The Feasibility of Managing Artichoke Thistles in Wildcat Canyon

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Introduction

One of the more challenging pest management problems facing the East Bay Regional Park District (EBRPD) is the artichoke thistle (*Cynara cardunculus*) infestation in Wildcat Canyon Regional Park (Figure 1). This escaped exotic species is in the same genus as the domestic globe artichoke and was itself originally introduced as a food source by immigrants in the Benicia area around 1880. It spread out of their gardens and into the surrounding grasslands where it quickly became a troublesome pest (Robbins, 1940). Because of its Mediterranean origin, the artichoke thistle is well equipped to compete with California's native species (Audd, 1987). A variety of control options have been tried on this species throughout the world, but none is without drawbacks. People have tried herbicides, various grazing animals, fire, mechanical destruction of the plants, and the most direct method, hand removal. Each of these strategies has environmental and economic costs which must be balanced against the effectiveness of the management technique.

The artichoke thistle population in Wildcat Canyon needs to be reduced, or eliminated if feasible, because land thoroughly covered with the thistle is useless. The plant's large size, prickly nature, and high density effectively block both cattle and humans from utilizing the land (Robbins et al., 1970). One of the control methods currently being tried by EBRPD centers around removing the seed heads before their dispersal each season. Because the artichoke thistle out-competes and displaces native plant species, the California Native Plant Society has also been involved with this program (Shea, 1988, pers. comm.).

The purpose of my research was to ascertain whether seed head removal could have an appreciable impact on the seed bank in the soil. I sampled the seed content of the soil in Wildcat Canyon to determine whether the quantity and viability of the seeds already in the soil would dwarf the additional contribution of the new seed heads each spring. This comparison will indicate the potential effectiveness of seed head removal as a control method. The seed bank data are also useful for evaluating other control options. The long term success of any management technique which stops short of complete sterilization of the soil will directly depend on the quality of the seed bank in the soil (quality is a measure of the number of viable seeds in the soil). The plant's resistance to complete eradication is largely determined by its

