Chapter 7. The Development of Riparian Ecosystem Restoration in California

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Introduction

The evolution of our modern-day understanding of riparian ecology and the development of the field of riparian ecosystem/habitat restoration underwent significant advances from 1970 to 2000. The four parts of this chapter include: (1) a chronological overview of the major activities, events and publications that documented, and punctuated, the progress of our understanding of riparian ecology and riparian ecosystem restoration in California; (2) a discussion of the various types of riparian restoration projects with the projects categorized by the primary reason they were undertaken; (3) examples of the various types of research, experimentation, field investigations, and monitoring programs associated with the early riparian habitat restoration projects; and (4) concluding remarks.

The Society for Ecological Restoration (SER), incorporated in 1988, defines "ecological restoration" as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004). We use the term "restoration" in this chapter in a broad sense. We use the same terminology as used by the early "restorationists" to describe their projects even though many of the early projects do not meet the exact intent of SER's definition. For example, many of the early projects were described as rehabilitation, enhancement, creation/fabrication, reclamation, ecological engineering, etc., rather than "ecological restoration" and/or "habitat restoration."

In the broadest sense, restoration activities have been occurring within California's rivers, creeks, and riparian ecosystems for centuries. The cultural stewardship practices of California Indians directed at promoting ecological services also promoted continuance of the ecosystems (rivers, creeks, riparian areas) upon which they relied. Anderson (2005) documents a number of traditional cultural practices and horticultural techniques (traditional resource management) used by California Indians within the riparian corridor. For example, Stevens (2003) studied the relationship between California Indian groups that tended white root—an herbaceous perennial understory plant in valley oak riparian woodlands with long roots used for basket weaving—and how they affected the distribution and ecology of the plant. Unfortunately, the traditional ecological knowledge of California's Indian Tribes was seldom, if ever, incorporated into riparian area restoration projects implemented in the 20th century[1].

We recognize that prior generations of landowners performed remedial work on their properties (e.g. stabilization of eroding streambanks using woody live and dead plant material) within the riparian corridor. In addition, workers employed under the Works Progress Administration between 1935 and 1942 and Civilian Conservation Corps between 1933 and 1940 performed various tasks along rivers and streams in California (Riley 1998).

[1] An example of how this might occur in the 21st century is the partnership developed in 1997 between the U.S. Forest Service Lake Tahoe Basin Management Unit (LTBMU) and the Washoe Tribe of Nevada and California to conduct the Meeks Meadow Washoe Restoration Project to restore the ecological and cultural function of the Meeks Meadow.

The field of riparian ecosystem/habitat restoration did not evolve solely on its own, but rather, in combination with the development of the fields of: (1) stream restoration; (2) erosion control; 3) (water quality/nonpoint source pollution control; (4) biotechnical/soil bioengineering; (5) watershed management; (6) landscape ecology; and (7) greenway design and management. Practitioners attempting to restore riparian areas drew from the experience of professionals involved in these related activities and interacted with many of these professionals during the course of restoration project planning and design.

There is an extensive body of gray literature associated with the field of riparian restoration: project proposals, conceptual plans and detailed planning documents, project plans and specifications, as-built plans, monitoring programs, and monitoring reports. We avoided referencing these documents since they are difficult to locate. In almost all instances the literature cited herein is from books, conference proceedings, and other available documents.

Over the years, a number of conferences were convened in California to address issues related to the conservation and restoration of riparian ecosystems. Conferences and symposia pertaining to riparian ecosystems, riparian ecology, riparian habitat restoration, and riparian area conservation throughout the western United States including California are presented in Volume 1 Appendix B.

Part 1—Publications, Activities, and Events: 1960s to 2000s

The 1960s

Smith (1977) stated: “Prior to 1960, few people showed any concern for the demise of California’s Riparian Forest communities.” Warner and Hendrix (1984) asserted that “descriptions of historical extent and character of the Sacramento Valley’s riparian systems by Kenneth Thompson (1961) were among the first writings to demonstrate their importance.”

The California Department of Water Resources (CWDR) recounted, “During 1961, a flood of protests against the denuding of levees in the Sacramento-San Joaquin Delta was launched by sportsman’s organizations, wildlife conservation groups, and the public in general.”(At that time, “Levee maintenance regulations dictated that virtually all shrubs and trees be cleared from levees to insure (sic) that the flood control protection provided by the levees would not be impaired” (CDWR 1967).

The CDWR (1966) reported: “In 1961, the California State Legislature authorized the Sacramento River and Delta Recreation Study. One of the recommendations was that ‘a program of pilot studies on selected reaches of levee be initiated to test various types of vegetation, determine control measures necessary, study methods for these controls, and determine the costs of this type of maintenance’. In response to that legislative recommendation, the Department of Water Resources initiated the Pilot Levee Maintenance Study in 1962.”

Thus, “The Pilot Levee Maintenance Study was begun to conceive and test alternative methods of levee maintenance that would provide for multiple use of levees. A number of tests[2] were conducted to determine if vegetative growth could be allowed on levees and

[2] Refer to part 2 below (Riparian Restoration Projects–Bank Stabilization/Erosion Control Projects) for a brief discussion of the types of tests conducted and the types of plant materials used in these tests.

berms to preserve and enhance esthetic, recreational and wildlife habitat values without impairing the flood control capacity of the levees" (CDWR 1967).

Two annual progress reports were prepared in 1963 and 1964 and a Preview to Bulletin 167 was published in 1966 (CDWR 1966). Findings during the last year of study and the conclusions and final recommendations of the Pilot Levee Maintenance Study were presented in CDWR Bulletin 167 (CDWR 1967). The study "concluded that with proper vegetative management programs, certain delta levees can be adapted and maintained to serve the needs of esthetics, recreation and wildlife as well as the primary purpose of flood control."

One of the earliest acknowledgments of the ecological values and severely limited extent of riparian systems appeared in Volume III of the 1965 California Fish and Wildlife Plan (CDFG 1965 per Warner and Hendrix 1984. Smith (1977) cited this document when he stated that "of the 29 habitat types listed in the 'Inventory of Wildlife Resources, California Fish and Wildlife Plan' (Vol. III), riparian habitat provides living conditions for a greater variety of wildlife than any other habitat type found in California."

The 1970s

The 1970s were the period of heightened awareness of riparian habitat loss and the importance of riparian habitat for many of the wildlife species in the State of California.

In *An Island Called California,* Elna Bakker pointed out that "no natural landscape of California has been so altered by man as its bottomlands. The grass-rich stretches of the great Central Valley are, for the most part, lost to orchards and vineyards, cotton and alfalfa fields. Many miles of curving green ribbon along its watercourses have been eradicated, replaced by the sterile concrete of flood control and navigation channels. Most of the tule marshes of the Delta country are now neatly diked rice paddies. On the freeway between San Francisco Bay and Sacramento one forgets that this was once wild land with golden beavers going about their industrious ways and great blue herons on guard with that watchful immobility so peculiarly their own. To recreate this world of slough, bank, and riverway takes more than the simple listing of what can be recalled, or guessed, was there. It needs imagination coupled with a persistent searching for the last few remnants of the original river country" (Bakker 1971).

Concerns arose over the loss of riparian habitat and the degradation of remaining riparian areas due to land clearance for orchards and field crops, logging for wood products, grazing by livestock, streambank stabilization, channelization and other flood control activities, and altered water flow due to dams and irrigation throughout California (especially California's Central Valley). Consequently, scientists, conservationists, and agency personnel came together to share their observations, express their concerns, and seek solutions in the early and mid-1970s.

Warner and Hendrix (1984) stated: "In the early 1970s, studies by the Nongame Wildlife Investigations Section of the Department of Fish and Game (e.g., Gaines 1974) began to bring into focus the impact of riparian system loss to the State's wildlife populations. At about the same time, disturbing figures of riparian vegetation loss along the upper Sacramento River were reported (e.g., McGill 1975)." Burns (1979) reported, "Based on historical accounts, there were nearly 775,000 acres of riparian forests along the Sacramento River and its tributary streams in 1850." Others (Katibah 1984; Roberts et al. 1977) cite a figure of 800,000 acres of riparian forest remaining after 1848. By 1952, only about 20,000 acres of riparian forest remained (Smith 1978). During the 20-year period between 1952 and 1972, 53 percent of the mature riparian forests that existed in 1952 had been removed and the land converted to agricultural uses (Burns 1979). By 1972, only about 12,000 acres of riparian forest remained in the Sacramento Valley (Gaines 1976; Roberts et al. 1977). Those interested in greater detail on the decline of California's Central Valley riparian forests should refer to Katibah (1984).

In the fall of 1975, the California Secretary of Resources established the Upper Sacramento River Task Force "to solve the acute resource problems centered primarily along the 170-mile section of the river below Shasta Dam" (Burns 1979). The initial task force was made up of State agencies[3] within the Resources Agency. Soon after its formation, the task force was enlarged to include Federal and local agencies and later enlarged again to include special interest groups. The objectives of the task force were "to coordinate intergovernmental activities and to take actions to ensure the protection of the fish, wildlife, recreation, and aesthetic values of the river while considering the other beneficial used of the river and adjacent lands, for such uses as water conveyance and agriculture," (Burns 1979). Encouraged by Napa County's 1974 adoption of an ordinance allowing for the protection of riparian vegetation along water courses (Burns 1977; Dunlap 1977; Gaines 1976), the task force "drafted a model, county general plan element, and ordinance that would bring the removal of riparian vegetation under a permit process," (Burns 1979). The task force gave these models to the boards of supervisors of five counties along the Sacramento River and asked them to adopt similar regulations. Only the northernmost county adopted a riparian protection ordinance (Burns 1979).

The first riparian forest conference in California titled "Conference on the Riparian Forests of the Sacramento Valley" was held in Chico in May of 1976. Cosponsored by the Davis and Altacal Audubon Societies, the conference was organized by David Gaines. There were about 70 participants (Abell 1989). There were no published conference proceedings; however, David Gaines prepared abstracts of the presentations (Gaines 1976). During this one-day conference, speakers gave a historical perspective on Sacramento Valley's riparian forests, described riparian vegetation, and discussed the animals that rely on riparian habitat. Staff from the CDWR described land use changes in the Sacramento River riparian zone and discussed the activities of the Sacramento River Task Force. A representative from the Army Corps of Engineers described Corps project work for flood control and bank protection on the Sacramento River. The President of the Sacramento Valley Landowner's Association presented a landowner's perspective of the bank erosion and loss of agricultural land due to the management of the river for water transport. CDWR staff described the recreational values of the Sacramento River and State Department of Parks and Recreation staff addressed boating on the river. A land agent with the California Wildlife Conservation Board discussed riparian forest acquisition along the Sacramento River, a supervisor from Tehama County discussed the county's approach to riparian forest habitat, and a U.S. Fish and Wildlife Service field supervisor addressed the need to mitigate habitat loss due to bank protection. Summing up, an attorney encouraged everyone to fight for their vision of the future of the Sacramento River and its riparian forests.

[3] Department of Fish and Game, Department of Water Resources, Department of Parks and Recreation, Department of Navigation and Ocean Development, Wildlife Conservation Board, Reclamation Board, Water Resources Control Board, and State Lands Division.

The second riparian forest conference in California titled "Riparian Forests in California: Their Ecology and Conservation" (Sands 1977) was held at the Davis Campus of the University of California in May 1977. Cosponsored by the Institute of Ecology, University of California, Davis, and the Davis Audubon Society the "symposium" was coordinated by Anne Sands. This was the first riparian conference for the United States with published proceedings. There were approximately 128 people in attendance (Abell 1989). Symposium topics were divided into two sessions; the morning session dealt with historical and ecological subjects followed by an afternoon session dealing with management and preservation. Presentations in the first part of the morning addressed the historical extent of riparian habitat loss (Roberts et al. 1977; Smith 1977), the diverse flora and fauna dependent on riparian areas (Roberts et al. 1977), accounts of the historical condition of Sacramento Valley riparian lands and remnants (Thompson 1977), and the concepts necessary for understanding the fluvial system (Keller 1977).

Following the morning break, experts went into greater detail describing the vegetation/flora of the Sacramento Valley (Conard et al. 1977), the importance of valley riparian forests to bird populations (Gaines 1977), and the habitats of native fishes in the Sacramento River Basin (Alley et al. 1977). Afternoon speakers addressed the need for legislation to study and protect California's riparian forests (Dunlap 1977), the activities of the U.S. Army Corps of Engineers (CE) protecting the Sacramento Valley levee system with rock bank protection (Kindel 1977), and the planting of trees and shrubs at selected sites along the Sacramento River (Kindel 1977). Speakers also described the progress made by the recently established Upper Sacramento River Task Force in coordinating the activities of the many governmental agencies that have jurisdiction over developments along the Sacramento River so as to ensure the protection of the fish and wildlife and recreational aspects of the river (Burns 1977). The symposium closed with a brief presentation on the value of riparian forests in today's society (Frost 1977) followed by a panel discussion.

It is noteworthy that no riparian restoration projects were mentioned, nor were the words "restoration" or "revegetation" used in any of the papers presented at the 1977 Symposium. The only mention of planting is by the Corps of Engineers—planting of trees and shrubs in 1967 along 3 miles of riverbank where the levee had been set back and a new berm had been created and protected by rock.

Anne Sands and Greg Howe presented a paper titled "An Overview of Riparian Forests in California: Their Ecology and Conservation" (Sands and Howe 1977) at the Symposium on the Importance, Preservation and Management of Riparian Habitat (Johnson and Jones 1977) held in Tucson, Arizona, in July 1977. This paper was comprised of abstracts from Sands (1977).

In 1978, Anne Sands (1979) presented a paper titled "Public Involvement in Riparian Habitat Protection: A California Case History" at a floodplain wetlands and riparian ecosystem symposium in Georgia. Anne Sands addressed the restoration[4] of damaged riparian areas as "probably the most difficult protection strategy, but certainly it is one of the most rewarding" (Sands 1979). In this paper, Anne Sands (1979) provided an example of how public concern over riparian habitat loss due to flood control project works had resulted in the State Reclamation Board commissioning a civil engineering study (Murray

[4] This is possibly the first mention of "riparian restoration" in the literature.

et al. 1978) on the retention of riparian vegetation as a means for controlling bank erosion along the upper Sacramento River.

Warner and Hendrix (1984) reported: "In 1978, a coalition of conservation organizations, led by the Riverlands Council chaired by Anne Sands, sponsored State legislation to protect riparian resources. The resulting legislation, AB 3147 (Fazio), appropriated $150,000 to the Department of Fish and Game (CDFG) for a study of riparian resources of California's Central Valley and desert." The stated goal of the CDFG in mounting its California Riparian Study Program (CRSP) was to "protect, improve, and restore the riparian resources of the State" (Warner 1984). There were multiple elements to the CRSP including: development of background information on California's riparian resources; mapping of riparian vegetation in the Sacramento and San Joaquin valleys; determination of the areal and linear extent of Central Valley riparian vegetation; conducting a remote-sensing survey and a ground inventory of riparian vegetation in the Central Valley; field surveys of California's desert riparian systems; reporting on State, Federal, and local programs affecting riparian systems; analysis of riparian conservation needs; and the development of a riparian conservation program.

The 1980s

In 1981, the California Reclamation Board, a governor-appointed body with statutory responsibility for maintaining Central Valley floodways, adopted a Riparian Vegetation Management Policy (King 1985). This policy recognized the benefit of riparian vegetation in maintaining the integrity of floodways and established a permit system for its removal. The Reclamation Board initiated a program, managed by the CDWR to ensure the retention of riparian vegetation at selected sites along the Sacramento River. Beginning in 1981, CDWR began installing native trees and shrubs in rock reinforced levees downstream of Sacramento (King 1985).

