Selections from Miriam Sachs Martín's Master's Thesis

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Introduction

Santa Clara County is an area with naturally high biodiversity that is currently undergoing increasing pressure towards real estate development and urbanization. It is also a region rich in protected resources, with four major public agencies administering over 75,000 acres of parks and open space areas.

Figure 1: Parks and Open Space in Santa Clara County[1]

In order to maintain habitat values at their highest and fulfill the rationale for protecting these lands, it is necessary to research and publicize best practices in the ongoing struggle to balance habitat with humanity. One area of focus in park management today is how to combat the spread of invasive plants. Pimentel, et al. (2005) estimate that over 50,000 alien species have invaded the United States. Many invertebrate and microbe introductions were accidental, while most plant and vertebrate animal introductions were intentional. This creates a sociological as well as an ecological concern. Exotic plant infestations are created anthropogenically yet have consequences on the biota and community processes

of an ecosystem. Both solution and problem are an interdisciplinary affair; methods for invasive plant removal must involve quantitative scientific experimentation to establish best practices - yet these practices are often labor-intensive, requiring a high level of community engagement and the work of dedicated volunteers.

Volunteerism

Habitat restoration is a matter of difficult questions and no easy answers. Almost never is there an economically and ecologically 'perfect' way to go about removing an invasive plant. Herbicides, while cost-effective, may have unwanted consequences on soil and water biota. Biocontrol agents take years to be tested and released for use, and sometimes lead to unintended biological consequences as well. While involving volunteers in habitat restoration presents its own difficulties, such as carbon output for vehicle transportation to open-space areas, it also brings the benefit of providing opportunities to engage and educate potential future stewards of the land. As such, volunteer labor is a primary component in habitat restoration efforts in both the non-profit and government sectors. In the San Francisco Department of Parks and Recreation alone, 60,100 park volunteer hours and 28,300 recreation volunteer hours were donated to the city parks in fiscal year 2006-2007 (SFGOV, 2008). According to the United States Census, approximately 61.8 million people, - 26.4 percent of the population - engaged in some form of volunteer activity during 2006 (US Bureau of Labor Statistics, 2008). Many junior and senior high schools are adding a required community service component to their curriculum, thus swelling the already-high numbers of available volunteers. Measham and Barnett (2007) proposed a set of six factors which motivate volunteers participating in environmental causes. These are:

1. Helping a cause

2. Social interaction

3. Improving skills

4. Learning about the environment

5. General desire to care for the environment

6. Desire to care for a particular place (Measham and Barnett, 2007, p.7).

Successful integration of volunteer labor will retain dedicated workers and utilize their talents in order to fulfill the agency's mission. In order to do this, the recruiting agency must provide a structure which fosters these six experiences, and also allow time for work of both quality and quantity to be performed. Designing volunteer programs which allow participants to improve skills and learn about the environment presents its own particular challenges. Complex scientific information must be delivered in a way that is accessible, socially relevant to diverse populations, and meaningful with regards to the day's work. The objective is to provide enough information so that volunteers learn the context and background of the tasks to be done and achieve an appreciation of the impacts that they can have, but not feel overwhelmed with information or feel that they spent more time talking than working. Appendix A - Restoration Work Days is an excerpt from a handbook created for Acterra, the agency with whom this thesis project was conducted. It provides a sample schedule and details for organizing habitat restoration workdays in a way that provides balance between education, support, and a positive working environment.

One approach to help engage volunteers from different backgrounds is that of biocultural diversity, the connection between diverse human cultures and a wide variety of animal and plant species. Maffi (2005) suggests connections between linguistic, cultural, and biological diversity as "manifestations of the diversity of life" (p. 599). In 1988, in the Declaration of Belém, the First International Congress of Ethnobiology asserted that "there is an inextricable link between cultural and biological diversity." (ISE, 1988). Although biocultural diversity is discussed most often in reference to indigenous/traditional

cultures, Cocks (2006) argues that it can have more relevancy and applicability if it is reconceptualized. She argues that culture may be considered a selective, dynamic force which adapts under change. Dispersed communities may thus continue to be informed by cultural values, even if those are not always expressed in an integrated, ancestral place-based system. Cocks suggests that conservation programs should include adaptation of cultural values regarding biodiversity to newly emerging socio-economic conditions.

