcp.org/EXOTICSP/commonreed.htm

#43 Techniques from TNC Stewards for the eradication of *Lythrum salicaria* (purple loosestrife) and *Phragmites australis* (common reed/Phrag) in wetlands
Edited by Mandy Tu
The Nature Conservancy 2001, Wildland Invasive Species Program, 13 pages

#44 Integrated Management of *Phragmites australis* at the Lower Cape May Meadows Cape May Point Environmental Restoration Project
Gian Dodici. Timothy Kubiak & Clifford G. Day
US Fish and Wildlife Services, Region 5, New Jersey Field Office

#45 Effects of prior common reed (*Phragmites australis*) cutting on herbicide efficacy
A. Monteiro, I Morerira & E. Sousa
Hydrobiologia 415: 305-308, 1999

#46 Efficacy of Wipe-on Application of Glyphosate and Imazapyr on Common Reed in Aquatic Sites
Stratford H. Kay
Journal of Aquatic Plant Management. 33: 25-26

#47 The Establishment, Expansion and Ecosystem effects of Phragmites australis, an Invasive Species in Coastal Louisiana
A Dissertation, Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Oceanography and Coastal Sciences by Lee Ellis Stanton, B.S., Livingston University, 1993, M.S., University of South Alabama, 1998, May 2005

#48 Identification and Control of Common Reed (*Phragmites australis*) in Virginia
Virginia Pitman Barnes
Virginia Cooperative Extension, publication 427-101, posted November 2003, pages 4

#49 Common Reed Phragmites australis: Control and Effects Upon Biodiversity in Freshwater Nontidal Wetlands
M. Stephen Ailstock, C. Michael Norman & Paul J. Bushmann
Restoration Ecology Vol. 9 No. 1, pp. 49-59

#50 Guidance: Single Page on Mowing/Cutting
Unknown author
Undated, unknown article title

#51 Advantages and Limitations of Different Control Options
http://www.dnr.cornell.edu/ext/wetlans/ponds/adv-limitaions.htm

52 The long-term effects of burning and utilization on Phragmites australis reed in the Muzi Swamp of the Tembe Elephant Park, South Africa
J. A. Tarr, M. W. Rooyen & J. du P. Bothma
Center of Wildlife Management, University of Pretoria, Pretoria, South Africa, 0002, pg 41-59

#53 Community Regulations in *Phragmites communis* Trin, II. Mixed Stands
S. M. Haslam
Botany School of Cambridge, February 1970, pg 75-88

#54 The influence of different grazing regimes on Phragmites and shrub vegetation in the well-drained zone of a eutrophic wetland
J. TheoVulink, Hans J. Drost & Luc Jans
Applied Vegetation Science, 3: 73-80, 2000

#55 Common Reed
B. Blossey, M. Schwarzlander, P. Hafliger, R. Casagrande & L Tewksbury
Biological Control Center of Invasive Plants in the Eastern United States, USDA Forest Service Publication FHTET-2002-04, 413p. (10 pages)

#56 Fragmentation of Phragmites Habitats, Minimum Viable Population Size, Habitat Suitability, and Local Extinction of Moths, Midges, Flies, Aphids and Birds.
Teja Tscharntke
Conservation Biology Volume 6, No. 4, December 1992, pg 530-536

#57 Comparison of Biology and Host Plant Use of *Archanara geminipuncta, Archanara dissolute, Archanara neurica, and Arenostola phragmitidis* (Lepidoptera: Noctuidae), Potential Biological Control Agents of *Phragmites australis* (Arundineae; Poaceae
Patrick Hafliger, Mark Schwarzlander & Bernd Blossey
Annals of the Entomological Society of America Vol 99 (4): 683-696 (2006)

#58 Proposed *Phragmites* Host Specificity Test Plant List
Bernd Blossey, Richard Casagrande, Patrick Häfliger & Lisa Tewksbury
To allow a timely submission to TAG we would appreciate receiving your comments by July 20th, 2007

#59 First-year response of Phragmites marsh community to seasonal burning
D. J. Thomas & Jennifer M. Shay
Canada Journal of Botany, volume 67, 1989, pgs 1448-1455

60 The effects of fire on *Phragmites australis* in the Delta Marsh, Manitoba
D. J. Thomas & Jennifer M. Shay
Canada Journal of Botany, volume 63, 1985, pgs 1864-1869

#61 Fire as a Tool for Controlling Nonnative Invasive Plants
Peter M. Rice, University of Montana, Missoula Mt.
Center for Invasive Plant Management Report, 52 pages

#62 A success story Phragmites control at Kampoosa Bog, Massachusetts
Tunyalee Martin
The Nature Conservancy, Wildland Invasive Species Program January 2001

#63 Morphological differences between native and introduced genotypes
Bernd Blossey
Ecology and Management of Invasive Plants Program, Cornell, 2002

#64 Native and Introduced Invasive Plant Morphological Differences
Bernd Blossey
Ecology and Management of Invasive Plants Program, Cornell, 2002

#65 Project Summary: Phragmites Survey: Phase 1.
Andrew Kulmatiski & Karen Mock
Utah Division of Forestry, Fire and State Lands, page 3

#66 What you can do
#66 Instruction/checklist
#66 Phragmites form

#67 Common Reed *Phragmites australis* Grass Family (Poaceae/Gramineae)
Department of Environmental Protection
Environmental and Geographic Information Center, Hartford, CT

#68 *Phragmites australis* (Cav.) Trin. Ex Steud Syn.: Phragmites communes Trin. James
Phragmites vulgaris B.S.P. Poaceae, Common Reed
A. Duke
Source: Handbook of Energy Corps, unpublished, 1983, 4 pages

#69 Phragmites: Controlling the all-to-common common reed
Ralph Tiner, Technical Note 1, April 1995
Wetlands Restoration & Banking Program Massachusetts Executive Office of Environmental Affairs

#70 Vegetation Management Guideline: (*Phragmites australis* (Cav.) Trin ex. Steud)
Illinois Nature Preserve, Vol. 1, No. 38, 8/02/2005
Kari M. Foster & Bob Edgin

#71 Problems and Control Methods
Bernd Blossey
Ecology and Management of Invasive Plants Program, Cornell, 2003

#72 Common Reed: Insects
Bernd Blossey
Ecology and Management of Invasive Plants Program, Cornell, 2003

#73 Prescribed Burning as a Management and Restoration Tool in Wetlands of the Upper Midwest
Morgan M. Robertson
Unknown date, web site

#74 Manchester Urban Pond Restoration
Manchester New Hampshire, unknown author
Unknown date, pages 2

#75 Hazardous Substance Fact Sheet
New Jersey Department of Health and Senior Services
CAS Number: 1071-83-6, DOT Number: UN2783
Date June 1999, pages 6

#76 Material Safety Data Sheet
Dow AgroSciences
Effective date: 3-23-04, pages 3

#77 Material Label, Glypro
Dow AgroSciences, pages 15

#78 Ground Water and Drinking Water Fact Sheet for Glyphosate
U.S. Environmental Protection Agency, February 2006

#79 Biological Control
Unknown publication
Unknown author

#80 Shropshire Biodiversity Action Plan
Reedbeds
Unknown author 2002?

#81 Cattail Control Methods in Utah
Nolan F. Nelson & Ruben H. Dietz
Federal Aid Project W-29-R, Publication No. 66-2, 1966
Utah State Department of Fish and Game

#82 Commercial uses of wild and traditionally managed plants in England and Scotland
Helen Sanderson & Hew D.V. Prendergast
Centre for Economic Botany Royal Botanic Gardens, Kew Richmond
February 2002

#83 Notes on *Phragmites australis* (Poaceae: Arundinoideae) in North America
Kristin Saltonstall Donald Hauber
J. Bot. Res. Inst. Texas 1(1): 385 – 388. 2007

#84 Partners for Fish and Wildlife Program, New Jersey Field Office
July 2001, pages 6

#85 Investigation and Long-term Monitoring of Phragmites australis at Lake Point, LakeErie, Ontario
Kerrie Wilcox & Scott Petrie
LPWWRF researchers, undated

#86 Phragmites Control and Management Workshop
October 19, 2006, Green Bay Wildlife Sanctuary
Lower Cape May Meadows-Cape May Point NJ, December 2006

Sources of Unpublished Material

Val Bachman, Personal Communication, Wetland Manager, Utah Division of Wildlife Resources, Ogden Bay Waterfowl Management Area, Utah

Bernd Blossey, Personal Communication, Associate Professor and Director Ecology and Management of Invasive Plants Program Department of Natural Resources, 202 Fernow Hall, Cornell University, Ithaca, New York 14853

Kristin Saltonstall, Personal Communications, University of Maryland Center for Environmental Science

Steve Dewey, Personal Communication, Utah State University, Extension Weed Specialist

Rich Hansen, Personal Communication, Wetland Manager, Utah Division of Wildlife Resources, Farmington Bay Waterfowl Management Area, Utah

Jeff McCreary, Personal Communication, Manager of Conservation Programs, San Francisco Bay & Delta, Ducks Unlimited, Inc.

Bridget Olson, Personal Communication, Wetland Biologist, Bear River Migratory Refuge, Utah

Part II: Hoary Cress
Lepidium draba L., previously Cardaria draba (L.) Desv. (L.)
Species-Specific Control and Containment Strategies

Hoary Cress Treatment Plan Objectives

Because hoary cress spreads rapidly and can reduce plant and wildlife diversity, the DWR's efforts to control and contain this plant on the WMAs have been ongoing. The agency does not expect to eradicate hoary cress totally due to on-site seed sources and off-site sources from adjacent private lands. However, even though established infestations will require repeated treatments for several years, effective timing and diligent monitoring should reduce control efforts. The objective is to reduce the population to two percent or less of the available compatable WMA's acreage.

Hoary Cress Treatment Plan

An extensive root system, varying phenological stages in development during the growing season, and copious seed production make hoary cress a difficult plant to control. Because hoary cress is somewhat toxic to cattle, and sheep only graze the plant early in the growing stage, the agency cannot use livestock grazing extensively as a control method. Likewise, mechanical control methods are labor intensive and time consuming, and tilling is difficult because many infestations are small, isolated patches spread throughout thousands of acres. Therefore, the agency will use herbicide treatment to initiate hoary cress control and containment efforts.

Strategy AA: Herbicide treatment

For Strategy AA, the DWR will apply herbicide to established infestations of hoary cress. After experimenting in selected sites with different products to determine effectiveness, the agency will monitor and re-treat the sites during the growing season. Single treatments on rosettes and flowering plants are inadequate, and the agency will re-treat late developing plants during the summer. Fall treatments will focus primarily on the rosette stage of plants.

The agency will investigate the following herbicides and add other products to this list as information becomes available: glyphosate; 2,4-D amine or ester; Tordon; chlorsulfuron; metsulfuron; Vanquish; Ally; Escort; Cimarron; Banvel; MCPA; sulfometuron methyl; Milestone; imazethapyr; Weedmaster; imazapic; and imazamox.

NOTE: Because choosing an herbicide depends on a treatment site's intended use, the DWR recommends consulting with Utah State University Extension personnel or a chemical company representative before applying any herbicide. The agency also recommends following all product safety instructions.

Strategy BB: Integrated management with herbicide, tilling, and livestock grazing

Strategy BB applies to sites where hoary cress infestations are in crop-production areas or lands identified for mechanical renovation. If repeated frequently for two or more

years, tilling successfully controls hoary cress by deeply burying the available seed for germination and by removing new seedlings before seed set occurs. The DWR will use tilling in fallow areas waiting for mechanical renovation because other plant species, such as annual grasses, may warrant the same control method.

To improve treatment effectiveness on new shoots and damaged plants, the agency will combine tilling and herbicide application. Also, to reduce the amount of tilling required during the growing season, the agency will use sheep grazing in the early spring followed by herbicide application and tilling (possibly twice) then, in the fall, apply herbicide to the sites again.

Strategy CC: Biological control with insects

If possible, Strategy CC will use an insect or host of insects as biological control agents to treat hoary cress infestations. In Idaho, researchers are carrying out trials with insects to control hoary cress.

Assessment and Monitoring

Early spring, summer, and fall monitoring are, and will continue to be, part of the DWR's management practices. The agency will collect GIS points for hoary cress infestation sites and will use ARCGIS software to map these sites. The agency will also use ocular methods to estimate the size of infestations then record this information, along with notations about herbicides, application rates, and application dates. After annually revisiting treatment sites, the agency will report observed results and file documents in WMA weed control files.

Literature Review of Hoary Cress Information Sources

Weed Species: Hoary Cress *Lepidium draba* L. previously *Cardaria draba* (L.) Desv.; The genus name derives from the Greek word *kardia* (heart) and refers to the heart-shaped fruit of *C. draba*.

Taxonomy (202, 203, 207, 211, 218)

Family: *Brassicaceae*
Genus: *Lepidium* previously *Cardaria*
Species: *Lepidium draba* previously *Cardaria draba*
Similar Species: *Lepidium appelianum* previously *Cardaria pubescens* (C.A. Meyer) (globe-podded hoary cress) Jarmolenko. *Cardaria chalepensis* (lens-podded hoary cress) is no longer an independent species but a subspecies of heart-podded hoary cress *Lepidium draba*. Please refer to the CABI Bioscience annual report.
Common Names: (*Cardaria draba*) heart-podded hoary cress, (*C. pubescens*) globe-podded whitetop, (*C. chalepensis*) lens-podded hoary cress, or hoary cress, white weed, white-top hoary cress, white-top, perennial peppergrass, chalk weed, devil's cabbage, hoary pepperwort, pepper cress, Thanet cress, Thanet weed, whitlow peppermint

Hoary cress, *Cardaria*, actually consisted of three European and Asian species: *C. chalepensis* (L.) Hand.-Maz., *C. pubescens* (C.A. Mey.) Jarmolenko, and *C. draba* L.

Distribution
Hoary Cress is thought to have originated from the Mediterranean to central Asia (204).

Hoary Cress is found on every continent but Antarctica (208). It is reported in the following countries as native: southern Europe, the former USSR, Afghanistan, southwestern Asia, the Balkan Peninsula, Armenia, Turkey, Israel, Syria, Iraq, and Iran (201, 203, 208). Hoary Cress has been introduced to southern Africa, Saudi Arabia, Australia, New Zealand, western North America, Austria, Hungary, Italy, Greece, Jordan, former Yugoslavia, Canada, England, Germany, Lebanon, Portugal, South Africa, Tunisia, Argentina, Belgium, Chile, Czechoslovakia, Guatemala, Israel, the Netherlands, New Zealand, former Rhodesia, Tasmania, and Finland (201, 202, 203, 204).

History in North America
It is thought hoary cress arrived in the United States in the ballast of ships or in contaminated alfalfa seed, possibly from Turkestan in the early 1900s (202, 208). Alfalfa production increased in the 1900s, leading to importation of six million pounds in 1913 from areas in Europe and central Asia. Surveys of imported clover and alfalfa seed lots in 1906 contained *Lepidium* species. Surveys of seed lots imported from Spain and Turkestan in 1928 found 90% and 40%, respectively, contained *Lepidium draba* (211). In the United States, hoary cress was first reported collected in Yreka, California, in 1876 (201, 202). It was found in Napa, California, in 1893 and New York City in 1898. It was identified in Ontario, Canada, in 1878. (202).

Hoary cress is considered a noxious weed in most of the United States. Colorado considers it one of the top ten worst for that state. It is considered a serious pest in Australia, New Zealand, and the Pacific Northwest (201, 209).

Description

Hoary cress is a hardy perennial herb (201).

Hoary Cress in June Blossom
Photo by Randy Berger

The plant has a taproot that penetrates deeply, four to five meters (13 to 16 feet), and lateral roots spread horizontally (four or more meters, also reported 12 to 30 feet) under the soil surface to initiate new above-ground shoots and below-ground growth, vertical roots. Rhizomes and shoots develop from adventitious buds on vertical and lateral roots. Shoots development tends to be near the point where lateral roots bend downward to form vertical roots. Buds can form anywhere on the root system, and single plants, without competitions, have produced over 450 shoots in a single year. Typically, plants produce less than 50 shoots per square yard. Root development is rapid: in six months, one-meter deep and two-meter horizontal spread. This vegetative reproduction makes control difficult (203, 207).

Stems are described as stout, procumbent, erect, and decumbent, 15 to 90 centimeters (six to 35 inches), sometimes pubescent and hairy on the bottom and glabrous at the top. Stems are grayish, leafy below and branching above (201, 202, 203).

Leaves are 1.5 to 10 centimeters (½ to 4 inches) long, and basal leaves are obovate to oblong, tapered to a short petiole. Middle and upper leaves are sessile, often clasping and elliptic to oblong or lanceolate. The leaf bases may have two sagittate lobes. Margins of all leaves are irregular and may be smooth (entire) to remotely toothed. They appear blue-green to gray-green in color and weakly to densely hairy, hence the name “hoary”. Leaves may wither before flowering and be shed prior to seeds maturing (201, 202).

Inflorescences are a corymbose panicle or flattened corymbs of racemes. Flowers are showy white with petals 2.5 to 4 millimeters long (3/32 to 5/32 inch) with long narrow bases like a spoon. The sepals are 1.5 to 2.5 millimeters (1/16-3/32 inch) long and green. The flowers contain six stamens and one pistil, like other plants in the mustard family. Flower pedicles diverge slightly from the stems. Hoary cress can self-pollinate and can produce up to 850 fruits per flowering stem (201,202).

The fruit of hoary cress varies by species. Pod shapes are described as heart-podded, lens-podded, and globe-podded. The fruit is 2 to 4.5 millimeters long (3/32 to 3/16 inch), 3 to 5 millimeteres wide (1/8 to 3/16 inch), and contains two chambers. The fruit pedicels are 6 to 15 millimeters long (1/4 to 19/32 inch) and are ascending to spreading. The fruit is hairless and can have a distinct beak on the upper end. Each fruit will

contain approximately two seeds. The seed is 2 to3 millimeters long (3/32 to1/8 inch) and 1 to 1.5 mm wide (1/32 to 1/16 inch) and are shaped oval to round on one end and narrow to blunt on the other. They are dark reddish-brown (201, 202, 206).

Seed viability is less than three years. Studies have reported a one-year-old seed at 84% germination, two-year-old seed at 31% germination, and the three-year rate of germination at 0%. Flooding seed for one month had germination rates of 12% and less than 2% after six months (207).

The distinguishing feature of seedlings is the hypocotyls (the portion of the embryonic plant axis below the cotyledons), which is dull brown-green but green above. The leaves are 2.5 millimeters wide (3/32 inch), 7 to 9 millimeters long (5/16 inch), and have a sharp pepper taste. The young plant leaves are opposite below and alternate above and obscure the stem (202).

Haplotypes. A study of 684 individual plants from Eurasia and the United States found 41 different haplotype of hoary cress. Twenty were from the 341 samples taken in the United States, and 31 were from the 343 Eurasian plant samples. Clonal and multiple haplotype plants can be found within small populations. It is suggested that multiple haplotype specimens were involved with the introduction to the United States and genetic variation may warrant consideration in selecting treatments, primarily biological agents (211).

Habitat and Environmental Conditions

Hoary cress prefers irrigated or frequently wet sites or high-ground water areas. It will grow in disturbed sites and also encroach into pastures (sub-irrigated) and croplands. Hoary cress grows in a variety of areas, including along roadways, ditches and watercourses, cultivated and fallow fields, pastures, and waste places. Hoary cress can be found in alkaline (wet during spring, 12- to 16-inch precipitation zone) and irrigated saline soils, heavy clay (>50%) and light, sandy, or gravelly loams. It does prefer non-acidic soils (201, 202, 203).

In Colorado, it is found at elevations from 3500 to 8500 feet (209).

Reproduction and Adaptive Strategies

Hoary cress is self-compatible and largely autogamous. A single plant can produce 1,200 to 4,800 seeds. If conditions are favorable, a second crop of seed can be produced annually. Seeds can germinate in salt stressed environments. Seeds can germinate in fall or delay germination until spring (201, 202, 203, 109).

Hoary cress has an extensive root system that has a short period of maximum allocation to below-ground tissue. Lateral roots can develop in three weeks. A 25-day-old plant can develop a taproot 25 centimeters deep (9 inches) and five to six horizontal roots with vegetative buds. At 100 days in an area within 30 centimeters (11 ¾ inches), there can be up to 48 shoots and 80 root buds. Buds can form anywhere on the root system and a single plant; typically, plants produce less than 50 shoots per square yard. Hoary cress is capable of vegetative reproduction. Intact root segments can re-sprout

and thrive in irrigated and disturbed sites. Root segments 1.3 centimeters long (1/16 inch) can regenerate into new plants within 7 to 10 centimeters (2 3/4- 4 inches) of soil (201, 202, 203).

Plants are in a wide variation of phenology during the growing season (201).

Hoary cress has been reported to exhibit some degree of allelophathy, which reduces competition (204, 209).

Limitations
Hoary cress establishment and spread can be reduced by competition from healthy growing perennials, such as alfalfa, in crop-pasture rotations, and in non-irrigated sites. Reseeding areas grazed by sheep may be effective at increasing competition and reducing hoary cress infestations (202, 203, 209).