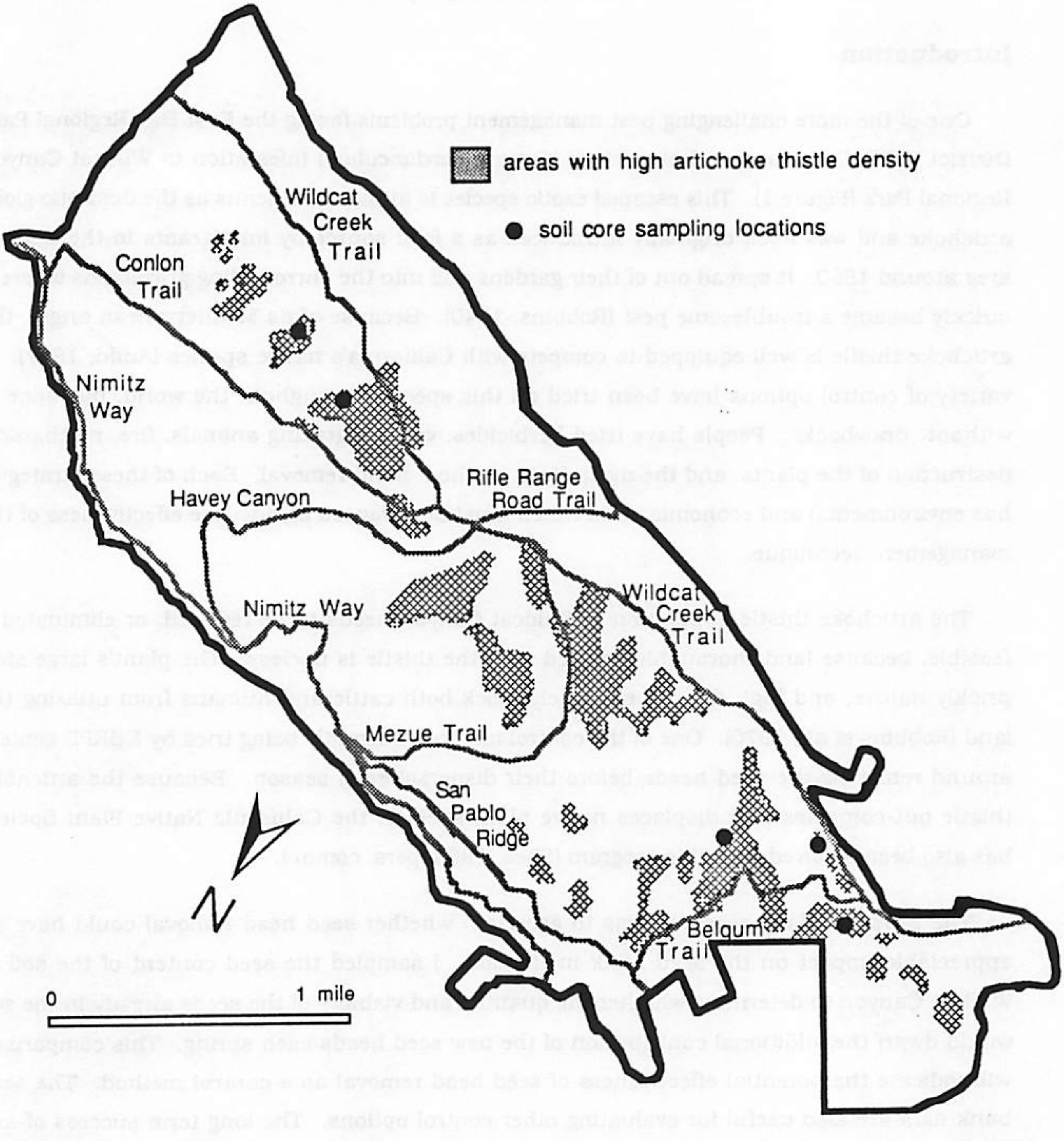

Figure 1. Wildcat Canyon Regional Park showing areas of artichoke thistle infestation and sampling sites

reproductive ability during the next growing season, and this reproductive effort is directly related to the quantity of viable seeds already present in the soil.

Past Studies

There have been no studies done on the usefulness of removing seed heads as a control option, and the published research on artichoke thistles is minimal. There are no detailed descriptions of the general biology and ecology of the species. However, there has been research on the genealogy of the domestic globe artichoke, which is probably a domesticated form of the artichoke thistle (Zohary and Basnizky, 1975). Most research conducted on managing artichoke thistles has concentrated on herbicide application. Research conducted in Italy concentrated on optimizing the timing of application and choice of chemical combination to produce maximum control (Magnifico, 1984). In California chemical control methods have also been evaluated and applied. The herbicide 2,4-D was tested for effectiveness in the 1950s by the University of California Agricultural Extension Service (1972). The herbicides "Oust" and "Roundup" were recently tested by Orange County's Environmental Management Unit (Tidwell, 1987) on a heavily infested tract of county-owned land. In the 1930s, before effective herbicides were available, 70,000 acres near Benicia were successfully reclaimed from thistle infestation without chemical use. The plants were either dug up manually or disked mechanically with heavy equipment. This non-chemical approach was extremely expensive even during a period of much lower labor costs. In fact, the cost of the thistle control effort actually exceeded the value of the land (Thomsen and Barbe, 1986).

Extent of Problem

The artichoke thistle infestation in Wildcat Canyon presents a very difficult management problem. The morphology and ecology of the thistle makes it effective at competing with the native grasses in the Canyon (Thomsen and Barbe, 1987). The spines discourage cattle from grazing on it, and instead they graze on annual grasses. This selective feeding pattern contributes to the dominance of the thistle in heavily grazed parkland. The perennial lifecycle and large seed size give the artichoke thistle a significant advantage at the start of the spring growing season. The stolon root system and starch reserves inside the seeds provide a nutritional reserve which the annual grasses lack. These reserves allow the thistle to exploit the favorable growing conditions more effectively. The foliage shades the competing seedlings of other species. In more mature stands the accumulation of dead foliage also provides an effective mulch which only the vegetative sprouts of the thistle can penetrate.

At the present time, the artichoke thistle covers approximately 33 percent of Wildcat Canyon Regional Park's 2450 acres, or about 800 acres. The individual stands have widely varying plant densities and do not appear to favor one particular micro-habitat. The areas covered with very dense populations are not available for recreational or grazing use, because the prickly foliage prevents any navigation through the infested area. This devaluation of the land is the primary motivation for the current action on this problem. EBRPD has received a lot of pressure from the ranchers whose land borders on Wildcat Canyon. They are concerned that their land will also become incompatible with ranching. The artichoke thistle seeds and vegetative sprouts from these dense stands could cross the property line and infest their ranchlands (Shea, 1988, pers. comm.).

