REVEGETATION & WILDLIFE MANAGEMENT CENTER

River Glen Mitigation Project
Second Annual Report

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Research Reports & Management Recommendations
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INTRODUCTION

A construction project initiated by Needles River Glen, LLC in the Needles, California area resulted in the need for the mitigation involving 8.5 acres. The mitigation project was to include habitat suitable for riparian wildlife in general and specifically for Gila woodpecker (*Melanerpes uropygialis)* and the Bell's vireo (*Vireo belli*). The mitigation project is located immediately adjacent to the Colorado River east of Blythe, California (Fig. 1).

Figure 1. The River Glen mitigation project is located at the Goose Flats Wildlife area near Blythe California.

METHODS

Vegetation Analysis

The vertical configuration of the vegetation was determined in August 2004 according to the Anderson and Ohmart (1985) technique. This methodology allowed for calculation of foliage at various levels in the vegetation. The proportion of the foliage occurring within various levels, representing the herbaceous level (0.0–2 ft) including herbs (as well as vegetation other than herbs that had foliage low to the ground), the shrub layer (2–15 ft), and the tree layer (>15 ft). The vertical configuration of the vegetation was classified on the basis of the distribution of foliage in these 3 layers. In addition 6 vegetation types based on the numerically dominant vegetation were recognized.

Numerical dominance was determined on the basis of tree and shrub counts. Counts were made of all trees and shrubs that occurred within a transect 100 feet wide for the length (3000 or 5500 ft) of the stand of transected vegetation, thus including all trees and shrubs in 6.9 or 5 ha. The stands usually encompassed roughly 50 or 40 ha. On the basis of the vertical distribution of the foliage stands were designated as types I–VI. If the bulk of the foliage was in the top 2 layers the stand was called type I or type II; if in the layer 2–15 ft, type III, if greatest in the lowest 2 levels, type IV; and if the foliage was concentrated in the lowest level, type V or VI with VI having the most foliage in low levels.

On the basis of tree counts we recognized 6 vegetation types along the lower Colorado River: (1) cottonwood/willow (*Populus* sp., *Salix* sp.), (2) screwbean (*Prosopis pubescens*)/salt cedar (*Tamarix ramosissima*) mix, (3) honey mesquite (*Prosopis glandulosa*)/saltcedar mix, (4) honey mesquite (5) saltcedar, and (6) arrowweed (*Pluchea sericea*). All of these included shrubs, the most ubiquitous of which was arrowweed. Stands of nearly pure arrowweed were the only shrub community recognized because it was the only type that occurred in plots encompassing at least 10 ha. Other shrubs were found in small patches of varying size within the other dominant vegetation types. The most common shrubs were quailbush, four-winged saltbush, and wolfberry. Mulefat (*Baccharis salicifolia*) was found only in small disjunct patches or as scattered individuals embedded within stands dominated by other species.

Considering the vertical distribution of the foliage theoretically all the dominant vegetation types could have 6 structural types, bringing to 36 the number of possible plant community types (Anderson and Ohmart 1986).

Wildlife Data

Bird censusing—We used a somewhat modified (Anderson and Ohmart 1981, 1984) version of the line transect method developed for censusing birds by John T. Emlen (1971). Censusing is being done times each month beginning in May 2007 and will continue until project's end. Between 1975 and 1984 we collected wildlife data from all major habitats on the lower Colorado River, at a time when habitats were in somewhat better condition than now. We refer to this as he "data base". We will use this data base as a reference point as data for the revegetation site accumulate. The data base includes information on all terrestrial vertebrates as well as insects.

The River Glen revegetation (mitigation) project has as a goal the creation of habitat that might be suitable for gila woodpecker and Bell's vireo. It is ideally located in that both species occurred regularly less than 200 m to the north of the River Glen site. The former species has been an inhabitant of the Goose Flats areas for the last several years. Of critical importance, then, is methodology associated with developing the habitat. We have developed and employ the Nine Step Plan for revegetation projects.

THE NINE STEP PLAN (TNSP)

The Nine Step Revegetation Method is a synthesis of a quarter century of full-time research on riparian vegetation, its associated wildlife and the autecological factors associated with vigorous growth of native riparian plant species. This plan represents a new paradigm for revegetation. Rather brief summaries of this information have been published in two general works (Rosenberg, Ohmart, Hunter and Anderson 1991; Ohmart, Anderson and Hunter 1988). An extended analysis and findings are presented in Anderson, Russell, and Ohmart (2004). Details concerning wildlife-vegetation relationships have been presented in Anderson and Ohmart (1984) and in somewhat abbreviated form by Anderson and Ohmart (1985), Anderson and Ohmart (1987) and Anderson, Russell, and Ohmart (2004). The suitability of our designs for attracting wildlife has been thoroughly documented in Anderson and Ohmart (1984, 1985), Anderson, Hunter and Ohmart (1989), and Anderson, Russell, and Ohmart (2004). The basic steps of The Nine Step Revegetation Method occur in two papers (Anderson 1989 and Anderson and Laymon 1989). Some follow-up details and important ancillary information occur in Anderson and Miller (1991, 1992). Some of our findings regarding salinity tolerance of riparian plant species have been independently confirmed by Jackson, Ball, and Rose (1990), and Busch (1992). The objective was to develop a method that would, in the shortest time possible, lead to a habitat with maximal wildlife value. This, of course, requires maximum survival and growth of the plant species involved.

1. Preliminary Analysis

Vegetation

In the preliminary phase any existing vegetation is studied to determine its value to wildlife. Any existing habitat will have some value to wildlife. A revegetation project should, of course, provide a wildlife habitat that is superior to the one eliminated. In practice, however, precise requirements relative to wildlife that the revegetation or mitigation project should live up to are almost never delineated. This project is an exception in that it is required that the new habitat should at least be of a type that would or could support Bell's vireo and gila woodpeckers.

The habitat at Goose Flats is marginal for these two species, but both occurred in the area each year between 2004 through 2007. Bell's vireo was detected on formal bird censuses in 2007. Gila woodpeckers have been observed by us on an informal basis each year since 2004 and on formal bird censuses in 2007.

The planned site, encompassing only about 3.2 ha is, by itself, not large enough to ensure that these species would be attracted to it. But given that both species already occur in the immediate vicinity means that the existing, marginal, habitat could be enhanced with the River Glen project.

The existing habitat is evaluated with respect to the overall vertical distribution of the foliage. This information provides us with information about the structural type of the vegetation present before clearing. The second thing is to determine the dominant vegetation. The habitat can then be named on the basis of the dominant plant species and its structural type, for example saltcedar type IV is common in the lower Colorado River valley.

Autecological characteristics

The preliminary phase involves collection of soil at about 15 systematically distributed sample points per 4 ha over a site. At each sample point two soil samples are taken, one near the surface, the other just above the water table or 2-2.5 m below the surface whichever is shallowest. For each of these samples the soil type, and electrical conductivity of saturated soil pastes are taken, and a surface-to-water-table depth is determined. If possible a water sample is taken and the electrical conductivity is determined for it. Preliminary analysis provides a preview of variation for each variable tested thus permitting an assessment of how much success, given the desired outcome, can be realistically expected from planting on the site. In view of site conditions goals may have to be revised. Depth to the water table is often critical to survival and is determined at each sample point. This is a fact finding step where climate, geologic features other than soil, development of roads, and any other ancillary item or action that would be relevant to the outcome of the project are taken into consideration. It also may include a vegetation analysis that provides at least a partial list of plants occurring in the area as well as revealing the soil conditions in which they are found. This analysis is not extensive enough to permit accurate mapping of the distribution of a variable across a site. Final determination of what should be planted and where it should be planted should not be made until this step is complete. Realistic assessments can not be made until this crucial information is available. This is the step that puts wishful thinking in line with reality. We used the sampling done in 1988 as the preliminary sampling effort for this project and it showed that there was at least 1 major *problem* that should affect expectations for this project, that being the great depth to the water table. Another potential *problem*, low soil moisture is important, but no estimates of soil moisture were made in the earlier work.

2. Propagules

We grow many of our own propagules. Cuttings and seeds from local genetic stock are collected, cuttings are treated with rooting hormone and started in one-gallon pots. Potting material includes a mixture of equal portions of sandy soil from habitats in the area to encourage Micorrhizal fungi, vermiculite, and peat moss. Micorrhizal fungi help in the uptake of nutrients from the soil assuming that nutrients are present above certain minimal levels. Propagules are watered daily at our facility and require 8-12 weeks to develop to a stage adequate for planting, except in the case of mesquite, which require 6-8 months to reach a reasonable planting height. It is crucial that projects get started in time for saplings to be started in the greenhouse with sufficient lead time that planting can take place near the beginning of the growing season.

