Evaluation of Techniques and Costs for Valley Oak Riparian Forest Restoration on the Sacramento River[1]

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***Abstract**: In 1989 The Nature Conservancy, in conjunction with both state and federal agencies and private landowners, initiated a riparian forest restoration program along the 161-km section of the Sacramento River between Red Bluff and Colusa. By 1995, valley oak (*Quercus lobata*) had been planted at six different restoration units. Survival and growth varied among the units because of different maintenance regimes and different site conditions. Seed germination and survival through the first year was highly variable, ranging from 35 to 90 percent. Mean height ranged from 20 to 45 cm. Seven years into this project we will report costs associated with different restoration techniques and our recommendations for site selection, maintenance (irrigation, weed control, herbivore control), and performance standards for establishing valley oaks in large (>80 ha) retired agricultural fields.*

Riparian forests support more species of wildlife than any other forest type in California (Williams and Kilburn 1984). Two important factors may be their proximity to water and the complex structure of their vegetation, which allows many species of wildlife to find habitat space.

Valley oak (*Quercus lobata* Nee) grows on deep alluvial soils in the floodplains of the rivers and streams of the Great Central Valley and the Coast Ranges of California. It is the dominant species in a distinctive and threatened riparian forest community (Holland 1986). Valley oak riparian forest of the Great Central Valley is best developed on finer-textured soils (clay- and silt-loams of the Columbia soil series) at sites which are flooded only infrequently. It was formerly abundant on the high terraces of the Sacramento River floodplain. These comprise some of the best agricultural soils in the state, and most were cleared and converted to agriculture in the nineteenth century. With the completion of Shasta Dam in 1945, most of the remaining valley oak riparian forest in mid-terrace, flood-prone areas near the river was converted to agriculture. In the past decade remnant individuals and groves have been severely affected by urban development in the Great Central Valley.

In 1989, the Sacramento River National Wildlife Refuge was created by the U.S. Congress, to protect riparian forest habitat. The Refuge was to be established only on parcels of land contiguous to the river, prone to flooding, and available for purchase from a willing seller.

Two of the problems confronting the creation of this new wildlife refuge along a highly developed section of the river, with its hydrology altered by a dam, were that land purchases often included sub-optimal valley oak habitat and that optimal lands had mostly been converted to agriculture. The first step to deal with these problems was a program to test the feasibility of restoring relatively large areas of riparian forest and to evaluate different techniques for restoring sites having a range of soils and hydrology.

This program was entrusted to The Nature Conservancy (TNC). In cooperation with several agencies (U.S. Fish and Wildlife Service, California Department of Fish and Game, California Department of Water Resources) and private landowners (Parrott Investment Co.), TNC began implementing riparian forest restoration projects along the 161-km section between Red Bluff and

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Colusa. The immediate goal was to develop the technology to implement large (40+ ha) restoration plantings. The ultimate goal of the project was to double the existing extent (ca. 8,100 ha) of riparian forest by means of revegetation on ecologically appropriate sites; that is, sites which still flood today. One highly desirable outcome would be to improve the ecological health of wildlife populations in the Great Central Valley.

Since 1989, nine units (8 to 50 ha) have been planted at five different locations, totaling 223 ha. Valley oak was planted on all units, in differing densities, depending on local site conditions. For example, more valley oak was planted on the higher terraces and finer soils, while cottonwoods were planted on terraces with more varied soil strata.

In 1989, little was known of the biological and technical requirements for large-scale riparian forest restoration in general. Few previous efforts to restore valley oak riparian forest were available to guide the program (Reiner and Griggs 1989, Griggs 1990, Pavlik and others 1991). As the program developed and implemented successive, larger plantings, TNC's staff carefully monitored survival and growth of the individuals planted. This paper reports the results of monitoring the survivorship and growth of valley oak seedlings and saplings in the riparian forest restoration plantings along the Sacramento River for four years. Six different units (plantings) dating from 1992 are included.

Methods

Restoration Units

Table 1 compares important characteristics of each restoration unit. Site conditions which varied between units include area, patterns of soil texture, and depth to water table. Planting design and methods were tailored to each unit's site conditions and the existing farming infrastructure (primarily, the existing irrigation system). For example, River Vista II is adjacent to the river and soil textures are highly variable across the unit, while at Sam Slough, one mile from the river, soil is is mostly silty loam. River Vista II was irrigated by a solid-set sprinkler system already on site, while at Sam Slough, a drip system was installed. At each unit a mixture of species were planted. This conservative approach was based upon the recognition of the dynamic complexity of riparian ecology, and was designed to ensure that at least some species would establish. The relative proportion of valley oak in the planting mix was based upon site conditions: valley oak was planted at higher densities on finer texture soils that were more than 4 m from the water table.

