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The cost and effectiveness of small-scale control methods on fennel, Foeniculum vulgare, in Natividad Creek Park, Salinas, CA

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To the SEP Faculty:

Non-native, invasive species around the world out-compete their native counterparts for resources. This often results in the degradation of biodiversity in the area that has been invaded, harming habitat for native species. In the United States, invasive species cost about $23.4 billion per year in annual crop losses and about $125 billion per year to control. Invasive weeds are estimated to be invading US wildlife habitat at a rate of 700,000 hectares per year. This scientific inquiry capstone project focuses specifically on one invasive plant species in California, *Foeniculum vulgare*, commonly known as fennel.

Most of the literature written about fennel control methods concerns large infestations, such as those on Santa Cruz Island and in Camp Pendleton, California, and involve large-scale methods such as mowing or aerial application of herbicides. For small infestations, the available literature recommends digging individual plants up to remove the thick, fleshy root from which the plant can re-sprout. However, in Natividad Creek Park (NCP) and Upper Carr Lake (UCL) in Salinas, the ground becomes quite hard and difficult to dig in once the seasonal rains stop. As the main growing season for fennel observed in NCP and UCL is through the summer months, this poses a challenge for controlling this species.

My experiences volunteering with the Bureau of Land Management (BLM) on Fort Ord, working for Return of the Natives as a Weed Warrior and attending the California Invasive Plant Council (Cal-IPC) 2005 Symposium in Chico have taught me many things about controlling invasive weeds in California, such as the fact that many weed management groups are working with small budgets and limited resources, including time. It was with this in mind that I designed my capstone project. I tested three different methods for controlling fennel and compared the monetary and labor cost of each option. The methods included: digging out the plants with a shovel, chopping the plants repeatedly throughout the summer with a machete, and chopping the plants once before immediately applying the herbicide Rodeo (glyphosate). The question this project sought to answer was which method is most effective at controlling fennel and is the least expensive in both Salinas locations.

This paper assumes a bias against invasive plants and that fennel should be removed from Salinas' parks. I place value in undisturbed natural areas, as well as open space within cities to provide natural corridors for wildlife to travel through what might otherwise be an impassible obstacle. These parks also provide the city's residents with recreation opportunities and chances to learn about the natural world. My methods may also suggest a bias against certain control methods, though I tried to choose commonly used tools in the invasive species management trade, and methods that could be easily translated to other tools and locations. The tools I used are discussed further in my discussion section.

This paper is intended as a resource for those who seek information on fennel eradication, and audiences which include those who attended the Cal-IPC 2006 Symposium in

Rohnert Park and those who attended the War on Weeds conference at CSU-Monterey Bay. I presented the results of this project at both of these conferences in poster format. I believe that my capstone could be very useful for others working to eradicate fennel in similar situations and help to establish some weed management practices for Return of the Natives in Salinas' parks. I also hope that this paper will encourage further sharing of weed control methods for different species and situations among weed management groups and others who could use the information, such as city park managers.

Sincerely,

Abigail Gwinn

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A Capstone Project

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Abstract

Invasive species in the United States cost the federal and state governments billions of dollars per year and are spreading through wildlife habitat at a rate of about 700,000 acres per year. Information on effective methods of controlling various invasive species is crucial to land managers and others who seek to remove invasive, exotic species and restore their lands to a more natural state. This study examines which of three methods will work most effectively at controlling fennel (*Foeniculum vulgare*) in a small-scale infestation in two sites in Salinas, while costing the least. The methods are: digging out individual plants with a shovel, chopping the plants repeatedly during the summer with a machete, or chopping the plants and immediately spraying the stumps with an application of the herbicide Rodeo. I discovered that the most effective method was digging each plant individually, with chopping and spraying with herbicide a close second. The method of chopping repeatedly was not effective at all, with a mortality rate very similar to my control group of plants which received no treatment. I also found that the least expensive method was chopping and spraying, with chopping repeatedly a close second. Digging the individual plants was the most time consuming and therefore the most expensive. My recommendation for controlling fennel based upon my results is that if herbicide application is not an issue, then chopping and spraying each plant with an herbicide is the best treatment method. If soils are soft and the infestation is small, digging up each individual plant is the best treatment method.

Introduction

Across the United States, invasive species cost federal and state governments billions of dollars each year. The estimated cost of the control of invasive species in the

US is $125 billion per year, and in annual crop losses invasive plants account for approximately $23.4 billion per year (Myers and Bazely 2003). Another estimate of the damage caused by invasive plants was approximately $97 billion caused by 79 exotic species during the period between the years 1906 and 1991. This includes losses in agriculture, forestry, and harm to the environment (Pimental et. al 2000). Invasive plants can be defined as "an alien plant spreading naturally (without the direct assistance of people) in natural or seminatural habitats, to produce a significant change in terms of composition, structure or ecosystem processes" (Cronk and Fuller 2001).