Cocks' approach can be embodied in habitat restoration work in the Bay Area, where ecosystems naturally high in biodiversity co-exist with a wonderful mélange of cultures and languages. Utilizing cultural diversity as an analogue to biological diversity is an accessible way to get volunteers interested in, and identifying with, the rich natural resources adjacent to their communities. "You are stewards of the land" is an important refrain for youth and adults who may have, at some point, felt marginalized from traditional methods of garnering acceptance and praise. Showing how the strengths of different team members increase the effectiveness of the whole creates a vehicle through which participants can enjoy social interaction while learning about the idea of structure- and function-based ecological restoration.

Study Site

Palo Alto and the greater San Francisco Bay Area are part of the California Floristic Province, an internationally recognized hotspot of endangered biodiversity (Conservation International, 2006, Wilson, 2000). This region was designated a global hotspot in 1996, and has received international conservation attention in part because of its high number of endemic species; animals or plants that are found here and nowhere else (California Academy of Sciences, 2006). For example, of the nearly 3,500 species of vascular plants found in this area, 2,120 are endemic (Conservation International, 2006).

The study site, Enid Pearson-Arastradero Preserve (Preserve), is nestled at the foothills of the Santa Cruz mountain range, in Santa Clara County, and is within one of the Floristic Province's many microclimates, so that it tends to be warmer in the summer, cooler in the winter, and dryer all year round, than San Francisco, its northern counterpart. The July average temperature for the county is 21° C, and January averages 10° C. Snow is rare, and rainfall averages about 37 centimeters per year.

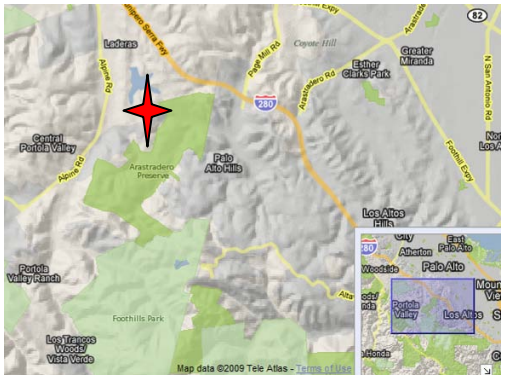

Figure 2: Enid Pearson-Arastradero Preserve[2]

Acterra is a 501(c)(3) community based non-profit organization providing restoration stewardship on the Preserve. Founded in 2000, Acterra is the result of a merger between Bay Area Action (founded 1990) and the Peninsula Conservation Center (founded in 1970). As a representative of several generations of place-based environmental stewardship, Acterra boasts a large, educated, and dedicated corps of volunteers. Its Stewardship Program alone had 1300 volunteers participating in the 2007-2008 fiscal year (Acterra 2008). The newly built Gateway Facility, an off-the grid, recycled-material building located at the entrance to the Preserve, houses educational exhibits about local ecology and serves as a classroom and meeting place for volunteer orientations.

The Preserve is located adjacent to Foothill Park, and both Preserve and Park are owned by the City of Palo Alto in Santa Clara County, California. The Preserve supports 247 hectares of foothill oak woodland, where the characteristic golden summertime hillsides are a result of "one of the most dramatic

ecological invasions worldwide" (Seabloom, et al., 2003, p. 1). In Northern California, approximately 9.2 million hectares of native perennial grasslands and forbs were replaced by exotic annuals brought in by Spanish and other European ranchers, and spread because of drought and preferential cattle grazing (Seabloom, 2003). Invasive annual grasses are not the only issue of concern at the Preserve. The site, which has a long history of intensive recreation use and former cattle grazing, is host to a variety of aggressive invasive species.

