Evaluating Degraded Riparian Ecosystems to Determine the Potential Effectiveness of Revegetation

Mark Briggs

Abstract—Revegetation is often limited in its ability to improve the condition of degraded riparian ecosystems. In some cases, revegetation was implemented in riparian areas that were fully capable of coming back naturally. In other instances, plantings were placed in riparian sites where they could not survive.

To use riparian revegetation most effectively, the causes of site decline and the current ecological condition of the site need to be understood. This can best be accomplished by evaluating the condition of the degraded riparian ecosystem from a watershed perspective that takes into consideration how perturbations in surrounding ecosystems may be affecting site conditions.

Riparian ecosystems are declining throughout the Southwest; many have disappeared completely. The rapid decline of these valuable ecosystems has made riparian conservation a focal issue for many federal, state, and private organizations. Nevertheless, progress toward checking the decline of riparian ecosystems has been marginal. This is due, in part, to the fact that the "science" of repairing damaged riparian ecosystems is relatively young, and some of the fundamental questions on riparian ecosystem processes and how human activities are affecting the ecological condition of riparian areas are still being investigated. In addition, the results of only a relatively small number of riparian mitigation efforts have been evaluated for the benefit of future projects (mitigation is defined here as any project that is performed to improve the ecological condition of an area.) Consequently, we have learned only marginally from past mitigation efforts and are just beginning to understand how to effectively repair degraded riparian ecosystems.

The objective of this paper is to discuss the limitations of using revegetation to improve the condition of degraded riparian ecosystems. This paper also reviews riparian site characteristics that play a significant role in determining the effectiveness of riparian revegetation to improve the condition of degraded riparian ecosystems in arid environments. These issues are discussed in greater detail in a guidebook—Repairing Degraded Riparian Ecosystems—being prepared by the Rincon Institute in cooperation with the University of Arizona, Arizona Game & Fish Department, U.S. Fish and Wildlife Service, and other agencies. The guidebook also reviews approaches to evaluating degraded riparian ecosystems so that effective mitigation strategies can be developed.

The information presented in this paper is based on the results of two studies on improving the condition of degraded riparian ecosystems. The first study was funded by the U.S. Fish and Wildlife Service, and evaluated the results of 25 riparian revegetation projects and two alternative mitigations in Arizona (Briggs 1992). The second study, funded by World Wildlife Fund, investigated methods for evaluating the condition of degraded riparian ecosystems so that the potential effectiveness of revegetation can be determined (Briggs 1993).

Riparian Revegetation

Riparian revegetation (planting trees, shrubs, forbs, and grasses to replace lost vegetation) is probably the most widely used of the strategies that have been employed to repair degraded riparian ecosystems. Revegetation has been used to improve degraded riparian conditions along many of the major drainageways in the southwestern United States, including the Colorado River, Santa Cruz River, Gila River, and the Rio Grande. When used in appropriate situations, revegetation can produce dramatic results by helping to replace lost riparian vegetation and stabilize deteriorating conditions, thereby initiating recovery of the ecosystem (Maddock 1976; Miller and Borland 1963; Porter and Silberberger 1961).

The Limitations of Riparian Revegetation

Despite the wide use of revegetation, results are often marginal. In many cases, revegetation could have been used more effectively in other locations, or other mitigation strategies should have been used instead of revegetation (Briggs 1992).

Although 19 out of 27 riparian revegetation projects evaluated by Briggs (1992) achieved their objectives, most did so despite low survival rates of planted vegetation. Out of this group of projects, almost a third experienced natural regeneration so prolific that plantings were completely obscured by regrowth, while over one-half of the projects experienced less than 20% survival of the vegetation that was planted (Fig. 1). Many of the revegetation projects that did achieve their objectives did so primarily by using mitigation techniques that addressed the causes of site degradation, while others succeeded because of prolific natural regeneration at the site (Briggs 1992).

