An Overview of Riparian Forests in California: Their Ecology and Conservation[1]

Anne Sands and Greg Howe[2]

This paper is comprised of abstracts from presentations made at the Symposium on Riparian Forests in California: Their Ecology and Conservation held in Davis, California on May 14, 1977. Sponsors of the symposium were the Institute of Ecology (University of California at Davis) and the Davis Audubon Society, Inc. The purpose of this symposium was to encourage a strong alliance of individuals and agencies which will work together to establish protection for the endangered riparian ecosystems of California. Complete texts of these papers will appear in proceedings of the Davis symposium.

A SHORT REVIEW OF THE STATUS OF RIPARIAN FORESTS IN CALIFORNIA

Felix Smith, Field Supervisor
Division of Ecological Services
United States Fish and Wildlife Service
Sacramento, California

Riparian vegetation along streambanks, where there is usually fertile soil and an ample water supply, is a most striking feature of California's landscape. These forests appear as a green belt along permanent and intermittent water courses, sloughs, flood plains, overflow channels and oxbows, drainage ditches and lakes.

One can quickly see that the riparian community with its soil, water, and vegetation is a complex ecosystem. Cheatham and Haller (California Fish and Game, 1965), in their "Annotated List of California Habitat Types" have identified four major riparian habitats with 11 subhabitat types. 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. It was estimated in 1963 that riparian vegetation covered about 347,000 acres -- less than one-half of one percent of the total land area of the State.

Factors affecting or adversely impacting riparian vegetation include upstream reservoir construction, levee and channelization projects, and water conservation. The reservoir, levee and channelization activities, along with clearing for agriculture, are common activities that have occurred throughout the State. Removal of vegetation is a common practice in the Colorado River area. Let's look at a riparian area from a local viewpoint. In An Island Called California, Elna Bakker (1971) states that no natural landscape in California has been so altered by man as its bottom lands. It was in the Central Valley that riparian forests were most extensive and were called gallery forests. Coupled with the extensive grasslands and rivers, large and small, a unique setting was created. It is now one of the richest agricultural areas in the world, blessed with good climate, rich soil, and until the last couple of years, ample water supplies.

The Sacramento River from Red Bluff to its mouth in the Delta is a meandering alluvial stream. The Sacramento Valley extends about 150 miles north-south and spreads about 45 miles east-west at its widest point, averaging about 30 miles wide. The area of the Sacramento Valley,

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[2]Anne Sands, Institute of Ecology, University of California, Davis, California 95616; Greg Howe, Department of Wildlife and Fisheries Biology, University of California, Davis, California 95616. Both editors are also representing the Davis Audubon Society, Incorporated, P.O. Box 886, Davis, California 95616.

so defined, is about 5,000 square miles; the area of the entire Sacramento River drainage basin is 26,150 square miles.

The Sacramento Valley is bounded by the Coast Ranges on the west, the Klamath Mountains on the north, and the southern Cascade Range and northern Sierra Nevadas on the east. The southern margin is extremely low terrain, cut by numerous branching channels of the Delta. This whole low-lying and level area is formed by the combined Delta of the Sacramento and San Joaquin Rivers. Lands of the Sacramento Valley, excluding the Sutter Buttes, are essentially flat, almost featureless, and were formed by the long-continued accumulation of sediments in a great structural trough lying between the Coast Ranges and the Cascades-Sierra Nevada. Large and small streams break up the landscape. Each had its green belt of riparian vegetation that stretched from the base of the foothills to the big river and adjacent wetlands.

Vegetation will grow on any portion of a streambed and its banks if the soil or other substrate is exposed long enough during the growing season. The fertile loam soils of the Sacramento River riparian land coupled with favorable ground water conditions and a long growing season provide near optimum conditions for the establishment of the extensive riparian forests.

The riparian woodlands occurred on the natural levees formed by the Sacramento, Lower Feather, American, and other aggrading streams. These levees rose from 5 to 20 feet above the streambed, and ranged in width from 1 to 10 miles. Based on historical accounts, it has been estimated that there were about 775,000 acres of riparian woodlands in 1848-1850. Diaries and field notes written in the early 1800's describe the extent of the forests. They also describe the lush jungles of oak, sycamore, ash, willow, walnut, alder, poplar, and wild grape which comprised almost impenetrable walls of vegetation on both sides of all the major valley rivers and their tributaries. Notes were made of giant sycamore 75 to 100 feet tall and of oaks 27 feet in circumference. By the late 1800's, however, vast tracts of riparian forests had already been cut by settlers for fuel, fences, and building materials. In addition, many thousands of acres were cleared to free the fertile alluvial soil for agricultural use. By 1952, only about 20,000 acres of riparian forests remained. Today's estimate of 12,000 acres is probably generous.

Prior to 1960, few people showed any concern for the demise of California's Riparian Forest communities. In addition, very little botanical data had been collected. During the early 60's, the first major work at removing the riparian forest remnants in an effort to protect levees occurred in the Delta. The removal of this riparian vegetation from along the lower Sacramento River was viewed with great concern by the public. Statements, both written and oral, voiced strong opposition to the methods of levee maintenance and stated that better methods should be employed so as not to destroy the esthetic beauty and wildlife habitat of the Delta waterways. Most of the same concerns exist today. However, today dedicated and enthusiastic botanists, ornithologists, mammalogists, entomologists and other field scientists are compiling species lists, recording observations, and beginning to publicize their findings. People now realize that public awareness must be coupled with political pressure.

The previously expressed concerns demonstrate a clear need for a higher order of planning and evaluation before additional irreparable alterations to this river system occur. Although no governmental body, agency, interest, or person would deliberately set out to destroy the Sacramento and other California Rivers, adjacent lands and natural resources, all too often there has been insufficient concern about the singular or cumulative effects of work accomplished by one agency or interest on the resources under the jurisdiction or responsibility of another, or how such work affects the entire riverine ecosystem and the public interest.

The realization of a Sacramento River environmental/open space corridor is a valid and long-term planning objective. Implementation is the difficult part. However, it can be done. It will require the formulation of a multigovernmental agency and concerned citizen group to see that modifications and developments are accomplished without further deterioration of the existing resources and that efforts are undertaken to enhance these same resources in the public interest while at the same time protecting the integrity of the levees and communities of the Sacramento Valley. Can one imagine a Sacramento River Parkway from the Redding area to Collinsville patterned after the American River Parkway? What a valuable recreational resource it would be to the public and especially for future generations.

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GEOLOGICAL HISTORY OF THE RIPARIAN FORESTS OF CALIFORNIA

Robert Robichaux
Department of Botany
University of California, Davis

The plant communities that we see today are the products of evolutionary processes acting over long periods of geological time. As individual species have evolved and migrated in response to changing environments, the corresponding plant communities have changed in composition and distribution. The evidence relating to the rates and direction of this change comes from an analysis of numerous fossil deposits laid down at various times and in various regions in the past (Axelrod, 1967b). This analysis involves the systematic description of the component species in each fossil flora and the reconstruction of the ancient topographical, climatic, and vegetational settings at the site of deposition. Regional comparison of various floras then allows us to piece together the history of individual lineages and the corresponding plant communities.

