Salt Cedar, Revegetation and Riparian Ecosystems in the Southwest

Bertin W. Anderson
Revegetation and Wildlife Management Center
201 South Palm Drive, Blythe, CA 92225

Salt cedar, variously identified as *Tamarix chinensis* or *T ramosissima,* was introduced into the southwest 75-100 years ago. Since that time it has become an increasingly dominant element in riparian vegetation over much of the area. Ecologists wonder why different kinds of soil should consistently support different species of trees, instead of a jumble of all possible species. They find that each species is relegated to the kind of soil where it has an advantage over other potential inhabitants. In this paper I provide soil data indicating that salt cedar is so widespread in and land river systems because it is, in fact, better adapted than native species to the suite of abiotic factors currently found in many river systems.

I provide data indicating that salt cedar removal followed by revegetation with native trees species is often not, and in fact cannot realistically be expected to be, successful. Because the balance of autecological variables now favors salt cedar over native species, revegetation efforts can be expected to have lower wildlife use values than the stands of salt cedar that they replace unless careful consideration is given to this possibility. Where revegetation sites are prudently selected on the basis of autecological factors present, native species can be successfully reintroduced. Habitats resulting from these efforts can be better than salt cedar as wildlife habitat.

Methods

Field Data

Sampling, usually done in 25 acre subplots, includes 10-15 randomly distributed samples within each subplot. At each sample point a soil sample is collected from the first few centimeters and another 2 meters below the surface or just above the water table. The dominant vegetation within 5 m of the sample point is recorded. The soil type is quantified (Anderson 1982) and the electroconductivity (EQ is determined in the laboratory for each sample at each point. The method has been detailed elsewhere (Anderson 1987). Depth to the water table (DWT) is recorded if sampling is done to that depth or an estimate of DWT is made. The sampling is done with the immediate objective of determining suitability of 25 acre plots for revegetation and in the long term the overall suitability of the river system for native species. Sampling began for this study in 1985 and is ongoing. Preliminary sampling has been followed-up with intensive sampling (5-10 random samples per acre) in about 21 plots found to be ecologically suitable for revegetation. Roughly 50,000 trees were planted including about 5,000 trees used for collecting growth and survival data for from one year to 10 years after planting. I refer to these as experimental trees. Intensive sampling is done in order that various conditions (EC, DWT, soil type) can be mapped for each subplot. A planting design developed on the basis of the distribution of critical variables ensures that only a small number of trees will be planted at points where they do not have a realistic probability of maturing into healthy, robust trees.

Determining Thresholds

Thresholds of salt cedar, cottonwood *(Populusfremontii), willow (Salix* spp.), honey (Prosopis *glandulosa)* and screwbean mesquite (P. *pubescens)* with respect to soil EC was determined by following the development of the 5,000 experimental trees mentioned above. Data relative to requirements for germination and survival of saplings long enough for sapling roots to reach a depth of I meter was determined from data presented by Jackson et al. (1990). The threshold is defined as the point beyond which trees are stunted and in poor condition with relatively high mortality rates (>25% in three years). These trees can persist for from one to many years and some may even produce low to moderate amounts of seed, but they generally form poor wildlife habitat; stands have little canopy development above three meters (Type VI profile of Anderson and Ohmart 1987).

Tree roots eventually penetrate deeply into the soil. Threshold levels at greater depths in the soil profile for the various species have been developed from the 5,000 experimental trees (Anderson and Ohmart 1985, Anderson 1989, Anderson and Laymon 1989, Anderson and Miller 1990,1992; Anderson, unpublished data).

Wildlife Data

To illustrate wildlife use of various habitats I draw primarily on bird data for which there is long term seasonal census data on the Colorado River. The bird census categories used include total species and density (n/ 40 ha) of resident and migrant insectivores, seed eating song birds, doves, and quail. Data were standardized using the mean number of species or mean density for each density category across all habitats on the Colorado River. In this way a value smaller than the mean has a negative value; one greater than the mean, a positive value. Using this procedure data can be grouped across bird categories, seasons, and years.

Averages for the bird categories for all riparian habitats on the Colorado River are from Anderson and Ohmart (1985). Salt cedar data are for 5 seasons (winter, spring, summer, late summer, fall) for seven years (Anderson and Ohmart 1984).

Use of intensive techniques in revegetation efforts such as those described by Anderson (1989) have not been used often because they are "considered expensive and time consuming" (Nelson and Mannan 1994). Less intensive procedures have now become the standard method of revegetation.

Data for what is referred to as revegetation by "standard" and "intensive" methods are presented. The former is represented for two sites on the Colorado River (Nelson and Mannan 1994) and for two sites representing the latter (Anderson and Ohmart 1984), also on the Colorado River. Bird data for the standard revegetation practices are for two years beginning when the revegetation sites were 3 or 4 years old. Similarly two areas where intensive methods were used were evaluated for bird use beginning when they were 3 years old. Statistical differences between sites were evaluated with t-tests. Test outcomes were evaluated for significance at an alpha level of P=0.05.

Revegetation

As far as I know the major differences between the standard revegetation practices and the more intensive efforts (e.g. Anderson 1989) are of three major types:

1. Site selection in the intensive method is made on the basis of preliminary soil testing, but not with standard procedures.
2. The intensive method involves intensive soil sampling as the basis for developing a planting design. Typical projects often include a planting design, including species composition and plant densities, before any work has been done on the site relative to the range of variation for salinity or soil moisture on the site.
3. Intensive revegetation efforts involve intensive monitoring of individual plants during the irrigation phase and less intensively in the second and subsequent seasons. Little or no monitoring is typically associated with the standard procedures.

River Systems Sampled

Here I report on sampling done within seven drainages distributed over 850 miles of southern California, Arizona, New Mexico, and Texas. Sampling within each drainage was statistically representative within sampled areas, however the intensity varied significantly between drainages. For example, sampling along the Colorado River, one of the major riparian zones in the and Southwest, was done at an intensity adequate for evaluating the system's suitability for riparian tree species, but included only a small fraction of the total 25 acre plots available for testing (Anderson 1987). In contrast, sampling intensity in the Salt Creek drainage (Anderson and Miller 1992) was done at many times the intensity done on the Colorado River. This does not reflect sloppy design. This large soil sampling effort has been an overriding goal of mine for a decade and is ongoing. However, funding comes from varied sources; work is directed toward slightly different to vastly different objectives in each area. Funding levels have not been equal; funds for the Salt Creek and San Jacinto drainages were many times the level than for the similar sized stretch of the Kern River that was sampled.

