Ephemeral Drainages in the Southwestern United States: a Literature Review

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INTRODUCTION

In recent years, there has been an emphasis on perennial riparian areas, that is, streams that flow water throughout the year. State and federal agencies and conservation organizations have participated in hosting numerous workshops about managing and restoring of perennial riparian systems. The importance of these corridors to wildlife, especially birds, has been documented by several authors (Anderson et al. 1977a, Leal et al. 1996, Stevens et al. 1977, Yong and Finch 1996). However, little has been published about ephemeral drainages in the arid Southwest. It is speculated from the observations of various ecologists and conservationists (Dick-Peddie and Hubbard 1977, Freeman and Dick-Peddie 1970) that ephemeral drainages are important to wildlife, and may act as corridors between the desert floor and higher elevation habitats. However, little has been done to quantify the vegetation or the wildlife use of ephemeral drainages.

Interest and concern for the protecting and managing perennial riparian corridors has been supported by regulations and definitions pertaining to wetlands. This effort has increased since the inception of the National Environmental Policy Act (NEPA) of 1969. Four federal agencies provide regulating authority for wetlands: the U.S. Army Corps of Engineers (USACE), the Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), and the Natural Resources Conservation Service (NRCS). Each agency provides a different definition of a wetland depending on the agency's function. However, all agencies include in their definition three basic elements: hydrology, vegetation, and soil characteristics (Mackenthun and Bregman 1992).

The EPA and USACE have adopted the definition of wetland from the Clean Water Act, Section 404 (Mackenthun and Bregman 1992):

> *Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.*

It is important to note that this definition identifies saturated soil conditions and a prevalence of vegetation suited to saturated soils. The presence of indicator species such as cattails that grow only in saturated, conditions has been used to identify wetlands.

Arroyos and ephemeral drainages or wadis do not contain saturated soil conditions and do not qualify as wetlands by the EPA definition. However, they do support plant species that do not grow on other sites. They also support a variety of wildlife species and appear to be critical habitat. However, little research has been done to quantify plant or animal species occurring in the ephemeral drainages. Studies are needed to test if ephemeral drainages support unique species or a higher species richness compared to the adjacent watershed.

A review of the literature indicates that only three studies have been conducted on the vegetation of ephemeral drainages in New Mexico (Browning 1989, Dick-Peddie and Hubbard 1977, Freeman and Dick-Peddie 1970). Other research has been conducted on perennial streams and arroyos.

Mismanaging ephemeral drainages and their associated uplands may lead to accelerated erosion and ar-

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royos forming downstream (Meyer 1992). For these reasons, we have included in the literature review excerpts on research and observations from both perennial riparian corridors and arroyos in the arid Southwest. Since little has been done in the Southwest on vegetation associated with ephemeral drainages, we have included the Israeli and Egyptian literature to learn more about the function of true ephemeral drainages, which are called "wadis" in that part of the world.

DEFINITIONS

Because words used throughout the literature are ambiguous, there is a need to establish terminology. Riparian systems have water flowing throughout the year; arroyos are caused by accelerated erosion; and ephemeral drainages are a natural feature of many watersheds in the arid Southwest characterized by seasonal flowing water or only during rainfall events.

Definition of Riparian

Some authors have expanded the definition of a riparian ecosystem to embrace perennial streams, ephemeral drainages, and arroyos. Kauffman and Krueger (1984) stated that a riparian ecosystem, including ephemeral drainages, consisted of "an assemblage of plant, animal, and aquatic communities whose presence can be either directly or indirectly attributed to factors that are stream-induced or related."

