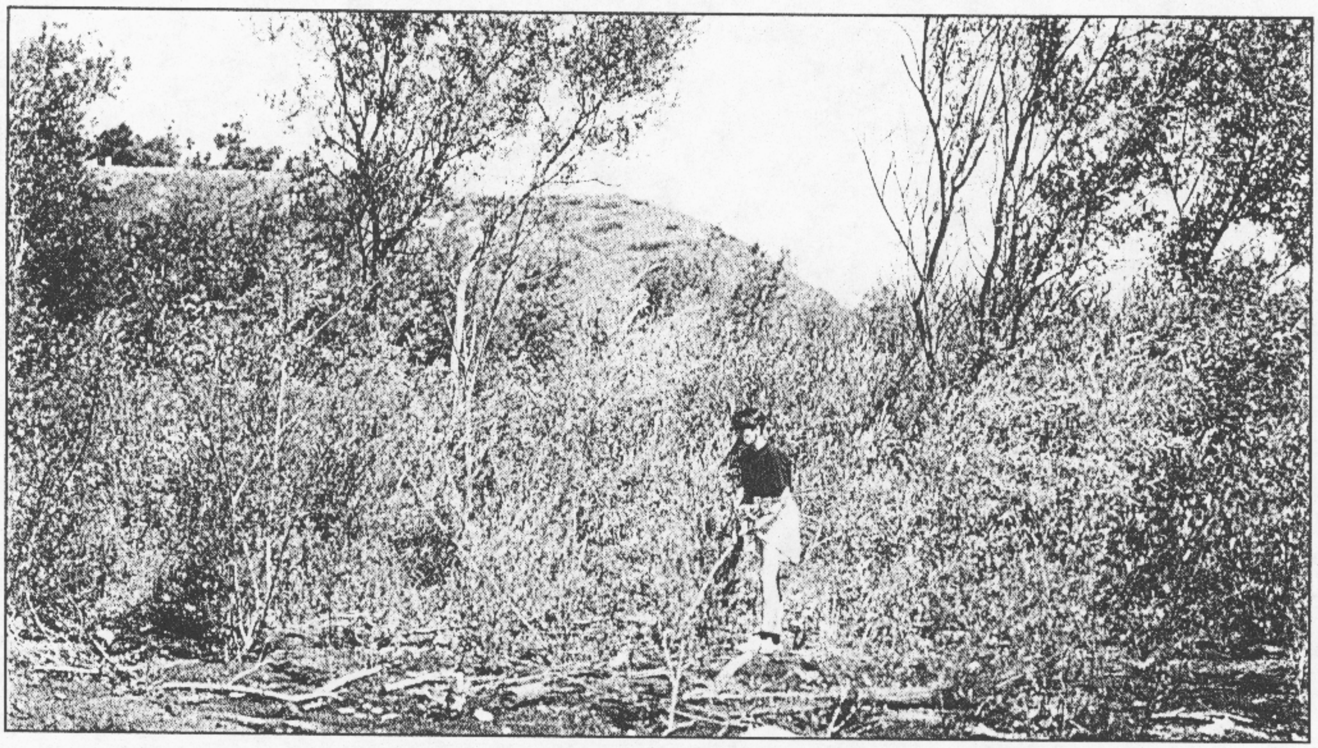

Details of community structure are a critical factor in the development of habitat for birds such as the least Bell's vireo in riparian areas of southern California. Structure may be controlled to some extent by the choice of species and placement of plants, but it also depends on soil mycorrhizae, which influence the uptake of water and minerals. Here author Kathryn Baird spreads litter to introduce mycorrhizae at a restoration site.

High Quality Restoration of Riparian Ecosystems

The attempt to create habitat for rare bird species is leading to the refinement of tecñniques for creating authentic replicas of these environmentally critical systems.

by Kathryn Baird

Despite the legal and grassroots efforts to preserve riparian ecosystems during the past three decades, today the few remaining areas are being threatened by intensified development accompanied by growing political pressure. As a result these areas are often the objects of efforts to preserve natural areas or to mitigate their loss through restoration. Work of this kind is sometimes associated with highway development, and staff biologists at the California Department of Transportation in San Diego County have been involved in the restoration of numerous riparian systems during the past eight years.