Though some plant invasions naturally occur because of climate and habitat changes, the great majority of invasions have been caused either intentionally or unintentionally by humans (Luken and Thieret 1997). Invasive plants are estimated to be spreading in the United States at a rate of 3 million acres per year and are estimated to occupy over 100 million acres. The costs of invasive plants includes losses in agricultural productivity and the costs of controlling these plants on both agricultural lands and natural lands, which are being over taken by invasive species at a rate of approximately 700,000 hectares per year (Myers and Bazely 2003; Pimental et. al. 2000). The rapid spread of invasive plants and these associated costs have resulted in various laws passed in the United States over the past fifteen years calling for the oversight of the spread of invasive plants. This includes a Presidential Executive Order that instructs federal agencies to develop policies regarding invasive species on federal land, and to form Invasive Species Councils (Myers and Bazely 2003).

The State of California is one of the most ecologically diverse places in North America, though human land use practices and the invasions of non-native plants have

reduced the habitat for many of the unique plants found in California (Ornduff et al. 2003). Due to these land use practices and the encroachment of invasive plants, in the last 200 years thirty-nine California native plant species have become extinct and another 675 species have become rare or endangered (Barbour et al.1993).

In the Salinas Valley in Central California, land management practices have reduced the amount of native habitat severely, leading to the invasion of exotic species on the remaining or restored habitats. Before the 1870s, the land where the city of Salinas now sits was a series of streams, marshes and sloughs (Cameron et al. 2003). The highly saturated land was undesirable to people who began settling in the area, and so projects to drain the land and channelize the water began in order to render the highly fertile land underneath suitable for agriculture and the construction of buildings and roads (Cameron et al. 2003).

Based on population density, the amount of open space available to the people in the City of Salinas is far below the national norm, making its park space all the more important. Salinas has approximately 2.18 acres of open space per 1000 people, which is well below the national standard of 10 acres per 1000 people (Cameron et al. 2003). In recent years, the City of Salinas has created several new parks, helping somewhat to expand the amount of open space available to the public in the city. These city parks are managed by the Parks Department which has been severely understaffed for a number of years due to budget constraints. Since the Parks Department is also in charge of invasive weed control, some invasions have gotten out of hand. These plant invasions further reduce the quality of parks and their capability to serve people. However, Return of the Natives has stepped up to help the City of Salinas reclaim its parks.

The Return of the Natives (RON), a non-profit environmental organization associated with the Watershed Institute at CSUMB, has collaborated with the City of Salinas in restoring native plants in several of the city's parks for over a decade (Plotsky 1996). Some of RON's goals include restoring waterways and native habitats in areas where they have been removed or damaged. An example of this can be seen at Natividad Creek Park. Alongside of the typical playground equipment, picnic tables and playing fields, native plants are colonizing the hillsides and the creek flows in a broad, vegetated channel instead of through the narrow irrigation ditch it once was. A better example might be Upper Carr Lake, also known as Lower Natividad Creek Park or Laurel Lake. Upper Carr Lake, a large pond frequented by water birds is surrounded by fields and hillsides which are in the midst of the restoration process. Upper Carr Lake serves as a hopeful preview for the agricultural fields across Laurel Drive that will someday be restored to the historic Carr Lake, creating a park that will be comparable in size to San Francisco's Golden Gate Park (Cameron et al. 2003).

Part of the restoration process at Natividad Creek Park and Upper Carr Lake involves removing the invasive plant species in the park. This includes *Foeniculum vulgare*, commonly known as fennel, sweet fennel, aniseed, anise or sweet anise (Bossard et al. 2000), here referred to as fennel. Although the fennel in the park is currently not as widespread as in other places, it has the potential to become a much larger problem. Fennel is a perennial herbaceous species that grows rapidly and can spread by seed or re-grow from its root crown. It was introduced to California from the Mediterranean region at least 120 years ago (Bossard et al. 2000), and it generally occurs in open, disturbed areas or along roadsides (Brenton and Klinger 2002). A single fennel plant can produce

thousands of seeds during its first growing season and it can produce hundreds of thousands of seeds during its second year (Erskine Ogden and Regmánek 2005). It has been known to form dense, monospecific stands that compete with other plants for resources (Holloran et al. 2004). Fennel has some value as an agricultural crop (Brenton and Klinger 2002) and has likely escaped from cultivation several times (Robbins et al. 1941 cited in Bossard et al. 2000). It is able to successfully compete with native perennials in coastal sage communities, probably due in part to its ability to grow during the summer when most native species are dormant (Weber 2003).