Pase and Layser (1977) used the adjective "riparian" to describe a condition where soil moisture is seldom limited. They inventoried 279,600 acres (114,000 ha) of riparian habitat in Arizona and estimated that 100,700 acres (40,800 ha) of the habitat were located along the Gila River. They also projected similar riparian acreage in New Mexico. However, they did not state how they measured the acreage or if it included ephemeral drainages. Personnel in New Mexico State University's Department of Geography have stated that the acreage figures presented by Pase and Layser are low for New Mexico. They also said that even with the most modern Geographic Information System (GIS), arriving at accurate figures for riparian habitat is a difficult task. The New Mexico Riparian Council (1995) has stated that a 1981 survey estimated 280,000 acres (113,310 ha) of riparian habitat in New Mexico. To date, there are no reliable estimates for the acreage of ephemeral drainages in New Mexico.

Dick-Peddie and Hubbard (1977) associated riparian habitat with a water course. They also identified phreatophyte vegetation as having roots in the water table or capillary fringe during a major portion of the growing season. They identified obligate riparian vegetation as restricted to a riparian-like situation including microsites. They identified facultative vegetation as plants other than obligate plants that are found in both riparian and upland situations.

Definition of Arroyo-Riparian

The word "arroyo-riparian" has evolved from the need to distinguish ephemeral streams from perennial water courses. In the Southwest, the word "arroyo" has been applied to drainages of recent geologic origin often produced by accelerated erosion resulting from man-initiated activity. Many of these drainages appeared on the landscape in the late 1800s after the Anglo settlement of the Southwest (Antevs 1952). "Pseudo-riparian" has been used to describe higher climax vegetation that fingers downward into drainages (Campbell and Green 1968). A riparian community has been described as having distinct climax vegetation from its immediate surroundings (Lowe 1964).

Cooke and Reeves (1976) suggested that arroyos are a recent feature across the Southwest. Their definition of an arroyo includes the accelerated erosion of once smooth grasslands and cienegas with high water tables. Accelerated erosion was initiated by over-use of the land due to agricultural practices and livestock grazing particularly in the 1880s.

Antevs (1952) said the term "arroyo" in the Southwest described a trench with a flat floor and vertical banks up to 30 m deep. Arroyos may be many tens of meters wide, and over 50 km long. They are incised in unconsolidated material, and carry water only from rain storms or melting snow.

Definition of a Wadi or Ephemeral Drainage

Conversely, there are desert washes incised in gravel that may or may not have experienced accelerated erosion from human activity including deforestation and livestock grazing. They are limited to the headwaters of valleys, occur in moist areas, and are limited in size, especially length. This type drainage is typically 4 m deep, 15 m wide, and 900 m long (Antevs 1952). It has been studied in Israel and Egypt and is frequently called a "wadi." Antevs (1952) suggested that this term be adopted to describe the drainages in the Southwest's mountain foothills that do not fit the descriptions of arroyos caused by accelerated erosion.

VEGETATIONAL CHARACTERISTICS OF EPHEMERAL DRAINAGES

Some studies of drainages' vegetation were restricted to trees and shrubs (Browning 1989, Freeman and Dick-Peddie 1970, Szaro and King 1990). Cover, density, and presence of individual plant species were measured in most studies. These data were frequently transformed to describe importance and diversity (Freeman and Dick-Peddie 1970, Malhotra 1973).

Species Richness

Species richness information was generally derived from plant density data, but not without some confounding or compromise by the techniques used. Szaro and King (1990) used the total number of species observed on a site as a diversity index. The researchers identified total species richness as the total number of different species observed on all plots within a sample area. Average species richness was calculated as total species richness divided by the number of plots in the sample area.

Szaro and King (1990) sampled trees along riparian corridors. They found that variability in total species richness was lower on more diverse sites and concluded that the variability in total species richness was a function of tree species frequency rather than tree species richness. The required sample size increased as tree species frequency decreased.

Szaro (1990) found few significant relationships among species presence and elevation, direction of stream flow, and stream gradient. But he did find significant density differences among different community types along these gradients.

Leitner (1987) found species density and richness were greater on north-facing slopes than south-facing slopes. He also found that arroyos had lower species richness, diversity, and density than the slopes. He excluded forbs from the density data and eliminated species that occurred in fewer than three plots.