The history of California's vegetation as a whole has recently been reviewed by Axelrod (1977). Three general principles emerge from his discussions. First, the modern plant communities of California are composed of taxa of diverse geographical sources. The two principal floristic elements are a "Madro-Tertiary" or southern, and an "Arcto-Tertiary" or northern element. The former includes species in such genera as Arbutus, Arctostaphylos, Ceanothus, Cercocarpus, Cupressus, Quercus (some species), and Umbellularia, while the latter includes species in such genera as Acer, Alnus, Castanopsis, Fraxinus, Picea, Quercus (some species), and Sequoia. Second, the modern communities are relatively impoverished representatives of richer, more generalized ancestral communities that include taxa related to species now found only in the southwestern United States and northern Mexico, the eastern United States, or eastern Asia. These "exotic" taxa were gradually eliminated from this region during the later Tertiary in response to a general trend to a cooler and drier climate, to a shift in the seasonal distribution of precipitation, and to progressively decreasing equability (Axelrod, 1968). Third, some of the species that are associated in these modern communities have apparently been associated, as ancestral forms in fossil communities, throughout most of California's later Tertiary and Quanternary history, covering a time span of at least 20 million years.

Distributions of the Species

One of the most important factors facilitating a species entry into the fossil record is a proximity to a site of sedimentation. As many fossil deposits accumulate along stream and lake borders, riparian taxa are generally well-represented in the record. Many of the dominant species in the modern riparian community of the Sacramento River have counterparts in the fossil record of the western United States. The present and past distributions of eight of these species are particularly informative in terms of understanding the floristic sources of the modern forest. These include Acer negundo, Alnus rhombifolia, Fraxinus latifolia, Platanus racemosa, Populus fremontii, Quercus lobata, Salix lasiandra, and Salix lasiolepis.

The California sycamore, Platanus racemosa, ranges in distribution from the upper reaches of the Sacramento River southward into Baja California (Griffin & Critchfield, 1972; Little, 1976). In the Central Valley, this species is locally abundant along the Sacramento and San Joaquin Rivers, ascending their main tributaries to low elevations in the Sierran foothills. It is notably absent from the North Coast Ranges and the western side of the Sacramento Valley (Jepson, 1910). It is distributed throughout the South Coast Ranges, where it is "one of the most widely distributed aboreous species" (Jepson, 1910), and occurs in the Transverse and Peninsular Ranges of southern California (Griffin & Critchfield, 1972). The California sycamore is generally confined to sites with an abundant water supply, as along perennial streams, around springs, and in moist gulches (Sudworth, 1908). Two distinct late Tertiary species have been referred to the modern P. racemosa. To the north, Platanus dissecta is a characteristic species in the Miocene floras of the Columbia Plateau and northern Great Basin (Chaney & Axelrod, 1959). It survived into the Pliocene in this region as evidenced by the Dalles flora of Oregon (Chaney, 1944a) and the Upper Ellensburg flora of Washington (Smiley, 1963). To the south, Platanus paucidentata is a characteristic species in both the Miocene and Pliocene floras of southern California (Axelrod, 1939, 1940, 1950c, d). The distributions of these two species overlapped in central Nevada in the Miocene (Axelrod, 1956) and in central California in the Miocene and Pliocene (see Axelrod, 1944a, b; Renny, 1972). The question arises as to which of these species is more closely allied to the modern P. racemosa. Judging from the available record, it appears that P. paucidentata shows more definite relationship to the modern species (Axelrod, 1939, 1956, 1967), while P. dissecta may be more nearly related to the modern P. orientalis of the Middle East or P. occidentalis of the eastern U.S. (Axelrod, 1956; Renney, 1972). The two fossil species probably diverged from a common ancestor during the early or middle Tertiary. Leaves of the modern P. racemosa appear in abundance in the Pleistocene Soboba flora of southern California (Axelrod, 1966).

Discussion

The evidence from these fossil floras suggests that lowland riparian forests comparable to that along the modern Sacramento River have had a long and virtually continuous history in the western United States during the last 20 million years. These widespread ancestral communities showed regional variation as a consequence of major climatic differences from north to south. In southern regions, the riparian communities originally included several species with relatives in the modern forest (P. racemosa, P. fremontii, and S. lasiolepis) plus numerous taxa now restricted to the summer-wet region of the southwestern U.S. and Northern Mexico. In contrast, the original riparian communities of northern regions included several other species with relatives in the modern forest (A. negundo, A. rhombifolia, F. latifolia, O. lobata, and S. lasiandra) plus many others now confined to the summer-wet regions of the eastern U.S. and eastern Asia. It is in the intermediate areas that we first see the intermingling of these northern and southern riparian taxa that is apparent in the modern community. This is first evident in the interior (Middlegate), where the northward migration of southern taxa with spreading aridity was apparently aided by the Sierra Nevadan rainshadow. This mixed type of community subsequently appeared on the western slopes of the Sierra Nevada (Remington Hill) and disappeared from western Nevada. It became well-established over lowland west-central California by the middle Pliocene (Mulholland) and persisted in this region with some modifications down to the present. In all of these regions, we see the gradual loss of the exotic taxa in the communities as climate became progressively cooler, drier, and less equable, and as summer rainfall was reduced.

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RIPARIAN FORESTS OF THE SACRAMENTO VALLEY, CALIFORNIA

Kenneth Thompson
Department of Geography
University of California, Davis

Although edaphic and biotic influences precluded trees from most of the Sacramento Valley in its pristine condition, the riparian lands (Mainly natural levees) supported a flourishing tree growth--valley oak, sycamore, cottonwood, willow, and other species. A number of factors contributed to their presence -- principally subirrigation, fertile alluvial loam soils, and relative freedom from surface waterlogging and fire. These riparian forests varied considerably in width, from a narrow strip to several miles. They also varied greatly in the spacing of the trees, from irregular open to fairly crowded stands, but were generally of sufficient extent and closeness to justify the term "forest".

Pristine Condition of the Riparian Lands

Among the first outsiders to visit the Sacramento Valley were fur trappers of the Hudson's Bay Company in the period prior to 1814. The Spaniard Luis Antonio Arguello investigated the valley in 1817 and again in 1821, and Jedediah Smith, in 1825, may have been the first American to reach the Sacramento River. However, it was not until the 1840's that significant outside influence was felt in the northern end of the Central Valley. This seclusion, however, could not survive the meteoric developments of the Americanization of California. After 1849 came a huge influx of population, lured by gold but often quickly to adopt other pursuits. These immigrants, mostly with rural backgrounds, could not overlook the agricultural promise of the Sacramento Valley. Heightening the attractions of the Sacramento Valley for agricultural settlement was its virtually vacant condition. Its relatively sparse and peaceful aboriginal population, having been greatly reduced in numbers by an epidemic in the early 1830's was unable to offer more than token resistance to the American invaders (Cook, 1955).

After recognizing the promise of the Sacramento Valley, the invading Americans quickly set about its realization. To do this called for new patterns of occupance and land use; and in the initiation of these the environment was substantially modified. The agencies of change were sufficiently drastic to transform the physical, biotic, and cultural landscape. One of the very first transformations concerned the natural levees and riparian lands, which were thickly forested in their pristine condition.

Because of the brief period between initial investigation and development, little information was accumulated on the aboriginal condition of the Sacramento Valley. One of the earliest observers to report on the riparian forests was John Work (in Mahoney, 1945) in the course of a fur-trapping expedition from his headquarters at Fort Vancouver. Writing in 1832, he described the riparian forests of the Sacramento Valley, below Red Bluff as follows:

> All the way along the river here there is a belt of woods principally oak which is surrounded by a plain with tufts of wood here and there which extend to the foot of the mountain, where the hills are again wooded.