Many studies on the control of invasive fennel have been done on Santa Cruz Island, California, where heavy agriculture practices introduced and spread fennel throughout the island's central valley (Brenton and Klinger 2002). The fennel became a dominant invasive species on the island after the agriculture stopped and land managers removed feral sheep and cattle in the mid-1990s, eliminating the control measures provided by livestock browsing (Erskine Ogden and Regmánek 2005). Fennel removal practices have occurred on a large scale and have included controlled burns and the aerial application of herbicides (Cronk and Fuller 2001). Burning was determined to be effective only in removing dead stems from the previous year to prepare the stand and make it more susceptible to herbicide applications (Erskine Ogden and Regmánek 2005). Cutting the plant before applying herbicide has also been reported not to lead to a greater reduction in fennel cover, and in some cases cutting the plants inhibited the effectiveness of the herbicide because cut stems blocked the spray from coming in contact with the new growth (Brenton and Klinger 2002). Herbicides that have been determined to be effective are amine and ester formulations of triclopyr (Garlon 3A and Garlon4) and

glyphosate (as Roundup), with all treatments most effective in the spring (Bossard et al. 2000).

The purpose of this project is to determine which control methods work most effectively at killing or preventing the spread of fennel in Natividad Creek Park in Salinas. In light infestations, such as the ones in Natividad Creek Park and Upper Carr Lake, the literature indicates that manual and mechanical methods seem to be most effective (Bossard et al. 2000). However, these methods are labor-intensive since individual plants must be dug out or chopped repeatedly in order to exhaust the resources in the large taproot (Bossard et al. 2000). Additionally, I have noticed in my work as a Weed Warrior at Natividad Creek Park and Upper Carr Lake that the heavy clay soils are very difficult to dig in, which makes the method of digging out each plant very time consuming. In the summer of 2005, I practiced some fennel control in conjunction with removing other invasive plants from the park. In most cases this involved chopping individual fennel plants with a machete, usually with the intent to remove flowering stalks to prevent them from going to seed. In some cases, the fennel plants were chopped with a machete with the intent to kill the plant by removing as much of the leaves and stalk as possible. Some fennel plants were also weed-whacked along with annual grasses and Italian thistle to reduce the amount of invasive plants in an active restoration area. I noticed that some of these chopped fennel plants regenerated but was unsure if this was true for all fennel plants that had been chopped.

In this project, I attempted to determine which of the available physical, chemical, and mechanical methods removed *Foeniculum vulgare* in Natividad Creek Park and Upper Carr Lake with the greatest frequency of success and lowest monetary and labor

cost. I tested three different treatment methods and compared them with a group of control plants. The three treatment methods were, 1) digging the plant out with the intent to completely remove the root, 2) chopping the plant every two weeks during the summer months, and 3) chopping the plant once and then applying the herbicide Rodeo to the chopped plant. Additionally, the time required for each method was recorded, as were any other costs (such as the price of Rodeo). Other individuals or organizations working to remove fennel in a similar setting should be able to use my data to determine which method to use for maximum fennel mortality with minimum labor and cost.

Methods

Site Description:

Natividad Creek Park is between the North and East sections of Salinas and extends from Boronda Road down to Las Casitas and from there down to Laurel Drive. This second portion of the park has more recently been referred to as Upper Carr Lake to distinguish it from the Boronda to Las Casitas portion of the park. Upper Carr Lake includes a large pond frequented by water birds, a bike path and several restored areas including the hillside near a county yard. This hillside is the location of one of the invasions of fennel in the park and was my first study site (Figure 1).

Figure 1: Aerial photo and roadmap of Upper Carr Lake, Salinas with Site 1 outlined in black (Google 2006).

Natividad Creek Park proper also has a bike path as well as playing fields, picnic benches, a small amphitheatre, playground areas, a skate park and other common city park facilities. There are also several open fields with a mix of native and exotic plant life. One of these fields, bordered by Freedom Boulevard and Nogal Drive, is also being invaded by fennel and was the location of my second site. I chose to use the plants along the hillside (Figure 2) bordering this field because the field burned in mid-June 2006 (Briscoe 2006). The fennel plants in this field did re-emerge after the fire but they did so nearly a month after my study began.

Figure 2: Aerial photograph and roadmap of Natividad Creek Park with Site 2 outlined in black (Google 2006).

The soil at both sites was very hard-packed and the surrounding vegetation consisted of non-native annual grasses with a few native bunch-grasses as well as young oak trees (*Quercus* sp.), coyote brush (*Baccharis pilularis*), and other native plants that were most likely planted as part of the restoration program for the park. Other invasives, such as curly dock (*Rumex crispus*), bristly oxtongue (*Picris echioides*), and English plantain (*Plantago lanceolata*), were also present.

Determination of Sample Size:

I visually surveyed the two sites on March 24, 2006, to find out how many plants were present in order to determine what my sample sizes should be. Based on this survey, I determined that my sample should consist of a total of one hundred plants, with fifty plants per site and twenty-five plants per treatment method.