Potential Options

There are a variety of control measures available for most weed species. However, the first alternative any control officer should investigate is biological control. Usually investigators look for a natural enemy in the target species' home range. Typically this enemy has evolved along with the target species and is a natural population control mechanism which is highly specific. This is the key feature of biological control which makes its use, when possible, highly desirable. Instead of affecting all the plants in the area along with the target species, the predator species affects only its target. Unfortunately the artichoke thistle cannot be biologically controlled. Unlike most other weed species, *Cynara cardunculus* is very closely related to *C. scolymus*, the domestic globe artichoke, an important cash crop. Any species which would attack *C. cardunculus* would also attack *C. scolymus*, especially considering the domestic artichoke's more succulent nature (Thomsen and Barbe, 1986).

Many different herbicides have proven to be effective at managing the artichoke thistle (Thomsen and Barbe, 1986; Magnifico, 1984). The choice of which chemical compound to use depends on a careful balancing of the good and bad characteristics of that particular herbicide. The selectivity of the chemical's effects is one of the most important considerations. Not only is it important for an herbicide to have a minimal impact on other plants, but the effects on both aquatic and terrestrial animals also need to be considered. The other major consideration is the degradation rate. It is possible for a very potent herbicide which affects a broad range of plants to be more appropriate for an application than a less powerful but more selective chemical, if the latter chemical has a slower degradation rate. The danger of contaminating adjacent areas and non-target plants is much greater when the herbicide degrades very slowly (Simmons, 1985).

The artichoke thistle has been successfully managed by a variety of state-approved herbicides. When 2,4-D appeared on the market in 1945, it was applied to many broad-leafed weed species, including the artichoke thistle (Thomsen and Barbe, 1986). 2,4-D is a foliar translocated herbicide which is now on the restricted use list. This type of herbicide enters the plant through the foliage and is then translocated throughout the plant. Foliar translocated herbicides are usually required to control a perennial like the artichoke thistle effectively, because the toxin actually needs to reach the root mass to kill the plant completely. Perennials are able to regenerate themselves from their root mass if only the upper portions of the plant are killed. 2,4-D's use is now restricted, because it is actually too effective and can damage other desirable plants even at extremely low doses. This makes containing its effects particularly difficult and necessitates special protocols for its use. It is also somewhat more toxic towards most animals than the average herbicide (Gowgani and Holmes, 1985). The risk of exposing cattle to 2,4-D makes its use too controversial for EBRPD to consider as a viable control option (Shea, 1988, pers. comm.).

There are other translocated foliar herbicides which are also very effective but potentially dangerous to use. For example, Round-up (glyphosate), tardon, and banvel have all been successfully used by the Contra Costa County Commissioner of Agriculture to control the artichoke thistle in the East Bay. All four of these chemicals (2,4-D included) are very effective at controlling the artichoke thistle, because they all share the same foliar translocation property. EBRPD has occasionally used banvel in the past. However, today only ammate is used. It is an inorganic contact herbicide which is less effective and requires more intense treatments for the same level of effectiveness. Because this herbicide is not translocated to the starchy root system, its effects are only concentrated on the upper portion of the plant. But it has the very desirable properties of a relatively rapid degradation rate and a breakdown product which is actually a fertilizer. It is currently being used as a potential control agent for artichoke thistles on test plots in Wildcat Canyon. The initial results appear very positive with a high death rate for treated plants (Brownfield, 1989, pers. comm.).

The artichoke thistle's distribution in Wildcat Canyon precludes the use of heavy equipment as a control measure in much of its range. The thistle is abundant on many slopes and hilltops which are simply too steep or too inaccessible for the use of large equipment. However, on the gentler slopes some mechanical control methods are being investigated. A new system using a Caterpillar vehicle with a spiked attachment is being evaluated for use on some of the very dense stands of thistle. It performs like a large rake which pulls up most of the thistle's root mass in large pieces (Figure 2). The long term effectiveness of this control method is very dependent on both the seed bank already in the soil and the vegetative growth potential of the root mass which remains after the treatment (Brownfield, 1989, pers. comm.).