Nitrogen fertilizers can enhance growth of grasses and slow invasion or re-invasion of a site (203, 209).

Uses and Values
Hoary cress is palatable to sheep in early growth stages. Foliage becomes bitter and coarse as it matures. Nutritional levels are adequate to meet most grazing classes. However, hoary cress contains glucosinolates and is potentially toxic. Cattle have been reported to eat seed heads. Cattle forced to eat hoary cress can have tainted meat and milk (204, 208, 209, 212).

Seed of hoary cress has been used as a pepper substitute (209).

Risk and Impacts
Hoary cress reduces crop production, livestock, and wildlife forage and is reportedly toxic to cattle. It reduces native biodiversity of plants and animals. It reduces available soil moisture and nutrients. It can devaluate land prices and increase operating costs or weed control costs (202, 203, 208, 212).

Hoary cress can harbor pathogens, viruses, and insects, which can spread to crops (204).

Invasion and Expansion
Diligence in monitoring to identify establishment of plants and rapid response with effective control methods is the best strategy for reducing invasion and expansion of hoary cress (203).

Disturbance is a primary factor for the introduction of hoary cress into new environments. Seed dispersal is the means of colonization, or, in some cases, plant parts can establish colonies. Care should be taken to clean all equipment that comes into contact with plant parts and seed of hoary cress (202, 203, 204, 208).

Livestock should not be allowed to graze or enter infested areas during the flowering and seed development period. If livestock are found in infested areas, they should be contained in a holding area for at least 10 to 14 days after removal from the site to allow for excretion of the ingested material (202, 203, 204, 208).

Control Methods
Hoary cress is difficult to control and will take repeated treatments and possibly multiple methods to be successful. Herbicide application, grazing, disking, and pulling are methods mentioned in the literature. Biological control with insects is being tested and may someday be a method for use in the United States.

Chemical Control. Herbicide mentioned in the literature for use to control hoary cress and rates and time of application follow (201, 202, 203, 208, 209, 210, 212, 213, 214, 215, 216, 217):

- *Glyphosate* (1.5 lb/acre; or 2-3 lbs ae/acre; apply during flowering stage)

- *2,4-D amine or ester* (Esteron 99, Weedone 638, 1-2 lb ai/acre; or 2.3-3.4kg acid equivalent/ha; or 800g/L 2,4-D butyl ester product at the rate of 700ml/ha in crops and 1.4 – 2.8L/ha in pastures; apply spring and fall; ester formulation should only be sprayed preferably below 70 degree Fahrenheit to reduce vaporization; water table close to surface and areas adjacent to water or marshy areas, apply 2# of 2,4-D spring and fall and repeated for 3 years) NUFARM

- *Corsair + 2,4-D amine* (Corsair @ 1 gram + 2,4-D amine @ 1.5 tablespoons /1000 sq ft. in the spring at the bloom stage or in the fall for turf grass) UNKNOWN

- *Dicamba* (Diablo, a combination of 2,4-D and dicamba) NUFARM

- *Tordon* (1 pint product per acre, a good penetrating MSO or silicone surfactant is essential, apply at the “popcorn” stage) DOW ARGOSCIENCE

- *Picloram* (Tordon) + 2,4-D amine (Spot spray with a 75 g/L Picloram + 300 g/L 2,4-D amine product at 1.3L to100L water)

- *Chlorsulfuron* (Telar, 0.5-1 oz per acre; or 26-53gm ai/ha; apply pre-bloom to bloom growth stage, or to rosettes in the fall; in root zone of desirable trees apply Telar @ 1oz/acre on non-cropland) DUPONT

- *Metasulfuron* (Escort, 0.5 to 1 oz/acre; or 21-42gm ai/ha; at least 10 gallons of water per acre and to use a nonionic surfactant at a rate of 2 quarts per 100 gallons of solution or with an 80% ai surfactant; apply pre-bloom to bloom growth stage, or to rosettes in the fall; in root zone of desirable trees apply Escort @1oz/acre) DUPONT

- *Escort* + *Vanquish* (Escort @ 1oz/acre + Vanquish in the spring at 2pts/acre in non-sensitive rangeland)

- *Escort @ 1oz/acre* + *Vanquish* in the spring at 2pts/acre.

- *Ally* **(**35gm/ha; or 1⁄10 ounce of product per acre) DUPONT

- *Ally* + *Banvel* (1/10oz of Ally (ag label for Escort) + 1/4 pt of Banvel for in small grains)

- *Amber* (in root zone of desirable trees apply 0.56 oz/acre; 0.47 oz/acre in small grains)

- *MCPA* (Rhonox, 2-methyl, 4-chlorophenoxyactic acid, 2.2 or 4.5kg/ha) NUFARM

- *Sulfometuron Methyl* (Oust, 0.16-0.27kg ai/ha or 0.21-0.35kg/ha, apply at early growth stages) DUPONT

- *Milestone* (5 oz or 1 gallon 2,4-D plus 3 quarts surfactant/acre, Milestone provides some residual for 1-2 years) DOW ARGROSCIENCE

- *Imazethapyr* (Pursuit, in alfalfa-grass pastures can provide greater than 90% hoary cress control the year of application, but no control the following year) BASF

- *Imazethapyr* (Pursuit + MSO + Nitrogen, 6 fl oz + 1 qt MSO/acre, apply rosettes spring and fall in crop, alfalfa)

- *Weedmaster* (1 quart/acre, a good penetrating MSO or silicone surfactant is essential, apply at the “popcorn” stage) BASF a good penetrating MSO or silicone surfactant is essential, apply at the “popcorn” stage

- *Imazapic* (Plateau, 2-10 oz/acre or 8-12 fl oz with MSO 1 qt/acre, apply during full bloom; Plateau® has the potential to control hoary cress when applied at peak flowering or early post-flowering when soil moisture is adequate for continued growth of the plants and in fall for rosette control; should be applied when there is a good likelihood of precipitation to carry it into the soil or degradation may occur) BASF

- *Imazamox* (Raptor + MSO + Nitrogen, 6 fl oz + MSO 1 qt/acre, apply rosettes spring and fall in crops, alfalfa) BASF

Caution: Chlorsulfuron and metsulfuron persist in alkaline soils (high pH) for several years, and a good penetrating MSO or silicone surfactant is essential; apply at the “popcorn” stage, and follow all chemical herbicide labels.

Dr. Dewey reports that in his experience the most effective herbicides for hoary cress control by far are chlorsulfuron (Telar) and metsulfuron (Ally, Escort, Cimarron). Glyphosate applied at the late bud to early blossom stage can be fairly effective too. Products containing 2,4-D generally give only mediocre control. Tordon, Vanquish, and Banvel are usually no better than 2,4-D alone when it comes to members of the mustard family (Personal communiqué, Steve Dewey).

Herbicide should be applied when roots are accumulating sugars, from late April to early May through late-June to early July, according to a Colorado study (202). Some reports indicate herbicide after mowing enhances effect (201).

Organic Herbicide. Two organic herbicides are mentioned for use on hoary cress. AllDown (manufactured by KPT, LLC dba, Summerset Products) is a mixture of vinegar, garlic, and other organic ingredients. Burnout II (manufactured by St. Gabriel Laboratories) contains acetic acid and other organic ingredients and, as the name implies, may only affect the above-ground plant material, and re-growth is likely. Both products are considered non-selective (215).

Mechanical. Mechanical (tillage) treatments are typically labor intensive and require repeated operation. The other consequence of tillage is the non-selectivity of the process; all plant material is subject to the treatment (Personal observation). Repeated cultivation can provide some control of hoary cress. A recommendation was for deep plowing followed by tilling to a depth of 10 to 13 centimeters (4-5 inches) every five days for the first six to eight weeks and then less frequently until October, which would result in the plants being killed after two years of this treatment. Hoeing is only recommended on small infestations. Cultivation that is not repeated can actually spread plants and increase the infestation. Plant roots are reported to survive one year without top growth present. It is suggested cultivation that removes above-ground portions be performed every three to four weeks or within ten days of reemergence for two to four years to kill hoary cress. A single tillage treatment prior to seed development can reduce seed production and reduce plant vigor; however, this will not eliminate hoary cress from the area (202, 208).

Cutting has been suggested as a control method if combined with an herbicide application of 2,4-D shortly after cutting is accomplished. Cutting followed by grazing was also recommended as a control method (202). Regular and frequent cutting that can reduce food reserves may provide some control. Repeatedly cutting during the flowering stage may reduce plant vigor (207).

Mulching is not considered a good control method. It has been stated hoary cress can survive mulching with straw or paper (207).

Water Level. In many cases, prolonged flooding isn’t an option where hoary cress is established. Flooding can be used as a control method if that potential exists. It is useful in heavy texture soils that can hold water and where fertility loss following prolonged submersion and drainage is minimal. Submersion is required from May to September to be successful (203).

Flooding seed for one month had germination rates of 12% and less than 2% after six months (207).

Grazing. Grazing can reduce above-ground plant parts and may induce some stress to hoary cress but will not effectively control it. Grazing by sheep in early growth stages can remove plant material. Cattle do not prefer hoary cress and may avoid it. Hoary cress contains glucosinolates and is potentially toxic. Cattle have been reported to eat seed heads. Cattle forced to eat hoary cress can have tainted meat and milk. Caution should be used when animals are grazed on hoary cress. Supplemental iodine should be provided, and mature, non-lactating animals should be chosen for grazing areas containing hoary cress (202, 207, 208).

Managers should use caution when allowing animals to graze infested range and pasture by providing supplemental iodine and utilizing mature, non-lactating animals since hoary cress is considered at least mildly toxic to livestock (McInnis et al. 1993). Livestock may also act as vectors for seed and increase weed spread.

Insects. Biological control in the mustard family, Brassicaceae, may prove to be difficult. There are a number of closely related important crops, and some Brassicaceae species are considered threatened and endangered (218).

Biological controls are not yet approved for the control of hoary cress in the United States. The literature identifies the following insects found on hoary cress in central Europe:

- Homoptera: *Brevicoryne brassicae* L. and *Myzodes persicae* Sulz.
- Lepidoptera*: Pieris brassicae* L., and *P. napi* L.
- Coleoptera: *Ceutorrhynchus turbatus* Schul. (larvae on silicles*), Phyllotreta namorum* L. (larvae on leaves), *Meligethes* spp., and *Nacerdes* sp.
- Diptera: *Phytomyza horticola* Gour., *Scaptomyza flaveola* Meig. (both larvae on leaves), and Hymenoptera: *Halictus* spp. (202).

Fungal and parasites and diseases from central Europe found on hoary cress are reported as *Cercospora bizzozeriana* Sacc & Berl. *Albugo* sp. (Chev.) Kunth, and *Peronospora lepidii-sativi* Gaum. (202).

Field surveys conducted by CABI Bioscience Switzerland Centre in Europe in 2002 found 80 insects, one mite, and two fungal pathogens on hoary cress. In 2002, CABI Bioscience started the process for conducting host specificity tests to determine the suitability of the biocontrol agents for release. Two flea beetles (*Psylliodes wrazei* and *Psylliodes* sp.); four weevils (*Ceutorhynchus turbatus*, *Ceutorhynchus cardariae*, *Ceutorhynchus merkli,* and *Baris semistriata*); and two gall midge species (*Contarinia cardariae* and *Dasyneura cardariae*) were selected for the specificity tests. One native

weevil (*Ceutorhynchus americanus*) was found in the western United States feeding on hoary cress. This weevil is being studied as potentially a native biocontrol agent (218).

Eriophyid mites were suggested as a possible biocontrol because of strong host specificity to hoary cress (201).

Monitoring. Monitoring must be a part of any treatment plan, and follow-up spot treatment can be anticipated for many years until no new plants emerge or seeds germinate (212).

Bibliography for Hoary Cress Information Sources

#201 Cardaria draba (L.) Desv. (Brassicaceae) Hoary Cress
Compiled by D.Wilken and L.Hannah
Santa Barbara Botanic Garden, for Channel Islands National Park. 12-15-98.

#202 Element Stewardship Abstract *Cardaria draba* (L.) Desv., Heart-podded hoary cress; *Cardaria chalepensis* (L.) Hand-Maz., Lens-podded hoary cress; *Cardaria pubescens* (C.A. Meyer) Jarmolenko, Globe-podded hoary cress
The Nature Conservancy

#203 Hoary Cress (Whitetop)
by Roger L. Sheley and Jack Stivers,
revised by Kim Goodwin
Montana State University.

#204 Hoary Cress (Whitetop) Cardaria draba
Coconino NF/ SFPWMA Created on 3/12/2001 10:28 AM
Last printed 8/12/2003 3:43 PM

#205 Farmnote 40/00: Hoary cress (Cardaria draba)
This file: F04000.HTM Date converted: 22 August 2000
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#206 Hoary cress & Hairy whitetop Cardaria draba (L) Desv & Cardaria pubescens (C.A. Mey.) Mustard Family
Stevens County Noxious Weed Control Board, January 2004

#207 The biology and non-chemical control of Hoary Cress (*Cardaria draba* (L.) Desv.)
W Bond, G Davies & R Turner
HDRA, Ryton Organic Gardens, Coventry, CV8, 3LG, UK
http://www.gardenorganic.org.uk/organicweeds
November 2006 1

#208 Hoary Cress Management (*Cardaria* sp.)
Celestine A. Duncan[1] and Mark J. Renz
New Mexico State University

#209 Hoary cress Cardaria draba (L.) Desv.
Dirk V. Baker, Tara L. Steinke & Sandra K. McDonald
Colorado State University Extension 1/03

#210 Weed Control Notes, Hoary Cress
Government Animal and plant control Commission of South Australia

#211 Invasion of *Lepidium draba* (Brassicaceae) in the western United States: distributions and origins of chloroplast DNA haplotypes
John F. Gaskin, Dao-Yuan Zhang & Marie-Claude Bon
Molecular Ecology (2005), 14, 2331–2341

#212 Managing Hoary Cress
Tina Kadrmas & Wayne S Johnson;
University of Nevada, Reno
Extension Fact Sheet-02-56

#213 Hoary Cress Whitetop: Options for Control
Lincoln County Noxious Weed Control Board

#214 Hoary Cress *Cardaria draba (L.) Desv*.
A Guide to Weeds in British Columbia

#215 Organic Noxious Weed Management Hoary Cress, *Cardaria draba (L.) Family Brassicaceae*
Sarah Doyle, Micaela Morgan, and Sandra K. McDonald
May 2005

#216 Integrated Weed Management of Hairy Cress (Whitetop)
Jonathan Rife
Douglas Co. Weed Division, Castle Rock, CO 80109

#217 Paradise Valley Weed Control Demonstration Plots: Hoary Cress
Brad Schultz
University of Nevada, Extension Special Publication 05-20

#218 Biocontrol pre-release studies on hoary cress in Idaho, adjacent states, and central Europe
Mark Schwarzlaender **,** Jessica McKenney & Michael Cripps
Progress Report 2002
Department of Plant, Soil, and Entomological Sciences, University Of Idaho, Moscow, ID 83844-2339

Sources of Unpublished Material

Steve Dewey, Personal Communication, Utah State University, Extension Weed Specialist

Part III: Poison Hemlock and Western Water Hemlock
Conium maculatum L. and Cicuta douglasii
Species-Specific Control and Containment Strategies

Hemlock Treatment Plan Objectives

The plant's toxicity and potential for poisoning animals make hemlock a concern on the WMAs. Although not widespread, hemlock is scattered throughout the WMAs in elevated, moist topography and on dikes, roadsides, wet soils, and water delivery ditches and channels. The DWR will inventory then treat hemlock in these areas. The agency's objective is to totally eradicate the plant.

Hemlock Treatment Plan

To eradicate hemlock on the WMAs, the agency will use these treatment methods.

Strategy AA: Herbicide treatment

Strategy AA, herbicide treatment, is the DWR's eradication method of choice. The agency will apply herbicide to treatment sites in the spring or summer. These herbicides include Escort; Telar; 2,4-D; or glyphosate.

NOTE: Because choosing an herbicide depends on a treatment site's intended use, the DWR recommends consulting with Utah State University Extension personnel or a chemical company representative before applying any herbicide. The agency also recommends following all product safety instructions.

Strategy BB: Digging

Strategy BB is only for single plant incidents. When the DWR first observes hemlock, digging will provide a more practical eradication method than applying herbicide. To reduce contact with bare skin, the agency will wear protective clothing, including gloves, dispose of plant material, and bury exposed root material. The agency will revisit treatment sites to ensure that hemlock has not re-sprouted.

Assessment and Monitoring

Early spring and summer monitoring are, and will continue to be, part of the DWR's management practices. The agency will collect GIS points for hemlock infestation sites and will use ARCGIS software to map these sites. The agency will also use ocular methods to estimate the size of infestations then record this information, along with notations about herbicides, application rates, and application dates. After annually revisiting treatment sites, the agency will report observed results and file documents in WMA weed control files.

Literature Review of Hemlock Information Sources

Weed Species: Poison Hemlock, *Conium maculatum* L., and Western Water Hemlock, *Cicuta spp.*; Greek Name, *Konas*, means to whirl about because the consumption of the plant causes ataxia, tremor, and convulsions. The specific name, *maculatum*, is a Latin word meaning "spotted" and refers to the very characteristic brownish-reddish spots of stem.

Taxonomy: (301, 302, 309)

Family: *Apiaceae* (parsley family) formerly Umbelliferae (carrot family)
Tribe: *Oenantheae Dumort.*
Genera: *Cicuta, Conium*
Species: *Cicuta maculate* L. (common water hemlock, spotted water-hemlock, or spotted cowbane)
Varieties: var. *angusifolia* Hook and var. *bolanderi* (S. Watson) G. A. Mulligan; var. *maculata*, and var. *victorinii* (Fernald B. Boivin); *Cicuta bulbifera* (bulbiferous or bulbet-bearing waterhemlock); *Cicuta virosa* L. (northern water hemlock); *Cicuta douglasii* L. (western water hemlock); and *Conium maculatum* L (Poison hemlock)
Common Names:

Water hemlock: beaver poison, cowbane, five-finger root, wild carrot, wild parsnip, false parsley, common water hemlock, spotted water hemlock, spotted cowbane, bulbiferous, bulbet-bearing waterhemlock, northern water hemlock, and western water hemlock
Poison hemlock: hemlock and poisonous hemlock

Distribution

Poison hemlock (*Conium maculatum*) is reported distributed in Europe, North and South America, Australia, New Zealand, Ethiopia, Pakistan, Norway, and Hungary (309).

Western water hemlock *(Cicuta douglasii*) is found primarily in the western United States while common spotted water hemlock *(Cicuta maculate)* is found primarily in eastern North America (302).

Common spotted water hemlock or spotted water-hemlock, or spotted cowbane *(Cicuta maculate* var. *bolanderi* and var. *angusifolia)* are western North American taxa, and *Cicuta maculate* var. *maculata* and var. *victorinii* are eastern North American taxa (301).

Bulbiferous or bulbet-bearing water hemlock (*Cicuta bulbifera*) is found in Canada and the United States from Alaska to Newfoundland in the north and Oregon to Florida in the south (301).

Northern water hemlock (*Cicuta virosa*) has a range from Alaska reaching south to British Columbia, across the northern Prairies and into northern Ontario and Quebec (301).

Common spotted water hemlock, or spotted water-hemlock, or spotted cowbane, *Cicuta maculate* has a range from Alaska to southern Mexico and from the Pacific to Atlantic Oceans (301).

Western water-hemlock, *Cicuta douglasii*, extends from Alaska south to central California and east to British Columbia, western Montana, Idaho and western Nevada (301). This plant is native to the intermountain region (303).

History in North America
Poison hemlock (*Conium maculatum* L.) was brought to the United States from Europe as a garden plant. In other European countries, it may have been transported in contaminated grains (302, 303, 309).

The genus *Cicuta* L., water hemlock, is considered a native plant and considered one of the most poisonous plants in the north temperate zone of North America (303).

Poison hemlock juice and extract was allegedly administered to criminals and was the lethal poison the Greek philosopher Socrates was forced to drink in 399 BC (309).

Description
Water hemlock is a perennial native plant with thick, tuberous rootstalk that contains numerous small chambers. These chambers hold a brown- or straw-colored liquid that is highly poisonous. The root system is made up of thick fleshy tubers and slender individual roots. An enlarged horizontally divided root is easily recognized. Water hemlock has erect stems three to seven feet tall and usually enlarged at the base. The leaves are alternate, pinnate with toothed margins. The leaf veins terminate at the bottom of the leaf serrations and not at the tips (distinguishing characteristic). The flowers are white in umbrella-shaped clusters and are two seeded. The seeds are tea-colored and somewhat kidney-shaped with corky ridges. The plant root is the most toxic part in the spring and less toxic later in the growing season, but the leaves and stem contain enough poison to be toxic (301, 302, 303).


