

The Distribution and Composition of Woody Species in Riparian Forests along the  
Middle Sacramento River, California

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## Introduction

Riparian forest is a dynamic vegetation type that is shaped by river processes. Channel movement and sediment deposition initiate a succession sequence that is comprised of several different types of plant communities (Thompson 1961, Holstein 1984, Katibah 1984, Strahan 1984, Cepello 1991, Chapin et al. 2002). Specifically, plant ecologists recognize four major forest-types of woody riparian vegetation in upland (as opposed to permanent wetland) habitats in the Central Valley of California such as along the Sacramento River (Holland 1986, Sawyer and Keeler-Wolf 1995): willow scrub, on newly created sand and gravel bars; willow-cottonwood forest; mixed riparian forest, and valley oak-elderberry forest. These four community types are generally thought to occur along a succession sequence, with the main driving variable of change being continued floodplain accretion and consequent elevation increase (Nanson and Beach 1977, Cepello 1991, Peterson 2002). Increased elevation above the river level results in greater drought stress for plants, and thus the community type changes as species better adapted to summer-dry conditions gain a competitive advantage. However, it has not been well documented that Sacramento River riparian vegetation always changes according to the succession sequence outlined above. It is possible that other pathways exist along the Sacramento River (McCune and Allen 1985, Peterson 2002). Even if the hypothesized succession sequence is correct, the rate of community change is not known. In order to effectively plan, conservation managers need to know how much of a given community is being created under the current management regime and determine whether this differs from what would take place in an unregulated setting. For example, if natural succession processes are constrained due to river regulation such that little new valley oak forest is being created from existing mixed riparian forest, managers might seek to find ways to accelerate the transition to valley oak from mixed riparian or other earlier succession stages.

Few studies of riparian forest chronosequences along the Sacramento River have used field-based quantitative sampling (exceptions are Strahan 1984, Cepello 1991, A. Fremier, unpublished, and M. Vaghti, unpublished). Most recent work on riparian vegetation along the Sacramento River used remote sensing techniques such as air photo interpretation (Greco 1999, Nelson 2002). Whereas remote sensing techniques excel in their geographic extent, they generally are poor in obtaining detailed data on such ecological parameters as understory species composition and tree size, density and age. This latter type of data comes best from field studies. For example, an overstory of Fremont cottonwood forest with an understory of fig, black walnut and tree-of-heaven saplings is not a healthy forest condition by many

standards due its high potential for becoming a forest dominated by non-native species, but this unhealthy condition would not be recognized as such by existing remote sensing. Thus, a combination of extensive remote-sensed geographic data with intensive field data will be the most productive course of study for obtaining information on actual riparian forest community composition.

The goals of this study are to: (1) quantify the distribution of previously mapped plant communities as a function of river subreach and to determine if there is a difference in plant community distribution among reaches. Such a difference among subreaches, if it exists, might arise from such factors as land use history, hydro-geomorphic attributes of the river (Singer and Dunne 2001) or the effect of tributaries. Tributaries tend to add species more typical of upland or foothill habitats to bottomland forests at the confluence with the mainstem from downstream dispersal of propagules. Thus the community composition around a confluence can be slightly different than at sites away from confluences (examples of species here are California buckeye (*Aesculus californica*), hop tree (*Ptelea trifoliata*), white alder (*Alnus rhombifolia*), and additional willows (*Salix* spp.; T Griggs, pers. comm.; D Wood, pers. obs); (2) inventory remnant riparian forests of different community types (as mapped by the GIC) along the middle Sacramento River to document species composition and age; (3) formulate hypotheses as to the timing of invasion of undesirable species; and (4) establish a well-documented, baseline set of forest conditions against which to measure future changes and trends in succession.

## Methods

A GIS map of riparian vegetation community types along the mainstem Sacramento River (Nelson, 2002) was used to describe community composition along the four different river subreaches located between the towns of Red Bluff and Colusa (river miles 163 to 243; Fig. 1). This map, created from air photo interpretation of 1999 photos, classifies vegetation into ten community types and four habitat types. Community types used in Nelson (2002), approximately based on Holland (1986), were: blackberry scrub, great valley cottonwood riparian forest, eucalyptus, giant reed, herbland cover, valley freshwater marsh, great valley mixed riparian forest, great valley riparian scrub, tamarisk, and valley oak. Habitat types were: disturbed, disturbed riparian, gravel and sand bars, and open water. The three most common natural vegetation types, and those analyzed in this study, are great valley cottonwood riparian forest (hereafter CRF), great valley mixed riparian forest (hereafter MRF), and valley oak (hereafter VO). For mapping purposes the CRF community was defined by Nelson (2002) as:  $\geq 80\%$  Fremont cottonwood (*Populus fremontii*) by canopy cover and older than one year; the MRF community as a type where neither willows nor cottonwoods dominate, but rather a mixture of what are commonly thought of as more upland, later successional species including valley oak (*Quercus lobata*)  $< 60\%$  canopy coverage, black walnut (*Juglans californica* var. *hindsii*), Oregon ash (*Fraxinus latifolia*), tree of heaven (*Ailanthus altissima*), and sycamore (*Platanus racemosa*); and the VO community as  $\geq 60\%$  canopy cover of valley oak. Using ArcView software and the GIS map, the area extent of the three communities was tabulated as a function of subreach. All vegetation along the mainstem was captured by this analysis, but any vegetation along tributaries  $> 0.5$  miles from the mainstem, if mapped at all, was not included.

The GIS map of riparian vegetation described above (Nelson, 2002) was also used to identify remnant forest study sites for the forest inventory study. Potential study sites were selected in areas mapped as cottonwood riparian forest (CRF), mixed riparian forest (MRF), and in the immediate vicinity of valley freshwater marsh (VFM). The VFM community, defined as being dominated by emergent monocots, is not a forest type and was not intended to be sampled in this study, but rather the locations were used to locate landform features and habitats characteristic of old oxbow lakes, sloughs, etc., for later sampling.

