Riparian Valley Oak (*Quercus lobata*) Forest Restoration on the Middle Sacramento River, California[1]

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Abstract

In 1989 The Nature Conservancy initiated a riparian horticultural restoration program on the floodplain of the middle Sacramento River, California. At nearly all restoration sites Valley oak (*Quercus lobata* Nee) comprised a major component of the planting design. Valley oaks are a keystone tree species of lowland floodplain habitats in California's Central Valley, contributing greatly to the structural and biological diversity of riparian forests in the region. Here we present preliminary comparisons of survival and structural development of oaks planted as acorns at six sites from 1990 to 1994. Our focus is on how the plants responded to natural site conditions following the cessation of maintenance activities (including irrigation and weed control). Initial comparisons demonstrate considerable variability among sites in survival and structural development (i.e., stem diameter, canopy cover, and dominance). Although we were able to ascribe some of this variability to known physical and biological differences in site conditions (e.g., soil type, herbivore pressure), furthering our understanding of factors that affect valley oaks on the Sacramento River floodplain will require additional study and more detailed assessments of site conditions.

Introduction

Prior to European contact riparian forests of the Sacramento Valley covered over 800,000 acres (Katibah 1984). Valley oaks were a primary component of these forests, typically growing on fine-textured soils on the higher portions of the floodplain. They are deciduous, quick growing trees that thrive in hot, sunny conditions when supplied with sufficient water and nutrients. The largest individuals have trunks of over 2 m in diameter, and typically support sets of massive craggy limbs soaring upwards of 30 m. Valley oak riparian forest has the most complex structure of any vegetation type in California, and as a result, is among the most diverse in terms of the animal life it supports (Pavlik and others 2000).

In the late 1800s the rich soils of the Sacramento River floodplain were cleared of riparian vegetation to provide fencing, lumber, fuel for steamships, and open areas for agriculture (Thompson 1961, Scott and Marquiss 1984). In 1945 Shasta Dam was completed, bringing with it a reduction in the threat of catastrophic flooding and an associated increase in conversion of lower floodplain forests to farmlands. Today less

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than 20,000 acres of riparian woodlands remain, mostly in degraded condition (Katibah 1984, Hunter and others 1999).

In 1989, The Nature Conservancy (TNC) initiated the Sacramento River Project with the goal of restoring properties adjacent to the channel of the Sacramento River to wildlife habitat for the benefit of native species (Reiner and Griggs 1989). This project, which is entirely driven by willing sellers, provides an opportunity for growers to escape the economic burden of farming low on the river's floodplain. As was made evident by four major recent floods, including the January 1997 event (one of the most costly and geographically extensive flood disasters in the state's history), the present flood-control system of the middle Sacramento River watershed still cannot guarantee protection to those who invest in agriculture close to the river (US Army Corps of Engineers 1999). The erosion and deposition of sediment associated with high flow events translate into onerous maintenance costs for growers whose fields become inundated (Ginny 2001). Today, numerous state and federal agencies are implementing riparian restoration projects on flood-prone lands along the river. These include the US Fish and Wildlife Service, the US Army Corps of Engineers, the US Bureau of Reclamation, the US Bureau of Land Management, the California Department of Fish and Game, the California Department of Water Resources, and the California Department of Parks and Recreation. As well, several local watershed conservancies and land trusts are actively engaged in restoration efforts in the area.

Although it is widely recognized that revitalizing degraded river systems requires the restoration of natural river processes (Poff and others 1997), horticultural restoration can provide complementary benefits, particularly in instances where there is a critical need for increased habitat in the near term. This is certainly the case in the Central Valley, where over 90% of the riparian forests have been lost in the last two centuries (see Golet and others, in press, for a map comparing current and historical riparian habitat in the Sacramento River Project Area). Horticultural restoration on a wide scale is a new practice, however, and as such is in need of evaluation. As a first step in this process Alpert and others (1999) reported initial results of horticultural restoration efforts at several of TNCs riparian restoration projects following three years of maintenance. Here we provide a brief follow up to Alpert and others' study by characterizing the development of valley oaks following the cessation of maintenance activities. The trees we studied were 7 to 11 years old, and had been growing unattended for 4 to 7 years.