Varying sampling intensities among drainages poses some problems with respect to analysis. It is possible to scale data so that each set of samples represents the appropriate proportion of the total area studied when data from all nine areas are combined. However, this, too, poses difficulties in that precisely determining the area represented requires subjective judgments. Actually all reasonable considerations of the data that I can think of lead to the same conclusion. For this reason I simply show the results for each system separately, and draw some broad generalities on the basis of the pooled, unweighted sample.

Santa Clara River - Sampling was done along about 10 miles of the Santa Clara River in the vicinity of Valencia, CA. Riparian habitats in this area are badly disturbed through overgrazing and development. The altitude is about 1000 ft. There is little salt cedar present.

Kern River - Sampling was done along about 12 miles of the Kern River at an altitude of about 2800 feet near Weldon, CA. The area floods annually; there are still relatively large stands of cottonwood/willow dominated habitats and little salt cedar occurs in this region. Habitat losses are mainly through conversion to agricultural cropland and grazing. Salt cedar is unimportant in the local flora.

Upper San Jacinto River - Sampling in the area called the Upper Jacinto River included about 6 miles upstream from the upstream end of the "lower" San Jacinto River. It differed from the following locality in that flow is through upland areas with more canyons and a narrow flood plain. Patches of riparian habitat, although damaged through flash floods, fires and grazing, are small and disjunct.

Lower San Jacinto River - The lower San Jacinto is much different in that the flood plain broadens greatly, the valley being much flatter than in the upper reach. San Jacinto, CA is nearly in the middle of the study area. Sampling was done for about 15 miles downstream to Lake Elsinore. This reach now has flow only during the rainy season. Dams have resulted in heavy siltation in the broad upstream flood plain, the original stream lying 10-15 feet below the current streambed. Riparian stands are small and widely scattered, the original vegetation having been largely destroyed by commercial developments and agriculture. Much of this stretch is devoid of trees, but where trees do occur salt cedar is common.

White Water River - Sampling was done from Thermal, CA to just above the mouth of the river at the Salton Sea in southwestern CA, a distance of about 12 miles. The vegetation is dominated by salt cedar. The area has been regularly cleared of vegetation for flood control purposes. Stands of native vegetation are restricted to an occasional cottonwood that manages now and then to escape the blade of the dozer and scattered small stands of willows. Drainage of irrigation water from adjacent agricultural land adds tons of salt annually to the system.

Salt Creek drainage - Sampling in this area included about 5 miles of Salt Creek near Mecca, CA. Sampling was done in the vicinity of numerous desert oases and their drainages. The oases result from the numerous springs located along faults subsidiary to the San Andreas fault. Salt Creek empties into the Salton Sea. Native species, include mesquite and fan palm *(Washingtonia filifera*); cottonwood and willow occur sparingly in this relatively undisturbed area. Salt cedar is abundant. The total area sampled included about 3000 acres.

Colorado River - Sampling along the Colorado River included the lower 275 miles of the river beginning at Davis Dam on the Arizona-Nevada border southward to the international boundary with Mexico. Habitats of native vegetation have been highly disturbed as a result of dam construction, agriculture, and development. The extent of man's abuse of this system have been summarized by numerous authors (e.g. Ohmart et al. 1988). The area sampled included the lower 10 miles or so of the Bill Williams River which empties into Lake Havasu north of Parker, AZ. This tributary has the largest cottonwood/willow stands now found in the lower Colorado drainage. The dominant riparian habitat on the lower Colorado River is now salt cedar/arrowweed *(Tessaria sericea).*

Rio Grande at Socorro and Presidio - Sampling along the Rio Grande was done primarily under the direction of John Taylor, USFWS, near Socorro, NM and in the vicinity of Presidio, TX by me. Native riparian habitats have been severely damaged by man's activities in these areas and salt cedar is the dominant riparian species. There are a few scattered stands of cottonwood/ willow and mesquite.

Results and Discussion

Characteristics of the Overall Data Set

Near the surface there are 4,714 soil samples among which 36% were collected at Salt Creek and 2% along the upper San Jacinto (Table 1). All other locations were intermediate with respect to these extremes. Among the 3,465 deep soil samples, 15% were collected along the Rio Grande near Socorro, NM. There are fewer total deep samples because at some localities a deep sample was not taken at all points. Depth to the water table was determined at 3,465 points.

Threshold Levels

Surface-Jackson et al. (1990) provide data indicating that sapling cottonwood show a 68% reduction in stem growth in 90 days at 9.4 mmhos/cm and 22% at 2.3 mmhos/cm. Soil EC of 3 mmhos/cm was selected (Table 2) as the threshold on the basis of these data. Data for willow are approximately the same as for cottonwood (Jackson, et al. 1990). For honey mesquite seed germination is high at high EC levels but shoot growth at 120 days is reduced by 58% at 9.4 mmhos/cm, but only by about 40% at 8 mmhos/cm. This level, although rather high, was selected as the threshold for this species. Screwbean is more salt tolerant, having lost only 29% of shoot growth at 9.4 mmhos/cm (Jackson et al. 1990); this level was selected as the threshold limit for screwbean. Salt cedar loses about 37% of shoot growth at 120 days at about 18.5 mmhos/cm. This was selected as the threshold (Table 2). Use of this threshold will tend to slightly underestimate an area's suitability for salt cedar.

Again, the threshold levels do not represent points above which individuals do not survive, rather it is an approximate point above which individual saplings have a significantly reduced stature and presumably a highly increased chance of not surviving to maturity or if they do survive they do so as stunted individuals of marginal value to wildlife.

Table 1.
Extent of soil sampling in nine study areas (% of total) along seven southwest and zone rivers.

		Number of Samples (%)	
River System	Acronym	Near surface	4 - 6 ft below surface
Santa Clara	SC	507(10.8)	507(14.6)
Kern	KR	390(8.3)	390(11.3)
Upper San Jacinto	USJ	73(1.5)	66(1.9)
Lower San Jacinto	LSJ	367(7.8)	205(5.9)
White Water	WW	142(3.0)	142(4.1)
Salt Creek	DP	1682(35.7)	633(18.3)
Colorado	CR	707(15.0)	675(19.5)
Rio Grande, Socorro	RGS	727(15.4)	727(21.0)
Rio Grande, Presidio	RGP	119(2.5)	119(3.4)
TOTALS		**4714 100.0**	**3464 100.0**

Table 2.
Thresholds of various tree species and the proportion of the samples that were above these thresholds.