Remnant forest sites were selected for plot sampling from CRF and MRF types that were at least 10 acres in size and in public ownership. Very few VFM sites met these criteria, so the selection criterion for these sites was relaxed to 2 acres. Using the GIS map in ArcView, nine sampling points at least

100m from the mapped edge of each forest type were randomly chosen from within a site (18 points total) and entered into a hand-held GPS unit. Where possible, two or more sample points were chosen from the same contiguous area of the same community type to afford a measure of within-site replication. In the field, the location of the random point was assessed for evidence of human disturbance (4WD activity, trails, trash, etc.). If disturbed, another point was randomly chosen nearby to locate the sampling plot.

For each forest inventory plot a marker tree was selected and a blue, numbered aluminum tree tag (Ben Meadows Company) was attached to it with a galvanized nail 1.5m above the ground on the north side. This marker tree was required to be of medium size and in good health, in order to have a reasonable likelihood of persisting through the next decade to facilitate precise plot relocation. GPS coordinates of the marker tree were also recorded. The marker tree formed the southwest corner of the plot, and from it a 20m x 30m (0.6 hectare; 0.148 acre) rectangular plot was laid out using tape measures, with the 30m sides running east-west as determined by a sighting compass (uncorrected for magnetic declination).

Within the plot the diameter of all trees or tree-like shrubs with stems  $>2.5$ cm dbh (diameter at breast height) was recorded. Stem diameters (cm) were converted to basal area ( $\text{cm}^2$ ) using standard formulas for circles. Basal area is typically referred to as dominance, or ecological influence, by forest ecologists (Kimmins 1997). Importance values for all tree species in a plot were then calculated as the sum of relative density (each species' density divided by total density of all species) plus relative dominance (each species' basal area divided by total basal area of all species). Importance values thus reflect both the number and size of individual species. In this way, saplings can be compared along with mature trees. Multivariate analyses were performed using the PCORD software version 4.2 (MjM software, Glenden Beach, OR). Ordination was by detrended correspondence analysis, and cluster analysis used Euclidean distances and Ward's method of clustering.

Shrub and vine cover were recorded using the line intercept method. Three 10m line transects were placed perpendicular to the long axis of the plot at the 7.5m, 15m, and 22.5m marks on the tape. The total fraction of the 10m length (to the nearest 0.25m) intercepted either above or below the line by each species was then recorded and multiplied by 10. This value is equal to the percent cover of that species per transect (Barbour et al. 1999). Cover values were averaged over the three transects.

Three to four trees from within each plot or the immediate vicinity were selected for age determination. One tree each of Fremont cottonwood, California black walnut, box elder (*Acer negundo*), and Goodding's black willow (*Salix gooddingii*) was selected if present in the immediate vicinity. These species were selected because of their common occurrence throughout the study region. An increment corer was used to extract a 5mm thick core, which was then placed into a plastic soda straw for transport back to the lab. The hole was then plugged with a twig dipped in tree wound healing compound to seal the cavity. If upon inspection a core did not have identifiable pith (tree center) it was discarded and another core was taken. In the lab cores were glued to wooden holders and sanded smooth using 400 grit sandpaper. To facilitate counting age rings, cores were treated with 5% phloroglucinol in ethyl alcohol for 45 seconds and then acid-washed using 50% aqueous hydrochloric acid. This procedure stains lignin red and thus accentuates yearly growth rings because lignin is more concentrated in the smaller diameter xylem cells at the end of the growing season. Rings were counted using a dissecting microscope by two independent technicians and the tree ages compared. If there was a large discrepancy in calculated age (>3 years), a third independent count was done and the closer of the two values was used. If there was such a poor ring presentation that aging would be problematic, the core was discarded without further analysis.

In the spring and summer of 2003, after leaf-out, additional data will be collected on all plots. The cover of all herbaceous species in a plot will be tallied according to the Daubenmire abundance scale (Barbour et al. 1999). A complete plant species list will be compiled and the presence of any large patches of non-native invasive species such as giant reed (*Arundo donax*) or Himalayan blackberry (*Rubus discolor*) will be noted, should they not have been sampled already by the line transects. Canopy cover will be estimated using a densitometer.

## Results

The distribution of previously mapped community types by the Geographic Information Center, CSU, Chico in four subreaches along an 80-river mile stretch of the Sacramento River is shown in Figure 1. There is no significant difference in community composition among the four subreaches (chi-square,  $p=0.4$ ). Mixed riparian forest (MRF) was the most common community in all four subreaches, followed by cottonwood riparian forest (CRF) and valley oak (VO). No VO was mapped from river mile 163 to 177, and the largest occurrence of this community type (at only 3%) occurred in the Rio Vista subreach, primarily at Woodson Bridge State Park (Fig. 1). Figure 2 expresses the extent of the three community types in acres per river mile. The Beehive Bend subreach contains the most remnant riparian forest per river mile. The amount of riparian vegetation decreases somewhat as river mile increases, although this trend is not statistically significant (chi-square,  $p=0.3$ ).

In the forest inventory study, 18 plots were established at eight sites during fall and winter 2002-2003 from river mile 169 (Sul Norte) to river mile 197 (Chico Landing) (Table 1). Nine plots were established in CRF and nine in MRF. The VO community and sites in old oxbows and sloughs will be sampled later in 2003.