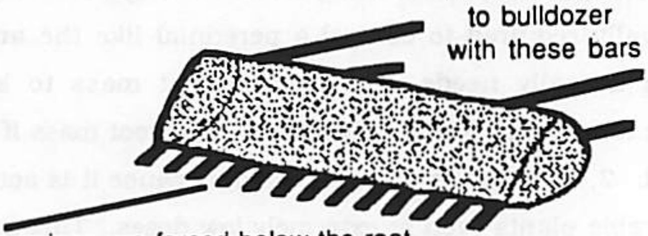

Figure 2. The rake-like Caterpillar attachment for up-rooting artichoke thistles

Methods

In order to determine the impact of removing the seed heads of artichoke thistles in Wildcat Canyon, one requires a detailed knowledge of the seed bank's quality. To evaluate the seed bank's reproductive potential, a survey was made of both the seed density and viability. The seed content in the soil was determined by taking core samples of soil and counting the number of artichoke thistle seeds present. Fourteen soil cores were taken from five areas of thistle infestation to obtain an overview of seed density in the Park (Figure 1). The choice of sampling sites took into account that the thistle's large seeds can only travel a few feet by wind dispersal. Cores were taken at varying distances from source plants, and the distance to the stalk was noted along with the distances to the nearest three plants. The value of the average distance to the nearest three plants roughly quantifies variations in the number of plants surrounding a sampling location. A high density of plants near a sample location could greatly increase the number of seeds in the soil at that particular site, and this needs to be accounted for when the data are interpreted. In order to analyze the fluctuations in seed density found in different soil core samples, one of the two confounding variables (variables which are independent of eachother, yet which jointly affect some outcome) needed to be held constant. The distance from the reference plant was held constant at 28 inches, while the distance between the neighboring plants was varied by taking samples in areas with different artichoke thistle densities.

In order to evaluate whether the direction of the wind has an appreciable impact on the distribution of seed density in the soil, an isolated plant was located. The average distance to the neighboring plants was greater than 35 feet. This distance is large enough to consider the contribution of seeds from other plants to the local soil around the reference plant negligible. The distance from the reference plant was held constant at 24 inches. To eliminate the effects of gravity as a potential influence on the seed density distribution, a level sampling site was chosen.

After the site for the sample was selected, an empty 3 pound coffee can was driven, open end-down, into the soil to a depth of 2.5 inches. The individual sample size was a cylindrical core of soil with a volume of approximately 70 cubic inches. The soil was moist enough to hold its shape inside the can, and a quick twist separated the soil in the can from the soil still remaining in the ground. The can was then simply lifted up, and the sample remained inside as one cohesive cylinder of dirt, but a metal spatula was placed under the opening as a safety precaution to prevent any loose soil from falling out. After the soil samples were collected, the seed density was determined by a simple but time-consuming counting process. The artichoke thistle seeds are readily identifiable without magnification, and their appearance is quite distinctive (Figure 3).

The density of seeds in soil is only one of the important factors which regulate the reproductive success of the artichoke thistle. The viability of the seeds is equally critical, and perhaps even more important than the density. Only one viable seed is required to propagate the species, and a large number of sterile seeds is completely useless. The viability of the seeds can be determined by testing the percentage of successful germinations.

For this study seeds from soil cores, undeteriorated seed heads, and burnt seed heads were all germinated under identical conditions. All three groups were planted in new potting soil in an indoor planter. They were exposed to 24-hour lighting by incandescent bulbs which also served as a heat source to maintain a constant warm temperature.

All of the seeds from soil cores without obvious defects which could make them unviable were planted at one of two times. The initial group of 60 seeds collected during November and December (1988) was planted during the first week in January. The seeds were placed about 2 inches below the soil surface. However, because of the loose packing of the soil, and the high buoyancy of the seeds, the first heavy watering caused many of the seeds to float to the surface. The second group, which consisted of 35 seeds from soil cores, was collected during January and was planted during the first week in February. This group of seeds was placed about half an inch from the soil surface, but it was watered with greater care, and less seed movement occurred.

A group of 100 seeds was also collected from seed heads which appeared to have deteriorated very little from weathering (Figure 4). This group was also planted during the first week in February, along with 60 seeds collected from seed heads found in an area burnt two years ago. The seeds collected from the burnt seed heads are at least two years old, because the only fire in the area occurred in July 1986. Only the outside edges of the seed heads were burnt. The seeds inside did not appear to be affected by the fire. The undeteriorated seed heads were of an undeterminable age, but they must have been at least 6 months old (the end of the last spring/summer growing season).

