Use of Fire and Cutting to Control Yellow Starthistle
(Preliminary Results of a Yellow Starthistle Control Experiment)

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Abstract

Six combinations of winter burning, spring cutting, and summer cutting were applied to seven plots containing yellow starthistle, *Centaurea solstitialis* L, at Indian Grinding Rocks State Historic Park, Amador County, California. No summer burning was included in the trials, since burning at that time could conflict with the park's major event of the year. From the results of the initial plots, three replicate plots were initiated, each containing seven treatments and a control. Treatment locations were assigned randomly within each plot. Although the replicate plots have been in use for less than a year, their results have provided quite different results from the original non-replicated plots. While the first plots indicated that a winter flaming was as effective a control of yellow starthistle as any of the other combinations, the new plots show that a spring cutting may be the preferred method of managing yellow starthistle at Indian Grinding Rock State Historic Park. Summer cutting may provide more complete control, but reduction of native *Clarkia* and *Elymus* are possible consequences of this method. Longer term study will clarify this and other effects.

Introduction

Yellow starthistle, *Centaurea solstitialis* L., has become a major weed in California. It has spread over large areas in the state since its introduction in the 1800s and increased from 1.2 million acres in 1958 to over 8 million today (Maddox and Mayfield 1985). While the plant provides fairly good forage in the rosette stage, it becomes increasingly unpalatable after bolting, to the point of being poisonous to horses (Cordy 1978). In the flowering stage, the characteristic spines on each flowerhead add additional herbivore defense.

Yellow starthistle has several attributes that make it a successful weed. Its seeds begin to germinate with the first autumn rains and continue germinating through the last spring rains. This early and extended germination can give it competitive advantages over plants that germinate late or only once. Additionally, yellow starthistle does not mature until long after most annuals have finished their life cycle. Especially in late-rainfall years, this gives yellow starthistle the advantage of being one of the few plants competing for resources during the summer. Its long tap root enables it to survive in areas where there are few other plants alive above the soil surface during the summer months. Once it starts to flower, it may continue to produce seed from early June through November.

The control of yellow starthistle by mowing has been investigated by Vayssieres et al. 1993, who found that, as long as the mowing was completed at the appropriate time, good control of yellow starthistle resulted (although other control methods might be needed). Summer burning of yellow starthistle is also showing some promise of reducing yellow starthistle populations while increasing native forbs (DiTomaso, this publication). However, the combination of winter burning and cutting in a California foothill setting has not been seriously addressed. In this study, I investigated several possible control methods within the constraints of state park management at Indian Grinding Rock State Historical Park. The main concerns of park personnel and the Tribal Council, who also play a role in the management of the park, were to control yellow starthistle and to promote native grasses without using herbicides or grazing.

Methods and Materials

This study was started in the fall of 1993 as part of a management plan for Indian Grinding Rock State Historic Park, located in Amador County off Highway 88, 2.1 kilometers (1.3 miles) northeast of the town of Pine Grove, California (38° 25' N. latitude and 120° 37' W. longitude). The park consists of 54.6 ha. (135 acres) at an elevation of 730 m. (2400 feet). The study site within the park is a meadow about 1 hectare (2.5 acres) in size that was used for more than 70 years for hay and pasture. It is now dominated by introduced grasses and forbs (Table 1). Yellow starthistle has been in the park for at least 10 and possibly as many as 40 years - and is especially well established in this meadow. It was most likely introduced with feed or seed, or by farm machinery.

In the fall of 1993, seven 2x2 in plots were subjectively placed within the 5 hectare study site in order to assure yellow starthistles would be in each plot. Four of the plots were placed fairly closely together (all within 2m of each other), with the other three quite widely spaced (one is more than 10 m from the closest plot). No buffer zones were established, as yellow starthistle seeds are unlikely to disperse more than 2 m. Combinations of treatments were applied to six of the plots, with one plot left untreated to serve as a control. The combinations were 1) winter burn; 2) spring cut; 3) summer cut; 4) winter burn and spring cut; 5) winter burn and summer cut; and 6) spring and summer cut.