One of the principal reasons why riparian revegetation often produces only marginal results is that the factors

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Mark Briggs is the Director of Research at the Rincon Institute, 6842 E. Tanque Verde Rd, Tucson, AZ 85716.

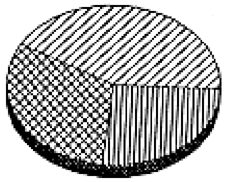

Figure 1—Classification of successful projects by percent survival of artificially-planted vegetation for 19 riparian sites in Arizona.

responsible for the initial degradation of the site often hamper or prevent establishment of artificially planted vegetation as well. In a group of successful riparian revegetation projects evaluated by Briggs (1992), the majority addressed the causes of site degradation (either indirectly or directly) by including secondary mitigation such as bank stabilization structures, check dams, irrigation, and/or improved land management strategies in their overall project design. The ability of these secondary mitigations to overcome the causes of site degradation appeared to have a more significant impact on the overall results of the projects than did revegetation.

Determining the Causes of Riparian Decline from a Watershed Perspective

One of the most important lessons learned from the experiences of past riparian mitigation efforts is the importance of evaluating site conditions to identify the causes of degradation (Briggs 1992). Only after the causes of degradation are identified can mitigation strategies be developed that will directly address the causes, not just the symptoms, of degradation. Evaluating site conditions will provide the information needed to better understand the potential effectiveness of revegetation to improve degraded riparian conditions.

Evaluating only isolated components of a watershed (e.g., a specific stream reach) will be ecologically incomplete and will often fail to provide the information needed to fully understand why the riparian ecosystem has become degraded. Therefore, evaluating degraded riparian ecosystems from a watershed perspective can determine the success of mitigation efforts. More than any other type of ecosystem, the structure and processes of lotic ecosystems are determined by their connection with adjacent ecosystems (Gregory and others 1991). (Lotic environments are areas, such as rivers and streams, that are influenced by running water that is unidirectional; these environments therefore differ from lakes and oceans which are characterized by water flow in more than one direction.) A disturbance in any part of a watershed will create disequilibrium that will be felt through rippling effects by many ecosystems within the watershed. Since riparian ecosystems are in the bottomlands of a watershed, changes in the way that sediment and water run off of surrounding lands impact them most. Riparian ecosystems are affected by perturbations (e.g., timber harvesting, livestock grazing, urbanization, etc.) along upstream and downstream reaches, tributaries, and surrounding uplands.

Resource managers must therefore avoid the myopic approach of developing mitigation strategies that are based solely on an evaluation of the immediate degraded riparian site. It is likely that mitigation based on such a narrow evaluation will not be very effective because the factors that initially caused degradation may continue to affect the site. The evaluation process should include a significant amount of the riparian ecosystem's watershed, taking into consideration the condition of surrounding uplands, upstream and downstream reaches, and tributaries.

The evaluation process should also be broadened from a time perspective. Broadening one's time frame from the present to include historical information may significantly help to determine the extent to which a riparian area has changed, the reasons for the change, and the types of mitigation strategies that may be effective in improving the condition of a degraded ecosystem.

Determining the Potential Effectiveness of Riparian Revegetation

Riparian revegetation is most effectively used in sites where conditions will allow plantings to survive and where natural regrowth will not overrun plantings after they have established. Four site characteristics play a particularly important role in determining whether or not plantings will survive: water availability, channel stability, intensity of direct impacts, and soil salinity. The role that natural regeneration and the above four factors play in determining the potential effectiveness of riparian revegetation is discussed below.

Natural Regeneration

Riparian revegetation is used most effectively in riparian areas that are not likely to experience natural regrowth. This does not imply that natural regeneration is a negative result. On the contrary, natural regeneration is often the restorationist's strongest ally, and fostering natural regrowth should be the aim of most riparian mitigations. The extent and rapidity of natural recovery can be a "concern" when revegetation is being considered as a way of improving the condition of a degraded riparian area. Riparian revegetation can be misused when the area is fully capable of coming back naturally.