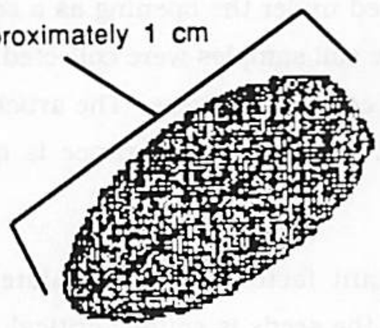

Figure 3. An artichoke thistle seed

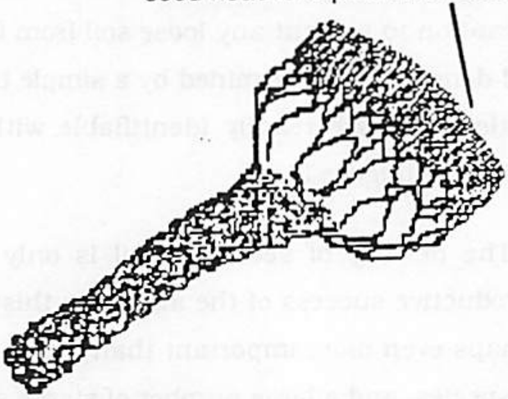

Figure 4. Morphology of an artichoke thistle seed head showing changes due weather (seeds heads are typically 3-5 inches in diameter)

The final piece of necessary data was an estimate of the total seed output of a single flowering head. An upper end approximation of this output was obtained by counting the number of pollen tubes inside a seed head in bloom. Each pollen tube has the potential to produce a single seed. Therefore, if 100 percent of the seeds were fertilized and developed, the number of seeds would equal the number of pollen tubes. This is the maximum number of seeds a single head could produce. The plant from which the pollen tubes were counted had a source of water late into the summer from a roadside drain. The extra moisture is probably what caused it to bolt (send up a stalk with a seed head on it) late in the year. Normally all the thistles are in bloom in the early part of the summer, but this plant was still in bloom in December.

Data

The seed density data presented in Table 1 displays a number of important values for each of the 14 soil core samples. The total number of seeds found has only a limited significance for evaluating the quality of the seed bank. There was a wide variability in the number of seeds present in the constant volume of dirt sampled. The highest total number of seeds in a single core was 69, and the lowest total number was only 4 seeds. However, these totals included many fragments of seeds which were obviously unviable. The total number of seeds in each soil core which lacked obvious damage (the last column in Table 1) is important for evaluations requiring seed density measurements. When these values are combined with the percent of successful germinations for seeds from soil core samples (Table 2), the seed bank's quality can be evaluated. Only the quantity of *viable* seeds are important for this evaluation.

Soil core sample number	distances from reference plant to the nearest three neighboring plants (feet)			average distance to nearest plant (feet)	distance from nearest plant to sample location (inches)	number of seeds found in soil core	number of seeds with no obvious flaws
1	4.5	6.5	6.0	5.6	12	69	18
2	35.0	35.0	35.0	35.0	24	12	4
3	35.0	35.0	35.0	35.0	24	6	2
4	35.0	35.0	35.0	35.0	24	5	3
5	35.0	35.0	35.0	35.0	24	16	4
6	10.0	16.0	5.0	10.3	28	4	2
7	1.1	7.0	9.0	5.7	28	42	19
8	8.0	7.9	8.7	8.2	28	9	3
9	4.8	17.0	17.0	12.9	28	9	9
10	1.1	1.2	1.5	1.3	28	11	6
11	6.0	8.0	6.0	6.7	28	30	9
12	13.0	15.0	11.0	13.0	36	16	6
13	5.0	5.5	5.0	5.2	48	31	18
14	4.5	6.5	6.0	5.7	60	9	6

Table 1. Data from soil core samples

Table 1 also displays two parameters which are useful for analyzing the fluctuations in the total number of seeds found. The average distance to neighboring plants varied with the choice of sampling site. The site in the densest stand of artichoke thistles where a soil core was taken had an average distance between neighboring plants of 1.3 feet. The greatest distance between plants in a sampling area was 35+ feet. A graph of the number of seeds found vs. the average distance to neighboring plants (Figure 5) shows that there are generally a higher number of seeds in the soil when cores were taken in areas of high artichoke thistle density. There was, however, a significant amount of fluctuation in the data. For example, there were a greater number of seeds found in a soil core taken from an area with a plant spacing of 5.7 feet than there were in a soil core taken from an area with a spacing of 1.3 feet.

