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TITLE: Riparian Woodland Restoration Project

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13. Abstract ***(Maximum 200 Words)*** *(abstract should contain no proprietary or confidential information)*

The purpose of this project was to plant native woody species on a 15.6-acre parcel of land in the Lower Dry Creek area of Beale Air Force Base in Northern California, while simultaneously investigating some factors (plant age, plant protection) that are thought to contribute to efficient riparian restoration and to affect plant performance. The project was funded ($49,500.00) by the U.S. Army Medical Research Acquisition Activity (USAMRAA) for the period from Oct. 1999 to Sept. 2002. None of the factors investigated proved to be consistently associated with high survivorship or favorable plant growth: at one site the least expensive tree protector resulted in highest survivorship, while at the other site, the highest-input protector was most effective. Similarly, the effect of plant age varied from field to field. Not surprisingly, plant growth as measured in height was consistently greater with the taller tree protectors. Valley oak survival rates of 34% were attained in this study; a previous restoration conducted by the author in adjacent fields with similar methodology resulted in valley oak survival rates between 50 and 75%. The low survival rates and highly variable results between fields are attributed largely to herbivory (gophers and field mice) and weather-related effects.

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INTRODUCTION:

The Riparian Woodland Restoration Project (Award No. DAMD17-99-2-9051) was a planting and maintenance plan to restore the wildland habitat of a 15.6-acre parcel of land in the Lower Dry Creek area of Beale Air Force Base in northern California. The project was initiated in the fall of 1999 and completed in the fall of 2002. The project took advantage of existing irrigation and pumping equipment already present due to the presence of another federally-funded restoration project at the Base (Contract no. DACMO5-95-D-0003) subcontracted from The Nature Conservancy and also headed by the principal investigator of this project. The purpose of this project was to apply the knowledge gained from previous experience at this site and further investigate the factors thought to contribute to effective restoration, while restoring an additional 15.6 acres.

BODY:

Overall survival of plants at the end of the three-year period was just over 34%, lower than that previously observed at an adjacent and similar site. Poor survival, as will be explained later in this document, is thought to be attributable primarily to inordinately high herbivore populations following the Army Corps of Engineers' creek location activities to the immediate north-east of the restoration site in spring and summer of 2000. Nonetheless, over 800 planting sites were planted to acorns or oak seedlings between the period of December 1999 and June 2001, and those plantings resulted in the establishment of nearly 300 oak trees, for a final plant density of 18 trees per acre, well within the target numbers for savanna / woodlands.

Preliminary to discussion of data, a discussion of problems faced in accomplishing tasks is in order, and a discussion of the ensuing modifications of those tasks.

1. (**Task 1.8: Planting**) As described in the 2000 Annual Report for this project, Acorns needed to be replanted in fall 2001 due to heavy flooding immediately after the first planting in winter 1999-2000. Consequently, the oak plants in the "acorn" treatment are effectively one year younger than their comparable treatment, "seedlings".
2. (**Task 1.5: Irrigation**) High mortality in some fields of the other restoration planting at Beale Air Force Base (The Nature Conservancy Project) suggested that, even with infrequent irrigation, the oaks were suffering from excessive water, due to the high water-holding capacity of the soil. This mortality, in combination with the losses incurred by herbivory, threatened to reduce plant numbers to unacceptable levels. Consequently, it was decided to eliminate the high-frequency irrigation treatment.
3. (**Task 2.1: Experiment Design**) In the interest of ensuring adequate survival of the older oak trees, we modified the planting methodology in hopes of offering some protection against gopher damage. Thus, the older group of trees, transplanted in summer 2001, was not exposed to the three types of tree protector treatments, but rather, they were all protected by Treepros™, which seemed to offer the greatest potential protection. Consequently, no data are available on the effect of type of tree protector on this age of tree. In addition, the tree protectors were imbedded in the soil around the seedlings, to a depth of approximately 8 inches, in the hopes that this cylinder of plastic around the taproot would deter gopher damage. Consequently, this older group of trees was not included in the analysis of data on effect of plant age on tree survival. However, since the contrast between this group and the seedlings was so great, survival data were

collected and analyzed, with the recognition that age and planting methodology effects are confounded.