Anderson et al. (1983) used wildlife density and species richness values typical of different habitats at various seasons to indicate their value to wildlife and to test ecological theories. They used principal component analyses (PCA) to summarize a complex data set of 16 variables and to provide a smaller set of principal components that corresponded to readily observable features in the field.

Diversity

The concept of diversity has become controversial and somewhat confusing. Diversity in the news may not be a measure of diversity at all, but rather a ploy to preserve habitat for a select few species (Mann and Plummer 1993). Diversity as a measurement is a complex characteristic and should be framed in the context of a spatial or temporal scale. For example, alpha diversity is a measure of within habitat or intracommunity diversity, which includes species richness (Chambers 1983). Although quantitative assessment of species diversity has been questioned by Hulburt (1971), it has been assessed through the use of diversity indices, rank correlation, and similarity indices (Chambers 1983, Whittaker 1970). Despite these conceptual problems, the idea of plant species diversity has important implications for ephemeral drainages. In a general sense species diversity represents the number of species and the number of individuals of each species.

Comparing diversity between sites on a larger spatial scale is a difficult task. Freeman and Dick-Peddie (1970) cautioned against making comparisons between drainages located on different mountain ranges in southern New Mexico. In comparing the Sacramento Mountains and the Black Range, they found that the Sacramento Mountains had a lower base-level elevation that would favor xeric conditions. The mass of a mountain range affects local thunderstorms (a mesic condition). Local geology also has an effect. Vegetation zones are highest (xeric condition) on limestone ranges such as the Sacramento Mountains, and higher on volcanic ranges such as the Organ Mountains that are rhyolitic, and lowest on granite (Freeman and Dick-Peddie 1970). Thus, factors on the Sacramento Mountains confound xeric and mesic conditions and make comparisons to other mountains difficult. Waters (1985) made similar precautions for drainages in southeastern Arizona.

On a local scale, Szaro (1990) noted that periodic disturbance plays an integral role in the establishment and development of southwest riparian ecosystems. Variation in species diversity is a function of disturbance rate; communities with a high species mix may indicate areas with a high disturbance rate or more recent disturbance. Species that are a result of frequent disturbance may be short-lived and may not be represented in other areas. Thus, obtaining adequate samples in space and time is extremely difficult, and challenges the validity of making comparisons.

Youngblood et al. (1985) detected a similar scenario when they inventoried more than 600 species along riparian corridors in the vicinity of the Idaho/Wyoming state line. A wide diversity of community types were identified based on species constancy and average cover data. However, the relative importance of a species in a given community type was often not reflected across community types. Although this is a reflection of high diversity between communities, it puts the researcher in the position of comparing data that are not comparable in terms of species composition.

MECHANICAL PROCESSES OBSERVED IN ARROYOS

Ephemeral drainages are a natural part of the landscape in desert watersheds. In deteriorated condition, they may contribute to arroyos forming downstream in their own course, or below alluvial fans at the mouth of their course.

The following discussion on formation and cause is primarily directed at arroyos that developed through accelerated erosion. It is not known if the same processes influence natural ephemeral drainages. However, knowledge of the processes may shape management decisions further upstream in the ephemeral drainages.

Initiation of Arroyo Cutting

Two schools of thought have been developed to explain how arroyos form in the West. One theory is that vegetative cover decreases due to heavy livestock grazing and/or climatic change to a drier or wetter climate. The other theory involves changes in the intensity of rainfall (Schumm and Hadley 1957). Proponents of the grazing theory cite the introduction of large herds of cattle into the West around 1870, and serious arroyo cutting observed in 1880 (Antevs 1952, Bryan 1925, Duch 1918, Swift 1926, Webb et al. 1991).

Balling and Wells (1990) suggested that arroyo filling and stability in Zuni, NM occurred as precipitation patterns changed to fewer intense summer storms and lower annual rainfall. They concluded that new arroyos haven't developed since about 1930. Antevs (1952) also looked at climate relative to forming arroyos, but suggested that overgrazing in drier climates is more likely to cause arroyos than overgrazing in a wet climate. He concluded that, in a stable environment, the vegetation cover is proportional to the moisture available for plant growth.