Methods

Table 1 presents the size, year planted, and year of last maintenance of each of the six restoration sites sampled in this study. All sites are located on the mainstem of the Sacramento River between Corning and Princeton *(fig. 1)*.

Each restoration site was planted with different proportions of ten woody species (see Alpert and others 1999) based upon limited available information on initial soil texture and stratification, depth to ground water, and frequency of flooding. For example, sites with soils composed of a high proportions of sands with higher relative water tables were planted with more willows (*Salix* spp.) and cottonwoods (*Populus fremontii*) and less oaks and elderberries (*Sambucus mexicana*) than sites with fine textured silty-loam soils and greater depths to ground water. In addition, each site supported different weed communities and had different densities of herbivores (e.g., rodents and deer). Differences in the initial responses of planted species to site conditions led to differences in maintenance activities (e.g., irrigation and weed control). Obviously, these sites cannot be considered as true replicates of one another in an experimental sense. Nonetheless, comparing them is useful, as evaluating past efforts can inform us how to better do restoration the future.

Table 1—*Description of riparian restoration units on the Sacramento River. RM stands for river mile, and L and R refer to left bank and right bank (looking downstream) respectively.*

Site	Location	Size	Year planted	Last maintenance
Princeton	RM 164L	16 ha	1993	1995
Sam	RM 190R	28 ha	1992	1994
Vista 1	RM 215.5L	9.6 ha	1993	1995
Vista 2	RM 216L	53.6 ha	1994	1996
Kopta 2	RM 220R	28 ha	1990	1992
Kopta 3	RM 220.5R	17.2 ha	1992	1993

We collected data at the restoration sites during July and August 2001. For each site we calculated density, percent survival, canopy cover (m^2 per ha), mean diameter at breast height (dbh, in mm) and dominance (cm^2 stem area at breast height per ha). Sampling was based upon the point-centered quarter method as described in Mueller-Dubois and Ellenberg (1974). We used a simple random sampling protocol (Scheaffer 1990) to select starting points for transects along borders of the restoration sites. Starting points were selected in such a way that every point had an equal probability of being chosen. We used a hand-held compass to stay on transect and sampled points at regular intervals. Intervals between sampling points varied from 30 to 100 m in accordance with the size of the sites (shorter spacings between sampling points were opted for at smaller sites to bolster sample size). A minimum of 10 points were sampled at each site. Upon reaching the sampling points, we placed the compass on a level surface and used its readings to divide the horizontal plane into four quadrants. Within each quadrant, the nearest woody tree or shrub of all species was identified, and the distance of this individual to the sampling point center was measured. For each of these plants of breast height or taller, we measured the dbh of the largest stem. Thus, four species identifications, four distance measurements, and four dbh measurements were recorded at each point along the transect. Also at each point, we measured the maximum horizontal spread of the nearest oak, and the spread at 90 degrees perpendicular to this maximum. The average of these two measurements was used to calculate canopy cover, expressed in m^2 per ha. The absolute density of oaks was calculated as $10{,}000/D^2$ where D=the mean distance between each sample point and its nearest oak (Mueller-Dubois and Ellenberg 1974). Percent survival was calculated as the planting density in 2001 divided by the initial planting density of acorns. Dominance of oaks was calculated as ($\pi \times [\text{mean dbh}/2]^2 \times \text{density}$), and is presented in cm^2 of horizontal stem-area at breast height per ha.

We used simple linear regression techniques (SYSTAT 1997) to test for possible relationships among parameters at the six sites.[4]

