Appendix K.
Habitat Restoration

A. Introduction

Extensive loss and degradation of riparian habitat throughout the U.S. Southwest is considered to be the primary factor responsible for the decline of the southwestern willow flycatcher (*Empidonax traillii extimus*), as well as of other species dependent upon this habitat during part or all of their annual cycles (Unitt 1987, USFWS 1995). Consequently, recovery of the flycatcher will require increasing the availability of suitable habitat through the combined approaches of habitat protection and restoration. In this paper, we present an approach to habitat restoration, supported by examples, that we believe will provide the greatest long-term success in reversing the decades-long loss of riparian woodlands and thereby augment habitat for obligate riparian species such as the flycatcher. We use the term "restoration" in a broad sense to include enhancement of degraded habitat, and re-establishment of riparian vegetation to sites where it occurred historically but is currently absent as a result of reversible alterations of the conditions necessary for supporting it (Jackson et al. 1995). We also include the concept of "creation" of habitat in our restoration category, recognizing that ingrained changes in the infrastructure of flowing water in the U.S. Southwest may necessitate spatial shifts in habitat from historical sites to new areas that have greater potential for restoration success. There are different degrees of restoration that are achievable at any given site, ranging from full restoration to partial restoration, sometime referred to as rehabilitation or naturalization (Cairns 1995).

We begin by describing some of the causes of symptoms of habitat degradation, referring to other Appendices in this Recovery Plan that treat these topics more fully. We then describe methods for restoration, including restoration of physical elements and processes, restoration of animal populations and processes, and restoration of essential plants, fungi, and biotic interactions. We also address some of the factors to consider when selecting sites, to optimize restoration success. Finally, we address the topic of restoration as mitigation, and offer some recommendations regarding design, implementation, and evaluation of projects within this context.

1. Goal of Restoration: What Do We Want to Restore?

Our scope in this discussion includes river systems throughout the seven-state historic range of the southwestern willow flycatcher, recognizing that not all riparian habitat within this range was or can again become suitable for flycatchers. An implicit goal is to restore habitat to a level that is deemed *suitable* for flycatchers as evidenced by (1) the presence of breeding flycatchers (although even some of this habitat may benefit from enhancement) and (2) the presence of habitat attributes that characterize suitability for flycatchers. These attributes include dense shrubby and forested vegetation interspersed with small openings near surface water or saturated soil (see Appendix D for a complete description).

Although we offer guidelines for habitat restoration within the context of willow flycatcher recovery, our scope in this issue paper is a general one and not specific only to the flycatcher. Habitat loss has produced declines in many riparian species; thus, we strive for an approach that will restore entire plant and animal communities and the physical processes upon which they depend. To the degree possible, we seek to restore ecosystem integrity, defined as the "...state of ecosystem development that is optimized for its geographic location, including energy input, available water, nutrients and colonization history... It implies that ecosystem structures and functions are unimpaired by human-caused stresses and that native species are present at viable population levels" (Woodley 1993). We recognize that this developmental state is neither feasible nor desirable in all areas, given the large size of the human population. Thus, we also suggest compromises that allow rivers and riparian ecosystems to meet human needs and the needs of other riparian-dependent biota. This ecosystem-based approach is consistent with the goals of the Endangered Species Act, which include conserving the ecosystems upon which the endangered species' depend.

The approach we advocate is guided by the recognition that functional plant communities are necessary to support the large and diverse animal communities typical of native riparian habitat. With this perspective, restoring structure to the plant community means restoring a wide array of plant species and functional groups, restoring viable age structures for the dominant species, restoring vertical complexity, and restoring a mosaic of vegetation patches in the flood plain. Restoring function includes restoring bioproductivity, and restoring the ability of the plant communities to capture and store nutrients, build soils, stabilize stream banks, and create habitat for animals. Essential to ecosystem integrity is that the plant community be self-sustaining and resistant or resilient to various types of natural disturbances. Once structure, function, and self-sustainability have been restored to the plant community, the potential exists for establishment of viable animal populations through the provision of food, cover, shade, breeding sites, foraging sites, and other resources essential to survival and reproduction.

2. *Causes and Symptoms of Habitat Degradation.*

Before we attempt to restore an ecosystem, we need to understand the factors that have caused the degradation (Briggs 1996, Hobbs and Norton 1996, Goodwin et al. 1997). This step in the identification of root causes hinges upon an understanding of the ecological impacts of a lengthy list of human activities relating to water and land use, and species introductions and extirpations. Symptoms of degradation vary depending on the type and extent of anthropogenic stressors. Fluvial geomorphic changes such as reduced channel movement and channel incision can result from dams and diversions; channel widening can be symptomatic of overgrazing by livestock and/or stream dewatering and loss of streambank vegetation. Hydrologic indicators of degradation, including lowered ground water levels or stream flow regimes that deviate from climatic patterns, can be direct results of water management and/or indirect consequences of land use actions in the watershed that influence the water cycle (Richter et al. 1996). Plant communities may lose their capacity for self-repair or revegetation after flood disturbance, if subject to stressors such as dewatering or overgrazing. Replacement of species-rich communities by homogenous thickets of single species, be they native or exotic, can be symptomatic of dam-related reductions in fluvial disturbances and/or imposition of stressors such as grazing that select for a small number of tolerant species. Many factors, including landscape-level habitat fragmentation, can produce symptoms in the animal community such as declining diversity of bird species, or population declines of riparian specialist species such as southwestern willow flycatchers or yellow-billed cuckoos (*Coccyzus americanus*). A loss of biotic interactions, such as a loss of pollinators, a breakdown of plant-disperser interactions, or a loss of symbiotic relationships such as plant-fungi mycorrhizal relationships, are other indicators of degradation. Suites of symptoms, such as soil compaction, stream channel downcutting, lack of tree regeneration, and spread of unpalatable plant species together can be symptomatic of a particular stressor such as overgrazing (Prichard et al. 1998). Collectively, these and other symptoms provide a list of inter-related ecosystem components that form the basis for examination of root causes of degradation, and identification of appropriate strategies for restoration.

