Controlling *Cynara Cardunculus* (Artichoke Thistle, Cardoon, etc.)

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The wild artichoke (also known as artichoke thistle and cardoon) *Cynara cardunculus* L. is a perennial in the thistle tribe (Cynareae) of the sunflower family (Asteraceae). It shares a recent common ancestor with the modem cultivated "globe" artichoke *Cynara skolymus* L. Both plants have their origin in edible *Cynara* cultivars used by early farmers in the Mediterranean region (1). These cultivars were probably subjected to the unintentional selective pressures of the repetitive disturbance environment that is characteristic of agricultural activities such as cultivation and grazing.

This early Mediterranean and Middle Eastern agricultural disturbance regime is postulated to have given rise to many of the worst agricultural weeds and invasive plant species (2), including several thistles (3). In combination with the naturally robust growth properties of thistles world-wide, this evolutionary selection gave the *Cynara* cultivars the genetic potential to become highly successful weeds. *C. skolymus* was developed from the early *Cynara* cultivars in medieval monastery gardens, by artificial selection for superior agrinomic properties (1). Many of the aggressive and invasive traits of *C. skolymus* may have been lost during this selection process, as the globe artichoke has not been reported as a problem invasive anywhere in the world (1).

The wild artichoke came to the U.S. in the mid- 1800s as the cultivated edible cardoon, *Cynara cardunculus.* Escape from cultivation and subsequent propagation by seed probably resulted in a reversion to many of this cultivar's aggressive and 'wild' characteristics. The result of this evolutionary history is a robust, invasive plant that shares many vegetative and reproductive characteristics with the world's worst weeds (4, see box: 'Weedy Characteristics of *Cynara cardunculus*').

Characteristics of *C. cardunculus*

C. cardunculus has large, deeply lobed leaves and can be 5-6 feet in height and 5 feet in diameter. The solitary composite flowering heads have spiny phyllaries and showy purple disk flowers. Like the globe artichoke, the bases of the phyllaries and the fleshy recepticle of *Cynara cardunculus* are edible. Others have reported that the petioles and roots are also edible if properly prepared (3,5). *Cynara* has a large perennial tap root, from which the plant regenerates each year. The artichoke grows well in several regions of California, and has been a problem invasive in San Diego, Orange, and Los Angeles Counties, the San Francisco Bay area, portions of the Central Valley, and elsewhere.

C. cardunculus has long been recognized as a horrific pest plant on poorly managed and overgrazed range lands. The artichoke thistle can also become a serious invasive in relatively undisturbed natural habitats such as coastal sage scrub, chaparral, and riparian woodlands.

The 3,500 acre Los Peñasquitos Canyon Preserve, located in a rapidly urbanizing area of San Diego, California, encompasses 14 distinct plant communities and over a dozen sensitive and endangered plant species (6). Prior to control efforts, there were populations of artichoke scattered throughout the preserve, ranging in size from a few volunteer individuals to solid stands several acres in size. In one 14 acre site, an abandoned sewage pond, artichoke constituted about 50% of the vegetative cover, in a mix with early successional chaparral species.

In several other sites the plant formed monocultures several acres in size. In these colonies, artichoke constituted 100% of the vegetation cover, to the complete exclusion of *all other plant species.* Plants in similar populations have been known to reach densities of 20,000 plants per acre (1). We estimate that prior to the instigation of control measures in 1991, there were greater than 200,000 plants in the preserve.

The large infestations were centers for seed production, facilitating the dissemination of outliers. Once such a massive seed production was established, even undisturbed native habitats were vulnerable. The most invasible habitats were disturbed locations, European annual grasslands, and open forb covered *(Hemizonia fasciculata,*

Haplopappus spp., *Isomeris* spp.) canyon bottomlands. However, we observed healthy volunteers growing in riparian woodlands, under willow (*Salix* spp.), mulefat (*Baccharis salicifolia*) and sycamore (*Platanus racemosa*), as well as sizable populations in southern mixed chaparral, chamise chaparral and in high quality coastal sage scrub.