There was no difference in either mean tree density or mean basal area between CRF and MRF community types (t-tests,  $p=0.54$  for density,  $p=0.47$  for basal area). CRF had a mean density of 42 stems/plot and a mean basal area of 4712 cm<sup>2</sup>/plot, whereas MRF had a mean density of 48 stems/plot and a mean basal area of 4209 cm<sup>2</sup>/plot (Table 1). Analyses of the shrub data will not be reported here, due mostly to the lack of a well-developed shrub layer in the plots. A majority of the line transects had few or no shrubs present. The lack of an apparent shrub layer at the time of sampling (before leaf-out, but stems and old leaves still visible) could be real and due to scouring or by shading from overstory trees, or (more likely) by shrubs and vines being buried (fresh silt was often present in plots). It is possible that shrubs will rebound from burial when spring growth resumes; if so, transects will be resampled when plots are revisited to sample the herbaceous layer. When all vegetation data are collected, both the shrub and the herbaceous data will be analyzed together.

Importance values of species in common between CRF and MRF are shown in Figure 3. As expected, the pioneer species Fremont cottonwood, Goodding's black willow, and narrow-leaved willow (*Salix*

*exigua*) all have higher importance values in CRF than in MRF, although wide variability among plots within a community type and a low overall sample size renders all statistical comparisons as not significant (t-tests; all  $p > 0.2$ ). Species higher in MRF than in CRF are Oregon ash, California black walnut, valley oak, arroyo willow (*Salix lasiolepis*), and blue elderberry (*Sambucus mexicana*), but again statistical comparisons between the two community types are not significant. Boxelder shows no difference between CRF and MRF. A power analysis using the variance in importance values among plots revealed that a sample size of 35-40 should result in some statistical comparisons becoming significant at the  $p=0.05$  level, assuming current data are accurate representations of the populations sampled.

Multivariate analyses such as ordination and classification are commonly used in community ecology because they consider both species-level and plot-level data simultaneously, and as such may reveal fine-scale patterns that may not be evident from single-species comparisons. However, this was not the case in this study. The results of a detrended correspondence analysis ordination using the tree importance values are shown in Fig. 4. There is no apparent natural grouping of CRF or MRF plots based on the tree data. If there were, one would expect to see most or all plots of a given community occurring together in the same graph space. This result reinforces the lack of statistical differences found above for importance value comparisons. However, plot CL-1 (Chico Landing 1) was omitted from the results plotted in Fig. 4 because its presence heavily skewed an earlier result to the point of illegibility (CL-1 was all alone at the right-hand edge on Axis 1, with all 17 other plots plotted as overlapping points on the left-hand edge). CL-1 was the only plot that contained any valley oak and Oregon ash. Thus, CL-1 is so different, even from the other MRF plots, that it could not be considered in the same ordination dataset. A cluster analysis (Fig. 5) shows how different CL-1 is, as well as further illustrating the lack of community type discrimination observed in the ordination results. From Fig. 5 it is apparent that CL-1 is only 25% similar to any other plot or cluster, and plots of type CRF and MRF cluster together apparently independently, with some CRF and MRF plots joining at  $>95\%$  similarity.

One of the goals of this study was to determine forest stand age and quantify the timing of invasion of undesirable species such as California black walnut into maturing riparian forest. Tree cores were obtained from 46 trees of six species, of which 35 cores yielded countable rings. Cottonwood was the most difficult species to age (11 cores obtained, but only 6 with countable rings). Other results were: box elder, 12 cores and 9 counts; Gooding's black willow, 9 cores and 6 counts; black walnut 12 cores,

11 counts. Only one core was obtained for sycamore (*Platanus racemosa*) and fig (*Ficus carica*), due to their rarity near the sample plots, but both cores yielded countable rings.

Regressions of tree size on age for the four species with sufficient sample size are presented in Figure 6. All regressions are significant at  $p < 0.05$ , and as expected the hardwoods (black walnut and box elder) exhibited better regressions ( $p < 0.01$ ) than did the softer woods (Fremont cottonwood and Goodding's black willow). The significance of these pilot regressions means that with more data, tree size may be used as a reasonable surrogate for tree age, within the error bounds of the regression, eliminating the time-consuming steps of coring and aging.

Estimated tree ages at the different sites are given in Table 2. Perhaps unexpectedly, cottonwood is not always the oldest tree in a plot—sometimes it is Goodding's black willow. Although this result could easily be an artifact of the single tree per species cored in a plot, this result does suggest that early successional communities may be composed of willows and not cottonwoods, and that cottonwood may invade later. The age data for black walnut, box elder, sycamore, and fig all support the concept that these species invade the forest some years after initial establishment. For example, in the four cases where both cottonwood and black walnut were aged in the same plot, walnut was 8, 17, 25, and 46 years younger than the cottonwood. To quantify this trend further will require more data. However, using the significant regressions between tree size and age presented above (a result obtained in general for forest trees; Kimmins 1997), a working hypothesis as to timing of invasion may be gleaned from the tree diameter data. Figure 7 shows the relationship between mean Fremont cottonwood dbh and California black walnut dbh in all 18 study plots. The regression is positive and significant ( $p < 0.01$ ;  $R^2 = 0.64$ ). As cottonwoods get larger (i.e. plot age gets older), so do black walnuts. Of greater interest is the fact that the regression line, when back-extrapolated, does not go through the origin, rather it intercepts the x-axis around 14 years. This suggests that black walnut invasion commences about 10 to 20 years after cottonwoods are established, presumably well before any transition occurs from CRF to MRF. Box elder apparently establishes independently of cottonwood or plot age, as the regression between cottonwood size and boxelder size is not significantly different from zero (Fig. 8).

## Discussion

The results from this study are at once informative, tantalizing, and incomplete. Concluding anything about a complex fluvial-biological system from only 18 plots is at best dangerous. Still, this study is of value for several reasons: it is one of the first of its kind to be undertaken on riparian forests in the Central Valley using on-the-ground, replicated, detailed measurements on actual organisms and not their photographs; it is open-ended—as more plots are added the statistical power of the analyses and hypotheses proposed here will increase; as more information is made available on historical trends in river movement and landform age, interpretation will rapidly improve; and the procedure is in place for repeated censusing of plots to better understand riparian succession and timing and pattern of invasions.

