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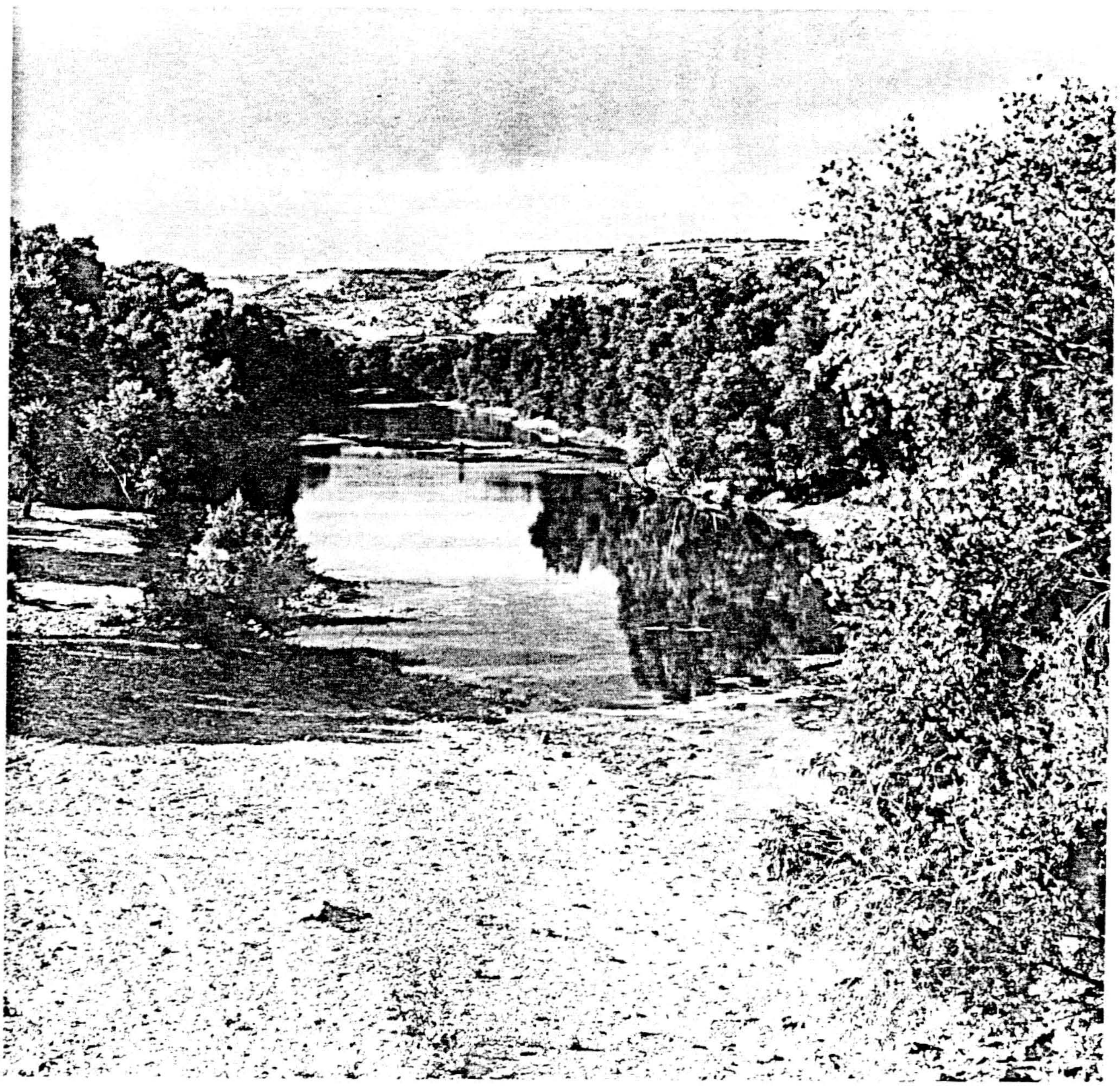
Importance, Preservation and Management of Riparian Habitat:

A Symposium

Tucson, Arizona

July 9, 1977



Foreword

The material offered in this symposium is both urgently needed and late in coming. Only in very recent years have scientists and managers begun to shift their perspective on riverine systems away from localized, single-practice values toward a broader, more cooperative and ecological set of approaches.

The dearth of relative and detailed historic data on riparian habitats is lamentable. We begin investigations on a complex and closely interwoven ecosystem without a reliable baseline. Much of our knowledge to date focuses on the aftermath of decades of abuse. But armed with this hindsight, we are beginning to collect, organize and apply hard data to difficult problems. What percentage of breeding birds are dependent on riparian habitat? How much grazing is too much? How many species of plants occur only in riverine ecosystems?

We have begun the long and expensive task of quantifying our generalities about the riparian habitat, so that we can offer valid alternatives to managers in their attempts to preserve the scant remnants of what was once a vast network of thriving and varied habitats.

Agencies and individuals that favored cutting, grazing, damming, and channelizing were opposed by those who favored preserving intact areas that supported unique plant and animal species, or were of high recreational or esthetic value. We are beginning to reevaluate both these polarized positions, realizing that entire riverine systems cannot be solely maintained for a single interest, whether it be water salvage or the remnant population of a species endangered by our activities.

This symposium stresses the continuity and interrelationships of riparian ecosystems, their wildlife and vegetation, historic and current uses. We have designed this proceedings to bring together material that represents the current state of knowledge, and to point out directions for the next critical steps in the interlocking problems of research and management.

This symposium and its proceedings evolved after much planning. Some individuals on the steering committee have discussed a symposium such as this for several years. However, with riparian research and management still in its infancy, only recently has a good symposium seemed possible. Even now many of the prominant researchers and managers whom we contacted during the preparation of the symposium felt that their grasp of the workings of riparian ecosystems was still inadequate. We found research projects and management plans developing as rapidly as the state of the art allows in the western United States, especially the arid Southwest. And although subjects such as river recreation are developing rapidly in the eastern United States (see Proceedings, River recreation management and research symposium--January 24-27, 1977, General Technical Report NC-28, North Central For. Exp. Stn., Minneapolis, Minn.) one is hard pressed to find riparian projects east of the Rocky Mountains, except for those associated with the continuing destruction of even more riverine ecosystems.

We predict that by the early 1980's research projects currently being planned and undertaken will lead to a vast expansion in the knowledge necessary to properly manage riparian ecosystems. In 3 to 5 years, a full-scale workshop on sophisticated means of research, preservation, and management of riparian habitat seems possible. Today we offer a relatively primitive state of the art in the "importance, preservation, and management of riparian habitat." If our predictions are correct, this science will have developed from a newly born discipline into progressing maturity within two decades. Far-sighted men like the late Douglas C. Morrison, to whose memory this symposium is dedicated, will have played a major role in the birth of scientific management of riparian habitat.

R. Roy Johnson

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Technical Coordinators:

R. Roy Johnson
National Park Service
and
Dale A. Jones
USDA Forest Service

Cosponsored by:
Arizona Game and Fish Department
Arizona-New Mexico Section, The Wildlife Society
Arizona State University
Bureau of Land Management
Museum of Northern Arizona
National Park Service
U.S. Fish and Wildlife Service
USDA Forest Service

Acknowledgment

We wish to thank the authors of the papers in this proceedings for their enthusiasm and cooperation. The one day available for the symposium provided insufficient time to present all of the fine papers brought to our attention. Thus, we are pleased to have several excellent contributed papers published in the same volume with the presented papers. The authors of contributed as well as presented papers submitted camera-ready manuscripts to expedite their publication. The Bureau of Land Management provided generous financial support for the publication of these papers.

Finally, we acknowledge those who assisted with the mechanics of organizing and conducting a symposium of this scope. The steering committee, composed of representatives from the sponsoring agencies listed, assisted in organizing and publicizing the symposium. And the fact that you are able to read these papers so shortly after the symposium is due largely to the combined efforts of the authors and the Publications Group, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. To all of these we owe our sincere thanks.

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Abstract

Twelve presented and 15 contributed papers highlight what is known about this unique, diminishing vegetative type: characteristics, classification systems, associated fauna, use conflicts, management alternatives, and research needs. Speakers stressed the continuity and interrelationships of riparian ecosystems, their wildlife and vegetation, historic and current uses.

Contents

Session I

Discussion Leader: Dale Jones
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Importance, Preservation, and Management of Riparian Habitats: An Overview[1]

Steven W. Carothers [2]

In the early 19th century, huge and numerous squawfish were being taken along the lower Gila; there was a commercial fishery of the humpback sucker in the San Pedro; wild turkeys hatched out of the waist-high grasses of the Auga Fria; and grizzly bears and mountain lions were encountered with alarming frequency in the riparian woodlands associated with some of these drainages. The historical literature that documents the early exploration and settlement of the southwestern United States is replete with similar accounts of the original condition of the area's rivers, streams and springs (see Lacey et al., 1975; Hastings and Turner, 1965, for original references).

The river valleys of the arid Southwest have undergone significant physical and biological changes since the early 1800's. This change has involved almost exclusively a deterioration of the natural resources. Drainages like the Gila and San Pedro Rivers that once supported pristine riparian communities are now, in many sections, dry and devoid of native trees and shrubs. Concomitant with the deterioration of the riparian habitats, the range habitats throughout the same area also reflect a decline in the production of palatable forage plants and an increase in topsoil erosion.

We can, and have, argued about the causes of deteriorating range quality. But there is, in my opinion, no controversy concerning the causes of the irrevocable consumption of the riparian habitat that has occurred in less than 150 years. The imminent demise of the riparian woodland can be most assuredly linked to the land utilization practices of man.

The title of this symposium indicates that we will address the "importance, preservation and management" of riparian habitats. The word "importance" here is meant to reflect the relative contribution of riparian habitats in a natural ecosystem; "preservation and management" refer to implementing land management practices that will forestall the possible extinction of these habitats. We are tempted to approach these issues in purely scientific definitions. But the issues extend beyond the realm of biology. Man has contributed, in large part, to these problems. It is only by examining how he views the riparian habitat as important to his economic base, and thereby consumes this resource, that we can understand why it is in danger of extirpation.

The settlement patterns of the native American Indians clearly reflect the initial consumptive use of riparian habitats. They first settled the river valleys, needing water for themselves, and subsequently drinking water for livestock and irrigation water for crops. This pattern of consumption accelerated greatly in the early 1820's, with the settlement of the early Anglo-Americans in the Southwestern river valleys. Prospectors, farmers, and ranchers all found uses for the limited water and its associated vegetation. The area was rapidly settled and in 1896 the Governor of Arizona Territory could report, "In Arizona by 1883-84 every running stream and spring was settled upon, ranch houses built, and adjacent ranges stocked." (Report of Governor, 1896:21 fide Hastings and Turner, 1965).

The settlers cleared large expanses of native vegetation, using some for building materials; but for the most part, they did not view the woodlands as a valuable resource, and removed them so that the soil of the alluvial bottom could be put into "production" for agricultural and domestic livestock grazing purposes. Eventually, farming and ranching became thriving concerns; river water was channeled into irrigation canals, wells were excavated and in time the water tables began to drop. Responding to changing water regimes, damaging floods, or in simple attempts to increase the yield of the land, dams were finally constructed, inundating and destroying even more riparian woodland and free-flowing streams and rivers. By the late 1920's, America had shifted from a rural to a predominantly urban population. The beginning of an urban-industrial civilization in the arid Southwest required the

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[1]Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9 , 1977.

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utilization of many innovative technological advances in developing veritable oases where once only parched deserts prevailed. As population centers experienced rapid and prolific expansion, terms such as water production, water management, and water salvage became very meaningful.

As recently as the late 1960's, belts of native riparian woodland along the river valleys of central and southern Arizona were still being actively removed by water salvage and flood control agencies. These "phreatophyte control" and channelization projects were easily justified when based on the standard cost/benefit ratio that was used for project evaluation at the time. The important parameters of these evaluations were: 1) streamside vegetation requires substantial amounts of water, water that is lost to the atmosphere through evapotranspiration; and 2) streamside vegetation impedes the rapid transport of flood waters and increases the apparent severity of floods by temporarily and partially damming channels, thus forcing high water into the adjacent floodplain lands.

The question of how much water is gained and to what degree floods are prevented by phreatophyte control and channelization has been a battle of the minds almost since vegetation removal was first suggested (see Lacey et al., 1975; Paylor, 1974, for references). Still, we have not seen the last of phreatophyte control and streambed channelization in the Southwest, and we know for certain that additional dams will consume even more of the still extant riparian areas. But the most insiduous threat to the riparian habitat type today is domestic livestock grazing. Many riparian areas appear to be in good health; on closer examination, we find that while the mature vegetation approaches senescefice, grazing pressures have prevented the establishment of seedlings. We are very concerned that when many of these mature stands of trees die of natural causes, there will be no young forms to take their place. Heavy grazing pressures can and do produce even-aged, non-reproducing vegetative communities. Our concern for this habitat's survival can only mount until this situation is remedied.

For more than a century, then, the riparian habitats of the Southwest were viewed only in terms of their consumptive value, while their values for non-consumptive purposes--aesthetics, recreation, wildlife, and so on--were largely ignored. It was not until the mid-1960's that various agencies and individuals, particularly in the Arizona Game and Fish Department (see Bristow, 1969; Gallizioli, 1965) and the United States Forest Service (pers. communication, Dale Jones and Douglas C. Morrison) began to point out that substantial numbers of both game and non-game wildlife species were dependent upon riparian vegetation. And it was only in the fall of 1968 that efforts to quantify the impact of streamside vegetation removal on wildlife were first undertaken. It is for his efforts in this regard that this symposium is dedicated to the late Douglas C. Morrison.

Working through the wildlife staff on the Coconino National Forest, in 1968 Mr. Morrison participated in the design of a research project that would quantify the effects of phreatophyte control on breeding birds in the native riparian woodland of the Verde River. A Forest Service contract was awarded to the Department of Biology at the Museum of Northern Arizona in the spring of 1969. Through Mr. Morrison's efforts, the study was funded for two years by the Forest Service. After that time, the Arizona Game and Fish Department supported the project for an additonal three years.

The results of that study (see Carothers et al., 1974) substantiated, for the first time, two facts that had long been suspected by many wildlife biologists: 1) that vegetation manipulation in native riparian communites was extremely detrimental to breeding bird populations, the extent of the impact being significantly correlated with the degree to which phreatophytes were removed, and 2) that for a given number of acres of habitat, the riparian type supports higher population densities than any other forest habitat type. Indeed, the surprising discovery resulting from these studies is that the homogeneous cottonwood riparian type of the Verde River contains some of the highest avian population densities per unit area that have been recorded in the continental United States. Recently, other investigators working in the river valleys of the Gila (Hubbard, 1971), the Colorado (Anderson, Ohmart et al., this symposium; Carothers and Sharber, 1976) and the Salt (Johnson and Simpson, 1971) have demonstrated the remarkabley high wildlife potential of riparian habitat types.

The influence of the riparian type on wildlife is not limited to those animal species that are restricted in distribution to the streamside vegetation. Preliminary investigations conducted by us (see Stevens et al., this symposium), in both river valley and mountain riparian types, demonstrate that the population densities of birds in habitats adjacent to the riparian type are influenced by the presence of a riparian area. Our present interpretation of these preliminary data is that when a riparian habitat is removed or severely manipulated, not only are the riparian species of the area adversely influenced, but wildlife productivity in the adjacent habitat is also depressed. The actual width the zone of influence riparian habitats have on adjacent habitat wildlife productivity may, for some animal species, extend several hundred meters beyond the edge of the streamside vegetation. Under the auspices of the Forest Service, we are presently attempting to determine this for a variety of riparian types in Arizona and New Mexico.

Thus, the history of man's use of the riparian habitats in the Southwest indicate that it has been and continues to be an important and valuable asset to the settlement and progress of this country. On the other hand, ecological research on this habitat type has conclusively demonstrated that riparian areas are integral and indispensable components of desert and mountain ecosystems. Past riparian habitat management practices have resulted in widespread destruction of these areas. That they are non-renewable resources as suggested by Lacey et al. (1975) is a frightening possibility. And even though there are many Southwestern drainages still forested by riparian vegetation, current land use practices still threaten the future existence of these native communities.

We should not look back on the land management practices of the past with too much remorse and certainly with no blame. A summary of man's activities in and the destruction of woodlands, streams, and rivers simply reflects man's successful settlement of this arid land, allowing those of us who live and work in the Southwest the lifestyle we now enjoy. Land management practices of the past should, in fact, be a foundation for learning and understanding how to cautiously move forward in our interactions with the environment.

We are here today to exchange information. The time is at hand for the ecologist, economist, engineer, environmentalist and land manager to strike a compromise...a compromise that will provide a future for native Southwestern riparian habitat types. Accepting and assessing the environmental mistakes of the past, becoming aware of the intricate needs and associations of man and the environment can lead to the implementation of land management practices that will achieve this end.

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Classification of Riparian Habitat in the Southwest[1]

Charles P. Pase, and Earle F. Layser[2]

Abstract.--The riparian areas in Arizona and New Mexico are uniquely productive wildlife habitats. A tentative classification based on the work of Brown and Lowe is proposed as a working model. Six biomes, nine series and 23 associations are tentatively recognized. Additional research is proposed to further refine the classification. The classification of riparian vegetation can provide a strong management tool.

INTRODUCTION

Riparian habitats in arid and semiarid environments are unique reservoirs of plant and animal diversity. Breeding bird densities are likely to be high, especially in the most productive Fremont cottonwood (Populus fremontii) stands, with as many as 1,000 pairs or more per 100 acres (Carothers and Johnson 1975). Also, the small but highly productive riparian communities support the greatest variety of birds (and probably other vertebrates) in the Southwest.

"Riparian" type habitats are streamside or riverside communities, stretching from high forest to low desert. Soil moisture is seldom a limiting factor, at least for successfully established perennials, although surface water may be lacking at times in marginal areas. The wide array of habitats thus included sustains an equally wide array of plant and animal communities.

FLORISTIC HISTORY

The southwestern mountains and valleys contain diverse floristic elements, which have mixed and adapted to provide a unique flora.

Madro-tertiary elements such as Celtis, Juglans, Prosopis, Platanus, and Sapindus along the Mexican cordillera are representative of families with strong subtropical affinities. During the drier postpluvial period, increasing dryness forced their retreat to the riparian zones, where today they form characteristic deciduous forests and woodlands. According to Martin (1963), many of the Mexican flora and fauna probably were isolated in the southern Arizona mountains during the mid-postglacial, perhaps 4,000 to 8,000 years ago. If so, modern communities were relatively recently composed.

During the Pliocene-Pleistocene era, Arcto-tertiary Geoflora extended southward into the mountains of Arizona and New Mexico, establishing such northern-affinity genera as Alnus, Salix, Populus, and Betula. The same xerothermal conditions—the so-called altithermal—that isolated the mexican plateau elements also trapped these genera in moist, riparian habitats (Lowe 1964).

Development of modern riparian plant and animal communities, and the isolation of many species into highly restricted habitats, happened relatively recently. Further restriction of these small, sensitive areas by agriculture, recreational, and other developments may pose a serious threat to species largely or wholly dependent on this habitat.

THE RIPARIAN ZONES

Despite the species diversity and productivity of the riparian zone, it is relatively small. The total riparian area in Arizona is some 279,600 acres (Babcock 1968), of which 100,700 acres are along the Gila River. The areas within New Mexico may be comparable or slightly larger, with the inclusion of substantial areas of mesquite, Fremont cottonwood, and salt cedar (Tamarix spp.) along the main stem of the Rio Grande.

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[1]Paper presented at the Importance, Preservation and Management of the Riparian Habitat Symposium, held at Tucson, Arizona, July 9, 1977.

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The most productive Fremont cottonwood areas are surprisingly small--about 6,000 to 8,000 acres in Arizona, according to Barger and Ffolliott (1971). Unfortunately, estimates of area by plant associations are not yet available for other types. However, National Forests in USDA Forest Service Region 3 plan to inventory riparian habitat, because of its high wildlife value, as part of forest land management planning.

Riparian communities generally exhibit a predictable vertical zonation in relation to each other (fig. 1), although absolute upper and lower limits may vary within the Region (Freeman and Dick-Peddie 1970). Certain species, such as box elder (Acer negundo), are found throughout the area, and may occur as scattered minor components in a number of related associations. Others such as Salix irrorata, have much lower ecological amplitudes.

WHY A CLASSIFICATION SYSTEM?

While there is substantial intergradation between adjacent riparian units, certain species or combinations of species tend to dominate stands. Recognition of these natural ecological units may help the land manager as follows:

1. It would assist the identification, description, and communication about riparian habitats.
2. Utilizing a classification system would allow for more uniform identification of the different riparian situations, thus providing a means to more accurately assess the distribution and the relative amounts of the different communities that may exist.
3. Development of the classification would provide an inventory of the major plants that exist in the different communities. Inventory of fauna associated with the different plant communities could also be done.
4. Successional roles of the different species would be better determined which would allow more accurate prediction of results of management practices.
5. It would provide a framework for additional research and reporting of research results.

The development of a site-based vegetation classification system for riparian habitats is not an end in itself. The purpose of the classification is to provide land and resource managers with a management tool. As pointed out above, this would enable managers and research to better deal with problems involved in the management of riparian habitats in the Southwest.

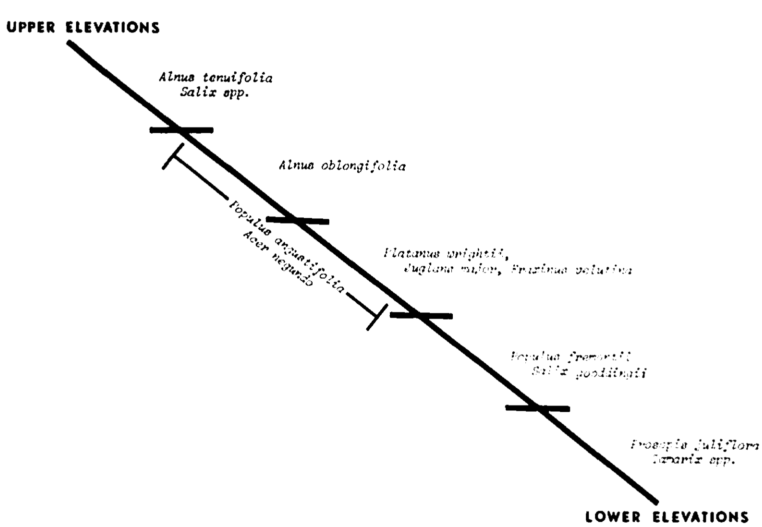

Figure 1.--Altitudinal zonation of major riparian communities in the Southwest.

STATUS OF CLASSIFICATION

While there have been notable studies of riparian vegetation in the Southwest (Campbell and Green 1968; Lacey, et al. 1975; Lowe 1961; Freeman and Dick - Peddie 1970; Horton 1960), there has been only little work to date towards development of a systematic classification of riparian vegetation or sites. Such classification involves methodology as described by Pfister and Arno (1977). In generalized terms this means:

1. Sampling of stands or communities in respect to ecological and floristic characteristics.

2. Analyzing the above data by various techniques.

3. Considering various groupings (classes) based on the data and analysis; and selecting groupings appropriate to the purpose.

4. Defining the classes as simply and precisely as possible.

The taxonomic classification is then used to apply the appropriate class name to communities as they are encountered in the field. This is called "identification", and differs from the actual development of the classification (Bailey, et al. in press).

A TENTATIVE CLASSIFICATION OF RIPARIAN COMMUNITIES
(generally after the system of Brown and Lowe 1974)

Boreal Riparian Mixed Forest Biome
- Spruce--Mixed Shrub Series
  - Picea pungens - Alnus tenufolia Association

Temperate Riparian Deciduous Forest Biome
- Mixed Broadleaf Series
  - Mixed Broadleaf Associations (fig. 2)
  - Acer negundo Associations
  - Alnus oblongifolia Associations (fig.3)
  - Platanus wrightii Associations (fig. 4)
  - Fraxinus velutina Associations (fig. 5)
  - Juglans major Associations
- Cottonwood--Willow Series
  - Populus fremontii--Mixed Broadleaf Associations
  - Populus fremontii Associations (fig. 6)
  - Salix bonplandiana Associations
  - Populus fremontii--Salix gooddingii Associations
  - Salix gooddingii Associations
  - Populus angustifolia Associations

Subtropical Riparian Evergreen Forest Biome
- Palm Series
  - Washingtonia filifera Associations

Boreal Riparian Woodland Biome
- Willow Series
  - Salix bebbiana Associations
  - Salix irrorata Associations
  - Salix mixed Associations (fig. 7)
- Alder Series
  - Alnus tenuifolia Associations
  - Alnus tenuifolia--Salix Associations (fig. 8)

Temperate Riparian Deciduous Woodland Biome
- Willow Series
  - Salix exigua Associations

Subtropical Riparian Deciduous Woodland Biome
- Mesquite Bosque Series
  - Prosopis juliflora Associations
  - Prosopis juliflora--Mixed narrowleaf (Tamarix, Chilopsis, Celtis) Associations
- Tamarix Disclimax Series
  - Tamarix chinensis Associations

The above list is not to be considered complete. Lacey et al. (1975) suggests that a number of these should be subdivided further. The listing, however, generally displays the current "classification" of riparian vegetation, and represents a tentative identification of types which are a first approximation toward the development of a classification.

Figure 2.--Mixed broadleaf Association with Platanus, Populus, Fraxinus, Juglans, Prunus, and Sapindus. This is primary habitat for rose-throated becard and Apache fox squirrel. Arroyo Cajon Bonito, Sonora, Mexico.

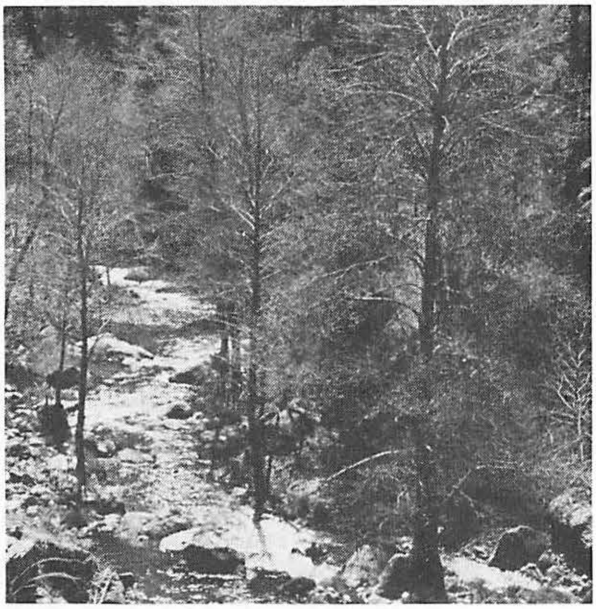

Figure 3.--Alnus oblongifolia Association on the upper Gila River. This type occur only on upper middle elevation living streams, where roots can reach the water table during much of the year (Freeman and Dick-Peddie 1970).

Figure 5.--A nearly pure stand of Fraxinus velutina along Ash Creek, Rincon Mountains. Heavy past cattle use will be restricted under new management plans in this area.

Figure 4.--Platanus wrightii Association along Turkey Creek, Rincon Mountains, Coronado National Forest. Limited understory and absence of reprodection charaterizes these grazed channel bottoms.

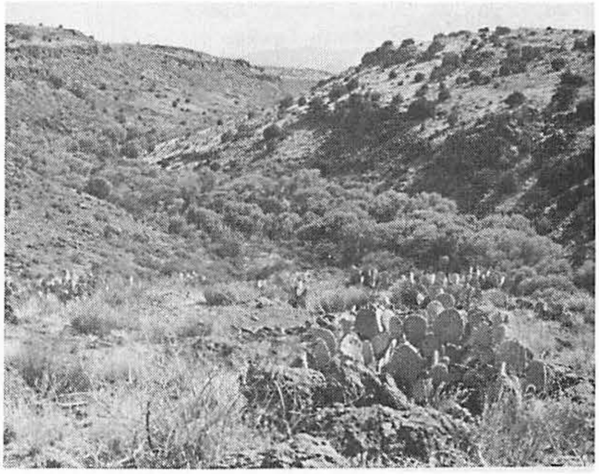

Figure 6.--Narrow bands of Fremont cottonwood, sycamore, velvet ash and Goodding willow provide sharp contrast to dry grassland communities on the Prescott National Forest.

Figure 7.--Salix Mixed Association, upper Black River, Apache-Sitgreaves National Forest. S. pseudocordata and S. lasiolepis provide shade and cover along one of Arizona's productive trout streams. The area is valuable elk summer range, with little livestock use.

Figure 8.--A lush Alnus tenuifolia - Salix Association flanks Los Pinos Creek on the Carson National Forest. The narrow, overhanging riparian woodland community greatly improves trout habitat.

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Inventory of Riparian Habitats[1]

David E. Brown[2]
Neil B. Carmony[3]
Raymond M. Turner[4]

Abstract.--A recently published map of Arizona's perennial streams and important wetlands was presented and discussed. Perennial streams are illustrated rather than riparian vegetation because the streams are of more direct biotic significance and are more readily identifiable. Inventory procedures used in preparing the map were outlined and the categories of streams and wetlands described. A planned revision of this map will incorporate selected altitude contours, base-flow classes, and an inventory of seasonal streams.

The map distributed to members of the symposium presents Arizona's perennial streams and important wetlands; it is a synthesis of information compiled by numerous investigators (Brown, Carmony, and Turner, 1977). While the map implies the distribution of riparian and marshland vegetation, it does not show riparian vegetation directly: rather, it shows the distribution of live streams and wetlands—the physical basis upon which riparian and wetland biotic communities depend.

Efforts and plans to modify and even eliminate many of the Southwest's remaining riparian communities have stimulated interest in the inventory and preservation of riparian habitats. One of the results of this interest was the formation in 1972 of a "Riparian Recovery Committee" within the New Mexico-Arizona Section of the Wildlife Society. This committee has promoted the investigation of riparian habitats, and its efforts resulted in this symposium sponsored by the U.S. Forest Service. It soon became apparent to the committee and to other workers involved with riparian vegetation and fauna that the classification and inventory of the various riparian habitats is a necessary first step in understanding the problems associated with riparian habitats.

Because of the immense biological importance of these habitats, it was originally planned to prepare a map of Arizona's natural and potential riparian deciduous forests and woodlands as described by Lowe (1964, p. 60-62) and as classified by Brown and Lowe (1974a, 1974b). An informal program of collaboration between the Arizona Game and Fish Department and the U.S. Geological Survey was initiated to map riparian vegetation from low-level aerial photographs of sub-Mogollon Arizona (photographs were taken in June 1973, and later checked at a limited number of sites for ground truth). Although the determination of established deciduous forests proved feasible, it soon became apparent that the inventory of riparian forest vegetation in itself left much to be desired for the purposes of biotic assessment. Two major deficiencies of this approach were:

1. Extreme variations in the biota within the riparian deciduous forests were not measured. Deciduous forests can and do exist along near-perennial as well as perennial streams. Habitats along intermittent or nearly perennial streams do not, of course, support fish and other important aquatic forms that are found in perennial streams. Therefore, the presence or absence of a potential riparian aquatic biota and its predators, e.g.

[1] Paper presented at the Riparian Habitat Symposium, Tucson, Arizona, July 9, 1977.

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black hawks *(Buteogallus anthracinus)*, ospreys *(Pandion haliaetus)*, bald eagles *(Haliaeetus leucocephalus)*, otters *(Lutra canadensis)*, and kingfishers *(Megaceryle alcyon, Chloroceryle americana)*, would not be indicated by an inventory of riparian deciduous forests alone.

2. The dynamic nature of riparian communities is such that potential riparian deciduous forests could not always be determined. It soon became apparent that floods, intensity of livestock grazing, geologic and hydrologic conditions, and other factors could continually or temporarily affect the presence of several deciduous-forest species and thereby determine the presence of the forest community itself. These factors can result in the presence of successional stages from seedlings to decadent stands, or in the absence of trees altogether. These conditions may prevail over a relatively short term or may be as long as several human generations.

For these reasons we decided to determine the feasibility of modifying existing map(s) of live (perennial) streams and rivers to show wetlands and potential riparian vegetation. To our surprise no comprehensive inventory of perennial-flow reaches existed, and the only map of "permanent streams" available for Arizona was a small-scale drainage map by Miller (1954).[5] This map was presumably based on fish collections and, while serviceable, was very much in need of revision. Perennial-stream data were transferred and extrapolated from Miller's map to a 1:500,000-scale U.S. Geological Survey map of Arizona. This became the base work map. U.S. Geological Survey minimum flow records were used, where available, to identify the nature of flow in streams. Those streams for which no streamflow records were available became the subject for interviews with wildlife managers, U.S. Forest Service personnel, back packers, fishermen, and others who had visited them. Fortunately, these efforts coincided with a statewide stream inventory conducted by the Arizona Game and Fish Department (Silvey, 1977) and with a statewide map inventory of biotic resources, including perennial streams, by regional personnel of the Arizona Game and Fish Department. Personal knowledge and investigation by the authors supplemented these data and allowed for further comparison and correction. A major but not sole criterion used in determining the permanence of flow in an ungaged stream was the presence or absence of fish. We considered as perennial those streams which supported a fish fauna regardless of minimum flow. Perennial streams, as classified here, may have surface water only in pools during times of extreme drought or other low-flow periods.

It soon became obvious that there are three major categories of perennial streams based on the biota actually or potentially present. These categories and their characteristics are:

1. Unregulated perennial streams. These streams usually possess a native and/or introduced aquatic fauna. Those that are now devoid of native fishes possess the potential for restoration if the native species formerly present are still available. Native riparian communities and their associated biota are actually or potentially present, and the riparian exotic saltcedar (*Tamarix chinensis*) can be expected to be poorly represented. Some of these streams may be partially regulated by relatively small upstream storage or diversion.

2. Regulated perennial rivers and streams. These rivers and streams are characterized by a totally unnatural streamflow pattern. They lack normal seasonal high water, and on occasion base flows may be artificially reduced or eliminated. There may also be major daily changes in streamflow that negatively affect the life cycles of many fish species. Water-temperature regimes are also greatly altered. This factor, and the lack of normally occurring high flows, tend to inhibit natural reproduction of those plants and animals which evolved with a natural flowing system. These "managed" streams are now often largely populated by introduced fishes, reptiles (for example, the soft-shelled turtle *(Trionyx spinifera)*), and amphibians (for example, the bullfrog *(Rana catesbeiana)*), and the native biota are reduced and some species are extirpated. Exotic plants occupy many extensive riparian habitats. Numerous species of birds characteristic of riparian communities usually persist, however.

3. Stream reaches containing only effluent or waste-water dishcarge. These stream reaches are characterized by an almost completely introduced aquatic fauna adaptable to polluted waters, and include mosquito fish *(Gambusia affinis)*, sailfin

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[5] Perennial-flow reaches are indicated on U.S. Geological Survey topographic and other maps, but in many cases these streams do not appear to have been adequately field checked and are in error.

mollies *(Poecilia latipinna)*, carp *(Cyprinus carpio)*, and crayfish *(Astacidae)*. The riparian vegetation is usually a mixture of native and exotic species. The status of these reaches is expected to change significantly in the future as consumptive uses for these waters are developed.

Important wetlands, the other major category shown, are separated into two size categories, classified by regulatory criteria similar to those for perennial streams, and plotted on the base map in the appropriate size and color. Wetlands are here defined as poorly drained lands, seasonally or periodically submerged lands, and shallow bodies of water supporting emergent vegetation. Important wetlands are those that, because of their size and/or location, are much used by nesting, migrating, and wintering waterfowl or that provide habitats for rare, unusual or interesting wetlands species of flora and fauna. We were highly dependent on Game and Fish personnel, especially Richard L. Todd and Thomas K. Britt, for the locations of many of these major wetlands.

All these data were transferred from the 1:500,000 work map to a U.S. Geological Survey Drainage Map, scale 1:1,000,000. This map is now out of print but approximately 1,800 copies are in circulation. Its rapid dissemination was due to the interest of fishermen, hikers, realtors, gold miners, and others as well as those interested in natural-resource inventory. Because of this broad appeal we intend to publish a second edition, possibly in 1978. In an effort to make the map more useful and meaningful to biologists, we propose to incorporate additional data and criteria, in addition to making those corrections called to our attention. These new items include:

A. The addition of altitude contours 1,000 ft, 3,500 ft, 5,500 ft, and 7,750 ft above mean sea level. These contours, based on the occurrence of riparian species, were selected after consultation with biologists possessing knowledge of Arizona's endemic fishes (R. R. Miller; W. L. Minckley; W. Silvey, personal communications, 1977). These contours will roughly partition the state into arctic-boreal, cool-temperate, warm-temperate, and subtropical zones. In addition to providing information as to which species of riparian flora and fauna can be expected, these contours will allow for rapid identification of cold montane waters and associated fishes, waters dominated by cool-water fish, waters dominated by warm-water fish, and waters populated exclusively by warm-water species.

B. The division of unregulated streams into size categories on the basis of base-flow data. Streams would be categorized as those possessing a 7-day minimum flow of >50 cubic feet per second (ft^3/s), >10-<50 ft^3/s, and <10 ft^3/s. These divisions would roughly separate Arizona's natural flowing streams as follows:

1. Base flow >50 ft^3/s

Unregulated perennial streams with a base flow greater than 50 ft^3/s potentially support a varied aquatic fauna of both native and introduced species. Some fish species present can be expected to reach sizes of 20 lbs or more. Consequently, these rivers are potential habitat for some of the larger piscivorous animals, e.g. otter, black bear *(Ursus americanus)*, bald eagle, osprey, etc. While these rivers potentially support all native species of riparian vegetation common to their life zone, periodic floods and seasonal fluctuations in flow regimes usually prevent the establishment of "gallery" forests, and long stretches of river are often characterized by wide, barren flood plains. Examples are few and include the Lower Little Colorado River below Blue Springs, the Verde River from below Perkinsville to Clarkdale, the Verde River from West Clear Creek to Horseshoe Reservoir, and the Salt River above Roosevelt Lake. Formation of a perennial river from effluent discharge is a recent phenomenon in Arizona. Rivers in this class are formed by sewage releases from growing cities and from irrigation return flow. The aquatic fauna is almost entirely introduced, as is the dominant riparian plant, saltcedar *(Tamarix chinensis)*. Native vegetation is profuse, however, and appears to be increasing.

2. Base flow >10-<50 ft^3/s

Unregulated perennial streams in this category can also be expected to support a varied native and introduced aquatic fauna. Select habitats can be expected to support species of fish over 1 lb. These streams are potential habitat for most piscivorous species and normally possess well-developed native riparian communities and their animal associates. Riparian deciduous forests are common features below 6,500 ft. Examples of streams in Arizona with base flows in this range are the Virgin River, Bright Angel Creek, the Verde River above Perkinsville, Oak Creek, the lower portions of West Clear Creek, Black River, north fork of the White River, and the San Francisco River.

3. Base flow <10 ft^3/s

Unregulated perennial streams of this size usually support only the smaller fishes and their predators. The native fish fauna may be rich in species, and a surprising number of amphibians and aquatic reptiles can be expected. Riparian deciduous species frequently form "gallery" forests, and excellent examples are present at many places.

C. We plan also to add seasonal streams. These streams, termed semi-perennial by Zimmerman (1969), flow during the winter and early spring; they do not have a sufficient base-flow component to maintain a surface flow during warm dry months when evapotranspiration losses are high, but can be expected to flow from mid-winter to about April. These streams potentially support well-developed riparian vegetation, including deciduous forests. The aquatic biota is, of necessity, limited to those forms adapted to withstand periods of desiccation, and fishes are lacking. Nonetheless, avian and amphibian species characteristic of, and associated with, riparian forests may be well represented, with the exception of piscivorous species. Such non-piscivorous animals include in the appropriate environments the zone-tailed hawk *(Buteo albonotatus)*, grey hawk *(Buteo nitidus)*, summer tanager *(Piranga rubra)*, blue grosbeak *(Guiraca caerulea)*, Woodhouse's toad *(Bufo woodhousei)*, the canyon tree frog *(Hyla arenicolor)*, etc. These streams will be differentiated from those of an ephemeral nature.

We believe that these inventory procedures are applicable to other Southwestern States and will prove useful in the delineation of their aquatic, riparian, and wetland biotic resources.

We suggest that future mapping be at the scale of 1:1,000,000, which would be an effective standard for the illustration of biotic resources because of its easy metric conversions (1 mm = 1 km), adaptability for demonstration purposes, and utility for field use.

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Importance of Riparian Ecosystems: Biotic Considerations[1]

John P. Hubbard[2]

By biotic considerations I am referring to flora and fauna, and specifically I would like to probe the question of the importance that riparian ecosystems play in sustaining the rich biotas of the Southwest, i.e. Arizona and New Mexico. To begin, these two states are among the richest of any in the United States as far as their diversity is concerned in species of plants, terrestrial vertebrates, and many invertebrates. This biotic richness stems from several factors, including the great environmental variety of the region and the fact that several major biotic areas impinge on the area, i.e. the Great Basin, Rocky Mountains, Great Plains, Mexican Plateau, and the Southern (Chihuahuan and Sonoran) Deserts.

New Mexico is the fourth and Arizona the fifth largest of the United States, with areas of 121,666 and 113,909 square miles, respectively. In size these states are thus on a par with such well-known entities as the British Isles, Italy, and the Philippines. In elevation New Mexico ranges from 2800 to 13,161 feet above sea level, while Arizona ranges from near sea level to 12,670 feet. Although often through of as "deserts", both states support extensive montane forests, and New Mexico especially is crowned with alpine tundra in the north. On the other hand, aridity is a dominant climatic feature of the region, and particularly at elevations below 6000 feet surface water is scarce and naturally restricted to a few thousand miles of generally narrow drainageways in the two states.

Floristic diversity is revealed by the fact that New Mexico supports 3500 to 3600 species of higher native plants within its borders (Wagner, 1977), while the latest summary for Arizona lists 3438 (Kearney and Peebles, 1960). For the continental United States and Canada as a whole, an estimated 40,000 to 50,000 species of higher plants have been recorded. Thus, the floras of New Mexico and Arizona comprise about 7 to 9 percent of the total flora of what might be termed temperate North America.

Among terrestrial vertebrates one finds that even higher percentages of the overall temperate North American faunas are recorded in these two states (Table 1).

Table 1. Vertebrate Fauna of the Southwest, Including Species Totals and as Percentages of the Total Fauna of North America North of Mexico.[3]

Mammals	Arizona	New Mexico
species	134	139
percent	41.6	43.2
Birds		
species (all)	431	413
percent	62.0	59.4
species (breeding)	245	245
percent	38.0	38.0
Reptiles		
species	93	80
percent	35.2	30.3
Amphibians		
species	21	22
percent	13.5	14.2

As one can see, except for amphibians, Arizona and New Mexico harbor disproportionate portions of the terrestrial vertebrates of temperate North America, with figures ranging from about one-third to almost two-thirds among mammals, birds, and reptiles. Amphibians, which mainly depend on water for reproduction, in the two states constitute about one-sixth of the North American fauna.

[1]Paper presented in Importance, Preservation, and Management of the Riparian Habitat, Tucson, Az, July 9, 1977.

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[3]Data sources include Findley et al., 1975; Hubbard, 1970; Lowe, 1964; Phillips et al., 1964; Stebbins, 1966.

Fishes, although they face an overall scarcity of habitats in the Southwest, are nonetheless well-represented in the faunas. Arizona has 32 native species (Minckley, 1973), while New Mexico has 59 species recorded within its boundaries (Koster, 1957). The latter area supports a richer fauna by virtue of its location in both the Atlantic and Pacific drainages of the continent. In fact, several species from the very rich Mississippian ichthyofauna reach western limits in New Mexico, including the blue sucker (Cycleptus elongatus). Even with their limited faunas, these two states still host--or hosted--reasonably rich percentages of the overall U.S. fish fauna in their boundaries, i.e. 5.3% in Arizona and 9.3% in New Mexico.

From the above it should be apparent that Arizona and New Mexico are truly diverse in their floras and faunas, even when one largely restricts the discussion of animals to vertebrates. Thousands of species of invertebrates also occur in the two states, including especially terrestrial arthropods. For example, Howe (1975) lists almost 700 species of butterflies from temperate North America, and of these about one-third are recorded from New Mexico and somewhat higher figure from Arizona.

In evaluating the biotic importance of a region, one approach is through the consideration of endemism, i.e. the degree to which species are restricted to an area in question. Both Arizona and New Mexico are host to endemic plants and animals, including vertebrates as well as invertebrates. Although I know of no compendium of such species, several examples illustrate some of the endemism. For example, among vertebrates New Mexico hosts the only known populations of such species as the White Sands pupfish (Cyprinodon tularosa), Jemez Mountain salamander (Plethodon neomexicanus), and Sacramento Mountain salamander (Aneides hardii). Both states boast endemic plants as well, while together they share a number of other endemics that occur nowhere outside the Southwest, including the minnow genera, Tiaroga and Meda, in the Gila Basin.

Although endemism is an important means of evaluating the biotic importance of an area, other considerations also pertain. For example, the kinds of assemblages of plants and animals are important, and in these two states virtually unique associations have arisen because of the interdigitation and/or mingling of diverse biotas. Such associations are interesting and important form evolutionary, ecological, and other biological points of view. Unique or unusual assemblages of plants and animals provide scientists and others the extended opportunity to understand better our ecosystems and life itself. An example of a notable biological assemblage is the breeding avifauna of the lower Gila Valley of New Mexico, where species characteristic of the Sonoran, Mexican Plateau, and Holarctic avifaunas occur side-by-side (Hubbard, 1971). That fauna has been compared to another in the ecologically similar San Juan Valley, 250 miles to the north and in the same drainage basin (i.e. Colorado River). Both avifaunas have similar numbers of species (i.e. 105 versus 112 in the Gila), but they differ importantly; for example, only 58.7% of the Gila species breed in the San Juan, while only 64.8% of the species in the latter area breed in the Gila (Schmitt, 1976).

The essence of the above comparisons is that not only are Arizona and New Mexico biotically diverse and host to certain endemics, but they also show significant and important area-to-area differences in the composition of biotas occupying similar situations. Each river valley, mountain range, hot spring, or alkaline playa is apt to differ from those occurring nearby, and this fact alone underscores even more the biotic importance of these two states. This is not to imply that other regions are lacking in biotic importance, for such is not the case. However, Arizona and New Mexico stand apart from most other states in having both very rich floras and faunas and in having many factors that promote ecological departures from the "norm", i.e. disjunct or limited habitats, varied biotic sources, and so on.

Having established the credentials of the Southwest in terms of richness and importance of its floras and faunas, let us turn to the question of how riparian ecosystems may be important in perpetuation of these features. In terms of any one group for which such riparian ecosystems must be regarded as essential, certainly no question exists that the most important would be fishes. I have already mentioned that Arizona hosts--or hosted--32 native species and New Mexico 59. Together these total 75 species when combined, no fewer than 6 of which are federally endangered, i.e. Colorado River squawfish (Ptychocheilus lucius), humpback chub (Gila cypha), woundfin (Plagopterus argentissimus), Gila trout (Salmo gilae), Gila topminnow (Poeciliopsis occidentalis), and Pecos gambusia (Gambusia nobilis), plus one species that is threatened, the Apache trout (S. apache). In addition, the New Mexico Department of Game and Fish lists 30 species of native fishes as endangered in the state, including the squawfish, Gila trout, topminnow, and gambusia mentioned above. On a percentage basis, about half of New Mexico's ichthyofauna is regarded as endangered at the state level, whereas 8 percent of the overall southwestern fauna is federally endangered.

It is obvious that riparian ecosystems are of paramount importance in the survival of native fishes in the Southwest, where the vast majority of the species are riparian (versus lacustrine) in their habitat occupancy. The major threat to the survival of these fishes involves degradation of the required habitats, including lowering of the water table, construction of dams, diversions, and reservoirs, vegetation clearing, pollution, roads, grazing, and the introduction of exotics. This degradation will no doubt continue, for it is partly an outgrowth of man's quest for water and the environments that it fosters. There is little that the dependent biota can do to stem this quest, and man continues to take the aqueous spoils and leave the biota high and dry. Obviously, this approach cannot continue if the ichthyological portion of the rich and important biota of the Southwest is to persist.

Next to fishes, there is no single large group of southwestern vertebrates so dependent for survival on water, that essential and basic element of riparian ecosystems. Yet, there are aquatic plants and invertebrate animals that are just as dependent, including invertebrates. Among the latter are certain mollusks and arthropods, such as Exosphaeroma thermophilum--an endemic crustacean confined to a warm spring run near Socorro, New Mexico. Some animal and plant species are seasonally dependent of riparian ecosystems, such as many amphibians which breed in water. The exact numbers of nonfish species dependent on aquatic habitats in the area has not been determined, but it is significant.

So far, the emphasis on the importance of riparian ecosystems to the biota of the Southwest has concentrated mainly on the question of surface water, as in the cases of fishes and of certain other animals and plants. However, there are other riparian features involved that should also be mentioned, and among the most important is the vegetation characteristic of these ecosystems. A great variety of plants utilize stream courses in the Southwest, including both obligate and facultative species. Typical of the obligates are cottonwoods (Populus spp.), willows (Salix spp.), alders (Alnus spp.), and other broadleaf trees. Facultative species are those that invade stream courses from other habitats, but which may survive without riparian systems. Over 100 kinds of woody plants occur regularly in floodplains in New Mexico, of which about 40% are obligates (Hubbard, ms.).

Riparian plants are biologically important from a number of standpoints. One aspect of their importance is an individual species, for some are restricted in range, numbers, or both. For such species, degradation of the riparian ecosystem could be especially detrimental, even critical to survival. Conversely, for some such species the continued availability of acceptable riparian ecosystems is essential if survival is to continue. Another aspect of importance is at the level of plant assemblages, such as vegetational communities. The matter of communities is especially important, for a great deal of diversity exists among riparian communities in the Southwest (Hubbard, ms.) and this deserves perpetuation. In addition, the assemblage concept is important from the standpoint of revealing evolutionary, ecological, and other biological information, such as any divergence among fragmented populations. There is even a historic (or prehistoric) consideration, in that we may view the broadleaf assemblages of trees and shrubs along many southwestern streams as the major remnant of the ancient Arctotertiary Flora that was dominant in North America 50 to 100 million years ago.

Besides assemblages of plants, aggregations of considerable biological importance are those involving animals as well. Perhaps the aggregation that has attracted most attention recently involves riparian vegetational communities and their attendant birdlife. Although virtually unstudied until recent decades, this biotic aspect of the Southwest has now become better known, and studies have included such streams as the Verde (e.g. Carothers and Johnson, 1973) and Colorado (Ohmart, mss.) in Arizona and the San Juan (White and Behle, 1961; Schmitt, 1976) and Gila (Hubbard, 1971) in New Mexico. All of these systems are extremely rich in breeding birds; for example these two New Mexico river valleys support 16-17% of the entire breeding avifauna of temperate North America over the course of only a few score of miles.

The requirements of these avifaunas involve both the aquatic and the vegetational aspects of riparian ecosystems, but the greater, direct dependence is on the plant communities. Actually, on both the San Juan and the Gila, aquatic habitats other than the river per se are limited, and thus few aquatic species are present. Considering both aquatic and vegetational aspects together as constituting together riparian habitats, one finds that in the Gila Valley some 25.0% of the 112 breeding bird species are restricted to them, while 24.1% occur in them primarily (Hubbard, 1971). Neither group of bird species, totalling 49.1% of the breeding avifauna, would probably occur in the area in the absence of these riparian habitats. The figures for the 105 breeding species in the San Juan Valley are similar, i.e. 26.5% and 19.4%, or a combined total of 45.9% showing riparian dependence (Schmitt, 1976). In addition, 22.3% of the Gila species and 28.6% of the San Juan species also show some to much utilization of riparian habitats, and several species achieve maximal numbers in them. Clearly, in these two areas the presence of riparian habitats is extremely important, and in essence they double the avian diversity that might otherwise be present. The same degree of importance no doubt pertains elsewhere in the Southwest, and is apparent that riparián ecosystems play a key role in maximizing avian diversity in the region.

Other riparian faunal-plant assemblages seem to have been little studied, but there is no doubt that others will show a strong relationship between biotic diversity and the presence of riparian ecosystems. For example, although there appear to be fewer southwestern mammals than birds with a strong riparian dependence, nonetheless there are certainly some species that do show this, e.g. water shrew (Sorex palustris), Arizona gray squirrel (Sciurus arizonensis), beaver (Castor canadensis), meadow vole (Microtus pennsylvanicus), muskrat (Ondatra zibethica), raccoon (Procyon lotor), mink (Mustela vison), and otter (Lontra canadensis). The same can be said of reptiles, such as various turtles (e.g. Kinosternon spp., Trionyx spp.), green snakes (Opheodrys spp.), water snake (Natrix erythrogaster), and garter snakes (Thamnophis spp.). On the other hand, amphibians show a pronounced dependence on riparian--or at least aquatic--ecosystems, because of the general need of water for reproduction, e.g. in various toads and frogs.

At this point, I believe that it has become readily apparent that riparian ecosystems are of paramount importance in producing and maintaining a large degree of the biotic diversity of the southwestern United States. Although this importance is perhaps most apparent in fishes and best quantified in birds, it is clear that, for many plants and animals, riparian ecosystems are critical for them to flourish or evén survive in the region. I am hopeful that more studies will be done to quantify this importance, particularly with reference to the degrees of dependency that exist among biotic elements on these ecosystems and to the niches that are occupied. It goes without saying that the better we understand these aspects, the better we can anticipate the needs of the biota and manage for its preservation. We have already witnessed extremely widespread destruction and modification of riparian ecosystems in the Southwest, mainly as the result of man's activities over the last several decades. As population pressures and the demands on the riparian ecosystem grow, we will be hard-pressed to preserve what is left of the southwestern riparian biota. Yet, if we do not meet the challenge and achieve better preservation, we will have allowed one of the richest of all of the world's temperate floras and faunas to have been diminished.

The time to obtain data and take positive management steps is all too short, but at the same time it is not too late to act. For example, several important examples of riparian ecosystems remain in the Southwest, such as in the lower San Francisco Valley in southwestern New Mexico and southeastern Arizona. This particular tract lies in U.S. National Forest, and with more enlightened management it could provide along over 30 river miles of public land for the maintenance of the very rich lowland riparian biota. At the present time, grazing and off-road vehicles are causing much damage to the tract, which embodies everything about a wilderness or wild river except in terms of management. At higher elevations, more extensive riparian ecosystems lie on public land and are available for preservation, although management again is frequently not accomplishing this.

The sad fact is that even public lands have priorities upon them that are not in the best interest of preserving riparian ecosystems, and changing this outlook for even limited areas is often difficult. On private lands the situation is generally worse, although here and there some degree of preservation has been obtained for some tracts. There is a critical need for a better education of managers of both public and private lands supporting riparian ecosystems as to their importance and values, which range from esoteric to the practical. For example, points of practical importance and value include the role of vegetation in soil retention, effect on climate, and in the harboring species that provide both consumptive and non-comsumptive recreation. These practical uses combine with esoteric considerations to provide a telling argument in favor of better preservation of our native riparian ecosystems, fragmented and misused as they have become. Hopefully, individuals and agencies will soon join forces to ensure such preservation, which is long overdue and which cannot be delayed much longer.

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Importance of Riparian Ecosystems: Economic Considerations[1]

Kel Fox[2/]

Efforts to preserve riparian habitat must recognize man's growing demands to put this area to other uses. Economic pressures, at conflict with environmental concerns, pose an inevitable threat to vegetation and wildlife. A compromise in the balance of preservation and development must be maintained.

Everyone here today feels the riparian zone is important, or we would not be holding this symposium. Most of you want to preserve it. A few of you will admit, grudgingly, that it needs to be managed. We all can agree that huge areas of riparian habitat have been removed by development-oriented pressures. But few will admit, in this age of environmental concern, that the same economic realities of past decades still pose a threat to much of the remaining habitat. These threats are direct, as, for example, through conversion to farming or residential use, or indirect, as through lowered groundwater levels due to pumping.

These are the general conclusions reached by the staff of the Arizona Water Commission, who helped in the preparation of this paper. Now let's examine them in detail.

When the white man first came to this country, the low deserts were broken by oases along the major rivers. To farm he had to irrigate and the bottom lands were the closest to water. Mesquite bosques and cottonwood thickets were cleared and put into production. Southern Arizona hasn't been the same since, but that's not necessarily bad. The major metropolitan areas, wouldn't be here but for the pioneering efforts of those early farmers.

Clearing the riparian[3/] zone for agriculture is not a historic phenomenon; it still goes on. The bulk of the clearing is of phreatophytes, and most of that is along the Colorado River, below Davis Dam on Indian lands. The Indian reservations along the river in Arizona and California have decreed rights that allow the consumption of 546,000 acre-feet primarily for irrigation. In 1961 there were 80,000 acres of prime arable land on these reservations that were covered with phreatophytes. Clearing will no doubt continue as the tribes develop lands to use their water.

If Senator Kennedy has his way with the Indian water rights bill, 250,000 acres of land on the Gila River Indian Reservation will be irrigated. It is a safe bet that some of the new development will be on areas now in phreatophytes.

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[3/] In this paper, riparian is used in reference to vegetation which occurs in or adjacent to drainage ways or their floodplains which may be perennial or ephemeral. Phreatophytes are those riparian plants which habitually obtain their water supply either directly or through capillary fringe, from the zone of saturation.

There are concentrations of private land along all of the desert rivers. Much of this land is suitable for agriculture and is subject to clearing.

Farther up the watershed, the higher elevation riparian zone tends to be immune from these pressures. Much of it is locked up in federal administration. It probably will remain unchanged. That small fraction that is in private hands is often too rough, too stony or otherwise unsuited for agriculture. But that doesn't mean it's safe from development pressures.

It's prime country for subdivisions. Pick up a map of a National Forest in Arizona. Those white spots along the major headwater streams are private land, turn-of-the-century homesteads. When the ranchers retire, those places will be up for sale. In a land where small lots in the pines sell for thousands of dollars to greenery-starved desert dwellers, lots in and along a creek bottom, with real running water, are pure gold. And cost as much. Pave the road to the homestead and it's good-by habitat, hello homesite.

Most of the headwater streams are protected from this pressure by ownership and topography. The mid-elevation streams, however, are as a rule, totally exposed. Privately owned bottom lands along Oak Creek, Tonto Creek, the Verde River and the upper San Pedro are now actively being offered for sale and converted into retirement homes.

And what phreatophytes the farmers didn't clear along the Colorado River are subject to clearing or encroachment by the subdivisions sprouting up there for winter visitors.

Water yield improvement projects have taken most of the blame for removal of riparian habitat. However, if you were to analyze the areas cleared, you would find that the large majority of the clearing was a result of direct development pressures; it was the land that was needed for other purposes, rather than the water. Clearing and/or conversion for downstream water yields was much in vogue in the 50's and 60's, however.

The Los Angeles report of the Phreatophyte Subcommittee of the Pacific Southwest Inter-Agency Committee of August 1969 listed nearly two dozen major clearing projects in Arizona. A multitude of benefits were listed, but the common thread was water. The biggest of these was the 42,000 acre project of the Bureau of Reclamation along the Colorado River from Davis Dam to the Mexican boundry.

The project was designed to salvage water to enhance the supply available to the C.A.P. The Bureau surveyed the floodplain in this reach of the river in 1961, identifying 155,000 acres of phreatophytes. Environmental concerns have stalled the project, as it has most of the others, and it is not now being actively pursued. That doesn't mean that clearing of the floodplain won't be accomplished however. Of the nearly 65 percent of surveyed habitat, 98,000 acres, was on private, state, or Indian lands. About half of the proposed clearing program, 20,000 acres was on nonarable Indian lands. All of this is subject to clearing for irrigation or homesites. Only 6,000 acres were in wildlife refuges.

The term "water salvage" has fallen from repute in describing the benefits of these projects, but the intent remains; to make more water available for man's direct use. The U.S. Geological Survey, in a study reported in the Proceedings of the 1968 Arizona Watershed Symposium, estimated annual evapotranspiration of all phreatophytes in Arizona to be about 940,000 acre-feet annually. The monumental study of Ffolliott and Thorud in 1974 indicates that water yield in the riparian habitat in Arizona might be increased as much as 600,000 acre-feet per annum by clearing and conversion. The Comprehensive Framework Study for the Lower Colorado Region estimated 435,000 acre-feet could be salvaged each year under a feasible management program from the phreatophyte habitat. No matter whose estimate you use--it's a great deal of water, a potential increase from 15 to 35 percent of the state's dependable supplies.

Increasing the dependable supplies will become more important as energy costs for pumping and groundwater levels increase. Changes in groundwater law, mandated during this session of the legislature, will no doubt be aimed at reducing groundwater overdraft. This will reduce local supplies still further, which will intensify the demand for increased dependable supplies from other sources. Under these sorts of pressures, environmental considerations will have less importance.

Flood control, or more properly, flood damage reduction, will become more important with time as development increases in or near riparian areas.

Salt cedar, with its prolific growth, will rapidly take over a bare, well watered site. Frequently, that's in the main stem of the channel, and as the stand develops, the channel's conveyance is reduced. Not that high flows, or flood waters, won't get downstream, they do, but at the expense of increased depth of flow and consequent enlargement of the inundated area.

The flows will eventually sweep out the choking vegetation but only after building up to sufficient head and unnecessary levels of damage. Clearing or maintaining a channel thus duplicates Mother Nature's handiwork, and avoids the incremental flood damage.

About a third of those two dozen clearing projects mentioned earlier claimed flood control as one of the project's benefits. The clearing of cottonwoods in the Verde Valley some years back was designed to aid in flood hazard reduction. The phenominal growth of bottom land subdivisions in that Valley may well work to reinstitute such a program.

Environmental pressures have so far worked to set aside the Corps of Engineer clearing projects on the Gila River downstream of Phoenix. Sportsmen and hunter groups joined in that cause, and as a result of their efforts to save dove nesting and roosting cover, they have been denied hunting access to the privately owned portions of the bird's habitat. As more and more hunting areas are denied them, sportsmen may well choose to side with the Corps to work out a compromise solution.

Conservationists are getting more sophisticated with time. They had to, as increasingly they've lost habitat to esoteric causes. Mesquite bosques and salt cedar thickets have died from unseen causes throughout Southern Arizona. Not fire, flood, or pestilence. Not from developers or bulldozers or other direct threats. Still the habitat died.

The cause--a decline in water levels in response to pumpage under developed areas miles distant. Groundwater basins in southern Arizona underlie the valleys from mountain to mountain. The aquifers are quite productive, but recharge is low. This means the cones of influence from a pumping well, or more commonly, hundreds of pumping wells, spread wide, reaching seemingly protected riparian habitat.

The famed San Xavier bosque south of Tucson so died, as have large areas in the thickets along the lower Santa Cruz on the Gila Indian Reservation. It's not done yet, either.

The riparian habitat of the upper San Pedro, site of the proposed Charleston Dam, so successfully opposed by conservationists, is threatened nonetheless. The expansion of Fort Huachuca's mission has brought a subdivision boom to the area. Water level declines are accelerating, the cone of depression rapidly expanding toward the San Pedro.

As I said, conservationists have become more sophisticated, but they've yet to really embrace technology in their fights. The impact of the Fort's expansion in the riparian areas was predicted by our Water Commission in a computer model study of the Fort's groundwater supplies. No one used the information in assessing the proposed expansion. Not that it would have necessarily helped. The move had strong local support. But at least all impacts would have been discussed.

If the march of progress can't be averted, perhaps technology can be used to facilitate the necessary compromises. Recently the Maricopa County Flood Control District acquired a small tract of privately owned riparian habitat along the lower Salt River for mandated mitigation of the impacts of the county flood control program. Will that parcel eventually dry up and die as groundwater withdrawals continue in the Valley? No one knows--the eventuality wasn't even considered. The Arizona Game and Fish Department intends similar purchases in the area. Should they utilize existing computer models to select tracts? Most assuredly, if they wish to preserve the habitat.

Recreation ranks right next to mom and apple pie as typifying the American. No where else is the pressure on the riparian habitat, and the wildlife it supports, more aptly described by the character from Pogo: "We have met the enemy, and he is us." The physical presence of people is the problem.

Those that sought to protect the eagles at the Orme Dam site enlisted the aid of the river's tubers in the fight. But the tubers themselves are a threat to the eagles, and no doubt one day these bedfellows will part.

The riparian zone is especially attractive to recreationists in this water short land. Demand for this type of recreation exceeds the supply, causing continual pressure on the developed sites, and insuring the certainty of loss of more habitat.

So what does the future hold for riparian habitat when faced with the economic realities of life? Without a doubt, more of the habitat will be lost--there are too many pressures for it to be entirely preserved. Most of the loss will be on private and Indian lands. Here the pressures are felt most keenly, and the management goal is not preservation. Federal lands will probably be preserved to a large extent, although demands for flood control, grazing and recreation will require some concessions.

Society will come to realize that our standard of living cannot be maintained without utilization of all of our resources--today's topic of concern is no exception. Our current preoccupation with wildlands is a luxury we can afford only because the wilderness was subjugated. We must strike a balance today, if only because society did not do so in the past.

Vegetation Structure and Bird Use in the Lower Colorado River Valley[1]

Bertin W. Anderson and Robert D. Ohmart[2]/

Abstract.--Data from riparian communities along the lower Colorado River are used in discussing relationships between the avifauna and the structure of plant communities. Correlations between bird population parameters and vegetation structural characteristics were found to vary seasonally. The mean habitat breadth of all species is narrowest with respect to vegetative structure in winter and broadest in summer; permanent residents occupy the structural types more evenly than visitors. The habitat breadth of various species is greater in summer than winter. Narrower habitat breadths are accompanied by reduced habitat overlap among the species in winter, suggesting that winter is potentially the time of greatest stress. Permanent residents tend to be less specialized with respect to structure than visitors. These facts suggest that since winter requirements are different from but equally as important as breeding requirements, they should receive at least equal attention. The requirements of wintering visitors should receive special attention because they showed a higher degree of habitat specialization than permanent residents.

Since MacArthur and MacArthur (1961) first reported the relationship between breeding bird species diversity (BSD) and foliage height diversity (FHD) much research effort has been expended and quantitative data gathered in an effort to explain relationships between various bird population parameters, such as BSD, and various features in the landscape (e.g. Balda 1969, Cody 1968, Karr 1968, Karr and Roth 1971, Willson 1974). Although of great heuristic value to the theoretician and manager alike, the approach, as Balda (1975) stated, is too impersonal; that is, it does not consider the biology of individual species. This problem has been successfully attacked in part by analyzing the vegetation in the vicinity of singing males during the breeding season (Anderson and Shugart 1974, Conner and Adkisson 1977, James 1971, Whitmore 1975 a, b). These investigators have successfully applied multivariate analyses to the problem of habitat selection. Such analyses have an advantage of reducing problems associated with data interpretation, although multivariate axes are often difficult to precisely verbalize (Shugart et al. 1975). While studies of the vegetation around individual singing males undoubtedly provide valuable information concerning the characteristics of the breeding environment, it is only a small step toward understanding species' habitat requirements and there are definite problems associated with the technique. Anderson (1974) found that sub-adult male grosbeaks (Pheucticus ludovicianus and P. melanocephalus) tended to establish territories in suboptimal portions of the habitat. Furthermore, several of these sub-adults failed to acquire mates although they sang almost constantly. The suboptimal portions of the habitat often included parks and roadsides, and therefore, these birds were much more easily found and observed than the adult males which tended to inhabit denser thickets. Inclusion of these males in greater proportion than their occurrence in the population could result in misleading conclusions concerning their breeding habitat requirements. Misleading conclusions could also be reached in spatially restricted studies for many other species, especially polygynous species such as the Long-billed Marsh Wren (Cistothorus platensis)

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(Verner and Engelsen 1970), Yellow-headed Blackbird (Xanthocephalus xanthocephalus) (Willson 1966), Red-winged Blackbird (Agelaius phoeniceus) (Holm 1973, Linsdale 1938), and Dickcissel (Spiza americana) (Harmeson 1974, Martin 1971, Zimmerman 1966). In the southwest desert there is an additional problem--several species breed in a number of vegetative types over a relatively long period of time (four or five months). Obviously, analysis should include males proportionate to their occurrence in all vegetative types throughout the breeding season. Breaking the analysis into several spatial and temporal components perhaps would be most appropriate.

Seasons other than the breeding period have received little attention even though they may be equally or more important than the breeding season. Fretwell (1972) provided cogent arguments to the effect that quality of the wintering habitat is critically important to survival of the breeding population and that populations will decrease despite abundant high quality breeding habitat when wintering habitat is poor. Shugart et al. (1975) presented two discriminant functions for seven species from data gathered in fall and winter, but such studies are rare.

Another factor which may affect the way a habitat is utilized by a species, but which is often neglected, is population size. Population sizes, in turn, are affected by a number of biotic and climatic factors. Some measure of the population size should be related to statements concerning species' requirements. All of these factors can best be studied and understood by censusing large areas several times a year for a period of years. Unfortunately, such studies require a relatively large staff and are, therefore, costly; but if quality data are the result, such studies may prove to be the most efficient and inexpensive in the long run.

In this report we evaluate the importance of vegetative structure at the habitat level to birds in the valley of the Colorado River from Davis Dam to the Mexican boundary, about 443 km. The relationship of entire avian communities, guilds, and individual species to structure of the vegetation will be discussed on a seasonal basis. The importance of season (especially winter), climate, and population sizes will be presented. Although our data are suited for multivariate analyses, we are not prepared to present the results of such analyses as they relate solely to structure at this time. Such analyses are underway and preliminary results are consistent with our comments here.

In defining habitat we concur with Whittaker et al. (1973) that terms such as niche and habitat should be stabilized, and we follow their recommendation in considering the niche as an intracommunity variable and the habitat as a broader concept usually encompassing more than one community. Communities, in this report, refer to fairly homogeneous areas with respect to dominant vegetation and structure and range in size from 10 to 40 ha. Niche requirements, as opposed to habitat requirements, are not presented here because of space limitations. Similarly, data concerning dietary preference and feeding behavior must be omitted from this report but will be available at a later date.

CORRELATIONS

The relationships between bird population parameters and the various vegetative parameters were examined with regard to the spatial and temporal dimensions of the environment. Further, the diversity measures are of all birds and not just breeding birds and are used to discuss the value of vegetative structure in evaluating the wildlife use values of an area. Each year was divided into five seasons: winter included December, January and February; spring included March and April; summer included May, June and July; late summer included August and September; and fall included October and November.

Our study area encompasses about 4,828 km^2 between Davis Dam, located on the Nevada-Arizona border, and the Mexican boundary south of Yuma, Arizona. The riparian vegetation was divided into six community types based on the dominant plant species and into six structural types based on the vertical profile of each community. Methodology employed for determining structure and for censusing birds is discussed elsewhere in these proceedings (Anderson, Engel-Wilson, Wells and Ohmart).

Vegetation Parameters

Since the data did not fit a normal curve, correlations were determined using the nonparametric Kendall rank correlation (Sokal and Rohlf 1969). Correlations between structural variables are significant and positive in four cases and significant and negative in one instance out of ten comparisons (Table 1).

Bird Density and Vegetation Structural Parameters

Bird density in winter correlated with vegetation at the 1.5 to 3.0 m level (Table 2).

Table 1.--Correlations between vegetative structural characteristics in the riparian vegetation along the lower Colorado River Valley.

	Height			Total Relative Density	FHD
	0-0.6 m	1.5-3.0 m	>4.5 m		
0-0.6 m	-	-0.076	-0.42**	0.02	-0.12
1.5-2.0 m	-	-	0.49**	0.67**	0.11
>4.5 m	-	-	-	0.54**	0.35*
Total	-	-	-	-	0.02
FHD	-	-	-	-	-

* and ** significant at p<0.05 and <0.005 respectively.

Table 2.--Correlations between bird population parameters and vegetation parameters at five seasons in the lower Colorado River Valley.

Relative Density of Vegetation at	Season: Dec 1974 Jan 1975 Feb	March April	May June July	Aug Sep	Oct Nov
BIRD DENSITY					
0.6 m	-0.02	-0.25	-0.36*	-0.22	0.18
1.5-3.0 m	0.10	0.05	0.42*	0.31	0.04
>4.5 m	-0.16	0.14	0.52*	0.18	0.12
Total	0.16	0.04	0.39*	0.26	0.03
FHD	0.04	0.13	0.02	-0.18	0.19
BSD					
0.6 m	-0.40*	-0.23	0.48*	0.01	-0.10
1.5-3.0 m	-0.10	-0.39*	-0.18	0.51**	0.25
>4.5 m	-0.14	-0.13	-0.12	-0.59**	0.43*
Total	-0.19	-0.32*	-0.04	-0.74**	0.16
FHD	0.29*	0.11	0.09	0.03	0.63**
BSD WITH 10% DOVES					
0.6 m	-0.16	-0.21	0.17	-0.02	-0.01
1.5-3.0 m	-0.02	-0.25	0.03	-0.35*	0.14
>4.5 m	0.23	0.15	0.11	-0.52*	0.23
Total	-0.07	-0.18	-0.04	-0.35*	0.09
FHD	0.38*	0.09	0.43*	-0.25	0.45**
SPECIES					
0.6 m	-0.32*	-0.30*	-0.24	0.04	-0.12
1.5-3.0 m	-0.37*	-0.34*	0.20	-0.14	-0.02
>4.5 m	0.00	-0.17	0.17	-0.28	0.22
Total	-0.44**	-0.35*	0.22	-0.20	-0.07
FHD	0.32*	0.09	0.31*	-0.13	0.58**

* and ** significant at p<0.05 and <0.005 respectively.

This is at least partly because honey mesquite stands with volume at this level are correlated with mistletoe. The presence of mistletoe adds another dimension to the habitat and supports several species which are nearly absent elsewhere. In spring, bird densities were relatively high in several structural types, thus density was not correlated with any structural parameter. Spring is a period of transition--winter residents are still present and summer residents are returning. In the summer, after winter residents have departed, the greatest numbers of birds were found in areas with the greatest total vegetation. Late summer is another transition period; many summer residents depart and wintering species arrive. In fall the greatest numbers of birds were found in relatively open areas (low total density of vegetation) as well as in areas with volume at the intermediate levels. Explanations of this are too numerous and conjectural to present here.

BSD and Vegetation Structure

In winter there was a significant negative correlation between volume of 0 to 0.6 m and BSD (Table 2). Areas with greatest vegetative volume at the lower levels tended to be dominated numerically by White-crowned Sparrows (Zonotrichia leucophrys). There was a positive correlation in winter with FHD. In the spring BSD was significantly negatively correlated with the densest areas with relatively dense vegetation at 1.5 to 3.0 m. In the summer BSD was significantly correlated with density of vegetation in the lower layer (0 to 0.6 m). Doves in summer in the more lush areas have such overwhelming numerical dominance that BSD in such areas is suppressed. In fall, after many doves had migrated, BSD and FHD were positively correlated. Removing 90 percent of the doves from the data revealed a correlation between FHD and BSD in winter, summer, and fall but not in spring or late summer. The number of species is correlated with FHD in winter, summer, and fall. Number of species and BSD are correlated with each other at all seasons (Anderson and Ohmart, unpubl. data).