The third riparian forest conference in California titled "California Riparian Systems[12]: Ecology, Conservation and Productive Management" (Warner and Hendrix 1984) was held at U.C. Davis in September 1981. This conference drew 711 participants (Abell 1989). The fact that approximately 150 technical papers were presented at the conference of which 128 were included in the 1,035 pages of conference proceedings is evidence of the exponential growth in the fields of riparian ecology, conservation, management, and restoration. Although only seven papers were presented under the category of riparian restoration, many of the other papers reported on critical background research pertaining to the structure and function of riparian systems, especially hydrologic and hydraulic considerations. Also at this conference, Richard Warner (1981) reported on the structural, floristic, and condition inventory of Central Valley riparian systems conducted as part of the CRSP mentioned above (Warner 1984).

In the early 1980s, Randal L. Gray and Ron Schultze of the USDA Soil Conservation Service (now the Natural Resources Conservation Service) in Davis, California, organized the Riparian Revegetation Study Group (RRSG) to bring together individuals working on, or interested in, the reestablishment of riparian vegetation along degraded streams in California. Beginning as an interagency group, RRSG quickly expanded to

[5] This was the first conference convened at the University of California, Davis, under the "California Riparian Systems" title (Abell 1989).

include Federal, State, and local agency personnel, staff of non-profit organizations, and consultants. Semiannual meetings were hosted by members in San Jose, Hayward, Marin County, and Sacramento. The agenda for most meetings included short presentations of restoration projects and discussions of difficult issues associated with the restoration of riparian areas (for example, vandalism). Some meetings included field tours of recently completed revegetation projects. A subgroup of RRSG was organized in southern California because travel time and distance to meetings held in the northern part of the State precluded the involvement of most southern Californians. RRSG became the Riparian Guild of the California Society for Ecological Restoration (SERCAL) after SERCAL's formation in 1991.

Several of the papers presented at the Native Plant Revegetation Symposium (Rieger and Steele 1985) held in San Diego in November 1984 dealt with the restoration of riparian areas (Barry 1985; Capelli 1985; King 1985; Riley and Sands 1985). Two hundred and two people were in attendance. This meeting was the first that addressed restoration as the theme of the symposium. It was an effort to survey and promote communication between restoration practitioners in the State.

In the late 1970s and early 1980s, it became apparent that the protection and restoration of riparian areas was in direct conflict with traditional floodplain management (Riley and Sands 1985). Conservationists encouraged Federal and State flood management agencies and local flood control districts to find ways in which the retention and/or planting of riparian vegetation within channels and on floodplains could be compatible with flood management. At the 1984 "Native Plant Revegetation Symposium," Ann Riley and Anne Sands (1985) suggested that flood control planners and engineers should adopt the concept that "restoring streams is environmentally less damaging and less expensive than traditional channelization," an approach that was being promoted by Nelson Nunnally and Ed Keller (1979). Nunnally and Keller's central theme was "to preserve natural stream morphology wherever possible, and when change is essential, to design channels with morphological characteristics similar to those of natural channels." Riley and Sands (1985) argued for restoring the "natural balance between the river, its floodplain, and the riparian forest" and that to restore and maintain the riparian forest/fluvial system balance, we must recognize that floodplains must be allowed to function as they were intended. Riley and Sands (1985) also touted the combined use of vegetation and structural means for bank stabilization as presented in Gray and Leiser (1982) and Scheichtl (1980). Williams and Swanson (1989) proposed that flood management agencies should take a new approach to planning channel modifications for flood damage reduction. They pointed out that there were significant problems with conventional flood control project design including: (1) underestimation of the roughness of lined channels; (2) failure to account for channel bed erosion and deposition; (3) failure to account for debris; and (4) underestimation of maintenance requirements. Williams and Swanson argued that flood channel design should be multi-objective and should incorporate proper consideration of hydrologic, geomorphic, and biological factors that influence stream hydraulics. They pointed to the Wildcat Creek Flood Control Project as an opportunity to use the integrated design approach they discussed in their paper.

During the early- to mid-80s, some flood control agencies sponsored the preparation of design-it-yourself manuals so that flood control planners, engineers, and landscape architects could make decisions on the species to be planted along reconfigured channels and their appropriate planting locations without the input of biologists on each project site. In 1983, Harvey and Stanley Associates, Inc., prepared a “Revegetation Manual for the Alameda County Flood Control and Water Conservation District Revegetation Program” (Stanley and Stiles 1983). The manual contained detailed information on the characteristics of 97 species of riparian plants including their appearance, ecological relationships, wildlife habitat value, planting location, planting options, plant requirements, and maintenance requirements. A map and table allowed project planners to select plant species suitable to each of the planting zones within Alameda County. This was to be used in conjunction with a representative cross section of a typical channel and an accompanying table indicating the appropriate planting zone (streambed, toe of channel, lower, middle, and upper slope, top of bank, outside levee slope) for each species in order to select the appropriate native plants for each planting location. It was also possible to sort for native plant species to be used, or avoided, in special situations (for example, plants that are invasive, fire resistant, less than a certain height, colorful, a barrier to access, evergreen, good for erosion control, high in wildlife food and shelter value, and providing screening).

In 1984, the Urban Creeks Council sponsored the Urban Creek Restoration and Flood Control Act which was signed by California’s Governor in September 1984 (Riley and Sands 1985). The Urban Streams Restoration Program began in 1985 and was administered by the CDWR. “The purpose of the program is to provide grants and technical assistance to those local governments and community groups that want to implement less costly and more environmentally sensitive responses to erosion and flooding problems,” said Riley (1998). Over the next 10-year period, “the program funded 160 alternative restoration projects, including: innovative bank stabilization projects using live and dead plant materials; innovative channel design to increase flood capacities; culvert removal and stream daylighting (sic) to correct storm-water management problems; and land acquisition solutions to reduce flood damages.”

In May 1985, the CDFG released a Final Draft of “Riparian Resources of the Central Valley and California Desert” (Warner and Hendrix 1984). This report was the final product of Phase II of the CRSP that began in 1978 (see above). The report: (1) examined the structure and dynamics of riparian systems; (2) summarized the attributes, values, and vulnerabilities of riparian systems; (3) quantified their historical and present distribution in the Central Valley; (4) presented the major findings of field studies on riparian system distribution, structure, and condition in the Central Valley; (5) examined the nature and problems of desert riparian systems; (6) reviewed riparian resource conservation mechanisms available through Federal, State, and local laws, regulations, and programs; and (7) proposed a series of actions to reverse the chronic, long-term trends of riparian resource decimation and to restore some of these systems to their former status as productive major ecological elements in the California landscape.

In 1986, Aqua Resources Incorporated and Holton Associates (1986) prepared a “Riparian Planting Design Manual for the Sacramento River: Chico Landing to Collinsville” for the U.S. Army Corps of Engineers, Sacramento District. The purpose of the manual was to guide Corps personnel in designing plantings as mitigation for bank protection projects, mainly riprap, along the Sacramento River. The manual provided a list of recommended plant species for each of four plant communities (willow scrub, cottonwood riparian forest, mixed riparian forest, and valley oak riparian forest), which naturally occur in each of four hydrologic zones (river channel, low terrace, high terrace, upper high terrace) along the Sacramento River. The manual defined the planting zone for each plant community based on the average annual flood duration for each hydrologic zone. The manual also provided information on recommended planting densities and spacing patterns and guidelines for the preparation of revegetation plans and specifications. An appendix contained plant data sheets for 26 woody species recommended for riparian plantings (Granholm et al. 1988)

The "Second Native Plant Revegetation Symposium" was held in San Diego in April 1987 (Rieger and Williams 1988). In attendance were 257 people. Six papers dealing with riparian habitat restoration in California were presented at the conference. Results of several riparian revegetation projects implemented by the California Department of Transportation were reported as well as several private development mitigations.

The fourth riparian forest conference in California titled "California Riparian Systems Conference[6]: Protection, Management, and Restoration for the 1990s" (Abell 1989) was held at the University of California, Davis, in September 1988. This conference drew nearly 900 participants. Thirteen papers were presented in the session titled "Implementing Revegetation Projects" and six papers were presented in the session titled "Urban Streams." Other sessions dealing with channel dynamics, rangeland and desert riparian systems, and coastal streams also addressed the restoration of riparian areas.

In 1988, Faber and Holland (1988) published *Common Riparian Plants of California: A Field Guide for the Layman.* This book of photocopies of riparian plants and information on their characteristics and where they typically occur (distribution and elevation) was used by conservationists and community-based organizations seeking to restore riparian areas.

In January 1989, the Society for Ecological Restoration (SER) held its first annual meeting in Oakland, California. The conference proceedings titled "Restoration '89: The New Management Challenge" (Hughes and Bonnicksen 1989) contained a section on the restoration of riparian areas and a section on stream restoration. Other professional societies and conservation organizations also convened conferences in the latter part of the 1980s that included papers pertaining to riparian corridor and riparian ecosystem restoration. Some of these groups that recognized the relationship between restoring riparian areas and achieving the mission of their organization included: Association of State Wetland Managers, Inc.; California-Nevada Chapter of the American Fisheries Society; Salmonid Restoration Federation; Society for Range Management; and the Urban Creeks Council.

In 1989, the U.S. Fish and Wildlife Service published *The Ecology of Riparian Habitats of the Southern California Coastal Region: A Community Profile* (Faber et al. 1989). The purpose of this publication was to describe the structure and function of riparian habitat in southern California. This biological report: (1) described the physical setting and geofluvial processes in riverine systems; (2) outlined the effect of water regime on the establishment and succession of riparian plant communities; (3) described the most common species of riparian plants; (4) detailed the fauna dependent upon and that uses the riparian habitat; (5) summarized riparian ecosystem processes and values; and (6) spelled out the myriad of governmental jurisdictions and relationships that

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[6] This was the second "California Riparian Systems Conference" convened by U.C. Davis Extension (Abell 1989).

affect the use of, and the ability to conserve, riparian habitat. The publication concluded with a section on riparian ecosystem restoration including a number of case studies. Unfortunately, no similar publication was ever produced for the riparian ecosystems of northern California.

Also in 1989, the United States Environmental Protection Agency published *Wetland Creation and Restoration: The Status of the Science.* Volume I (Regional Reviews) contained a paper on riparian wetland creation and restoration in California (Stanley 1989). An appendix to this paper contained profiles for 37 riparian restoration projects in California.

The 1990s

By the 1990s, some biologists, ecologists, and hydrologists had gained enough experience conducting riparian restoration projects that they began offering training in riparian habitat restoration. The Wetland Training Institute, Inc., offered workshops on Riparian Habitat Restoration at various locations in California throughout the 1990s. SERCAL and SER offered Riparian Habitat Restoration workshops in connection with conferences held in California during the latter part of the 1990s and 2000.

In 1991, State legislation created the California Riparian Habitat Conservation Program (CRHCP) within the Wildlife Conservation Board (WCB). The mission of the program is to develop coordinated conservation efforts aimed at protecting and restoring the State's riparian ecosystems. The goals of the CRHCP, as noted in its enabling legislation, are to protect, preserve, restore, and enhance riparian habitat throughout California. To accomplish the program's objectives, the WCB was authorized to award grants for riparian conservation purposes (acquisition and restoration) to non-profit organizations, local government agencies, State departments, and Federal agencies.

Also in 1991, the California State Lands Commission published *Delta-Estuary—California's Inland Coast: A Public Trust Report* (Argent 1991). This report described the Delta's geologic, hydrologic, biologic, and cultural history and the public trust uses that are dependent on these resources. Citing Madrone Associates (1980), the report stated that "riparian habitat is used by more vertebrate wildlife, 107 species, than any other Delta habitat type." The report indicated that the clearing of levees for maintenance or placement of rock revetment has resulted in a severe loss of riparian habitat and shaded riverine aquatic habitat. The report concluded with a survey of the institutions and entities that manage the delta's resources.

In 1992, the National Research Council's Committee on Restoration of Aquatic Ecosystems concluded: "Given that healthy, vegetated riparian habitat and bottomlands are essential to the natural ecological functioning of associated streams and rivers—and are among the nation's rarest habitats due to prior devastation—riparian habitat and bottomland restoration should be made a high national priority along with the restoration of the stream and river channel itself" (NRC 1992). The committee recommended that a national aquatic ecosystem restoration strategy be developed for the United States. By this time, California's State agencies were already actively moving to preserve, conserve, and restore California's rivers, creeks, and riparian ecosystems in cooperation with local agencies, academic institutions, non-governmental organizations, and professional consultants.

In 1992, representatives of 28 agencies gathered at the request of California Resources Secretary Douglas Wheeler. These agencies recognized that diverse programs, goals, missions, regulations, and geographic regions required diverse information to support decisions regarding the management and conservation of California's rivers. They recommended a process that began with a survey of professional judgment of California's river conditions. They continued with the accumulation, organization, and internet publication of a large and diverse body of facts and tools dedicated to the analysis and management of California's rivers. The Information Center for the Environment (ICE) the University of California, Davis, conducted the California Rivers Assessment[7] (CARA) Project under the oversight of the WCB. ICE submitted the Final Report for the CARA Project titled *California Riparian Habitat Inventory and Assessment* (ICE 2009) to the WCB in April 2009.

The first phase of the CARA Project, a Professional Judgment Assessment (PJA), drew upon the knowledge, expertise, and opinions of resource managers, scientists, and other river experts to assemble a database of information about the condition of riparian and aquatic resources for California's 196 largest rivers. Riparian criteria included the presence (or absence) of a natural flow regime, vegetation size and land coverage, the trend in riparian habitat distribution over the past 25 years, and the impact of human activities on the areas. The PJA succeeded in collecting information for 616 segments on 145 rivers. Numerical scores for each river segment were distributed into quartiles labeled "Outstanding," "Substantial," "Moderate," or "Limited." A pilot comparative evaluation of the PJA responses was performed to illustrate how the PJA survey information could provide a Statewide perspective on the relative condition of riparian and aquatic river resources. In the final report, ICE (2009) indicated that out of California's 172,000 miles of rivers, 13,631 miles were rated by the CARA PJA. Of the 13,631 miles rated by PJA, 1,379 miles were rated "Outstanding" for riparian and 1,828 miles were rated "Limited" for riparian[8].

The fifth riparian forest conference in California titled "California's River Heritage[9]: A Conference on Conservation Issues, Policy and Implementation Strategies" (McCoy 1992) was held in Sacramento in May 1992. Concurrent sessions focused on: (1) Wild, Scenic and Recreation Rivers; (2) River Corridors and Parkways; and (3) Urban Riverfronts, Creeks, and Streams. Several of the speakers described river corridor restoration programs wherein riparian habitat restoration was, or would become, a major component including: Putah Creek (Sanders 1992); San Lorenzo River (Hall 1992); San Luis Creek (Jones 1992); and San Joaquin River (Dangermond 1992). Several stream restoration projects that received funding from the Department of Water Resources Urban Stream Restoration Program were described by Earle Cummings (1992).

In 1993, the California State Lands Commission published *California's Rivers: A Public Trust Report* (Argent 1993). The subject of this report was the condition of the

[7] CARA is a computer-based data management system designed to give resource managers, policy-makers, landowners, scientists, and interested citizens rapid access to essential information and tools with which to make sound decisions about the conservation and use of California's rivers. Cara contains 39 sets of mapped geographical information system (GIS) layers, 60 sets of tabular (database) and textual (text) data, as well as links to 510 additional maps, tables, and texts. All these data are organized by watershed and theme.