The results of several riparian revegetation projects indicate that in some situations natural regeneration can meet or exceed the revegetation objectives established by resource managers. In short, natural regeneration occurred so strongly at some sites that, after a number of years, the manager's careful plantings and site manipulations became difficult or impossible to locate.

Revegetation projects that experienced prolific natural regeneration were not unique. All told, 32% of the successful riparian revegetation sites evaluated by Briggs (1992) experienced prolific natural regeneration that completely obscured the results of artificial planting efforts. It is therefore important for resource managers to recognize the potential for dramatic natural regeneration in riparian ecosystems and consider the possibility that artificial revegetation may not be necessary.

This point is valid even if a riparian site is characterized by low diversity and volume of vegetation. The health of a riparian ecosystem should not be determined solely by changes in vegetation components. A riparian ecosystem may be "healthy" even if it is characterized by low vegetation density, diversity, and volume, as long as all the components required for natural regeneration are intact.

Of the numerous factors that determine natural regeneration in riparian ecosystems, there are a few that appear to have an overriding role in determining the extent, location, and timing of natural regeneration. Of the revegetation sites evaluated by Briggs (1992), those that experienced prolific natural regeneration had three characteristics in common:

1. Riparian sites were not characterized by a decline in groundwater, channel instability, high soil salinity, or a high frequency of direct impacts. These four factors are the same factors that play an important role in determining the effectiveness of riparian revegetation. This should not be surprising. Whether a plant is placed in the ground naturally or artificially, the likelihood that it will establish and survive is determined by many of the same factors;
2. Seed sources were located in or near the riparian sites; and,
3. The majority of sites experienced large flood events. Large flood events (floods large enough in magnitude to remove streamside vegetation and rework and deposit alluvium on upper flood plain surfaces) produce the site conditions suitable for natural establishment of many riparian species.

Water Availability

In arid climates, the amount of water that is available for plant use is probably the single most important characteristic for determining where phreatophytes can establish. Riparian vegetation communities are commonly composed of phreatophytes that exist only in areas where they can develop root systems to saturated soils (Campbell and Green 1968; Stromberg and others 1992). Groundwater conditions therefore play an important role in determining how much water is available for phreatophytes.

The riparian water table is the primary source of water for most phreatophyte trees (Busch and others 1992), and when the water table drops below the root zone it becomes very difficult for these species to survive (Fenner and others 1984; McBride and Strahan 1984). Many phreatophytes develop relatively shallow root systems that often spread out great distances laterally, but frequently do not penetrate more than 3 m below the soil surface.

This characteristic makes riparian species vulnerable to changes in subsurface water. Not only does water have to be available in the shallow subsurface for phreatophytes to survive, but flood plain areas also must be inundated for certain periods of the year to produce moisture conditions necessary for germination and seedling establishment (Fenner and others 1984; Stromberg and others 1991).

Just as groundwater decline can affect the overall health of riparian ecosystems, a decline in groundwater can also have a tremendous influence on the effectiveness of artificial revegetation. Artificially planted phreatophytes will not survive if their root systems cannot reach the water table. Over 80% of the unsuccessful revegetation projects evaluated by Briggs (1992) experienced low survival rates of planted vegetation (0% in some cases) due to low water availability. For the purposes of this paper, areas described as having low water availability are those areas where the saturated part of the soil profile frequently drops to 3 meters or more beneath the soil surface.

Determining the current depth to groundwater is therefore an important step for understanding the potential effectiveness of riparian revegetation. Comparing current groundwater conditions in degraded riparian areas to past groundwater conditions will provide resource managers with a good sense of groundwater stability, and how and to what extent groundwater characteristics have changed.

If information describing the current condition of groundwater in the degraded riparian ecosystem is insufficient, resource managers will need to collect their own hydrogeologic data. A description of current groundwater conditions should include depth to groundwater, how depth to groundwater varies within the revegetation site, and how groundwater conditions vary throughout the year. Such information will allow resource managers to choose vegetation species, plan irrigation schedules, and develop planting designs tailored to the specific area, greatly improving overall effectiveness of revegetation.