Another early visitor to the Sacramento Valley, Captain Sir Edward Belcher, R.N., noted the profusion of oak, ash, plane, laurel, sumach (sic), hiccory (sic), walnut, roses, wild grapes, arbutus, and other small shrubs in the vicinity of the river (Belcher, 1843). He described its lower course as follows:

> Having entered the Sacramento, we soon found that it increased in width as we advanced, and at our noon station of the second day was about one-third of a mile wide. The marshy land now gave way to firm ground, preserving its level in a most remarkable manner, succeeded by banks well wooded with oak, planes, ash, willow, chestnut (sic), walnut, poplar, and brushwood. Wild grapes in great abundance overhung the lower trees, clustering to the river, at times completely overpowering the trees on which they climbed, and producing beautiful varieties of tint. . . . Our course lay between banks. . . . These were, for the most part, belted with willow, ash, oak, or plane (Platanus racemosa), which latter, of immense size, overhung the stream, without apparently a sufficient hold in the soil to support them, so much had the force of the stream denuded their roots.
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> Within, and at the very verge of the banks, oaks of immense size were plentiful. These appeared to form a band on each side, about three hundred yards in depth, and within (on the immense park-like extent, which we generally explored when landing for positions) they were seen to be disposed in clumps, which served to relieve the eye, wandering over what might otherwise be described as one level plain or sea of grass. Several of these oaks were examined, and some of the small felled. The two most remarkable measured respectively twenty-seven feet and nineteen feet in circumference, at three feet above ground. The latter rose perpendicularly at a (computed) height of sixty feet before expanding its branches, and was truly a noble sight.

Most of the historical reports give no indication of the actual depth of the woodland. Where Belcher examined the lower Sacramento banks, probably the delta section, in 1837 he noted a belt of large oaks (including one with a trunk 27 feet in circumference at 3 feet above the ground) "about three hundred yards in depth" (Belcher 1843). John Work (Mahoney, 1945) in 1832, probably referring to French Camp Creek, a Sierra stream that flows to the delta, wrote: "the plain is overflowed and we had to encamp at the skirt of the woods about two miles from the river." Derby's report of 1849 (Farquhar, 1932) noted a two-mile-wide belt of woods on both sides of the lower Feather River. The map accompanying this report shows forest bordering all the major and minor streams in the lower Sacramento River system. Thus, riparian forest seems to have bordered the entire mapped portion of the river system from the vicinity of Clarksburg in the south to Glenn in the north. These riparian forests are shown as being fairly uniform in width, about four to five miles. Derby's map also shows riparian forests along the tributary streams almost equal in width to those of the main stream, and flanking the tributaries to the edge of the valley. On the Derby map Cache and Putah creeks have forests about three miles wide, the American and Feather rivers about four miles wide (which checks with a section of his report), and Butte Creek and Yuba and Bear rivers each have levee forests about two miles wide. A note of caution should be inserted here. Derby, although a topographical engineer, performed only a reconnaissance type of survey of the valley. This being so, together with the undoubted fact that the tree symbols are intended to be approximate rather than precise, his map should not be invested with undeserved (and unintended) accuracy. However, even with these limitations the Derby map does suggest riparian forest of substantial width and continuity, and in 1849 these were, of course, still virtually in their pristine condition.

It is highly improbable that the forest belt was of uniform width along both banks of the streams. Indeed, historical accounts clearly indicate the irregular occurrence of the trees. Belcher (1837) refers to the trees as being "disposed in clumps." Derby also speaks of "clusters of beautiful trees - oaks sycamore and ash" on the banks of the Yuba River to differentiate the forests there from those of the Sacramento and Feather rivers, which were "thickly wooded." Elsewhere he speaks of riparian forests along the Feather River "dotted" for two or three miles back from the river.

The Railroad Reports of a few years later (1855) speak of the riparian forest as being a "varying breadth, from a mile or more. . . to a meager border. Even more generally, but clearly indicating the variation of width in the riparian forests, the Railroad Reports refer to the riparian forests as "of greater or less width." Moreover, the riparian forests varied not only in width but also in tree size and density, "the number and size of trees being apparently proportioned to the size of the stream and the quantity of moisture derived from it."

The preceding discussion shows that in their pristine condition the streams of the lower Sacramento River system were flanked by forests. The historical evidence suggests that these riparian forests had varied characteristics. They included trees of all sizes, from brush to very large valley oaks or sycamores, 75 to 100 feet high, growing closely spaced or scattered irregularly in groves. On the banks of the lower Sacramento, where the natural levees are widest, the riparian forests achieved their greatest width, four to five miles. On the lesser streams and in the delta, with smaller levees, the forests formed a narrower belt, generally about two miles wide but less in the delta. Dominant species in the riparian forest were valley oak (Quercus lobata), interior live oak (Quercus wislizenii), California sycamore (Platanus racemosa), Oregon Ash (Fraxinus oregana), cottonwood (Populus fremontii), alder (Alnus rhombifolia), and several willows, (Salix gooddingii, S. exigua, S. Hindoiana, S. Lasiandra, and S. Laevigata).

Present Condition of the Riparian Forests

Although the Sacramento Valley riparian forests were an early casualty of the white man, their destruction, far-reaching as it was, was not complete. Today, parts of both banks of the Sacramento and its tributaries are bordered by many shrunken remnants of the once extensive riparian woodland. The numerous traces that remain corroborate the historical evidence examined by the author. The same tree species mentioned in the historical records - mainly valley oaks, cottonwoods, willows, sycamores, and ash - still grow on the river banks, natural levees, and channel ridges. Typically, cottonwoods and willows predominate on the immediate stream banks, whereas valley oaks are spread irregularly over the natural levees farther away from the river.

Instead of a strip measurable in miles, the forested zones along the Sacramento Valley streams are now often only yards deep, and discontinuous at that. Generally, the remaining fragments (not necessarily virgin stands, of course) form a belt less than 100 yards wide and are largely confined to bank slopes of streams and sloughs, abandoned meanders, and on the river side of artificial levees.

Examination of the Sacramento River levees reveals hundreds of larger relict stands of riparian forest. Some cover only a few acres; others several hundred. Most prominent are fully mature specimens of valley oaks in the "weeping" stage of development described by Jepson (1893) as indicating an age between 125 and 300 years. Such trees occur mostly on natural levee or channel ridge sites and are frequently around older settlements, presumably preserved for shade and ornament. Even small house lots may contain two or more oaks that predate the Anglo-American settlement period, presumably relicts of a more extensive stand. Some tracts of uncleared land near the Sacramento River (including two in Yolo County between Knights Landing and Elkhorn Ferry) are still so thickly studded with trees, including many valley oaks in the "weeping" stage, that they form the definite, if open, forest described by early visitors to the region.

Near Woodson Bridge, Tehama County, another expanse of apparently virgin riparian forest can be seen. It is still subject to almost annual overflow and is composed mainly of mature valley oaks, forming an open woodland that extends discontinuously for about a mile from the river's edge. Some splendid mature specimens of valley oak remaining from the Cache Creek riparian forest can be seen in the older residential sections of Woodland in Yolo County, which is named for the fine oak forest in which the settlement was established in 1855. Again, in and around Davis, also in Yolo County, there are many large relict oaks of the Putah Creek Forests.

In view of the general lack of trees in the Sacramento Valley, the riparian forests must have served as a source of fuel, construction, and other types of wood for a wide area. There was doubtless little incentive to conserve the riparian forests, since few of the tree species have much value as lumber. Typically the riparian forest species are fit only for low economic uses. For example, the numerous members of the genus Salix (willow) generally yield soft, light, and brittle wood of poor form for saw timber. Rather similar is the cottonwood, which is soft, brittle, not durable, and especially liable to cracking. The largest, and probably most numerous, riparian tree, the valley oak, is "very brittle, firm, often cross-grained and difficult to split or work. On account of its poor timber form the trees are rarely if ever cut for anything but fuel, for which, however, they are much used" (Sudworth, 1908).