Comparison of Years

Correlations between the bird parameters and structural features were nearly the same each year (Table 3). The greatest deviation was found in summer 1976 when total bird density was significantly correlated with FHD, contrary to findings in 1975. This may have occurred because doves, which are most numerous in areas of low or moderate structural diversity, were at least 40 percent fewer in numbers in most areas in 1976.

In summary, it would appear that dense vegetation is more important to birds in the early summer than at other times of the year. This is generally true, but the presence of up to 1500 doves per 40 ha tends to exaggerate the importance of dense vegetation. Similarly, because of large numbers of White-crowned Sparrows and Phainopeplas (Phainopepla nitens), the reaction of many species to sparse vegetation is obscured in the winter. White-crowned Sparrows are primarily granivorous and are found in relatively open areas, whereas Phainopeplas are found wherever there is mistletoe, which is most abundant in areas of moderate density.

BSD was not correlated with FHD in summer, but this is misleading for the excess of doves in summer masks the real diversity of birds found in areas where doves predominate. This relationship is revealed by using only 10 percent of the doves in calculating BSD or by simply considering the number of species involved. By using either of the above alternatives, the data suggest a correlation in summer between BSD and FHD.

The correlation between BSD and FHD in this study does not provide as good a fit to a regression line as in a number of other studies, thus indicating that along the lower Colorado River only a relatively small part of the observed diversity is due to structural complexity. That it is significant in three of five seasons, however, suggests that structural complexity does have important management implications. Obviously, BSD must be evaluated within the context of other population parameters, such as the number of species and the density of vegetation.

HABITAT BREADTH BY STRUCTURE OF VEGETATION

The extent to which each species occupies the various structural types of vegetation is referred to here as a species' habitat breadth by structure (HB_s). This is calculated by $HB_s = -\Sigma p_i \log_e p_i$ where p_i is the proportion of individuals found in the ith structural type. This parameter is independent of the distribution in which we designate habitat breadth for vegetative type (HB_v). For example, a species equally abundant in all six structural types in cottonwood-willow communities would have the same HB_s as one found in equal numbers in all dominant vegetation of all structural types. The former would, of course, have HB_v of 0.0 while HB_v of the latter would be $\log_n$ of 6 or 1.8 (based on six dominant community types in riparian vegetation). HB_s and HB_v are calculated for each species and the means for all species occurring at densities of at least 1/40 ha each month and for each season are calculated.

Mean HB_s

Mean HB_s for each season (fig. 1) reveals four things of potential ecological importance as related to seasons. First, high summertime values in mean HB_s are followed by a lower mean in the cooler time of year. Second, the smallest mean HB_s occurred in the winter of 1974-75. Third, visiting species tend to have lower mean HB_s than permanent residents.

Table 3.--Correlations between bird population parameters and structural features in summer 1975 and 1976 along the lower Colorado River Valley.

	Height			Total Relative Density	FHD
	0-0.6 m	1.5-3.0 m	>4.5 m		
DENSITY					
1975	-0.36*	0.42**	0.52**	0.39**	0.02
1976	-0.55**	0.44**	0.67**	0.47**	0.36**
BSD					
1975	0.48**	-0.18	-0.12	-0.04	0.09
1976	0.49**	-0.22	-0.39*	-0.15	-0.15
BSD WITH 10% DOVES					
1975	0.17	0.03	0.11	-0.04	0.43**
1976	0.04	0.09	0.31	0.17	0.34*
SPECIES					
1975	0.24	0.20	0.17	0.22	0.31*
1976	0.15	0.20	0.28*	0.24	0.24

* and ** significant at p<0.05 and <0.005 respectively.

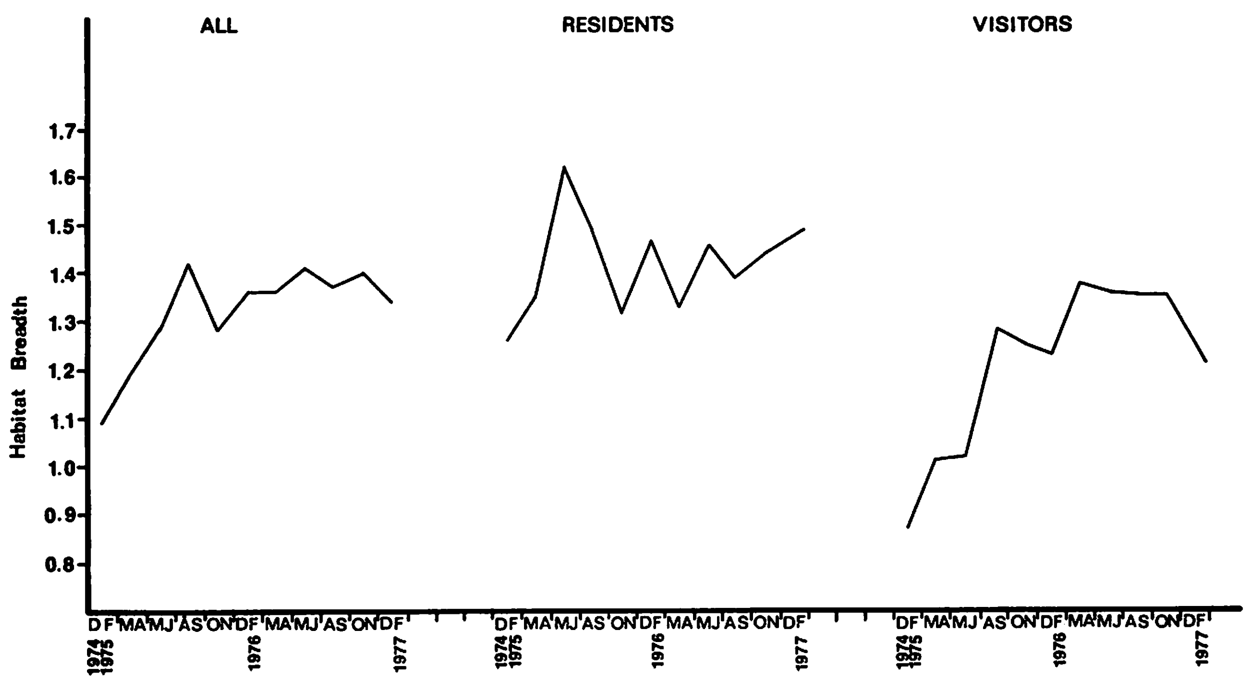

Figure 1.--Seasonal changes in mean habitat breadth for all species at various seasons along the lower Colorado River.

Finally, HB_s was not reduced in fall 1976; in fact, it increased for permanent residents.

The relatively low mean in cooler seasons coincides with the time of year when productivity is lowest. As insects decline in number, they probably become more restricted in their distribution (Raitt and Pimm 1976); this disjunct distribution is probably mirrored by the restricted distribution of insectivorous birds which tended to have narrower HB_s. Similarly, the patchy distribution of seeds in the sparser areas is reflected by the relatively narrow HB_s of wintering seed eating birds.

The low HB_s in winter 1974-75 appears to be accounted for in that the winter was significantly colder with more days of frost and was windier than subsequent winters (Anderson and Ohmart, MS3/). We predict that habitat breadth will increase in a given season only if resources become so abundant that consumption is limited more by the birds' ability to harvest than by competition during the season or if regulation during that season is by predation (Anderson and Ohmart, MS3/). Insects were probably less abundant (Raitt and Pimm 1976) and this, in addition to the fact that the colder windier conditions required more energy per day per bird, appears to have restricted HB_s during that period. The subsequent winter was milder than average and mean HB_s was correspondingly higher. Visitors tend to have narrower mean HB_s than do permanent residents, indicating that they are more sensitive to features of the vegetation structure on the average than permanent residents (see below).

Unusually heavy rainfall in September followed by above average fall temperatures may have resulted in greater insect productivity than normal and allowed expanded HB_s in the fall of 1976.

In summary, these data indicate that the use of structure is not static. Not only is there variation in mean HB_s from species to species, but from season to season and year to year, reflecting seasonal and annual differences in climate and other factors. In addition, permanent residents and visitors adapt to vegetation structure in different ways. HB_s and HB_v and their ecological significance are discussed at greater length, especially with respect to the theory of competition in Anderson and Ohmart (MS3/).

FORAGING GUILDS AND VEGETATION STRUCTURE

The Flycatcher Guild

In summer the Ash-throated Flycatcher (Myiarchus cinerascens) was the numerically dominant flycatching species in all structural types and was fairly evenly distributed with somewhat greater density in structural type II (Table 4). The Western Kingbird (Tyrannus verticalis) was found most frequently in type II. The Wied Crested Flycatcher (Myiarchus tyrannulus) was most numerous in type I. The mean HB_s for this group in the summer was 1.435.

In winter the Say Phoebe (Sayornis saya) was the only flycatcher occurring in densities of at least 0.5 per 40 ha. Its HB_s was 1.363 which is 5.7 percent smaller than the summer average for the group.

Medium-sized Insectivores

In summer a group of six medium-sized insectivores were present at densities of at least 0.5 per ha. Among them, the Blue Grosbeak (Guiraca caerulea), Cactus Wren (Campylorhynchus brunneicapillus), and Northern Oriole (Icterus galbula) had relatively large HB_s (Table 4). The Yellow-breasted Chat (Icteria virens) was intermediate and the Summer Tanager (Piranga rubra) and Yellow-billed Cuckoo (Coccyzus americanus) were specialists, being found most extensively in structural type I. The average HB_s for the group was 1.413.

The Cactus Wren is the only member of this group present in winter. Its winter HB_s, 1.695, is larger than the average for the group in summer but is about 5 percent smaller than its own summer HB_s.

Ground Feeders

In the summer the ground feeders included three permanent resident species (Table 4). All were rather evenly distributed throughout the structural types of vegetation (Table 4). The average HB_s was 1.650.

In winter the three ground feeders were somewhat less general in their distribution (Table 4). The Abert Towhee (Pipilo aberti) was found most frequently in structural type I. The average HB_s was about 5 percent smaller than in summer.

Small Insectivores

In the summer there were three insectivorous species weighing less than 15 g (Table 4). All three (two were permanent residents, one visitor) were widely distributed among the structural types (Table 4) as reflected by their mean HB_s of 1.694. The Lucy Warbler (Vermivora luciae) was numerically dominant in types I and II. The Verdin (Auriparus flaviceps) was numerically dominant in all the other types. In winter the number of small insectivores increased to five. Among them the Yellow-rumped Warbler (Dendroica coronata),

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3/ Manuscript in preparation discussing seasonal changes in habitat breadth and overlap among birds along the lower Colorado River.

Table 4.--Densities (N/40 ha) of various birds by vegetation structure for winter 1975-76 and summer 1976.

Species Groups	Structure Type I	II	III	IV	V	VI	HB_s	J
Flycatchers								
Winter								
Say Phoebe	1.00	2.67	3.00	0.60	-	0.50	1.37	0.765
Summer								
Ash-throated Flycatcher	7.00	16.00	11.25	11.60	7.75	11.20	1.76	0.982
Wied Crested Flycatcher	4.00	1.33	1.25	0.20	-	-	1.05	0.586
Western Kingbird	0.50	4.50	1.80	0.80	0.50	1.50	1.50	0.837
Medium-sized Insectivores								
Winter								
Cactus Wren	1.00	0.33	1.00	0.80	0.33	0.50	1.70	0.949
Summer								
Northern Oriole	10.50	18.33	12.75	8.40	3.75	4.20	1.65	0.921
Summer Tanager	16.00	3.00	2.50	0.40	-	-	0.82	0.458
Blue Grosbeak	7.00	10.33	9.00	6.40	5.50	7.40	1.77	0.988
Cactus Wren	1.00	2.00	1.75	1.40	0.75	1.80	1.74	0.971
Yellow-billed Cuckoo	3.00	1.67	1.75	0.20	-	-	1.16	0.647
Yellow-breasted Chat	6.50	7.33	3.50	2.00	0.25	-	1.33	0.742
Ground Feeders								
Winter								
Abert Towhee	22.00	6.67	4.00	4.20	2.00	6.75	1.49	0.831
Crissal Thrasher	1.00	0.33	1.67	1.60	2.00	2.25	1.68	0.938
Gambel Quail	-	2.67	5.00	6.20	7.00	2.75	1.54	0.860
White-crowned Sparrow	-	-	0.67	18.00	10.33	14.00	1.14	0.636
Sage Sparrow	-	-	-	2.00	3.33	0.75	0.95	0.535
Summer								
Abert Towhee	14.50	29.33	50.00	15.80	11.50	11.40	1.69	0.943
Crissal Thrasher	-	4.33	5.00	4.20	4.25	2.20	1.24	0.691
Gambel Quail	0.50	20.00	10.25	15.40	21.00	18.00	1.61	0.898
Small Insectivores								
Winter								
Verdin	5.00	0.33	3.33	4.00	3.00	10.25	1.54	0.859
Black-tailed Gnatcatcher	1.00	1.00	4.67	6.81	5.67	8.00	1.58	0.882
Brown Creeper	4.00	5.00	1.00	0.40	-	1.00	1.27	0.882
Ruby-crowned Kinglet	69.00	17.67	15.00	9.00	5.67	9.75	1.38	0.770
Yellow-rumped Warbler	62.00	10.33	10.33	3.20	3.00	6.00	1.16	0.647
Bewick Wren	8.00	-	1.67	1.60	1.33	1.50	1.28	0.714
Summer								
Verdin	4.50	14.33	18.50	22.80	13.75	16.80	1.71	0.954
Lucy Warbler	21.50	26.67	14.00	14.40	10.25	5.20	1.68	0.938
Black-tailed Gnatcatcher	8.50	3.00	3.00	7.40	6.50	2.80	1.69	0.943
Woodpeckers								
Winter								
Ladder-backed Woodpecker	9.00	6.33	6.00	3.00	1.67	2.00	1.63	0.910
Common Flicker	5.00	5.00	3.33	1.60	1.33	0.75	1.60	0.893
Summer								
Gila Woodpecker	8.50	6.37	2.25	1.20	0.75	1.20	1.43	0.798
Ladder-backed Woodpecker	12.00	13.33	6.75	5.40	2.75	4.40	1.66	0.926
Common Flicker	2.00	3.00	1.25	0.20	-	-	1.14	0.639

Brown Creeper (Certhia familiaris) and Ruby-crowned Kinglet (Regulus calendula), all visitors, were the most specialized (Table 4). The Black-tailed Gnatcatcher (Polioptila melanura) and Verdin, both permanent residents, were the structural generalists. The mean HB_s of the group was 18 percent lower than in the summer (Table 4).

Woodpeckers

The Ladder-backed Woodpecker (Picoides scalaris) is the most generalized woodpecker both in winter and summer (Table 4). The Gila Woodpecker (Melanerpes uropygialis) is the most specialized in winter. The Flicker is intermediate for both seasons. The average HB_s for the group was the same in summer and winter (Table 4). No visitors occurred in either season.

SPECIES OVERLAP IN USE OF STRUCTURE

Because two species have similar HB_s does not necessarily mean that the overlap in habitat breadth by structure (R_o) is 100 percent. We quantified overlap between pairs of species using Horn's (1966) formula. The method is discussed more fully elsewhere in these proceedings (Anderson, Engel-Wilson, Wells, and Ohmart). The overlap in the five groups of ecologically similar species was greatest in the summer (Table 5). Mean overlap of all of these species was significantly smaller in winter than in summer.

The analysis of HB_s and habitat overlap by structure (R_{o_s}) points out several significant ecological considerations. One is that winter and summer visitors tend to be more specialized with respect to their use of vegetation structure as well as the dominant types of vegetation (Anderson and Ohmart, MS[3]/) than permanent residents. Both visitors and permanent residents tend to be more specialized in the use of vegetative structure in the cool times of the year--woodpeckers being the exception. This suggests that winter requirements may be different from summer requirements. Our findings corroborate Fretwell's (1972) prediction that winter residents in a given area will have larger populations and be more specialized than the local populations of permanent residents. In the Colorado River Valley winter residents do tend to have the largest populations (Anderson and Ohmart, MS[3]/) but are rather habitat specific. This indicates that if these rather restricted habitat types are destroyed, a relatively large breeding population from some more northerly area could be reduced or eliminated.

STRUCTURAL SPECIALISTS

Some species prefer certain structural characteristics within a particular community type; a few seem to be more specialized as to structure and less specialized with regard to the type of dominant vegetation. For this analysis we have used the number of each species in the structural types in each dominant vegetative type and calculated simple correlations between the bird numbers and particular structural characteristics. The species we attempted to find were those preferring, for example, dense vegetation at 3.0 m and not discriminating between different kinds of dominant vegetation. A structural specialist found only in type I cottonwood-willow would not qualify as an overall structural specialist but would be a specialist in two dimensions--structure and dominant vegetation.

Some Simple Cases

The Abert Towhee showed a slight, but not statistically significant, preference in summer for dense vegetation. In winter, however, the correlation is significant (Table 6). The towhee cannot be considered a structural specialist because it is also fairly common in relatively sparse vegetation, but it does seem to show a preference for dense vegetation and this correlation becomes stronger in winter.

The Summer Tanager shows a significant (Table 6) correlation with vegetation taller than 9 m. Although much of the vegetation above this height is cottonwood or willow, when salt cedar or other vegetation is available, the tanager uses it.

The Western Kingbird also shows a preference for tall vegetation (Table 6). Unlike the tanager which is restricted mainly to the denser area, the kingbird occurs in areas where there are only a few tall trees but reaches peak numbers in areas where tall trees are dense. The Ruby-crowned Kinglet, a winter visitor, reaches peak densities in the tallest vegetation (Table 6). It cannot be considered a structural specialist, however, because it also accepts other structural types including rather sparse vegetation completely lacking in tall trees.

The three woodpeckers (Ladder-backed, Gila, and Common Flicker) are all significantly correlated with foliage greater than 9 m (Table 6). The Ladder-backed Woodpecker, while showing a preference for areas with taller trees, was also quite common in some structural types totally lacking in tall trees. The other two, however, can be considered structural specialists.

Table 5.--Overlap in use of vegetation structure by various groups of species in summer and winter along the lower Colorado River.

	Overlap Matrices					Mean R_o	
						Summer	Winter
Flycatchers							
Summer	WK *	WF					
Ash-throated Flycatcher	0.963	0.757					
Western Kingbird	-	0.621					
Wied Crested Flycatcher	-	-				0.780	
Winter							
Say Phoebe							0.000
Medium-sized Insectivores							
Summer	ST	BG	CW	YBCu	YBCh		
Northern Oriole	0.744	0.974	0.968	0.899	0.939		
Summer Tanager	-	0.676	0.602	0.944	0.868		
Blue Grosbeak	-	-	0.955	0.837	0.863		
Cactus Wren	-	-	-	0.745	0.802		
Yellow-billed Cuckoo	-	-	-	-	0.962		
Yellow-breasted Chat	-	-	-	-	-	0.833	
Winter							
Cactus Wren							0.000
Small Insectivores							
Summer	V	LW					
Black-tailed Gnatcatcher	0.933	0.954					
Verdin	-	0.892					
Lucy Warbler	-	-				0.926	
Winter	YW	BG	V	BW	BC		
Ruby-crowned Kinglet	0.893	0.689	0.591	0.700	0.790		
Yellow-rumped Warbler	-	0.728	0.576	0.714	0.219		
Black-tailed Gnatcatcher	-	-	0.926	0.931	0.288		
Verdin	-	-	-	0.869	0.144		
Bewick Wren	-	-	-	-	0.000		
Brown Creeper	-	-	-	-	-		0.798
Ground Feeders							
Summer	CT	GQ					
Abert Towhee	0.938	0.885					
Crissal Thrasher	-	0.971					
Gambel Quail	-	-				0.931	
Winter	CT	GQ	WS	SS			
Abert Towhee	0.659	0.892	0.509	0.527			
Crissal Thrasher	-	0.833	0.808	0.825			0.748
Gambel Quail	-	-	0.928	0.928			
White-crowned Sparrow	-	-	-	-			
Sage Sparrow	-	-	-	-			0.748
Mean of all R_o's						0.862(.115)	0.602(.312) $p<0.01$

* Abreviation for the species in the vertical column, e.g. WK=Western Kingbird; V=Verdin;etc.

The relationship between the Yellow-breasted Chat and structure is more complex. The chat, a summer visitor, seems to prefer areas with vegetation at both 3 m and >9 m (Table 6). It occurs in very low numbers or is absent from areas lacking at least moderate development in these two layers and is clearly associated with vegetation of a specific structural configuration.

The Crissal Thrasher (Toxostoma dorsale), a permanent resident, seems to prefer areas which are dense at 3 m but which lack vegetation above 9 m. The line of prediction (Table 6)

Table 6.--Species which show preferences for vegetation structure along the lower Colorado River.

Species	Correlated with relative volume at	Season	Regression Equation	Correl. Coef.	Prob. of assoc. being due to chance
Abert Towhee	Total Volume	S	Y=15.65x+8.51	0.375	1.64<0.100
Abert Towhee	Total Volume	W	Y=9.86x-0.62	0.580	2.38<0.050
Yellow-breasted Chat	3m+≥9m	S	Y=25.54x-1.92	0.752	4.63<0.001
Summer Tanager	≥9m	S	Y=21.94x+0.48	0.731	4.58<0.000
Crissal Thrasher	3m-≤9m	S	Y=24.75x+2.11	0.726	3.33<0.000
Ruby-crowned Kinglet	≥9m	W	Y=17.30x+7.09	0.910	5.22<0.001
White-winged Dove	3m+4.5m+9m	S	Y=3.43x-10.36	0.782	3.58<0.002
Mourning Dove	3m+4.5m+9m	S	Y=316.30x+50.05	0.547	2.51<0.020
Yellow-rumped Warbler	0.1-0.6m	W 1974-75	Y=266.74x-41.83	0.599	2.32<0.050
Yellow-rumped Warbler	≥9m	W 1975-76	Y=93.09x+3.09	0.913	3.76<0.002

was obtained by subtracting the relative volume greater than 9 m from that at 3 m. Since thrashers occur commonly but in somewhat reduced numbers in vegetation with other structural configurations, they were not considered structural specialists.

Some Complex Examples

The White-winged Dove (*Zenaida asiatica*) and the Mourning Dove (*Zenaida macroura*) showed very complex relationships with vegetative structure. Both species reached greatest nesting densities in areas with relatively dense vegetation at 3.0, 4.5, and 6.0 m and a lack of vegetation above 9 m (Table 6). The highly significant regression line was obtained by subtracting the relative volume above 9 m from the sum of the relative volumes at the other three layers. The White-winged Dove was more of a specialist in this regard as nesting densities are low in other structural types. Mourning Doves on the other hand reached moderate densities in other types, too. The White-winged Dove seemed to suffer less nest predation under these conditions of vegetation structure (Butler 1977).

A Special Case

In winter 1975-76 Yellow-rumped Warbler densities were found to be significantly correlated with the volume of vegetation 0 to 0.6 m (Table 6); the following winter there was a significant positive correlation with volume above 9 m but not with volume at 0 to 0.6 m ($r = 0.2$, $p<0.05$). While this may appear to defy explanation, it is apparently related to climate. In the winter of 1975-76 the Yellow-rumped Warbler population was about the same in type I but much reduced in sparser areas lacking tall vegetation. It seems possible that the areas with tall trees are in fact preferred; but when the limited amount of this structural type is filled, the excess goes to the sparser areas. A constellation of factors including climate and food supply are probably important in determining the number of Yellow-rumped Warblers which move into and winter in the Colorado River Valley.

The Yellow-rumped Warbler was considered a structural specialist in winter. Obviously, erroneous conclusions could be drawn if only one year's data or data from only one community type had been used in analyzing Yellow-rumped Warbler wintering habitat requirements.

Significantly, of the nine species which show structural preferences, six are visitors and three are permanent residents in spite of the fact that the number of species of permanent residents and visitors are present in about equal numbers. One of the permanent residents showed a preference only in winter. All of the species showing greatest structural preference are visitors.

CONCLUSIONS

From data presented here, correlations between bird population parameters and vegetation structural characteristics vary seasonally in the lower Colorado River Valley. Although the relationships to structure were considered on a rather coarse-grained level in this report, the same trends are apparent at finer levels of distinction as well as for other vegetative characteristics (Anderson and Ohmart, unpubl. data). Habitat breadth is narrowest in winter and broadest in summer; permanent residents occupy the habitat more evenly than visitors. R_o of the various species are greater in summer than winter. Narrower HB_s and reduced Ro_s in winter suggest that winter is potentially the time of greatest stress. Permanent residents tend to be less specialized in structural preference than winter visitors. These facts have management implications. First, since winter requirements may be different but of equal or greater importance than summer (breeding) requirements, they should receive at least equal attention. The requirements of wintering visitors should receive particular attention for they tend to be specialists with large populations. If the portion of the habitat in which they specialize is destroyed or damaged, its loss could mean total loss of a breeding population. Finally, the requirements of summer residents also need special attention as they too tend to be specialized--although probably not to the same degree as winter visitors.

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A Riparian Case History: The Colorado River[1]

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Abstract.--Historically to present cottonwood communities have declined in abundance along the lower Colorado River to the condition that the future of this natural resource is precarious. Avian species showing strong specialization to cottonwood communities may be extirpated should the cottonwood community be lost from the river. Only through the concern and action by responsible agencies can we assure the persistance of this natural resource.

An overview of the ecological changes that have occurred on the lower Colorado River can be obtained by selecting an important plant community and examining its condition through time. To adequately describe the lower Colorado River riparian ecosystem and discuss the ecological changes from our first written records (1539) to the present is not possible within the space constraints of these proceedings. Therefore, we have elected to analyze an important plant association in this ecosystem and examine its distribution from the early 1600's to present. Although we refer to this association as the cottonwood (Populus fremontii) community, it frequently occurs mixed with such species as willow (Salix gooddingii) and/or screwbean mesquite (Prosopis pubescens) and infrequently with such species as arrowweed (Tessaria sericea), honey mesquite (Prosopis juliflora) and recently the introduced salt cedar (Tamarix chinensis).

Some avian species that inhabit this community along the lower river appear to be very specific in their habitat requirements (Anderson and Ohmart 1975). Consequently, as the unit area of this plant community changed, in all probability, so did the abundance of these habitat-specific species. By examining this biotic community from past to present, we gain an appreciation of the areal changes that have occurred and can make better predictions as to the future of this community type. This analysis should be helpful in providing impetus for management decisions relative to the cottonwood community along the river.

It is tempting to speculate that early man lived in harmony with his environment and that the earliest descriptions of the plant communities along the lower Colorado River reflect the natural environment unaltered by man. Because of space constraints, we will assume this is true, but it must be kept in mind that man could have had a strong influence on his environment through burning and other habitat alterations, especially at the local level.

If we assume that the Indians did not drastically modify the environment, we can examine alterations, classed as natural or unnatural, brought about by the Spaniards and later the Anglo-Americans. It has been argued that man is a natural part of his environment and that alterations brought about by his activities are as natural as changes produced by other animal activities (Malin 1956). This is academic when it is considered that natural resources are finite, and regardless of the causes of degradation and loss, if we value these resources, then we must preserve and manage them for their continued existence.

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INDIANS AND SPANIARDS

Long before European man viewed the waters of the lower Colorado River, a variety of Indian cultures evolved and became established along its banks. However, they left no written record, so Spanish documents provide our earliest information about the region. The Spaniards claimed the region of the lower Colorado for over 250 years. Interested in converting the Indians to christianity, discovering a land passage to the South Sea (Gulf of California) and acquiring mineral wealth, their missionary-military expeditions explored the Pimeria Alta. These early explorers left diaries often containing descriptive information on the areas they traveled.

In February of 1699, Father Eusebio Francisco Kino, accompanied by Juan Mathes Manje, an excellent diarist, viewed the junction of the Gila and Colorado rivers from a distance of 15-18 miles. Manje wrote: "...we plainly saw at a distance of six or seven leagues [1 league = 2.5 miles] the banks and junction of the very great Rio Colorado with this one [the Gila], grown with dense groves with new leaves and although we saw it at a long distance the groves appeared to us to be more than a league wide,..." (Bolton MS 203:20).

Kino, a student of both the Faith and geography, spent twenty years in the area known as the Pimeria Alta, delineated on the east by the San Pedro River, the north by the Gila Valley and on the west by the Rio Colorado and the Gulf of California. Two of his major goals were to convert the Indians to christianity and to find a land passage to California to prove it was not an island. In 1700, Kino was again near the junction of the Colorado and Gila rivers. He ascended a hill in hopes of viewing the Gulf of California: "...but looking and sighting toward the south, the west, and the southwest, ...we saw more than thirty leagues of level country, without any sea, and the junction of the Rio Colorado with this Rio Grande..., and their many groves and plains." (Bolton 1919: 1, 249). In the flood plain in 1701, Kino wrote that the Indians: "...showed themselves most affectionate toward us, ...especially in opening for us some good, and straight and short roads through the thickets of the abundant and very dense woods, which were on these most fertile banks." (Bolton 1919: 1, 316).

Cottonwoods are first mentioned specifically by Father Sedelmayr in 1744 during his endeavors along the Colorado at the junction of the Bill Williams River: "The Indians burn the trunks of the alders [willows] and cottonwoods and when they fall they burn the tops of them until they have a pole of the size desired." (Dunne 1955: 31).

Thirty years later, in 1774, Fathers Diaz and Garces accompanied Captain Anza to the Colorado River. After they crossed the river near Yuma, Arizona, Diaz wrote: "On its banks there are many cottonwoods, most of them small." (Bolton 1930: 2, 264). The following day (9 February), Diaz wrote: "...we camped on the bank of this river below its junction with the Gila... Its banks and adjacent lands are very thickly grown with cottonwoods, which would serve for any kind of building." (Bolton 1930: 2, 267-268). On that same day, Captain Anza measured the Colorado River and commented on the plant communities: "...one can see clearly the junction of the rivers and the immense grove of cottonwoods, willows useful for thatching, and other trees, both upstream and down." (Bolton 1930: 2, 169).

Diaz and Anza journeyed westward to the coast, leaving Garces to continue his missionary work. In his travels north along the river in the vicinity of Ehrenberg, on 28 February 1774, he wrote: "...I arrived at eleven o'clock in the forenoon at the beaches and the groves of the Colorado, halting at a very long and narrow lagoon..." (Bolton 1930: 2, 379). As he traveled north above the Bill Williams River, he viewed the Chemehuevi Mountains and described the area now under the upper end of Lake Havasu: "In the vicinity of the sierra I saw much water, groves and large beaches, which must be those of the Colorado River." (Bolton 1930: 2, 385).

TRANSIENT PIONEERS

The crude Spanish Missions built on the lower river were destroyed in 1781, and most of the inhabitants, including Father Garces, were killed. Spanish activity in the area waned and between the late 1700's and 1850, only a few passing explorers, trappers and pioneers visited the lower Colorado River. One diary, that of Jose Joaquin Arrillaga, contained worthwhile vegetative descriptions where he approached the Colorado near its mouth and then traveled north to Yuma. On 19 September 1796 he wrote: "At half past three in the morning I took up my march to the east,...and at sunrise I was already in sight of the cottonwoods of the Rio Colorado." He crossed the Colorado River near Yuma and continued east: "After one leaves the banks of the river there is not a useful tree to be found, except the mezquite grove where I set out, and this serves for nothing but firewood," (Arrillaga 1796 MS).

A number of trappers were known to have illegally entered the now Mexican territory (Weber 1971) which included the region of the Colorado River. They were tight-lipped and only one, James Ohio Pattie, in 1827 left records of the Colorado River environment: "The river, below its junction with the Helay, is from 2 to 300 yards wide, with high banks, that have dilapidated by falling in. Its course is west, and its timber chiefly cottonwood, which in the bottoms is lofty and thick set." (Pattie 1831: 129).

AMERICAN EXPLORERS

The best and most complete records of cottonwood distribution, abundance and size occur from the late 1840's on when soldiers and scientists began working in the area of the lower Colorado River either because of war or to conduct various surveys. The United States boundaries were expanded to the Pacific Ocean in the 1840's and in 1846, the United States went to war with Mexico for land acquisition, the Colorado River being part of this region.

Lt. William H. Emory (1848: 99-100), Topographical Engineer accompanying the "Army of the West" in 1846, recorded his observations in the area of the Colorado-Gila junction: "The banks are low, not more than four feet high, and judging from indications, sometimes, though not frequently, overflowed.... The growth in the river bottom is cotton wood, willow of different kinds,..."

A member of Emory's party, A. R. Johnson, also kept a journal and observed that: "The Colorado disappears from here in a vast bottom; the last we can see of its cottonwoods is in the southwest." (Emory 1848: 609). The following day, after a 10 mile march, they again reached the river and Johnson stated: "...the river here is about ten miles wide, and much of the land could bear cultivation; it is all now overgrown with the most impenetrable thickets of willows, mesquite, Fremontia, etc." (Emory 1848: 609). The term "Fremontia" was frequently used to denote cottonwoods because the species was named in honor of the naturalist J. C. Fremont.

One of the many commissioners of the trouble-plagued boundary survey, John R. Bartlett, published his "Personal Narrative of Explorations" along the Colorado River in 1854. His following description of the Algodones area in 1852 is duplicated by a photograph (plate 1a) some 50 years later and then again in 1976 (plate 1b). In his description of the area (Bartlett 1854: 149-151) he wrote:

> June 9th, 1852 - Our journey was through a bottom filled with mezquit and cotton-woods; ...Our eyes were greeted with a sight of the great Colorado River, twelve miles below its junction with the Gila, at a place called "The Algodones," and soon after, we halted upon its bank. It was much swollen, and rushed by with great velocity, washing away the banks and carrying with it numberless snags and trees. The road ran along the river's bank, which, as well as the bottom-land, was filled with a dense forest of willows, cotton-woods, and mezquit.

Lt. Amiel Weeks Whipple (1856: 3(1), 109) in his exploration of a railroad route along the 35th parallel described the Chemehuevi Valley (79 years after Garces): "On both banks are strips of bottom lands, from half a mile to a mile wide. The soil is alluvial, and seems to contain less sand and more loam than is found in the valley of the Rio del Norte. But here, as there, are occasionally spots white with efflorescent salts. A coarse grass grows luxuriantly upon the bottoms. Bordering the river are cotton-woods, willows, and mezquites, or tornillas." Dr. J. M. Bigelow, surgeon and botanist in Whipple's party, described the same area: "From the mouth of Bill Williams' fork to the point above where we crossed the Rio Colorado, is about sixty miles.... Along the valley of this river, alamo [cottonwood], mezquite, and willow form the principal, and almost entire, kinds of trees." (Bigelow 1856: 4, 13).

The interest in river navigability was so strong in 1857 that a government expedition was organized. Lt. Joseph C. Ives, Corps of Topographical Engineers, was directed to determine how far and to what extent the Colorado River was available for steamer traffic. At Camps 50 and 53, Ives described Cottonwood Valley and Round Island. The latter was commonly called Cottonwood Island because of the heavy forest of large cottonwood trees. Of Cottonwood Valley, Ives (1861: 78) reported: "Groves of cottonwood trees, of a larger growth than any seen before, indicate that there is some alluvial land, but the valley does not appear to be of great extent.... The Cottonwood valley was found to be only five or six miles in length and completely hemmed in by wild-looking mountains. The belt of bottom land is narrow, and dotted with graceful clusters of stately cottonwood in full and brilliant leaf."

AMERICAN EXPANSION

Ives' steamer exploration up the river, and the demonstration that the river was navigable, generated an abundance of steamer travel and allowed shipment of goods to the mining industry. In 1862, placer gold was discovered midway between Fort Yuma and Mohave, and the

Plate 1a (1894). Looking southeast into Mexico at Mexican-American Boundary Monument 207. Maturing cottonwood community with trees 20 to 30 feet tall can be seen in the background following the cessation of the fuel wood industry for steam boats. A community of arrowweed occurs between the marker and the cottonwoods.

Plate 1b (1976). Looking southeast into Algodones, Mexico.

town of LaPaz was born (Renner 1974). Fuel for steamers was readily available in the form of cottonwood, willow and mesquite, the latter being less desirable because of its slow-burning properties. Large quantities of fuel were needed frequently and fuel stations were established at 25-mile intervals. The Indians, realizing that a profit could be made, cut and corded the wood, selling it at $2.50 a cord (Leavitt 1943).

The continuing search for gold revealed deposits near present-day Oatman and in El Dorado Canyon (Dunning and Peplow 1959; Casebier 1970). The expanding mining activities increased the military presence and businessmen soon realized the potential for development.

G. W. Gilmore, a member of the Colorado Steam Navigation Company, submitted a report on the availability of fuel along the river after having taken a trip on the steamer Esmeralda in 1866 in which he stated: "...bends of the river in the bottom lands, which, as below Fort Yuma, are covered with vegetation and timber; the trees of the varieties already named are suitable for fuel, and are of very rapid growth. It is found that upon new lands formed by the cuttings of the river cottonwood, willow, and mesquite trees will be produced in three years large enough to cut for fuel... Trees are quite abundant for most of the distance, and plenty of fuel to be had."

His statements about Cottonwood Island were as follows: "...about 10 miles long by an average of about three miles wide, is a fine, level island, fertile and covered with grass, and having considerable timber.... An immense quantity of this wood was upon the island, estimated at several thousand cords" (Browne 1869: 462-464).

The need for exploration was almost over and although further expeditions would be sent, they would be of a very different nature. In 1875 and 1876, Lt. Eric Bergland, under the direction of George Wheeler, leader of the United States Surveys West of the 100th Meridian, examined the Colorado River as a potential irrigation source. Describing the vegetation of the Colorado River, he stated: "A most pleasant sight... Cottonwood Island, with its majestic cottonwood trees and rich vegetation, afforded a pleasant relief to the eye.... Along the river there is a rich growth of trees, principally cottonwood, and here the fuel is obtained for the river steamers." (Bergland 1876: 330-333).

In 1877, Lt. A. G. Tassin authored a document entitled "Report on the Forestry, Elevation, Rainfall, and Drainage of the Colorado Valley together with an Apercue of Its Principal Inhabitants the Mahhaos [Mohave] Indians" compiled while he was stationed at Camp Mohave. Never published, the report remains in handwritten manuscript form, often undecipherable. In his discussion of the vegetation, Tassin (1877: 5-6) noted: "Finally along the margin of 'lagunas' the most substantial of the Colorado timber the willow and cottonwood. The largest of these in the entire course of the river, are in what is called 'Cottonwood Island' between Camp Mohave and the Grand Canyon where they have attained a size which may be styled majestic.... The cottonwood, mesquite and willow are the principal, if not the only fuel of the country, the first having a diameter varying from two to twenty inches." In a latter section of his report, Tassin (1877: 30) wrote: "Cottonwood island the sole bottom-land between the Grand Canyon and Camp Mohave, is, as denoted by its appellation, celebrated for its splendid cottonwood trees which here attain their full size. Its area varies between from four to six miles in length and from one to three-fourths of a mile in width.... In a few years, however, its beautiful trees will have disappeared, a large demand being made on them yearly for fuel for the use of the ________ Mormons."

The General Land Office, now known as the Bureau of Land Management, initiated the original township surveys or cadastral mapping along the river in 1855. Not all the land was surveyed during the same time period. Figure 1 shows a reconstruction of the general vegetative types below Blythe, California in 1879 derived by interpreting floral descriptions contained in original field notebooks and then transferring these to the original field plats. The field notes contain exact measurements from section corners to points where the vegetation or topography changed. At each change notes were taken on soil, vegetation and general character of the land. Once a section (1 square mile) was chained, the surveyors took random walks (giving specific localities) through the section and again took notes at various places on vegetation, etc. Insight into the maturity of the community was also indicated when tree diameter values at breast height were noted and when trees were used as section corners. Although these data are semi-quantitative and highly time consuming to obtain, they yield the earliest aerial view of plant community extent, abundance and placement along the lower river. They further support previous and subsequent written descriptions in the historical record.

By about 1890, the use of and need for steamboats had declined, as had the fuel supply. Some steamer traffic ran north of Yuma, but to insure adequate amounts of fuel, they had to travel into the delta area (Sykes 1937: 37). The decreased need for steamers was in part due

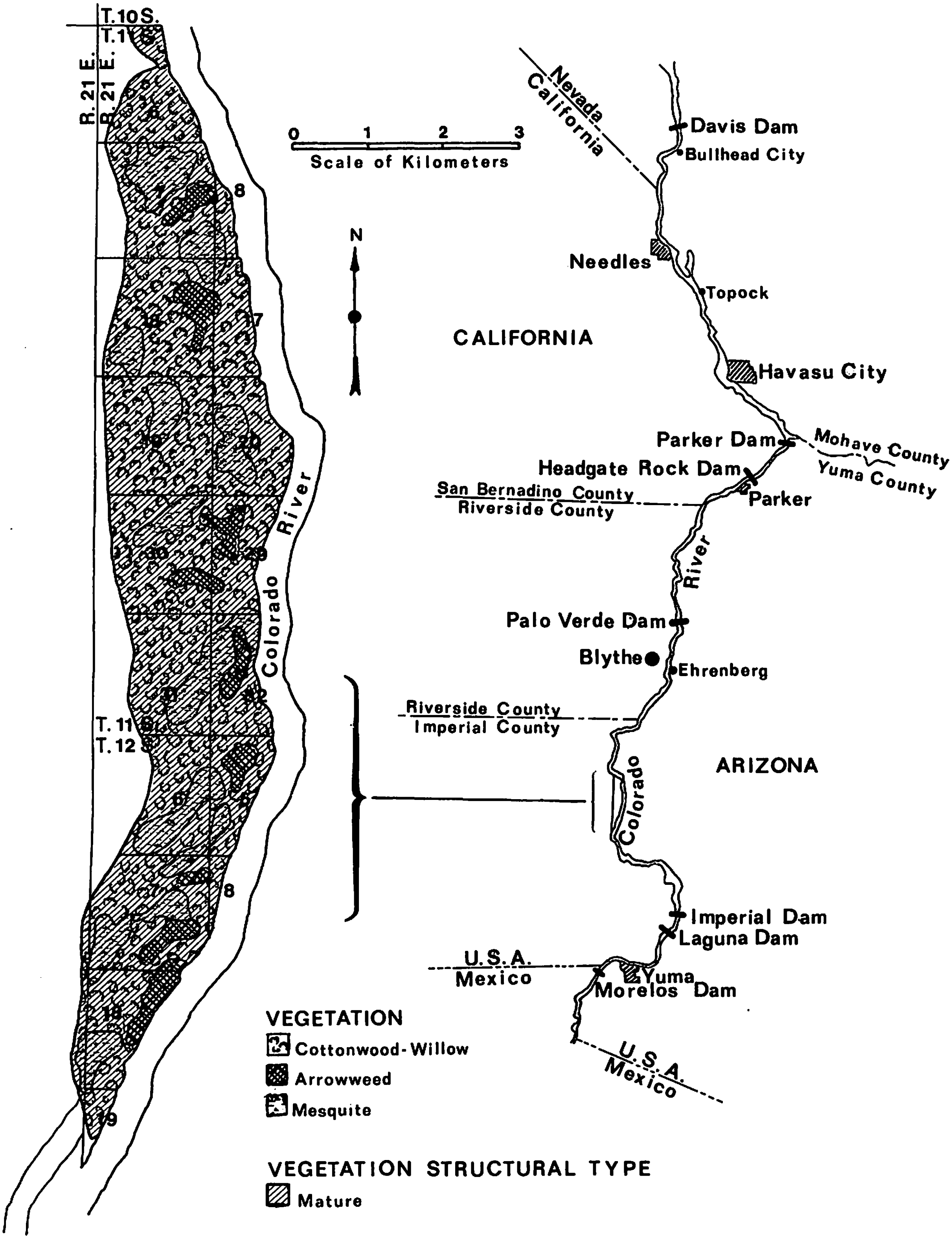

Figure 1.--Reconstruction of native plant community placement and species composition from original surveyor notes and plats along the lower Colorado River in 1879. Area surveyed by Benson.

to the completion of the railroad to Yuma (1877) and Needles, California (1883).

By the late 1800's, the importance of mining and other uses of the river had slowly declined and agriculture along the river was precarious because of the annual floods and constant shifting of the channel. In 1892 Imperial Valley was rediscovered by the Arizona and Sonora Land and Development Company. George Chaffey was instrumental in bringing water into the basin, and by 1904 the California Development Company claimed seven hundred miles of irrigation ditches and seventy-five thousand acres were under cultivation.

The winter of 1905 was one not to be forgotten. Unlike other years, the river began to rise in February and "the condition continued...until February of 1907" (Sykes 1937: 57). Despite attempts to control the flooding waters, by August 1905 the entire river was flowing into the intake of the Imperial Valley canal. Thus, the Salton Sink became the Salton Sea (Cory 1915; Tout 1931; Sykes 1937; Hundley 1973).

The flood of 1905 brought heavy public pressure for river management in the form of flood control and water storage. The Reclamation Act had been passed in 1902, the settlers were having continual problems with the development company, there were difficulties with the Mexican government, and the disastrous floods of 1905 and 1907 increased pressures to evict the promoters and have the Reclamation Service assume responsibility for the river. From about this period on, the Reclamation Service, now U. S. Bureau of Reclamation, played the most important role in developing the river as a utility, although lesser agencies such as the Imperial Irrigation District also played important parts.

One of the major roles in development was the installation of dams for flood control; the first, Laguna Dam, became operational in 1909. A flood in the fall of that same year "...was instrumental in completing the filling of the basin above Laguna Dam with detrital material within six months after the completion of the dam itself." (Sykes 1937:152). Floods continued and levees were raised until the big flood of 1922 which convinced people in Washington that larger dams were needed. In 1935 Hoover was operational. In 1943 Davis Dam, 1938 Parker Dam and Imperial Dam were completed. Lesser dams for water diversion also were constructed.

Concomitant with and following dam construction, engineers began to examine water movement rates, channel siltation and bank erosion. Many of these problems can best be solved by channelization, riprapping of banks and removal of sedimentation through dragline or dredge. All of these methods were employed to straighten and open channels to expedite flows. New and old eroding banks were fortified with riprap to increase bank stability.

Once the dangers of floods were reduced and flows were controlled by Hoover Dam, this allowed for agricultural expansion throughout the floodplain. Settlers claimed new lands and removed large and continuous tracts of natural vegetation for agricultural purposes. These activities, along with city and rural development, continue to claim numerous acreages once vegetated with natural communities. Much of this land, especially near the river, once supported cottonwood communities.

In the 1950's through the 1960's, two plans were formulated by the Bureau of Reclamation to remove riparian vegetation for the purpose of water salvage. Only one of these was ever implemented and this was in the Yuma flood plain area (Curtis W. Bowser, USBR, pers. com.). Van Hylckama (1970 and in press) has pointed out that water losses from a plant varies considerably during the year and past measurements have not taken this into consideration, possibly resulting in large errors.

In the late 1960's and early 1970's, a small flame of environmental concern was beginning to burn throughout the nation. In 1969 the National Environmental Policy Act was passed and federal agencies began to review policies and action decisions more closely. During this period the Regional Director of the Bureau of Reclamation, Mr. Edward A. Lundberg, established an environmental office headed by Mr. F. Phillip Sharpe. Efforts by these individuals in 1972 resulted in an extensive assessment of the little known flora and fauna of the lower river and a comprehensive and long-termed study was begun which was entitled "Vegetation Management for the Enhancement of Wildlife." These studies are still in progress and the legacy of environmental concern generated in the early 1970's is strongly supported by the current Regional Director, Mr. Manuel Lopez, Jr.

DISCUSSION

How extensive was the cottonwood community in historical times? As we swim through a sea of qualitative data, there is little quantitative information available to help answer this question. We know from historical records that cottonwoods were primarily restricted to the river's edge where seedlings became established in newly deposited soils. The following is an attempt to give some quantification to the extent of cottonwood communities in historical times. If we assume that cottonwoods were absent in areas where the river cuts through canyons and thus remove 75 miles of the 275 miles of river between Davis Dam and the Mexican boundary, this leaves approximately 200 miles of potentially suitable habitat for cottonwoods. If the mean width of the cottonwood community along the river was 100 feet on each side of the river, we can compute a minimum area of 5,000 acres of cottonwood habitat. This figure is conservative, but it yields a value which will be instructive in later discussion.

The Indians exerted some influence on the ecology of the cottonwood community, especially by using fire to fall and size timbers. Cottonwoods cannot tolerate much heat and do not resprout from the roots following a hot fire. But to expedite discussion, in this report we will assume the Indians' influence on the cottonwood community along the river was minimal and capricious.

The influence of the Spaniards on the cottonwood community appears more minimal than that of the Indians except for the introduction of livestock in the early 1700's (Forbes 1965). Spanish activity was concentrated primarily around the Yuma area. The spread and extent of use of domestic livestock by the Indians is not well known, but Forbes (1965:287) reported from hearsay evidence in 1842 that the Quechan and Mohave Indians "...own large numbers of horses and cattle..." Not all the Indians owned or had access to livestock or Browne (1864) would not have observed them starving and eating rodents and reptiles. The primary damage of livestock to cottonwood communities would have been to seedling or sapling stands which would have been important foraging areas for domestic livestock. More mature communities were sometimes cut if livestock forage was scarce; Pattie (1905:188), for example, stated, "Our horses also fared well, for we cut plenty of cotton-wood trees, the bark of which serves them for food nearly as well as corn."

The first and most widespread reduction of cottonwood communities appears to have taken place during the period of steamboat use on the lower river (1855 to 1890). Cottonwoods and willows, fast burning woods, were located nearest to the river and were one of the primary fuels for powering the vessels. The extent of reduction of the cottonwood community is supported by Tassin (1877:30) who predicted the denuding of cottonwoods from Cottonwood Island, which came to pass. Another indication of the reduction of maturing cottonwood communities is exemplified by the necessity for steamers planning long trips up river from Yuma to go into the delta for wood to insure an adequate fuel supply (Sykes 1937). As fuel demands abated in the late 1880's, cottonwood communities began returning; and the photograph (plate 1a) taken in April 1894 by Mearns shows redeveloping cottonwood communities at the Mexican-United States boundary.

The floods which occurred during the years of 1905 and 1907 were of a greater magnitude and longer duration than any described in historical accounts. The destruction and removal of natural communities must have been far greater and more widespread than the 1852 flood which washed away banks and carried in its waters "numberless snags and trees" (Bartlett 1854:50). Presumably, the newly deposited and moist soils again would have provided the basic habitat for cottonwood seed germination and the repetitious reforestation process. Accounts by Grinnell (1914) in 1910 indicate that the cottonwood communities were returning and the 1945 photograph (plate 2a) provides pictorial testimony. Aerial photographs taken every three to five years, beginning in 1942, show that the majority of the trees were gone by 1967 and plate 2b, taken in 1976, revealed only four or five isolated trees in the bottom right. Dense stands of salt cedar presently cover areas previously supporting cottonwoods.

Salt cedar was introduced in the New World in the early 1800's both as a soil stabilizer and as an ornamental (Horton these proceedings). Its entry to the lower Colorado River must have been sometime after 1910 when Grinnell (1914) made extensive museum collections of plants and animals. He makes no mention of it in his publication or field notes, and had it been at all common, he would have found and collected it. The species appears to have become established between 1910 and 1920 and began to spread rapidly in the 1930's and 1940's. By the 1940's it dominated large areas along the Gila (Marks 1950; Haase 1972; Turner 1974) and Colorado (Robinson 1965) rivers.

Horton (these proceedings) discusses the biology of salt cedar but a brief discussion is necessary to gain insight into the events that transpired between 1945 and 1976. The species produces seeds over a long period of time and seeds are both wind and water disseminated. They germinate vigorously in newly deposited alluvial soils. The species is deciduous and when in relatively dense stands (periphery of adjacent trees touching), the annual litter accumulation after 10 to 12 years produces a highly flammable condition. The above ground portions are killed following a fire, but suckers from the root stock reappear in one to two weeks, the burn cycle repeats itself every 10 to 20 years (Anderson and Ohmart MS).

Plate 2a (1945). Aerial oblique looking west into California about 25 miles north of Blythe. The river is flowing in the foreground to the right and then to the left. In bottom right, cottonwoods can be seen along the old braided stream channels on the cut bank. Understory is primarily sparse arrowweed with taller willows or salt cedar near the cottonwoods. The peninsula supports many cottonwoods, willows and arrowweed.

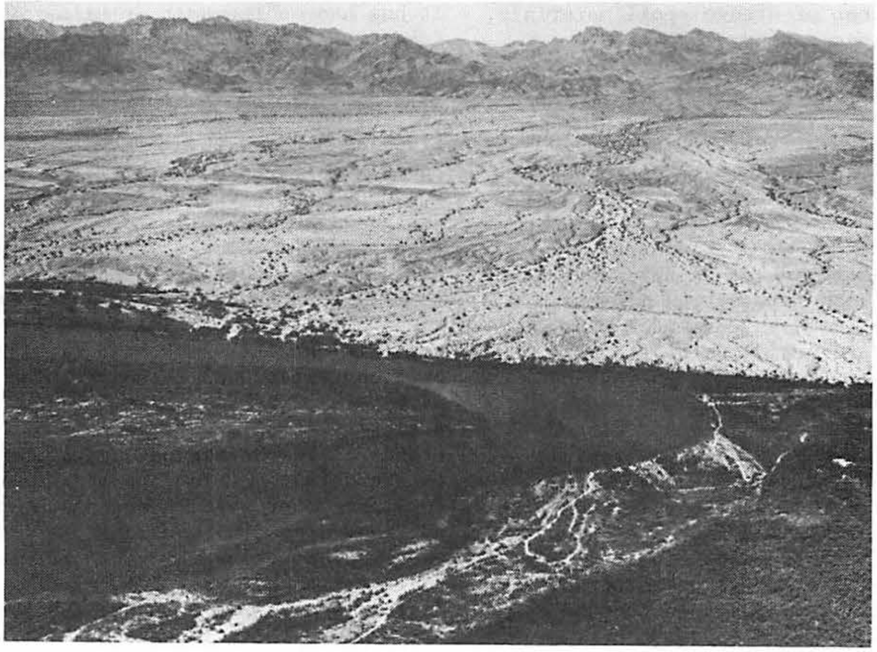

Plate 2b (1976). The camera station is higher and closer than in the previous photograph. Dense salt cedar and arrowweed have invaded the areas previously occupied by cottonwoods. Isolated cottonwoods persist in the lower right. On site remnant blackened tree stumps are persistent testimonials of past fires. Mesquites have become established along the peninsula on the higher and better drained soils.

Cottonwood communities were in the process of returning following the floods; but when salt cedar began invading the lower river, it must have started mixing with the maturing cottonwoods. The proximal location of the cottonwood communities to the river and on soils only inches above the water table provided the type of habitat that salt cedar does best on and aggressively spreads over. Some individual cottonwoods were probably removed for firewood by man and for food by beavers. Today remaining cottonwoods occur as isolated trees or as irregular rows with little understory, mixed with sparse willow communities, in pure stands or temporarily mixed with salt cedar. The latter being temporary as exemplified by the area around Hunters Hole in the Limitrophe Division which burned two years ago and killed all the mature cottonwoods. Many of the remaining cottonwoods along the lower river are mixed with sparse willows and these willows may have served as a buffer which prevented or slowed the invasion of salt cedar by shading out seedlings. Anderson and Ohmart (MS), in studying rodent succession in fire altered salt cedar communities along the lower river, have only found two salt cedar communities of 50 acres or more that have survived fire for more than 20 years.

Many cottonwood communities have been lost to expanding agriculture channelization projects, inundation of lakes behind dams and possibly the placement of dredge spoil materials. Agriculture only poses a minor threat to remaining cottonwood communities since there are only so few left, and they occur primarily on lands between the levees which are not farmed. River management activities tempered by environmental concern, require an Environmental Impact Statement and mitigation for project losses.

The demise of cottonwoods on the lower Colorado River has been related to implementation of dams, and the data indicates that dams expedited the natural loss by stopping annual overflow. This periodic flooding and water movement through the communities covered or washed away litter accumulations. Litter covered with sediment during overflow rapidly decomposed to release nutrients and add humus to the soil. River management stopped these natural overflows and allowed litter accumulation which in turn has resulted in the increased frequency of communities being burned. This has led to the loss of many cottonwood communities from fire.

Cessation of annual overflows and natural channel movements also curtailed the formation of the basic cottonwood seedling habitat, bare sandy soils with high water tables, which appears essential for cottonwood seed germination. The rapid spread of salt cedar and slow demise of cottonwoods began about the time major dams were implemented, the mid 1930's. It is somewhat of a moot point whether major dams tipped the ecological balance to favor dominance of salt cedar over cottonwoods or if cottonwoods could have retained their dominance over the invading salt cedar on the lower Colorado River. Currently the success of cottonwood regeneration has not been stopped, but it has been lowered to the point where it is negligible. Campbell and Dick-Peddie (1964) reported that cottonwoods could maintain their dominance over salt cedar in natural conditions on the upper Rio Grande in New Mexico, but it is doubtful this would be valid along the lower Colorado River. Even without dams it appears highly unlikely that cottonwood communities could have maintained their dominance along the lower Colorado River over the aggressive and fire adapted salt cedar.

This conclusion is supported by examining the loss and persistence of cottonwoods in natural communities along other southwestern streams. A reach of the Gila River in Arizona between Kearny and Florence is still intermittently flooded but contains few lone cottonwoods and no gallery forest. Conversely, the Verde River in Arizona above and below the dams possesses good cottonwood gallery forest and salt cedar appears to be having more difficulty invading this riparian system than it has had on the Salt or Gila rivers. Another factor appears to be important--total dissolved solids (TDS). Further support of the importance of TDS is indicated by the return of native vegetation along the Salt River below the Flushing Meadows sewage treatment plant in west Phoenix, Arizona. In this area, salty native ground water is being displaced by secondary sewage water and following the flood conditions in the 1960's which scoured away much of the salt cedar in that area, native communities are rapidly returning. It is highly improbable that these native communities would have returned in competition with salt cedar if salt cedar removal by flood waters was the only cause. Many areas have been cleared of salt cedar only to have it promptly return. Observations along the Rio Grande in New Mexico and Texas further support the importance of low TDS and cottonwood dominance over salt cedar. Along the upper portion, around Albuquerque, New Mexico, cottonwoods appear to be thriving and maintaining their dominance. But between Las Cruces, New Mexico, and El Paso, Texas, the frequency of extensive gallery forests declines and individual trees show heavy plant parasite infestations; to the extent that they are dying. Further down river in Texas between Presidio and Fort Quitman there are no gallery forests remaining; only lone cottonwoods remain isolated along ditches or canals from the tall and dense salt cedar forests. All along the river from Albuquerque to El Paso extensive agricultural and industrial effluent enters the river to slowly work its way down stream. Salts from these and natural sources can be seen covering many acres between Fort Quitman and Presidio following the subsidence of sluggish and intermittent winter floods. Dams have stopped the once rapid moving floods which once flushed and leached salts into the gulf, leaving rejuvenated soils.

Other factors, both man caused and natural, may or may not be involved in each case and should be examined in depth before reaching a final conclusion as to the reasons for cottonwood disappearances. We know that domestic livestock concentrate in riparian communities and heavily utilize young cottonwoods, but we know nothing about possible climatic changes and their effects postulated by Hastings and Turner (1965). What effects have these changes had on cottonwood communities, if their thesis is correct? Much remains to be learned about the ecology of riparian communities and unfortunately there is little information available on the natural history of most of these plant species.

Cottonwood communities have declined from high abundance (5,000 acres plus) along the lower Colorado River in the 1600's to scattered groves containing a few mature individuals today. Anderson and Ohmart (1976) have estimated that only 2,800 acres of cottonwood-willow community remain along the lower river. If one was to consider pure cottonwood communities, it would be less than 500 acres.

In conjunction with the loss of the cottonwood resource, we must have experienced population reductions in bird species which show a strong preference for cottonwood habitats. Summer Tanagers (Piranga rubra), Yellow-billed Cuckoos (Coccyzus americanus), Wied Crested Flycatchers (Myiarchus tyrannulus), Brown Creepers (Certhia familiaris), and many small insectivorous birds (mostly warblers) breed or winter in these habitats. Numbers of some of these species are very low (Anderson and Ohmart 1975) and for all practical purposes some species would be extirpated from the lower river if cottonwood communities were eliminated.

Can anything be done and is anything being done to prevent the further loss of this resource? The U.S. Fish and Wildlife Service has recently bought the remaining cottonwood gallery forest that was not previously part of the Havasu Wildlife Refuge on the Bill Williams River and incorporated it into the refuge. Although adjacent to the Colorado, along the lower end of the Bill Williams River, there is a young gallery forest of about 700-800 acres. If this area is properly managed and prevented from burning, it should survive. Willow Valley Estates, a private housing development in the Mohave Valley was designed with open space areas and has planted natural vegetation (especially native cottonwoods). It is a small area, but some of the habitat specific bird species are found in this community. Recently, the Bureau of Reclamation has begun experimenting with the redevelopment of cottonwood-willow communities for operational enhancement and mitigational measures. Currently 25 acres of dredge spoil in the Cibola Division are being revegetated with cuttings or seedlings of native cottonwoods, willows and honey mesquite, the results look promising. A smaller area below Parker Dam also is being revegetated with cottonwoods and the young trees are doing well.

A look at the past allows us to examine changes and postulate causes. Hopefully we can then turn to the future, with the knowledge of the past, and formulate management plans so we can ultimately move with dispatch to manage and expand the availability of a valuable resource that is rapidly disappearing. To insure the preservation and perpetuation of this resource, all responsible agencies must make special efforts to preserve what cottonwood communities remain on their public trust lands and even attempt to reestablish new communities through transplants of native stock. It is expensive and requires a lot of manpower and attention but if this biotic community is to be preserved for future generations the effort must be undertaken soon.

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Session II

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Wildlife Conflicts in Riparian Management: Grazing[1]

Charles R. Ames[2]

Abstract.--Grazing has a negative impact on riparian zones. These zones constitute a small but critically important part of the range resource.

The riparian types in southern Arizona have increased from what they were 100 years ago. The increase has occurred through stream eutrophication and is most noticeable where the streams pass through the grassland type.

Protection of the riparian type where grazing is an established use can only be effectively achieved through fencing.

Wildlife managers frequently express their concerns about the impact of grazing in the reparian zones and justifiably so. We have all seen examples of riparian types where there is virtually no reproduction or mixed age classes of the trees or shrubs. The type is dominated by mature and overmature trees. Trees growing in riparian sites are usually relatively short-lived. It is entirely possible for a riparian zone to completely disappear within a span of a man's lifetime where grazing use is prevalent.

Cattle exhibit a strong preference for the riparian zones for a number of reasons. Cattle prefer the quality and variety of forage available. Riparian forage is higher in palatability because it has more moisture in it whether it be shrubs, forbs, or grass. Moisture content, probably more than any other factor, influences palatability. A preferred species of forage growing on a dry hillside will not be nearly as palatable as the same species growing in a riparian zone.

Availability of water in most riparian areas provides a strong influence for livestock to frequent the area.

If the surrounding country is rough and rocky, livestock tend to concentrate along the riparian areas just to give their feet a rest. In hot climates, livestock seek the shade available along the riparian areas. In cold climates, they seek shelter from the cold winds.

If livestock are left to their own preference the riparian zones get continued yearlong use with no respite from grazing. These critical zones represent a small but important percentage of the total range area. This is where the nongame birds and animals congregate unless it is totally devastated.

On the Coronado National Forest, approximimately 20% of the grazing allotments have significant riparian zones. Southern Arizona perhaps is unique in that we probably have more riparian zones today than there were 100 years ago. The increase has been due to overgrazing during the 1890's and early 1900's.

Figure 1.--Monument No. 98 on Mexican border. Located on west bank of San Pedro River. Photo taken 1892. Drainage virtually devoid of any riparian growth . San Pedro River was perennial stream with fish, frogs and turtles.

[1] Paper presented at the Importance, Preservation and Management of the Riparian Habitat Symposium, Tucson, Arizona, July 9, 1977.

[2] Charles R. Ames is the Range and Wildlife Staff Officer of the Coronado National Forest, Tucson, Arizona.

Figure 2.--1969 photo showing dense growth of mesquite. Entire San Pedro River has dense growth of mesquite and other riparian growth.

During this period, there was a continual buildup of cattle to a peak number of 173,000 head by 1900 in the area now encompassing Pima and Santa Cruz Counties. Needless to say, the country was devastated. During the rainy seasons, the runoff resulted in serious flooding causing gullying and heavy soil loss.

Figure 3.--Monument 111 where Santa Cruz River leaves U. S. No riparian growth showing along stream bank. Photo taken 1892.

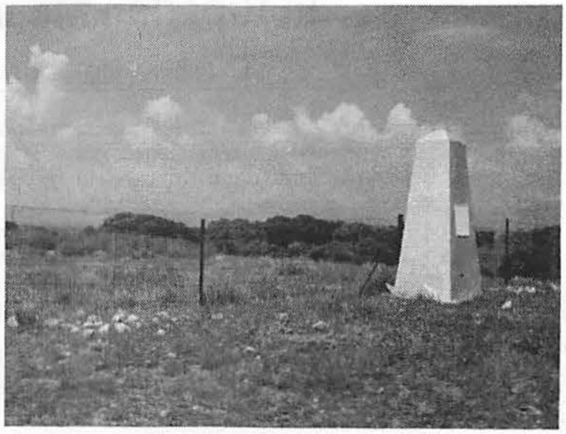


Figure 4.--1969 photo shows heavy riparian growth along water course.

Prior to this period, the San Pedro and Santa Cruz Rivers were perennial streams inhabited by fish, frogs, and turtles.

The resulting accumulation of silt in the stream with the soil nutrients provided the seedbed for the riparian growth now so prevalent along these streams. This process is called eutrophication.

A recent example of this is along the Santa Cruz River where the Nogales Highway was washed out in the 1967 flood. This occurred about 20 miles north of Nogales. The resulting silt bed formed in the bend of the river produced a dense stand of cottonwood trees now 30 to 40 feet high.

The riparian types in the mountain areas of the Coronado have probably remained fairly stable with little change through the years. The increase of this type has occurred by extension through the grassland type by the stream eutrophication process.

In general, it would seem we can conclude that riparian types undergo change. They recede in some areas and increase in others.

It is a well established fact that we are in trouble trying to retain riparian zones in a reproductive condition. The question arises - what can we do about it?

First of all, I believe we need to do an intensive classification job on our riparian types. These would logically fall in two categories: threatened and unthreatened. Of those in the threatened category, select the key areas. These would be the zones determined to be essential to keep. They may be critical habitat for rare and endangered species. Therefore, reproduction of the tree and shrub species must be ensured.

Figure 5.--photo of Monument 118 where Santa Cruz River comes back into U.S. Note limited scattered growth along water course.

Figure 6.--1969 photo shows a veritable jungle of heavy riparian growth. Original masonry monument washed out in flood in 1914 and replaced with steel monument in 1917.

It has been our experience on the Coronado Forest, that there is no known system of livestock management that will give adequate protection to a riparian zone. Even short term use or seasonal use is inadequate. Because these areas are usually extremely narrow and linear in character, grazing for only a few days can seriously impair its reproductive capability. It's like having the milk cow get in the garden for one night.

The only way we have been able to ensure adequate protection of our riparian types is by fencing them out from livestock use. This, of course, is coordinated with the livestock management plan to provide for watering places and logical pasture divisions.

We have initiated a riparian fencing program of our key drainages with excellent results. One in Parker Canyon has been fenced for nearly 2 years. The response here has really been encouraging. We have another currently in progress of being fenced which we hope will be equally productive.

Wildlife Conflicts in Riparian Management: Water[1]

Charles E. Kennedy[2]

INTRODUCTION

This paper is a summary of observations of the need for a better understanding of the interactions of stream-riparian-vegetation-energy-nutrients-water production-aquatic life and terrestrial life. Most of the riparian ecosystem interactions have had very little attention in Arizona and New Mexico.

WHAT IS WATER

In its pure form water is a colorless, clear liquid compound of hydrogen and oxygen. Water in the riparian zone is never just H_2O. It is a building block for photosynthesis by riparian and aquatic vegetation. It carries assorted dissolved salts (many of which are nutrients). Water carries dissolved organic matter, fine and coarse particulate organic matter, and supports numerous aquatic life forms, vertebrate and invertebrate, large and small (fish plankton, bacteria, etc.) Water, through the riparian vegetation, supports a wide assortment of interesting and valuable terrestrial wildlife species. Water is an energy source in itself as it forms natural, meandering channels and transports particles, large and small.

ENERGY-RIPARIAN ECOSYSTEM

A number of studies have shown that fish production is much lower where grazing occurs in the riparian zone. For example, in the Rock Creek Floodplain Investigation (Marcuson 1970) there were 63 pounds per acre of brown trout in the heavily grazed area as compared to 213 pounds per acre in the ungrazed area.

Bob Phillips (USFS) and others demonstrated the presence of 31 steelhead in a 100-foot heavily grazed section and 75 steelhead present in a nearby lightly grazed section (personal communication).

[1]Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

[2]Fisheries and Non-Game Biologist, U.S. Forest Service, Albuquerque, New Mexico.

(Fisher 1970) demonstrated that 99% of the annual energy budget for Bear Brook comes from the surrounding forested watershed or from upstream areas. Even in large streams, such as the Missouri River, fifty-four percent of the organic matter ingested by fish is of terrestrial origin (Berner 1951).

(Cummins 1974) diagrammed the fate of heterotrophic stream organic materials (dissolved and particulate) and showed a conceptual model of stream ecosystem structure and function.

(Ensign 1957) found that in Mt. Vernon Creek, southern Wisconsin, where cattle were free to graze the streambanks, terrestrial insects made up only 4% of the annual food of brown trout. In Black Earth Creek (a few kilometers from Mt. Vernon Creek) where streambanks were protected from grazing, terrestrial insects comprised 15% of the annual diet of brown trout.

Thus, we find in the literature that streams are often energy dependent upon the riparian vegetation and the watershed. (Likens and Bormann 1974) have demonstrated the nutrient linkages between streams and watersheds. They state clearly that the key to wise management of aquatic ecosystems is wise management of the watershed.

We can extrapolate these works and assume that many streams in Arizona and New Mexico will also be dependent upon the riparian zone and their associated watersheds for their primary energy sources. But in this area, we have streams which can begin at elevations up to 11,000 feet on Mt. Baldy on the Apache National Forest (where they are comparable to streams in Northern United States or Canada) descend to intermediate elevation where they support warm water species comparable to southern and Midwestern United States streams. Others, purely desert streams, are unique in the United States. Just as Arizona and New Mexico are rich in the number of wildlife species produced in the wide diversity of habitats, Arizona and New Mexico streams are also rich in diversity running the gamet from high altitude, cold, clear, mountain streams, through warm, algae rich mid-elevation reaches, finally to low elevation pure desert reaches. For instance, we have grayling, an arctic fish, in a lake above the Mogollon River; while only 50 miles away there are channel catfish, a warm water species, in the Verde River.

Energy interdependence will follow a similar gradation. The high streams are most likely to be dependent on outside sources of energy for the aquatic organism food base. The mid-elevation streams may have somewhat more ability to capture energy in the stream through algae, diatoms, and rooted vegetation. The low desert streams with riparian vegetation and with tributaries supporting riparian vegetation may fix substantial energies in the aquatic environment, but will also receive substantial inflows of plant detritus during storm flows. (Burns 1977)

We need to develop a stream classification system which incorporates these energy sources as a significant criteria, and we need to study stream energy budgets on typical reaches of several stream types, i.e. cold water, intermediate, and warm water to document the stream-energy system sources and gradations of dependence upon terrestrial sources.

No doubt we will find streams which are largely dependent upon the riparian vegetation for a substantial portion of their organic-energy and partially dependent upon the watershed for dissolved organic matter.

As I said earlier, fish weigh less and are less abundant in grazed portions of streams. Putting this fact with the dependence upon energy from the riparian zone, we can understand that plant material eaten by cattle in the streamside strip will not be available for food for aquatic organisms in the stream. Fish will have less food. I used the term "streamside strip" here because on many miles of our streams in the southwest free choice grazing by cattle has brought about complete type conversions in those immediate areas alongside streams.

After many years (50 to 100 or more) of grazing in this "most palatable area" the old riparian trees have died, seedlings are eaten and killed until only the most "grazing resistent" unpalatable grasses and/or trees remain. This type conversion at higher altitude has eliminated alders and willows, leaving only associated grasses. In the middle elevations the sycamore cottonwood and others are often entirely missing to be replaced by bermuda grass-desert willow-seep willow and at some elevations, tamarisk. Thus, grazing is a significant force in altering streamside composition - just as it is throughout the watersheds.

Actual streamside composition varies from those areas where all of the natural species are gone with no seed sources remaining, to other streams that have a few decadent widely scattered specimens with most species present. Fencing alone will start the stream toward recovery, but plantings of seedlings will be needed on many.

In figure 1 we see only a few remnants of willow and narrowleaf cottonwood. The stream is appropriately called the Rio de las Vacas and is on the Cuba District of the Santa Fe National Forest, at elevations from 7000 to 9000 feet. The loss of shade for the stream, the loss of bird habitat and the premption by cattle of often the only source of green feed is obvious. The loss of energy to the stream is not so obvious. In fact, all too many times little thought has been directed towards learning how energy used by the stream flows through the ecosystem.

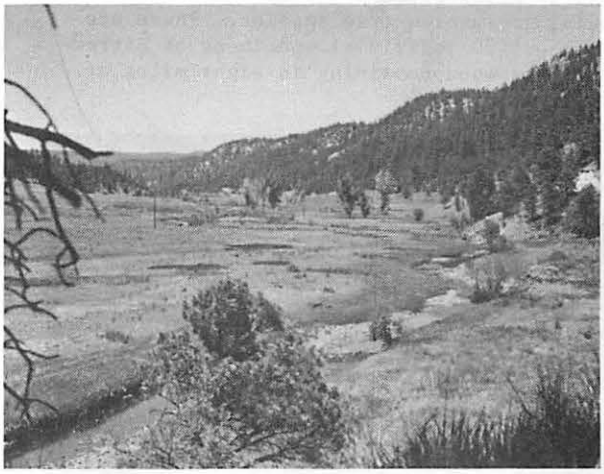


Figure 1

STREAM MORPHOLOGY

Another, more subtle, impact on the fishery occurs when riparian trees are eliminated by continual grazing. The stream is less confined to its banks and will have a more constant sediment load, especially from unvegetated stream banks. Overgrazing in associated watersheds creates higher peak storm flows. Overgrazing combined with hydraulic force of these peak storm flows plus the grazing by cattle on young seedlings keeps many streams in a young, undeveloped and raw condition.

Region 3 of the Forest Service (Arizona and New Mexico) has in National Forest streams approximately 4000 fish habitat improvement structures to make more pools in the miles and miles of flat, shallow streams.