The best timing for a winter burn is when yellow starthistle is in full rosette stage, but before most of the native annuals have germinated. This window of opportunity can be quite narrow and the tendency is to wait as long as possible to get maximum exposure of the rosettes. A flaming method, using a gasoline and kerosene mixture from a hand-pumped tank, was effective in igniting the rather wet biomass and keeping it burning until the plots were completely blackened (the temperatures reached at ground level are insufficient to harm seed). However, flaming also removed all thatch from the burned area, which appears to increase erosion. The winter burns were conducted on December 6 in 1993 and February 10 in l995.

Cutting was done at approximately the same height as the park's mower blade (5 cm/2 inches), but using a hand-held, gas-powered weed-eater with nylon string instead. The spring cut took place on April 6, 1994, when the thistle had bolted but with less than 2% flowers showing. This approximate percentage is important in the phenology of the yellow starthistle, as, beyond this tirne, some of the earliest flowers may begin to fade to a dull yellow indicating that seed has been set. The sumrner cut was on June 6, 1994 with approximately 5% flowers showing.

In the fall or 1994, three 4x8 m replicate plots were subjectively located in the meadow. Each plot was subdivided into 8 2x2 m subplots and one of 7 treatments or a control was randomly assigned to each subplot. The three plots were placed in a row with about 2rn between each plot and the next. These were the same treatments as the year before, but with an additional combination of winter burn/spring and summer cut. The timing of the treatments followed the phenology of the plants as before, but was quite different by the calendar (Table 2). The winter burn was February 2, 1995, and the spring cut June 26, 1995. The timing of the summer cut was virtually the same, August 2, 1995, showing that yellow starthistle can mature rapidly once conditions are favorable.

All density counts were reported in one of two ways: in subplots with substantial numbers, the numbers of stems in a $0.25m^2$ portion of' the subplot were counted and then inul6plied by 4 to yield a value of stems m^{-2}; in plots with very few individuals, the number of stems in a $4m^2$ plot were counted and then divided by 4.

Results

The first year of the study produced excellent control of yellow starthistle with all treatment methods. Since winter burning alone was not significantly different than any of the other control methods, and since it yielded greater biodiversity while requiring the least labor, it was my method of choice going into the second year of the study. However, with the exceptionally wet and long winter of 1994/5, it quickly became clear that winter burning was not always an effective means of controlling yellow starthistle (Tables 3 and 4). Multiple cuttings, by contrast, provided complete control of yellow starthistle, but unfortunately also had the greatest negative

effect on biodiversity (See Table 1). These preliminary data would suggest that a winter burn/spring cut or a spring cut alone may provide the best control given the desire to maintain or increase biodiversity.

Table 1
Complete meadow flora and average occurence of species in 1994-1995 treatment plots.
Counts made 9/5/95 (number of stems per $4m^2$)

		Treatments							
		spring & summer cut	control	winter burn	winter burn/ spring cut	spring cut	winter burn/ summer cut	winter bum/ spring & summer cut	summer cut
Latin name	**Common name**								
Asclepias speciosa	milk weed								
Avena fatua	wild oats		2	5					
Bromus molfis	soft chess		3.6	200					
Calystegia sp.	field bind- weed		1			1			1
Capsella bursa-pastoris	shepherd's purse								
Centaurea solstitialis	yellow starthistle		273.3	320	7.6	9		4	
Gynosurus echinatus	hedgehog dogtail		20	80					
Clarkia purpurea	Winecup Clarkia								
Clarlda wiffiamsonii	Farewell to spring								
Coffinsia sp.	Collinsia								
Elymus glaucus	blue wild rye				4				
Elymus lanceolatus	Thickspike wheatgrass								
*Erodiurn o*rcutarium	Filaree								
*Erodjum b*otrys	long-beaked filaree								
Gallium aparine	Beadstraw								
Geranium sp.	cranesbill								
Lamium amplexicaule	henbit								
Lactuca serfida	wild lettuce								
Madia elegans	common tar weed		8.7	16	3	29			
*Nemophila m*enziesfi	baby blue-eyes								
Phlox gracifis									
Plantago lanceolata	plantago	8	2		17.5	22			
Poa pratensis	Kentucky bluegrass								
Quercus lobata	valley oak								
Ranunculus occidentalis	western buttercup								
Rumex cnspus	curly dock								
Rumex acetosella	sheep sorrel								
Sanicula bipinnatilida	Snakeroot, purple sanicle								
Taraxacum officinale	mountain dandelion								
Tfifolium pratense	red clover		326.7	223.3					
Vica villosa	winter vetch								
Vica sp.	vetch								
Wyethia angustifolia	narrowleaf mule ears								

Plant nomenclature follows The Jepson Manual : Higher Plants of California (Hickman 1993).