The Acterra Stewardship Program at Pearson-Arastradero Preserve has created a list of the top six noxious weeds; Italian thistle (*Carduus pycnocephalus*), yellow and purple star thistle (*Centaurea solstitiales* and *C. calcitrapa*), bull thistle (*Cirsium vulgare*), teasel (*Dipsacus sativus*), poison hemlock (*Conium maculatum*), and Harding grass *(Phalaris aquatica*) (Acterra, 2006). Options for removal available to the staff include mowing, disking, grazing, flaming, hand-pulling, and weed-whipping. Although the agency has a large volunteer base and labor is less of an issue, the most effective control method for each plant will still depend on its biology and life cycle and other factors. For example, biocontrol agents - such as weevils - can help combat yellow star thistle. In contrast, preliminary research has indicated that there are no known biocontrol agents for *Conium maculatum.*

Foothill oak woodland can be found at the base of the Coast Range and other mountain ranges of California. It is characterized by wide, rolling hills covered with non-native annual grasses, interspersed with wooded canyons and riparian zones. This ecosystem is primarily dependent on the more than twenty species of oak found in California, ten of which are endemic. Mule deer, California quail, acorn woodpeckers, western fence lizards, California kingsnakes, coyotes, red tailed hawks, and pocket gophers compete for resources against non-native plant and animal species. Besides the control of invasive

weeds, other issues of concern at the park are maintenance and promotion of native perennial grasses and forbs, erosion control, managing recreation impacts and educating visitors about restoration efforts.

Over 334 different plant and animal species have been observed at this relatively small site, including special status species such as golden eagle (*Aquila chrysaetos*), Northwestern pond turtle (*Clemmys marmorata marmorata*), and dusky-footed woodrat (*Neotoma fuscipes*). The Preserve is part of a larger "necklace of parks" surrounding the Santa Clara Valley geographic area, is adjacent to both Foothills Park and Los Trancos Open Space Preserve and is close enough to other preserves and protected lands to provide migration corridors and expanded habitat areas.

Problem Statement

This project will experimentally compare success in replanting natives in plots overrun by one of Acterra's "worst offenders" - *Conium maculatum*. It will also map the preserve's *Conium* populations and compare 2007 information with data from 2001 to determine if and to what extent the infestation has spread. It will explore effective volunteer education curriculum for diverse populations working in habitat restoration.

Research Design

The 2007 population of *Conium* on the Preserve was mapped using a Trimble GPS (Global Positioning System) unit. Prior to the setting up the research plots, it was important to understand whether the plant had spread since it was last mapped in 2001, and if so, in what way. Appendix B - *Conium maculatum* 2001/07 Distribution, shows that hemlock has spread considerably since 2001, primarily along trails and

waterways. This is especially evident in the map of the southern preserve, in which the sole recorded 2001 population near the eastern perimeter had spread in all four directions via trails.

Experimental plots were set up to compare the effects of replanting blue wild rye (*Elymus glaucus*) with yarrow (*Achillea millefolia*) and Hayfield tarweed (*Hemizonia congesta ssp. luzulifolia*) in sites that had been hand-cleared of hemlock. Five grouped sites and three single sites were selected for treatment based on the following criteria: Percent *Conium* coverage (minimum 80%), trail accessibility, volunteer safety, and habitat areas of concern to Acterra. Forty-nine 0.25 m^2 quadrats were established in the grouped and single sites.

Figure 3: Sample quadrat – red flag indicates control treatment[3]

Quadrat location within each site was selected by measuring site width and length, generating random numbers along the axis of each, and locating each plot at the intersection of those coordinates. Appendix C - location of *Conium maculatum Study Plots*, shows the location of each quadrat. Experimental treatments were distributed through all sites, and randomized to avoid pseudoreplication.