In the course of constructing a number of these systems and reviewing many more we have begun to identify some of the factors that are critical for successful restoration of these systems. In general what we have found is that, while properly installed plantings may be successful on riparian sites, the composition and structure of the resulting community is frequently quite different from that of the natural or model community. This may not be critical if one is concerned only with establishing vegetative cover. It becomes critical, however, in projects designed to provide habitat for a particular species, or when the goal is creating functioning, self-sustaining ecosystems. As a result we have paid special attention to structure and dynamics as well as species composition in our projects. This has led to a number of refinements in technique, and the results, though still incomplete, do suggest an improvement in our ability to create habitat for particular target species.

This article summarizes what we feel are the most important lessons we have learned in the course of this work. These should be of value to others attempting to create habitat for native species. They may also be of value to those restoring native ecosystems under comparable conditions, in which rainfall is low and seasonal, and water is drawn directly from the water table a meter or so beneath the soil surface or is supplied by periodic flooding.

Design Aspects

The use of an ecosystem model has been a key feature of our attempts to create habitat for the least Bell's vireo (*Vireo bellii pusillus*) at sites along the San Luis Rey River and the San Diego River in San Diego County. Admittedly,

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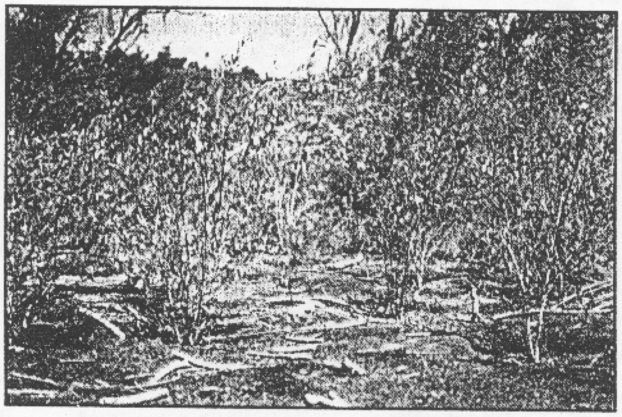

The same site about two months after work was completed in May, 1989.

understanding an ecosystem is difficult at best, but an ecosystem approach appears to be the surest way to create a functioning habitat. The goal of any habitat creation project should encompass both long and short term objectives. The short term objective for these projects is to provide suitable least Bell's vireo habitat. The long term objective is to create a framework within which natural selective forces can operate to create a self-sustaining, functioning riparian habitat that not only provides habitat for a complete assemblage of riparian species, including the vireo, but which is also capable of long-term regeneration and recovery following natural disturbances.

Vireo Habitat Model

Restoration projects aimed at a particular species are not unlike general habitat restoration projects, except that the baseline studies require directed analysis of the target species in addition to habitat studies. We began our projects by analyzing biological data on 30 active vireo nest sites and 10 non-nesting riparian sites (Hendricks and Rieger, in press). We then selected five factors as the basis for the model we used to develop restoration objectives at our various sites. These were: plant density, percent cover, species composition, and community structure and arrangement in the landscape. (A detailed account of the model development process can be found in the 1988 California Riparian Systems Conference Proceedings (Baird and Rieger, in press).)

The first parameters we considered were density and percent cover for each of the plant groups (trees, shrubs and herbs) (Table 1).

Next we developed a list of the native species at project sites on each of the river drainages. Percent abundance for the tree species varied from site to site, but species composition did not. A list of species and their relative abundances on both river drainages is provided in table 2.

These values then became the "target" values for restoration sites in these drainages and the basis for our planting program.

To maximize survivorship and reduce the need for disruptive replanting we used 1-, 5- and 15-gallon container-grown plants from a local native plant nursery. Contrary to popular dogma, we have had lower mortality and better results generally with 5- and 15-gallon than with 1-gallon stock, both in the short and long term. If the nursery has handled the larger plants correctly, and the root systems are healthy the larger plants are simply more vigorous and reliable.

The percent of each size class used was modeled after the height variation and ranges found in the field, taking into consideration the anticipated growth rates for each species. In preparing planting plans we also allowed for field mortality and recruitment for each species, using estimates based on earlier restoration projects and communications with other biologists. We then calculated the actual planting numbers for each species and size according to the following formula:

[(Density)(Species abundance)(% Size class)] +
[(% Mortality)(Density)(Species abundance)] -
[(% Recruitment)(Density)(Species abundance)]=
Planting number.

Planting Pattern

To develop a pattern for setting out plants in the specified age and size categories, we first made scale maps of our original 30 vireo nesting sites. We then chose four of the "best" maps and used them as the basis for the planting layout. On this basis we constructed a 100 X 100 foot (30m X 30m) "cell," checking it against the percent cover and linear edge values calculated from the field studies. What resulted was a mosaic planting design that included areas of trees, shrubs and open space. We then used this cell as a module that can be replicated and joined together to accommodate an area of any size or shape.

