WRITTEN FINDINGS OF THE
WASHINGTON STATE NOXIOUS WEED CONTROL BOARD
Updated 2015

Scientific Name: *Centaurea solstitialis* L.

Common Name: Yellow starthistle, yellow cockspur, St. Barnaby's thistle, Barnaby star-thistle, yellow centaury, geeldissel

Family: Asteraceae

Legal Status: Class B Noxious Weed in 1988

Images: left, *Centaurea solstitialis* blooming flowerhead with spine-tipped bracts, image WSNWCB; center, mature plant habit with branching stems; right, winged stem, center and right image by Steve Dewey, Utah State University, Bugwood.org.

Description and Variation:

Overall habit:

Centaurea solstitialis is typically a winter annual or occasionally noted as being a biennial, with branched stems that are grayish to bluish green in appearance as the plant is covered in fine woolly hairs. Plants have winged stems and yellow flowerheads with large spines at the base.

Roots:

Centaurea solstitialis develops a taproot that can extend over 6 feet deep in the soil (DiTomaso et al. 2013). These deep, penetrating roots allow *C. solstitialis* to access water deeper in the soil profile than many species, particularly annual grasses (Spencer et al. 2011).

Stems:

Centaurea solstitialis stems are simple or branched, gray-tomentose (covered in short woolly hairs), and grow up to 3.3 feet (1 meter) tall, though sometimes taller (Keil and Ochsmann 2006, Keil 2013). The

branched stems can create an overall bushy appearance (Keil and Ochsmann 2006). Stem leaves have long-decurrent bases, giving the stem a “winged” appearance (Keil and Ochsmann 2006).

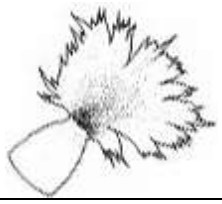
Leaves:
Plants start as a basal rosette of leaves that can grow up to7.9 inches (20 cm) long by 2 inches (5cm) wide (Hitchcock et al. 1955). Basal leaves are lyrate and pinnately lobed, with their distal portions more rounded and longer than the lower leaf blade lobes (Hitchcock et al. 1955). The basal rosette typically withers away by the time the plant is in flower (DiTomaso et al. 2013). Stem leaves are alternate and reduce in size going up the stem, 0.4 to 3.9 inches (1 to 10 cm) long, becoming narrower and more pointed and having decurrent leaf bases. Basal and stem leaves are covered in fine woolly hairs.

Flowers:
Flowerheads occur singly at stem tips or in open, leafy arrays (Keil and Ochsmann 2006). Heads are up to 1 inch in diameter, wider toward the base and on long peduncles. Bracts at the base of flowerheads have palmately radiating clusters of spines, with a central straw-colored, stout, spine that is 0.4 to 1 inches (1 to 2.5 cm) long (Keil and Ochsmann 2006, Keil 2013). Flowerheads are comprised of many yellow disk flowers, 0.5 to 0.8 inches (1.3-2 cm) long, with some sterile flowers that are slender and inconspicuous (Keil and Ochsmann 2006).

Fruit:
Fruit, called cypselae, are 0.08 to 0.12 inches (2 to 3 mm) long and hairless (Keil 2013). The fruit from the outer area of the flowerhead are dark brown and do not have a pappus, while the fruit from the inner area of the flowerhead are mottled light brown and have fine pappus (bristles), 0.08 to 0.16 inches (2 to 4mm) long (Keil 2013). Benefield et al. (2001) found that, on average, 85% of the seeds in a flowerhead had a pappus while 15% did not have a pappus.

Images: left, the two types of *Centaurea solstitialis* seed-above with pappus and below without; center, young seedling, prior to developing its lobed leaves, left and center image by Cindy Roché, Bugwood.org; right, rosette with its characteristic lobed leaves, image by Steve Dewey, Utah State University, Bugwood.org.