An alternative to these structures and their maintenance is to fence cattle out of the narrow riparian zone so that the streams can progress through successional stages toward more stable conditions. As vegetation and trees become established in the immediate water edge area, the stream will, over time, become more narrow and deeper provided the associated watershed is properly grazed. Grazing levels must provide for suitable vegetative cover to insure soil protection and retard rapid runoff. The number of pools and their suitability for fish habitat will improve. Figures 2 and 3 show an area along a one mile reach of the Rio de las Vacas that has cattle fenced out. Stream profiles, photos, etc., are being established to document changes in stream morphology and riparian composition. Water temperatures in June 1977 reached 70°F. in this area. Narrowleaf cottonwood (Populus angustifolia), Arizona alder (Alnus oblongifolia) and willow (several species) comprise the bulk of the remaining riparian tree species. There are only about 50 individual specimens of narrowleaf cottonwood remaining in eight miles of the stream.

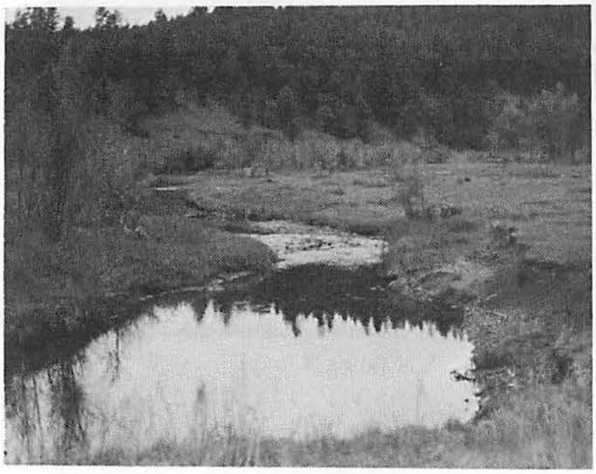


Figure 2

Figure 3 shows the remnants of an old trash catcher type stream improvement structure, entering the water at the arrow. Stones, silt, etc., caught by the fence posts and wire have somewhat constricted the stream making a slightly deeper spot just to the left of the fence. How much better for the fishery, the bird life, the esthetics, and the cattle if the dead trees had survived and reproduced until the roots provided cover, formed a pool and dropped leaves and insects into the stream.

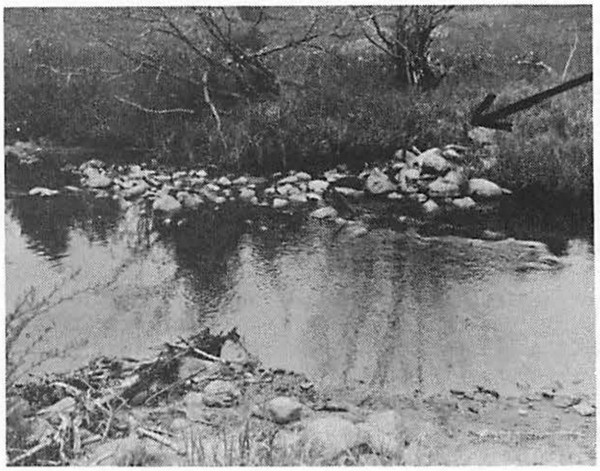


Figure 3

(White and Brynildson 1967) have documented successional stages with drawings which clearly demonstrate the process (see figure 4). Time in these changes will no doubt be faster in Arizona and New Mexico at low elevations with long growing seasons and perhaps slower on the Rio de las Vacas at 8500 feet with a short growing season.

A great deal of research has gone into ways to produce more water on National Forests in Arizona. Much has been written about the evapotranspiration of water by riparian species, native and introduced. There have been no concentrated, integrated efforts to determine which mixture of riparian species might best serve the needs of all resources, the fishery, the bird and wildlife resource, esthetic needs and water production.

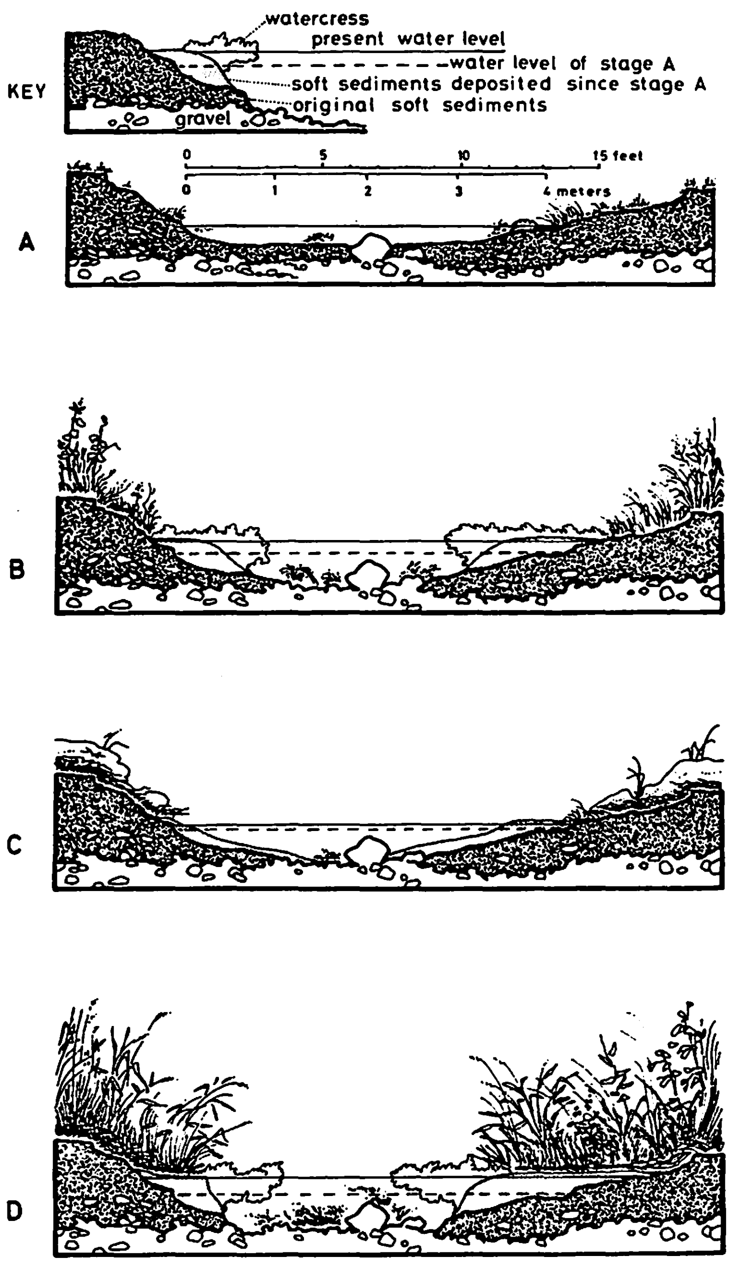
As manipulations are applied to watersheds (chapparal and timber) to produce more water, it will become more important to manage the riparian zone (which in one aspect becomes a water "pipeline") to insure all the intrinsic values while producing the maximum amounts of high quality water for downstream users. It is certain that a vigorous stand of well established riparian trees will produce the amenities we are interested in.

There may be ways to improve tree composition to favor energy flows for the fishery, reduce evapotranspiration for water production, and provide habitat for the bird life and other animal needs for green forage and cover. Perhaps leaves from Arizona walnut transpire less water and are better food for aquatic insects. Maybe the leaves have a higher calorie count - a better mix of nutrients.

Some stages in natural development of a fertile lowland Wisconsin trout stream from overgrazed (A) to very productive (D-E-F) to overforested (G&H) when protected from grazing. A hypothetical 14-foot wide cross-section plus adjacent bank shown.

The complete sequence from stage A to stage E-F has been observed on Black Earth and Mt. Vernon Creeks near Madison.

Later succession — stages G and H with many intermediates — is to be seen on other streams. Details of this succession vary from stream to stream, especially after stage E-F, but the passage from predominantly herbaceous to predominantly woody vegetation generally has the same detrimental effects. Good management for trout — and other wildlife — would be control of vegetation to maintain stages D-E-F.



MIDSUMMER CONDITIONS UNDER HEAVY GRAZING BY LIVESTOCK: Bank vegetation and watercress grazed and trampled. Banks eroding, and stream bed mostly covered by shifting silts. Submergent plants grow poorly. Whole surface of water and stream bed exposed to sun. Greatest depth in cross-section only 9 inches (22 cm). These conditions offer trout no shelter, no place to spawn, little food, and frequently unfavorable temperatures.

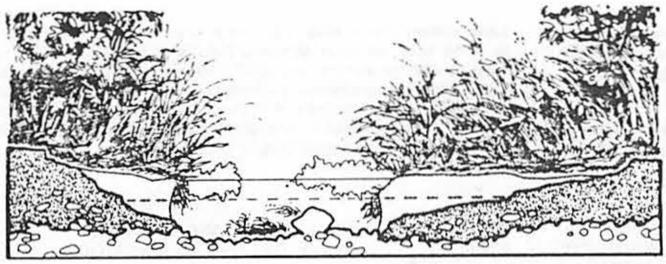
MIDSUMMER CONDITION AFTER 2 TO 4 YEARS OF PROTECTION AGAINST GRAZING: Bank vegetation forming a turf. Abundant watercress at edges of stream constricts channel, thus deepening and speeding water. Soft sediments scoured from much of stream bed and trapped in cress beds. Submergent plants thriving. Only about half the former stream width exposed to sun. Greatest depth about 20 inches (50 cm). Trout have ample shelter beneath watercress, beside rock, and among submergent plants. Firm stream bed and many plants provide substrate for many animals that trout eat. Newly exposed gravel is a place to spawn.

LATE IN THE NEXT WINTER: Watercress has withered and drifted away. The silts it held slump into the channel, smothering many of the trout eggs buried in gravel and preventing fry from emerging into stream. Food is scarce. Broad surface of water exposed to cold. Shelter for trout almost as poor as at stage A and will not redevelop until May or June.

MIDSUMMER CONDITION IN ABOUT 3RD TO 5TH YEAR AFTER GRAZING HALTED: Further scouring of fine sediments from stream bed. Silt bars at stream edges being tied down by reed canary grass with its tough system of roots and runners. Watercress flourishing, and submergents at peak of development. Only 4 feet of stream width exposed to sky, and this shaded much of day by high grasses. Greatest depth in cross-section about 2 feet (60 cm). For trout, shelter, food, and spawning gravels are ample.

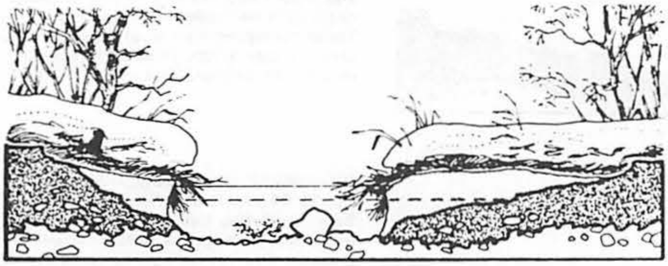
Figure 4

E



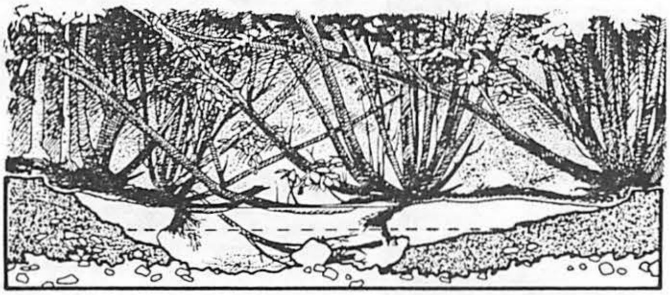
MIDSUMMER A FEW YEARS LATER:
Silt bars further stabilized by turf. Channel narrowed by 40% to 50% since stage A. Only 2 feet of stream width exposed; therefore submergents less abundant. Also less volume of watercress due to shade of taller plants. Woody vegetation starting to dominate.

F



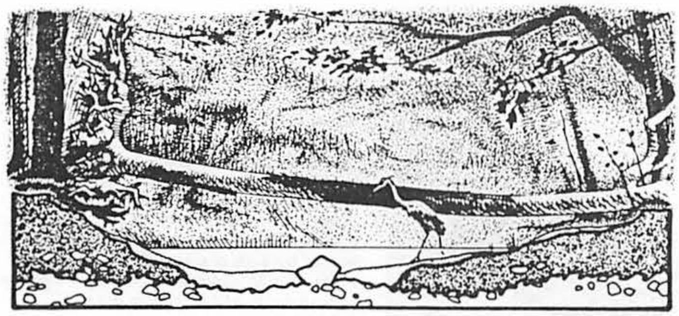
LATE WINTER DURING STAGES D AND E:
Turf still holds bank materials firmly. Overhanging fringes of matted grass provide shelter for trout. Gravels remain clean enough to allow normal hatching and emergence of fry.

G



MIDSUMMER 10 TO 20 YEARS LATER:
Alders or other high bushes predominate (saplings of ash, elm or maple at left). Turf completely shaded out. Water level high due to clogging by debris. For trout, food may be scarce, shelter is excellent beneath banks, among roots and fallen branches.
But:
Innermost rows of alders will soon tip into channel, further clogging flow and destroying overhanging bank. The largely vegetational processes of bank-building will not be repeated as long as shade persists.

H



MANY YEARS LATER:
Mature forest . . . Dense shade. Few plants on forest floor. Banks have eroded, channel has spread and silts again cover stream bed. Channel less than 1 foot deep. Little shelter for trout. Even trees undermined by current and toppled across the stream may provide poor hiding cover. Conditions almost as bad as in stage A.

Figure 4

This example reminds us that there are hundreds of plants which regularly grow in the riparian. We know very little about their intrinsic values and how they interact in a normal, managed (not overgrazed) riparian ecosystem. Certainly a shaded stream with a nearly closed canopy over a narrow, deep stream will produce cool, clear, water and less sediment will reach the reservoirs, extending their lifetime. The fate of many species such as the bald eagle may ultimately depend upon the subtle energy flows needed to produce the fish which the eagles are dependent upon. The fate of several fish like the endangered squawfish and others are also dependent upon a properly functioning riparian ecosystem.

This managed "riparian pipeline ecosystem" will hopefully produce ample quality waters for other downstream uses. The evapotranspiration in the pipeline is not wasted, society needs the products produced.

J. Stokley Ligon wrote 50 years ago, "Cold water fish and fishing streams are as seriously affected by overgrazed watersheds as is game. Not only do the extremes of low and high water, caused by floods and erosion, affect the normal flow and temperature of waters, but the destruction of willows, alders, weeds and grasses eliminates both food and shelter for cold water fish. No experienced angler fishes in sun-exposed streams where the water spreads shallow in unprotected flood-ravished watercourses; he seeks the cool shadows where the alders, willows or conifers overhang the banks, where the stream is narrow and banks with matted roots are secure along New Mexico's cold water streams today. Abuse by overgrazing of watersheds and watercourses, as no other cause, has deteriorated New Mexico's fishing."

The creation or perpetuation of the little winding stream jungles everywhere are a national as well as a state need. The space they occupy, whether on the farm, deep in the creek bottom, canyon course or on overflow lands, has no appreciable value from the standpoint of agriculture or stock raising, but as little jungles they have an intrinsic value. As boys how many of us got our greatest thrills and enjoyment from these little jungles - the jungles we resorted to at every opportunity to follow our dog after rabbits, squirrels or coons, or to hunt quail, fish, or to set our traps for furbearers? The intensity of the job and satisfaction thus derived demands that this little institution, the wasteland jungle, be perpetuated for the American boy and man. These little spaces, properly protected, are the only means of conserving the small game in reclaimed canyons and valleys as commercialism agressively overrides every weakling of Nature that does not have the sympathetic support of organized forces to oppose it."

CONCLUSIONS

1. The fishery resource is often energy dependent upon the riparian vegetation and the watershed.

2. Uncontrolled grazing brings about complete type conversions in the riparian zone and prevents streams from progressing to more stable conditions.

3. Trees and other vegetation in the riparian zone control sediments, provide stream stability and tend to narrow and deepen channel morphology, which benefits the fishery resource.

4. Research is vitally needed to document and study the interactive and intrinsic value of the many plant species in the riparian ecosystem.

5. The fishery, wildlife, esthetic resources, and water quality and quantity are dependent upon these interactions and our efforts to integrate the needs of the various resources. Free choice, uncontrolled grazing is incompatible with these resources.

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Management Alternatives for the Riparian Habitat in the Southwest[1]

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Abstract -- Exploitation, by man, has significantly altered the riparian habitat in the Southwest. For decades, the primary or dominant use of riparian habitat has been water management; other values were not considered. Management alternatives and objectives are evaluated for environmental consequences.

Diversity and numbers of plant and animal species are continually changing through geologic time. Disappearance of some plant and animal species and the emergence of others results from evolutionary processes of natural selection. Plant and animal species are constantly adapting to changing environmental pressures. Fossil records indicate that extinction is the inevitable fate of all species. Continual variation in the physical and biological environment initiate extinction in nature. When an individual species is unable to adapt to changing environmental stresses, it is replaced by others.

Prior to the appearance of Homo sapiens on this planet, extinction occurred as a consequence of natural phenomena. With the advent of humans, an additional stress was exerted on the physical environment. Some data imply that the rate of extinction increased as a result of human stress (Martin, 1967). Human stress on the environment has many forms -- agricultural practices, timber harvesting, domestic animal grazing, industry, hunting, predator control, and pollution. Often it is the interaction of numerous types of stress which results in the extinction of a species.

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The primary causal factors of animal extinction include, but are not limited to: ecosystem alteration, introduction of exotic species, predator and pest control, pollution, poaching, and the capture of wild animals for legitimate and illegal purposes. Ecosystem alteration is one of the more significant causes of extinction. When wildlife niches are altered, animals must move to other areas, adapt to a new environment, or die. Even though some habitats are not totally destroyed, there may not be enough suitable area remaining to maintain a viable population. Habitat destruction is responsible for approximately 30 percent (%) of the presently endangered species (Uetz & Johnson).

Riparian habitat in the Southwest is a classic example of the effect man can exert on a particular habitat. Records of early explorers (Emory, 1948) reveal that riparian communities have been altered significantly from the original type. Significant man-caused impact on the riparian type began approximately 450 years ago, when European man first journeyed into the Southwest from Mexico. Early day grazing undoubtedly had an effect on riparian areas. In the last 100 years, the rate of alteration has increased significantly. This is due largely to ever-increasing human pressures, land clearing for agriculture, dam construction, grazing, pumping of ground and surface water for irrigation, and increased recreational pressures. For decades the primary or dominant use of riparian habitat in the Southwest has been water management; other values were not considered. The dominant use was to supply metropolitan areas with water.

Wildlife populations have adapted to survive in these alterations of the riparian type.

The importance of the riparian type for wildlife has been well documented, particularly for avian species. MacArthur (1964) established a correlation between bird species diversity (BSD) and floral height diversity (FHD). He also reported that habitats with permanent water had higher avian populations than those without. Johnson & Carothers (1975) recorded the highest population of non-colonial nesting birds ever reported in North America in a homogenous cottonwood stand along the Verde River in Arizona. Of the 70 breeding species investigated in the riparian type, 50% were obligate nesting species, 20% indicated a decided preference for the riparian type and 30% nested in either the riparian type or non-riparian without a significant preference for either type (Carothers & Johnson, 1975).

Gavin & Sowls (1975) found 476 pairs of nesting birds per 40 hectares in a mesquite (Prosopis juliflora) bosque in Southern Arizona. The adjacent habitat type was temperate and desert grassland. Balda (1967) found 31 and 46 pairs per 40 hectares (ha.) in the mixed grass and yucca-grassland types in Southern Arizona. Carothers (1974) found 332 pairs/40 hectares (ha.) in the mixed broadleaf type in the Verde Valley in Arizona. Beidleman (1960) and Hering (1957) reported 30 pairs per 40 hectares in the adjacent pinyon-juniper type. Obviously, bird densities are significantly higher in the riparian type than in adjacent communities.

Riparian vegetation enhances aquatic habitats through reduction of solar radiation, reduced erosion, decreased sedimentation, and energy input in the form of vegetational debris and terrestrial insects. Most of the food for important aquatic insects comes from land vegetation. Several studies show that these sources contribute a 50-70% of the energy responsible for producing fish in a stream. (Fisher & Likens, 1973).

Riparian habitats have three basic prerequisites for wildlife: food, water, and cover. The cover component has proportionately more ecotones than any other type. Ecotonal areas are a result of horizontal and vertical stratification of deciduous and evergreen trees, water and hydrophilic plants, and the undulating configuration of the type. Vertebrates that either live or reproduce in water are confined to these zones. Riparian habitats receive proportionately more use per unit area than any other type. A large percentage of terrestrial species known to occur in a given area are either directly dependent on riparian zones or utilize them proportionately more than any other habitat type. In short, the riparian type is the most important habitat type in the Southwest for wildlife.

A substantial volume of literature documenting the importance of the riparian type has been published but some key questions need to be answered prior to initiating a realistic attempt to manage this type.

1. What floristically is a riparian community?

2. Where is it located and what is its ecological condition?

3. What are the ecological factors limiting perpetuation of the community?

4. Is the community maintaining itself through natural reproduction? If not, what are the factors preventing perpetuation?

5. What should our management objectives be for riparian habitat? Water production, habitat for wildlife, water quality, recreation, fuelwood, aesthetics, fisheries, grazing, and agriculture are all potential uses of the riparian type.

6. What is the species composition and age class of a healthy riparian community?

Verbose definitions of what constitutes a riparian type abound in the literature, but, simply stated, it is an aggregation of floral species which depend on a flow of water on or near the surface for subsistence. Riparian habitat occurs in every life zone in Arizona with the possible exception of the Hudsonian. Species composition changes with elevation. Often the climatological conditions prevalent in drainageways allow the downward extension of a higher elevation species such as ponderosa pine (Pinus ponderosa) fingering down a canyon into the Upper Sonoran Life Zone. These inclusions are ecologically important as they provide an additional ecotone within the arid Upper Sonoran Life Zone and should properly be classified as a riparian community.

These riparian communities should be mapped and classified as to type and condition rating. Until we know where they are and what their ecological condition is, we cannot manage them. This should be an integral component of our planning process.

Prior to implementation of any type of management, the most critical need is knowledge of the ecological requirements of individual plant and animal species for self propagation. It is not realistic to believe that we can artifically maintain a vegetative type through perpetuity. Classification of riparian communities and documentation of their condition class will reveal whether or not these communities are maintaining themselves. If not, the next logical step is to carefully determine what are the causal factors. Generally speaking, failure of the riparian type to regenerate itself in Arizona can be related to several factors either operating independently or in conjunction with one another.

1. Loss of water flow as a result of diversions for irrigation, impoundments for metropolitan usage, and lowering of water tables by pumping for sundry uses.

2. Loss of significant portions of entire communities as a result of devestating floods. These periodic floods are significant because they remove substantial numbers of older mature trees which serve as seed sources. Many of the riparian species are adapted to periodic flooding and an occasional flood is necessary for germination and survival of the seedlings, but floods of a significant magnitude are detrimental.

3. In areas of high recreational use, soil compaction, trampling, and inability of the soil to retain moisture prevent seedling establishment. Also, loss of ground vegetation (herbaceous) dries out the site and prevents regeneration of some species.

4. Phreatophyte control essentially eliminates the vegetation, removes the seed source, and changes the micro-site relationships.

5. Overgrazing by domestic livestock, in my opinion, is probably the major factor contributing to the failure of riparian communities to propagate themselves. Continued overuse of riparian bottoms eliminates essentially all reproduction as soon as it becomes established. Overstocking and the consequent loss of vegetative cover on the adjacent watersheds is probably the main reason for the frequency of high intensity floods resulting in drastic changes in the density and composition of riparian bottoms.

An evaluation of a riparian community necessitates making a judgment of whether the type is in good, fair, or poor condition. In the Southwest we are talking about many different species aggregations within the riparian type. Significant research data is needed to answer some of these questions:

a. Should a certain percentage of the vegetation be comprised of a particular species?

b. What should the age class distribution be in a healthy stand?

c. What is an ideal canopy coverage in percent?

d. What should the composition and density of herbaceous vegetation be?

e. Does a particular site have potential to develop a riparian community under proper management?

Research has been initiated here in the Southwest in an attempt to answer some of these questions. During the interim we have developed the following scorecard to use in our evaluations.

RIPARIAN STAND ANALYSIS

This rating of the riparian habitat will be based principally on its attraction to associated wildlife and ecological stability of the type.

The 100-point transect described for browse and the aspen stand analysis will be used. Certain modifications in the technique and score card will make it adaptable for the riparian type. A description of this technique follows:

A. Mapping

Riparian types will be delineated on aerial photographs.

B. Establishing Transects

1. Riparian types to be analyzed will be sampled with paced condition transects.
2. Transect locations will be carefully selected to fall within representative portions of the type.
3. Additional transects will be run in the same stand whenever a change in condition is recognized.
4. Within the stand to be sampled, select a route and pace interval that will

provide a good cross section of the stand. The starting point should be identified and pin pricked on an aerial photo.

5. Pace along the chosen route, walking as straight as practically possible. Along a meandering stream course, cross back and forth across the channel but do not take sample points in the channel.

6. At each sample point, record whatever is found with a 3/4 inch loop immediately in front of a mark on the boot toe. This may be bare ground or erosion pavement, rock, litter, grass, or forb. Grasses and forbs will be identified and tallied by individual species when all or part of the live root crown falls inside the loop. Record as litter if more than one-half of the loop covers dead plant material older than that resulting from current growth. Record hits on rock only for rock in place. Small, loose moving rock should be tallied as erosion pavement.

7. At each sampling point, the examiner will record, by species, the nearest woody riparian plant to the boot toe that occurs within a 180 degree arc in front of the sample point ("hit"). If the species involved can be described in timber terminology as a sprout (less than 4½ feet tall), a sapling (4½ feet tall to 4.9 inches diameter breast height d.b.h.), a pole (5 inches to 8.9 inches dbh), or mature (over 9 inches dbh), it should be tallied as such. If, however, the species involved is mature (at 4 inches dbh), the observer should use his best judgment on where the specimen of that species fits into the above described sale (i.e., if a species is mature at 4 inches dbh and one is "hit" that is 3 inches dbh., it should be tallied as a pole, not as a sapling.) If a dead riparian species is "hit", tally it and then record the size class for the nearest live riparian species. This will result in a transect sample of 100 live riparian species. If a riparian species is a sprout, determine if the sprout has been browsed or not. Dot tally this information on the appropriate column.

8. At each tenth sampling point, obtain the basal area and crown density of all woody species. Crown density will be taken with a spherical densiometer. Count each corner which intersects an opening in the canopy. Each corner represents approximately 6% of the total canopy. Multiply the number of corners which intersect openings by 6 and subtract this figure from 100 for crown density percentage. Basal area will be computed in the following manner: using a 1/100th acre plot (11'9" radius) record the dbh of all woody species at breast height and dot tally into the following size classes. All specimens greater than 12" dbh will be recorded individually by species. Basal area in sq. ft/ acre will be computed by using standard basal area tables.

9. At each tenth sampling point, a 1/100-acre pellet group plot will be run. Include all countable groups for deer, elk, cattle or horses.

C. Composition

"A species" (must be 4 or more) making up 75% or more of the composition. = H

"A species" (must be 2 or more) making up 35% or more of the composition. = M

"A species" comprise less than 35% of the composition or only one "A species" represented. = L

Species Rating - A

Cottonwood	Ash	Mulberry
Sycamore	Willow	
Walnut	Alder	
Hackberry	Elm	
Grape	Box Elder	
Rhus	Oak	

D. Crown Density

Crown density, as utilized in this particular scorecard, serves as a criterion of relative dominance, of potential productivity, of the influence of plants on precipitation interception and soil temperature, and of the value of vegetation to animals. It is applicable to almost all ecosystems, owing to the universal importance of light coming from above.

Crown density will be taken with a spherical densiometer. Count each corner on the grid which intersects an opening in the canopy. Each intersection represents approximately 6% of the total canopy. Multiply the number of intersections which occur in openings in the canopy by 6 and subtract the result from 100 for crown density percentage.

Crown Density Rating Guide

80%-100% = High (H)
50%-80% = Medium (M)
0-50% = Low (L)

E. Basal Area

Basal area refers to a comparison of species as to the aggregate cross-sectional area of the individual plants taken at or near ground level, per unit of land area. Basal area gives a relative indication of dominance and biomass (by species) for the riparian community.

Basal area will be computed utilizing a 1/100th acre plot (11'9" radius) at each tenth sampling point. Record the d.b.h. of all woody species at breast height and dot tally into size classes. All specimens greater than 12" d.b.h. will be measured and recorded individually by species. Conversion factors for all d.b.h. size classes from 0"-12" are included on the scorecard. For those species greater than the 12" d.b.h. use the standard basal area tables included in the handbook.

Basal Area Rating Guide

60 sq. ft/acre or greater = High (H)
30 sq. ft/acre - 60 sq. ft/acre = Medium (M)
0-30 ft. sq/acre = Low (L)

F. Vigor

Vigor is determined by utilizing three (3) criteria: (1) the percentage of "A species" which are sprouts, (2) the percent of "A species" sprouts which have been browsed, (3) the number of "hits" on dead "A species." Summarize data for each measurement, apply to Riparian Vigor Rating Guide and indicate appropriate vigor rating (L-M-H) on the riparian scorecard. (See example below)

Riparian Vigor Rating Guide

Riparian type has at least 10% sprouts/seedlings of "A species"	and	No more than 25% of the sprouts/seedlings are browsed	and	No more than 10 "hits" on dead riparian species
Riparian type has over 5% sprouts/seedlings of "A species"	and	No more than 75% of sprouts/seedlings are browsed	and	No more than 30 "hits" on dead riparian species
Riparian type has less than 5% sprouts/seedlings of "A species"	or	More than of sprouts/seedlings are browsed	or	"Hits" on dead riparian species exceed 30

G. Stand Structure

The age class distribution of "A species" determines the stand structure rating which will be applied to a riparian stand. This rating is based on the percentage of sprouts and saplings in relation to poles and mature "A species". Summarize this percentage and apply to the Riparian Stand Structure Rating Guide and indicate score on Form.

Riparian Stand Structure Rating Guide

All age classes represented with sprouts/seedlings and saplings of "A species" making up 30% or more of the stand. = H

At least 3 age classes represented with sprouts/seedlings and/or saplings of "A species" making up 10% or more of the stand. = M

Less than 3 age classes of "A species" represented with sprouts/seedlings and/or saplings of "A species" making up less than 10% of the stand. = L

The key question that needs to be answered is what should our management objectives be for the riparian habitat? Should the management objective be identical for all the riparian type, or should they be tailored to fit different species aggregations?

The riparian type has many potential uses but our primary objective should be to maintain the type in a healthy ecological condition, a condition which enables natural perpetuation of the community. It should be managed as the most sensitive habitat in the Southwest. This is particularly important because it is an area of maximum potential conflict between resources such as timber, wildlife, grazing, recreation, and water production. Past management has tended to overlook or disregard the intangible or non-economic uses of the community. Public land management agencies, partially as a consequence of public pressures, have had difficulty recognizing uses that are superficially lacking in tangible economic benefits. The dominant use of riparian type has been grazing and water production with little thought given to its value for wildlife and recreation or preservation as a unique community.

In order to evaluate management alternatives, an investigation of potential benefits versus ecological consequences is needed. Multiple use management should not assume that all uses should necessarily occur on the same acre of ground. Typically, management objectives are complicated by a variety of environmental situations and conflicting demands on resources.

If our management objective is to maximize the net gain in usable water, we should treat the upper watersheds and eliminate the riparian vegetation along the stream channel. Heindle (1965) estimated that we were harvesting approximately 5 million acre feet of surface water annually in Arizona, New Mexico and western Texas and predicted this amount could be doubled by treating upper watersheds, eradicating all riparian vegetation, suppressing evaporation from reservoirs, salvaging excessive surface water, diversions, and capturing uncontrolled streamflow.

Predictable amounts of water salvaged as a result of the complete removal of riparian vegetation have not been thoroughly documented. Estimates vary with different studies: Culler (1970) estimated an approximate savings of 0.8 acre/ft. per acre when dense tamarix (Tamarix Pentandra) and mesquite were completely cleared. Bowie and Kam (1968) estimated that complete removal of 22 acres of cottonwood (Populus fremontii), willow (Salix. spp), and seepwillow (Baccharis spp.) would salvage approximately 1.7 acre ft./acre or a savings of 6 percent of the inflow. Converting 15 acres of riparian shrubs and trees to grass in Southern California increased water yield 17 acre feet (1.1 acre ft./acre) in eight months (Rowe, 1963). Average water savings in certain habitat types is approximately 1 to 2 acre ft./acre (Horton & Campbell, 1974).

Control of riparian vegetation for water production appears to be most feasible on flood plains where the water table is between 8 to 20 feet in depth and on upper watersheds above 7,000 feet in moist coniferous sites. Removal of riparian vegetation along perennial streams is probably not economically feasible because evaporation exceeds transpiration (Horton & Campbell, 1974).

Several logical assumptions can be postulated from the aforementioned studies: (1) removal of riparian vegetation increases surface flow but to what degree depends on the species, composition, and density; (2) increases in surface flow are modest because of the attendant increased surface evaporation; (3) re-treatment of the site is necessary as a result of reinvasion. (Campbell, 1970)

Evaluating the data brings to mind an interesting hypothesis. If we assume that water is a natural resource and the demand for water in large metropolitan areas for municipal and industrial uses will increase significantly, the price of water will also increase. If the demand is such that we need to increase our water yields we can accomplish this task and also improve the condition of our riparian habitat if we concentrate our efforts on the upper forested watersheds and the floodplains below 3500 feet with dense stands of mesquite or tamarix.

Dortignac (1965) reported maximum water yields emanate from forested high-elevation watersheds. He estimated that, in the Rio Grande Basin in New Mexico, 32 percent of the total water yield comes from the spruce-fir-aspen forest above 8,000 feet, while 40 percent is derived from the ponderosa pine forest. Horton & Campbell (1974) suggested that phreatophyte control is most effective on floodplains in lower elevations which support a dense stand of phreatophytes.

Riparian habitat that occurs between 7000-3500 feet in elevation has the highest ecological diversity, the greatest value to wildlife, and is the most abused by overgrazing. Increased streamflow through this elevational zone as a result of treatment in the upper watersheds would, if accompanied by reductions in domestic livestock, change some ephemeral streams to perennial, enhance regeneration potential as a result of increased moisture conditions, enhance density and vigor, improve aquatic habitat, and reduce stream temperatures as a result of more shading. Riparian vegetation in this zone, in most cases, is relatively sparse. Increasing the streamflow would increase the density of vegetation with an attendant increase in the amount of water lost through evapotranspiration. However, if this anticipated increase flows into perennial streams with a dense stand of riparian vegetation, no significant increase in evapotranspiration is predicted. (Campbell, 1970)

What would be the consequences of maximizing water yields without mitigating for other resources? The answer must be speculative, but the following results can be visualized:

1) All riparian plants will be temporarily suppressed.

2) Erosion and sedimentation will increase significantly because stream banks will lack vegetation for stabilization.

3) Transpiration losses will be negligible, but evaporation from the soil will increase as a result of higher soil temperatures and shallower water tables.

4) Rate of siltation of downstream reservoirs will increase.

5) Degradation of aquatic habitat will occur as a result of:

a. increased water temperatures

b. loss of energy from vegetational debris

c. loss of niches for aquatic insects

d. increased algae growth

6) Riparian habitat for wildlife will be lost; many species would be completely extirpated.

7) Aesthetic quality would be significantly diminished.

8) Potential recreational opportunities would be eliminated.

9) Potential for torrential type floods will increase.

10) Forage and cover for domestic livestock would be reduced.

What management strategies and alternatives are available if the stated objective is to manage the riparian type for production of domestic livestock? Obviously, the riparian type consists of many different aggregations of species, occurs within many habitat types, and is subjected to numerous management situations. Management strategies must, because of the diversity of the type, be referred to in a general sense. There is no panacea which is applicable to all situations.

Logically, prior to proposing a management strategy we need to know: What are the problems and what are the desired consequences? The problem is that the riparian areas are in poor condition, particularly when their potential productivity is considered. In order to correct a problem, one needs to determine what was/is the cause. Overgrazing by domestic livestock, in my opinion, is the obvious answer. The desired consequence is to create a situation within the riparian type which will support an optimum number of domestic livestock on a sustained basis. This implies maintaining a suitable forage base through perpetuity to support livestock numbers for future generations.

The effect overgrazing has had on the riparian type is twofold: 1) increased potential for devastating floods due to elimination of vegetative cover on adjacent watersheds; 2) removal of herbaceous material and seedlings and/or sprouts of woody riparian in the bottoms. Consequently, the following situation exists:

1) failure of the type to reproduce itself;

2) poor representation of age classes;

3) low vigor;

4) lack of sufficient vegetative cover to prevent erosion;

5) elimination due to channel-scouring floods of older mature trees which constitute critical seed sources;

6) elimination of moist microsites required for reproduction of such species as sycamore (Platanus wrightii);

Proper stocking on adjacent watersheds is needed to reduce both the volume and frequency of flooding. If this cannot be accomplished, efforts to obtain reproduction in the riparian type will not be as effective.

An expedient procedure to rejuvenate riparian stands is to exclude livestock by fencing until reproduction is out of reach. In steep canyons this can be accomplished easily because of restricted accessibility, but in other areas many miles of fence would be required. Riparian species are prolific growers. If conditions are amenable to growth, cotton (Populus spp.), alder (Alnus spp.) and sycamore can grow 10 to 15 feet in several years if protected from grazing.

Once re-establishment has occurred, grazing under a rest-rotation management program accompanied by proper utilization factors, salting and riding can be utilized to maintain the optimum species composition for a sustained yield of domestic livestock.

Anticipated environmental and social consequences of managing the riparian habitat for domestic livestock are:

1) a significant reduction in stocking rates would temporarily have an adverse economic effect on many livestock operators;

2) decreased flooding potential;

3) improvement of terrestrial and aquatic habitats;

4) reduced erosion and sedimentation;

5) improvement in water quality;

6) reduction in water yield;

7) retention of long term site productivity;

8) improved forage production for domestic livestock;

9) enhanced recreational opportunities;

10) increased esthetic quality;

Management of the riparian habitat for wildlife could best be accomplished by the total exclusion of domestic livestock with the exception of water gaps for watering purposes. A theoretical exception whereby periodic grazing would be beneficial would be a marsh area occupied by nesting waterfowl. Dense vegetation along the periphery should be eliminated periodically by grazing to retain a terrestrial herbaceous food source. A logical question as regards a recommendation to exclude livestock would be: Can livestock be prudently utilized to maintain a desirable understory composition? Realistically, the time necessary to restore the riparian habitat to a healthy condition is decades. The potential use of livestock to manipulate vegetation in the riparian habitat may be worthy of consideration in 30 years. Horizontal and vertical stratification, diversity of floral species, and floral volume is needed for optimization of wildlife habitat -- regardless of what is done, this will not be realized for many years.

Environmental consequences of managing riparian habitat for wildlife are essentially the same as listed for managing for livestock with the following exceptions:

1. Adverse economic effect would be permanent, i.e., production of domestic livestock from the riparian type.

2. Forage production for livestock would not improve because they would be excluded.

3. Reduction in water yield would increase.

Management for recreation would utilize the procedures mentioned for wildlife, but access should be provided by trails, campgrounds, etc. Environmental consequences are the same.

Riparian habitat in the Southwest is rapidly dwindling. Land managers need to initiate management to stop the rate of loss and insure the perpetuation of the community.

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Endangered Species vs. Endangered Habitats: A Concept[1]

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Abstract. - Although the great diversity within riparian ecosystems was recognized earlier, their extreme productivity was not discovered until this decade. The highest densities of nesting birds for North America have been reported from Southwest cottonwood riparian forests. Complete loss of riverine habitat in the Southwest lowlands could result in extirpation of 47 percent of the 166 species of birds which nest in this region.

INTRODUCTION

Since 1600 more than 120 bird and mammal species have become extinct while more than 300 are now threatened (Fisher et al. 1969). In addition, dozens of fishes, amphibians and reptiles have become extinct or are endangered to say nothing of invertebrate species. Habitat disruption and destruction have been a major cause of extinction. Only 24 percent of the birds and 25 percent of the mammals became extinct through natural causes. Of the 76 percent of the birds and 75 percent of the mammals which died from human related causes, well over half have been through indirect means, such as introduction of exotic speices and habitat disruption (Fisher et al. 1969 and IUCN Red Data Books issued periodically).

In an attempt to reduce the numbers of species which will soon become extinct, several steps have been taken. A major step involves the formation of recovery teams, comprised of authorities on a given species, such as the Bald Eagle. The activities of these teams have apparently been beneficial in slowing down rates of loss in wildlife species. However, the efforts of recovery teams cannot possibly prevent continued extirpation if we continue to disrupt habitat through activities such as overgrazing, urbanization, "modern, clean" agricultural practices, dam construction and channelization. Continued research is needed to provide answers to questions posed by management regarding means through which critical wildlife habitat may be preserved.

DISCUSSION

Extirpation

The extirpation of wild animal species has been a cause for concern for decades. People only mildly interested in conservation can bring to mind the examples of the Passenger Pigeon (Ectopistes migratorius - extinct 1914), the Carolina Parakeet (Conuropsis carolinensis- extinct 1914), the Dodo (Raphus cucullatus- extinct 1681) and the Great Auk (Pinguinus impennis - extinct 1844). Dates for extinction are from Pettingill (1970) and Van Tyne and Berger (1971). An entire book has been written about the Passenger Pigeon (Schoerger 1955) and people are still trying to find out whether or not the Ivory-billed Woodpecker (Campephilus principalis) is now extinct. Several recent books have been written appealing to citizens of the world to help save these rapidly diminishing species (Greenway 1958, Fisher et al. 1969, Prince Phillip and Fisher 1970, Simon and Geroudet 1970, Tylinek and Ullrich 1972, and Ziswiler 1967). Information from the International Union for Conservation of Nature and Natural Resources (I.U.C.N.) Red Data Books (issued periodically) presents a dismal picture (Table 1).

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1 Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

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Table 1.--A history of species' extirpation. (adapted from I.U.C.N. Red Data Books)

Date	Number of extinctions	Direct[1]	Indirect[2]
1600s	21	86%	14%
1700s	36	84%	16%
1800s	84	24%	76%
1900-1974	85	28%	72%

[1] Direct = Hunting for food or commercial causes.
[2] Indirect = Habitat disruption, introduction of exotics, etc.

Attempts to Prevent Extinctions

The concern over the increasing numbers of species being exterminated in the United States caused the U.S. Fish and Wildlife Service to begin work on classification of "threatened" wildlife in the early 1960's. The 1st edition of the "Redbook" was issued in July 1966. We use the words "threatened" and "endangered" in an unofficial sense (see U.S. Fish and Wildlife Service 1973 for official definition). Endangered species are assigned in the United States according to the Endangered Species Conservation Act of 1969 and listed periodically in the U.S. Federal Register by the U.S. Fish and Wildlife Service. It is not our intent to go into great depth regarding endangered speices programs. The forementioned I.U.C.N., U.S. Fish and Wildlife Service and others (e.g. American Committee on International Wildlife Protection, National Audubon Society and World Wildlife Fund) publish periodic information on endangered wildlife (e.g. Arbib 1976). Other governmental agencies besides the U.S. Fish and Wildlife Service publish information regarding endangered wildlife (Arizona Game and Fish Department 1977[4], Behnke and Zarn 1976, U.S. Forest Service 1975, U.S. National Park Service 1974). Symposia are held periodically focusing on general problems of endangered wildlife (New Mexico Game and Fish Department 1972) or even devoted to a single species such as the Peregrine Falcon (*Falco peregrinus*) (Hickey 1969) or the Red-cockaded Woodpecker (*Dendrocopos borealis*) (Thompson 1971). Periodically, reports are issued on endangered species such as the Southern Bald Eagle (U.S. Fish and Wildlife Service 1976). Recovery teams to address the problem of impending extinction have been set up by the U.S. Fish and Wildlife Service for many species of endangered wildlife. For example, several avian species are now being raised by methods of direct intervention such as egg manipulation (Zimmerman 1976). In addition, several agencies are now involved in establishing endangered plant lists.

In addition to teams concerned with the protection of terrestrial wildlife, such as the Peregrine Falcon and Southern Bald Eagle, other recovery teams have been organized to focus on one or more fish species. Recently, however (Johnson[5]) the U.S. Fish and Wildlife Service has designated teams which focus on river systems instead of individual species, e.g. the Colorado River Fishes Recovery Team. This approach has been advocated for years by many of us who have seen the wholesale extermination of species in certain areas as a result of habitat destruction. Nowhere is this chain of destruction more certain than in riverine ecosystems. This has long been recognized by ichthyologists such as Deacon and Minckley (1974), Holden and Stalnaker (1975), Minckley and Deacon (1968) and Sigler and Miller (1963).

Glen Canyon Dam: An Example

The construction of Glen Canyon Dam on the Colorado River above Grand Canyon is an outstanding example of habitat modification. The effect on the aquatic ecosystem has been devastating. The original heavy silt burden which rendered the Colorado River "too thick to drink and too thin to plow" is dropped in Lake Powell before the water enters Grand Canyon. The river waters are now clear. The reddish color for which the Colorado was named can be seen only after flooding from tributaries which enter below the dam. This has created an entirely new riverine ecosystem (Carothers et al. in press, Dolan et al. 1974 and in press, Johnson and Martin 1976,and Laursen and Silverston 1976). The management implications are staggering. On one hand, a new riparian ecosystem has developed, protected from the scouring and siltation of pre-dam floods. On the other hand this white water river has been converted from a stream which was warm in the summer and cold in the winter to a relatively constant 9-10°C (48-50°F) along most of its length. The only insect family recorded using these cold waters are Chironomid midges (Stevens 1976) while the

[4] Arizona Game and Fish Department. 1977. Endangered and threatened species in Arizona; 3 p. memo

[5] Johnson, J. Paper presented at New Mexico-Arizona section meeting, the Wildlife Society, Farmington, N.M., Feb 5, 1977.

small crustacean, Gammarus lucustris, abounds. The cold, clear water is conducive to the rapid growth of exotic species such as rainbow trout, which commonly reach lengths of more than 2 feet and weigh over 5 pounds (personal observation). While exotic fish flourish, our native species are declining. In the 277 miles of the Colorado River in Grand Canyon National Park several species listed in Fishes of Arizona (W. Minckley 1973 and pers. comm.) occur either in low numbers, or cannot be found at all, e.g. the Humpback Chub (Gila cypha), Bonytail Chub (G. elegans), Colorado Squawfish (Ptychocheilus lucius) and Razorback Sucker (Xyrauchen texanus) (Johnson 1977, C. Minckley and Blinn 1976, Miller 1975[6], and Suttkus et al. 1976).

Endangered Species and Related Acts

When the Endangered Species Act of 1973 (PL #93-205) was passed it was hoped by many of us concerned about extirpation of wildlife that this might prevent further wholesale extinctions through degradation of habitat. It seemed that the Endangered Species Act combined with the National Environmental Policy Act of 1969 (PL #91-190) should slow down direct extermination as well as massive destruction of the type that has converted nearly all southwestern rivers to poor or impossible habitat for most native species. Just how effective these laws will be remains to be seen. Legal decisions involving the case of the Tennessee Valley's Tellico Dam on the Little Tennessee River vs. the Snail Darter (Percina tanasi) may have important implications regarding the future interpretation of Section 7 of the Endangered Species Act, including possible amendation by congress (Holden 1977).

It seems inevitable that riverine ecosystems will become the battleground for those advocating the "progress of civilizing processes," e.g. hydroelectric and irrigation projects. Economic interests oppose those who advocate saving a few rivers to protect associated wildlife and recreational values and perhaps, "just to let them run."

The two forementioned acts coupled with the Wild and Scenic Rivers Act of 1968 (PL #90-542) would seem to be sufficient to reduce further decimation of river ecosystems. However, it is a difficult, uphill battle. Prevention of the use of streams for waste disposal is gradually becoming an accepted philosophy. Conversely, industrial, domestic and irrigation demands for water for a growing population continue to escalate.

6 Miller, R.R. 1975. Report on fishes of the Colorado River drainage between Lees Ferry and Surprise Canyon, Arizona. Unpublished Grand Canyon Natl. Park Res. Rpt. 6 p.

Major Causes of Habitat Loss

The impact of dams on aquatic ecosystems has long been understood by biologists even if ignored by dam builders and water users. The area above the dam is converted into a lake, rapidly filling with sediment. The area below the dam too commonly becomes a dry stream bed, as is the situation with most of the Salt and Gila River dams of the Lower Colorado River drainage. Neither habitat is conducive to most of the pre-dam riverine plants or wildlife. Other rivers are greatly reduced in volume by practices such as pumping of underground water which dries up spring sources, or by modification of runoff patterns through overgrazing. The latter often results in the development of vegetation types which demand more water than the original vegetation. The area may be denuded, resulting in flash floods followed by quick drying up of streams rather than a slower, steady runoff. The effects of such practices on native fishes have been well documented (Minckley and Deacon 1968). However, we have only recently begun to understand the impacts on riparian ecosystems.

Recent work by various investigators (Boster and Davis 1972, Clary et al. 1974, and Hibbert et al. 1974) advocates the conversion of shrub types, commonly resulting from overgrazing, to grassland. This conversion to grassland usually results in increased water yield which, in turn, often results in an increase in acreage of riparian vegetation (personal observation, Sierra Ancha and Three Bar watersheds).

Some investigators propose large scale "phreatophyte control" projects as well as the conversion of shrub types to grassland (see Ffolliott and Thorud 1974 for discussion). These "water salvage" projects are often advocated even at the expense of both game and nongame wildlife values. Earlier work commonly featured "pure" scientists as well as "applied" scientists, all concentrating on single purpose management of watersheds and their runoff for man, his farms and cattle (Barr 1956, Duisberg 1957, and Warnock and Gardner 1960). In recent years there has been a gradual trend toward multiple use of this critical resource, water (Horton and Campbell 1974). The Arizona Annual Watershed Symposia reflect this change in philosophy (Arizona Water Commission; annually) placing increasing emphasis on wildlife values, recreation and even aesthetics (Arizona Water Commission 1972).

Riparian Exploration, Development and Research

It seems incredible that man would so badly mistreat riverine ecosystems. We have used them for exploratory routes, fur trapping, temporary settlements and forts, agricultural land and cities. Finally, we have dammed them up, dried them up, and turned them into sewers and garbage disposals.

Early explorers commonly were army officers, geologists, engineers or "soldiers of fortune" who left incomplete to poor records regarding the riparian habitat. This is true throughout the Southwest. Thus, early notes from rivers such as the Gila (Emory 1858) and even the mighty Colorado (Powell 1961) often mention vegetation and wildlife only in general terms. We do not even have good species' lists for the pre-dam ecosystems, much less information on population densities or other more sophisticated data. Even as late as the 1950's (Woodbury et al. 1959) scientists gathered information regarding the area to be inundated by Lake Powell, above Glen Canyon Dam. However, the more than 250 miles of river between Glen Canyon Dam site and the upper reaches of Lake Mead, which were also to be heavily impacted by the dam, were totally ignored.

Riverine environments, including their riparian ecosystems, have been ignored by biologists as well as geologists, explorers and laymen for many reasons. Riparian ecosystems have several characteristics which make them interesting but involved, difficult systems to study. Riparian habitat may be considered an ecotone between the aquatic habitat of the stream itself and the surrounding terrestrial habitat. As such, the riparian ecosystem contains elements of both the aquatic and terrestrial ecosystems plus retaining unique characteristics found in none of the other ecosystems exemplifying the edge effect. The concept of the edge effect is relatively new. Earlier treatises did not even mention this phenomenon and it was not until the mid-1900s that ecology texts, e.g. Allee et al. (1949) contained a discussion of the edge effect. Odum (1959) defines the edge effect as "the tendency for increased variety and density at community junctions."

Ornithologists and birders have long recognized the importance of riparian habitats to birds. We chose at random 20 inland Christmas Bird Counts for 1974 (National Audubon Society 1975). Nineteen (95%) of the 20 contained streamside and/or lake side vegetation. The large number of species utilizing riparian woodland has been documented by numerous studies (Carothers and Johnson 1975b). In California, Miller (1951) emphasized the importance of riparian avifaunas, stating "the number of species of birds associated with riparian woodland is larger than that of any other formation." However, the extremely high densities of riparian avian populations was not recognized until this decade (Carothers et al. 1974, Carothers and Johnson 1971 and 1975b, Gaines 1974, Johnson 1970, O'Brien et al. 1976, and Table 2).

The ecological analysis of riparian birds is complicated at best. Studies are further complicated by recent changes, some of which are related to man's activities and others which may be operating independently of man. One cannot help postulating however, that nearly all of the recorded recent changes are due to man's activities. For example, there are records for the arrival of several species of birds which have moved into Arizona as breeding species within historic times. This includes the Mississippi Kite, Inca Dove, Thick-billed Kingbird, Starling, House Sparrow, Great-tailed Grackle and Bronzed Cowbird. The Starling and House Sparrow are European introductions. The Inca Dove, Great-tailed Grackle and Bronzed Cowbird are closely associated with man and his animals. Their movements are discussed by Phillips et al. (1964) and Phillips (1968). Other cases are not as clear but may have profound effects on the native avifauna. The subtleness with which human activity may affect the natural ecosystem can be shown through a discussion of the Brown-headed Cowbird. Phillips (1968) discusses at length the historic expansion of range by Brown-headed Cowbirds. Of the 33 species of Southwestern lowland birds listed by Friedmann (1929) as hosts to the Brown-headed Cowbird, 22 (2/3) are obligate or preferential riparian nesting species. The role of these brood parasites in reducing populations of riparian birds in the Sacramento Valley, California, is discussed by Gaines (1974). Thus, Brown-headed Cowbirds may be suspected of causing problems in Arizona and other southwestern areas similar to those reported for California.

SUMMARY AND CONCLUSIONS

During our recent analysis of the dependency of the breeding avifauna of the Southwest lowlands on water related habitat (Table 3), we discovered some sobering facts. 166 species of nesting birds were analyzed from southern Arizona, southern New Mexico and west Texas, south through the lower

Table 2. -- A comparision of breeding bird densities in selected habitats. (After Carothers and Johnson 1975b).

Habitat Type (Community)	Locality	Authority	Breeding Bird Density Males or Estimated Pairs/40 ha [or 100 acres] nonriparian	riparian
Boreal Forest[1]				
Spruce-Alpine Fir	Arizona	Carothers et al. (1973)	178	-
Temperate Forest				
Spruce-Douglas Fir	Arizona	Balda (1967)	380	-
Ponderosa Pine	Arizona	Balda (1967)	336	-
Ponderosa Pine	Arizona	Haldeman et al. (1973)	232	-
Mature Deciduous	West Virginia	Audubon F.N. (1948)	724 [2]	-
Virgin Spruce	West Virginia	Audubon F.N. (1948)	762 [2]	-
Forest Bird Sanctuary	Germany	Bruns (1955)	5600 [2]	-
Relict Conifer Forest				
Cypress post climax	Arizona	Johnston and Carothers (1975)	93	-
Riparian Deciduous Forest				
Mixed Broadleaf	Arizona	Balda (1967)	-	304
Mixed Broadleaf	Arizona	Carothers et al. (1974)	-	332
Cottonwood	Arizona	Carothers et al. (1974)	-	847
Cottonwood	Arizona	Ohmart (no date)	-	683
Flood-plain Deciduous	Illinois	Fawver (1947)	-	216 [2]
Temperate Woodland				
Pinyon-Juniper	Arizona	Hering (1957)	33	-
Pinyon-Juniper	Arizona	Beidleman (1960)	30	-
Encinal	Arizona	Balda (1967)	224	-
Subtropical Woodland				
Mesquite Bosque (riparian)	Arizona	Gavin and Sowls (1975)	-	476 [3]
Mesquite	Arizona	Ohmart (no date) [5]	236	-
Grassland				
Temperate Grassland	Arizona	Balda (1967)	64	-
Tropical Grassland	Tanganyika	Winterbottom (1947)	4000 [2]	-
Desert Grassland				
Yucca/Grassland	Arizona	Balda (1967)	31	-
Chihuahuan Desert Scrub				
Creosotebush	New Mexico	Raitt and Maze (1968)	8.5-17.7	-
Sonoran Desert Scrub				
Paloverde/Sahuaro	Arizona	Tomoff(1974 & pers.comm.)	105-150	-
Temperate Marshland				
Cattail Marsh	Arizona	Carothers and Johnson (1975b)	-	175-176
Cultivated, Urban and Suburban Lands				
Park (zoological garden)	Germany	Steinbacher (1942)	1170 [2]	-
Bird Sanctuary (Whipsnade)	England	Huxley (1936)	5800 [2]	-
Urban	Arizona	Emlen (1976)	1230 [2]	-
Cottonwood	Arizona	Carothers and Johnson(1975a)	-	605.2 [4]

1 Arizona vegetation types after Brown and Lowe (1974).

2 Density given in number of adult birds per 40 hectares (100 acres) instead of males or nesting pairs (after Welty 1962).

3 Average density for April and May, the height of breeding activity in the mesquite bosque.

4 Riparian cottonwood habitat disturbed by urbanization. Two years prior, when the habitat was undisturbed, the density was 1058.8 pairs/100 acres.

5 Ohmart, R.D. and N. Stamp. No date. Final report on the field studies of the nongame birds and small mammals of the proposed Orme Dam site. Bur. of Recl. Proj., Boulder City, Ariz. 54 ms. p.

Table 3. -- Nesting birds of the Southwest Lowlands (Modified from Haight and Johnson 1977)[1]

WETLANDS (2%)

1. Clapper Rail *Rallus longirostris*
2. Black Rail *Laterallus jamaicensis*
3. American Avocet *Recurvirostra americana*
4. Snowy Plover *Charadrius alexandrinus*

WETLANDS AND OBLIGATE RIPARIAN (19%)

1. Least Grebe *Podiceps dominicus*
2. Pied-billed Grebe *Podilymbus podiceps*
3. Double-crested Cormorant *Phalacrocorax auritus*
4. Olivaceous Cormorant *Phalacrocorax olivaceus*
5. Great Blue Heron *Ardea herodias*
6. Green Heron *Butorides striatus*
7. Great Egret *Casmerodius albus*
8. Snowy Egret *Egreta thula*
9. Black-crowned Night Heron *Nycticorax nycticorax*
10. Least Bittern *Ixobrychus exilis*
11. Black-bellied Whistling-Duck *Dendrocygna autumnalis*
12. Mallard *Anas platyrhynchos*
13. Mexican Duck *Anas diazi*
14. Gadwall *Anas strepera*
15. Blue-winged Teal *Anas discors*
16. Cinnamon Teal *Anas cyanoptera*
17. Redhead *Aythya americana*
18. Ruddy Duck *Oxyura jamaicensis*
19. Osprey *Pandion haliaetus*
20. Virginia Rail *Rallus limicola*
21. Sora *Porzana carolina*
22. Common Gallinule *Gallinula chloropus*
23. American Coot *Fulica americana*
24. Black-necked Stilt *Himantopus mexicanus*
25. Killdeer *Charadrius vociferus*
26. Long-billed Marsh Wren *Cistothorus palustris*
27. Common Yellowthroat *Geothlypis trichas*
28. Yellow-breasted Chat *Icteria virens*
29. Yellow-headed Blackbird *Xanthocephalus xanthocephalus*
30. Red-winged Blackbird *Agelaius phoeniceus*
31. Song Sparrow *Melospiza melodia*

OBLIGATE RIPARIAN (26%)

1. Common Merganser *Mergus merganser*
2. Mississippi Kite *Ictinia mississippiensis*
3. Cooper's Hawk *Accipiter cooperii*
4. Zone-tailed Hawk *Buteo albonotatus*
5. Gray Hawk *Buteo nitidus*
6. Common Black Hawk *Buteogallus anthracinus*
7. Bald Eagle *Haliaeetus leucocephalus*
8. Spotted Sandpiper *Actitis macularia*
9. Red-billed Pigeon *Columba flavirostris*
10. Yellow-billed Cuckoo *Coccyzus americanus*
11. Violet-crowned Hummingbird *Amazilia verticalis*
12. Buff-bellied Hummingbird *Amazilia yucatanensis*
13. Broad-billed Hummingbird *Cynanthus latirostris*
14. Green Kingfisher *Chloroceryle americana*
15. Red-shafted Flicker *Colaptes auratus cafer*
16. Rose-throated Becard *Platypsaris aglaiae*
17. Tropical Kingbird *Tyrannus melancholicus*
18. Thick-billed Kingbird *Tyrannus crassirostris*
19. Kiskadee Flycatcher *Pitangus sulphuratus*
20. Black Phoebe *Sayornis nigricans*
21. Willow Flycatcher *Empidonax traillii*
22. Western Wood Pewee *Contopus sordidulus*
23. Vermilion Flycatcher *Pyrocephalus rubinus*
24. Northern Beardless Flycatcher *Camptostoma imberbe*
25. Bank Swallow *Riparia riparia*
26. Cliff Swallow *Petrochelidon pyrrhonota*
27. Bridled Titmouse *Parus wollweberi*
28. White-breasted Nuthatch *Sitta carolinensis*
29. Bewick's Wren *Thryomanes bewickii*
30. American Robin *Turdus migratorius*
31. Bell's Vireo *Vireo bellii*
32. Yellow-green Vireo *Vireo flavoviridis*
33. Tropical Parula *Parula pitiayumi*
34. Yellow Warbler *Dendroica petechia*
35. Hooded Oriole *Icterus cucullatus*
36. Northern Oriole *Icterus galbula*
37. Bronzed Cowbird *Molothrus aeneus*
38. Summer Tanager *Piranga rubra*
39. Blue Grosbeak *Guiraca caerulea*
40. Painted Bunting *Passerina ciris*
41. White-collared Seedeater *Sporophila torqueola*
42. Lesser Goldfinch *Carduelis psaltria*
43. Albert's Towhee *Pipilo aberti*

PREFERENTIAL RIPARIAN (26%)

1. Peregrine Falcon *Falco peregrinus*
2. American Kestrel *Falco sparverius*
3. Gambel's Quail *Lophortyx gambelii*
4. White-winged Dove *Zenaida asiatica*
5. Mourning Dove *Zenaida macroura*
6. Common Ground Dove *Columbina passerina*
7. White-fronted Dove *Leptotila verreauxi*
8. Greater Roadrunner *Geococcyx californianus*
9. Groove-billed Ani *Crotophaga sulcirostris*
10. Barn Owl *Tyto alba*
11. Common Screech Owl *Otus asio*
12. Ferruginous Pygmy Owl *Glaucidium brasilianum*
13. Lesser Nighthawk *Chordeiles acutipennis*
14. Black-chinned Hummingbird *Archilochus alexandri*
15. Anna's Hummingbird *Calypte anna*
16. Gila Woodpecker *Melanerpes uropygialis*
17. Golden-fronted Woodpecker *Melanerpes aurifrons*
18. Ladder-backed Woodpecker *Picoides scalaris*
19. Western Kingbird *Tyrannus verticalis*
20. Cassin's Kingbird *Tyrannus vociferans*
21. Wied's Crested Flycatcher *Myiarchus tyrannulus*
22. Ash-throated Flycatcher *Myiarchus cinerascens*
23. Rough-winged Swallow *Stelgidopteryx ruficollis*
24. Green Jay *Cyanocorax yncas*
25. Common Raven *Corvus corax*
26. Verdin *Auriparus flaviceps*
27. Northern Mockingbird *Mimus polyglottos*
28. Long-billed Thrasher *Toxostoma longirostre*

29. Curve-billed Thrasher *Toxostoma curvirostre*
30. Crissal Thrasher *Toxostoma dorsale*
31. Black-tailed Gnatcatcher *Polioptila melanura*
32. Phainopepla *Phainopepla nitens*
33. Common Starling *Sturnus vulgaris*
34. Lucy's Warbler *Vermivora luciae*
35. Lichtenstein's Oriole *Icterus gularis*
36. Brown-headed Cowbird *Molothrus ater*
37. Cardinal *Cardinalis cardinalis*
38. Pyrrhuloxia *Cardinalis sinuata*
39. Indigo Bunting *Passerina cyanea*
40. Lazuli Bunting *Passerina amoena*
41. House Finch *Carpodacus mexicanus*
42. Olive Sparrow *Arremonops rufivirgatus*
43. Rufous-winged Sparrow *Aimophila carpalis*

SUBURBAN AND AGRICULTURAL (4%)

1. Black Vulture *Coragyps atratus*
2. Rock Dove *Columba livia*
3. Inca Dove *Scardafella inca*
4. Barn Swallow *Hirundo rustica*
5. House Sparrow *Passer domesticus*
6. Great-tailed Grackle *Quiscalus mexicanus*

NON-RIPARIAN (23%)

1. Turkey Vulture *Cathartes aura*
2. Red-tailed Hawk *Buteo jamaicensis*
3. Swainson's Hawk *Buteo swainsoni*
4. Ferruginous Hawk *Buteo regalis*
5. Harris' Hawk *Parabuteo unicinctus*
6. Caracara *Caracara cheriway*
7. Prairie Falcon *Falco mexicanus*
8. Common Bobwhite *Colinus virginianus*
9. Scaled Quail *Callipepla squamata*
10. Great Horned Owl *Bubo virginianus*
11. Elf Owl *Micrathene whitneyi*
12. Burrowing Owl *Athene cunicularia*
13. Long-eared Owl *Asio otus*
14. Poor-will *Phalaenoptilus nuttallii*
15. Pauraque *Nyctidromus albicollis*
16. White-throated Swift *Aeronautes saxatalis*
17. Lucifer Hummingbird *Calothorax lucifer*
18. Costa's Hummingbird *Calypte costae*
19. Gilded Flicker *Colaptes auratus chrysoides*
20. Say's Phoebe *Sayornis saya*
21. Horned Lark *Eremophila alpestris*
22. Purple Martin *Progne subis*
23. White-necked Raven *Corvus cryptoleucus*
24. Cactus Wren *Campylorhynchus brunneicapillus*
25. Canyon Wren *Catherpes mexicanus*
26. Rock Wren *Salpinctes obsoletus*
27. Bendire's Thrasher *Toxostoma bendirei*
28. LeConte's Thrasher *Toxostoma lecontei*
29. Loggerhead Shrike *Lanius ludovicianus*
30. Eastern Meadowlark *Sturnella magna*
31. Western Meadowlark *Sturnella neglecta*
32. Scott's Oriole *Icterus parisorum*
33. Varied Bunting *Passerina versicolor*
34. Brown Towhee *Pipilo fuscus*
35. Grasshopper Sparrow *Ammodramus savannarum*
36. Lark Sparrow *Chondestes grammacus*
37. Rufous-crowned Sparrow *Aimophila ruficeps*
38. Cassin's Sparrow *Aimophila cassinii*
39. Black-throated Sparrow *Amphispiza bilineata*

166 Total

(Information from A.O.U. 1958, Bailey 1928, Bent-various dates, Hubbard 1970 and 1971, Johnson et al. 1973[2], Johnson et al.-manuscript[3], Monson and Phillips 1964, Monson-personal communications, Oberholser 1974, Phillips et al. 1964, Rea 1977, Todd 1975 and undated, Wauer 1973, and Wolfe 1956)

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Rio Grande Valley. Habitats up through desert grasslands were considered, stopping at the lower edge of woodland and forests. 127 (or 77%) of the 166 nesting species were in some manner dependent on water related habitat. Of this 77% dependent on water related habitat well over half, 84 of the 166 species, are completely dependent on water related habitat. Only 39 species are non riparian nesting birds. Thus, if water dependent habitats were completely destroyed in the Southwest (not including suburban and agricultural) we could completely lose 47% of our lowland nesting birds while only 23% of our lowland nesting species would probably not be affected. 43 (26%) of the 166 species would be partially affected. Granted, several of the species which are preferential riparian at lower elevations, such as the Western and Cassin's Kingbirds, extensively use non riparian habitat at higher elevations. Still, the overall populations of these species would diminish with the reduction or loss of riparian habitat at lower elevations. In a dissertation on "Historic Changes in the Avifauna of the Gila Indian Reservation," near Phoenix, Rea (1977) uncovered the following information. Through the use of archaeological, ethnographic and historic sources he found that 101 species breed or have bred on the reservation with 5 more species that probably bred and 7 species that could have bred, based on biogeographic distributions. During the past 100 years, 22 breeding species were extirpated of which 18 were related to the former riverine ecosystem. Six speices of non-nesting birds dependent on the Gila River, now dry, are also gone. At least 13 species have recently recolonized the area as a result of reestablishment of a depauparate form of the original riparian habitat. This newly established habitat has developed as a result of the use of the Salt and Gila Rivers for disposal of effluent from the Phoenix sewage treatment plants.

Others, e.g. Hubbard (1972) have pointed out the lack of attention given to song birds when designating threatened and endangered species. However, to our knowledge, ours is the first attempt to quantify the number of species threatened or endangered by practices which greatly modify or destroy riparian habitat.

Some proponents of water salvage projects have pointed out that many breeding species of the Southwest lowlands are at the northern limits of their range. This, of course, is an attempt to justify phreatophyte control, channelization, dam construction, grazing and other practices which reduce riparian vegetation and consequently riparian wildlife. The main populations are found in Mexico for a large percentage of the birds that also occur in the Southwest lowlands. Thus, it is argued, even complete loss of riparian and marshy habitat should cause no great problem at the total population level for that species. No argument could be further from the truth. The destruction of riparian habitat in northern Mexico is progressing at an alarming rate. One need but drive a few hundred miles south from the United States-Mexico border to observe the frantic rate at which Mexicans are draining their streams and clearing riparian forests and woodlands in an attempt to feed a rapidly expanding population. One reads with nostalgia Sutton's book, "At a Bend in a Mexican River" (1972). His accounts from travels in Mexico only four decades ago tell of ferrying across rivers such as the Rio Purificacion and of the lush growth in the Valley of the Rio Corona. The riparian groves along these rivers are being cut at a rapid rate to make room for houses and fields. Rivers throughout Mexico as well as the United States are being dammed to provide water for municipal and industrial use and for large irrigation projects.

Thus, the same basic stages of "development of natural resources" which took place in the United States during two centuries promise to occur in Mexico in a matter of decades. When adding the available improved technology to Mexico's great wealth of natural resources, synergism may result. This may effect an even greater cummulative ecological disaster in a much shorter period of time than we have experienced in riverine ecosystems in the United States. Thus, when evaluating the ecological health of riparian species we must approach the problem from the standpoint of a systems analyst. One may start with his or her area of responsibility whether it be a few yards of small stream or several hundred miles of a large river. However, we must be cognizant of the resources up and downstream from our area. We must show concern for the entire drainage system, even if primary responsibility for its management rests elsewhere. The managers of resource plots, cities, counties, states, and countries need to recognize that streams commonly flow thru lands in different ownership and across political boundaries.

MANAGEMENT RECOMMENDATIONS

1. The riparian habitat is the most productive and possibly the most sensitive of North American habitats and should be managed accordingly. Due to the complexity of riverine ecosystems, scientists have only recently

developed techniques to document the importance of these ecosystems to wildlife.

2. In addition to the importance of riparian habitat from an ecological standpoint, other values include:

(a) Recreational uses including hunting, fishing (Meehan et al. this symposium) and bird watching.
(b) Reservoirs for preservation of gene pools and to allow recolonization of areas hit by disasters such as forest fires, severe droughts and storms.
(c) Aesthetic values including painting, photography and just looking, listening, smelling, etc.

Thus, recreational, wildlife, and aesthetic values should be weighed against other values and alternative uses. This is especially important in land use planning for a habitat which has high pressures from alternative uses such as water for industrial and domestic purposes, irrigation, grazing and urbanization.

3. Use interdisciplinary teams, including recreation specialists, economists, etc., to develop improved means for determining wildlife values. This is especially important in figuring cost-benefit ratios for determining the best use for an area. We hope there will never be a need for putting a dollar figure on everything in order to establish its "value." (What is the value of 2 or 3 days vacationing along a streamside?) However, economic values have been placed, in part, on recreation such as hunting, fishing, and "general rural recreation" (Davis 1967, and Martin et al. 1974). Attempts to quantify these values should make them more competitive with other uses, such as those mentioned in No. 2 (above).

4. Finally, encourage investigations to clarify areas of knowledge which are currently poorly, if at all, known. We have discussed the complexity of riverine ecosystems and further reasons for the late development of this area of ecology.

Problems which need to be solved include:

(a) The minimum area and suitable configurations necessary to retain both plant and wildlife values in different riparian habitats.

(b) The maximum distance which can separate islands of a given habitat type before the loss of wildlife species or a great reduction in populations occurs.

(c) Optimal as well as minimal requirements for enhancing wildlife values for a given habitat type. These include ground cover, trees and shrubs per hectare, foliage volume, plant species present, and disturbance types and frequencies.

We will close by quoting Carothers and Johnson (1975a),

> "Determining these factors may be the most important problem facing us today. All the 'threatened species recovery teams' we can possibly amass will not prevent many species from becoming extinct in their native habitat if we degrade their habitats past the point of no return."

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Riparian Research Needs[1]

David R. Patton[2]

Abstract.--Approximately 22 studies on riparian habitat are in progress in the western United States. Six categories of studies are needed to provide managers with data for making decisions about the riparian ecosystem. The concept of "validation sites" can be used in a team approach to solve plant and animal problems in the riparian zone.

INTRODUCTION

Riparian zones, characterized by mesic vegetation and more or less permanent surface water, contrast with adjacent semiarid or dry subhumid environments (fig. 1). Early settlers gravitated to these limited river and stream areas. As a result, ranches, farms, and towns all have taken their toll of riparian zones. Human population growth has increased this pressure in the years following settlement. Introduction of livestock, use of streamflow for irrigation, and construction of dams and roads have compartmentalized the riparian zone with varied but mostly harmful effects to native fauna. The importance of riparian vegetation to wildlife habitat has become apparent only in this decade. Even now its overall importance is not widely recognized.

A search of some 24,000 research resumes in the U.S. Department of Agriculture's Current Research Information System (CRIS) revealed 10 related to riparian habitat. CRIS information and other sources indicate 22 active studies (10 plant, 5 animal, and 7 combined) in the western United States. These figures show that riparian vegetation is not receiving research at a level comparable to its importance as wildlife habitat. A concentrated effort directed at specific problems with realistic goals is needed.

A problem analysis for Forest Service wildlife habitat research in the Southwest that identified riparian research needs (Patton 1976)[3] can serve as a guide for developing priorities for other areas. Six general categories of studies are necessary to provide natural resource managers with sound data for making decisions (fig. 2).