B. How Do We Restore Degraded Ecosystems?

1. Restoration of Physical Elements and Processes

Hydrologic regimes and fluvial geomorphic processes are prime determinants of riparian community structure (see Appendices I and J). To restore a diversity of plant species, growth forms, and age classes, we need to restore the diversity of fluvial processes, such as movement of channels, deposition of alluvial sediments, and erosion of aggraded flood plains, that allow a diverse assemblage of plants to co-exist. To restore bioproductivity and maintain plant species with shallow roots and high water needs, we have to ensure the presence of the necessary hydrogeomorphic elements; notably water flows, sediments and nutrients. We need to restore flows of water, sediment, and nutrients not only in sufficient quantities but with appropriate temporal patterns (Poff et al. 1997).

Hydrogeomorphic conditions have been altered and fluvial processes disrupted over much of the U.S. Southwest. There are over 400 dams that are managed for municipal or agricultural water supply, flood control, hydropower, or recreation (Graf 1999). Surface water is diverted from dammed and undammed rivers alike. Ground water is pumped from flood plain aquifers and regional aquifers. Dikes and berms constrain channels, reducing or eliminating river-flood plain connectivity. Throughout watersheds, livestock grazing, fire suppression, and urbanization reduce rates of water infiltration into soils and increase surface runoff. This, in turn, results in larger flood peaks, higher sedimentation rates, and reduced base flows.

Flood flows and river dynamism.

Full restoration of riparian ecosystems hinges on removing impediments to the natural flow regime (Schmidt et al. 1998). This type of approach, wherein one restores natural conditions and processes by removing stressors, and then allows the biotic communities to recover of their own accord, falls within the realm of passive restoration (Middleton 1999).

Dam removal is a passive restoration approach that allows for full ecosystem restoration. Dams are being removed throughout the U.S. for the purpose of restoring habitat, most often for endangered fish species. Working within drainage basins or at larger spatial scales, some groups have contrasted the relative costs and benefits of a suite of dams with respect to economics and ecology (Shuman 1995, Born et al. 1998). In some cases, removal of a dam can provide substantial ecological benefit, while causing minimal reduction in the production of 'goods': along the Elwha River in Washington State, removal of two dams is expected to cause a small loss of hydropower but a gain in fisheries productivity (Wunderlich et al. 1994). In Arizona, a recent decision was made to decommission the hydropower dam on Fossil Creek and restore full flows to the stream, because the benefits from restoring aquatic and riparian habitat outweigh the small loss of hydropower. Elsewhere in the arid Southwest, storage of water in ground water recharge basins may be a feasible alternative to reservoir storage, obviating the need for some dams.

Dam removal and decommissioning should be explored systematically throughout the range of the southwestern willow flycatcher. During this process, attention should be paid to effects of dam removal on the upstream as well as downstream riparian ecosystem, and an assessment should be made on a landscape or regional level of the overall net change in suitable habitat expected from dam removal. Many reservoir edges, because of the availability of water, fine sediments, and nutrients, support large patches of riparian habitat suitable for flycatchers and other wildlife. Much of this habitat is at risk or has been destroyed due to reservoir management for water supply or flood control, but additional losses could occur with dam removal. In other cases, flood-suppressing dams may stabilize habitat to some degree, perhaps locally buffering bird populations from the strong temporal fluctuations that may have characterized the pre-dam system. Assessments would be needed to determine whether habitat gains would compensate for habitat losses, were the dam to be removed.

If dams are to remain in place, there are ways to meet dual management goals of improving ecological integrity and maintaining the production of goods. Creative ways can be found to rehabilitate, if not fully restore below-dam ecosystems, while still allowing for municipal or agricultural water supply, hydropower, or flood control. Sediment and nutrients can be restored to some below-dam reaches by adding sediment bypass structures to dams (Schmidt et al. 1998). Riparian ecosystems on regulated rivers can be rehabilitated by naturalizing flows so as to mimic the natural hydrograph, or flow pattern, of the river. In arid parts of Australia and South Africa, there is growing recognition of the need to incorporate environmental flow requirements into river management plans (Arthington 1992). In Alberta, Canada, input from scientists and Environmental Advisory Committees has led to changes in the operation of dams (Rood et al. 1995, Rood et al. 1998, Mahoney and Rood 1998). The St. Mary and Oldman rivers, for example, are managed for delivery of summer irrigation water, and still flood fairly regularly during wet years. Rates of river meandering and channel realignment are relatively intact, and so too are the processes that create the "nursery bars" needed for germination of cottonwood (*Populus* spp.) seeds. Changes have been made, however, such that flood waters now recede slowly enough to allow for high survival of the seedlings; ecological models call for the stream stage to drop less than four cm per day, allowing the roots of cottonwood seedlings to keep in contact with moist soil. Another part of the agreement calls for an increase in summer base flow levels, thereby reducing the risk of tree death from drought. Operating agreements that address ecological concerns and restore 'environmental flows' should be incorporated into the management of dams that effect the habitat of the willow flycatcher throughout its range.

