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RIPARIAN REVEGETATION EVALUATION IN NORTH COASTAL CALIFORNIA

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ABSTRACT: We conducted a cross-sectional survey of 70 existing riparian revegetation projects in Marin, Sonoma and Mendocino Counties with the goal of improved understanding of riparian restoration efficacy. The project is a collaborative effort between the University of California Cooperative Extension, resource agencies, consultants, private landowners, and watershed groups. Restored sites ranged from 4 to 39 years in project age and received treatments of exclusionary fencing and active planting (active revegetation) or fencing alone (passive revegetation). Preliminary results indicated that restored sites had greater woody plant density compared to control sites where no restoration activity had occurred. As project duration increased woody plant density and percent shade increased. Conversely, annual and perennial herbaceous cover and channel width-to-depth ratio decreased with years since restoration, but landform class and watershed area were both important factors. For example, the greatest tree density was documented on depositional floodplain plots while the greatest shrub density was on erosional floodplain plots in comparison to channel and upper bank landform classes. Tree density for passive and active sites were similar but shrub and exotic woody plant densities were greater at passive sites. Tree, shrub, and exotic woody plant densities were correlated to the duration of grazing per year. In addition, sites with livestock and deer exclusion had higher woody plant densities than sites with livestock exclusion only. These results should help generate realistic expectations for similar planned and existing restoration projects in the region. Furthermore, results such as these should be used by the restoration partnerships consisting of practitioners, agriculturalists, and funding organizations to select restoration methods and implement effective future projects.
KEY TERMS: riparian revegatation; restoration evaluation; stream vegetation monitoring; functional assessment; vegetation management.

INTRODUCTION

Coastal California's riparian corridors provide habitat and hydrologic functions, while contributing to viable agricultural production systems. Area ranchers and farmers working with resource agency staff and restoration practitioners have implemented revegetation efforts over the last four decades to meet these resource management objectives. Ecological restoration and riparian revegetation typically have minimal institutionalized project monitoring, evaluation, and feedback. This results in limited documentation of project outcomes and effectiveness. Such post project analysis should provide valuable feedback for the design, installation, and management of future projects (Kondolf, 2004).

In addition to the need for restoration project feedback is the need for documentation of the levels of success with regard to ecological restoration objectives. Ecological restoration has been defined as the establishment of pre-disturbance functions and related physical, chemical and biological characteristics (Goodwin et.al., 1997; NRC, 1992). Another definition simply describes ecological restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER, 2002). Unfortunately, the ideal multiple-function goal has not been feasible in certain situations because of ongoing anthropogenic disturbances (Goodwin et. al., 1997) and determination of pre-disturbance conditions is elusive. As a result, reclamation and rehabilitation projects have deliberately managed to improve select functions such as water quality or single-species benefits. The metric for project success is typically linked to the attainment

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of site-specific goals and the ensuing resiliency of vegetation following environmental perturbations and stochastic events. As a result of such single-function goals, projects have had mixed results including utilization of exotic species for desired functions that prevented colonization by native species (Lindig-Cisneros, 2000). Other projects have recreated a community structure of native species different than any historical assemblage ever present at the site (Clewell, 2000).

In a typical revegetation project scenario, monitoring focuses on survival of planted vegetation, and seldom extends beyond a contracted three to five year period. Rarely do monitoring surveys attempt to quantify the resulting ecosystem and plant communities. Hourdequin (2000) summarized the importance of research to restoration ecology at the July, 2000 Conservation Biology Conference when he stated, "All of these presentations emphasized the importance of evaluating different techniques and monitoring outcomes, key elements in initiating ecological restoration. However, the presentations raised interesting questions about the long-term fate of restored sites. Especially in disturbance-dependent ecosystems, it will be necessary to address ecological restoration over long time-scales." Jelinski and Kulakow (1996) emphasized the need for long-term monitoring regarding the Natural Resource Conservation Service's Conservation Reserve Program when they explained that "These recovering landscapes offer remarkable opportunities for research on how the structure – that is, size and configuration, spatial arrangement and context – of ecosystems affects ecosystem processes and community dynamics."

Realistic expectations are needed for landowners, government agencies and consultants to make informed decisions about riparian restoration. Recognizing the need for documentation of ecological outcomes and feedback to the practitioner, we are conducting a cross-sectional survey of riparian revegetation projects. The goal of this survey is to determine the efficacy of riparian restoration by further understanding plant succession, community dynamics, and site potential within agricultural landscapes. The history of intensive riparian restoration in north coastal California since the 1970's has produced many projects from which to learn. This survey is a collaborative effort between the University of California Cooperative Extension and resource agencies, consultants, private landowners, and watershed groups implementing riparian restoration.