All plots burned on December 6,1993 had excellent control of yellow starthistle (Table 3). In the plot to which the single winter burn was applied, the count went from 100 plants/plot in 1993 to only 5 plants/plot in 1994 (95% reduction). The winter burn/spring cut and the winter burn/summer cut also had excellent results with 79 and 95% reductions, respectively, in yellow starthistle populations (Table 3).

Cutting also proved to be very effective in reducing starthistle numbers in this setting, with 100% reduction of yellow starthistle in the plot that was cut both spring and summer. The plot treated with a spring cut went from a count of 50 plants/plot in 1993 to a count of 4/plot in 1994 (92% reduction). The summer cut plot went from a count of 19/plot to 2/plot in the same period. The plants that did grow to be counted in these plots were small and had very few flower heads on them, thus reducing the number of seeds contributing to the seed bank. Compare this with the control which went from 20 plants/plot to 110 - a 550% increase!

Table 2.
Comparison of treatment dates
While the treatments were at the same time relative to the starthistle's phenology, they were considerably different by calendar dates. The spring cut was a full 7 weeks later in 1995 than in 1994.

	Phenology	93/94 season	94/95 season
Winter burn	full rosettes	12/6/93	2/10/95
Spring Cut	< 1% yellow	4/6/94	6/26/95
Summer cut	< 5% yellow	8/8/94	8/2/95

Table 3.
Yellow starthistle density (number per $4m^2$) by treatment
These are the original plots which were treated for two years.

Treatment	8/1/93	9/3/94	% change	9/5/95	% change
Winter burn	100	5	-95	35	**+700**
Winter burn/ spring cut	14	3	-79	*	*
Winter burn/ summer cut	90	5	-94.5	0	-100
Spring cut	50	4	-92	5	+25
Summer cut	19	2	-89.5	0	-100
Spring and summer cut	7	0	-100	0	0
Untreated	20	110	**+550**	640	**+580**

* Plot damaged

Table 4
Yellow starthistle density(plants /m2) by treatment

Plots 1,2,and 3 are replicates treated in 1994/5; original plots were treated in 1993/4 and 1994/5.

Treatment	Plot 1	Plot 2	Plot 3	Original plots
Winter bum	360	200	400	8.7
Winter bum/spring cut	2	2.75	1	0.0
Winter burn/ spring and summer cut	0.0	0.5	1.5	0.75
Spring cut	3	0.0	1.5	5.0
Summer cut	0.0	0.0	0.0	0.0
Spring and Summer cut	2.5	0.0	0.0	0.0
Untreated	176	228	416	160

An unfortunate side effect of repeated cutting seems to have been the elimination of bunch grasses (*Elymus glaucus*) and the reduction of numbers of *Clarkia* in some plots. A single cutting in spring or summer did not appear to hurt the *Elymus*, but repeated cuttings did. Plot 6, treated with both spring and summer cuttings for two years, originally had three well established bunches of *Elymus glaucus* but now has none. And while each of the onginal plots had at least one *Clarkia* plant at the first species count, now only two of the six plots still contain *Clarkia*. While there is a reduction in the number of *Clarkia* in the plots that have had treatments, *Clarkia* was also absent in the control - perhaps being crowded out by the dramatic increase in yellow starthistle. Similarly, the *Elymus* densities decreased in the untreated plots as the yellow starthistle numbers increased.

No other negative consequences of treatments have so far occurred. Since large areas are now freed from competition and open to more sunlight and disturbance, other invasive pest plants might be expected to occupy the available space. However, so far there is no indication of this happening. In fact, there is a slight, though non-significant, decrease in some of the other introduced plants.