3. Site Clearing, Leveling

Site preparation ordinarily involves clearing and leveling the area with a D-7 or D-6 Caterpillar dozer (or equivalent) over as much of the area as deemed necessary. This clearing was done (March 2006) in a selective manner, thus extant vegetation deemed valuable to wildlife was saved. This included primarily screwbean.. We emphasize that trees left intact on a site are potentially potent competitors with planted saplings. The total trees left intact does not include any trees on the periphery of the site.

Figure. 2. River Glen revegetation site shortly after clearing in April 2007. Section A on top; Section B, -bottom.

4. Intensive Soil Sampling

Intensive sampling involves taking soil samples at 10-30% of all holes on 6 m centers (roughly 250 per ha, thus 25 to 75 samples per ha). Obtaining an adequate sample size that will represent all species to be monitored is the essential feature of the sampling effort. Sampling, done with sufficient frequency, allows reasonably accurate mapping of the distribution of salts, nutrients, soil texture, depth to the water table, and soil moisture across the site. With this information a planting design is developed that leads to planting only at points where growth can be expected to be at or near maximum for each species. There is often a desire to see a detailed planting design and set growth requirements reveal prior to the time that the project is initiated.. A moment's reflection indicates that this cannot be accurately, therefore meaningfully, done until intensive soil sampling has been completed and contemplated. Because the site must be nearly ready for planting before intensive soil sampling occurs, it is too costly (and often inappropriate) to be practical to be done prior to initiation of the project—hence the need for a preliminary analysis. Without intensive soil sampling data however, a planting design and goal heights are farcical, being based largely on guessing and wishful thinking. Guess work and wishful thinking have no legitimate place in a scientific approach to revegetation; such procedures leave the outcome—the value to wildlife—to chance.

Soil samples were collected according to a systematic sampling design Fig. 3. We sampled in sets of 5 points, these sets systematically distributed across the site in a way that gives a reasonably good idea of the distribution of each variable considered across the site. At each of the 5 points where sampling was done a tree was planted. These trees constitute the sample that is monitored--they will be the trees that reflect the progress on the whole site throughout the monitoring period. Since soil moisture varies little over considerable space we assumed that in each series of 5 sample points a soil moisture sample from the mid-point would be sufficient to represent the entire set.

Collectively we sampled at 175 points or 21% of all planting points on 6 m centers. We consider a sampling effort including 7% of all points on 6 m centers to be minimally adequate. Sampling at greater than 10% of all points leads to only tiny increases in additional accuracy, but may be necessary in order to ensure an adequate sample size (minimum 35) of all plant species to me measured (3 for this project).

5. Tillage

Tillage for trees was accomplished by augering holes a minimum of 38 cm in diameter to a depth of 2 m or so or to the water table. This, sometimes called vertical tillage, allows for rapid root penetration to the water table. The need for, and effectiveness of, this step has been documented by Anderson (1988), Anderson and Ohmart (1982, 1985). In some instances and for some species tillage may not be necessary, or, in some cases, it may not be possible. This conclusion must not, however, be drawn without serious consideration of all available facts and weighing these against the conclusion that failing to provide tillage could cost the project 40% or more of its potential growth.

6. Irrigation System Design and Installation

The irrigation system for trees consists of what is commercially referred to as ½ inch black polyethylene drip tubing emanating from black polyethylene main line two inches in diameter. Each lateral drip tube line is supplied with a screen filter and ball shut-off valve. At about every 5-6 m, 7.6 l pressure compensating emitters are installed in the line. Water is ordinarily drawn from existing wells or from the stream channel. Water can also be delivered to drip systems from water trucks. Details of the irrigation system design cannot be made until intensive sampling design is complete. The economy of water associated with drip irrigation is common knowledge. It also keeps weed problems to a minimum and encourages rapid root penetration to the water table.

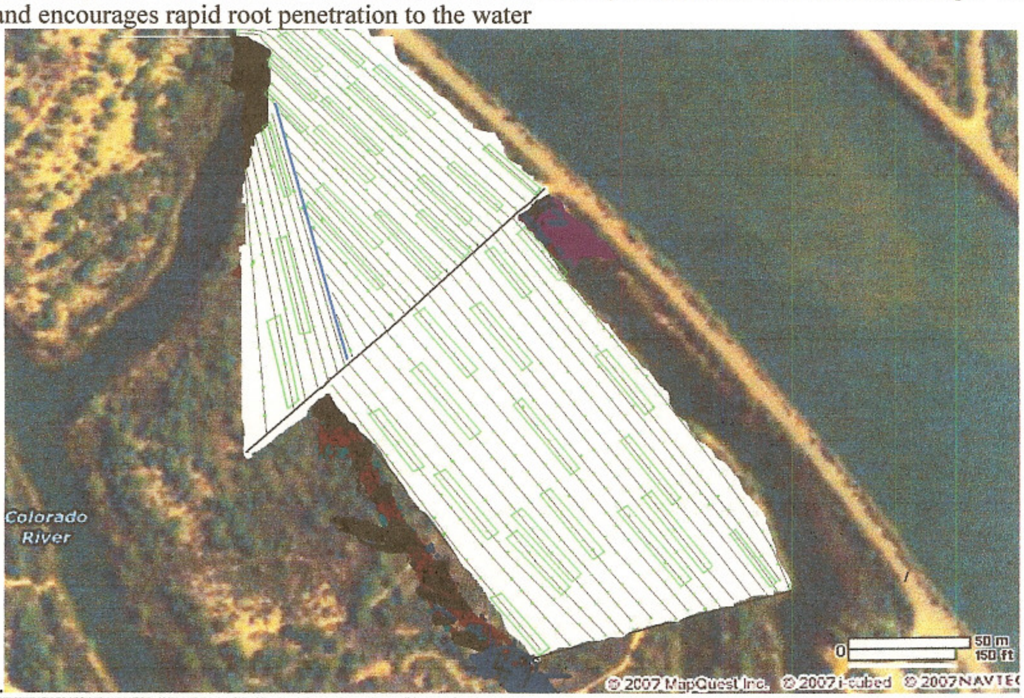


Figure 3. River Glen mitigation project irrigation system design and soil sampling design. The lines with green dots represent lateral irrigation line and tree planting points. In each of the rectangular areas soil samples are collected at 5 points. A each soil sample point one sample was taken from near the surface, the other at about 1.5 m below the surface or just above the water table, whichever was shallowest. The dark line across the site represents the main irrigation delivery line. The blue line in the upper portion of the plot is a berm consisting of cleared vegetation and debris.

7. Planting

Trees appropriately distributed on a site are ordinarily planted in densities of roughly 250-338 per ha. This may vary somewhat depending on species and locations. Planting occurred at roughly 300 trees per day between April and July. Planting was delayed as a result of failing to get contracting details completed in time to get the trees started in August 2003. Only cottonwood were ready to be planted in May. The screwbean mesquite were planted as they became sufficiently developed in July 2004. At planting cottonwood propagules were about 38-50 cm tall. Wire fencing was used to protect cottonwood and *Tubex*, a commercially manufactured protective tubing, was used for mesquite that appeared especially vulnerable (those near relatively large patches of vegetation) to rabbits or rodents.. This protective tubing has the added benefits of slowing competitor growth, deterring browsing, and increasing water use efficiency. Chemicals were added to reduce pH and phosphates and nitrates were added to increase growth.

Figure 4. Planting on the River Glen mitigation project.

8. Irrigation/weeding

Irrigation was done at a basic rate of 30 liters of water per day delivered through 8 liter per hour pressure compensating emitters for five days each week for 18-24 weeks the initial season. In general, cottonwood and willow trees were not planted where the water table or perched water table or permanently wet soil was further than 2.5 m below the surface. Irrigation during the second season will be done five days per week from April through September. Weeding to prevent or reduce the negative impacts of competition from weeds, was done on an as needed basis during irrigation period.

Weeding is a nasty but necessary job accomplished in 2 ways. If salt cedar or relatively large patches of arrowweed are coming back we used a backhoe to take them out. Otherwise weeding is done by hand with shovels and hoes.