Observations on the effects of tree-protection devices and tree age on survival did not give consistent results between the two planting sites in this study, suggesting that microenvironment effects related to herbivore habitat more strongly affect tree growth survival than do the aforementioned factors. In Field 1 (one of two fields included in the current study), acorns exhibited significantly better survival over a two-year period than did one-year-old seedlings (Fig. 1), but in Field 7, the seedlings survived at a significantly higher rate (Tables 1 and 2).

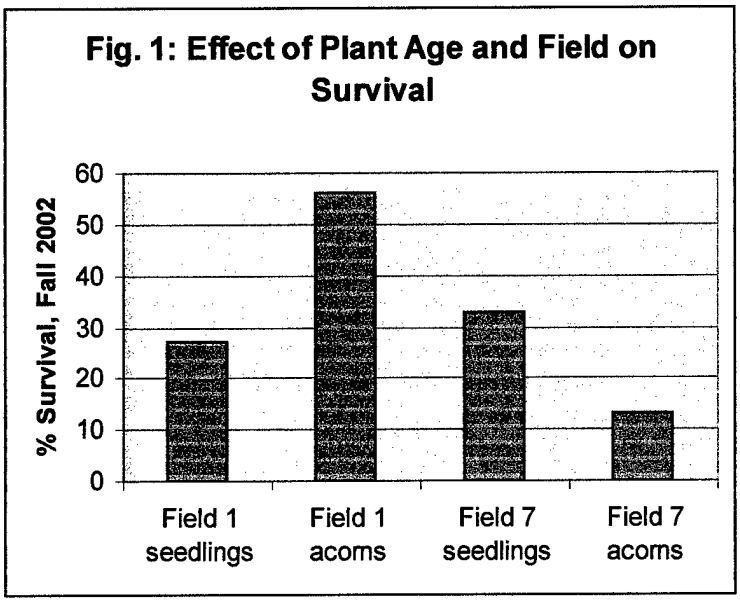


Table 1: ANALYSIS OF VARIANCE: Effect of plant age on survival, Field 1

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
Treatment	3200.45	1	3,200.450	10.16	1.10E-02
Block	3050.45	9	338.939	1.08	4.57E-01
Error	2,834.050	9	314.894		
Total	9,085	19			

Table 2: ANALYSIS OF VARIANCE: Effect of plant age on survival, Field 7

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
Treatment	1420.071429	1	1,420.071	8.66	2.58E-02
Block	1802.857143	6	300.476	1.83	2.40E-01
Error	983.429	6	163.905		
Total	4,206	13			

Data collected only late in the study indicate that, at least at this site, gopher populations may be the largest challenge to effective riparian restoration under conditions of adequate irrigation and browsing control, and may, in part, be responsible for the erratic effects we saw on survival in the two fields. Overall, over 50% of the mortality in oaks observed in fall 2002 could be directly attributed to herbivory by gophers; sometimes the animals remove the entire plant, but sometimes they leave behind plants that display distinctive symptoms (Fig. 2). In Field 1, there was no significant difference due to plant age in the gopher-induced mortality rates of oaks (Table 3), although one might expect that acorns would be more palatable to herbivores than would be older seedlings. However, it may be that still more of the seedling mortality was due to gophers but went undetected. Gopher damage was scored only at the end of the growing season in 2002. In addition, while burrowing animals such as moles and gophers damage the root system, nesting mammals such as mice also threaten the plant, especially those plants that are protected by a tree tube. Abundant mouse nests at the bases of oaks protected by either Treepees™ or Treepros™ explain some of the mortality we observed. It is likely, although not proven, that the abundant vegetation produced as a result of the Army Corps' engineering project in the adjacent field offered habitat for particularly large numbers of small mammals. The lush effects of residual soil moisture could be seen in the summer of 2001 and even into 2002.

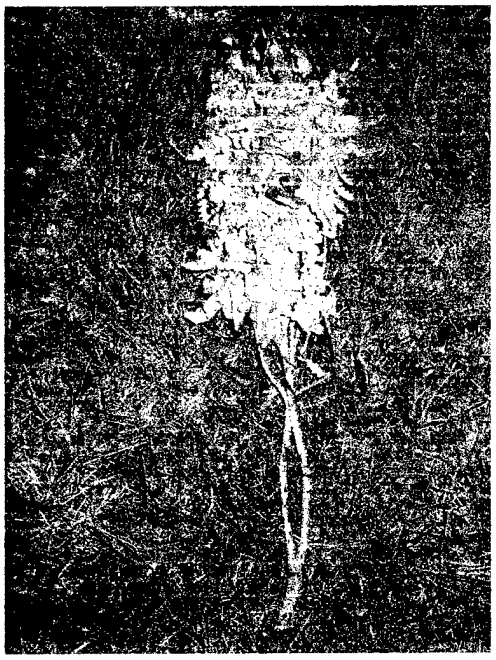
A.  B. 