Western Water Hemlock
Photo by Randy Berger

Poison hemlock is a biennial exotic plant introduced from Europe. The rootstock is a long, forked, white to pale yellow fleshy taproot that smells similar to carrots or parsnips and has been described as having a “mousy” smell. The stem can grow from six to eight feet in height (1.8 to 2.4 meters); is smooth, slightly ridged, and stout below and much branched and hollow above; is bright green; and has purple spots. Leaves are numerous, long stalked, alternate and tripinnate (divided along the midrib into opposite pairs of leaflets and these divide again divided and subdivided). Fern-like leafs are single leafs with leaflets growing from opposite sides on the stalk. Upper leaves are much smaller, dipinnate or pinnate, and quite smooth. The umbels are numerous, with

12 to16 rays to the umbel, small and terminal. Small white flowers have stamens longer than petals with white anthers. They are stalkless and have five petals. Inconspicuous bracts are green in the center and whitish on the edges and ¼ inch long (0.6 centimeters). The umbel cluster is supported by a stalk. The fruit is double achene, ovoid in shape, and contains two grayish-brown seeds (1/8 inch long or 0.3 centimeters) with five wavy, longitudinal ridges. A single plant may produce 35,000 to 40,000 seeds. Seeds fall near the parent plant and may be transported by water and animals. Basal rosettes are produced the first year and then flower stems the second year. First-year plants have fern-like leaves, which can confuse unsuspecting gatherers looking for edible wild plants (303, 308, 309).

Poison Hemlock
Photo by Randy Berger

Young hemlock plants can sometimes confuse gathers of edible wild plants and cause human poisonings (302).

Habitat and Environmental Conditions
Hemlock (poison and water) grows in wet habitats such as marshes, along rivers and ditches, and along roadsides, fence lines, waste areas, and the edge of cultivated fields. It can survive in dry sites with poorly drained soils but is less competitive. Poison hemlock is found at lower elevations. Water hemlock has a high water requirement and is more closely associated to wet environments. It occurs in fertile deep loam, clay loam, and clay soils (301, 303, 308).

Reproduction and Adaptive Strategies
Poison hemlock is an extremely poisonous plant. All plant parts contain piperidine alkaloid compounds; coniine and y-coniceine are the predominant toxicants. These alkaloids are chemically related to nicotine. These toxins can be found in all plant parts and are thought to develop in the roots, fruits, and shoot tips (302, 306, 308, 309).

Water hemlock is considered one of the most poisonous plants in the United States. The compounds are polyactylenes, such as cicutoxin, an unsaturated aliphatic alcohol: (trans) heptadeca-8: 10:12-triene4:6-diene-1:4 diol, which can have a strong carrot-like odor (302, 303, 304, 305).

Seed production in hemlock is high at an estimated 35,000 to 40,000 seed potential from a single plant. High seed production can create a competitive advantage (309).

Uses and Values
Poison hemlock has been used as a medicinal plant. It is limited in importance because of the closeness between therapeutic and poisonous levels. The extracts and tinctures of hemlock have been used because of their sedative, anodyne, and antispasmodic effects to treat cases of asthma, epilepsy, whooping cough, angina, chorea, and stomach pains. Dried, unripe seeds were used as an antispasmodic, a sedative, or an

analgesic. Hemlock juice was mixed with betony (*Stachys officinalis*) and fennel (*Foeniculum vulgare*) seeds for the bite of a mad dog. This mixture was later used as a last resort antidote for strychnine and other strongly poisonous compound poisonings. External use of plant material was used to treat herpes, erysipelas (a form of superficial cellulites), and breast tumors. Religious groups, in the 15th and 16th centuries, roasted roots and used that for treating gout. The United States imported about 14,000 kilograms (30,800 pounds) of seed and 7000 kilograms (15,430 pounds) of dried leaves for use as drugs annually prior to World War I. Hemlock remains a homeopathic agent and is said to be long-acting remedy and is of special value to the aging when vital powers of the body are failing. Hemlock has been used as a treatment against a serious malignant tumor. Fresh flowers are used to prepare the mother homeopathic tincture. There are contradictory opinions as to the use and value of hemlock as a medicine. It has to be administered carefully to reduce the chance of a narcotic poisoning when used internally. Dried leaf and juice had been listed in the pharmacopoeias of London in 1864 through 1898, and the last official recognition appeared in British Pharmaceutical Codex in 1934 (309).

Risk and Impacts

The greatest risk associated with hemlock is human and animal poisoning. Reports of human death go back to Socrates' time. Symptoms were described as a rapid loss of power in the extremities, staggering, ataxia, trembling, paralysis, loss of power to chew, loss of sensation, and fixed pupils. Death occurred due to paralysis of respiration and asphyxia from the poison hemlock (302, 309).

More recently numerous medical publications have identified hemlock poisonings to help medical personnel recognize the symptoms and possible supportive treatment options. There is no antidote for hemlock poisoning. Hemlock poisoning of humans has a relative quick onset time of approximately 45 to 60 minutes after ingesting the plant material, although death has been reported to occur in as little as 18 minutes (302, 304, 308).

Symptoms from the cicutoxin in water hemlock are described as early muscarinic and cholinergic symptoms of nausea, abdominal cramping and epigastric distress, excessive salivation, bronchorrhea, and hypotension, and death is usually from respiratory failure and cardiopulmonary arrest, which can follow grand mal seizures (302, 304).

The alkaloids in poison hemlock affects the neuromuscular junction where they act as nondepolarizing blockers, similar to curare, and death occurs when muscles of the respiratory system become paralyzed (302, 308).
Water hemlock is considered one of the most poisonous plants that grow in the United States. It is known to be extremely toxic to livestock and to humans, with an overall mortality of 40% to 70% being reported. The reported lethal dose for humans is 2.8 mg/kg (0.000045 oz/lb or 45/1000th oz/100 lb) of body weight (302, 304, 308, 309).

Human poisonings are primarily attributed to misidentification of hemlock for some edible wild plant. Renewed interest in living off the land and getting back to nature has

increased interest in wild plant gathering and consumption. Poison hemlock has been mistaken for parsley leaves, parsnip roots, and anise seeds. Ingestion of poison hemlock is less frequent and believed to be due to the “mousy” odor, bitter taste and burning in the mouth, throat, and abdomen when ingested. It was referred to tasting like carrot tops. Western water hemlock is reported to have an odor similar to parsnip or celery and has been mistaken for wild parsnip, celery, artichokes, sweet potatoes, or sweet anise (302, 304, 308, 309).

Livestock losses due to hemlock are significant. It was reported in 1992 that over $340,000,000 annually was lost due to livestock poisonings from poison hemlock. Cattle, goats, and horses appear to be the most sensitive grazers. Sheep seem to be less affected, but this may also be due to animal avoidance. For cows, a dosage of 5.3 g plant/kg (0.08 oz/lb) body weight is lethal, whereas with sheep it is 10g plant/kg (0.16 oz/lb) body weight. All classes of livestock and wildlife can be poisoned from hemlock. Sixteen Tule elk died within two days from eating roots, stems, and leaves of poison hemlock (307, 309).

Symptoms of livestock poisoning include nervousness, trembling, knuckling at the fetlock joints, ataxia, and dilation of the pupils, a weak and slow heartbeat, and excessive salivation or frothing at the mouth, teeth grinding, coffee-colored urine, vomiting, coma, and ultimately death from respiratory paralysis. These symptoms can occur within 15 minutes to six hours after ingestion. Fetal deformation (i.e., cleft palate and limb, spine, and neck contractures) is likely when hemlock is ingested during pregnancy. Toxin can pass through milk to young nursing animals. Poultry or wild game birds can ingest green plant material or seeds of hemlock and pass toxins on to humans when consumed. Clinical signs of toxicity in fowl were reported as 25 mg/kg (0.0004 oz/lb) body weight for quail, 50 mg/kg (0.0008 oz/lb) body weight for chicken, and 100 mg/kg (0.0016 oz/lb) body weight for turkeys (303, 307, 308, 309, 310).

Invasion and Expansion

Prevention is the best defense to reduce infestations of hemlock. When plants are located, prompt action should be taken to remove the plants and not allow seeds to develop. If seeds have developed and are released from the parent plant, disturbance to the site should be kept to a minimum. Care should be taken to wear protective gloves and clothing when handling hemlock (303).

Hemlock expansion is due to seed transport by water or animal, primarily birds and rodents (308, 309).

Control Methods

When handling hemlock, care should be taken to wear gloves and protective clothing to reduce contact and exposure to plant material. Hemlock is an extremely poisonous plant. Repeated applications of control methods can be anticipated (303).

Chemical (303). For pre-emergent control of poison hemlock tebuthiuron or in combination or alone, chlorsulfuron (Telar) and metsulfuron (Escort) or hexazinone, metribuzin, and terbacil provide good control.

Dr. Dewey reports in field tests the most effective products have always been chlorsulfuron and metsulfuron. Dicamba (Banvel, Clarity, Vanquish) have performed very poorly (Personal communiqué, Steve Dewey).

Post-emergent control of poison hemlock requires phenoxy herbicides or glyphosate applied early in the spring.

For western water hemlock, applying herbicide in late spring and early summer is most effective. A herbicide containing 2,4-D or MCPA should be applied at a rate of 2 lb/ae/acre in the early bolt stage of growth. Glyphosate is excellent for controlling western water hemlock.

Toxicity of plants may increase prior to death after herbicide application. Animal use of the area should be carefully monitored for three weeks after application of herbicide.

Mechanical (303). Tillage can prevent hemlock from establishing and may have to be repeated. Repeated mowing can deplete root carbohydrate reserves, reduce seed production, and remove green material that may potentially be grazed.

Pulling or hand digging can be effective on single plants or small infestations. All exposed root material and above-ground plant material should be disposed of.

Grazing (309). Grazing is not recommended due to the toxicity of hemlock. However, if grazing is to occur, some information is provided and some guidelines are recommended. Sheep are less affected than cattle when hemlock is eaten. Goats are similar to sheep, and pigs are the most tolerant but still will get toxicosis from hemlock ingestion. Pregnant animals should not eat hemlock prior to day 70 of gestation for cows and 60 days for pigs.

Insects (303, 309). For poison hemlock, biological control by the European Palearctic moth (*Agonopterix alstroemeriana*) has demonstrated success. It is unknown how this moth was first introduced to the United States where it has rapidly moved throughout and colonized the western states. The larva lives in leaf rolls and feed on foliage, buds, and flowers in spring and early summer. Poison hemlock can be infected by virus strains of ringspot virus, carrot thin leaf virus, alfalfa mosaic virus, or celery mosaic virus.

There are currently no approved biological control agents for western water hemlock.

Bibliography for Hemlock Information Sources

#301 Phylogenetic relationships within *Cicuta* (Apiaceae tribe Oenantheae) inferred from nuclear rDNA ITS and cpDNA sequence data
Chang-Shook Lee and Stephen R. Downie
Unknown where published

#302 Seizures and Death on a White River Float Trip-Report of Water Hemlock Poisoning
Landers D & Seppi K, Blauer W:
West J Med 1985 May; 142:637-640

#303 Managing Poison and Western Water Hemlocks
Jessica Graham & Wayne S Johnson
University of Nevada, Reno, Cooperative Extension Fact Sheet 04-09

#304 Water hemlock poisoning
Julie Short
emergency nurse vol 14 no 7 november 2006

#305 Exploring the Structural Basis of Neurotoxicity in C17-Polyacetylenes Isolated from Water Hemlock
Koji Uwai,† Katsuyo Ohashi, Yoshiaki Takaya, Tomihisa Ohta, Takeshi Tadano, Kensuke Kisara, Koichi Shibusawa, Ryoji Sakakibara, and Yoshiteru Oshima
J. Med. Chem. 2000, *43,* 4508-4515

#306 Secretory Structures and Localization of Alkaloids in *Conium maculatum* L. (Apiaceae)
Gabriella Corsi and David Biasci
Annals of Botany 81: 157±162, 1998

#307 The Effect of Natural Toxins
on Reproduction in Livestock'
Lynn F. James, Kip E. Panter, Darwin B. Nielsent & Russell J. Molyneux
J. Anim. Sci. 1992. 70:1573-1579

#308 Ingestion of Poison Hemlock (Conium maculatum)
Frank BS, Michelson WB, Panter KE & Gardner DR:
West J Med 1995; Vol 163, December, No. 6, 163:573-574

#309 Poison hemlock (Conium maculatum L.)
J. Vetter
Food and Chemical Toxicology 42 (2004) 1373–1382

#310 Comparative Toxicity of Coniine, an Alkaloid of Conium maculatum (Poison Hemlock), in Chickens, Quails, and Turkeys
A. A. Frank; W. M. Reed
Avian Diseases, Vol. 34, No. 2. (Apr. - Jun., 1990), pp. 433-437.

Sources of Unpublished Material

Steve Dewey, Personal Communication, Utah State University, Extension Weed Specialist

Part IV: Perennial Pepperweed
Lepidium latifolium L.
Species-Specific Control and Containment Strategies

Perennial Pepperweed Treatment Plan Objectives

Because perennial pepperweed spreads rapidly and can reduce plant and wildlife diversity, the DWR's efforts to control and contain this plant on the WMAs have been ongoing. Even though established perennial pepperweed infestations will require repeated treatments for several years, effective timing and diligent monitoring should reduce control efforts. The objective is to reduce the population to two percent or less of the available compatable WMA's acreage.

Perennial Pepperweed Treatment Plan

An extensive root system and copious seed production make perennial pepperweed difficult to control and contain and limit effective treatment methods. Most likely, the DWR will combine the following control and containment methods to treat perennial pepperweed.

Strategy AA: Herbicide treatment

For Strategy AA, the DWR will treat perennial pepperweed with chlosulfuron (Telar); metsulfuron (Escort or Cimarron); imazapyr (Habitat); glyphosate; and 2,4-D. Due to differences in the phenological development of perennial pepperweed over the growing season, the agency will carry out at least two herbicide treatments during late spring or early summer and fall. To be effective, these treatments will continue for several years. Although total eradication is unlikely, the agency expects to reduce and contain perennial pepperweed on the WMAs.

NOTE: Because choosing an herbicide depends on a treatment site's intended use, the DWR recommends consulting with Utah State University Extension personnel or a chemical company representative before applying any herbicide. The agency also recommends following all product safety instructions.

Strategy BB: Integrated management with herbicide, mowing, and livestock grazing

Strategy BB involves using mowing or livestock grazing to treat perennial pepperweed infestations during the growing season. When livestock no longer consume plants or during the late summer, the DWR will treat perennial pepperweed with herbicide. Because the objective is to transport herbicide into the root system and kill plants prior to seed production, this treatment should occur when perennial pepperweed begins to flower and livestock consumption rates are no longer keeping up with plant development or the agency ceases mowing operations.

This treatment method will work only where equipment and livestock can function properly. For example, most livestock dislike having wet feet, so a wet treatment site will

undoubtedly concern livestock owners, which will complicate the agency's efforts to control perennial pepperweed. To prevent these types of problems, the agency will make sure to inform all livestock owners of wetland-grazing requirements (grazing durations, water hauling, and supplemental feeding); potential outcomes (weight gain or loss); and concerns (plant poisonings, hoof rot, insect inflictions, and potential diseases).

Assessment and Monitoring

Early spring, summer, and fall monitoring are, and will continue to be, part of the DWR's management practices. The agency will collect GIS points for perennial pepperweed infestation sites and will use ARCGIS software to map these sites. The agency will also use ocular methods to estimate the size of infestations then record this information, along with notations about herbicides, application rates, and application dates. After annually revisiting treatment sites, the agency will report observed results and file documents in WMA weed control files.

Literature Review of Perennial Pepperweed Information Sources

Weed Species: Perennial Pepperweed, *Lepidium latifolium* L.

Taxonomy (401, 404, 405)

Family: Brassicaceae
Genus: *Lepidium*
Species: *Lepidium latifolium* L. (synonym: *Cardaria latifolia* (L.) Spach),
Common Names: tall whitetop, giant whiteweed, perennial peppergrass, slender perennial peppercress, broadleaf or broadleaved pepperweed, and ironweed.

Distribution (401, 402, 403, 404)
Perennial pepperweed is found in all states west of the Continental Divide in the United States, except Arizona. Infestations have been reported in New England in coastal, mountainous, and intermountain areas. It is reported in western Canada and Mexico

History in North America (402, 404)
Perennial pepperweed is native to southeastern Europe and western Asia. It was accidentally introduced to North America in the 19th century, perhaps in the 1930s. It was reportedly introduced to Yolo County, California, in European-imported contaminated sugar beet seed.

Description
Perennial pepperweed, as the name implies, is an herbaceous perennial that can produce dense monotypic stands with stems 0.6 to 2.4 meters (two to seven feet) in height. Stems are woody at the base, persist for several years, and can form into thick mats of residual. The stems are produced by a large underground network of perennial roots or existing woody crowns and emerge in early spring or late fall. Stem densities of four to eight stems per square foot create a nearly closed canopy. Other densities reported are two to 50 plants per square meter. Shoots remain in a rosette stage for several weeks before stems bolt, elongate (402, 404, 405, 406, 411).


Perennial Pepperweed Pre-bloom
Photo by Randy Berger

Roots are typically long, thick and minimally branched, and 85% of the root biomass is found in the top 60 centimeters (24 inches) of the soil. Perennial pepperweed is reported to be phreatophytic (roots growing in or within capillary action of water table) and can have roots growing to a depth greater than three meters or ~10 feet. New plants can develop from small, two-inch (five-centimeter) sections of creeping root material (404, 405, 406).

Rosette leaves have serrated margins, a long petiole approximately three to15 centimeters long (1.2 to six inches), are 10 to 30 centimeters long (four to 12 inches) and six to eight centimeters wide (2.4 to three inches), are glabrous, and green to gray in color. Stem leaves are reduced, less sessile, tapered at the base with margins entire or weakly serrated and are alternate and lanceolate to elliptic or oblong in shape. The foliage for stem leaves is described as green to gray in color and can be glabrous. Basal and rosette leaves commonly senesce as the plant matures and the canopy develops. The leaf canopy is composed of cauline leaves just below and on the branches of the inflorescence (402, 404, 405, 406).

The inflorescence have four small white spoon-shaped petals approximately 1.5 millimeters long (1/16 inch) with six stamens (four long and two short) and a single pistil two millimeters long (3/32 inch) and with four green oval sepals less than one millimeters long (1/32 inch). The flowers are born in dense clusters near the stem tips. Flowers can occur from early summer to fall (402, 404, 405, 406).

Perennial Pepperweed in Bloom
Photo by Randy Berger

The fruits are small-flattened pods (silicles) with two chambers and each pod containing two seed two millimeters long (1/10th inch). The pod develops on a pedicel that is much longer than the pod itself and is round to slightly ovate in shape covered with long simple hairs. Seed is ellipsoid, slightly flattened one millimeter long (1/32 inch) and 0.5 millimeters wide (1/64 inch) and is reddish-brown with a shallow groove on each side. Seeds fall periodically throughout the winter. Infestations have been reported capable of producing 15 billion seeds per hectare (6 million/acre). Plants will abort seed if under stress, such as drought, during fruit set. Seed production will be low in years of prolonged spring and summer precipitation if infestation of white leaf rust (*Albugo sp*) becomes rampant in perennial pepperweed stands (401, 402, 404, 406).

Above-ground parts typically die during late summer; however, late growing plants have been observed into September with numerous green leaves and conspicuous flowers (406; Personal observation).

For perennial pepperweed, the above-ground green standing biomass has been reported as 96,450 kg/ha (109,600 lbs/acre) while the dry biomass has been reported at 21,307 kg/ha (24,200 lbs/acre) in California (402).

Emerging seedlings are somewhat rare in established perennial pepperweed stands. Most reproduction is by vegetative means from buds and expansion of root systems. Seedlings have bright green cotyledons, which are obovate to oblong, two to eight millimeters long (1/10-5/16 inch), with rounded tips and a base tapered to a short petiole 1.5 to three millimeters long (1/16- 1/8 inch), and the first leaves are alternate, but may appear opposite (402, 406).

Habitat and Environmental Conditions
Perennial pepperweed typically grows in wet environments. This can be along rivers, irrigation ditches and canals, in freshwater marshes, salty marshes, flood plains, coastal wetlands, croplands, moist waste areas, wet meadows and riparian areas. It isn't adapted to areas that remain dry for extended periods. In Wyoming perennial pepperweed was found within 30 meters of a direct water source in riparian areas and the majority was within 10-20 meters (401, 402 404, 405, 411).

It is primarily found in fine-texture, saline to sodic soils, although some populations persist in coarse-textured, alluvial soils (405).

Reproduction and Adaptive Strategies
Perennial pepperweed is a prolific seeder capable of producing 15 billion seeds per hectare (6 billion/acre) that have a high germination potential. Seeds are transported by wind, humans, animals, vehicles and by water (401).

Perennial pepperweed can propagate from rhizomes as small as 2.5 cm long and 0.5-0.75 cm in diameter (1 inch long x 3/16-9/32 inch wide). Cut root material exposed over winter on the soil surface can sprout the following spring and exposed roots are very resistant to drying. Perennial roots can lie dormant in the soil for several years. Roots are brittle and segments easily break off when exposed by water erosion or mechanical actions and segments can be carried down stream to begin new infestations (402, 404, 406).