9. Monitoring and Reports

Monitoring—Monitoring began shortly after planting was complete and continued for 14 weeks during the year of planting. It will be done in spring and fall in subsequent years. Plants selected for monitoring are those planted in the systematically selected sample holes used for the intensive sampling. We monitored 99 screwbean, 36 cottonwood, and 40 honey mesquite. Monitoring is done by measuring each tree from its base to the top of the tallest up-stretched leaf throughout the first season. Ground cover (crown diameter) and space occupied by vegetation (foliage volume) can be calculated from this measurement (Anderson and Ohmart 1982, 1984). These measurements are entered on the computer the day they are taken. We analyze growth in context of the variation in autecological factors on the site determined from the intensive sampling step of TNSP. If growth of, say, cottonwood or willow is less than expected (0.7-0.9 cm/day, depending on area, soil factors and species) we take immediate steps to improve the growth rate; if growth rates are at or exceed expected rates, we strive to achieve even better growth. (For a more in-depth discussion of monitoring see Anderson 1989). Monitoring in the second growing season was done May through October by measuring the height of the same trees as during the initial year and placing them in height classes. Small increments in mortality can perhaps be expected to be compensated for by natural germination on many revegetation sites, but natural germination is unlikely on this sandy site.

Reports—We provide substantive reports with quantified data (ecological conditions, monitoring, growth rates) at the end of each growing season. Items such as irrigation and planting designs and results of weekly monitoring will be made available on an "as requested" basis. Reports are based largely on information garnered as a result of the first eight steps. Information of the initial year provides the general outline for reports. In subsequent years only new information is added. This leads to production of 4 annual reports in which errors in substantive matters can be identified by us or other readers and they can be corrected prior to production of the final report after the fifth year (growing season).

RESULTS

Vegetation Analysis

Vertical configuration

The vertical configuration of the vegetation on the site selected for revegetation is closest to Type IV where 85% of the foliage occurs at less than 5 meters above the ground with about 45% occurring at less than 1 m above the ground (Fig. 5). This type of vertical distribution is perhaps the most common one along the lower Colorado River. We now consider the plant species present.

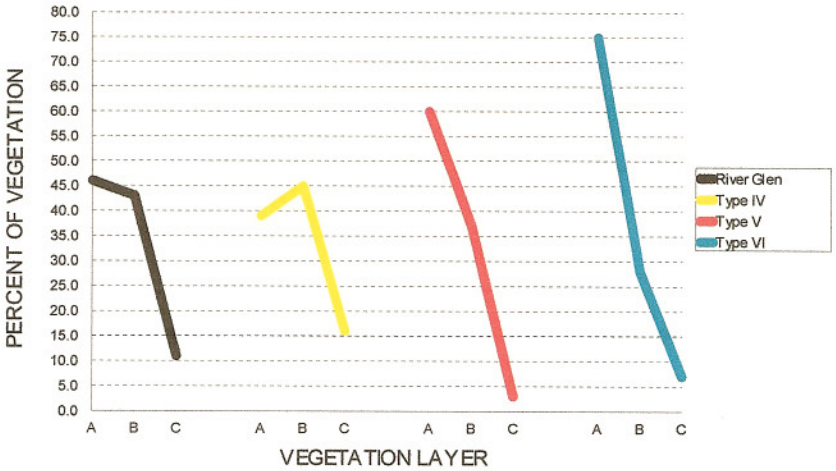


Figure 5. Vertical configuration of vegetation on the River Glen mitigation project before clearing.. The observed distribution most closely matches that of Type IV. A=percent of vegetation 0-1 m tall; B, 1-4 m; C, >4 m above the ground.

Dominant Vegetation

Among plant species where individual plants could be counted, including saltcedar, screwbean mesquite, sandbar willow, seep willow (mulefat), creosote bush, and cottonwood, saltcedar was by far the numerically dominant species accounting for 378 individuals or nearly 74% of the total individuals counted(Table 1). This leads, inexorably, to the conclusion that saltcedar is a dominant species on this site and that there is a significant influence exerted by screwbean mesquite. However, arrowweed had a conspicuous presence but they are notoriously difficult to count since individual plants are interconnected making it difficult or impossible to determine where one individual ended and another began. We evaluate their presence by evaluating how much of the area is covered by foliage of the various species.

It turns out that arrowweed accounts for about 45% of the ground cover. Data in Table 2 also highlight the fact that much of the area was bare ground, which accounted for 29% of the area. Thus bare ground and arrowweed account for nearly three-quarters of the surface area of the site. This perspective greatly modifies the initial impression of dominance by saltcedar and screwbean.

	Number	
Species	per ha	on site
Saltcedar *Tamarix ramossissima*	110.0	378
Screwbean mesquite *Prosopis pubescens*	23.8	81
Sandbar willow *Salix exigua*	3.0	41
Seep willow *Baccharis salicifolia*	2.3	8
Creosote bush *Larrea tridentata*	1.3	4
Fremont cottonwood *Populus fremontii*	1.3	3

Table 1. Tree and shrub count on the River Glen mitigation project at Goose Flats.

Species	Pct
Arrowweed *Pluchea serricea*	44.5
Bare ground	28.9
Saltcedar *Tamarix ramossissima*	13.3
Screwbean mesquite *Prosopis pubescens*	11.1
Seep willow *Baccharis salicifolia*	2.2

Table 2, Ground cover by species prior to clearing.

AUTECOLOGICAL VARIABLES

Depth to the water table—The mean depth to the water table was about 1.6 m (Fig. 6) but the median was only 1.2 m. This is because there are relatively few points at which the DWT is much greater than for most of the site and these few points pull the average up: the median represents the midpoint for the site. In general about 2.1 is the maximum depth for cottonwood/willow, 2.5 m for screwbean mesquite and 3.7 for honey mesquite, all else being suitable. It appears then that about 81% of the site is at least marginally suitable for cottonwood and all but a small portion of it suitable for both mesquite species, using the mean DWT and its associated standard deviation. Although DWT is very important relative to what species to plant other factors are also important and must be carefully considered.

Texture—Soil texture on the surface and deep in the soil profile is primarily sand. The vast majority at both levels were judged to have a texture score of -3, which equates to medium sand. More than 90% of all soil samples are -3 sand (Fig. 6.). Sand is a suitable medium for planting cottonwood or mesquite, but again other factors such as soil moisture must be taken into consideration.

Soil Moisture—Soil moisture present in sand is largely available for use by plants in contrast to denser soils where water is bound so tightly to the soil particles that it is not available to plants. On the other hand denser soils are capable of holding much more water and looses it less rapidly. Dense soil, however, has less oxygen than sand when the soil is saturated with water. Cottonwood requires relatively high soil oxygen levels. We evaluated soil moisture at 34 points deep in the soil profile. At that level mean water content was 19.4% or roughly 66% of that at soil saturation (Table 3). Only at points where DWT is much greater than over most of the site are the soil moisture levels low, being less than 1% at the lowest point. At least mesquite can extract soil moisture in sand to a level of about 2%; cottonwood to about 5%.

Electrical conductivity—Electrical conductivity (EC) should be less than 3 decisiemens per cm^2 (dsc) for cottonwood but up to about 8 dsc for mesquite. Less than 3% of the site has intolerably high salinity levels for mesquite and only about 10% for cottonwood (Fig. 7)..

Statistics

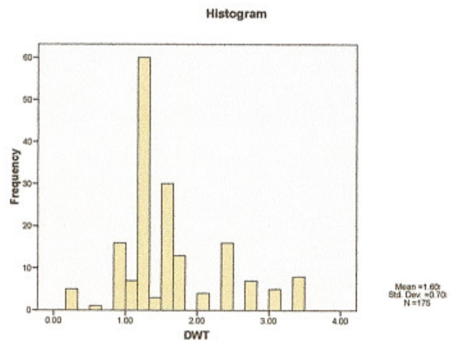
DWT

N	Valid	175
	Missing	0
Mean		1.5993
Std. Error of Mean		.05291
Median		1.2195
Std. Deviation		.69988
Minimum		.30
Maximum		3.35

Statistics

S1

N	Valid	175
	Missing	0
Mean		-3.0571
Std. Error of Mean		.02251
Median		-3.0000
Std. Deviation		.29778
Minimum		-4.00
Maximum		-2.00



2007

Statistics

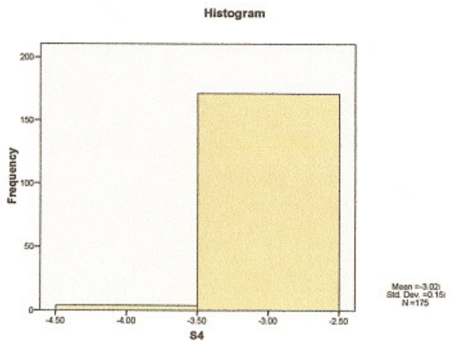
S4

N	Valid	175
	Missing	0
Mean		-3.0229
Std. Error of Mean		.01133
Median		-3.0000
Std. Deviation		.14988
Minimum		-4.00
Maximum		-3.00

Statistics

PCTW

N	Valid	34
	Missing	141
Mean		19.3170
Std. Error of Mean		1.44736
Median		22.1351
Std. Deviation		8.43949
Minimum		.88
Maximum		31.03



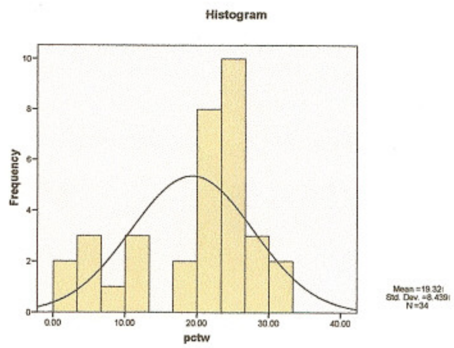


Figure 6. Depth to the water table (meters), surface and subsurface soil texture (increasing clay and decreasing sand with increasing positive values), and soil moisture (percent of dry soil weight).