Collection and Planting

To minimize disturbance of natural genetic population structures and to increase the probability that individuals would survive under local conditions, acorns were collected as near to each planting unit as possible. In all cases, collections were from the mainstem of the Sacramento River, and from trees growing on the Columbia Soil Series. The planting density for the acorns varied from about 250 to 1500 acorns per ha, depending upon the number of other species to be planted at a unit. In particular, on units where a mixture of tree and shrub species was planted, valley oak acorns were planted at lower densities.

Acorns were collected when ripe in October or November, stored in a refrigerator between 1 and 5 °C, and planted into the unit before mid-December. Acorns were planted across the unit in rows to facilitate weed control and irrigation.

Table 1–Characteristics of the restoration planting units

Planting units Soil types (ha)	Year planted	Depth to water table	Irrigation system	Valley oak density	Overall plant density
		meters		*acorns/ha*	*seedlings/ha*
Sam Slough					
Silty Loam (26)					
Sandy Loam (3)	1991	5	Drip	1580	1830
Princeton Ferry					
Loam (12)					
Clay Loam (1)					
Sand (5)	1992	3-5	Drip	740	1450
River Vista I					
Sandy Loam (7)					
Sand (2)	1992	5	Solid set sprinkler	395	650
River Vista II					
Loam (8)					
Sand (16)					
Gravel (8)	1993	5	Solid set sprinkler	285	650
River Vista III					
Loam (9)					
Sandy Loam (25)					
Sand (17)	1994	5	Solid set sprinkler	390	740
Lohman					
Loam (6					
Sand (2)	1994	3	Flood	100	1000

Weed Control Strategy

Each planting unit was tilled just before planting to control germinating weed seedlings. Mowing of the aisles between rows and spraying glyphosate around the trees controlled weeds during the first growing season. During the second and third seasons, only mowing of the aisles between the trees rows was needed. Another very important reason to control weeds is to destroy vegetative cover for rodents. Pocket gophers and meadow voles can consume a large number of planted acorns and seedlings in a few months. Mowing several times during the growing season is sufficient to control voles.

Irrigation Strategy

During the first year, irrigation was applied to maintain a moist root zone from the soil surface down to the top of the ground water table (usually 3.6-6 m). The application schedule was about every 10 days to 2 weeks. During the second and third years, long-duration irrigations that moistened the deeper soil strata were employed to promote deep root growth. The time between irrigations was also increased to about once every 6 weeks in the second year, and only two times during the third year.

At several locations over the unit, commercially available gypsum blocks were placed at different depths to monitor the relative moisture status of the layers of soil and to track the downward movement of irrigation water through the soil.

Monitoring Methods

At the end of each growing season, usually in October, each revegetation unit was sampled at permanent 0.04-ha plots. Plots were established in a stratified random design covering between 5 and 10 percent of the total area of the unit. Saplings were counted and measured for height. Implementation success is reported as percent survival of the number of acorns planted, and height, in cm.

Results and Discussion

Survival

Variation in valley oak survival (*figure 1*) among the units reflects ecological differences among units, including patterns of soil texture, flooding regime, abundance of rodents, and weather patterns. For example, the Sam Slough Unit is composed of uniform soils (91 percent is silt-loam). It was planted with a very high density of acorns (1580 per ha), and nearly half failed to survive the first season. Nevertheless, after four growing seasons, there are more than 370 healthy saplings surviving per ha. Comparison of first-year survival at the three River Vista sub-units shows a dramatic increase for River Vista III, apparently caused by the elimination of the rodent population by the floods of early 1995.

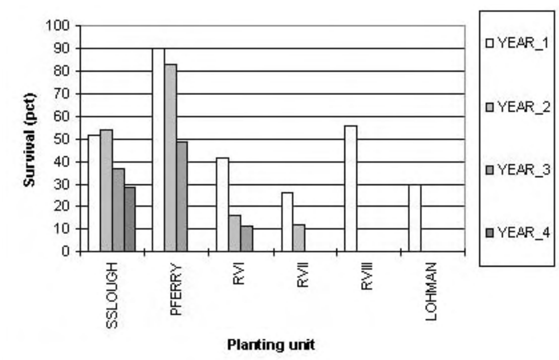

Figure 1—Percent survival of valley oak seedlings and saplings at six riparian forest restoration units. Planting units are: SSLOUGH = Sam Slough, PFERRY = Princeton Ferry, RVI = River Vista I, RVII = River Vista II, RVIII = River Vista III.