Similar Species:

	Habit	Leaves	Flower	Bracts	
Yellow starthistle, *Centaurea solstitialis*	Branched stems with wings, grayish-green, plant covered in woolly hairs, up to 3.3 feet	Basal and lower leaves deeply lobed, upper stem leaves smaller, thin and pointed	Flowerheads terminal, up to an 1 inch; made up of small, yellow flowers	Tip of bract with still, straw-colored spine, up to 1 inch long	Image from PNW 432 
Bighead knapweed, *Centaurea macrocephala*	Tall perennial, grows up to 5.6 feet	Light-green, broadly lance-shaped with toothed edges and pointed tips	Large, solitary flowerheads are 1 to 3 inches in diameter; flowers yellow	Bracts light green to golden, with thin, papery, fringed margins	Image from PNW 432 
Purple starthistle, *Centaurea calcitrapa*	Forms a rosette with cluster of spines at center; multiple branched stems; bushy growth habit; young plants covered with cobwebby hairs, becoming hairless with age.	Basal and lower leaves deeply lobed and divided; upper stem leaves narrow and undivided.	Flowerheads narrow; made up of light to dark purple flowers; seeds without a pappus (plume)	Bracts with spine tips, up to 1.2 inches long	
Iberian starthistle, *Centaurea iberica* (note: not currently found in WA, has been found in OR, documented once in WA in 1929 from Kittitas County)	Similar habit to purple starthistle, Grows up to 3 feet tall (sometimes taller), branched stems	Basal and lower leaves deeply divided, upper stem leaves oblong, entire or toothed	Flowerheads with rose-pink, light purple, or +/- white flowers; seed with white pappus (plume), 1 to 2.5 mm	Bracts with spine tip, straw colored, up to 1.2 inches	 http://commons.wikimedia.org/wiki/File:Centaurea_iberica_10.jpg

(Keil 2013, WSNWCB and Winterowd 2003)

Habitat:

Centaurea solstitialis has the ability to germinate and develop in nearly all of the semiarid to sub-humid rangelands in the west. It is commonly found in open disturbed sites, hillsides, grasslands, rangelands and canyon rangelands, open woodlands, fields, pastures, and roadsides (DiTomaso et al. 2013). Plants readily invade disturbed habitats but can also establish in undisturbed habitats such as nature preserves (DiTomaso et al. 1999a in DiTomaso et al. 2006). *Centaurea solstitialis* grows in open habitats, not tolerating low light or shade (DiTomaso et al. 2013). In Washington, *C. solstitialis* grows best in deep silt loams on the south slopes of the Blue Mountains. However, it also forms dense infestations in shallow rocky soils with as little as ten inches precipitation. This adaptability enables it to establish on poor quality rangeland, edges of cropland, idle farmlands and pastures, roadsides, railways and recreational areas (WSNWCB 1988).

Geographical Distribution:

Centaurea solstitialis is native to parts of Europe, Asia, and northern Africa. The USDA GRIN database (USDA ARS 2015) specifically lists *C. solstitialis* native in:

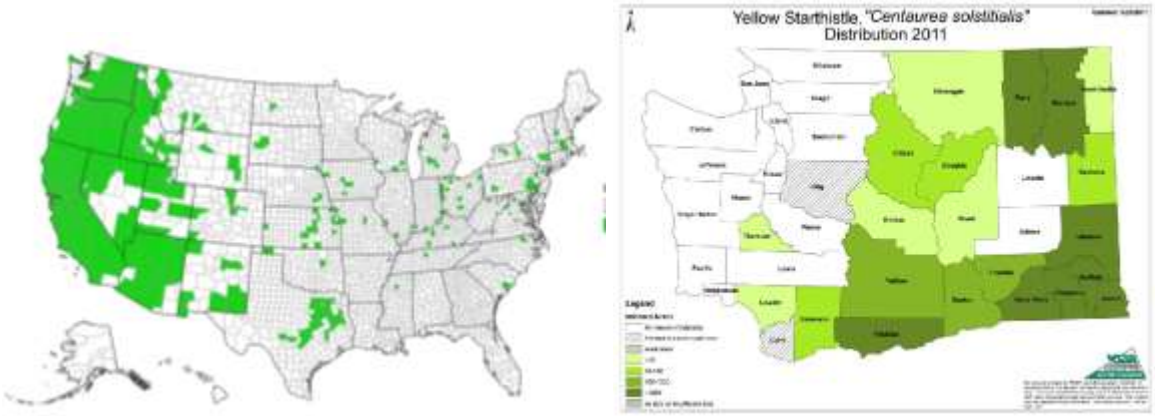
- Northern Africa: Algeria, Morocco, and Tunisia
- Asia: Cyprus, Iran, Iraq, Jordan, Lebanon, Syria, Turkey, Armenia, Azerbaijan, Georgia, Russian Federation, Tajikistan, Turkmenistan
- Europe: Hungary, Ukraine, Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Italy, Macedonia, Montenegro, Romania, Serbia, Slovenia, France and Spain.