	Near surface (N=4,714)		4-6 below surface (N=3,412)		Depth water table (N=4,714)	
	Obs. No(%)		Obs. No(%)		Obs. No(%)	
species	threshold	> threshold	threshold	> threshold	threshold	> threshold
Ctd/wil	3.0	2453(52.0)	3.0	1429(41.9)	10	2385(50.6)
H. mesq	6.0	1671 (35.4)	8.0	772(22.6)	12	825(17.5)
Sb mesq	9.4	1354(28.7)	9.4	616(18.1)	12	825(17.5)
Saft Cedar	18.5	746(15.8)	18.5	197(5.8)	12	825(17.5)

Deep Soil Samples - From our own data (e.g. Anderson 1989, Anderson, unpublished data) the threshold for cottonwood/willow for EC at deep soil levels is about 3 mmhos/cm. Above that point the loss in trees three seasons old is about 70% of total foliage volume relative to trees growing where EC levels are less than 3 mmhos/cm (Table 2). Three year old honey mesquite showed 44% reduction in growth at 8 mmhos/cm relative to trees growing where EC was less than 8 mmhos/ cm and mortality was 48% compared to 13% where deep soil EC was less than 8 mrnhos/cm. Thus, 8 mmhos/cm was considered the threshold level for honey mesquite. Screwbean seems to be somewhat more salt tolerant in that trees growing where deep soil EC was 39.4 mmhos/cm showed only 19% less growth than those where EC was less than3 mmhos/cm. Above 9.4 mmhos/cm screwbean showed 73% less growth and mortality was 62%; 9.4 mmhos/cm was selected as the threshold. A total of 348 mesquite were involved in the determination of these thresholds. For 119 relatively robust salt cedar growing along the

Colorado River the mean EC at deep levels was 9.4 mmhos/cm. It was assumed that 9.4 mmhos/cm was the threshold (Table 2). This may well prove to be low, thus rendering my estimations of the suitability of the drainages included in this study conservative for salt cedar.

Depth to the water table - When depth to the water exceeds 2.5 meters the growth of cottonwood and willows is significantly restricted in arid riparian zones (Anderson, unpublished data).

We no longer plant these species if the water table or capillary fringe is greater than 2.5 meters below the surface (Table 2). In and land riparian situations depth to water, per se, may not be as important as the amount of moisture in the soil profile. Test data with respect to the importance of DWT to mesquite and salt cedar are lacking, however, since soil moisture is probably important for these species as well, and since soil moisture deficits are likely to increase as depth to the water table increases, it is probable that depths greater than 4 meters render an area inhospitable to mesquite and salt cedar. This is based on the observation that where DWT is greater than 3 meters, other factors being within the range of threshold, mesquite and salt cedar tend to be stunted and sparse. On the Colorado River, structural type VI vegetation of Anderson and Ohmart (1989) characterized by sparse vegetation with few trees over 5 meters tall, typically has 35 to 150 rather stunted trees per acre. On this basis I assume that when DWT is greater than four meters it is basically beyond the threshold of mesquite and salt cedar (Table 2). We are conducting one study on the Santa Clara and one on the Colorado where depth to the water table and lack of soil moisture are intercorrelated and both are negatively correlated with tree density and robustness (Anderson and Vasquez, unpublished data).

Thresholds and Current Conditions

Threshold levels and near-surface soil - For cottonwood/willow the threshold level of near surface soil EC is exceeded by the average in 6 (67%) of the nine areas sampled including the Colorado River and both localities along the Rio Grande (Fig. 1). Only on the Kern, Santa Clara and upper San Jacinto do nearly all of the samples (2 standard deviations) fall below the threshold level for cottonwood/willow. The overall situation is more favorable for honey mesquite; mean EC in surface soil is above the threshold level for honey mesquite for only three sample areas and for only two for screwbean (Fig. 2). However, these two species do not occur naturally along the Kern or Santa Clara Rivers, thus the mean EC excluding these areas exceeds the threshold level in 3 (43%) of 7 sample areas for honey mesquite and 2 (29%) of 7 for screwbean. For salt cedar, the threshold level is exceeded only on the White Water and in the Salt Creek drainage, two (22%) of nine sample areas (Fig. 3).

Electroconductivity of deep soil samples - The EC threshold of cottonwood/willow is exceeded by the average soil EC value in 6 (67%) of the nine sample areas (Fig. 4). For mesquite the threshold level is exceeded by the average found along 2 (28%) study areas for screwbean and three for honey mesquite (Fig. 5). However, even for these species the proportion of unsuitable area is 30-40% within most sample areas (Fig. 5). For salt cedar the threshold level is exceeded only in the Salt Creek drainage (Fig. 6), a relatively small system.

Depth to the water table - The average depth to the water table exceeds the threshold of cottonwood/willow only on the lower San Jacinto and Colorado Rivers, but EC level is suitable the depth to the water table must not both of these are important areas. In several of the other areas, although the mean threshold level is not exceeded, a large proportion, 30% or more, exceeds the threshold (Fig. 7).

Interactions - In order for a tree to survive over the long term it must have an electroconductivity level below the threshold level not only on the surface but also at greater depths in the soil profile. And even if the soil be too great. Although there is a tendency for deep soil EC levels to track surface EC levels this relationship ex plains no more 60% of the variance on any single area studied and for 64% of the variance across all rivers for log 10 transformed data. To evaluate the suitability for natives and salt cedar the statistical interaction between the three variables must be evaluated. There was a total of 3,465 samples across all study areas for which data from the surface, and a deep soil layer as well as DWT estimate was made. Among them 973 (28%) were suitable for cottonwood/willow for all three (Fig. 8). For mesquite, Kern River and Santa Clara River data were omitted because mesquite are not indigenous to those areas. Conditions are suitable for honey mesquite on the surface, below the surface where the water table is less than three meters below the surface at 46% of 2,392 samples points (Fig. 8). For screwbean, 1,408 (59%) of all points are suitable (Fig. 8). For salt cedar 2,746 points (79%) are suitable (Fig. 8).