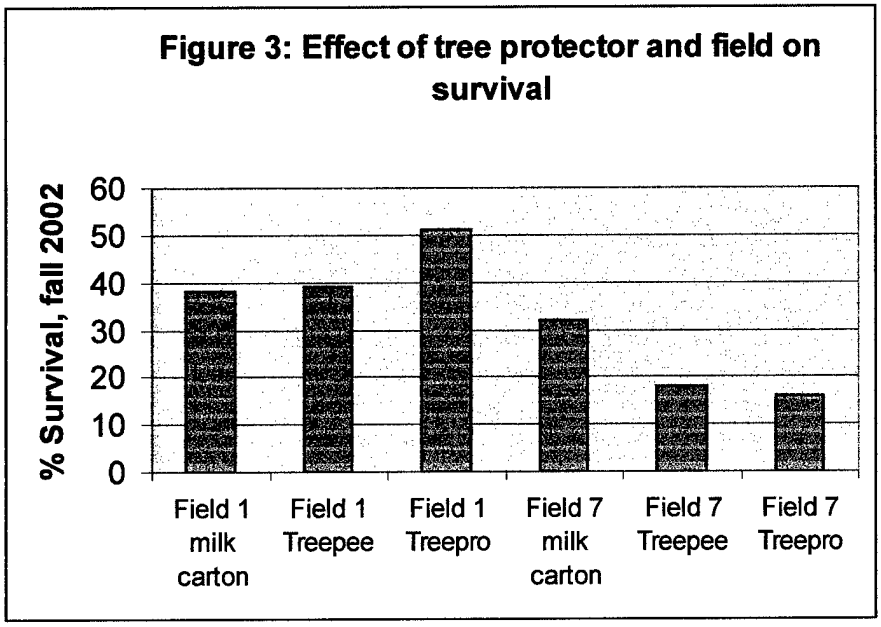
Figure 2A, B: Typical leaf color and diagonal cut at the base of the stem, on oaks that have been killed by gophers.

The original planting plan and schedule were adjusted to compensate for changes to the landscape imposed by an engineering project undertaken by the Army Corps of Engineers on property to the immediate north of the restoration site. Releases of drainage water over the summer of 2000 precluded planting in the larger portion of the restoration site designated "Field 7" (See Plan of work, 1999) until the summer of 2001.

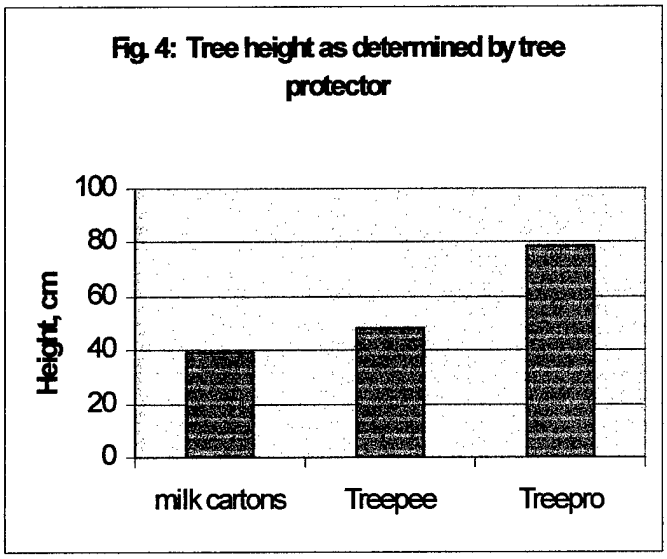
Table 3: ANALYSIS OF VARIANCE:
effect of plant age on gopher mortality

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
Treatment	4.5	1	4.500	0.02	8.96E-01
Block	4698.5	3	1,566.167	7.03	7.18E-02
Error	668.500	3	222.833		
Total	5,372	7			

Type of tree protector used on the oaks had a significant effect on tree survival in Field 1, but had no significant effect on survival in Field 7 (Fig. 3). In Field 1, 51% of the trees protected by Treepros™ survived, while 38 and 39%, respectively, of those protected with milk cartons and Treepees™ survived. In Field 7, there was a trend for the milk cartons to protect better but it was not significant.