Study Area

We are surveying riparian revegetation sites north of the San Francisco Bay on streams in Marin, Mendocino, and Sonoma Counties. Collaboration between consultants, agencies and landowners has been crucial in developing a survey of restoration efforts that are representative with regard to perceived degree of project success or failure. Cooperating organizations include: Natural Resource Conservation Service, Marin Resource Conservation District (RCD), Southern Sonoma RCD, Mendocino RCD, Prunuske Chatham, Bioengineering Associates, Fort Ross Environmental Restoration, Land and Places, Forest, Soil and Water, Circuit Rider Productions, City of Santa Rosa, Sonoma County Water Agency, State and National Parks, Regional Water Quality Control Board, California Department of Fish and Game, and Sonoma County Farm Bureau Federation.

METHODS

Riparian revegetation projects solicited for this survey ranged in age from 5 to 30 years along streams of first, second and third orders. Project cooperators identified both "successful" and "unsuccessful" projects to be included in the study. These project sites included riparian revegetation and exclusionary fencing as well as associated control (non-restored) sites. We characterized identified sites by the following components: 1) Site revegetation goals, design, and maintenance activities; 2) Site physical conditions; and 3) Plant populations.

Historic site information and project goals are being summarized from past reports. In addition, project design and installation are being characterized to define management variables (e.g. total area excluded, duration of exclusion, stocking rates, season of use, type) and revegetation variables (e.g. density, diversity, plant protection, maintenance). These variables will be combined with the landscape and watershed scale information to provide context and serve as covariates for comparison to the current plant community and habitat data measured at each restored site.

Site physical conditions and plant communities were quantified at each site with plot data derived from transects perpendicular to the channel. Plot location was based on channel morphology by using three cross-sections per site. Six eight-yard wide belt transects were established up each stream bank from the thalweg at cross-sections until the upper bank was sampled. Plot length was variable and based upon the length of the given landform class for each plot. Landform classes include channel, erosional flood plain, depositional flood plain, or upper bank and were based upon artifacts and clues of stream processes. Channel plots were considered the active channel from the thalweg up to bankfull depth. Erosional plots showed evidence of hydrologic degradation or streambank cutting. Depositional plots were terraces with flotsam or general aggrading features. Upper bank plots received the least amount of hydrologic disturbance. Data gathered within each plot included species composition (Hickman, 1993), age-form class, canopy composition, slope, particle size, and landform class (Harris, 1999). Ground cover was assessed with three quadrats per plot using a modified Daubenmire Frame (20x50 cm) placed perpendicular to channel (BLM, 1996). Cross-section variables gathered include canopy cover (CDFG, 1998), bank slope, aspect, channel width-to-depth ratio, and entrenchment (Rosgen, 1996). Site characterization included within-site variation of soil texture (Lynn, 2000), particle size, floodplain area, and depth-to-ground water.

Statistical analysies were conducted on plant community variables including ground cover, woody species number, and plant density. In addition, comparisons of project age and watershed area as well as landform class, revegetation method, and livestock grazing duration at surveyed sites were made. All statistical summaries were performed with SYSTAT Version 9.0.

RESULTS and DISCUSSION

Project Age and Outcomes

Revegetation efforts are leading to changes in site conditions (Table 1) that are generally considered to be indicators of successful restoration. As project duration increases so does woody plant density and canopy (%). Conversely, annual and perennial herbaceous cover (%) and channel width-to-depth ratio decreased with project age. These are anticipated outcomes because projects are typically designed to improve bank stability, reduce erosion, decrease stream temperature, and increase riparian plant community structure and diversity. Improving these functions occurred through the utilization or encouragement of woody vegetation. As vegetation matures and expands cover, stream functions such as width and depth are expected to narrow (Wehren, 2002) and deepen which is indicative of improved habitat for salmonid species. However, increased density of woody exotic vegetation is often not desirable (i.e. *Rubus discolor*, *Cytisus scoparius*, *Spartium junceum*, and *Hedera helix*). Dominant tree species included *Salix lasiolepis*, *Alnus rhombifolia*, *Salix lucida*, *Fraxinus latifolia* and *Umbellularia californica*. Shrub and vine species most commonly observed include *Rubus ursinus*, *Baccharis pilularis*, *Rosa californica*, *Toxicodendron diversilobum*, and *Vitis californica*.