Table 1. Percent Cover and Density Values

	San Diego River		San Luis Rey River	
	Percent Cover	Density No./acre	Percent Cover	Density No./acre
Trees	50	1056	47	1000
Shrubs	39	1890	33	3966
Herbs	4	2655	8	2655
Open	7	NA	12	NA

Table 2. Species composition and abundance (as percent of individuals in class)

	San Luis Rey	San Diego
Trees		
Salix gooddingii	37	40
S. lasiolepis	40	37
S. hindsiana	11	6
S. laevigata	10	6
Populus fremontii	1.3	6.5
Platanus racemosa	0.7	4.5
Shrubs		
Baccharis glutinosa	100	100

Following the resulting plan, we then set out the appropriate willow species in monotypic groups of 12-15 of mixed sizes within areas designated as tree cover. To encourage the *Baccharis* shrubs to develop their characteristic, multi-stemmed, fountain-like growth form, we planted some in clusters of two or three. We also developed lists of herbaceous species based on information obtained in the original field studies but excluding exotic species present on the model sites. A local seed specialist developed a planting prescription for these species, specifying the amount and purity of seed to be used on each site, using the method described by Schaff (1988). To help in locating specific areas during construction and later during trouble shooting and monitoring, we superimposed the sprinkler system on the planting plan and numbered the sprinkler heads to establish a convenient system of coordinates on each site.

Site Specifications

The success of any restoration project depends in part on how closely the site you've chosen meets the criteria for the community or ecosystem you are trying to restore. With enough water and work we can force most any group of plants to survive, at least for a time. However, if the conditions on the site differ significantly from those under which the system occurs naturally, its long term survival and regeneration are unlikely. A key criterion for riparian system in the arid West is the elevation or depth-to-groundwater requirements of the habitat in question—in this case riparian willow scrub.

Unfortunately, information on this subject is limited. There is general information on days per year of inundation for specific habitats and species types (Granholm et al, 1988). But this provides only an indirect indication of normal ground water relations. To obtain a more direct reading, we measured elevation profiles across shorelines at several points along the San Luis Rey River to determine the normal depth-to-groundwater range. On the basis of this limited information we designed a surface elevation about 0.9m to 1.2m above the average low water table. So far, our experience makes it clear that there is a real need for more information about the relationship between depth-to- groundwater and community type and dynamics. This underscores the importance of measuring, recording and publishing information about groundwater relationships in carrying out restoration projects on riparian sites, and suggests an area in which restorationists may make an important contribution to the understanding of an ecological system.

We next determined final elevation grades for each of our restoration sites by drilling well holes at various locations and then sketched out the topographic relief and elevations for each site. We specified surfaces ranging between 1m and 1.6m above the water table and included gentle hills throughout the sites. This topographic variation together with a rough surface provided microclimatic variation we think is likely to increase biological diversity in the community developing on the site. On soils containing clay we included networks of channels to facilitate drainage and water movement. Past experience has shown that even small amounts of clay in the soil can cause ponding and loss of plants. Depending upon the amount of clay in the soil other modification may be needed for successful plant establishment. Sandy soils, on the other hand, require little or no channelling, since water moves readily through these soils.

IMPLEMENTATION

Weed Competition

In the six riparian restoration projects we have carried out, competition from exotic weed species has been a major factor in mortality and site failure. If the site is not being graded (assuming that it is already within the acceptable elevation range) a large weed seed bank will usually have accumulated by the time restoration begins, the number and kinds of seeds in the bank depending both upon the current condition and history of the site (See R&MN 7(1) p.24). As a result, in most cases with the addition of water you will find yourself with a field of weeds so vigorous you will be unable to locate anything smaller than a 5- gallon plant.

One way to avoid this is to remove the seed bank by removing the surface soil. This has several obvious disadvantages, including removal of nutrients, mycorrhizal fungi, bacteria, and insect and invertebrate populations critical to a healthy habitat. However, since the majority of areas selected for our restoration sites have been dominated by undesirable exotic species, we have frequently resorted to soil removal to reduce weed problems. To reiterate, our experience shows that weed and weed seed removal by mechanical means, repeat burning or some other method is mandatory in projects such as ours.