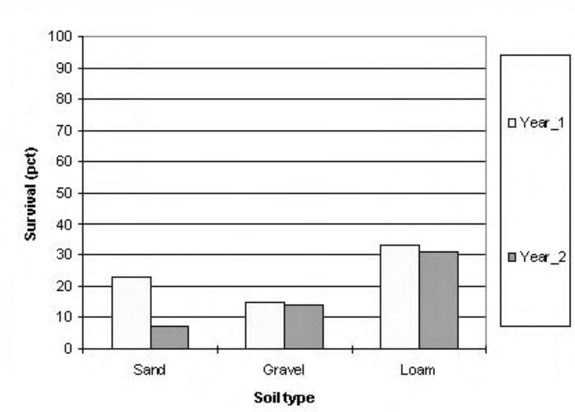

Figure 2—Percent survival of valley oak seedlings on three soil textures at River Vista II unit.

To further demonstrate ecological variability between, and within units, *figure 2* compares survival on different soil textures at the River Vista II unit during two seasons. The valley oaks planted into each soil texture class were all planted on the same day, at the same density, and were given identical irrigation and weed control management.

Growth

Variation in valley oak height growth among the units is a reflection of the variation in soil conditions. *Figure 3* compares age-specific height of oak seedlings. As with survival, there are differences in annual height growth among the units: The relatively finer soil texture at Sam Slough probably caused the superior height achieved by its saplings.

Figure 4 compares height growth in the first two seasons on three soil textures at the River Vista II unit. Coarse soil texture resulted in less growth compared to finer texture soil.

The message here is that one should have some idea of the variety and pattern of soil textures across a restoration unit before developing a planting design and expect differences in growth based upon differences in soil texture. Ecologically, this is a positive outcome. Spatial patchiness in height growth results in more structural diversity across the unit, which, in turn, will support a greater diversity of wildlife.

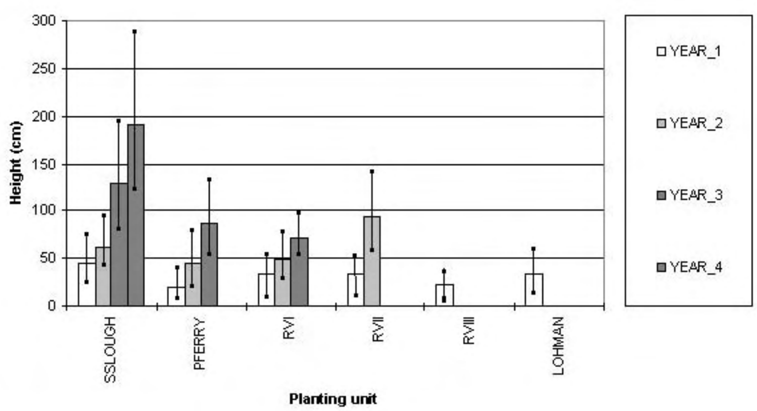

Figure 3—Mean and standard deviation for age-specific height of valley oak seedlings and saplings at six riparian forest restoration units. Planting units are: SSLOUGH = Sam Slough, PFERRY = Princeton Ferry, RVI = River Vista I, RVII = River Vista II, RVIII = River Vista III.

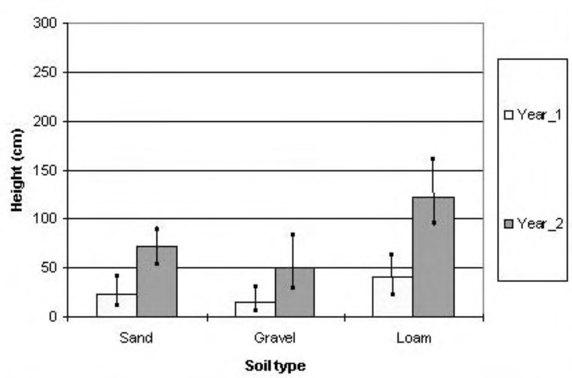

Figure 4—Mean and standard deviation of height of valley oak seedlings on three soil textures.