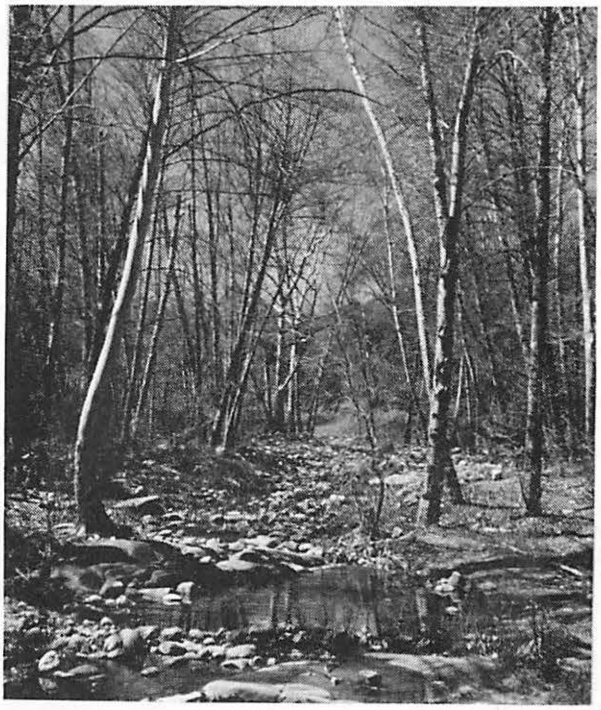

Figure 1.--Riparian habitat along East Verde River, Tonto National Forest, Arizona.

[1]Paper presented at the Symposium on Importance, Preservation, and Management of Riparian Habitats, Tucson, Ariz., July 9, 1977.

[2]Principal Wildlife Biologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, at the Station's Research Work Unit at Arizona State University, Tempe. Central headquarters is maintained at Fort Collins in cooperation with Colorado State University.

[3]Patton, David R. 1976. Habitat criteria development for southwestern wildlife. A problen analysis. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Tempe, Arizona. Unpubl. rep.

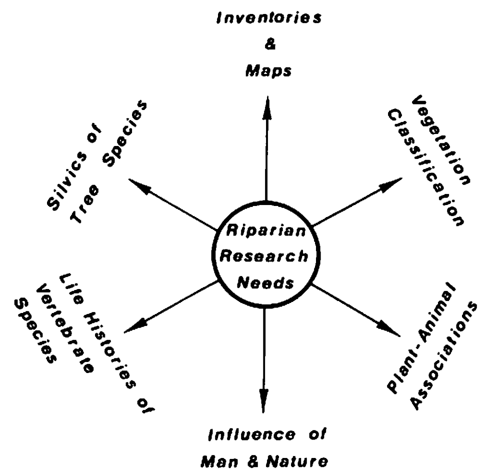

Figure 2.--Riparian Research Needs

These categories only provide an outline for research. Each researcher will have to determine his own priorities depending on the need for data at the local, state, or regional level. Most of the problems, however, can be placed into one of these groups. The research categories are not mutually exclusive, and can be dealt with using a team or multidisciplinary approach.

INVENTORIES AND MAPS

A map and inventory of the riparian resource are very much needed. Aldo Leopold always emphasized that these tools were basic to all management decisions. Preparation of maps and inventories may not be a researcher's job, but he can provide some of the necessary information. In the Southwest, the vegetation map by Brown et al. (1977a) is a major step in the inventory and mapping process. In addition, Brown et al. (1977b) prepared a stream map for Arizona that identifies areas where riparian vegetation should or could exist.

VEGETATION CLASSIFICATION

No comprehensive classification of riparian vegetation suitable either for research or management has been prepared for the Southwest. The hierarchical system proposed by Brown and Lowe (1974) as part of the Arizona Resource Inventory System (ARIS) is an important step in characterizing vegetation on a regional basis to the community and association level. Studies are needed to determine plant species composition and abundance for every identifiable successional stage for riparian vegetation, from low-elevation desert to high-elevation spruce-fir forests. An important part of the work should be to develop techniques for evaluating the riparian habitat's "state of health." Emphasis should be placed on studies of indicator plants.

PLANT-ANIMAL ASSOCIATIONS

Once successional stages have been determined, there is a need to identify animals that depend on a given stage or stages for their life requirements. Such studies do not have to be complex and can provide excellent field training for graduate students interested in the habitat approach to wildlife management.

Riparian habitats are oases in arid environments and support a great density and diversity of bird species. More is known about bird life in riparian vegetation than any other vertebrate group, but a check of the literature quickly shows a lack of detailed information on any animal. Some birds, such as the black hawk (Buteogallus anthracinus) and zone-tailed hawk (Buteo albonotatus), that inhabit or are semiriparian-dependent, are on state threatened lists and probably will become endangered unless research provides managers with information on their habitat requirements.

The needs of mammals that inhabit or are closely associated with riparian vegetation have not been well identified. Bats, squirrels and skunks often are seen in or near riparian vegetation, but their use of the type for food and cover is known only in general terms. Small rodents are probably the least understood and documented group of animals in the riparian habitat. These animals could be an important link in the food chain of threatened hawks.

Researchers have neglected amphibians and reptiles in favor of more economically important animals. Herps are not as esthetically pleasing to recreationists because of a lack of understanding of their ecological value. Yet, data on the two herp groups are necessary-to understand the complete riparian ecosystem.

Although fish are not restricted to streams with riparian vegetation, the presence or absence of streamside cover affects temperature which determines species composition. There probably is more detailed information available on game fish than on any single group influenced by riparian vegetation. Less data are available on threatened or endangered species. In addition many remote streams have not been surveyed or were insufficiently surveyed.

Invertebrates must be included in plant-animal relationship research. These animals are an important source of energy in the food chain of riparian vertebrates. For this reason, there needs to be an understanding of the invertebrate populations associated with the hundreds of terrestrial and aquatic microhabitats in riparian vegetation.

INFLUENCE OF MAN AND NATURE

Grazing, pollution, recreation, flooding, and water reclamation projects all can influence plant and animal species composition and abundance. Managers need to know if desirable trees and shrubs can survive under any grazing system, or whether protection will be required during critical seasons to restore the balance between production and utilization.

Most natural systems can withstand some pollution, but overloads soon become toxic to both plants and animals. At that point it may be too late for recovery. Studies are needed to determine recovery rates associated with different amounts of pollutants and their chemical toxicity of the plant-animal complex. Recreational activities can cause pollution from human wastes and physical damage. Managers need information on carrying capacity to regulate access when overuse becomes a problem.

The riparian habitat must have water. In most of the West, demands for water lead to conflicts between human uses and needs and other uses and needs. Floods, caused by either man or nature, can be either beneficial or detrimental. Some riparian plants need occasional flooding to perpetuate the species. However, removal of large amounts of vegetation in watershed treatments may create conditions conducive to flooding that can destroy desirable plants. Minimum flows to maintain the riparian habitat as a viable biological system must be determined soon, or managers will not have the information they need to mitigate habitat losses from dam and reservoir projects.

SILVICS OF TREE SPECIES

Life history data on the important riparian deciduous tree species--sycamore, cottonwood, willow, ash, and walnut--are almost nonexistent. The lack of data on these species resulted from a research emphasis on species with direct economic value. Studies are needed to document site requirements for germination and sprouting of seedlings or suckers, effects of insects and fire, and techniques for artificial regeneration.

LIFE HISTORY OF VERTEBRATE SPECIES

Life history information provides biological data necessary for understanding each species' role in the ecosystem and the effects of man's activities. Because of the large number of vertebrates that live in or are influenced by the riparian habitat, the task of documenting all their relationships with the plant complex will be a difficult one. Species on the state and federal threatened and endangered lists should receive top priority. In many cases it may be possible to group species for study by common requirements or life forms.

USEFUL CONCEPTS

Two concepts may help to plan and initiate research in the riparian habitat. The first is establishing validation sites. A validation site is an area that represents a given vegetation condition or successional stage. It is permanently documented by maps and aerial photographs and used for long-term studies. In some areas, validation sites may need permanent exclosures for protection from grazing. By using validation sites, scientists of many different disciplines can work together on separate studies to solve common problems.

Roy Johnson discussed the second concept, "endangered habitat", earlier. Several years ago I found the same terminology useful for describing riparian vegetation in a wildlife problem analysis. These select words directed attention to a habitat containing endangered and other species that depend on a vegetation type that itself is in a precarious position. The concept of threatened and endangered habitat, when properly used, may increase the chances of getting funds for research for a variety of species, living in that habitat, that otherwise would not receive high priority.

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Riparian Habitat Symposium Closing Remarks[1]

M. J. Hassell[2]

I don't know about you folks, but I personally have found this symposium to be very interesting and enlightening.

My only regret is that Bill Hurst, the man I replaced as Regional Forester, was not here to participate. When he first came to the Southwestern Region, I was a staff assistant in the Range and Wildlife Division. The first time I remember hearing the word "riparian," Bill was remarking worriedly that there was something wrong with our sycamore and cottonwood stands. No trees, shrubs and forbs in the younger age classes were represented, and this was a worry to this keen-eyed forester.

Now I know the reason. Age class "poverty" has been the subject of many papers. But, when Bill Hurst was expressing concern; few, if any, had even recognized the problem. He deserves much credit for the fact we are here today.

Bill Morris, you made a good point which I agree with. Therefore, another reason this symposium has been so meaningful to me is personal and perhaps even selfish. Our Region of the Forest Service has been attempting to put out a policy statement on the riparian type. As competition for resources intensifies, we desperately need basic information that identifies the trade-offs of resource conflicts. I don't believe it is acceptable to jump up and down totally in the dark - we need more information to make better choices. The speakers today have supplied much of the needed information, and I, for one, am extremely grateful. It is my hope that you have been able to glean some helpful information from the discussions.

Steve Carothers set the stage for our concerns and our reasons for being at the symposium. Of course, the basic reason is that changes are taking place in riparian habitat, and these changes and their direction are significant.

The riparian type is a key type to many kinds of uses and species. Both Kel Fox and John Hubbard covered this well in their discussions on domestic livestock, wildlife and fish; humans, water source and recreation.

Earle Layser and Charlie Pase highlighted the fact that this valuable type is very limited and the need we have to classify it. The framework provided through classification would permit scientists and managers better communication about what the problems and possibilities are.

Dave Brown highpointed the need for inventory in the riparian type, and we were able to see some of the difficulty of getting this basic data.

The challenge is to understand the importance of the type for all the various uses, to exchange what is known, to research what is not known, and to finally reach workable adjustments and compromises.

We realize it has been difficult to digest all the information you have heard today. But, in case you missed a point or two, Director Herrick of the Rocky Mountain Station has volunteered to print these transactions. They should be available for all registrants at a later date.

On behalf of all the cosponsoring groups, we would like to thank you for making this symposium a success. If riparian habitat and its associated fauna receive the attention it has long deserved, we will all be the richer for this experience.

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[1]Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

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Contributed Papers

Classification of Riparian Vegetation[1]

William A. Dick-Peddie[2] and John P. Hubbard[3]

Abstract--Historically, little attention has been given to vegetation associated with water courses. The reasons for this neglect are reviewed. Today there is considerable interest in riparian vegetation and a classification system would be of value. A classification system is proposed for riparian vegetation of New Mexico.

INTRODUCTION

Vegetation growing along rivers, streams, arroyos, and drainages in general has seldom been separately classified as a unit.

Reasons For No Classification System

Apparently there have been a number of conditions contributing to this omission. One condition is that historically, vegetation occurring on open flats, rolling hills, and mountain slopes has been of far greater economic importance than the vegetation associated with water courses. As a consequence, these areas of grassland and forest have tended to monopolize the attention of researchers.

Another condition responsible for the lack of separate classifications is that the area occupied by drainage associated vegetation often constitutes a small fraction of the total area being considered. The scale frequently used for mapping (continent, region, state, etc.) makes the recognition of this vegetation impractical or impossible. This is particularly true in mountainous regions where due to steep slopes, the drainages are relatively narrow and the vegetation associated with these systems constitutes only a thin band bordering either side of the reach. In addition the reach may be at the bottom of a gorge, canyon, or arroyo gully. In the plains and rolling country of the midwest and east, vegetation which is associated with wide old meandering drainage systems (floodplains) may make up a considerable portion of the total vegetation. When it does, these areas have sometimes been classified and mapped. Kuchler's (1964) southern Floodplain Forest (113) and Northern Floodplains Forest (98) are examples of this situation.

A third condition which has undoubtedly provided resistance to classification is the apparent lack of sufficiently discreet boundaries to the species aggregations as one proceeds up or down a drainage. Complicating this strong continuum condition is the fact that most species which grow out in the open are also able to grow along drainages. These species may be associated with typical drainage species in aggregation which are highly varied in both diversities and densities making creation of vegetative units exceedingly difficult.

Need for a Classification System

During the last fifteen or twenty years some conditions which prevented or restricted the development of classification systems for drainage associated vegetation have changed or disappeared and new priorities have even created a demand for a classification system.

There has been a considerable increase in the economic importance of wildlife which has resulted in an increase of research activity associated with the vegetation which supports wildlife. Much of this wildlife habitat is along drainage systems. A vegetation classification system would be of value in the management of these habitats.

The public has become interested in safeguarding examples of its natural heritage and the resultant competition between preservation and economic development of sites, necessitates biotic inventories. Biotic inventories are facilitated by a workable classification system.

Increased demand for water has focused an inordinate amount of attention on drainage systems in western United States and particularly in the southwest. This attention has led to various studies of water salvage. A natural consequence

[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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of this intensive activity is an interest in the role of drainage associated vegetation and water use. For an extensive literature review of this activity see Horton (1973). A realistic vegetation classification would be valuable for this continuing research effort.

The following is quoted from Lowe and Brown (1973) because it incorporates some of what we have said and indicates why we should be concerned about this type of vegetation.

> "The riparian communities are not shown on the color map. In total they comprise a limited geographic area that is entirely disproportionate to their landscape importance and recreational value and their immense biological interest."

> "It should not go unnoticed that in Arizona these riparian woodlands and streams forests have been rapidly dwindling just as the water table has been rapidly lowering, and our broadleaf trees are now the native phreatophytes of the water users. With present plans for increasing dams, flood control, water salvage, water forests are now truly endangered. Unless those concerned with projects such as the above do not quickly reasses their commitments, it will not be long before our riparian forests are destroyed forever in Arizona. They cannot be replaced."

Because of the changed and new conditions just explained, it is our opinion that a classification system for drainage associated vegetation is timely and highly desirable. We are also of the opinion that such a system is feasible.

TERMINOLOGY

Some terms used when discussing and describing this type of vegetation need clarification because their use has not always been consistent. In our view the following definitions are the most consistent and useful for these terms.

Riparian

Riparian - associated with water courses. Riparian may refer to vegetation associated with large rivers or with small, even intermittent drainages such as arroyos.

Phreatophytes

Phreatophytes - plants whose roots are growing in the water table or its capillary fring during a major portion of the growing season. Riparian vegetation may or may not include plants which are growing as preatophytes. Horton and Campbell (1974) have used riparian for situations along water courses where conditions are not suitable for phreatophytes. This use of riparian and phreatophytic as conditions which are mutually exclusive is a restrictive use and it can be confusing.

Bosque

Bosque - a stand of riparian vegetation including plants which are growing as phreatophytes. Consequently, the term bosque is usually limited to stands along major rivers or floodplains. Bosque is not as common a term as are riparian and phreatophyte. Bosque has a historical use in the southwest and has a different meaning here than in Mexico where it usually means merely forest, woods, or grove.

Bosques may vary from gallery forest-like stands of cottonwood *(Populus fremontii)* with their associated shrubs to impenetrable thickets which may include combinations or pure stands of such plants as screwbean *(Prosopis pubescens)* mesquite *(Prosopis glandulosa)*, seepwillow *(Baccharis glutinosa)*, saltcedar *(Tamarix spp.)*, arrowweed *(Pluchea sericea)*, and various species of willow *(Salix spp.)*.

Obligate Riparian Species

Obligate Riparian Species - species restricted to riparian or riparian-like situations. Riparian-like situations are those typlified by areas receiving large amounts of run-off water from surfaces with zero infiltration such as from the boulders of a talus slope or when the local topography creates an area of catchment which slows run-off sufficiently to allow greater infiltration than that of surrounding areas on the slope. We are aware that the term "obligate" implies a restrictive occurrence which has not been definitely ascertained for most of the species so designated. However, the term serves to segregate the species which may occur in riparian situations but are more commonly found elsewhere.

Facultative Riparian Species

Facultative Riparian Species - species other than "obligates" found in a riparian situation. Some riparian habitats are virtually restricted to obligate species because of poor aeration and/or high slainity. This is often the case along large river systems where there may be high water tables and phreatophytic conditions. However, in montane situations where there is good drainage or where running water is intermittent or sporadic (arroyos), any species including obligate species can be expected. These facultative species can usually be found out in the open at higher elevations. This is a result of the increased water availability in riparian situations. This increased water availability is due to the additional surface or ground water and/or the reduced evapotranspiration rates (canyon effect) associated with riparian situations.

RIPARIAN CLASSIFICATION

Recent Research Related to Classification

During the past two decades there has been considerable interest in riparian vegetation. Particularly in the west (Horton 1973). This interest has slowly been heading toward attempts at classification.

In the southwest, the biologist who has perhaps led the way toward recognizing the importance and character of riparian biotas is Charles H. Lowe, Jr. For example, Lowe (1961) defines riparian associations - or communities - and discusses various aspects of them in his treatment of the Sub-Mogollion region of New Mexico, Arizona, Chihuahua, and Sonora. He defines the associations as those occurring "in or adjacent to drainage ways and/or their floodplains and which are further characterized by different species and/or life-forms than those of the immediately surrounding non-riparian climax." He emphasizes that "it is incorrect to regard this biotic formation as merely a temporary, unstable seral community," as "it is an evolutionary entity with an enduring stability equivalent to that of the landscape drainageways which form its physical habitat."

In recent years the pronouncements of Lowe have underlain an increasing concern and interest among biologists and others in riparian associations and their biotas. For example, several studies (e.g. Campbell and Dick-Peddie, 1964; Campbell and Green, 1968; Freeman and Dick-Peddie, 1970; Campbell, 1974) have focused directly on riparian plant communities, while others have related such communities to their use by such elements as birds (e.g. Hubbard, 1972; Carothers and Johnson, 1973; Schmitt, 1976). Even earlier papers were published in ichthyology (e.g. Miller, 1961) touching on the importance of riparian habitats to native fishes, but in general these views have been little appreciated by biologists until recently.

The awakening among biologists as to the importance of riparian biotas has also sparked increasing study, as indicated above. Initial studies have been valuable but limited to date, and a great deal remains to be learned. One thing that is apparent however, is the fact that a great deal of complexity exists in riparian biotas. Not the least item among this complexity is the matter of sorting riparian vegetation into a workable and valid system of classification. Attempts have already been made to achieve this classification, but to date none of these is entirely satisfactory.

Inclusion of Riparian Elements In Vegetation Classification Systems

Lowe and David E. Brown have collaborated in developing a vegetation classification system for the southwest, to include riparian types. In their latest endeavor, for example, Brown and Lowe (1974) recognized twelve different riparian communities. Following are two examples:

- Forest Formation
  - Boreal Forest
    - Sub-Alpine Conifer Forest
      - Bristlecone-Limber Pine Communities
      - Spruce-Alpine Fir Communities
  - Temperate Forest
    - Montane Conifer Forest
      - Douglas-fir - White Fir Communities
      - Pine Communities
    - Relict Conifer Forest
      - Cypress postclimax Communities
    - Riparian Diciduous Forest
      - Mixed Broadleaf Communities
      - Cottonwood-Willow Communities
- Woodland Formation
  - Boreal Woodland
    - Sub-Alpine Riparian Woodland
      - Willow Communities
  - Temperate Woodland
    - Rocky Mountain Conifer Woodland
      - Pinyon-Juniper Communities
    - Madrean Evergreen Woodland
      - Mexican Oak-Pine Communities
      - Encinal (Oak) Communities
    - California Evergreen Woodland
      - Oak-Pine Communities
      - Encinal (Oak) Communities
  - Subtropical Woodland
    - Riparian Deciduous Woodland
      - Mesquite Bosque Communities
      - Tamarisk disclimax Communities

In a preliminary classification of New Mexican vegetation, Moir (1975)[1] included

[1]Moir, W.H. 1975. Vegetation Classification System for use in New Mexico. Developed for the New Mexico Natural Areas Problem, UNBUB.

riparian elements as parts of his major categories as follows:

Coniferous Forest Association
  Blue Spruce Series
    Blue Spruce/Grass Streamside Association
      Aspen Community
      Willow-Alder Community

Deciduous (Riparian) Woodland Formation
  Fremont Cottonwood Bosque

  Arizona Sycamore Series
    Arizona Sycamore/Fremont Cottonwood Association
    Arizona Sycamore/Arizona White Oak Association
    Arizona Walnut Series
    Bigtooth Maple Series
    Other Series

Forest Steppe (Mountain Grassland) Formation
  Wet Meadow Series
    Mesic Forb Community
    Sedge-Grass Community
    Willow-Sedge Community

Pase and Layser (1977)[4] have further refined ghe Brown and Lowe system in a tentative classification. Following are two examples:

Temperate Riparian Deciduous Forest Biome
  Mixed Broadleaf Series
    Mixed Broadleaf Associations
    Acer negundo Associations
    Alnus oblongifolia Associations
    Platanus wrightii Associations
    Fraxinus velutina Associations
    Juglans major Associations

  Cottonwood-willow Series
    Populus fremontii - mixed broadleaf Associations
    Populus fremontii Associations
    Salix bonplandiana Associations
    Populus fremontii - *Salix goodingii* Associations

Subtropical Riparian Deciduous Woodland Biome
  Mesquite bosque series
    Prosopis juliflora Associations
    Prosopis juliflora - mixed narrowleaf (*Tamarix, Chilopsis, Celtis*) Associations

[4]Pase, C.P. and Earl F. Layser. 1977. Classification of Riparian Habitats. Paper presented at Riparian Habitat Symposium, Tucson, Arizona.

A Riparian Classification System

The previous examples of the inclusion of riparian categories in classification are all worthy and valid. However, in light of its importance and the fact that it represents an unbroken continuum somewhat independent (particularly in the case of obligate species) of the surrounding vegetation, it would appear that riparian vegetation might well be treated as an independent vegetative unit. By concentrating upon obligate species, the seemingly bewildering array of combinations, is greatly reduced. Research on correlations of obligate species with such variables as surface and subsurface hydrology; canyon or valley cross sections and dimensions; and reach elevations and exposures should render more predictable the presently unpredictable occurrences of many obligate species. Such occurrence predictability would enhance the validity of a classification system.

Selection of Obligate Riparian Species

Some of the obligate riparian species found in one area have counterparts in their genera as obligates in other areas. For example some dominant floodplain genera in eastern United States are *Acer* (maple), *Fraxinus* (ash), *Platanus* (sycamore), *Populus* (cottonwood), *Juglans* (walnut), and *Salix* (willow). These same genera include major obligate riparian species in the southwest. Other species are obligate riparian species in the southwest but their counterparts in the same genera are merely facultatives elsewhere. Some examples of these genera are *Betula* (birch), *Celtis* (hackberry), and *Cornus* (dogwood).

Even though the obligate nature of the species so designated has not been scientifically established it is not difficult to arrive at a list of these species for any given area. For example, following is a list of woody and grass or grass-like obligate riparian species in New Mexico. This list is undoubtedly incomplete and some specialists may take exception to a few of the included items. The list is the result of lists compiled by the authors and a list compiled by Dr. Hal McKay while working as a consultant for the New Mexico Heritage Program. Concensus on a list of obligate forbs is equally easy to compile but due to the large number of forb species a list of forbs is not included in this paper.

Major Obligate Riparian Plants
Found in New Mexico

*Exotic (introduced)

Trees	
Acer negundo	Box elder
Alnus oblongifolia	New Mexican alder
Betula fontinalis	Birch
Celtis reticulata	Desert hackberry
Fraxinus spp.	Velvet ash
Juglans major	Walnut, Nogal
Juglans microcarpa	Little walnut
Morus microphylla	Mulberry
Picea pungens	Blue spruce
Platanus wrightii	Sycamore
Populus acuminata	
Populus angustifolia	Narrow-leaf cottonwood
Populus fremontii	Fremont cottonwood
Populus sargentii	Plains cottonwood
Prunus virginiana	Common chokecherry
Salix gooddingii	Southwestern black willow
Sapindus saponaria	Soapberry
Shrub-Trees	
Acer grandidentatum	Bigtooth maple
Alnus tenuifolia	Thin-leaf alder
Amelanchier spp.	Service-berry
Amorpha fruticosa	False indigo
Cercis occidentalis	Redbud
Chilopsis linearis	Desert willow
Crataegus spp.	Hawthorn
**Elaegnus angustifolia*	Russian olive
Prosopis glandulosa	Mesquite
Ptelea angustifolia	Hop-tree
**Tamarix* spp.	Salt cedar
Shrubs	
Acacia greggii	Catclaw
Allenrolfea occidentalis	Iodine bush
Apocynum spp.	Dogbane
Baccharis emoryi	Baccharis
Baccharis glutinosa	Seep willow
Baccharis sarothroides	Desert broom
Brickella californica	Brickel bush
Brickella laciniata	Brickel bush
Chrysothamnus nauseosus	
Var. graveolens	Rabbit-brush
Var. bigelovii	Rabbit-brush
Chrysothamnus pulchellus	Rabbit-brush
Cornus stolonifera	Red-osier dogwood
Fallugia paradoxa	Apache-plume
Forestiera neomexicana	New Mexico Olive
Hymenoclea monogyra	Burro weed
Lonicera involucrata	Inkverry
Lycium torreyi	Wolfberry
Philadelphus microphyllus	Mock orange
Pluchea sericia	Arrow weed
Rhamnus betulaefolia	Birchleaf buckthorn
Rhus microphylla	Little-leaf sumac
Salix spp.	Willow
Sarcobatus vermiculatus	Greasewood
Shepherdia argentea	Buffalo-berry
Grasses & Grass-like	
**Alopercurus* spp.	Fox-tail
**Arundo donax*	Giant-reed
Bulbostylis spp.	
Carex spp.	Sedge
**Catabrosa aquatica*	Brook grass
cyperus spp.	Flat-sedge
Distichlis stricta	Salt grass
Eleocharis spp.	Spike-rush
Equisetum spp.	Horsetail
Fimbristylis spp.	
Glyceria spp.	Manna grass
**Hordeum hystrix*	Barley
**Hordeum jubatum*	Barley
Juncus spp.	Rush
**Leersia oryzoides*	Cut grass
Luzula spp.	Wood-rush
**Phragmites communis*	Reed
Polypogon spp.	Rabbitfoot
Scirpus spp.	Bulrush
Typha latifolia	Cat-tail

Potential Classification of
New Mexican Riparian Vegetation

We present a potential classification of riparian vegetation in New Mexico. This is done to illustrate the validity of a system based upon obligate riparian species and the major topographic features which dictate their presence. The classification does not rely upon categories such as Boreal, Temperate, Subtropical, Forest, Woodland, and Scrubland which were developed primarily for non-riparian vegetation.

380 RIPARIAN FORMATION

- 381 Alpine Sub-Formation
  - 381.1 Forb Series
    - 381.11 Rush Association
    - 381.12 Spike Rush Association
    - 381.13 Sedge Association
- Montane Sub-Formation
  - Willow-Alder Series
    - Willow Association
    - Alder Association
    - Willow-Alder Association
  - Blue Spruce Series
    - Blue Spruce Association
  - Mixed Dedicuous Series
    - Willow-Dogwood Association
    - Alder-Willow Association
    - Boxelder-Ash-Walnut Association
    - Sycamore Association

Hackberry Association

Arroyo-Floodplain Sub-Formation
Arroyo Scrub Series
Greasewood Association
Rabbitbrush Association
Desert Willow-Brickelbush Association
Burroweed-Four-Winged Saltbush Association

Floodplain (Bosque) Series
Cottonwood Association
Cottonwood-Willow Association
Mesquite Association
Arrowweed-Seep-willow Association
Saltcedar Association
Mixed Bosque Association

It would not be difficult to incorporate this riparian classification into existing systems. We have included digits for the first series as an illustration of how this classification could utilize the Brown and Lowe system. We have used the major unit terminology of Formation, sub-Formation Series, and Association to illustrate the applicability of this proposed classification to the system being developed by the Forest Service.

The proposed classification is intentionally labelled "potential." Some units may not be valid or have utility when applied in the field. Possibly, some units should be raised or lowered in the hierarchy. There will undoubtedly be additions and possibly a need for deletions. Continued research and use of the classification should serve to remove any such errors.

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Fishes Inhabiting the Rio Grande, Texas and Mexico, Between El Paso and the Pecos Confluence[1]

by Clark Hubbs[2], Robert Rush Miller[3], Robert J. Edwards[2], Kenneth W. Thompson[2], Edie Marsh[2], Gary P. Garrett[2], Gary L. Powell[4], D. J. Morris[5], and Robert W. Zerr[5]

Abstract --The fishes of the middle part of the Rio Grande can be divided into three faunal assemblages: The saline Rio Grande fauna (made up of widely distributed and salt tolerant species) upstream from the Conchos confluence; the Rio Conchos-Rio Grande fauna (mostly south Texas and Mexican species) in the Rio Grande between the Conchos and Pecos; the tributary creek fauna (Chihuahuan species plus some derivatives) that depend on tributary creeks for all or part of their life history stages. Endangered species are found in the last assemblage but two presumed endangered species (Notropis simus and Scaphirhynchus platyrynchus) seem to have been eliminated already.

INTRODUCTION

The fishes of the Rio Grande (Belcher, 1975: fig. 3) have been intermittently studied for the past 130 years. Reasonably extensive reports exist for Colorado (Beckman, 1952), New Mexico (Koster, 1957), and the Rio Grande downstream from its confluence with the Pecos River (Trevino-Robinson, 1959). No comparable summarization exists for the intervening segment, although Miller (1977) treated the Mexican part of the middle Rio Grande basin. Proposals to channelize about 300 kilometers of the river and to designate another 200 kilometers as a wild river underscored the absence of a summarization of the fish fauna. The bulk of this paper is a report on fishes collected on two recent visits to the Rio Grande in the two project areas. We also include a summarization of a large number of collections made from the Rio Grande in Big Bend National Park between 1954 and 1976.

The Rio Grande "enters" Texas as a small stream most or all of which is diverted to irrigate fields south and east of El Paso. Commonly, the stream is dry over much of the distance between El Paso and Ft. Hancock. Southeast of this town the valley narrows and the ground water surfaces to form a salty stream. The river remains small for the next 300 km until it "receives" the Rio Conchos. Small volumes of water are added by small salt laden springs (such as Indian Hot Springs) and fresh tributary creeks (such as Capote Creek). These increases are commonly exceeded by losses from evaporation or irrigation diversions. Drastic increases in flow periodically follow intense desert rains. These torrents soon subside and the Rio Grande again becomes a small, sometimes intermittent stream. This pattern is of long duration as Emory (1859) reported periodic dry stream beds and occasional severe flooding and Thomas (1963) reported high salinities in the Rio Grande in 1936. This reach of the river has been extensively impacted by human activities. Much of the flow (and most of the low saline water) is diverted at or north of El Paso. The northwestern 150 kilometers have been leveed and channelized. A 16 kilometer segment around the Conchos confluence has also

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[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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been leveed and channelized. The intervening 300 kilometers has been proposed for channel "rectification" and is extensively leveed already.

Much of the flow of the Rio Grande east of the Conchos is dependent upon that "tributary". Historically, the contribution of the Conchos has been considerably greater than that of the Rio Grande above the confluence and that difference has been magnified by the Rio Grande diversions upstream. Present flow rates depend chiefly on releases from Luis L. León Reservoir; at the time of our visit on 18 March, 1977, the Conchos flow was nearly 2 orders of magnitude greater than that of the Rio Grande. Strangely, the man-made conjunction has the Conchos entering at a right angle; in effect a forced right angle turn of the huge stream where it enters the small stream. Between the end of its rectified channel below Presidio and the upper part of Amistad Reservoir (just upstream from the Pecos confluence), the Rio Grande has not been substantially impacted by human activities. The major items are the stream measurement weirs just below Alamito Creek and just above Amistad Reservoir, river fords at Stillwater Crossing and Boquillas, and a bridge near Stillwater Crossing. Other impacts are indirect such as minor irrigation diversions, overgrazing, exotic plants and fishes, pesticides washed from nearby fields, leaching from mine tailings, etc. Much of this distance is little disturbed and one can see the diverse geology and magnificent land formations.

COLLECTION SITES

Most of the newly reported locality records are based on two collecting trips, 14-18 March and 3-7 April, 1977. Collections were concentrated in the channelization and wild river segments, respectively. Previously, only one sample had been obtained from each of those reaches. The 1977 and previous (1954) locations are plotted on figures 1 and 2. The bulk of the 1954 (and subsequent) Rio Grande collections were from the Big Bend National Park and have been reported in Hubbs (1958), Hubbs and Wauer (1973) and Hubbs and Williams (in press).

RESULTS

The 15 collections from the Rio Grande west of the influence of the irrigation water from the Rio Conchos that enters the Rio Grande between Stations 15 and 16 contain 11 fish species (Table 1). The redundant nature of these samples is reflected by the presence of 7 fishes (*Dorosoma cepedianum*, *Cyprinus carpio*, *Notropis lutrensis*, *Carpiodes carpio*, *Ictalurus punctatus*, *Gambusia affinis*, and *Lepomis cyanellus*) in 9 or more collections.

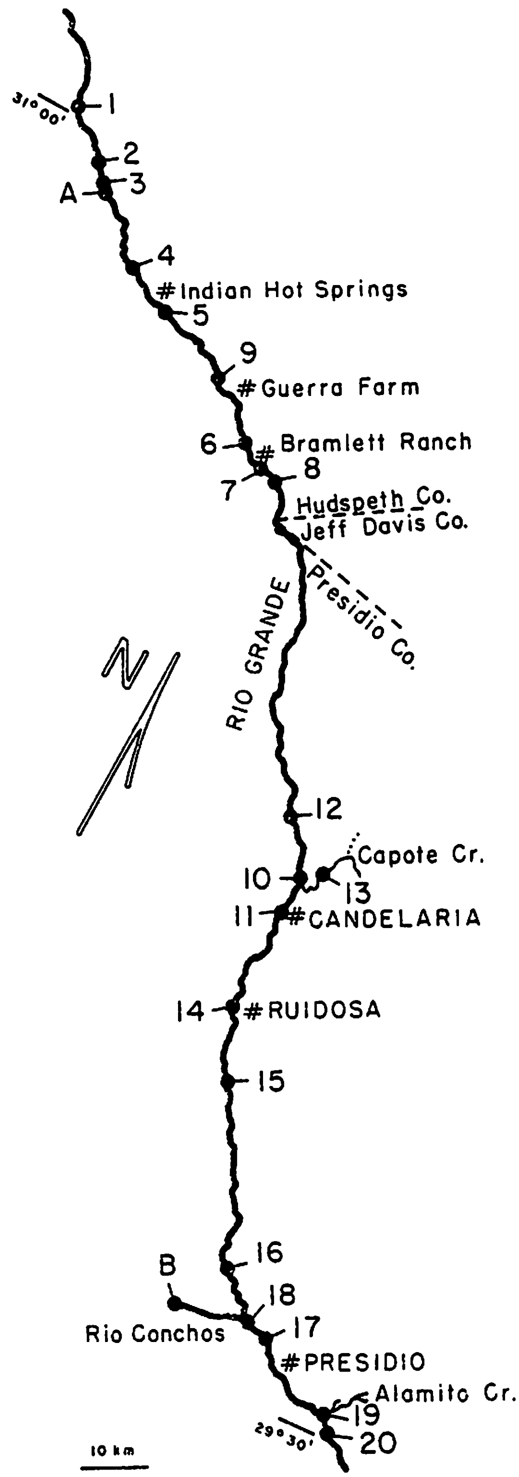

Figure 1.--Location of collection stations in the Rio Grande from and adjacent to the proposed channelization.

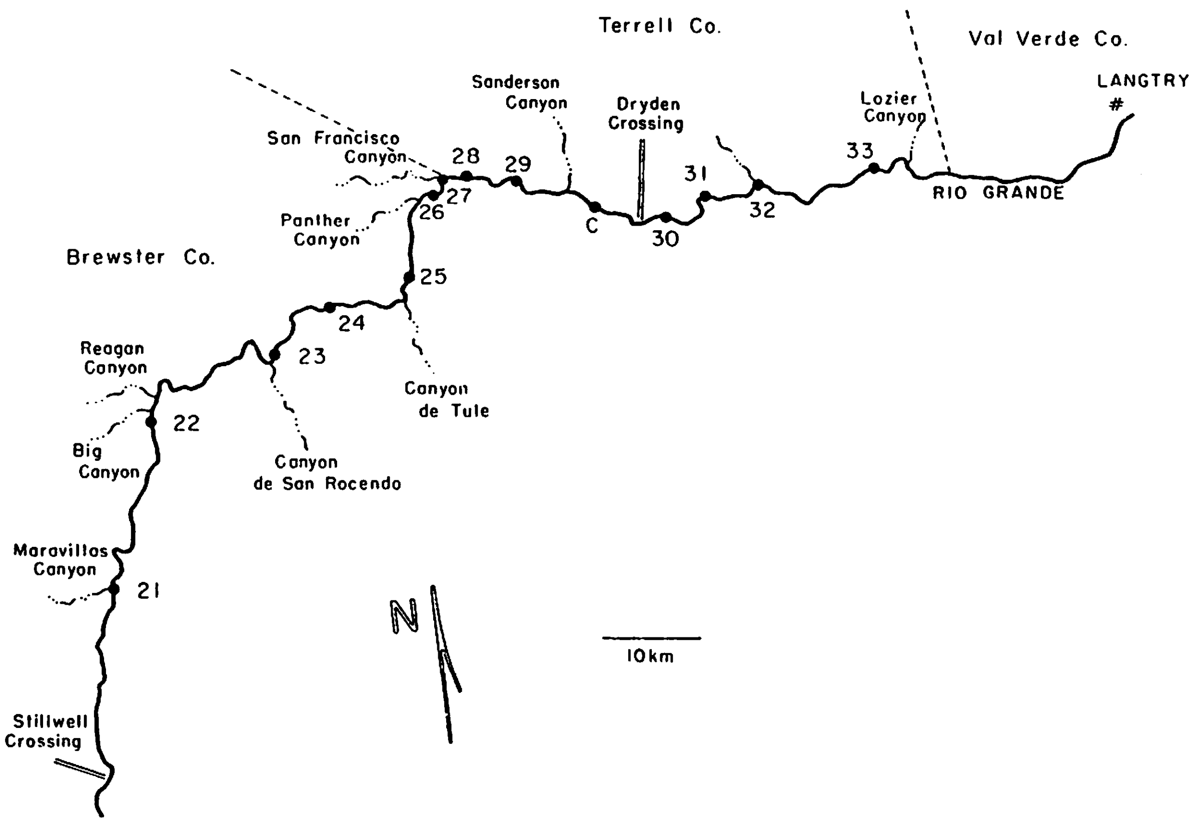

Figure 2.--Location of collection stations in the Lower Canyons of the Rio Grande.

Their widespread abundance suggests that they would be expected anywhere in this stream segment. The second listed species (Cyprinus carpio) is an exotic but the others are all widely distributed native fishes. Two of the other four species (Lepomis megalotis and Morone chrysops) were collected at widely separated sites. The former was found at very brushy sites. It is likely that this species can be obtained wherever those conditions prevail. The latter (undoubtedly, derived from fishes stocked near Del Rio) is an open-water top carnivore. This fish would be expected to be sparsely distributed because of dependence upon a complex food chain and consequently high primary productivity per fish. In a similar way, a large fish like Ictalurus furcatus would be expected to be rare in a small stream like the Rio Grande in this reach. The last species Pimephales vigilax, has not previously been taken east of Val Verde Co. As this fish is commonly used as a bait minnow, it is likely that the samples obtained are descendants from escaped bait.

The six collections from the vicinity of Presidio (16B on Table 1) contain 20 species; 11 were not taken upstream but 2 from there were absent. We expect that increased effort would have produced an Ictalurus punctatus, but that Pimephales vigilax is not present. Nine of the additional 11 species, Astyanax mexicanus (as A. fasciatus), Hybopsis aestivalis, Notropis chihuahua, Notropis braytoni, Notropis jemezanus, Pimephales promelas, Campostoma ornatum, Pylodictis olivaris, and Lepomis macrochirus, were reported from the Big Bend region by Hubbs (1958). One exception, Cyprinodon eximius has subsequently been reported from Terlingua creek by Miller (1977). The other, Menidia beryllina, is undoubtedly derived from descendants of bait-released stocks now abundant in Amistad Reservoir. We expect that Menidia (a euryhaline species) will soon spread and become abundant in the saline Rio Grande waters upstream from the Conchos confluence.

The distinct difference between the Rio Grande fishes on either side of the Conchos confluence is reflected by similar differences between the fishes inhabiting the tributary creeks, Capote and Alamito (stations 13 and 19, respectively).

Table 1.--Numbers of fishes collected from the Rio Grande from and adjacent to the proposed channelization between Presidio and El Paso

Species	A	1	2	3	4	5	9	6	7	8	12	10	13	11	14	15	16	18	17	19	20	B
								Stations														
Dorosoma cepedianum		14	108	133	1	23	3		6		3	43		1	21	14	159	18	4		4	10
Astyanax mexicanus																				1		8
Cyprinus carpio	2	58	26	28	1	29	5	50	16	1	14	125	6	65	86	28	57	2		1	1	7
Hybopsis aestivalis																			17		13	4
Notropis chihuahua																			1	3		
Notropis braytoni																				1	1	44
Notropis lutrensis	74	11	13	83	130	242	66		49	85	55	335	118	40	11	65	54	50	354	166	63	36
Notropis jemezanus																						22
Pimephales vigilax			2	1		1																
Pimephales promelas																				1		3
Campostoma ornatum																				262	16	
Carpiodes carpio	x	1	2			26			2	2		74		2			2	1				3
Ictalurus punctatus		1	1		1		1		1	5	3	1		4								
Ictalurus furcatus							1												1		2	5
Pylodictis olivaris																					1	1
Cyprinodon eximius																				13	1	
Gambusia affinis	18	1		1		9		7	1	61		1		7	5	122	57			78	28	14
Menidia beryllina																	2	4	4	10	1	
Morone chrysops		1		2	1							1		1								
Lepomis cyanellus	2	4		2	4	8	2	11	7	2	4	23		29	38	105	168	2		11	4	3
Lepomis megalotis	2								1	2				2			1					
Lepomis macrochirus																		1				
H'		1.7	1.3	1.5	0.4	1.5	0.9	1.1	1.8	1.4	1.4	1.7	0.3	2.1	1.8	2.0	2.2	1.6	0.5	1.6	2.3	
% Introduced		65	18	12	1	9	6	74	19	1	18	26	5	44	53	8	12	8	1	2	2	
Fish/seine hour		46	101	119	92	193	156	136	166	351	79	316	248	151	161	445	500	78	381	527	133	

Table 2--List of fishes collected from the Lower Canyons of the Rio Grande.

Species	21	22	23	24	25	26	27	28	29	30	31	32	33	C
						Stations								
Lepisosteus osseus			1			1			2	1		1		1
Dorosoma cepedianum	15				3	21	1	2	7	11	3	5	1	
Cycleptus elongatus	108	2	15	1	6	7	2			5	4	19	1	
Carpiodes carpio	5	1		1	1		1	2		1	2	8		31
Ictiobus bubalus	1											1		1
Astyanax mexicanus						1						33		1
Cyprinus carpio	3						1							1
Rhynichthys cataractae	188	182	209	92	87	77	47	184	141	191	168	850	167	
Hybopsis aestivalis	4	13	36	8	6	7	4	6	3	3	11	9	9	2
Pimephales promelas			1							1				
Notropis chihuahua	1													
Notropis jemezanus	3	5	7	4	20	19	3	3	48	5	16	6	12	11
Notropis lutrensis	6	1	19	1	5	112	4	6	2	12	29	37		1
Notropis braytoni		2	11	3	15	9	4	19	6		6	10	3	25
Ictalurus punctatus		1	7	2	2		3		2		2	1	7	2
Ictalurus furcatus		5	13	10	6		4	3	8	1	4		2	69
Pylodictus olivaris		1	4		2						3	1	2	6
Fundulus kansae	2													
Gambusia affinis	3		4			4	4					1		
Menidia beryllina				2		1			1			2		
Micropterus salmoides				1	1							4		
Lepomis cyanellus	1													
Lepomis macrochirus	1		1											

Chemical and physical conditions in the two creeks are reasonably similar - Capote is slightly smaller and has been reported dry near the mouth. We attribute the fish faunal differences to the impact of seasonal migrations into the Rio Grande as reported for Terlingua Creek by Hubbs and Wauer (1973). Those salty Rio Grande waters at the mouth of Capote Creek may exclude the typical Rio Grande tributary creek fauna from any upstream tributary. Regardless of the cause, these fishes were not found in Capote Creek. We looked carefully for fishes in the waters of Indian Hot Springs to determine if an endemic fauna were there. These warm, salt-laden springs were fishless. We did note Gambusia affinis was concentrated in the warm outflow waters emptying into the colder Rio Grande waters during our March visit.

The faunistic difference between the fishes of the two segments is of long duration. The 1954 samples (A and B) are well representative of the faunal units found in 1977 samples.

The 13 collections from the Lower Rio Grande Canyons contained 23 species (Table 2). Thirteen (Dorosoma cepedianum, Carpiodes carpio, Astyanax mexicanus, Hybopsis aestivalis, Pimephales promelas, Notropis chihuahua, Notropis jemezanus, Notropis lutrensis, Notropis braytoni, Ictalurus furcatus, Pylodicitis olivaris, Gambusia affinis, and Lepomis macrochirus) were found in the collections near Presidio and reported from the Rio Grande in Big Bend National Park (Hubbs, 1958). The absence of Cycleptus elongatus and Rhinichthys cataractae from the upstream stations is likely to be a seasonal artifact because both have been reported from the Rio Conchos. Both species are also absent in the August 1954 collection (C). All of the Cycleptus collected downstream were young of the year. Similarly, the bulk of the Rhinichthys were young. It is unlikely that adult Cycleptus would be collected with the seines used in such high water (and none were). Samples taken near the mouth of Tornillo Creek in April commonly have many young Cycleptus but no adults are in collections from that spot. Similarly, Rhinichthys are likely to be most abundant just after the breeding season. Our station 20 (Rio Grande just east of the mouth of Alamito Creek) included one fish tentatively identified as a Rhinichthys that escaped prior to being preserved. Rhinichthys abundance in the area is supported by its presence in a collection from the Rio Grande just upstream from Mariscal Canyon in Big Bend National Park. Specimens have also been taken from the Conchos system in Chihuahua. The absence of Lepisosteus osseus, Ictiobus bubalus and Micropterus salmoides in the collections near Presidio is likely to be a sampling artifact. The high-water flows made it very difficult to sample deep-water environments commonly occupied by these (especially Ictiobus and Micropterus) and our downstream samples were sufficiently infrequent that chance occurrence in the Presidio samples is likely. Two species (Menidia beryllina and Lepomis cyanellus) were collected near Presidio but not reported from Big Bend National Park by Hubbs (1958). It is unlikely that the former existed in the region before 1960 as Tilton and White (1964) showed that this fish was then just being distributed across Texas. Hubbs and Echelle (1972), documented a similar and recent spread of this fish in the Pecos Basin. Lepomis cyanellus is now known from Big Bend National Park (Hubbs and Williams, in press), supporting Hubbs' (1958) prediction that it existed within the park. Similar to Menidia audens, Fundulus kansae has recently been introduced into the region. Its introduction and subsequent spread was reported by Hubbs and Wauer (1973). The fish from the Rio Grande at the mouth of Maravillas Cr. surely reflects an additional spread. We herein also report the presence of Fundulus kansae in McKinney Spring in Big Bend National Park. It is likely that the specimens of Micropterus salmoides reflect a modest population of indigenous fishes that can serve as a recreational resource. We expect that largemouth bass occur throughout the Rio Grande east of the Conchos confluence (and also in much of the Conchos system).

The 23 species extensively overlap those reported from the Big Bend by Hubbs (1958) who recorded 7 additional fishes. Four of them, [Dionda episcopa, Gambusia gaigei, Lepomis (=Chaenobryttus) gulosus, and Lepomis microlophus] were recorded as inhabiting small clear tributaries and would be rare or absent in the river proper. Moxostoma congestum was subsequently reported from Tornillo Cr. by Hubbs and Wauer (1973). Three fishes, Anguilla rostrata, Hybognathus placitus, and Aplodinotus grunniens) were reported from Big Bend by Hubbs (1958), but not obtained in the 1977 samples. The first is catadromous and upstream migrants would be unlikely to pass Falcon Dam (much less Amistad); samples have not been obtained since Falcon was filled. The other two would be expected to occur in the area. Aplodinotus could easily have been overlooked but the absence of Hybognathus is inexplicable.

DISCUSSION

The fishes inhabiting the Rio Grande in west Texas can be placed in three faunal assemblages: Saline Rio Grande fauna, Rio Conchos-Rio Grande fauna, Tributary Creek fauna.

The Saline Rio Grande Faunal assemblage is dominated by four wide spread species, Dorosoma cepedianum, Cyprinus carpio, Notropis lutrensis, and Lepomis cyanellus. The limited diversity (Shannon H' values are generally well below 2) seems to be due to harsh conditions - salinity and periodic interrupted stream flows. The latter may be most critical as the fish present are ones expected in pools in west Texas streams. Our repeated efforts in riffles were generally unproductive. This assemblage has been impacted by human activities. Certainly the three exotics (Cyprinus, Morone, Pimephales) must have some impact. It is likely that Cyprinus has depressed Carpiodes abundance but the impact of Morone and Pimephales is difficult to assess, and the absence of prior studies makes any conclusions conjectural.

The Rio Conchos - Rio Grande faunal assemblage is made up of those species living in the Rio Grande and not dependent upon tributary creeks for a part of their life history. The abundance of these fishes is not correlated with the presence of tributary flows. Typical fishes of this assemblage are Notropis jemezanus, N. lutrensis, N. braytoni, Rhinichthys cataractae, Hybopsis aestivalis, Ictalurus punctatus, Ictalurus furcatus, Pylodictis olivaris, Dorosoma cepedianum, Cycleptus elongatus, and Carpiodes carpio. Seven other fishes (Lepisosteus osseus, Ictiobus bubalus, Pimephales promelas, Menidia beryllina, Micropterus salmoides, Aplodinotus grunniens, and Hybognathus nuchalis) are reasonably abundant in the Rio Conchos-Rio Grande faunal assemblage.

Only one (Menidia beryllina) of those 18 species is introduced. Its impact is not yet fully assessed as its entry into the region is so recent that its abundance may be in a growth phase. It is not likely that this quiet water euryhaline form will become excessively abundant in the fresh-flowing waters of the Rio Grande. Rhinichthys cataractae is not only a prominent member of this faunal assemblage, it also seems to be absent or very scarce in adjacent areas. This population is isolated from other stocks by the saline and frequently dry Rio Grande upstream from Presidio. It is likely that it represents a race adapted to deep canyons with relatively warm water. Essentially, a collection from Texas with numerous Rhinichthys and/or Cycleptus is likely to be from the Rio Grande between Presidio and Amistad Reservoir. The Rio Conchos - Rio Grande faunal assemblage will often be supplemented by representatives from the tributary creek faunal assemblage.

Two fishes (Scaphirhynchus platyrynchus and Notropis simus) may once have inhabited the Rio Conchos - Rio Grande faunal assemblage. Scaphirhynchus was reported from the Rio Grande near Albuquerque by Cope and Yarrow (1875). We have obtained hearsay reports of a sturgeon from near Dryden Crossing (and also from Mexican tributaries in Coahuila) that support the former occurrence of shovelnose sturgeon in the river. Notropis simus has been recorded from the Rio Grande in New Mexico and downstream from Del Rio but the collections preceded or were at a similar time interval as the first collections from our study area. We doubt that Notropis simus now lives in the Lower Canyons of the Rio Grande and suggest that work to ascertain if it still exists concentrate on the lower Rio Conchos. We have no suggestions as to the conditions that may have led to the extinction or substantial decline of these two fishes that once were part of this faunal assemblage. Both species are commonly found on listings of endangered species and N. simus may be extinct in U.S. waters. Its absence in Trevino-Robinson's collections is particularly alarming as most Texas records are from that stream segment. The New Mexico records are from the Rio Grande in areas that now have reduced flow or are dry.

The tributary creek faunal assemblage is made up of a group of fishes that spends all or a substantial fraction of their time in the small tributaries. Three species (Notropis lutrensis, Pimephales promelas, Notropis braytoni) may occur in the creeks or Rio Grande. Except for the first, they are seldom found far from the creek mouth. Three (Moxostoma congestum Carpiodes carpio, Cycleptus elongatus) are creek inhabitants only as young and the adults may be found with equal abundance elsewhere in the Rio Grande. Eleven species (Cyprinodon eximius, Campostoma ornatum, Notropis chihuahua, Fundulus kansae, Astyanax mexicanus, Gambusia affinis and the sunfishes, Lepomis gulosus, cyanellus, microlophus, macrochirus, and megalotis) are most commonly collected in creeks but have been found in the Rio Grande. The first six are listed by relative frequency of creek vs. river abundance. Hubbs and Wauer (1973) had reported that this assemblage moved out of the creeks seasonally but our 1977 samples of the first two are the first demonstration of fish that must have moved into the river. Samples of the five sunfishes are sufficiently infrequent that definite patterns are difficult to ascertain. Two species (Gambusia gaigei, Dionda episcopa) are limited to the tributary waters. The former is on all lists of endangered fishes; its status has been discussed recently by Hubbs and Williams (in press). The fishes in the tributary creek assemblage often present special problems. Three of them (Cyprinodon eximius, Campostoma ornatum, Notropis chihuahua) are commonly found on endangered species listings as their U.S. distribution is restricted to the creek mouths. These areas should be watched with care to reduce the possibility of extermination of this fragile assemblage. The spread of the introduced Fundulus kansae is of primary concern (Hubbs and Wauer, 1973). Future introductions of bait minnows should be avoided.

ACKNOWLEDGMENTS

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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

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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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[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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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

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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, Q. 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

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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.
>
> 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

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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

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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

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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

[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	Guild: Nesting
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

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	-	generalist omnivore	tree
Yellow-billed Magpie (Pica nuttalli)	res	4	generalist omnivore	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	-	generalist omnivore	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

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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

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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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Regeneration and Distribution of Sycamore and Cottonwood Trees Along Sonoita Creek, Santa Cruz County, Arizona[1]

Richard L. Glinski [2]

Abstract.--This study describes the effects of livestock grazing and streambed erosion on the regeneration and distribution of sycamore and cottonwood trees. Sycamores reproduced from root and trunk sprouts and because of this their distribution is not as likely to change significantly. Cottonwood reproduction was nearly absent in areas grazed by cattle, and was confined to the narrow erosion channel. If this regeneration pattern continues, the future maximum width of the cottonwood forest will decrease nearly 60%.

INTRODUCTION

Many Riparian Deciduous Forests in the Southwest contain extensive groves of sycamore (Platanus wrightii) and cottonwood (Populus fremontii) trees. (Plant community terminology follows Brown and Lowe 1974.) In many areas either one or both of these species are the sole tree component of the riverine habitat. They increase habitat diversity and create invaluable niches for a variety of wildlife, particularly birds (Bottorff 1974, Carothers et al. 1974, Johnson and Simpson 1971, and others).

Along Sonoita Creek in southeastern Arizona cottonwoods exclusively are used as nest trees by rare birds like the Gray Hawk (Buteo nitidus), Zone-tailed Hawk (B. albonotatus) and Black Hawk (Buteogallus anthracinus), and sycamores are the favorite nest tree of the Rose-throated Becard (Platypsaris aglaiae) (pers. obser.).

This study is an assessment of the numbers, condition, regeneration and distribution of these important trees along Sonoita Creek. It provides some basis for comparing populations of these species in areas of varied livestock grazing use. This paper also describes the effects of streambed erosion on the regeneration and future distribution of these trees in riparian habitats of the Southwest.

THE STUDY AREA

Sonoita Creek originates in the Plains Grassland about 1 km northwest of Sonoita, Santa Cruz County, Arizona, and flows in a southeasterly direction through the Desert Grassland to its confluence with the Santa Cruz River 14 km north of the Mexico-United States border. Its 51 km reach occurs along an elevational gradient ranging from 1480 to 1035 m. Its tributaries drain habitats from Boreal Forests at 2865 m elevation through Temperate Woodlands (Madrean Evergreen Woodlands) and Desert Grasslands at 1035 m elevation.

The low hills immediately bordering the creek are covered in moderate density with oaks (Quercus spp.), mesquite (Prosopis juliflora), juniper (Juniperus monosperma), cliff-rose (Cowania mexicana), mountain-mahogany (Cercocarpus sp.) and ocotillo (Fouquieria splendens). Groundcover, consisting mainly of gramma grasses (Bouteloua spp.) and love grasses (Eragrostis spp.), is moderately dense near Sonoita where soils are better developed, and sparser along the middle and lower reaches where steeper hillsides and rockier soils prevail.

The upper 19 km of the alluvial valley-floor from the headwaters to the town of

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[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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Patagonia consist of eroded grass- and scrub-covered plains, irrigated pastures and croplands, and remnants of a Sacaton Grass-Scrub Community. Here surface waterflow is mainly ephemeral. Streambed erosion as reported by Bryan (1925) is a common feature of this upper valley-floor. The erosion, which begins about 2.9 km southwest of Soniota, forms vertical banks 1 to 5 m high and separated by a channel from 15 to 37 m wide. The evidence of this erosion decreases progressively downstream for 5 km, first through weedy grasslands then past irrigated pastureland beginning near Adobe Canyon. For the next 5 km flood-irrigated pastures border the dry creekbed. Erosion produces cuts here less than 2 m high and occurs only locally where the creekbed borders steep hillsides.

The widest reach of this upper alluvial valley is nearly 1 km across and continues for 5.6 km downstream from the pastureland. The flood plain here supports a Sacaton Grass-Scrub Community. In early 1975 many large mesquite trees with basal diameters up to 0.6 m and a few walnut trees (Juglans major) with basal diameters of nearly 0.8 m were removed from here. This area is gradually being cleared of natural vegetation and transformed into irrigated fields. Streambed erosion is absent in the upper 4.0 km of this Sacaton Grass-Scrub plain, where the creekbed branches out among dense sacaton clumps that reach over 2 m in height, but begins about 1.6 km upstream from the lowest reach of this community. Through this eroded reach, vertical banks are 1 to 2 m high and 10 to 40 m apart. Irrigated cropland borders remnants of the Sacaton Grass-Scrub plain about 0.8 km above Patagonia.

Scattered individuals and small clumps of large cottonwood and sycamore trees occur along this upper valley-floor. The predominant tree of this upper floodplain is mesquite, which occurs mainly as a shrub or small tree up to 7 m tall.

About 0.8 km below Patagonia perennial surface water begins and continues downstream for about 19.3 km. Along this reach there is a near-continuous belt of Riparian Deciduous Forest, consisting of cottonwood, sycamore, willow (Salix gooddingii), ash (Fraxinus velutina) and walnut trees. This riparian forest varies in width from 15 to 150 m and in density of trees. It is bordered frequently by small bosques of mesquite and hackberry (Celtis reticulata).

Willow is the most abundant large riparian tree at the head of this forest, and ash is the commonest large tree along the middle and lower reaches. Cottonwood, the third most prevalent tree, is irregularly distributed throughout the forest, and densities of mature tree and sapling cottonwoods vary considerably. Sycamore and walnut are the least common large trees, and occur in small clumps or singly, mainly along the lower reaches of the forest.

The forest floor is covered with annual and perennial grasses and forbs that in some open areas form dense thickets up to 2 m tall after the onset of summer rains in July. In many places livestock grazing and human recreation eliminate summer groundcover by the following spring.

The watercourse, which normally varies in width from 2 to 5 m, is usually less than 10 cm deep, and is often lined with seep-willow (Baccharis glutinosa). In areas that are not grazed by livestock, water-cress (Rorippa nasturtium-aquaticum) blankets the flowing water most of the year.

Since much of the Riparian Deciduous Forest is within the confines of a narrow rocky canyon less than 0.5 km across, alluvial deposits are limited and extensive creekbed erosion is restricted usually to reaches near the entrances of side canyons where alluvium has accumulated. In many areas this erosion has resulted in vertically cut banks up to 4.9 m high. In 1881 a railroad track was completed along the entire length of Sonoita Creek, altering the watercourse along many reaches, including that of the Riparian Deciduous Forest. The railroad levee often constitutes the bank of the creek and contains floodwaters.

The continuity of the Riparian Deciduous Forest was disrupted in the early 1960's with the construction of Lake Patagonia. This lake covers 650 hectares beginning 11.6 km below the head of the Riparian Deciduous Forest and continuing downstream for 3.5 km. Below the dam, surface flow and patches of Riparian Deciduous Forest persist for about 2.9 km.

Thereafter, for the next 11.7 km to its confluence with the Santa Cruz River, Sonoita Creek flows intermittently with scatterings of large cottonwood, ash and willow trees.

The creek proper dissects two general soil types (Richardson in press). Ending about 10 km below Patagonia, the upper type is usually more than 1.5 m deep in old alluvium from igneous and sedimentary rocks and is composed of fine to moderately coarse textured soils with about 35 percent gravel and cobble throughout. The lower type consists of rocky, very cobbly and sandy loams less than 0.5 m deep on weathered granitic, tuff-conglomerate, or andesite-tuff bedrock. Here sediment yield is low.

The most complete climatic data for this area is from Nogales, Arizona, which lies just south of the watershed 27 km southwest of Patagonia and is 1158 m in elevation. Records from 1893 through 1962 show that maximum daily temperatures occurred during June and averaged 34.9°C; minimum daily temperatures occurred during January and averaged -1.4°C. Temperature extremes for the area were -14.4° and 43.3°C. Precipitation was biseasonal, and about 60 percent of the annual average of 396 mm fell during July through September. The driest months were May and April, respectively (Green and Sellers 1964). The spring of 1974 was an extremely dry year and some reaches of the

Riparian Deciduous Forest were without surface flow.

METHODS

From April 1974 through April 1977 I surveyed the trees of the Riparian Deciduous Forest on foot and recorded numbers, height classes, conditions, locations and evidence of regeneration of sycamores and cottonwoods. Multi-trunked trees were counted as one tree if the trunks were joined above ground level. To estimate percentage of sprouting, closely clumped sycamores were counted as an individual tree since they probably shared a common root system. I estimated the numbers of densely clustered seedlings and saplings. Tree heights were estimated and grouped into three size classes: seedling (< 2 m), sapling (2-9 m), and trees (> 9 m). I made brief notes on the conditions of mature trees, especially cottonwoods that had experienced excessive leaf-drop or canopy die-out, or ones with fully leafed canopies that had fallen over for no apparent reason. The numbers and locations of other riparian trees were only casually recorded.

At 100-m intervals I measured the width of the creekbed between the tops of the banks, and the height and approximate slope (to the nearest 30° angle) of the creek banks. To determine the maximum distance that cottonwoods occurred from the creekbed, within each 100-m interval I measured the distance between the edge of the creekbed and the cottonwood farthest removed from the creekbed on both sides of the creek. Lateral bounds of the creekbed often were easily defined by vertically cut banks, but at times were estimated for banks with shallow slopes. Frequently the railroad levee obviously confined the watercourse and was counted as a bank. Bank height and slope were not recorded where the hillside bordered the creekbed. Bank Slopes were classified as shallow (0-30°), intermediate (30-60°) or vertical (60-90°) to the plane of the creekbed.

The Riparian Deciduous Forest was divided into five segments that differed in livestock-grazing use. The grazing practices along Sonoita Creek have varied greatly within the past 100 years, and exact grazing use, past or present, was not measured. However, it is possible to place each of the five segments in different use categories based upon livestock class or use intensity. Segment 1 is 2.7 km long, lies between 1234 and 1204 m elevation, and consists of the Patagonia-Sonoita Creek Sanctuary of the Nature Conservancy, an area fenced to exclude all livestock grazing in 1966. Segment 2 is 2.1 km long, lies between 1204 and 1189 m elevation, and has been grazed by cattle and horses for at least 50 years. Segment 3 is 0.8 km long, lies between 1189 and 1183 m elevation, encompasses the RL Ranch, and has been grazed by horses only since 1966. Segment 4 is 5.9 km long, lies between 1183 and 1143 m elevation at the head of Lake Patagonia, and has been grazed by both horses and cattle for at least 50 years. Segment 5 is 2.9 km long, lies below Lake Patagonia at elevations between 1116 and 1097 m, and has been grazed mainly by cattle for at least 50 years. The soil and vegetation in the upper third of Segment 5 was highly modified in the early 1960's when the dam was built.

RESULTS

Sycamore regeneration, distribution and condition

Sycamores reproduced mainly vegetatively by sprouts from lateral roots and trunk bases. Either root or trunk sprouts were found in 74% of mature sycamores (clumped and individual trees). I never encountered sycamore seedlings, but in Segment 4 I located one sapling that was more than 30 m from mature sycamores and was not a root sprout (Table 1).

Root sprouts occurred on 39% of the sycamores. On the average, root sprouts grew a distance of 1.0 m from the trunk bases (SD 0.5, r 3.0), were 3 m tall (SD 5, r 23), and 5 cm in diameter (SD 10, r 46). Trunk sprouts occurred on 56% of the sycamores and, on the average, sprouted 0.1 m above ground level (SD 0.1, r 0.6), were 3 m tall (SD 3, r 13) and 4 cm in diameter (SD 6, r 28). Trees with root sprouts averaged 8 sprouts per tree (SD 12, r 31), and those with trunk sprouts averaged 6 sprouts per tree (SD 10, r 30). Both root and trunk sprouts occurred on 22% of the sycamores. Root sprouts that were either less than 0.1 m tall or growing among dense debris and brush may have been overlooked, while probably all trunk sprouts were counted.

I was unable to determine what stimulates a sycamore to sprout. There was no significant correlation between either the presence of sprouts or the number of sprouts and the percent of canopy die-out, soil texture at tree base, or proximity of tree to surface water. Possibly the more latent factor of subsurface rock formations affected the presence of groundwater near individual trees and thus their tendency to sprout. The dependence of sprouting sycamores on abundant shallow water remains to be examined.

The large variance in the size of sprouts, some of which themselves were mature trees nearly 30 cm in diameter, indicates that sprouting has been a major means of regeneration along Sonoita Creek for some time. Many even-aged, large sycamores were growing in circular clumps with their trunk bases touching or nearly touching (fig. 1), suggesting that these clumped trees had been sprouts from a common parent tree that has long since decomposed.

Table 1.--Length, grazing use, and numbers of sprouts, seedling, sapling, and mature tree sycamores and cottonwoods for each of five stream segments.

	Stream Segment					Total
	1	2	3	4	5	
Sycamore						
Sprouts (Sprouts / km)	0 (0)	3 (1)	0 (0)	160 (27)	99 (34)	259
Seedlings (< 2 m) (Seedlings / km)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
Saplings (2-9 m) (Saplings / km)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	1
Trees (> 9 m) (Trees / km)	0 (0)	7 (3)	1 (1)	35 (6)	15 (5)	58
Cottonwood						
Sprouts (Sprouts / km)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
Seedlings (< 2 m) (Seedlings / km)	400 (148)	500 (238)	700 (875)	1500 (254)	100 (34)	3200
Saplings (2-9 m) (Saplings / km)	1078 (399)	11 (5)	586 (732)	20 (3)	2 (1)	1697
Trees (> 9 m) (Trees / km)	638 (236)	385 (183)	68 (85)	612 (104)	64 (22)	1767
Segment length (km)	2.7	2.1	0.8	5.9	2.9	
Grazing use	none	cattle & horses	horses	cattle & horses	cattle	

Sycamores were absent in Segment 1 and most abundant in Segment 4 (Table 1) except along the reach where surface flow was absent during the spring drought in 1974. They were distributed most frequently as scattered clumps of up to 10 trees. The clumps occurred from 0 to approximately 140 m from the watercourse (m 33, SD 48). Since regeneration was mostly from sprouting, almost all seedlings and saplings occurred near mature trees.

Livestock had browsed on only 13% of root and trunk sprouts. Most sprouting sycamores were growing on steep banks or amidst brush and litter, which probably prevented cattle from browsing sprouts. Aside from the limited canopy die-out that some trees had experienced, mature sycamore trees appeared healthy. They did not respond to the severe drought in 1974 as did the cottonwoods; however, their occurrence along specific reaches of Sonoita Creek may indicate the presence of abundant surface or subsurface water, thus they would not be expected to reflect initial drought conditions that might affect other trees.

Cottonwood regeneration, distribution and condition

All cottonwood regeneration along Sonoita Creek was from seeds. In July of 1975 cottonwood seedlings about 10 cm high were ubiquitous on moist, sandy alluvium along the watercourse in all segments of the Riparian Deciduous Forest. By the following spring almost all seedlings were absent except those that had germinated in Segments 1 and 3, where cattle were excluded. In January of 1975 cottonwood seedlings were most abundant in Segment 3 (875 seedlings/km) and least abundant in

Figure 1.--Clumped mature sycamore trees.

Segment 5 (1 sapling/km). Segments 1 and 3 averaged 399 and 732 saplings/km, respectively, and Segments 2,4 and 5 averaged 5,3 and 1 saplings/km, respectively (Table 1).

All seedlings occurred below the banks, many immediately along the watercourse. Many cottonwood seeds had germinated on damp soil around isolated, ephemeral pools of rain water that had collected away from the watercourse, but the resulting seedlings wilted and died when the pools became dry several weeks after germination. A continuous supply of supplemental water (treated sewage water) existed in Segment 1, and sustained 93% of the established seedlings outside the creekbed in that segment.

Mature cottonwoods were not evenly distributed throughout the Riparian Deciduous Forest, but were densest in Segment 1 (236 trees/km) and sparsest in Segment 5 (22 trees/km) (see Table 1). The construction of Lake Patagonia Dam eliminated many mature trees from Segment 5. Within each segment cottonwoods were not homogeneously distributed, but occurred with greatest density where alluvial deposits were plentiful. Individual, small clumps or large groves of cottonwoods occurred a mean maximum distance of 26 m from either edge of the creekbed (SD 40, r 196). The mean maximum width of the cottonwood forest, including the creekbed width, was 83 m.

On numerous occasions I observed cattle grazing seedlings on sand deposits along the watercourse. I never observed horses grazing cottonwoods, although many times I saw them nose aside a cottonwood seedling to get at a nearby sprig of grass or water-cress.

The extremely dry spring of 1974 obviously affected many mature and sapling cottonwoods along the entire reach of the Riparian Deciduous Forest. Extensive leaf-drop and canopy die-out occurred in May and June, and many areas of the creekbed and forest understory at that time were blanketed with small, partially developed cottonwood leaves that ranged in color from yellow to yellowish green. Leaf-drop occurred in all segments but was most obvious in Segment 4, where the surface flow failed in May and June along a reach about 150 m long. Many trees regained fully developed canopies after the onset of summer rain in July, but others remained bare and lost large canopy limbs.

Several large cottonwood trees were uprooted in the spring of 1974, having fallen over with canopies in full leaf. The exposed roots of these fallen trees were dry and had been severed less than 1 m below ground level and less than 2 m laterally from the trunk. Uprooting occurred mainly in Segment 1, where five trees fell over. Three trees in Segment 2 and two trees in Segment 4 also were uprooted in early 1974.

Characteristics of valley-floor erosion

Along Sonoita Creek erosion has resulted in banks that are sloped in a shallow, intermediate or vertical manner to the plane of the creekbed. In many instances the shallow and intermediate slopes probably are the result of gradual trampling of once-vertical slopes by livestock. Including the railroad levee, which accounted for 12% of the sampled banks, the average slope of the banks was 56° (SD 17). Nine percent of the sampled banks were vertically cut (fig. 2). The mean height of the banks was 2.3 m (SD 1.6, r 5.8). The width of the creekbed averaged 31 m (SD 23, r 104). There was no trend in these characteristics. Each characteristic was independently and heterogeneously distributed along the valley-floor, and probably reflected the variable alluvium deposits and geometry of the valley-floor.

DISCUSSION

Effects of grazing

Regeneration and distribution of sycamore and cottonwood were affected differently by livestock grazing. The full effects of grazing on sycamore are uncertain, largely because sycamores were absent in Segment 1 where livestock were excluded so the chance of seeds germinating in this segment was reduced. In other segments livestock may have grazed some small sycamore seedlings that I had overlooked, but sycamore seedlings certainly were not common along Sonoita Creek. The germination requirements of sycamore seeds are unknown. Perhaps the soil chemistry of the eroded valley-floor has changed significantly and now inhibits either germination of seeds or growth of seedlings.

Livestock did not heavily browse sycamore sprouts for several reasons: Sprouts were necessarily associated with mature trees and

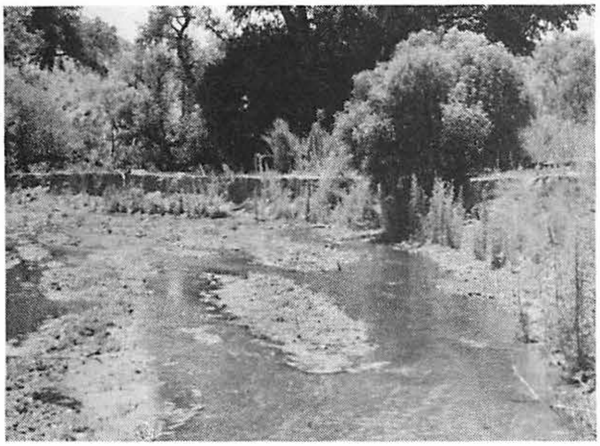

Figure 2.--Vertical-bank erosion along Sonoita Creek. Cutbank here is 1.5 m high.

thus were scattered and were neither as readily encountered by livestock, nor as easily browsed and trampled as dense clusters of seedlings on exposed alluvium. Small sprouts were frequently well protected and hidden by leaf and branch litter from the nearby mature trees and often the trunks of the parent trees obstructed browsing attempts. Several sprouting sycamores were growing on steep eroded banks or among dense brush, both of which hindered browsing. Also, the stems and leaves of sprouts may be less palatable to livestock than those of seedlings.

Because livestock may graze occasional sycamore seedlings, grazing may be preventing a limited increase in the distribution of sycamores along the streambed. Livestock did not appear to be inhibiting regeneration of sycamores by browsing on sprouts, which constituted the vast majority of sycamore regeneration along Sonoita Creek. These observations indicate that the future distribution of sycamores along Sonoita Creek will be nearly identical to the present distribution, except that where mature trees fail to reproduce vegetatively by sprouting the sycamore will disappear.

Grazing of small seedlings by cattle was the most obvious factor preventing regeneration of cottonwood. Seedlings averaging 9 cm in height and 345 seedlings/m^2 in density were commonly grazed and trampled by cattle. Both the proximity to the creek water, which was used by cattle for drinking, and the unprotected openness of the creekbed alluvium where seedlings occurred made seedlings vulnerable to trampling and grazing by cattle. Horses did not graze seedling cottonwoods, but frequently trampled young seedlings that were growing on open alluvium. Horses did strip the bark from some sapling cottonwoods that had been bent over by flooding.

Thus, by grazing seedlings cattle have severely reduced the establishment of cottonwood in the Riparian Deciduous Forest of Sonoita Creek. In Segments 2, 4 and 5, where cattle have grazed for at least 50 years, the combination of decreased establishment and normal mortality of the mature trees will eventually severely reduce in number or eliminate the cottonwoods from this forest. Dry years such as the one reported for 1974 could hasten the mortality of mature trees and the elimination of the cottonwood.