USDA GRIN database (USDA ARS 2015) lists *Centaurea solstitialis* naturalized or adventive in:

- Africa: Egypt, South Africa
- Asia: Oman
- Australia
- New Zealand
- Europe: Norway, Germany, Slovakia, Switzerland, United Kingdom, Austria, Belgium, Czech Republic, Netherlands, Poland, Estonia
- Canada
- United States
- Southern South America: Argentina, Chile, Uruguay

History:

In the United States, *Centaurea solstitialis* was first referred to in adobe bricks of the Mexican period in California, beginning in 1824, and then reported growing on ballast grounds near western seaports (Hendry and Bellue 1936 in Roché and Thill 2001). The earliest California herbarium record documents *C. solstitialis* growing in Oakland in 1869 and the next earliest record is from Vacaville, California in 1887 (Maddox et al. 1985). Plants were dispersed by its introduction and spread in contaminated alfalfa seed (Roché and Thill 2001). By 1965, the California Department of Food and Agriculture estimated 1.9 million acres were infested. Current estimates for the western United States report *C. solstitialis* to have infested approximately 15 million acres of rangelands and annual grasslands (Duncan et al. 2004 in Kyser et al. 2013), and it is estimated to be annually spreading at a rate of 13 to 17% (Duncan and Jachetta 2005 in Goehring et al. 2010).



Maps: left, county level presence/absence distribution information of *Centaurea solstitialis* in the United States by EDDMapS 2015; right, Washington State Department of Agriculture's county level distribution map of *C. solstitialis* in Washington (2011).

Washington:

By the 1920's, *Centaurea solstitialis* was widely distributed in eastern Washington. The first herbarium record of *C. solstitialis* in Washington was collected in 1926 in Klickitat County on waste ground (WTU 33091), followed by a collection in Whitman County in 1929, also on waste ground (WTU 33167), and another from Klickitat County in 1935 along a roadside (WTU 34840) (WTU 2015). In Columbia County, between 1954 and 1964, *C. solstitialis* populations dramatically increased from just 60 to 4,000 hectares (Roché 1965 in Roché et al. 1997). An outbreak in Okanogan from certified but contaminated seed occurred following seeding after a fire. It is now a restricted noxious weed in seed. *Centaurea solstitialis* still occurs widely throughout eastern Washington as well as a few counties in western Washington including Skamania, Cowlitz, Pierce and Thurston County (WSDA 2011, WTU 2015). Recently, a small number of plants were found in King County along a bike trail and were controlled (King County NWCB pers. comm.).

Listings:

Centaurea solstitialis is listed as a noxious weed in Arizona, California, Colorado, Hawaii, Idaho, Minnesota, Missouri, Montana, New Mexico, Nevada, North Dakota, Oregon, South Dakota, Utah, and Washington, West Virginia, and Wyoming (USDA ARS 2015).

Images: left, infestation of *Centaurea solstitialis*; center, cattle grazing among *Centaurea solstitialis* plants, image by Marty Hudson Klickitat County NWCB; right, roadside infestation of *C. solstitialis*, image by John M. Randall, The Nature Conservancy, Bugwood.org.

Growth and Development:

Centaurea solstitialis is a winter annual that begins its growth in the fall from seeds that germinate when moisture conditions improve. Oblong, tongue-shaped cotyledons emerge in the early spring. Secondary leaves develop, forming a rosette of leaves that increase in size and number (from 5 to 25 leaves in a rosette). Plants overwinter as rosettes. Taproots grow quickly. In a study by DiTomaso et al. (2003 in Spencer et al. 2013), taproots grew to over 3.3 feet (1 meter) in 65 to 80 days after planting in December, while Spencer et al. (2013) measured taproots growing over 3.3 feet in 38 days and to 2.7 m in 94 days after planting in a controlled experiment.