Perennial pepperweed has an extensive root system, as much as 40% of the plants' biomass, which increases nutrient and water uptake, while increasing carbohydrate reserve for early shoot development. These plants can act as "salt pumps" by bringing salt ions up from deep in the soil and depositing them near the surface thereby reducing competition with other less salt tolerant plant species (406).

It is reported that areas where perennial pepperweed plants are present can have greater soil enzyme activity of several amidohydrolases, which suggests this plant can enhance nitrogen (N) availability (407).

Perennial pepperweed has adventitious rooting capabilities. This adaptive mechanism allows for the replacement of damaged or killed roots caused by stressed environments. Flooding causes such a stress and induces adventitious rooting on submerged portions of the stem above the soil line. These roots will grow towards the surface and provide a pathway for respiration in the plant. Adventitious roots are important when plants are in hypoxia or anoxia environments because they can obtain oxygen directly from the surroundings. The oxygen is transported through the aerenchyma, another important adaptation in wetland plants subjected to flooding. The root porosity (aerenchyma) provides a low-resistance pathway for exchange of oxygen between the plant parts above the water and those below the water. Flooded seedlings also exhibited a concurrent activity of both fermentative pathway and aerobic metabolism. Flooded plants did have a 53% lower root to shoot ratio than non-flooded plants after 50 days of flooding. However, all flooded plants survived (408, 409).

Residual from previous year's growth is slow to decompose in perennial pepperweed infestations. This litter accumulation, up to 10 cm reported (4 inches), creates an environment that other plants seed can't germinate in and few plants have enough stored energy to grow through the thick mat layer (405, 406).

Limitations
Perennial pepperweed seed is highly viable, but rarely produce seedlings in the field. Seeds lack a hard coat and lose viability rapidly and do not seem to survive long in the soil. This suggests that re-infestation from a seedbank may not be a strong likelihood or that great of a concern (404, 406).

Uses and Values
Perennial pepperweed has traditionally been used as anti-escrobte, stomach tonic, aperitif and diuretic. Flavonoids are the active principles in perennial pepperweed. These have demonstrated an anti-estrogenic and anti-androgen activity as well as having an important role in retarding the development of hormone-dependent cancer cells. Further investigation using integral suspensions of perennial pepperweed showed significant activity against induced prostate hyperplasia in rats (410).

Risk and Impacts
Perennial pepperweed reduces biodiversity in the plant and animal communities, causes economic lose in crop or forage production and increased costs for control efforts. Monotypic stands displace more desirable native plants. Infestations reduce palatability, digestibility and protein content in meadow hay infested with perennial pepperweed, even though total forage may increase. Reduced livestock-carrying capacity is a net result of infested pastures (401, 402, 404).

Wildlife and insects are affected by perennial pepperweed reducing quality habitat and displacing native plants. The threatened Wandering Skipper butterfly (*Pseudocopaeodes eunus obscurus*) and the marsh harvest mouse (*Reithrodontomys raviventris*) are mentioned in the literature. A decrease in waterfowl nesting frequency has been reported (404, 406).

Invasion and Expansion
Perennial pepperweed establishes by seed germination or through propagation of root material. Clonal spread is primarily by expansion of root material and development of shoot buds. Poor ecological conditions or disturbance tends to increase the likelihood of invasion. Salt affected soils are locations where perennial pepperweed will establish. These areas provide sites with less competition from other plants. No allelopathic tendencies or substances have been found in perennial pepperweed (402, 403, 407).

Perennial pepperweed establishes around wet areas and is often associated with water delivery systems for irrigation or river system riparian areas. Water is typically the conveyor of root parts or seed to newly invaded areas. Expansion may be further enhanced by the potential increase in germinability from seed hydration and from the mucilage (gelatinous substance similar to plant gum with adhesive qualities) its seeds

produce upon wetting. The mucilage aids in substrate attachment and germination under low osmotic conditions (403).

Perennial pepperweed can expand rapidly with a single plant in the second season becoming a population several meters in diameter and within as few as 5 years the infestation can be nearly monotypic with stem density near 150 stems/square meter or 14 stems/sq. ft. (407).

Control Methods
Perennial pepperweed is difficult to control. It has extensive root systems and adaptations to reduce competition from other plants once established. Any control method should consider the value of seeding desirable species to establish a more competitive environment once control methods have been initiated. One study reported that on grazed only land economic return for control methods took 15 years to break even, on grazed and hay harvested land returns of the cost of treatment was 4-5 years (401, 405). If resources are lacking to treat the entire infestation then efforts should be directed to contain spread by treating outlying populations and the advancing edge of the infestation (406).

Chemical. Perennial pepperweed should be chemically treated when the plant is allocating photosynthate to below ground plant parts. This period begins during the flower bud stage and is greatest during the period between flowering and seed filling stage. Care should be taken to treat in advance of seed set and maturation. Control needs to be 100% or sprouting and re-growth will reinvade the treated area within a short period of time. Repeat treatments are necessary within the year and over numerous years for control to be effective (402, 404, 406).

Combining chemical treatment with mowing or grazing is suggested for improved herbicide effectiveness. Grazing in the spring followed by chlorsulfuron or imazapyr application at flower bud or mowing in the spring (mechanical grazer) followed by the same herbicide treatment is recommended. Using glyphosate on less dense stands at flower bud stage or following spring mowing at bud stage in wetlands is recommended (404).

The following herbicides, rates and comments are provided from the literature (404, 405, 406):

- *Telar* (chlorsulfuron), 0.75-2 oz ai/acre, use a nonionic surfactant at 0.25% or 01% silicone based surfactant; use on non-crop, pastures and rangelands; doesn’t harm grasses; excellent control 1-2 years; soil residual activities, keep away from sensitive crops, trees and away from water; can be mobile in soils with high pH

- *Escort* (metsulfuron methyl), .03-.06 oz ai/acre with 0.25% nonionic surfactant; highly mobile in soils with high pH

- *Habitat* (imazapyr, aquatic label), follow label instruction; riparian and wetland use; treated areas usually void of any plants for 1-2 years

- *Arsenal, Chopper, Stalker* (imazapyr, non-aquatic label), 4-6 oz ae/acre of imazapyr (16-24 oz Arsenal) with 0.1% silicone surfactant; control most grasses and some broadleaf plants; treated areas usually void of any plants for 1-2 years

- *Roundup and other Glyphosate* (Glyphosate aquatic and non-aquatic labels have different formulas, follow label instructions), 2-3 lb ae/acre, nonionic surfactant required for aquatic label; effective unless infestation is dense, mow and treat re-sprout plants may be best

- *Weedar 64* (2,4-D), 1-2 lb ae/acre, follow label for use of surfactant; application required for 2 or more years, broad leaf herbicide and keep away from sensitive plants

- *Raptor* (imazamox) 0.047 lb ai/acre, add methylated seed oil and nitrogen fertilizer; soil residual activities

- *Pursuit* (imazethapyr) 0.095 lb ai/acre, 1.5 oz ai/acre, (6 oz pursuit/acre), add methylated seed oil and nitrogen fertilizer; use in alfalfa or edible legumes, see label; soil residual activities; for post emergent control, apply to rosettes spring and fall; reported to have limited control effect on perennial pepperweed in one study

Mechanical. Disking, mowing and hand pulling are reported to be ineffective at controlling perennial pepperweed (401, 406).

Where perennial pepperweed is established, it does not always lend itself to mechanical manipulation. Some areas where infestations exist are characterized as riparian areas or wetlands; wet areas, wood lands, and or rock covered. The extensive creeping root system also makes tillage or disking control difficult and in fact may expand the infestation and increase density (402, 404).

Mowing can help with removal of old accumulation and may improve herbicide application treatments. Mowing by itself would require frequent treatments over the growing season and again sites are not always conducive for operation of such equipment (402, 405). Mowing during the time below ground stored energy is at a low point is the most effective time for such an activity. This time coincides with the bolting stage in perennial pepperweed. However, it is reported quick recovery and re-growth can be expected from dormant buds near the soil surface and within 14 days root reserves were similar between mowed and un-mowed plants. This suggests mowing is not an effective control method by itself. Mowing in conjunction with herbicide application following re-growth may improve herbicide effectiveness due to the new growth of leafy material being in closer proximity to the roots and transport of herbicide being more efficient (406).

Water Level. Deep continuous flooding has been reported as a control method (404, 406). One report indicated that two consecutive years of flooding produced no surviving perennial pepperweed plants. Removal of dikes and restoration of natural tidal fluxes reduced perennial pepperweed infestations by 34%. Highly competitive plants were present and may have helped suppress the perennial pepperweed in these locations (406).

As previously stated perennial pepperweed can withstand flooding for up to 50 days. The plants developed adventitious roots and aerenchyma, and ethylene production increased, but biomass decreased. The plant exhibits plasticity to tolerate and survive saturated conditions (408).

Fire. Burning can help to remove the residual plant material and increase herbicide contact with the plant. This may also increase light penetration and improve germination for other plant species seed. Burning may be difficult due to difficulty in ignition and fire carry within monotypic stands. The nutrient release from burning may actually increase perennial pepperweed density (405, 406).

Grazing. Grazing by cattle, sheep and goats is considered a control method, although short term, i.e. annual suppression. Grazers seem to prefer the early plant development stage or early growth stage when new leaves are emerging. There is some conflict in the literature as to phenological stage of development and willingness to graze by livestock. Some suggest grazing during the entire season, while others suggest early seasonal grazing only. In dense stands some effort should be initiated to remove dead standing stem and litter to gain animal access to new plant growth. Injury can occur to animals from stiff erect stems, although in salty environments cattle have been observed eating dried stems (402, 403, 406).

Cattle grazing in the winter and spring accompanied with a thick mixed pasture grass stand has stopped expansion from adjacent un-grazed stands of perennial pepperweed (personal observation).

Mowing and sheep grazing were reported to reduced density and standing crop for up to one year after treatment (403). However, another report indicated sheep suppressed growth, but once sheep where removed re-sprouting occurred rapidly (406).

If animals graze perennial pepperweed plants bearing seed they should be held for 7 days following grazing plants in a confined area before being moved to un-infested areas. Seed viability is thought to increase in the digestive process of livestock, 15-23% greater. Seed hydration and scarification were considered the mechanisms improving seed germination when ingested and deposited through animal waste. Also, seeds can be transported in animal hoofs (403, 405).

Insects. Within the family Brassicaceae there are 11 species of *Lepidium* that are native to the western United States. This includes important crops, broccoli, radish, canola, mustard, cabbage, and kale. One species is reportedly on the endangered species list. These facts make it difficult to foresee an insect as a biological control

insect for the control of perennial pepperweed. Specificity test would most likely require any biocontrol agent to be specie specific or at least non-threatening to other *Lepidium* species, excluding *Lepidium draba* L., hoary cress (402, 406).

Several insects from the genus *Lygus* feed on perennial pepperweed, but do not significantly damage the plant. Seed production may be reduced, but root expansion and clonal expansion are not slowed. White rust (*Albugo sp*.) has been found in the west in several areas. During wet years this rust can infect numerous flowers and reduce seed production (406).

Assessment and Monitoring

All weed control projects require monitoring and vigilance to detect new establishments, to analyze treatment effectiveness and determine need for repeat treatments. Large areas are difficult to examine and costly to survey. Some new techniques using remote sensing are being studied for appropriateness of use. Hyperspectral remote sensing data was used to identify perennial pepperweed and three methods (field spectrometer, Advanced Visible and Infrared Imaging Spectrometer (AVIRIS), and HyMap) were tested with success were 10%, 13% and 16% error rates respectively (412).

Bibliography for Perennial Pepperweed Information Sources

#401 Dynamic Benefit–Cost Analysis for Controlling Perennial Pepperweed (*Lepidium latifolium*): A Case Study
Mark E. Eiswerth, Loretta Singletary, John R. Zimmerman & Wayne S. Johnson
Weed Technology. 2005. Volume 19:237–243

#402 Ecology and Control of Perennial Pepperweed (*Lepidium latifolium* L.)
James A. Young, Debra E. Palmquist, Robert S. Blank & Charles E. Turner
California Exotic Pest Plant Council 1995 Symposium Proceedings

#403 Effect of Ruminal Incubation on Perennial Pepperweed Germination
Michael F. Carpinelli,1 Christopher S. Schauer,2 David W. Bohnert,3 Stuart P. Hardegree,4 Stephanie J. Falck,5 and Tony J. Svejcar6
Rangeland Ecol Manage 58:632–636 | November 2005

#404 Perennial Pepperweed *Lepidium latifolium* L. Mustard family (Brassicaceae)
Debra A. Boelk,
7 June 2005 Page 1 of 3
Plant Conservation Alliance®s
http://www.nps.gov/plants/alien

#405 Perennial Pepperweed
Integrated Pest Management for Home Gardeners and Landscape Professionals
PEST NOTES Publication 74121
R.G. Wilson, J. DiTomaso & M.J. Renz
University of California, Agriculture and Natural Resources, October 2004

#406 Element Stewardship Abstract for *Lepidium latifolium* L., perennial Pepperweed, tall whitetop
Mark J. Renz.
The Nature Conservancy's Wildland Invasive Species Program
4 April 2000

#407 Effects of CO2 enrichment on plant-soil relationships of *Lepidium latifolium*
Robert R. Blank1,3 & Justin D. Derner2
Plant and Soil 262: 159–167, 2004.

#408 Adaptive responses of *Lepidium latifolium* to soil flooding:
biomass allocation, adventitious rooting, aerenchyma formation and ethylene production
Hongjun Chen, Robert G. Qualls & Glenn C. Miller
Environmental and Experimental Botany 48 (2002) 119–128
www.elsevier.com/locate/envexpbot

#409 Anaerobic metabolism in the roots of seedlings of the invasive exotic Lepidium latifolium
Hongjun Chen, Robert G. Qualls
Environmental and Experimental Botany 50 (2003) 29_/40

#410 Effect of an integral suspension of *Lepidium latifolium* on prostate hyperplasia in rats
S.Martın´ez Caballeroa, C.Carricajo Ferna´ndeza & R.Pe´r ez-Ferna´ndezb
Fitoterapia 75 (2004) 187–191

#411 Weed Invasion Susceptibility Prediction (WISP) Model forUse withGeographic Information Systems
J. H. Gillham, A. L. Hild, J. H. Johnson, E. R. Hunt Jr. & T. D. Whitson
Arid Land Research and Management 18: 1–12, 2004

#412 Spectral and physiological uniqueness of perennial pepperweed (*Lepidium latifolium*)
Margaret E. Andrew & Susan L. Ustin
Weed Science, 54:1051–1062. 2006

#413 Weed Notes: *Lepidium latifolium*
TunyaLee Morisawa
The Nature Conservancy, Wildland Weeds Management and Research
http://tncweeds.ucdavis.edu
18 June 1999

Part V: Saltcedar
Tamarix spp.
Species-Specific Control and Containment Strategies

Saltcedar Treatment Plan Objectives

Saltcedar, also called Tamarisk, refers to six species and numerous hybrids of shrub-like species now found in the United States that were introduced from Eurasia in the 1800s. At least four of these species are present in Utah: *Tamarix chinensis*, *T. gallica*, *T. parviflora*, and *T. ramosissima*.

Saltcedar is a difficult plant to control and can have severe consequences to wildlife habitat. Because saltcedar is present on all of the WMAs, the DWR initiated a treatment plan years ago. Due to these control efforts, the agency has prevented large infestations. Most small infestations of saltcedar on the WMAs are a single plant or only a few plants. Containment to small isolted population of few individuals is the objective for this species.

Saltcedar Treatment Plan

To control and contain saltcedar on the WMAs, the agency will use the following treatment methods.

Strategy AA: Herbicide treatment

For Strategy AA, the DWR will treat saltcedar from early June to late September with imazapyr (Habitat), glyphosate, and triclopyr (Garlon). The agency may also use foliar and stump treatment applications. To be effective, these treatments will continue for several years. Although total eradication is unlikely due to seed sources from adjacent lands, the agency expects to reduce and contain saltcedar on the WMAs.

NOTE: Because choosing an herbicide depends on a treatment site's intended use, the DWR recommends consulting with Utah State University Extension personnel or a chemical company representative before applying any herbicide. The agency also recommends following all product safety instructions.

Strategy BB: Biological control with insects

Strategy BB involves using biological control with the chrysomelid leaf beetle, *Diorhabda elongata,* to treat saltcedar. In the spring or early summer, the DWR will collect and release these beetles within heavily infested areas. Beetles are available from numerous established populations. Currently, Antelope Island is the closest population to northern Utah WMAs.

The agency will continue to investigate other biocontrol insects for this treatment method.

Strategy CC: Physical removal

To stop expansion, Strategy CC is to pull small saltcedar infestations, use specialized equipment to remove larger plants, and burn slash piles to prevent re-sprouting. The agency will carry out this treatment method prior to seed development, which will reduce seed spread.

Assessment and Monitoring
Early spring, summer, and fall monitoring are, and will continue to be, part of the DWR's management practices. The agency will collect GIS points for saltcedar infestation sites and will use ARCGIS software to map these sites. The agency will also use ocular methods to estimate the size of infestations then record this information, along with notations about herbicides, application rates, and application dates. After annually revisiting treatment sites, the agency will report observed results and file documents in WMA weed control files.

Literature Review of Saltcedar Information Sources

Weed Species: Saltcedar, *Tamarix* spp.

Taxonomy (501, 503, 508)

Family: Tamaricaceae (Tamarisk Family)
Genus: *Tamarix*
Species: *Tamarix aphylla, Tamarix chinensis, Tamarix gallica, Tamarix parviflora, Tamarix ramosissima* Ledeb., *Tamarix pentandra* Pall.; Numerous hybrids, *T. chinensis*, *T. gallica*, *T. parviflora*, and *T.; Ramosissima* are identified as being in Utah

Distribution
The native range of saltcedar is considered Eurasia, Russia, the Middle East and Africa (501, 511).

Saltcedar is found in the United States and Mexico. It is reported to occur on 1.6 million acres or 470,000-650,000 hectares from northern Mexico to central Montana and from central Kansas to central California and in 23 states. It is distributed from sea level to 2500 meters in elevation (8200 feet) (503, 509).

History in North America
Saltcedar was introduced into the United States in the early to mid 1800's. It was imported as an ornamental shrub and for erosion control up to the 1930's. This shrub-like plant was considered naturalized in 1877 and was dominating several riparian areas along numerous major river systems by the 1960's (501, 503, 505).

Saltcedar was reported to have first been sold on the East Coast in 1823 and it arrived in California in the 1850's or 1860's. By 1877 it had gone wild in Texas, but didn't expand extensively until the early 20th century (511).

Saltcedar Shrub/Tree Form
Photo by Randy Berger

Description
Most saltcedars are a deciduous shrub or small tree. It grows to 12-15 feet in height (3.6-4.5 meters), forms dense thickets and can form closed canopies. *Tamarix aphylla* is an evergreen and can grow to a height of 50 feet (15 meters) and tends to flower in winter. The shrub-like plants have slender branches and gray-green foliage. New branches have a smooth bark that is reddish-brown and older bark becomes brownish-purple with ridges and furrows. The 1/16-inch long (2 mm) scale-like leaves overlap each other along the stem and are often encrusted with salt secretions. A large number of pink to white flowers appear in dense masses, from May to September, along 2 inch long (5 cm) spikes at the branch tips (501).

Saltcedar produces copious amounts of small seeds throughout the growing season. Wind, water, animals and human activity disperse the seeds. The small seeds, 1/25 of an inch in diameter (1 mm), are contained in a capsule, which has a small tuft of hair that aids in wind dispersal (502, 507, personal observation). Seed viability has been reported as 98% for *Tamarix ramosissima* and 100% for *T. aphylla* when germinated in tap water within a week of collection. However, seed viability can decrease to as low as 20% after 10 weeks under field conditions (508).

Saltcedar Seedling
Photo by Randy Berger

Seedlings of saltcedar develop quickly on bare moist soil sending down deep taproots. Saltcedar is a facultative phreatophyte (gains water directly from the water table or the capillary fringe of the water table), which gives it the ability to withstand extended periods of drought. It can also withstand alluvial deposits and short periods of inundation by water (502, 507).

Haplotypes. Saltcedar has numerous haplotype and hybrid populations. Haplotypes mention in the literature are A, D, G, Q. Haplotype A was found to be present in 77%, haplotype D was 3%, haplotype G was 17% and 2.6% were haplotype Q, as reported in 2003, for sampled populations in the United States. Hybrid or morphological intermediates, as they are sometimes referred to, have been found in the United States. These hybrids are *Tamarix ramosissima* with *T. aphylla* (athel) and *Tamarix chinensis* with *T. aphylla* (athel). Athel, *Tamarix aphylla* is an invasive plant found in Australia. Seed of one of the hybrids was collected and seed viability was considered low at 3.8% (508).