Experimental Design:

Sampling Procedure:

On June 26, 2006, I randomly selected one hundred fennel plants (fifty each at Natividad Creek Park and Upper Carr Lake). Each plant was measured and placed into one of three height categories: less than 60 cm, between 60 and 120 cm, and greater than 120 cm (Figure 3). I also recorded the circumference of each plant at approximately twenty centimeters above the ground (Figure 4). The position of each plant was recorded using Trimble GPS equipment. Each plant was also flagged with flagging tape and numbered in order to keep track of the locations of the plants. Each plant was then randomly assigned to a treatment method.

Treatment Methods:

There were three treatment methods as well as a control. The amount of time spent on each individual plant for each method was recorded in order to determine the cost of labor for each method. Treatment methods began on July 10, 2006, and monitoring was conducted every two weeks during the summer of 2006. This monitoring included chopping any new growth on the "chop repeatedly" plants and removing the flower heads from the control plants. These methods were:

1) Control: These plants were generally left alone, though they were monitored throughout the summer for the production of any flowering heads. These flower heads were removed with hand clippers or by pinching them off at the stems without disturbing the rest of the plant. This was done in order to prevent the control plants from producing seed and furthering the invasion of fennel in the parks. The time spent on each of these plants was not recorded.
2) Dig: The digging method was conducted with shovels, and the amount of time spent per plant was recorded. The goal of the digging method was to remove all of the plant and as much of the root as possible.
3) Chop Repeatedly: A machete was used to remove all stalks and reduce the plant to a height of no more than twenty centimeters. These plants were revisited every two weeks during the summer to remove any new growth with the machete. The times recorded for this method included the time spent per plant each day it was chopped.
4) Chop and Spray: At the beginning of the study, each of the twenty five plants in this group was reduced to a height of no more than twenty centimeters by using a machete. As each plant was chopped, a 2.5% solution of the herbicide Rodeo (glyphosate) was immediately sprayed on the cut stump ends. These plants were not chopped or treated again during the remainder of the study. This method was the only one to use two people, one to chop the plant and the second to spray the sumps with the herbicide. This was done for safety reasons.

Choice and Application of Herbicide:

I specifically chose to use the herbicide Rodeo in this study rather than Roundup, which has been used in other studies (Bossard et al. 2000; Weber 2003), to try to reduce my impact on the surrounding parks. The herbicides Rodeo and Roundup are both formulations of glyphosate; the difference is that Rodeo does not contain a surfactant while Roundup does (Relya 2005). Directions for the usage of Rodeo recommend the addition of a surfactant since there is not one already present. Some studies have shown that it is the surfactant that is present in Roundup and added to Rodeo that can be lethal to amphibians (Relya 2005; Trumbo 2005). In order to reduce my impact upon riparian zones downstream from my study sites, I did not add any surfactant to my Rodeo mixture.

I mixed a 2.5% solution of Rodeo with water in a standard 1-Liter spray bottle. The label on the bottle of Rodeo recommended a 0.75 – 1.5% solution to control fennel. However, the recommended concentration for cut-stump application was much higher, 50 to 100%, though this method was recommended for woody vegetation. Since I was not using a surfactant I decided that a slightly stronger solution than the recommended 1.5% would be more effective, so I used 2.5%. This solution was sprayed on the cut stems of the fennel after they were chopped with a machete. No plants were only sprayed with herbicide, even though there is no research to suggest that chopping the plant prior to herbicide application increases the effectiveness (Brenton and Klinger 2002). In this study I wished to reduce the impact of herbicide on the surrounding environment, and by chopping the plant first I reduced the area of the plant that needed to be sprayed with the herbicide, and thus reduced the drift of the herbicide onto other plants and into other parts

of the park. This also reduced the impact of the herbicide on visitors to the park and on the waterways within the park.

In order to prevent the possibility that the plant might be able to seal off the cut stems, thus blocking the penetration of the herbicide, the herbicide was sprayed on the plant immediately after it was cut. This treatment was the only method to use two people, one to chop and one to spray, since juggling a machete, stopwatch, spray bottle and the necessary safety gear could have been dangerous.

Assessment of Effectiveness:

All plants were evaluated on September 4, 2006, to measure the effectiveness of each method. Each plant was categorized as either 'dead,' 'stressed' or 'alive.' For a plant to be considered dead, it could not have any new growth or be green on any part of its stem. In cases where the plant had been dug up, the plant was considered dead if it had not resprouted. Stressed plants were plants that showed obvious signs of being stressed and not fully healthy, such as having wilted, yellowed leaves or drooping stalks. Plants that were considered alive were plants with green leaves and stems and they generally showed signs of new growth. The plants were surveyed again on October 12, 2006, to check if the recent rainfall had dramatically changed the status of the plants. There were no changes since September 4th.

Data Analysis:

I computed the total time spent per plant, as well as the mean time per method. This was converted into mean cost per method by assuming a pay rate of $10 per hour for

a single person. I also created a tally of the survivability per method in Excel and then imported that data into SPSS where I ran a chi-squared test on the survivorship versus the method used.