In late May to June, the plant begins to bolt, sending up a stalk to about 3.3 feet in height and whose top is a firm bud. The stalks branch, and flower buds form at the end of each and flower from July and on until frost or plants senesce (Roché et al. 1997). *Centaurea solstitialis* flowers are predominantly self-incompatible (Harrod and Taylor 1995; Maddox et al. 1996, Sun and Tirland 1998 all in Roché and Thill 2001). Flowers are pollinated by generalist insect pollinators, including *Apis mellifera* and *Bombus* sp. (Swope and Parker 2010, 2012, Swope unpublished data in Swope 2014). Plants begin to dry in August and become easily identifiable skeletons that are silvery gray with a white cottony flowerhead. Seeds are of two types are produced: with a pappus (plumed) and without a pappus (plumeless).

The seeds germinate near the base of the mother plant. With the onset of late fall rains, yellow starthistle seeds begin to germinate and the cycle is repeated. However, because of varying conditions, distribution and maturation rates, and long viability, some may germinate at any time of the year.

Reproduction:

Reproduction is only by seed. *Centaurea solstitialis* seed production varies, with some plants producing as many as 85,000 seeds per plant (Benefield et al. 2001 in Lortie et al. 2010). Seed production can vary depending on soil moisture and other properties (Maddox 1981, Pitcairn et al. 1997, Roché 1991 all in Benefield et al. 2001). Benefield et al. (2001) found in a California study that plants averaged between 65 and 83 seeds per seedhead. Seeds added to the seedbank are viable for at least two years, though the majority of seeds appear to germinate or die during the first year (Callihan et al. 1993, Benefield et al. 2001 in Lortie et al. 2010; Joley et al. 1992 and Garren and Strauss 2009 in Swope and Parker 2010). Seeds do not require any type of dormancy, cold temperatures or other treatment to germinate (Benefield et al. 2001 in Swope and Parker 2010). Some of the seeds are viable as early as eight days after flowering is initiated (DiTomaso et al. 2013). Seed densities can vary in the seedbank, with some counts ranging 3,438 to 10,127 seeds of per square meter (DiTomaso et al. 1999). Seeds with a pappus, upon maturity, are thrust upward into the opening at the top of the bracts. In that position, they are subject to dispersal by gusts of wind or other disturbance which results in movement of the stem. Seeds without a pappus remain in the flowerhead until the plant breaks down and the heads falls to the ground (Roché et al. 1997). This provides a second period and method of seed dispersal. Besides wind, seeds can be dispersed as a contaminant of commercial seed, alfalfa, clover, hay, straw, on vehicles, construction and maintenance equipment, farming equipment, motor rail vehicles, animals including birds, and humans.

Economic Importance:

Detrimental:

Centaurea solstitialis has spread extensively throughout California and to the Pacific Northwest and is considered one of the worst invasive rangeland weeds in the western U.S. (DiTomaso et al. 2013). Centaurea solstitialis can form nearly solid infestations, growing at densities exceeding 100 plants m^{-2} (Thomsen and Williams 1992 in DiTomaso et al. 2003). These infestations dominate existing plant

communities, resulting in monocultures, excluding native species and other desirable plants (DiTomaso et al. 2003). *Centaurea solstitialis* can establish itself quickly at a site and can survive repeated defoliation (Spencer et al. 2013). Plants produce an abundance of seed with nonrestrictive germination requirements, allowing it to quickly spread and take over a new site (DiTomaso et al. 2003). *Centaurea solstitialis* uses an excessive amount of soil moisture, limiting the resource for other plants (Enloe and DiTomaso 2004 in Young et al. 2011). *Centaurea solstitialis* can access water deep in the soil during summer months when other annual plants have gone dormant (Enloe and DiTomaso 2004 in Spencer et al. 2011). Spencer et al. (2011) found that in controlled experiments, *C. solstitialis* was able to deplete soil moisture to a depth of 8.9 feet (270 cm). High densities of *C. solstitialis* can result in low levels of soil moisture in the spring, competing with shallow-rooted annual species as well as deeper rooted annuals and perennial species for water (DiTomaso et al. 2003). The loss of soil moisture can be calculated as equivalent to a loss of 15 to 25% mean annual precipitation, which Gerlach (2000) estimated to be a value of $16 to $75 million per year in the Sacramento River watershed alone (DiTomaso et al. 2003).