	H. Congesta & A. Millefolia	*E. Glaucus*	*E. Glaucus, H. Congesta and A. Millefolia*	No replanting
Hand-pull	**11**	**9**	**10**	**9**
None				**10**
Total				**49**

Ten quadrats were left as-is, to serve as a control. The remaining thirty-nine were hand-weeded of *Conium*, including senesced *Conium* biomass from previous years, and identifiable seedlings. Nine quadrats were not replanted, eleven were replanted with *Hemizonia congesta ssp. luzulifolia* and *Achillea millefolia* seeds, nine were replanted with *Elymus glaucus* seeds and ten replanted with a mix of both *Elymus* and the forbs. All seeds used in the experiment were watershed specific; the *Elymus* and some of the *Achillea* were donated by Acterra's Native Plant Nursery, and the *Hemizonia* and more *Achillea* were gathered late in the summer of 2007 from several patches on the Preserve. All *Conium* biomass was removed from the Preserve to avoid potential toxicity to wildlife and additional allelopathic effects. The treatments were applied in January, 2007 and each quadrat was color-code flagged to indicate the treatment value.

Acterra generously made their volunteer list available to recruitment for assistance with this project, and over the fifteen months of the experiment, dozens of park users became involved as volunteers. A presentation was designed for this and other Acterra Stewardship Program volunteer events which used games, ice-breakers, acronyms, and audience participation to convey information about historical land-use, invasive plant ecology, and nature’s services. The presentation was utilized in a ½ hour orientation

prior to each work event, and in brief dialogues during the lunch break and at the end of the day. Appendix D - Presentation Outline and Narrative details the materials developed for Acterra.

Volunteers specific to this research project, in addition to participating in the general orientation, learned specific skills of using a compass and clinometer, sowing and gathering native seed, and gathering data to be used in statistical analyses. As trails have been the primary vector for the spread of *Conium maculatum* at the preserve for the past six years, having an educated recreational user population of the park is a valuable resource. Study volunteers also learned how to identify hemlock in all of its life stages and developed an understanding of its impacts on native plants and park recreation users. A sample volunteer participation handout is included as Appendix E. Volunteer participants ranged from current and former Acterra staff to workday participants working on their assigned tasks. "Regulars" (long-term Acterra volunteers) who were interested in doing something different often attended workparties after, or outside of, Acterra's regular volunteer events. Ads placed on Craigslist and queries sent to personal email lists yielded approximately 30 one-time volunteers, and one dedicated, on-going community volunteer, who was essential to the various stages of sampling the plots. Volunteer work primarily focused on weeding and data collection, although some of the planting, plant ID, GPS and GIS work received volunteer technical assistance as well.

Results

Statistical tests and graphs were generated using the computer program MYSTAT. An analysis of variance (ANOVA) was performed on the log transformed difference between pre-treatment and post-treatment numbers of *Conium maculatum* seedlings. The results did not yield a statistically signifcant difference between the 5 treatment categories ($F = .72$ and $p = .58$). Grouping the treatments into three categories – control, pulled and not replanted, and pulled and replanted (with any species) – improved the

p value to .35 (F = 1.09) but neither of these is strong enough to suggest a valid correlation between treatment types and post-treatment results.

Analyses of variance were also run on site-specific data. An ANOVA performed on the log transformed pre- and post-treatment *Conium* counts and soil moisture counts did not yield significants results (F= .92, p = .53), indicating the soil moisture did not have a significant effect on how much hemlock grew back after the treatments were applied. Similarly, analyses performed on canopy cover, plant associations, or plot slope or aspect did not discover valid correlations between these variables and *Conium* counts.