At present, the data show that there is no significant difference between the CRF and MRF communities as mapped by the CSUC GIC, at least in terms of tree importance values. Although the comparison of importance values between the two community types (Fig. 3) suggested a difference, neither the ordination nor the cluster analysis (Figs. 4 and 5) uncovered any meaningful pattern other than that there are major differences in woody species composition among sites. Mapped MRF sites can include high importance values of Fremont cottonwood (which one associates with CRF), and not all MRF has representation of later succession trees such as Oregon ash and sycamore as might be expected. The addition of understory herbaceous data to the ordination may also help refine the analysis, although a report by Holl on understory vegetation in remnant forests failed to uncover any meaningful correlation with overstory species composition (K. Holl, unpublished manuscript). Even our best efforts may fail to fully categorize riparian forest dynamics. For example, it may be that different communities develop on similar sites (McCune and Allen 1985), possibly as a result of initial species composition effects (Gleason 1926, Peterson 2002), and then these initial communities are influenced by the complex interaction among physical variables such as soil stratigraphy, depth to groundwater, scouring and flooding.

One of the goals of this study was to analyze the presumed succession pathway from CRF to MRF and then to valley oak forest (VO). Figure 3 identifies some trends in importance values between CRF and MRF, which may be accentuated when more data are collected. This analysis will be far better clarified when more plots like CL-1 are sampled and included in the analysis. As noted above, CL-1 was the only plot to contain valley oak and Oregon ash, two species often described as characteristic of later

succession communities, i.e. mature MRF or immature VO. It is possible that most of the MRF plots sampled in this study are on the young edge of the succession spectrum. It is also possible that the mapping of community types by the GIC is misleading. Aerial photo interpretation can only see the uppermost canopy species; it generally cannot see species of mid or understory position, and in the absence of historical photo sequences, it cannot age vegetation except through indirect measures such as canopy cover or height. For example, the leafy crown of two or three mature cottonwoods can dominate the uppermost canopy of a 20 x 30m plot, yet beneath that canopy dozens of black walnut and box elder individuals may occur. In the author's opinion, ecological community classification must be based on all species within a site, not just a few large individuals.

This study reports some basic data on existing riparian forest composition (Table 1, Figure 3). These data are useful now, and forthcoming data on elevation and landform age will add to their current interpretation (S. Greco, pers. comm.). In addition, these forest plots will provide valuable baseline data for future comparisons. Long-term data are essential for detecting ecological trends and for putting the present in perspective (Magnuson 1990). For the present study, an attempt was made to locate detailed, site-specific historical data to compare to the current data. However, aside from general accounts of the riparian vegetation of the Sacramento River (Thompson 1961, Holstein 1984, Katibah 1984, Griggs and Small 2000), the only other reference known to contain quantitative information of the type presented here is (Strahan 1984). In her study, using the point-quarter method but in undescribed sample locations at unknown dates, she reported densities (in trees per hectare) for Riverside Forests (her category) of: boxelder=1 (but also a seedling density of 96), black walnut=1, Fremont cottonwood=53, and tree willows (*Salix* spp.)=49. Densities in Oxbow Lake Forests (her category) were higher: box elder=42, black walnut=40, Fremont cottonwood=57, and valley oak=74. In this study, boxelder had an overall density (in stems per hectare) in the 18 plots=61, Fremont cottonwood =56, black walnut=26, and tree willows=32. Thus the values for Fremont cottonwood and tree willows in the present study are comparable to those of Strahan's Riverside Forests, but her values for boxelder and black walnut trees are far lower than reported here. It appears therefore that either Strahan sampled CRF sites of a younger age than this study, when they were less invaded by other species, or that riparian forests on average are in later succession stages now than they were prior to 1984. This latter hypothesis is at least plausible—the additional 18 years of regulation by Shasta dam since 1984, yielding a reduced disturbance regime, could have resulted in increased forest maturation.

The occurrence of non-native invasive species in riparian forests is of great concern to the conservation community. Species such as fig (*Ficus carica*), tree-of-heaven (*Ailanthus altissima*), and giant reed (*Arundo donax*) are widespread in Sacramento River riparian forests. In addition, California black walnut is regarded by many as an undesirable native species in riparian forests of the middle Sacramento River due to its presumed out-of-natural-range presence there (Thomsen 1963). The Sacramento River Project of The Nature Conservancy does not plant California black walnut in its riparian restoration tracts. Some vegetation managers are even beginning the wholesale removal of black walnut from large tracts of remnant forest (J. Dempsey, California State Parks, *personal communication*). Based on preliminary data on tree ages in permanent plots obtained from increment coring, and significant regressions relating size to age of individuals, this study proposes the hypothesis that black walnut invades Fremont cottonwood/Goodding's black willow forests (the initial forest type to form on point bars) after only 10 to 20 years, but that box elder invades any time during or after forest initiation. This hypothesis, for black walnut, suggests that vegetation managers may wish to act preemptively on this species at early, rather than later succession stages, when seedlings and saplings are more vulnerable to vegetation control measures.

### **Acknowledgments**

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Figure 8. Relationship of mean Fremont cottonwood size to mean boxelder size.

Table 1. Site information, tree density, and basal area for 18 forest inventory plots in remnant riparian vegetation, sampled fall and winter 2002-2003. Plot size is 20m x 30m, or 600m<sup>2</sup>. Conversion of plot data to a hectare basis is for ease of comparison to other published studies. Community types sampled were cottonwood rip forest (CRF) and mixed rip forest (MRF).