We have also used a cover crop of native wildflowers, hand- broadcast over the site to aid in weed control. These species (for example, California poppy (*Eschscholtzia californica*), lupine (*Lupinus bicolor*), and common phacelia (*Placelia parryi*), are not expected to survive in large numbers beyond the first year or two, and we hope they will reduce competition from exotics while contributing organic matter to the soil. The initial results have been mixed. On our drier, sandy sites germination of the wildflowers has been low, limiting their value as a weed deterrent. On the wetter, heavier soils, however, the wildflowers have established better and do seem to be helping to control weeds.

Unfortunately, the only sure way to control weeds during the first growing season is by frequent hand weeding. The important thing here is to weed frequently, keeping ahead of weeds before they get out of control.

Soil Flora

There is considerable evidence that fertilizing a restoration site in southern California favors exotic weeds over native plants (Grime and Hunt, 1975; Grime, 1978; St. John, 1987 and 1988). Many plants native to southern California have evolved under a low nutrient regime and are less capable of utilizing added fertilizer than are many exotics. Rather than fertilize we have chosen to inoculate our sites with mycorrhizal fungi, which enable seedlings of some species to better utilize limited supplies of both water and nutrients (Hayman, 1983; Stribley, 1987; Miller, 1987). By the same token, the rate of establishment of many native species may be reduced by the diminished inoculum levels on a disturbed site, since succession may depend on the establishment of critical mycorrhizal associations (Warner et al, 1987).

Thus introduction of an appropriate inoculum of mycorrhizal fungi may play a key role in the establishment and long-term development of a restoration project. If the plants in question are endomycorrhizal plants we find it is usually easiest to have a nursery inoculate all potted material. Direct inoculation of the soil with endomyrorrhizae is also possible. Most riparian species are ectomycorrhizal, however, and the spores of appropriate species are generally abundant in the leaf litter and duff under mature riparian plants. To inoculate our sites, we simply collected litter from mature communities upstream from our sites and spread it thinly over our sites following planting.

This procedure raises questions about the quality and performance of an inoculum. An assemblage of organisms obtained in this way will include a variety of organisms, including bacteria and actinomycetes in addition to mycorrhizae, which are adapted to field conditions, and may or may not be more effective than inoculation with pure cultures of mycorrhizae (Perry et al., 1987). In any case, this is hardly an option in most instances, since pure-culture inoculum is not readily available for most systems. (This problem is being addressed by at least one native plant nursery in southern California, the Tree of Life Nursery in San Juan Capistrano (Ted St. John, personal communication).)

Table 3. Performance Criteria

Percent Cover	Goal	Range
Tree*	50	40-60
Shrub*	39	30-50
Herbaceous*	4	2-9
Open*	7	3-9

Species Composition	Goal (percent)	Range (percent)
Salix gooddingii	40	30-50
S. lasiolepis	37	30-50
S. laevigata	6	3-9
S. hindsiana	6	3-9
Populus fremontii	6.5	4-10
Platanus racemosa	4.5	3-7

* The combined cover of trees and shrubs must total at least 82 percent, while the combined total of herbaceous and open is not to exceed 18 percent nor fall below 5 percent.

Soil microbes, bacteria, fungi and invertebrates are critical components of most ecosystems, yet are often overlooked because of the complexity of the underground part of the system and the difficulty of obtaining detailed information about it. This being the case, we have done as restorationists generally do and have relied on the introduction of soil, principally in the form of the rootballs of transplanted stock, to introduce these organisms into the restored community.

In our case, this was introduced in the form of large (1.2m deep by 2.8m wide) rootballs of mature trees brought in from riparian sites to meet Caltrans' tight schedule for restoration projects. Smaller, more economical soil plugs scattered throughout the site can serve the same purpose. The number of soil plugs needed to ensure the establishment of soil flora is directly related to the distance of the restoration site from a similar, mature community.

Criteria for Success

The U.S. Fish and Wildlife Service and Caltrans have jointly developed performance criteria for the riparian projects, and these criteria have become more specific as both parties have progressed in experience and knowledge. For the majority of Caltrans' projects these criteria must be met before initiation of highway construction is permitted. Our San Luis Rey River sites will be considered successful when a pair of least Bell's vireos has nested successfully on the site, or when the vegetation on the site matches that on active breeding sites within specified limits. On the San Diego River, the vegetation must match the values for percent cover and species composition specified in Table 3. Sampling to measure for these goals will be performed by dividing the site into eight cells of approximately 2.6 ha each. Each cell must be sampled at four randomly selected points using the same sampling technique employed in the collection of original vireo habitat data. Prior to construction, seven of the cells must meet the designated criteria, the eighth cell may miss the goals by up to 5 percent, with corrective measures being taken in that area concurrently with final review. A cell will be considered successful regardless of the vegetation condition if a least Bell's vireo, willow flycatcher or yellow-breasted chat nests within that cell.