Since *Centaurea solstitialis* can invade crop areas such as fields, orchards, and other cultivated crops, crop seeds and feed can become contaminated (Maddox et al. 1985). Removal of *C. solstitialis* seeds increases the expense of certified seed. In Idaho, *C. solstitialis* is reported to have caused reductions and harvesting issues in dryland wheat fields (Callihan et al. 1982 in Maddox et al. 1985). Recreation lands that become infested have decreased value and accessibility for users (DiTomaso et al. 2003).

Centaurea solstitialis can invade and reduce available edible forage on rangelands (Maddox 1981 in Maddox et al. 1985). Cattle feeding on *Centaurea solstitialis* may be poorly nourished and can be damaged by the spiny heads (Callihan et al. 1982 in Maddox et al. 1985).

Horses may be poisoned and develop "chewing disease" or E.N.E. (Equine *nigropallidal encephalomalacia*) if they ingest large quantities (86 - 200% body weight) of *C. solstitialis* over 1 to 2 months. The disease is characterized by acute inability to eat or drink and the horses may die from dehydration and starvation. Only horses are affected. Chemical substances in *C. solstitialis* are somehow altered in the processes of digestion and metabolism producing a toxin which causes death of nerve centers in the brain controlling normal eating and drinking mechanisms. There is no cure. Horses in south central Washington have contracted chewing disease and died.

Beneficial:
Centaurea solstitialis has been noted as being an important plant for the bee industry and in the production of honey (Maddox et al. 1985). It was noted that in 1959, the value of honey from yellow starthistle was between $150,000 to $200,000 annually and that many colonies of bees in California depend on *C. solstitialis* as their primary source of pollen (Maddox et al. 1985).

Control methods: (from DiTomaso et al. 2013 unless otherwise noted)
It is necessary to use an integrated weed management plan to control *Centaurea solstitialis*. Since C. solstitialis is an annual, it is key to deplete the seedbank with multiple years of management to control infestations (DiTomaso et al. 2006).

Removing invasive species can open up a habitat to reinvasion if follow up management does not occur (Kyser et al. 2013). By planting a variety of desirable species, a community will be present to provide competition and shading to *C. solstitialis* seedlings and to also provide a food source for pollinators. When possible, carry out control methods when pollinators are not active on plants. Wear protective clothing when working among plants with developed flowerheads to avoid injury from the spines.

Mechanical methods:

Centaurea solstitialis plants can be hand-pulled. The best time to pull plants is after they have bolted but before they have produced viable seed—so before they begin to flower. Do not leave any above ground plant parts or plants may recover. Bag and trash pulled plants if they have started to produce seeds. Plants will be easier to pull if they are under stress from competing vegetation.

Repeated mowing over many years can provide control of *Centaurea solstitialis,* but it will depend on timing and the growth stage of the plant. Mow plants when not more than 2% of the total flowerheads in the population are in bloom—if mowed too early, higher seed production can occur (Benefield et al. 2001). Spencer et al. (2013) conducted a mowing experiment where plants were mowed three times, essentially once a month (between May 1 and June 30); plants grew to 20% of the control size by the final sample date. This mowing treatment resulted in dense, compact plants with a prostrate growth form. The final number of flowerheads was reduced by the multiple mowing treatments by 67% compared to control plants. Mowing also resulted in smaller flowerheads being produced by *C. solstitialis*, which then resulted in fewer seeds being produced per plant. Mowing may not be possible in rough or steep terrain. If mowing mature plants that are in flower, collect mowed material to prevent dispersing the seed. Make sure mowing does not hinder other management methods happening on site.

Tilling can also provide effective control in agricultural areas and along roadsides if desirable plants are not present. Tilled areas will need to be replanted with desirable species to create competition. In California, frequent cultivation slows or inhibits *C. solstitialis*, preventing it from fully exploiting cultivated grassland steppes.