Arroyo Growth

The amount and velocity of runoff and the amount of particles being transported in the flow are primary variables in determining arroyo growth (DeGraff 1980). The velocity of runoff is increased with reduced plant cover, steepened slopes, compacted ground, and changes in the natural drainage pattern. The timing and magnitude of change in a channel at a particular location is controlled primarily by the magnitude, duration, intensity, and frequency of floods (Parker 1993). The location of channel change and its magnitude are controlled by topography, geology, and hydraulic and artificial factors (Parker 1993).

Controlling the amount of bed material available may be the key to curtailing arroyo growth. Meyer (1992) reported that arroyos do not widen when only a small amount of material is transported in the flow. Smaller scale arroyos of the headwater areas cut and fill at a faster rate than arroyos lower in the watershed because of their proximity to areas that generate runoff and sediment (Lagasse et al. 1990).

If left unchecked, the growth rate can be astounding. Baer (1985) documented a new arroyo's formation and growth which eroded at a rate of 1.4 m per hour with 442 m^3 material being eroded per hour. The material was wet, unconsolidated silt with lenses of fine sand and gravel layers.

Arroyo Function

Width/depth ratios have been used to describe arroyos (Crafton 1991, Meyer 1992). Narrow arroyos have a width/depth ratio range of 1.5-3.1; intermediate arroyos range from 2.5 to 4.8; wide arroyos are greater than 4.9 (Meyer 1992). Crafton (1991) found this ratio related to the inverse of the mean weighted percentage of silt-clay present in the bed and bank.

Width, depth, and velocity increase exponentially in the downstream direction as discharge increases (Crafton 1991). These are regulated by transmission losses controlled by the permeability of the bed material and underlying alluvium. At some point, transmission loss over increased channel width removes flowing water, and the width of the channel further downstream decreases (Crafton 1991).

MECHANICAL PROCESSES OBSERVED IN WADIS

The following discussion was taken primarily from Israeli and Egyptian literature pertaining to wadis, because the wadi most closely resembles the ephemeral drainage of the Southwest.

Wadi Function

Wadi flow is in direct response to rainfall and runoff (deVera 1984, Mucha and Fara 1987, Wallace and Lane 1978). Predictions are enhanced by width/depth ratios (Wallace and Lane 1978). Calculating surface runoff requires measuring numerous variables. Mucha and Fara (1987) listed the following variables, but suggested that it is easier to install wadi gauging stations:

- Basin precipitation (distribution in space and time)
- Basin extent and shape (catchment factors)
- Basin evaporation and climate factors
- Geomorphological conditions
- Geological factors
- Hydrogeological conditions

- Wadi bed characteristics

- Artificial barricades

Wadi Soil

Wadi Zin in the Negev Desert of Israel experienced a 100-year flood documented by Ish- Shalom-Gordon and Gutterman (1991). Their research indicated that catastrophic floods are an important environmental factor affecting soil depth and textural composition in a desert wadi. Their work involved identifying three topographic positions: wadi bed, slope (wadi bank at the half distance from the wadi bed to the shoulder), and shoulder (highest part of the bank).

The fine fraction of the soil is active in physiochemical processes important for holding water and inorganic nutrients (Ish-Shalom-Gordon and Gutterman 1991). Flooding is active in placing soil as well as cleansing soil. Porath and Adar (1992) reported that flooding rinsed the gravel bed free of toxic ions such as sodium, and introduced favorable nutrients such as nitrates. In both shallow and deep soils, the silt-clay fraction increased with wadi width in the alluvial fan. It also was high in the shoulder and even higher in the wadi bed and slope (Ish-Shalom-Gordon and Gutterman 1991).