Statistics

		ec1	ec4
N	Valid	85	85
	Missing	90	90
Mean		1.7342	1.9008
Std. Error of Mean		.19944	.22606
Median		1.3500	1.4000
Std. Deviation		1.83870	2.08418
Minimum		.42	.25
Maximum		13.18	13.18

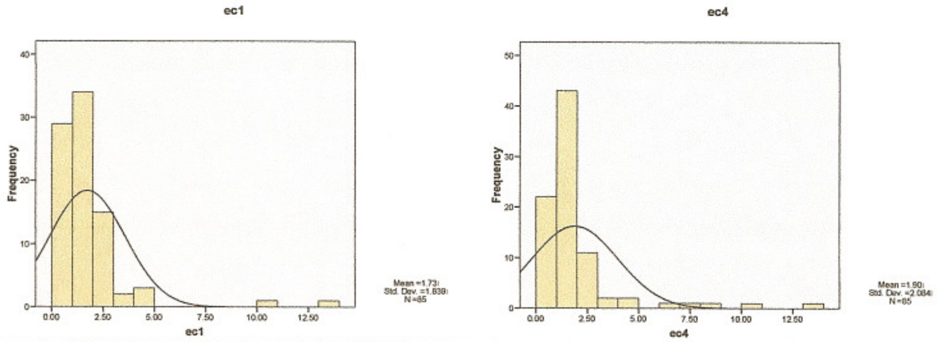


Figure 7. Electrical conductivity, expressed as decisiemens per cm2 on the River Glen mitigation project.

Specific ions, pH and soil moisture saturation percentage—Although the site seems relatively good with respect to DWT, soil moisture, salinity levels and soil texture, the vegetation present on the site prior to clearing was not lush. This suggested that something was wrong that is not revealed by the usual procedures used for evaluating site suitability. Indeed the analysis for specific ions of a portion of the collected samples revealed some major potential problems.

None of the specific ions were particularly high except calcium (Table 3). This is instructive because, although many calcium compounds are insoluble, carbonates of calcium can contribute to soil pH, therefore the high calcium levels leads immediately to examination of pH levels. Indeed pH levels were high with both the mean and median being about 8.5. Although pH tolerance levels are not known for most species of native riparian plants it is generally understood that levels above 8.0 are beginning to reach tolerance levels for many plant species. All of the samples tested were greater than 8.0. The high pH could contribute to plants in the area prior to clearing appearing significantly less lush than might be expected given the general suitability of the site. Nutrients for growth, such as nitrates and phosphates also contribute to plant stature.

Essential plant growth factors such as nitrates and phosphates were exceedingly low on this site, barely registering presence (e.g readings of 0.1, Table 3). Nitrates are used in above ground plant growth and phosphates for root growth. In addition to the low presence of phosphates it is important to note that phosphate uptake is inhibited when pH is on the alkaline side, that is greater than 7.0. This project suffers from high pH, and low nitrate and phosphate levels. Fortunately these problems can be eliminated with addition of sulfur to reduce the pH and fertilizer with nitrogen to increase the soil content of this essential nutrient. Phosphate uptake can be promoted by adding the phosphates in an acid medium in order to counteract the effects of high pH.

Case Summaries

		ca	k	esp	na	mg	ph	satpct	no3	po4
1		942.6	6.5	8.2	103.1	35.8	8.58	30.9	.1	.1
2		849.6	3.2	6.7	71.8	13.5	8.42	25.0	.1	.1
3		949.8	4.7	6.6	86.5	71.0	8.72	26.8	2.9	.4
4		1317.4	4.1	7.2	130.1	82.7	8.42	28.1	.1	.1
5		1323.5	5.9	5.4	102.4	135.4	8.39	26.9	.1	.1
6		971.5	12.1	2.5	31.0	45.1	8.39	29.8	.1	.1
7		1144.0	4.8	5.4	81.6	63.0	8.90	32.1	.1	.1
8		1232.6	5.8	8.9	142.8	25.3	8.60	34.0	.1	.1
9		1256.3	5.2	5.6	98.4	107.0	8.41	28.8	.1	.1
10		1078.6	4.6	6.1	90.2	69.8	8.40	26.2	.1	.1
11		1626.5	23.7	12.3	302.4	139.5	8.45	33.0	.1	.1
12		1302.2	4.8	8.4	153.8	94.6	8.57	27.7	.1	.1
13		1063.5	3.8	5.2	72.0	43.4	8.55	28.6	.1	.1
14		1209.9	6.9	5.2	82.5	50.0	8.46	30.3	.1	.1
15		1465.1	9.3	9.9	199.5	70.1	8.32	30.5	.1	.1
Total	N	15	15	15	15	15	15	15	15	15
	Mean	1182.207	7.035	6.907	116.540	69.747	8.5053	29.247	.287	.120
	Median	1209.900	5.200	6.600	98.400	69.800	8.4500	28.800	.100	.100
	Minimum	849.6	3.2	2.5	31.0	13.5	8.32	25.0	.1	.1
	Maximum	1626.5	23.7	12.3	302.4	139.5	8.90	34.0	2.9	.4
	Std. Deviation	212.4004	5.1390	2.3648	65.2884	37.2055	.15198	2.5867	.7230	.0775
	Std. Error of Mean	54.8415	1.3269	.6106	16.8574	9.6064	.03924	.6679	.1867	.0200

Table 3. Specific ions, pH, and soil moisture saturation percentage on the River Glen mitigation site. Esp=exchangeable sodium percentage, satpct=water expressed as percent of dry soil weight, ca=calcium; k, potassium; na, sodium; mg, magnesium; no3, nitrate; po4, phosphate.

Planting

We planted honey and screwbean mesquite and cottonwood saplings. In general honey mesquite were planted where DWT was greatest, followed by screwbean and finally, cottonwood were planted where DWT was least and soil moisture was greatest. Precise numbers of each species were dictated by availability. The available plants included 195 honey mesquite, 160 cottonwood and 580 screwbean. All of the mesquite were planted in April, but cottonwood were not ready for planting until late May. In addition in two small areas much of the surface was wet when releases from dams into the Colorado River were greatest. These areas can be viewed in Fig. 2 in the upper right and lower left, respectively. Combined these 2 areas occupy about 0.6 acre. These areas were seeded with cottonwood, honey mesquite, screwbean mesquite, a few palo verde, and fan palm. At season's end these areas included 26 cottonwood, 32 sandbar willow which spread to the area naturally, 22 honey mesquite, 16 fan palm seeds, and many screwbean, numbers of which are irrelevant because they will eventually become diseased and die. Disease in screwbean mesquite is discussed further below. These germinated trees collectively add 87 trees to the site, bringing the total trees to 1022 trees. Regretfully, nearly 57% of them are screwbean, and these trees are doomed. Those involved with this study must quickly decide what, if anything, should be done at this point to correct this situation.

Monitoring

From May through October 2007 saplings were monitored 13 times as were those developing from seed but those from seed were measured only at the end of the growing season. Measurements of trees from seeds and saplings were kept separate. Those from seed germinated gradually mostly throughout May and June 2007, thus averaged much smaller than those planted as saplings throughout the initial season. There was some additional germination in 2008. Our tallies do not include tiny saplings. These will probably suffer from acute competition from older plants or be eaten by rodents or rabbits.

In 2007 trees were irrigated for about 450 hours from May through September. This amounts to about 4 hr (8 gallons) per day, 5 days per week. In 2008 trees were irrigated about 315 hours from mid-May through mid-September or about 4 hours per day 5 days per week. Irrigation could not be done past 17 September because of low water in the back water where irrigation water was drawn.