Results

Fennel Sizes:

Most of the fennel plants in my sample fell into 'the greater than 120 cm' height classification (Figure 3) and between 0 and 80 cm in circumference (Figure 4).

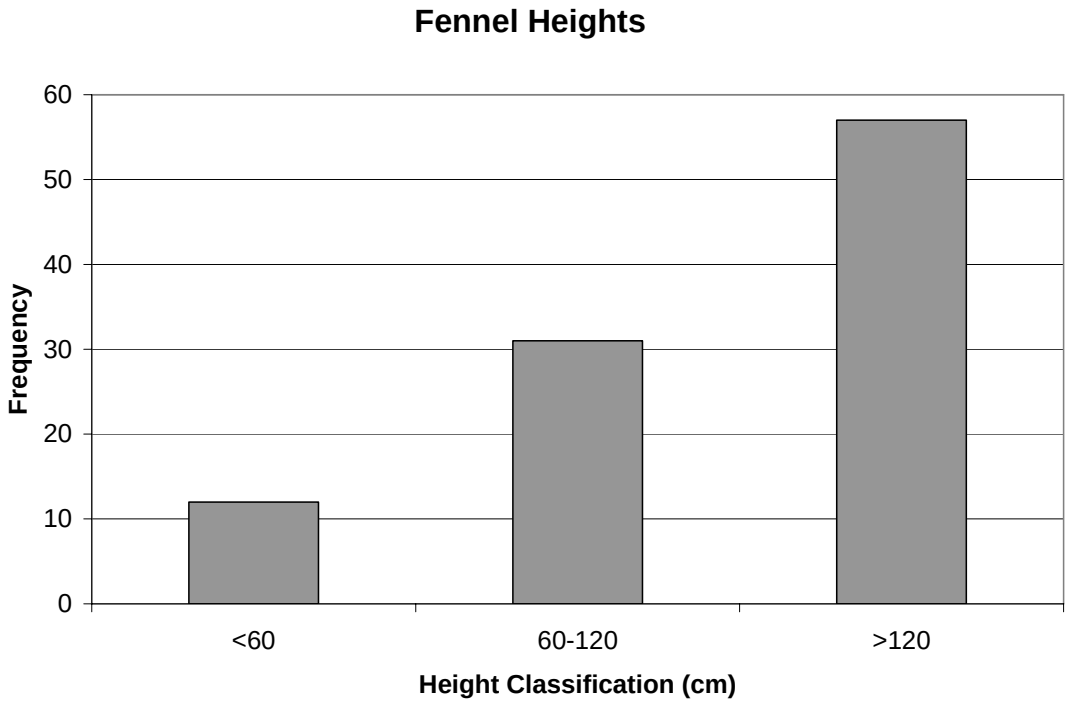

Figure 3: Each fennel plant in the study was measured and placed into a height classification: less than 60 cm, between 60 and 120 cm, and greater than 120 cm.