Large flows are released from many dams during occasional wet years, and the water often flows downstream in a fashion that does not optimize its environmental benefits. Sometimes, these releases fortuitously meet the regeneration needs of riparian plants. In 1992-93, for example, El Nino weather patterns assisted in the restoration of populations of cottonwood and willow (*Salix* spp.) trees along the lower Gila and Colorado, by filling reservoirs to levels that required large releases during winter and spring (Briggs and Cornelius 1998). With operating agreements in place, dam managers could be prepared in periodic wet years to intentionally release flows in ways that mimic the natural hydrograph and favor the establishment of native species adapted to the natural flow pattern. To keep the trees alive, 'maintenance' water sources would have to be secured. Certainly, the flood releases would not be essential every year. On unregulated rivers, cottonwood and willow recruitment flows occur only about once a decade or so (Mahoney and Rood 1998).

Along some dammed rivers, there are constraints on the degree to which the natural flood regime can be restored. The Bill Williams River in western Arizona is regulated by Alamo Dam, which was built to minimize flood pulses into the Colorado River. Over the past 25 years, the size and frequency of winter and summer flood peaks in the Bill Williams River have decreased, while base flows have increased. The U. S. Fish and Wildlife Service, Army Corps of Engineers, and university scientists have worked together to develop a flow-release plan that calls for high base flows and restoration of periodic flood (flushing) flows. The goals are to improve the quality of the riparian habitat in the below-dam wildlife refuge, while also maintaining recreational and wildlife benefits in Alamo Lake and flood control. However, there are constraints on the maximum flow release from the dam, that need to be addressed to allow for increased riparian restoration. Without the large scouring floods, rates of establishment of pioneering cottonwoods and willows are predicted to decline in the future, despite the release of appropriately timed spring flows (Shafroth 1999). Without the large floods to remove dead stems and woody debris, the dense post-dam vegetation (much of which is the exotic shrub tamarisk: *Tamarix ramosissima*) will remain susceptible to fire damage (see Appendix L).

There are other 'active' restoration measures that can mimic hydrogeomorphic processes and conditions at sites where these natural processes cannot be fully restored (Friedman et al. 1995). Flood pulses can be released through water control structures to small, cleared areas of the flood plain (Taylor and McDaniel 1998). Wet habitats can be created by excavating side channels or back-water depressions, and/or releasing water into off-channel sites, along rivers that no longer receive large, channel-moving floods (Ohmart et al. 1975, Schropp and Bakker 1998, Bays 1999). Low check dams can be constructed across channels, to locally concentrate sediments and nutrients and raise water tables to levels that support desired species. Such a structure (called a gradient restoration facility), with a fish apron, is planned to improve habitat for the willow flycatcher and endangered Rio Grande silvery minnow as part of the Bureau of Reclamation's Santa Ana project along the middle Rio Grande in New Mexico (Boelman et al. 1999). Additional research is needed to assess the efficacy of these and other rehabilitation approaches to restore desired conditions such as channel complexity, high water tables, or desired levels of fine sediments and nutrients in below-dam reaches.

Restoration efforts should strive to restore hydrogeomorphic conditions needed for more than just one or two of the many biotic elements in riparian ecosystems. It is impossible to manage directly for every single species in an ecosystem. We can, however, focus on a subset of species that we treat as indicators of intact physical processes (Lambeck 1997). We increase our odds of meeting the needs of more native species and providing sustainable ecosystem improvement if we take an ecosystem approach that accounts for natural cycles of disturbance, stream hydrology, and fluvial geomorphology (Bayley 1991, Stanford et al. 1996). This concept is exemplified in the case of the Truckee River in Nevada (Gourley 1997). Dams, channelization, and diversions of water from the Truckee have contributed to a loss of age class and structural diversity within the cottonwood forests and a collapse of native fish populations including the endangered cui-ui (*Chasmistes cujus*). To stimulate spawning of the fish populations , the U. S. Fish and Wildlife Service began managing Stampede Reservoir for spring flood release; an ancillary benefit was the establishment of cottonwood seedlings particularly in abandoned channels where the water table was close to the surface. The take-home message here is that "when restoring a basic ecosystem process, such as the natural flow regimes of the river, a whole array of ecosystem components may begin to recover" (Gourley 1997).

Water Quantities

Although stream water is fully-allocated and even over-allocated in parts of the arid Southwest, there are opportunities for restoring perennial flows and raising ground water levels in dewatered river reaches. Recycling of paper, plastic, and aluminum has become a way of life for many urbanites; if we approach municipal water the same way, we can create restoration opportunities by recycling treated municipal water back into river channels near to the point of initial diversion. Indeed, many cities are releasing their effluent directly into stream channels. At sites where the alluvial aquifer has not been depleted, the net result has been restoration or rehabilitation of large expanses of riparian vegetation. Below the 91st Avenue water treatment plant in Phoenix, Arizona, the channel of the Salt River is lined by herbaceous plants and young stands of cottonwoods, willows, and tamarisk trees. Vegetation extends across the wide flood plain, sustained by ground water that is recharged by effluent and agricultural return flows. Along the Santa Cruz River near Nogales, Arizona, cottonwood and willow forest ecosystems similarly have redeveloped as a consequence of the release of treated municipal wastewater to the dry river channel (Stromberg et al. 1993). Effluent also is released into the Tucson-reach of the Santa Cruz River. Due to long-term dewatering in the region, the stream flow is no longer hydraulically connected to the alluvial aquifer, thereby limiting the extent of the effluent-stimulated riparian corridor. Release of effluent from Lompoc, California into the mostly dewatered Santa Ynez River channel produced riparian habitat that was used by flycatchers for a number of years. There can be a short 'sacrifice zone' below the effluent-release point where poor water quality selects for a depauperate and pollution-tolerant aquatic biota, but the presence of a functional riparian and aquatic ecosystem can allow nutrient concentrations to return to ambient levels after a short distance (Stromberg et al. 1993).