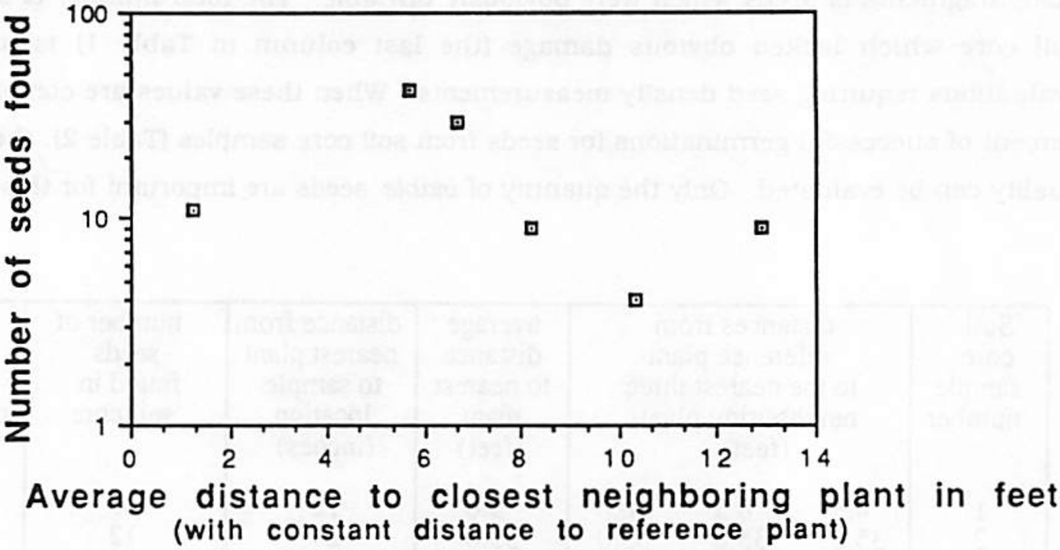

Figure 5. Seeds found vs. average distance to nearest neighboring plant

Data on number of seeds vs. distance to the reference plant (Figure 6) also shows a considerable amount of variability. This wide range probably results because the distance to the neighboring plants was not held constant. The effects of a neighboring plant's contribution on the seed bank could easily overwhelm the seed output of the reference plant. There should have been a trend showing a decreasing seed count as the distance from the reference plant was increased, because heavy seeds do not travel far by wind dispersal. However, no such trend was found, probably because of the influence of neighboring plants.

Table 2 displays the results of the germination studies. The two groups of seeds which came from the 14 soil cores had very low percentages of successful germinations, 5 and 5.9 percent. The group of seeds which came from seed heads with little weathering damage had a very high rate of germination. Almost 70 percent of the 59 seeds planted germinated. The group of seeds from burnt seed heads had an 11.5 percent germination rate. This is slightly higher than the rate from the seeds from the soil cores, but much lower than the germination rate for the seeds from the unweathered seed heads.

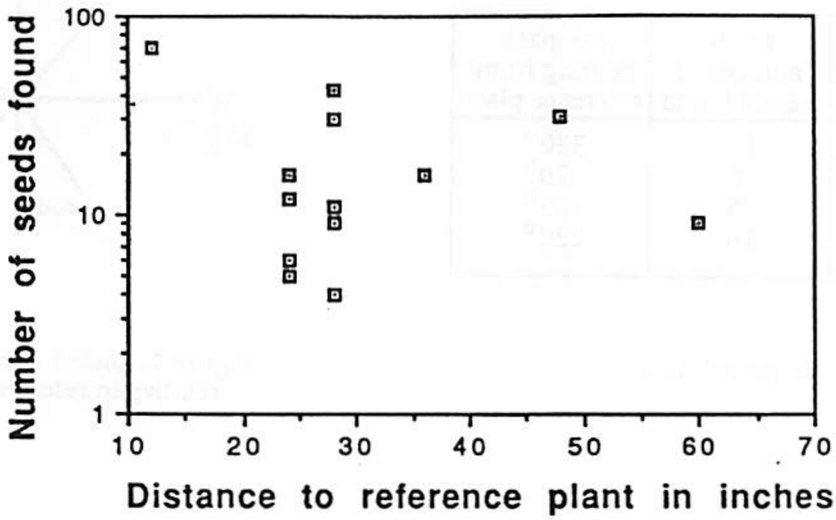

Figure 6. Number of seeds found vs. distance to reference plant

Seed source	number of of seeds planted	number of seeds that germinated	percent which successfully germinated
Seeds from group #1 soil cores	60	3	5.0
Seeds from group #2 soil cores	34	2	5.9
Seeds from unweathered seed heads	59	41	69.5
Seeds from burnt seed heads	60	7	11.7