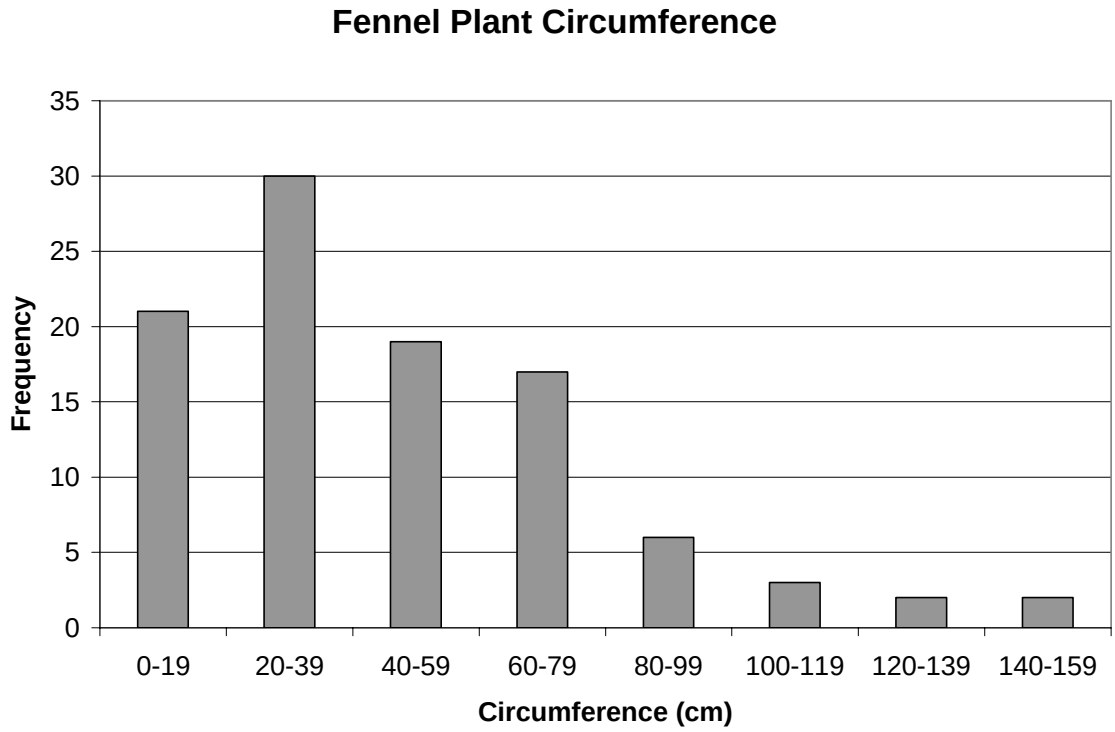

Figure 4: The circumference of each fennel plant in the study was measured at about 20 cm above the ground.

Effectiveness at Killing Fennel:

The three fennel control methods I tested had very different effects on the fennel population (Chi-Square = 67.7, $p<.001$, df = 6). The most successful method I tested, resulting in 100% mortality, was digging the individual plants out (Figure 5). Chop and spray with herbicide was a close second with 96% mortality. The method of chopping repeatedly was completely ineffective, resulting in survivability very similar to that of the control plants (Figure 5).

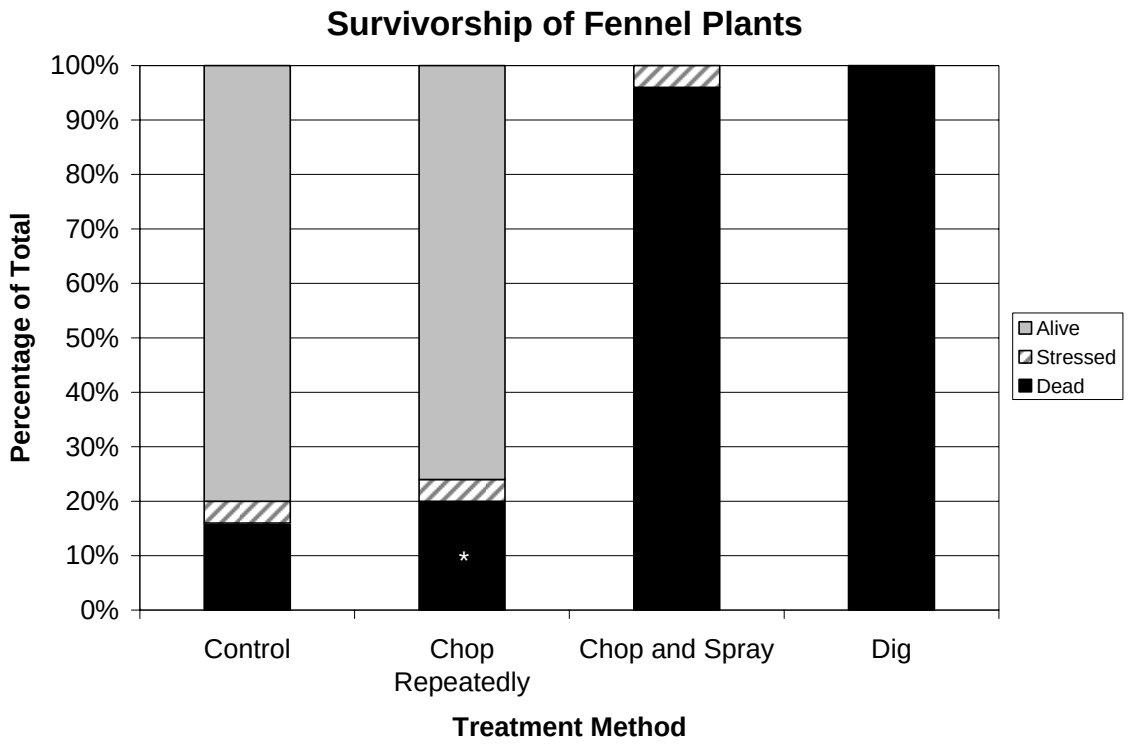

Figure 5: The cumulative percent of fennel survivorship in each of the four treatment methods. *Two of the plants listed as dead in the chop repeatedly method were missing during the assessment.

Cost per Method:

The most expensive method was digging, with an average cost of $3.49 per plant. The least expensive was to chop and spray each plant, with an average labor cost of $0.16 per plant. This does not include the cost of Rodeo used, which was less than $0.39 for the entire study. Chopping repeatedly was also fairly inexpensive (Figure 6, Table 1).