Riparian vegetation also can be restored by recharging ground water into appropriate sites. Through water-banking, some of the Colorado River allocation of Arizona is recharged or “banked” in aquifers. In the arid Southwest, where open water evaporation rates exceed 2.7 m per year, aquifer recharge is a more viable and desirable method of water storage than storage in surface impoundments. At some sites, we can accomplish the dual goals of ground water recharge and riparian restoration. In a dewatered reach of the Agua Fria River below the New Waddell Dam in central Arizona, the shallow-bedrock layer would allow for re-establishment of extensive riparian forests, if Central Arizona Project water was released from the dam (Springer et al. 1999). The river corridor could be used as a conduit for water delivery to the recharge/ recovery zone, while also providing surface and ground water to sustain riparian vegetation. The total amount of water transpired by the vegetation would be less than the amount that presently evaporates from the reservoir. This and other such projects could restore diverse and productive riparian ecosystems to dry river reaches.

Agricultural return flows constitute another source of water for riparian restoration efforts. For example, agricultural return flows are being considered as a water source to maintain cottonwood-willow habitat in the Limnitrophe area of the Lower Colorado River, to allow for survivorship of plants that established after the 1992-93 winter floods (LCRBR 2000). Elsewhere in the lower Colorado River flood plain, agricultural return flows have been used to increase the survivorship of riparian trees and shrubs planted as part of revegetation efforts (Briggs and Cornelius 1998). Such efforts could be expanded. When using return flows to maintain or restore riparian habitat, it may be necessary to periodically flush the soils to reduce the concentrations of salts below the levels that are toxic to the desired species.

A recent decision in Pima County, Arizona allows the county to buy reclaimed water for riparian restoration projects. Projects that secure endorsement by the U.S. Fish and Wildlife Service will be eligible for a portion of a 5,000 acre-foot pool for each of the first five years of conservation efforts. A key question is, "where to utilize the water to maximize its habitat value?" Up-front regional planning efforts would be of great value in allowing Pima County and other groups to identify sites that would maximize the environmental benefits of reclaimed water. Planning efforts are needed throughout the flycatchers range to determine the best locations for effluent-based and groundwater-recharge-based riparian restoration efforts. Hydrogeologic studies can identify sites where shallow water tables exist or are likely to develop, and thus sites where phreatophytic riparian vegetation is likely to develop. Ecological studies can identify sites likely to have high wildlife value by virtue of traits such as proximity and connectivity to existing high quality patches of riparian vegetation. In some cases, it may make sense to release the reclaimed water closer to the aquifer-pumpage or stream-diversion sites, to reduce the length of the river that is dewatered.

Channel-Floodplain Connectivity

Riparian ecosystems can be restored or improved along some rivers by removing the physical barriers that separate a channel from its flood plain. Along the Colorado River, for example, there are opportunities to remove dikes and levees and restore some degree of channel-flood plain connectivity (LCRBR 2000). By allowing water to periodically flow onto the flood plain, one provides the input of water, and in some cases the nutrients, sediments, and plant propagules to sustain the productivity and diversity of the riparian forest. Small flood releases along the Rio Grande in New Mexico, although too small to serve as recruitment flows, have reconnected the floodplain vegetation with the river water and served to partially restore riverine functioning in cottonwood forests (Molles et al. 1998).

Integration of Natural and Managed Ecosystems

On flood plains managed for agriculture or as urban centers, there are some benefits to be had from restoring small patches of native riparian vegetation. Riparian forests restored to strips between agricultural fields, similar to the hedgerows used in Europe and elsewhere (Petit and Usher 1998), can provide services such as crop pollination and consumption of crop pests. We caution, however, that some of the restored riparian patches that are small and isolated might not be self-sustaining and might have adverse environmental effects on overall recovery efforts of the southwestern willow flycatcher or other riparian species. For example, riparian bird populations in small habitats might be populations sinks, producing a net-drain on an overall metapopulation. Such projects could draw water resources, funding and planning efforts from other project sites that have the potential for greater environmental benefit.

Watersheds

Full restoration of riparian ecosystems depends on restoration of hydrogeomorphic conditions and processes throughout the watershed. Long-term overgrazing and extensive urbanization have, in places, reduced plant cover and soil in the uplands. In many cases this has produced 'flashier' systems characterized by larger flood peaks and smaller base flows. In other areas, fire suppression has resulted in higher tree densities, higher transpiration rates, and smaller stream flows (Covington and Moore 1994, Covington et al. 1997). Watershed restoration will require a mix of passive measures, such as restoring natural fire regimes and grazing regimes, and active measures (see Appendices G and L). Controlled burns may be useful for restoring structure and function to upland forests. Check dams on tributaries may allow for more infiltration of water into the aquifers, thereby helping to sustain base flows year round while also reducing the frequency of catastrophic floods.

2. *Restoration of Animal Populations and Processes*

Ungulate Grazing

Just as it is important to restore the hydrogeomorphic regimes to which native riparian species are adapted, it also is important to maintain biotic interactions, such as herbivory, within evolved tolerance ranges. Herbivores exert strong selective pressure on plant species. Alteration of herbivore grazing patterns or grazing intensity selects for a different assemblage of plant species. In the past few centuries, cattle ranching has been a nearly ubiquitous influence, constituting a new and major stressor for riparian plant communities in the hot deserts of the U.S. Southwest. High intensities of grazing, from cattle or elk, similarly constitute a major stressor for riparian communities of higher elevations. Many adverse changes to riparian ecosystems have been documented as a result of overgrazing (GAO 1998, Belsky et al. 1999). Heavily grazed plant communities, more often than not, do not provide us with a wide range of desired functions and services (see Appendix G).