The clearing of the riparian forest for fuel and construction also served another end: it made available for agricultural use some of the most fertile and easily managed land in the valley. In its pristine, or nearly pristine condition, much of the valley was more or less unusable for agriculture because of waterlogging and inundations. The original limitations of many valley areas have been partially overcome in recent decades with improved drainage, irrigation, and other technical advances. However, initially these limitations were such as to discourage permanent settlement and agriculture on much of the valley floor with the exception of the natural levee lands. There both settlement and cultivation were concentrated; utilization of the remainder of the valley was uncertain and irregular, with much attention paid to livestock raising. The general superiority of the levee lands still holds. The most profitable form of land use in the valley, orchards, shows a very marked concentration on levee soils, a final confirmation of their inherent suitability for tree growth.

Perhaps because the riparian forests were largely effaced during the first two or three decades of Anglo-American occupance, their existence is largely overlooked by modern students of the Sacramento Valley. But this neglected element in the landscape is by no means of negligible importance. The riparian trees served to reinforce the river banks and provide greater stability to the stream channels. They also acted as windbreaks, reducing evaporation, transpiration, and wind damage. In addition, the riparian forests provided a haven for the wildlife of the valley, furnishing cover and food sources for land and arboreal animals. Even more important was the fact that acorns, mainly from Quercus lobata, were a staple foodstuff of the Indian population. Furthermore, the forests furnished an important source of wood in an area otherwise poorly supplied.

The mere existence of the riparian forests, however, inevitably spelled their doom. The conditions, characteristic of natural levee sites, that permitted their development -- comparative freedom from flood and waterlogging, high soil fertility, and favorable soil moisture - eventually led to their destruction, for the existence of the forest was incompatible with the modes of land use initiated by the Anglo-Americans. Today, only a few traces of the formerly extensive riparian forests remain, and the Sacramento Valley exhibits a striking lack of trees.

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THE FLUVIAL SYSTEM: SELECTED OBSERVATIONS

Edward A. Keller
Environmental Studies and
Department of Geological Sciences
University of California, Santa Barbara
Santa Barbara, California 93106

Human use and interest in the riverine environment extends back to earliest recorded history. We have used the river system as an avenue for transportation and communication, a water supply, a waste disposal site, and a source of power. Massive dams and channel works to dissipate the disastrous effects of floods and droughts have been constructed, and even though we can sometimes control a river we still know little about the processes which form and maintain the natural fluvial system. Only recently have we realized that rivers are natural resources that must be conserved and properly managed if we are to continue a meaningful existence.

The natural stream channel generally has sufficient discharge to emerge from its banks and flood areas adjacent to its banks on the average of once every year or two. It is this natural process of overbank flow which slowly but relentlessly builds floodplain features such as natural levees along the stream channels. The overbank flows also supply water to adjacent lowlands on the floodplain which serve as a storage site for excess runoff, much of which may enter the groundwater system. A main philosophical concession that must be recognized by more communities which compete with the riverine environment is that overbank flow (flooding) is a natural process rather than a natural hazard and that, if we are to maintain the integrity of the riverine system, we must consider the channel and floodplain as a complementary system.

Human use and interest in the fluvial environment has historically included significant drainage modification. This modification--whether termed channelization, channel works, or channel improvement--generally is controversial because of its potential adverse effects on the biological communities in the riverine environment. The loss of fish and wildlife habitat due to channel modification generally leads to simplification with less variation in the biological communities of the fluvial environment.

The reduced variability of the biological community in response to channel modification is directly attributed to the loss of variability in the physical environment. That is, stream channel modification tends to reduce the diversity of flow conditions, the diversity of bed-material distribution, and the diversity of bed forms. If environmental deterioration caused by stream channel modification is to be minimized then new design criteria must be developed such that the stream's natural tendency to converge and diverge flow and sort the bed material is maintained. That is, we must apply environmental determinism or "designing with nature" to our channel works if we are to maintain a quality fluvial environment.

The natural fluvial environment is an open system in which the channel-floodplain form and processes evolve in harmony. Significant changes in the fluvial system often occur when a geomorphic or hydraulic threshold is exceeded. These changes are partly responsible for maintaining the quasi- or dynamic equilibrium state of the stream system. Human use and interest in the fluvial environment has led to human interference with the fluvial system. This interference generally reduces the channel, floodplain and hydraulic variability and thus the biologic variability which depends on the physical environment.

The behavior of natural streams is not completely understood. Particularly important is the need to know more about relationships between erosion, deposition, and sediment concentration, as well as the effect of organic debris on stream channel morphology. In addition, if we are going to understand more about relationships between the biology of stream channels and the geomorphology, then we must begin to study complex interactions between the two. That is, we must learn more about processes which produce channel morphology necessary for biological productivity and thresholds that control the maintenance and development of the physical and biological environment.

RIPARIAN VEGETATION AND FLORA OF THE SACRAMENTO VALLEY

Susan G. Conard
Ronald L. MacDonald
Robert F. Holland
Department of Botany
University of California, Davis

Research on Sacramento Valley riparian vegetation has primarily concerned land-use patterns (McGill, 1975; Brumley, 1976) or distribution and ecology of birds and mammals in riparian habitat (Stone, 1976: Michny, Boos and Wernette, 1975; Brumley, 1976). These studies frequently include partial floristic lists or brief vegetation descriptions. Michny et al. (1975) provide quantitative vegetation data at each nine study sites. Most of these stands were apparently less than 15 m. in width and several were highly disturbed.

The objectives of this study were 1) to obtain preliminary floristic and vegetation data on several major riparian vegetation types, and 2) to use this data to a) delineate important vegetation units, b) describe structure of mature stands of riparian forest, and c) describe major seral and topographic relationships within the riparian vegetation.

The major riparian vegetation types were 1) Valley oak woodland, 2) Riparian forest dominated by cottonwood, 3) Gravel bar thickets, 4) Open floodplain communities, 5) Hydric communities.

Valley Oak Woodland

The valley oak phase of the riparian forest is typical of high terrace deposits and cut banks along the outside of meanders. These forests are dominated almost exclusively by Valley oak (Quercus lobata). Common associates include Sycamore (Platanus racemosa), willows (Salix spp.), Box elder (Acer negundo), Oregon ash (Fraxinus latifolia) and Black walnut (Juglans hindsii). Canopy height is 15-20 m. and tree cover ranges from 30-60%. A typical valley oak woodland sampled at the Cosumnes site had a density of 124.5 trees/ha and basal area of 18.35 m^2/ha. The relative density of Q. lobata in this stand is .73 and its relative basal area is .81, indicating strong dominance by Q. lobata at this site.

Valley oak woodlands are characteristically heterogeneous with areas of high density, smaller trees interspersed with more open areas of larger trees. Openings contain typical grassland species of genera such as Avena, Lolium, Hordeum and Elymus. Where tree cover is higher, the understory is characterized by poison hemlock (Conium maculatum), poison oak (Rhus diversiloba), ripgut brome (Bromus diandrus), soap plant (Chlorogalum pomeridianum), several species of Carex and Erigeron sp.

Riparian Forest

Cottonwood (Populus fremontii) dominates the riparian forest of lower terrace deposits and stabilized gravel bars along the Sacramento River. Common associates are similar to those in the valley oak woodland including willows (Salix lasiolepis, S. goddingii, S. laevigata, S. lasiandra), Fraxinus latifolia, Acer negundo, Juglans hindsii, and, on higher ground, Quercus lobata and Platanus racemosa. Canopy height is approximately 30 m. in a mature riparian forest, with a tree cover of 20-30%. Tree density in these forests is about 250 stems/ha--double that of the valley oak woodland sampled. Basal area is about 50 m^2/ha. The relative basal area of Populus fremontii is .75, reflecting its high dominance in the vegetation. The low relative density (.33-.44) of cottonwood in these stands reflects the large number of small subcanopy (10-12 m) trees (particularly Acer negundo, Fraxinus latifolia, and Salix spp). Understory species are mostly shrubs (Sambucus mexicana, Cephalanthus occidentalis, Rubus spp, Rosa Californica). Lianas such as Rhus diversiloba and Vitis californica are a dominant feature, frequently providing 30-50% ground cover and festooning trees to heights of 20-30 m. Herbaceous vetetation is $< 1\%$ cover except in openings where species such as Artemisia douglasiana, Urtica dioica, and various shade tolerant grasses may occur.