Wadis and Groundwater Recharge

Ephemeral drainages and wadis are known to have local and regional effects on groundwater recharge. In the San Juan Basin of New Mexico, groundwater at shallow depths in the alluvium and bedrock flows toward a major ephemeral drainage in a strike valley (Stephens 1983).

Locally, soil textures in the wadi alluvium affect groundwater recharge through hysteresis. Here, water content in the soil pores is not the determining factor in calculating the energy status of soil water due to the presence of air-water interfaces and the nature of surface films (Baver et al. 1972). Parissopoulos and Wheater (1992) reported that layered alluvium profiles complicate the response, because different types of soil exhibit different hysteretic behavior. Hysteresis can enhance water table depth at some lateral distance from the edge of the recharging strip with differences in water table rise of up to 50% (Parissopoulos and Wheater 1992). The hysteretic phenomenon can complicate monitoring, however, because monitoring gauges are usually placed in alluvium in the zone of the most hysteretic activity.

Similarly, recharge to the groundwater can be encouraged through wadi management, especially in the upper part of the wadi. Much and Fara (1987) encouraged recharge through control of either natural or artificial means. They suggested flood control in the upper wadi, ploughing the wadi bed to encourage infiltration, and building stone sils across the wadis.

Native wadi vegetation has been altered by frequent flooding where lakes have been created. Pulford et al. (1992) noticed a major increase of true riparian plant species along Wadi Allaqui, which sits above Lake Nasser in Upper Egypt.

CLASSIFICATION OF RIPARIAN ECOSYSTEMS

Classifying riparian ecosystems has received much less attention than the classifying upland habitats. Early attempts often involved three classes: wet meadow, dry meadow, and browse shrub (Winward and Padgett 1989).

Reasons to Classify

Reasons for the lack of classification range from economics to lack of technique. Historically, upland vegetation had more economic value. Drainages generally provide a small amount of acreage relative to the greater watershed under consideration; riparian courses lack discrete boundaries from which to facilitate mapping (Dick-Peddie and Hubbard 1977).

Reasons to classify include increased economic importance of riparian corridors, especially for wildlife habitat, increased public interest in the preservation of biotic inventories and multiple use planning, and increased demand for water (Dick-Peddie and Hubbard 1977, Kauffman and Krueger 1984). The benefits of classifying include identifying stream reaches requiring woody vegetation, selecting appropriate plant material for restoration, identifying appropriate types and locations of instream structures, increased knowledge of appropriate restoration techniques for improving wildlife habitat (Winward and Padgett 1989), and increased understanding of the ecological processes involved in drainage function and the upland drainage area.

Drainage vs. Range Site

The science of classifying stream corridors poses some unique challenges not encountered in upland situations. In upland situations, vegetation types are related to the soil. It has been widely accepted in range science that one habitat type can be correlated with many soils, but an individual soil can be correlated with only one habitat (Neiman and Hironaka 1989). A system of habitat classification developed by the Natural Resource Conservation Service (former Soil Conservation Service) includes identifying seral stages or potential production based on a climax concept (SRM 1986).

The vegetation patterns along stream and ephemeral drainages also are related to the soil, but their classification differs in that no climax community can ever be achieved because of frequent disturbance from flood events. Therefore, vegetation is more likely to be in an early seral stage, and this can be reinforced by human-induced influences. Such influences are cumulative in a downstream direction (Laurenzi et al. 1983, Winward and Padgett 1989). Due to the continual disturbance and elevational gradient, Winward and Padgett (1989) suggested that a community type is a repeating stand of similar vegetation without reference to succession, and that types be named after one or two dominant features. This leaves a classification system based on "actual vegetation" rather than "potential climax vegetation" and seral stages. The keys to mapping "actual vegetation" are overall geomorphology, substrate, and general vegetation pattern (Winward and Padgett 1989).