With 79% of all sample points across the nine sample areas suitable for salt cedar, but no more than 59% for any other species it is not surprising that salt cedar is now the dominant species within the flood plains of these areas. Note also that in areas where conditions are suitable for cottonwood and willow, salt cedar is not dominant. This includes the Kern and Santa Clara rivers. In the Colorado River system the Bill Williams River has conditions suitable for cottonwood/willow and these species, not salt cedar, are dominant there. It seems that where conditions are suitable for native species they are able to resist invasion by salt cedar to a significant degree.

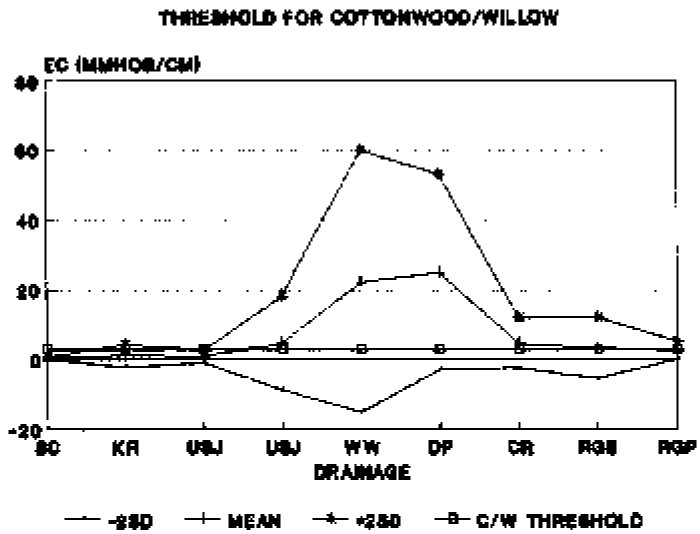

Fig. 1. Electroconductivity (EQ threshold for cottonwood and willow in soil near the surface and distribution of EC levels (2 Standard Deviations, Mean) for nine study areas in and Southwestern riparian systems. Abbreviations for rivers: SC=Santa Clara; KR=Kern River; USJ and LSJ=Upper and lower San Jacinto-, WW=White Water; RGS and RGP=Rio Grande at Socorro, NM and Presidio, TX.

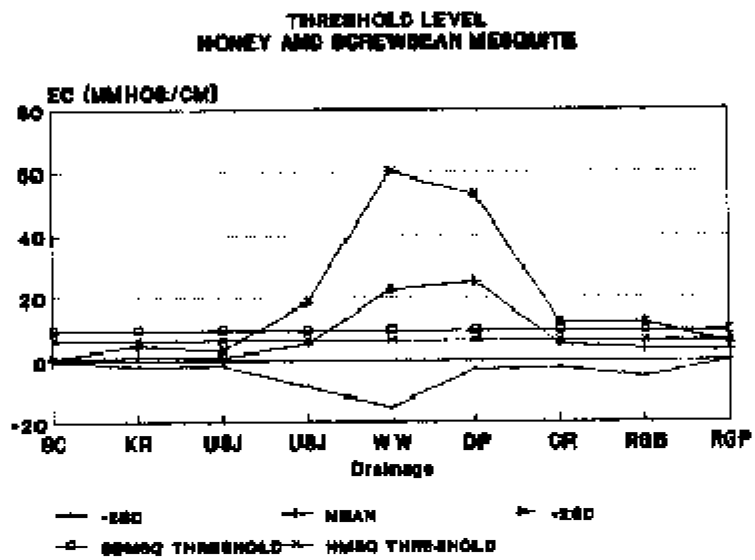

Fig. 2. Electroconductivity (EQ threshold for honey and screwbean mesquite in soil near the surface and distribution of EC levels (2 Standard Deviations, Mean) for nine study areas in and southwestern riparian systems. Abbreviations for rivers: SC=Santa Clara; KR=Kern River; USJ and LSJ=Upper and lower San Jacinto; WW=White Water; RGS and RGP=Rio Grande at Socorro, NM and Presidio, TX.

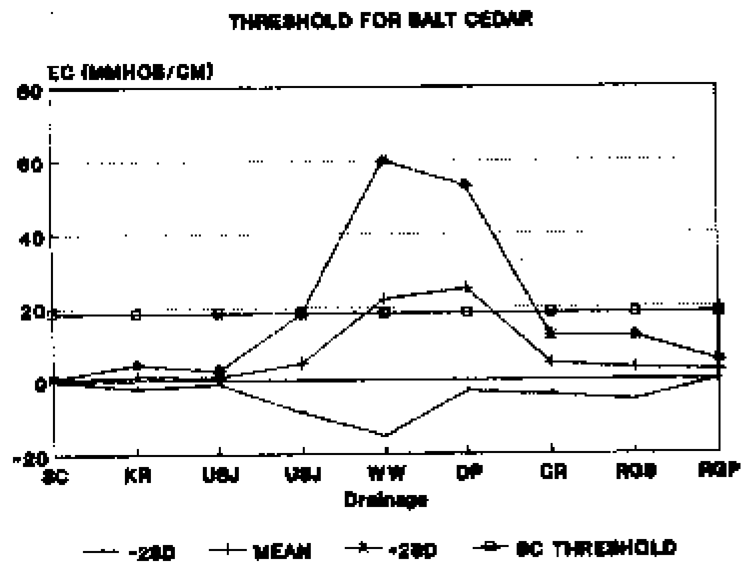

Fig. 3. Electroconductivity (EQ threshold for salt cedar in soil near the surface and distribution of EC levels (2 Standard Deviations, Mean) for nine study areas in and south western riparian systems. Abbreviations for rivers SC=Santa Clara; KR=Kern River; USJ and LSJ=Upper an lower San Jacinto; WW=White Water-, RGS and RGP=Rio Grande at Socorro, NM and Presidio, TX.