Channel Stability

Including the drainageway that passes through the degraded riparian ecosystem in the evaluation process is integral to understanding the condition of bordering vegetation communities. Here the focus turns to issues associated with repairing riparian ecosystems bordering unconfined alluvial stream channels, particularly methods for evaluating their general stability.

Revegetating near unconfined alluvial channels is inherently risky because there is often a fine line between planting in areas that are too dry and planting in areas that are too unstable. Even when these channels are "stable," they are still prone to dynamic changes that can affect the results of revegetation (or any other type of mitigation, for that matter).

Reichenbacher (1984) described riparian communities as a continuum. The continuum is most unstable closest to the stream channel where floods are common, and most stable in areas further removed from the stream channel (e.g., flood plain terraces) where flood disturbances are relatively infrequent. Planting further away from the channel may provide the newly planted vegetation with the stability it needs to establish and grow. However, increased distance from the stream channel is often accompanied by increased depth to the riparian water table. This may produce a dilemma for revegetation planners, particularly if phreatophytes are being used in the revegetation project (Fig. 2).

Channels that have incised into their beds epitomize this dilemma. In such a situation, revegetation may be limited to two choices: planting in a narrow and deep channel, where vegetation can be removed by even minimal flow events, or planting on abandoned terraces, where water availability can be greatly reduced.

When an unconfined alluvial channel falls out of equilibrium and becomes unstable, it can alter its dimensions (e.g., channel width) quite rapidly (Schumm and others 1984; Wallace and Lane 1976). In general, revegetating near alluvial stream channels that are characterized by instability should be avoided because abrupt changes in channel dimensions can be disastrous to streamside revegetation projects.

Emphasized throughout this paper is the concept of evaluating degraded riparian ecosystems from a watershed perspective that includes upstream and downstream reaches, tributaries, and surrounding uplands. This broad evaluation approach is especially relevant to evaluating drainageway stability. The reach of the drainageway that passes through the degraded riparian ecosystem cannot be evaluated in isolation from the rest of the drainage system. Instability along one part of the drainage system can spread to other areas as the various reaches attempt to reestablish stability. This means that channel reaches not characterized by obvious signs of instability at the time of revegetation can exhibit unstable characteristics years after rehabilitation work is completed as a result of disturbances in other parts of the drainage system. For example, Schumm and others (1984) cautioned that renewed instability can quickly return to a channel reach if downstream nickpoints are present. Nickpoints downstream from a revegetation site can work their way upstream during succeeding years, ultimately affecting site stability and the effectiveness of revegetation.

A broad evaluation approach will more accurately define the causes of degradation and trends in channel stability. Such an understanding will allow resource managers to better predict the direction, type, and magnitude of channel adjustment so that mitigation strategies will work in harmony with natural stream processes, rather than against them (Brookes 1985; Harvey and Watson 1986; Heede 1981; Keller and Brookes 1984; Leopold 1977; and Schumm and others 1984).

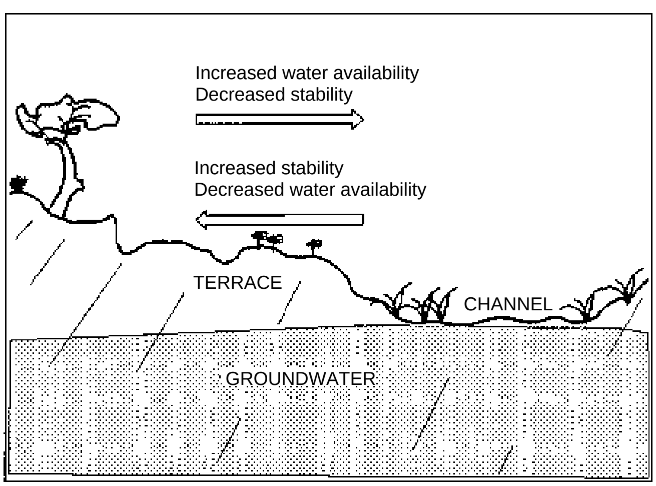

Figure 2—A riparian revegetation dilemma. Increased water availability often means decreased stability for planted vegetation.