Gravel Bar Thickets

Well-stabilized gravel bar deposits are dominated by sand bar willow (Salix hindsiana) which forms dense thickets 3-5 m. tall of up to 95% cover. Common associates include saplings of Alnus rhombifolia, Acer negundo, Fraxinus latifolia, and Populus fremontii, and shrubs of mule fat (Baccharis viminea). Scattered herbaceous species are also present but cover is generally low due to the dense canopy.

Open Floodplain Communities

Sand and gravel bars which are flooded annually support a sparse vegetation cover (5-25%) dominated by small (1 m) shrubby and herbaceous perennials and annuals. The frequent disturbance normal to this habitat has favored invasion by many introduced species such as Bromus diandrus, B. tectorum, Salsola kali, Raphanus and Brassica spp, Tunica prolifera, Polypogon monspeliensis, and Verbascum thapsus. Native species of floodplains include the small shrubs Chrysopis oregona, Trichostema lanatum, and Bidens laevis.

Hydric Communities

In old oxbows and low areas a series of hydric communities occurs. Open water supports emergent and free-floating mat vegetation containing plants such as Polygonum hydropiperoides, P. coccineum, Ludwegia peploides, Azolla filiculoides, Potamogeton crispus, Elodea spp, and Myriophyllum spicatum ssp exalbescens. Shallow water and low mud flats are dominated by Scirpus acutus (50-100% cover) 2-3 m. tall. On higher areas, where Scirpus acutus is less dominant, the species diversity of the fresh water marsh increases considerably. Hummocks in higher areas of the marsh support shrub thickets of Cornus stolonifera, Cephalanthus occidentalis, Rubus vitifolius with occasional Alnus rhombifolia and Fraxinus latifolia. It is also in this zone that the rare Hibiscus californica may be found. The Cornus and Cephalanthus hummocks are in turn invaded by understory (Alnus rhombifolia, Salix spp, Fraxinus latifolia, Rubus vitifolia, Rosa californica) species typical of the riparian forest, as well as Populus fremontii. This turns higher hummocks into Alnus dominated thickets and eventually Populus forests.

The riparian zone is a dynamic habitat: the vegetation of a given site reflects the history of flooding, aggradation, and degradation by the river. These habitats are subject to varying frequencies of flooding and of lateral erosion by the meandering river. The major riparian plant communities can be aligned along topographic gradients. The low, recent, gravel bar deposits are flooded frequently. Plant cover is low and is dominated by introduced annuals and low perennials. As gravel bars become more removed from the river and begin to stabilize, they are colonized by thickets of tall shrub and tree saplings generally dominated by Salix hindsiana. Riparian forest will become established (on lower terrace deposits) as flood frequency decreases. These junglelike gallery forests are dominated by Populus fremontii and characterized by heavy cover of lianas. Higher ground in these forests supports Quercus lobata and Platanus racemosa. The older, higher terrace deposits support stands of valley oak woodland dominated by Q. lobata. These woodlands gradually thin out and grade into valley grassland vegetation with increasing distance from the river.

Oxbows and overflow basins are characterized by a series of hydric communities. Fresh water marsh in low, wet areas is dominated by Scirpus acutus. On higher ground, this is succeeded by shrubs such as Cornus Stolonifera and Cephalanthus occidentalis. These shrub-dominated habitats appear transitional to typical Populus fremontii dominated riparian forests on higher ground.

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THE VALLEY RIPARIAN FORESTS OF CALIFORNIA: THEIR IMPORTANCE TO BIRD POPULATIONS

David A. Gaines
Institute of Ecology
University of California, Davis

Those who have heard the spring chorus of songbirds, watched herons feed their young in tree-top nests, glimpsed swarms of warblers in the early autumn greenery and tried to count wintering flocks of sparrows know first-hand the wealth and diversity of California's valley riparian forest avifauna. Today, with the last extensive remnants of these forests in jeopardy, it behooves us to weigh the importance of riparian habitat to birds and other wildlife (Gaines 1976).

Diversity

California's riparian forests support a high diversity of breeding birds (Miller 1951). Excluding Ring-necked Pheasant and Western Meadowlark (included because some census plots edge on grassland) 67 species are known to nest in the forests of the Sacramento Valley. Species richness (number of species) equals or exceeds that in any habitat for which census data is available (Gaines 1974b). Using the Shannon-Weaver species diversity index, the average species diversity for the cottonwood-willow census plots (3.17) is considerably higher than that for the oak-cottonwood plots (2.51). Species richness, however, is only slightly higher (27 to 24). Thus the high diversity values in cottonwood-willow reflect a large number of species with relatively even densities. This high diversity seems to depend, not on edge effect or plant species diversity, but on foliage volume and foliage height profile. One of the most interesting census results is the lack of correlation of diversity with the extent that riparian forest habitat edges on openings or other types of vegetation. Most species are more or less evenly dispersed within the forest with little or no tendency to concentrate near the edge (DeSante 1972). Thus the theory that diversity is enhanced by the mixture of species from adjacent habitats may not apply to riparian forests.

Beginning with MacArthur and MacArthur (1961) a series of studies has linked bird species diversity in forest communities with foliage height diversity, foliage volume, and other habitat characteristics. This complex, fascinating subject has recently been summarized by Balda (1975). In addition to foliage, such factors as food resources, nest sites, nesting material, song posts, proximity to water, extent of habitat, geological history, and human disturbance need to be considered. Understanding these factors is important to assuring a diverse avifauna in sanctuaries, state parks, and other lands set aside as riparian forest preserves.

The percentage of breeding individuals which are migratory differs strikingly between the cottonwood-willow and oak-cottonwood census plots. In the former a large influx of birds which winter in subtropical areas, such as Western Wood Pewee, Yellow Warbler, and Northern (Bullock's) Oriole, account for 36% of the nesting bird density. In the valley oak forest, in contrast, only 4% of the nesting birds are migratory. Moister conditions in the cottonwood-willow forests may promote lusher plant growth, higher invertebrate populations and, therefore, more available food for flycatchers, warblers, and other migratory, insectivorous birds.

Based on Miller's (1951) analysis of the California avifauna, 43% of the species and 38% of the individuals breeding in cottonwood-willow habitat have a "primary affinity" to riparian forest (Table 1). In other words, in comparison to 21 other California vegetation types, these forests probably support the highest concentrations of these species. In cismontane California Red-shouldered Hawk, Yellow-billed Cuckoo, Willow Flycatcher, Bell's Vireo, Yellow Warbler, Yellow-breasted Chat, and Blue Grosbeak breed in no other forest habitat.

The breeding avifauna of California's riparian forests has intriguing affinities to that of the similarly winter-deciduous hardwood forests of eastern North America (Miller 1951). Many typically "Eastern" or "Mid-eastern" species, such as Red-shouldered Hawk, Yellow-Billed Cuckoo, Downy Woodpecker, Bell's Vireo, Warbling Vireo, Yellow Warbler, Yellow-breasted Chat, Blue Grosbeak, American Goldfinch, and Song Sparrow, have been able to colonize the arid West primarily because humid, broad-leaved riparian forests offered congenial haunts. Interestingly, all of these birds have evolved western subspecies (American Ornithologist's Union 1957). Three of these races, the Red-shouldered Hawk _Buteo lineatus elegans_, the Bell's Vireo _Vireo belli pusillus_, and the Blue Grosbeak _Guiraca caerulea salicaria_, breed only in the valleys of California.