Effects of streambed erosion

Sonoita Creek flows through the Desert Grassland, a biome which has undergone major vegetational changes in the past century (Hastings and Turner 1965, and others). The erosion that is associated with these vegetation changes consists, in part, of extensive vertical cutting or channeling of the streambeds of major drainages and their tributaries by floodwaters. Both overgrazing by livestock and climatic shifts have been associated with the start of this erosion. Bryan (1925) reported that "Nearly all streams in southwestern United States flow between vertical banks of alluvium that vary in height from 10 to as much as one hundred feet. Although subject to periodic floods, these streams no longer overflow their banks, nor build up their adjacent flood-plains. Floods merely deepen and widen the channels (arroyos) which continually grow headward into the undissected valley floors of the headwater valleys and tributaries."

The extent of erosion along Sonoita Creek is limited by both the width and depth of alluvial deposits in this narrow valley-floor, although the heights of some vertically cut banks have increased up to 0.3 m from 1973 to 1976.

Two significant consequences of this channeling are the containment of floodwaters within the confines of the relatively narrow channel, and the scouring of the vegetation that occurs within the erosion channel. Precipitation that now falls within the Sonoita Creek watershed spends relatively less time in this drainage since the channel quickly transports the water along the valley-floor, preventing water dispersion laterally from the creekbed onto the adjacent floodplain. Such rapid transport may also affect the water table recharge rate.

It seems that once streambed cutting begins it is further perpetuated and accelerated by the concentrated floodwaters in the erosion channel, which transport and remove vegetation and debris that would, prior to the channel, have remained in place and promoted dispersal of less forceful floods, thus decreasing the water velocity and inducing silt deposition. The overgrazed hillsides that border Sonoita Creek no doubt assist in increasing the floodwater velocity since they support relatively less vegetation to intercept precipitation.

I witnessed the effects of channeling on 1 July 1974 when a heavy thundershower occurred over the watershed starting about mid-afternoon. At approximately 1700 hours the water level in Segment 1 had risen almost 0.8 m, and only in unchanneled areas did it overflow laterally onto the shallow banks. The current was swift, removing or flattening vegetation on the shallow banks and scouring most aquatic plants and streamside stands of seedling cottonwoods and willows. Only seedlings that were growing among dense stands of seep-willow remained. The next morning scouring of creekbed vegetation was evident all the way to Lake Patagonia. Relatively few stream terraces had been flooded since the erosion channels or railroad levee had contained the floodwaters. In the afternoon of 2 July the water was still turbid and about 10 cm above pre-flood level in Segment 1. A layer of sand and finer silt had been deposited only on the slightly elevated banks that had been flooded and along the edges of the creekbed where the water had receded.

Coupled with recent erosion are factors of future precipitation trends. Seemingly, higher rates of precipitation would cause more intense flooding and involve a greater volume of water in the channel. Possibly the present extent of channel erosion could not contain such volumes of water and lateral flooding could result. However, if precipitation rate decreases in the future, the chance of lateral flooding would be further reduced by the channel.

The single sycamore sapling in Segment 4 that was not a root sprout had been pushed over by flooding and was partially covered by flood debris. The bark of this sapling was scraped in many places, and it appeared unhealthy and not likely to survive. Possibly sycamore seedlings are intolerant of severe flooding, and mortality from floods during the seedling stage is responsible for decreased regeneration from seeds. Root and trunk sprouts probably suffer less mortality from flooding since they are more solidly rooted and protected by parent trees.

Most cottonwood seedlings were removed by floodwaters. The cottonwood seedlings and saplings that occurred in the erosion channel usually were growing among dense stands of seep-willow, where competition for sunlight and water may affect their survival. Those occurring away from seep-willow were bent over by floodwaters and seemed unlikely to survive, and many such saplings had leaves browsed by cattle or bark stripped by horses.

While the streambed within the confines of the erosion channel transports increasingly more floodwater, the elevated terrace adjacent to the erosion channel becomes increasingly more xeric due to reduced overbank flooding outside the channel and increased depth of the water table as erosion progresses. Since cottonwood seedlings were absent from these benches, it is likely that in the absence of saturating floods they seldom contain the reliable surface water necessary for seedlings to extend tap roots to permanent water. This problem is compounded by increased distance to the ground water on benches.

The ability of mature trees to survive on the benches is questionable for they too must cope with relatively drier conditions. Most mature cottonwoods which had fallen over during the drought of 1974 were growing away from the creekbed on slightly elevated benches. Zimmermann (1969) noted that along the San Pedro River cottonwoods occurred where ground water exceeded 300 feet in depth, and he suspected that some tree species "may depend for growth during at least part of the year only on moisture in the alluvium." Where channeling has increased the depth of the water table and prevented lateral flooding onto benches, the only moisture available to vegetation on these benches may be from precipitation. For cottonwoods and sycamores this may not be sufficient to sustain growth, especially if bench alluvium and topography permit rapid runoff of precipitation. If mature sycamores require saturated alluvium for sprouting, the frequency of sprouting may decrease with increased erosion.

SUMMARY AND CONCLUSION

Sonoita Creek provided comparison of regeneration of sycamore and cottonwood trees in areas of various livestock grazing uses. It also afforded observations on the relation between regeneration and streambed erosion, which along Sonoita Creek is limited yet effective in containing and quickly transporting floodwater along the valley-floor, and ultimately in transforming the broad cottonwood forest into a relatively narrow strip of trees that grow in the erosion channel.

Livestock grazing did not appear to prevent regeneration of sycamores, which produced by sprouting from roots and trunk bases. The apparent absence of sycamore seedlings may be related to the erosion and turbid flooding that now periodically occurs in this drainage. Because of vegetative reproduction, sycamore distribution along Sonoita Creek is not likely in the near future to change appreciably from its present distribution unless mortality of sprouts occurs. An increase in soil aridity associated with the erosion channel may induce sprout and parent tree mortality.

Cottonwood, which reproduced from seed, was nearly absent in stream segments grazed by cattle, but abundant in areas grazed by horses only. Because stream flow needed for cottonwood regeneration is confined to the eroded channel, all cottonwood regeneration is confined to this narrow habitat, which averaged 31 m wide. The present mean maximum width of the cottonwood forest including the pre-erosion remnants is 83 m. Thus the future maximum width of the cottonwood forest along Sonoita Creek will decrease nearly 60 percent if the present natural regeneration pattern continues.

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The Development and Perpetuation of the Permanent Tamarisk Type in the Phreatophyte Zone of the Southwest[1]

Jerome S. Horton [2]

Abstract.--Several species of tamarisk were introduced into the United States in the 19th century for ornamental use. Saltcedar (Tamarix chinensis Lour.) became naturalized and by the 1920's was a dominant shrub along the Southwestern rivers. Its aggressive characters suit it to be a permanent dominant in much of the phreatophyte vegetation of this region. Successful management of this vegetation for any resource must carefully consider its ecological characteristics.

INTRODUCTION

Tamarisk (Tamarix spp.), first introduced into the United States for ornamental uses in the early 1800's (Horton 1964), soon spread throughout the nation. Most dramatic, however, was its invasion onto the flood plains of the Southwestern rivers, where it soon became a major vegetation type. These stands attracted little attention until it was realized they were using large amounts of water (Horton 1973). Their aggressive spread, associated with local water shortages, resulted in many action programs to remove phreatophytes.

Robinson (1965) reported that saltcedar, as the aggressive tamarisk (Tamarix chinensis Lour.) is often called, was occupying an estimated 900,000 acres of flood-plain land by 1961. Although this acreage has now been considerably reduced by agricultural and industrial developments and various projects for control of the species for water salvage, the remaining stands are becoming increasingly important for wildlife and other resource management. In many cases, these values outweigh those of the water that might be saved by eradication of the cover. Most of these values are dicussed in accompanying papers. If should be kept in mind that flood-plain vegetation can be managed for perpetuation of wildlife habitat and still reduce water losses (Horton and Campbell 1974).

SPECIES CHARACTERISTICS

To become an aggressive part of any vegetation community, a species must establish itself successfully under existing conditions or to spread into new habitats created by man's modifications. Of primary importance are seed production and germination, followed by successful seedling establishment.

Many phreatophyte species--such as saltcedar, cottonwood (Populus spp.), willow (Salix spp.) and seepwillow (Baccharis glutinosa Pers.)-- are spread primarily by abundant wind-borne seeds which germinate quickly on water or moist soil. Seeds of these species will usually lose viability rapidly, and must germinate within 2 to 4 months (Horton et al. 1960). Though the seeds will germinate rapidly, the new seedlings require wet soils for several weeks. These species thrive best in open sun, such as along sandbars or areas disturbed by floodflows. Of the species disseminated by wind-borne seed, tamarisk is the most aggressive, and when conditions are ideal, invasion will be rapid.

Seed germination of mesquite (Prosopis juliflora (Swartz) DC.) and associates is not dependent on such rigid soil-moisture conditions. While germination may be started by floodflow, especially in gravel washes, seeds are spread more by animal activity, such as defecation by cattle, coyotes, etc. Thus, mesquite has spread into the grasslands and hillsides of southern Arizona where summer rains are more frequent (Schuster 1969). In the drier areas of central Arizona, however, the species is more common in alluvial soils above the deeper groundwater tables.

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[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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Root systems of phreatophyte species vary greatly. Mesquite is usually deep rooted and saltcedar can also be deep rooted. In contrast, seepwillow is shallow rooted, growing only where the groundwater is close to the surface. Arrowweed (Pluchea sericea (Nutt.) Coville) shrubs send out lateral roots just below the surface of the soils which sprout to form dense clusters over relatively large areas (Gary 1963). Some seedlings of this species have been noted, but the dense thickets are probably caused by lateral spread.

All of the aboveground portions of saltcedar will develop adventitious roots and form new shrubs if kept wet in moist soil. Gary and Horton (1965) found that 100 percent of stem cuttings would sprout at all times of the year if they are kept moist and warm. If the stem cuttings are allowed to dry, even as short a period as one day, the sprouting ability is quickly reduced. Root cuttings did not show any signs of sprouting. Wilkinson (1966), however, reported that a small percentage of completely buried root cuttings formed stem sprouts in a mist-bed in the greenhouse. How frequently similar conditions might occur in the field is not known. Spreading by lateral roots from established saltcedar shrubs has never been observed.

After burning or cutting, saltcedar shrubs redevelop rapidly; the sprouts from the root crown will grow as much as 10 to 12 feet in a year under favorable conditions. In a study of the effect of grazing upon resprouting tamarisk shrubs, cattle removed approximately 50 percent of the foliage produced. The shrubs still grew vigorously, however, and by the second year the stand became so dense that cattle would not enter the area (Gary 1960).

Cattle and probably sheep will also browse heavily on young seedlings as well as the more mature plants if the stand is open.

Mature saltcedar shrubs are more drought resistant than the native species. They are also long lived and will mature into small trees. In New Mexico, individual trees reportedly 75 to 100 years of age have not yet shown signs of deterioration due to age.

VEGETATION OF THE PHREATOPHYTE FLOOD PLAINS

The original vegetation of the flood-plain areas was determined primarily by the water supply available to the plant roots. Undoubtedly the rivers flowed rather constantly and the water tables were high in much of the valley area. The area close to the river was usually dominated by a wide band of trees, principally Fremont cottonwood (Populus fremontii Wats.), with associated willows. On the higher ground were large areas dominated by mesquite. Arrowweed was dominant in many areas. In the more saline sites, there were large patches of salt-tolerant grasses such as saltgrass (Distichlis stricta (Torr.) Rydb.), surrounded by saltbushes (Atriplex spp.) and other salt-tolerant plants.

The early pioneers used the cottonwood, mesquite, and other trees and larger shrubs for fuel and for building their homes. In the Arizona desert, the lands dominated by mesquite were some of the best soils in the valley and were soon cleared for farming. Along the Rio Grande, the first and finest farmland was created by removal of cottonwood.

These activities soon removed or at least greatly reduced the natural wooded areas along the rivers. Thus, the saltcedar found conditions ideal for rapid invasion of the flood plains. Shortly after the turn of the century saltcedar began spreading aggressively. By the 1940's, extensive areas were dominated by saltcedar along the Gila (Marks 1950, Haase 1972, Turner 1974), Salt (Turner and Skibitzke 1952, Gary 1965), and Rio Grande (Campbell and Dick-Peddie 1964) as well as along the Pecos and Colorado (Robinson 1965). It is now also found along many smaller streams, around springs and seeps, by roadsides, and in many other areas of the West wherever there is sufficient moisture to germinate the seeds and establish the seedlings.

In recent years, much of the land dominated by saltcedar has been converted to farms or industrial use near the towns and cities, or cleared for water salvage projects.

In spite of these major changes, there are still large areas occupied by wildland vegetation, although they are usually altered by man. Haase (1972), in his study of the lower Gila River, indicates that saltcedar occupies about 50 percent of the total bottom-land area. Under present conditions he feels this dominance will not be changed unless there is some marked fluctuation in the water table or in other environmental conditions. His analysis and breakdown of the communities is very similar to Marks (1950).

Somewhat similar communities were studied along the Salt River above Granite Reef dam east of Tempe (Gary 1965). The saltcedar communities were separate and distinct fromthe arrowweed, and occupied sites with shallower water tables and a silt loam soil, contrasted to the sandy loam found under the arrowweed and mature mesquite. There were a few cottonwood trees, but not enough to be included in the analysis.

Along the Rio Grande, Campbell and Dick-Peddie (1964) found that saltcedar was the major dominant in southern New Mexico, but that cottonwood, Russian-olive (Eleagnus angustifolia L.), and other species increased upstream. These authors observed that cottonwood assumes dominance over saltcedar if the cottonwood is left to develop into a full tree without disturbance. In mature stands of cottonwood, saltcedar grows only in natural openings and along the outer edge of the cottonwood stand.

Along some flood-plain reaches, dropping water tables have reduced the stand of saltcedar, because ground water is now apparently out of reach of its roots. In the 1940's a dense stand of saltcedar extended along the Salt River from east of Mesa through Tempe and Phoenix to its confluence with the Gila River. Shrubs are now growing along this river only as widely spaced desert-type plants dependent on floodflows and rain for survival. In dry periods, these saltcedar shrubs will make almost no growth and tend to drop their leaves. They leaf out quickly when water becomes available, however.

Fires burning through such stands kill a fairly large number of plants and create an even more open stand. It is probable, in this desert climate, that shrubs must be spaced 15 or 20 feet or more apart to have sufficient root systems to withstand lengthy droughts. A heavy, dense stand will survive only where the water table is within 15 or 20 feet of the surface.

Thus, although saltcedar has aggressively spread over a large portion of the western flood plains, it has probably reached its maximum spread or is being reduced in most of the area. However, it will always threaten to invade aggressively after any change in local conditions. Its ecology must be understood if management of flood-plain vegetation is to be successful.

FUTURE OF TAMARISK STANDS

Future changes in the vegetation cover of flood plains now dominated by saltcedar is a concern of many land managers. The aggressiveness of saltcedar suggests that it will remain a dominant in most areas if conditions remain as at present and often may invade where conditions change in other types.

Seeds of cottonwood, willow, and seepwillow have characteristics similar to saltcedar. Thus, in theory they are highly competitive. However, saltcedar produces seed over a much longer period and also can become established after a summer recession flow when seeds of the other species are not present. In addition, tamarisk seedlings can tolerate drying at an earlier stage and, while often grazed, are less sought after than cottonwood and willow. Also the mature shrubs are more drought resistant which tends to eliminate many of the competing native shrubs and trees.

With the characteristics of the various species in mind, let us consider the different types of vegetation along the rivers. A dense, mature stand of tamarisk would not have any bare soil underneath, and thus there would be no opportunity for regeneration of any species. Unless subjected to fire or flood, the stand would not deteriorate. However, if cottonwood was present in the initial seedling establishment stage, there can be a gradual increase of dominance of this species as the tree grows. This relationship can often be observed along the Rio Grande south of Albuquerque and, very rarely, at lower elevations such as along the San Pedro River, south of Winkelman, Arizona. Thus, mature saltcedar stands should not be expected to yield to any invading vegetation type unless the water table drops or the existing stand is altered by man, fire, or flood.

Lowering water tables may kill a large portion of the shrubs. The degree of damage would depend upon the rapidity of the drop and the depth of the final water table. In some cases, shrubs may die back but readjust to the lower groundwater if it stabilizes at 20 feet or so. The resulting stand after the root systems are extended downwards may be nearly as dense as had previously existed.

If the water table is at 5 feet or less, saltcedar does not develop densely and the intershrub spaces are usually dominated by saltgrass or Bermudagrass (Cynodon dactylon (L.) Pers.) Dropping water tables in such an area will allow the saltcedar to grow dramatically and replace the grass.

Fire burning through a saltcedar stand will not kill the shrubs, as they tend to sprout vigorously unless they are growing under stress. Then as many as half of the shrubs may not survive.

Floods do, at times, remove large areas of saltcedar. If this occurs during or just before the seeds are flying, seedlings will likely be established along the edges of the receeding flows more aggressively than other species. Sometimes, such as after flash summer floods, drying is too rapid for seedling survival. Buried root crowns or above-ground portions of branches and smaller stems will often sprout, however, even if conditions are not favorable for seedling establishment.

STUDIES IN TAMARIX TAXONOMY

The identification of saltcedar and its proper relationship to Old World form has long been confused. The taxonomy of Tamarix is difficult primarily because of the lack of distinct identifying floral characteristics, and the great variation among plants in the same community. Major confusion is caused by the length of the blooming season (March to October in desert climates) with changing inflorescence types and floral characters as the season progresses. Thus, accurate species identification requires several collections from a shrub to sample seasonal variations.

The early floras usually listed T. gallica as the introduced species. This terminology continued until McClintock (1951), in a study of horticultural tamarisks, stated that T. gallica was a rare shrub in the West, and the common aggressive saltcedar was Tamarix pentandra Pall.

Baum (1966), after extensive study of the genus Tamarix at the Hebrew Univeristy, Jerusalem abandoned the name T. pentandra because it did not follow the standard rules of nomenclature. He considered the widespread American tamarisk, after examining material from various American herbaria, as consisting of two species: Tamarix ramosissima Lebed. and Tamarix chinensis Lour. (Baum 1967). T. gallica was reported as occurring mostly on the Texas Gulf Coast. Tamarix africana Poiret and several others were reported as horticultural species.

After detailed studies of many shrubs of diverse species and forms obtained from various American and Old World localities and grown on the Arizona State Univeristy Farm as well as herbarium specimens collected elsewhere in the United States, I feel that our aggressive saltcedar, though extremely variable, should be considered as one species and not two as outlined by Baum. The oldest synonym applied to the aggressive tamarisk group is Tamarix chinensis Lour.; thus this name should now be accepted for the species so commonly naturalized in the West.

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Avian Use of Saltcedar Communities in the Lower Colorado River Valley[1]

Bertin W. Anderson[2], Alton Higgins[3], and Robert D. Ohmart[4]

Abstract.--Bird densities and bird species diversities (BSD) in saltcedar (Tamarix chinensis) stands of the lower Colorado River Valley were determined on a seasonal basis from May 1974 through February 1977. Comparisons were made between six saltcedar structural types as well as on a community level with seven other vegetation types. A method of determining the relative value of the communities, as well as the saltcedar structural types, based on density, density with 10 percent doves, BSD, BSD with 10 percent doves, number of species, structural diversity, and size of census area is described. Results showed the saltcedar community supported fewer birds than native communities, although tall, dense stands were valuable for nesting doves and rarer bird species in riparian communities along the lower Colorado River.

INTRODUCTION

Events of the past century have resulted in tremendous changes in the flora and fauna of the lower Colorado River Valley. The Colorado River has been channelized and controlled, and vast stretches of honey mesquite (Prosopus juliflora) have been converted to agricultural use--a practice which has continued at an accelerated rate in the past few years. These conditions have favored the Brown-headed Cowbird (Molothrus ater) and have reduced or extirpated the breeding populations of such species as the Yellow Warbler (Dendroica petechia) and Bell Vireo (Vireo bellii).

This loss of habitat has also been accompanied by a deterioration of the remaining bottomland by the now well-entrenched exotic saltcedar (Tamarix chinenses). First recorded in Arizona in the late 1800's, saltcedar was not an important species until after 1910 (Robinson 1965). Nevertheless, it is now present in pure communities or mixed with virtually all riparian community types, being absent only from a few stands of honey mesquite. Knowledge concerning those avian species which utilize saltcedar is essential for those agencies involved with river or riparian vegetation management.

Areas containing saltcedar are regularly swept by fire, as demonstrated by the fact that 21 of the 25 stands involved in our study have burned during the last 15 years. The other four stands of saltcedar developed after some other form of severe disturbance. Many of these areas obviously supported another community type in the past. Saltcedar is a fire-adapted species and shows a greater recovery rate than the native riparian species. Willow (Salix gooddingii) and arrowweed (Tesseria sericea) respond quickly after fire while honey mesquite shows slower growth. Species such as cottonwood (Populus fremontii) are killed during fire. With the initiation of a burn cycle, the dominance of an area by saltcedar becomes successively more complete (see Horton, these proceedings).

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METHODS

Structural Types

The saltcedar community (stands in which saltcedar is virtually the only tree was divided into six structural types, based on distribution and density of foliage at varying heights, as explained elsewhere in these proceedings (Anderson, Engel-Wilson, Wells, and Ohmart). Structural types IV and V (trees not dense and seldom taller than 5 or 3 m, respectively) represent typical stands found in the lower Colorado River Valley. Data were gathered in these areas from the summer of 1974 through February 1977. Beginning in 1976 data were gathered from about 18 transects averaging over 0.8 km in length, using censusing techniques described by Anderson, Engel-Wilson, Wells, and Ohmart (these proceedings). These included one transect in structural type I (dense vegetation at 10 to 20 m), established in March 1976; one transect in type II (dense vegetation at 5 to 10 m), established in June 1975; two transects in type III (trees dense, seldom exceeding 6 m), established in March 1976; four transects in type IV, eight transects in type V and two in type VI (sparse vegetation representing regrowth after disturbance), established in 1974.

Ranking Technique

We developed the ranking technique for assessing the relative value of structural types of saltcedar stands and of saltcedar compared to other community types. A rank value for bird density in the structural types of saltcedar was determined using all doves and 10 percent doves, by assigning the smallest value (1) to the structural type with the greatest density and the largest value (n) to the one with the smallest density. This was repeated using numbers of species and BSD with all doves and with 10 percent doves. A mean rank for these parameters was calculated for five seasonal periods throughout the year. The average of these seasonal values was the rank assigned to a particular type.

The relative value of saltcedar compared with other community types was achieved by assigning the smallest score to the community type with the greatest average density (or number of species, or BSD's, all structural types combined) and the largest score to that community type with the smallest density (or number of species, or BSD's) as described above for saltcedar structural types.

The number of species may increase with the diversity or size of area censused. We attempted to compensate for this by ranking the most heterogeneous community or structural types with the greatest diversity or largest census area last.

We assumed that each of the parameters considered were of equal importance, a point of potential contention.

RESULTS

Densities and Diversities

Types IV and V, 1974-76

Data for three consecutive summers (May, June, July) from structural types IV and V were fairly consistent. Large dove densities in type IV in 1976 and in type V in 1975 (Table 1) resulted in relatively depressed BSD's in those years. Type IV diversities with 10 percent doves were higher than those of type V in 1974 and 1975. Dove densities for 1976 in type IV increased threefold from 1975, depressing the diversity value just lower than that of type V.

Fall (October, November) data for type V were similar in the first two years but showed a rather dramatic increase in all parameters in 1976 (Table 1). Type IV showed greater values in 1975 than in 1974 and increased further in 1976. Few doves were present at this time of year and this is reflected in slight differences in BSD's with 10 percent doves and BSD. We feel that increased densities in the fall of 1975 and 1976 over 1974 can be traced in part to the much milder conditions which existed during the late fall and winter seasons, allowing increased and prolonged use of the saltcedar community, particularly by small wintering insectivores.

Diversity values appeared to be more closely correlated with the structural parameters than were densities or species numbers. For example, in the fall of 1974 and 1976, densities in type V were greater than those of type IV; the reverse was true in 1975. Diversity values, however, were always greater in type IV.

Types I - VI, 1976

Bird densities in the six saltcedar structural types generally follow the same annual pattern of low winter numbers, increasing in the spring and peaking in the summer (Table 2). Densities dropped in late summer and continued dropping through the following winter. Spring (March-April) densities were apparently

Table 1.--Summer and fall densities, diversities, and number of species in saltcedar. Structural types IV and V, lower Colorado River Valley 1974-1976.

Structural Type	Year	Density	Density with 10% Doves	BSD	BSD with 10% Doves	Number Species
SUMMER						
IV	1974	120	64	2.2801	2.7009	19
IV	1975	126	77	2.4377	2.6237	19
IV	1976	241	98	1.9255	2.6055	18
V	1974	129	91	2.4135	2.5871	21
V	1975	182	120	2.4022	2.5631	22
V	1976	131	86	2.4411	2.6760	20
FALL						
IV	1974	42	40	2.3878	2.3062	14
IV	1975	76	75	2.4033	2.3644	16
IV	1976	105	103	2.6336	2.5934	22
V	1974	60	55	2.2369	2.1274	14
V	1975	75	63	2.0881	2.0126	14
V	1976	110	110	2.5772	2.5772	22

related to structure. Abert's Towhee (Pipilo aberti) provides a good example of a species whose density was strongly correlated with structure in saltcedar, with 1, 5, 14, 19 and 27 birds per 40 ha in types V through I respectively.

The preference of nesting doves for dense vegetation at 3 to 6 m is strongly reflected in the bird density value of type II saltcedar in the summer. There were, in fact, as many doves in this type as birds of all species in most of the other structural types.

Type II continued to show a large dove population in late summer (August-September), although types I and III had higher populations of birds of other species. Type V had the greatest diversity values and a relatively large number of species, but by far the lowest density.

The dove population was extremely low in the fall. Diversities and numbers of species, however, continued to show an inverse relationship with structure as in late summer.

Densities during the winter (December-January-February) season of 1976-77 were high compared with the fall, and especially high compared with the previous winter (Table 2). The majority of these birds, however, were small insectivores such as the Ruby-crowned Kinglet (Regulus calendula), Orange-crowned Warbler (Vermivora celata), and Yellow-rumped Warbler (Dendroica coronata). As previously mentioned, the relatively mild winter was at least partly responsible for the densities of these birds. The monthly totals for these species in the saltcedar community as a whole decreased throughout the winter, whereas the total found in the cottonwood-willow community was higher in January and February than it was in December. This demonstrates that cottonwood-willow maintained a high value for these species throughout the winter--unlike saltcedar (Table 3).

COMPARISON OF COMMUNITIES

Knowledge of the value of the different saltcedar structural types is necessary, but more important is the relative value of the saltcedar community as compared with other community types--many of which are either being displaced by saltcedar or lost in other ways. Communities to be compared include six riparian communities as well as desert wash and citrus orchard communities.

Community Densities

Bird densities in saltcedar were consistantly greater than those in arrowweed only (Tables 4 and 5) while numbers of species in seasons other than winter were comparable with other communities (Table 6). Winter densities

Table 2.--Densities, diversities and number of species in six saltcedar structural types, lower Colorado River Valley, December 1975 - February 1977.

Structural Type	December January February	March April	May June July	August September	October November	December January February
Total Density (N/40 ha)						
I	--	146	290	213	165	107
II	42	111	503	363	268	275
III	--	101	316	296	129	119
IV	25	39	241	187	105	50
V	29	54	131	89	110	125
VI	293	89	226	280	171	153
Density 10% Doves (N/40 ha)						
I	--	136	193	183	165	107
II	37	91	238	177	267	272
III	--	81	156	239	129	115
IV	20	28	98	155	103	49
V	27	50	86	75	110	125
VI	132	83	157	104	95	103
BSD						
I	--	2.1739	2.5036	1.8976	1.9097	1.7062
II	2.0383	2.2129	2.0411	1.8211	2.2582	1.9667
III	--	1.7179	1.8521	2.3969	2.3934	2.2683
IV	2.4850	2.5366	1.9266	2.4985	2.6336	2.3853
V	2.5825	2.4147	2.4411	2.7965	2.5772	2.0141
VI	1.6514	2.2435	2.5269	1.5361	1.8744	2.0174
BSD 10% Doves						
I	--	2.0930	2.7312	1.7129	1.9097	1.7062
II	1.9487	2.0597	2.5425	2.1160	2.2397	1.9367
III	--	1.6070	2.1643	2.3143	2.3934	2.2128
IV	2.5191	2.6939	2.6055	2.3894	2.5934	2.3272
V	2.5284	2.3437	2.6760	2.7972	2.5772	1.9908
VI	2.5715	2.1687	2.6214	2.7467	2.5127	2.2271
Number Species (N/40 ha)						
I	--	12	25	8	12	11
II	8	13	20	13	18	19
III	--	6	19	26	20	18
IV	12	15	18	23	22	14
V	15	13	20	24	22	19
VI	21	17	24	25	21	23

of birds in saltcedar are greater than those found in saltcedar-honey mesquite and arrowweed but included the greatest percentage and nearly the greatest dove densities of all communities. Densities decreased from summer through the winter while densities with 10 percent doves remained fairly stable through the fall. Although doves comprised fully 50 percent of the summer density in the saltcedar community, there were actually more doves in all of the other community types, excepting arrowweed and desert washes. There was a distinct relationship between departure of doves and rising BSD values from August through November (Tables 7 and 8). Bird densities in honey mesquite rose sharply in October-November, and bird densities in desert wash and saltcedar-honey mesquite not only increased from late summer to fall, but the greatest number of species occurred at this time.

Table 3.--Winter densities of small insectivores in cottonwood-willow and saltcedar communities, lower Colorado River Valley, 1976.

Community	Month	Ruby-crowned Kinglet	Yellow-rumped Warbler	Orange-crowned Warbler	Total	Percent of Total Population
Cottonwood-Willow	Dec	323	258	83	664	51
	Jan	340	516	92	984	57
	Feb	321	327	109	757	45
Saltcedar	Dec	152	535	47	734	59
	Jan	176	130	32	338	46
	Feb	89	100	6	195	32

Table 4.--Total densities for eight community types December 1975 - November 1976, lower Colorado River Valley.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	148	172	336	262	210
Screwbean Mesquite	73	109	318	307	183
Honey Mesquite	193	193	323	195	270
Saltcedar-Honey Mesquite	42	111	295	184	177
Saltcedar	54	71	216	177	129
Desert Wash	68	115	176	118	185
Arrowweed	18	23	124	141	99
Orchard	158	158	678	540	135

Table 5.--Densities including 10% doves for eight community types December 1975 - November 1976, lower Colorado River Valley.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	134	151	223	195	201
Screwbean Mesquite	58	82	174	218	159
Honey Mesquite	161	166	169	148	265
Saltcedar-Honey Mesquite	40	91	170	151	176
Saltcedar	26	62	119	126	120
Desert Wash	67	106	121	98	185
Arrowweed	17	23	101	135	99
Orchard	144	97	132	178	128

Table 6.--Number of species for eight community types found in the lower Colorado River Valley from December 1975 through November 1976.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	28	40	35	41	34
Screwbean Mesquite	16	27	24	33	26
Honey Mesquite	19	30	22	28	27
Saltcedar-Honey Mesquite	16	20	20	19	22
Saltcedar	10	19	25	27	26
Desert Wash	16	20	20	21	30
Arrowweed	8	13	21	23	18
Orchard	17	20	18	25	17

Table 7.--BSD for eight community types found in the lower Colorado River Valley from December 1975 through November 1976.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	2.7401	3.1762	2.8494	3.1817	2.9502
Screwbean Mesquite	2.6422	2.9067	2.4015	2.4451	2.8087
Honey Mesquite	2.1850	2.8608	2.1850	2.6826	2.6206
Saltcedar-Honey Mesquite	2.5428	2.4575	2.327	2.5476	2.5095
Saltcedar	1.8071	2.8537	2.405	2.7038	2.8167
Desert Wash	2.5047	2.2293	2.364	2.5706	2.7706
Arrowweed	1.9652	2.4643	2.665	2.7037	2.5160
Orchard	1.8823	2.0460	0.693	1.3052	2.2837

Table 8.--BSD with 10% doves for eight community types found in the lower Colorado River Valley from December 1975 through November 1976.

Community	Dec, Jan, Feb	Mar, Apr	May, June, July	Aug, Sept	Oct, Nov
Cottonwood-Willow	2.6941	3.2125	3.2225	3.3940	2.9067
Screwbean Mesquite	2.7721	3.1914	2.9040	2.4758	2.8263
Honey Mesquite	2.1561	2.8937	2.8276	2.7997	2.5844
Saltcedar-Honey Mesquite	2.4869	2.4888	2.675	2.4660	2.4971
Saltcedar	2.6848	2.8443	2.883	2.8544	2.7827
Desert Wash	2.4718	2.1516	2.564	2.5943	2.7706
Arrowweed	1.9652	2.4229	2.6108	2.6562	2.5160
Orchard	1.7105	2.2931	1.897	2.3454	2.1917

USE BY VARIOUS GUILDS

The percentage of the total lower Colorado River Valley population of sixteen of the more common breeding species (representing six guilds) which would occur in saltcedar, using 40 ha of each of the six riparian community types, should approximate 16.6 percent (1/6 the population of a species) if there were no selection for a particular vegetative type by any of these species, i.e. if they were evenly distributed in all community types. Two of three small (<15 gm) insectivorous species apparently exhibited no selection against saltcedar (Table 9), occurring in densities at or slightly above the expected. Woodpeckers demonstrated much less flexibility in adapting to saltcedar, possibly as a result of body size in relation to tree limbs and trunks suitable for making nest cavities. The Ladder-backed Woodpecker (Picoides scalaris), the smallest species, was more common than the Gila Woodpecker (Melanerpes uropygialis); the Common Flicker (Colaptes auratus), the largest species, did not occur in saltcedar at all. Fifty to 86 percent of the population of three medium-sized insectivores were found in structural types I and II, but only the Summer Tanager (Piranga rubra) used saltcedar to any significant extent (Table 9). The density of Abert's Towhee was slightly above that which would be expected by chance while other ground feeders (Gambel's Quail, Lophortyx gambelii and the Crissal Thrasher, Toxostoma dorsale) were slightly below expected values (Table 9). All four species of granivores occurred at greater than expected levels although a constantly wet condition was probably the greater attractant for the Song Sparrow (Melospiza melodia), considered here to be a granivore.

OVERALL VALUE OF SALT CEDAR TO BIRDS

Value of Structure

The structural types found in saltcedar (all types except type VI) were ranked to

Table 9.--Differential use of community and structural types by foraging guilds of birds in the lower Colorado River Valley, 1976.

Species	Total/240 ha all communities	Total in saltcedar 40 ha	% total in saltcedar	% population in each structure, all communities					
				I	II	III	IV	V	VI
Small Insectivores									
Verdin	108.60	10.17	9.4	5.0	15.8	20.4	25.1	15.2	18.5
Lucy's Warbler	87.37	17.50	20.1	23.4	29.0	15.2	15.6	11.1	5.7
Black-tailed Gnatcatcher	34.03	5.83	17.1	27.2	9.6	9.6	23.7	20.8	9.0
Woodpeckers									
Ladder-backed Woodpecker	31.80	2.17	6.8	26.9	29.9	15.1	12.1	6.2	9.9
Gila Woodpecker	11.57	.17	1.4	42.0	31.3	11.1	5.9	3.7	5.9
Medium-sized Insectivores									
Northern Oriole	46.30	5.67	12.2	18.1	31.6	22.0	14.5	6.5	7.2
Summer Tanager	8.83	3.00	34.0	73.1	13.7	11.4	1.8	0.0	0.0
Yellow-breasted Chat	11.00	.17	1.5	33.2	37.4	17.9	10.2	1.3	0.0
Cactus Wren	7.73	.67	8.6	11.5	23.0	20.1	16.1	8.6	20.7
Ground Feeders									
Abert's Towhee	102.55	20.50	20.0	12.3	25.0	29.8	13.4	9.8	9.4
Crissal Thrasher	21.10	2.83	13.3	0.0	21.7	25.0	21.0	21.3	11.0
Gambel's Quail	93.25	13.67	14.7	0.6	23.5	12.0	18.1	24.7	21.1
Granivores									
Song Sparrow	9.17	2.00	21.8	69.7	4.8	21.6	3.8	0.0	0.0
Blue Grosbeak	40.78	9.50	23.3	15.3	22.6	19.7	14.0	12.1	16.3
House Finch	5.92	3.17	53.5	56.5	15.7	9.4	5.7	7.1	5.6
Brown-headed Cowbird	105.63	18.50	17.5	18.3	27.4	20.8	14.7	11.6	7.2
Flycatchers									
Ash-throated Flycatcher	65.52	6.83	10.4	10.8	24.7	17.4	17.9	12.0	17.2
Western Kingbird	8.37	1.00	12.0	4.8	45.2	12.1	17.4	4.8	15.5

determine their relative value. Type II can be seen to be, overall, the preferred structure by birds in general, followed by types I, III, V, and IV, the values of the last two being very close (Table 10). The changes in the avian community that occurred when saltcedar reached a structure of type II or I were significant not only in terms of increasing densities of some birds but also in the addition of species. For example, the White-winged Dove (Zenaida asiatica) and the Mourning Dove (Zenaida macroura), Abert's Towhee, Lucy's Warbler (Vermivora luciae) and the Black-chinned Hummingbird (Archilochus alexandri) were much more abundant in type II than in type III. Type I attracted the Song Sparrow and relatively high densities of Abert's Towhee as well as the Summer Tanager and Yellow-breasted Chat (Icteria virens) in the summer.

Relative Community Value

The communities, including the two non-riparian communities, were analyzed to determine their overall relative value to birds during 1976 using the "ranking" technique discussed above. Ranked in this way cottonwood-willow communities proved the most valuable, followed by honey mesquite, screwbean mesquite, saltcedar-honey mesquite, desert wash, saltcedar, orchard and arrowweed (Table 10). Since orchards do not represent a naturally occurring community, it can be seen that saltcedar is only slightly more valuable than arrowweed (Table 11).

DISCUSSION

It has been demonstrated that the saltcedar community does not compare favorably with essentially native communities (except arrowweed, which lacks trees). Nevertheless, in the face of present environmental conditions and continuing loss of native vegetation, a concomitant increase in the proportion of the riparian habitat dominated by saltcedar is inevitable. Of particular interest was the comparison between saltcedar and orchards. The occurrence of these communities in the lower Colorado Valley has been relatively recent, and both present a uniform monoculture regardless of structural types. The birds have thus responded in a similar overall manner to these exotic communities.

Although it would appear that few species of birds are actually attracted to saltcedar during the breeding season, the addition of one or more of the native tree species, even in small numbers, would no doubt greatly enhance the overall attractiveness of an area. Addition of cottonwood or willow trees would add nest site potential, an important community component, especially for the woodpecker and flycatcher guilds. Screwbean or honey mesquite, if infested with mistletoe, would attract frugivores, a guild entirely missing from pure saltcedar.

Managing areas of saltcedar for structural types I and II appears to have significant potential (Ohmart and Anderson, MS[5/]). Saltcedar type II and mature orchards support the greatest densities of doves (Mourning Dove in orchards, both species in saltcedar type II), which are important game species in the lower Colorado River Valley. Saltcedar type I provides a habitat for avian species which are normally restricted to cottonwood-willow communities, such as the Summer Tanager, and is another important reason land managers should strongly consider managing saltcedar communities. Fire prevents saltcedar from reaching maturity and/or persisting as mature communities for any length of time along the lower Colorado River. Maintenance of mature

Table 10.--Relative value of saltcedar structural types to birds as determined by Ranking Technique, lower Colorado River Valley, March 1976-February 1977. Lower rank indices indicate greater relative value.

Structural Type	Density	Density 10% Doves	BSD	BSD 10% Doves	Number Species	Size of Census Area	Grand Rank
I	2.6	2.2	3.8	3.8	4.0	1.0	2.90
II	1.2	1.6	3.6	3.6	2.6	1.2	2.30
III	2.6	2.6	3.6	3.4	3.2	2.8	3.03
IV	4.6	4.6	1.8	1.4	2.8	4.0	3.20
V	4.2	4.0	1.0	1.8	1.8	5.0	3.13

5/ Manuscript in preparation discussing management alternatives of saltcedar communities for wildlife.

Table 11.--Relative value of eight community types in 1976 using Ranking Technique. Lower rank indices indicate greater relative value.

Total Density		Density with 10% Doves		Number of Species	
Honey Mesquite	2.0	Cottonwood-Willow	2.0	Cottonwood-Willow	1.0
Cottonwood-Willow	2.4	Honey Mesquite	2.4	Honey Mesquite	2.8
Orchard	2.6	Screwbean Mesquite	3.8	Screwbean Mesquite	3.2
Screwbean Mesquite	4.0	Orchard	4.0	Desert Wash	4.4
Saltcedar-Honey Mesquite	5.4	Saltcedar-Honey Mesquite	4.4	Saltcedar	4.8
Desert Wash	5.4	Desert Wash	4.8	Saltcedar-Honey Mesquite	5.4
Saltcedar	6.4	Saltcedar	6.8	Orchard	5.4
Arrowweed	7.8	Arrowweed	7.8	Arrowweed	6.8

Bird Species Diversity (BSD)		BSD with 10% Doves		Community Diversity		Grand Rank	
Cottonwood-Willow	1.0	Cottonwood-Willow	1.2	Saltcedar-Honey Mesquite	1.0	Cottonwood-Willow	2.47
Screwbean Mesquite	3.2	Screwbean Mesquite	2.6	Arrowweed	1.0	Honey Mesquite	3.50
Saltcedar	3.4	Saltcedar	2.7	Desert Wash	3.0	Screwbean Mesquite	3.83
Arrowweed	4.2	Honey Mesquite	4.0	Orchard	4.0	Saltcedar-Honey Mesquite	4.40
Honey Mesquite	4.8	Arrowweed	5.2	Honey Mesquite	5.0	Desert Wash	4.63
Desert Wash	4.8	Desert Wash	5.4	Screwbean Mesquite	6.2	Saltcedar	5.10
Saltcedar-Honey Mesquite	4.8	Saltcedar-Honey Mesquite	5.4	Saltcedar	6.6	Orchard	5.27
Orchard	7.8	Orchard	7.8	Cottonwood Willow	7.2	Arrowweed	5.47

saltcedar communities for 20 or more years would enhance the overall value of this plant species for birds.

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Influences of Riparian Vegetation on Aquatic Ecosystems with Particular Reference to Salmonid Fishes and Their Food Supply[1,2]

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Abstract.--The riparian zone has important influences on the total stream ecosystem including the habitat of salmonids. Shade and organic detritus from the riparian zone control the food base of the stream and large woody debris influences channel morphology. Temporal and spatial changes in the riparian zone, the indirect influences of riparian vegetation on salmonids, and the effects of man's activities are discussed.

INTRODUCTION

Streamside vegetation strongly influences the quality of habitat for anadromous and resident coldwater fishes. Riparian vegetation provides shade, preventing adverse water temperature fluctuations. The roots of trees, shrubs, and herbaceous vegetation stabilize streambanks providing cover in the form of overhanging banks. Streamside vegetation acts as a "filter" to prevent sediment and debris from man's activities from entering the stream. Riparian vegetation also directly controls the food chain of the stream ecosystem by shading the stream and providing organic detritus and insects for the stream organisms.

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WHAT IS RIPARIAN VEGETATION?

Riparian vegetation is at the interface between aquatic and terrestrial environments. It has, therefore, been defined and examined from a number of perspectives. Plant ecologists speak in terms of riparian species and plant communities. The riparian zone may also be defined geographically in terms of topography, soils, and hydrology. We prefer to take a functional approach; that is, to consider riparian vegetation as any extra-aquatic vegetation that directly influences the stream environment.

Consequently, in defining riparian vegetation we must consider the full scope of its biological and physical influences on the stream. Riparian vegetation regulates the energy base of the aquatic ecosystem by shading and supplying plant and animal detritus to the stream. Shading affects both stream temperature and light available to drive primary production; therefore, the balance between autotrophy and heterotrophy is determined by multiple functions of riparian vegetation.

Although imperfect, the stream order system(Leopold et al. 1964) is a useful way to classify elements of a drainage system. In small and intermediate-sized streams (up to about fourth-order) in the Pacific Northwest, riparian vegetation exercises important controls over physical conditions in the stream environment. Rooting by herbaceous and woody vegetation tends to stabilize streambanks, retards erosion, and, in places, creates overhanging banks which serve as cover for fish. Above ground woody riparian vegetation is an obstruction to highwater streamflow, sediment and detritus movement, and is a source of large organic debris. Large organic debris in streams (1) controls the routing of sediment and water through the system, (2) defines habitat opportunities by shaping pools, riffles, and depositional sites and by offering cover, and (3) serves as a substrate for biological activity by microbial and invertebrate organisms (Triska and Sedell 1976; Swanson et al. 1976; Sedell and Triska 1977; Anderson et al. in press).

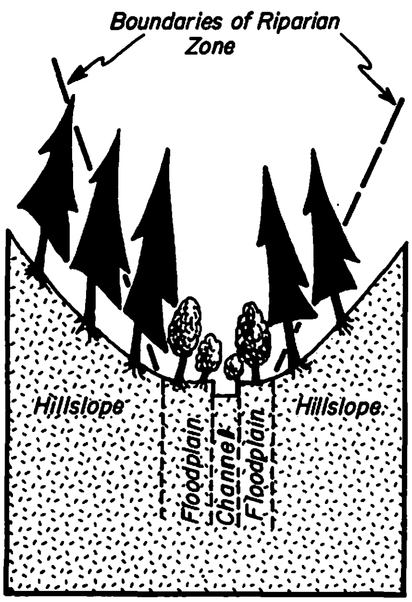
The influences of riparian vegetation on coniferous forest stream ecosystems in the Pacific Northwest are summarized in figure 1. In a functional approach to defining riparian vegetation, all floodplain vegetation as well as trees on hillslope areas which shade the stream or directly contribute coarse or fine detritus to it are considered part of the riparian zone. In the Pacific Northwest, vegetation in the zone of riparian influence includes herbaceous ground cover, understory shrubby vegetation (commonly deciduous), and overstory trees on the flood plain (generally deciduous) and on hillslopes (generally coniferous).

VARIATIONS OF THE RIPARIAN ZONE IN TIME AND SPACE

The character and importance of riparian vegetation varies in time and space. Temporal variation involves patterns of vegetative succession following disturbances. Major processes of vegetation disturbance include wildfire and clearcutting (important to upslope vegetation) and damage due to impact of sediment and floating ice or organic debris during flood flows. Spatial variation occurs along the continuum of increasing stream size from small headwater streams to large rivers.

Temporal Variations of Riparian Zones

The effectiveness of a riparian zone in regulating input of light, dissolved nutrients, and litterfall to the stream varies through time following wildfire, clearcutting, or other disturbances (fig. 2). In the first decade or two following deforestation, streamside vegetation may increase in height growth and biomass more rapidly than upslope communities. Shading of the stream by riparian vegetation gradually diminishes the potential for aquatic primary production until maximum canopy closure. Deciduous shrubs and trees within the riparian zone will contribute most



RIPARIAN VEGETATION

SITE	COMPONENT	FUNCTION
above ground-above channel	canopy & stems	1. Shade-controls temperature & in stream primary production 2. Source of large and fine plant detritus 3. Source of terrestrial insects
in channel	large debris derived from riparian veg.	1. Control routing of water and sediment 2. Shape habitat-pools, riffles, cover 3. Substrate for biological activity
streambanks	roots	1. Increase bank stability 2. Create overhanging banks-cover
floodplain	stems & low lying canopy	1. Retard movement of sediment, water and floated organic debris in flood flows

Figure 1.--Extent of riparian zone and functions of riparian vegetation as they relate to aquatic ecosystems.

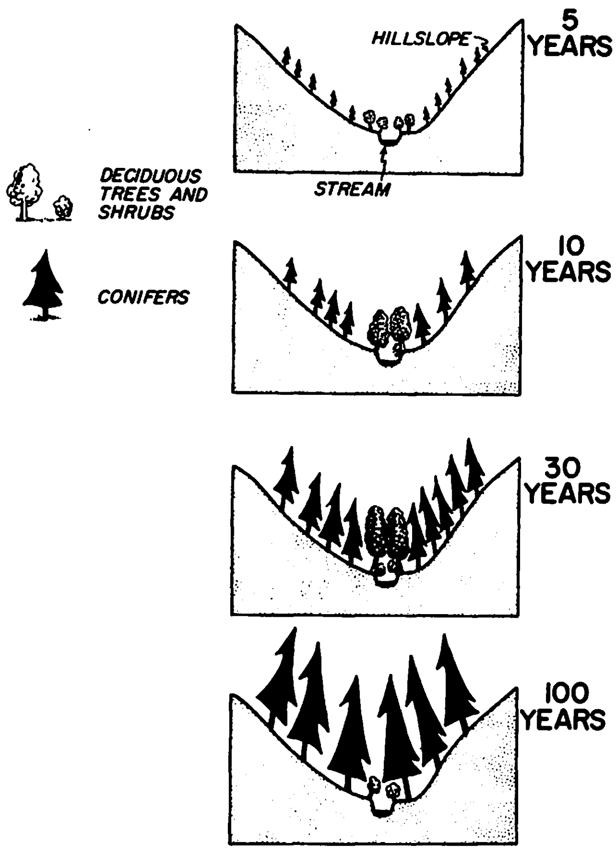


Figure 2.--Changes in the riparian zone through time.

of the litter inputs during early watershed recovery. These deciduous inputs will more readily decompose than coniferous litter which dominates inputs late in watershed recovery and in old-growth forests (Sedell et al. 1975; Triska and Sedell 1976).

The temporal development of riparian zones causes a shift in the energy base of the stream from algae to deciduous leaves to a combination of deciduous and coniferous leaves. The last stage in riparian succession is a complex mosaic of coniferous overstory, deciduous shrub layer, and herbaceous ground cover. Streams flowing through older, stratified forests receive the greatest variation in quality of food for detritus-processing organisms. Herbaceous vegetation is high in nutrient content, low in fiber, and utilizable by stream organisms as soon as it enters the stream. Leaves from the deciduous shrub layer are higher in fiber content and take 60 to 90 days after entering the stream to be utilized fully by stream microbes and insects. The conifer leaves take 180-200 days to be processed. Thus there is a sequencing of utilization of inputs from these three distinctive riparian strata. The results for the stream are rich and diverse populations of aquatic insects which are keyed into the timing and varied quality of the detrital food base.

Spatial Variation of Riparian Zones

A stream should be viewed as a continuum from headwaters to mouth (Vannote, personal communication; Cummins 1975, 1977). The influence and role of riparian vegetation will vary with stream order and position along the continuum. Some broad characteristics of streams and rivers are depicted diagrammatically in figure 3.

Extensive networks of small first to third order streams comprise about 85 percent of the total length of running waters (Leopold et al. 1964). These headwater streams are maximally influenced by riparian vegetation (the ratio of shoreline to stream bottom is highest), both through shading and as the source of organic matter inputs. Even in grasslands, the distribution of trees and shrubs follows perennial and, occasionally, intermittent watercourses except where land use practices have resulted in removal or suppression of riparian vegetation.

These low light, high gradient, constant temperature headwater streams receive significant amounts of coarse particulate matter (CPOM > 1-mm diameter). Their most striking biological features are the paucity of green plant life or primary producers (algae and vascular plants) and the abundance of invertebrates that feed on CPOM (Cummins 1974, 1975). Shredders reduce detritus particle size by feeding on CPOM and producing feces which enter the fine particulate organic matter (FPOM < 1-mm diameter) pool.

Although the transition is gradual and varies with geographical region, the shift from heterotrophy to autotrophy usually occurs in the range of third- to fourth-order streams (fig. 3). Rivers in the range of fourth- to sixth-order are generally wide and the canopy of riparian vegetation does not close over them. Direct inputs of CPOM from the riparian zone are lower in larger rivers because of the reduced ratio of length of bank to area of river bottom.

The importance of floodplain vegetation (mainly deciduous) increases relative to the hillslope species (mainly coniferous) and in a downstream direction. Generally this is so because the floodplain width increases downstream and the canopy opening over larger streams allows greater arboreal expression of deciduous riparian vegetation. Development of deciduous riparian trees is suppressed by shade along small streams.

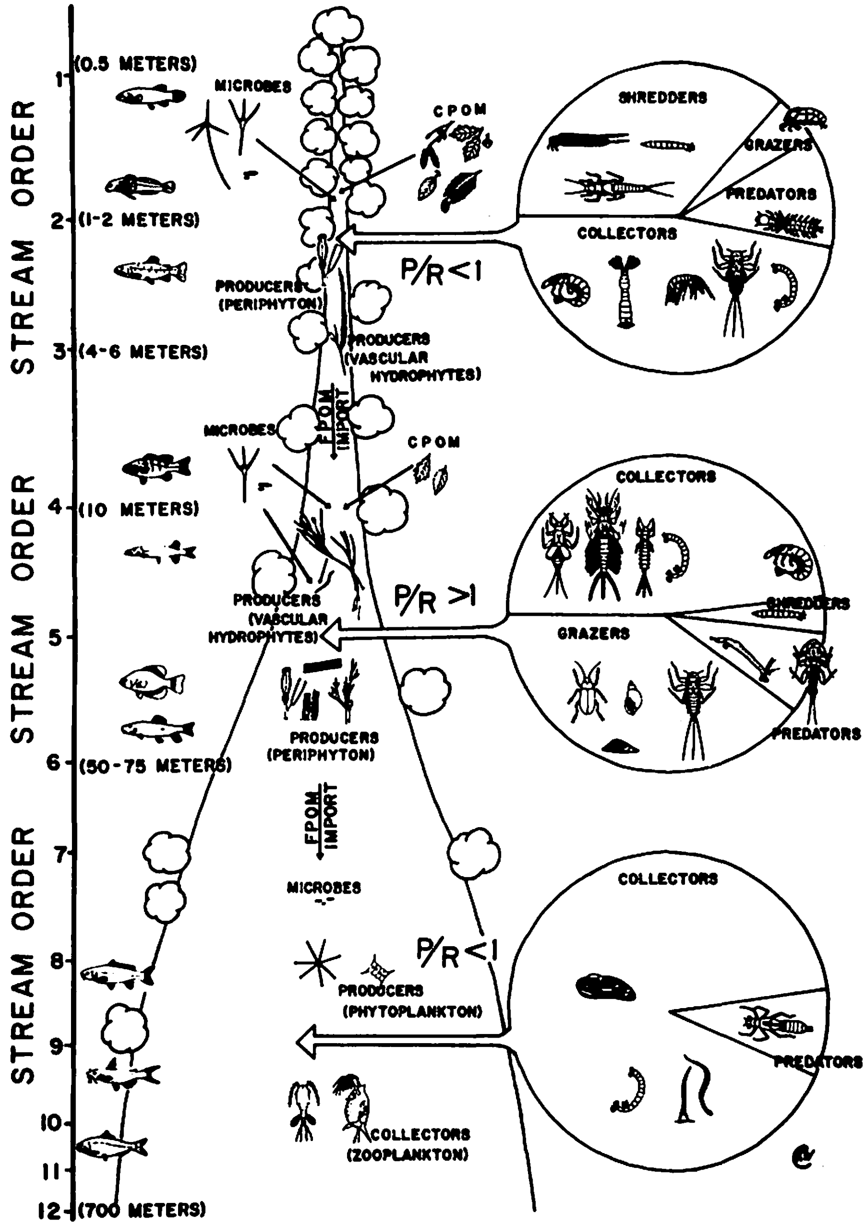


Figure 3.--A diagrammatic representation of some of the changes that occur in running water systems from headwaters to mouth. The organisms pictured are possible representatives of the various functional groups occurring in the size ranges of streams and rivers. Although a large network of smaller tributaries coalesce into larger rivers, the system is shown diagrammatically as a single headwater through all orders to the river mouth (orders and approximate ranges of stream or river width are shown at the left margin). The decreasing direct influence of the adjacent terrestrial vegetation of the watershed and increasing importance of inputs from upstream tributary systems is a basic feature of the conceptual scheme. The proportional diagrams at the right show the changes in relative dominance of invertebrate functional groups from headwaters to mouth. Important shredders include certain species of stoneflies, caddisflies, and craneflies that feed on CPOM (coarse particulate organic matter). Dominant collectors are netspinning caddisflies, blackflies, clams, and certain midge species which filter FPOM (fine particulate organic matter) from the passing water. Also, certain species of mayflies, midges, oligochaetes, and amphipods (may also function as shredders) gather particles from the sediments. Grazers or scrapers include certain species of caddisflies, mayflies, snails, and beetles. In addition to the fish shown at the left, the major predators are helgramites, dragonflies, tanypod midges, and certain species of stoneflies. The midregion of the river system is seen as the major zone of plant growth (algae, or periphyton, and rooted vascular plants) where the ratio of gross primary production (P) to community respiration (R) is greater than 1. Fish populations grade from invertebrate eaters in the headwaters to fish and benthic invertebrate eaters in the midreaches to benthic invertebrate and plankton feeders in the large rivers. (Modified from Cummins 1975).

FOOD BASE AND BIOLOGY OF FORESTED STREAMS

The food base for the biological communities of forest streams consists of leaves, needles, cones, twigs, wood, and bark. The large boles which help shape the small stream are usually biologically processed in place. The input of bole material to the stream is not a regular annual occurrence. Leaves, cones, twigs, lichens, and other components of fine litter have a reasonably predictable timing of input to and export from streams. Of the organic material which falls or slides into first-order streams every year, only 18-35 percent may be flushed downstream to higher order streams. These streams are very retentive, not mere conduits exporting materials quickly to the sea. Sixty to 70 percent of the annual organic inputs are retained long enough to be biologically utilized by stream organisms. Big wood debris dams serve as effective retention devices for fine organic material, allowing time for microbial colonization and insect consumption of this material. Functionally the invertebrates of streams flowing through forests have evolved to gouge, shred, and scrape wood and leaves and to gather the fine organic matter derived from breakdown of coarser material (Cummins 1974; Anderson et al. in press).

Woody debris and leaves, the two major allochthonous components entering a stream from the riparian zone, operate in different ways in relation to quantity, quality, and turnover time of standing crop. The leaves form a small pool of readily available organic material, while the wood forms a large pool of less available organic matter. The slowly processed wood also constitutes a long term reserve of essential nutrients and energy. The composition, metabolic structure, and nutrient turnover time of the particulate organic pool effectively provide both flexibility and stability within the system.

The amount of debris processed in a defined reach of stream depends on two factors: (1) the nature of the debris (abundance and species of wood or leaves) and (2) the capacity of the stream to retain finely divided debris for the period of time required to complete processing. Debris undergoing utilization by stream biota may either be utilized fully within a stream reach or be exported to a downstream reach. Processing continues as small debris moves along the drainage because export from one reach constitutes downstream input. Processing includes both material used metabolically by bacteria and fungi and those debris pieces physically abraded by mineral sediment or by insect consumption. In all cases, the debris is broken into smaller pieces which increases the surface- to-volume ratio and makes a debris particle increasingly susceptible to microbial attack.

Wood in streams is a substrate for biological activity and it creates other habitat opportunities by regulating the movement of water and sediment. To measure the importance of large organic debris from the riparian zone in streams, Swanson and Lienkaemper (unpublished data) examined several streams and measured percent of stream area in (1) wood, (2)wood-created habitat, principally depositional pools, and (3) nonwood habitat such as bedrock and boulder cascades. In a 245-m section of Mack Creek, a third-order stream flowing through an old-growth Douglas-fir stand in the western Cascade Range, Oregon, 11 percent of the stream area is in wood, 16 percent in wood-created habitat, and 73 percent in nonwood habitat. Figure 4 shows an example of the distribution and quantity of debris in a section of Mack Creek. In a first-order tributary draining 10 ha, wood comprises 25 percent of the stream area and another 21 percent is habitat created by wood. Much of the biological activity by detritus-processing and consumer organisms is concentrated in the areas of wood and wood-created habitat. Each habitat type has a different faunal composition.

Wood Habitat Community

Wood habitat communities are distinctive. The primary utilizers are beetles, midges, and snails. In addition to the food supplied to the major wood eaters, the surface area and large number of protective niches on wood afford considerable living space and concealment. Wood is used for oviposition, as a nursery area for early instars, for resting, molting, pupation, and emergence. Because of its unique capillary properties, it affords an ideal air-water interface where gradients of temperature and moisture can be selected by different taxa for various activities.

Wood-Created Habitat

The depositional areas behind large debris are prime areas for processing leaf material and the fine organic matter derived from wood. These areas are richer than the wood habitat community both in numbers and biomass of invertebrates. Leaves and the shredders (primarily caddis- and craneflies) are concentrated in these areas. Many of the shredders feeding here will use the wood habitat to molt, pupate, and emerge.

The difference in invertebrate biomass on leaves and wood is attributed primarily to differences in food quality. Although both are low in nitrogen compared with periphyton, seeds, or fresh macrophytes, the wood is so high in the refractory components lignin and cellulose that it becomes available at a very slow rate. The greater surface area and penetrability of leaves results in microbial con-

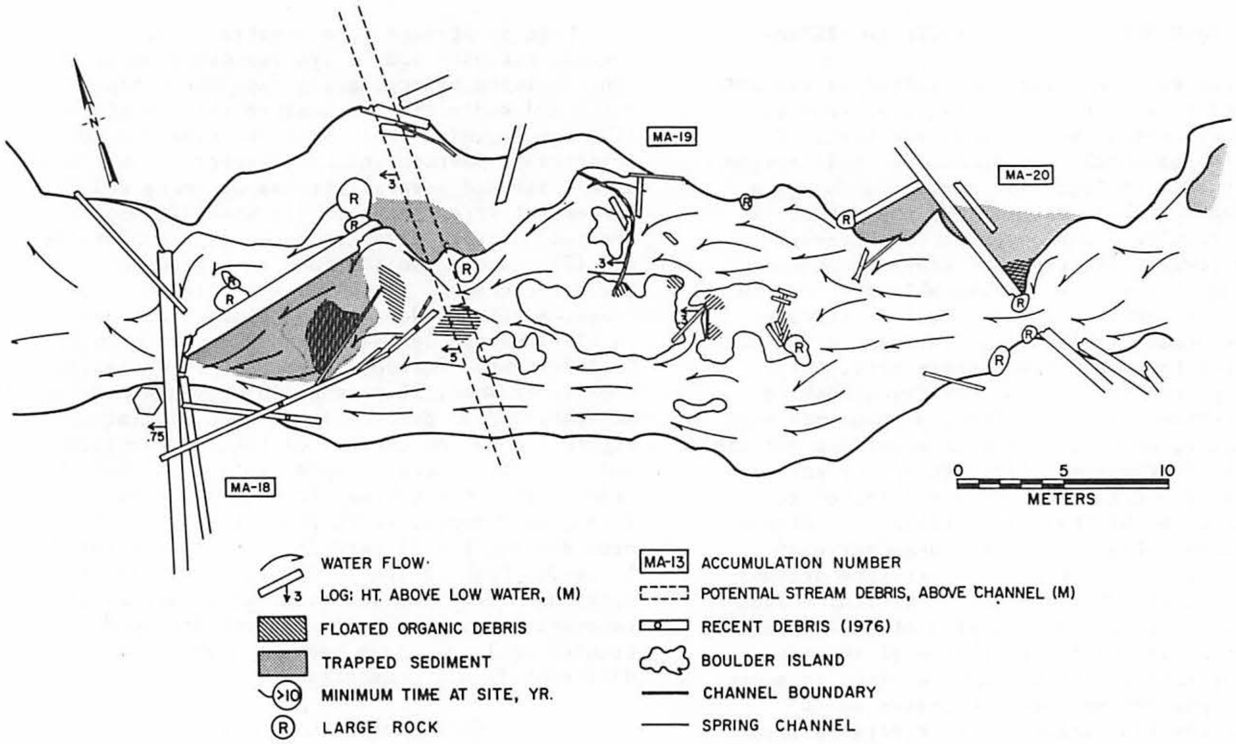


Figure 4.--Distribution of debris in a section of Mack Creek, western Oregon. Courtesy of George W. Lienkaemper.

ditioning occurring within months, compared with years for wood. Conditioning is a key factor in the debris becoming available as food for the invertebrates.

RELATIONSHIP OF RIPARIAN VEGETATION TO SALMONIDS

Direct Influences

The previous discussion has described how riparian vegetation contributes to primary stream productivity through input of organic material and nutrients which are utilized by various components of the stream biota. These relationships directly affect the production of fish by establishing the basic components of the food chain which eventually lead to the fish themselves. Likewise, necessary portions of salmonid habitat are created by large pieces of debris from the riparian zone. Logs and debris jams create pools and protective cover. This type of habitat also provides communities of benthic organisms different from those associated with the shallower and faster waters of riffles and runs. This increase in diversity of invertebrates provides a more useable food base for the fishes, which depend to a great extent upon them. A large part of the diet of fish in the family Salmonidae (the various Pacific salmon, trout, and char) is aquatic insects and other invertebrate organisms.

Indirect Influences

In addition to the effect of riparian zone material which directly becomes a part of the stream system, streamside vegetation has many important indirect influences on the habitat of salmonids.

Water Temperature

The principal source of heat which raises water temperatures is direct solar radiation (Brown 1969). Consequently, streamside vegetation is important in maintaining water temperatures suitable for spawning, egg and fry incubation, and rearing of anadromous and resident salmonids. Several studies in the last decade have demonstrated how streamside vegetation directly controls water temperature (Levno and Rothacher 1967, Brown and Krygier 1970, Meehan 1970, Burns 1972). The literature is also rich with documentation of the effects of streamside canopy removal on stream temperatures (Hall and Lantz 1969, Meehan et al. 1969, Brown and Krygier 1970, Burns 1972, Moring 1975).

Stream temperature is directly proportional to surface area and solar energy input, and inversely proportional to streamflow (Gibbons and Salo 1973). Therefore, small forested streams are the most susceptible to temperature change. The insulating effect of riparian vegetation is thus of primary importance in maintaining acceptable stream temperatures in the many small streams which cumulatively produce a significant portion of the salmon and trout populations of the Western United States.

Sediment

Another major function of riparian vegetation is to act as a buffer or "filter" against sediment and debris which would otherwise be deposited in the stream. Surface runoff is a primary vehicle for the transportation of sediment to streams from adjacent sources, either natural or man-created. The herbaceous communities within the riparian zone are effective in reducing the impacts of this runoff, and the larger shrubs and trees prevent larger debris from entering the stream channel. The value of streamside vegetation for stream protection has been quantified in economic terms by Everest (1975).

Sediment which affects salmonids occurs in two general forms. As suspended sediment, it can be harmful if concentrations are high and persistent (Cordone and Kelley 1961). Under these conditions, silt may accumulate on the gill filaments and actually inhibit the ability of the gills to aerate the blood, eventually causing death by anoxemia and carbon dioxide retention.

Bedload sediment, however,probably limits salmonid production more than suspended sediment. Excessive deposited sediment reduces the flow of intragravel water, which in turn limits the supply of oxygen available to incubating eggs and alevins, and hinders the removal of metabolic waste products (Sheridan 1962, Vaux 1962, Cooper 1965, McNeil 1966). Bedload sediment may also act as a physical barrier, preventing the emergence of newly hatched fry up through the gravel (Koski 1966, Hall and Lantz 1969).

Another effect of sediment is the alteration of habitat used by aquatic insects (Wagner 1959) which directly relates to the growth and condition of the fish which utilize them. Although biomass may not decrease, the species composition may change such that the new forms are not as readily available to the fish.

Cover

The extensive rooting of herbaceous riparian vegetation aids in streambank stabilization. As a result, where streamside vegetation is intact, the occurrence of undercut banks is higher. This is prime habitat for trout and young salmon. Overhanging streamside vegetation also acts as escape cover and in some instances as a deterrent against predation by birds and mammals.

Insects

As discussed earlier, riparian vegetation contributes to the food base of stream biological communities in the form of wood and other organic debris. In addition, streamside vegetation is important in directly providing insects to the stream which then become part of the available fish food. Terrestrial insects which are associated with the various strata of the riparian zone become "accidental" fish food items. Many of the aquatic insects use streamside vegetation during emergence and in the adult stages of their life cycle.

EFFECTS OF LAND USE PRACTICES

Many of man's activities affect the riparian zone to varying degrees. We must consider logging and road construction to be among the most severe disturbances. Until recently it was common practice to clearcut timber to the stream's edge. In addition to removing the trees which provided shade to the stream surface, the understory vegetation and ground cover were usually cut down or severely disturbed. In recent years, the importance of the smaller streams has been more fully recognized and buffer strips along streams are often left.

The riparian zone is also affected by livestock grazing. In addition to cropping off much of the herbaceous vegetation along streambanks, livestock also use the smaller shrubs and young trees as forage. As a result, much of the ground cover and many of the plants which provide shade to small streams are removed. The soil along the streams is compacted by trampling, and together with the removal of the "filtering" plants a situation is created which promotes the addition of fine sediment to the streams. Wild ungulates also utilize the riparian zone, but their presence is much less noticeable than that of cattle and sheep. A workshop was conducted in Reno in May 1977 to bring together existing knowledge on the relationships between livestock and fisheries, wildlife, and range resources. A large part of the material which was discussed at this workshop concerned the riparian zone, and will soon be available.[4]

[4] USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California (in press).

SUMMARY

The riparian zone is a very important area influencing the habitat of salmonids. Much of the wood which forms the food base for stream biota comes from the riparian zone. This same wood, when it falls or slides into a stream, has an important role in shaping the stream and creating its habitat types. Streamside vegetation provides shade to the stream surface, thereby maintaining water temperatures acceptable to salmonid fishes. The roots of woody and herbaceous plants provide streambank stability and help to create overhanging banks, an important component of salmonid habitat. Streamside vegetation provides habitat for the later life history stages of aquatic insects and for terrestrial insects which accidentally become part of the food utilized by salmonids.

When the riparian zone is affected by man's activities, the quality of fish habitat will likewise be affected.

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Ecological Study of Southwestern Riparian Habitats: Techniques and Data Applicability[1]

Bertin W. Anderson, Ronald W. Engel-Wilson,

Douglas Wells and Robert D. Ohmart [2]

Abstract.--Techniques used in a comparative ecological study of bird and rodent populations along the lower Colorado River are presented. Data were gathered to examine not only faunal community relationships to various plant community types but also to gain detailed knowledge of an individual species' vegetational preference and its niche within the riparian habitat. Examination of parameters such as habitat breadth, habitat and niche overlap and dispersal is instructive in the determination of a species' niche and is of use for the resource manager and the theoretical ecologist alike.

INTRODUCTION

Agencies responsible for the management of natural resources are beginning more to recognize and approach management from the ecosystem level as opposed to monospecific research. As a result of this, many governmental agencies are currently developing ecosystem approaches to management or are providing financial support for studies of this nature. A central problem in implementing management based on the ecosystem approach is often a direct lack of knowledge concerning species' requirements and the relationships and composition of faunistic communities.

This paper reports on the field techniques employed and the applicability of data gathered during a comparative ecological study of the avian and small mammal populations in riparian habitat along the lower Colorado River. The approach is primarily synecological in that the focus is on entire floral and faunal populations and their relationships within the riparian ecosystem; the design of the study also allows collection of in-depth autecological data.

The specific objectives of the study were as follows: 1) to determine the relative value of each of the various plant communities to birds and small mammals found within the riparian system; 2) to examine ecological relationships of the avifaunal and mammalian components within each plant community type; 3) to determine how these relationships, and other factors, are important in population regulation and habitat selection. In addition to gathering in-depth and repeatable data which would satisfy the above requirements, field techniques had to be chosen and developed which would be suitable for studying a large area with a limited number of personnel.

The study area embraced all of the riparian vegetation in the lower Colorado River Valley between the Mexican boundary north to Davis Dam--a distance of approximately 425 km. The width of the valley varies from 0.8 km to 16 km. Much of the natural vegetation has been cleared and developed for agriculture or other purposes. The remaining riparian vegetation is scattered throughout the valley in tracts of various sizes.

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[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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VEGETATION MEASUREMENTS

Establishment of study sites in relatively homogeneous stands of riparian vegetation was begun in June 1973. As personnel increased (currently 13 persons), more study sites were added, and by April 1976, 84 sites had been established. Study sites varied in length from 0.8 to 1.6 km. Initially a line was cleared 0.7 m wide and 0.8 to 1.6 km long. The sampled area was considered to extend laterally 126 m from the center line on each side. Each line was numbered and designated as orienting in a specific compass direction. As a vegetation type map was developed for the entire valley, every attempt was made to sample each plant community type by line establishment, proportionate to their total area in the valley. The level of quantification of the plant community types was such that if a sample area of a given structure was lost (i.e. cleared or burned), another could be established without drastically affecting comparisons between years.

Although great care was taken to locate sample sites in relatively homogeneous communities, vegetation analyses indicated that considerable variation existed along many of the sites. To quantify this variation along each study site and to better understand bird-habitat relationships, each lateral portion of the study site from the center line was subdivided into 150 m long intervals. Each 150 m interval was marked with surveyor's tape and a wooden stake on which was painted the distance from the start of the line. A line 1,500 m long, orienting north to south, now was conceptualized as being composed of twenty distinct 150 m units--ten on the west side and ten on the east side of the line. Hereafter, each distinct (150 m) unit will be referred to as a plot.

Tree Counts

A direct tree count was conducted along all transects. The count area extended 15 m laterally to the line on each side. Within each 30 m advancement along the transect, all trees were counted and listed as to tree species, size class of trees (<3 m or >3 m) and presence of mistletoe (Phoradendron sp.). Tree counts could either be summed to yield number of trees per plot or number of trees along the line in the study site.

Relative Foliage Volume

The relative foliage volume within each study site and within each plot was determined using the board technique (MacArthur and MacArthur 1961). The number of sampling points per study site was dependent on the number of plots comprising each study site. The vegetation within each plot was sampled in three predetermined locations. The sampling points were at 15, 76, and 137 m along the line from the beginning point. Each foliage volume sampling point was displaced laterally 4.6 m from the line. At each sampling point a measuring tape was used to determine the distance to the nearest foliage that would cover approximately 50 percent of the foliage board. This was determined at 0.15, 0.6, 1.5, 3.0, 4.6, 6.0 m and every 3.0 m height interval thereafter until the tallest foliage present was measured. The plant species to which the distance measurement was taken at each height interval was also recorded. Measured distances were converted to m^2 of foliage per m^3 of space using the formula

$$K = \frac{\log_e 2}{D},$$

where K is foliage density and D the measured distance. The foliage density within each plot for the various height intervals and for total foliage density was determined by using the average of the measurements from the three sample points within each plot. The foliage density for the study site as a whole was determined by using the average density of all plots within the site.