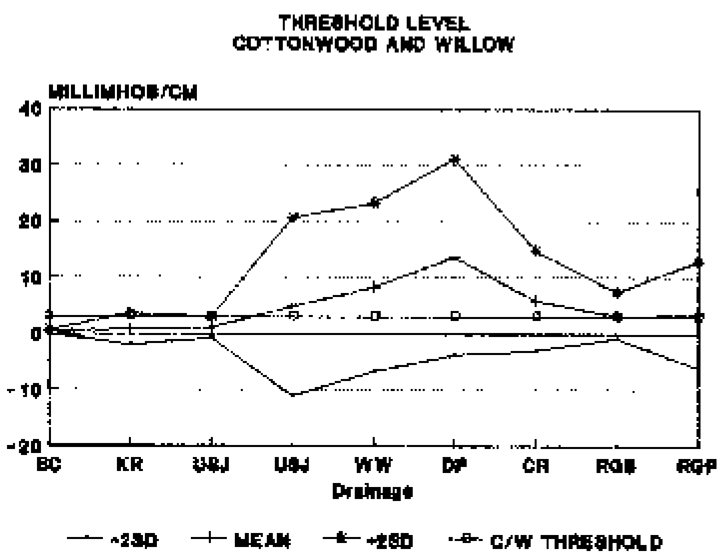

Fig. 4. Electroconductivity (EQ threshold for cottonwood and willow in soil >3 ft. below the surface and distribution of EC levels (2 Standard Deviations, Mean) for nine study areas in and southwestern riparian systems. Abbreviations for rivers: SC=Santa Clara; KR=Kern River; USJ and LSJ=Upper and lower San Jacinto; WW=White Water; RGS and RGP=Rio Grande at Socorro, NM and Presidio, TX

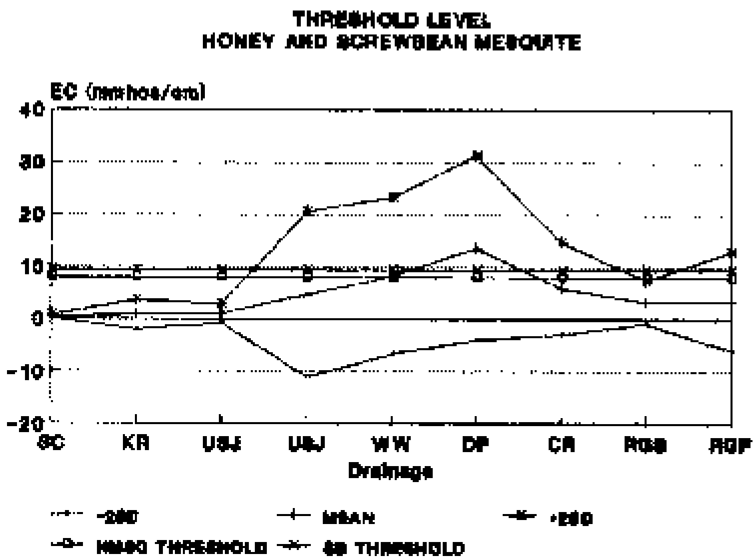

Fig. 5. Electroconductivity (EQ threshold for screwbean and honey mesquite in soil >3 ft. below the surface and distribution of EC levels (2 Standard Deviations, Mean) for nine study areas in and southwestern riparian systems. Abbreviations for rivers: SC=Santa Clara; KR=Kern River; USJ and LSJ=Upper and lower San Jacinto; WW=White Water; RGS and RGP=Rio Grande at Socorro, NM and Presidio, TX.

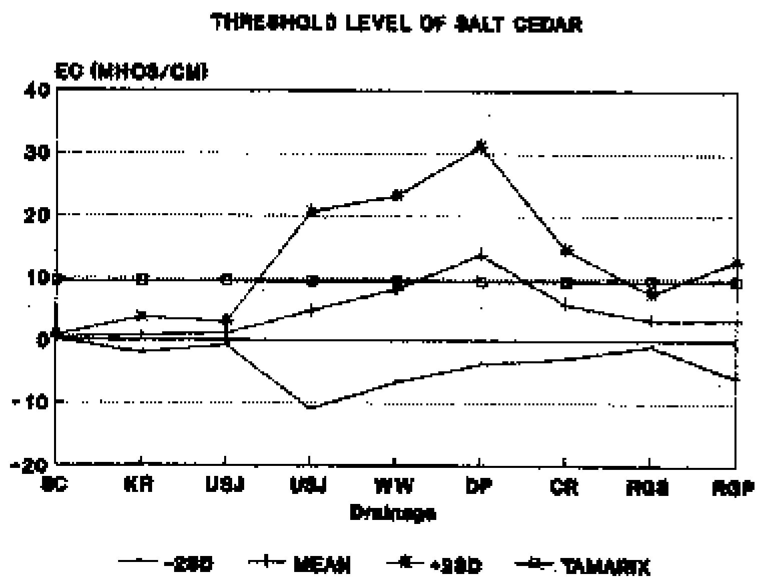

Fig. **6. Electroconductivity (EQ threshold for salt cedar in soil >3 ft. below the surface and distribution of EC levels (2 Standard Deviations, Mean) for nine study areas in and southwestern riparian systems.** Abbreviations for rivers: SC=Santa Clara; KR=Kern River; USJ and LSJ=Upper and lower San Jacinto; WW=White Water; RGS and RGP=Rio Grande at Socorro, NNI and Presidio, TX.

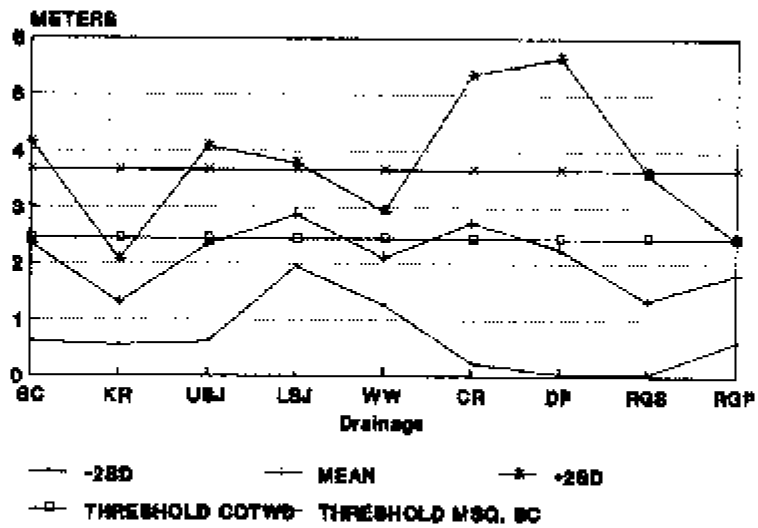

Fig. 7. Depth to the water table (DWT) threshold for cottonwood/willow (2 Standard Deviations, Mean) for nine study areas in and southwestern riparian systems. Abbreviations for rivers: SC=Santa Clara; KR=Kern River; USI and LSJ=Upper and lower San Jacinto; WW=White Water; RGS and RGP=Rio Grande at Socorro, NM and Presidio, TX

Long Term Trends in Soil Electroconductivity

With the exception of Salt Creek soil EC levels are not available for most study areas from 50 or more years ago so we can only surmise from indirect evidence that they have been increasing. Fifty years ago 35% of soil in the Salt Creek area was greater than 15 mmhos/cm; now the figure is 63% (Anderson and Miller 1992). In this area soil EC level has been increasing at a rate of 0.6% annually. The trend toward increasing soil salinity is probably reflected in the soil along most southwestern river systems (Busch and Smith 1995), although the absolute rate may not be as great as in the Salt Creek drainage. Nonetheless, although invasion by salt cedar receives nearly all the attention, the slow but inexorable increase in soil salinity is the real cause of the decline in native trees, not the invasion of salt cedar. In another 100 years the soil in these systems will be largely unsuitable for even salt cedar. If salt cedar continues to get al.1 of the attention while other problems continue to exacerbate the situation, in another 100 years native trees will be remembered primarily from photographs as members of and land riparian systems.