Breeding Densities

The average density of nesting birds on the cottonwood-willow census plots (2088/km^2) is strikingly higher than that on the oak-cottonwood plots (1279/km^2). This difference is due primarily to migratory species. If we only consider residents, the density in cottonwood-willow (1336/km^2) is only slightly higher than that in oak (1227/km^2). Breeding bird densities in cottonwood-willow forests equal or exceed those in any California vegetation type for which census data is available(Gaines 1974). The dense, stratified cottonwood-willow forest vegetation may facilitate these high breeding bird densities. With increased trunk, branch, and foliage foraging space, bird territories may occupy less ground surface area.

The large number of migratory birds implies a seasonal abundance of insect food during the warmer months (DeSante 1972). A recent study, however, suggests that bird densities do not depend on habitat productivity (Willson 1974). In this regard it would be interesting to try to correlate bird densities in riparian forest habitats with plant productivity and invertebrate populations.

Wintering Densities

The average density of wintering birds on the valley oak plots (2439/km^2) is strikingly higher than that on the cottonwood-willow plots (997/km^2). It is interesting to compare these figures with breeding bird densities. The data suggests that oak forests support 90% more wintering than nesting birds, and cottonwood-willow forests almost the reverse. This same trend, although less pronounced, is reflected by the data on species richness and diversity.

These seasonal changes are due primarily to migrants. The large number of breeding birds which leave cottonwood-willow forests before the autumn leaf-fall deplete wintering bird densities. In the oak forests, in contrast, a large influx of migratory wintering species augments the largely resident breeding population. Most (69%) of these migrant birds subsist on seeds and/or fruits. More open conditions in the oak forests may promote the growth of herbaceous, seed-producing forbs and grasses. Berry-producing plants are probably more abundant. The available census data suggests that average bird density in oak riparian forest exceeds that in coastal mixed forests, coastal coniferous forests and chaparral (Stewart 1972). Wintering bird diversity is also high; 60 species are known to winter in the riparian forests of the Sacramento Valley.

Migration

Large numbers of passerine birds forage and shelter in riparian forest habitat during their migratory journeys. Most are foliage-gleaning or sallying insectivorous species which winter in subtropical Mexico and Central America. During the spring migration, these birds pass northwards on a broad front through the forests and woodlands of lowland California. The hills are green, the deciduous foothill oaks have just leafed out, and insect life is everywhere abundant. By late summer, however, the long dry period has seared the hills to golden brown. At this season riparian forests provide the only lush, insect-rich forest habitat in lowland, cismontane California. The importance of these forests to southward (fall) migrants cannot be underestimated.

An Endangered Habitat

Nothing better illustrates the destruction of riparian forest habitat than the decline in Californian populations of the Yellow-billed Cuckoo. This sinuous bird is closely restricted to broad expanses of cottonwood-willow forest. In the early part of this century the clearing of these forests was recognized as a threat to the cuckoo's survival (Jay 1911). At that time, they were still "fairly common" (Grinnell 1915). Only three decades later, however, Grinnell and Miller (1944) concluded that "because of removal widely of essential habitat conditions, this bird is now wanting in extensive areas where once found." Recent studies have confirmed this gloomy picture. Only in the relatively large remnants of forest that hug the Sacramento River between Colusa and Red Bluff are a few pairs still known to nest within cismontane California (Gaines 1974b).

Over most of this area, once extensive riparian forest habitat has been sacrificed to civilization. The Santa Ana River in the San Bernardino Valley of Southern California is an excellent example. Here the Yellow-billed Cuckoo was first discovered nesting in California by Stephens in 1882 (Bendire 1895). During the 1920's Hanna (1937) found 24 nests in the "miles of cottonwood and willow" watered by the river. "In contrast with those good old days," he writes, "we now have very little water in Warm Creek and seldom any surface water in the Santa Ana River, the large thickets have been replaced by farms and pastures, the trees cut down, and the evergrowing population has crowded in on the old haunts of the cuckoos to such an extent that if they come here now at all they must be exceedingly rare."

In California, as throughout western North America, the last remaining groves of valley riparian forest are in jeopardy. Each year more of these forests are bulldozed and cut for pulpwood, or to make way for orchards, gravel extraction, rip-rap bank protection and urban development. Unless immediate measures are taken, this endangered habitat will no longer provide a home for the Yellow-billed Cuckoo and the many other birds and animals which dwell there.

As Eleanor Pugh (1965) recognized a decade ago, the choice is ours. "As long as housing tracts start landscaping from bare soil," she writes, "rather than plan around existing mature willows, cottonwoods, sycamores and oaks, with their entangled undergrowths so rich in the shyer birds; as long as willow shrub riparian cover is scraped away and replaced with ubly concrete channeling, breeding success will be low for many species . . . small wonder that Willow Flycatchers, Swainson's Thrushes, Yellowthroats, Yellow Warblers and Yellow-breasted Chats, though quite adaptive and once numerous, are becoming a rare sight to behold or even hear above the roar of traffic on the nearby freeway."

Table 1. The breeding riparian forest avifauna of the Sacramento Valley, California.

Species	Status	Riparian Affinity	Guild: Foraging	Guild: Nesting
Double-crested Cormorant (Phalacrocorax auritus)	res?	-	-	tree
Great Blue Heron (Ardea herodias)	res	-	-	tree
Green Heron (Butorides virescens)	mig	3	-	tree
Great Egret (Casmerodius albus)	res?	-	-	tree
Wood Duck (Aix sponsa)	res	2	-	tree hole*
Common Merganser (Mergus merganser)	res?	-	-	tree hole*
Turkey Vluture (Cathartes aura)	mig	8	ground carrion	tree stump
White-tailed Kite (Elanus leucurus)	res	1	ground mammal	tree
Cooper's Hawk (Accipiter cooperi)	res	1	foliage bird	tree
Red-tailed Hawk (Buteo jamaicensis)	res	5	ground mammal	tree
Red-shouldered Hawk (Buteo lineatus)	res	1	ground mammal	tree
Swainson's Hawk (Buteo swainsoni)	mig	-	-	tree
Bald Eagle (Haliaeetus leucocephalus)	res	-	-	tree
Osprey (Pandion haliaetus)	mig	-	-	tree
American Kestrel (Falco sparverius)	res	4	ground insect	tree hole*
California Quail (Lophortyx californicus)	res	-	ground seed	ground
Ring-necked Pheasant (Phasianus colchicus)	res	-	ground seed	ground
Mourning Dove (Zenaida macroura)	mig	3	ground seed	tree
Yellow-billed Cuckoo (Coccyzus americanus)	mig	1	foliage insect	tree
Screech Owl (Otus asio)	res	2	ground insect?	tree hole*
Great Horned Owl (Bubo virginianus)	res	4	ground mammal	tree
Long-eared Owl (Asio otus)	res?	1	ground mammal	tree
Anna's Hummingbird (Calypte anna)	res?	-	foliage nectar	tree
Black-chinned Hummingbird (Archilochus alexandri)	mig	1	foliage nectar	tree
Common Flicker (Colaptes auratus)	res	1	ground insect	tree hole**
Acorn Woodpecker (Melanerpes formicivorus)	res	-	foliage seed	tree hole**
Downy Woodpecker (Picoides pubescens)	res	1	bark insect	tree hole**
Nuttall's Woodpecker (Picoides nuttalli)	res	2	bark insect	tree hole**
Western Kingbird (Tyrannus verticalis)	mig	-	air insect	tree
Ash-throated Flycatcher (Myiarchus cinerascens)	mig	5	air insect	tree hole*
Black Phoebe (Sayornis nigricans)	res	2	air insect	-
Willow Flycatcher (Empidonax thraili)	mig	1	air insect	tree

[1]res = resident; mig = migratory.