Table 1: Mean (SE) values for restoration metric representing revegetation objectives at surveyed sites by project duration groups (n=# of plots for each duration category).

Restoration metric	**Project duration (years)**				
	0 (n=159)	**4 - 7** (n=450)	**8 - 11** (n=399)	**12 - 19** (n=212)	**20 - 39** (n=170)
Tree density (individuals/m^2)	0.14 (0.04)	0.57 (0.05)	0.70 (0.06)	0.79 (0.10)	0.52 (0.08)
Shrub & vine density (individuals/m^2)	0.06 (0.01)	0.36 (0.04)	0.35 (0.04)	0.50 (0.07)	0.67 (0.14)
Woody exotic density (individuals/m^2)	0.03 (0.01)	0.06 (0.01)	0.19 (0.03)	0.25 (0.05)	0.48 (0.13)
Canopy cover (%) *	19.7 (2.2)	51.6 (1.67)	46.1 (1.6)	67.2 (1.9)	79.9 (1.7)
Annual herbaceous cover (%)	17.0 (1.7)	14.2 (1.0)	11.0 (0.9)	11.6 (1.4)	9.1 (1.4)
Perennial herbaceous cover (%)	23.0 (2.0)	22.8 (1.3)	20.8 (1.4)	19.8 (2.1)	10.1 (1.3)
Channel width:depth	38.0 (2.3)	32.5 (1.1)	28.2 (0.8)	30.4 (1.7)	28.1 (1.1)

Notes
SE = Standard Error
* Percent canopy cover measured using a densiometer (CDFG, 1998).

Plot and Site Factors

The restoration metrics documented at revegetated sites are influenced by a number of plot and site factors. For example, plant density was greatest in the erosional and depositional floodplain landform classes (Figure 1). Plot-based species richness based on landform class demonstrated similar patterns. These results hint at differential revegetation potential within a site and provide clues about locations within the riparian corridor where specific plant density and composition goals should be targeted. Monitoring efforts should also take this landform stratification into account when trying to determine restoration success. A single planting density or composition throughout the riparian corridor is unlikely to persist given environmental gradients from the bottom to the top of the channel. Furthermore, the use of landform classes in monitoring should standardize comparisons between project sites. This is especially important given the high degree of spatial and temporal variability associated with riparian zones (Kondolf, 2004). One site may not contain the proportion of landform classes found at another and this information should be accounted for when comparing restoration sites. Landform class will be an important factor in development of data-driven models of revegetation outcomes for the remainder of this project.

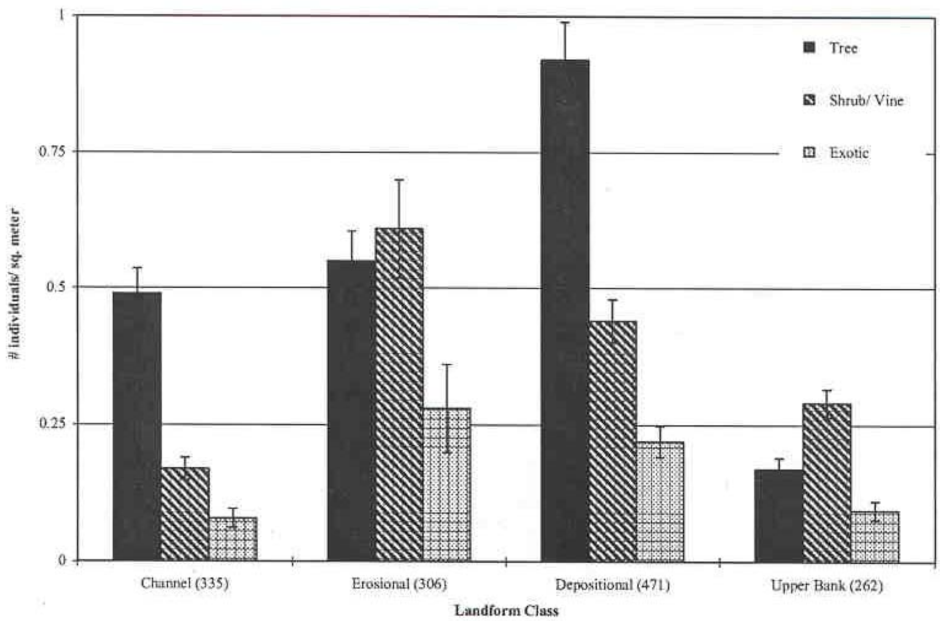

Figure 1: Mean woody plant density as function of landform class.