[8] These small numbers for the ranking of riparian and aquatic resources as "Outstanding" and "Limited" were the result of the limited number of miles of river segments evaluated. Funding was never obtained to complete the evaluation for the remainder of California river segments.

[9] This was the third "California Riparian Systems Conference" convened by U.C. Davis Extension.

rivers of California and their watersheds. The report documented the causes of their alteration and the nature and extent of their degradation; identified means by which their degradation could be avoided or reduced; and suggested measures to be taken for their restoration. The report addressed the need for riparian habitat restoration and explained the role of numerous Federal, State, and local agencies and organizations in the protection, management, and restoration of riparian areas. The report indicated that "in California, many riparian restoration projects have been implemented, but most are on a relatively small scale, rather than for whole systems" (Argent 1993).

Recognizing the importance of riparian habitat for landbirds in California, California Partners in Flight (CalPIF) initiated the Riparian Habitat Joint Venture (RHJV) Project in 1994. Eighteen Federal, State, and non-profit organizations signed a Cooperative Agreement to protect and enhance habitats for native landbirds throughout California. Modeled after the successful Joint Venture projects of the North American Waterfowl Management Plan, the RHJV reinforces other collaborative efforts that protect biodiversity and enhance natural resources as well as the human element they support. "The mission of the RHJV is to promote the protection, restoration and enhancement of riparian habitat sufficient to support the long-term viability and recovery of California's native landbirds and other associated species" (Chrisney 2003).

The sixth riparian forest conference in California titled "California's Riparian-River Ecosystems Conference IV:[10] Addressing Current Land Use and Resource Conflicts" (Laird et al. 1995) was hosted by U.C. Davis in Sacramento in November 1995. Speakers provided a historical perspective of the physical and fluvial processes and riparian and aquatic resources of California's rivers. There were updates on recent flooding and discussions of floodplain management. River management case studies addressed restoration of the Klamath, Trinity, Los Angeles, Russian, San Joaquin, and Sacramento rivers.

In October 1998, The Federal Interagency Stream Restoration Working Group, comprised of 17 Federal agencies, published *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG 1998). Part II (Developing a Restoration Plan) provided suggested approaches for identifying problems and opportunities; developing goals, objectives, and alternatives; and planning the implementation, monitoring, and evaluation of restoration projects. Part III (Applying Restoration Principles) contained guidance on analysis of corridor conditions, restoration project design, and restoration project implementation, monitoring, and management. Although only one agency representative (USFWS) from California was on the Production Team for this document, much of its contents was in line with the approaches and practices already in use for stream and riparian restoration in California. This document was useful for those entering the field of stream and riparian restoration and managers and administrators of restoration projects.

The 2000s

The following noteworthy documents were published after 1999; however, they report on, or synthesize, knowledge that was generated in the latter part of the 20th century.

In August of 2000, CalPIF and RHJV released the first version of *The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian Associated Birds*

[10] This was the fourth "California Riparian Systems Conference" convened by U.C. Davis (McCoy 1995).

in California. "The Riparian Bird Conservation Plan seeks to synthesize and summarize the current state of scientific knowledge concerning the requirements of birds in riparian habitats. It provides recommendations for habitat protection, restoration, management, research, monitoring, and policy to ensure the long-term persistence of birds dependent on riparian ecosystems," (RHJV 2004). "The RHJV chose to emphasize the ecological associations of individual species as well as those of conservation concern. In doing so, the RHJV included a suite of focal species whose requirements define different spatial attributes, habitat characteristics, and management regimes representative of a 'healthy' system". (RHJV 2004).

Version 2.0 of the Conservation Plan (RHJV 2004) expanded the original list of 14 "focal" riparian bird species to 17 "focal species." Criteria for the selection of focal species included: (1) use of riparian vegetation as their primary breeding habitat in most bioregions of California; (2) warrant special management status—endangered, threatened, or species of special concern on either the Federal or State level; (3) have experienced a reduction from their historical breeding range; (4) commonly breed throughout California's riparian areas; and (5) have breeding requirements that represent the full range of successional stages of riparian ecosystems.

The seventh riparian forest conference in California titled "California Riparian Systems[11]: Processes and Floodplains Management, Ecology, and Restoration" (Faber 2003) was convened by the Riparian Habitat Joint Venture in Sacramento in March 2001. The conference focused on riparian and floodplain processes, habitat management and restoration, monitoring, and partnerships in riparian area activities. Seventy papers were presented in this volume. Most of the 18 papers in Section III (Restoration) report on work performed in the 1980s and 1990s.

In October of 2003, the CDFG published additional elements to the third edition of the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). The new Part XI (Riparian Habitat Restoration) addresses measures for the conservation and management of riparian habitats and measures for the the restoration of native riparian habitats. It provides guidance on riparian revegetation project planning, provides information on the sources of native plant material, and discusses revegetation techniques. Appendix XI-A contains fact sheets for numerous central and north coast native riparian plants while Appendix XI-B contains fact sheets for a number of invasive nonnative plant species common to riparian areas.

The eighth riparian conference in California was held by the American Water Resources Association (AWRA) in Olympic Valley, California, in June of 2004. Titled "Riparian Ecosystems and Buffers: Multi-scale Structure, Function and Management" (Dwire and Lowrance 2006), the conference included papers on the role of riparian ecosystems and riparian restoration projects in protecting the water quality of the Lake Tahoe Basin. Key papers were published in a special issue of the Journal of the American Water Resources Association (JAWRA 2006).

The ninth riparian conference in California was convened in Sacramento by the Riparian Habitat Joint Venture in December of 2007. Titled "Riparian Habitat Conservation and Flood Management in California[12]" (RHJV 2007), the conference proceedings

[11] This was the fifth "California Riparian Systems Conference."

[12] This was the sixth "California Riparian Systems Conference." It was mistakenly referred to as the "Fourth Conference on California Riparian Systems" in the introduction to the proceedings.

contained nearly 80 papers and discussions focused on integrating levee management, flood protection, riparian conservation, and wildlife protection so as to sustain a safe, vibrant, and healthy environment along the streams and rivers of California. The conference was specifically designed to address the critical need for restoring the essential biodiversity of riparian areas while also ensuring good water quality and flood safety.

In 2007, RHJV partners identified a need for guidelines for planning and implementing riparian restoration projects on the ground. RHJV convened a group of restoration experts for a workshop to produce a handbook of restoration strategies, standards, and guidelines. The goal was to provide practitioners, regulators, land managers, planners, and funders with basic strategies and criteria to consider when planning and implementing riparian conservation projects. River Partners, a RHJV partner, took the lead in developing this handbook. In July 2009, River Partners published the second edition of the *Riparian Habitat Restoration Handbook* (Griggs 2009). The goal of the handbook is to explain the proposal/planning process for a site-specific riparian restoration project for wildlife habitat to the first-time, as well as the experienced, restoration project manager. The handbook can be used for planning projects, creating budgets, and assessing restoration success. Ecological, biological, and regulatory components of a riparian restoration project are described. The handbook emphasizes the ecological river processes operating on floodplains and in river channels that create characteristic vegetation structure that forms wildlife habitat—as the foundation for planning a riparian restoration project. Case studies of Statewide riparian restoration projects that faced site-specific conditions illustrate implementation of the principles presented in this handbook.

Part 2—Riparian Restoration Projects: 1960 to 2000

The California Wildlife Habitat Relationships system of classification identifies seven major riparian habitats in California: montane riparian, valley foothill riparian, desert riparian, palm oasis, freshwater emergent wetland, wet meadow, and aspen (RHJV 2004). The vast majority of riparian restoration projects in the last half of the 20th century were conducted in the valley foothill riparian habitat type. This is because human impacts were the greatest in the Central Valley, in the lower foothills of the Cascades and Sierra Nevada, and in the Coast Ranges. Therefore, most of the riparian habitat restoration projects discussed below pertain to the valley foothill riparian habitat type.

In 1990, the Riparian Revegetation Study Group conducted a survey[13] of riparian restoration projects in California. Information was collected for more than 276 riparian restoration projects in California, of which 226 projects had been implemented or were in the process of being implemented. Fifty-nine percent of the projects were less than 5 acres in size, 72 percent of the projects were less than 10 acres, and 83 percent of the projects were less than 20 acres. The primary purposes for which these riparian restoration projects were conducted were: streambank stabilization (40 percent); mitigation for project impacts (34 percent); fish/wildlife conservation (13 percent); urban stream restoration (8 percent); and restoration of degraded public lands (5 percent).

[13] Survey conducted by John Stanley on behalf of the RRSG. Survey records and data were not published.

We have divided the projects discussed in this section into the following categories, which differ only slightly from the "purposes" mentioned above:

- Bank stabilization/erosion control
- River/stream/watershed restoration
- Urban creeks restoration
- Compensatory mitigation
- Habitat conservation/restoration
- Rangeland restoration
- Invasive plant removal/control

We recognize that many of these early projects were multi-purpose. Assignment of restoration projects to these categories is based on the primary reason for the restoration project. Refer to table 7 for additional information on the restoration projects mentioned in the text, including their general location (city/county), project sponsor(s), and the various actions involved in project implementation. Within each category in table 7, the projects are organized in order of the year(s) when they were implemented. Refer to table 8 for the scientific names of plant species mentioned in the text and in table 7.

We have placed our emphasis on "early" restoration projects—projects that were implemented in the 1970s and 1980s. However, in doing so we have not done justice to many of the projects implemented in the 1990s—many of which are larger projects that provided greater benefits to wildlife and the environment. We set an arbitrary cut-off date of the end of Year 1999 by which a project had to have begun construction/installation to be included in the text and table 7. This means that many significant projects that were planned in the 1980s and 1990s but which were not constructed until Year 2000 or thereafter are not mentioned in this chapter. We recognize that many of these early projects did not achieve all, or even most, of the ecological attributes of restored ecosystems as outlined in the SER Primer (SER 2004) and expanded upon in Clewell and Aronson (2013).

Additionally, we have focused on "Horticultural Restoration" (formerly referred to as "revegetation," "active revegetation," or "active restoration") and have given much less attention to "Process Restoration" (formerly referred to as "passive restoration"). Griggs (2009) stated: "'Horticultural Restoration' refers to a high level of site management and external human inputs that include site preparation (land-leveling, disking), planting of nursery-grown trees and shrubs in predesigned patterns, irrigation, and chemical [and/or mechanical] weed-control for three or more years. Horticultural restoration is typically employed along rivers where the river's physical processes have been severely modified by humans with dams, levees, bank stabilization, and water diversions."

Griggs (2009) also specified: "'Process Restoration' strives to reestablish river processes onto the site. Process Restoration is appropriate on riparian sites along a river that retains functioning river processes (e.g., no dams, and few levees or water diversions). Process Restoration attempts to restore a site by working with existing river processes." "Process Restoration" has also been referred to as "Process-based Restoration." A Process-based Restoration approach might simply be the removal of a perturbation (for example, livestock) from a riparian corridor or a change in management (for example, grazing regime) followed by allowing native plants to reestablish on the site through natural processes. Process-based restoration projects often involve a single action (for example, removing livestock, breaching of a levee to reconnect the river to its floodplain, conducting a controlled burn, removal of invasive plants) followed by sitting back and letting natural regeneration occur.

Table 7—Examples of California riparian ecosystem restoration projects: 1967-2000.

Project name	Date(s)	Location	Project sponsor	Actions taken to implement project
			Bank stabilization/erosion control projects	
Monument Bend Demonstration Project	1967	Sacramento County	U.S. Army Corps of Engineers	Planted a variety of trees and shrubs along 3 miles of riverbank where the levee had been set back and the new berm protected by rock.
Bull Creek Bank Stabilization Project	1971-974	Humboldt County	CA Dept. Parks and Recreation	Planted willow cuttings and alders in riprapped banks along Bull Creek in Humboldt Redwoods State Park.
Intertidal Zone Levee Experimental Planting (UC Davis Environmental Horticulture Department)	1978-1980	San Joaquin County	CA Dept. Water Resources	In 1978, UC Davis researchers planted intertidal zone sites at the Webb Tract and Mandeville Island with buttonbush, three species of spikerush, Goodding's willow, and common tule. In 1980, planted intertidal zone on Terminous Tract with tules and willow cuttings and spikerush along with erosion control fabric. Seeded with alkalai bulrush and water grass.
Lost Canyon Rehabilitation	1983-1985	Near Wishon Reservoir, Fresno County	Pacific Gas & Electric Company	Restored eroded watercourse downstream from PG&E Helms Pumped Storage Project. Planted montane riparian vegetation along 3 miles of eroded streamside (90 acres) at elevations between 6,300 and 7,700 ft. Planted over 50,000 seedlings over a 2-year period. Riparian species planted included blue elderberry, mountain alder, mountain ash, black cottonwood, quaking aspen, and willow. Compared various planting treatments.
McDonald Creek Restoration Project	1983 & 1986	Humboldt County	Redwood Community Action Agency	Planted approx. 4,000 trees (alder, willow, spruce, redwood) along 1 mile of McDonald Creek and ½ mile along the north fork (total of 9 acres).
Tryon Creek Restoration Project	1984-1987	Del Norte County	Redwood Community Action Agency	Planted riparian trees and upland conifers on private property along one-mile reach of Tryon Creek, tributary to the Smith River. Fenced streambanks to exclude livestock.
Prairie Creek Restoration Project	1986	Humboldt County	Redwood Community Action Agency	Planted 8 acres of streamside deciduous forest (primarily willows and red alders) and adjacent conifer forest (Sitka spruce and coast redwood) along approximately 2 miles of eroding streambank on Prairie Creek (tributary of Redwood Creek). Installed fencing to exclude cattle. Installed log and hog wire bank stabilization structure on some of laid-back banks.
Red Clover Creek Erosion Control Demonstration Project	1986-1987	Plumas County	Plumas Corporation	Revegetation of streambanks along 1 mile of Red Clover Creek (elevation 5,497 ft.), tributary to East Branch of the North Fork of the Feather River, with montane riparian vegetation. Installed check dams to reduce channel gradient and downcutting of streambed. Studied survival rates of four hardwood species (coyote willow, mountain alder, black cottonwood, quaking aspen) native to Red Clover Valley. Compared survival of unrooted stakes vs. rooted liners planted in fall vs. spring. Installed 3 miles of exclosure fencing to control cattle access.
Georgiana Slough Pilot Bank Protection Project	1999	Near Walnut Grove, Sacramento County	California Bay-Delta Authority	Installed biotechnical bank protection measures (brush boxes, brush bundles, coir biologs) along 7,000 feet of Georgiana Slough. Established 8,000 feet of tules along Georgiana Slough and North Fork Mokelumne River.