[2]scale 1-8; 1 = primary affinity; 8 = species breeds in greater density in 7 other habitats (Miller 1951).

*does not excavate tree hole nesting cavity.

**does excavate tree hole nesting cavity

Table 1, continued.

Species	Status	Riparian Affinity	Guild	
			Foraging	Nesting
Western Wood Pewee (Contopus sordidulus)	mig	4	air insect	tree
Tree Swallow (Iridoprocne bicolor)	mig	1	air insect	tree hole*
Purple Martin (Progne subis)	mig	-	air insect	tree hole*
Scrub Jay (Aphelocoma coerulescens)	res	-	genera-list om-nivore	tree
Yellow-billed Magpie (Pica nuttalli)	res	4	genera-list om-nivore	tree
Plain Titmouse (Parus inornatus)	res	-	bark insect	tree hole*
Bushtit (Psaltriparus minimus)	res	4	foliage insect	tree
White-breasted Nuthatch (Sitta carolinensis)	res	-	bark insect	tree hole*
Wrentit (Chaemaea fasciata)	res	-	foliage insect	shrub
House Wren (Troglodytes aedon)	mig	2	foliage insect	tree hole*
Bewick's Wren (Thryomanes bewickii)	res	3	foliage Insect	tree hole*
Mockingbird (Mimus polyglottos)	res	-	foliage insect	tree
California Thrasher (Toxostoma redivivum)	res	-	ground insect	shrub
American Robin (Turdus migratorius)	res?	6	ground insect	tree
Swainson's Thrush (Catharus ustulata)	mig	1	ground insect	tree
Blue-gray Gnatcatcher (Polioptila caerulea)	mig	4	foliage insect	tree
European Starling (Sturnus vulgaris)	res	-	genera-list om-nivore	tree hole*
Hutton's Vireo (Vireo huttoni)	res?	3	foliage insect	tree

Table 1, continued.

Species	Status	Riparian Affinity	Guild	
			Foraging	Nesting
Bell's Vireo (Vireo bellii)	mig	1	foliage insect	tree
Warbling Vireo (Vireo gilvus)	mig	1	foliage insect	tree
Yellow Warbler (Dendroica petechia)	mig	1	foliage insect	tree
Common Yellowthroat (Geothlypis trichas)	mig	2	foliage insect	shrub
Yellow-breasted Chat (Icteria virens)	mig	1	foliage insect	shrub
House Sparrow (Passer domesticus)	res	-	ground seed	-
Western Meadowlark (Sturnella neglecta)	res	-	ground insect	ground
Northern Oriole (Icterus galbula)	mig	1	foliage insect	tree
Brown-headed Cowbird (Molothrus ater)	mig	1	ground seed	-
Black-headed Grosbeak (Pheucticus melanocephalus)	mig	1	foliage insect	tree
Blue Grosbeak (Guiraca caerulea)	mig	1	foliage insect	shrub
Lazuli Bunting (Passerina amoena)	mig	3	foliage insect	shrub
House Finch (Carpodacus mexicanus)	res	6	ground seed	tree
American Goldfinch (Carduelis tristis)	res?	1	foliage seed	tree
Lesser Goldfinch (Carduelis psaltria)	res?	3	ground seed	tree
Rufous-sided Towhee (Pipilo erythrophthalmus)	res	2	ground seed insect	ground
Brown Towhee (Pipilo fuscus)	res	3	ground seed insect	shrub
Lark Sparrow (Chondestes grammacus)	res?	-	ground seed insect	ground

Table 1, continued.

Species	Status	Riparian Affinity	Guild	
			Foraging	Nesting
Song Sparrow (Melospiza melodia)	res	1	ground seed insect	shrub

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HABITATS OF NATIVE FISHES IN THE SACRAMENTO RIVER BASIN

Donald Alley
David H. Dettman
Hiram W. Li
Peter B. Moyle
Wildlife and Fisheries Biology
University of California, Davis

Fish habitat in the Sacramento River Basin has been degraded severely through placer mining, dredging, wetland reclamation, destruction of stream side vegetation, livestock grazing, lumber operations, irrigation and water diversion, dams, stream channelization and bank stabilization, dewatering, and domestic pollution. The general effect has been severe. Several species are now so rare as to be virtually extinct. Salmon and steelhead runs are a fraction of previously recorded levels. But the specific effect on many species is unclear because historically the study of the ecology of native species was unfashionable. Through survey and experimental studies we have been trying to reconstruct habitat requirements and preferences of native fishes in order to estimate the impact of human activities.

The task of understanding the stream fish communities has been difficult because the streams of California have been badly disturbed. The destruction of the riparian forests has been only one part of this perturbation, although one of the most visible. One of the first major disturbances was placer mining which destroyed salmonid spawning grounds, increased siltation, removed or covered up riparian vegetation, and drastically changed stream morphology. As agriculture became more and more important to California's economy the deterioration of aquatic habitats continued (and continues) at an ever-increasing rate. Then, as irrigation and flood control became necessary, channelization of streams started to become as common as did irrigation diversions and the construction of bypasses for flood waters. Channelization consists of vegetation removal, straightening channels (thus removing meanders), dredging the stream bed and stabilizing the banks with loose material (riprapping). This type of habitat alteration has been well documented in terms of its effect (Whitney and Baily 1959, Peters and Alfond 1964, Funk and Ruhr 1971, Barton et al. 1972, Moyle 1976a). Essentially, the environment has been simplified: cover by stream side vegetation is removed, pools are eliminated, and undercut banks are destroyed. The substrate is made more uniform as snags and fallen logs are removed. As expected, species richness and standing crops diminish as a result. Irrigation diversions and flood bypasses often divert migratory young of anadromous fishes from the main streams. The degree of impact of these diversions is not presently known; however, there is some concern that substantial mortality of young may contribute to declining chinook salmon and steelhead runs. Dewatering streams for irrigation also reduces flows, which triggers a series of changes: water temperatures increase, current is reduced, silt deposition increases, dissolved oxygen decreases, the stream becomes more shallow, and finally production decreases.

Bad forestry practices can lead to severe problems very similar to overgrazing of livestock. Small streams are often used as chutes to transport downed trees, badly damaging banks and substrate. If slash is dumped into creeks, this will cause dams to form which will impede spawning migrations, decrease flow, and increase siltation. Major problems in logging areas have also been caused by poorly designed roads which often follow stream courses. Such roads can accelerate soil erosion tremendously which dramatically increases the silt burden of the stream (Platts and Megahan 1975, Megahan and Kidd 1972, Arnold and Lundeen 1968). Fine sediment can smother embryos, alevins, and fry. Fish migrations may also be impeded when roads cross the stream and improperly designed conduits are constructed.

Numerous water diversion projects completed in California during the past 60 years have drastically altered natural hydrologic factors and increased water temperatures. A 90% reduction in flow caused average width, depth, and velocity to decrease by 22%, 44%, and 75% (Curtis 1959). A similar reduction in flow can result in a 75% decrease in riffle area, a 55% increase in shallow runs, and 96% decrease in deep, fast runs (Kraft 1972). This type of disruption of the natural hydrologic regime can explain recent imbalances in native fish populations and is more probable than interspecific competition.