Mature plant communities in each study site were measured for foliage density once between May and July. Plant communities undergoing succession were measured each year at the beginning and at the end of the growing season to quantify growth changes. These data were extrapolated for all seasons under the rationale that measurements involving leaves in the summer correspond to potentially leaf-bearing parts in the winter. Thus a community with dense leaves in summer should have more leaf-bearing parts in winter than a community that possessed few leaves in the summer. This assumption was validated by field measurements in selected study sites.

Foliage Height Diversity

Foliage height diversity for each transect was computed using information theory (Shannon and Weaver 1949) where

$$H = -\Sigma_{n=1}^{s} p_i \log p_i .$$

In this instance H equals foliage height diversity, and p_i equals the proportion of the total foliage volume contributed by the volume at height level i.

Litter Height Diversity

Litter height diversity (LHD) was measured every 100 feet along the center line in each study site where litter was present in the trees. The measurement consisted of recording the presence or absence of litter within a 1.5 m radius at height intervals similar to those used in foliage volume measurements. Information theory was also used in calculating this parameter; p_i was the proportion of the total points with litter occurring in the ith layer.

In some vegetative types it was theorized that the amount and distribution of leaf litter above the ground was partly responsible for high rodent populations. Litter may provide additional nest sites, foraging substrate, or cover for some rodent species and even some birds and allow higher population numbers.

Phenology

Phenological data were recorded monthly for trees located in study sites. The objective was to record information which might explain population movements or trends within the mammalian and avian communities. Types of data gathered included duration and initiation of flowering, initiation and amount of stem growth, and fruit production.

Vegetative Communities

The various plant associations within the riparian habitat were classified as being components of six communities. These communities are listed in Table 1 along with the criteria used to distinguish each. The dominant tree species (total numbers) in some communities classified as cottonwood-willow was neither cottonwood nor willow, yet one or both of these species were responsible for the presence of one or more additional canopy layers to which the numerically dominant tree species did not contribute. If mature cottonwoods or willows were in densities of 2 or more per ha, the avian data indicated they exerted enough influence in the study site to be classified as cottonwood-willow.

Structural Types

Foliage density in the combined height intervals of 0.15 to 0.6 m, 1.5 to 3.0 m and >4.6 m was used in computing the amount of overlap in foliage density and structure between all pairs of study sites using Horn's (1966) formula where:

$$R_o = \frac{\Sigma(x_i+y_i)\log(x_i+y_i)-\Sigma x_i \log x_i - \Sigma y_i \log y_i}{(X+Y)\log(X+Y)-X\log X-Y\log Y}.$$

For study sites x and y, x_i and y_i represent the proportion of the volume occurring at height interval i, and X and Y represent the total foliage volume. From a matrix of these overlap values a dendrogram was constructed (fig. 1) showing study sites with greatest affinities between foliage density and structure. The dendrogram was constructed following Cody (1974) where

$$\alpha C, AB = \frac{\alpha C\ A + \alpha C\ B}{2}.$$

This simply states that the overlap of C with A and B is equal to the average of the overlap of C with A and C with B. The dendrogram was interpreted as showing the existence of six structural types of vegetation within the riparian habitat. Each study site within a structural type is more closely related in structure to the other members of that type than to any other site or group of sites.

Structural types I and II are the most heterogeneous, but as a group, they are separated by a substantial number of units from any other structural type.

Structural type I was the most dense overall and was characterized by the amount of volume over 9 m (fig. 2) although there were relatively well developed layers below the 9 m level. Type II was characterized by having less vegetation above 9 m but more volume between 3.0 and 6.0 m than type I. The other types were mainly characterized by having less volume at higher layers and more at 0.0 to 0.6 m (fig. 2).

RODENT POPULATION DATA

Small mammal populations were sampled by snap-trapping. We used two parallel rows of trap stations. One row was placed along the line of the sample site, and the second row was placed at a lateral distance of 15 m. Each row consisted of 15 stations, each station being 15 m apart. Two museum specials and one Victor rat trap were set at each station yielding a total of 90 traps. All traps were set for three consecutive nights using an oatmeal-peanut butter bait which contained an ant repellant (Anderson and Ohmart 1977). Traps were checked daily and the catch recorded. All mammal densities are expressed

Table 1.--Vegetative communities and criteria used to classify study sites within a community.

	Community	Criteria
I.	Cottonwood (Populus fremontii)	Populus and/or Salix constituting at least 20% of the total trees
	Willow (Salix gooddingii)	
II.	Screwbean mesquite (Prosopis pubescens)	P. pubescens constituting at least 20% of trees
	Salt cedar (Tamarix chinensis)	
III.	Honey mesquite (Prosopis velutina)	Approximately equal numbers of each
	Salt cedar	
IV.	Salt cedar	Constituting 95-100% of total trees
V.	Honey mesquite	Constituting 95-100% of total trees
VI.	Arrowweed (Tessaria sericea)	Constituting 95-100% of total vegetation in area

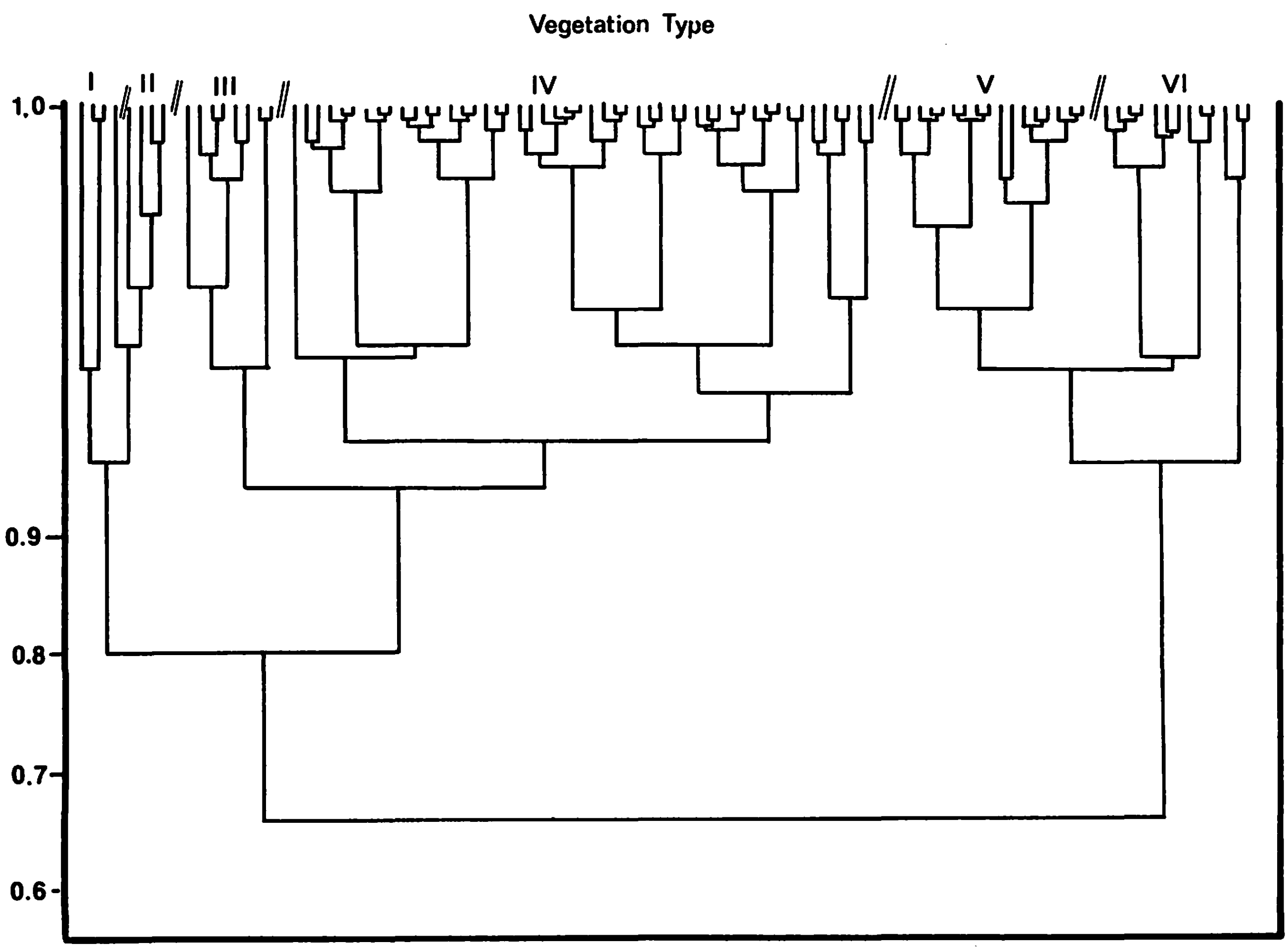

Figure 1.--Dendrogram showing relationships between all transects based on overlap in foliage density and structure.

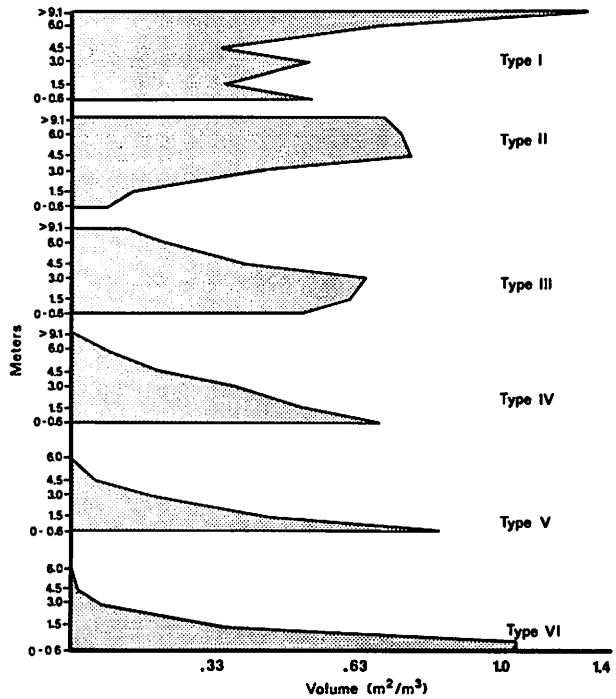

Figure 2.--Foliage volume characteristics of structural types.

as the number per 270 trap nights. No area was trapped consecutively within a six-week period.

Trapping of small mammals was organized so that all structural types represented within a community were sampled on an equal basis. Even with 60,000 trap nights in 1976, the data were not sufficiently adequate to examine some populations for more than two seasons, April through October and November through March. Any analyses utilizing finer divisions of time suffered from inadequate sample sizes for several species.

Standard reproductive measurements were recorded on all mammals to examine possible differential breeding rates and timing between communities. Cheek pouch contents were saved from all heteromyids for later analysis.

In an effort to better understand preferences of small mammals for particular microhabitat types, the vegetation present at three levels around each trap station was recorded. Species caught at a particular trap station could then be correlated with the vegetation around that station.

Rodent Species Diversity

Rodent species diversity for all community and structural types was computed using information theory where p_i is the proportion of the total density per 270 trap nights contributed by species i.

AVIAN POPULATION PARAMETERS

Avian Densities

Estimates of avian densities in each study site were calculated using a technique developed by Emlen (1971). Bird detections were recorded as being within 0 to 15, 15 to 30, and 30 to 60 m lateral distance from the study site center line. At the termination of each census of a study site the distribution of detection points for each species was used to determine the density per sampled area. All densities were converted to the number of individuals per species per 40 ha. Each study site was censused two to three times per month, and the mean was used as a monthly population estimate for each site. The number of censuses required per unit of plant community is discussed elsewhere in these proceedings (Anderson and Ohmart[3/]). In addition, mean monthly densities for each structural type in each community type allows analysis of seasonal changes in number of individuals and species composition.

As part of the regular census, bird detections were also recorded in the specific plot in which they occurred (fig. 3). This refinement was not necessary to obtain density estimates but served to document preferred vegetation profiles of each species as discussed later in the text.

Bird Species Diversity

Bird species diversity (BSD) was determined using information theory where p_i is the proportion of the total bird density contributed by the ith species. BSD's are calculated over a monthly and seasonal basis for each study site as well as for each structural type in each community.

Foraging Behavior

Foraging behavior of birds was recorded in all study sites to better understand the foraging niche of each species and to determine how each species utilized specific parts of its environment. By gathering these data in specific study sites, it was possible to compare foraging behavior to the structure, density, and vegetative species composition of the sites. Much of the behavior was gathered while conducting

3/ Climatological and Physical Characteristics Affecting Avian Population Estimates in Southwest Riparian Communities using Transect Counts.

READ North TO South   Colorado River   BIRD DATA 06504   PAGE 1 OF 1

TRAN Pv10 DATE 10 May '77 TIME 0600-0715 CLOUDS Clear WIND Calm TEMP 60 F READER DGW

SPECIES	INT. m	DIRECTION: East 0-15m	15-30m	30-60	60-120	DIRECTION: West 0-15m	15-30m	30-60	60-120	BIRD HT	TREE HT	TREE SP	POS
Verdin	0-150							1					
Mourning Dove		1				1							
Abert's Towhee			2										
Cactus Wren	150-300		1										
Verdin							1						
Gambel's Quail				4									
Lucy's Warbler			1										

Figure 3.--Sample bird census form showing location of detection points within plots and at lateral intervals.

regular censuses. Specific parameters recorded for each species included:

- Climatic conditions
- Bird species and sex
- Foraging method
- Substrate
- Height of substrate
- Height of bird
- Branch diameter
- Location within tree
- Shade or exposed

APPLICABILITY OF DATA

Data obtained in this study provide information concerning the extent of wildlife use in each of the various plant communities. Statistical analysis of many plant communities over a relatively large area permits examination of some of the factors responsible for these use values--be they specific vegetational configurations or the presence or absence of an ecologically close species. Through a comparison of species compositions and densities between community types and structural groupings, insight is gained into particular aspects of community ecology. A greater understanding of these relationships is necessary for management decisions. Specific examples are given below of ways in which these data may be examined in order to satisfy the outlined objectives. The analyses do not exhaust the list of possibilities but are primary ones found to be useful in this particular study.

Wildlife Use

The various avian and rodent population parameters and the vegetational parameters with which they are associated are as follows:

Avian Population Parameters
- Bird species diversity
- Number of species
- Bird density (total and by individual species)

Rodent Population Parameters
- Rodent species diversity
- Rodent density (total and by individual species)

Vegetation Parameters
- Foliage volume (total and by height classes)
- Foliage height diversity
- Tree counts (of a species by height class)
- Litter height diversity

Each comparison can be made on the basis of different area and time units. The possible units include:

Area Units
- Individual transects
- Communities
- Structural types
- Total riparian habitat

Time
- Individual months
- Seasons
- Different years

The specific ones chosen are dependent upon the specific needs and requirements of the study. We have found analyses of data by groups of months or seasons to be practical in determining wildlife use values, but we also utilize data from individual months in certain analyses where more precise resolution is needed.

In examining wildlife use values one begins to see not only which species utilize an area, but also what factors in that environment have an important influence or at least show strong correlations with the various population parameters. Figure 4 presents correlation coefficients between several rodent populations and vegetational parameters in a honey mesquite community. It can be seen (fig. 4) that there is generally an inverse relationship between rodent density and rodent species diversity. One can predict that in an area with dense foliage at 1.5 to 3.0 m the rodent density would be relatively high, whereas the rodent species diversity would be depressed. This example only serves to show a small part of the total picture, but the implications in this case are evident concerning possible options to achieve the desired management goals.

Habitat Breadth

Habitat breadth values indicate the extent to which a species' population is evenly distributed throughout the habitat. It can be calculated using a species' distribution among the six categories of dominant vegetation and six structural types separately or combined. Habitat breadths are calculated on a monthly and seasonal basis. Since we currently (May 1977) have about 100 study sites in riparian vegetation and since each site is censused about three times per month, monthly habitat breadths are based on about 300 censuses. On a seasonal basis this increases to 900 censuses for winter (December, January, February) and summer (May, June, July); and 600 censuses for spring (March, April), late summer (August, September), and fall (October, November). This allows monitoring of monthly and seasonal changes in habitat breadth of each species.

Habitat breadth for each species is calculated using information theory where p_i represents the proportion of a species' total population contributed by its density within a community or structural type i. When expressed as the percent of maximum (J), habitat breadth can be used to designate species as generalists or specialists within communities or structural types. Any species with a percent value of maximum habitat breadth below an arbitrarily set limit would be classified as a specialist. It is possible for a species to be a specialist with regard to communities and a generalist with regard to structural types, and vice versa. Designating species as specialists or generalists is especially valuable to decision makers for management of critical habitats (i.e. those habitats containing several specialist species). It is these species which have the most exacting habitat requirements and which require special management efforts.

Niche Breadth

Niche breadth values are calculated in a manner similar to habitat breadth values but are based on the distribution of a species within a particular community. The proportion of the total community population of a species contributed by its density per individual study site in that community represents the p_i values in the information theory formula.

Calculation of niche breadth is an attempt at a more sensitive analysis of distribution of species within a portion of the habitat--the community. In combination with other measures of resource utilization, niche breadth is instructive in understanding the vegetational preferences of a species and how this changes through time and in comparison to other closely related species.

Preferred Vegetation Profiles

Using the data gathered on occurrence of birds within plots, it is possible to compute the preferred vegetation of each bird species. All bird detections within a plot located within a lateral distance of 15 m (0.2 ha) from the center line of the study site are compared to the vegetative characteristics of the plot in which the detection occurred. The 15 m lateral distance was selected because it was thought to be a complete census coverage of that area (i.e. all birds in that area were detected) and because it corresponded closely with the area of vegetation measurements, such as tree counts and foliage volume estimates. Given a suitable sample size of detections for each bird species, it is possible to calculate an average vegetation profile where a species is most often found. Collectively there are between 1,000 and 1,100 of these 0.2 ha areas. This profile will vary seasonally and will indicate the changing temporal requirements of a species. This can be done for all individuals of a species or during the breeding season for adult males only. The data can be further subdivided by dominant vegetation and/or structural types. These data are suitable for multivariate techniques such as discriminate function and principal component analyses.

Figure 5 (Anderson and Ohmart 1975) presents the preferred vegetation profiles of the Verdin (*Auriparus flaviceps*), Lucy's Warbler (*Vermivora luciae*), and Black-tailed Gnatcatcher (*Polioptila melanura*). Each is a small (<10 gm) insectivore with generally similar foraging behavior patterns. However, they each show a significantly ($p<0.05$) different preferred foliage profile. Lucy's Warblers generally inhabit the areas with

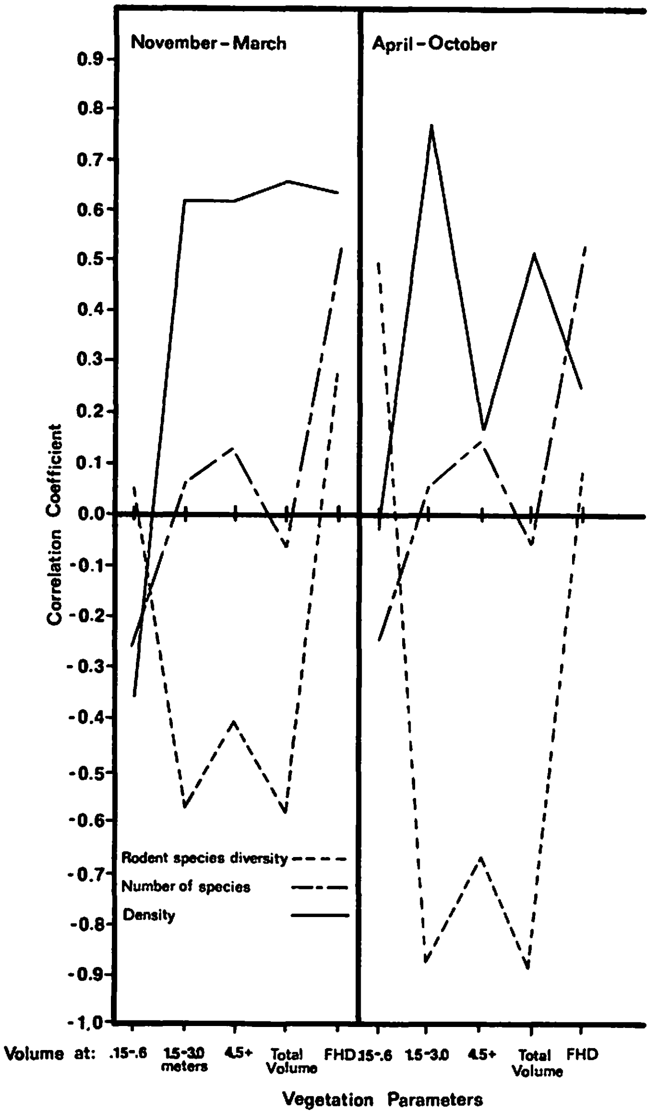

Figure 4.--Correlations between rodent population parameters and vegetation parameters in honey mesquite (Anderson and Ohmart 1975).

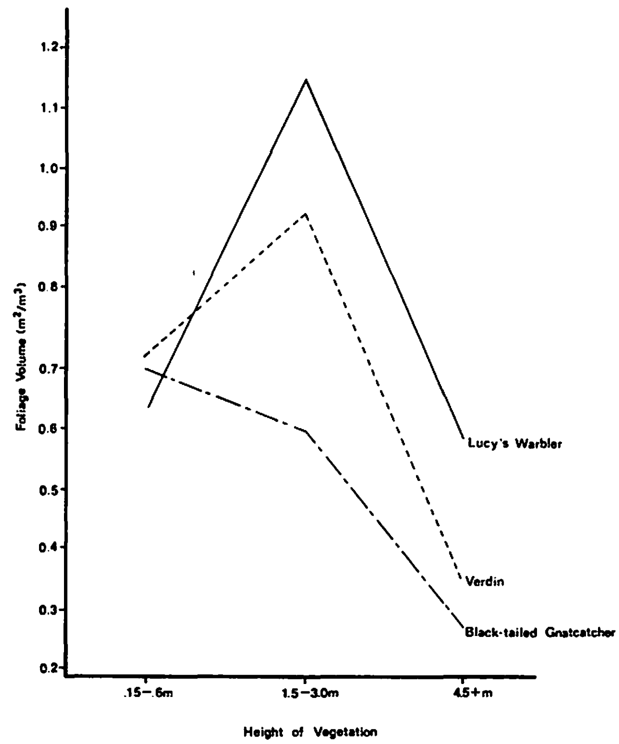

Figure 5.--Preferred structural configuration and foliage density of three bird species April through August 1975 (Anderson and Ohmart 1975).

denser vegetation at 1.5 to 3.0 m and the Black-tailed Gnatcatchers inhabit the sparser areas. These subtle divisions of the habitat are sometimes obscured by an analysis at the study site level due to the amount of heterogeneity within each site. By utilizing bird detections and vegetational measurements made within plots, some of the heterogeneity is reduced and more definite relationships can be observed.

Dispersal

We obtained a measure of the extent and time of dispersal in birds by calculating the average number of individuals of each species in each plot each month. The times of interspecific compatibility are indicated by the times of greatest average number per plot; dispersal is indicated when the average drops. These data are calculated monthly and are based on 1,000 to 1,100 plots.

Habitat and Horizontal Niche Overlap

Habitat and horizontal niche overlap are similar in that they compare the level of coexistence of two species within an area. As in the calculation of habitat breadths, habitat overlap can be calculated using two approaches to the composition of the habitat-i.e. community and structural types. Habitat overlap values are computed using Horn's formula (1966) for ecological overlap where x_i and y_i represent the density (per 40 ha for birds; number per 270 trap nights for rodents) in community or structural type i, and X and Y represent the sum of the x_i and y_i values.

Horizontal niche overlap values computed for birds only are based on the co-occurrence of species within plots. It is based on the ratio of the number of plots two species hold in common to the geometric mean of the number of plots they occupy separately as shown by Cody (1974) where:

$$H,12 = P_{12}/[(P_{11} + P_{12})\ (P_{22} + P_{12})]^{1/2}.$$

Here P_{12} equals the number of plots the two species hold in common and P_{11} and P_{22} represent the number of plots occupied by one species but not the other.

Overlap values, either habitat or niche, when organized into a matrix of species by species overlaps, can be used to construct a dendrogram (Cody 1974). A dendrogram illustrates those groups of species which are most similar to each other with respect to habitat or horizontal niche overlap. Figure 6 presents a simple dendrogram of horizontal niche overlap among the birds in salt cedar. The Mourning Dove (Zenaida macroura) and the White-winged Dove (Zenaida asiatica) are the only species with a high level of overlap. Each of these species obtains most of its food from agricultural areas (Anderson and Ohmart 1975). It is possible that the low overlap values exhibited among the other bird species may be due to the fact that salt cedar is an exotic plant to which the native avifauna has only partially adapted. Examination of overlap patterns within other communities as well as examination of patterns shown by other measures of resource utilization is necessary before any conclusions can be drawn.

Balda (1975) mentioned different approaches which have been used in the study of birds and their vegetative substrate. These approaches vary from intensive studies of single species to studies where assemblages of bird species were identified, counted and related to some component of the vegetative community. Each of these approaches has its advantages and disadvantages for the manager in a decision-making position. The techniques and procedures outlined above enable one to gather data which are in a versatile form. Pertinent information is available for a resource manager interested in managing for critical habitat of a rare species as well as for a theoretical ecologist exploring community organization patterns.

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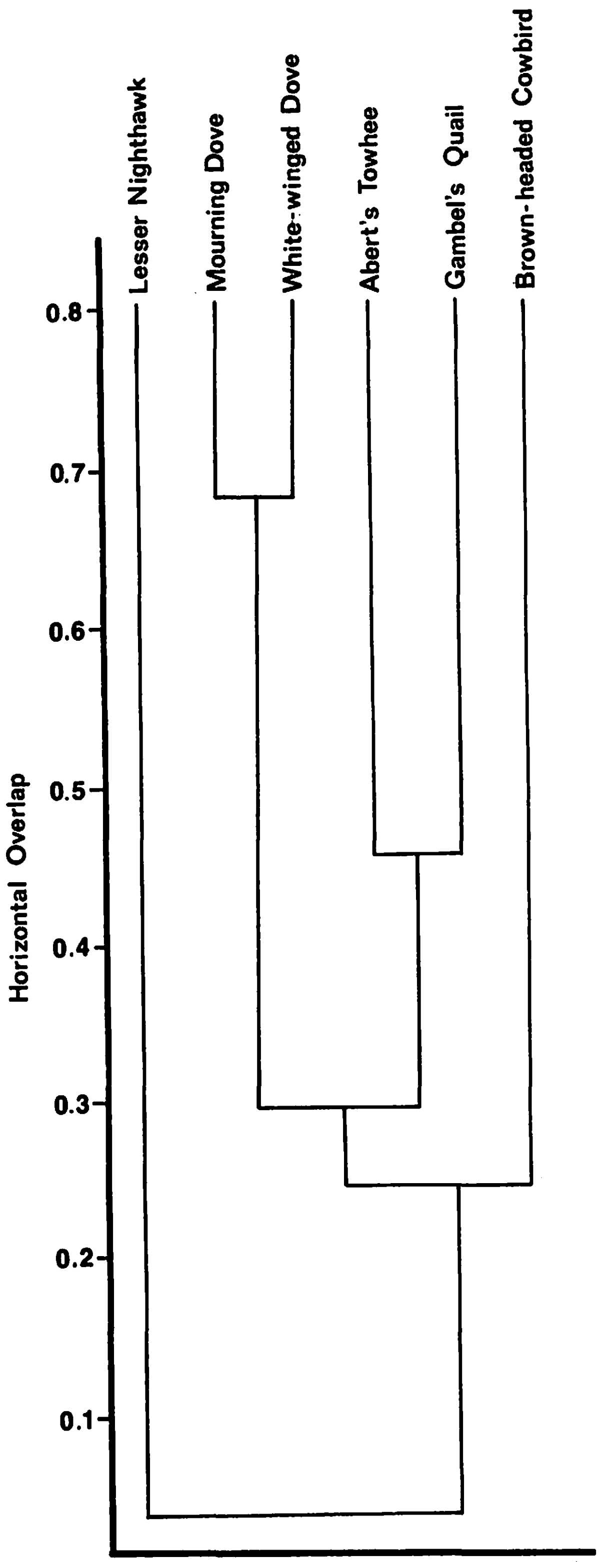

Figure 6.-- Horizontal niche overlap among birds in salt cedar April through August 1975 (Anderson and Ohmart 1975).

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The Importance of Riparian Habitat to Migrating Birds[1]

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Abstract.--Seven pairs of study sites in riparian and adjacent, nonriparian habitats were censused for spring migrant passerines. Riparian plots contained up to 10.6 times the number of migrants per hectare found on adjacent, nonriparian plots. Stop-over habitat selection is indicated by differing migrant densities and species diversities in various habitats. Passerine migration strategies are discussed.

INTRODUCTION

Field investigators have long noted that migrating passerines show a decided preference for riparian habitats over nonriparian habitats; however, virtually no data have been published concerning the nature of this preference. Riparian habitats provide an important source of food and cover for migrants and these habitats are being eliminated at such an alarming rate that the damage to migrant populations may be significant. The aim of this paper is to illustrate the importance of stop-over riparian habitats to migrant passerines in the Southwest. Only a few aspects of migration of western passerines are mentioned here but it is hoped that the data presented will stimulate additional research in this important field.

Many researchers have contributed to our knowledge of the timing of migration in southwestern passerines (Phillips 1951, Phillips et al. 1964, Hubbard 1971, Johnson and Simpson 1971, and others), but as yet no large-scale synthesis of migration patterns has been attempted. A growing concern for improved riparian habitat management practices has provided the impetus for a number of studies on riparian habitats by various government agencies (Johnson et al. 1974[6], Carothers and Johnson 1975, Lacey et al. 1975, Smith 1975, Carothers et al. 1976, Pace 1977[7], and others). Nearly all studies to date have ignored migrant passerines and their relationships to stop-over habitats in the Southwest (Sprunt 1975).

Migration, as Emlen (1975) indicated, is a multifaceted phenomenon. Some aspects of vernal (spring) migration related to stop-over habitat selection include migratory strategy, the influence of weather, and the development of migration routes. Literature for eastern North America indicates that passerines generally migrate nocturnally, resting and foraging during the day (Helms 1959, Able 1970, Welty 1975, and others). Gauthreaux (1972) suggested that vernal migrant passerines generally fly singly or in small, unispecific flocks. Vernal nocturnal migration in land passerines has been correlated with atmospheric stability and wind direction (Raynor 1956). Pleistocene speciation of Parulidae was discussed by Mengel (1964) and contemporary continental migration patterns were reviewed by Dorst (1962).

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6/ Johnson, R.R., S.W. Carothers, and D.B. Wertheimer. 1974. The importance of the lower Gila River, New Mexico, as a refuge for threatened wildlife: a multiple agency land management program. Unpublished, 53 pp.

7/ Pace, C.P. 1977. Classification, restoration and management of riparian habitats in southwestern forests. Rocky Mountain Forest and Range Experiment Station Study Plan 1710-44. Tempe. Unpublished, 44 pp.

Parnell's (1969) investigation of habitat selection in migrant eastern Parulidae (the North American wood warblers) demonstrated some correlation between warbler species and the stop-over habitat-niche chosen. Unexpectedly, he could not clearly demonstrate selection of major habitat types by migrant warblers in eastern forests.

METHODS

During the spring of 1977 a total of seven pairs of study areas were censused to determine migrant passerine densities and migrant diversities in stop-over habitats. The study sites, ranging in size from 1.6 hectares to 20.0 hectares, were located throughout Arizona. One site of each pair was situated in mature, riparian growth and the other in adjacent, nonriparian growth. Four pairs of study plots, those being used in the Rocky Mountain Forest and Range Experiment Station (RMFRES) riparian habitats study program, were examined in greater depth using the spot-map method (Williams 1936, Kendeigh 1944, and Franzreb 1976). The remaining three pairs of study sites were censused using a modified Ėmlen (1971) transect technique wherein an absolute count of birds was made. Data on the vegetation of the four paired RMFRES sites were gathered using the plotless point-quarter method of Cottam and Curtis (1956) and are included in Table 1. Tree heights were measured with a clinometer.

In addition, observation data on the spring migration of paulids for the Blue Point cottonwood stand was gathered from 1969 through 1974.

STUDY SITE DESCRIPTIONS

Terminology follows that of Hubbard (1971) with modifications. Study site sizes are included parenthetically.

1. Wet Beaver Creek (WBC) - Sullivan Ranch near Camp Verde, Yavapai Co., elev. 1250 m. A heterogeneous riparian forest with Platanus-Fraxinus overstory (4.1 hectares).

Wet Beaver Creek Adjacent (WBCA) - a mixed microphyll (valley and slope mesquite)-evergreen woodland of Prosopis, Juniperus and Canotia (3.0 hectares).

2. Ash Creek (AC) - Rincon Mountains, Coronado Forest, Pima Co., elev. 1200 m. A heavily grazed heterogenous riparian woodland of Prosopis, Fraxinus and Celtis (4.1 hectares).

Ash Creek Adjacent (ACA) - A heavily grazed, mixed microphyll (valley and slope mesquite)-evergreen-xeric shrubland of Prosopis, Mimosa, Quercus and Fouquieria (20.0 hectares).

3. Rucker Canyon (RC) - Chiricahua Mountains, Coronado National Forest, Cochise Co., elev. ca. 1600 m. A heterogenous, mixed riparian and evergreen forest with Quercus-Platanus overstory (5.0 hectares).

Table 1.--Vegetation of four RMFRES study sites

STUDY SITE	TREE SPECIES COMPOSITION	# TREES /HA	AVERAGE HT. TREES (METERS)	SHRUB SPECIES COMPOSITION	# SHRUBS /HA	AVERAGE HT. SHRUBS (METERS)
WBC	Platanus (25%) Juniperus (21%) Fraxinus (20%)	193	13.8	Mimosa (19%) Fraxinus (18%) Rubus (17%)	489	1.8
WBCA	Juniperus (68%) Prosopis (19%)	54	3.2	Canotia (28%) Juniperus (19%) Prosopis (17%)	1290	1.1
AC	Prosopis (52%) Fraxinus (23%) Celtis (17%)	124	5.3	Mimosa (41%) Baccharis (25%)	1510	0.9
ACA	Prosopis (86%) Quercus (14%)	59.3	3.6	Mimosa (44%) Gutierrezia (20%)	2638.5	0.8
RC	Juniperus (45%) Platanus (20%) Quercus (20%)	142	9.3	Rhus (43%) Juniperus (23%)	476	1.4
RCA	Quercus (61%) Juniperus (34%)	228	5.0	Rhus (36%) Nolina (33%)	691	1.3
TC	Juglans (31%) Prosopis (28%) Platanus (26%)	121	11.1	Juglans (48%) Prosopis (13%) Mimosa (12%)	490	1.6
TCA	Prosopis (33%) Quercus (32%)	29.4	4.4	Arctostaphylos (36%) Mimosa (27%) Prosopis (11%)	809	1.5

Rucker Canyon Adjacent (RCA) - a heavily grazed evergreen woodland of Quercus and Juniperus (6.0 hectares).

4. Turkey Creek (TC) - Rincon Mountains, Cornado National Forest, Pima Co., elev. 1250 m. A grazed homogeneous riparian forest with Platanus-Fraxinus overstory (5.9 hectares).

Turkey Creek Adjacent (TCA) - A grazed, mixed microphyll (slope mesquite)-evergreen shrubland of Prosopis, Quercus and Arctostaphylos (11.4 hectares).

5. Watson Lake (WL) - Near Prescott, Yavapai Co., elev. 1600 m. A homogeneous riparian forest with Populus-Salix overstory (7.5 hectares).

Watson Lake Adjacent (WLA) - A grazed, xeric grassland (7.1 hectares).

6. Blue Point (BP) - On the Salt River near Fort McDowell, Maricopa Co., elev. 400 m. A grazed, homogeneous riparian forest-woodland of Populus and Prosopis (10 hectares).

Blue Point Adjacent (BPA) - A grazed, xeric shrubland Cercidium association (10 hectares).

7. Indian Gardens (IG) - Grand Canyon National Park, Coconino Co., elev. 1150 m. An island of homogeneous riparian forest with Populus overstory (1.6 hectares).

Indian Gardens Adjacent (IGA) - A xeric, Coleogyne shrubland association (1.6 hectares).

RESULTS AND DISCUSSION

Tables 2, 3, and 4, and Figures 1 and 2 present the results of our 1977 spring migrant passerine survey. Residents and all possible breeding individuals and species were combined in the breeding bird category. This constitutes a significant overestimation of breeding bird populations and an underestimation of MPDen (migrant passerine density) and MPSD (migrant passerine species diversity) because some migrants were treated as breeding birds. Thus, in terms of migrants, these data are extremely conservative.

Table 2 presents the migrant species seen on the fourteen study plots. Note the generally higher MPSD of insectivores and the uniformly higher total MPSD on the riparian plots.

Table 3 and Figure 1 present MPDen data. The total number of migrant individuals in riparian habitats is shown to be uniformly greater (by up to 10.6 times) than the total number in adjacent, nonriparian habitats, with one exception. The open understory on the Turkey Creek plot attracted large flocks of Chipping Sparrows (Spizella passerina) and White-crowned Sparrows (Zonotrichia leucophrys) from the surrounding grasslands. Table 4 and Figure 2 show that the MPSD on all riparian study areas was distinctly higher than the MPSD on adjacent plots.

Other trends in these data can be observed. As in Table 2 insectivorous migrants generally preferred riparian habitats (WBC, TC, IG) and a higher insectivorous MPSD was also evident in most of those habitats. The larger number of granivorous individuals and smaller species diversity (WBCA, AC, TCA) of this group is an indication of flocking behavior in Fringillidae (the Finches, Sparrows and their allies). Granivores displayed habitat selection by avoiding dense riparian forest and woodland situations (WBC, BP); they tended to concentrate in adjacent shrublands (WBCA, WLA) and open, riparian forests (TC, IG). The importance of riparian habitats to breeding birds is also shown; in general, at least twice as many breeding individuals and species occurred in the riparian plots as did on the nonriparian plots.

Figures 1 and 2 illustrate differences in migrant use of heterogeneous and homogeneous habitats. Heterogeneous deciduous riparian habitats (WBC, AC) had generally higher MPDen and higher MPSD than did uniform stands of riparian growth (TC, WL, BP). Mixed riparian and evergreen forest habitats (RC) had lower MPDen and MPSD. Heterogeneous deciduous vegetation offers the greatest variety of habitat-niches for migrants, thus it is not unreasonable to expect substantial migrant use of these habitats. While uniform stands of riparian growth may be expected to support a lower MPSD the extremely low numbers on the Blue Point plot reflect inadequate sampling and poor weather conditions. Inaccessibility to migrants may account, in part, for the limited usage of the Rucker Canyon study area. Able (1970) has shown that 75% of eastern passerines migrate below an altitude of 920 meters and the same is probably true in the Southwest. A narrow canyon at a higher elevation may not be used by many migrants simply because the birds fly between mountain ranges rather than over them.

Moderately high MPDen and MPSD occurred in the only island stand of riparian vegetation studied (IG). It is not surprising that high MPDen and MPSD were found in riparian islands because these situations provide the only available food and cover for passage birds. The high percentage of granivores may reflect differences in migration patterns between fringillids and the insectivorous passerines.

Adjacent habitat depauperacy promotes a higher concentration of migrants in riparian habitats. Adjacent, nonriparian habitats which were not heavily grazed (WBCA and, to a lesser extent, TCA) supported a higher MPDen and MPSD than did those areas which were more heavily grazed (ACA, RC, WLA).

Patterns of migration in the Southwest have not been explored in depth. We observed only one wave migration of parulids in a five-year study of the Blue Point cottonwood stand; this concurs with Parnell's (1969) observation that wave migration is quite uncommon in eastern North American parulids. More frequently, though still not commonly, we have observed wide fronts of single species of parulids and fringillids. Most spring migration through the Southwest probably occurs in small, unispecific flocks,

Table 2.--Migrant passerine species occurrence and number of censuses per plot

	Paired (riparian and nonriparian habitats) study sites[1]													
	Heterogeneous						Homogeneous						Island	
MIGRANT PASSERINE SPECIES	WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Empidonax spp.	X	X	X	X	X	X	X	X			X			
Western Wood Pewee (*Contopus sordidulus*)											X			
Olive-sided Flycatcher (*Nuttalornis borealis*)			X											
Mountain Chickadee (*Parus gambeli*)					X								X	
Hermit Thrush (*Catharus guttata*)											X			
Western Bluebird (*Sialia mexicana*)			X											
Blue-gray Gnatcatcher (*Polioptila caerulea*)					X									
Ruby-crowned Kinglet (*Regulus calendula*)			X		X			X						
Cedar Waxwing (*Bombycilla cedrorum*)					X									
Solitary Vireo (*Vireo solitarius*)	X	X									X			
Warbling Vireo (*Vireo gilvus*)	X	X	X		X	X	X		X					
Virginia's Warbler (*Vermivora virginiae*)	X	X												
Lucy's Warbler (*Vermivora luciae*)					X									
Yellow-rumped Warbler (*Dendroica coronata*)	X	X	X	X	X	X	X	X	X				X	
Black-throated Gray Warbler (*D. nigrescens*)	X		X				X							
Townsend's Warbler (*D. townsendi*)							X				X			
Hermit Warbler (*D. occidentalis*)											X			

Table 2.--continued

	Paired (riparian and nonriparian habitats) study sites[1]													
	Heterogeneous						Homogeneous						Island	
MIGRANT PASSERINE SPECIES	WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
MacGillivray's Warbler (*Oporornis tolmiei*)				X					X					
Wilson's Warbler (*Wilsonia pusilla*)	X		X	X	X		X	X			X			
Western Tanager (*Piranga ludoviciana*)	X		X	X	X		X				X			
Black-headed Grosbeak * (*Pheuticus melanocephalus*)	X		X						X		X			
Lazuli Bunting (*Passerina amoena*)					X		X							
Pine Siskin (*Carduelis pinus*)	X												X	
Green-tailed Towhee (*Pipilo chlorurus*)		X	X	X				X	X					
Dark-eyed Junco (*Junco hyemalis*)			X			X								
Chipping Sparrow (*Spizella passerina*)	X	X	X	X			X	X		X			X	
Brewer's Sparrow (*Spizella breweri*)										X				
White-crowned Sparrow (*Zonotrichia leucophrys*)									X				X	
Total # migratory insectivorous species	9	5	10	5	10	3	7	4	4	0	9	0	2	0
Total # migratory granivorous species	2	2	3	2	1	1	2	2	2	2	0	0	3	0
Total # migratory species	11	7	13	7	11	4	9	6	6	2	9	0	5	0
Total # breeding passerine species	18	11	19	11	14	12	20	23	15	8	14	6	10	2
Total # passerine species	28	18	32	18	25	16	29	29	21	10	23	6	15	2
Total # censuses/plot	1	1	2	2	3	3	3	3	1	2	2	1	2	2

* Insectivorous migrant species through Black-headed Grosbeak; granivorous migrant species below Black-headed Grosbeak.

1 Study sites are of varying sizes and are not comparable.

Table 3.--Spring migrant and breeding passerine densities in riparian and adjacent nonriparian habitats

		Heterogeneous						Homogeneous						Island	
		WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Average # migrant birds/ha	Insectivorous	34.7	5.0	4.3	0.3	1.7	0.3	3.4	0.8	4.1	0	1.5	0	1.8	0
	Granivorous	0.7	7.0	3.5	0.8	0.5	0.3	5.3	13.0	0.4	0.5	0	0	8.8	0
	Total	35.4	12.0	7.8	1.1	2.2	0.6	8.7	13.8	4.5	0.5	1.5	0	10.6	0
Average # breeding birds/ha *		12.4	7.7	11.1	2.9	8.4	3.8	18.0	7.0	6.1	0.6	7.0	0.4	9.9	1.3
Average total # birds/ha		47.8	19.7	18.9	4.0	10.6	4.4	26.7	20.8	10.6	1.1	8.5	0.4	20.5	1.3

* Including all potentially breeding passerine individuals

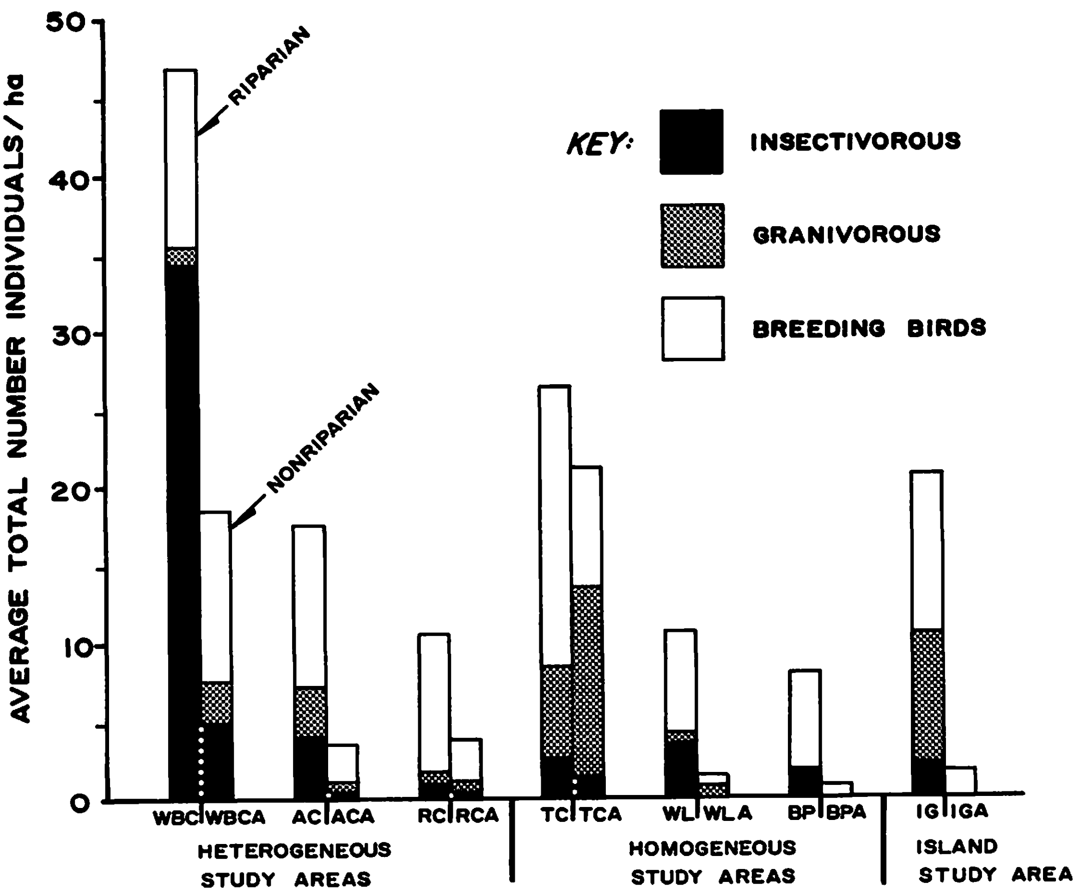

Figure 1.--Spring migrant and breeding passerine densities/ha in riparian and nonriparian habitats.

Table 4.--Spring migrant and breeding passerine species diversities/ha in riparian and adjacent, nonriparian habitats

		Heterogeneous						Homogeneous						Island	
		WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Average # migrant species/ha	Insectivorous	2.7	1.7	1.2	0.3	0.7	0.2	0.8	0.5	0.8	0	0.9	0	0.6	0
	Granivorous	0.2	0.7	0.4	0.1	0.2	0.1	0.2	0.2	0.3	0.1	0	0	1.6	0
	Total	2.9	2.4	1.6	0.4	0.9	0.3	1.0	0.7	1.1	0.1	0.9	0	2.2	0
Average # breeding species/ha *		4.4	3.7	2.3	1.0	2.7	1.2	2.9	2.1	2.6	0.4	1.4	0.5	6.2	1.3
Average total # species/ha		7.3	6.1	3.9	1.4	3.6	1.5	3.9	2.8	3.7	0.5	2.3	0.5	8.4	1.3

* Including all potentially breeding passerine species

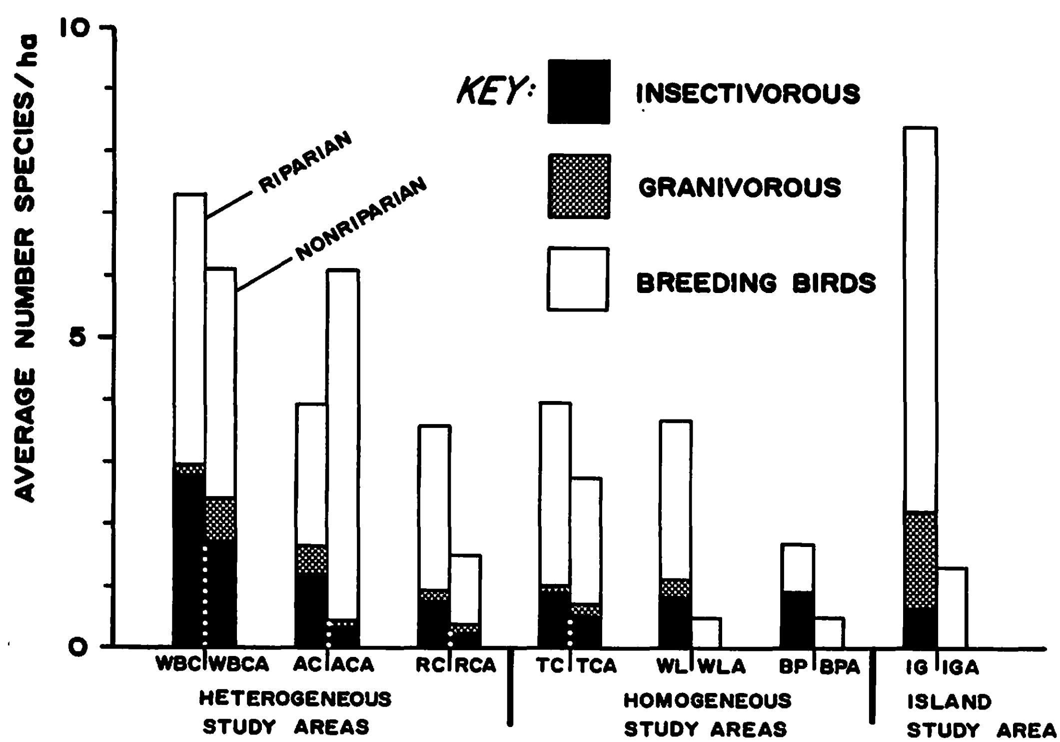

Figure 2.--Spring migrant and breeding passerine species diversities/ha in riparian and adjacent, nonriparian habitats.

as has been suggested by Gauthreaux (1972) for passerines migrating across the Gulf of Mexico.

CONCLUSIONS

From the data presented above it is evident that stop-over habitat selection by migrants occurs commonly in the Southwest. Riparian habitats support significantly higher MPDen and MPSD than do adjacent, nonriparian habitats. Insufficient data have been gathered as yet to substantiate the occurrence of niche selection, but the likelihood of this phenomenon is great. While Parnell (1969) could not clearly demonstrate habitat selection in migrant eastern warblers, habitat delineation is more distinct in the Southwest than in eastern deciduous and coniferous forests.

Parameters influencing migrant passerine use of riparian habitats include: specific habitat preferences of the bird (stop-over habitat selection); floral components (niche diversity and vegetational species composition); location of habitat (island situations and, perhaps, accessibility); and quality of the adjacent habitat (including the amount of grazing and other forms of impact).

The importance of riparian habitats to migrant passerines is substantial. Riparian habitat managers should consider the impact of proposed management not only on breeding species but also on migratory species. As Balda (1975) suggests, managers must be concerned with the quality of the avian populations they are indirectly managing through habitat manipulation. Riparian habitat management in vegetational islands and in heavily-grazed areas may have a greater effect on migrants and manipulation of these areas must be carefully evaluated.

ACKNOWLEDGMENTS

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Significance of Rio Grande Riparian Systems Upon the Avifauna[1]

Roland H. Wauer[2]

ABSTRACT.--The Rio Grande corridor in West Texas serves as a significant migratory and emigration route for avifauna, and 38 species are known to nest within the riparian habitat. A total of 94 species are known to breed within riparian systems within the American Southwest. The Rio Grande area provides suitable habitat for 40% of those. Nine species--great blue and green herons, peregrine falcon, American kestrel, white-winged dove, screech owl, Bell's vireo, yellow warbler, and bronzed cowbird--are discussed as indicators of changes within the system and the important of the Rio Grande area as a refugium.

Few rivers on the North American continent stimulate the imagination as does the Rio Grande. It is that magical line that blends cultures and links natural environments from the highlands of the Rocky Mountains to the lowlands of the Chihuahuan Desert. It is a legendary river that joins, rather than separates, two countries. Both countries contribute to its flow and utilize its precious ingredients.

The Rio Grande begins in the mountains of Colorado and New Mexico, but little water is left by the time it reaches Texas. Irrigation and channelization claim a good deal of its cargo above El Paso. For another 100 miles below El Paso the once proud Rio Bravo del Norte, as it is known south of the border, is little more than a trickle. Below Presidio, Texas, however, the Rio Grande is rejuvenated by the Rio Conchos that brings water northward from the slopes of Mexico's Sierra Madre Occidental.

Tamayo (West, 1964) reported that the Rio Conchos supplies 18 percent of the Rio Grande's total flow, and that almost one-half of the Rio Grande's annual discharge is derived from Mexican tributaries. Since 1964 the flow of the Rio Conchos has been restricted by Granero Dam, and so an increasing amount of its water is utilized for irrigation in Mexico before reaching the Rio Grande influence. The least changed portion of the entire Rio Grande probably is within a strip of about 250 miles that lies between Colorado Canyon and Langtry, Texas. There the river makes a great southern swing into the Mexican states of Chihuahua and Coahuila. This paper is restricted to the riparian zone of that "Big Bend" area and eastward through Langtry to Amistad National Recreation Area.

Area Description

A satellite view of West Texas provides a realistic assessment of the contrast of the Rio Grande to its environment. The river appears like a green ribbon winding through a maze of grays, browns and blacks. This ribbon of greenery truly does meander its way through the arid desertscape of canyons, arroyos, and mesas. Elevations adjacent to the riverway range from 2,000 to 3,500 feet above sea level. A few mountains that are at least several miles from the river, such as the Chisos and del Carmens, may reach 7,800 feet elevation, but these have little influence upon the riparian zones along the riverway.

The general physiographic character of the Lower Canyons (an area from Big Bend National Park to near Langtry) of the Rio Grande was discussed by Johnson, et. al. (in press) in describing the vegetation found there. The zones include riverbed, riverbank, lower terrace or high floodplain, talus slope, canyon walls, side-canyon, and uplands or mesa-butte-rim. Although riparian vegetation does not

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exist in all of these zones, wildlife in each is influenced by the nearest riparian habitats. Wauer (in press) described the avifauna within each of the above seven zones. A good deal of the following material is taken from that publication and an earlier one by Wauer (1973), Birds of Big Bend National Park and Vicinity.

Riparian vegetation usually is considered to include that growing upon the floodplain and in adjacent arroyos, generally, wherever periodic flooding occurs. On the Rio Grande, riparian vegetation may extend from a few feet to one-half mile from the riverbed, except where sheer cliffs rise directly out of the river.

Common reed (Phragmites communis) and giant reed (Arundo donax) form tall "cane" stands along isolated or protected places and often hang out over the waterway. Other mesic forms that grow on the riverbank include lanceleaf cottonwood (Populus acuminata), honey mesquite (Prosopis juliflora), seepwillow (Baccharis glutonosa), the exotic salt cedar (Tamarisk sps.), and willows; the tall treewillow is southwest black willow (Salix gooddingii), and black (S. niger) and sandbar willows (S. interior) are also present.

Just beyond this zone is another one that includes all the above plants and several others, including screwbean (Prosopis pubescens), catclaw acacia (Acacia greggii), black brush (A. rigidula), huisache (A. farnesiana), desertwillow (Chilopsis linearis), tree tobacco (Nicotiana glauca), common buttonbush (Cephalanthus occidentalis), and Texas palo verde (Cercidium texanum).

Ponds can be found in a few places where the Rio Grande has changed its course or where high water has dredged a deep hole. Seepwillow, salt cedar, and cowpen daisy (Verbesina encelioides), are early invaders of the silty soils. Common cattail (Typha latifolia), lanceleaf cottonwood, willows and Mexican devilweed (Aster spinosus) appear soon if there is sufficient moisture.

In places where the river regularly scours the rocky shoreline, a mat of Bermuda grass (Cynodom dactylon) may form a luxuriant cover. In protected flats within the lower canyons, extensive grassy vegas may result.

Riparian Avifauna of the Southwest

The American Southwest comprises a large and extremely diverse section of the United States. Elevations range from below sea level to over 12,000 feet, and environmental conditions vary from arid, desert lowlands to pine-clad forests. For the purpose of this discussion, the Southwest is the land mass north of the Mexican border between southeastern California (east of the Sierra Nevada foothills) and west Texas (west of Del Rio), north through the southern one-third of Utah and all of New Mexico but the northern highlands.

Two major river systems drain the Southwest, the Colorado River on the west and the Rio Grande on the east. Major tributaries include the Gila, Virgin, and San Juan on the Colorado, and the Rio Conchos, Pecos, and Devil's on the Rio Grande.

Table 1 includes 94 known avifauna that nest within riparian vegetation below the mountain woodlands and forests, below approximately 5,500 feet elevation. This list includes ground nesters and social parasites. It does not include species that nest in habitats that may be adjacent to riparian zones, such as peregrine falcon (Falco peregrinus) and cliff swallow (Petrochelidon pyrrhonota) that are cliff-nesters, and common yellowthroat (Geothlypis trichas) and red-winged blackbird (Agelaius phoeniceus) that utilize swamps and marshes. It does include species such as American kestrel and great horned owl that usually nest on cliffs but have been found nesting on riparian vegetation.

Several earlier publications were utilized in developing the list of breeding avifauna. They include Death Valley National Monument, California, studies by Wauer (1962a, 1962b, and 1964), and Remsen's 1976 breeding bird survey near Needles, California, (1977); Nevada avifaunal summary by Linsdale (1936) and studies at Las Vegas (Austin, 1970) and the lower Virgin River (Wauer, 1969); Utah studies on the upper Virgin River (Wauer, 1967; Wauer, 1969), Zion National Park (Wauer and Carter, 1965); the Arizona summary by Phillips, Marshall, and Monson (1964); the New Mexico summary by Hubbard (1970); and west Texas studies in Big Bend National Park (Wauer, 1973), the Lower Canyons on the Rio Grande (Wauer, in press), and Amistad Recreation Area (LoBello, 1976).

Examination of the 94 riparian species indicates that only the mourning dove, verdin, northern oriole, brown-headed cowbird, and house finch occur within all nine riparian areas. Additional dominant species include ladder-backed woodpecker, ash-throated flycatcher, yellow-breasted chat, hooded oriole, and blue grosbeak--recorded for eight areas--and white-winged dove, black-chinned hummingbird, northern mockingbird, and Bell's vireo recorded for seven areas. Seventy-nine additional species were recorded on one to six of the areas, and only 13 species are listed only once: gray hawk in Arizona, California quail in Death Valley

TABLE 1 con't

Breeding Avifauna of Riparian Systems in Southwest U.S.

SPECIES[a]	SE Calif		Nev	Utah	Ariz	NMex	W. Tex		
	1*	2	3	4	5	6	7	8	9
Verdin (*Auriparus flaviceps*)	X	X	X	X	X	X	X	X	X
Bushtit (*Psaltriparus minimus*)			X	X					
White-breasted Nuthatch (*Sitta carolinensis*)					X	X			
House Wren (*Troglodytes aedon*)				X		X			
Bewick's Wren (*Thryomanes bewickii*)			X		X	X			
Carolina Wren (*Thryothorus ludovicianus*)								X	
Cactus Wren (*Campylorhynchus brunneicapillus*)			X		X	X	X	X	
Northern Mocking bird (*Mimus polyglottos*)	X		X		X	X	X	X	X
Gray Catbird (*Dumetella carolinensis*)					X	X			
Crissal Thrasher (*Toxostoma dorsale*)			X		X	X			
American Robin (*Turdus migratorius*)			X	X	X	X			
Western Bluebird (*Sialia mexicana*)			X		X	X			
Blue-gray Gnatcatcher (*Polioptila caerulea*)	X	X	X	X					
Black-tailed Gnatcatcher (*Polioptila melanura*)			X		X		X		
Phainopepla (*Phinopepla nitens*)		X	X	X	X	X		X	
Starling (*Sturnus vulgaris*)				X	X	X			
Bell's Vireo (*Vireo bellii*)			X	X	X	X	X	X	X
Solitary Vireo (*Vireo solitarius*)				X	X	X			
Warbling Vireo (*Vireo gilvus*)	X		X	X		X			
Lucy's Warbler (*Vermivora luciae*)	X		X	X	X	X			
Yellow Warbler (*Dendroica petechia*)	X		X	X	X	X	h	h	h
Yellow-breasted Chat (*Icteria virens*)	X		X	X	X	X	X	X	X
Orchard Oriole (*Icterus spurius*)						X	X	X	X
Hooded Oriole (*Icterus cucullatus*)	X	X	X		X	X	X	X	X
Northern Oriole (*Icterus galbula*)	X	X	X	X	X	X	X	X	X
Great-tailed Grackle (*Quiscalus mexicanus*)					X	X	X	X	X

TABLE 1 con't

Breeding Avifauna of Riparian Systems in Southwest U.S.

SPECIES[a]	SE Calif 1*	2	Nev 3	Utah 4	Ariz 5	NMex 6	W. Tex 7	8	9
Broad-billed Hummingbird (*Cynanthus latirostris*)					X	X			
Common Flicker (*Colaptes auratus*)				X	X	X			
Golden-fronted Woodpecker (*Centurus aurifrons*)							X		X
Gila Woodpecker (*Centurus uropygialis*)			X		X	X			
Lewis' Woodpecker (*Melanerpes lewis*)						X			
Hairy Woodpecker (*Dendrocopos villosus*)			X	X		X			
Downy Woodpecker (*Dendrocopos pubescens*)						X			
Ladder-backed Woodpecker (*Dendrocopos scalaris*)		X	X	X	X	X	X	X	X
Rose-throated Becard (*Platypsaris aglaiae*)					X				
Eastern Kingbird (*Tyrannus tyrannus*)						X			
Tropical Kingbird (*Tyrannus melancholicus*)					X				
Western Kingbird (*Tyrannus verticalis*)	X		X	X	X	X			p
Cassin's Kingbird (*Tyrannus vociferans*)							X		
Thick-billed Kingbird (*Tyrannus crassirostris*)					X	X			
Wied's Crested Flycatcher (*Myiarchus tyrannulus*)				X	X	X			
Ash-throated Flycatcher (*Myiarchus cinerascens*)		X	X	X	X	X	X	X	X
Olivaceous Flycatcher (*Myiarchus tuberculifer*)					X	X			
Willow Flycatcher (*Empidonax traillii*)			X	X	X	X	X		
Hammond's Flycatcher (*Empidonax hammondii*)						X			
Western Flycatcher (*Empidonax difficilis*)				X					
Western Wood Pewee (*Contopus sordidulus*)	X			X	X	X			
Vermilion Flycatcher (*Pyrocephalus rubinus*)			X	X	X	X	X	X	
Beardless Flycatcher (*Camptostoma imberbe*)					X	X			
Violet-green Swallow (*Tachycineta thalassina*)				X	X	X			
Black-billed Magpie (*Pica pica*)			X	h	h	X			
Black-capped Chickadee (*Parus atricapillus*)				X					

TABLE 1

Breeding Avifauna of Riparian Systems in Southwest U.S.

SPECIES[a]	SE Calif 1*	2	Nev 3	Utah 4	Ariz 5	NMex 6	W. Tex 7	8	9
Great Blue Heron (*Ardea herodias*)			X	X	X	X			
Green Heron (*Butorides striatus*)			X	X	X	X	h		p
Great Egret (*Casmerodius albus*)					X	X			
Snowy Egret (*Egretta thula*)					h	X			
Black-crowned Night Heron (*Nycticorax nycticorax*)					X	X			
Cooper's Hawk (*Accipiter cooperii*)				X	X	X			
Gray Hawk (*Buteo nitidus*)					X				
Black Hawk (*Buteogallus anthracinus*)				X	X	X			
American Kestrel (*Falco sparverius*)			X	X	X	X			
California Quail (*Lophortyx californicus*)	X								
Gambel's Quail (*Lophortyx gambelii*)	X	X	X		X	X			
White-winged Dove (*Zenaida asiatica*)			X	X	X	X	X	X	X
Mourning Dove (*Zenaida macroura*)	X	X	X	X	X	X	X	X	X
Common Ground Dove (*Columbigna passerina*)					X	X	X	X	X
Inca Dove (*Scardafella inca*)					X		X		X
Yellow-billed Cuckoo (*Coccyzus americanus*)	X			X	X	X	X	X	p
Greater Roadrunner (*Geococcyx californianus*)	X		X	X	X	X	X		
Common Screech Owl (*Otus asio*)			X	X	X	X	X	X	
Great Horned Owl (*Budo virginianus*)	X			X	X				
Ferruginous Owl (*Glaucidium brasilianum*)					X				
Elf Owl (*Micrathene whitneyi*)					X	X	X	X	
Long-eared Owl (*Asio otus*)			X	X	X				
Lesser Nighthawk (*Chordeiles acutipennis*)			X	X			X	X	p
Black-chinned Hummingbird (*Archilochus alexandri*)			X	X	X	X	X	X	X
Costa's Hummingbird (*Calypte costae*)		X	X		X				
Violet-crowned Hummingbird (*Amazilia verticalis*)					X	X			

TABLE 1 con't

Breeding Avifauna of Riparian Systems in Southwest U.S.

SPECIES[a]	SE Calif		Nev	Utah	Ariz	NMex	W. Tex		
	1*	2	3	4	5	6	7	8	9
Brown-headed Cowbird (Molothrus ater)	X	X	X	X	X	X	X	X	X
Bronzed Cowbird (Molothrus aeneus)					X	X	X		
Summer Tanager (Piranga rubra)			X	X	X	X	X	X	
Northern Cardinal (Cardinalis c.)					X	X	X	X	X
Black-headed Grosbeak (Pheucticus melanopephalus)		X		X	X	X			
Blue Grosbeak (Guiraca caerulea)	X	X		X	X	X	X	X	X
Indigo Bunting (Passerina cyanea)				X	X	X			
Lazuli Bunting (Passerina amoena)	X	X	X	X	X	X			
Painted Bunting (Passerina ciris)						X	X	X	X
House Finch (Carpodacus mexicanus)	X	X	X	X	X	X	X	X	X
American Goldfinch (Spinus tristis)	X		X						
Lesser Goldfinch (Spinus psaltria)	X	X	X	X		X			
Lawrence's Goldfinch (Spinus lawrencei)					X				
Rufous-sided Towhee (Pipilo erythrophthalmus)	X			X		X			
Abert's Towhee (Pipilo aberti)			X	X	X	X			
Song Sparrow (Melospiza melodia)			X	X	X	X			
TOTALS	24	16	47	51	69	75	33	27	20

a = names follow AOU (1957, 1976)
h = historical only
p = probable

*1 = Wauer, R.H., 1962a, 1962b, 1964
2 = Remsen, J.V., 1977
3 = Linsdale, J.M., 1936; Wauer, R.H., 1969; Austin, G.T., 1970
4 = Wauer, R.H., 1967; Wauer, R.H. and D.L. Cater, 1965
5 = Phillips, A., J. Marshall, G. Monson, 1964
6 = Hubbard, J.P., 1970
7 = Wauer, R.H., 1973
8 = Wauer, R.H., (in press)
9 = LoBello, R.L., 1976

(an introduced species there according to Wauer (1962)), ferruginous owl in Arizona, Lewis' and downy woodpeckers in New Mexico, rose-throated becard and tropical kingbird in Arizona, Cassin's kingbird in west Texas, eastern kingbird and Hammond's flycatcher in New Mexico, western flycatcher in Zion National Park, Utah, Carolina wren in the Lower Canyons of the Rio Grande, and Lawrence's goldfinch in southern Arizona.

Significance of Riparian Habitat in West Texas

Before roads, the Rio Grande corridor was the most sensible route of traveling through the harsh, arid environment. It provided a practical passageway between the Chihuahuan Desert region of west Texas and the semi-tropical Lower Valley. It was used by man and wildlife alike. Today, the Rio Grande route is left to wildlife and plants, to a few recreationists, and those of us who need the "spirit of the river."

The Rio Grande still serves as migratory and emigration routes for plants and animals. Plant species washed away by high water from one place may be deposited in an appropriate place to take root many miles downriver. Downriver species may edge slowly along or be transferred distances by some natural agent. Extensions of western and eastern forms occur all along the Rio Grande waterway. This phenomena, as it pertains to the flora, is discussed by Johnson, et. al. (in press), but the natural parameters that restrict plant species, such as temperatures and soils, do not always apply to the more mobile avifauna.

Several breeding birds known to occur within the Texas Big Bend Country appear to owe their presence there to the river corridor. Good examples of breeding birds of the Rio Grande area with eastern affinities are orchard oriole, hooded oriole, and great-tailed grackle. Orchard oriole frequents deciduous environments throughout the eastern United States and its breeding range extends through west Texas to El Paso along the Rio Grande. Two races of hooded orioles breed within riparian zones along the lower Rio Grande. The nominant form occurs from near the eastern border of Big Bend National Park downriver to near Laredo (Oberholser, 1974). The breeding range of I.c. nelsoni extends westerly along the river in Texas through Big Bend National Park. The breeding race of great-tailed grackle (C.m. monsoni) extends only within the Trans-Pecos and along the Rio Grande to about Amistad Reservoir where C.m. prosopidicola occurs (Selander and Giller, 1961).

The Rio Grande corridor further explains the presence of a number of post-nesting birds that breed out of the area and wander into the area afterwards. The green kingfisher (Chloroceryle americana) breeds in central and southern Texas and disperses outward after the breeding season. Records exist along the Rio Grande to the west edge of the Big Bend National Park (Wauer, 1973; Oberholser, 1974). The great-crested flycatcher (Myiarchus crinitus), a species that nests throughout the eastern two-thirds of Texas (Oberholser, 1974), has been recorded only from August 24 through October 29 in Big Bend National Park (Wauer, 1973). The third example is the Carolina wren that breeds to the eastern edge of the area of concern, and all records west of Del Rio exist along the Rio Grande (Wauer, 1973; Oberholser, 1974).

The use of the Rio Grande corridor for a migratory route is one of the well recognized patterns of southwestern avian behavior. Wauer (1973) thoroughly discussed the spring and fall migration through Big Bend National Park, and much of that discussion applied to the rest of the lower Rio Grande area.

Although the characteristic of northbound and southbound bird movement along major waterways is common elsewhere, it is likely that a river corridor is more important to migrating birds in arid parts of the country than in humid, heavier vegetated areas. In west Texas, hot-dry desert conditions prevail during the principal portion of the spring and fall migration. Therefore, the availability of food, water, cover, and suitable north-south routing are exceptionally important and strongly influence migrants. A quantitative analysis of bird movement along the Rio Grande corridor is not available, although such a study would be extremely worthwhile.

The migration periods for Big Bend National Park were analyzed by Wauer (1973) who stated that "Fall migration in the lowlands is only a shadow of the spring movement." To understand the migration patterns for the avifauna it is necessary to point out that the area is split into two halves by a mountain range that runs north-south along the eastern side of Big Bend National Park. This range--the Sierra del Carmens--extends north of the Rio Grande for about 60 miles and south for about 100 miles. It results in a splitting of the northbound migrants so that the north-south valleys on both sides of the del Carmens are utilized. Fall migrants following the valleys southward are diverted along the northern boundary of the park by the Santiago Mountains (an extension of the Sierra del Carmens that continue northwesterly) toward the southeast and along the eastern side of the del Carmens. This route is through the desert north of Persimmon Gap and into the Black Gap Wildlife Management Area and then into the Rio Grande canyons and riparian habitats. Southbound migrants undoubtedly find water and food within the lush riparian vegetation along the river that is more inviting than that in the adjacent desert landscapes.

The lower Rio Grande also is a refugium for nesting avifauna that rely upon the riparian systems. I have selected nine species to analyze: great blue heron, green heron, peregrine falcon, American kestrel, white-winged dove, screech owl, Bell's vireo, yellow warbler and bronzed cowbird.

Great blue heron and green heron are known to have nested within the riparian vegetation along the Rio Grande in historic times (Van Tyne and Sutton, 1937). Wauer (1973), reported that great blue herons are present in Big Bend National Park all year but no recent nesting. He stated that, "Today, between Boquillas and Presidio, there is only a single grove of cottonwoods and willows large enough to support a rookery; it is located on the floodplain near Santa Elena Crossing, where there probably is too much human activity for nesting herons." More recently, LoBello (1976), reported a nest containing four eggs, on Javelina Bluff near Rough Canyon Marina, Amistad Reservoir, April 26, 1975. The nest was located on a sheer cliff about 200 feet above the water. It is possible that this species can adapt to solitary nesting on cliffs within the Rio Grande canyons to continue its status as a breeding bird of the lower Rio Grande. It will undoubtedly continue to utilize the riparian vegetation for perching, cover, and finding food.

There are no known records of breeding green herons in recent years. I suspect that nesting does occur in out of the way places within the riparian zone. It is present throughout the summer months at Big Bend National Park (Wauer, 1973), and LoBello (1976) found it at Amistad Reservoir consistently in summer, including an immature bird on August 11. Riparian vegetation is essential to the survival of this heron for perching, roosting, and hunting. It is extremely unlikely that cliff-nesting is feasible for this species.

Peregrine falcon is an excellent tribute to the wilderness character of the Rio Grande canyons and the accessability of relatively non-polluted food. It nests on high canyon walls and hunts for food along the riverway. Mourning and white-winged doves, common nesting birds of the riparian habitat, provide sufficient food supplies for at least five pairs of this endangered species from Big Bend National Park to Amistad Reservoir (Wauer, 1973; Hunt, 1975).

Peregrines have declined drastically within the United States since the 1940's. The population east of the Mississippi River and south of the boreal forests was estimated at 400 pairs, and today not a single breeding wild pair remains. In the western United States the population is only ten percent of what it was in the 1940's. So, the Rio Grande canyons serve as a significant refugium for this highly endangered species. American kestrel is a common nesting bird along the Rio Grande canyons. It is an adaptable species that obtains its food from many sources, including the riparian habitats within the Rio Grande corridor and adjacent arroyos. Also, I have found it numerous in migration, when up to half-dozen birds can be expected along a few miles of riparian habitats. The principal migration occurs from late September through November and mid-March through early May (Wauer, 1973).

White-winged dove is resident along the Rio Grande throughout the Big Bend area, and flocks at the more extensive riparian zones during winter; Wauer (1973) recorded 70 individuals at Rio Grande Village on January 22, 1970. Generally, white-winged dove populations have been severely depleted throughout much of their range in recent decades. In the Lower Valley of the Rio Grande, thousands of acres of land were cleared of native brushland during the 1940's and 1950's, and the white-winged population took a drastic nosedive. Since then, citrus trees have been planted and support nesting white-wings, although the population has not returned to what it was under natural conditions.