Cultural Methods:

Competitive plants, such as grasses and forbs, can cause plants to produce stems that are more slender, have fewer basal leaves, are more brittle and easier to hand pull (WSNWCB 1988). Young et al. (2011) found the native perennial grass *Elymus glaucus* (blue wildrye) able to successfully establish and spread as well as provide resistance to *C. solstitialis* invasion. Young et al. (2011) also found out through their research that *Elymus glaucus* is able to resist invasion by *C. solstitialis* primarily due its ability to suppress light during a critical period in *C. solstitialis* development.

Integrating different control methods can provide successful control of *Centaurea solstitialis*.

Burn, herbicide treatment, native seeding (Kyser et al. 2013):

- In California, Kyser et al. (2013) found that treating a site that was burned the previous year, with aminopyralid between January and March and drill seeding native grasses in January provided the most consistent results for establishing native species three years after *Centaurea solstitialis* control. Broadcasting the seed did not provide native plant establishment. Burning an infestation before the seeds have dispersed, followed by a combination aminopyralid treatment and native perennial grass drill seeding treatment in January may provide successful control.

Fire and herbicide treatment, or two herbicide treatments or herbicide treatment and fire (all from DiTomaso et al. 2006):

- Recommended: fire then herbicide treatment. Prescribed burning can provide control when plants are in the very early flowering stage. In California, DiTomaso et al. (2006) tested an integrated management approach using fire and an herbicide treatment using clopyralid as these control methods have proven to be the most successful for large *C. solstitialis* infestations. They found that burning plants the first year of treatment and then using clopyralid the second

year provided successful control. Burning also provided control of invasive annual grasses such as medusahead and ripgut brome. Burning the first year, followed by a clopyrilid treatment the second year, also resulted in good forage levels the following year. Burning can stimulate seed germination, so following the burn with an herbicide treatment can provide good control and deplete the seedbank .

- Not recommended: herbicide treatment then fire. Reversing the order of treatment, a clopyralid treatment the first year followed by fire the second year, did not provide effective control of *C. solstitialis;* in fact, in some cases it increased the plant's biomass and cover. Burning is not recommended as the final treatment method in an integrated weed control plan as fire promotes seeds to germinate when there is fall rain.
- Not recommended unless sufficient fuel on site: two consecutive fires. Repeated burns of an infested area may be difficult to achieve due to lack of sufficient fuel the second year (DiTomaso et al. 2006). If there is sufficient fuel on site, for example a good population of annual grasses, consecutive burns may be possible and provide effective control (DiTomaso et al. 2006). Burning a location one time will not be enough to provide control of *C. solstitialis* as fire stimulates germination of *C. solstitialis* with the first fall rains (Kyser et al. 2013).

So, when adding another year of treatment of one of these methods, a burn-clopyralid-clopyralid treatment provided better control, 98.3% reduction in density the year following last treatment, than a burn-clopyralid-burn treatment, which produced only a 75.4% reduction. These methods must be continued for at least 3 years to provide significant depletion of the seedbank.

DiTomaso et al. (1999) also conducted research using three consecutive year burns on open grassland in California. These burns were conducted after desirable annual grasses and broadleaf species had gone to seed and before *C. solstitialis* produced viable seed. This particular timing of the burn is very important for success. A significant reduction of cover occurred after the second year of treatment and there was further reduction yet after the third treatment, but it was not significantly different from the second year. After 3 years of burning, *C. solstitialis*'s seedbank was reduced in the range of 96.3 to 99.5%, and seedling density was also decreased between 97.9 to 99.6 %. The timing of the burns was also found to increase the cover of native forbs in the treatments by about 5 times. Native perennial grasses decreased after the first burn but then increased significantly after the third year of burning. The effect of burning is not permanent though, and further management is needed to prevent the re-infestation of *C. solstitialis* (Kyser and DiTomaso 2002).

Monitoring and additional control work will be essential when using any management plan, to prevent *C. solstitialis* from reestablishing.

In some locations, it may be possible to create shade where there are *C. solstitialis* infestations. Deep shade on rosettes dramatically reduced root growth rates by 45% to 64% (DiTomaso et al. 2003) and when aboveground growth had a 50% reduction of sunlight, aboveground biomass was reduced by 75% (Roché et al. 1994 in Young et al. 2011). Planting and/or seeding densely to shade rosettes can provide this type of cover (Roché et al. 1994 in Roché et al. 1997).