Other Important Variables

Soil type - Gloomy as it is, the situation just described is almost certainly overly optimistic. Other important variables that are more or less independent of soil EC and DWT have not been considered. One of these is soil type. I have not discussed soil type because we do not know the threshold levels for the native species. We do know that cottonwood/willow and screwbean mesquite do not, in general, thrive in clay soils. On the other hand salt cedar and honey mesquite seem to have at least some threshold of clay soils.

Soil moisture - Soil moisture is critical to survival of plants rooted in it. But with dams controlling the annual floods that were important to recharging soil water, moisture is often critically low in many floodplain soil where depth to water tables has increased as a result of channelization. We have begun collecting soil moisture data on the Santa Clara, White Water, and Colorado rivers. Preliminary analysis suggests that a high proportion (50-75%) of points otherwise suitable for native tree species are actually unsuitable because of very low soil moisture content. In such areas survival of natives, especially cottonwood/willow, is seriously threatened. The result is that stands of mesquite are sparse and individuals are stunted.

Fire - Fire kills cottonwood outright and mesquite recover only very slowly, if at all, after being burned. With the advent of hydroelectric dams, annual flooding has been all but eliminated on the Colorado and other rivers. Without annual flooding, debris collects in riparian woodlands (as does salt), setting the stage for fires. Salt cedar recovers quickly after fires kill the above ground portions. Thus the increase in the occurrence of fire has been a boon to the spread of salt cedar at the expense of native tree species (Busch 1992, Busch and Smith 1995). Fire also increases soil salinity levels (Busch and Smith 1993).

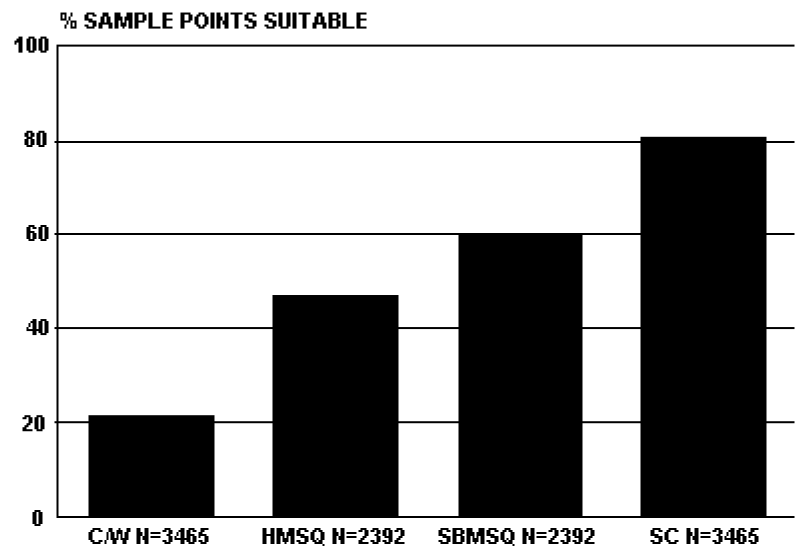

Fig. 8. Proportion of soil samples collected from nine study areas in and Southwestern riparian systems below the threshold in surface and deep soil and for depth to the water table for cottonwood/willow (CIW), honey (HMSQ) and screwbean (SBMSQ) mesquite and salt cedar (SC). N=total samples from each of the nine study areas.

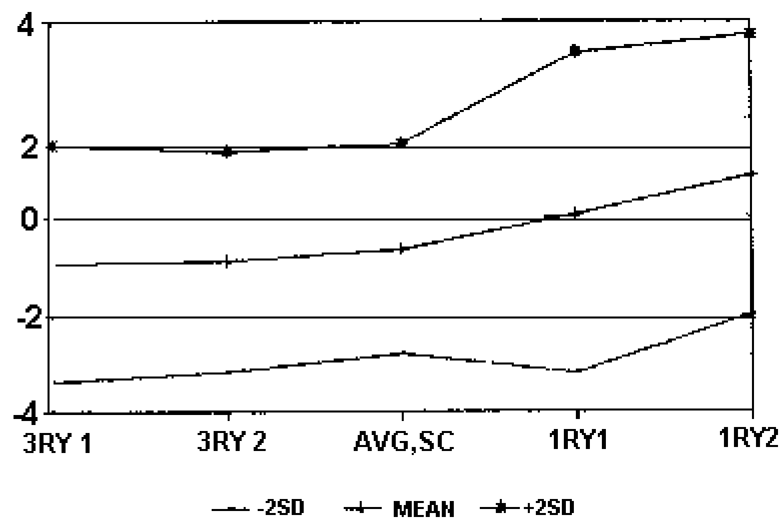

Fig. 9. Comparison of standard and intensive revegetation methods relative to use of revegetated areas by birds. Data are standardized using the mean and standard deviation of average values across all habitat types on the lower Colorado River. See text for details.

Revegetation and Use by Birds

Bird variables for two revegetation sites established with standard methods were below average for riparian vegetation during both years of study beginning when they were 3-4 seasons old (Fig. 9). 1 would expect the sites to show increased avian use in the second year relative to the first year. This did not happen, in fact the mean actually decreased in the second year for one of the sites where standard methods were used for revegetation (Fig 9). Worse, bird use values averaged below the values for salt cedar. Across the two years combined the mean value across seven avian variables was significantly ($t=2.01$, $P<.01$) lower than for salt cedar. At least one of these sites was dominated by salt cedar prior to the revegetation effort. Since this site had less value to birds after five years of development it would seem that the use of standard methods in revegetation led to a habitat with less value than salt cedar for birds.