Table 7—*Continued.*

Project name	Date(s)	Location	Project sponsor	Actions taken to implement project
			River/stream/watershed restoration projects	
Lagunitas Creek Watershed Restoration Program	1982-1988	Marin County	Marin County Resource Conservation District	There were 70 individual work sites in this project. Activities included gully repair, installation of check dams, post and wire fencing, gabion and riprap placement, and willow sprig planting. Treated 21 miles of unpaved roads to control erosion (regrading and installation of culverts, fords, and waterbars).
San Simeon State Beach Riparian Restoration Program	1985-1986	San Luis Obispo County	California Dept. of Parks and Recreation and California Coastal Commission	Removal of nonnative trees and shrubs along San Simeon Creek followed by installation of riparian trees and shrubs along both the north and south banks of the creek. Plant species installed included California sycamores, Fremont cottonwoods, California bay, coyote bush (sic), coast live oaks, willows, breadless (sic) wild-rye, and purple needle grass.
Walker Creek Watershed Restoration Program	1986-1990	Tomales, Marin County	Marin County Resource Conservation District	Rangeland erosion control and gully repair. Streambank repair including riprapping toes of banks, constructing of log crib wall interplanted with willows, and erecting gradient control structures. Rehabilitation of dirt road system.
Uvas Creek Park Preserve Restoration Project	1995	City of Gilroy, Santa Clara County	City of Gilroy Dept. of Parks and Recreation	Reconstructed sinuous, meandering channel on 0.6-mile reach of Uvas Creek within Uvas Creek Park Preserve in November 1995. In-stream channel improvements included rock vortex weirs (placement not as designed) and log and rootwad bank stabilization. Most improvements washed out in February 1996 resulting in an irregular, braided sand and gravel channel and eroding streambanks. Riparian plantings on channel banks did not have time to become established, or were not installed, prior to bank erosion.
Cold Creek/Pioneer Trail Stream Habitat Restoration	circa 1998	City of South Lake Tahoe, El Dorado County	California Tahoe Conservancy	Stabilization of eroding streambanks using boulders, logs and rootwads. Woody material and boulders were placed in the stream so as to improve fishery habitat. (Lake Tahoe Basin - Trout Creek Watershed)
Trout Creek Wildlife Enhancement and Stream Restoration Project	1999-2001	City of South Lake Tahoe, El Dorado County	City of South Lake Tahoe and California Tahoe Conservancy	Relocated Trout Creek to its historic position in middle of Trout Creek Meadow. Constructed approx. 3.5 miles of new sinuous stream channel and restored 107 acres of meadow. Creek was reengineered to reestablish hydrologic connectivity between the stream and its former floodplain thereby increasing flood frequency and duration, raising groundwater levels, and improving health of wetland and riparian vegetation. Used stacked sod revetments to stabilize streambanks along with planting of willow sprigs.
Bear Creek Meadow Restoration Project	1999-2000	Shasta County	California Dept. of Fish and Game	Restored historic floodplain and channel connection in Bear Creek Meadow. Constructed and revegetated 2.2 miles of channel to mimic pre-disturbance conditions. Filled incised gully to floodplain elevations. Propagated and planted 4,500 shrubs from 20 native species. Used sod mat transplants to stabilize new exposed banks. Transplanted large willows, rose, hawthorne, chokecherry, and spirea. Planted over 109,000 plugs of native sedge and rush species.

Table 7—*Continued.*

Project name	Date(s)	Location	Project sponsor	Actions taken to implement project
			Urban creeks restoration projects	
Strawberry Creek Park	1983	City of Berkeley, Alameda County	City of Berkeley Public Works Department	Daylighted 200-foot long section of Strawberry Creek by removing concrete culvert (20 feet below grade) in place since 1904. Revegetated with coastal riparian plant species along 1,200-foot long reach of reconstructed streambanks stabilized with concrete recycled from removal of cross-street.
Miller Creek Restoration Project	1985-1986	Marin County	Deerfield Park/ Lucas Valley Site Developer	Regraded deeply incised stream channel to create a compound channel with a low flow channel and an overflow terrace. Installed vegetated riprap and vegetated spur dikes to protect meander bends. Stabilized toes of eroding banks with rocks and willow cuttings. Planted willows and a mixture of native trees and shrubs and hydroseeded with native perennial grasses.
Wildcat-San Pablo Creeks Flood Control Project	1986-1988	City of Richmond, Contra Costa County	USACE and Contra Costa County Flood Control District	Restoration of a channelized stream. Constructed “natural-like,” “two stage”, flood control channel with a meandering bankfull channel and floodplain. Installed riparian plantings along both sides of low-flow channel.
Carmel River Biotechnical River Restoration	1986-1988	Monterey County	Monterey Peninsula Water Management District	Regraded pilot channel flanked by second-stage floodplain at level inundated by approx. 2-year flood. Planted 25-acre Schulte Road Restoration Project site with a series of willow rows at toe of eroding streambanks and willow groins in herringbone pattern on floodplain to narrow excessively wide sections of channel and stabilize river meanders. Also, installed biotechnical revegetated riprap and post and wire revetment with revegetation on outside bends. Installed some Fremont cottonwoods translocated from Central Valley whereas Carmel Valley had only a native black cottonwood forest.
Strawberry Creek Restoration Project	1987-1988	City of Berkeley, Alameda County	University of California, Berkeley	Repaired old check-dams and installed new ones on section of Strawberry Creek on UC Berkeley Campus. Stabilized eroding streambank using redwood log crib wall. Crib wall was backfilled and planted with about 25 species of native plants.
Strawberry Creek Management Plan/ Program	1987+	City of Berkeley, Alameda County	University of California, Berkeley	UC Berkeley Campus watershed management strategies consisting of erosion control, non-point source pollution mitigation, and stormwater management. Gully control and repair through the use of biotechnical and soil bioengineering methods utilizing native vegetation and indigenous materials.
First San Diego River Improvement Project	1987-1989	City of San Diego, San Diego County	City of San Diego	Revegetation of 26.8 acres of riparian woodland along a 7,000-foot section of the San Diego River in Mission Valley. Planted willows, Fremont cottonwoods, sycamores, live oaks and other appropriate riparian corridor species.
Buena Vista Creek Restoration Project	1988	City of Vista, San Diego County	City of Vista and California State Coastal Conservancy	Installation of series of drop structures to slow water flow. Riparian habitat restoration along Buena Vista Creek to reduce sedimentation in Buena Vista Lagoon.

Table 7—*Continued.*

Project name	Date(s)	Location	Project sponsor	Actions taken to implement project
			Compensatory mitigation projects	
Sacramento River Maintenance Area 9	1981	Sacramento County	CA Dept. of Water Resources	Installed 1,142 native trees and shrubs on the upper banks of a 9.5-mile section of rock-reinforced levee located just downstream of Sacramento. Planted white alder, coyote brush, Oregon ash, western sycamore, live oak and valley oak. Plants were planted in clusters of 3-5 individuals, 100 feet apart in accordance with Reclamation Board standards. Monitored plantings through 1983.
Guadalupe River Revegetation Project	1981	Santa Clara County	Santa Clara Valley Water District	Planted California native plant species on bank slope along channelized section of Guadalupe River.
I-8/I-15 Mitigation	1982	San Diego County	Caltrans	Lowered upland adjacent to San Diego River in Mission Valley 10-14 feet in elevation to create floodplain planting bench. Planted 6 acres of willow/cottonwood riparian woodland with sycamores.
Caldecott Park Creek Revegetation	1983-1985	Alameda County	Alameda County Flood Control District	Installed riparian plant species along Caldecott Creek within Caldecott Park. Planted alder, toyon, big-leaf maple, coast live oak, and bay laurel.
Alamitos Creek Revegetation Project	1984	Santa Clara County	Santa Clara Valley Water District	Planted riparian trees, shrubs and groundcover along three miles of Alamitos Creek totaling approx. 20 acres.
Llagas Creek Watershed Mitigation	1984-1987	Santa Clara County	USDA SCS and Santa Clara Valley Water District	Revegetation with riparian trees, shrubs and herbaceous plants along 10-mile creek corridor.
Morena Street Site	1985 & 1988	San Diego County	Caltrans	Planted willow, sycamore, and cottonwood groves (3.5 acres) and Coastal Sage Scrub and Mixed Chaparral communities on 9-acre site along the San Diego River.
Crescent Bypass Riparian Revegetation Project	1985-1988	King County	Kings River Conservation District	Planted riparian vegetation along 6 miles of the Crescent Bypass between the south and north forks of the Kings River.
Saratoga Creek Flood Control Project Revegetation	1986 & 1988	Santa Clara County	Santa Clara Valley Water District	Installed 3,000 native riparian plant species in planting pockets and open bottom concrete planters within 7 acres of gabion-lined (stacked and mattress) flood control channel and in bare earth at top of bank.
Sweetwater Bridge Mitigation	1986-1987	San Diego County	Caltrans	Lowered 2-acre site alongside the Sweetwater River down 5-8 feet. Planted willow scrub woodland to replicate the habitat of least Bell's vireo.
Lower Coyote Creek Pilot Revegetation Project	1986-1987	City of San Jose, Santa Clara County	Santa Clara Valley Water District	Planted total of 3,640 plants comprised of 15 native riparian corridor plant species on 4.4-acre site on floodplain adjacent to lower Coyote Creek. Woody plant species included California box elder, white alder, Oregon ash, California black walnut, western sycamore, Fremont cottonwood, coast live oak, valley oak, red willow, yellow willow, blue elderberry, and California bay. Multiple types of plant materials (i.e., propagule types) were tested for each plant species. Comparison of approx. equal areas irrigated by overhead irrigation versus flood irrigation. Tested a variety of weed management strategies and techniques.

Table 7—*Continued.*

Project name	Date(s)	Location	Project sponsor	Actions taken to implement project
M&T Ranch Elderberry Mitigation	1987	Butte County	CA Dept. of Water Resources	Scattered plantings of blue elderberry on 167-acre parcel as mitigation for endangered Valley Elderberry Longhorn Beetle (VELB) habitat loss associated with Sacramento River Bank Protection Project.
Novato Creek Flood Control Project	1987-1988	Marin County	Marin County Flood Control District	Planted riparian trees and shrubs on approx. 7 acres of riparian corridor along Novato Creek. Plants included California buckeye coyote bush (sic), black walnut, Oregon ash, red alder, coast live oak, valley oak, bay laurel, and elderberry.
Spring Creek Flood Control Project	1987-1988	Sonoma County	Sonoma County Water Agency	Off-site revegetation of approx. 12 acres of riparian habitat along the Laguna de Santa Rosa. Primary plantings were oaks in the upper regions and Oregon ash in wetter areas.
Sacramento River Mile 154.6 Right	1987-1988	Colusa County	U.S. Army Corps of Engineers	Planting of blue elderberry and other high terrace riparian species at two sites totaling 2 acres as mitigation for loss of VELB habitat due to installation of rock slope protection.
San Joaquin Marsh Mitigation Bank	1987-1988	Irvine, Orange County	The Irvine Company	Planted 8.5 acres of willows, cottonwood and sycamore adjacent to San Diego Creek in Irvine out of ultimate total of approximately 30 acres.
SR-52 Mitigation/Mission Trail Park	1989-1990	San Diego County	Caltrans	Lowered 33 acres on 48-acre parcel adjacent to the San Diego River 10-17 feet. Planting of riparian species followed prescription for endangered least Bell's vireo habitat generated by Baird and Rieger (1989). Upland slopes created by the grading were seeded with coastal sage scrub which provided habitat for the threatened California gnatcatcher.
Hwy 85 Mitigation	1993	San Jose, Santa Clara County	Caltrans	Lowered 24-acre off-site mitigation area adjacent to middle Coyote Creek 10-15 feet in order to bring the final grade closer to the groundwater table. Constructed side channel to convey stream flows through project site. Revegetation included streamside, floodplain and valley oak riparian forest associations. A total of 10,484 container plants were installed.
Habitat conservation/restoration projects				
Colorado River Dredge Spoil Revegetation	1979-1980	Near Palo Verde, Imperial County	USDI Bureau of Reclamation	Planted cottonwoods, willows, and quail bush on three sites located along the lower Colorado River including one 49-acre site on the Cibola National Wildlife Refuge. Studied effects of deep tillage and irrigation on plant growth and survival of rooted cuttings of Fremont cottonwoods on total of 79 acres of dredge-spoil.
Sepulveda Wildlife Reserve Revegetation Project	1984 & 1986	City of Van Nuys, Los Angeles County	US Army Corps of Engineers	Planted 17 acres of riparian woodland within the Sepulveda Flood Control Basin adjacent to the Los Angeles River. Installed 1,544 plants in 1984. Installed plants and cuttings in three 1-acre test plots in 1986 to compare irrigation methods (overhead vs. hand watering) with no irrigation. Plantings included box-elder, white alder, velvet ash, western sycamore, Fremont cottonwood, black cottonwood, coast live oak, Engelmann oak, valley oak, arroyo willow, and California bay.
Kern River Preserve Yellow-billed Cuckoo Habitat Enhancement	1986-1989	Near Weldon, Kern County	The Nature Conservancy	In 1986, Bertin Anderson planted 25-acre pilot project at TNC's Kern River Preserve situated along the south fork of the Kern River. Between 1986 and 1989, Bertin Anderson supervised the planting of 142 acres of cottonwoods and willows (four species) at the Kern River Preserve.

Table 7—*Continued.*

Project name	Date(s)	Location	Project sponsor	Actions taken to implement project
Cosumnes River Preserve Riparian Restoration	1988-2000s	Sacramento County	The Nature Conservancy and Partners	Planted 10 acres of valley oak riparian forest on fallow agricultural land adjacent to the Cosumnes River. New technology—collar and screen developed by Frank Chan of PG&E—was used to protect acorns and seedlings from predation by rodents and grasshoppers. First use of drip-irrigation by TNC. Documented growth of seedlings with irrigation.
Kopta Slough Preserve Riparian Restoration	1989-1995	Tehama County	The Nature Conservancy	Planted approx. 300 acres. Planted Fremont cottonwood, four willows (red, sandbar, arroyo, black), box-elder, Oregon ash, California wild rose, blackberry, coyote brush. First large-scale native grass plantings – blue rye, creeping rye, meadow barley, purple needlegrass. Soil moisture was studied as to depth to water-table and root growth rates into its surface, as revealed by backhoe pits. Irrigation movement through the soil was monitored by electrical moisture probes.
Stony Creek Preserve Riparian Restoration	1991	Glenn County	The Nature Conservancy and CA Dept. of Water Resources	Planted approx. 500 acres. Conducted more experiments with the timing of weed management and the timing of irrigation on plant growth. Refinement of implementation monitoring.
Sacramento River National Wildlife Refuge (Llano Seco Unit) Riparian Restoration	1991	Butte County	U.S. Fish and Wildlife Service and partners	Species planted included all of those mentioned for Kopta (above) plus additional understory species, such as mugwort, gumplant and evening primrose.
Rangeland restoration projects				
Willow Creek Restoration	1980	Near Adin, Modoc County	USDA Soil Conservation Service - (Now NRCS)	Dumped large rocks into slots cut across the eroded stream channel and keyed into the channel banks and bottom to create a series of rock sills across the channel. Disturbed channel banks were planted with willows and other woody shrubs. Area was fenced to prevent indiscriminate use by livestock.
Clark Canyon Riparian Demonstration Area	1984-1987	Mono County	U.S. Bureau of Land Management	Constructed multiple check dams along one mile of Clark Canyon Creek (tributary to Aurora Creek), East Walker River sub-basin, to control gully head-cutting, trap sediment, raise water table, and restore meadow riparian areas. Elevation 7,000 to 7,300 ft.
Invasive plant removal/control				
Thousand Palms Canyon Tamarisk Control Project	1986-1992	Riverside County	The Nature Conservancy and Partners	Volunteers and California Conservation Corps crews removed tamarisk in Thousand Palms Canyon—a 25-acre, 1-mile long wetland in the center of Coachella Valley Preserve. Infestation of tamarisk threatened native riparian community of desert fan palms, coyote willow, Fremont cottonwoods, common reed, honey mesquite, and screwbean mesquite. Outplanted mesquite grown in on-site nursery. Spread seeds collected on-site from natives including palm, cottonwood, mesquite, saltbush, quailbush, and alkali goldenbush.