<u>Biological Control:</u>

There are a number of biological control agents that are approved for use on *Centaurea solstitialis* (IWCP n.d.). The yellow starthistle hairy weevil*, Eustenopus villosus*, larvae and adults interfere with the seed production of *C. solstitialis*. The adults feed on young seedheads and the larvae feed inside flowerheads. The yellow starthistle flower weevil, *Larinus curtus*, larvae feed on developing yellow starthistle seedheads. The yellow starthistle bud weevil, *Bangasternus orientalis*, larvae feed within

seedheads and reduce seed production. The yellow starthistle peacock fly, *Chaetorellia australis*, larvae feed within seedheads. The yellow starthistle rust, *Puccinia jaceae* var. *solstitialis*, is a fungus that attacks yellow starthistle. The yellow starthistle gall fly, *Urophora sirunaseva*, larvae are associated with galls formed within seedheads. For more information about biological control agents that can be used in Washington and to inquire about obtaining these biocontrol agents, please contact the WSU Extension Integrated Weed Control Project at 253-445-4657 or http://invasives.wsu.edu/index.htm.

Centaurea solstitialis can be grazed to reduce infestations. At least some goats will consume mature yellow starthistle seedheads with spine-tipped bracts (Goehring et al. 2010), but other livestock will not graze the mature plants (Hovde 2006 in Goehring et al. 2010). Goat grazing may be needed twice in a year, to treat the regrowth of *C. solstitialis*, or grazing can occur once later in the season (Goehring et al. 2010). In a study by Goehring et al. (2010), where grazing was repeated on sites for 3 years, the first year the goats grazed late June to late August and again mid-October to mid-November. The subsequent two years the grazing occurred just one time, around the end of July/early August to early September. The timing of this one late grazing was when there was not enough soil moisture to support plants resprouting. This single, late season grazing did reduce *C. solstitialis* populations (Goehring et al. 2010).

Timing is important when using grazing as a *Centaurea solstitialis* control method. If plants are grazed in their rosette or bolting stage, plants will resprout vigorously, creating even more biomass and seedheads than were produced before grazing began (Hovde 2006 in Goehring et al. 2010). So when using early season grazing, it is important to follow up with a second grazing treatment later in the season to target regrowth (Thomsen et al. 1993 in Goehring et al. 2010).

Proper grazing management, including rest and deferment to allow grasses to regain vigor, will both limit *C. solstitialis* invasions and improve the rangeland condition. Seeds tested after being ingested by goats from grazing viable seed were just 3% viable (Goehring et al. 2010). Grazing alone will not eradicate *C. solstitialis,* but it can be a method used to reach hard to treat locations and is a useful tool to have in an integrated management plan.

Response to Herbicides:

Many herbicides can be used to control *Centaurea solstitialis*. Please refer to The Pacific Northwest Weed Management Handbook for a thorough list and information on timing, herbicides and herbicide rates to use for *C. solstitialis* control. http://pnwhandbooks.org/weed/other-items/control-problem-weeds/starthistle-yellow-centaurea-solstitialis

In general, use herbicide control in combination with other control methods to reduce usage when possible. If using a foliar spray, treat plants when pollinators are not present or are the least active.

DiTomaso et al. (1999b in DiTomaso et al. 2006) found low rates of clopyralid (105 to 280 g ha $^{-1}$) provided successful control of *C. solstitialis* seedlings and rosettes. Clopyralid also has pre-emergent activity. Repeated clopyralid use may have detrimental effects on other species (such as legumes) or promote the increased cover of invasive annual grasses such as medusahead, ripgut brome, or barb goatgrass or even develop resistance to the herbicide (Callihan and Schirman 1991, Miller et al. 2001 in DiTomaso et al. 2006).

Aminopyralid also has been found to completely control *Centaurea solstitialis.* In California, research found that at the lowest registered rate (0.75 oz ae ac^{-1}), aminopyralid applied with a surfactant in

January and March on seedlings and rosettes provided over 95% control the following year (Kyser et al. 2011 in Kyser et al. 2013). Applying the herbicide in November provided only partial control of plants.

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