In contrast, on sites where the use of the more intensive methods of revegetation were used showed significant (t=1.99, P<.05) increases in avian use from the first to the second year of the study. In both years avian use in the areas where intensive methods were used were significantly greater than where standard methods were used (t=6.65, P<001). In both years the intensive method led to greater than average avian use than in salt cedar (t=3.4, P<01, yr 1; t=7.0, P<001, yr 2). It seems clear that revegetation using the more intensive revegetation methods on these sites led to greater use of the areas by birds.

Although use of intensive revegetation methods has potential for creating a habitat with greater value to birds than that of salt cedar the dwindling level of available funds and the lack of motivation to fully implement intensive methods make it unlikely that this methodology will be widely used any time soon. Would-be eradicators of salt cedar should take pause at this. They must also consider the fact that revegetation methods compared were for work done on the Colorado River. Going eastward the value of salt cedar to birds increases (Hunter 1987, Hildebrandt 1982, Engel-Wilson 1978), thus putting even greater demands for success on revegetation efforts. Of course, it is true that some of those driven to rid the Southwest of salt cedar don't care about wildlife. Those of us who do care about wildlife must be alert to the agendas of these individuals.

Conclusions

Autecological conditions now favor salt cedar over native tree species in the flood plains of most river systems in the and southwestern United States. This is largely due to the activities of man including irrigation practices, overgrazing, and flow control from hydroelectric: dams and associated channelization. and rip-rapping projects. With an increase in hydrologic control of rivers there has been an associated drop in water table levels in land adjacent to rivers. All of these activities have tipped the balance in favor of the facultative riparian salt cedar over obligate riparian species such as cottonwood and willow. In the absence of annual flooding debris and salt that was formally flushed from the system now accumulates. The accumulation of debris increases the chances of fire, an event, at best only marginally tolerable by native tree species.

Busch and Smith and associates, in a series of papers (1992, 1993, 1995), have detailed the physiological basis behind the superiority of salt cedar over cottonwood and willow in riparian habitats. In this report I show that ecological conditions favoring salt cedar are widespread across the and southwestern United States. It should be no surprise that one cannot conduct large scale salt cedar removal projects and expect to replace lost habitat through revegetating with native tree species. Yet I regularly review plans that call for the elimination of salt cedar from large (>20 ha) areas. Although relatively poor as wildlife habitat salt cedar supports more wildlife than bare ground or arrowweed. Yet in many proposals no consideration whatsoever is given to the damage that the clearing will do to wildlife, and clearing does do damage (Anderson and Ohmart 1984). Sometimes, a finding of no significant impact to wildlife is reported and accepted uncritically by federal and/or state agencies.

Lamentably revegetation plans for the areas where salt cedar is to be destroyed routinely include planting schemes in the absence of data concerning soil studies or DWT. Worse, sometimes it is blithely assumed that if duty is done and the salt cedar is killed nature will reward such efforts with the development of a stand of native trees. Pure chance dictates that such naive efforts will occasionally succeed. This decreases the probability that reality will ever be faced because such statistically scarce events are then cited as justification for continuing the use of unrealistic procedures; evidence to the contrary being ignored.

I have reviewed many revegetation plans over the past decade. In almost all of them there is no or very inadequate soil testing and little or inadequate plans for monitoring during the season of planting among other problems. In some proposals that do include data, it is clear that the planners have little or no idea of how to interpret the data. It seems fair to conclude that these plans, on average, describe "planned failure". However, even failure fails to deter implementation with inappropriate techniques. The failures are simply ignored or declared successful without reference to reality and the status quo remains intact. Another ploy is to blame flooding, or drought, or vandalism, or grazing, or anything but the procedures employed, for failure. (On occasion we have been bailed out by one of these culprits; only deep within the bowels of our office complex do we examine our own culpability.)

One of the most common excuses for not using intensive revegetation methods is their cost. However, I find that most projects using the standard procedures cost anywhere from equally as much to many times more (e.g. Roessler 1993).

In the lower Colorado River riparian zone, salt cedar/ arrowweed habitats constitute roughly 60% of the total hectares of riparian vegetation (Ohmart, et al. 1987). If we include habitats where salt cedar is a co-dominant, the total rises to nearly 75% of the total riparian vegetation. Clearly if salt cedar could suddenly be eliminated there would be a very large decrease in wildlife habitat in the area. Nearly all riparian bird species would be seriously reduced in number or even eliminated. Data in this study show that revegetation with the standard revegetation techniques would result in very little new habitat to replace that lost by the elimination of salt cedar. Since much of the wildlife using the revegetated plot described above is due to the re-invasion of salt cedar, if re-invasion were to be aggressively prevented it would ensure that wildlife populations would be seriously reduced. Some species would be eliminated. Yet massive salt cedar eradication programs are being seriously considered at this writing (e.g. Ecoregion Team, 1995; Busch et al. 1992).

If permitted to go forward on a scale encompassing the riparian habitat in the entire and Southwest these plans could result in one of the most serious wildlife calamities of all time. Those endorsing and executing the plan would be immortalized.

Occasionally in science or any field procedures are so overwhelmingly accepted that they attain the status of dogma. Of course, dogma and the advance of science are antithetical, because science demands skepticism. Skepticism regarding dogma incites people to a state of moral outrage. In the "old days" skepticists met with a fiery end at the stake. Those interested in and land riparian ecosystems from a purely scientific point of view are facing two propositions that have attained dogma status: (1) Salt cedar must be eradicated; this eradication will automatically be to the benefit of the local flora, and (2) revegetation must be done with "standard" procedures and that they will negate any damage done to wildlife by the removal of salt cedar. Hopefully this paper in concert with those of others such as, Nelson and Mannon, and Busch and Smith, will help bring people back to the sensibilities associated with scientific procedures with wishful thinking and dogma washed away.

If we think of any given species as occupying a time/ space trajectory from some starting, point it is immediately obvious that there are an infinite number of such trajectories. If the trajectory represents the total range of environmental factors a species is or has been adapted to through time/space then it follows that no two species occupy exactly the same trajectory. Individuals most likely to compete are those that occupy similar trajectories. Only individuals of the same and closely related species have the same or similar trajectories and it is only these to which the term competition actually applies. It seems clear that salt cedar, a facultative riparian species adapted to saline, and land environments is on a trajectory substantially different from that of obligate, non-saline adapted riparian species such as cottonwood and willow. It follows then that they are on entirely different trajectories-trajectories so different that when one replaces the other in a given area it indicates a fundamental change in the environment that now favors one species over the other rather than competition. Above I have presented something substantially more than a trivial data set indicating that this is true over much of the riparian habitats in the and Southwest.