Plant Performance

Figure 5 shows the average end-of-season-height by age class across all units, soil textures, and planting dates. The resulting curve over 4 years gives us a "standardized growth curve" for valley oak on riparian restoration units along the Sacramento River. The standard growth curve can be used to predict valley oak seedling and sapling growth on future restoration units. Further refinement could include developing standard growth curves for plants growing on each soil texture class.

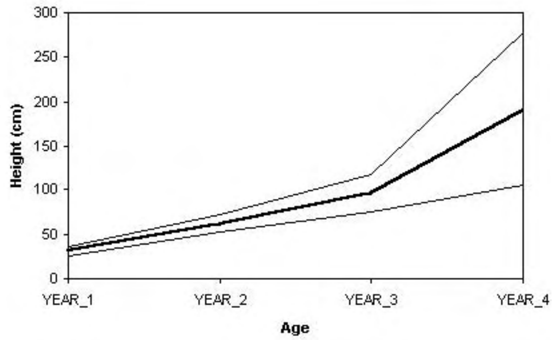

Figure 5—Standard growth curve: mean height (dark line) and standard deviation by age class across all six restoration units and soil textures.

We should remember that this growth curve reflects implementation success, not restoration success. Restoration implies much more —namely ecologically healthy natural processes (Jackson and others 1995). Ecological success is the primary goal of TNC's restoration projects. Ecological success may go beyond the boundaries of each unit and become evident when ecological processes have been restored and native plant communities and wildlife populations demonstrate improved vigor.

Implementation Costs

Each restoration unit represented a unique challenge for implementation because of the differences in soils, topography, characteristics of flooding (erosion and deposition), and existing road and irrigation system infrastructure. Implementation cost is influenced by many variables. Site preparation can be minimal if the unit has been farmed recently. If the unit has been abandoned for several years, or a flood event has rearranged the topography, then time and labor must be expended on removing flood-debris and weeds, and land-planing of the unit to allow access for equipment. Costs for planting and weed control are similar for all units. Irrigation costs, however, are highly variable among units and can amount to the single most expensive component of the implementation, up to 70 percent of total cost. For example, at Princeton Ferry we needed to drill a well, purchase a pump and pipes, and install a mainline and drip system.

Our current cost estimate for a new unit is less than $12,350 per ha, much less (by half) if an irrigation system is present. Also, ever larger units result in an economy of scale as fixed costs, such as planning, wells, equipment hauling, etc., are amortized over a larger area.

Recommendations

1. Plant large numbers of acorns per hectare (over-plant). Acorns are inexpensive compared to nursery stock, so the dollar cost to plant more acorns is trivial. With our methods, the cost of irrigation and weed control per hectare is essentially the same regardless of planting density. A high-density planting will develop habitat structure earlier — more stems per hectare — than a low-density planting because more individuals per hectare will survive. Thus, a high-density planting is not only cost effective, it is also ecologically effective. Stated differently, a higher-density planting will provide higher-quality "interim habitat" until the structure of the forest develops over future decades.
2. Weed control on these restoration units was minimal, by orchard standards, yet the best height growth occurred on the Sam Slough

unit where weed control was given the least amount of effort. The message here is to know the ecological impacts of the weeds on the unit: do they create dense shade or light? What season are they most competitive? What soil conditions does each species of weed indicate? Do they provide cover for rodents, or do they hide seedlings from deer?

3. Irrigation method is not as important as management of the irrigation. Manage the irrigation with the objective of maintaining soil moisture that is adequate for root growth in the deeper soil strata. This translates into low-frequency, long-duration irrigation events.

An alternative method for managing soil moisture that has been used successfully at the Parrott Ranch is to bank the soil moisture each spring by cultivating (disking) the unit before the spring weeds have fully developed. This method conserves soil moisture in the entire soil profile by sealing it under a "cultivated-soil mulch." This method has worked well on silt loam soils, allowing first-year valley oak seedlings to establish without applying any irrigation water.

Conclusion

These results show that (1) Over all the restoration units, a percentage of the oak seedlings survived and grew to saplings, demonstrating that the implementation of valley oak riparian forest restoration is feasible. (2) Growth and survival were better on fine-textured soils. This dictates the need for a comprehensive soil survey before planning a restoration project. (3) Simple methods of weed control and irrigation are cost-effective and result in adequate survival and growth of valley oak.

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