In the second year the winter bum was not nearly as effective on these plots as in the previous year (Table 3). The increase from 5 plants/plot the year before to 35/plot in 1995 is a 700% increase. However, this is still a good reduction from the original count or from the control.

In the replicated plots, the cutting once again provided excellent control, with winter burn/spring cut providing the best (100%) control (Table 4). With the exception of the winter burn treatment, all treatments showed good control of yellow starthistle.

Discussion

The rainfall data from the park for the two years of the study (Table 5 and Fig. 1) indicates that the amount of moisture available for germination after burning was considerably greater in the 1994/5 season than in 1993/ 4. In fact, precipitation after the February 10, 1995 was almost exactly double that following the December 6, 1993 burn and far more than the rainfall for the entire 1993/4 season. Since yellow starthistle can germinate into July if there is enough moisture (Thomsen et al., 1994), and the park received over 80 cm (30 inches) from March through June of 1995, there was certainly enough moisture to promote germination after flaming. However, only several more years of data will show whether flaming can ever be counted on to give adequate control of yellow starthistle in most years.

Since winter burning provided excellent control of yellow starthistle only in a dry year, it is hard to make recommendations for its use as a control method in any given year because the amount and timing of precipitation are so unpredictable. The second year of winter burning still had dramatic reductions in density of yellow starthistle when compared to the control, but unfortunately, this reduction may have been attributable to the reduction in seed from the previous year and not to the effectiveness of winter burning over two years. More

plots will have to be added to the experiment to eliminate this confounding effect and to show whether winter burning can be effective over a longer period of time.

While the summer cutting was the most effective means of reducing numbers of starthistle, it also eliminated (until the next rain) above ground growth of all other plants from the plot (see Table 1). The spring cut, while not quite as effective at reducing starthistle, at least allowed some other plants to survive through the summer. Since some seed may have been set by the time the summer cut was completed, the actual number of seed produced could be similar. Hence, a new plot to track differences in seed bank reduction will be added to next year's study.

For the 1994/5 season, winter bum/spring cut provided the best results. However, with the exception of the winter bum treatment, these results are not statistically different from those of the other treatments, which also provided excellent control. For the winter bum plot, the increase in actual numbers of plants compared with the control was statistically insignificant, as were biomass, percent cover, and the number of flower heads per plant. However, there were differences in numbers of seeds produced per plot: while the control plot would have produced around 32,000 seed, the winter bum plots would have produced about 48,000. Given the huge number of seed in either case, this difference still may not be biologically significant, however, this clearly shows that winter burning was not the answer this particular year. Indeed, at least one other researcher also had disappointing results from a winter flaming during the 1994/95 season (Brown 1995). Thus, while the 1993/4 season could have been an exception, it seems more likely that the huge difference in the amount of rainfall between the 1993/4 and 1994/5 seasons (Table 4) accounts for the success of winter burning in the dry 93/94 season and its failure in the wet 94/ 95 season. However, only another year of repeat treatments will tell whether winter burning can be relied upon as an effective control method for yellow starthistle.

Table 5
Precipitation by month

Boxed numbers show precipitation after winter burn was completed.

	Inches		Centimeters	
	1993/4	1994/5	1993/4	1994/5
September	0.00	0.91	0.00	2.31
October	0.76	2.76	1.93	7.01
November	2.74	6.87	6.96	17.45
December	4.56	7.37	11.58	18.72
January	3.81	19.09	9.68	48.49
February	6.12	1.45	15.54	3.68
March	0.43	17.17	1.09	43.61
April	3.85	6.17	9.78	15.67
May	1.91	4.82	4.85	12.24
June	0.30	2.45	0.76	6.22
July	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00
	24.48	69.06	62.18	175.41
	Total after winter burn			
	16.42	32.06	41.71	81.43

Alternatively, the summer bums that will be added to the treatments next year may provide an additional method of control. The research that Marla Hastings has been conducting at Sugarloaf Ridge State Park indicates that summer burning may be effective at reducing starthistle while increasing biodiversity (DiTomaso 1995). Hopefully, the work at Indian Grinding Rocks State Historic Park will confirrn her results, thus broadening the management tools available to the park.