Site Name	River Mile	Tree Tag #	Community Type	Northing	Easting	Estimated Forest		Estimated Forest	
						Tree Density (stems/plot)	Tree Density (stems/hectare)	Basal Area (cm <sup>2</sup> /plot)	Basal Area (m <sup>2</sup> /hectare)
Chico Landing	195	11	CRF	4396618	590339	57	950	5,301	8.84
Sunset Ranch	197	5	CRF	4398781	587923	22	367	1,691	2.82
Kaiser	194	8	CRF	4395633	590407	65	1,083	5,143	8.57
Kaiser	194	9	CRF	4395759	590367	56	933	5,275	8.79
Jacinto	186	12	CRF	4389188	588038	60	1,000	7,317	12.20
Jacinto	186	15	CRF	4389179	588318	30	500	4,333	7.22
Phelan Island	190.5	16	CRF	4392350	588765	28	467	5,329	8.88
Sul Norte	169	17	CRF	4369194	586271	37	617	4,201	7.00
Sul Norte	169	18	CRF	4368833	586358	22	367	3,818	6.36
<b>Mean</b>						42	698	4712	7.85
Chico Landing	195	1	MRF	4397293	590383	53	883	3,117	5.20
Sunset Ranch	197	2	MRF	4399154	588500	37	617	4,996	8.33
Sunset Ranch	197	3	MRF	4399049	588509	50	833	4,704	7.84
Sunset Ranch	197	4	MRF	4399044	588229	40	667	3,115	5.20
Sunset Ranch	197	6	MRF	4398770	588358	51	850	5,622	9.37
Kaiser	194	7	MRF	4396483	589977	67	1,117	5,219	8.70
Deadman's Reach	185	10	MRF	4388673	587223	93	1,550	5,935	9.89
Jacinto	186	13	MRF	4389345	588228	18	300	2,402	4.00
Jacinto	186	14	MRF	4389456	588322	22	367	2,775	4.62
<b>Mean</b>						48	798	4209	7.02

Table 2. Tree ages in study plots as determined by ring counts of increment cores.

	TREE AGE (yrs)					
	Cottonwood	Black willow	Black walnut	Box elder	Sycamore	Fig
CRF						
Chico Landing			22	18	35	16
Sunset Ranch	40		15			
Kaiser		16	14			
Kaiser			16	26		
Jacinto			23			
Jacinto	64	22	18	26		
Phelan Island			24	49		
Sul Norte						
Sul Norte						
MRF						
Chico Landing						
Sunset Ranch		31		24		
Sunset Ranch	47			16		
Sunset Ranch	28	19	20	18		
Sunset Ranch	28	52	11	30		
Kaiser	30	45				
Deadman's Reach						
Jacinto			41	48		
Jacinto			32			

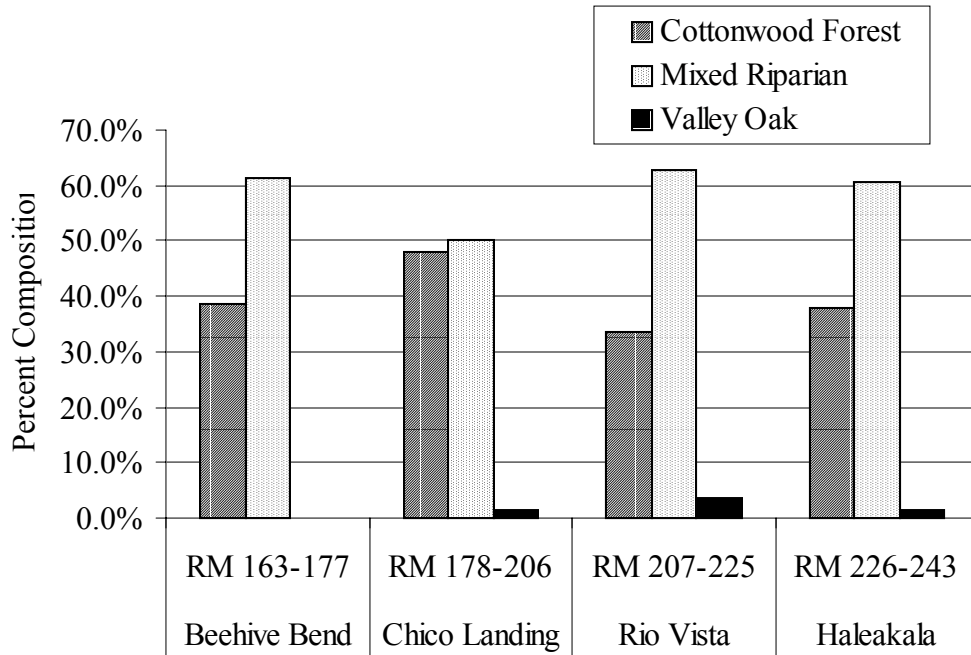


Figure 1. Community composition of different subreaches. Community types were mapped by the Sacramento River Mapping Project (2002).

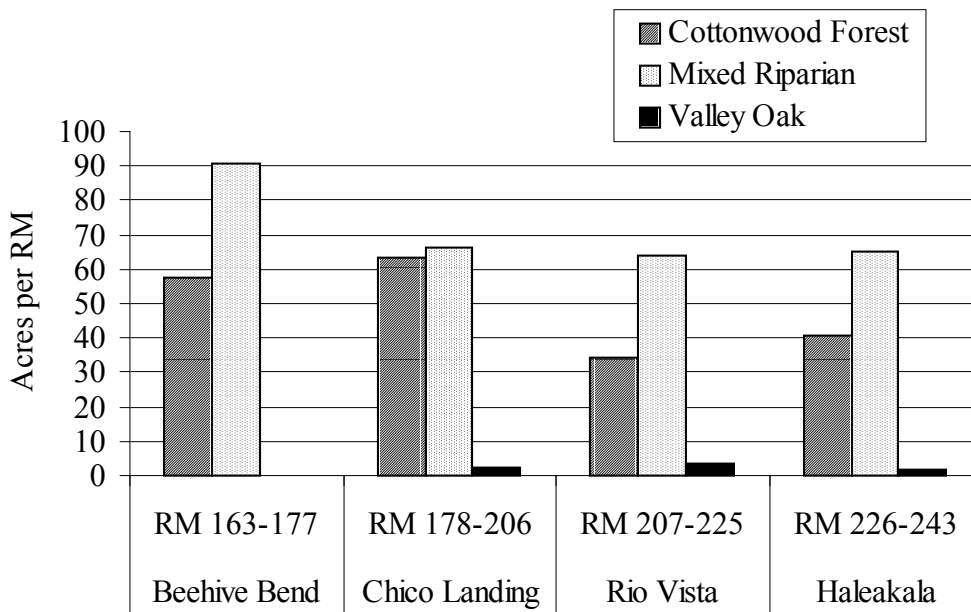


Figure 2. Acreage per river mile of three major community types along different subreaches. Subreach names Rio Vista and Haleakala are the author's nomenclature.