Discussion

Based upon this analysis, there is no significant difference between pre- and post-treatment *Conium maculatum* plant counts using the management treatments described above. This is helpful information to those working in the field, as oversowing and replanting from seed are common practices in the control of invasive weeds. Given that hemlock can attain heights of up to 10 feet, using the small 0.25 m^2 quadrat size provides an opportunity for edge effects and seed rain to negatively impact treatment results. To better evaluate these treatments, future experiments should use a larger plot size. Although Andrews (2001) cites native grasses as possible competitors against invasive plants such as poison hemlock, restoration field experience garnered since the inception of this study suggests that other native plant species could have been stronger choices. For future experiments, plants that thrive in dark moist environments and spread rhizomatously, such as marsh baccharis (*Baccharis douglasii*), mugwort (*Artemisia vulgaris*) or wet meadow rye (*Leymus triticoides*), should be transplanted or plug planted to help combat the prolific seed germination of *Conium maculatum*. If this experiment were to be repeated in the future, a minimum plot size of 9 m^2 should be used, with an additional one meter buffer in which

the hemlock is regularly mowed or cut. Plug plantings or rhizome transplants should be installed at a density of at least 20 per meter. This design would probably yield more favorable results.

Selecting a study site that will both benefit the land stewardship agency and provide plot stability is also a challenge. The plots in this study were selected to provide ease of access to volunteers, and to overlap with Acterra's restoration efforts. However, this overlap contributed to high plot attrition, as other stewardship activities disturbed the research areas. In future studies, during discussions of research plot location, this possibility should be mentioned to the stewardship agency. It is probable that undisturbed research away from restoration areas would benefit the agency's knowledge base more than a research project in the restoration area where data is lost due to overlapping activities.

At the inception of the study, it was proposed to integrate an economic analysis into the experimental results; by tallying volunteer and other hours, and comparing those against time frames for alternative methods of invasive plant control, insight could be gleaned as to the real-world feasibility of the treatment options. Over time, as the project grew to encompass hundreds of hours of volunteer labor and was combined with several Acterra Stewardship Program work parties, the integrity of that data was not maintained. Future efforts would benefit by creating a small database that could be transported on a laptop to work events, facilitating on-site sign-in and more efficient record keeping so that an economic analysis of labor costs could be performed.

Formalizing and evaluating the volunteer education component of this study could also be a fruitful direction of exploration. Visual analysis of Appendix B - *Conium maculatum* 2001/07 Distribution shows that hemlock has spread on the preserve primarily through trails, thus, at what point could the

recreational user population become sufficiently informed as to halt the spread? In order to register significance preserve-wide, such an effort would have to take place on a much larger scale, such as during Acterra's habitat restoration workdays, which garner about 1000 participants annually. Pre- and post-tests could be designed which measure participants awareness of recreation impacts and weed-seed spread. Annual mapping of target weeds, combined with data on outreach efforts could determine whether or not there is a correlation between the two.

Conclusion

Invasive plants generate profound negative ecological and economic impacts which are felt world-wide and especially reflected in the high land-use pressure environment of the San Francisco Bay Area. Treatment and control options are varied, but should take into account the ecosystem-wide importance of the particular land parcel being evaluated, and take a functional, rather than species-specific approach. When planning restoration or control of specific plants, the biology of the invader and its native competitors should be matched as closely as possible. Volunteer labor is an important aspect of many habitat restoration programs. The concept of biocultural diversity can provide a relevant and accessible vehicle through which to introduce habitat restoration terms and information to volunteers. Applying treatments to *Conium maculatum* of hand-pulling and re-seeding with *Elymus glaucus, Achillea millefolia,* and *Hemizonia congesta ssp. luzulifolia* in 0.25 m^2 quadrats at Pearson-Arastradero Preserve in Palo Alto yielded insignificant statistical results, however, the need to find a cost-effective way in which to combat this invasive plant still exists. Future studies could experiment with a different native plant palette, and use specific software tools to be able to integrate an analysis of the economic impacts of labor-hours into the research.

Image Citations

[1] Map of Santa Clara County Parks and Open Space, retrieved from http://www.parkhere.org/SCC/docs%2FParks%20and%20Recreation%2C%20Department%20of%20%28DEP%29%2Fattachments%2Fparks_map_2007.pdf on 4/30/2009.

[2] Map of Enid Pearson-Arastradero Preserve, retrieved from http://parkinfo.org/ on 4/30/09.

[3] Photo taken by Miriam Sachs Martín in December, 2007.

[4] Photo taken by Miriam Sachs Martín in December, 2007.

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