* The combined cover of trees and shrubs must total at least 82 percent, while the combined total of herbaceous and open is not to exceed 18 percent nor fall below 5 percent.

RESULTS

It is still too early to make definitive statements about any of our least Bell's vireo restoration projects. Investigators are monitoring insect population dynamics and avifauna use. However, by all initial indications they appear healthy and are showing great promise. Within the first season a variety of passerine birds has been spotted foraging within the sites, among them pairs of least Bell's vireos, yellow-breasted chats, black grosbeaks, warbling vireos and common yellow-throats with young, yellow and orange-crowned warblers and western flycatchers. One of the sites even contained a passerine nest with two chicks. Unfortunately, the nest failed before positive identification could be made.

In summary, the most important thing we have learned from our experience so far is the value of imitating the natural habitat closely in designing a restoration site. In visiting sites throughout California we have been troubled by what could best be described as a lack of depth and completeness in the planning and implementation of many projects. While the appropriate dominant plant species may be present, we often cannot shake the feeling of an artificial, landscaped habitat. In some instances, moreover, failure to use an ecosystem approach has resulted in sites permanently dependent upon an artificial water source or lacking critical understory components, and we also have the impression that these sites are less attractive to wildlife as well.

All this underlines the importance of restoration planning based on careful analysis of species composition, density, community structure, arrangement, ground water and soil characteristics. This may be difficult in some situations. But in most cases a little work and perseverance can provide the data required to design a responsible restoration project.

References

Baird, K.J. and J.P. Rieger. In Press. Restoration design for least Bell's vireo habitat in San Diego County. In: Proceeding of the California Riparian Systems Conference, 1988; Davis, California.

Granholm, S., W.P. Henry, W.D. Kanemoto and R.E. Palmer. 1988. Designing riparian plantings to mimic native forests within four hydrologic zones along the Sacramento River. In: J.P. Rieger and B.K. Williams (eds.) Proceedings of the Second Native Plant Revegetation Symposium, San Diego, California. pp. 198-212.

Grime, J.P. 1978. Interpretation of small-scale patterns in the distribution of plant species in space and time. In: A.J.H. Freysen and J.W. Woldendorp (eds.) Structure and Functioning of Plant Populations. Elsevier, North-Holland, Amsterdam, New York, pp.101-104.

Grime, J.P. and R. Hunt. 1975. Relative growth rate: its range and adaptive significance in a local flora. J Ecology 63:393-422.

Hayman, D.S. 1983. The physiology of vesicular-arbuscular endomycorrhizal symbiosis. Can. J. Bot. 61:944-963.

Hendricks, B.J. and J.P. Rieger. In Press. Description of nesting habitat for Least Bell's Vireo in San Diego County. Proceeding of the California Riparian Systems Conference, 1988; Davis, California.

Miller, R.M. 1987. The ecology of vesicular-arbuscular mycorrhizae in grass-and shrublands. In: Gene Safir (ed.) Ecophysiology of V.A. Mycorrhizal Plants. CRC Press, Boca Raton, Florida. pp. 135-170.

Perry, D.A., R. Molina and M.P. Amaranthus. 1987. Mycorrhizae, mycorrhizospheres and reforestation: Current knowledge and research needs. Can. J. Forest Research. 17:929-940.

St. John, T.V. 1987. Mineral acquisition in native plants. In Elias, Thomas S. (ed.) Conservation and Management of Rare and Endangered Plants. Sacramento, Calif.; California Native Plant Society. pp. 529-536.

St. John, T.V. 1988. Soil disturbance and the mineral nutrient of native plants. In: Rieger J.P. and B.K. Williams (eds.) Proceedings of the Second Native Plant Revegetation Symposium; San Diego, California. pp. 34-39.

Schaff, V.W. 1988. Using seeds of native species for revegetation. In: Rieger, J.P., and B.K. Williams (eds.) Proceedings of the Second Native Plant Revegetation Symposium; San Diego, California. pp. 32-33.

Stribley, D.P. 1987. Mineral nutrition. In: Gene Safir (ed.) Ecophysiology of V.A. Mycorrhizal Plants. CRC Press; Boca Raton, Florida. pp. 59-70.

Warner, N.J., M.F. Allen and J.A. MacMahon. 1987. Dispersal agents of vesicular-arbuscular mycorrhizal fungi in a disturbed arid ecosystem. Mycologia 79(5) 721-730.