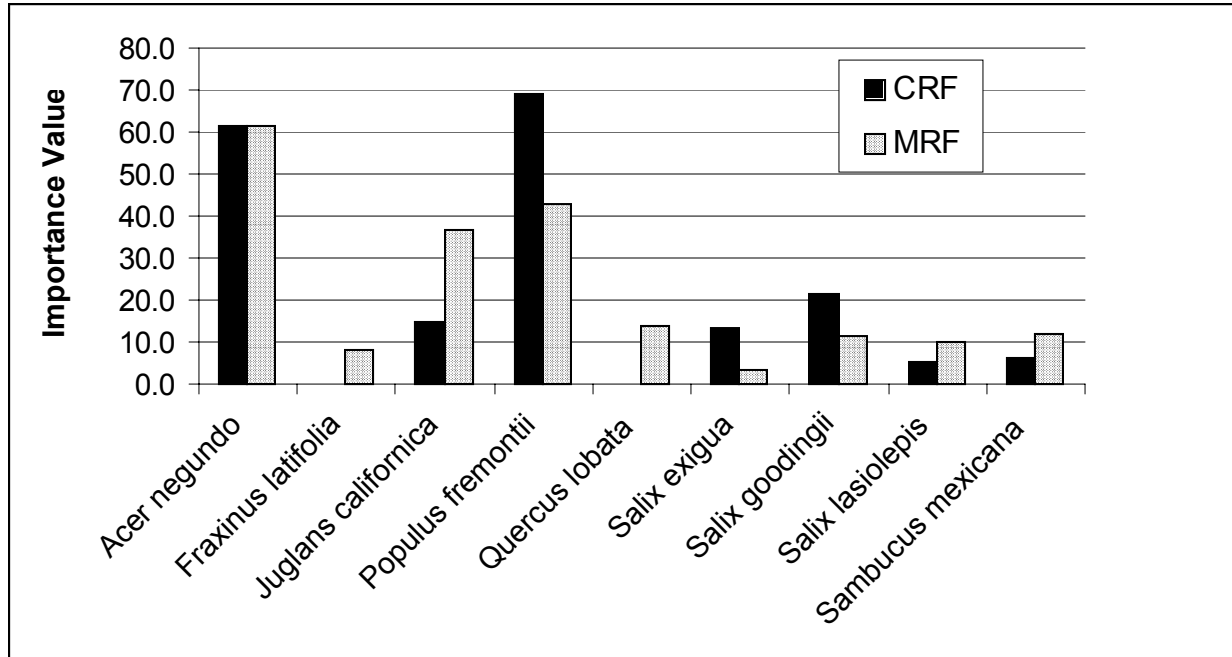


Figure 3. Comparison of mean importance values of common species in Fremont cottonwood riparian forest (CRF) versus mixed riparian forest (MRF). Importance values are calculated as the sum of relative density plus relative dominance (basal area).

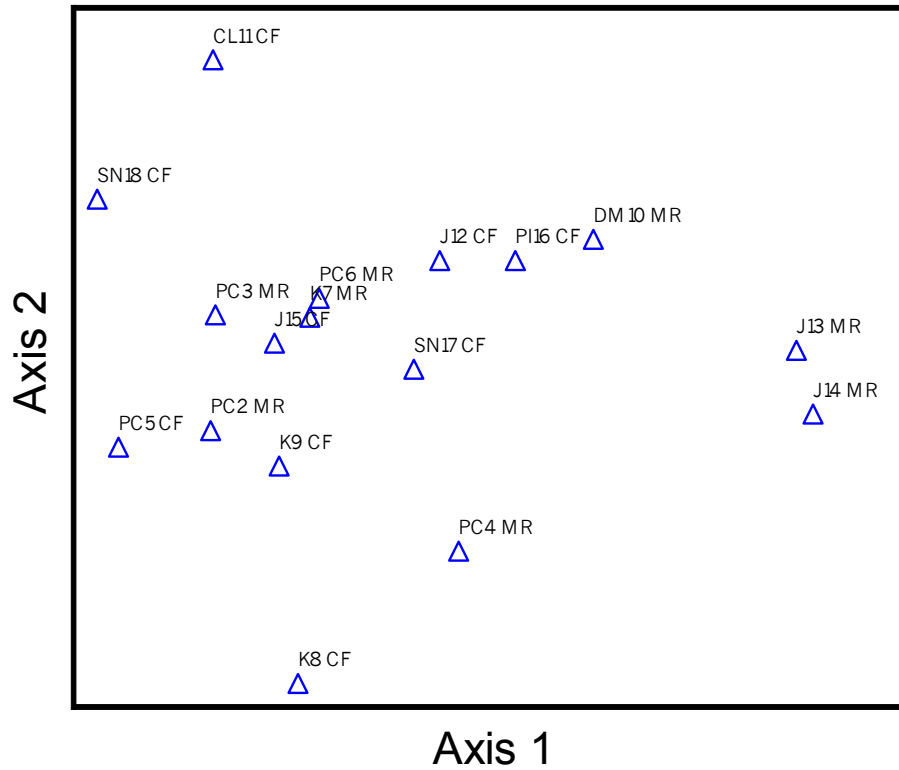


Figure 4. Detrended correspondence analysis (DCA) of 17 cottonwood forest and mixed riparian forest plots, using importance values of trees. Downweighting of rare species was used. Proximity of plots to one another indicates overall similarity in species space. Analysis was run without plot CL-1 (see text). About 40% of the variance is explained by Axis 1, and 20% by Axis 2. CL=Chico Landing, DM=Deadman's Reach, J=Jacinto, K=Kaiser, PC=Pine Creek, PI=Phelan Island, SN=Sul Norte.