Table 7—*Continued.*

Project name	Date(s)	Location	Project sponsor	Actions taken to implement project
Afton Canyon Riparian Restoration Project	1992-1996	San Bernardino County	Barstow Resource Area Office, Bureau of Land Management	300-acre pilot project within the Afton Canyon Area of Critical Environmental Concern (ACEC) on the Mojave River. Actions included construction of barriers to OHV travel; installation of cattle allotment exclusion fencing; use of prescribed fire in dense saltcedar stands; herbicide application to saltcedar resprouts; manual saltcedar stem cutting and herbicide application; revegetation of saltcedar removal areas using natural revegetation; pole planting of cottonwood and willow trees (7,000+); and seeding of native shrubs and grasses.
Russian River Watershed Giant Reed Eradication Program	1992+	Mendocino and Sonoma Counties	Circuit Rider Productions and Partners	Conducted research on control methods, including non-toxic approaches to giant reed removal. Conducted digital mapping of giant reed locations in riparian zones within the watershed. Prioritized sites for giant reed removal and follow-up habitat restoration. Educated landowners and community about values of riparian zones and problems associated with giant reed. Coordinated volunteer and community involvement in giant reed removal and habitat restoration. Conducted long-term monitoring.
Santa Ana River Watershed Arundo Habitat Management Program	1997+	Orange County and Riverside County	Santa Ana Watershed Project Authority (SAWPA) and Partners	Since 1997, SAWPA and its Partners (primarily the Santa Ana Watershed Association and the Riverside County Regional Park and Open-Space District) have removed over 3,000 acres (out of approximately 10,000 acres) of Arundo from the Santa Ana River Watershed. Cleared areas have been replaced with native riparian or wetland vegetation.

Table 8—Common and scientific names for plant species.

Common name	Scientific name
Alkalai bulrush	*Scirpus robustus*
Alkali goldenbush	*Haplopappus acradenius*
Arroyo willow	*Salix lasiolepis*
Arundo (see Giant reed)	*Arundo donax*
Athel	*Tamarix aphylla*
Beardless wildrye	*Leymus triticoides*
Big-leaf maple	*Acer macrophyllum*
Blackberry	*Rubus ursinus*
Black cottonwood	*Populus trichocarpa*
Black walnut	*Juglans hindsii*
Black willow	*Salix nigra* (aka *S. gooddingii*)
Blue elderberry	*Sambucus caerulea*
Blue elderberry	*Sambucus mexicana*
Blue rye	*Elymus glaucus*
Box elder	*Acer negundo*
Buttonbush	*Cephalanthus occidentalis*
California bay or bay laurel	*Umbellularia californica*
California blackberry	*Rubus ursinus*
California buckeye	*Aesculus californica*
California wildrose	*Rosa californica*
Chokecherry	*Amelanchier pumila*
Coast live oak	*Quercus agrifolia*

Table 8—*Continued.*

Common name	Scientific name
Coast redwood	*Sequoia sempervirens*
Common reed	*Phragmites australis*
Common tule	*Scirpus acutus*
Coyote brush	*Baccharis pilularis*
Coyote willow	*Salix exigua*
Creeping rye	*Leymus triticoides*
Engelmann oak	*Quercus engelmannii*
Evening primrose	*Oenothera elata* ssp. *Hirsutissima*
False bamboo (Arundo)	*Arundo donax*
Fan palm	*Washingtonia filifera*
Fremont cottonwood	*Populus fremontii*
Giant reed	*Arundo donax*
Goodding's willow	*Salix gooddingii*
Gumplant	*Grindelia camporum*
Honey mesquite	*Prosopis glandulosa*
Hawthorne (hawthorn)	*Crataegus douglassi*
Meadow barley	*Hordeum brachyantherum*
Mountain alder	*Alnus tenuifolia*
Mountain ash	*Sorbus scopulina*
Mugwort	*Artemesia douglasiana*
Oregon ash	*Fraxinus latifolia*
Palo verde (paloverde)	*Parkinsonia L.*
Purple needlegrass	*Stipa pulchra*
Quailbush	*Atriplex lentiformis*
Quaking aspen	*Populus tremuloides*
Red alder	*Alnus rubra*
Red willow	*Salix laevigata*
Saltbush	*Atriplex polycarpa*
Saltcedar (tamarisk)	*Tamarix ramosissima (*aka *T. pentandra)*
Sandbar willow	*Salix interior;* aka *S. exigua*
Screwbean mesquite	*Proposis pubescens*
Sitka spruce	*Picea sitchensis*
Spikerush	*Eleocharis* spp.
Spirea	*Spiraea* sp.
Tamarisk	*Tamarix ramosissima (*aka *T. pentandra)*
Toyon	*Heteromeles arbutifolia*
Tule	*Scirpus* spp.
Valley oak	*Quercus lobata*
Velvet ash	*Fraxinus velutina*
Water grass	*Echinochloa crusgalli*
Western sycamore	*Platanus racemosa*
White alder	*Alnus rhombifolia*
White root	*Carex barbarae*
Willow	*Salix* spp.
Yellow willow	*Salix lasiandra*

Rieger et al. (2014) refer to these two different approaches to restoration as "Construction and Installation Strategies" (horticultural/active) versus "Management Strategies" (process-based/passive). Actually, many riparian restoration projects employ both strategies on the same site at the same or different times.

Most of the early restoration projects employed horticultural restoration because the project planners were dealing with: (1) land surfaces that were well above active flooding; (2) lowered groundwater tables; (3) altered stream hydrology due to construction and operation of dams in the watershed and an increase in impervious cover in urban watersheds; (4) the presence of certain invasive plants that colonize a site so quickly so as to preclude the natural reestablishment of native plant species; and (5) pressure from clients and/or regulators to get riparian vegetation established quickly.

Notwithstanding our emphasis on horticultural restoration, it needs to be recognized that some restoration projects have operated under the principle that "revegetation projects can sometimes be best accomplished by planting nothing," (Riley 1998). Riley (1998) went on to state, "The best revegetation project from a standpoint of ecological diversity, and the most economical, may be the project that simply creates the conditions needed for native vegetation to 'reinvade' a site." Unfortunately, the presence of invasive nonnative plants on, or near, most riparian restoration project sites makes this a risky proposition for most project funders and sponsors.

Many of the early riparian restoration projects were not given formal names; in other instances, the authors of papers did not provide the project name but rather only the project location. We have assigned names to these projects in order to facilitate their discussion. Also, we have used the same terms (for example, revegetation) used by the authors in the literature describing the project.

Bank Stabilization/Erosion Control Projects

In 1960, at the request of the State of California, Congress authorized the Sacramento River Bank Protection Project to protect the Sacramento Valley levee system (Kindel 1977). Initially, bank protection was provided at the most critical areas (in other words, areas where erosion had extended well into the levees). Jannssen (1976) recalled: "In order to rebuild the levee and construct the rock protection (riprap), trees, and vegetation growing on the levee were removed. Public concern over this practice led to attempts by the U.S. Army Corps of Engineers (CE) and the state to establish experimental test planting areas … to determine if selected vegetative species could be found that would not constitute a threat to the structural integrity of the levees." These test plantings were considered unsuccessful (Jannssen 1976).

As mentioned in part 1 above, DWR conducted a Pilot Levee Maintenance Study (CDWR 1966; CDWR 1967) between 1962 and 1967. Field testing for the Pilot Levee Maintenance Study was conducted within the Sacramento-San Joaquin Delta primarily on levees bordering the Sacramento River. The five test sites selected were at Garcia Bend, Ryde, Steamboat Slough, Hood, and Isleton. Much of the work done at the test sites was conducted by other governmental agencies under contract to CDWR. Between 1963 and 1965, tests were conducted under three categories: plant performance and maintenance; levee protection and repair; and revetment with vegetation. Specific types of experiments were conducted under each category. Most of the plant species used in these tests were nonnative groundcovers and trees, with the exception of tests involving the management of existing vegetation. The experiments conducted in this study led to the general conclusion that "alternative levee maintenance practices can be used to allow vegetation on levees" and that "this vegetation can be maintained for the multiple use of levees without jeopardizing the primary function of flood control" (CDWR 1967).

In the late 1960s, the Corps planted trees and shrubs at several selected sites along the Sacramento River to "demonstrate that such vegetation can be successfully grown, can be compatible with flood control requirements, and can offer a significant improvement to aesthetics and other environmental aspects of the river" (Kindel 1977). The most noteworthy project was the CE Monument Bend Demonstration Project in 1967 (Kindel 1977).

Most early streambank stabilization projects relied heavily on structural measures for controlling bank erosion. Riparian vegetation was planted within these structures to soften the visibility of concrete or to take over the function of slowing water adjacent to the banks initially provided by the revetment. The California Department of Parks and Recreation conducted some of the earliest projects; for example, Bull Creek Bank Stabilization in 1971-1974 (Barry 1984; Barry 1985; Barry 1988).

Between 1978 and 1980, researchers from the Environmental Horticulture Department at the University of California, Davis (Whitlow et al. 1984) investigated the potential for using vegetation as an agent for erosion control in the tidal zone on levees in the Sacramento/San Joaquin Delta. They conducted experimental plantings for the CDWR to identify species and planting techniques suitable for application in the intertidal zone[14]. The ultimate goal was a vegetative replacement for riprap. Unfortunately, both research sites were riprapped before the investigations could be completed.

The USDA Soil Conservation Service (SCS, now NRCS) commonly worked with landowners in rural areas and sometimes in urban areas to control streambank erosion. Patterson et al. (1984) described some of the more common streambank stabilization techniques used by the SCS during the 1970s and 1980s. Many of these measures provided "physical protection" (for example, rock riprap, post and wire revetment, gabion baskets), while others employed "vegetative protection" (for example, woody cuttings, rooted woody plants, herbaceous plants) but often in combination with some form physical protection at the toe and/or on the lower bank slope. This woody vegetation grew to cover the physical measures and provide valuable fish and wildlife habitat.

Severe storms in 1978, 1979, 1980, and 1982 caused considerable damage to streams in California. Drawing on Emergency Watershed Protection (EWP) funds, the SCS used structural and vegetative measures to stabilize severely eroding streambanks and reestablish riparian vegetation. From 1978 through 1982, a total of 371 EWP projects was completed. Some of the river systems on which these EWP streambank stabilization/riparian revegetation projects were constructed were the Cuyama River in Santa Barbara and San Luis Obispo counties, Carmel and Salinas rivers in Monterey County, Aptos Creek in Santa Cruz County, and the Santa Clara River in Ventura County (Gray et al. 1984). Although most of the streambank stabilization projects were small, SCS completed work on over 100 miles of streambanks. In 1983, Schultze and Wilcox (1985) evaluated the results of the revegetation work for 29 projects in California's central coast area. "Early SCS revegetation efforts used nonnative species of plants or species not considered riparian," (Gray et al. 1984). Although native species (primarily willows) were most

[14] Although research sites were within the intertidal zone, they were presumably influenced by fresh and/or brackish water based on the plant species used in the experiments. (See table 7.)

commonly used in SCS bank stabilization projects by the late 1970s, unfortunately, during this period, SCS sometimes incorporated invasive nonnative plant species in bank stabilization measures. For example, woody cuttings of saltcedar and athel[15] were planted behind pipe and wire revetment and at the toe of reshaped banks on over 2 miles of the Cuyama River as part of an EWP project constructed in 1979 (Gray et al. 1984). Also, *Arundo donax* (referred to as false bamboo) was planted along with willows in EWP projects constructed on the Carmel and Salinas rivers in Monterey County in 1978 and 1979 (Gray et al. 1984).

The Pacific Gas and Electric Company (PG&E) developed early revegetation techniques for riparian areas affected by its projects. The Lost Canyon Rehabilitation Project in 1983-1985 (Chan and Wong 1989), implemented as mitigation for erosion and habitat loss along a Sierra stream caused by a pipeline rupture, required the development of techniques for revegetation with Sierran montane riparian species in Fresno County. Frank Chan devised and tested some of the earliest innovative measures for native plant revegetation within the riparian corridor.

During the 1980s, citizens voiced opposition to the use of totally engineered structures for streambank erosion control. Revegetation of streambanks with native vegetation became an integral part of streambank stabilization projects. These types of projects often occurred in the northern part of the State and were driven by a concern to restore salmon and steelhead habitat, especially for listed fish species. Salmonid streams had been severely impacted by timber harvesting, road construction, and livestock grazing. The goal was to reduce nonpoint source sediment that was impacting salmonid spawning and rearing habitat. In some cases, the primary action was the construction of fencing to exclude livestock from the streambanks. Some of these projects employed the use of vegetative and quasi-vegetative bank/slope protection techniques such as presented in Schiechtl (1980) and Gray and Leiser (1982).

Several natural resources employment training programs were active in stream and riparian restoration in the 1980s. The Redwood Community Action Agency conducted a number of streambank stabilization and riparian revegetation projects along coastal streams in northern California in the early and mid-1980s. Reichard (1989) reported on restoration projects performed along McDonald Creek, Tryon Creek, and Prairie Creek. The Plumas Corporation performed similar streambank restoration projects in the northern Sierra. The Red Clover Creek Erosion Control Demonstration Project (Lindquist and Bowie 1989; Lindquist and Filmer 1988) involved the cooperation of multiple State and Federal agencies, landowners, and organizations through the use of the Coordinated Resource Management and Planning (CRMP) process[16].

More recent publications on the use of biotechnical/soil bioengineering techniques involving the use of riparian vegetation include Gray and Sotir (1996), Hoag and Fripp (2002), Schiechtl and Stern (1992), and Schiechtl and Stern (1997). An example of a biotechnical bank stabilization approach developed as an alternative to rock revetment (riprap) in the Sacramento-San Joaquin Delta is the Georgiana Slough Pilot Bank Protection Project conducted in 1999 (Hart and Hunter 2004).

[15] According to Bossard et al. 2000, athel (*T. aphylla*) is not considered an invasive pest under most circumstances whereas saltcedar (*T. ramosissima*) is invasive.

[16] The CRMP process is a collaborative public-private project planning and implementation process that seeks to involve all interested parties in management and restoration decisions and in project implementation.

River, Stream, and Watershed Restoration Projects

A wide variety of river, stream, and watershed restoration projects were implemented in the 30-year period between 1970 and 2000. Many of these projects were components of a larger vision expressed in long-range river and watershed management plans prepared by Federal, State, and local agencies. The USDA Forest Service and the USDI Bureau of Land Management prepared management plans for Federally-designated Wild and Scenic Rivers while The California Resources Agency prepared management plans for State-designated Wild and Scenic Rivers; however, these plans dealt mostly with the preservation and management of the designated river section and not with the restoration of riparian resources. CDFG (now DFW) coordinated with local agencies to prepare State Protected Waterway Management Plans for the San Lorenzo River (Ricker 1979), Big Sur River (County of Monterey 1983), and Little Sur River (Harvey and Stanley Associates, Inc. 1983). Riparian vegetation management and riparian revegetation were components of these plans. Riparian habitat protection and management within the coastal zone was addressed in Local Coastal Plans prepared by counties. There were also locally-driven enhancement plans for watersheds such as the Garcia River (Mendocino County RCD 1992) and Huichica Creek (Napa County RCD 1993). Sometimes, it worked the other way around in which the success of the early restoration projects prompted the preparation of a management plan to address issues in the entire watershed.

In-stream restoration projects focused primarily on restoring fish spawning and rearing habitat; however, planting of riparian vegetation on streambanks was generally included in these projects so as to provide Shaded Riverine Aquatic (SRA) Cover for fish. Large woody debris (LWD) was often reintroduced into the stream system in the form of logs and rootwads to improve fish habitat and cover. The LWD was typically secured to the streambanks and woody cuttings were inserted into eroding bank slopes. Boulders were used for grade control and channel stabilization. Rock groins constructed to slow and redirect streamflow away from the banks were planted with woody cuttings. Streambank stabilization typically employed biotechnical measures incorporating live vegetation as well as dead woody material resulting in riparian habitat benefiting fish, aquatic life, and riparian dependent wildlife species. Many projects also involved the removal or modification of migration barriers such as log jams and culverts. The provision of adequate filter strips of riparian vegetation was a concern for lands managed for timber production, especially within USFS Streamside Management Areas.