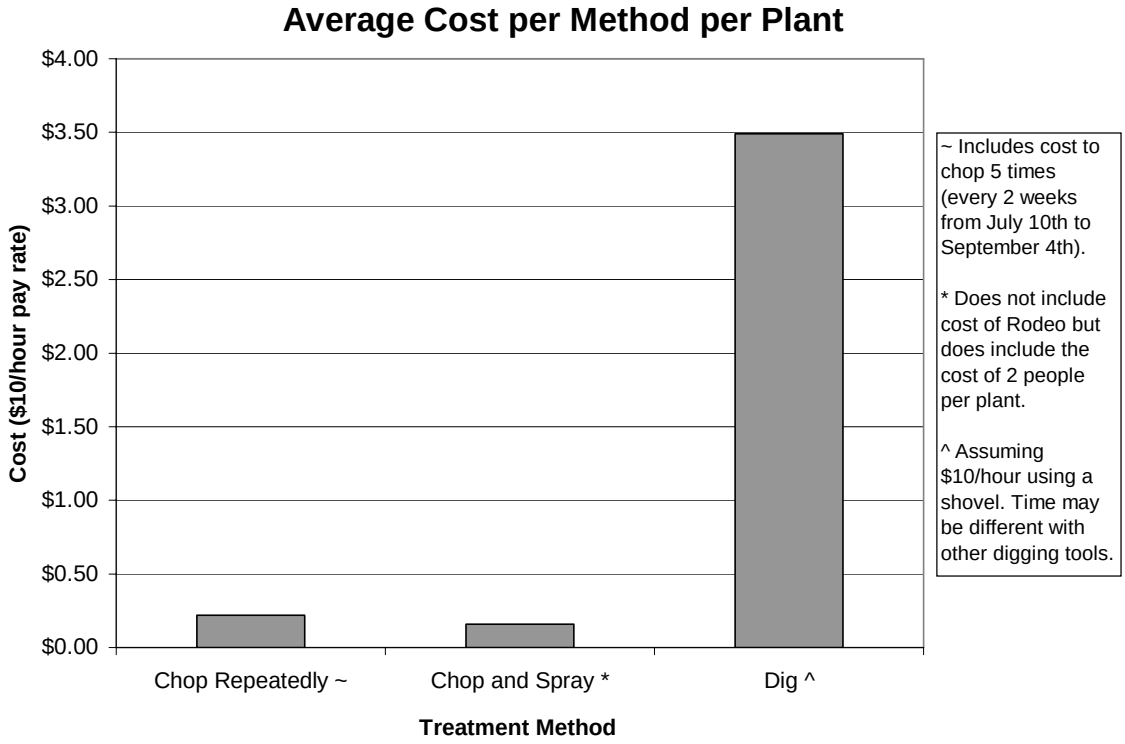

Figure 6: The average cost of labor for each method (not counting the control), assuming a pay rate of $10.00 per hour.

Table 1: The average cost of each method per plant, as well as the range of cost. (Note the maximum cost for digging). Each method involved 25 plants.

	Chop Repeatedly	**Chop and Spray**	**Dig**
Average Cost	$0.22	$0.16	$3.49
Minimum Cost	$0.06	$0.06	$0.36
Maximum Cost	$0.77	$0.31	$11.33

Discussion

I found that the most effective method of killing fennel was also the most expensive. Assuming a pay rate of $10 per hour, the most expensive method was the digging method with an average of $3.49 per plant, a minimum of $0.39 and a maximum

of $11.33. This method was extremely time consumptive with each plant averaging about 20 minutes to dig out and one notable plant taking over an hour -- 68 minutes -- to dig out. It is possible that this time may be reduced by using a different tool, such as a Pulaski or mattock instead of a shovel, however only the shovel was used in this study. The digging method was completely successful with none of the twenty-five plants surviving.

The chop repeatedly method cost on average $0.22 per plant with a minimum of $0.06 and a maximum of $0.77. This method was also the least effective in killing the plants. Only five of the twenty-five plants in that method ended up classified as dead and two of those five missing, possibly from rodent activity. This mortality rate was roughly equivalent to the mortality rate of the control sample which had only four out of twenty-five plants die.

The chop and spray method was nearly as effective as the dig method in killing the plants, with twenty-four dead and one stressed plant. The chop and spray method was also the least expensive in labor cost with an average of $0.16 per plant with a minimum of $0.06 and a maximum of $0.31. However, this cost does not include the cost of the herbicide used. I used a very small amount of the herbicide (25ml) and still had about half of my mixture left after treating all twenty-five plants that received that treatment. Rodeo sells for about $60.00 per gallon, so the cost of the herbicide I used was about $0.39, or less, since I did not use all of the solution I made. For broadcast application, the amount of herbicide that should be used per acre varies depending on the target plant and size of the invasion. The product label lists 1.5 pints per acre, plus surfactant, if

weeds are less than six inches tall and 2.5 pints per acre for plants greater than six inches tall.

The fennel plants used in my study tended to be moderately sized compared to other invasions. While most of them were taller than 120 cm, they were also generally smaller than 80 cm in circumference. It is important to note that this study focused on a small invasion of plants of this size that were often spread out by several feet. Larger plants likely would have taken even longer to dig out or chop. Other fennel invasions often involve much larger plants growing in a more densely packed manner.