We documented the invasion of artichoke into populations of San Diego thorn mint, *Acanthimentha ilicifolia* (California listed Endangered Species). The invasion of artichoke was highly disruptive to the fragile canyon ecosystem. The artichoke is not subject to significant herbivory by deer; although the younger seedlings are sometimes eaten by rabbits. The absence of observable wildlife trails or spoor among the artichoke indicated that the large infestations of artichoke were a significant obstacle to wildlife movement. The artichoke was not heavily used for nesting or predative activities of birds; however the seeds did provide a seasonal food source. The major ecological effects of the artichoke were displacement of native vegetation in a significant portion of the preserve, resulting in the fragmentation of higher quality habitat, and the continuing invasion of habitats occupied by sensitive plant species and communities.

Strategies for the control of *C. cardunculas*

C. cardunculus is quite large, and more importantly, it has a perennial tap-root, capable of vigorously regenerating unless the entire root system is destroyed. It is for this reason that previous attempts to control the artichoke by plowing, chaining, scraping and bulldozing have been unsuccessful. Removing the deep tap root system from the often hard clay soils of Peñasquitos canyon was a nearly impossible task for an individual plant, let alone for tens of thousands. Biocontrol is not an option due to the close phylogenetic relationship to the cultivated artichoke, *C. skolymus*. We therefore adapted an artichoke control strategy for Peñasquitos canyon based mainly on the application of herbicide. We chose glyphosate (Monsanto's Round-Up®, Ortho's Kleen-Up®) because of its well known effectiveness in the control of perennial dicots (7) and for its favorable safety and environmental characteristics (e.g. 7,8,9).

Control of *C. cardunculus* in Los Peñasquitos Canyon Preserve

We utilized a two part control method as follows:

1. Decapitation of flowers and seed heads prior to maturity. This action was undertaken to reduce total seed production and was accomplished by volunteers equipped with machetes. This method was most valuable in slowing the spread of the plant in areas where herbicide spraying was not possible at the time.
2. Foliar application of 2% glyphosate (Round-Up®, Monsanto) during the active growth period (January-July). This has been accomplished by trained volunteers, under the general supervision of the San Diego City Parks Department.

Backpack sprayers were well suited for spraying in remote canyons and on hillsides. For larger populations on the canyon bottom, the Friends of Los Peñasquitos Canyon Preserve purchased a 25-gallon poly-herbicide tank with a 10 horsepower pumping motor and 100 ft. of hosing (about $400 total investment). This equipment, mounted on a 4-WD pickup truck, was invaluable in treating large colonies where it was possible to drive into the area. A 14-acre patch could be sprayed in a single, long day with a truck mounted sprayer, a three person crew and additional herbicide and water for refilling the sprayer tank. While one person sprays, the second and third crew members move the hose and truck as needed. Our chief volunteer artichoke sprayer found a pair of chainsaw chaps to be invaluable for moving through the dense spiny patches.

Three year results

Volunteers from the Friends of Los Peñasquitos Canyon Preserve began their artichoke control efforts in 1991 and are now about to begin a fourth season. In our first and second seasons, we were limited by not having identified all of the populations of the plant, not having a truck-mounted sprayer and having only limited number of volunteer hours.

Our third year was most successful. Due to the efficiency of the truck-mounted sprayer in treating large colonies, and the efforts of dedicated volunteers with backpack sprayers in locating and treating outliers, we believe we sprayed nearly every known plant in the preserve. Many of the established colonies and individuals were treated three to four times between January and August. Since 1993 was a very wet year, new artichokes were germinating as late as July; these were also sprayed with 2% Roundup®. It is our hope that this late germination, and the subsequent spraying of new seedlings, depleted the seed bank.