Table 2. Germination data

Table 3 displays the total number of seeds found in four of the soil cores (#2-#5 in Table 1), along with the compass bearing of the sample's position relative to the reference plant. The number of seeds found in the N-W (330^{o}) direction and the S-W (220^{o}) were about double the number of seeds found in the N-E (70^{o}) and the S-E (165^{o}) directions (Figure 7). A larger sample size would be required to show definitively whether the orientation of the core sample relative to the source plant has a bearing on the number of seeds found. Measurements of the predominate wind direction at a particular site would also need to be correlated with the quantity of seeds found, to establish the wind's relevance as a factor in determining seed density distribution.

soil core sample number	total number of seeds found	compass bearing from reference plant
#2	12	330°
#3	6	70°
#4	5	165°
#5	16	220°

Table 3. Wind dispersal data

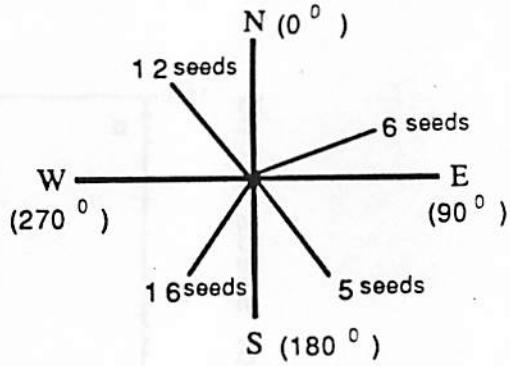

Figure 7. Distribution of seeds relative to reference plant

Discussion

The actual number of seeds found in the soil was lower than expected. The potential seed output of a single artichoke thistle seed head could be over 400 seeds, based on the number of pollen tubes found inside a dissected seed head which was in bloom. This should lead to a larger quantity of seeds in the soil than was actually encountered. One possible explanation is that the seeds never reached the soil. According to Jeff Wilson, a park supervisor at Wildcat Canyon Regional Park, birds, including Lazuli Buntings, Lesser Goldfinches, and American Goldfinches, feast on the seeds when they have developed, and the seed heads are open during late spring. Another possibility is that the seeds do reach the soil and are then consumed by some organism while on the ground. Insects, rodents, or other birds could all be possible consumers of seeds in the soil.

A more surprising finding was the very low viability of both groups of soil core seeds planted for germination studies, especially considering that only viable-appearing seeds were planted. This suggests that the actual germination potential of seeds already in the soil is extremely low. The seeds which came from unweathered seed heads were almost 70 percent viable. There is a very large discrepancy between this viability rate and the rate for seeds from the soil cores. The low viability of the seeds in the soil is probably due to a variety of factors. Because the seeds from the undeteriorated seed heads were very viable, poor initial viability caused by an inherent defect in the artichoke thistle seeds is very unlikely. If viable seeds are reaching the soil, then what could account for the low observed viability in my samples?

One likely possibility is that the bulk of the viable seeds which reach the soil, do germinate. The remains of many seeds without embryos were present in all of my samples. If the seeds do germinate reliably, then only the defective seeds would remain in the soil. The germination studies of seeds from soil cores would then show that seeds left in the soil are unviable. Unfortunately, after growing for a month the seedlings closely resemble the appearance of vegetative growth. This prevents a simple surveying of the plant population to find out if there is an appreciable seedling population. Another possible explanation is that something in the soil attacks the seeds and renders them unviable. Some type of micro-organism could be killing the seeds after they reach the soil. The new potting soil used for my germination studies was presumably sterile, and this would allow the seeds which were never exposed to this micro-organism (the seeds from the seed heads) to germinate However, the viability of the seeds from the burnt area was also much lower than the viability of the seeds from the unweathered head. These seeds (from burnt seed heads) were probably at least two years older, and this could be the cause of the change, but the effects of the fire could also have effected their viability. Heat from the fire may have sterilized the seeds, but other factors could also be involved.

There could also be a flaw in my methodology. The initial group of seeds from the soil cores could have been planted too deeply in the soil, and this conceivably could have prevented the seeds from germinating. However, a second group of seeds was planted later to confirm the low viability of seeds from soil cores. This second group of seeds was planted close to the surface, but still failed to germinate at appreciable levels. More importantly the seeds from the undeteriorated seed heads, which were planted with the second soil core seeds and exposed to identical conditions, did germinate at a much higher rate (almost 70 percent as compared to 5.9 percent). The conditions must have been close to ideal for the number of germinations to be that large.