Will livestock exclusion restore riparian health? Natural recovery of some ecosystem elements after cattle exclusion can be slow and problematic, particularly on severely overgrazed sites or where there are ongoing stressors including improper livestock grazing elsewhere in the watershed (Kondolf 1993). For example, water tables that have been depressed as a result of livestock grazing may be slow to rise to desired levels (Dobkin et al. 1998). Sometimes, though, eliminating a stressor is all that is needed to enable natural recovery (Hobbs and Norton 1996). Removal of livestock or reductions of higher-than-typical populations of elk and deer can result in dramatic and rapid recovery of some elements of the riparian ecosystem, particularly where the ecosystem has not been degraded by other factors. Along the free-flowing upper San Pedro River in Arizona, exclusion of cattle (in tandem with other management restrictions) was followed by rapid channel narrowing and vegetative regrowth (Krueper 1992). New stands of cottonwood and willows and herbaceous plants developed in the wide, open stream banks, and songbird populations increased dramatically.

Elmore and Kauffman (1994) provide other examples of rapid recovery of riparian vegetation structure, diversity, or productivity after livestock exclusion. They indicate that recovery of stream features and woody and herbaceous vegetation is more rapid in response to livestock exclusion than to other types of riparian livestock management. If exclusion is accomplished through fences, the fences should be constructed to standards that allow for wildlife movement (Gutzwiller et al. 1997).

Can we manage for economically viable livestock grazing and riparian ecosystem health on the same parcel of land? There is some consensus that this compromise is best met by reducing the stocking rate rather than by imposing rest and rotation schemes (Holechek 1995). Restriction of grazing to certain seasons of the year can allow for recovery of certain components of the riparian ecosystem, but may not always provide for full recovery (Elmore and Kauffman 1994). Probabilities of achieving restoration success increased when there is coordination, communication, and goal-consensus among land managers throughout the watershed, such as has occurred in the Mary River watershed of Nevada (Gutzwiller et al. 1997).

Ungrazed reference allotments, located at a variety of elevations and in different geomorphic settings, can provide benchmark or reference sites against which to compare the condition or integrity of grazed allotments (Bock et al. 1993, Brinson and Rheinhardt 1996). Ideally, the ungrazed areas should encompass entire watersheds. Monitoring efforts in grazed and ungrazed sites should focus on a wide variety of measures of ecosystem integrity, such as herbaceous plant cover and composition, woody plant growth, establishment rate, and structure, and stream channel morphology, in addition to traditional range measures such as utilization rates (Ohmart 1986). Monitoring of the reference sites can help to identify factors responsible for riparian ecosystem changes, and to separate the effects of weather from land use. In the past few decades, for example the Sonoran Desert has been wetter-than-normal (Swetnam and Betancourt 1998), and conditions have been favorable for regeneration of many pioneer riparian trees including cottonwoods, willows, and sycamores (*Plantanus* spp.) (Stromberg 1998). Without ungrazed reference sites, it is difficult to determine if changes such as increased willow regeneration or increased bird populations are due to land use change or weather change.

Keystone Species

Reintroduction of missing or extirpated keystone species, such as beaver, can be an effective restoration tool in some areas. Beaver are considered to be a keystone species in riparian ecosystems because of the extent to which they modify local hydrology, stream geomorphology, and habitat conditions for plants and animals. Dams built by beavers serve to raise ground water levels, minimize seasonal variations in surface and ground water levels, and expand the areas of the flood plain and channel inundated by shallow water, all of which enhance habitat suitability for southwestern willow flycatchers (see Habitat Paper) and other wildlife. Because of the flashy, highly variable nature of stream flow in the arid Southwest, these changes increase habitat for hydrophytic, wetland vegetation and promote shifts in vegetative communities from facultative to obligate wetland species. Unlike large dams constructed by humans, the beaver dams tend to be short-lived and do not impede the flows of flood-borne sediments and propagules.

The combined effect of beaver activities serves to create a more heterogeneous flood plain. The felling of trees, building of dams and lodges, and impoundment of water create a diverse mosaic of habitat patches, such as open ponded water, marshland, and various types of forested swamps. Habitat can be created for the many threatened and endangered aquatic and wetland species that depend on slow-moving, nutrient-rich waters. There is a need, however, for additional scientific study of the effects of beaver on arid region riparian ecosystems (Naiman and Rogers 1997).

Prior to reintroducing beaver, one should assess site conditions to insure that the habitat and food supply are suitable. As with other natural forces such as floods, beavers can be problematic and cause further loss of quality at degraded sites. For example, if preferred food sources such as cattails (*Typha domingensis*) are sparse as a result of stream dewatering, beaver may be forced to feed heavily on cottonwoods and willows. The net effect can be further reduction in site quality. Restoration actions could be undertaken at degraded sites to improve them to a level that would enable beaver to exert positive effects.

3. *Restoration of Plants and Fungi*

Restoration Plantings

Opportunities exist to restore integrity to riparian ecosystems in the U.S. Southwest by re-establishing riparian vegetation, including cottonwood-willow forests and shrublands, to sites where it has been eliminated. Such sites include abandoned or retired agricultural fields, burned sites, or sites from which exotic plants have been removed. These efforts can augment the amount and structural complexity of habitat available to animal populations, and generally enhance ecological diversity. Before forging ahead with plantings, the potential restoration sites should be assessed for limiting factors including ground water depth, soil texture, and salinity; for the potential to alleviate intolerant conditions; and for the potential to manage the river to allow for natural plant establishment processes.

A decade or so ago in the U.S. Southwest, 'riparian restoration' was synonymous with 'cottonwood pole planting'. Not long after, the idea that riparian habitat could be created through plantings of native trees and shrubs took hold in southern California, where it has been used extensively to produce habitat for the endangered least Bell's vireo (*Vireo bellii pusillus*). While several sites have been successfully colonized by nesting vireos within 3-5 years of planting (Kus 1998), we have concerns regarding the self-sustainability and long-term value of planted sites to vireos and other riparian species. These concerns center on the fact that many planted sites are isolated from the river channel. They are not subject to the natural processes, such as flooding, which influence plant establishment as well as other ecosystem processes such as maintenance of bioproductivity of mature trees (Stromberg 2000).