Habitat and Environmental Conditions

Saltcedar can be found in disturbed and undisturbed sites. It is primarily associated with wet environments or high water table areas such as streams, waterways, bottomlands, drainage washes, moist rangelands and pastures, and lakeshores. Saltcedar, as the name implies, can grow in salty environments reported to be up to 15,000 ppm (parts per million) soluble salt and can tolerate alkaline conditions. Alkaline conditions are common in the Great Basin of the western United States (501, 502).

Reproduction and Adaptive Strategies

Saltcedar, once established, is drought tolerant and can withstand detrimental reduction in ground water greater than cottonwoods and willow where they are competitively growing in riparian areas. Anthropogenic flow regulations can lower the water table and provide saltcedar with a competitive advantage (502, 507).

An Arizona study reported *Tamarix pentandra* exists and thrives in saline conditions that prevent other species from establishing. It is thought the adaptive mechanism is the ability to exude salt through salt glands, reducing solute concentrations at the evaporating surfaces. Apparently the active salt glands are not part of the vascular

bundles, but are primarily desalting organs reducing salt concentrations at the surface of the leaf mesophyll cells. The salt glands are an efficient adaptation for desalting available water used by the plant. Another report states saltcedar draws salt up from deep in the soil and deposits it at the surface. This creates a changed environment that native plants may not survive in (506, 509).

Young plants subjected to alluvial deposits can have lower branches buried, which in turn will produce new plants along the entire length. This adaptation allows for clonal colony expansion (507).

Saltcedar can withstand submersion for up to 3 months and survive prolonged droughts where deep ground water is available (509).

Fire may assist saltcedar expansion by consuming its litter and salinizing the soil. Saltcedar re-sprouts readily from underground parts (509).

Limitations
Shading by plains cottonwood (*Populus deltoides*) canopies reduced saltcedar vigor, growth form and densities in Montana (507).

Uses and Values
Saltcedar has some limited practical uses and provides some wildlife habitat, while providing little direct food value for wildlife.

Human Use. Saltcedar was imported as an erosion control plant and for windbreaks. It has been used and continues to be sold as an ornamental plant for landscaping (503, 505, personal observation).

Wildlife Use. Wildlife association with saltcedar is largely associated with food sources near by (insect and seed) or present (insects), and by the microclimate characteristics and the structure provided by the shrub-like plant (503, 513).

In some instances saltcedar can provide a habitat type that wasn't present or most likely wouldn't develop. This is due to saltcedars ability to grow in saline soils where other shrub species may not grow and by trapping sediments and through accretion enlarge banks and islands increasing available habitat. This also increases water consumption and narrows stream beds reducing the water holding capacity. Saltcedar was considered "better than nothing" in one report (503, 509, 511). Saltcedar in Utah marshes is used by mule deer *Odocoileus hemionus* for cover and shade (personal communiqué Val Bachman).

Conflicting information is reported in the literature on bird use, species richness and species diversity in association with saltcedar. There is a trend that indicates birds will use saltcedar and individual specie numbers (density) may actually increase with increased opportunity created by the availability of more plants in dense stands. There is also a trend that fewer bird species are likely to be encountered in saltcedar stands and the composition may change from what would be there with native plants present.

One bird was identified as being attracted to saltcedar, Abert's towhee (*Pipilo aberti*) (503, 509, 511, 512).

The yellow-billed cuckoo (*Coccyzus americanus*) candidate for the federal endangered species list, prefers native forests, but has used saltcedar stands on the Pecos River. The endangered southwestern flycatcher (*Empidonax traillii extimus*) uses saltcedar. It is reported that patch size, plant phenology and stature, proximity to water, microclimate conditions and rainfall patterns determined use. This has curtailed control efforts in areas known to be used by the southwestern flycatcher. It is suggested saltcedar habitat is still inferior to native habitat and sequential control should be initiated along with restoration activities to replace saltcedar stands with more desirable native trees that southwestern flycatchers traditionally used. This would be over an extended time frame to allow sufficient development of restored forests to reach the maturity required. Re-vegetation efforts may require irrigation and other manipulations to increase establishment in what are now modified environments created by saltcedar infestation (503, 509, 512).

It was stated that some small mammal species, such as deer mice (*Peromyscus* spp.), might actually increase in saltcedar stands (503).

A saltcedar control project in New Mexico on the Bosque del Apache National Wildlife Refuge reported, from 5 years of monitoring, a doubling of avian richness and higher reptile and amphibian species richness than other riparian areas on the refuge. This demonstrated the potential loss of species richness with infestations of saltcedar (504).

Insects Use. Saltcedar is used by numerous insects, which in turn can become food resources for birds. Anthropods, predator and detritivores, use saltcedar as a substrate. Few native insects feed on saltcedar with a noted exceptions being Apache cicadas (*Diceroprocta apache*) (503).

Bees, wasps and butterflies are attracted to saltcedar during pollination, which may occur for several months (503).

An introduced leafhopper (*Opsius stactogalus*) is closely associated with saltcedar in North America. This insect is an important prey item for some birds. There is evidence that birds and small mammals will feed on the introduced leaf-beetle (*Diorhabda elongata*), which is being used as a biocontrol agent (503).

Other. Saltcedar traps sediments and in some cases may reduce channel erosion by increased sediment deposition. Sediment buildup may also create “new land” where cottonwoods and willows might expand (511).

Risk and Impacts

Saltcedar can have positive aspects as well as negative ones. Over the past 50 years it is reported to have invaded 470,000-650,000 hectares (1,161,395-1,606,185 acres) in 23 states in the United States, having increased by as much as 200,000 hectares (~500,000 acres) in the 1990’s alone (505).

Saltcedar is a fire-adapted species, re-sprouts easily and is a high consumer of water. It alters native environments with increases in salt deposits near or on the surface and competes directly for nutrients and water. It can increase flood events by growing in thickets in old channels or by narrowing existing flowing streams and reduce flow capacity. It is believed that control of saltcedar will increase available water and increase flow in affected areas. It is reported to alter wildlife use, diversity and abundance, in some cases, and displace native vegetation, increase soil salinization and create significant economic loses (501, 503, 509).

There is considerable discussion in the literature that increasing available water with saltcedar removal may or may not be significant. The terms “salvage” water and “marginal water” are use to identify water being consumed by saltcedar that might be maintained in the system if saltcedar was removed. Estimates that have been reported for evapotranspiration (ET) rates for saltcedar are 0.7 to 3.4 meter per year. One recent study compared various methods for estimating water use. The following rates are reported using the eddy covariance method for determining ET rates. Saltcedar ET rates was 0.7-1.2 meters/year, cottonwood ET rate was reported as being 1.0-1.2 meters/year, mesquite ET rate of 0.6-0.7 meters/year, and annual weeds, grasses and bare soil ET rate was reported to be 0.6-0.7 meters/year. Water salvage when calculated should be -0.5 (i.e., increased water consumption by natives) to 0.6 meter/year with removal of saltcedar. Another study measured water salvage at 0.5 ± 0.15 meters/year when replacement of saltcedar was by bare ground or sparse annual weeds (501, 503, 509, 510, 511).

Saltcedar in one report was considered not to be a prodigious water user, about 2.5 acre-feet/year (326,000 gallons). It was stated it might actually use less water than other riparian trees. Cottonwood was reported to use about the same as saltcedar when they are growing at the waters edge and willow uses more at about 4 acre-feet /year (521,600 gallon) and mesquites use 3 acre-feet/year (391,000 gallons). However, because saltcedar grows in thick stands it uses more water than open woodland trees such as cottonwood and mesquite (511).

The economic impact of saltcedar is significant. An estimate of annual impacts of saltcedar to the United States was reported as $280-$450 per hectare ($110-$180/ acre). Eradication and restoration cost estimates for saltcedar were reported at $7,400 per hectare ($3,000/acre). It was estimated that eradication and restoration costs would be recovered within 17 years, after which the benefits would continue to accrue. The two costs associated with benefits were the cost to replace loss to water supplies and costs for flood protection associated with infestations of saltcedar for the analysis of this study. Other cost-benefit values not calculated or considered in the analysis were decreased salinity and groundwater pumping costs, improved recreational opportunities, crop pollination, and wildlife habitat quality. This study calculates marginal water losses to be 3000-4000 cubic meters per hectare per year (42,900-57,000 cubic feet/acre/year) more water use by saltcedar than native vegetation that it replaced. It was reported that saltcedar is costing the western United States 1.4-3.0 billion cubic meters (49-106 billion cubic feet) of water every year. In dry areas this is considered a major loss of significant importance with high associated costs to replace lost water. California and Arizona

municipal water costs for lost water due to saltcedar is estimated at $26-$67 million. Crop water loss based on the lowest water values to crop weighted values is estimated at $38-$120 million and hydroelectric generation losses are estimated at $16-$44 million per year. This totals $127-291 million in lost ecosystem services from saltcedar in the western United States. Flood damage estimates are $52 million based on 1998 values (509).

Invasion and Expansion
Saltcedar produces copious amounts of small seeds throughout the growing season. Wind, water, animals and human activity disperse the seeds. The seed are contained in a capsule, which has a small tuft of hair that aids in wind dispersal (501, 502, 507, personal observation).

Saltcedar can spread vegetatively from burial of lower branches by alluvial deposits and develop roots and shoots along the entire branch. It has adventitious roots and submerged stems develop into clones (501).

Saltcedar can invade disturbed sites, typically caused by processes that altered natural hydrologic and geomorphic processes or by land uses such as livestock grazing, land clearing, and groundwater pumping. It can also invade and infest pristine areas (503).

Control Methods
Saltcedar is an expensive and difficult plant to eradicate. It requires a long-term commitment and constant monitoring. In many cases it will require restoration efforts to reestablish desirable plants. Without active restoration efforts re-invasion is likely. In saltcedar infestation areas soil salts have most likely increased and water depths may be lower than before invasion. These environmental conditions will require mitigating activities to establish desired native plant species in adequate abundance to reduce re-invasion potential and develop quality habitats. The methods of control are mechanical, chemical and biological and most likely will require some of each to eradicate or contain infestations of saltcedar (501, 503, 504).

Saltcedar control cost estimates range from $750-$1300/hectare ($300-$525/acre) for herbicide, mechanical and burning operations, based on 1991-1998 dollars (503, 504). Whatever treatment or combination of treatments is selected it is important to plan for follow-up treatment the next year and it is suggested the area be retreated on a 3-year cycle following that (512).

Chemical. For saltcedar control a systemic herbicide is recommended and application methods include foliar sprays, cut stump treatments, basal bark treatments, and aerial sprays. Suggested chemicals are imazapyr (Habitat), or a mixture of imazapyr and glyphosate for foliage treatment, or triclopyr (Garlon) for stump treatment (note: ester formulation of triclopyr is regarded as slightly toxic to birds and mammals and highly toxic to aquatic organisms). Success was reported as 93%-95% control with imazapyr, or imazapyr mixed with glyphosate, on foliage applied with fixed wing aircraft. Imazapyr mixed with glyphosate applied by helicopter was reduced to 76%, while imazapyr alone applied by helicopter achieved 90%-95% plant mortality (503).

Mechanical. Hand pulling, root cutting, stump cutting or bulldozing is reported as mechanical methods used in the control of saltcedar. Hand removal is recommended on small infestations and on plants with stems less than 1 inch in diameter (2.54 cm). The problems identified with mechanical treatments are the disturbance created by equipment and the costs. Re-sprouting is mentioned as being somewhat common. Removal of root crowns is critical to improving success in mechanical treatments with heavy equipment. Burning slash pile should be a part of mechanical removal activities. Burning of litter may salinize the soils in the immediate area of the burn (501, 503, 509).

Fire. Fire has been used to control saltcedar, but the plant is considered to be fire-adapted and can readily re-sprout after a burn (510).

Water Level. Saltcedar has been reported to be killed by prolonged flooding for a continuous period of at least 3 months. The months identified to flood saltcedar are June-September (501, 502).

Insects. For saltcedar fifteen insects have been investigated as potential biological control agents. As of May 2005 two had preliminary approval for release, a mealybug (*Trabutina mannipara*) and the chrysomelid leaf beetle (*Diorhabda elongata* Brulle´ *deserticola* Chen*)*, and 5 others are being tested in the United States and 8 are being tested overseas. Over 15 years of overseas and quarantine testing was required for approval by the Animal Plant Health and Inspection Service (USDA, APHIS) to release insects to control saltcedar. The leaf beetle was released into the open in 2001 (501, 503 514, 515).

The leaf beetle, *Diorhabda elongate*, has established self-sustaining population north of the 38th parallel, but developmental asynchrony with seasonal day length has limited success of population to the south. At day length of 14 hours 30 minutes or less, adults stop reproduction and enter diapause. More southerly species in Eurasia are being investigated for testing and introduction for control of saltcedar in southern latitude sites of North America (503, 514, 515).

Saltcedar defoliation is caused by the leaf beetle and hundreds to thousands of acres have been affected in the northern latitudes, but southern latitudes where much of the saltcedar infestation occurs have failed to reproduce significantly to affect the plants. Some areas have had partial and repeated refoliation and this suggests control may be a gradual and heterogeneous process. The potential benefits of biocontrol have been demonstrated with some dramatic successes in some areas (503, 515).

Assessment and Monitoring

Monitoring is a critical element of any weed control plan. Monitoring can be expensive and time consuming. New methodology is continually developing to increase sensitivity and effectiveness of monitoring. Advanced Visible and Infrared Imaging Spectrometer (AVIRIS) is one that has been tested on saltcedar infestations. This involves the use of high spatial (0.5 meter or 1.6 feet) and high spectral (4 nm) resolution imagery (510).

Bibliography for Saltcedar Information Sources

#501 Saltcedar, *Tamarix aphylla*, *T. chinensis*, *T. gallica*, *T. parviflora*, and *T. ramosissima*, Tamarisk family (Tamaricaceae)
Rose-Marie Muzika & Jil M. Swearingen
20 May 2005
Plant Conservation Alliance®s
http://www.nps.gov/plants/alien/

#502 Ecological strategies for managing tamarisk on the C.M. Russell National Wildlife Refuge, Montana, USA
Peter Lesica & Scott Miles
Biological Conservation 119 (2004) 535–543
www.elsevier.com/locate/biocon

#503 Control of Tamarix in the Western United States: Implications for Water Salvage, Wildlife Use, and Riparian Restoration
Patrick B. Shafroth, James R. Cleverly, Tom L. Dudley, John P. Taylor, Charles Van Riper III, Edwin P. Weeks & James N. Stuart
Environmental Management Vol. 35, No. 3, pp. 231_246, March 18, 2005

#504 Restoration of Saltcedar (Tamarix sp.)-Infested Floodplains on the Bosque del Apache National Wildlife Refuge
John P. Taylor & Kirk C. McDaniel
Weed Technology, Vol. 12, No. 2. (Apr. - Jun., 1998), pp. 345-352.

#505 Importing exotic plants and the risk of invasion: are market-based instruments adequate?
Duncan Knowler & Edward Barbier
Ecological Economics 52 (2005) 341– 354

#506 Osmotic Water Stress: Mesophyll Saturation Deficit and Transpiration Rates of Tamarisk
Arnett C. Mace, Jr.
The Southwestern Naturalist, Vol. 16, No. 1. (Jul. 23, 1971), pp. 117-120.

#507 Tamarisk Growth at the Northern Margin of its Naturalized Range in Montana, USA
Peter Lesica & Scott Miles
Wetlands, Vol. 21, No. 2, June 2001, pp. 240–246
2001, The Society of Wetland Scientists

#508 Hybridization of Tanarisx ramosissima and T. chinensis (Saltcedars) with T. aphylla (Athel) (Tamaricaceae) in the Southwestern USA Determined from DNA Sequence Data
John F. Gaskin & Patrick B. Shafroth
MADRON˜ O, Vol. 52, No. 1, pp. 1–10, 2005

#509 The Economic Value of Controlling an Invasive Shrub
Erika Zavaleta
Royal Swedish Academy of Sciences 2000, Ambio Vol. 29 No. 8, Dec. 2000

#510 Detecting Tamarisk species (Tamarix spp.) in riparian habitats of Southern California using high spatial resolution hyperspectral imagery
Yuki Hamada, Douglas A. Stow, Lloyd L. Coulter, Jim C. Jafolla & Leif W. Hendricks
Remote Sensing of Environment 109 (2007) 237–248

#511 Tiff over Tamarisk: Can a Nuisance Be Nice, Too
Jeffrey P. Cohn
Bioscience, August 2005/Vol. 55 No. 8, 648-654

#512 Vegetation Response Following Invasive Tamarisk (Tamarix spp.) Removal and Implications for Riparian Restoration
Rebecca S. Harms and Ron D. Hiebert
September 2006 Restoration Ecology Vol. 14, No. 3, pp. 461–472

#513 Use of Exotic Saltcedar (Tamarix chinensis) by Birds in Arid Riparian Systems'
William C. Hunter, Robert D. Ohmart & Bertin W. Anderson
The Condor 90: 113-l 23, 1988

#514 Diapause in the Leaf Beetle *Diorhabda elongate* (Coleoptera: Chrysomelidae), a Biological Control Agent for Tamarisk (*Tamarix* spp.)
Daniel W. Bean, Tammy Wang, Robert J. Bartelt & Bruce W. Zilkowski
Environ. Entomol. 36(3): 531Ð540 (2007)

#515 Seasonal Timing of Diapause Induction Limits the Effective Range of *Diorhabda elongata deserticola* (Coleoptera: Chrysomelidae) as a Biological Control Agent for Tamarisk (*Tamarix* spp.)
Daniel W. Bean, Tom L. Dudley & Julie C. Keller
Environ. Entomol. 36(1): 15Ð25 (2007)

Sources of Unpublished Material

Val Bachman, Personal Communication, Wetland Manager, Utah Division of Wildlife Resources, Ogden Bay Waterfowl Management Area, Utah

Steve Dewey, Personal Communication, Utah State University, Extension Weed Specialist

Part VI: Dyer's Woad
Isatis tinctoria L.
Species-Specific Control and Containment Strategies

Dyer's Woad Treatment Plan Objectives
Several years ago, the DWR implemented a treatment method for controlling and containing dyer's woad. Although present infestations and plant densities do not pose a great threat to the WMAs, the agency plans to totally eradicate dyer's woad.

Dyer's Woad Treatment Plan
The DWR will eradicate dyer's woad using these treatment methods.

Strategy AA: Herbicide treatment

To control dyer's woad, Strategy AA is to continue using metsulfuron (Escort); chlorsulfuron (Telar); Weedmaster; 2,4-D ester and amine; and glyphosate. The agency will apply these herbicides in April and May and on rosettes in the fall, around the end of September.

NOTE: Because choosing an herbicide depends on a treatment site's intended use, the DWR recommends consulting with Utah State University Extension personnel or a chemical company representative before applying any herbicide. The agency also recommends following all product safety instructions.

Strategy BB: Biological control with rust fungus

When necessary, Strategy BB requires applying rust fungus (*Puccinia thlaspeos)* to growing dyer's woad and in infested sites. Most likely, this treatment will be in solution form. The agency will take all necessary precautions to use this product safely.

Strategy CC: Integrated management with herbicide, mowing, and livestock grazing

Strategy CC is only for sites sufficiently infested with dyer's woad where the DWR can implement mowing or sheep grazing. When performed repeatedly over several years, mowing has been successful in some treatment sites. Similarly, sheep grazing has reduced dyer's woad in heavily infested sites. However, if these methods are insufficient, the agency will apply herbicide to contain dyer's woad.

Assessment and Monitoring
Early spring and fall monitoring are, and will continue to be, part of the DWR's management practices. The agency will collect GIS points for dyer's woad infestation sites and will use ARCGIS software to map these sites. The agency will also use ocular methods to estimate the size of infestations then record this information, along with notations about herbicides, application rates, and application dates. After annually

revisiting treatment sites, the agency will report observed results and file documents in WMA weed control files.

Literature Review of Dyer's Woad Information Sources

Weed Species: Dyer's Woad (*Isatis tinctoria*)

Taxonomy (602, 605)
Mustard Family: Brassicaceae
Genus: *Isatis*
Species: *Isatis tinctoria*

Distribution
Dyer's woad is a serious problem in the western states of Utah, Idaho, Wyoming, California, Oregon, Montana and Nevada. Dyers woad exists in the eastern states of New York, New Jersey, Virginia, West Virginia and Illinois, where it is considered less of a nuisance (601, 602).

History in North America
Dyer's woad is considered to be originally from Russia and was introduced in the United States in the 1700's. It was introduced as an herbal medicinal plant and as a source for blue textile dye. Dyer's woad has been used since pre-Christian times and is still cultivated for use by Dyers and herbalists (601, 606).

It was accidentally spread to California and Utah as a seed contaminate and as a horticultural and medicinal plant. The spread continued into adjacent western states (601).

Description
Dyer's woad is a diverse plant that can grow as a biennial, short-lived perennial or winter annual (602, 606, 608). It begins growth in the fall as a small rosette and generally doesn't flower until the second year (606). The plant can grow to a height of 4 feet (1.2 meters). Roots can grow to a depth of 5 feet (1.5 meters). Growth of the stem is from the center of basil leaves and doesn't branch until near the top where abundant bright yellow flowers are formed.
Flowers are ¼ inch (0.6 cm) wide and grow in flat-topped clusters developing in May and June. This gives way to a black or purplish brown teardrop seeds hanging or dangling in a pendulum fashion. Each pod up to ¾ inch (1.9 cm) in length contains one seed. Leaves are alternate, simple petiolate and are bluish-green with prominent whitish mid-vein and are up to 8 inches long (20.3 cm) (602, 605).