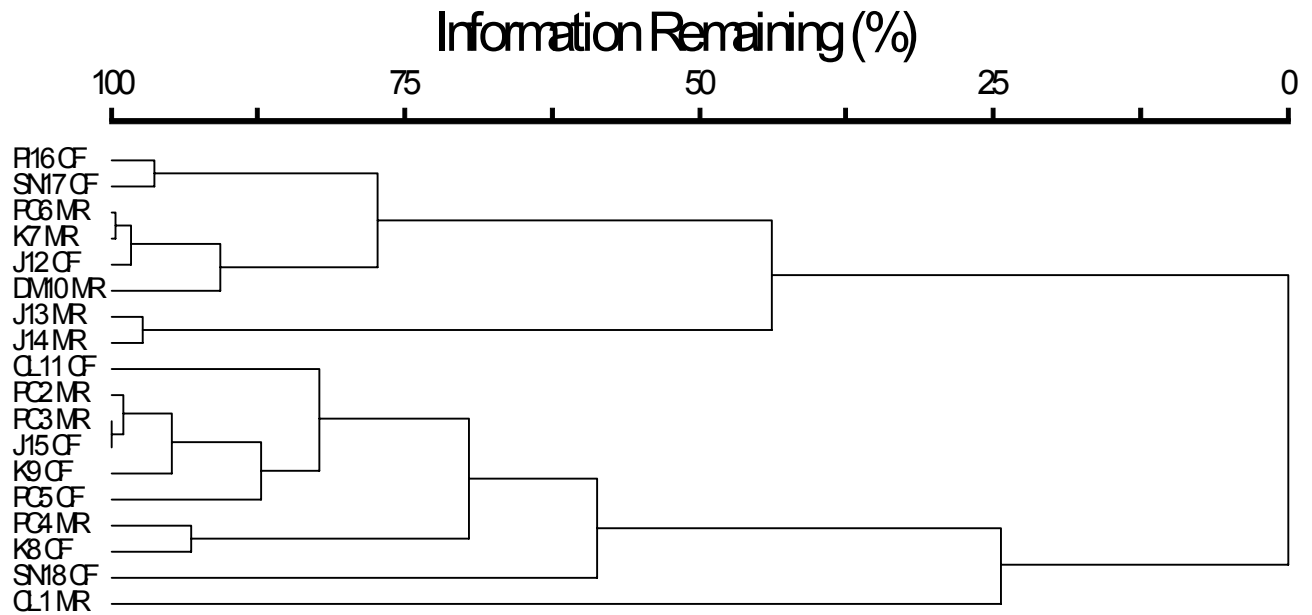


Figure 5. Cluster analysis of 18 Fremont cottonwood forest and mixed riparian forest plots, using importance values of trees and Euclidean (Pythagorean) Distance and Ward's method of clustering. CL=Chico Landing, DM=Deadman's Reach, J=Jacinto, K=Kaiser, PC=Pine Creek, PI=Phelan Island, SN=Sul Norte.

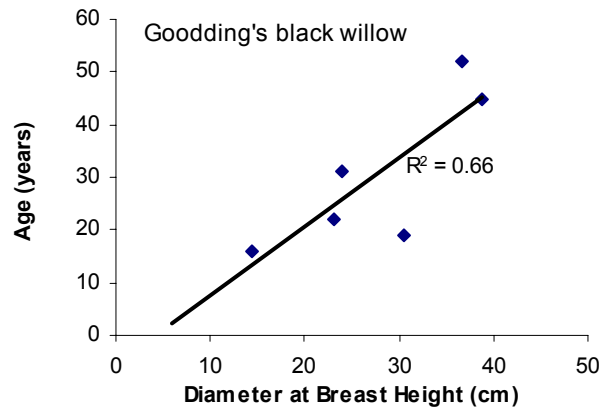
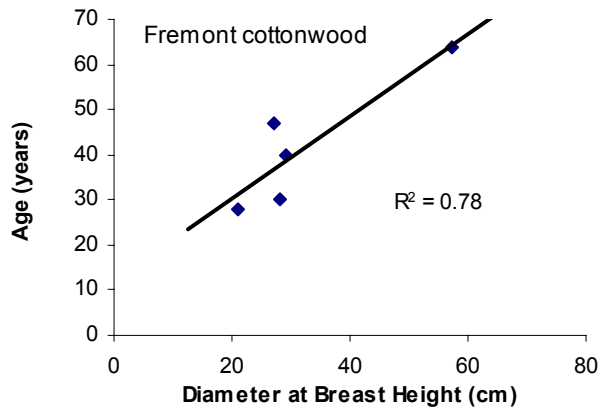
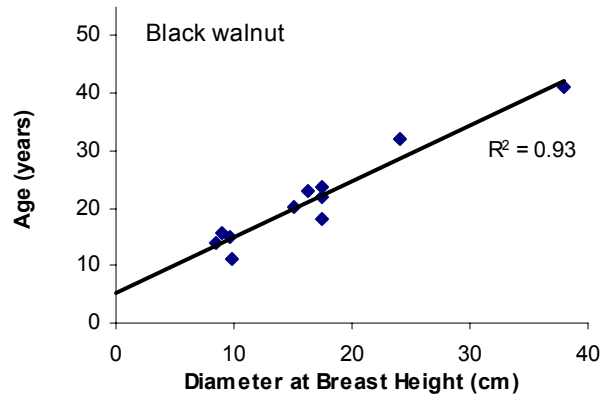
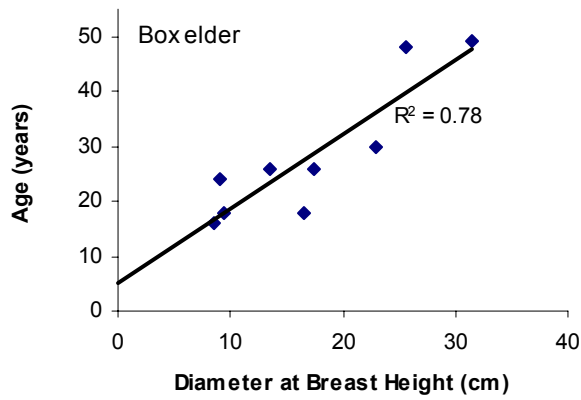