Conclusion

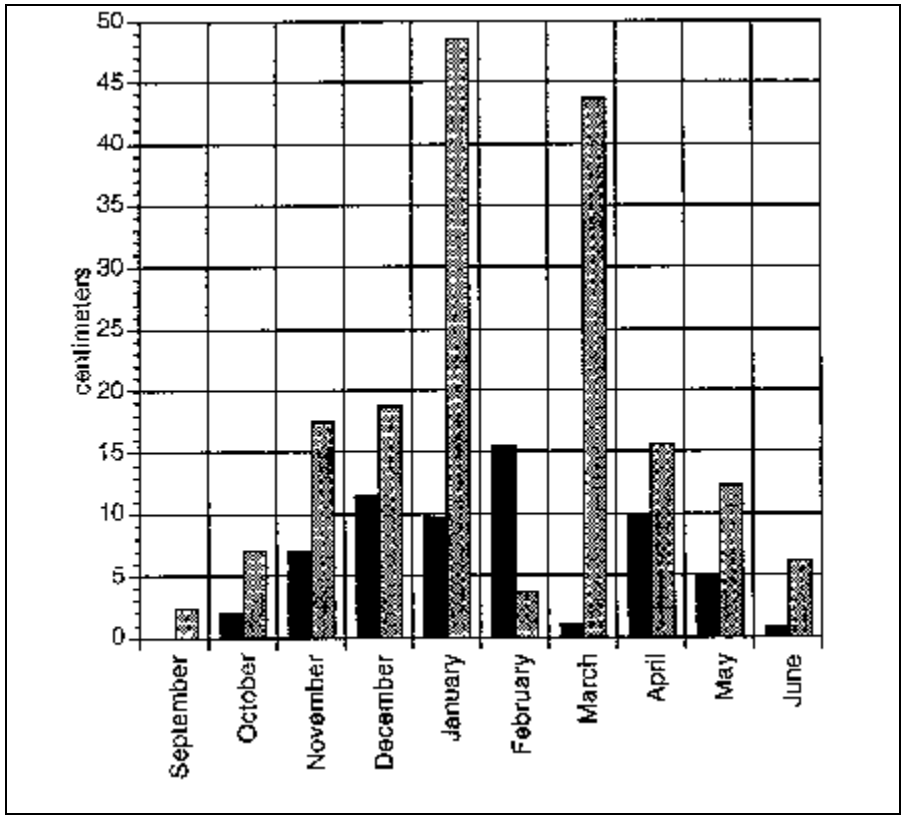
The most reassuring outcome of this study is that yellow starthistle is indeed controllable under managed conditions. In fact, all of the treatments provided good control (at least 90% reduction of flower and seed) under the proper conditions and timing. Unfortunately, some conditions are not predictable, and some control methods are detrimental to biodiversity.

A winter bum in a year when there is little moisture following the bum may provide excellent control of yellow starthistle and allow native forbs and grasses to thrive. However, since weather is always an unknown, this method of control appears to be chancy at best. Multiple cuttings provide excellent control but severely limit other species. While the spring cut alone may not always give the best control, its timing allows most annuals to have set seed and perennial grasses to recover before the soil moisture is depleted.

To achieve maximum control of yellow starthistle, control methods need to be applied according to the plant's phenology, not the calendar (control times varied by as much as seven weeks in the two years of this study). Close monitoring of the site is needed to assess when control methods should be applied.

Even when the appropriate method is used and the timing is perfect, results of control methods may not be evident for several years while the seed bank is being reduced. It is therefore important to insure a continued management plan when initiating control. The ability to use different methods of control can add flexibility to the management plan and take advantage of the attributes of different control methods. For example, summer burning may be very good for control, but may not be possible or desirable on a yearly basis. Spring cutting could then be substituted on alternate years to allow the fuel load to increase.

If control of yellow starthistle is all that is desired, multiple cuttings are the most reliable method of control. However, this method decreases biodiversity. Under the proper conditions, burning can provide good control and perhaps even increase biodiversity. Spring cutting, on the other hand, seems to be a more reliable method and could be the best compromise between reducing yellow starthistle, and maintaining biodiversity.



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