Dyer's Woad
Photo by Randy Berger

Habitat and Environmental Conditions
Dyer's woad grows in sandy, rocky, dry disturbed and undisturbed sites. Typically it can be found in rangelands, forests and uncultivated areas such as right-of-ways and

roadsides. It will invade cultivated areas when cultivation is not an annual event (602, 605, 606).

Reproduction and Adaptive Strategies
Reproduction is by seed. A single plant can produce up to 10,000-15,000 seeds with a reported average of 383 per plant. Dispersal of seed is by wind, water, animal and human (601, 602, 603).

Dyer's woad releases a chemical that can inhibit the germination of other plant seeds, allelopathy (605).

Dyer's woad has been measured in the Pacific Northwest to spread 14% annually on Bureau of Land Management rangelands and reduce grazing capacity by 38% (606, 608).

Uses and Values
Dyer's woad has and continues to be used for the creation of blue dye and for herbal medicinal uses. Dyer's woad has been used since pre-Christian times and is still cultivated for use by Dyers and herbalists (601, 606). Dyers woad was introduced into Virginia and cultivated for a blue dye (602).

Risk and Impacts
Dyer's woad impacts livestock and wildlife forage production. It out-competes native and annual grasses, and other native plants. It alters the natural plant community (602, 604, 606).

Invasion and Expansion
Dyer's woad invasion is from seed transport and expansion of an infestation is from dispersal of seed in the immediate area. This plant has the adaptation to grow in alkaline soils and arid conditions, two conditions found in the western United States. In Montana an infestation spread from 0.8 to 40.5 ha in 2 years. Plant growth characteristics provide some competitive advantage such as the ability to accelerate growth rate, up to 10cm in 1 week, from rosette to flowering stages (601).

Control Methods
Control is not the same as eradication. Control is containment of large infestations and reduction of the population to an acceptable level. Eradication implies the complete elimination of plants, propagules and seed from the site (601).

Any weed program should consider four key elements: early detection, treatment technologies, repeat site visitation with site monitoring, and education. Repeat treatment is likely in order to reduce the seed-bank (601).
Prevention by early detection, surveillance and treatment can significantly reduce efforts later on (606).

Chemical. Herbicide application can be an effective control method for Dyer's woad. Timing of application is important. Most chemicals recommended for control are to be

applied in spring prior to bud or flower stage or in fall on the rosettes (601, 602, 603, 604).

The following chemicals and application rates are suggested:

- Metsulfuron applied at 70 g ai per hectare plus nonionic surfactant or 0.3 to 0.6 oz (0.5-1 oz Escort) per acre applied during pre-emergence to bloom stage in spring with the following caution, extremely long lasting in soil, crop rotation restrictions apply (602, 604, 605, 606).

- Chlorsulfuron applied at 0.75 to 2.25 oz (1-3 oz Telar) per acre, applied during per and post emergence and is best on actively growing weeds with the following caution, non-cropland use only with several restrictions (603, 604, 605, 606).

- Telar (chlorsulfuron) has a pasture and cropland label that can be used according to the label recommendations (Personal communiqué, Steve Dewey). A non-ionic surfactant is recommended with Chlorsulfuron and Metsulfuron at a rate of 0.25% v/v (604).

- Weedmaster is recommended at a 2 oz per acre application rate in the early spring and fall (603).

- 2, 4-D LV ester applied at 2.0 lb ae per acre during the spring and fall to rosettes and early summer in bud stage, caution to avoid drift to sensitive crops (602, 605, 606). A 1 % solution is recommended for spot treatments and 1.9-2.85 lb ae per acre is recommended for heavy infestations (602).

- Glyphosate (Roundup) was mentioned, but no rate was recommended (605).

Caution: Whenever applying herbicide always follow the manufactures directions and recommendations. Safety and proper use are paramount to any project.

Mechanical. It is recommended that Dyer's woad be pulled, root and all, or cut below the crown, if not, re-growth can occur from remaining root material. A combination of cutting and removal of flowering or seedpods and spot spraying basal leaves with herbicide is considered an effective treatment. Multiple treatments may be required and monitoring treatment areas is important (601, 602, 603, 605, 606).

Grazing. Sheep will graze Dyer's woad during the bloom stage and readily remove most of the upper leaves and flowers. The result has been reduced plant production of seed and overall decline in the density of plants over the four years observed (personal observation).

Biological or Pathogen Control. No known insects are approved to work as biological control for Dyer's woad. A Eurasian rust fungus, *Puccinia thlaspeos* C. Schud, can effect seed production and can increase mortality in rosettes and seedlings. The rust is a systemic entering through the leaves. A product called Woad Warrior can be applied

in a solution or dry. It should be applied in April or May to existing plants. Symptoms may not be evident until the second year. In heavily infested areas repeat treatment in subsequent year is advised (602, 603, 606, 607).

Bibliography for Dyer's Woad Information Sources

#601 Evaluationg Montana's Dyer's Woad (Isatis tinctoria) Cooperative Eradication Projcet
Monica L. Pokorny & Jane M. Krueger-Mangold
Weed Technology 2007, 21:262-269

#602 Dyer's Woad Isatis tinctoria L.
Weed of the Week (WOW) 08-30-06
USDA Forest Service, Forest Health Staff, Newtown Square, PA.
Invasive Plants website: http://www.na.fs.fed.us/fhp/invasive_plants

#603 Dyer's Woad (Mustard Family)
Unknown author
Unknown Publication

#604 Dyer's Woad (Isatis tinctoria)
Unknown author,
http://www.ag.state.co.usc/csd/weeds/mapping/countyprograms.html
Colorado Department of Agriculture

#605 Common Weeds of Utah Forests
Morgan Mendenhall
Utah State University Extension, NR/FF/012

#606 Recognition and Control of Dyers Woad in Nevada
Jason Davison
Cooperative Extension, Fact sheet 99-90
University of Nevada, Reno

#607 Woad Warrior for control of Isatis tinctoria-dyer's woad
EPA reg. No. 73417-1, EPA Est. No. 73417-UT-1
Puccinia thalaspeos "strain woad" on rust-infected pieces of dyer's woad

#608 Satellite Remote Sensing to Predict Potential Distribution of Dyer's Woad (Isatis tinctoria)
Steven A. Dewey, Kevin P. Price & Doug Ramsey
Weed Technology 1991, Volume 5:479-484

Sources of Unpublished Material

Steve Dewey, Personal Communication, Utah State University, Extension Weed Specialist

Part VII: Canada Thistle, Bull Thistle, Musk Thistle, and Scotch Thistle
Cirsium arvense, *C. vulgare*, *Carduss nutans,* and *Onpordum acanthium*
Species-Specific Control and Containment Strategies

Thistle Treatment Plan Objectives

Thistle is widespread on the WMAs, scattered throughout dikes, roadsides, and water delivery ditches and uplands. Although plants have some positive effects, the DWR will inventory and repeatedly treat these areas to control and contain thistle. The objective is to reduce invasive thistle populations to two percent or less of the available compatable WMA's acreage.

Numerous native thistle species are not noxious or problematic. Land managers should learn to recognize target species and avoid treating native noninvasive species.

Thistle Treatment Plan

The DWR will use the following treatment methods to control and contain thistle.

Strategy AA: Herbicide treatment

Strategy AA, the agency's treatment method of choice, is to apply herbicide to thistle in the spring, summer, and fall. The agency will experiment with these herbicides to determine best results: Dicamba (Vanquish, Banvel, or Clarity); triclopyr (Garlon or Crossbow); triclopyr plus 2,4-D (Weedmaster or Brash); aminopyralid (Milestone); metsulfuron (Escort or Cimarron); chlorsulfuron (Telar); clopyralid (Transline); clopyralid plus 2,4-D (Curtail); picloram (Tordon); and glyphosate. Thistle infestations, especially Canada thistle, will require multiple treatments. To reduce the possibility of seed maturing before dying of herbicide, the agency will target thistle during the rosette stage or mature plants prior to flowering.

NOTE: Because choosing an herbicide depends on a treatment site's intended use, the DWR recommends consulting with Utah State University Extension personnel or a chemical company representative before applying any herbicide. The agency also recommends following all product safety instructions.

Strategy BB: Integrated management with herbicide, livestock grazing, tilling, and planting

For strategy BB, the DWR will use herbicide, livestock grazing, tilling, and planting to create a healthier, more productive competitive plant community. Initially, the agency will apply herbicide to degraded habitats infested with thistle then use tillage equipment to prepare a seedbed for planting a mixture of highly competitive grasses and forbs. The agency will investigate these grasses and forbs:

- Intermediate wheatgrass (*Agropyron intermedium* Host)
- Russian wildrye (*Elymus junceus, Fish*.)
- Tall fescue (*Festuca arundinacea Screb*.)
- Western wheatgrass (*Agropyron smithii Rydb*.)
- Smooth bromegrass (*Bromus inermis* Leyss.)
- Timothy (*Phleum pratense L.*)
- Orchardgrass (*Dactylis glomerata L.*)
- Redtop (*Agrostis alba L.*)
- Sweetclover (*Melilotus indica All*.)
- Alfalfa (*Medicago sativa L.*)
- Hybrid wheatgrass (*Agropyron repens L*. and *Beauv. X Agropyron spicatum Pursh. Schrib F* hybrid)

After applying the initial herbicide treatment (glyphosate for complete renovations) and tilling, the agency may need to mow and repeat tilling through the summer months. Planting the mixture of grasses and forbs will take place in the fall, and, in some cases, the agency will split planting, grasses in the fall and forbs in the spring. Following planting, and until planted species are successfully established, thistle may require weed control herbicides or repeated mowing in habitats where herbicides will damage young, sensitive desirable plants.

Once the agency establishes competitive desirable plants, livestock grazing will stimulate the growth of grasses and forbs and reduce annual weeds and any surviving thistle. The agency will use high-intensity, low-frequency grazing during the growing season and monitor treatment sites to identify forage and the introduction or reestablishment of thistle species.

The agency will re-visit treatment sites to prevent re-sprouting and will hand pull or dig single plants or small thistle infestations.

Assessment and Monitoring
Early spring and summer monitoring are, and will continue to be, part of the DWR's management practices. The agency will collect GIS points for thistle infestation sites and will use ARCGIS software to map these sites. The agency will also use ocular methods to estimate the size of infestations then record this information, along with notations about herbicides, application rates, and application dates. After annually

revisiting treatment sites, the agency will report observed results and file documents in WMA weed control files.

Literature Review of Thistle Information Sources

Weed Species: Thistle spp.; *Cirsium* is derived from the Greek *kirsos,* a swollen vein, referring to the effect when pricked by the spines and the species name is from the Latin *vulgare* and means “common.”

Taxonomy (105, 701, 703, 707, 710, 711, 723)

Family: Asteraceae (Compositae)
Tribe: Cardueae
Genus: *Cirsium*
Species: *Cirsium vulgare* (Savi) Tenore, Bull thistle
Common Names: England refers to it as “spear thistle” even today. Other common names are bank thistle, bell thistle, bird thistle, blue thistle, button thistle, burr thistle, common burr thistle, horse thistle, lance leaved thistle, plume thistle, and roadside thistle

Family: Asteraceae (Compositae)
Tribe:
Genus: *Carduus*
Species: *Carduus nutans* L., Musk thistle
Common name: Nodding thistle

Family: Asteraceae (Compositae)
Tribe:
Genus: *Onopordum*
Species: *Onopordum acanthium* L., Scotch thistle

Family: Asteraceae, Sunflower Family, (formerly Compositae)
Tribe: Cynareae
Genus: *Cirsium*
Species: *Cirsium arvense* (L.) Scop., Canada thistle

Distribution

Bull Thistle. Bull thistle is native to Europe and can be found from Britain and Siberia north to Scandinavia and west to western Asia, including the Balkans, Asia Minor, Turkish Armenia, Kurdistan, Iran, and Chinese Turkestan, and south to northern Africa. In the North America, where it was introduced, it is found in all 48 of the United States, as well as Hawaii and southeastern Alaska, and southern Canada. It has been introduced to Australia, New Zealand and temperate South America, primarily Argentina and Chile, and to the Arabian Peninsula, east Africa and Southern Africa. Bull thistle has become naturalized and widespread on every continent except Antarctica (701, 703, 730).

Musk Thistle. Musk thistle is a native of western Europe and was introduced to the United States and is reported to occur in all states except Maine, Vermont, Florida and Hawaii (707).

Scotch Thistle. Scotch thistle is a weed of central Asia, southern Europe and Asia Minor and was introduced to the United States and reported to be well established in the western states (708).

Canada Thistle. Canada thistle is considered native in temperate regions of Eurasia. It was introduced in the United States and Canada (hence the name). It can be found in 43 states from California, the Pacific Northwest, to Maine, south to Virginia and in the Midwest and Plain states (711).

History in North America

Bull Thistle. Bull thistle was introduced in the North America in the late 1800's through the major shipping port in Portland, Oregon. It was reported in Canada in 1821. Seed was collected in 1882 from The Dalles in Oregon, which is the earliest western record. It is thought to have been introduced in the southwestern United States after 1824 from evidence of seed found in adobe bricks used in mission buildings. The most recent report of new invasions was 1987 in Gillespie County, Texas (701, 704).

Musk Thistle. Musk thistle was introduced into the eastern United States in the early 1800's. The first records are from Pennsylvania between 1853 and 1866 and were first discovered in Davidson County, Tennessee in 1942 (707, 727).

Scotch Thistle. Scotch thistle was introduced into the United States the 1800's (726).

Canada Thistle. Canada thistle is though to have been introduced in North America in the early 17th century in Canadian French settlements. It was also directly introduced to the Eastern United States and legislation to control this species was enacted in Vermont in 1795 and New York in 1831 (704).

Description

Bull Thistle. Bull thistle is a prickly annual or biennial species that reproduces by seed only and appears bushy. Its signature is the winged stem with long pointed spines and spiny leaf surface on mature plants. The erect, hairy and stout, spiny winged stems can reach 2 meters in height (6 ½ feet) and are branched. Root systems are made up of several primary roots with numerous lateral smaller roots. Mature plant leaves are green and covered with coarse hair on the upper side and have gray and woolly hairs on the

Bull Thistle
Photo by Randy Berger

underside. The leaves are coarsely lobed, short and broad. The deeply lobed stem leaves are alternate, lanceolate, pinnatifid and usually under 30 cm in length (12 inches). The long yellow spines extend from the mid-rib and at each lobe. The spiny margins extend beyond the stem attachment to form a very prickly stalk. Leaf bases extend downward on the stem to form long wings (701, 703).

The compact flower is large, purple and borne singly at the tip of a stem. Each flower can produce up to 250 light straw colored seeds. Each flower head is made up of numerous, fragrant, purple, or reddish-purple, compact tubular florets packed tightly into a composite flower head. Mature plants have been reported to produce upwards of 4,000-8000 seeds. The fruit (achene) is shiny, nearly smooth, yellow or yellowish-brown with grayish-black stripes and is elongated to 4 mm (5/32 inch). The plumes pappus is comprised of soft white-branched hairs with bristles united at the base that dehiscent together as the achene matures. Winds have been reported to carry seed over several kilometers distance from the parent plant. On average a bull thistle plant produces 100 seed heads, but some have reached 350 under favorable conditions. Once seed-set has occurred the plants die. Seed shows little tendency to dormancy with germination upwards of 90% over a period of 1 week. Seeds remain viable for 1 year or longer and in soil a small amount of seed may be viable for up to 5 years. Rodents are reported to consume about 20% of available bull thistle seed. Germination in the summer and fall is related to moisture (702, 703, 705, 730).

Seedlings of bull thistle form rosettes up to 65 cm in diameter (25 ½ inches). A stout fleshy-branched taproot develops and penetrates deeply in the soil. The rosette is oblanceolate to elliptical with coarsely toothed green leaves about 30 cm long (12 inches). The leaves are lance-shaped, slightly indented and woolly and grayish on the underside. Plants bolt the second year in most instances. Rosette growth slows or can stop in winter and severe frost or drought may kill the rosette of bull thistle, but new growth can emerge from the rosette rootstock (701).

Musk Thistle. Musk thistle is a biennial herb. The stems are erect and multi-branched are 1 1/2 – 6 feet tall (0.5-1.8 meters). The smooth waxy surfaced leaves are dark green and coarsely lobed with yellowish to white colored spine at the tip. The flowers are large disk-shaped (1 ½-3 ½ inches in length or 3.8-9 cm), reddish-purple and are a composite of hundreds of tiny individual flowers. They occur at the tip of stems. Flower heads will droop up to 90-degrees from the stem, which gave them the name “nodding thistle”. A single flower head can produce up to 1200 seeds and a plant, which can have from 1-56 flower heads

Musk Thistle
Photo by Randy Berger

dependant on environmental conditions, has a potential to produce 120,000 seeds. The seeds are straw-colored and adorned with plume-like bristles. Seeds can be blown for many miles. Seeds may remain viable in the soil for over 10 years. Seedlings develop in mid to late July and rosettes can reach 4 feet in diameter (1.2 meters) (105, 707).

Scotch Thistle
Photo by Randy Berger

Scotch Thistle. Scotch thistle is generally considered a biennial plant. Mature plants have an erect and branched stem that can reach 8-9 feet in height (2.4-2.7 meters) and the plant can be 5-6 feet wide (1.5-1.8 meters). Under poor environmental conditions this plant may not exceed 1 foot in height (0.3 meters). The leaves are somewhat lobed with long stiff spines along the margins. The spiny margins continue down the stem as prominent spiny wings. The flower head is 1-½ inches across (3.8 cm) and is a composite of numerous purple flowers. The involucral bracts each taper to a stiff spine at the tip. The receptacle inside the flower head in *Onopordum* is deeply pitted or honeycombed, and without the hairs that are found on the flat receptacle in *Cirsium*. Scotch thistle plants can produce 100-50,000 seeds (cypselas) depending on the plant. Seeds can germinate rapidly or remain dormant in the seed bank for many years. One report had a 46% germination rate after 39 years. Seed germinated better when buried (18%) compared to laying on the soil surface (8%) and 77% germinated when buried in 3 cm (1 inch) of soil as opposed to 10% germination is seed buried in 15 cm (6 inches) of soil. Silt loam soil provided a better (17%) germination environment than sand (9%) (105, 708, 709, 726).

Canada Thistle
Photo by Randy Berger

Canada Thistle. Canada thistle is an herbaceous perennial plant. It has erect, branched, often slightly hairy and ridged stems 1 1/2 -4 feet in height (0.4-1.2 meters). Roots are extensive and creeping, and vegetative reproduction is common. This occurs due to the fibrous taproot that can send out lateral roots as deep as 3 feet (0.9 meter) below the surface. This lateral roots can send up shoots at frequent intervals creating clonal spread. Canada thistle can also regenerate from root material less than 1 inch in length (2.54 cm). A first year plant can have root spread up to 6 meters in diameter (19 ½ feet). The green leaves are lance-shaped, irregularly lobed with spiny, toothed margins and borne singly and alternately along the stem. The flowers can be

rose-purple, lavender or white and occur in rounded, umbrella-shaped clusters. The fruits (achene's) of Canada thistle are dry small and single-seeded and 1-1 ½ inch long (2.5-3.8 cm) and have a feathery structure attached to the seed base. A single female plant can produce 1,500-4,500 bristly-plumed seeds that are easily dispersed by wind. Many seed will germinate within a year, but some may last up to 20 years in the soil (105, 711, 722).

Canada thistle is dioecious (male and female plants) and populations do not require many male plants for seed pollination or may not include male plants if male plants are in nearby populations (722).

Habitat and Environmental Conditions

Bull Thistle. Bull thistle invades disturbed sites in pastures, arable fields, and poor rangelands, forest clear-cuts, along roads, ditches, fences and waste places. Bull thistle grows best in nitrogen-rich soils that are near neutral pH and have moderate moisture. It is typically absent from pure clays and is found in sand or soils with high humus content (701, 702, 703).

Musk Thistle. Musk thistle grows in disturbed sites and open natural areas such as meadows, prairies and grassy balds. It can spread rapidly in areas frequently disturbed by landslides or flooding, but does not grow well under excessively wet, dry or shady conditions. It can be found from sea level to 8,000 feet in elevation (2,400 meters). It grows in soils from near neutral to acidic pH (707).

Scotch Thistle. Scotch thistle grows in similar environmental conditions and locations as bull thistle, with the exception that it can grow in drier sites (708).

Canada Thistle. Canada thistle can be found in prairies, barrens, savannas, glades, sand dunes, fields and meadows that have been impacted by disturbance. It thrives in uplands and invades wet areas and stream banks (711).