Figure 6. Regressions of tree size (diameter at breast height) on age (determined by ring counts). All regressions are significant at  $p < 0.01$ .

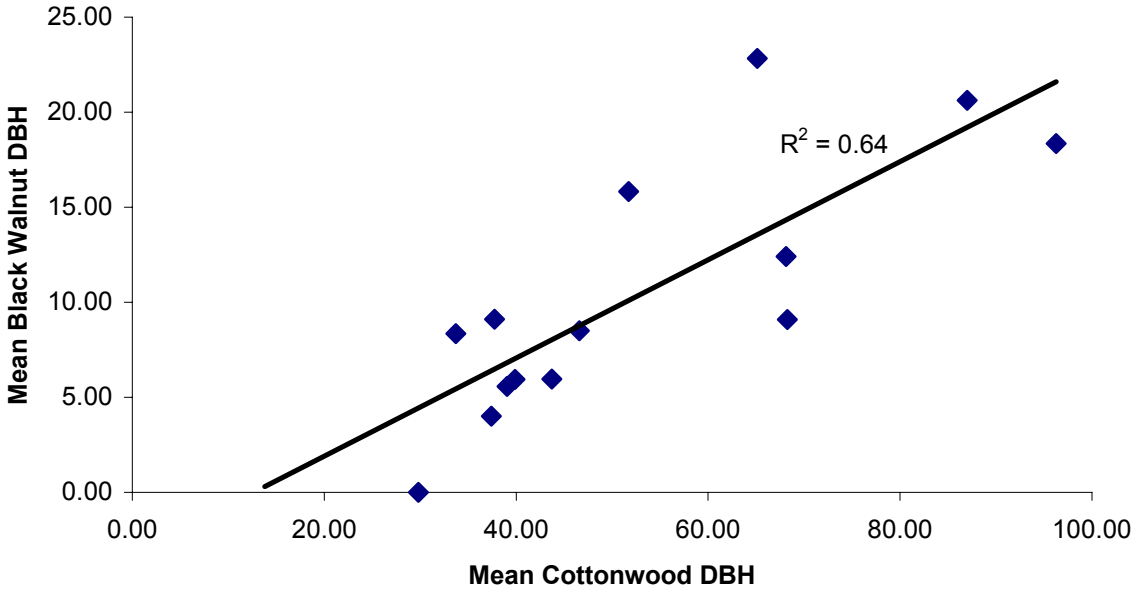


Figure 7. Relationship of mean Fremont cottonwood size to mean California black walnut size. The slope of the regression line is significant at  $p < 0.01$ .

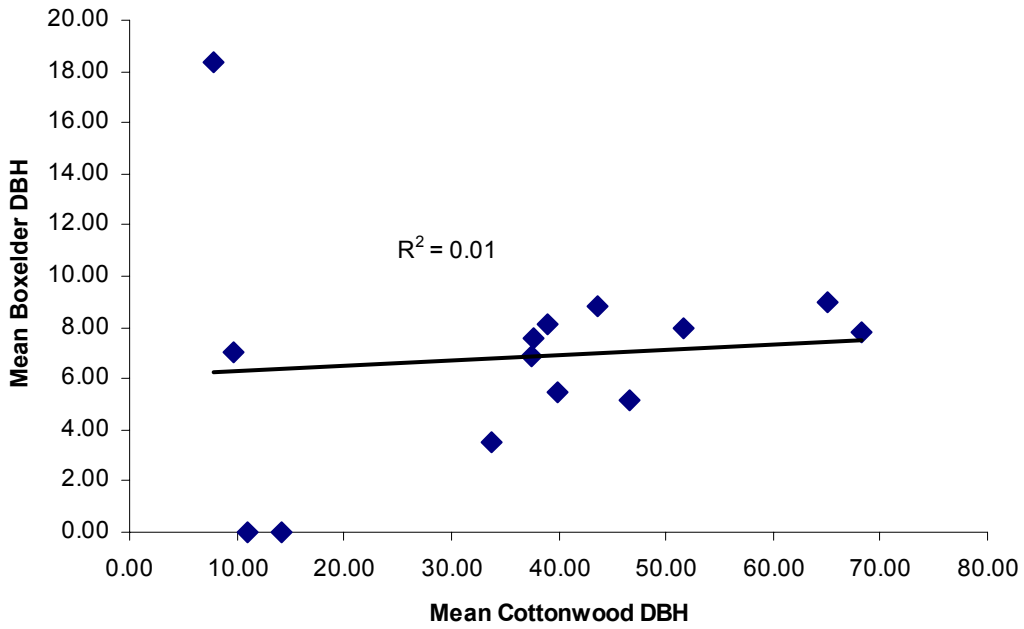


Figure 8. Relationship of mean Fremont cottonwood size to mean boxelder size. The slope of the regression line is not significantly different from zero.

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