All goals for survival and growth are derived from Anderson et al (2004). Goal heights for screwbean and cottonwood represent the mean heights after 3 and 5 growing seasons for projects successfully executed with no significant problems. For honey mesquite goal heights are based on the high probability that growth of this species will be affected negatively by sap sucking insects known as psyllids. Psyllids usually attack honey mesquite in May and again in August. If attacks are severe they can cause extensive death. This is the most likely result in younger saplings. To help avoid death we planted saplings grown in the greenhouse for at least 2 full seasons. Although older saplings are still attacked the death rate is less. Goals for tree survival and heights are based on large samples over many projects and years and are discussed along with potential problems extensively by Anderson et al (2004). Those wishing further information on these subjects should consult the cited reference.

Screwbean mesquite—At planting screwbean averaged about 1.45 m tall with 95% of all saplings falling between 0.97 and 1.93 m. Throughout the initial season their growth was steady, if unspectacular (Fig. 8). At season's end screwbean mesquite averaged about 2.2 m tall with 95% of all individuals falling between 1.5 and 2.8 m (Fig. 8). The 3-year goal for 80% of screwbean planted to attain a height of 2.7 m had already been attained by about 6% of screwbean. At the end of the first season screwbean seemed on track to attain the 3 year goal height, but as will become apparent in the next section, this is illusory.

By season's end in 2008 screwbean had attained a mean height of 2.7 m (Fig. 8). Roughly 95% of the screwbean trees fell between 0.9 and 3.5 m tall. The 3 year goal for 80% of them to attain a height of 2.7 m had been attained by about half of them. In fact about 7% of the planted trees had attained the 5 year goal height (Fig. 8). This seems like marvelous progress and ordinarily it would be considered as such, but with 89% displaying symptoms of disease, any reason for joy is thereby crushed. It takes several years for afflicted trees to become absolutely lifeless, but their general stature is alarming well before they are totally dead.

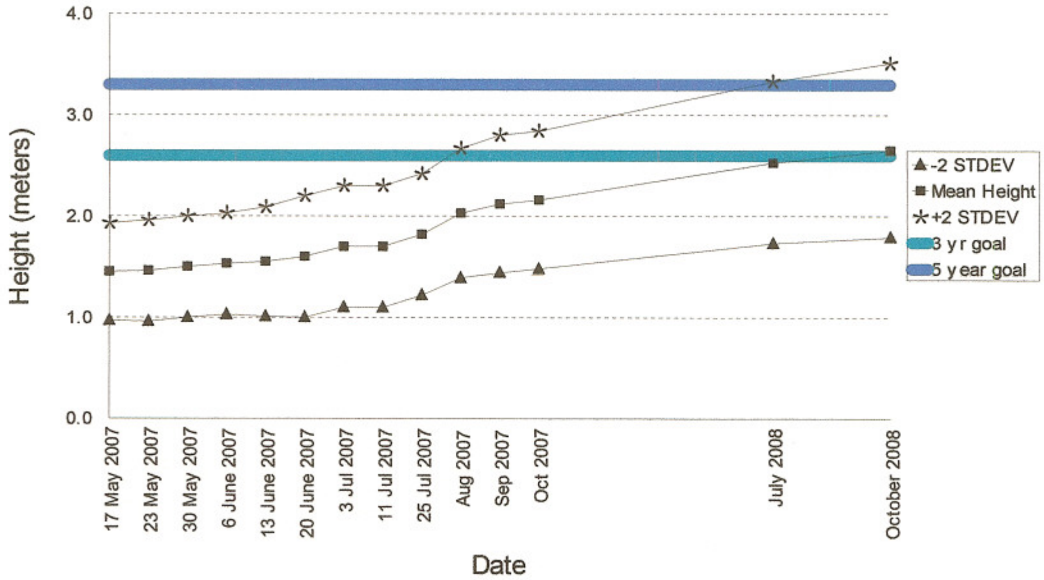


Figure 8, Growth of screwbean mesquite from May 2007. Only live trees are included. N=99

The general condition of screwbean improved as the first season advanced. Shortly after planting 60 (61%) of screwbean were considered to be in only fair condition, but by the end of August 2007, 84 of them (86%) were considered to be in excellent condition. This robust condition extended through mid-October (Fig. 9). Thus, at the end of the 2007 growing season all seemed well with screwbean mesquite, and so it is, at this time, on this particular revegetation site. Unfortunately this is one of a few, or perhaps the only, place on the entire lower Colorado River valley where screwbean are still in anything approaching a robust condition. A mysterious disease has struck this species and almost all of them from Bullhead City to Yuma are infected and, it appears, they will soon be dead (Anderson 2007). It has been noted (Anderson 2007) that trees planted for revegetation projects since 2004 maintain a rather healthy appearance and grow well for 1-3 seasons after planting, but ultimately they appear to be doomed unless there is some unanticipated, major turn around in the current situation. At the time of planting for this project (April 2007) we were aware that screwbean at Goose Flats Wildlife area appeared diseased, but at that time we failed to comprehend the magnitude of the eventual outcome. By July 2007 we had collected data from Havasu National Wildlife area, one area about 5 km north of the Goose Flats area, and the Goose Flats area and feared that the malady was spreading and that it probably was engulfing screwbean throughout the entire lower Colorado River valley. By October we had made formal evaluations from Bullhead City to Yuma and could see that our worst fears were developing. In many areas more than 90% of screwbean have degraded significantly.

Near season's end in 2008, 87% of the screwbean planted for the project were infected. This is probably reflected by the observation that 2/3 of them were in only fair condition (Figure 9). This compares with just over 80% being in excellent condition a year earlier. Even with irrigation in the 2009 it seems likely that the general condition of screwbean would continue to decline.

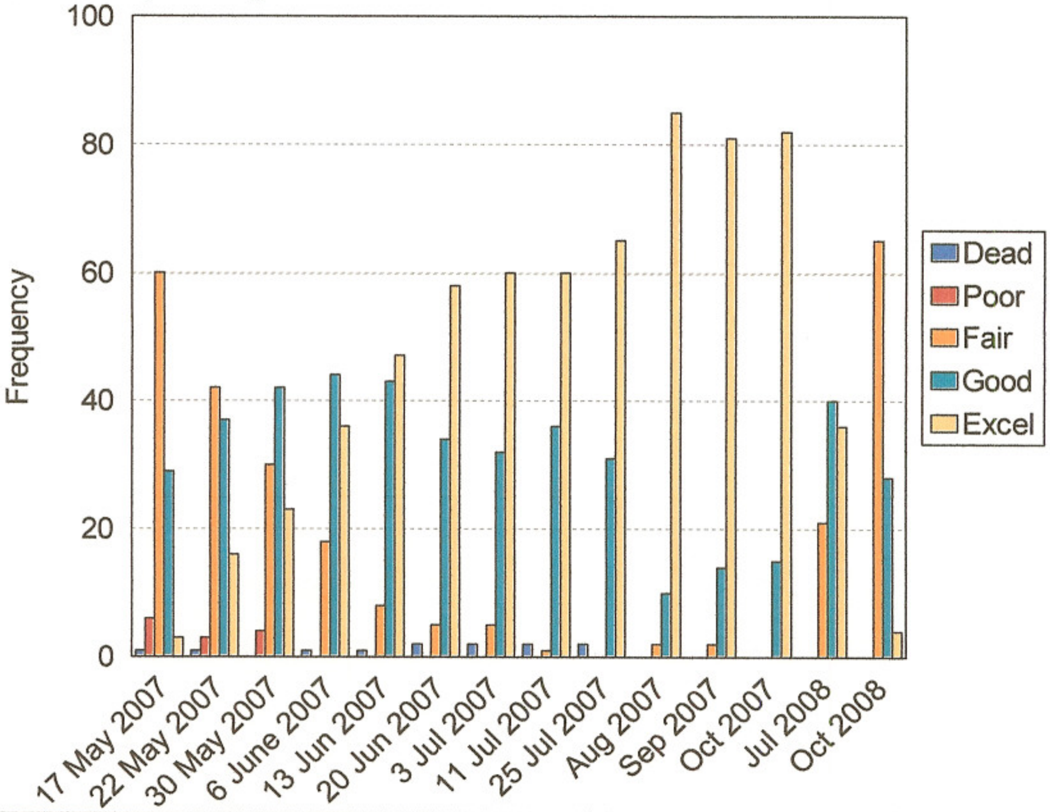


Figure 9. Condition of screwbean mesquite from May 2007. N=99

Honey mesquite—In our experience (Anderson et al 2004) larger plants that occupy 5-gallon pots in the greenhouse are slow to start growing after being planted in the field. This observation proved to hold for this project where honey mesquite were already 176 cm tall at planting in April, but their growth was virtually nil through 3 July 2007 (Fig., 10). By the end of July they attained a height of 181 cm and finally attained 191 cm by 22 August 2007. However at this point they sere attacked by psyllids and finished the season with a mean height of 188 cm, only 18 cm taller than at planting. About 95% of all honey mesquite trees fell between 146 and 276 cm tall at season's end in 2007. Perhaps the only advantage of starting with taller trees at planting is that, in spite of slow growth rate, some ended the season at or above typical 3-year height standards. On this project about 25% of the honey mesquite at the end of the initial season had attained the 3-year goal height of 216 cm and 7% even attained the 5-year goal height of 234 cm (Fig. 10). It was anticipated that if these trees are not hurt seriously by psyllids in the 2008 season they will do well.