Vegetation Studies Conducted on Arroyos

Winward and Padgett (1989) suggested that one riparian complex has four to eight community types with a pattern related to local soil and water table features. Laurenzi et al. (1983) achieved similar results by using reciprocal averaging and clustering techniques to identify five forest types on an elevational gradient in Arizona. On a regional scale for New Mexico and Arizona, Pase and Layser (1977) suggested six biomes, nine series, and 23 associations.

Browning (1989) identified eight arroyo habitat series in New Mexico. In southern New Mexico, he described three series including an Apache plume-mixed shrub community, a cutleaf bricklebush series, and a burrobush series. Browning (1989) described Apache plume (*Fallugia paradoxa*) as the most commonly found riparian species in New Mexico, with more than 80% of the arroyos in a southern New Mexico study containing this shrub. Littleleaf sumac (*Rhus microphalli*), and cutleaf bricklebush (*Brickellia laciniata*) were listed as close associates in areas where elevations approximated 1,550 m. Burrobush (*Hymenoclea monogyra*) was listed as an associated species in washes at lower elevations.

Raitt and Maze (1968) conducted research in a creosote (*Larrea tridentata*) community in the western slopes of the Organ Mountains. Singh (1964) conducted the vegetation analyses for this study. He recognized three habitat types: major arroyo vegetation, small arroyo vegetation, and undissected or upland vegetation. Although Singh recognized a vegetation change between the arroyo and the mesa top in a creosote community, his study did not consider vegetation changes between arroyo and nonarroyo along the length of an arroyo through different habitat types.

Kear (1991) attempted to describe the different types of arroyo-riparian habitats found in the southern Organ Mountains by looking at arroyo and nonarroyo habitats. She inventoried 46 shrub species in the arroyos and found 16 to be unique to the arroyo. Of the 33 nonarroyo shrub species inventoried, four were unique to the uplands. Among grass/forb data, 130 species were inventoried in the arroyos compared to 83 in nonarroyo habitat. Of these species, 47 were unique to the arroyos, while only 11 were unique to the nonarroyo habitat.

Microhabitats

Microhabitats formed by microcatchments and various soil types have been identified as major factors affecting plant production and distribution along wadis in the Negev Desert of Israel (Shanan et al. 1969) and the Egypto-Arabian Desert (Batanouny 1973, El Rahman and Batanouny 1965). Microcatchments up to 0.1 ha in size produced 20-30 times greater annual average water harvest than larger wadis. Even in the most extreme drought years, at least one flood supplied enough irrigation water to farm the catchment (Shanan et al. 1969). El Rahman and Batanouny (1965) measured the total water output of desert vegetation in microhabitats of Wadi Hof in the Egypto-Arabian Desert near Helwan. They made comparisons of vegetation among the shaded areas under first and second terraces and the plateau. In the wet season, total water output was nearly equal in the plateau and shaded areas, but plateau vegetation had only one-third the fresh weight of shaded vegetation. In the dry season, water output showed a slight increase in most microhabitats due to a rise in the plants' transpiration rate.

Batanouny (1973) also described the microhabitats along Wadi Hof and attributed them to the numerous terraces mentioned by El Rahman (1965). He concluded that soil texture and depth in the microcatchments affected the water resource and shaped the distribution of plant communities along the wadi.

Obligate and Facultative Species

Researchers in the Southwest have noted that some plant species (particularly shrubs and trees) seem to be restricted to the drainage channel, while others take advantage of the water resource in the channel but are not restricted to it. This defines obligate and facultative species, respectively.

Gardner (1951) approached a description of obligate species when he identified shrubs that form islands in drainage channels. These included desert willow (*Chilopsis linearis*), Apache plume, burrobush, cutleaf bricklebush, and littleleaf sumac. He observed that channels with vegetated islands are less likely to discharge damaging flows than those without islands. Dick-Peddie and Hubbard (1977) listed some of the same species as obligate riparian, but noted that obligate riparian species in the Southwest may be facultative in another region.