Examples of influential site factors included project duration and watershed area. The youngest project site surveyed was fenced and planted in 1997 and the oldest site excluded livestock in 1964. Such passively revegetated sites surveyed to date were comprised of older projects relative to the actively revegetated sites (Table 2). The survey site with the largest drainage area represented a watershed of 13,314 hectares while the smallest watershed was 30 hectares. Passive surveyed sites had larger watershed areas relative to active sites (Table 2). An example of the influence of these factors was indicated by the difference in shade by revegetation method. While mean shade for all passive sites was greater than that for all of the actively revegetated sites, the active sites had about five percent more shade than passive sites when utilizing a General Linear Model for comparison.

Table 2: Mean (SE) years since project installation and watershed area are examples of site factors and demographics.

Site Factor	**Passive Sites** (n=521)	**Active Sites** (n=704)
Project Duration (years)	17.6 (0.4)	8.7 (0.1)
Watershed Area (ha)	4049 (183)	2943 (158)

The differences between surveyed sites with regard to project duration and watershed area indicate a potential bias in our dataset. Anecdotal indications are that revegatation began in the region with cooperative exclusionary fencing on private grazing livestock ranches. These passive projects were often on larger more visible and prominent streams. Passive revegatation continues today but there was an initiation of active revegatation that began possibly in the early 1980s. These actively planted projects appear to have occurred on smaller streams than the initial phase of restoration activities. The

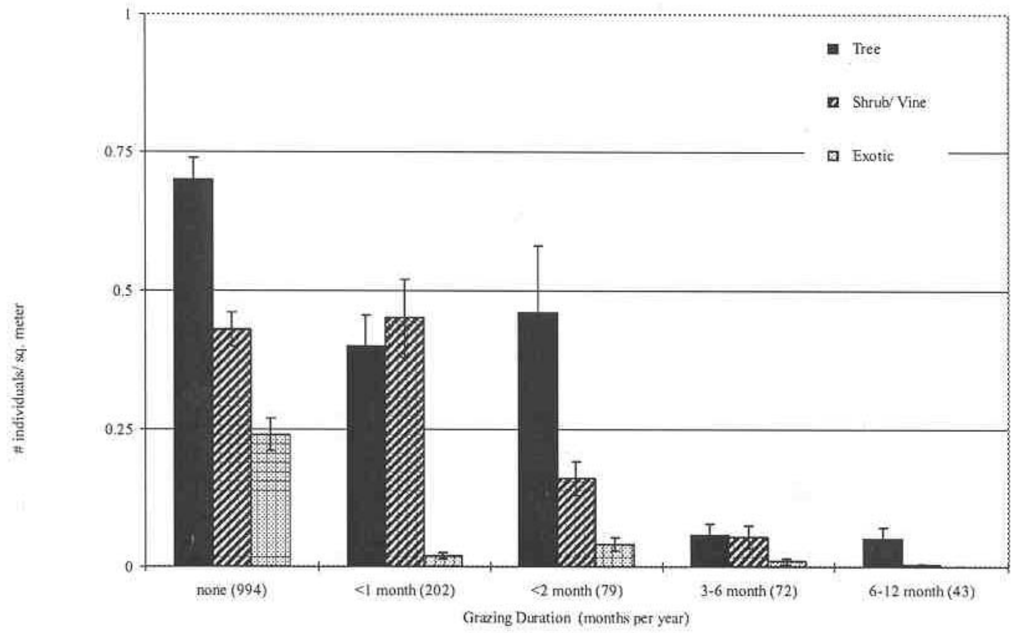

Figure 3: Mean woody plant density as function of grazing duration.

CONCLUSIONS

Survey results to date indicate that riparian revegetation efforts in Marin, Sonoma, and Mendocino Counties have promoted desirable woody vegetation density and species richness, stream shade, and channel width-to-depth ratio. These restoration metrics were influenced by landform class, project duration, revegetation method, and management practice. With these results, restorationists, agriculturalists, and funding organizations can place realistic expectations on projects that are currently being developed or already in place. These results should inform future projects to set objectives that account for the long-term costs and effectiveness of given design, installation, and management alternatives. For example, if the management objective for a particular site is to establish stream canopy and shade, these results indicate that such an objective can likely be achieved through both active and passive methods. If tree or shrub diversity is desired to provide particular habitat, then actively planting certain desired species may be needed. Implementing a concise and specific riparian revegetation plan given a better understanding of long-term outcomes affords restoration partnerships the opportunity to integrate agricultural operations with natural resource conservation and enhancement efforts.

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