This anticipated result did not come to fruition. +In 2008 growth of honey mesquite was almost imperceptible. By season's end mean height had increased by only 25 cm from the time of planting. At season's end mean height was 1.95 m with 95% of all individuals falling between 1.3 and 2.6 m. The 3 year goal for 80% of honey mesquite saplings to have attained 2.16 m had been attained by 26% of them. The 5 year goal of 2.34 m had been attained by 11% of honey mesquite.

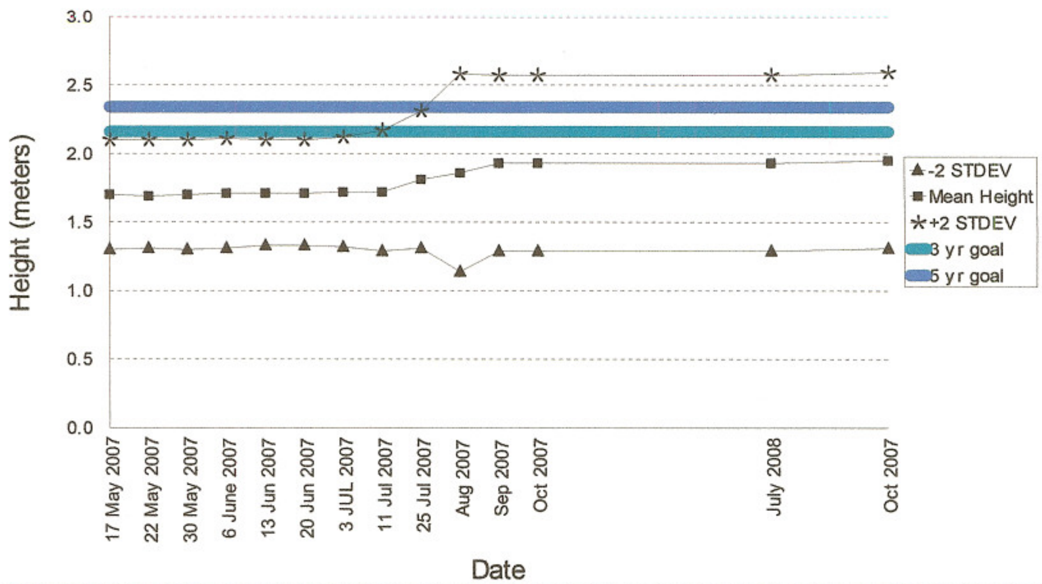


Figure 10. Growth of honey mesquite from April 2007. Only live trees are included. N=36

At planting only 3% of honey mesquite were considered to be in excellent condition but an additional 61% were in good condition. Only 3% were in poor condition but about one-third were considered to be in only fair condition (Fig 11). Plant condition improved gradually until by mid-July 97% were considered to be in good or excellent condition. In August, with the onslaught of psyllids, plant condition began to decline, until at season's end only 39% were in good or excellent condition and about 61% were considered to be in poor or fair condition (Fig. 11).

By the end of the 2008 season a single honey mesquite was dead, representing 2.7% of all plantings. About 22% were considered to be excellent condition and 46% were considered to be in good condition. This represents a slight improvement over that observed at the end of the 2007 season.

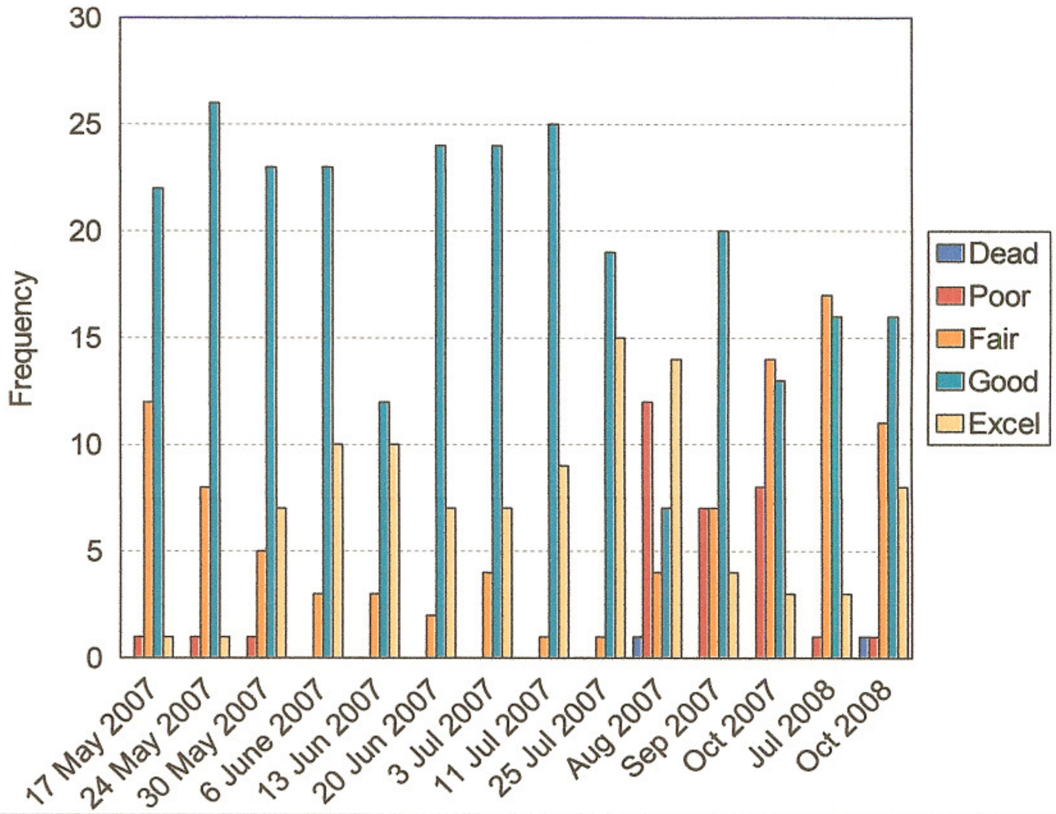


Figure 11. Condition of honey mesquite from April 2007. N=37.

Cottonwood—At planting cottonwood averaged only 65 cm tall with 95% ranging between 25 and 113 cm. As with screwbean growth was steady, but unspectacular (Fig. 12). By the end of July they had doubled their height, attaining 132 cm with 95% of them falling between 64 and 200 cm. By season's end they had added an additional 34 cm reaching a mean height of 166 cm with 95% of cottonwood falling between 82 and 250 cm. None attained the 3 year goal for 80% of all cottonwood planted to attain a height of 400 cm.

At the beginning of the irrigation in 2008 we added additional fertilizer in an acid base. This was done on the basis of the information provided above that indicated very low nutrient levels in the soil on the site. The fertilizer was added in an acid solution because the high alkaline conditions on the site can interfere with nutrient uptake by roots.

Over the 2008 growing season cottonwood grew about 1 m. At season's end they averaged 2.8 m tall with about 95% of them falling between 1.9 and 3.7 m (Fig. 12). The tallest cottonwood was greater than 5 m tall (Fig. 14). Although the graphic (Fig. 12) doesn't suggest it, about 13% of the cottonwood on the site attained the 3 year goal height of 4 m. In fact, about 3% attained the 5 year goal of 5 m. This is not apparent from Fig. 12 due primarily to the fact that some cottonwood planted where depth to the water table was greater than about 2 m performed poorly, relative to those planted under more appropriate conditions. Height of the 18% planted under marginal conditions was only about 1.25 m.