Reproduction and Adaptive Strategies

Bull Thistle. Bull thistle produces phenolic acids that inhibit competing plants through allelopathic effects and serves as a defense against herbivores. Like other thistles covered in this document, bull thistle has spines that provide a defensive barrier. Seeds of bull thistle germinate rapidly exhibiting little tendency for dormancy, however exposure to wetting and drying cycles can initiate dormancy, ensuring intermittency of germination in time, which contributes to the success of the weed (702, 703).

Musk Thistle. Musk thistle is a monocarpic species requiring a cool period of vernalization, a minimum of 40 days below10 degrees Celsius (50 °F.) to bloom. It is very plastic in nature and in some studies has been reported to function as a true annual. It has also been reported as a winter annual. Some seeds can germinate without a period of dormancy. Musk thistle is a high seed producer.

This thistle extends seed production by flowering over a 7-9 week period (727, 728, 729).

Scotch Thistle. The seeds of scotch thistle have an extended germination period. The long dormancy is thought to reduce self-competition from dense infestations, which have been observed to die out and remain weed free for several years. It was reported seeds that ripen in warm conditions appear to have higher germinate in the year collected more so than seeds ripened in cooler temperatures, which emerged in later years. Some seeds require scarification while others do not (708, 709).

Canada Thistle. Canada thistle has a strong bias toward producing female progeny. To ameliorate the reduction of male plants in the population required for pollination, non-pollinated female plants stay receptive over a longer period of time. It is reported the reduction of seeds may be compensated by have larger sized offspring. Canada thistle also reproduces vegetatively, but one study reported seed was the primary source for expansion of populations. There are conflicting reports on which method of expansion is the most prevalent. Another study reported adventitious root buds as the primary expansion mechanism. Once Canada thistle is established localized spread can come from extensive spreading root systems (up to 6 meters or 19 ½ feet in the first year of growth) forming dense competitive clonal stands. Ecotypic variation (a subdivision of an ecospecies that survives as a distinct group through environmental selection and isolation) is common in Canada thistle and considered to be advantageous to expansion and survival (710, 720, 722).

A study of carbon dioxide use by plants as a possible reason for the rapid expansion and invasive growth rates was conducted for Canada thistle. When simulated CO2 rates at the beginning of the 20th century were compared with future estimated CO2 rates for the end of the 21st century Canada thistle showed an increase in biomass production of 76%. However, CO2 stimulation growth of Canada thistle was 180% when compared with levels at the beginning of the 20th century and current levels. This leads to the speculation that the increase of additional CO2 to the system will not have the same dramatic effect as the past increases have had for Canada thistle (714).

As with many plants Canada thistle has demonstrated the use of sucrose and inulin carbohydrates to supplement photosynthate in the spring for shoot growth. Replenishment of carbohydrates in the root material occurs in late summer and fall (715).

Limitations

Bull Thistle. Bull thistle does not grow well in shade and is not very drought tolerant. Damage by herbivores can substantially reduce seed production. One report indicated production declined by as much as 80%. Seed dispersal was reported to be 50% within 1 meter of the parent plant and only 11% was

dispersed outside the population. Rodents ate 60% of the dispersed seed. Only 1% of bull thistle seed was still viable after 1 year (703, 705).

Canada Thistle. Canada thistle pollination is sometimes inadequate and numerous seeds will be aborted. Cold temperatures and dry conditions can reduce Canada thistle survival. Depth in the soil of over wintering buds was considered important as well as surrounding environment (vegetation or lack of vegetation) and snow cover (increased insulation). For Canada thistle horizontal roots in the top 20-30 cm (8-12 inches) of soil were most vulnerable. The LD50 (lethal dose for 50% mortality) of Canada thistle was reported at -7C (19 degrees Fahrenheit) (710, 713).

Uses and Values

Human Use. Thistle species (*Cirsium*) have been used as medicinal herbs for centuries. They have been referred to the "holy thistle" for their supposed healing powers. Native North Americans used roots and leaves as food and when bull thistle was introduced they used the newly bolted stems raw or cooked as a food source. In Australia thistle roots have been sold commercially as rabbit bait (710).

Wildlife Use. Birds use thistle seed as a food resource. Bull thistle is referred to as "bird thistle". Goldfinches (*Carduelis sp*) are fond of bull thistle seed and use the thistledown in the construction of their nest, which has gained them the name of "thistle bird" (701).

Mice and voles are among the rodents that consume large quantities of available thistle seed (705).

Risk and Impacts

Bull Thistle. Bull thistle is reported as a serious weed in cereal crops in Italy, alfalfa crops in Argentina and rangelands, pastures, ornamentals and forest nurseries in the United States, and barley, corn, oats, sorghum, wheat, rice and pastures in Australia, and pastures in Hungary, wheat in Uruguay, and pastures and ranges in New Zealand, Tasmania and Scotland. Heavy infestations may exclude livestock from grazing pastures and rangelands (701, 703).

Musk Thistle. Musk thistle is unpalatable and when present in grazed lands creates selective use of native plants, which can lead to overgrazing and degradation of pasture and rangelands (707).

Scotch Thistle. Scotch thistle is very competitive and can reduce livestock forage. Livestock tend to avoid areas infested by this thistle due to the armoring of the plants with sharp spines. In dense infestations avoidance of these plants has been observed to reduce livestock movement into adjacent grazing areas (726).

Canada Thistle. Canada thistle crowds out native and more desirable plants and impacts wildlife by changing the structure and composition of the community and can reduce plant and animal diversity. It competes for soil nutrients, shades out neighboring plants and there is some speculation it may release compounds toxic to other plants. Canada thistle was considered one of the most noxious weeds when survey lists of noxious were compared, was on 33 surveys with musk thistle occurring on 24 lists. Invasive or noxious weeds are estimated to cause losses of $7.4 billion in 64 crops in the United States (1999 USDA report). Herbage yield losses in pastures from Canada thistle were estimated to be 2 kg/hectare (1.8 pound/acre) for each kilogram of standing thistle biomass and 4.3 kg/hectare (3.8 pounds/acre) for each additional thistle stem per square meter. Twenty Canada thistle shoots per square meter (2 stems/square foot) reduced yields of canola, barley and wheat by 26%, 34% and 51%, respectively (711, 714, 716).

Invasion and Expansion

Wind, water, animal and human activities transport thistle seeds. Seed production can be significant and germination rates are reported as good in most cases (701, 703, 707, 709, 722).

Canada thistle can also regenerate from root material less than 1 inch in length (2.54 cm) and a first year plant can have root spread up to 6 meters in diameter (19 ½ feet) (722).

Control Methods

Thistle is a hard plant to control and multiple methods may be more satisfactory than a single treatment strategy. Mowing, application of different herbicide products, burning and biocontrol methods have been used for controlling thistle species (711, 717).

Chemical

Bull Thistle. (730, 730, 731,) apply spring and fall to rosettes, and spring on mature plants pre bloom. Dicamba (Vanquish, Banvel or Clarity), triclopyr (Garlon or Crossbow), 2,4-D or a combination of 2,4-D and dicamba (Weedmaster or Brash), and aminopyralid (Milestone) are recommended for control when applied in the spring before elongation and in the fall on rosettes. Metsulfuron (Escort) and chlorsulfuron (Telar) can be applied anytime to actively growing plants and clopyralid should be applied up to bud-stage. Glyphosate can be used, but is a non-selective herbicide.

Musk Thistle. (105, 707), apply to rosettes or before flowering

- Glyphosate (Roundup®) at 2% solution of with water and 0.5% non-ionic surfactant spray to wet all leaves and stems

- Triclopyr (Garlon®) at 2 % solution of with water and 0.5% non-ionic surfactant spray to wet all leaves and stems

- Clopyralid (Transline®, Banvel/Stinger are agricultural label for Transline) at 0.5%

- Picloram (Tordon)

- Clopyralid and 2,4-D combined (Curtail)

Scotch Thistle. (105, 708, 725), apply to rosettes and flowering plants

- Picloram (Tordon) at 0.25 lbs/acre or 1 pint/acre for flowering plants

- Picloram (Tordon) at 0.03-2.0 lbs/acre, all rates killed rosettes when applied in June

- Picloram (Tordon), 1 pint/acre, plus 2,4-D, 1 quart/acre, applied in the spring

- Dicamba (Banvel/Vanquish/Clarity) at 4 lbs/acres applied in June to rosettes

- Dicamba (Banvel/Vanquish/Clarity), 1 pints/acre, plus 2,4-D, 1 quart/acre applied in the spring

- Amitrol 6 lbs/acre for flowering plants

- 2,4-D at 2 quarts/acre

- Glyphosate at 4.5 pints/acre

- Clopyralid and 2,4-D combined (Curtail) at 2 quarts/acre

- Clopyralid (Transline/Stinger) at 2/3 pint/acre
- Metsulfuron (Escort), 1/10 oz/acres, plus dicamba (Vanquish/Banvel/Stringer, agricultural label for Transline), ¼ pint/acre

Canada Thistle. (105, 715, 717), apply in rosette and mature plants in the fall

- Clopyralid at 0.28 kg ae/ha (2 ½ oz/acre) with a non-ionic surfactant at 0.25% v/v, applied in the fall, September, had a 92% kill, applied to late bud and early flower resulted in root biomass reduction of 50%-65%

- Glyphosate at 2.52-3.78 kg ae/ha (2.2-3.4 lbs ae/acre) applied in late bud to early flower stage reduced root biomass by 20%-24%

- Clopyralid and 2,4-D combined (Curtail)

- Picloram (Tordon)

- 2,4-D at 0.98 kg ae/ha (0.88 lb ae/acre) had little effect but is reported to reduce density by 39% when applied in the fall

- 2,4-D alone is not considered a good choice for Canada thistle

- Milestone (aminopyralid) is very effective against Canada thistle and other thistles (personal communiqué Steve Dewey).

Mechanical (105, 712, 717, 726). Repeated mowing of thistle can reduce seed production and reduce carbohydrate reserves in roots. Mowing combined with herbicide treatment can be effective. Mowing in areas with competitive grasses was reported to reduce Canada thistle by 60-70%. Tall fescue (*Festuca arundinacea* Screb.), smooth bromegrass (*Bromus inermis* Leyss.) timothy (*Phleum pratense* L.), orchardgrass (*Dactylis glomerata* L.), redtop (*Agrostis alba* L.), sweetclover (*Melilotus indica* All.), and alfalfa (*Medicago sativa* L.) are all good competitor species to be used for suppression of Canada thistle.

Repeated tillage may reduce some thistle species, bull thistle, musk thistle and scotch thistle, which are seed dependant for establishment. Canada thistle can re-sprout from small root segments and root segments can remain dormant for extended period.

Fire (711). Burning thistle should be accomplished in the late summer or early fall to reduce above ground biomass prior to seed formation. This may increase stress due to less time to accumulate carbohydrates before onset of winter dormancy. Early season burning may stimulate growth and flower production.

Grazing (720). In Aspen Parkland Alberta, Canada cattle grazing was used in three experimental designs for control of Canada thistle. Season-long grazing was determined to maintain or increase severe infestations and reduce forage yield. High intensity-low frequency grazing reduced shoot density, plant biomass and flowering, and resulted in greater weeds suppression than short duration or low intensity-high frequency grazing. Two intense defoliations annually over 2-3 years nearly eliminated Canada thistle in this study. Grazing was conducted from late June until the end of September during the study. Forage quality of Canada thistle increased under the high intensity, low frequency grazing regime.

Insects. Insects used as biocontrol agents for thistle control have had mixed reviews as to how successful they are. Numerous species have been intentionally or unintentionally introduced that have some impacts on thistle

species. Two weevils, the thistlehead-feeding weevil (*Rhinocyllus conicus*) and the rosette weevil (*Trichosirocalus horridus*) have been introduced in the United States for Musk thistle control. The thistle-headed weevil has been observed feeding on some rare native thistle species in the western United States. A seed-eating fly (Diptera: Tephritidae: *Urophora stylata* Fabricius) has been selected for bull thistle control. This species is well established in the western United States with 60%-90% of seed heads infested in some areas. The rosette weevil was released in Montana for bull thistle control. Following a release in Virginia of a rosette weevil (*Carduus acanthoides*), 20% of bull thistle plants were exploited (703, 707, 724).

Eight insects and one rust disease have been introduced to control musk thistle and bull thistle in Maryland. These species are: *Cassida rubiginosa* Muller; *Larinus planus* (F.); *Rhinocyllus conicus* Froel.; *Trichosirocalus horridus* Panzer; Ceutorhynchus litura; *Cheilosia corydon* (Harris); *Psylloides chalcomera* Illiger; *Puccinia carduorum* Jacky; and the rust disease, *Puccinia punctiformis* (Strauss) Roehl (704).

In South Dakota numerous insects where monitored for control effects on Canada thistle. The Canada thistle gall fly [(*Urophora cardui* (L.) (Diptera: Tephritidae)] caused stunted growth and reduced flowering. The seedhead fly [*Orellia (= Terellia) ruficauda* (F.) (Diptera: Tephritidae)] is a seed predator of Canada thistle and reduced seed production by 21.5% and was found in 70% of the heads. The seedhead weevil [(*Rhinocyllus conicus* (F.) (Coleoptera: Curculionidae)] reportedly reduced musk thistle in many location and also attacks Canada thistle. The Canada thistle bud weevil [(*Larinus planus* (F.) (Coleoptera: Curculionidae)], the Canada thistle stem weevil [(*Ceutorhynchus (= Hadroplantus) litura*)] and the Canada thistle gall fly all reduced nonstructural carbohydrates in thistle stems. The Canada thistle tortoise beetle [(*Cassida rubiginosa* Muller (Coleoptera: Chrysomelidae)] population was too small and no affects were reported (719).

A combination a stem-mining weevil, *Ceutorhynchus litura*, biocontrol and three herbicides, 2,4-D, Glyphosate or clopyralid, application was conducted to see if the two could be synergetic, antagonistic or additive. The results of the study indicated if herbicide was applied after the insect left the plant and entered the soil the results where additive. No antagonism was found with careful timing of herbicide application, late bud and early flower stage. Synergistic effects was not evident when the use of both control agents where used together or independently. The combined additive effect provided good control on Canada thistle (717).

The stem-mining weevil, *Ceutorhynchus litura*, was used in a Montana study to determine impact and over winter survival of Canada thistle. Damage occurred to the plants and reduced photoassimilates transport from leaves to roots; however before winter carbohydrate (free sugars and fructans) levels in roots had regained or exceeded none attacked plants. At levels of 5.8-7.5 larva per Canada

thistle stem over winter mortality occurred. In the spring new shoots developed from rootstock and no long-term control was achieved. Insect attack combined with drought did show positive control on some infestations (718).

Fungal protein Nep1 and *Pseudomonas syringae* pv. *tagetis* (Pst) applied separately or in combination on Canada thistle causes leaf spot and apical chlorosis but only reduced shoot growth by 31% in Canada thistle (721).

Canada thistle rust (*Puccinia punctiformis*) production is stimulated by extracts from germinating seeds. It is thought this response makes this rust a possible effective agent in control of this thistle species. (723).

Other. Hand pulling is a method for controlling most thistle species. Canada thistle with its robust root system is less likely to be affected unless all root material is removed. The method if repeated can reduce weed production. If plants are in the flower stage it is suggested plants be bagged and removed. Any disturbance may increase germination of seed in the seed bank (720).

Creating a competitive environment with grasses has been suggested as a method of control. Rototilling prior to planting improved seedling establishment of grasses and improved control results on Canada thistle. Species of grass used where hybrid wheatgrass (Agropyron repens L., Beauv. X Agropyron spicatum Pursh. Schrib F, hybrid), intermediate wheatgrass (Agropyron intermedium Host), Russian wildrye (Elymus junceus, Fish.), tall fescue (Festuca arundinacea Screb.), and western wheatgrass (Agropyron smithii Rydb.), which provided 85, 74, 76, 78, and 66% Canada thistle control, respectively. This was considered as effective as applying clopyralid at 0.55 kg/hectare (0.5lbs/acre). The best method determined for perennial grass establishment for this study was to treat the area with glyphosate at 0.8 kg/hectare (0.7 lbs/acre) in early June and again in July, rototill the area in late August, followed by grass seeding. The following spring the grass was treated with 2,4-D at 1.1 kg/hectare (1 lb/acre) plus clopyralid at plus 0.19 kg/hectare (0.17 lb/acre) to control annual weeds and Canada thistle (712).

Bibliography for Thistle Information Sources

#701 Bull Thistle, Cirsium vulgare
Larry W. Mitich
Weed Technology, Vol. 12, No. 4. (Oct. - Dec., 1998), pp. 761-763.

#702 Effects of wetting and drying on seed germination and seedling emergence of bull thistle, *Cirsium vulgare* (Savi) Ten.
Michael P. Downs and Paul B. Cavers
Can. J. Bot. 78: 1545–1551 (2000)

#703 Bull Thistle (Spear Thistle)
L.-T. Kok1 and A. Gassmann2
Biological Control of Invasive Plants in the Eastern United States

#704 Density of Carduus and Cirsium Thistles in Selected Areas of Maryland
Philip W. Tipping
Weed Technology, Vol. 6, No. 2. (Apr. - Jun., 1992), pp. 434-436.

#705 Production, Dispersal and Predation of Seeds in the Biennial Cirsium Vulgare
Peter G. L. Klinkhamer; Tom J. De Jong; Ed Van Der Meijden
The Journal of Ecology, Vol. 76, No. 2. (Jun., 1988), pp. 403-414.

#706 Context-Dependent Biological Control of an Invasive Thistle
Katriona Shea; Dave Kelly; Andrew W. Sheppard; Tim L. Woodburn
Ecology, Vol. 86, No. 12. (Dec., 2005), pp. 3174-3181.

#707 PCA Fact Sheet: Musk Thistle *Carduus nutans* L. Aster family (Asteraceae)
Tom Remaley
Plant Conservation Alliance®s Alien Plant Working Group, May 20, 2005

#708 Control and Ecological Studies of Scotch Thistle
James A. Young; Raymond A. Evans
Weed Science, Vol. 17, No. 1. (Jan., 1969), pp. 60-63.

#709 Seed Bank Dynamics of Onopordum acanthium: Emergence Patterns and Chemical Attributes
Mirwais M. Qaderi; Paul B. Cavers; Mark A. Bernards
The Journal of Ecology, Vol. 90, No. 4. (Aug., 2002), pp. 672-683.

#710 Mating System, Life-History, and Reproduction in Canada Thistle (Cirsium arvense; Asteraceae)
R. G. Lalonde; B. D. Roitberg
American Journal of Botany, Vol. 81, No. 1. (Jan., 1994), pp. 21-28.

#711 PCA Fact Sheet : Canada Thistle *Cirsium arvense* (L.) Scop. Sunflower family (Asteraceae)
Gwendolyn Thunhorst & Jil M. Swearingen
Plant Conservation Alliance®s Alien Plant Working Group, May 20, 2005

#712 Effect of Perennial Grasses on Canada Thistle (Cirsium arvense) Control
Robert G. Wilson; Stephen D. Kachman
Weed Technology, Vol. 13, No. 1. (Jan. - Mar., 1999), pp. 83-87.

#713 Freezing Resistance of Overwintering Buds of Four Perennial Weeds
Wanda K. Schimming; Calvin G. Messersmith
Weed Science, Vol. 36, No. 5. (Sep., 1988), pp. 568-573.

#714 Evaluation of the growth response of six invasive species to past, present and future atmospheric carbon dioxide
Lewis H. Ziska1
Journal of Experimental Botany, Vol. 54, No. 381, pp. 395±404, January 2003

#715 Seasonal Changes in Carbohydrates in the Root of Canada thistle (*Cirsium arvense*) and the Disruption of these Changes by Herbicides
Robert G. Wilson, Alex R. Martin & Stephen D. Kachman
Weed Technology. 2006. Volume 20:242–248

#716 Herbage Yield Losses in Perennial Pasture Due to Canada Thistle (Cirsium arvense)
Chad W. Grekul; Edward W. Bork
Weed Technology, Vol. 18, No. 3. (Jul. - Sep., 2004), pp. 784-794.

#717 Combined impacts of Ceutorhynchus litura and herbicide treatments for Canada thistle suppression
Timothy R. Collier, Stephen F. Enloe, Joanna K. Sciegienka & Fabian D. Menalled
Biological Control 43 (2007) 231–236

#718 Impact of Ceutorhynchus litura Feeding on Root Carbohydrate Levels in Canada Thistle (Cirsium arvense)
Gary L. Hein; Robert G. Wilson
Weed Science, Vol. 52, No. 4. (Jul. - Aug., 2004), pp. 628-633.