A combination of land clearing, land flooding by Falcon and Amistad Reservoirs, and the addition of increasing hunting pressures upon the white-winged dove populations in Mexico (several populations from the United States winter in Mexico) have had severe negative effects upon the Texas white-wings. The riparian zones within the Big Bend country provide some of the most stable known habitat.

Screech owl occurs within the riparian habitat along the river and adjacent arroyos and oases throughout the year. The Rio Grande corridor appears to provide habitat for extensions of ranges of two races that overlap within the Big Bend area. Marshall (1967) found hybridizing *Otus asio suttoni* and *O.a. mccalli* in the riparian vegetation near Rio Grande Village.

Bell's vireo may be regarded as the most numerous breeding bird within the Rio Grande riparian systems of west Texas. Its song is ubiquitous among the floodplain and arroyo vegetation from late March through early June. Two races breed within the area; the nominant form along the eastern edge, and V.b. medius through the Big Bend National Park area (AOU, 1957).

In Arizona, the species is "scarce and local in at least the Phoenix and Benson areas, this tiny bird was certainly decimated in the latter by cowbird parasitism" (Phillips, 1968). It is strange that the species is so abundant within the west Texas riparian systems in spite of the abundance of brown-headed cowbirds.

Yellow warbler is absent or a rare breeding bird of riparian zones within west Texas. This apparently was not the case during earlier years. Wauer (1973) stated that, "Van Tyne and Sutton reported that it nested at Boquillas, Hot Springs, and San Vicente during the 1930's, but I have searched the floodplain for nesting birds without success. In five years (1966-1971) I have found only three summertime birds." Allan Phillips (1964) believes that the species has been extirpated by parasitism of brown-headed cowbirds in some parts of southern Arizona, and this may well be the case in the Big Bend; cowbirds have increased in recent years and are now abundant along the river floodplain where yellow warblers once nested.

Bronzed cowbird has been a summer resident within the Big Bend National Park only since 1969 (Wauer, 1973). There were no summertime records of the species prior to 1969, but there are numerous records within the riparian zones since. These recent sightings include several cases of parasitism, principally on hooded and orchard orioles. These orioles are common within the riparian zones, but long-range analysis of their status should be undertaken to determine if the recent impacts pose significant threats to their populations.

Phillips (1968) states that the species was first seen in Arizona in 1909, but spread through the southern one-half of the state within 20 years. He suggests that additional spread was restricted by the species failure to find enough hooded oriole nests to parasitize. Based upon these comments, it is likely that the bronzed cowbird will readily spread throughout the Rio Grande at least north of El Paso where hooded orioles breed.

Summary

The significance of the Rio Grande riparian zones within west Texas can only be speculated upon, but evidence suggests that it is of major importance. Several avian species are present that are absent or rare elsewhere, and numerous species utilize the river corridor as routes through inhospitable habitat. So much of the riparian communities of the Southwest have been destroyed and changed in recent decades, that one that possesses natural characteristics must be given special protection. The importance of a relatively unchanged extensive riparian system becomes more significant daily.

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Some Effects of a Campground on Breeding Birds in Arizona[1]

Stewart W. Aitchison[2]

Abstract.--Over a three year period, breeding bird densities were found to be similar between a constructed campground and a relatively natural area when the campground was closed to campers. However, bird species composition differed between sites, the campground having relatively heavier bodied birds ($\bar{x}$ = 48.5 g) than the control area ($\bar{x}$ = 38.2 g). Once the campground was opened for human use, the breeding bird population decreased in density and diversity. On the control site the population either remained the same or increased.

INTRODUCTION

It has been well documented that the human manipulation of Southwestern habitats greatly affects the configuration of the avian community that will continue to utilize the area (e.g., Carothers et al. 1974, Carothers and Johnson 1975). These studies have primarily concerned themselves with phreatophyte control, channelization, and other water management practices. Very little research has dealt with the impact caused by the construction of permanent structures and human occupation of these areas (e.g., subdivisions, trailer parks, and campgrounds). The present study examines the effects of a U.S. Forest Service improved campground upon breeding birds.

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STUDY AREA

Two sites were chosen which appeared similar in vegetative structure, each being composed primarily of ponderosa pine with some cottonwood, Arizona walnut and other deciduous trees and shrubs. (Table 1 summarizes the vegetation analysis of the study areas.) Both sites are within Oak Creek Canyon, Sec. 27, T19N, R6E, Coconino County, Arizona, at an elevation of 1,646 m. One plot was located within the Cave Springs Campground; the other plot, control, was slightly north and across the Oak Creek.

The Cave Springs Campground study site is 4.0 ha. Extensive timber and shrub removal, construction of roads, pit toilets, and erection of tables has occurred here. The campground is open for public use from approximately Memorial Day to Labor Day of each year.

Control is approximately 2.0 ha. Relative to the campground, this area is undisturbed by human activities.

Though the two sites are small in area, thus making extrapolation of figures somewhat misleading, they encompass as much homogeneous habitat as possible. Further, the small size enabled the investigators to know the avian components intimately, and therefore we feel a very accurate count of species was achieved.

Table 1.--Vegetation Analysis

Study Area		Tree Density Per Hectare	Basal Area (m^2) Per Hectare	Average Tree Height (m)
CAMPGROUND	Ponderosa Pine *Pinus Ponderosa*	437.1	2153.6	12.4
	*All other species	316.5	415.0	7.3
CONTROL	Ponderosa Pine	347.8	2118.4	14.0
	**All other species	1010.7	447.8	5.0

* *Acer negundo*, *Alnus oblongifolia*, *Juniperus scopulorum*, *Quercus gambelli*, *Populus lanceolata*, *Salix gooddingii*.

** *Acer negundo*, *Alnus oblongifolia*, *Fraxinus pennsylvanica* var. *velutina*, *Juniperus scopulorum*, *J. monosperma*, *Pinus edulis*, *Populus lanceolata*, *Quercus* spp.

METHODS

The populations of breeding birds were determined by the spot-map method (Williams 1936, Kendeigh 1944). On each census the location of singing males, song posts, and nest sites was recorded for each census and information on every species was later recorded onto species maps. Censusing was carried out from 4 April to 6 July 1973, 18 February to 1 July 1974, and 9 May to 10 July 1975; these periods included the entire observable breeding season. Densities were determined for each area before and after the date the campground was opened (e.g., 29 May 1973, 17 May 1974, and 16 May 1975). [Note: All densities were extrapolated to 40 ha to make inter-area comparisons easier.]

Foliage height diversity (FHD) was sampled along ten 100 m transects established at random throughout the study areas. Presence or absence of vegetation at 2 m intervals along the transects was noted at three layers chosen to approximate foliage stratification into herbaceous (0-0.6 m), shrub (0.6-4.49 m) and canopy ($\geq$4.5 m) layers. A 4.5 m rod marked at 0.6 m from one end was used to record the presence or absence of foliage for the herbaceous and shrub layers, and the ocular tube method (Winkworth and Goodall 1962) was used for the canopy layer. For recording the presence of vegetation in the herbaceous and shrub layers, it was necessary for green foliage to touch the vertically held rod.

All vegetative and avian diversity indices are computed as $H' = -\sum P_i \log_e P_i$ based on the Shannon-Wiener model of information theory (see Shannon and Weaver 1963) as it applies to biological parameters (MacArthur and MacArthur 1961; MacArthur 1965; Pielou 1966a,b; Lloyd et al. 1968).

Tree density, species composition and basal area were determined by the plotless point-quarter method of Cottam and Curtis (1956). Tree heights were determined by use of a clinometer. Samplings witha diameter at breast height (DBH) of less than 7.6 cm were treated as shrubs.

Avian standing crop biomass (SCB) was determined by taking the average adult weight (W) times the number of adults per unit area. Existence Energy (EE) or the amount of kcal consumed per ha per 24 hours was calculated from these two formulae:

$\text{Log EE} = 0.3581 + 0.5876 \text{ Log W}$ (for passerines)

$\text{Log EE} = 0.0649 + 0.6722 \text{ Log W}$ (for non-passerines).

These formulae give the energy requirements to maintain a constant weight at rest. To determine actual community energetics it would be necessary to include energy requirements of the immature birds, and the various energy demanding activities of breeding birds (e.g., singing, displaying, nest building). The limitations of this procedure notwithstanding, it is instructive to make inter- and intra-community comparisons with these low estimates of avian community energetics (see Karr 1968 and 1971).

RESULTS AND DISCUSSION

A total of 58 species (Table 2) of birds

Table 3.--Avian density and species richness

SPECIES	1973 CONTROL Before	1973 CONTROL After	1973 CAMPGROUND Before	1973 CAMPGROUND After	1974 CONTROL Before	1974 CONTROL After	1974 CAMPGROUND Before	1974 CAMPGROUND After	1975 CONTROL Before	1975 CONTROL After	1975 CAMPGROUND Before	1975 CAMPGROUND After
Mourning Dove	----	----	----	----	----	----	----	----	----	----	9.9	9.9
Broad-tailed Hummingbird	19.8	19.8	24.7	----	----	19.8	9.9	9.9	19.8	19.8	9.9	9.9
Red-shafted Flicker	----	----	9.9	9.9	----	----	9.9	9.9	----	----	9.9	19.8
Hairy Woodpecker	----	----	9.9	----	19.8	----	9.9	----	----	19.8	----	9.9
Yellow-bellied Sapsucker	----	----	----	----	----	----	9.9	----	----	----	----	9.9
Cassin's Kingbird	----	----	----	----	----	----	----	----	----	19.8	----	----
Black Phoebe	19.8	19.8	----	----	----	----	----	----	----	----	----	----
Western Flycatcher	19.8	19.8	----	----	----	----	----	----	----	----	----	----
Western Wood Pewee	----	39.5	----	9.9	----	19.8	----	19.8	----	39.5	----	----
Steller's Jay	39.5	19.8	49.5	24.7	19.8	----	19.8	19.8	19.8	19.8	19.8	19.8
White-breasted Nuthatch	----	----	9.9	9.9	----	----	29.7	19.8	----	----	----	----
Pygmy Nuthatch	----	----	----	----	19.8	19.8	19.8	9.9	19.8	19.8	9.9	19.8
House Wren	59.3	59.3	39.6	39.6	19.8	39.5	39.6	29.7	59.3	59.3	19.8	39.6
Robin	39.5	39.5	44.5	29.7	19.8	19.8	29.7	19.8	----	39.5	29.7	39.6
Solitary Vireo	49.4	49.4	9.9	----	----	19.8	9.9	9.9	19.8	19.8	----	----
Warbling Vireo	----	----	----	----	----	----	9.9	----	----	19.8	----	----
Virginia's Warbler	----	----	----	----	----	----	----	----	----	39.5	----	----
Grace's Warbler	----	----	9.9	----	----	19.8	19.8	----	----	9.9	29.7	19.8
Painted Redstart	----	----	9.9	----	19.8	39.5	9.9	----	----	----	----	----
Red-faced Warbler	----	19.8	----	----	----	19.8	----	4.9	----	----	----	----
Bullock's Oriole	19.8	19.8	14.8	14.8	----	19.8	19.8	19.8	----	19.8	----	19.8
Western Tanager	----	----	----	----	----	----	----	----	----	----	9.9	9.9
Hepatic Tanager	----	19.8	----	----	----	----	----	----	----	----	----	----
Summer Tanager	----	----	----	----	19.8	19.8	9.9	9.9	----	19.8	----	----
Black-headed Grosbeak	59.3	39.5	64.3	39.6	19.8	39.5	39.6	39.6	39.5	19.8	29.7	39.6
Lesser Goldfinch	----	----	----	----	----	----	----	----	----	19.8	----	----
Rufous-headed Towhee	----	----	----	----	----	----	----	----	19.8	19.8	----	----
Total Density	326.0	365.6	297.0	178.2	158.4	296.7	297.0	222.7	178.1	445.0	178.2	257.4
Species Richness	9	12	12	8	8	12	16	13	7	17	10	12
Weight/Individual	40.0	31.7	52.7	54.2	46.8	23.4	39.4	41.6	27.7	32.3	53.3	52.3
SCB	26078.4	23178.5	31315.7	19316.9	14830.2	13858.6	23397.6	18509.0	9854.2	28710.0	19013.8	26918.0
EE	11697.7	11438.6	12302.4	7698.6	6088.0	7785.7	10166.4	8079.5	4984.0	13783.8	7134.0	10203.0

Table 2.--Species recorded on or immediately adjacent to the study area. [Note; Bird scientific names according to A.O.U. Checklist, 1957; and 32nd A.O.U. Supplement, Auk 90(2): 411-419.]

Red-tailed Hawk	Buteo jamaicensis
Turkey Vulture	Cathartes fasciata
Band-tailed Pigeon	Columba fasciata
Mourning Dove	Zenaidura macroura
Great Horned Owl	Bubo virginianus
Flammulated Owl	Otus flammeolus
White-throated Swift	Aeronautes saxatalis
Broad-tailed Hummingbird	Selasphorus playcercus
Belted Kingfisher	Megaceryle alcyon
Red-shafted Flicker	Colaptes cafer
Hairy Woodpecker	Dendrocopos villosus
Yellow-bellied Sapsucker	Sphyrapicus varius
Western Kingbird	Tyrannus verticalis
Cassin's Kingbird	Tyrannus vociferans
Black Phoebe	Sayornis nigricans
Western Flycatcher	Empidonax difficilis
Western Wood Pewee	Contopus sordidulus
Violet-green Swallow	Tachycineta thalassina
Steller's Jay	Cyanocitta stelleri
Common Raven	Corvus corax
Mountain Chickadee	Parus gambeli
Dipper	Cinclus mexicanus
White-breasted Nuthatch	Sitta carolinensis
Pygmy Nuthatch	Sitta pygmaea
Brown Creeper	Certhia familiaris
House Wren	Troglodytes aedon
Canyon Wren	Catherpes mexicanus
Mockingbird	Mimus polyglottos
Robin	Turdus migratorius
Hermit Thrush	Catharus guttata
Townsend's Solitaire	Myadestes townsendi
Ruby-crowned Kinglet	Regulus calendula
Solitary Vireo	Vireo solitarius
Warbling Vireo	Vireo gilvus
Virginia's Warbler	Vermivora virginiae
Yellow Warbler	Dendroica petechia
Audubon's Warbler	Dendroica auduboni
Grace's Warbler	Dendroica graciae
MacGillivray's Warbler	Oporonis tolmiei
American Redstart	Setophaga ruticilla
Painted Redstart	Setophaga picta
Red-faced Warbler	Cardellina rubrifrons
Wilson's Warbler	Wilsonia pusilla
Hooded Oriole	Icterus cucullatus
Bullock's Oriole	Icterus galbula
Brown-headed Cowbird	Moluthrus ater
Western Tanager	Piranga ludoviciana
Hepatic Tanager	Piranga flava
Summer Tanager	Piranga rubra
Rose-breasted Grosbeak	Pheucticus ludovicianus
Black-headed Grosbeak	Hesperiphona vespertina
Indigo Bunting	Passerina cyanea
Pine Siskin	Spinus pinus
American Goldfinch	Spinus tristis
Lesser Goldfinch	Spinus psaltria
Rufous-sided Towhee	Pipilo erythrophthalmus
Gray-headed Junco	Junco caniceps

were seen on or immediately adjacent to the study areas. Of these, 23 species nested on one or both of the study areas at least once during the three years of censusing. The density and species' richness (Whittaker 1970) are summarized in Table 3. The changes in these values and other resultant calculations prior to and after the opening of the campground are discussed below as indicators of human impact upon the breeding bird community.

Avian Density and Species Richness

Every species is apparently adjusted to breed at the time of year at which it can raise its young most efficiently (Immelmann 1971). For most northern temperate birds this nesting period extends from late spring to mid-summer (Lack 1950). This is certainly true for the Cave Springs area of Oak Creek Canyon, where breeding begins about mid-April and lasts through July. The campground opening date falls within this period.

1973.--In 1973 a total of 17 species nested on one or both of the study areas (Table 3). A 40 percent decrease in density occurred on the campground after the opening day. Part of the losses incurred were through direct human manipulation of the nest site. Forest Service employees, by removing trees and slash, destroyed 20 percent of the Steller's Jay nests. Campers destroyed 30 percent more of the Steller's Jay nests and 20 percent of the Robin nests by removing branches for firewood, making room for tents, and other reasons.

The parulid warblers, Solitary Vireos, Broad-tailed Hummingbirds, and Hairy Woodpeckers abandoned their nests but occasionally foraged within the area. No losses can be attributed to adults leaving with fledged young prior to the opening date. Of those actually nesting on 20 May 1973, breeding had not proceeded beyond the incubation stage.

The density on the control site increased 12.1 percent after the opening date. This was not due to individuals emigrating from the campground but rather to the arrival of mid-summer breeders, namely, the Red-faced Warbler, Western Wood Pewee, and Hepatic Tanager (Bent 1968).

After the opening of the campground, species richness went from 12 to 8 on the campground and increased from 9 to 12 on control.

1974.--In 1974 a total of 17 species nested on one or both of the study areas (Table 3). However, these were not the same 17 of 1973. There was a change of three species, with Black Phoebes, Western Flycatchers and Hepatic Tanagers being replaced by Pygmy Nuthatches, Warbling Vireos and Summer Tanagers. This area in Oak Creek is an ecotonal situation between confierous forest and a deciduous riparian habitat. The Summer Tanager prefers cottonwoods along streams for nest sites and apparently found conditions suitable in 1974. On the other hand, the Hepatic Tanager prefers pines and oaks and found Cave Springs acceptable in 1973. It is probably subtle environmental differences (i.e., temperature, rainfall, etc.) that determine which tanager will be present in what might be considered marginal habitat for either.

A 25 percent decrease in densities occurred on the campground, whereas there was a dramatic 87.3 percent increase on control. The campground was opened 12 days earlier than in 1973 and may account for the initially low density on control. It was simply too early for many species to be breeding. Yet initial densities on the campground matched 1973 figures. No satisfactory explanation has been found.

Species richness dropped from 16 to 13 on the campground and climbed from 8 to 12 on control.

1975.--During 1975 a total of 21 species nested on one or both of the study areas (Table 3). New breeders included Mourning Doves, Cassin's Kingbirds, Virginia's Warblers, Western Tanagers, Lesser Goldfinches, and Rufous-sided Towhees. In previous years all of these had either appeared as transients or nested within the canyon but off the study areas.

In 1975 for the first time there was in increase in density (44.4 percent) on campground. In 1973 and 1974 breeding activity was well underway on the campground prior to the opening date. In 1975, however, colder temperatures, higher winds, and increased precipitation postponed breeding. In many species a positive correlation between temperature and the rate of testicular development or egg production has been found (Farner and Wilson 1957). In 1975 the average temperature two weeks prior to opening was 57.7°F and for the same period in 1973 and 1974 was 63.7°F and 62.5°F, respectively. Perusal of the 1975 censuses indicates almost no breeding activity (i.e., singing, displaying, nest building) before 16 May.

It is interesting to note that once breeding did commence, the maximum density reached was still less than the maximum measured in 1973 and 1974.

On control there was in increase of 149.8 percent. This phenomenal climb is also no doubt related to the later breeding period. Before the opening day, weather conditions were too severe for breeding to commence. In addition, several species that would normally nest elsewhere (e.g., Rufous-sided Towhees usually nest in the chaparral found on the canyon walls and Lesser Goldfinches usually nest above the rim) were found on the control. Perhaps environmental conditions were relatively less severe within the canyon than elsewhere and these species chose to accept marginal habitat under these limitations.

Species richness went from 10 to 12 on the campground and 7 to 17 on control.

Yearly fluctuations of density on each area are difficult to explain because of so many determining factors. Not only local weather but events on the wintering grounds can play an important role in predicting a particular year's breeding population. Attempts to explain avian population fluctuations have so far led to only ambiguous conclusions (Von Haartman 1971). It is pertinent to note, though, that over the three-year period there was nearly twice the range of densities on control as the campground.

Avian Diversity and Habitat Diversity

MacArthur (1964) found a correlation between BSD and FHD in "tall forests of sycamores and cottonwoods" in southeastern Arizona. The relationship in this study between BSD and FHD was almost identical to what he and others found in earlier studies in eastern deciduous forests (MacArthur and MacArthur 1961, MacArthur et al. 1962). Austin (1970), working in "desert riparian" habitats in Nevada, plotted his data against MacArthur's (1964) regression line for BSD vs. FHD and found similar results. Carothers et al. (1974) found that in "desert riparian" habitats immediately adjacent to areas of relatively higher productivity but low avian densities, the BSD and FHD correlation no longer held. Yet, Carothers found that in "desert riparian" habitats immediately adjacent to areas of relatively the same productivity and having a compliment avian community, the BSD and FHD relationships did come close to MacArthur's regression line.

The BSD's and FHD's obtained in Oak Creek are summarized in Table 4 and graphed in Figure 1. Although the points do cluster around MacArthur's line, there is enough deviation to suggest other forces at work besides foliage height diversity.

As in Carother's study plots, this is a riparian system and MacArthur's line fails to take into account the added dimension of permanent water. Also, human disturbance is not considered. An additional downfall of FHD is that there has been no stipulation by past investigators when to measure FHD. As we see here, BSD and FHD vary through time (or sampling error). BSD was measured from the first signs of breeding to the opening date and then from that date to the end of breeding activity. On the other hand, FHD was measured once before and once after. It is possible that a day could be found during the vegetative growing season when the FHD would be such that BSD for the entire period matched MacArthur's line. This leads me to question the value of FHD as a predictor of BSD except in those specific cases studied by MacArthur and the need for

Table 4.--Bird species diversity and habitat diversity.

	CAMPGROUND				CONTROL			
	Bird Species Diversity (BSD)		Foliage Height Diversity (FHD)		Bird Species Diversity (BSD)		Foliage Height Diversity (FHD)	
	Before	After	Before	After	Before	After	Before	After
1973	2.19	1.95	.98	1.00	2.08	2.34	1.04	1.08
1974	2.62	2.42	.96	.98	2.08	2.43	1.06	1.05
1975	2.19	2.34	.97	1.01	1.83	2.71	.99	.97

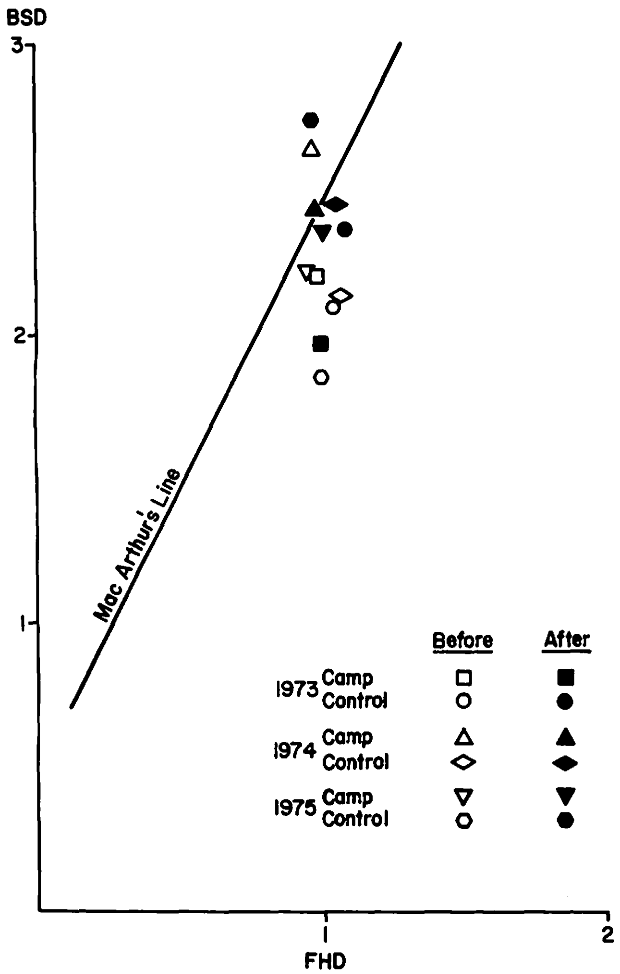

Figure 1.--Bird species diversity (SD) as a function of foliage height diversity (FHD) before and after occupation of the campground by campers. Regression line from MacArthur et al. 1966.

Table 5.--Individual bird weights[1] and individual existence energy.

Species	Weight in Grams	Existence Energy
Mourning Dove	137.5	31.79
Broad-tailed Hummingbird	4.0	2.94
Red-shafted Flicker	125.3	29.90
Hairy Woodpecker	69.8	20.15
Yellow-bellied Sapsucker	45.0	15.00
Cassin's Kingbird	45.4	21.47
Black Phoebe	18.6	12.71
Western Flycatcher	12.5	10.06
Western Wood Pewee	14.0	10.75
Steller's Jay	105.0	35.14
White-breasted Nuthatch	20.4	13.42
Pygmy Nuthatch	10.0	8.82
House Wren	10.5	9.08
Robin	88.0	31.67
Solitary Vireo	13.5	10.53
Warbling Vireo	11.3	9.48
Virginia's Warbler	8.4	7.97
Grace's Warbler	7.5	7.45
Painted Redstart	9.7	8.67
Red-faced Warbler	9.7	8.67
Bullock's Oriole	35.7	18.64
Western Tanager	28.0	16.16
Hepatic Tanager	40.0	19.93
Summer Tanager	35.5	18.58
Black-headed Grosbeak	46.0	21.63
Lesser Goldfinch	8.7	8.13
Rufous-sided Towhee	38.9	19.60

1 From Carothers et al. 1973, Marshall 1972, and collections of the Museum of Northern Arizona.

specific time limitations when these parameters are to be measured.

Examining BSD, we see that in 1973 and 1974 there was a decrease in diversity on the campground after it was opened. An increase occurred on control. In 1975, contol's diversity again increased but so did the campground's. The reason for this is, once again, the late breeding season in 1975 (see previous section).

Bioenergetics

In order to better understand the energetics and organization of these avian communities, it is important to look at standing crop biomess (SCB) and existence energy (EE) of the birds (Salt 1957, Karr 1968). The former is the total weight (in grams) of the entire avian community. In order to consider community metabolism, a conversion is made that reflects the difference in metabolism due to differences in body weight. This is expressed as existence energy (or Kcal) consumed by the total avian community (see Carothers et al. 1974 for limitations of this measure).

1973.--The SCB of control decreased slightly after 29 May, although density increased. This is possible because the average weight per individual bird decreased from 40.0 g to 31.7 g. Table 3 shows that several small-bodied birds, Western Wood Pewees and Red-faced Warblers, did move onto the area; see Table 5 for weights. Two larger species, Steller's Jays and Black-headed Grosbeaks, moved off the area.

The campground had a drastic SCB decrease; however, the average weight per individual remained essentially constant (52.7 g to 54.2 g). The decrease can therefore only be attributed to a general loss of birds of all sizes.

The initial and final differences between the average weight per individual values on the control and campground show that relative to each other light-weight birds inhabited the control and heavier birds inhabited the campground.

The existence energy values were initially the same but after the opening the campground EE showed a decrease of 37.3 percent.

We see then that before the intrusion of campers the two areas differed in the average weight per individual by 12.7 g but the EE was the same. Following campground occupation, the average weight per bird became more dissimilar (22.5 g), and the total community EE was nearly halved on the campground.

1974.--The SCB of control, once again, decreased slightly after the opening, although density increased. Again, this was due to a decrease in the average weight per individual bird (46.8 g to 23.4 g) caused by an influx of smaller-bodied species (Table 3 and 4).

The campground SCB decreased greatly, as in 1973, and the average weight per individual remained fairly constant.

In 1974, larger-bodied birds occupied the control initially, but this changed sharply after the opening of the campground.

EE values on control changed upwardly 27.8 percent, whereas the campground's was decreased by 22.3 percent.

Once again, the opening appears to be detrimental to the birds in the campground.

1975.--The overall trends remained the same in 1975. Smaller-bodied birds made up a majority of the population on control. The increase in SCB and EE on the campground, of course, was related to the density increase that year.

SUMMARY AND MANAGEMENT ALTERNATIVES

After three breeding seasons, several phenomena were discerned: 1) although bird densities on the campground and control are similar before the campground opening date, the average weights of an individual bird is greater on the campground($\overline{x}$ = 48.5 g) than on control ($\overline{x}$ = 38.2 g) and 2), population density and species diversity (H') decrease when the campground is occupied by people.

In other words, the presence of the campground produced a significant shift in the avian community to heavier bodied birds relative to the natural control area. This is probably a response to the "opening" of the habitat during campground construction. Inhabitation of the campground by people causes a direct reduction in the numbers and kinds of breeding birds.

Those in managerial posistions might consider the following suggestions:

1. Locations for new campgrounds should be carefully scrutinized in terms of usage by wildlife. In this specific case, riparian habitats are very important to birds and of such a limited extent in the Southwest that further destruction of habitat needs to be discouraged.

2. Existing campgrounds should be periodically closed to allow regeneration of vegetation and reduce stress on resident wildlife. This is being done in Oak Creek Canyon, but much too often the reason behind the closure is financial rather than ecological.

3. Opening the campground before or after the height of the breeding season may be better for the avifauna. If people are already present when birds arrive to nest, the birds may be able to find suitable habitat elsewhere instead of "wasting energy" by attempting to breed and then being disrupted during incubation. Of course, not opening the campground until after breeding season would be ideal for the birds but probably very impractical for the campers.

4. Habitat manipulation should be carefully controlled. This includes breaking off branches

for firewood, trenching for tents, running of noisy equipment, and even clearing of snags, slash, and brush by USFS crews.

5. Educational programs may be the only effectual solution of human recreation and wildlife problems. Government agencies have had very good results in some public educational canpaigns (e.g., Smokey the Bear). There is no reason the general public could not be exposed to broad ecological concepts such as camping with less impact.

Finally, it is hoped that studies of this type and education of the public will lead to a happy medium between preserving native wildlife and also allowing human enjoyment of an area.

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Population Fluctuations in Nocturnal Rodents in the Lower Colorado River Valley[1]

Bertin W. Anderson, Jeff Drake, and Robert D. Ohmart[2/]

Abstract.--An examination of population fluctuations in a sample of over 10,000 rodents comprising five species collected along the lower Colorado River revealed distinct seasonal (annual) cycles in Perognathus penicillatus and Dipodomys merriami. Overall rodent populations were decreasing for the 3.5 year period for which data are presented. This was most pronounced in Peromyscus eremicus. Although these populations were declining, there was significant intraspecific asynchrony among the populations in different vegetation types. There was also a significant degree of interspecific asynchrony in population fluctuations which renders the task of evaluating habitat difficult and subject to error unless carried out for several years in various vegetation types.

INTRODUCTION

Populations are said to be cyclic when they alternately irrupt and subside in a more or less uniform manner between high and low levels of density. These population fluctuations sometimes follow a general pattern with respect to time (annual, seasonal, monthly). Cyclic events broken into finer detail follow four fundamental phases: increase, peak, decline, and low density. Several studies have investigated cyclic events exhibited by microtine rodents, which experience cycles of three-to-four and nine-to-ten year intervals as well as annual fluctuations (Dymond 1947, Elton 1942, Keith 1963, Pearson 1966, Speirs 1939, Wing 1961), while McClosky (1972) has studied temporal changes in densities and diversities over short periods of time.

Designating fluctuations as cyclic implies considerable regularity. However, the cause of cyclic populations can usually be expected to contain random components inextricably mixed with any systematic ones. If the random components outweigh the systematic ones or if different substrates respond differently to the systematic components, the occurrence of noncyclic or asynchronous populations becomes predominant.

The causal mechanism of cycles include biotic as well as abiotic factors. Biotic factors affecting animal cycles are those inherent in the populations themselves and in the interrelations of different species. These include disease, predation, food, and physiological mechanisms. Abiotic factors are the physico-chemical element of the environment such as organic compounds, moisture, winds, solar radiation and others.

The purpose of this report is to examine the annual population cycles of nocturnal rodents in the lower Colorado River Valley. Coupled with this examination are observations dealing with general population trends over the course of the study, as well as an evaluation of fluctuations occurring in various community types. The study was initiated in September 1973 and is on-going; data will be presented through March 1977.

1/ Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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CLIMATE AND VEGETATION

Climate

The study area includes a major part of the riparian vegetation located along the Colorado River from the Mexican boundary north to the Nevada border at Davis Dam. Climatic data were supplied by the U.S. Bureau of Reclamation and the Palo Verde Irrigation District. Rainfall is highly irregular, with annual amounts rarely exceeding 26 cm (Table 1). Drought conditions prevail throughout most of the year. Over the 3.5 years of this study, the highest monthly rainfall was recorded in September 1976 (6.45 cm). The highest annual rainfall (12.97 cm) was also recorded in 1976. Although the area receives little rain, the water table is high and established vegetation with roots at least 3 m deep rarely shows ill effects. Annuals, a staple food source for rodents, are very dependent upon rainfall.

Temperatures in the desert are highly variable and show a wide range between daily and annual extremes (Table 2). The highest official temperature was 50.0°C in July 1973; the lowest was -5°C in January 1973, although we recorded a temperature of -14°C near

Table 1.--Rainfall on the lower Colorado River.

Month	Precipitation (cm)						
	1972	1973	1974	1975	1976	1977	Twenty-year average
Jan.	0.00	0.12	1.60	0.13	0.00	0.48	0.76
Feb.	0.00	3.07	0.00	0.08	3.66	0.02	0.81
Mar.	0.00	1.85	0.94	0.69	0.05	0.13	0.71
Apr.	0.00	0.00	1.50	1.75	0.00	0.00	0.33
May	0.00	0.12	0.00	0.00	0.00		0.03
June	1.75	0.00	0.00	0.00	0.00		0.08
July	0.00	0.00	2.06	0.00	0.00		0.51
Aug.	2.18	5.84	1.78	0.00	0.00		1.68
Sept.	0.00	0.00	0.00	2.44	6.45		0.84
Oct.	6.63	0.00	0.61	0.05	0.25		1.17
Nov.	1.55	0.28	0.00	0.00	0.38		0.66
Dec.	0.10	0.00	1.24	0.00	0.43		1.17
Total	12.2	11.3	8.23	4.89	12.97		8.75

Table 2.--Temperatures for the lower Colorado River.

Month	Mean High and Low Temperatures (°C)											
	1973		1974		1975		1976		1977		Twenty-year average	
Jan.	18.0	3.0	18.2	4.8	20.8	2.3	21.4	3.0	19.8	3.6	20.1	3.7
Feb.	20.9	7.6	22.3	5.1	21.6	3.9	21.8	3.3	25.4	4.7	22.8	6.5
Mar.	21.7	8.4	26.4	9.9	23.7	7.8	24.5	8.5	23.6	6.2	25.9	9.0
Apr.	29.1	11.4	30.0	12.2	25.1	9.7	27.5	11.2	31.9	11.3	29.8	12.3
May	37.2	17.5	35.1	17.8	33.8	14.9	35.4	18.0			34.8	16.9
June	41.3	22.9	43.2	23.3	39.6	20.6	40.2	20.9			39.8	21.5
July	42.7	25.6	41.2	26.2	42.2	26.3	40.5	25.7			42.3	26.0
Aug.	41.2	24.3	41.5	23.9	42.2	24.6	40.6	23.0			41.4	25.5
Sept.	38.3	19.3	38.8	23.3	38.3	22.8	34.6	21.4			38.4	25.5
Oct.	32.8	13.2	32.1	15.8	31.1	14.0	31.0	14.7			31.8	14.6
Nov.	23.9	7.8	24.7	8.5	25.8	8.7	26.2	8.0			24.5	8.1
Dec.	21.3	4.2	18.2	3.3	20.9	5.1	19.7	2.6			19.9	4.0

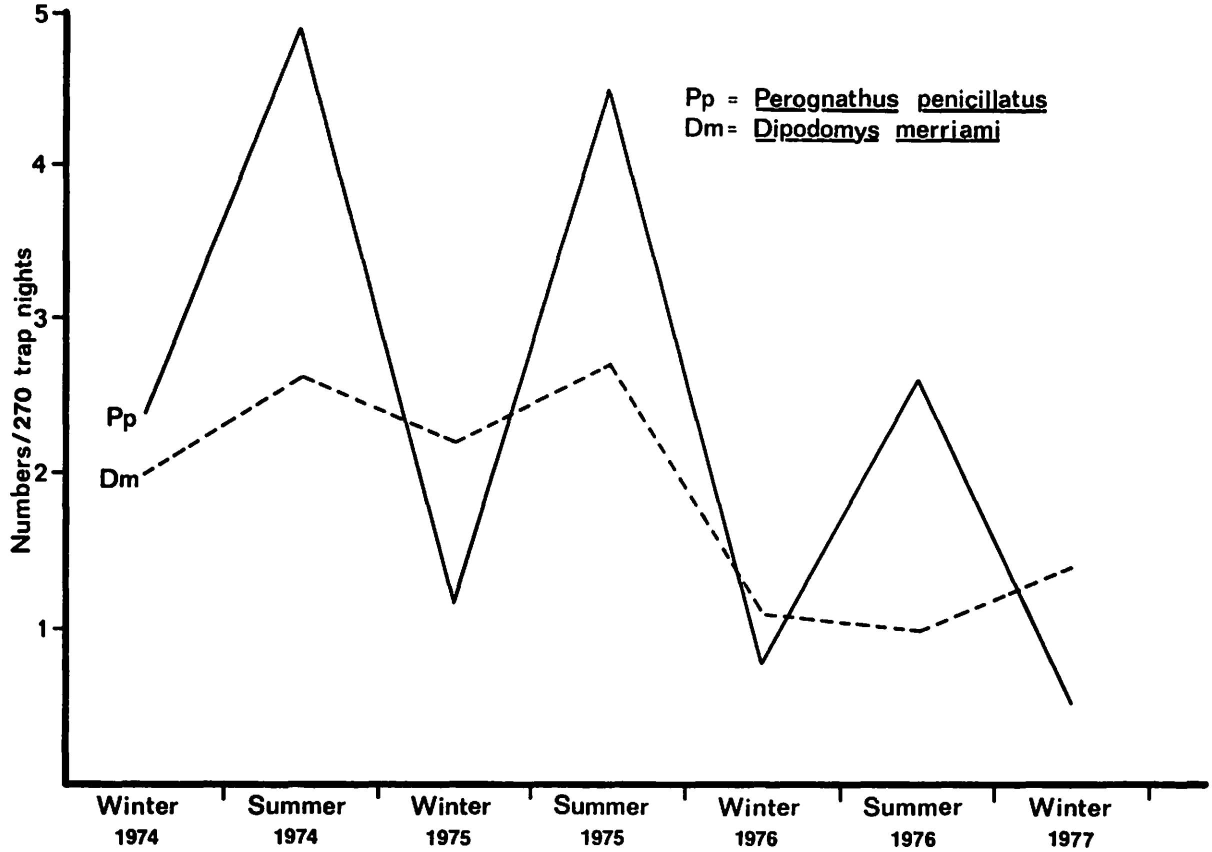


Figure 1.--Densities (N/270tn) of Perognathus penicillatus and Dipodomys merriami along the lower Colorado River Valley.

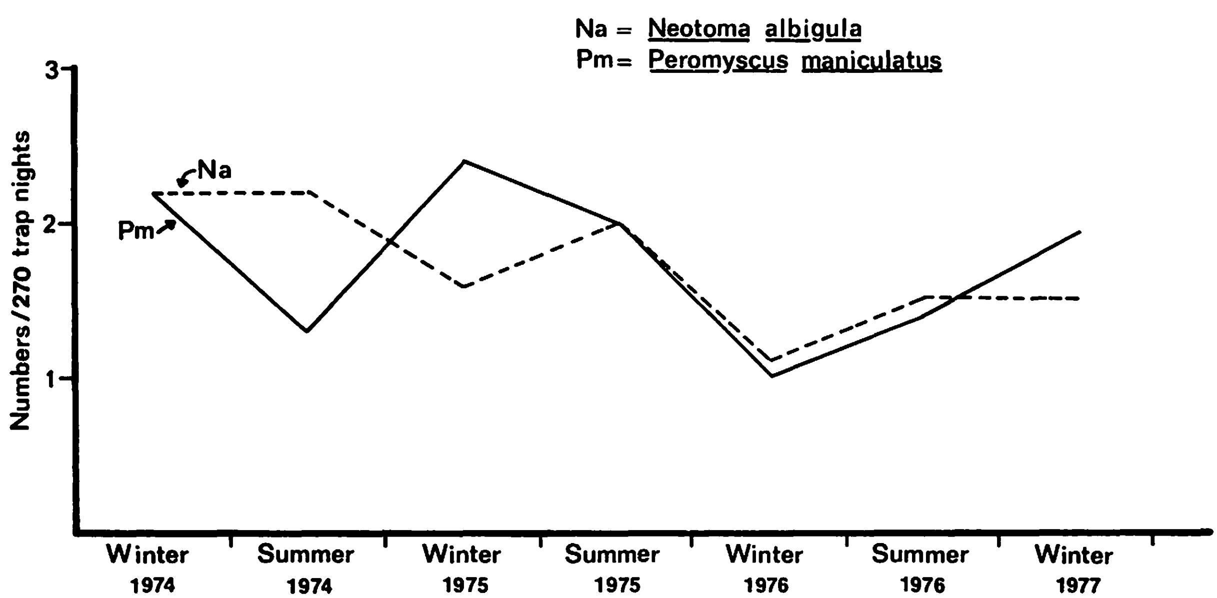


Figure 2.--Densities (N/270tn) of Peromyscus maniculatus and Neotoma albigula along the lower Colorado River Valley.

Needles, California in January 1975.

Vegetation

In this study we recognized six basic community types in the riparian vegetation. Data from four of these (cottonwood-willow, Populus fremontii-Salix gooddingii; salt cedar, Tamarix chinensis; honey mesquite, Prosopis juliflora; and screwbean mesquite, P. pubescens) are presented in this report. The criteria used in defining these communities are included elsewhere in these proceedings (Anderson, Engel-Wilson, Wells, and Ohmart) and will not be repeated here.

METHODS AND MATERIALS

Within the study area approximately 100 transects (the actual number varied from year to year) were established throughout the various community types. Rodent populations were sampled in transected areas with a snap trap grid consisting of two parallel lines 15 m apart. Each line included 15 stations that were each 15 m apart. At each station two museum special traps and one Victor rat trap were set and baited with rolled oats and peanut butter treated with a chemical to repel insects (Anderson and Ohmart, 1977). Trap lines were run for three consecutive nights. Catches are expressed as numbers per 270 trap nights. (For further details see Anderson, Engel-Wilson, Wells and Ohmart, these proceedings.)

All community types were sampled on an approximately equal basis throughout the study. Trap nights for the 3.5 year period totaled 150,930. The number of grids per season ranged from 44 (11 per community type) to 116 (29 per community type). For this study we recognized two seasons: summer, April through October, and winter, November through March.

The species which were most frequently caught and which were analyzed for this report were the cactus mouse (Peromyscus eremicus), deer mouse (P. maniculatus), desert pocket mouse (Perognathus penicillatus), white-throated woodrat (Neotoma albigula), and Merriam's kangaroo rat (Dipodomys merriami). During the study we caught 6,178 Peromyscus eremicus, 829 P. maniculatus, 881 Neotoma albigula, 1,736 Perognathus penicillatus, and 1,317 D. merriami. Other species such as the grasshopper mouse (Onychomys torridus), desert kangaroo rat (Dipodomys deserti) and several others were caught regularly but numbers were too small for analysis.

ANNUAL CYCLES AND POPULATION TRENDS

The presence of annual population cycles for the five numerically dominant rodent species was investigated by capture data, within each season, and from the four sampled community types. In the combined analysis we are considering seasonal population fluctuations within the total riparian habitat. The presence of an annual cycle should be evident if there are regular and predictable population fluctuations between seasons. Analysis of annual cycles should reveal general population trends, but obscure intercommunity trends. Therefore, overall trends are analyzed at the community level as well as the species level.

Perognathus penicillatus and Dipodomys merriami exhibited regular annual cycles (fig. 1). Peak population levels were reached in summer and low levels in the winter. The pattern was more developed in P. penicillatus than in D. merriami or Neotoma albigula. N. albigula maintained a nearly constant population level from winter 1974 to summer 1974 at which time the population began to fluctuate in a manner similar to that shown by P. penicillatus and D. merriami. The seasonal fluctuations shown by N. albigula and Peromyscus maniculatus (fig. 2) are not readily interpreted. P. maniculatus showed high populations in winter and low populations for summer 1974 through summer 1975, but in winter 1976 the population declined precipitously.

Peromyscus eremicus demonstrated a complete lack of any annual cycle (fig. 3). The pattern was almost a linear progression of declining population for nearly the entire study period with only a slight increase in winter 1977. This overall population decline was found with some degree of consistency in each species examined. In all cases 1976 winter populations were lower than 1974 winter populations, but most 1977 winter populations showed a slight increase. In Perognathus penicillatus and Neotoma albigula the summer populations also showed a gradual decline. Summer populations of Peromyscus maniculatus increased substantially from 1974 to 1975 whereas summer populations of Dipodomys merriami increased only slightly.

The general decline in rodent numbers appears to be related to precipitation. With the exception of September 1975, dry conditions prevailed from September 1973 through January 1976 (Table 1), but in 1972 and in spring 1973 wet conditions existed long enough for seed-producing annuals to flower abundantly (pers. obs., R. D. Ohmart). Seed production continued for a while after a return to dry conditions and species that cache seeds can probably survive on these stores for some time. There

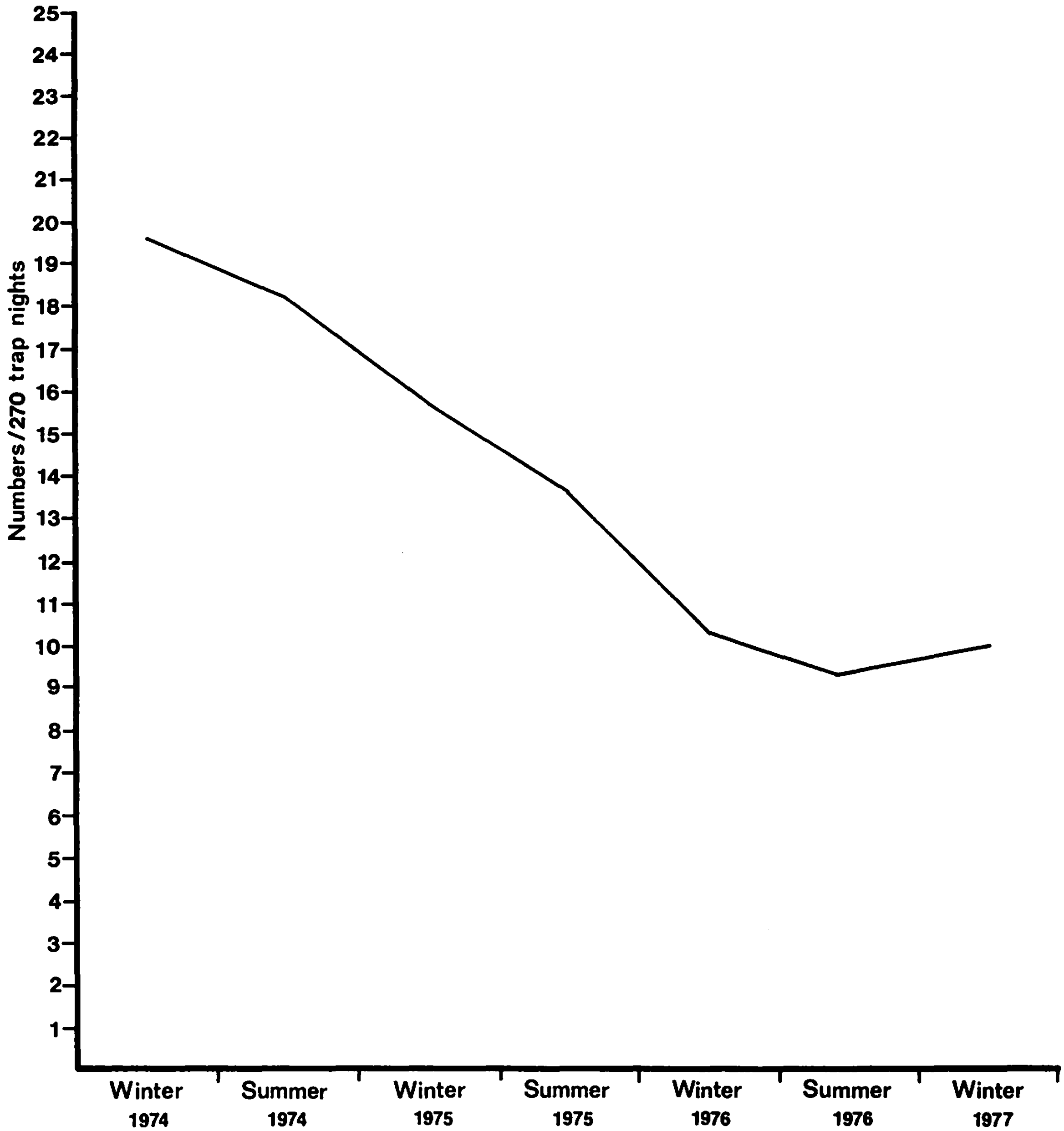


Figure 3.--Seasonal densities (N/270tn) of Peromyscus eremicus along the lower Colorado River Valley.

is a lag in the effect of changing conditions on the population densities. One might have expected populations to have peaked in 1974, following the second breeding season after the favorable wet conditions of 1973. This is seen to be the case in three of the five species (figs. 1-3). Subsequent dry conditions resulted in almost no flowering of annuals in 1974 and 1975. One might have expected populations to be lower in 1975 and 1976, following the second breeding season after the onset of poor conditions. There was some flowering in spring 1976 and rather profuse flowering in winter and spring 1977. These favorable conditions would be expected to lead to an increase in rodent populations beginning with the onset of reproduction. However, another factor must be considered. The precipitation in September 1976 probably was responsible for an initial decrease in rodent populations, because the relatively heavy rains caused extensive flooding in much of the prime rodent habitat in honey mesquite. Standing water, a few cm to a meter deep, remained in many places from a few days to two weeks or more and many additional days were required for the mud to dry.

During the rains there was running water which, in many areas, carried away most of the screwbean and honey mesquite pod crop. Trapping in these areas yielded few rodents through May 1977.

Low temperatures may also have negative effects on rodent populations. The spring of 1975 was unusually cool with locally occurring freezing temperatures in March, April, and early May. These frosts may have been responsible for an almost total lack of mesquite pod production the following fall.

In summary, decreasing rodent populations from 1974 through early 1977 were probably the result of (1) dry conditions in which annual plants were unable to reproduce, (2) freezing spring temperatures in 1975 which may have affected mesquite seed productivity and (3) flooding of prime habitat in September and October 1976.

RODENT POPULATION TRENDS IN DIFFERENT PLANT COMMUNITIES

One of our purposes was to study the extent of synchrony in fluctuations between species both within and between community types. To do this we studied population trends of the five most abundant rodents in each community separately. Considerable asynchrony in population fluctuations between species at a locality would introduce additional difficulties in evaluating the rodent diversities and densities of different habitat types. If these interspecific fluctuations in population size also were asynchronous between localities, evaluation of habitats would be further complicated. In this section we explore these points and offer suggestions for the collection of useful data.

Intraspecific Fluctuations between Community Types

Fluctuations in populations of Perognathus penicillatus in the four community types studied were highly synchronous (fig. 4). Dipodomys merriami populations were synchronous in screwbean (SM) and honey mesquite (HM) and in salt cedar (SC) and cottonwood-willow (CW), but these two sets were asynchronous with respect to each other (fig. 5). Peromyscus maniculatus showed moderately asynchronous fluctuations (fig. 6); populations were increasing in cottonwood-willow at a time when they remained about the same or increased slightly in other community types. Neotoma albigula population fluctuations tended to be quite asynchronous (fig. 7). Peak populations were reached at a different time in all community types.

Peromyscus eremicus populations also showed a marked degree of asynchrony (fig. 8). We also noted some evidence of reproduction in October and November of 1976 (juveniles, scrotal males, females with enlarged mammae) in screwbean mesquite. This may be the first indication that the overall population will be increasing again.

Interspecific Fluctuations between Community Types

Interspecific variations in population were not of the same magnitude for all species, i.e. peaks may not be as high nor valleys as low in some species as in others. In addition highs and lows do not occur at the same time in all species. Finally, there were intercommunity differences. McClosky (1972) has shown that there were significant changes in densities and diversities in a relatively brief period of time within a locality. Our data tend to support his findings, but since we did not trap continuously in the same area over a long period of time, our data are not well-suited for analysis on a local level.

Because changes in densities of different species occur at different rates from season to season, species diversities also change from season to season (fig. 9). From summer 1974 to summer 1975 the diversity in cottonwood-willow nearly doubled, due primarily to a reduction in numbers of Peromyscus eremicus. In general, the greatest diversities were reached in the warm months when Perognathus penicillatus was present in the greatest numbers. Ranked from greatest to least diversity the communities would be ordered SM-HM-SC-CW, SM-CW-SC-HM, and SM-HM-SC-CW in the three summers, respectively. In the four winters the order would be SM-HM-SC-CW, HM-SM-SC-CW, SM-HM-CW-SC, and SM-SC-CW-HM, respectively. Had trapping only been conducted in 1974, the results would have indicated that rodent densities were greater and diversities lower than they are on the average, whereas 1976 trap results would have indicated lower populations and greater diversities than the average of all years. Obviously, for an accurate assessment of rodent population densities and diversities one should trap extensively in several community types over several years. There are, however, a number of important conclusions that could have been drawn had a concerted trapping effort been made for a relatively short time, e.g., three months in the summer and three months in the winter.

First, trapping at almost any time would reveal Peromyscus eremicus as the most abundant species and Perognathus penicillatus as having greater densities in the summer. Second,

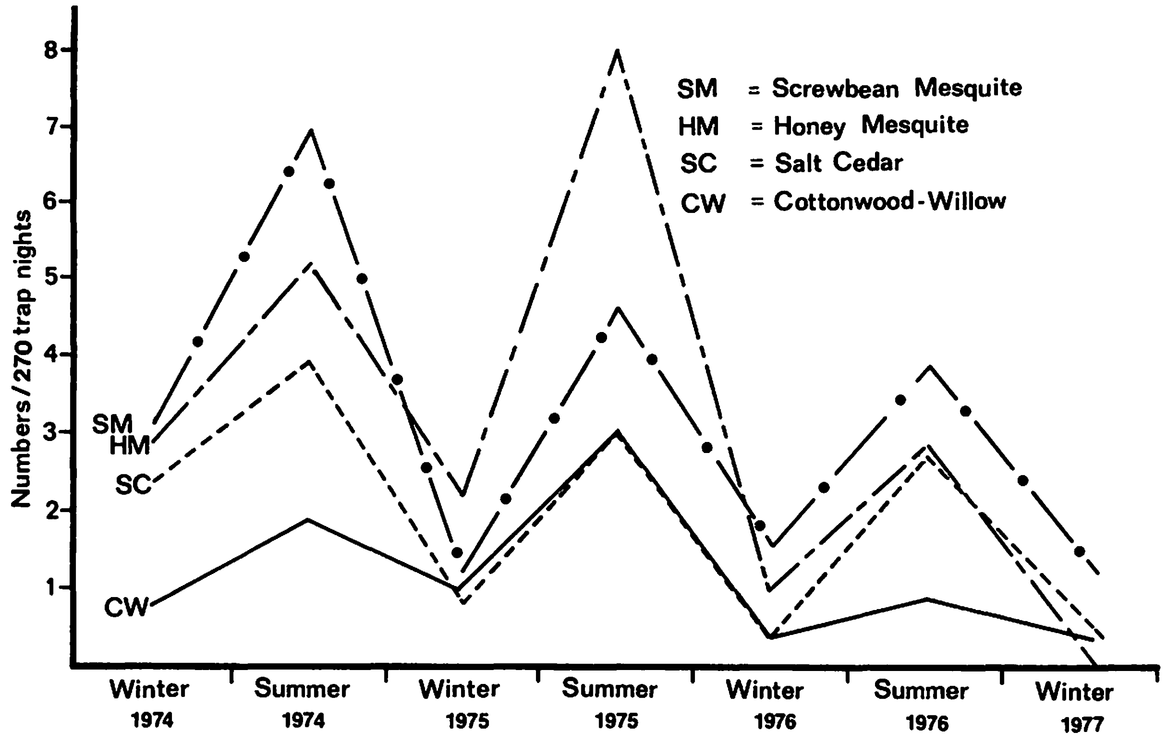


Figure 4.--Densities (N/270tn) of Perognathus penicillatus in four community types in the lower Colorado River Valley.

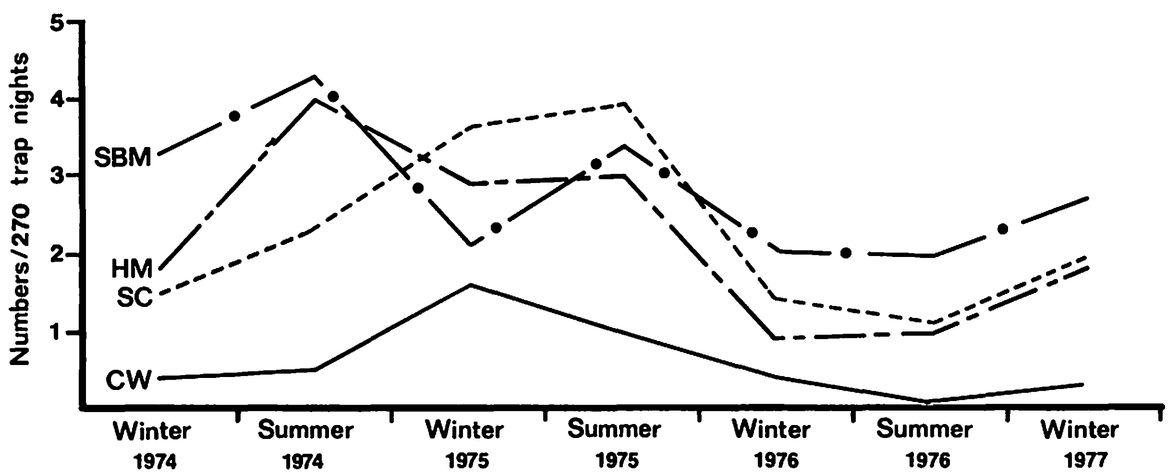


Figure 5.--Densities (N/270tn) of Dipodomys merriami in four community types in the lower Colorado River Valley.

diversities would be greatest in the summer. Caution should be exercised in determining the relative value of the various community types to rodents in terms of densities and diversities. Similarly, caution should be used in identifying community preferences of each species, but even with limited trapping Perognathus penicillatus and Neotoma albigula should be most numerous in screwbean mesquite, Dipodomys merriami and P. penicillatus should be scarcest in cottonwood-willow and Peromyscus maniculatus and P. eremicus should be scarcest in honey mesquite.

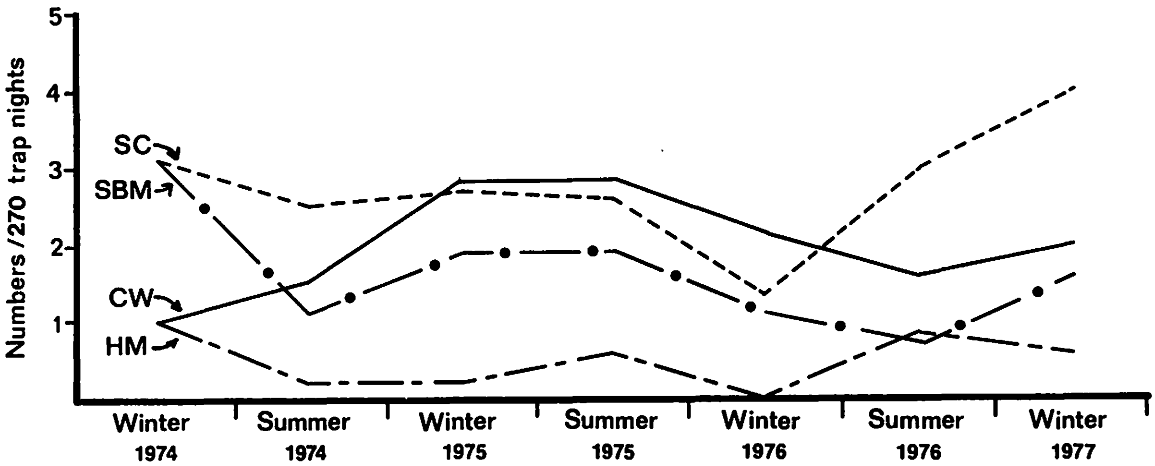


Figure 6.--Densities (N/270tn) of Peromyscus maniculatus in four community types in the lower Colorado River Valley.

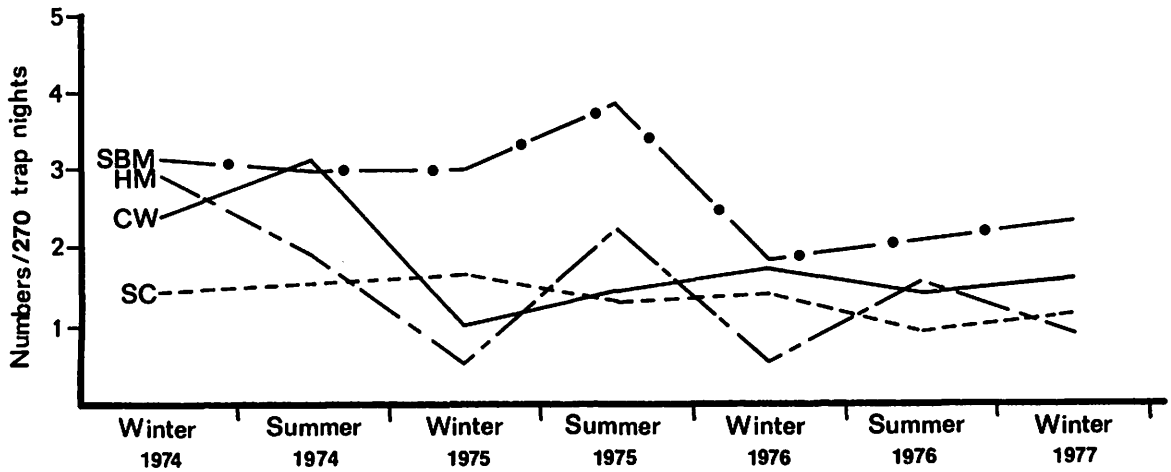


Figure 7.--Densities (N/270tn) of Neotoma albigula in four community types in the lower Colorado River Valley.

CONCLUSIONS

Perognathus penicillatus and Dipodomys merriami displayed distinct annual cycles which were synchronous with respect to each other and between the various community types. Longer term fluctuations displayed a high degree of asynchrony between community types within a given species as well as between species. The major factors which seem to have caused a steady decline in populations since 1974 are lack of rainfall up to September 1976, flooding in September 1976, and unusually cold temperatures in the spring of 1974. Because abiotic factors such as these occur in a more or less random pattern it seems possible that rodent populations in the lower Colorado River Valley do not display regular cycles although we have not trapped over a long enough period of time to draw a definite conclusion on this. The marked asynchrony in population fluctuations between community types within a given species and between species makes evaluation of habitat in terms of densities and diversities very difficult unless trapping is done over a period of two or three years in several community types.

ACKNOWLEDGMENTS

We wish to thank the many field biologists who have helped in collecting data. We are grateful to Jack Gildar for computerizing the data. The efforts of the secretarial staff in typing early drafts and of Penny Dunlop and Katherine Hildebrandt in typing the final manuscript are greatly appreciated. Linda Cheney kindly prepared the illustrations.

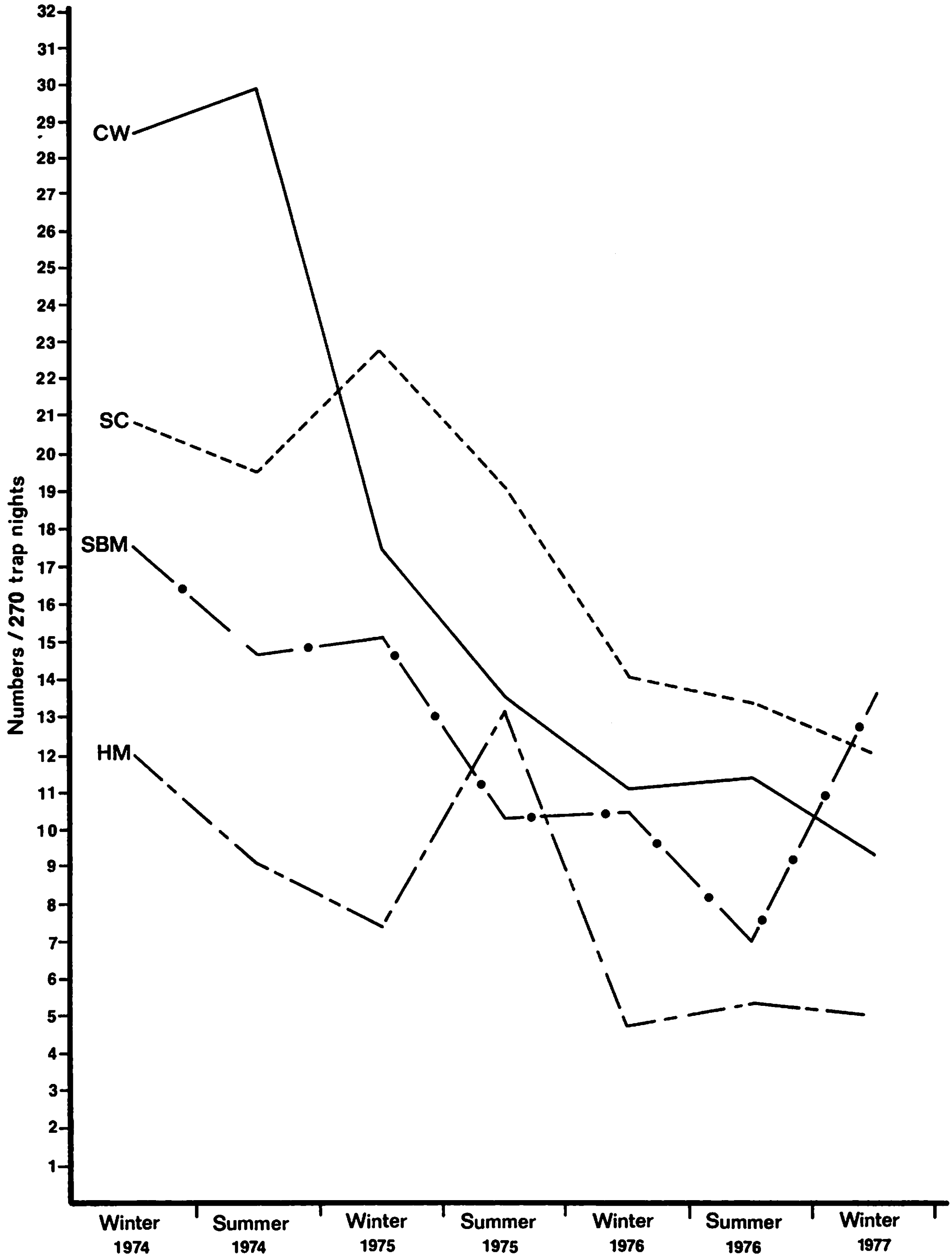
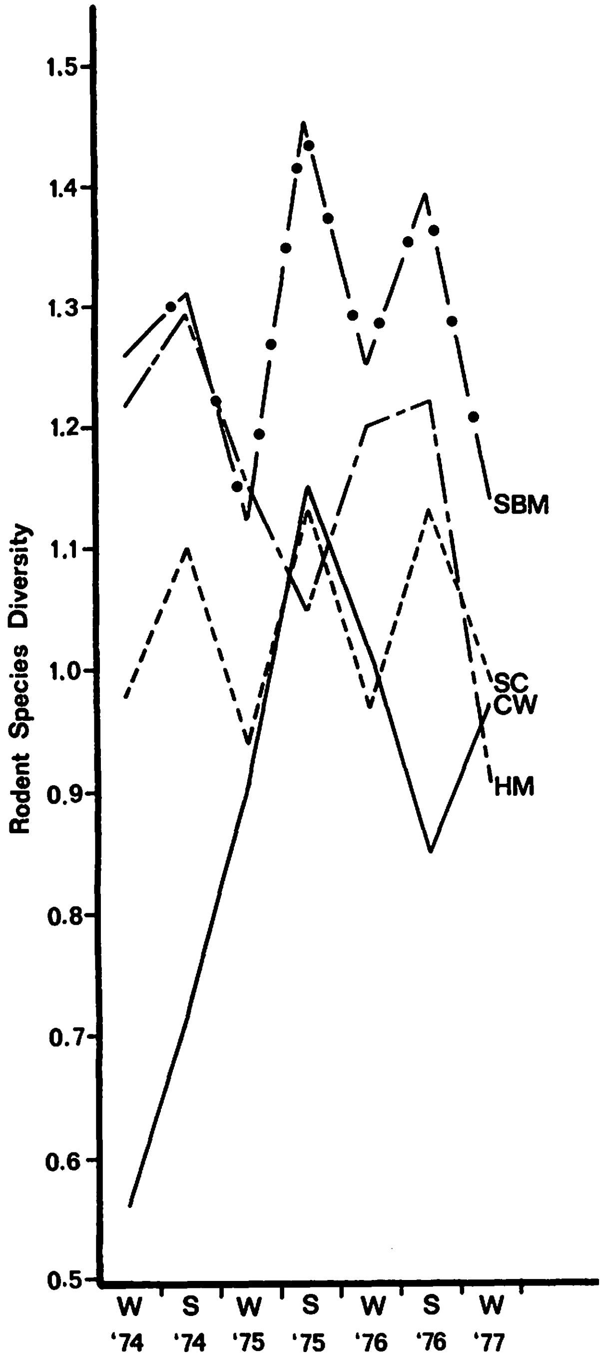


Figure 8.--Densities (N/270tn) of Peromyscus eremicus in four community types in the lower Colorado River Valley.



We thank Jane Durham, Jake Rice, James Bays and Kathleen Conine for critically reading the manuscript. The research was funded through grant number 14-06-300-2415 from the U.S. Bureau of Reclamation.

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Figure 9.--Rodent species diversities in four community types in the lower Colorado River Valley. The diversities are calculated from the average densities (N/270tn) of Peromyscus eremicus, P. maniculatus, Perognathus penicillatus, Dipodomys merriami, and Neotoma albigula caught in a given community type for a given time of year.

Climatological and Physical Characteristics Affecting Avian Population Estimates in Southwestern Riparian Communities Using Transect Counts[1]

Bertin W. Anderson and Robert D. Ohmart[2/]

Abstract.--Comparative data from about 10,000 censuses of line transects on the lower Colorado River show that strong winds (20 to 50 kmph) may reduce censusing accuracy but winds below 20 kmph appear not to strongly influence avian estimates. In winter, optimum censusing time is from 1 hour after sunrise to 2.5 hours after sunrise, whereas in summer the optimum period is 0.25 hours before sunrise to 1 hour after sunup. Consecutive censuses from the same area by highly experienced observers (>5 years of birding) are more consistent than less experienced personnel (10 to 16 months of birding).

Each transect should be censused at least twice monthly for minimum best density estimates and three times for maximum best density estimates and three times for minimum best avian species diversity estimates. Four censuses reveal a greater number of species than with two or three censuses. Number of transects needed for a minimum adequate sample of 3,200 ha of mature honey mesquite (Prosopis juliflora) habitat is four (sampled three times monthly) but for more precise population data for each species six to nine are required.

INTRODUCTION

Since 1973 we have been censusing birds in about 80,000 ha of riparian vegetation in the Colorado River Valley from Davis Dam to the Mexican boundary using the transect count technique (Emlen 1971). Censusing is conducted by 11 full-time observers; the turnover rate among observers being about 25 percent per year. Since the beginning of our study, we have made about 10,000 censuses each 0.8 to 1.6 km in length. With the increased need to determine avian population levels, it is important to quantify the effects of such factors as time of day and wind on censuses. Furthermore, if more than one observer is involved, it is important to know how results from the same area compare. Since the interrelated factors of available time, financial support, and manpower limit the extent of censusing, it is important to know the minimum area in which censusing must be done in order to get reasonably accurate results. Undersampling can lead to erroneous conclusions, while over-sampling is inefficient. This report, although not providing definitive answers, addresses these points and may be helpful to those planning bird censuses in large areas, especially riparian communities in the Southwest.

CLIMATIC FACTORS AFFECTING CENSUSES

Wind

Intuitively it seems that strong wind (20 to 50 kmph) would decrease bird activity and in general interfere with bird detection. In order to quantify this we censused 22 transects on days with winds 24 to 50 kmph and compared the number of detections with the

1/ Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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number made on the same transects on calm days immediately preceding or following windy days. The results (Table 1) are equivocal in that in three of five comparisons involving twelve transects, the number of detections on windy versus calm days were similar; on two occasions involving ten transects, the counts on windy and calm days were dissimilar with significantly greater ($p<0.01$) numbers of detections having been made on calm days. Visual and auditory detections will probably be reduced because birds tend to seek shelter and sounds may be drowned out by wind noises.

Table 1.--Number of bird detections on windy (20-50 kmph) and calm days.

Number of Transects	Detections		Probability of Difference Being Due to Chance
	Windy	Calm	
10	92	93	>0.05
9	59	203	<0.005
1	132	136	>0.05
1	258	259	>0.05
1	196	255	<0.01

In general, if there is a strong wind during the prime census time, we do not begin censusing; but if the winds develop after censusing has begun, we ordinarily finish the transect or set of transects but do not initiate censusing new ones. Winds less than 20 kmph apparently interfere very little with accurate censusing.

Time of Day

Winter censuses (December through January) initiated earlier than one hour after sunrise or later than 2.5 hours after sunrise resulted in significantly ($p<0.05$) fewer detections than those begun 1.0 to 1.5 hours after sunrise. Summer censuses begun between 0.25 hours before sunrise to sunup were significantly ($p<0.05$) greater than censuses begun later than 0.75 hours after sunup (Table 2).

Birds are active earlier and for shorter periods of time in summer than in winter. The often-expressed statement that birds are more active earlier than later at all times of the year and are active for longer periods of time with increasing photoperiod is not supported by data from the lower Colorado River Valley and appears to be an over-generalization. Time of day is, of course, related to temperature (Shields 1977). In summer the censusing can be continued longer on days which are relatively cool, and in winter censusing can be initiated earlier on days which are relatively mild.

In order to census all of our transects monthly, we frequently must begin before and continue beyond the time when birds are most active. To compensate for this we rotate the order in which a set of transects is censused. Shields (1977) indicated that this may be inadequate and significant differences in densities may be obscured. He provided a method for including time of day as a factor in the analysis of variance.

DIFFERENCES BETWEEN OBSERVERS

The relatively large area being studied has dictated the use of 8 to 12 observers. The experience of these individuals is quite varied. Highly experienced observers were those who had been observing birds for several years--sometimes for most of their lives. Others, which we shall refer to as less experienced observers, had not done much bird watching before joining our staff. On the average, the less experienced observers, after training, had been on the job for about ten months.