Watershed restoration projects/programs generally focused on the installation and use of best management practices for the control of erosion and the prevention of sedimentation of streambeds as well as proper stormwater management for the control of pollutants (nonpoint source pollution prevention/control). Landslides, unstable slopes, and eroding streambanks were often stabilized with biotechnical slope stabilization measures incorporating the use of live and dead riparian vegetation. Local Resource Conservation Districts often served as project coordinators—working with citizen's advisory committees and governmental agencies, preparing and submitting grant applications, keeping track of expenditures, administering work contracts, and coordinating volunteer activities. The Lagunitas Creek (tributary to Tomales Bay) Watershed Restoration Program (Berger 1990; Marcus et al. 1987; Marcus 1989; Witkin 1990) is an example of a program using multiple approaches to control erosion coming from numerous sources throughout a watershed to improve coho salmon and steelhead habitat and reduce sedimentation in Tomales Bay. This program included preparation of an erosion control handbook (Prunuske 1987) containing gully control and streambank stabilization measures utilizing combined vegetative and structural solutions. Copies of the handbook were given to participating landowners and agencies. The Walker Creek Watershed Restoration Project (Berger 1990; Marcus 1989; Marcus et al. 1987) also involved the repair of many erosion sites through the use of riparian vegetation often combined with structural stabilization measures in order to reduce sedimentation in Tomales Bay.

During the 1970s, 1980s, and 1990s, there was a growing movement toward the development of Cooperative Watershed Associations often called watershed councils or alliances. These organizations generally sought to involve all stakeholders in a watershed or stream reach including private landowners, local, State, and Federal agencies, resource users, and citizen's groups. These associations were actively involved in the planning and implementation of river, stream, and watershed restoration projects.

James Barry (1985) described ecosystem restoration underway at multiple sites with the California State Park System for the purposes of erosion control, alien species eradication, and natural ecosystem enhancement. Revegetation within the riparian corridor on State Park lands was being performed as far back as the mid-1970s, mostly to compensate for former logging practices and overzealous stream clearance programs. One such project was the San Simeon State Beach Riparian Restoration Program (Capelli 1985).

Through the years, hydrologists and fluvial geomorphologists played an increasingly important role in riparian corridor restoration. Their expertise was essential in a number of ways, for example: restoring incised and leveed stream systems (Haltiner and Beeman 2003), which allowed for the creation of floodplain terraces that could be planted with riparian vegetation; restoring flooding to floodplain riparian systems including revegetated sites (Swenson et al. 2003); and reconnecting stream channels with their historic floodplains—aka re-hanging streams in meadows (Poore 2003). They recognized the importance of restoring the "physical integrity" (environmental health specific to a particular catchment river system) of rivers and their floodplains created by a "process of dynamic equilibrium punctuated by natural disturbances" (Haltiner et al. 1996), the "natural dynamic character" (management toward a more natural flow regime) of river systems (Poff et al. 1997), and the "natural stability" of stream channels (Rosgen 1996). Moreover, their emphasis on fluvial geomorphological principles caused many restoration practitioners to focus on a process-based approach to riparian habitat and stream restoration (Tomkins and Kondolf 2003). The preferred approach to restoration was to remove or ameliorate the effects of human interventions in the river system and "allow the natural processes to recreate desirable habitat" (Haltiner et al. 1996). Using this approach, success was redefined as the "restoration of key ecologic processes (physical and biological conditions) that are both resilient and evolving" (Haltiner et al. 1996). However, not all stream/riparian restoration projects withstood the test of time. Sometimes, in-stream channel improvements and bank stabilization measures did not withstand high flows long enough for riparian vegetation to become established as was the case with the Uvas Creek Park Preserve Restoration Project (Kondolf et al. 2001; Rosgen 2006; Rosgen 2008).

Stream and meadow restoration projects in the Tahoe Basin were conducted to restore habitat, but primarily to reduce the amount of sediment reaching Lake Tahoe. Projects such as the Cold Creek—Pioneer Trail Stream Habitat Restoration Project (Tahoe RCD 2015), designed with the assistance of Dave Rosgen, stabilized eroding streambanks with logs and rootwads, not only reducing sediment loads, but also creating valuable fisheries habitat. Projects such as the Trout Creek Wildlife Enhancement and Stream Restoration Project (CTC 2015) reconnected channelized streams with their floodplains, resulting in periodic overbank flows depositing sediment on the meadows rather than impacting the clarity of Lake Tahoe.

Similarly, the Bear Creek Meadow Restoration Project (Poore 2003) in eastern Shasta County restored the historic floodplain and channel connection, preventing channel erosion and buffering peak flow events, thereby reducing sedimentation downstream in Fall River. Both the Trout Creek and Bear Creek projects utilized stacked sod mat transplants cut from the meadows to stabilize the banks of the realigned stream channels in conjunction with riparian plantings.

Urban Creeks Restoration Projects

In rapidly growing California cities and counties, creek corridors, however severely impacted, were generally the last remaining undeveloped natural environments within urban and suburban development. Multiple demands were placed on these areas for flood control, active and passive recreation, and trail systems. Urban creeks were used as dumping grounds for trash and discharge of polluted waters. Additionally, urban creeks were subjected to the impacts of significant amounts of impervious cover within their watersheds, which often resulted in channel incision.

In the 1970s and 1980s, there were nationwide and regional movements for the improvement of urban creeks and the remnants of riparian habitat on their banks. Urban planners, citizen groups, etc., recognized the value of these areas as refuge from urban life and as buffers between conflicting land uses. At the same time, scientists, conservationists, environmentalists, and others recognized the importance of these streams and riparian areas as habitat for fish and wildlife. Nationally, these "natural" corridors were referred to as "greenways," basically meaning linear open space. In California, use of the term greenways was not common; rather, these linear corridors were generally referred to as "urban creeks" or "urban creek corridors" or sometimes "parkways."

Due to the nature of the problems impacting urban creeks, many urban creek restoration projects required extensive planning and multiple funding requests for various stages of the restoration including trash removal, sanitary engineering to resolve water quality issues, removal of invasive plants, erosion control, bank stabilization, in-stream aquatic habitat enhancement, and the installation of native plant species. Funding for some urban creek restoration projects became available in conjunction with other planning efforts: for example, flood control planning and park planning. Much of the work was also accomplished through the use of volunteers.

In 1984, the Urban Creeks Council was formed to present an alternative flood control option to the Corps of Engineers, which was planning to place a major section of Wildcat Creek (Alameda County) into a conventional dirt/riprap and concrete trapezoidal flood-control channel. The Council advocated for a multi-stage channel design with a bankfull channel, riparian corridor, floodplain, and berms (levees). This "natural-like" channel design for the Wildcat-San Pablo Creeks Flood Control Project (Fishbain and Williams 1988; Haltiner et al. 1996; Meyer 1989; Riley 1989a; Riley 1989b; Riley 1998; Riley 2003) was approved and constructed by the Corps.

The Urban Creeks Council was instrumental in getting numerous urban stream restoration projects implemented in the San Francisco Bay Area, the first project being Strawberry Creek Park (Berger 1990; Wolfe 1988), which involved the daylighting of a section of Strawberry Creek that had been underground in a culvert since 1904.

Many urban creek restoration projects were implemented in conjunction with the development of new residential subdivisions adjacent to deeply incised stream reaches. One of the earliest examples of the compound (multi-stage) channel approach was the Miller Creek Restoration Project (Haltiner et al. 1996; Yin and Pope-Daum 2004), wherein a low flow channel-floodplain system allowing some of the dynamics of a natural channel was constructed and then revegetated.

The CDWR Urban Stream Restoration Program began in 1985. Counties, cities, and non-profit organizations interested in improving the conditions of their watercourses were encouraged to submit grant proposals for restoration projects. Many of these projects involved the planting of riparian vegetation and the enhancement of existing riparian habitat in urban areas. An example of a CDWR-assisted (in other words, partial funding) stream restoration project with a significant riparian revegetation component is the Carmel River Biotechnical River Restoration (Cummings 1992; Haltiner et al. 1996; Matthews 1990).

The California State Coastal Conservancy was also actively involved in funding riparian habitat restoration in coastal areas especially when stream degradation was contributing to sedimentation of coastal lagoons. One such example is the Buena Vista Creek Restoration Project (Marcus 1987; Marcus 1988; Marcus 1989) to reduce sedimentation in Buena Vista Lagoon.

Many urban creek restoration projects involved work on only a limited portion or segment (sometimes referred to as a reach) of a stream. The Strawberry Creek Restoration Project (Berger 1990; Charbonneau and Resh 1992; Pollak 1990) and Strawberry Creek Management Plan/Program (Charbonneau and Rice 1989) conducted on the UC Berkeley campus and in its watershed are examples of urban creek restoration projects that included restoration work in the mid and upper watershed thereby reducing impacts on downstream reaches.

Locally-sponsored flood management projects evolved as alternatives to traditional flood control projects. These projects involved coming up with a greenbelt floodway design that provided flood protection but also provided for protection and restoration of riparian areas and public access to these “parkways.” The First San Diego River Improvement Project (Burkhart 1989; City of San Diego 2001; Faber et al. 1989), a combination of flood control, natural area, and parkway, was initiated by private developers to allow commercial and residential developments in the Mission Valley to be approved by the City of San Diego.

The U.S. National Park Service River and Trail Conservation Assistance (RTCA) Program assisted local sponsors with the planning of urban creek restoration projects by bringing together diverse stakeholders and helping them find consensus solutions to restore degraded urban creeks. The RTCA published a book titled *How Greenways Work: A Handbook on Ecology* (Labaree 1992). The RTCA provided the impetus for the writing of *Ecology of Greenways: Design and Function of Linear Conservation Areas* (Smith and

Hellmund 1993), a book that bridges the gap between design and ecology. Publications like these were important since it was often landscape architects who were responsible for leading the design team for urban stream restoration projects.

Compensatory Mitigation Projects

Restoration of riparian habitat was undertaken as compensatory mitigation for riparian habitat loss due to unavoidable impacts resulting from infrastructure construction projects (for example, highway and bridge construction, flood control channel modifications, and utility corridors) and land development projects. These projects tended to be within, or adjacent to, urban areas where the stream corridors were often the only open space remaining. The major drivers behind these mitigation projects were NEPA and CEQA (both passed in 1970), the California Porter-Cologne Water Quality Control Act (1970), CCWA (1972), ESA (1973), CE Section 404 permitting, the California Coastal Act (1976), and CDFG stream alteration agreements. Often there was also a strong desire on the part of the community to develop public access to these "restored" stream corridors, sometimes leading to conflicts between regulators wanting the restored lands to be set aside for wildlife and park planners wanting to develop infrastructure (for example, pathways, lighting) for visitor use.

Some of the earliest projects involving native plant landscaping and native plant revegetation were installed by the Santa Clara Valley Water District (SCVWD) in the mid- and late-1970s. The District adopted a resolution in 1974 that set policy for the landscaping of District projects. In 1975, SCVWD published *A Landscaping Guide to Native and Naturalized Plants for Santa Clara County* (Stiles 1975). This guide contained pertinent information on characteristics and suitability of numerous plants native to the region, including species common to the stream systems in Santa Clara County. Dr. Bernie Goldner (1984) referred to projects installed in 1976 on Randol Creek, San Tomas Aquino Creek, Los Gatos Creek, and the Guadalupe River as "landscape projects" even though mostly native trees and shrubs were installed along these structurally modified channels. Various measures of structural bank protection were associated with these projects. Subsequent plantings of native vegetation installed in 1979 along Calabazas and Berryessa creeks were referred to as "revegetation projects" (Goldner 1984).

The fact that flood control managers were aware of the public's concern regarding the impact of flood control projects on riparian habitat at a local level is evidenced by the publication of *Valley Riparian Forests of California: An Overview of their Biological Significance and Physical/Chemical Processes* (Stiles 1978) by the SCVWD. In 1979, SCVWD adopted a new policy emphasizing mitigation of substantial adverse impacts, in conformance with CEQA (Goldner 1984).

There was a tendency for the early "revegetation" projects to end up appearing more like landscaping of structurally modified flood control channels than the creation of valuable fish or wildlife habitat. This was in part because there was an overreliance on engineered structures (for example, riprap, wire basket gabions) to prevent bank erosion and a resistance on the part of flood control maintenance personnel to allow the planting of riparian vegetation at the toe of the bank slope adjacent to the channel bottom. This prevented the establishment of shaded riverine aquatic (SRA) Cover.

Another reason why these "revegetation" projects often resembled landscaping is because many of these early projects were designed by landscape architects. Plantings were arranged for various visual purposes (for example, screening and aesthetics) without regard to the habitat requirements (for example, plant associations and vegetation structure) of riparian wildlife. Sometimes cultivars with showy appearance were installed instead of the native species or because of a failure to plan ahead for contract growing of native plant materials. Some common riparian plant species (for example, poison oak and stinging nettle) were almost always omitted because of undesirable characteristics (for example, poisonous and thorniness). Additionally, plantings were laid out in a linear fashion so as to be watered using drip irrigation.

Examples of "revegetation" projects installed along structurally protected flood control channels in the early and mid-1980s by the SCVWD include: Guadalupe River Revegetation Project (Goldner 1984); Alamitos Creek Revegetation Project (Berger 1990; Goldner 1988); Llagas Creek Watershed Mitigation (Berger 1990); and the Saratoga Creek Flood Control Project Revegetation (Berger 1990; Gray et al. 1984).

Up until the mid-1980s, almost all the SCVWD riparian revegetation projects were on the banks or immediate top-of-bank of flood control channels. The Lower Coyote Creek Pilot Revegetation Project (Berger 1990; Stanley et al. 1989), installed by the SCVWD in 1986-1987, was undertaken to determine the best means of revegetating historic floodplains that had been used for agriculture. Findings from revegetation on the 4-acre pilot project site were used for the selection of riparian species, propagule types, and planting, irrigation, and maintenance techniques on the remaining 28.5 acres of mitigation along lower Coyote Creek.

During the 1980s, other flood management agencies in the San Francisco Bay Region (for example, Alameda County Flood Control District, Marin County Flood Control District, and Sonoma County Water Agency) were also restoring riparian habitat as mitigation for flood control project impacts. Examples of these early revegetation projects include: Caldecott Park Creek Revegetation (Berger 1990); Novato Creek Flood Control Project (Berger 1990); and the Spring Creek Flood Control Project (Berger 1990).

Examples of early revegetation projects conducted as mitigations in the Central Valley in the 1980s include: California Department of Water Resources Sacramento River Maintenance Area 9 installed in 1981 (King 1985); and the Crescent Bypass Riparian Revegetation Project (Oldham and Valentine 1989; Oldham and Valentine 1990) installed between 1985 and 1988.

In southern California, Caltrans implemented a number of riparian revegetation projects as mitigation for impacts associated with highway construction. One of the earliest projects was the I-8 / I-15 Mitigation (Rieger 1988) constructed in 1982. Other Caltrans riparian revegetation projects in San Diego County included: Morena Street Site (Rieger 1988) installed in 1985; Sweetwater Bridge Mitigation site (Rieger 1988) installed in 1986-1987; and SR-52 Mitigation/Mission Trails Park (Rieger 1992) installed in 1989 and 1990.