Planted cottonwoods and willows often die, because water tables are too deep or too variable, or because the soils at the restoration site are too salty (Anderson 1998). In cases where the plantings are isolated from the ground water table, water is supplied through irrigation. Long-term watering commitments often are not met, and the increased water needs of the rapidly growing plants are not always taken into account, sometimes resulting in plant death. These experiences have taught us that planting is most successful as a restoration tool only if accompanied by other actions, i.e., if the root causes of the absence or scarcity of the native species are addressed (Briggs 1996). If the plants do survive, but we do not alter river management, the net effect often is the restoration of a single age class rather than restoration of a dynamic, multi-aged population. Nonetheless, such measures can constitute an important stop-gap measure to restore forest structure and bird communities as we also work towards longer-term and more sustainable solutions (Farley et al. 1994).

To attain the greatest ecological benefits, we propose the following hierarchy, with respect to establishment of desired native plant species such as cottonwoods and willows: (1) Where possible, fully restore natural processes by removing the management stressors that restrict riparian plant establishment; (2) Next best, modify the management stressors, by naturalizing flow regimes or modifying grazing regimes to allow for natural plant establishment. If a water source can be manipulated on the flood plain, use techniques such as 'wet soil management' combined with seeding to allow for natural seedling establishment; (3) Plant nursery grown plants or cuttings (e.g., pole plantings) if the above options are not available, or if there is a need to achieve more rapid results.

In cases where the natural processes that allow for plant establishment can not be restored, care should be taken to monitor and document the success of the restoration plantings. Along the Sacramento River in California, where there are societal constraints on river flooding, various species of willow, cottonwood and other woody plants were planted on sites that were considered suitable based on criteria including depth to ground water and proximity to existing riparian forest (Alpert et al. 1999). Analysis of survivorship patterns provided information of use to future projects, such as finding greater plant survivorship on sites with fine-grained vs. coarse-grained soils.

Where local seed sources are sparse, seeding or planting is necessary to achieve restoration success or hasten recovery in response to removal of stressors. On the Owens River in California, physical integrity was restored when stream flows were released back into the river (Hill and Platts 1998). Few trees had survived the long-term dewatering, however, so seed sources were in short supply. Cottonwood seeds were collected from other river sites and released into the Owens River gorge at an appropriate time in spring. Such natural seeding is preferable to plantings of poles, cuttings, or nursery-grown seedlings, because it typically allows for greater genetic diversity within the plant population and allows for selection at the seedling-stage for plants adapted to the local conditions. Seeds collected for sowing should consist of a genetically diverse mix obtained from the local area.

We need to remind ourselves, periodically, of the biological complexity of riparian corridors. The lower Rio Grande Valley has about 1000 native vascular plant species (Vora 1992). Cottonwood-willow streams in Arizona support several hundred plant species, the relative abundance of which changes from year to year depending, in part, on rainfall and flooding patterns (Wolden and Stromberg 1997). These diverse plant communities have many functions, including sustaining a diverse insect community and thus a rich food base for insectivorous birds. There have been many efforts to plant the woody dominants of riparian forests, including Fremont cottonwood (*Populus fremontii*), Goodding willow (*Salix gooddingii*), mesquite (*Prosopis* spp.), and quailbush (*Atriplex lentiformis*), as well as efforts to plant herbaceous species. It is a daunting task to attempt to restore hundreds of species through direct plantings or seedings (Vora 1992). Donor seed banks is a technique that may serve to restore some of this biodiversity to degraded sites. A soil seed bank is defined as a soil's reserve of viable, ungerminated seeds. Donor soils have been obtained from high-integrity reference ecosystems to restore biodiversity to various types of degraded or newly created wetlands (Brown and Bedford 1997, Burke 1997). Seeds of woody riparian dominants generally are not present in the seed bank, but many of the annual plants and herbaceous perennials form persistent or at least transient seed banks. Before adopting the donor soil approach, additional studies are needed to identify which species, and how many species, are present in the seed bank of possible donor sites.

Exotic Plant Species

Exotic species (those that have been introduced accidentally or intentionally by humans to a new ecosystem) pose a definite challenge to riparian restorationists. There are hundreds of exotic plant species that have become naturalized in riparian corridors. A small percentage of these have become management issues due to their prevalence, negative influences on the ecosystem, or inability to completely mimic the functions of displaced natives (see Appendix H).

In many cases, removal of exotics is an effective restoration strategy only if part of a larger plan that includes restoration of processes and conditions (but see Barrows 1998). We need to ask, "is the exotic the cause of degradation, a symptom of degradation, or both"? Often, the abundance of riparian exotics is one symptom or facet of a complex, systemic resource allocation problem. If we don't address the root causes of degradation that led to the loss of the native species, there is a risk that traditional control measures, such as herbicides and biocontrol insects, could worsen the situation by resulting in replacement vegetation of lower quality (Anderson 1998). Additional studies are needed on a river by river basis, to identify the stressors on the native vegetation and assess the ability for re-establishment of natives, under scenarios of exotic-removal with and without active changes in river and land management.