Direct Impacts

Land use activities can affect the ecological condition of riparian ecosystems both directly and indirectly. Direct impacts are the results of those activities that occur in the immediate riparian ecosystem. Common examples of activities that directly impact riparian ecosystems are removal of riparian vegetation (e.g., to make way for urban or agricultural expansion), livestock grazing, and recreational activities. Indirect impacts result from activities occurring outside the immediate riparian ecosystem. Activities on remote parts of the watershed, such as timber harvesting and urbanization, can indirectly impact bottomland ecosystems by altering the way sediment and water run off of upper watershed surfaces.

It is important to evaluate how land use activities are affecting the condition of a riparian site before using revegetation. Two of the more common direct impacts on wildland riparian ecosystems are the results of livestock grazing and recreation activities. Competition from nonnative vegetation species and wildlife activities can also directly impact the results of revegetation and should also be considered before planting vegetation in riparian ecosystems.

Soil Salinity

High soil salinity affected the results of several riparian revegetation projects in Arizona (Briggs 1992). It is therefore important for resource managers to recognize the potential that riparian soils may contain abnormally high levels of salts and include an analysis of soil salinity in the evaluation.

For most wildland riparian ecosystems, high soil salinity will not be a problem. Salts are unlikely to build up in healthy, lotic riparian ecosystems, where annual spring floods remove excess salts. However, human impacts have altered natural flow regimes and water quality in many river systems to the point where salinity is contributing to the decline of riverside ecosystems. In the southwestern United States, agricultural practices within the Colorado Basin have greatly impacted the quality of the Colorado River, which picks up roughly 10 million tons of salt per year as it traverses the seven basin states (Hedlund 1984).

Unfortunately, the Colorado River is not the only drainage system in the United States with salinity problems. The Rio Grande and Pecos Rivers, as well as the closed river systems in the Great Basin, the Arkansas River, areas of Texas and Oklahoma, and tributaries of the Upper Missouri River, have problems with increased salinity levels (Hedlund 1984).

Anderson (1989) noted that soil salinity can reach high levels in riparian areas where groundwater is near the soil surface and where stream waters are high in total dissolved solids (TDS). These characteristics unfortunately fit several rivers in the United States. Salt accumulation in flood plain soils can be especially rapid along drainages whose flood patterns have been artificially altered by impoundment. Along reaches of the Lower Colorado River (after the river has been subjected to the effects of 3 large dams), buffered spring flows are no longer capable of flushing accumulated salts from many parts of the formerly active flood plain. This greatly increases the likelihood that salts will accumulate to the extent that salinity will negatively affect establishment and growth rates of riparian species.

Conclusions

Revegetation is limited in its ability to improve the condition of degraded riparian ecosystems. Revegetation efforts are misused in riparian ecosystems that are capable of coming back naturally; revegetation is also misused in riparian ecosystems where plantings cannot survive. Four riparian site characteristics play a particularly important role in determining establishment success of plantings in desert riparian areas: groundwater characteristics, channel stability, direct impacts, and soil salinity.

To design mitigation efforts that will be effective in improving the condition of degraded riparian ecosystems, the causes of riparian decline must be understood. Understanding these causes can best be accomplished from a perspective that considers how the riparian ecosystem is being affected by perturbations in surrounding ecosystems in its watershed. Evaluating only isolated reaches of a stream system will often fail to provide the information required to understand why the riparian ecosystem became degraded, the severity of the decline, and what types of mitigation strategies will be most effective in improving its condition.

To assist in evaluating the condition of riparian ecosystems, the Rincon Institute, in concert with other agencies, has developed a guidebook that reviews strategies for evaluating the condition of degraded riparian ecosystems so that revegetation, and other mitigation techniques, can be used more effectively.

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