Some mitigation projects involved significant alteration of the project site topography in order to create a planting bench or artificial floodplain with suitable flooding frequency and/or depth to groundwater to support riparian vegetation. Project designers were sometimes forced to take this option of converting upland areas to floodplain because of the no-net-loss of wetlands policy of the regulatory agencies. Caltrans projects involving significant lowering of the surface elevation include: I-8 / I-15 Mitigation in San Diego County (Rieger 1988); Sweetwater Bridge Mitigation (Rieger 1988) in San Diego

County; SR-52 Mitigation/Mission Trails Park (Rieger 1992) in San Diego County; and Hwy 85 Mitigation in Santa Clara County (National Research Council 2001). Frequently, the cost of the excavation and earth removal was applied to the highway budget and not the restoration project since the excavated material was need for fill for nearby highway construction.

Some mitigation projects created significant habitat for wildlife, especially migrant passerine bird species. Construction projects that created gaps in the riparian corridor (fragmentation) were often required to agree to mitigation acreage ratios of 2:1, 3:1, or greater, resulting in the planting of floodplain riparian habitat much wider than the remnant streamside vegetation that was impacted. For example, construction of a high flow bypass channel for the Lower Coyote Creek Flood Control Project necessitated the removal of approximately 15 percent of the existing riparian trees in the project area creating breaks in the riparian corridor. SCVWD was required to create 32.5 acres of new riparian habitat on the floodplain within the project levees.

Some revegetation projects focused mostly, or solely, on the mitigation of riparian habitat loss for special status species, especially Federally-listed endangered species. Caltrans Sweetwater Bridge Mitigation (Rieger 1988) and SR-52 Mitigation/Mission Trails Park sites were constructed primarily to provide habitat for the endangered least Bell's vireo. The planting regime at the Mission Trails Park site followed the prescription for least Bell's vireo habitat generated from extensive research conducted by Baird and Rieger (1989). Three pairs of least Bell's vireos nested at the Mission Trails Park site within a year of planting (Rieger 1992). The M&T Ranch Elderberry Mitigation Project (Stanley 1989) in Butte County and the Sacramento River-Mile 154.6 Right Project (Chainey et al. 1989) in Colusa County were installed to provide habitat for the endangered valley elderberry longhorn beetle.

In the latter part of the 1980s, we saw the creation of mitigation banks used by development projects that were unable to achieve on-site mitigation; for example, the San Joaquin Marsh Mitigation Bank (Stanley 1989) developed by The Irvine Company in Orange County in 1987-1988.

Habitat Conservation/Restoration Projects

A number of governmental agencies and conservation organizations saw an opportunity to restore large swaths (both in terms of length and width) of riparian habitat by purchasing available low-lying agricultural land within floodplains and creating wetland and riparian conservation areas. Much of this land was prone to periodic flooding and no longer profitable for farming. Typically, the objective was to create a mix of habitat types for a variety of bird species (waterfowl, waterbirds, and riparian dependent bird species).

Beginning in 1977, Bertin Anderson and Robert Ohmart undertook experimental revegetation projects for the reestablishment of cottonwood/willow forest on a number of sites along the Lower Colorado River, for the USDI Bureau of Reclamation (Ohmart et al. 1977). Their 1979-1980 Colorado River Dredge Spoil Revegetation (Anderson and Ohmart 1985a; Anderson and Ohmart 1985b) project sites totaled 74 acres, the largest being a 49-acre site on the Cibola National Wildlife Refuge. Interestingly, none of these plantings prospered—as of 2008—due to the modified soil and hydrology everywhere along this reach of the Colorado River. However, Anderson demonstrated hydrological needs and soil alkalinity levels for establishment of cottonwood and red willow on restoration sites.

The Army Corps of Engineers (CE) began revegetation at the Sepulveda Wildlife Reserve in the Los Angeles Basin in 1981. The CE planted 17 acres of riparian woodland in 1984 as part of the Sepulveda Wildlife Reserve Revegetation Project (Parra-Szijj 1990). Due to low survival rates of the riparian plantings, CE installed test plots in 1986 to demonstrate the need for irrigation and determine the best means of watering pole cuttings and seedlings, especially in light of the heavy growth of weeds.

In the early 1980s, The California Nature Conservancy (TNC) saw habitat restoration as a new tool for the conservation of natural areas. Successful habitat restoration would add acres of habitat for target wildlife species on nature preserves. Habitat restoration would change how preserve design would configure nature preserves (based on restoration potential) and allow more opportunity for process-based conservation of wildlife. This logic carried weight with private financial donors that supported TNC.

TNC's Kern River Preserve, situated along the south fork of the Kern River, was one of the earliest locations for experimentation for restoration technology in California. Cottonwood cuttings were planted as early as 1982; however, after initial poor results, TNC quickly realized the need for organized scientific testing of restoration methods—irrigation needs, weed control, and soil factors (texture, alkalinity, and water table depth). TNC hired Dr. Bertin Anderson of the Revegetation and Wildlife Management Center to develop the restoration technology.

TNC's Kern River Preserve Yellow-billed Cuckoo Habitat Enhancement Project (Anderson and Layman 1989; Reiner and Griggs 1989; Tollefson 2003) began in 1986 when Bertin Anderson implemented a 25-acre pilot project testing planting and irrigation methods for the establishment of cottonwoods and willows at the site. Anderson's quantitative approach allowed for the rapid development of methods that proved to be effective at establishing Fremont cottonwood and red willow woodlands required by the targeted species, yellow-billed cuckoo (YBC). From 1986-1989, 142 acres of cottonwoods and willows (four species) were planted at TNC's Kern River Preserve. YBC began using these stands within 2-3 years of growth of the trees. As of 2001, a total of over 330 acres of native riparian trees and shrubs had been planted on the higher floodplain surfaces (Tollefson 2003). In addition, "over 500 acres of native riparian forest have recovered at the Kern River Preserve through 'passive restoration,' by limiting or excluding livestock grazing in low-lying areas that had been converted to pasture through clearing and intensive grazing" (Tollefson 2003).

TNC became involved in the restoration of riparian habitat in the Sacramento Valley beginning in the late 1980s at TNC's Cosumnes River Preserve. TNC contracted with Harvey and Stanley Associates, Inc. (John Stanley and Harold Appleton) to assist TNC (Dr. Thomas Griggs) and Ducks Unlimited with the design and layout of the initial riparian revegetation at Cosumnes. The first phase of the Cosumnes River Preserve Riparian Restoration Project (Griggs et al. 1993) involved the planting of 10 acres of valley oak forest on fallow agricultural land in 1988. Tom Griggs supervised the initial restoration work at the Cosumnes River Preserve. TNC's Habitat Restoration Team directed volunteers in conducting plantings in each successive year. As of 2001, a total of 500 acres of oaks, willows, and other trees had been planted at the preserve by volunteers and school children (Swenson et al. 2003).

In early 1985, a levee protecting the farm field adjacent to the Cosumnes River Preserve failed. Cottonwoods and willows rapidly colonized about 15 acres of sediment deposited by the river on the farmland. Although the levee was repaired, the "accidental forest" was well established and through time provided habitat for a variety of wildlife species. This farm property was acquired by TNC in 1987. The rapidly growing "accidental forest" inspired TNC to explore how natural flooding processes could be enlisted to expand the riparian corridor (Swenson et al. 2003). In the mid-1990s, TNC reoriented its forest restoration program at the Cosumnes River Preserve to focus on areas where natural regeneration could be encouraged by reestablishing natural flooding. The Cosumnes River has close to a natural hydrograph since there are no major dams in the watershed—the entire Preserve area historically flooded in El Nino years, even with levees. In fall 1995, TNC intentionally breached the levee (created a 50-foot gap) and cut a shallow channel through the floodplain thereby reopening about 200 acres of bottomland to natural flooding. Natural "cuttings" of willow and cottonwood became established on the site (Mount et al. 2003; Swenson et al. 2003). The floods of 1997 caused many levee breaks along the Cosumnes River. The preserve and local farmers reached an agreement on an "unleveeing" project and convinced the CE to fund a nonstructural flood management project instead of traditional levee repairs. The project involved breaching and abandoning 5.5 miles of levees. Construction started in the fall of 1997 with the levee breaches and construction of a setback levee. This added about 100 acres to the floodway (Swenson et al. 2003).

After initiating the riparian habitat restoration at the Cosumnes River Preserve, Tom Griggs then moved on to plan the riparian plantings at Kopta Slough, Stony Creek, and the Sacramento River National Wildlife Refuge. "Cultivated restoration became necessary on the Sacramento River because Shasta Dam has altered natural hydrology, changing the patterns and extent of natural vegetation succession. Furthermore, mid to high floodplain soils are prone to support weedy herbaceous vegetation …which competes with native woody vegetation in natural and cultivated succession. TNC developed agricultural-style techniques to restore relatively large acreages of riparian vegetation in a logistically and financially efficient manner" (Silveira et al. 2003).

In 1989, TNC began planting riparian vegetation at the Kopta Slough Preserve (Griggs 1993; Griggs 1994). Kopta Slough Preserve was the R&D center for TNC for riparian restoration along the Sacramento River. The goal was to use all riparian plant species that are characteristic of riparian habitat and to study their survival and growth relative to a variety of factors: soil moisture, depth to water table, and irrigation water movement through the soil. Root growth rates and root architecture were studied by digging up selected plants. The first large-scale native grass plantings in riparian areas were undertaken at Kopta Slough. A total of about 300 acres were planted.

In 1991, TNC began riparian revegetation at the Stony Creek Preserve (Alpert et al. 1999; Griggs and Petersen 1997; Reiner and Griggs 1989). Stony Creek Preserve was the first site purchased by TNC with the intention of transferring property ownership to the USFWS after it was restored, which occurred after 1995. Restoration technology was further refined at Stony Creek as the soils were more variable and irrigation timing and amounts were refined for most species that were planted. Implementation staff was of 6-month interns (mostly recent college graduates). Time and costs of inexperienced implementation became obvious. Hiring of a professional field manager with experienced laborers was decided for future projects. Approximately 500 acres were planted.

TNC began work at the Llano Seco Unit of the Sacramento River National Wildlife Refuge in 1991 (Griggs and Golet 2002; Silveira et al. 2003). Established by the U.S. Congress in 1987, the Sacramento River National Wildlife Refuge consists of 28 Units in Tehama, Glenn, Butte, and Colusa Counties comprising 10,353 acres within the 100-year floodplain (recent mixed alluvium and gravel bars/sandbars) along 81-river miles of the middle Sacramento River from Red Bluff to below Princeton (J. Silveira 2016, personal communication). The USFWS obtained these fee-title properties from landowners who were willing to sell existing riparian forest and flood-prone agricultural fields adjacent to the forests. There are roughly 4,581 acres of remnant riparian habitats on the refuge. TNC established a cooperative management agreement with the USFWS that allowed TNC to restore former farm fields. "Propagules from indigenous plants and local ecotypes are being used in large-scale restoration layouts of various designs associated with site-specific hydrologic and edaphic conditions" (Silveira et al. 2003).

As of summer 2015, 5,033 acres of former flood-prone agricultural lands (primarily walnut, almond, and prune orchards, but in some cases row crops) have been restored to various riparian and floodplain vegetation types (J. Silveira 2016, personal communication).

Rangeland Restoration Projects

The planting of riparian vegetation for gully control in mountain meadows has a long history. Kraebel and Pillsbury (1934) published a handbook for erosion control in mountain meadows in the Sierra Nevada for the USDA Forest Service in which they included specifications for the selection and planting of willow cuttings and the construction of willow wattles.

There were a number of projects in the 1980s to restore wet meadows and their associated streamside riparian buffer strips in eastern California. Project work typically involved the installation of erosion control devices, typically rock, gabion, or fabric grade-control structures (in other words, check dams), across eroded stream channels in high mountain meadows to trap sediment and raise the water table in the meadow. These projects were generally accompanied by the installation of temporary or permanent fencing to control livestock use, a reduced stocking level, or a revised grazing regime (for example, season of use). Many of these projects were planned using the Coordinated Resource Management and Planning (CRMP) Process because they involved work on both public and private land, including public land grazing allotments.

Sample rangeland riparian restoration projects include: Willow Creek Restoration (Clay 1984) in Modoc County and the Clark Canyon Riparian Demonstration Area (Key 1987; Key and Gish 1989) in Mono County.

This work was similar in approach to the demonstration projects on Bear Creek (Elmore and Beschta 1987) and Camp Creek (Elmore and Beschta 1987; Winegar 1977), conducted by Wayne Elmore in the Prineville area of southeastern Oregon (Crook County) during the 1960s and 1970s. However, Wayne Elmore's emphasis was less on the installation of structures and more on the improved management of rangeland riparian areas (Elmore and Beschta 1989).

Invasive Plant Removal/Control

The removal or control of invasive nonnative plants was often an initial action at riparian restoration sites. Thus, most of the projects mentioned above and described in table 7 had some element of invasive plant eradication or control. Some riparian restoration projects only involved the removal of invasive plant species. In these cases, it was assumed that native riparian plants would reestablish on the site(s) after competition for light, nutrients, and water was eliminated. Some of these projects were followed by plantings of riparian plants after the invasive species had been removed entirely or were under control.

Many modern-day strategies for invasive plant control were developed during the latter part of the 20th century. The Nature Conservancy played a significant role in sharing information on control techniques with the preparation of Element Stewardship Abstracts initiated in the late 1980s and early 1990s. Formed in 1992, the California Invasive Plant Council (Cal-IPC) contributed to the development and exchange of information on the eradication of invasive plants in riparian corridors through its symposia, publications, and sponsored research and trainings. Bossard et al. (2000) provides technical information on physical, biological, and chemical control measures for most of the invasive plants that occur in California's riparian corridors.

There are many nonnative invasive plant species known to occur in California's riparian corridors and these were generally dealt with on a project by project basis. Of these, two species in particular had virtually overtaken many stream corridors: giant reed and tamarisk. Below, we mention only four projects of the literally hundreds, if not thousands, of invasive plant removal projects that occurred between 1970 and 2000.

Giant Reed

Giant Reed (also referred to as *Arundo* and false bamboo) was recognized early on as a threat to the success of riparian restoration projects, not only because it often occurred on restoration project sites, which could be dealt with during site preparation and site maintenance, but also because flooding is the primary mechanism of dispersal of stems and rhizome fragments (Rieger and Kreager 1989). In the 1980s and 1990s, giant reed control projects were undertaken in river drainages in many parts of the State including the southern California coast, the central coast, the San Joaquin and Sacramento valleys, and even the north coast. Most restoration projects dealt with a specific reach of a stream and in many cases funding and/or authorization was not available to address upstream infestations of *Arundo* in the watershed. However, there have been some efforts at watershed-wide invasive plant removal. In northern California, in the Russian River Watershed (Gaffney and Gledhill 2003), community-based organizations have worked in collaboration with agencies, landowners, and community members since 1992 to identify and map invaded sites, conduct experimental and demonstration projects, remove giant reed, restore native habitat, and conduct education and outreach programs. In southern California, a large-scale effort called the Santa Ana River Watershed *Arundo* Habitat Management Program has been underway since 1997. Its purpose has been to to rid an entire watershed (largest drainage in coastal southern California) of *Arundo* and restore riparian areas (SAWPA 2016). Native riparian habitat has expanded into at least 60 percent of the reclaimed floodplain, providing valuable habitat for birds such as the endangered least Bell's vireo (Zembal and Hoffman 2007).