The destruction of riparian forests in the Central Valley has been an important factor contributing to the changes in the fish communities, mostly because of the effect on water temperature. However, there is much we do not understand about their relationship to fish populations, particularly in regard to the use of flooded vegetation by young fish and the role of logs and other debris in increasing habitat diversity.

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ENVIRONMENTAL APPLICATIONS IN CORPS OF ENGINEERS WORK WITH REFERENCE TO RIPARIAN VEGETATION MANAGEMENT

Fred Kindel
Chief of the Environmental Planning Section
Sacramento District
U.S. Army Corps of Engineers

Two aspects of the Corps activities in which environmental applications are important are protecting the Sacramento Valley levee system with rock bank protection and projects for which plans have been developed to protect riparian trees and vegetation.

A system of about 1,000 miles of levees has been constructed to provide flood protection to about one million acres and about 800,000 persons living in the flood plain of the Sacramento River (Environmental Statement, 1972). The levee system is threatened by continuing erosion, and normal maintenance and even emergency measures are not adequate to cope with the danger to the levees (Sacramento River Flood Control Project, 1960). In 1960 at the request of the State of California, Congress authorized the Sacramento River Bank Protection project to protect the levees (Sacramento River Flood Control Project, 1960).

Although there are some variations in the work, the usual circumstance is that erosion has progressed into or near the levee which is in danger of failure. To provide protection, a section of levee is prepared by sloping to a 1 on 2 or a 1 on 3 slope and placing the rock bank protection. All trees and vegetation in the area to be rocked must be removed to slope the bank to retain the rock. In the past, trees and vegetation were also removed from some areas adjacent to the actual worksite to facilitate equipment operation while the rock is being placed.

The following design changes were made in recent years to reduce the environmental impact of bank protection work (Environmental Statement, 1972; Bank Protection General Design, 1974):

Where feasible, contractors have been required to avoid disturbing any significant vegetation outside the limits of where the rock is placed. Besides careful equipment operation from the top of the levee, work is sometimes accomplished from a barge on the river which avoids unnecessary disturbance of vegetation to the maximum. However, barges can only navigate the deeper reaches of the river south of Colusa.

Trees have been surveyed and evaluated at the edge of the bank protection areas and all individual trees which would not interfere with construction and could be saved are marked.

At some erosion sites there is still some berm area remaining between the river and the levee. By placing rock only to the top of the berm, three things are accomplished: erosion is arrested and the levee is protected; the berm is protected, permitting vegetation growth; and there is much less rock required for construction. Protecting the berm means that trees and other vegetation on the berm will not have to be removed. Placing rock only to the top of the berm means there is much less visible rock when the river is at low flow. This appears to be the most desirable of the protection methods for environmental application. More of this type of work could be done if additional funds were available (with only limited funds work is restricted to the critical erosion sites and the other protection methods are utilized).

At some locations, the circumstances of the erosion and other factors led to a different design than adding rock for protection of the levee. Where more economical, the existing levees may be set back or relocated further from the river bank. Rock protection is placed on the riverside of the new berm, and vegetation may be planted on the berm. An example of this type of design is at a location near Monument Bend located on the right bank about one mile upstream from the Interstate 880 bridge crossing.

As each unit of bank protection is completed and turned over to the State for operation and maintenance, a supplement is provided to the standard operation and maintenance manual which covers specifically the operation and maintenance needs of that unit. Where measures are instituted for added vegetation in our construction work, it is required that this vegetation must be properly maintained.

On berm areas where there are significant trees and vegetation, the Corps has stipulated that the protected trees should remain when such sites are provided with bank protection. The State Reclamation Board has adopted a program of acquiring a stronger easement than solely for flood control purposes; this provides the landowner a higher price and requires him to leave the native riparian vegetation in place. This is an important companion feature to the berm protection design change (Bank Protection General Design, 1974).

Over the past several years, a number of experimental measures have been tested. The experimental program has had two primary purposes: to test the effectiveness of alternative bank protection methods and materials, and to determine costs of such alternative methods. The testing has been to determine engineering and economic characteristics on the effectiveness of the alternative methods as well as their environmental contribution. One important factor is whether alternative or supplemental methods are more costly to operate and maintain. Where possible, alternatives should be found that do not add significant maintenance expense.

A pilot levee maintenance study was conducted by the State of California and reported on in 1967 (Pilot Levee Maintenance Study, 1967). The study demonstrated that certain types of ground cover were compatible on levees, that some trees and shrubs may be allowed on some levees, and that in most cases unrestricted growth may be allowed on berms. The study indicated that costs of maintenance of levees would be increased with this vegetation.

The Corps has planted trees and shrubs at several selected sites along the Sacramento River (Environmental Statement, 1972) 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. The most outstanding example of such a demonstration is near Monument Bend just upstream from Interstate 880 bridge. In 1967 we planted a variety of trees and shrubs along about three miles of the riverbank where the levee had been set back and the new berm protected by rock. In 1970 after three years, the vegetation has provided a significant improvement (Environmental Statement, 1972) and this is still in evidence today. The State Department of Water Resources conducted some maintenance studies on this vegetation demonstration site and in 1973 reported on the survival rates of the various species in relation to the effects of inundation by floodwaters and accidental losses by fire. Cost of manpower for levee maintenance with the planted vegetation was increased by 64 percent over costs without vegetation on similar adjacent levee areas (Sacramento River Levee Revegetation Study, 1973).

The Sacramento River and Tributaries Bank Protection and Erosion Control Investigation, authorized by the House Public Works Committee, was initiated in 1977. The purpose of this study is: to determine the Federal interest in, and responsibility for, providing bank protection and erosion control; to study alternative means and the feasibility of providing a comprehensive program to stabilize the streams, protect the levees and banks, preserve riparian vegetation, wildlife habitat and aesthetic values, and provide outdoor recreation opportunities along the river; and to select and recommend the best and most balanced plan of improvement, provided that such a plan is found feasible. Completion of the study is scheduled for 1982.

CONCLUSION

The fate of Riparian Forests in California depends upon public education and protective legislation. The first "public hearing" of the plight of these habitats was a conference in Chico, California, on May 22, 1976, which was sponsored by the Davis and Altacal Audubon Societies. A second conference was held in Davis, California, on May 14, 1977, and sponsored by the Institute of Ecology at the University of California and the Davis Audubon Society. Public awareness of the demise of Riparian Ecosystems must now be coupled with political pressure. Governmental agencies which have jurisdiction over the fate of riverbanks must be made aware of the significance and uniqueness of these ecosystems. We must study these agencies' surveys, participate in their hearings, join their advisory committees and become well armed with facts and determination. However, even federal and state agencies have restrictions on their spheres of influence. Almost 95% of the yet unspoiled remnants of riparian hardwoods in California are in private ownership. Each year more of these areas are bulldozed for orchards, cut for pulpwood and cleared for "stream bank protection."

Several approaches can be made to solve the riparian protection problem. Land use plans must be established at county and state levels to encourage recreational and open space easements as well as wildlife sanctuaries. Zoning laws should be altered to relieve land owners from heavy taxes on riparian forest (many farmers are taxed on their forests as if they were fruit orchards). Forestry management acts should be amended to protect riparian species. Private landowners should be offered reasonable alternatives to tree cutting, such as tax deductable donations of land to non-profit, private organizations like the American Land Trust, Audubon, and the Nature Conservancy. Prime riverine forest land should be purchased by conservation groups if all other measures fail. We must all publicize what we know about the Riparian Forests and work together to bring about the political changes necessary to preserve these very special and vulnerable ecosystems. Interested persons should contact the Riverlands Council, P.O. Box 886, Davis, California 95616, to receive fact sheets and legislative updates.

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