[4] Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

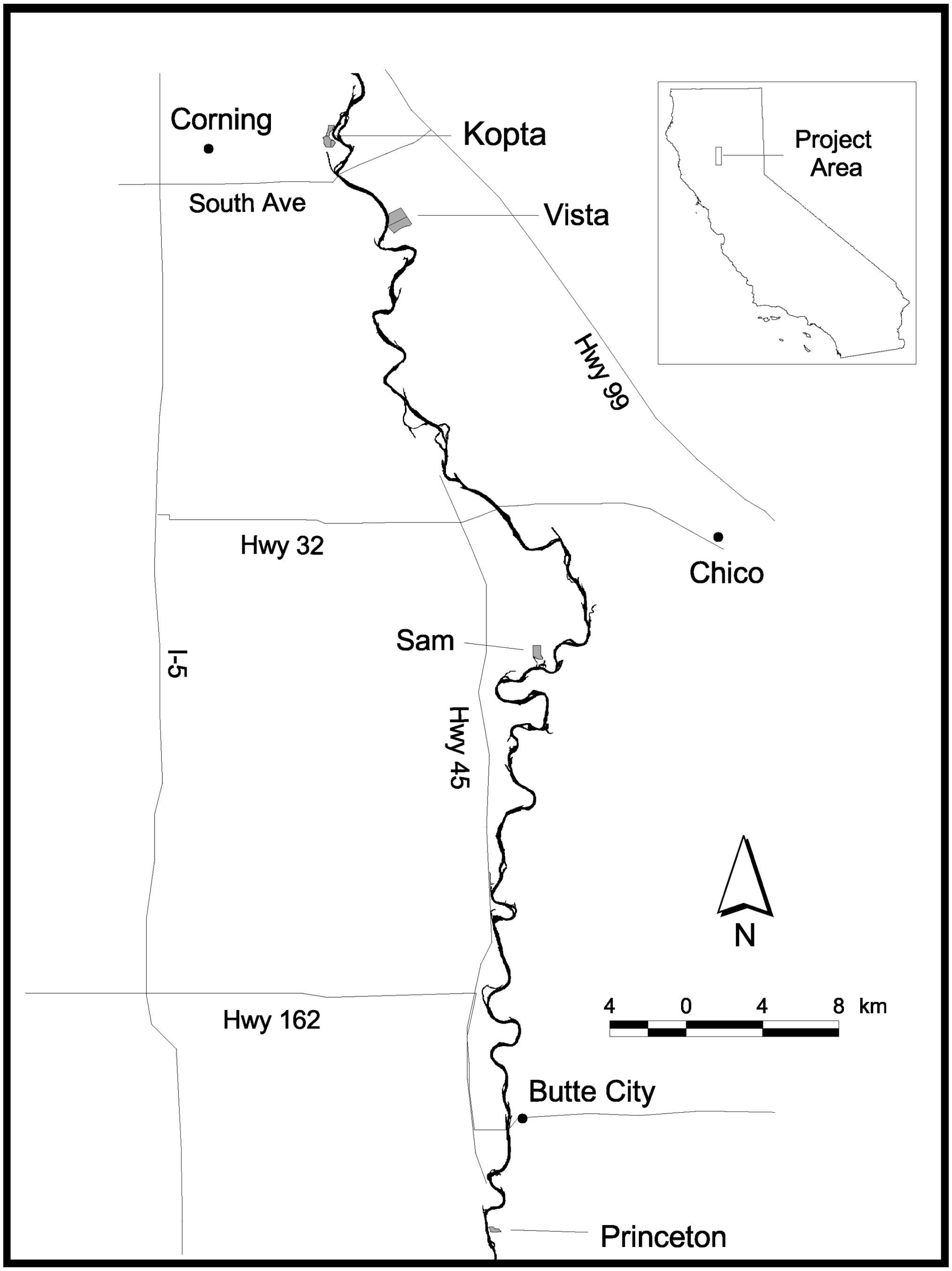

Figure 1 Location of restoration sites along the Sacramento River.

Results

Table 2 presents a comparison of characteristics of valley oaks at the six study sites. Overall we found that individual trees had grown quite well despite being completely unattended for the past four to seven years. We did, however, find considerable inter- and intra-site variability that is likely attributable to differences in local (and landscape-scale) physical and biological site conditions. Identifying the causes of this variability in response was beyond the scope of the current study, however.