Tamarisk

Removal or control of tamarisk or saltcedar and related species was one of the biggest challenges in the southeastern part of California, although it also had to be dealt with elsewhere in southern and central California. Saltcedar control in the Southwest had been attempted by various agencies and organizations since the 1950s (Rodman 1990), although not necessarily for the restoration of native ecosystems. TNC began removing tamarisk on the Coachella Valley Preserve in 1986 to restore native desert fan palm oases and associated riparian species through the Thousand Palms Canyon Tamarisk Control Project (Barrows 1993).

Numerous saltcedar removal projects were undertaken along rivers in southern California in the 1980s and 1990s. Some of these projects involved seeding or planting with native riparian species while others relied on "natural" recovery from nearby seed sources or the seed bank. Bay and Sher (2008) evaluated the success of "active revegetation" (with no irrigation) after Tamarix removal in riparian systems in the Southwest including sites along the Lower Colorado River in California. An example of a large-scale effort to remove saltcedar and restore riparian vegetation is the Afton Canyon Riparian Restoration Project (BLM 2015) on the Mojave River begun by the Bureau of Land Management in 1992.

Part 3—Research Associated With Restoration Projects

Various types of research, experimentation, field investigations, and monitoring programs were associated with early riparian habitat restoration projects. These programs addressed the following types of issues:

- Habitat requirements of target wildlife species
- Planting and irrigation techniques
- Plant survival and growth
- Plant, soil, and water relationships
- Competition from weeds and weed management techniques
- Wildlife usage of revegetated areas
- Proper functioning condition

Information on most of the projects used as examples below is presented in table 7.

Habitat Requirements of Target Wildlife Species

Significant amounts of data were often collected prior to the design of riparian revegetation projects, especially those projects intended to create habitat for special status species.

Lower Colorado River

In 1973, Bertin Anderson, Robert Ohmart, and John Discano began conducting studies of riparian vegetation-wildlife interactions on about 198,000 acres of riparian vegetation along the lower reaches of the Colorado River in an attempt to discover the vegetative characteristics to which birds were responding (Anderson and Ohmart 1977; Anderson and Ohmart 1979; Anderson et al. 1979). They developed a model for revegetating riparian areas from their 5-year database on vegetative-wildlife interactions (Anderson et al. 1979). In 1977, after clearing saltcedar from an area along the Lower

Colorado River, a revegetation design was developed for the site based on this model. While some palo verde volunteered on the site, willows, cottonwoods, and honey mesquite were planted in June-July of 1977. They monitored growth rates, root growth, plant mortality, and other factors for the first year and presumably longer. Anderson and Ohmart (1985a) later refined their modeling based on 7 years of data (1972-1979).

Yellow-billed Cuckoo Habitat at the Kern River Preserve

Anderson and Layman (1989) based the design of yellow-billed cuckoo habitat at the Kern River Preserve on data of cuckoo habitat requirements along the Colorado River from 1976-1983 (Anderson and Ohmart 1984) and on data collected along the South Fork Kern River from 1985-1988.

Least Bell's Vireo Habitat in San Diego County

In 1986, Hendricks and Rieger (1989) analyzed data of least Bell's vireo nesting sites on the Sweetwater, San Diego, and San Luis Rey rivers in San Diego County representing approximately 10 percent of the known species population. A variety of parameters at each nest site were measured to characterize the nesting habitat of the least Bell's vireo for the design of future restoration projects. Baird and Rieger (1989) used this baseline vegetation and habitat data for 30 nesting sites on the three rivers to develop a habitat restoration model for the creation of least Bell's vireo nesting habitat at Caltrans mitigation sites in San Diego County (Baird 1989).

Note: Chapter 8 (Conservation Recommendations) of the *Riparian Bird Conservation Plan* (RHJV 2004) provides recommendations pertaining to the design of riparian restoration projects for riparian dependent bird species.

Planting and Irrigation Techniques

Lower Colorado River

In 1979 and 1980, Bertin Anderson studied the effects of deep tillage (augered holes to various depths) combined with irrigation (daily irrigation discontinued after variable lengths of time) on the growth and survival of rooted cuttings of Fremont cottonwoods on 74 acres of dredge-spoil sites along the Lower Colorado River (Anderson 1989; Anderson et al. 1984). In 1981, Disano, Anderson, and Ohmart described the types of irrigation systems they used for riparian zone revegetation along the Lower Colorado River (Disano et al. 1984).

Kern River Preserve

Beginning in 1986-1987 at TNC's Kern River Preserve, Dr. Bertin Anderson conducted research on ways in which the physical characteristics of the site (soil salinity, soil texture, depth to groundwater) and the type and height of saplings affected plant survival and growth. He evaluated various methods for the propagation of cottonwoods and willows. He also evaluated plant survival and growth with various irrigation regimes at various depths of tillage (augered and then backfilled holes) with respect to the water table. In addition, he studied the effects of competition from weeds and the effects of browsing by wildlife and livestock (Anderson 1989; Anderson and Layman 1989).

Lower Coyote Creek

At the 4-acre Coyote Creek Pilot Revegetation Project site installed in 1986-1987, John Stanley, Larry Silva, Harold Appleton, William Lapaz, and others conducted a

3-year study on the effects of two different types of irrigation (overhead and flood) on the survival and growth of 3,640 plants comprised of 15 native plant species and multiple types of plant materials (propagule types) for each species. (Stanley et al. 1989)

Plant Protection

Frank Chan of PG&E developed the collar and screen plant shelter in the early 1980s. This device was used at the Lost Canyon Rehabilitation Project (Chan and Wong 1989). The collar (initially a cottage cheese container with the bottom cut out inserted into the ground) collected and concentrated precipitation into the root zone of the seedling and helped to deter gophers while the wire screen (tied to the collar) prevented damage from deer, rabbits, and insects. This device was used for direct seeding (for example, acorns) on numerous restoration project sites including at Coyote Creek and Cosumnes River.

Plant Installation

In the mid-1980s, Jonathan Oldham and Bradley Valentine of the Kings River Conservation District developed the "hydrodriller" for the planting of woody cuttings on streambanks at the Crescent Bypass Riparian Revegetation Project. This device was similar to the "waterjet stinger" described by the USDA Natural Resource Conservation Service (Hoag et al. 2001).

Translocation of Live Vegetation

Sutter et al. (1989) studied the survival of transplanted mature elderberry shrubs. The elderberries were transplanted as mitigation for the loss of habitat for the valley elderberry longhorn beetle along the Sacramento and American rivers.

John Rieger used a tree spade to translocate more than 2,000 cottonwood and willow trees that were being removed a mile upstream from the Mission Trails site for a previously approved development. The trees were installed at the Caltrans Mission Trails site and monitored for 5 years. Less than one-half of 1 percent mortality was observed (Rieger et al. 2014).

Application of Agricultural Methods

In 1989, the California Nature Conservancy gained management of the 700-acre Kopta Slough Preserve, which is owned by the Controller's Trust of the State of California. The Kopta property had been a productive almond orchard until the flooding of 1986 that killed over 60 percent of the orchard trees by drowning. The Nature Conservancy's goal was to demonstrate the feasibility of implementing large-scale riparian restoration by planting a minimum of 100 acres in one year. The farmer leasing the agricultural land at Kopta was hired to provide advice on farming technology. Only large acreage restoration would make a difference to target wildlife populations along the Sacramento River (Griggs 1993). Achieving large acreage restoration goals would require the use of modern agricultural technology and equipment. This resulted in the "farming" of native trees and shrubs for the first 3 years of growth to ensure their establishment, once irrigation and weed control were halted.

Plant Survival and Growth

Lower Colorado River

Bertin Anderson (Anderson et al. 1979) determined growth and mortality rates for palo verde, Goodding willow, cottonwood, and honey mesquite planted along the Lower Colorado River in 1977. In 1979 and 1980, Anderson (Anderson and Ohmart 1979; Anderson et al. 1984) measured the growth of rooted cuttings of Fremont cottonwoods planted in holes augered to various depths. Trees were measured (height and crown) three times during the growing season. Trees were irrigated daily with irrigation discontinued after varying lengths of time. Evaluations were made of the effects of deep tillage on tree growth and survival. The effects of differing periods of irrigation on growth and survival were also evaluated.

Lower Coyote Creek Pilot Revegetation Project

Each of the 3,640 plants installed at the 4-acre pilot revegetation site was monitored annually for the first three years (1987-1989). Assessments included survival, growth, vigor, and damage. A vegetation sampling program was employed to document semiannual changes in canopy height, canopy cover, foliage density, and diversity at different heights within the canopy and herbaceous cover. (Stanley et al. 1989)

First San Diego River Improvement Project (FISDRIP)

Monitoring at the 26.8-acre riparian revegetation component of FISDRIP involved the collection of data for comparison with the milestone performance standards that were established for the project (Burkhart 1989). Both quadrats and transects were used to evaluate the development of the riparian woodland and groundcover. Photo-documentation was an important component of the monitoring program.

TNC Sacramento Valley Project

Implementation monitoring involved daily evaluations of irrigation and weed control needs by the field manager. At the end of the growing season either a complete census, or a very focused sampling at preselected locations, was carried out at each project site. Survival and height growth were measured for each species. These data informed subsequent designs as to soil-plant placements.

Plant, Soil, and Water Relationships

Sacramento River National Wildlife Refuge

Lands purchased for the Sacramento River NWR were adjacent to the river channel and still flooded periodically. Channel deposits of sand and gravel were common on these lands, interspersed with the more productive floodplain deposits of fine sand and silt. In the first years, which species could grow on which soil texture was unknown. Likewise, the depth to water table affected the rooting behavior of each species differently. As irrigation was applied, careful monitoring was carried out of soil moisture in the soil profile by electrical moisture probes that had been placed at known depths previously. After 2 years of growth, backhoe pits were excavated to expose the root systems of selected saplings. Root system architecture and depth of development were mapped for each species, thereby informing future planning of design on sites with variable soils. For example, cottonwood "aggressively" grows roots deep to find the water table. Backhoe pits revealed abundant cottonwood roots down to 15 feet below the surface in less than 2 years; arroyo willow growing nearby had rooted only to 5 feet, given identical irrigation. Drought adaptations of native trees and shrubs was virtually unknown. Monitoring of growth on different soil textures and depths to water table informed future design based upon soil characteristics.

Competition From Weeds and Weed Management Techniques

Kopta Slough Preserve

Early on at Kopta Slough Preserve, TNC discovered what every farmer knows: weeds are not compatible with target plant growth. Even a "few weeds" are not conducive to optimum growth of the target species. Thus, aggressive weed control—herbicides, mowing, disking—throughout the season was required to achieve restoration and horticultural success. Lessons learned from several years of implementation were that herbicides are necessary only during the first year, with frequent mowing being sufficient for optimum plant growth during years 2 and 3. If herbaceous understory is to be planted, then herbicides or disking of the aisle between woody plants must be carried out each year to inhibit the production of weed seeds.

Wildlife Use of Revegetated Areas

A number of investigators implemented monitoring programs to document wildlife (especially avian) use of revegetation sites. Many of these programs also monitored avian use of mature riparian forest adjacent to, or nearby, revegetation sites.

Lower Colorado River Riparian Revegetation

Bertin Anderson, William Hunter and Robert Ohmart monitored avian use at three revegetation sites ranging in size from 25-74 acres along the Lower Colorado River from 1977-1984 (Anderson and Ohmart 1984; Anderson et al. 1979; Anderson et al. 1989)

Kern River Preserve Yellow-Billed Cuckoo Habitat Enhancement

William Humber, Bertin Anderson and Reed Tollefson censused birds utilizing naturally occurring cottonwood-willow habitats on TNC's preserve and on one 25-acre revegetation site implemented in 1986 and on two 25-acre revegetation sites implemented in 1987 (Hunter et al. 1989). Note: Appendix B of the *Riparian Bird Conservation Plan* (RHJV 2004) provides documentation on how birds responded to riparian restoration at the Kern River Preserve.

Lower Coyote Creek Pilot Revegetation Project

Based on a Fish and Wildlife Coordination Act Report issued by the U.S. Fish and Wildlife Service, the CE 404 permit for the Lower Coyote Creek Flood Control Project required the Santa Clara Valley Water District to monitor wildlife use of at least one riparian revegetation site for a minimum of 10 consecutive years after initial planting and then at year 15 and every 10 years thereafter for the life of the project[17]. In 1986, the Coyote Creek Riparian Station expanded a pre-existing bird banding program at lower Coyote Creek to include the 4.4 acre Lower Coyote Creek Pilot Revegetation Project site, which was installed in December 1986. In addition to the bird banding program, variable-radius circular plots were established in each of the three habitats (existing riparian corridor, newly installed pilot revegetation site, and the ruderal overflow channel landward of the revegetation site). A breeding bird census was also conducted in each of

[17] This permit requirement was later modified.

the three study habitats from March through July of each year. Other monitoring included mammal, reptile, and amphibian sampling and vegetation sampling within each of the 13 variable-radius circular plots. (Rigney et al. 1989)

Mission Trails Mitigation Project

Caltrans monitored the SR-52 (Mission Trails) Mitigation Site in San Diego for compliance with Section 404 Permit requirements. Vegetation composition and structure was monitored on the mitigation site to determine conformity with the Least Bell's Vireo Habitat Restoration Model (Baird and Rieger 1989). Bird populations were monitored to determine presence or absence of least Bell's vireos and nesting success. Success was defined as either a vireo pair nesting on site or no statistically significant differences between parameters on the mitigation site and those in functioning the vireo's habitat (Hendricks and Rieger 1989). Least Bell's vireos successfully nested on the site within 1 year with three territories and in subsequent years several other pairs nested in the remaining areas of the site. In addition, the vegetative parameters established in the habitat model were met for most of the monitored "cells" within the 5-year monitoring period.

Sacramento River National Wildlife Refuge

The Nature Conservancy hired Point Blue Conservation Science (PBCS, formerly PRBO) to monitor bird use of restoration plantings. Over 11 years of data were collected to show species use of restoration plantings at different times after planting (Golet et al. 2008). PBCS data also showed vegetation structural trends (tree-shrub ratios and densities) that affected bird diversity. These results informed future planting designs. Golet et al. (2003) reported on songbird use within the Sacramento River Project Area (over 100 river miles from Red Bluff to Colusa) including lands within the Sacramento River National Wildlife Refuge. At horticultural restoration sites, riparian bird diversity increased significantly over time as the revegetation sites matured.

Proper Functioning Condition

Afton Canyon Riparian Restoration Project

BLM conducted project monitoring using photoplot ground/canopy cover analysis and cross-sectional riparian plant frequency/cover trend analysis. BLM relied heavily on the use of the qualitative evaluation process referred to as Proper Functioning Condition Assessment conducted by an interdisciplinary team of specialists (BLM 2015).

Part 4 – Concluding Remarks

Progress in our understanding of riparian ecology and how to go about restoring riparian ecosystems proceeded at a rapid pace between 1970 and 2000. Many scientists, conservationists, land and resource managers, and volunteers contributed to the development of this field. Unfortunately, it was not possible to recognize the contributions made by many of the individuals involved. Between the 1970s and 2000s, some of this knowledge was recorded in the literature. However, since many restoration practitioners had little time and funding to publish their findings, many of the details of how restoration projects were conducted, their successes and failures, and lessons learned remain buried in project plans, specifications, monitoring reports, and unpublished final project reports. We offer our apology to anyone, and for any projects, we have overlooked in this chapter.

The authors hope that this overview provides those involved in promoting riparian conservation in the 21st century with an informative historical perspective regarding the evolution of the field of riparian ecosystem restoration in California. For those of our peers who played a role in the protection and restoration of riparian ecosystems in the 20th century, we hope that this read provided a pleasant trip down memory lane and reminded you that your contribution was worth the effort.

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