The tools used in this project, particularly the machete for chopping and shovel for digging, were chosen from personal experience with the tools. I tried to choose tools that would be appropriate to the methods I was testing. It is possible that the use of a tool such as a Pulaski for the digging method could have reduced the amount of time taken per plant. However, in my experience it is very difficult to judge how much of the root has been removed with the Pulaski since the tool is very good for chopping away at the root but it is not very precise in digging. The use of a shovel may have made the digging method take longer, but I was able to reliably determine if the large, fleshy part of the root had been removed. I must note, however, that none of the plants had their entire root removed. Once the large, bulbous portion of the root was removed, there was still a fibrous part of the root remaining which I was unable to fully extract. Some sources indicate that removing the top three to six inches of the root crown will kill the plant if the entire root cannot be removed (Holloran et al. 2004). However, there is some speculation that any portion of the root left behind will allow the fennel plant to resprout. In my study I have not seen any plants resprout from any pieces of the root that had been

left behind, but this study was only done in the scope of one growing season and there exists the possibility that these plants may be able to regenerate. Further study on this subject would be very useful for weed workers combating fennel invasions.

The machete was chosen for both methods that require chopping because previous experience has shown that the machete is generally able to chop an entire fennel plant more rapidly than clippers or garden shears, which I have often observed to be only able to cut one or two stalks at a time. Since the chop and spray method required that the plant's stump be sprayed with herbicide immediately after the plant was chopped, the machete seemed to be the more appropriate tool to use. However, I have noticed that clippers are more useful in cutting fennel plants that have many dead stalks mixed in with live growth, or plants with stems that grow horizontally along the ground for a ways before growing vertically. It is possible that clippers may be just as effective as the machete at the chop and spray method.

The study on fennel control on Santa Cruz Island, which found that cutting the plants before the application of herbicide did not lead to a greater reduction in fennel (Brenton and Klinger 2002), was conducted differently from my study. This could explain why my cut and spray method was more successful. Brenton and Klinger's (2002) study area was divided into 10 replicate plots 30 meters square, which were subdivided equally into sixteen 6-meter square sub-plots, each of which were separated by a 1.5 meter buffer strip. Five of these subplots were cut and had either an ester or amine herbicide applied via a backpack sprayer. The fennel was cut to a height of 0.5 meters immediately before herbicide application and the cut material was left on the ground. It was speculated that this may have been part of the reason why cutting seemed

to inhibit the effectiveness of the herbicide since the cut stems probably intercepted the spray (Brenton and Klinger 2002). My study focused upon individual fennel plants instead of plots, and the herbicide was applied directly to the cut stump as soon as the machete and the cut plant material were out of the way. This is probably why my cut and spray method was more effective than Brenton and Klinger (2002). However, Brenton and Klinger's (2002) study is probably more useful on a landscape level or when it comes to large invasions.

Flaming, or blanching as it is sometimes called, was discarded as a method since some of my research indicated that burning the plants was only useful in removing the previous year's dead stalks (Erskine Ogden and Regmánek 2005), and indeed I observed that the fennel in the field that burned in June of 2006 was one of the first plants to re-emerge. There is a possibility that the fire cleared the seed bank as I did not notice any seedlings in the burned field, only mature plants resprouting from their root crowns. In my research, I did not run across any references that indicated that the fennel seed bank is affected one way or another by fire. Further data on the population biology of fennel, such as seed bank viability, would be useful to weed managers.

My methods seemed to work well at the onset of a fennel infestation and could perhaps be more effective if volunteers are utilized. Both parks already have a history of being tended to by volunteers from the community, including school groups. These volunteers have picked up several thousand pounds of trash, planted many native plants, and have helped to remove invasive plants. Properly planned, a volunteer event could potentially remove a large amount of fennel. A few previous fennel removal events during the summer were not as successful as they might have been since the method was

to dig out each plant with a shovel or Pulaski. In less than an hour most of the volunteers were hot, tired, and discouraged since they had managed to dig up only a few plants. An alternative method might be to give volunteers clippers to chop plants followed by employees armed with spray bottles filled with the Rodeo mixture. There would need to be adequate considerations for safety, including finding some way to mark a plant that has been sprayed with herbicide, such as adding an indicator dye or flagging a plant already sprayed. Volunteers would also need to be properly introduced to the method so that they understand the importance of spraying the cut stump immediately after it has been cut.

My hope is that this data will be useful for other people who are trying to control fennel. As I discovered in my research, there are several studies on the control of a specific plant, but often these studies research only one type of control method or are performed at a very large scale. Since there are many different weed control methods available as well as many different situations in which weeds need to be controlled, these specific studies are not always useful. I hope that this paper will help provide further information to the weed control knowledge base.

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