Table 2—*Characteristics of Valley Oaks in riparian restoration units on the Sacramento River, CA. Standard deviation is in parentheses.*

Site	Sampling points	Planting density (acorns per ha)	Density in 2001 (per ha)	Percent survival (per ha)	Canopy cover (m^2 per ha)	Mean dbh (mm)	Dominance (cm^2 stem area at breast height per ha)
Princeton	30	581	356	0.61	761	42.4 (38.7)	13,420
Sam	32	1500	576	0.38	2392	81.8 (51.2)	38,070
Vista 1	10	390	57	0.15	487	71.5 (72.1)	4,514
Vista 2	20	390	70	0.18	696	76.8 (33.8)	3,830
Kopta 2	12	500	230	0.46	211	38 (47)	3,093
Kopta 3	18	500	85	0.17	708	88.5 (47.9)	8,486

The density with which oaks were planted appears to have had a large positive effect on their density in 2001 (n=6 sites, r^2=0.81, p=0.015). The dbh of individual trees measured in 2001 did not, however, appear to be related to either planting density (n=6 sites, r^2=0.07, p=0.62) or density in 2001 (n=6 sites, r^2=0.81, p=0.015). Strong positive associations were found between original planting density and both canopy cover (n=6 sites, r^2=0.92, p=0.003) and dominance (n=6 sites, r^2=0.96, p<0.001) measured in 2001. The growth performance of individual trees appeared to be somewhat variable among sites, and highly variable within them (see standard deviation associated with dbh in *table 2*).

Discussion

Many of the valley oaks that were planted as acorns 7 to 11 years ago have developed into robust individuals that appear well on their way to forming mature trees. Valley oaks are important members of the riparian vegetation communities along lowland rivers of the Great Central Valley of California (Pavlik and others 2000), and an increase in their distribution and abundance is expected to provide numerous ecosystem benefits. It is important that the success of these efforts be documented as horticultural restoration efforts in riparian zones of the semi-arid west have not always been successful. For example, a mass die-off Fremont cottonwood in Arizona was observed several years after planting (Patten, pers. comm.). Although we can not be certain that the sites surveyed in this study will have oaks that continue to thrive in the decades to come, we expect that this will be the case as the present status of these trees at many locations appears to be excellent.

Our results also suggest that there is considerable variability in the survival and growth patterns at the different restoration sites and that this is a function of both biological and physical factors. Our study thus provides preliminary information on some of the responses that may be expected when planted valley oaks adapt to the varied site conditions found on the Sacramento River floodplain.

The Sam site supported by far the greatest valley oak density, canopy cover, and dominance of any of the sites *(table 2)*. By contrast, the majority of the Kopta 2 site supported valley oak individuals that had not reached breast height after 11 years of growth. The most likely explanation for this difference is the soil characteristics of the two sites. At the Sam site the entire 28 ha is composed of a non-stratified heavy silt loam that extends downward 12 feet to the water table, while the majority of Kopta 2 site is a very sandy soil underlain by coarse sand and gravel (Alpert and others 1999). Preliminary soils data suggest that pockets of the Kopta 2 site that are composed of deep, non-stratified fine sandy loam support individual valley oaks as large as those observed on any other site. Our calculations suggest that 230 valley oaks per ha are present at Kopta 2, although many are severely stunted and few are likely to become large trees.

The Vista 1 and 2 sites have the lowest density of oaks today because of the very high mortality caused by pocket gopher populations at the time of project initiation. Most acorns and seedlings in Vista 1 and Vista 2 were consumed by the gophers in 1993 and 1994 (Griggs, personal observation). However, in early 1995 Vista experienced a flood that drowned vast numbers of gophers, voles, and ground squirrels. Not surprisingly, following the flood, valley oaks at Vista exhibited increased survival rates (Griggs, personal observation).

The variation in survival and growth of valley oaks observed within and among sites may be viewed as a favorable outcome from a restoration management standpoint. This variability in response does much to create a diverse mosaic of vegetation along the Sacramento River that can support the varied needs of the native wildlife species found in this region.

While the results of this study confirm that horticultural practices provide an effective tool in the restoration of riparian oak forests, many uncertainties remain. In particular we need to better understand how best to balance efforts directed at planting and maintaining woody overstory species with those focusing on restoring a native herbaceous understory. The importance of understory vegetation is evident from studies of songbirds conducted on restoration sites along the Sacramento River. Although Small and others (2000) found that in general, riparian breeding bird diversity increased as restoration sites matured, the degree to which individual sites were utilized by the avian community depended largely upon the understory component. Also, as alluded to earlier, restoration efforts on the Sacramento River floodplain will not be successful unless important attributes of the natural flow regime are restored. Without restoring the key components of the natural disturbance regime with which native species of this region evolved, we cannot expect to meet the complex and varied life history requirements of the rich array of organisms that this system is capable of supporting. Although gaining a sufficient understanding of ecosystem function to inform management decisions on the Sacramento River is a daunting task, initial steps are being taken to develop multidisciplinary studies of the type needed to inform this process (see Golet and others, in press, for descriptions of some of these efforts).