Restoring natural processes and removing stressors, and then stepping back, can be an effective strategy for restoring native riparian species to some exotic-dominated sites. Theoretically, by restoring natural flow regimes and herbivory patterns, we can tip the ecological balance in favor of the native species (Poff et al. 1997). The middle San Pedro River provides an interesting case study of natural recovery (Stromberg 1998). Stream flows in the San Pedro vary from perennial to ephemeral depending on local geology, tributary inputs, and the extent of local and regional groundwater pumping. Tamarisks dominate in the reaches with ephemeral flow and deep water tables, but grow intermixed with cottonwoods in the wetter reaches. In these perennial reaches, cottonwoods have been increasing in abundance relative to tamarisk in the past decade. During this time period, livestock have been removed from the sites, groundwater pumping has been reduced immediately upstream, and spring flows have been high. Under these conditions, cottonwoods apparently can outcompete tamarisks. Also necessary to the recovery were several winter/spring floods that created opportunities for species replacement. Without suitable control sites, however, it is difficult to determine the relative influence of weather and management actions on the vegetation change. Again, we stress the need for additional studies that assess the potential for natural recovery of native species to exotic dominated sites, upon removal of stressors and/or removal of the exotic species.

Populations of some exotic species can persist for a long time after removal of the disturbance factor(s) that facilitated their invasion. They may produce self-favoring conditions (e.g., tamarisk promote fire cycles that they can withstand more easily than can many native species), or may simply have a long life span. In such cases, there is a need to manually remove the exotics before, coincidental with, or even after the implementation of other restoration measures. In some cases, removal of the exotic species may be all that is needed to allow for restoration of the native community. In others, it is important to obtain a firm commitment to naturalize processes before proceeding attempting to expedite recovery of the natives by mechanically removing the exotics.

At the Bosque del Apache Wildlife Refuge, as on much of New Mexico's highly regulated Rio Grande, tamarisk has become the dominant plant species. Lowered water tables, increased river salinity, and lack of winter/spring floods for several decades have all contributed to a declining cottonwood forest, while past flood plain clearing and at least one appropriately timed summer flood allowed for the influx of tamarisk (Everitt 1998). To restore the site, managers of the Refuge have mimicked the effects of large floods by using bulldozers, herbicides, and fire to clear the extensive stands of tamarisk at a cost of from $750 to $1,300 per hectare (Taylor and McDaniel 1998). They then released water onto the bare flood plains in spring with a seasonal timing that mimicked the natural flood hydrograph of the Rio Grande. This allowed for the establishment of a diverse assemblage of native and exotic plants. Long-term monitoring will be required to determine whether the multi-level canopy, diversity of vegetation structure, and diversity of insect life provided by the riparian assemblage provides superior wildlife habitat to the tamarisk thickets that existed before. Tamarisk clearing was essential, but it is the appropriate timing and quantity of water flows that will drive the system toward an increasingly native composition. This type of 'wet soil management' also can be used on other bare sites, such as abandoned agricultural fields.

Team Arundo in California (http://www.ceres.ca.gov/tadn/index.html) is another example of a program implementing mechanical means to remove exotics. In this case, they are removing giant reed (*Arundo donax*), from rivers into which it was introduced decades ago. Giant reed, an aggressive rhizomatous weed, spreads rapidly through drainages, and appears to thrive under a wide range of hydrologic conditions. It produces dense stands that are used by few native birds. Using a combination of herbicides, burning, and manual clearing, Team Arundo designs and coordinates efforts to eradicate giant reed while simultaneously promoting public awareness of the problem and the need to prevent future introductions stemming from the use of giant reed as a landscaping plant.

Fungi

Soil fungi are an important, but often overlooked, component of riparian ecosystems. Many human actions that affect soils, such as various agricultural practices, can deplete populations of mycorrhizal fungi. Re-introduction of mycorrhizal inoculum may improve the chances of restoration success on the many abandoned agricultural fields that line arid-region rivers. There is evidence that growth and survival of giant sacaton (*Sporobolus wrightii*), a plant that once dominated flood plains of many rivers in the U.S. Southwest, is improved on abandoned fields by the addition of mycorrhizal inoculum (Spakes, unpubl. data). Additional research is needed to determine the functional relationships between fungi and other riparian plant species, and to assess the need for restoration of mycorrhizal fungi in a variety of riparian settings.

C. Restoration as Mitigation

The resiliency of riparian vegetation and the relative ease with which the structural dominants can become established under proper conditions has prompted interest in the use of habitat restoration to mitigate the loss of endangered species habitat accompanying otherwise legal and permitted activities. For example, in southern California, habitat restoration is a typical form of mitigation for actions that adversely affect habitat of the least Bell's vireo. The nature of the restoration varies from removing exotics from stands of native vegetation to the more commonly required creation of habitat through planting of cuttings or nursery stock. The success of created habitat in attracting nesting vireos (Kus 1998) and thus achieving mitigation goals, coupled with the fact that least Bell's vireos and southwestern willow flycatchers share the same habitat where their ranges overlap, offers a tempting rationale for applying this approach to flycatcher recovery. We advise caution in yielding to this temptation too quickly. We have little confidence that efforts to enhance or create habitat in the absence of treating root causes and restoring proper physical conditions will be successful. Restoration ecology is a young science, and we do not know yet whether our attempts to create habitat will yield functioning, self-sustaining ecosystems that support the full complement of species we seek to protect (Williams 1993, Goodwin et al. 1997). Failure in either of these regards will result in a net loss of riparian habitat, and does not constitute mitigation.

Given this, we recommend that restoration performed within the context of mitigation be carefully designed, implemented, and monitored (Kondolf 1995, Michener 1997). Below, we list some considerations to maximize the potential for success of the mitigation, and minimize risks to the flycatcher:

1. "Up-front" mitigation (mitigation achieved prior to destruction/degradation of habitat) is preferable to mitigation concurrent with habitat loss because it avoids even a temporary net loss of habitat, and increases the probability that the mitigation has been successfully achieved.