There is also some empirical evidence supporting the fact that the thistle seeds in the soil must have a low viability. The spread of these plants in Wildcat Canyon has proceeded very slowly. If their sexual reproductive cycle was even remotely effective, the entire Park would be completely infested with thistles. These plants are able to tolerate a wide range of micro-climates, and they could survive in nearly all areas in the Park. There are often no physical barriers to stop their spread at the margins of their distribution. Even when allowances are made for the large weight and size of the seeds, wind dispersal of seeds which are 70 percent viable is likely to be capable of advancing this species much faster than is actually happening Some factor is apparently limiting reproduction largely to vegetative growth.

Recommendations

The low viability of the seeds in the soil is a very positive factor which should help make controlling the artichoke thistle a more manageable task. No seedlings have developed yet (as of April) in the District's test plots cleared with the Caterpillar, but it may still be too cold. Hopefully, the low viability of seeds already in the soil is the reason nothing has yet developed. Any control technique which does not sterilize the soil needs to be evaluated, considering the potential of the seed bank to reinfest the area. It is not good enough simply to kill the existing plant. Some follow-up measure will probably be required to maintain control. Either seedlings, vegetative growth, or a combination of the two could cause a one-time control effort to fail. My research on the quality of the seed bank suggests that the seeds already present in the soil are unlikely to cause a major reinfestation, because of their low viability. Areas carefully cleared of the artichoke thistle's root mass should remain clear. The vegetative growth potential of the thistle seems to be a more important factor in the thistle's ability to resist eradication than the seed bank already in the soil.

However, there are still a few significant questions about the artichoke thistle's reproductive cycle which remain unanswered. A further study of the thistle's ecology is required to understand what happens to the viable seeds produced each spring. This missing information is critical because it is possible that these seeds are making a significant contribution to artichoke thistle population. Further research is needed to test where these seeds actually end up. A very useful experiment would be to place some type of collection device (such as an open-ended box with hardware cloth on top to protect the collected seeds from bird ingestion) on the ground under plants with seed heads in bloom. This experiment would determine if the viable seeds were actually reaching the soil. The actual seed output of seed heads could be directly measured by counting the seeds inside a few seed heads before their consumption or dispersal.

To determine if something in the soil at Wildcat Canyon kills the seeds which do reach the soil, a germination study could be conducted using soil from the Park. The results of this study would indicate whether the seeds were less viable than the ones planted in sterile potting soil. A survey of the number of seedlings which develop on the cleared test plots would also be useful to confirm whether the low viability encountered in my germination data also occurs in the field. Vegetative growth was the dominant form of growth in the early spring, but the seedlings could still develop once the temperature is warmer.

A survey of the average number of seeds found in weathered seed heads combined with a germination study of these seeds would yield very useful information. It would then be possible to determine whether the seed heads should be removed to prevent their seeds from making a further contribution to the thistle problem in Wildcat Canyon. These data might also help to answer the question of why the viability of the seeds from the seed heads found in the burnt area was very low. If the seeds from a non-burnt seed head were also unviable, then some factor other than the fire must be reducing their viability. Age could be an important factor or perhaps a micro-organism can reach the seeds and kill them while they are still inside the seed heads.

The removal of the seed heads before digging up the root masses of the thistles should be a mandatory practice. Physical removal of the artichoke thistle plants could release the remaining seeds from deep within the seed heads. This would cause potentially viable seeds to reach the soil. The extremely high viability of the seeds from the unweathered seed heads necessitates their removal before any disturbance which could cause their dispersal. The older seed heads may not be as critical to remove, since their viability appears to be lower.

Seed head removal used as an isolated technique, without attacking the root mass, would yield very marginal control results. The ammate treatments appear to be quite effective at killing the target plants. These treatments should either be applied before the plants bolt, or if the treatments occur late in the growing season, the seed heads should be removed to prevent their seeds from reaching the soil. Thick stands of artichoke thistle which are accessible should be removed mechanically. This could significantly reduce the total quantity of ammate required to control the thistle population throughout the park. The root masses which were missed by the Caterpillar blade could be controlled economically by a treatment with ammate later in the season. Remote locations and areas with low plant densities would be treated most economically with ammate. Because the seed bank's quality appears very low, and the spread of these plants appears to be very slow, a treatment program could be effective even on a limited scale. An all-out assault on the thistle population does not appear to be necessary. I would recommend a small steady treatment program which targets the densest stands of thistles first. The thistle population will take a long time to control, but it is not an insurmountable problem. The task of controlling the infestation becomes progressively more difficult as time elapses. And although the rate of increase is not excessive, the control of these plants will be a long process which should be started immediately.

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