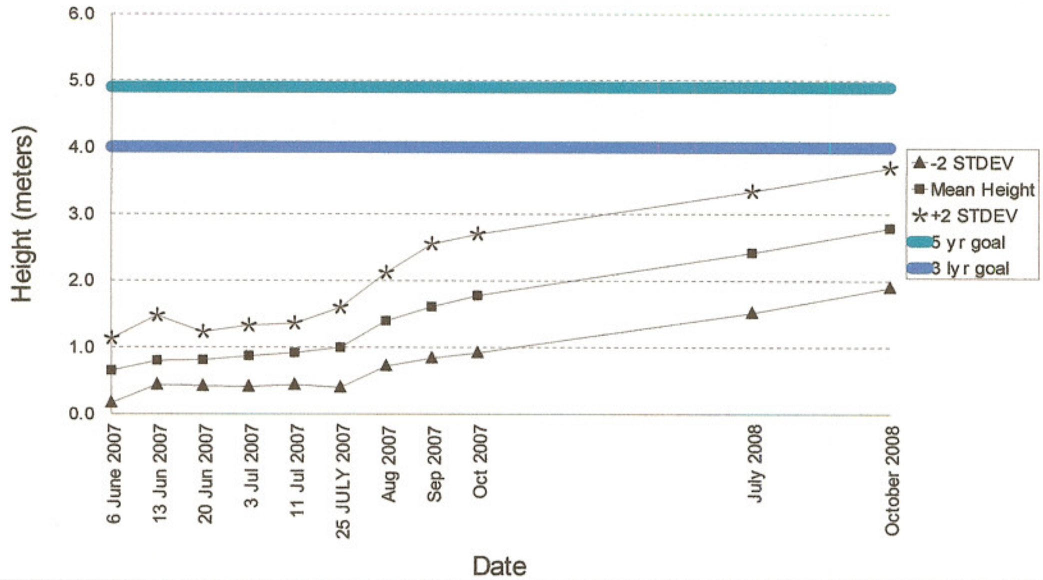


Figure 12. Growth of cottonwood from June 2007. Only live trees are included. N=38 at season's end.

At planting 73% of cottonwood saplings were considered to be in good or excellent condition (Fig.13). Early in the season about 8% of cottonwood died, but they were replaced. By the end of June 85% were considered to be in good or excellent condition. By mid-August this had increased to 95% (Fig. 13). Peak condition of cottonwood was attained in mid-September when 98% were rated good or excellent, dropping back to 95% at season's end. About 5% of original cottonwood plantings were dead at season's end. **With little or no irrigation in 2009 possibly 75% of the cottonwood will survive, but a number of them will be permanently stunted.**

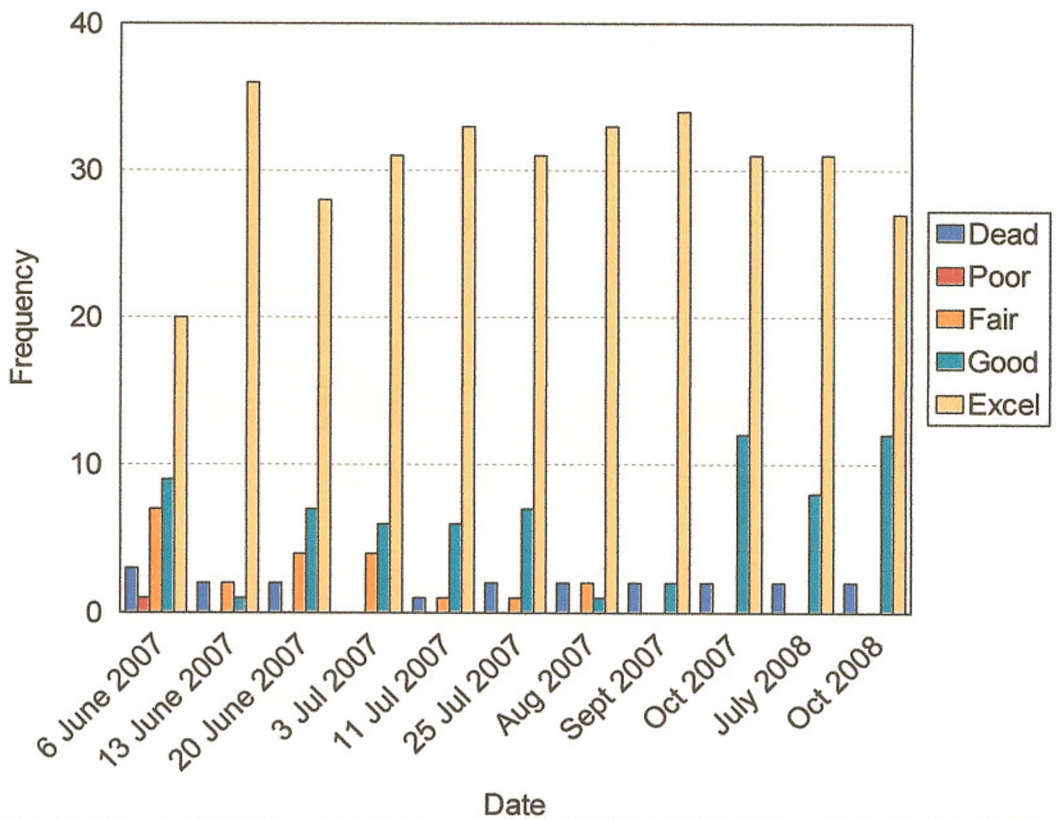


Figure 13. Condition of cottonwood from June 2007. N=40

Trees developed from seed--Fifty or more screwbean germinated and were 75 to 150 cm tall at season's end in 2007. Most of these were in excellent condition. Detailed data were not collected on these trees in 2007 because of the likelihood that all of these trees will die over the next 2 or 3 seasons because of some strange malady currently afflicting screwbean from Bullhead City to the border with Mexico (Anderson 2007). However, in 2008 we discovered even more that had developed from seed and decided to evaluate their height and condition, largely on the basis that only 16% of them seemed to be infected.

At season's end in 2008 these trees averaged 2.33 m tall with 95% of them falling between 1 and 3.7 m tall. An astonishing 43 (41%) of them had reached the 3 yr goal height of 2.6 m. The 5 year goal height is 3.33 m. Twenty five (24%) of these trees fell in the height class including trees 3.0 to 3.5 m tall. Examples of these trees can be seen in the photograph in the upper right in Fig. 14.

About 20 sandbar willow developed from either seed or runners during the period May-June 2007. They attained a mean height of 128 cm all falling between 60 and 200 cm (Table 4). All of them were considered to be in good or excellent condition (Table 4). In October 2008 we found 32 volunteer sandbar willow. They averaged 2.33 m tall with all of them falling between 1.25 and 3.75 m tall. Seventeen (53%) of them had already attained the 3 year goal height of 2.5 m and 5 (16%) had attained the 5 year target of 2.8 m (Anderson et al 2004).

In June 2007, 22 honey mesquite germinated from seed attained a mean height of 75 cm. Since their starting height was "0" they grew 75 cm on average over the first season. This compares with growth of only 15 cm, at best, for honey mesquite developed in 5 gallon pots. Honey mesquite from seed also suffered less from the attacks of psyllids, 7 of the 22 having been infected. Three of those attacked by psyllids were in poor condition at season's end, while 16 of 22 trees were in good or excellent condition.

Among 26 cottonwood that developed on site 24 were in good or excellent condition at the end of the growing season (Table 5). These trees grew 100 cm on average. Since their starting point was "0" this means that they grew 100 cms. Cottonwood started from cuttings in one-gallon pots in the greenhouse grew 101 cm on average (Fig. 12). The major advantage associated with planting the cuttings is predictability. Of the thousands of seeds that were disseminated over the moist area we had no idea how many would germinate. Ultimately this turned out to number only 24 germinated trees and these are not evenly spaced. Planted cuttings are evenly spaced, most in areas where soil testing told us they should do reasonably well (a few were planted in relatively poor areas to test our predictive abilities) and are spaced so as to minimize competition between individual planted trees for space, water, sunlight, and nutrients. Cottonwood from seed fell between 52 and 200 cm (Table 4) at the end of the first growing season. In 2008 these trees reached a height of 2.6 m with 95% of them falling between 0.6 and 4.6 m (Fig. 14, right), just 0.2 m shorter than planted cottonwood, which, as you will recall, were 0.65 m tall at planting.

Sixteen fan palm germinated from seed mostly in June 2007. Growth of these plants was slow with mean height at season's end being only 34 cm and with all of them falling between 20 and 60 cm. Nonetheless all of them seemed to be in generally good condition (Table 5). We have little experience with fan palm, thus have little data on which to develop expectations.