2. Mitigation plans should include the following:

a) *Goal*: The goal of the restoration must be clearly stated, as it sets the stage for the other elements of the plan. Examples include 1) to provide suitable habitat for willow flycatchers, 2) to provide habitat supporting nesting willow flycatchers, 3) to remove exotics and restore dominance to native vegetation, 4) to restore a more natural flooding regime, 5) to achieve a self-sustaining ecosystem. There are many other potential goals that could be specified; the important point is that a goal must be explicitly identified in order to establish relevant criteria by which the success of the restoration can be measured.

b) *Model:* A model provides a picture of what the restored habitat should look like and how it should function, with little or no further human intervention. It should be based on a natural, functioning system that the restoration is attempting to mimic (White and Walker 1997). A model of the desired conditions is necessary to design appropriate restoration and to provide a basis from which quantitative performance criteria can be developed (Baird 1989, Baird and Rieger 1989, Kus 1998).

c) *Performance criteria*: These criteria constitute the yardstick by which success of the mitigation will be evaluated. They must be quantifiable, and pertinent to the overall goal (National Research Council 1992, Kentula et al. 1993, Hauer and Smith 1998). For example, success criteria for the above goals might include 1) production of habitat with the following habitat characteristics (e.g., vegetation volume >x, perennial water present), or, alternatively, the following bird community (enumerate), 2) the presence of x nesting pairs of flycatchers, 3) cover of natives between x and y percent, 4) the occurrence of winter and spring floods with the following characteristics (enumerate), and 5) vegetation or bird goals met with no human intervention required. It is imperative that these criteria not be subjective (e.g., based on "how the site looks"). In instances where some level of maintenance is involved in establishing the site or modifying conditions (e.g., irrigation of plantings, weeding, etc.), the maintenance should have ceased for a specified period prior to final site evaluation.

d) *Monitoring plan*: A detailed plan for collecting and analyzing data on the project's performance is necessary to ensure that it will adequately monitor progress towards success, and reveal the need for remedial action when appropriate. The period of time over which monitoring is required should be long enough to have a high probability of capturing temporal variability in the events or processes being monitored. Adaptive management should be built-in to the plan: mechanisms should be in place to trigger alternate restoration approaches or require restoration of additional habitat should the current effort fail to achieve its goals and/or be functioning at lower levels than reference sites (Hauer and Smith 1998).

3. The greatest potential for successful mitigation occurs when the physical processes required for long-term site maintenance are present or restored. Projects proposing short-term approaches, such as riparian vegetation dependent on irrigation, independent of attention to intrinsic factors related to habitat maintenance should receive low priority as candidates for mitigation.

D. Closing Words

Habitat restoration has the potential to greatly improve the suitability of existing willow flycatcher habitat, and provide additional habitat for population expansion. We encourage scientists, managers, and others interested and involved in restoration to be creative in developing new approaches, adopting an experimental framework and to share results, even if they include failures. Only from an extensive and shared knowledge base can we avoid repeating the mistakes of the past and move towards a more desirable future.

E. Specific Recommendations

To allow for full ecological restoration, we recommend these general guidelines:

(1) Restore the diversity of fluvial processes, such as movement of channels, deposition of alluvial sediments, and erosion of aggraded flood plains, that allow a diverse assemblage of native plants to co-exist.

(2) Restore necessary hydrogeomorphic elements, notably shallow water tables and flows of water, sediments, and nutrients, consistent with the natural flow regime.

(3) Restore biotic interactions, such as livestock herbivory, within evolved tolerance ranges of the native riparian plant species.

(4) Re-introduce extirpated, keystone animal species, such as beaver, to sites within their historic range.

We recognize that the potential for restoration success varies among sites with many physical, biological, and societal factors. Where possible:

(1) Fully restore these natural processes and elements by removing management stressors.

(2) Next best, modify the management stressors, by naturalizing flow regimes, modifying grazing regimes, removing exotic species, or removing barriers between channels and flood plains, for example, to allow for natural recovery.

(3) Take over processes such as plant establishment (e.g., nursery stock plantings) only if the above options are not available.

Some additional general recommendations:

(1) Focus restoration efforts at sites with the conditions necessary to support self-sustaining ecosystems, and at sites that are connected or near to existing high quality riparian sites.

(2) Develop restoration plans that encompass goals, models, performance criteria, and monitoring.

(3) If mitigation is required, call for "up-front" mitigation (mitigation achieved prior to destruction/degradation of habitat).

Some specific recommendations dealing with water and channel management:

(1) Conduct regional planning to identify sites most suitable for riparian restoration upon the release of reclaimed water (effluent), ground water recharge, or agricultural return flows.

(2) Conduct regional assessments to determine the merits of dam removal as a riparian ecosystem restoration strategy.

(3) Secure operating agreements for dams that incorporate environmental flows, for example to allow for tree and shrub regeneration flows during wet years and maintenance (survivorship) flows at other times.

(4) Pursue options for restoring sediment flows to below dam reaches.

(5) Secure operating agreements to manage reservoir drawdowns in such a way as to allow for regeneration of desired plant species.

(6) Develop water use management plans for river basins that will sustain or restore shallow ground water tables and perennial stream flows.

(7) At appropriate sites, remove barriers that reduce the connectivity between channels and floodplains.

Some specific recommendations dealing with land management:

(1) Within grazed watersheds, coordinate and communicate to establish goal-consensus among land managers and to achieve grazing levels compatible with riparian restoration.

(2) Establish a series of livestock exclosures that encompass riparian lands and/or watersheds, to provide benchmarks against which sites managed for livestock production can be compared.

(3) Monitor reference sites and grazed sites for a wide variety of measures of ecosystem integrity, including stream channel morphology and plant cover, composition, and structure, in addition to direct measures of plant utilization.

F. Literature Cited

Please see Recovery Plan Section VI.