Facultative species take advantage of available water by producing more canopy but are not restricted to water sources. Many of the shrub species identified as facultative are introduced species or those that spread readily such as creosote and mesquite (*Prosopis spp.*). Creosote in southern New Mexico ranges in height from 50 to 75 cm but attains heights of 2 m on drainage ways, and 3 m in cultivation (Gardner 1951). Some facultative shrubs such as creosote, acacia (*Acacia spp.*), and krameria (*Krameria parvifolia*) decrease in density along drainage ways but increase in mean plant size (Balding and Cunningham 1974). Other species such as littleleaf sumac do not change in density in response to moisture gradients, but do increase in plant size (Balding and Cunningham 1974).

Near El Paso, Texas, Williams (1969) used ocotillo (*Fouquierria splendens*) to delineate arroyos of importance and reported that creosote disappeared as arroyo depth increased. He concluded that plants were responding to arroyo structure rather than moisture. Since ocotillo is generally seen on steep upland sites, his conclusion has merit.

Elevational Gradients and Continua

The authors listed below reported that an elevational gradient along ephemeral drainages affected plant communities. Most reported that the drainage contained a continuum of overlapping vegetation types, and that because of the continuum, identification of distinct plant communities was somewhat arbitrary.

Freeman and Dick-Peddie (1970) reported that dominant tree species were replaced by other trees species as elevation increased. Shrubs decreased in density as elevation increased, but they increased in importance value.

Laurenzi et al. (1983) related the species composition continuum directly to streamside environment. They identified steep local relief and high discharge velocities, a narrow but distinct flood plain deposed from upstream material, and a well-developed floodplain at high, mid-, and low elevations, respectively.

Reichenbacher (1984) described a continuum of vegetation along drainages in southern Arizona. He identified a moist unstable end dominated by cottonwood and willow, and a dry stable end dominated by mesquite and acacia. Everything in between he described as a continuum.

Szaro (1990) examined elevation, stream direction, stream gradient, and valley cross section area as they effect distribution of riparian tree species and community types. He found elevation to be the most significant factor along the first canonical axis in an analysis of community types. Stream direction and stream gradient also correlated but were significant only on a local level.

Lietner (1987) reported that arroyo vegetation communities in Sonora appeared to be variations of a single type, responding to slope, aspect, and soil texture as they influence water availability.

Springuel et al. (1991) used ocular reconnaissance to inventory wadi plant communities; they described 13 community types representing a continuum along a moisture gradient.

IMPORTANCE OF RIPARIAN CORRIDORS TO WILDLIFE

Several authors have described the importance of arroyos to avian populations (Anderson et al. 1977a, Anderson et al. 1977b, Austin 1970, Brown et al. 1977, Carothers et al. 1974, Johnson et al. 1977, Schlorff and Bloom 1984, Stamp 1978, Stevens et al. 1977, Strong and Bock 1990, Szaro and Jakle 1985, Tomoff 1974). For example, Stevens et al. (1977), while conducting research in southeastern Arizona, found twice as many breeding individuals and avian species in riparian plots as on the nonriparian plots. Similarly, Szaro and Jakle (1985) found that bird densities decreased from a riparian zone to adjacent upland.

Medin and Clary (1991) and Smith et al. (1993) noted the importance of riparian areas for livestock. These researchers compared riparian areas grazed by cattle to those not grazed by cattle. Medin and Clary (1991) noted no difference in total breeding bird densities, bird community composition, bird species richness, and estimates of bird standing crop biomass. Smith et al. (1993) observed more cattle in riparian areas than on upland sites, but no greater use of the forage resource. They concluded that cattle used upland areas similarly to riparian areas, as long as water was available.

Some of the differences in fish or wildlife use of a channel may be attributed to structural diversity. Anderson et al. (1983) considered vertical structure of the vegetation along the riparian corridor an important component in understanding vegetation use by wildlife. MacArthur and MacArthur (1961) showed strong correlation of bird species diversity with foliage height diversity. Bryant et al. (1992) considered the structure of the channel bed important in determining fisheries habitat.

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