#719 Canada Thistle Biological Control Agents on Two South Dakota Wildlife Refuges
Catherine C. Reed, Diane L. Larson & Jennifer L. Larson
Natural Areas Journal, Volume 26 (1), 2006

#720 Biological control of Canada thistle in temperate pastures using high density rotational cattle grazing
Sue L. De Bruijn & Edward W. Bork
Biological Control 36 (2006) 305–315

#721 Effects of the fungal protein Nep1 and Pseudomonas syringae on growth of Canada thistle (Cirsium arvense), common ragweed (Ambrosia artemisiifolia), and common dandelion (Taraxacum officinale)
John W. Gronwald, Kathryn L. Plaisance & Bryan A. Bailey
Weed Science, 52:98–104. 2004

#722 Genetic diversity of Canada thistle (*Cirsium arvense*) in North Dakota
Tracey A. Bodo Slotta, Jennifer M. Rothhouse, David P. Horvath & Michael E. Foley
Weed Science, 54:1080–1085. 2006

#723 Volatile Components of Canada Thistle
Ronald G. Binder & Richard C. French
J. Agric. Food Chem. 1994, *42,* 2942-2945

#724 Chemistry of *Cirsium* and *Carduus*: a role in ecological risk assessment for biological control of weeds?
Ingrid E. Jordon-Thaden, Svata M. Louda ∗
Biochemical Systematics and Ecology 31 (2003) 1353–1396

#725 Integrated Weed Management of Scotch Thistle
Jonathan Rife
Douglas Co. Weed Division, Castle Rock, CO.

#726 Scotch Thistle *(Onopordum acanthium)*
Matthew Schuster & Timothy S. Prather
College of Agricultural and Life Sciences University of Idaho

#726 Elemental Stewardship Abstract for *Carduus nutans* Musk Thistle
B. Heidel,
Revision Contracted By J. Randall & Teri Schulz, 3-13-1987

#728 Musk Thistle (Nodding Thistle)
A. Gassmann & L.-T. Kok
Biological Control of Invasive Plants in the Eastern United States
www.invasive.org

#729 Range, Musk Thistle
K. G. Beck
Colorado State University Cooperative Extension, no. 3.102

#730 Best Management Practices Bull thistle—*Cirsium vulgare* Asteraceae
Non-Designated Noxious Weed
Bull Thistle BMP
Author; Unknown
206-296-0290 Website: http://dnr.metrokc.gov/weeds *January, 2007*

#731 Bull Thistle
King County Noxious Weed Control
Program Line: 206-296-0290
www.kingcounty.gov/weeds
Revised June 2007

#105 Common Weeds of Utah
Morgan Mendenhall
Utah State University Extension, Rural/Conservation Forestry, NR/FF/012

Sources of Unpublished Material

Steve Dewey, Personal Communication, Utah State University, Extension Weed Specialist

Glossary

Definitions and information collected from the following sources:

- McGraw-Hill Dictionary of Biology
- http://en.wikipedia.org/wiki/Main_Page
- http://www.vplants.org/plants/glossary/index.html
- http://aquat1.ifas.ufl.edu/education/glossary.html
- http://aquat1.ifas.ufl.edu/education/glossary.html

abaxial: said of a surface facing away from the axis of the structure to which it is attached.

achene: small one-seeded, thin walled, indehiscent fruit smaller than a nut.

adventitious: sprouting or growing from unusual or abnormal places, such as roots originating from a stem, or buds appearing about wounds.

aerenchyma tissue: is an airy tissue found in roots of plants, which allows exchange of gases between the shoot and the root. It contains large air-filled cavities, which provide a low-resistance internal pathway for the exchange of gases such as oxygen and ethylene between the plant parts above the water and the submerged tissues. It is found in roots that are submitted to anaerobic conditions such as flooding.

allelopathic effects: allelopathy refers to the inhibition of growth of a plant due to biomolecules released by another.

alternate: one after the other along an axis; not opposite.

alluvial deposits: deposited by water as in soil (alluvial soil) or areas of such soil.

anoxia: means "without oxygen", an extreme form of hypoxia or "low oxygen."

anthers: the pollen-bearing portion of the stamen.

anthropogenic: effects, processes, objects, or materials are those that are derived from human activities, as opposed to those occurring in natural environments without human influences.

apex: the tip; end.

apical dominance: the phenomenon in which a terminal (end) bud inhibits the development of lateral (side) buds.

apical: pertaining to the apex.

asphyxia: is a condition of severely deficient supply of oxygen to the body that arises from being unable to breathe normally.

ataxia: meaning "lack of order". It is a neurological sign and symptom consisting of gross incoordination of muscle movements.

axillary bud: a bud that develops in the axil (the angle between the stem and the leaf) of a plant.

axil: the area or angle formed between the base of an organ and the structure from which it originated. Such as the upper angle between the leaf base and the stem.

axillary: pertaining to the axil.

axis: the central part of a longitudinal support (usually of a stem or inflorescence) on which organs or parts are arranged.

basal: pertaining to the base of the plant or some organ of the plant.

biennial: a plant which requires two years to complete a life cycle, the first year typically forming a rosette, the second year forming an inflorescence.

biodiversity: the abundance of different plant and animal species found in an environment.

bract: small leaf, particularly those at the base of flowers or pedicels.

callus: a hard protuberance or callosity; often (in grasses) the swelling at the base or joint of insertion of the lemma or palea.

cauline: pertaining to the stem or features of the stem.

clasping: tending to encircle or invest, as in the base of a leaf which forms partly around the stem to which it is attached.

clonal spread: A clonal colony or genet is a group of genetically identical individuals (e. g., plants, fungi, or bacteria) that have grown in a given location, all originating vegetatively (not sexually) from a single ancestor. In plants, an individual in such a population is referred to as a ramet.

clone: a group of individuals, resulting from vegetative multiplication; any plant propagated vegetatively and therefore, presumably a duplicate of its parent.

composite flower: a composite flower (like the sunflower) has a many individual flowers (called florets) on a wide, flat receptacle, that look like a single flower. The flowers in the central disk are called disk flowers; the flowers on the periphery are called ray flowers. This group is called Asteraceae (Compositae).

corm: a corm is a fleshy underground stem of some plants. It looks like a bulb, but is solid (it is not formed in layers).

corymbose: corymb-like.

corymb: a flat toped or rounded inflorescence with the outer most flowers on the longest stalks.

cotyledons: a seed leaf; the first leaf (or leaves) to appear during the development of a seedling.

culm: the stalk or stem for grasses and sedges and related plants, usually jointed and hollow.

cypselas: A one-seeded, one-celled, indehiscent fruit; an achene with the calyx tube adherent.

dehiscent: opening to release contents as a seed pod or anther.

dioecious: (male and female plants) male and female flowers borne on separate plants.

ecosystem: an ecosystem is the interrelationships between all of the living things in an area.

ecotypic variation: a subdivision of a ecospecies that survives as a distinct group through environmental selection and isolation.

elliptic: a circular shape which has been laterally compressed, widest about the middle.

elongated: drawn out into a form much longer than wide.

eradication: to do away with as completely as if by pulling up by the roots.

estuary: a water passage where the tide meets a river current.

fibrous root: a fibrous root is a type of primary root of a plant that has a lot of side branching (compare with tap root). Fibrous root are the most common type of roots.
fruits: (achene's) that structure which bears the seeds.

glabrous: (hairless) lacking hairs or other protuberances.

glume: the lowest two (sometimes one) empty scales subtending the usually fertile scales in grass spikelets.

halophilic: preferring saline soils.

haplotype: The term haplotype is a contraction of the term *"haploid genotype."* In genetics, a *haplotype* (Greek *haploos* = single) is a combination of alleles at multiple linked loci that are transmitted together on the same chromosome. *Haplotype* may refer to as few as two loci or to an entire chromosome depending on the number of recombination events that have occurred between a given set of loci.

In a second meaning, haplotype is a set of single nucleotide polymorphisms (SNPs) on a single chromatid that are statistically associated. It is thought that these associations, and the identification of a few alleles of a haplotype block, can unambiguously identify all other polymorphic sites in its region.

halophyte: a plant that grows in saline soils.

hydrophyte: is a plant that grows in water or in water-logged soil. Hydrophytes have a reduced root system, reduced support and vascular systems, and specialized leaves. Some hydrophytic plants include waterliles and Wolffia (which is the smallest flowering plant). Anchored hydrophytes have a rooting system that is embedded in the soil and they often have floating leaves. (Compare with mesophytes and xerophytes.)

invasive plant: a non-native plant species that is able to spread on its own, causing environmental or economic harm.

involucral bracts: involucre, the bracts whorled close to the base of a flower or flower cluster.

inflorescence: a flower or fruit cluster including axis or bracts but not vegatative leavesInflorescence is the a type of flower in which there is more that one flower in a single structure.

lanceolate: shaped like a lance blade. That is, pointed, much longer than wide and widest below the middle.

leaf: usually a blade-like organ attached to the stem, often by a petiole or sheath, and commonly functioning as a principal organ in photosynthesis and transpiration. Leaves characteristically subtend buds and extend from the stem in various planes. See also leaflet. A leaf axil is the upper angle between a leaf petiole, or sessile leaf base, and the node from which it grows. A leaf scar is formed on a twig following the fall of a leaf, usually revealing the pattern of vascular bundles in the leaf trace.

leaflets: one of the discriminate segments of the compound leaf of a dicotyledonous plant. Leaflets may resemble leaves, but differ principally in that buds are not found in the axils of leaflets, and that leaflets all lie in the same plane.

ligneous: woody.

lemma: the lowermost of the two scales forming the floret in a grass spikelet -- the uppermost, less easily seen, is called the palea.

lignifications: to become wood or woody.

ligule: thin, membranous extension of the leaf sheath on the upper surface of the leaf; may be hairy or bristly, hard or soft.

osmoregulatory mechanism: any physiological mechanism for the maintenance of an optimal and constant level of osmotic activity of the fluid in and around the cells.

monophagous: feeding on or utilizing a single kind of food; especially **:** feeding on a single kind of plant or animal.

monotypic: including a single representative, used especially of a genus with only one species.

moribund material: being in the state of dying **:** approaching death being in a state of inactivity or obsolescence.

noctuid moth: The Noctuidae or Owlet moths are a family of robustly-built moths that includes more than 35,000 known species, possibly 100,000 species altogether, in more than 4,200 genera. They constitute the largest family in the Lepidoptera.

node: a knob or joint of a stem from which leaves, roots, shoots, or flowers may arise. A node may contain one or more buds.

non-native plant: a plant species that is present in a region outside its original, historic range due to intentional or unintentional introduction; not necessarily invasive. Also referred to as non-indigenous or exotic. The introduction of the plant to a new area is often the result of human activity.

oblanceolate: like lanceolate except widest beyond the middle.

oblong: (leaf shape) elliptical, slightly rectangular and from two to four times longer than it is broad.

obovate: oval leaf widest near the tip.

ovoid: a solid with an ovate outline.

palea: the uppermost of the two scales forming the floret in a grass spikelet (often obscure.

panicle: a loose branching flower cluster with at least one branch between the peduncle and the pedicels.

parenchyma: are generalized (undifferentiated) cell or tissue in a plant. Parenchyma cells make or store food; they can often divide or differentiate into different types of cells and have thin cell walls. Parenchyma is the most common type of plant cell. The pith is parenchyma cells at the center of the primary stem of a dicot.

pedicle: the stalk of a single flower or fruit.

petals: a single segment of the corolla.

petiolate: (leaf attachment) - petiole (leaf stalk) is present.

petiole: the stalk or stem of a leaf. Completely absent in some leaves.

phloem: (tyloses), the tissue forming part of a plant's vascular system; used by the plant to transport carbohydrates and other organic (food) materials from the leaves to the rest of the plant.

photosynthate: a product of photosynthesis.

photosynthesis: a chemical process that takes place in virtually all plants including aquatic plants and algae (and many forms of bacteria). Using three simple ingredients (carbon dioxide, water, and sunlight), plants and bacteria are able to make their own food.

phytotoxin: a substance toxic to plants or a toxin produced by plants.

phreatophytic: roots growing in or within capillary action of water table.

pinnate: a leaf shape where leaflets or lobes are arranged on either side of a central axis or petiole.

pinnatifid: incompletely pinnate, the clefts between segments not reaching the axis.

pistil: the central organ of a flower containing the ovules. The female part of a flower.

plumes: plumose, Like a plume. Feathery.

pappus: a modification of the calyx, usually in the Asteraceae family, such that the segments are manifest as a low crown, a ring of scales, or fine hairs.

pubescent: with short soft hairs.

progeny: offspring of animals or plants.

propagation: vegetative propagation, reproduction of plants using a nonsexual process involving stems, leaves and parts of the mother plant; the process does not involve production of seeds or spores.

propagulum or **propagule:** a runner or sucker used in the asexual reproduction and dispersal of plants. (propagula or propagules – plural).

raceme: a flower cluster with the flowers on short pedicels which are arranged along a central stem.

rhizome: a horizontal underground stem. Commonly refered to as roots because they are underground they act functionally as stems and the true roots emerge from the rhizome.

root: the part of a plant, usually below ground, that holds the plant in position, draws water and nutrients from the soil, stores food, and is typically non-green, without buds or leaves.

rosette (leaf arrangement): clustered and crowned around a common point of attachment.

sagittate lobes: shaped like an arrow with the basal lobes pointing downward.

scabrous: having a coarse surface due to the structure of the surface or short stiff hairs. Rough to the touch.

seed: (cypselas), the part of a flowering plant that contains the embryo and will develop into a new plant if sown; a fertilized and mature.

self-pollinate: self-pollination is the transfer of pollen from the anther to the stigma of the same flower or another flower on the same plant.

senescence: growing old; aging.

sepals: floral leaf that occurs outside the petals. Often green they sometimes are colorful and mimic petals. Together they form the calyx.

serrate: toothed with the teeth pointing away from the stem or base.

sessile: having no stalk.

stamens: the part of the flower where the pollen is produced. Usually comprised of filament and an anther. The male part of a flower.

stolon: a branch at the base of a plant that can take root and form a new plant.

stomata: stoma, one of the minute openings in the epidermis of leaves, stems, and other plant organs through which gases are exchanged between the atmosphere and the intercellular spaces. stomata – plural.

suberization: infiltration of the plant cell walls by suberin resulting in the formation of corky tissue that is impervious to water.

sympatric: occupying the same geographical range without loss of identity from interbreeding translocation: the conduction of soluble material (as metabolic products) from one part of a plant to another.

tap root: is the main root of some plants; the tap root extends straight down under the plant with very little side branches (compare with fibrous root).

tripinnate: divided along the midrib into opposite pairs of leaflets and these divide again divided and subdivided. Said of a leaf in which the blade is pinnately compound with each of the divisions then bipinnately compound.

tuberous: having the character of a tuber; tuber-like in appearance.

tubular: tube-like.

tube: Usually referring to the connate parts of either the calyx or the corolla.

umbel: a flower cluster with all the flower stalks radiating from a central point.

volatile: readily vaporizable at a relatively low temperature.

xylem: woody tissue that is part of the water-transport system in plants and also acts as supporting tissue.

Appendix 1: Weed Watch List, 2008

1. Yellow Starthistle (*Centaurea solstitialis*)
2. Eurasian Watermilfoil (*Myriphyllum spicatum*)
3. Curly Pondweed (*Potamogeton crispus*)
4. Purple Loosestrife (*Lythrum salicaria*)
5. Field Bindweed (*Convolvulus arvensis*)
6. Mosquito Fern (*Azolla spp*.)

Appendix 2: Schedule of Tasks

November

Develop Habitat proposal and enter into database

December

Develop and submit burn plans

February, March, April

- Coordination meeting for planned burns
- Firebreak development completed
- Wildland fire training re-certification and new people complete training
- Develop and implement a public notification plan prior to the burn period
- Schedule Division of Forestry, Fire and State Lands and burn when appropriate
- Offer media an opportunity to film or provide pictures for news releases before and or after burns

April, May

- Spring treatment of noxious and invasive weeds
- Post burn evaluation of Alkali Bulrush, Salt Grass, Cattail, Hardstem and common reed survey/treatment sites

May

- Finalize this years fall treatment sites and map
- Map archeological survey needs and forward to DWR archeologist
- Determine acquisitions required for upcoming budget year
- Capital Outlay spreadsheet developed for upcoming budget year

June

- Bid specification developed and requisition prepared for herbicide
- Bid specifications developed and requisition prepared for fixed wing aerial application of herbicide
- Bid specifications developed and requisition prepared for rotary winged aircraft aerial application of herbicide

- Bid specifications prepared for lease, rental, and contractual services for ground application of herbicide under $5,000 and develop requisition for over $5,000

- Bid specification and requisition for equipment purchases over $5,000

July

- Bid release for herbicide, aerial application and contractual or equipment needs

- Bid opening and awards granted

- Monitoring of previous treatment sites for fall retreatment effort

August

- Orders received for all materials required

- Last evaluation of treatment sites for fall treatment aerial and ground operations

- Coordination and scheduling of aerial applications completed

- All GIS shape files reviewed and ready for pilot

- All treatment sites flagged for aerial application if no GSI system used

- Pre-treatment Alkali Bulrush, Cattail, Salt Grass and Hardstem sites GPS and measurements taken

- Ground application of previous phragmites treatment areas initiated

- Aerial application of herbicide initiated

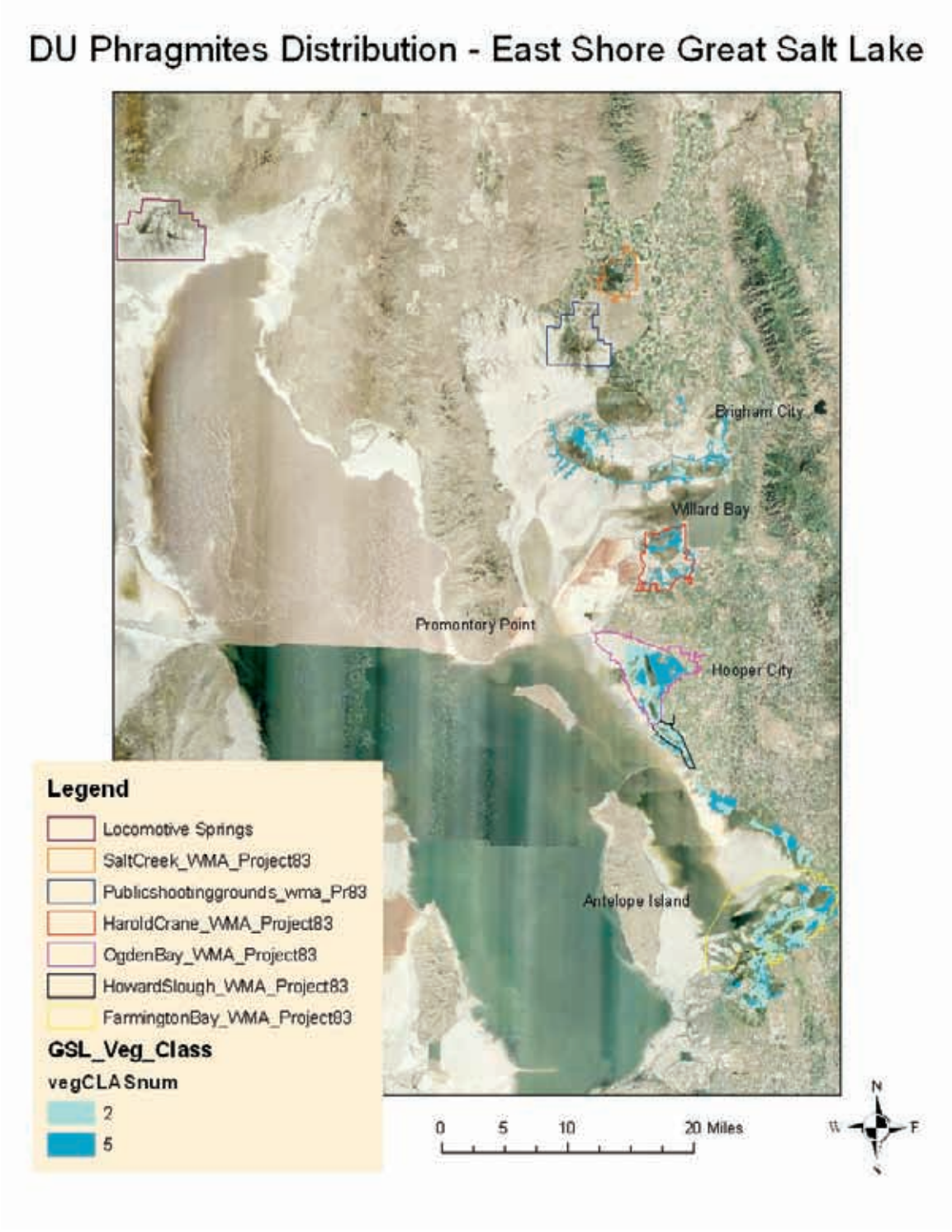
- Offer media an opportunity to film or provide them with pictures of treatment effort

September

- Completed aerial and ground herbicide application for common reed control effort

- Wrap up meeting with team

Appendix 3: Map of Ducks Unlimited Analysis of Common Reed Dominance on Great Salt Lake, Wasatch Front



Class 2 = > 75%: Class 5 = > 50% & < 75%

Created by James Christensen from DU Shape Files Courtesy of Ducks Unlimited

The author, Randy Berger, working in wetlands
July 2008 pretreatment assessment at Ogden Bay WMA
Photo by Val Bachman

Back Cover photographs depict the steps in the first treatment cycle for Common Reed
Starting clockwise from bottom left

Photos on back cover
by Randy Berger