Optimizing herbicide applications

The herbicide spray should cover the plant's leaf surface thoroughly to ensure there is enough herbicide in relationship to the underground root mass. Young seedlings can usually be killed with one application of 2% Roundup®. In larger plants, spraying is most effective when the flower stalk is bolting, the time of maximum growth. Spraying prior to this time gave less than satisfactory results. In mid-aged plants (2-3 feet tall) in their second season of growth we achieved 50% killing with one application of glyphosate. When larger clumps of plants, in their third or more season of growth, were sprayed at the same stage, only 20-25% killing was achieved. In contrast, at the bolting of the flowering stalk, a 95-98% effective kill was achieved with one application of 2% Roundup®. Even later in the season, we still had success in killing plants sprayed after the seed heads were mature and drying out.

As volunteers, we did not have the luxury of being able to schedule large crews during the optimal periods for spraying. We instead had to make use of volunteer work hours that spread out over several months. Early in the season we concentrated on remote areas reachable only on foot with backpack sprayers. These outlier populations are usually younger in terms of years of growth, and therefore more susceptible to an earlier application of glyphosate (since artichoke seedlings germinate over a period of months, rather than in a short burst, we revisited these sites two to three times more during the season to spray new seedlings and resprouts). We left the large populations, almost all reachable by the truck-mounted sprayer, for treatment during the optimal period.

To increase absorption of the herbicide, we added a non-ionic surfactant (Monterey Herbicide Helper). A blue dye was added (Ben Meadows Company) to keep track of our spraying efforts. We found that it pays to cut down the old stalks from the previous year's growth, particularly in large populations. Otherwise, walking in the patch is quite difficult, and much of the herbicide is wasted. We favor a powerful brush saw (Husquavarna 41) with a metal cutting blade. Although these are sold as weed whips, with nylon strings or blades, the larger models come with a conversion kit that allows them to use a metal blade. With large monocultures of artichoke, or artichoke mixed with other non-native weeds, we found that mowing is sometimes useful. Mowing before the active growth season will remove old growth and make later spraying easier and more effective. Mowing of actively growing artichoke will not kill the plant, but will "buy some time" if management considerations or the weather delay spraying. In addition, after mowing the plants will resprout less vigorously.

Cut stump, herbicide application – an experiment

Jo Kitz, of the Santa Monica chapter of the California Native Plant Society reports successfully killing *C. cardunculus* using a cut stump method. After cutting the plant off close to the base, a 25% solution of Roundup® was applied to the stump. Resprouts were similarly treated. In Peñasquitos Canyon Preserve volunteers began using this method in January 1994. We intend to use it on remote populations at different stages of growth to test its efficacy.

This method holds several possible advantages over foliar spray application in several situations. Carrying a 3-gallon backpack sprayer a mile or more up and down hills in brushy terrain to treat remote infestations is a strain for even the most dedicated volunteer. For cut stump treatment, however, a cutting tool such as a short garden hoe and a small hand-held herbicide sprayer and a pair of gloves are much lighter to carry. This approach - if effective - will be better when working in areas where collateral damage is possible, especially

with sensitive species nearby. To minimize possible damage when using a cut stump herbicide application for smaller plant stumps of any invasive species, the Friends use a brushing technique. Instead of a sprayer, volunteers use a plastic rubber cement jar with a brush built into the lid. Herbicide is brushed directly onto the cut stump with no chance of collateral damage.

Conclusions and future work

Cynara cardunculus is a robust, aggressive thistle capable of forming dense, massive monospecific stands in disturbed habitats, and capable of invading natural and semi-natural plant communities. Perhaps due to a limited range of dispersal, seed number seems to be an important factor in invasions by artichoke. Therefore control measures must focus both on limiting the spread of outliers and on reducing major seed sources. For this reason, managers of parks and natural preserves should be observant of invasive plant conditions on adjacent lands that have other uses, such as grazing.