To determine the extent to which differences in avian densities and diversities vary because of the way observers detect birds, we first evaluated the extent to which observers could reproduce their own results. To make this evaluation three different observers censused a set of transects (4 to 5 km) for four consecutive days. Following this we had five groups of four observers and one group of three observers census about 16 km of transects. Within each 16 km group of transects each observer censused one fourth of the area each day so that by the end of four days each had censused the entire area.

The first part of the test was conducted in April 1977; a difficult time to try to reproduce census results because of the potential for encountering transient individuals of newly arriving summer residents (strictly transient species were not included in the census results). For the three different highly experienced observers, nonsignificant differences in bird density were obtained in 12 of 18 possible comparisons (Table 3). The largest and smallest number of species tabulated differed by four in area 2 and by one in the other areas (Table 3). The largest BSD was 8.1, 9.2, and 11.9 percent above the lowest value in the three areas (Table 3). Thus, the same observer is not always able to reproduce his own results, suggesting day-to-day variation within a given population in an area.

Table 2.--Results of bird censuses taken at different times of the morning in winter and summer in riparian vegetation in the lower Colorado River Valley.

Censusing begun (hours after sunrise)	Number Transects	Totals					
		Detections	Phaino-peplas	Excluding Phaino-peplas	Non-Passerines	Passerines Excluding Phainopeplas	Number Species
Dec. 1974							
1.00	4	175	99	76	10	66	15
1.25	4	191	95	96	33*	63	15
2.00	4	234*	85	149*	64*	85	19
Dec. 1974							
1.50	6	234	149	85	39	46	18
2.50	6	186*	127	59*	30	29	19
Jan. 1975							
1.00	4	194	111	83	31	52	17
1.50	4	255*	119	136*	29	111*	13
1.50	6	179	48	131	30	101	15
2.00	6	166	50	116	30	86	19
Feb. 1975							
1.50	6	113	47	66	18	48	16
1.75	6	121	42	79	20	59	15
July 1974							
-0.25	2	449			292	157	19
1.00	2	308*			199*	92*	17
July 1975							
-0.25	2	294			166	128	20
1.00	2	187*			85*	102	20
June 1975							
0.00	2	328			183	145	19
0.75	2	242*			137*	105*	19

*Significantly different from earlier count at $p<0.01$.

Table 3.--Density estimates for three different areas with about 3.2 km of transects each. Each area was censused by the same observer for four consecutive days.

	Area 1	Area 2	Area 3
Density: Day 1	396	271**	455
2	411	306**	449
3	405	374	365***
4	352*	365	421
Species: Day 1	25	28	20
2	23	25	20
3	24	29	20
4	24	29	19
BSD: Day 1	2.502	2.616	2.475
2	2.405	2.801	2.302
3	2.480	2.648	2.534
4	2.205	2.574	2.399

*Significantly smaller than on days 2 and 3 ($p<0.05$).
**Significantly smaller than on days 3 and 4 ($p<0.005$).
***Significantly smaller than on other days ($p<0.05$).

When different observers censused the same transects, significantly different ($p<0.05$) densities were obtained in 18 (60 percent) of 30 possible comparisons between observers of the same transect (Table 4). Test 1 involved two highly experienced and one less experienced observer. The main source of difference was a flock of Chipping Sparrows (Spizella passerina) recorded by one of the highly experienced people but not by subsequent recorders. Test 2 involved four highly experienced recorders. The main difference was in density estimates of White-crowned Sparrows (Zonotrichia leucophrys), a flocking species. Tests 3 and 6 involved three less experienced and only one highly experienced observer and the results varied widely. Results of test 4, involving two highly experienced and two less experienced observers, were fairly similar. Test 5, conducted in desert washes by three highly experienced observers, revealed wide differences in population estimates; but all recorded the same number of species. Significant differences in tests involving two or more highly experienced observers were found in 8 (44 percent) of 18 comparisons. This is significantly fewer than expected based on the results of tests where at least three of the observers were not highly experienced (test 3).

Although some of the differences between observers are significant, they represent population estimates based on a single census. As we shall demonstrate in the following section, differences between observers may be due to this factor more than as a result of different abilities to detect birds. Furthermore, we have already pointed out that the same observer censusing the same area for several consecutive days was not always able to reproduce his own results. With this in mind, the real differences obtained by highly experienced observers in the same area appear quite small, with larger differences resulting when the same area is censused by observers with less experience. The conclusion to be drawn from this is obvious, but in practice it is not always

Table 4.--Six sets of census data obtained by different observers in the same area in the Colorado River Valley.

Test No.	Date/ Vegetation Type/ Area Length	Observer	Total Density	BSD	Total Species
1	21-23 Mar 1975/	1	259	2.66	27
	Honey Mesquite/	2*	209	2.69	27
	8.9 km	3*	216	2.73	25
2	6-9 Nov 1976/	1*	291	2.42	28
	Honey Mesquite/	2*	364	2.41	25
	11.3 km	3*	336	2.67	36
		4*	305	2.71	32
3	6-9 Nov 1976/	1	163	2.39	20
	Salt Cedar, Arrowweed,	2	53	1.97	13
	Screwbean, Willow mix/	3	229	2.36	19
	8.0 km	4*	127	2.51	21
4	6-9 Feb 1977/	1*	255	2.56	22
	Desert Washes/	2*	180	2.38	22
	9.7 km	3	129	2.70	23
5	6-9 Feb 1977/	1*	243	2.29	28
	Honey Mesquite/	2*	286	2.34	32
	11.3 km	3*	248	2.31	31
		4	213	2.51	37
6	6-9 Feb 1977/	1	83	2.59	24
	Salt Cedar, Arrowweed,	2	55	2.26	17
	Screwbean, Willow mix/	3	92	2.13	17
	8.0 km	4*	47	2.46	23

*highly experienced observer

possible to find highly experienced observers when they are needed.

To minimize the possibility that differences between two areas are due to the differences among observers, we schedule censuses so that no individual observer censuses the same transect twice in one month. If this is not possible, only highly experienced personnel census the same area twice.

NUMBER OF CENSUSES REQUIRED

The number of times a transect 0.8 to 1.6 km long must be censused monthly to obtain an accurate population estimate is of crucial importance both for scientific accuracy and to be as economically practical as possible. To acquire insight into this question we censused single transects, groups of three transects (about 3.6 km), and groups of eleven transects (about 13 km) on four consecutive days. The results of the first day are the extrapolated detections obtained on the first day. The totals for the second day represent the mean of the first two days and so on. Species occurring at densities less than 0.5 per 40 ha were dropped from the analysis, thus the number of species sometimes decreased with the addition of a second or third census. Rationale for this procedure is presented elsewhere in these proceedings (Anderson, Engel-Wilson, Wells and Ohmart).

Data for 55 single transects indicate that after the first census there was very little change in the estimated density (Table 5). BSD increased steadily through the fourth census of an area, but the increase (4 percent) with addition of a fourth census was small (Table 5). The number of species increased through the fourth census. Sixteen groups of three transects showed little change in estimated density after the first census; the inclusion of a third and fourth census resulted in very small changes in BSD and number of species (Table 5). Four groups of eleven transects were similarly censused. Once again a third and fourth census of the same area modified the results very little (Table 5). We conclude that if a community type is represented by only one or two transects, censusing should be done at least four times per month. If several transects have been established, two or three censuses appear to yield data as accurate as four censuses. It might be possible to census each area once or twice and to adjust the results by correction factors determined from a larger number of censuses. Such correction factors should be based on a larger data set than we have presented in this report. We have sufficient data to make such an assessment; but for the sake of brevity and because of time constraints, it is not presented here.

NUMBER OF TRANSECTS TO ESTABLISH IN AN AREA

Once it has been determined that there are, for example, 3,200 ha of honey mesquite, the next step is to determine how many transects are needed to obtain an accurate estimate of the population of each species in that area. We established nine transects (11 km) in 3,200 ha of structure type IV honey mesquite. To determine the number of transects necessary to accurately estimate avian populations, a single transect was selected at random, the density and BSD were computed and number of species counted. A second transect was added and new parameters calculated; the new density being the mean of the two transects. From this a new BSD was computed. This randomized process was repeated until all nine transects had been included. If the area was not adequately sampled, the density, BSD, and number of species should have increased or decreased through the ninth census. If a total of nine transects was more than adequate, these parameters should reach a plateau before the addition of the ninth transect. The point at which they level off indicates the number of transects necessary to adequately sample the area. Total density appeared to level off after inclusion of six transects (fig. 1) and BSD and the number of species after the random combination of four transects (fig. 2). On this basis we concluded that four transects rather than nine would have been sufficient in this 3,200 ha area. Three censuses for three transects are apparently as informative as four censuses (see above). For this reason we used data after three censuses from four transects selected randomly from the original nine transects to see if that number was adequate for reproducing the results obtained from all nine transects. Four observers censused the nine transects with each observer having censused all nine once each. This was done in November 1976 and was repeated in February and April 1977.

In November three censuses of four randomly selected transects revealed a density about 19 percent higher and a BSD 2.8 percent lower than that obtained when all nine transects were censused four times each. The two lists contained the same number of species: 24 (89 percent) species were common to both lists; three species occurred on one list but not on the other. These constituted a very small percent of the total density on either list (2.8 percent and 0.7 percent, respectively). Twelve species (44 percent) varied within a range of one individual on the two lists (not

Table 5.-- Changes in estimates of bird population parameters with four censuses of single transects, groups of three transects, and groups of 11 transects.

Number of Groups	Number of Transects Per Group	Number of Censuses	Mean Density (2SE)*	Mean BSD (2SE)	Mean Number of Species (2SE)
55	1	1	249 (42)	1.88 (0.14)	11.7 (1.5)
		2	243 (40)	2.07 (0.12)	15.1 (1.6)
		3	240 (19)	2.15 (0.11)	16.8 (1.5)
		4	239 (19)	2.24 (0.09)	18.7 (1.5)
16	3	1	222 (68)	2.28 (0.17)	17.1 (2.8)
		2	247 (62)	2.46 (0.14)	21.8 (2.8)
		3	246 (60)	2.40 (0.11)	21.5 (2.7)
		4	242 (60)	2.45 (0.10)	22.8 (2.5)
4	11	1	189	2.42	21.3
		2	196	2.72	26.5
		3	195	2.57	23.5
		4	200	2.61	25.0

*Not calculated for groups less than 5.

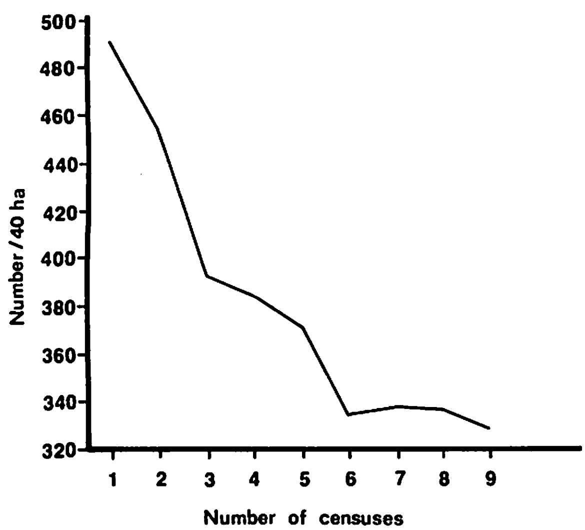

Figure 1.--Changes in avian density estimates with the random additions of transects in 3200 ha of honey mesquite woodland along the lower Colorado River.

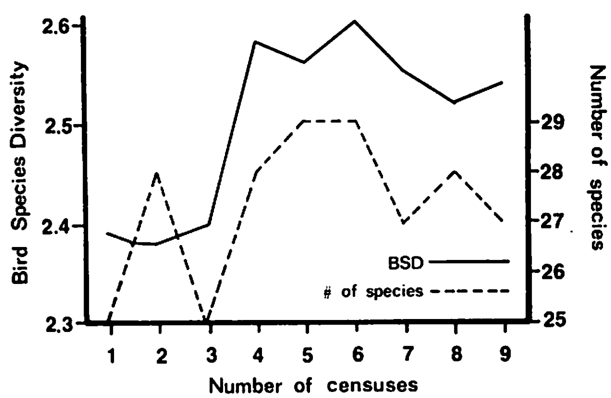

Figure 2.--Changes in the estimates of bird species diversity and number of species with the random addition of transects in 3200 ha of honey mesquite woodland along the lower Colorado River.

counting those cases of a zero (0) on one list and a one (1) on the other). Among the species occurring in densities of 10 or more on at least one list, the average of the four randomly selected transects was about 50 percent higher or lower than when all nine transects were included. Three of the five species varying by over 40 percent were flocking species.

In February three censuses of four randomly selected transects revealed a density 11.2 percent higher and a BSD 4.9 percent lower than that obtained on all nine transects (Table 6). The two lists contained 28 species, 26 of which were common to both lists. Seventeen species (63 percent) varied by only one individual. Those species occurring in densities of ten or more on at least one list varied in density by an average of 31 percent on the randomly selected transects. Both species varying by over 40 percent were flocking species.

In April three censuses of four randomly selected transects revealed a density 5.5 percent smaller and a BSD 2.6 percent larger than that obtained on all nine transects (Table 6). Both lists contained 31 species of which 29 (94 percent) were in common. Twelve species (39 percent) varied by only

Table 6.--Bird densities and diversities in honey mesquite for November, 1976 and February and April, 1977 in the lower Colorado River Valley.

	Density (N/40 ha)					
	November		February		April	
Species	9 transects (4 censuses)	4 randomly selected transects (3 censuses)	9 transects (4 censuses)	4 randomly selected transects (3 censuses)	9 transects (4 censuses)	4 randomly selected transects (3 censuses)
Gambel's Quail, Lophortyx gambelii	9	17	18	26	45	30
Mourning Dove, Zenaida macroura	1	2	12	16	34	29
Roadrunner, Geococcyx californianus	0	0	1	1	1	2
Common Flicker, Colaptes auratus	6	5	1	1	1	1
Gila Woodpecker, Melanerpes aurifrons	3	4	2	1	2	2
Ladder-backed Woodpecker, Picoides scalaris	5	6	3	1	5	8
Yellow-bellied Sapsucker, Sphyrapicus varius	0	0	1	2	0	0
Ash-throated Flycatcher, Myiarchus cinerascens	4	4	1	1	10	13
Say's Phoebe, Sayornis saya	0	0	0	0	1	0
Black Phoebe, Sayornis nigricans	1	1	0	0	0	0
Rough-winged Swallow, Stelgidopteryx ruficollis	0	0	0	0	1	1
Cliff Swallow, Petrochelidon pyrrhonota	0	0	0	0	2	3
Verdin, Auriparus flaviceps	12	14	12	9	18	22
House Wren, Troglodytes aedon	2	2	1	1	2	1
Bewick's Wren, Thryomanes bewickii	6	4	2	1	1	2
Cactus Wren, Campylorhynchus brunneicapillus	4	3	1	0	5	3
Mockingbird, Mimus polyglottos	6	6	7	5	13	11
Crissal Thrasher, Toxostoma dorsale	7	5	3	3	4	6
American Robin, Turdus migratorius	2	0	2	3	1	1
Western Bluebird, Sialia mexicana	5	2	3	2	0	0
Mountain Bluebird, Sialia currucoides	0	1	0	0	0	0
Blue-gray Gnatcatcher, Polioptila caerulea	0	0	0	1	0	1
Black-tailed Gnatcatcher, Polioptila melanura	11	18	8	8	10	8
Ruby-crowned Kinglet, Regulus calendula	20	33	21	22	8	12
Phainopepla, Phainopepla nitens	90	97	89	96	65	64
Loggerhead Shrike, Lanius ludovicianus	2	0	1	0	1	0
Orange-crowned Warbler, Vermivora celata	3	3	3	4	5	3
Lucy's Warbler, Vermivora luciae	0	0	0	0	46	49
Yellow-rumped Warbler, Dendroica coronata	48	43	2	2	24	20
Brown-headed Cowbird, Molothrus ater	0	0	0	0	6	7
Northern Oriole, Icterus galbula	0	0	0	0	0	0
Painted Bunting, Passerina ciris	0	1	0	0	0	0
House Finch, Carpodacus mexicanus	2	1	3	3	0	0
Lesser Goldfinch, Carduelis psaltria	0	0	0	1	1	2
Abert's Towhee, Pipilo aberti	13	23	14	10	15	22
Savannah Sparrow, Passerculus sandwichensis	2	1	0	0	0	0
Sage Sparrow, Amphispiza belli	13	24	6	7	1	3
Dark-eyed Junco, Junco hyemalis	4	2	4	2	4	3
Brewer's Sparrow, Spizella breweri	0	0	1	1	10	6
White-crowned Sparrow, Zonotrichia leucophrys	46	66	27	47	39	24
Lincoln's Sparrow, Melospiza lincolnii	0	0	0	0	0	1
Song Sparrow, Melospiza melodia	0	1	0	0	0	0
Total	327	389	249	277	381	360
BSD	2.54	2.47	2.43	2.31	2.74	2.81
Total Species	27	27	28	28	31	31

one individual. Those species occurring in densities of 10 or more on at least one list varied by an average of 28 percent.

Censuses of the smaller number of transects most frequently included species which did not really use the vegetation type but which were merely occasional visitors for brief periods of time or occurred in some edaphic situation. This was true for the Song Sparrow (Melospiza melodia), Painted Bunting (Passerina ciris), Mountain Bluebird (Sialia currucoides) in November, and the Lincoln's Sparrow (Melospiza lincolnii) in April. On the other hand, scarce species which occurred regularly in a small part of the area being studied tended to be missed with a small number of transects--Loggerhead Shrike (Lanius ludovicianus) in November, February and April; Western Bluebird (Sialia mexicana) and American Robin (Turdus migratorius) in November; Cactus Wren (Campylorhynchus brunneicapillus) in February; and the Say Phoebe (Sayornis saya) in April. It is also clear that species which occurred in densities greater than 10 per 40 ha and which are not evenly distributed were 20 to 50 percent over- or under-represented. The total population estimates, BSD's, and number of species were very similar when either four or all nine transects were used. Four transects censused three times are probably adequate for making general comparisons of overall density, BSD, and number of species in different vegetative types. However, if more precise population data for individual species is desired, more transects are necessary; but two censuses instead of three or more are probably adequate. If availability of time and manpower are severely limited, the smaller number of transects (3 to 6 km) will yield valuable data if censused at least three times monthly.

CONCLUSIONS

Time of day was found to be important in detectability of birds which became active earlier but which have a shorter activity period with increasing photoperiod. If censusing must begin before and last beyond the optimum time, the order in which transects are censused should be arranged so that the same transect is not censused first or last consistently.

Wind potentially reduces detectability and censusing should not begin if there are strong winds (20 to 40 kmph). If winds develop after censusing has begun, the transect or transect set can probably be completed without serious bias; but individual judgment should be exercised in such situations.

For relatively homogeneous areas, up to at least 3,200 ha, four transects totaling about 5 km are probably adequate for useful comparative work. Three censuses per transect per month are adequate. If more precise species by species population data are required, more transects should be established.

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Southwestern Riparian Communities: Their Biotic Importance and Management in Arizona[1]

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Abstract.--The various riparian communities occuring in Arizona and the Southwest are described and their biotic importance discussed. Recommendations are made concerning the management of streamside environments and their watersheds. These include recommendations pertaining to the classification and inventory of riparian habitats; the determination of limiting factors for key riparian species; the establishment of study areas; the regulation and elimination of livestock grazing; the greater consideration of streamside vegetation in authorizing water management projects; and the more conservative use of our watersheds.

INTRODUCTION

No report on riparian habitats would be complete without a discussion of the characteristics and limiting factors of Southwestern riparian vegetation and its associated fauna. These biotic communities have an importance to wildlife and outdoor recreation greatly disproportionate to their limited linear acreage. While man's various manipulations and alterations have resulted in enormous changes in the riparian vegetation, so have his watershed practices affected riparian environments. The long-term effects of past and present land management practices are imperfectly known, but the current situation for many of our riparian communities cannot be termed less than disastrous when compared to conditions of even a short time ago (Freeman 1930, Phillips et al. 1964, Lowe 1964, Jordan and Maynard 1970, Hubbard 1971, Davis 1973, Minckley 1973, Turner 1974 and others). Some understanding of our remaining riparian communities is therefore necessary if we are to make intelligent judgments about the desirability of future watershed projects in Arizona.

The various riparian communities of Arizona may be represented as formations or vegetation types of forest, woodland, marshland, and even grassland and scrub. A riparian community or association is one that occurs in or adjacent to a drainageway and/or its floodplain and which is further characterized by species and/or life forms different from those of the immediately surrounding non-riparian climax (Lowe 1964). A riparian community may be composed either of constituents peculiar to the riparian situation, or an extension of a higher, climax association fingering downward into the drainageway; the latter type has been termed "pseudo-riparian" (Campbell and Green 1968) to distinguish its faculative nature from the obligate nature of purely riparian species. Examples of pseudo-riparian communities are (1) ponderosa pine (Pinus ponderosa) forests above the Mogollon Rim that follow canyons into the pinyon-juniper woodland, and (2) extensions of some Arizona upland desert scrub species such as palo verde (Cercidium floridum), ironwood (Olneya tesota) and saguaros (Cereus giganteus) in arroyos and along washes within creosote communities in Yuma County. Another regularly observed riparian community of this kind is the extension of encinal or oak woodlands along creeks into plains and desert grasslands in southwestern Arizona.

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It is the riparian communities proper, commonly with distinctive plant and animal components not found elsewhere, that are of greatest concern here. This concern stems from their unique character and the resulting changes brought about by modern man, who has reduced and eliminated them at an alarmingly rapid rate. Hopefully an increased awareness and enlightened attitude on the part of public-spirited citizens will prevail and many of the more interesting riparian communities remaining will be available for future enjoyment and study. The following discussion and summary of these riparian communities generally follows the classification outlined in Brown and Lowe (1974).

I. Temperate Deciduous Forests and Woodlands

Warm-temperate, winter-deciduous gallery forest and woodlands, where they still occur, are the most interesting and spectacular riparian communities in Arizona. Originally, interior riparian forests occupied most of the major drainages in the Southwest from the Mohave and Sonoran Deserts through submogollon Arizona, northeastern Sonora, southern New Mexico, northern and eastern Chihuahua to the Rio Grande and its tributaries in southwest Texas. Other, cold-temperate deciduous forests occupy streamsides in montane habitats and in the Great Plains and Great Basin. These forests are maintained along perennial or seasonally intermittent streams and springs and can be divided into two major communities: mix broadleaf and cottonwood-willow. Today only a few drainage systems, such as the undammed Rio Magdalena in Sonora and (to a lesser extent) the San Pedro River in Arizona, present extensive linear riparian forest development. Where streamflows are seasonally intermittent, riparian deciduous forests can be expected only where surface runoff occurs from November through March (Zimmerman 1969, Hibbert et al. 1974) and where the advent of the spring growing season can be expected prior to April 15 (warm-temperate). After mid-April increased evapotranspiration and phytotranspiration may result in only subsurface flow, especially during daytime hours. Summer precipitation usually does not result in sustained streamflow (Zimmerman 1969, Hibbert 1971, Hibbert et al. 1974), and riparian deciduous forests in the Southwest are vernal adapted. As such, Arizona's warm-temperate forests require abundant water during March and April, when most species set seed and germinate (Zimmerman 1969). Probably for this reason, these forests are poorly represented or largely absent from the westerm pediments of the Sierra Madres in southeastern Sonora and Sinaloa, where winter-spring precipitation is less than 25 percent of the total.

Interior mixed broadleaf communities are usually found in Arizona between about 3,500 and 6,500 feet along rubble-bottomed perennial and semiperennial streams (fig. 1). They are represented in the western portions of the state along Trout, Francis and Burro Creeks in Mohave and Yavapai Counties, through the submogollon region to Rucker and Guadalupe Canyons in southeastern Cochise County. Arboreal constituents may be admixtures or stands of a variety of Holarctic genera consisting of sycamore (*Platanus wrighti*), ash (*Fraxinus pennsylvanica velutina*), cottonwood (*Populus fremontii*, *P. angustifolia*), boxelder (*Acer negundo*), alder (*Alnus oblongifolia*), bigtooth maple (*Acer grandidentatum*), willow (*Salix* spp.), walnut (*Juglans major*), mulberry (*Morus microphylla*), bitter cherry (*Prunus emarginata*), and other deciduous species intermingled with oaks and, to a lesser extent, conifers from the adjacent mountains. Arizona cypress (*Cupressus arizonica*) is not infrequent. Characteristic understory species include brackenfern (*Pteridium aquilinum*), scarlet sumac (*Rhus glabra*), poison ivy (*Rhus radicans*) and the deciduous vines, Virginia creeper (*Pathenocissus quinquefolia*) and canyon grape (*Vitus arizonica*).

Figure 1.--Interior riparian deciduous forest; mixed broadleaf series along Beaver Creek, Coconino National Forest, Yavapai County, Arizona; ca. 3850 ft., July, 1971. Arboreal associates at this locality in this warm-temperate "gallery" forest are alder, walnut, ash, cottonwoods and willows. Note the luxuriant understory and streamside vegetation without the presence of livestock.

Several species of wildlife are totally or largely dependent on this community. Among these are the Arizona grey squirrel (*Sciurus arizonensis*), otter (*Lutra canadensis*), zone-tailed hawk (*Buteo albonotatus*), black hawk (*Buteogallus anthracinus*), water ouzel or dipper (*Cincius mexicanus*), sulphur-bellied flycatcher (*Myiodyrcaster luteiventris*), summer tanager (*Piranga rubra*), Bullock oriole (*Icterus bullocki*), yellow warbler (*Dendroica petechial*), Arizona alligator lizard (*Gerrhonotus kingi*), Sonoran mud turtle (*Klinosternon sonoriense*), and canyon tree frog (*Hyla arenicolor*). These communities also provide major habitat types for white-tailed deer (*Odocoileus virginianus*), black bear (*Ursus americanus*), turkey (*Meleagris gallopavo*), as well as a myriad of nesting and migrating raptors and songbirds. Unfortunately, intensive investigations of the populations and nesting densities are lacking for most species of wildlife in this habitat type. An important exception is the lower Gila River in New Mexico where the biota has been inventoried by Hubbard (1977). Lowered streamflow has reduced a number of forests to scattered, individual constituents (woodlands), opening the canopy and presumably reducing its desirability to wildlife dependent on this type. Flash floods, such as the notorious Labor Day flood of September, 1970, have affected many miles of this beautiful streamside forest, and grazing by livestock has reduced the quality of the forest understory almost everywhere, curtailing or eliminating reproduction of some forest species.

Excellent examples of mixed broadleaf forests are still found in Arizona along Wet Beaver Creek above Rim Rock, along Oak Creek in Oak Creek Canyon, along Ash, Redfield, Eagle and Aravaipa Creeks and the San Francisco River. A revitalized forest along Rock Creek on the Three Bar Wildlife Area in the Mazatzal Mountains is especially worthy of mention. In 1959, after the elimination of grazing about 15 years before, the majority of the chaparral watershed burned; subsequent herbicide treatment prevented the rejuvenation of the nonriparian, climax chaparral community, and the sparsely forested vegetation along the drainage was transformed into a dense, excellent representative of mixed broadleaf deciduous forest. The area now provides habitats of importance to black bear and turkey, neither of which had utilized the area before the transformation (Gallizioli 1974). Since the streamflow was transformed from ephemeral to almost perennial prior to the application of herbicides (Pase and Ingebo 1965), the determining roles of fire and range restoration need further consideration.

Forests and woodlands in Arizona dominated by cottonwood and willow (*Populus fremonti*, *Salix gooddingii*, *S. bonplandiana* and others) are confined primarily to riparian environments below 3,500 feet on clay or other fine soil and rock deposits [1]/ (fig. 2). Streamflows are perennial or nearly so. The understory may be a tangle of riparian trees or shrubs or relatively open and parklike. Once extensive, these forests have diminished greatly over the past 100 years with the diversion, interruption and elimination of streamflows. Descriptions taken from accounts telling of the extent of these forests along the Santa Cruz, Gila and Colorado Rivers prior to 1900 are indeed difficult to envision today (Davis 1973). Upstream impoundments, channel cutting, channelization, increased water salinity, irrigation diversions, and ground water pumping have made and continue to make massive inroads on these now relict communities. As in the mixed broadleaf community upstream, cattle grazing has negatively influenced the understory and the quality of remaining stands. Many remaining

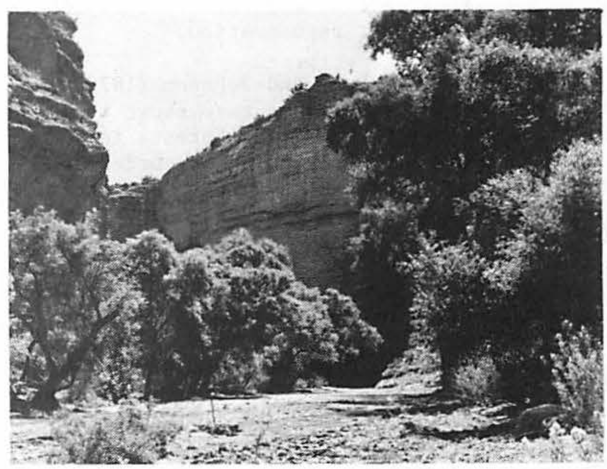

Figure 2.--Interior riparian deciduous forest; Cottonwood-willow series along Aravaipa Creek, Pinal County, Arizona; ca. 2800 ft., September, 1968. Willows, principally *Salix gooddingii*, outnumber cottonwood in this warm-temperate forest and woodland. The principal shrub is seep-willow and because of grazing, the understory vegetation is scant as oppossed to that shown in Figure 1. Photo by Richard L. Todd.

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[1]The limited woodlands of cottonwoods (*Populus acuminata* and others) willows (*Salix lasiandra*, *S. lutea* and others) and other deciduous trees north of the Mogollon Rim above 6,000 feet in northeastern Arizona are here considered extreme fasciations of riparian forest other than warm-temperate interior riparian deciduous forest.

mixed broadleaf riparian forests are under the jurisdiction of the U.S. Forest Service, where it is hoped future management of grazing and timber resources will give added consideration to these valuable environments (USFS 1969).

Interrupted examples of cottonwood-willow forests are still found along the Verde, Hassayampa, San Pedro, Bill Williams, Colorado and other rivers. Indications are that these communities are maintained through periodic winter-spring flooding. Stabilized water flows result in decadent stands, in which the dominant species are lacking in reproduction. Cottonwood regenerates itself principally from seed, unlike sycamore and other broadleaf riparian species that reproduce by sprouting, forming clones (Horton et al 1960). Further indications of the subclimax nature of this community are the "new" stands adjacent to portions of the Verde River and Santa Cruz Rivers, which were generated after heavy winter-spring runoffs on these drainages in 1965 and 1967 respectively. The presence of similar fasciations in California also indicates that these forests are vernal-adapted, and that late summer runoff is of little or no benefit to their regeneration.

Studies by Carothers and Johnson (1970) on the Verde River in Arizona have shown the importance of cottonwood-willow forests to breeding birds. More species are recorded as nesting in this vegetation type than any other; in Arizona several species such as the yellow-billed cuckoo (Coccyzus americanus) and blue-throated hummingbird (Lampornis clemenciae) are, for all practical purposes, restricted to it. A comparable study of the nesting birds of a cottonwood-willow community in California showed a similar importance to nesting birdlife (Ingles 1950). The importance of the cottonwood-willow community to avian species including raptors, particularly the black hawk (Buteogallus anthracinus), grey hawk (Buteo nitidus), and bald eagle (Haliaeetus leucocephhalus) is discussed by Todd (1969, 1970, 1971, 1972; Hubbard 1971) and others. The Sonoita Creek Natural Area retained by The Nature Conservancy along Sonoita Creek in Santa Cruz County is an overmature example of the cottonwood-willow association and a mecca for observers of songbirds and other wildlife. Because of its proximity to Mexico, several peripheral species of birds such as the sub-tropical becard (Pachyramphus agaiae) are regularly observed here. The importance of these communities in maintaining environments for the Southwest's aquatic biota is imperfectly known, but studies by Minckley (1969) on Sonoita Creek and other drainages indicate that they may be of great consequence (also see Miller 1961).

II. Subtropical Deciduous Woodland

The famous mesquite bosques of pre-settlement Arizona are discussed by Brandt (1951), Phillips et al (1964), Lowe (1964), Davis (1973) and others. Unfortunately, the major bosques such as the ones at San Xavier, Komatke (New York Thicket), and Texas Hill are now mostly of historical interest (Brown 1970, 1974; Wigal 1973) (fig. 3). Remnants, some of which are nonetheless excellent examples, still occur along the San Pedro, Santa Maria and Verde Rivers, on the Robbins Butte Wildlife Area adjacent to the Gila River, along the upper middle Gila, and in scattered patches along other Lower Sonoran water courses (fig. 4). While winter deciduous, these bosques are very much subtropical and in Arizona are largely restricted to below 3,500 feet elevation within the Sonoran Desert, where they attain maximum development on the alluvium of old dissected flood plains laid down between the intersection of major watercourses and their larger tributaries (fig. 5).

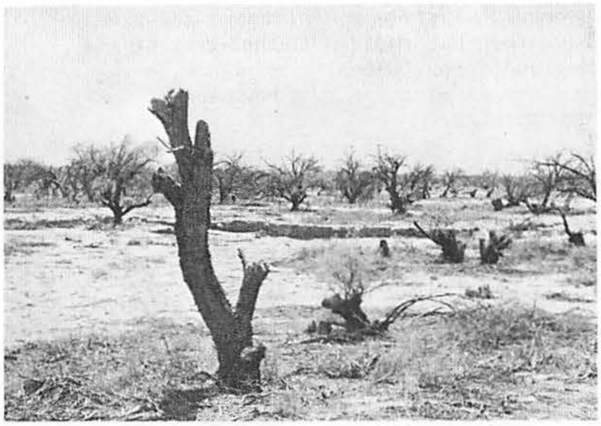

Figure 3.--Subtropical riparian deciduous woodland; remnant of the recently great mesquite bosque at Komatke (New York thicket) near confluence of the Gila and Santa Cruz Rivers, Gila River Indian Reservation, Maricopa County, ca. 1,050 ft., July, 1972. The rapidly dropping ground water table has resulted in this scene of dead and dying mesquites.

Figure 4.--Subtropical riparian deciduous woodland; interior view of mesquite bosque along San Pedro Rivers between Cascabel and Redington, Cochise County, Arizona; May, 1977. The thrifty appearance and abundant reproduction of the mesquites here is in marked contrast to most of the other bosques in Arizona. These bosques are being rapidly cleared for agriculture, however.

Figure 5.--Subtropical riparian deciduous woodland: mesquite bosque community along Gila River below its confluence with Bonita Creek, Graham County, ca. 3,100 ft., December, 1970. Note the sharp contrast between the riparian bosque and the nonriparian Sonoran desertscrub.

In the past these subtropic woodlands were almost completely dominated by mesquite (Prosopis juliflora velutina), once containing individuals of great size (see e.g., Brandt 1951). Hackberry (Celtis reticulata), screwbean (Prosopis pubescens), and increasingly the deciduous saltcedar or tamarisk (Tamarix chinensis) may now share dominance in local situations (Bowser 1957, Robinson 1965, Turner 1974). As in areas of former cottonwood-willow forest, riparian scrub and marshland, the introduced saltcedar now often exclusively constitutes a disclimax community (fig. 6) at the expense of native plant and animal diversity (see e.g., Phillips et al. 1964, Ohmart 1973).

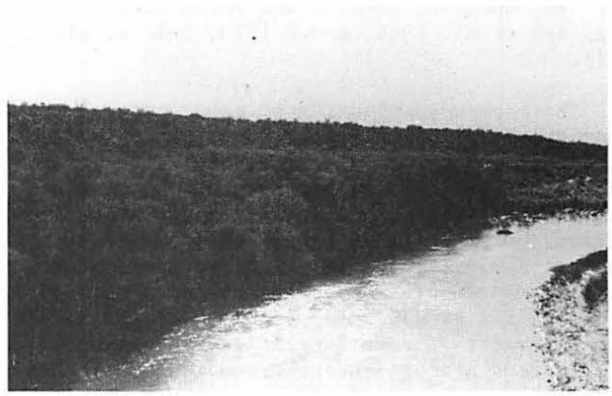

Figure 6.--Riparian deciduous scrubland; a subtropical disclimax consociation along the Salt River in south-central Arizona; September 1958. Scrublands and woodlands of the hybrid saltcedar (Tamarix chinensis) now occupy hundreds of miles of stream channels in the Southwest where they provide important nesting habitats for mourning doves, and in subtropical areas, mourning and white-winged doves.

Historically, saltbushes (Atriplex polycarpa, A. lentiformis), or annual and perennial grasses and forbs formed the ground cover in mature mesquite bosques; the understory was relatively open. Today, introduced annual forbs such as filaree (Erodium cicutartium), mustards (Cruciferae) and grasses, e.g. Cynadon dactylon, Bromis rubens, Schismus barbatus and others, are frequently encountered as understory species. Vines such as janusia (Janusia gracilis), canyon grape (Vitis arizonica), gourds (Cucurbita palmata) and others were, and still may be, conspicuous constituents. Individual cottonwoods, velvet ash and Goodding willow may be interspersed in more mesic sites within the bosque. Greythorn (Condalia lycioides) or a blue palo verde (Cercidium floridum) may occupy an occasional opening or sunny place.

The importance of this woodland type to colonial nesting white-winged (Zenaida asiatica) and mourning (Zenaidura macroura) doves is well documented (Neff 1940, Arnold 1943, Wigal 1973, Carr 1960 and others). Its importance to other avian species is discussed by Brandt (1951), Phillips et al. (1964), Gavin (1972) and others. This community too has suffered greatly from a variety of man-related causes including water diversion, flood control, agricultural clearing programs, and, principally, dropping water tables. This llast factor, including interrupted subsurface flow, has been responsible for the almost total destruction of the mesquite "forests" at San Xavier, Casa Grande Ruins National Monument, Komatke and Texas Hill (Phillips et al. 1964, Brown 1970, Judd et al. 1971).

The continued clearing of other bosques along the Gila and Colorado Rivers has resulted in their replacement by agricultural crops and other type conversions. It has been noted that where intermittent flooding and/or slowly receeding summer surface flow occurs, saltcedar tends to replace mesquite. This is particularly prevalent after the woodlands have been cleared or burned and ground water is close to the surface and water storage facilities and agricultural tracts are present upstream. Whether this replacement is partially due to irreversible changes in water quality and soil chemistry, or is entirely due to the inherent ability of tamarisk to repopulate floodplains rapidly, is a matter for some discussion.[2]

Saltcedar in Arizona has hybridized; it sets seed and germinates throughout the long Southwestern growing season (Horton 1960, Horton et al. 1960), and it is hypothesized that storage facilities which hold back winter-spring runoff and release water irregularly during the summer months favor the establishment of this adventive at the expense of native riparian communties. The aggressive ability of saltcedar to outcompete native riparian species after summer flooding has been well demonstrated by Turner (1974) and Warren and Turner (1975). Nonetheless, saltcedar now provides satisfactory and important nesting sites for mourning and white-winged doves (Carr 1960, Shaw 1961, Wigal 1973 and others). Several thousand acres of federal land along the Gila River, much of which is saltcedar and mesquite, have been withdrawn for these species under Public Law 1015 as the "Fred Weiler Greenbelt". Other areas receiving some degree of protection include the mesquite bosques on the Black Butte Wildlife Management Area, maintained by the Arizona Game and Fish Department, and Tonto National Forest lands along the Verde River. The high demands placed on both mesquite wood and ground water, however threaten all remaining bosques (see e.g., Lacey et al. 1975).

III. Subtropical Evergreen Forest

This complex tropic-subtropic formation has its northern terminus in moist canyons and warm springs in and adjacent to the Sonoran Desert in Arizona and California, where it is represented by stands of California fan palm (Washingtonia filifera). In Arizona native groves--but not all individuals--are limited to two canyons in the Kofa Mountains (Benson and Darrow 1954, Smith 1974), to three sites at end near Alkali Springs in the Hieroglyphic Mountains (Brown et al. 1976) and possibly Cienega Springs near Parker (fig. 7). Because of their miniscule acreage and disjunct occurrence, these communities lack the characteristic vegetational and faunal associates of more southerly subtropic evergreen forests and possess instead distinctive Sonoran oasis associates (Vogl and McHargue 1966, Brown et al. 1976). That these relics of the Miocene and Pliocene remained at all in Arizona was due to the continual presence of abundant subsurface waters in favored tropic-subtropic microenvironments. One also suspects that the adaptibility of this species to alkaline waters may have been a competitive advantage with certain warm temperate forms.

Figure 7.--Subtropical riparian evergreen forest; California fan palm series at Cienega Springs, Yuma County, Arizona. Abundant reproduction frequently characterizes native palm groves in Arizona; the fan palms, tolerant of alkaline waters, have outcompeted their cottonwood-willow competitors over the years at this and other sites.

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[2]For a discussion of the salt secretion abilities of saltcedar see Decker 1961.

California fan palms are attractive trees, and their adaptibility to cultivation has made them an ubiquitous ornamental landscape feature throughout the Southwest. The few native communities are considered botantical phenomena to be maintained with a minimum of disturbance. The palms in Palm Canyon, Hidden Canyon and elsewhere have had their shag of dead fronds burned but otherwise appear in good condition, with some reproduction noted. Palm groves and individuals in the Kofa Mountains are within the Kofa Game Range and are under the jurisdiction of the United States Fish and Wildlife Service. The palms at Alkali Springs and Cienega Springs are privately owned.

IV. Riparian Scrublands

While riparian scrub communities cover extensive areas of stream channels and flood plains, scientific investigations and resource managers have generally ignored them and concentrated on the more interesting and diverse communities upstream and downstream. They are, nonetheless, both interesting and important.

Above 8500 feet, a boreal riparian scrub is usually present along subalpine streams and in some wetlands. These scrublands are dominated by scrub willows (Salix bebbiana, S. scouleriana), although red-osier dogwood (Cornus stolonifera), blueberry elder (Sambucus glauca), rocky mountain maple (Acer glabrum) and thin-leaf alder (Alnus tenuifolia) may be locally important, particularly downstream as one approaches and enters more cold temperate conditions (fig. 8). Occasional trees such as blue spruce (Picea pungens) and aspen (Populus tremuloides) may stand out within the scrub. These streamside scrublands are nesting habitat for dusky flycatchers (Empidonax oberholseri), MacGillivary warblers (Oporornis tolmiei), orange-crowned warblers (Helminthophila celata), broad-tailed hummingbirds (Selasphorus platycercus), white-crowned sparrows (Zonotrichia leucophrys) and Lincoln sparrows (Melospiza lincolni). The perennial streams are themselves the habitat of the native Arizona trout (Salmo apache) and the now ubiquitous rainbow (Salmo gairdneri). These stream habitats are subject during the summer months to extensive and intensive livestock grazing, including use by sheep. Stream quality has also been altered by logging activity on adjacent watersheds, a situation which can be expected to increase with the demand for timber resources.

In temperate and subtropic situations in intermittent and perennial stream channels and in and along flood channels one also encounters riparian scrublands (fig. 9). Stream flows in these types are irregular and often occur in the form of flash floods. Dominant species are frequently but not necessarily seepwillow or batamote (Baccharis glutinosa), broom (Baccharis sarothroides or B. emoryi), arroweed (Pluchea sericea), and, increasingly, saltcedar. The reasons for the increase in saltcedar at the expense of the native seepwillow since 1940 have been discussed earlier and are well documented by Horton et al. 1960, Zimmerman 1969, Turner 1974, and Warren and Turner 1975. Riparian scrub may exhibit a dense "chaparral" aspect--scrubland--or present a very open one--desertscrub. Desert willow (Chilopsis linearis), mesquite, catclaw (Acacia greggi) and other arboreal species are frequent associates and may share aspect dominance. These trees as well as those of the riparian deciduous forest, if present, provide less than 15 percent of the ground cover. Faunal relationships within these riparian communities are poorly investigated, but there appears to be a considerable interaction with greater or lesser populations of adjacent or upslope nonriparian species. Bird species particularly well represented in riparian scrub include the Say's phoebe (Sayornis saya), crissal thrasher (Toxostoma dorsale), black-tailed gnatcatcher (Polioptila melanura), phainopepla (Phainopepla nitens) and the brown towhee (Pipilo fuscus). To date, little attempt has been made to "manage" these habitats.

Figure 8.--Montane riparian deciduous scrubland; Mixed series along the North Fort of White River, Fort Apache Indian Reservation; ca. 7500 ft., July, 1977. Prevalent and dominant plants here include two willows, thin-leaf alder, blueberry elder, and hawthorn (Crataegus erythropoda).

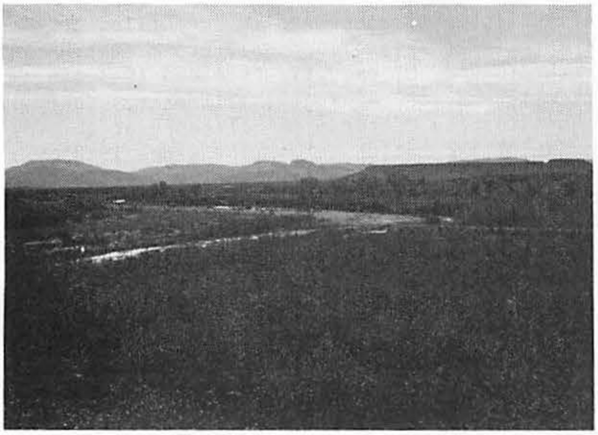

Figure 9.--Evergreen riparian scrubland in the channel of the San Carlos River, San Carlos Indian Reservation; ca. 3200 ft., March, 1975. The thick "Chaparral" in foreground is largely seep-willow or batamote. The deciduous scrub is mostly saltcedar. Note the decadent stand of cottonwood along the bank in the distance.

Figure 10.--Saltwater marshland; Saltgrass series at Obed Meadows, Navajo County, Arizona. Saltgrass occupies wetland and riparian areas throughout Arizona's subtropic and temperate zones wherever alkaline habitats exist. The deciduous trees in background are the now ubiquitous saltcedar.

V. Marshlands

These wetland formations may be comprised if any of several boreal, temperate or subtropical emergent communities and are defined as aquatic communities, the principal plant constituents of which are emergents not trees, woody shrubs, or nonhalophytic grasses [3], and which normally or regularly have their basal portions annually, periodically or continually submerged. In the Southwest these include communities in both fresh or brackish water environments. They range from the more xeric and alkali communities of salt grass (Distichlis stricta), and alkali bulrush (Scirpus paludosus) through the carrizo or reed communities (Phragmites communis) of the Colorado River and elsewhere to mesic freshwater communities of rushes (Juncus spp.), sedges (Carex spp.). bulrushes (Scirpus spp.) and cattail (Typha spp.) (fig. 10, 11).

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[3] Riparian grasslands of sacaton (Sporobolus wrightii), tobosa (Hilaria mutica) and other communities, while not discussed, occur in Arizona and the Southwest. See Lowe (1964) for a discussion of tobosa swales. Saltgrass communities are treated here as part of the marshland formation.

Figure 11.--Freshwater marshland; Topock Marsh looking north from north dike, Mohave County, ca. 550 ft. Bullrush and cattail are the principal vegetational constituents in foreground. This famous marsh is one of the few remaining on the Colorado River and is an important breeding area for the Yuma clapper rail. Photo by Richard L. Todd

These rapidly disappearing communities are found in riparian and littoral situations only where streamflow is turgid, shallow and dependable enough to permit their establishment. Since they are the most mesic of Arizona's vegetational and biotic communities, they have suffered most from the resultant desiccation of the state's natural environment through water diversions and water "management" projects (see e.g., Ohmart ca. 1974). The few riparian marshland communities that remain are habitats for a number of species of Arizona's rare and vanishing wildlife, such as the Yuma clapper rail (Rallus longirostris), black rail (Laterallus jamaicensis), bitterns (Ixobrychus exilis, Botaurus lentiginosus), and Mexican duck (Anas diazi) (Todd 1972a). Numerous other rails, shorebirds, and waterfowl are highly dependent on these diverse environments, both during nesting and migration (Todd 1972a). These marshland oases are now frequently dependent on stored and/or recycled argricultural and industrail waste waters from diverted upstream flow. Examples in Arizona are Picacho Lake in Pinal County and Quigley Pond on the Gila River in Yuma County (see also Brown et al. 1977). Exceptions are a few sloughs and old oxbows of the San Pedro, lower Salt, Verde and Colorado Rivers, almost all of which are threatened by existing or planned projects. It is also an ironic fact that Arizona's most valuable wildlife habitats are too frequently subjected to trampling and grazing by livestock, in addition to hydrological limitations.

VI. Recommendations

It has become increasingly evident that the most valuable and interesting of Arizona's streamside environments are greatly in need of more enlightened management of both the actual riparian communities and the watersheds upon which they depend. Their present limited acreage and importance to endangered, threatened, and peripheral wildlife species have prompted a growing concern by wildlife-oriented groups and individuals in addition to the concern long voiced by professional biologists. This concern has now manifested itself in the political arena and requires that our riparian environments receive greater consideration from resource management agencies.

The following recommendations are suggested to perpetuate and enhance those riparian communities of greatest value to wildlife and public interest:

1. Identify and classify Arizona's riparian environments. Identification and mapping of streamside vegetation is presently either being considered or in the process of inventory by land management agencies, other public agencies, academic groups and ad hoc consultants. These efforts should be coordinated and classifications of the various types determined. A statewide inventory, including maps, of remaining habitats should be prepared and published.

2. Investigate factors determining the limiting specific riparian constituents and communities. The environmental requisities and limits of many of the major riparian plant species must be determined, at least in part. These would of necessity be long-range and continuous studies to provide an understanding of the factors controlling the various communities and their constituents. Only then can we hope to preserve and manage our riparian constituents through regulated discharges of water from reservoirs, selective cutting and other techniques.

3. Establish representative study areas containing all major riparian communities and their surface and groundwater requirements. In addition, as reserves these areas would provide "bench marks" and controls for comparison with "managed" or other "modified" ecosystems.

4. Grazing and other distruptive influences should be eliminated or controlled in riparian forests, woodlands and marshlands. Many of these have had their public values compromised through the degradation of their flora and fauna. Areas presently supporting little or no understory and showing no reproduction of major riparian constituents should be restored where still possible.

5. Riparian and watershed management project planners should reconsider the values both actual and potential of streamside vegetation before irreversible alterations. Several "phreatophyte clearing" projects have resulted in unwarranted destruction of native riparian associations with little or no documented water "salvage" or other claimed conservation measures accomplished (Campbell 1970, Horton 1972, Patrick 1971).

6. Increase the effort to avoid torrential summer and fall flooding through more conservative use of grazing and timbering watershed resources. Shrub invasions of Southwestern watersheds, due to livestock grazing pressures and suppression of fire, have long been documented (see e.g., Leopold 1924, Humphrey 1958). Through proper management, streamflows can be stabilized and increased to the benefit of our riparian resources. These management techniques should be applied now throughout our rapidly deteriorating Southwest riparian wonderland.

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Terrestrial Mammals of the Riparian Corridor in Big Bend National Park[1]

William J. Boeer and David J. Schmidly[2]

Abstract.--Thirty species of terrestrial mammals inhabit riparian habitats in Big Bend National Park (BBNP), but only one species (the beaver, *Castor canadensis*) is restricted to these areas. Major changes in the vegetation during the past 30 years, involving an increase in basal and canopy cover, have resulted in the elimination of at least one species (*Dipodomys ordii*) from the river corridor as well as increased abundance and distribution for two other species (*Sigmodon hispidus* and *Peromyscus leucopus*). Compared to the other major plant communities in BBNP, the rodent fauna of the riparian community has lower evenness, richness, and diversity indices (based on the Shannon-Weaver Index). Human use and trespass livestock grazing are the major impacts acting upon the natural riparian communities in BBNP today.

INTRODUCTION

Mammalian studies of the Big Bend area began with general surveys (Bailey 1905; Johnson 1936; Borell and Bryant 1942; and Taylor *et al.* 1944) designed to identify and document the varied fauna of the area. After the park was established, the perspective of mammalian research changed somewhat and in recent years studies have concentrated on mammalian autecology and synecology (Porter 1962; Dixon 1958; and Easterla 1973). Most mammalian studies have focused on the mammals of the montane woodland and desert grassland habitats. There have been no comprehensive studies of riparian mammals. Baccus (1971) investigated the distribution of rodents in the park with respect to the major physical features, focusing on the effects of the elimination of grazing on the vegetation and the rodent populations. He also described the similarities and dissimilarities of the rodent faunas of the woodland, grassland, and desert shrub communities; however, he divided the fauna of the Rio Grande floodplain between the desert shrub and grassland communities and did not consider the riparian corridor as a unique habitat.

[1]Contributed paper, Symposium on the Importance, Preservation and Management of the Riparian Habitat, July 9, 1977, Tucson, Arizona.

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DESCRIPTION OF THE RIPARIAN CORRIDOR

Floodplain or riparian vegetation exists wherever periodic flooding occurs along the Rio Grande in BBNP. These riparian communities vary from areas a few meters (m) wide to areas extending inland a distance of one kilometer (km); furthermore, adjacent arroyos and creeks may carry enough surface or ground water to produce a similar floodplain environment. Topography along the river includes (1) sheer wall canyons (i.e., Santa Elena and Mariscal canyons which rise to elevations of 366 m) with few areas of alluvial deposits; (2) long deep canyons (i.e., Boquillas Canyon) where the walls do not rise abruptly and where larger areas of alluvial deposits occur; and (3) areas of broad flat floodplain with extensive alluvial deposits.

Denyes (1956) recognized three plant associations along the Rio Grande floodplain: (1) the riverbank association, consisting of mesquite (*Prosopis juliflora*), seep willow (*Baccharis* sp.), willow (*Salix gooddingi*), or cottonwood (*Populus palmeri*), located adjacent to areas of exposed silt and coarse gravel at the water's edge; (2) the *Baccharis* association, composed of dense stands of seep willow; and (3) the mesquite association, consisting of a thin line of extensive mesquite trees or an extensive area of several different plant forms. We have found these three associations to be somewhat altered from Denyes' description and, although difficult to document, our general impression is that significant vegetation changes have occurred in the riparian habitats of BBNP over the past 30 years. The major change is associated with the tremendous increase of salt cedar (*Tamarix chinensis*) along the river. The *Baccharis* association, mentioned by Denyes (1956) as common in the fine sandy loam soils along the river, is recognizable today only at a few places (for example, Black Dike) and appears to have been replaced by a mixed mesquite-salt cedar-bermuda grass (*Cynodon dactylon*) association. Similarly, salt cedar also appears to be replacing native cottonwood and willow trees at many places.

MAMMALIAN FAUNA OF THE RIPARIAN CORRIDOR

Thirty species of terrestrial mammals have been either collected or observed in the riparian habitats of BBNP. These are listed below in checklist fashion with their current status (C = common; U = uncommon; R = rare; E = previously present, but no longer occurs; P = possibly occurs) in the park.

- Pouched Mammals - Order Marsupialia
  - Opossum - Family Didelphidae
    - Virginia Opossum *Didelphis virginiana* - P
- Lagomorphs - Order Lagomorpha
  - Hares and Rabbits - Family Leporidae
    - Desert Cottontail *Sylvilagus audubonii* - C
    - Black-tailed Jack Rabbit *Lepus californicus* - U
- Rodents - Order Rodentia
  - Squirrels - Family Sciuridae
    - Texas Antelope Squirrel *Ammospermophilus interpres* - R
    - Mexican Ground Squirrel *Spermophilus mexicanus* - R
    - Spotted Ground Squirrel *Spermophilus spilosoma* - U
  - Pocket Gophers - Family Geomyidae
    - Yellow-faced Pocket Gopher *Pappogeomys castanops* - C
  - Pocket Mice - Family Heteromyidae
    - Silky Pocket Mouse *Perognathus flavus* - U
    - Desert Pocket Mouse *Perognathus penicillatus* - C
    - Nelson's Pocket Mouse *Perognathus nelsoni* - R
    - Ord's Kangaroo Rat *Dipodomys ordii* - E
    - Merriam's Kangaroo Rat *Dipodomys merriami* - C
  - Beaver - Family Castoridae
    - Beaver *Castor canadensis* - U
  - New World Rats and Mice - Family Cricetidae
    - Cactus Mouse *Peromyscus eremicus* - U
    - White-footed Mouse *Peromyscus leucopus* - C
    - Deer Mouse *Peromyscus maniculatus* - R
    - Hispid Cotton Rat *Sigmodon hispidus* - C
    - Southern Plains Woodrat *Neotoma micropus* - C
  - New World Porcupines - Family Erethizontidae
    - Porcupine *Erethizon dorsatum* - R
- Carnivores - Order Carnivora
  - Dogs and Relatives - Family Canidae
    - Coyote *Canis latrans* - C
    - Gray Fox *Urocyon cinereoargenteus* - U
  - Raccoons - Family Procyonidae
    - Ringtail *Bassariscus astutus* - U
    - Raccoon *Procyon lotor* - C
  - Weasels and Relatives - Family Mustelidae
    - Striped Skunk *Mephitis mephitis* - U
    - Western Spotted Skunk *Spilogale gracilis* - R
    - Hog-nosed Skunk *Conepatus mesoleucus* - R
  - Cats - Family Felidae
    - Mountain Lion *Felis concolor* - R
    - Bobcat *Felis rufus* - U
- Even-toed Ungulates - Order Artiodactyla
  - Peccaries - Family Tayassuidae
    - Collared Peccary (Javelina) *Dicotyles tajacu* - U
  - Deer - Family Cervidae
    - Mule Deer *Odocoileus hemionus* - U

During 1975-1976, we sampled small rodents at 18 different sites along the riparian corridor. Each site was trapped (using Sherman live traps) a total of 720 trap nights resulting in 12,960 trap nights for the entire river corridor. A total of 1,292 rodents representing two families (Heteromyidae and Cricetidae) were captured as follows (number trapped in parentheses): Family Heteromyidae: *Perognathus penicillatus* (896); *Perognathus nelsoni* (2); *Perognathus flavus* (5); *Dipodomys merriami* (65). Family Cricetidae: *Peromyscus leucopus* (162); *Peromyscus eremicus* (19); *Sigmodon hispidus* (70); *Neotoma micropus* (73). *Perognathus penicillatus* was overwhelmingly the most abundant small rodent in the riparian habitats and, for this reason, the total density of heteromyid rodents was greater than that of cricetid rodents. The three other heteromyid rodents were relatively rare along the river, although *D. merriami* was common at a few sites. Densities of the four species of cricetid rodents were more similar to one another than the densities of the heteromyid species. *Peromyscus leucopus* was the most common cricetid and *P. eremicus* the least common; *Sigmodon hispidus* and *Neotoma micropus* occurred in about equal numbers.

Borell and Bryant (1942) also found *Perognathus penicillatus* to be the most abundant rodent in the riparian corridor. However, comparing our data with that of Borell and Bryant (1942) for three other species (*Dipodomys ordii*, *Peromyscus leucopus*, and *Sigmodon hispidus*) reveals that significant changes in abundance and distribution have occurred in these species over the past 30 years. These differences correlate with major vegetative changes associated with the cessation of extensive livestock grazing. Early accounts (Taylor *et al.* 1944; Sperry 1938) describe the vegetation along the river as open and severely over-grazed. However, since ranching activities ceased at the inception of the park, plant densities seem to have increased greatly so that at several places (e.g., Johnson Ranch) mesquite forests now occur where the river bottom was once open and sparsely vegetated. Extensive fields of grass also occur today at sites (e.g., Smoky Creek and Coyote) which formerly were cultivated and farmed.

Generally, cricetid rodents prefer habitats with considerable ground cover. Thus, the increased density of grass and cane (*Phragmites communis*) along the riparian corridor, as a result of the elimination of grazing, has served to substantially increase suitable habitat for these rodents. Two cricetines (*Sigmodon hispidus* and *Peromyscus leucopus*) exemplify this trend. Borell and Bryant (1942) collected only four specimens of *Sigmodon hispidus* along the river among the cane and cultivated fields around the Johnson Ranch. We recorded 70 cotton rats from 12 different localities along the river in areas where thick bermuda grass, cane, and fleabane (*Erigeron* sp.) were present. Similarly, Borell and Bryant (1942) reported taking a few *Peromyscus leucopus* along the river from one mile SW Boquillas and the Johnson Ranch. Our trapping records indicate that *P. leucopus* is now one of the most common rodents of the riparian corridor and this mouse occurs all along the river from the mouth of Santa Elena Canyon to Rio Grande Village.

Ord's kangaroo rat (*Dipodomys ordii*) is a species which apparently has completely disappeared from the riparian corridor during the past 30 years. This species was first reported from BBNP in 1939 by M. D. Bryant who described a distinct subspecies (*D. o. attenuatus*) from the mouth of Santa Elena Canyon. In 1944, Dr. William B. Davis (pers. comm.) collected two specimens from the type locality and another from the Johnson Ranch. There have been no additional specimens captured along the Rio Grande since then, although Baccus (1971) trapped at the mouth of Santa Elena Canyon, the Johnson Ranch, and other sites along the river. In over 13,000 trap nights along the river, including efforts at the type locality and the Johnson Ranch, we failed to capture a single *D. ordii*. Baccus (1971), however, did obtain a few specimens from Upper Tornillo Creek Bridge (16 km NE Panther Junction), and this apparently represents the only remaining population of this subspecies in BBNP.

In order to ascertain the status of *D. o. attenuatus*, we spent eight days (from 4 April 1976 to 12 April 1976) trapping at Upper Tornillo Creek Bridge and other places where this species had been previously collected. Initially, 70 traps were set on both the east and west side of Upper Tornillo Creek. Later, the number of traps was increased to 110 on the west side and 160 on the east side. The traps were set out in various soil and vegetation types ranging from deep sand-sparse burro-brush (*Hymenoclea monogyra*), to packed sand-mesquite and gravelly-creosote (*Larrea divaricata*) flats. A total of 18 *D. ordii* and 21 *D. merriami* were caught during the first two nights of trapping. Thirty traps were also set at Lower Tornillo Creek Bridge and 120 were placed along Terlingua Creek where it enters the mouth of Santa Elena Canyon. Most of the Lower Tornillo Creek area was a creosote flat with clumps of catclaw (*Acacia greggii*) and lechuguilla (*Agave lechuguilla*) next to the creek bed. The dry creek bed itself was very rocky and surrounded a small knoll of deep sand covered with little vegetation. Eight traps were placed on this knoll and 22 in the surrounding flats adjacent to the creek bed. A single *D. ordii* was captured on the knoll and nine *D. merriami* were captured on the flats. At Terlingua Creek, the traps were placed in a sandy area and 10 *D. merriami* were captured.

A trapping grid established at Upper Tornillo Creek consisted of 10 lines of 40 traps per line with each trap 18 m apart; each line was 36 m apart. With regard to vegetation and soil, three distinct habitats (designated A, B, and C) were delineated on the grid. Habitat A was on the first floodplain stage adjacent to the creek and consisted of a very open area of deep sandy soil with burro-brush and a few desert willow (*Chilopsis linearis*) comprising the dominant vegetation. Habitat B included the second floodplain stage and consisted of a sandy but more compact soil with a moderate cover of vegetation including creosote, whitethorn (*Acacia constricta*), mesquite, burro-brush, grass, and prickly pear (*Opuntia* sp.). Habitat C was located on a bench about 3-4 m above habitats A and B. The soil was very compact and the vegetation moderate to thick. Typical desert vegetation, consisting of clumps of mesquite, prickly pear, allthorn (*Koeberlinia spinosa*), creosote, and tasajillo (*Opuntia leptocaulis*) were interspersed throughout habitat C.

The total number of captures of *D. ordii* and *D. merriami* for each of the 10 trap lines is presented in Table 1. The percentage of captures of *D. ordii* for each of the three habitat types was as follows: habitat A, 66.1%; habitat B, 30.6%; habitat C, 3.2%. Thus, *D. ordii* was most common in the deep,

Table 1.--Four day capture totals by trap line for *Dipodomys ordii* and *Dipodomys merriami* at Upper Tornillo Creek Bridge.

Habitat type	Trap line	Total captures	*D. ordii* captures	*D. merriami* captures	Percent *D. ordii*	Percent *D. merriami*
A	1	29	25 (40.3)[1]	4 (5.8)[1]	86.2	13.8
	2	20	16 (25.8)	4 (5.8)	80.0	20.0
B	3	11	3 (4.8)	8 (11.6)	27.3	72.7
	4	10	5 (8.1)	5 (7.2)	50.0	50.0
	5	18	7 (11.3)	11 (15.9)	38.9	61.1
	6	11	1 (1.6)	10 (14.5)	9.1	90.0
	7	8	5 (8.1)	3 (4.3)	62.5	37.5
C	8	19	0	19 (27.5)	0.0	100.0
	9	5	0	5 (7.2)	0.0	100.0
	10	0	0	0	0.0	0.0

[1]Represent percent of total catch of *D. ordii* or *D. merriami* in a particular trap line.

sandy and sparsely vegetated areas of the first floodplain stage and decreased in number in habitats away from the creek bottom. The percentage of captures of *D. merriami* for each of the three habitat types was: habitat A, 11.6%; habitat B, 50.7%; and habitat C, 37.7%. Thus, *D. merriami* was more generally distributed throughout the three habitats but was much less common in habitat A where *D. ordii* dominated. *D. merriami* seemed to prefer areas where the soil was more compact or gravelly and the vegetative cover was greater.

Dr. William B. Davis trapped at the Johnson Ranch and the mouth of Santa Elena Canyon in the early 1940's and his description of the vegetation there is completely different from what these areas are like today. According to Davis (pers. comm.), the river bank at the Johnson Ranch was a very open sandy area and was used as a river crossing point for Mexicans and cattle. The mouth of Santa Elena Canyon, according to Davis, was also a sandy, open area with a considerable growth of *Baccharis*. Davis collected Ord's kangaroo rat at both of these locations. Today, the Johnson Ranch and the mouth of Santa Elena Canyon are more like mesquite forests with very little open terrain. In over 1,500 trap nights at these two locations, not a single *D. ordii* was captured, although 15 *D. merriami* (two at Johnson Ranch and 13 at the mouth of Santa Elena Canyon) were collected. In fact, after examining the entire riparian corridor in BBNP, the only place which seeminly had suitable habitat for *D. ordii* was the Gaughing Station. Trapping at this site (720 trap nights), however, produced 15 *D. merriami* and no *D. ordii*. *D. ordii attenuatus* now seems to be confined to the first and second floodplain stages of Tornillo Creek in BBNP and no longer occurs along the river or at the type locality.

Another mammal affected by vegetative changes in the riparian corridor is the beaver which, more than any other mammal in BBNP, is dependent on the riparian corridor for food and shelter. Beaver along the Rio Grande utilize a variety of plants including cane, seepwillow, willow, and cottonwood. Cottonwoods occur today only in park service nurseries at Rio Grande Village and Cottonwood Campground; salt cedars are rapidly replacing cottonwoods and willows at other sites. For example, the Gauging Station is one of the few areas where extensive stands of willow still exist, and these are currently being used as a food source by beavers. Nowhere along the river corridor is there any evidence of beaver using salt cedar. As a result, beavers are literally eating themselves out of "house and home" because they utilize willow saplings for food and leave only salt cedar saplings which they will not use. Taylor *et al.* (1944) reported a beaver population of approximately 100 individuals for the river corridor. However, conversations with park personnel and the evident lack of beaver sign along most of the river indicate the beaver population today is well below the figure reported by Taylor *et al.* (1944).

The Shannon-Weaver Index of Diversity (Odum 1971) was used to compare the rodent fauna of the riparian community with that of the woodland, grassland, and desert shrub communities in BBNP. This index reveals information concerning the stability of a community in terms of its fauna. Compared to the other plant communities, the riparian community has the lowest evenness, richness, and diversity

Table 2.--Shannon-Weaver Index of diversity for the terrestrial rodent fauna of the four major plant communities in BBNP.

Parameters	Communities			
	Riparian[1]	Desert-shrub[2]	Grassland[2]	Woodland[2]
Diversity ($\bar{H}$)	1.157	2.008	2.249	1.849
Evenness (e)	.465	.783	.793	.771
Richness (d)	1.523	1.854	2.912	1.596
No. of Species	12	13	17	11

[1]Data from Schmidly *et al.* (1976a, table 20, p. 94).

[2]Data from Baccus (1971, table 10, p. 49).

indices (Table 2). In particular, the evenness value (0.465) for the riparian community is considerably lower than that of the other communities, indicating that one or two species tend to dominate the rodent fauna of this community. This is evident when examining the total catch figures along the riparian corridor. The two dominant species of the riparian community are *Perognathus penicillatus*, with a total of 924 individuals or 67.7% of the total catch, and *Peromyscus leucopus*, with a total of 162 individuals or 11.9% of the total catch. The grassland is the most diverse community, having the highest diversity, evenness, and richness indices as well as the greatest number of species (17). The desert-shrub, although it only has 13 species (one more than the riparian community), is a more diverse community because it has a more even distribution, which is indicated by the fact that the dominant species (*Perognathus penicillatus*) in this community accounts for only 38.6% of the total catch as compared to 67.7% for the riparian community.

IMPACTS IN THE RIPARIAN CORRIDOR

In recent years, many riparian areas along the Rio Grande have been impacted by human activity. Around El Paso and Presidio, man has destroyed or greatly altered natural riparian natural habitats through water salvage, cultivation and grazing. The International Boundary and Water Commission is presently considering a boundary restoration project along the Rio Grande from Fort Quitman (Hudspeth County) to Presidio (Presidio County). This project would straighten the channel of the river and result in the virtual destruction of riparian habitats along this stretch of the Rio Grande.

Human use (floating and camping) and trespass livestock grazing are the major impacts acting upon the natural riparian communities in BBNP today. In 1975 the Rio Grande accounted for 49% of the total backcountry use (in man-days) in BBNP (Ditton *et al.* 1976). Twenty-five percent of this use was float trips on the Rio Grande and 24% involved camping at primitive sites along the River Road. Schmidly *et al.* (1976b) used correlation analysis to investigate the relationship among human use, impacts, and biological parameters (i.e., rodent fauna and vegetation) at 18 riparian sites in BBNP. Their results revealed a positive and significant relationship between total subjective human impact ratings and annual camping use by site (man-days). However, the extent of human impact did not correlate significantly with rodent densities or vegetative parameters at the 18 sampling sites. Thus, correlation analysis revealed that site impacts have occurred as a result of recreational use, but not to the point where ecological conditions, as indicated by the biological health of the rodent fauna and vegetation, are in jeopardy (Schmidly *et al.*1976b).

Domestic mammals also occur in the riparian corridor and pose a major problem. The increase in grasses over the past 30 years has provided forage that is not available in the same quantity or quality across the river in Mexico. As a result, trespass livestock from Mexico are invading the riparian corridor in increasing numbers. Grazing by trespass livestock is a constant feature of almost all riparian sites and is not confined to one particular region or section of the river. Should this grazing activity continue to increase, it could have dangerous repercussions on the existing vegetation of the riparian corridor. Hence, dealing with the livestock problem may prove more difficult for park managers than dealing with human use and impacts which tend to be concentrated in some areas and virtually absent in others.

CONCLUSIONS

Analysis of small mammals, vegetation,

and impacts along the Rio Grande in BBNP has led to five important conclusions: (1) Major vegetative changes (including the replacement of cottonwoods and willows by salt cedar as well as a tremendous increase in basal and canopy cover) have occurred over the past 30 years. (2) These vegetational changes have resulted in an alteration of the rodent fauna so that certain species which were once rare in riparian habitats (i.e., cricetids such as *Sigmodon hispidus* and *Peromyscus leucopus*) have increased their numbers and ranges along the river, whereas other rodents which were once common (i.e, *Dipodomys ordii*) no longer exist in the riparian corridor. (3) The increase in vegetative cover, especially grasses, has caused a reinvasion of domestic livestock (trespass livestock from Mexico) into the riparian corridor and this may have potentially serious repercussions on the vegetation. (4) Impacts at certain riparian sites have occurred as a result of recreational use, but not to the point where ecological conditions are in jeopardy. Human impacts seem to be confined to areas of convenient access. (5) The riparian community (as revealed by Shannon-Weaver Index) is less stable than the other major communities in BBNP and possibly would be more susceptible to greater oscillations resulting from increased impacts (either human or livestock).

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Johnson, R. Roy, and Dale A. Jones, tech. coord. 1977. Importance, preservation and management of riparian habitat: A symposium. [Tucson, Ariz., July 9, 1977.] USDA For. Serv. Gen. Tech. Rep. RM-43, 217 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Twelve presented and 15 contributed papers highlight what is known about this unique, diminishing vegetative type: characteristics, classification systems, associated fauna, use conflicts, management alternatives, and research needs. Speakers stressed the continuity and interrelationships of riparian ecosystems, their wildlife and vegetation, historic and current uses.

Keywords: Riparian habitat, endangered habitats, aquatic ecosystems.

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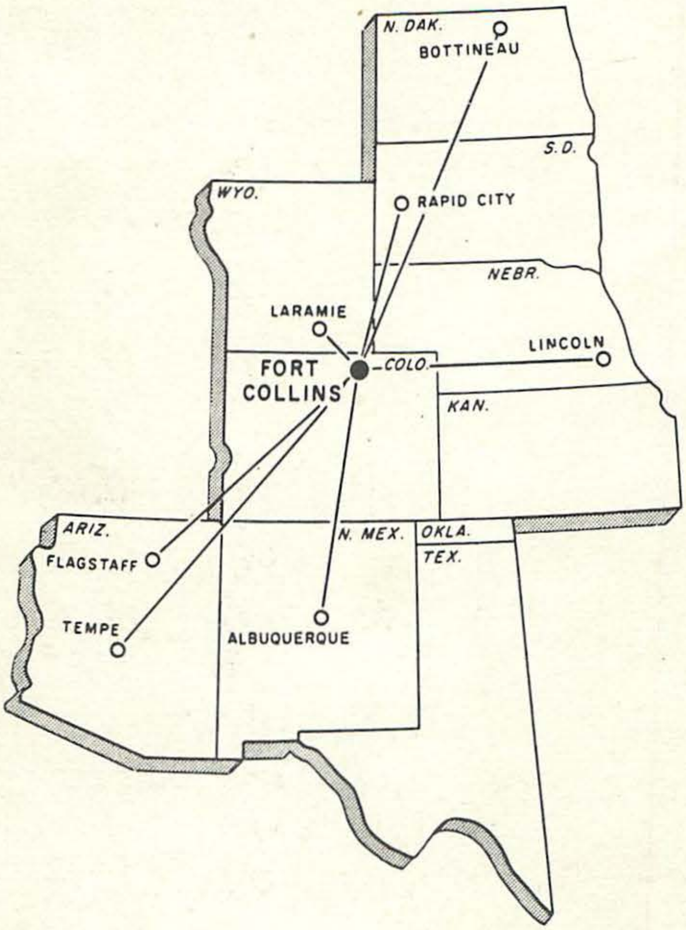
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