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References

Alpert, P.; Griggs, F.T.; Peterson, D.R. 1999. **Riparian forest restoration along large rivers: Initial results from the Sacramento River Project**. Restoration Ecology 7(4): 360-368.

Ginny, E.M. 2001. **Restoration opportunities at tributary confluences: Critcal habitat assessment of the Big Chico Creek/Mud Creek/Sacramento River confluence area**. Bidwell Environmental Institute. Unpublished report to The Nature Conservancy. Chico, CA.

Golet, G.H.; Brown, D.L.; Crone, E.E.; Geupel, G.R.; Greco, S.E.; Holl, K.D.; Hoover, K.A.; Jukkola, D.E.; Kondolf, G.M.; Larsen, E.W.; Ligon, F.K.; Marchetti, M.P.; Nur, N.; Orr, B.K.; Peterson, D.R.; Power, M.E.; Rainey, W.E.; Roberts, M.D.; Silveira, J.G.; Small, S.L.; Vick, J.C.; Wilson, D.S.; Wood, D.M. [In press]. **Using science to evaluate restoration efforts and ecosystem health on the Sacramento River Project, California.** In: Faber, P.M., editor. Proceedings of the riparian habitat and floodplains conference, 2001 March 12-25; Sacramento, CA.

Hunter, J.C.; Willett, K.B.; McCoy, M.C.; Quinn, J.F.; Keller, K.E. 1999. **Prospects for preservation and restoration of riparian forests in the Sacramento Valley, California, USA.** Environmental Management 24: 65-75.

Katibah, E.F. 1984. **A brief history of the riparian forests in the central valley of California.** In: Warner, R.E.; Hendrix, K.M., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 23-29.

Mueller-Dubois, D.; Ellenberg, H. 1974. **Aims and methods of vegetation ecology**. New York: John Wiley and Sons.

Patten, Duncan. Research Professor, Mountain Research Center, Montana State University, Bozeman, MT. [Personal communication with Greg Golet]. 2001 May.

Pavlik, B.M.; Muick, P.C.; Johnson, S.G.; Popper, M. 2000**. Oaks in California**. Los Olivos, CA: Cachuma Press.

Poff, N.L.; Allen, J.D.; Bain, M.B.; Karr, J.R.; Prestegaard, K.L.; Richter, B.D.; Sparks, R.E.; Stromberg, J.C. 1997. **The natural flow regime. a paradigm for river conservation and restoration.** Bioscience 47: 769-784.

Reiner, R.; Griggs, F.T. 1989. **TNC undertakes riparian forest restoration projects in California**. Restoration and Management Notes 7: 3-8.

Scheaffer, R.L.; Mendenhall, W.; Ott, L. 1990. **Elementary survey sampling**, fourth ed. Boston: PWS-Kent.

Scott, L.B.; Marquiss, S.K. 1984**. An historical overview of the Sacramento River.** In: Warner, R.; Hendrix, K., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 51-57.

Small, S.L.; Nur, N.; Black, A.; Geupel, G.R.; Humple, D.; Ballard, G. 2000. **Riparian bird populations of the Sacramento River system: results from the 1993-1999 field seasons.** Point Reyes Bird Observatory. Unpublished report to The Nature Conservancy and the U. S. Fish and Wildlife Service, Stinson Beach, CA.

SYSTAT [Computer program]. 1997. **Statistics, SYSTAT 7.0 for Windows**. SPSS, Chicago, IL.

Thompson, K. 1961. **Riparian forests of the Sacramento Valley, California**. Annals of the Association of American Geographers 51: 294-315.

US Army Corps of Engineers. 1999. **Sacramento and San Joaquin River Basins comprehensive study: phase 1 documentation report**. Sacramento, CA.