Not surprisingly, plant height was significantly affected by type of tree protector: all the tree protectors allowed trees to get just slightly taller than the container before the plants' heights were limited by browsing. Consequently the tall Treepros™ gave rise to the tallest plants (Fig. 4).



Perhaps the most promising results of this study are the comparison of survival rates between the one-year-old seedlings and the older oak plants, which were transplanted in the summer of 2001 using a more protective planting methodology, alluded to earlier (Table 4). The older plants survived from early summer 2001 to fall 2002 at a rate of 51%, while the one-year-old seedlings survived from summer 2000 to fall 2002 at a rate of 22%. This difference is statistically significant, but there are two reasons why the difference cannot be attributed to one factor or the other with certainty. Plant age and planting method are confounded in this test. In addition, the older plants were exposed to herbivory and other environmental hazards for only one growing season and one winter, while the younger plants were exposed longer. It is encouraging, however, to contemplate the possibility of effective and affordable protection from herbivory. Undoubtedly, an integrated program of physical barriers, vegetation management and building of raptor populations would contribute to vertebrate control. Abundant evidence of the presence of raptors was documented throughout both Fields 1 and 7.

Table 4: ANALYSIS OF VARIANCE: Confounded effect of plant age, planting method and time

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
Treatment	5351.115385	1	5,351.115	11.97	4.72E-03
Block	5822.384615	12	485.199	1.09	4.45E-01
Error	5,364.385	12	447.032		
Total	16,538	25			

RECOMMENDATIONS:

For this site and other riparian restoration sites, protection from herbivory is pivotal. Treepros™ offer protection from browsing by deer, and can be purchased in a variety of heights. Partial protection from gophers may be attained by sinking the tubular tree protectors in the ground, but under conditions of intense pressure, such as these, a stronger barrier such as hardware cloth may be warranted. This option is currently being explored at another site.

Other species do not appear to suffer the effects of herbivory to the extent that oak does. The coyotebush planted four or five years ago at the adjacent site is thriving, and may be more suited for this site than oak, or a mixed planting may be more suitable and successful.

KEY RESEARCH ACCOMPLISHMENTS:

- Demonstration of the significant role of vertebrate pests in successful establishment
- Demonstration of microenvironment effects on oak survival (significant differences between adjacent fields)
- Identification of a means of partial protection of oaks
- Demonstration of the feasibility of successful low-input revegetation
- Demonstration of the superiority of acorns as planting material in the right environment
- Development of a concept for a new type of tree tube to offer protection above and below ground, currently being tested at another site

REPORTABLE OUTCOMES:

1. Subsequent to this award, funding was sought and granted for a similar restoration project on the Sacramento River in Tehama County. That project was titled: "Enhancement of Plant Establishment in Restoration Sites". Clean Water Act Funds were channeled through the Bureau of Land Management ($20,000); matching funds for the same project were awarded by California State University's Agricultural Research Initiative ($17,000).
2. This award was cited as evidence of scholarly activity on the part of the project director, in her professional dossier, and in applications for additional research funding.
3. Part-time employment, education in ecological aspects practical management aspects of riparian restoration, hands-on experience in the farming component of reforestation, and greenhouse management experience, and data entry experience for undergraduate students are all opportunities that have emanated from the execution of this project.

CONCLUSIONS:

Type of tree protector, as well as age of plant, can have a significant effect on success of establishment in riparian restoration contexts. Local effects, such as vertebrate pests, can cause variation from field to field, making it difficult, if not impossible, to identify the "ideal" system of revegetation. Vegetation management in the immediate vicinity of the plants being established, to eliminate plant-to-plant competition, is probably not adequate, since abundant vegetative growth in field edges and between planting sites harbors pest populations. Where high populations of vertebrate pests are known to occur, revegetation with native plants can be accomplished through the following means: 1) selection of a native species less attractive than oaks to pests; 2) reduction in excessive vegetative ground cover in the immediate vicinity of the native plants, as well as in field margins and alleyways; 3) providing a physical barrier around the taproot of the native plants.