Finally, 3 palo verde germinated from seed. At the end of the 2007 growing season they were 40, 61, and 70 cm tall. Since these plants are growing in soil containing much more moisture than is typically associated with this species, they may not continue to thrive, but at this writing (December 2008) all 3 are in excellent condition (Table 5).

Most of these trees will survive even with no irrigation next season.

Table 4. Height (m) of trees that germinated from seed in May-June 2007. SB willow=sandbar willow, H msq= honey mesquite, Ctwd=cottonwood, SBM=screwbean mesquite.

	Species			
	SB willow	H msq	Ctwd	SBM
N	32	7	24	104
Mean	2.33	1.96	2.6	2.33
Median	2.75	1.75	2.75	2.25
St. Dev	0.78	0.49	1.02	0.69
Min.	1.25	1.25	1.25	1.25
Max.	2.75	2.75	4.25	3.25

Figure 14. Top photograph, marshy portion at north end of the site 2007 (see Fig. 2, upper left). Same area 2008. Middle, cottonwood on the revegetation site (compare to upper right in Fig. 2). Lower photograph is of cottonwood and screwbean on the north portion of the site (compare to lower left in Fig. 2).

Figure 14. The cottonwood on the left was the tallest tree on the site at the end of the 2008 growing season. This tree had already achieved typical 5 year expectations in just 2 growing seasons. The pole is about 5 m tall. The cottonwood on the right was planted as a one-gallon sapling but it was so close to the water table at the planting point that no irrigation was done for this tree or for 4 others behind it in the photograph.

Figure 15. The photograph on the left shows a healthy screwbean in the foreground and a diseased tree behind it. A series of diseased trees are shown on the front. The photographs were taken in October 2008.

Wildlife—For this project we have collected nothing more than anecdotal data for all wildlife except birds. As stated earlier, the area is formally censused for birds 3 times each month. We record the species and whether it was detected by auditory or visual cues. If we see the bird we record whether the bird was on the ground, i.e. in the area cleared for the project or in a tree. If detected in a tree we record the tree species and whether it was a planted sapling or a mature tree left intact at the time of clearing because of its potential to enhance wildlife.

Use of the newly planted trees has been minimal through the end of the fall season in 2008 (Table 5). However, in fall 2008 total detections in newly planted trees increased to 15% of total detections. The majority of detections through fall 2008 were still being made in trees (mostly screwbean) that remained on the site following selective clearing, thus demonstrating that mature trees left as a result of selective clearing are very important during the early years of revegetation project development.

Table 5. Use of newly planted trees and extant trees on the Needles River Glen revegetation project.

Season/ Year	Birds were detected in/on: Veg. planted for project	%	Mature trees on site	%	Ground	%	Detected by sound	%	Berm	%	Total
Summer 2007	1	3.23	16	51.61	4	12.90	10	32.26			31
Late summer 2007	1	4.55	14	63.64	4	13.64	5	18.18			23
Summer 2008	0	0.00	35	49.30	26	36.62	3	4.23	7	9.86	71
Late summer 2008	0	0.00	43	79.60	7	13.00	2	3.70	2	3.70	54
Fall 2008	14	15.05	73	72.04	8	7.53	2	2.15	3	3.23	93

Seventeen species were detected on 15 censuses of the revegetation site from May through September 2008 (Table 7). Only the verdin was regularly detected having occurred on 9 of the 15 censuses. It can be safely concluded that the site got relatively little bird use during the first summer. This is not surprising since the site was little more than a bare area., thus offering little that would encourage bird use. It should be noted that a gila woodpecker was detected. This would ordinarily mean very little, but it does give credence to the notion that this species is in the general area and that perhaps it will eventually benefit from this project.

In 2008 bird detections increased dramatically. Total detections across summer and late summer increased from 52 detections in 2007 to 121 detections in 2008. Increase in the number of white-winged and mourning doves accounted for most of this increase (Table 6). The yellow-rumped warbler, a fall-winter resident, and white-winged dove accounted for the greatest number of detections. The dove was detected 39 times in August 2008 and 37 yellow-rumped warblers were detected in October 2008 (Table 6). The verdin, a small, native insectivorous species, was present in 8 of 12 months.

Table 6. Bird use of the revegetation site. Summer includes May, June and July; late summer, August, September; fall, October, November.

		Year, month											
		2007					2008						
Species	Binomial	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep	Oct	Nov
Abert's towhee	Pipilo aberti	0	0	1	0	1	2	0	0	1	0	0	2
American kestrel	Falco sparverius	0	1	0	0	0	0	0	0	0	0	0	0
Ash-throated flycatcher	Myiarchus cinerascens	4	0	0	0	1	1	4	0	0	0	0	0
Black phoebe	Sayornis nigricans	0	0	0	0	0	0	0	0	0	1	2	0
Black-tailed gnatcatcher	Polioptila melanura	0	1	2	0	0	0	0	0	1	0	0	0
Blue grosbeank	Guiraca caerulea	0	0	0	0	0	1	0	0	0	0	0	0
Brewer's sparrow	Sjprizella breweri	0	0	0	0	3	0	0	0	0	0	0	0
Brown-headed cowbird	Molothrus ater	0	1	0	0	0	0	0	0	0	0	0	0
Pacific slope flycatcher	Empidonax difficilis	0	0	0	0	0	1	0	0	0	0	0	0
Crissal thrasher	Toxostoma crissalis	0	0	0	0	0	1	0	0	0	0	0	0
Gila woodpecker	Melanerpes uropygialis	0	0	0	0	1	0	0	0	0	0	0	0
Great blue heron	Ardea herodias	0	0	0	1	0	0	0	0	0	0	0	0
Greater roadrunner	Geococcyx californianus	1	0	0	1	0	0	0	0	0	0	0	0
Great -tailed grackle	Quiscalus mexicanus	0	1	0	1	0	0	0	0	0	0	0	0
House fince	Carpodacus mexicanus	0	0	0	0	0	0	0	0	0	0	0	1
Ladder-backed woodpecker	Picoides scalaris	0	3	1	0	0	0	1	4	1	0	0	0
Lesser nighthawk	Chordeiles acutipennis	0	0	0	0	0	1	4	0	2	0	0	0
Loggerhead shrike	Lanius ludovicianus	0	1	1	0	0	0	1	0	1	0	1	1
Lucy's warbler	Vermivora luciae	1	0	0	0	0	3	0	0	0	0	0	0
Mourning dove	Zenaida macroura	0	0	0	1	1	2	1	8	0	1	13	6
Northern flicker	Colaptes auratus	0	0	0	0	0	0	0	0	0	0	2	1
Phainopepla	Phainopepla nitens	0	0	0	0	0	0	0	0	0	0	2	3
Ruby-crowned warbler	Regulus calendula	0	0	0	0	0	0	0	0	0	0	2	1
Verdin	Auriparus flaviceps	2	3	2	6	0	1	1	1	0	1	0	0
Western kingbird	Tyranus verticalis	0	1	0	1	0	0	0	0	0	0	0	0
White-winged dove	Zenaida asiatica	2	0	1	6	0	6	6	19	39	0	0	0
Wilson's warbler	Wilsonia pusilla	0	0	0	0	0	1	0	0	5	0	0	0
Yellow-rumped warbler	Dendroica coronata	0	0	0	0	0	0	0	0	0	0	37	18
	Totals	10	12	7	17	6	18	18	32	50	3	59	33
	Species	7	9	6	8	5	11	7	4	7	3	7	8

CONCLUSIONS AND RECOMMENDATIONS

Development of saplings and seedling on the site was satisfactory during the initial season. Growth of honey mesquite was significantly slowed down because of infestation of sap sucking insects called psyllids. However, even without psyllids, honey mesquite barely grew at all in 2008. Arguably the best growing trees associated with this project were screwbean mesquite. However, individuals of this species are currently inflicted with a disease that has spread throughout the lower Colorado River valley. Although this disease had not affected trees planted for this project by the end of the 2007 growing season, by the end of the 2008 growing season 87% were affected. The only solution seems to involve replacement of the current screwbean with species such as honey mesquite, cottonwood, and palo verde. This should be done at the earliest opportunity so that replacements will reach goal heights by the 5 year duration for many revegetation projects. With little or no irrigation next season there should be more than 6% soil moisture and DWT should be less than 2.5 m below the surface. Purely from a probability basis the chances of having both 6% or more soil moisture and be less than 2.5 m to the water table in 0.93 X 0.87 = 0.81. On this basis 81% of the planted trees can be expected to survive next season without irrigation. This equates to about 7 acres. All of the trees that germinated from seed in the marshy area will survive through the 2009 season.

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