I am concerned because along any trajectory there are obvious as well as subtle environmental factors affecting the species occupying that trajectory. In this report what I have considered are factors that are almost blatantly obvious. In how many situations where these obvious factors are within the range of native species but where salt cedar is increasing in numbers are there subtle factors that swing the balance in favor of the exotic species? Research will provide an answer, but are we doing enough research? Unfortunately, we are not. How then, can we justify salt cedar eradication from a scientific point of view? We cannot. To claim the backing of science is, as one critic pointed out, pseudoscience. It would be more honest to simply admit that salt cedar is strange and new, and lacks aesthetic appeal and should therefore be killed.

Acknowledgements

Metropolitan Water District of Los Angeles, The Valencia Company, The Nature Conservancy, California Department of Fish and Game, Coachella Valley Water District., Riverside County Flood Control District, U. S. Fish and Wildlife Service, and the International Boundary and Water Commission all supplied funding for data presented in this paper. I thank all of them for their support. I thank John Taylor, Bosque National Wildlife Refuge, for supplying me with soil data collected under his direction. Field and laboratory work was advanced by J. Atkins, W. Hunter, E. Miller, S. Miller, R. Tollefson, J. Vasquez, V. Vasquez, and J. Washington. I am grateful to them for their dedication. I am grateful to several reviewers for their comments and suggestions.

Literature Cited

Anderson, B. W. 1988. Soil salinity conditions in the Kern River floodplain. California Dept. of Fish and Game. Sacramento, CA.

Anderson, B. W. 1989. Research as an integral part of revegetation projects. In: D. Abell, ed., California Riparian Systems. USDA Gen. Tech. Rpt. PSW- 110: 413-419.

Anderson, B. W. and S. Laymon. 1989. Creating habitat for the Yellow-billed Cuckoo (Coccyzus *aniericanus).* In: D. Abell, ed. a fornia riparian systems conference. USDA Gen. Tech. Rpt. PS 110:468-472.

Anderson, B. W. and E. R. Miller. 1993. Possible effects of canal seepage on soil salinity, vegetation and erosion. Pages 95-103 in Preserving our environment,. Proceeding of Conference XXIV, International Erosion Control Association. Steamboat Springs, CO.

Anderson, B. W. and E. R. Miller. 1990. Revegetation and the need to control exotic plant species. Pages 350-358 in: Natural areas and Yosemite: prospects for the future . Natural Areas Society. Oakland, CA.

Anderson, B. W. and R. D. Ohmart. 1982. Revegetation for wildlife enhancement along the lower Colorado River. U.S. Bur. Rec., lower Colorado Region. Boulder City, NV.

Anderson, B. W. and R. D. Ohmart. A vegetation management study for wildlife enhancement along the lower Colorado River. U.S. Bur. Recl. Boulder City, NV.

Anderson, B. W. and R. D. Ohmart. 1985. Riparian revegetation as a mitigating process in stream and river restoration. Pages 41-80 in: J. A. Gore, ed. The restoration of rivers and stream . Buterworth Publishers. Boston, MA.

Anderson, B. W. and R. D. Ohmart. 1990. Evaluation of the impact of vegetation removal on wildlife. U.S. Bur. Recl. Boulder City, NV.

Anderson, B. W. and R. D. Ohmart. 1986. Vegetation. Pages 639660 in: Cooperrider, A. Y., R. J. Boyd, and H. R. Stuart, eds. Inventory and monitoring of wildlife habitat, . U. S. Bur. Land Mgmt. U.S. Dept. Inter., BLM Service Center, Denver, CO.

Busch, D. E. 1992. Analyses of the structure and function of lower Colorado River riparian plant communities. Phl). dissertation. Dept. of Biol. Sci. Univ. Nev., Las Vegas.

Busch, D. E. N. L. Ingraham, and S. D. Smith. 1992. Water uptake in woody phreatophytes of the southwestern United States: a stable isotope study. Ecological Applications 2:450-459.

Busch, D. E. and S. D. Smith. 1993. Effects of fire on water and salinity relations of riparian woody taxa. Oecologia 94:186-194.

Busch, D. E. and S. D. Smith. 1995. Mechanisms associated with the decline of woody species in riparian ecosystems of southwestern United States. Ecological Monographs 65:347-370.

Busch, D. E. , L. Herbranson, E. Johns, F. Pinkney, and D. Sisneros. 1992. Vegetation management study. Bureau of Reclamation, Lower Colorado Region. Boulder City, NV.

Engel-Wilson, R. W. and R. D. Ohmart. 1978. Floral and attendant faunal changes on the lower Rio Grande between Fort Quitman and Presidio, TX. U.S. For. Serv. Gen. Tech. Rpt. WO- 12:139-147.

Hildebrandt, T. D. and R. D. Ohmart. 1982. Biological resource inventory (vegetation and wildlife)--Pecos River Basin, New Mexico and Texas. U. S. Bureau of Reclamation. Amarillo, TX

Hunter, W. C. 1987. Response to an exotic habitat by and riparian birds along an elevational gradient. NIS thesis. Ariz. State Univ. Tempe, AZ.

Jackson, J. J., J. T. Ball, and M. R. Rose. 1990. Assessment of the salinity threshold of eight sonoran desert riparian trees and shrubs. Desert Research Institute, University of Nevada System. Reno, NV.

Lower Colorado River Ecoregion Team. 1995. Draft Ecosystem Plan for the lower Colorado River ecoregion. U.S. Fish and Wildl. Service. Yuma, AZ.

Nelson, A. R. and R. W. Mannon. 1994. Revegetated sites as bird habitat along the lower Colorado River. School of Renewable Natural Resources, Univ. of Arizona. Tucson, AZ.

Ohmart, R. D., B. W. Anderson, and W. C. Hunter. 1988. The ecology of the lower Colorado River from Davis Dam to the Mexico-United States International Boundary: A community profile. U. S. Fish and Wildlife Service Rept 85 (7:19):1-296. Washington, DC.

Roessler, C. 1993. Urban woodland reborn through post-construction replanting. Aquafacts, Fall:4-9. Table 1. Extent of soil sampling in nine study areas (% of total) along seven southwest and zone rivers.