In Los Peñasquitos Canyon, we have made major advances toward the complete eradication of one of the worst invasive plants in the preserve. This was achieved with the tireless labor of a relatively small number of volunteers. Future control measures will focus on the treatment of resprouts and newly germinated seedlings. We plan to continue this effort indefinitely. We will also continue to survey the preserve for new plant locations, and have recruited members of a ranger-supervised volunteer bicycle/equestrian/foot patrol in this effort. The Friends of Los Peñasquitos Preserve also has an ongoing commitment to educating recreational users of the canyon and the general public about invasive exotics, through docent-led hikes and nature walks, and through articles in local newspapers. In the higher quality habitats, removal of the artichoke will stimulate the growth of endogenous native species. At the sites of the larger infestations, we will undertake active restoration by planting and seeding with species appropriate to the affected habitat.

The authors dedicate this article to the passionate volunteers who donated more than 230 hours of labor in 1993 alone to the artichoke projects in Los Peñasquitos Canyon.

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Postscript: Results with Cut Stump

In 1994 and 1995 the Friends used the cut-stump herbicide application method on numerous populations of artichokes at all stages of growth. The 25% solution first recommended by Jo Kitz was effective, producing a 98-99% kill rate, with very few, if any, instances of regrowth. This allows volunteers to attack the plant at times spraying is relatively ineffective and to reach scattered and remote populations without

lugging in heavy spray equipment. It is also ideal for treating plants in sensitive areas such as the San Diego thorn mint population mentioned above. With application of herbicide to the cut stump there is little opportunity for collateral damage. - Mike Kelly

Weedy Characteristics of Cynara Cardunculus

Rapid growth. Under favorable conditions *C. cardunculus* undergoes rapid growth to a large size. This growth (facilitated, in part, by food reserves stored in a perennial root) is a competitive advantage during reestablishment and allows rapid achievement of reproductive maturity.

Continuous seed production. Although there is a discrete reproductive phase of plant growth, with flowering occurring from March through July, there can be flowers at very different stages of maturity on any single plant, at any given time. This results in the production of viable seeds over several months of the year.

Versatile seed productivity. *C. carduriculus* grows well and produces viable seeds in a variety of habitats, from mesic riparian sites to quite xeric rocky slopes.

Dispersal mechanisms. We observed dispersal of fruits by birds and wind. The latter is facilitated by a well developed pappus.

Germination breadth. We observed the establishment of outlier seedlings in a variety of habitats and environmental conditions and at various times of the year. We consider this to be evidence that the artichoke seeds will germinate under a wide range of conditions.

Discontinuous Germination. Germinating artichokes are observed after the first winter rains in November or December, and germination continues, under favorable conditions, through July. We do not know whether the discontinuous germination is due to internal, physiological mechanisms, or environmental factors such as soil disturbance.

Vegetative reproduction. Resprouts vigorously from perennial root.

Rosette growth. Large leaves near the ground crowd out and shade competitors. Leaves also constitute a physical barrier that limits herbivory.

Brittle-hard to uproot. Stem often breaks at ground line. The root is deep and extensive.

Allelopathic mechanisms. Where *C. cardunculus* grows with other plant species, such as annual grasses, there is often a distinct zone of bare ground beyond the artichoke, suggesting some mechanism of inhibition. In addition, after the fall die back, the large dead leaves drop to the ground where they undergo virtually no decomposition, thus providing another barrier to competitor species.

Herbivore defenses. The wild artichoke is heavily armored, with spines on the leaves, stems and the phyllaries. Chemical mechanisms may be involved in these defenses as well, as several of the volunteers working on our projects had painful wounds requiring medial attention long after the spine was removed.

Other 'weedy' characteristics. Although we have not performed any rigorous studies on self-fertility, observations of small outlier populations have led us to suspect that *C. cardunculus* is at least facultatively self-compatible. Phenotypic plasticity has been observed in shaded environments, such as the riparian understory, where plants have narrower, longer leaves. The possibility of local genetic variants has been suggested anecdotally, as has the possibility of hybridization with cultivated artichoke, *C. skolvmus.*