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RESULTS OF BIOLOGICAL INVESTIGATIONS FROM THE LOWER VIRGIN RIVER VEGETATION MANAGEMENT STUDY

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16. ABSTRACT

The exotic salt cedar (*Tamarix chinensis*) has been identified as a widespread, dominant phreatophyte along many riparian flood plains in the Western States. Many problems have been documented as a result of the invasion by salt cedar including extremely high-water consumption, tendency to concentrate salts, acting as a flood stream impediment, and providing poor wildlife habitat. In 1982, the Lower Virgin River Vegetation Management Study was initiated to determine if clearing phreatophytic vegetation and planting less water consumptive species would result in measurable water savings. From June 1982 to December 1983, the value of salt cedar habitat for wildlife was assessed on a 600-acre study site along the Lower Virgin River in Nevada. Vegetation characteristics in the salt cedar study area are best described as a monotypic growth of bushy, multistemmed trees possessing little foliage volume above 10 feet and with moderately dense foliage volume at the 6-inch to 2-foot level. Permanent resident bird species such as the Song Sparrow, Bewick's Wren, and Aberts's Towhee occurred at higher densities throughout all months of the year than the migrant, summer breeding, or wintering species. Bird densities in salt cedar were substantially lower when compared to densities found in similar studies of native riparian habitat. An increase in marsh vegetation within the salt cedar habitat in 1983 enhanced wetland bird species densities. Of the seven species of rodents trapped in salt cedar, House Mouse and Western Harvest Mouse occurred at the highest densities. Rodent numbers were closely associated with the density of salt cedar growth. Detailed recommendations for maximizing successful revegetation plans were based on prior studies of native plants and agricultural crops.

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by

Mark J. Kasprzyk
Gary L. Bryant

Bureau of Reclamation
Lower Colorado Region
Boulder City, NV

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Applied Sciences Branch
Environmental Sciences Section
Research and Laboratory Services Division
Denver Office
Denver, Colorado

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PREFACE

The Lower Virgin River Vegetation Management Study was primarily designed to investigate the feasibility of salvaging the water used by one of the highest water-consumptive phreatophytes, the exotic salt cedar (*Tamarix chinensis*). This would be accomplished by replacing the nearly homogeneous salt cedar community along the Lower Virgin River floodplain with relatively low water-use vegetation such as small grains or native desert plants.

Environmental baseline studies were conducted on a selected 600-acre study site to ascertain the present wildlife habitat value of salt cedar and to determine the subsequent impacts of clearing. These studies were initiated in June 1982 and completed in December 1983. The Lower Colorado Region Planning Division was responsible for the biological inventory.

Once the biological and hydrologic baseline studies were completed and the measurable water salvage determined to be feasible by clearing the phreatophytes, the second phase of the management study could commence. During this second phase, about half of the 600-acre site would be cleared and replaced with a low water-use vegetation type. Studies would then resume across the control (uncleared) and experimental (cleared) plots to determine actual water savings and differences in wildlife habitat value.

The primary function of this report is to present the environmental findings and conclusions. To provide background and insight into the reasons for the study, the first section presents historical and phenological information on the major phreatophyte problem, salt cedar. This serves to outline the results of previous studies leading up to the objectives of this current study. Points discussed include when and where salt cedar was introduced, how salt cedar gained a foothold and the reasons behind its successful establishment, and why salt cedar control is being considered as an important issue.

The second section presents inventory results for birds, mammals, vegetation, and other wildlife aspects. The relative habitat value of salt cedar is reviewed based on study conclusions and prior biological research from other Southwest riparian communities.

The third section presents recommendations on how to replace salt cedar and initiate revegetation efforts. These recommendations are based on a literature review of previous studies and on discussions with experienced professionals in the field, and are directed at solving the problems with mutually beneficial results for both man and wildlife.

The fourth and final section presents procedures for monitoring the site after clearing. Sampling techniques, study design, and field equipment are discussed in detail.

HISTORY, PHENOLOGY, AND SUBSEQUENT IMPACTS OF SALT CEDAR

Introduction

Water salvage and salinity control have been studied in depth, and remain critical concerns due to expanding water requirements in the West. Solutions addressing these concerns have included the building of lined canals, diversion pipelines, desalting plants, and clearing phreatophytic vegetation (Culler, et al., 1970 [1] and 1982 [2]; Laney, 1977 [3]; Robinson, 1964 [4]; and Fletcher and Elmendorf, 1955 [5]) [1].

The relationship between the removal of phreatophytic vegetation and water salvage benefits has been poorly defined. The complex hydrologic regime associated with most riparian corridors and the incomplete consideration of all influencing environmental factors has historically resulted in a wide range of consumptive water use values for phreatophytes (Bittinger and Stringham, 1963 [6]; Blaney, 1933 [7]; Fletcher and Elmendorf, 1955 [5]; Robinson, 1952 [8] and 1958 [9]; and van Hylckama, 1963 [10] and 1970 [11]). This is especially true of the species identified as one of the most widespread phreatophytes, *Tamarix chinensis*, commonly known as salt cedar, which has drawn specific attention because of its high water consumption and rapid spread.

To fully understand the ecological and economical consequences of salt cedar's intrusion, this phreatophyte's life history characteristics and their implications on native vegetation and man must be known. The objective of this section is to document previous studies conducted on salt cedar and to present the compiled results.

History of Salt Cedar

Salt cedar, a naturalized shrub or small tree, has become the most widely distributed and important phreatophyte in the Southwest (Robinson, 1965 [12]; van Hylckama, 1970 [11]; Busby and Schuster, 1971 [13]; and Anderson, 1982 [14]). The stock of various species of salt cedar was introduced into this country by nurserymen in the early 1800's (Horton, 1964 [15]; Robinson, 1965 [12]; and cited by Anderson, 1982 [14]) as a horticultural plant, primarily used as ornamentals or windbreakers. *T. chinensis*, often confused with but now considered synonymous to *T. pentandra* and *T. ramoississima*, (Horton and Campbell, 1974 [16]; Elias, 1980 [17]) is a native of Mongolia, China, and Japan (Baum, 1967 [18]), and parts of Europe (Turner, 1974 [19]). Members of the genus of *Tamarix* are salt exuding euryhalophytes (Waisel, 1972 [20]), having a wide range of salt tolerance. Once established, salt cedar's reputation as a rapid colonizer and vigorous invader become apparent (Christensen, 1962 [21]; Everitt, 1980 [22]; and cited by Anderson, 1982 [14]). Robinson (1961) [23] cites salt cedar's rapid spread in the Pecos Basin. Prior to 1912, no *Tamarix* were recorded in that region. By 1960, 50,000 acres had been colonized. Robinson (1965) [12] also mentions how the total area of salt cedar growth has increased from an estimated 10,000 acres in 1920 to more than 900,000 acres in 1961. It was further postulated that by 1970, salt cedar would be growing on 1.3 million acres; this growth is also increasing in density as well as total area. The amount of water consumed by salt cedar was estimated to be 40,000 to 50,000 acre-feet in 1920, 3.5 million acre-feet in 1961, and 5.0 million acre-feet in 1970 in the Western States. Currently, this plant has virtually taken over many of the southwestern riparian communities causing serious problems for effective water and habitat management programs. Major concerns associated with salt cedar's characteristics and the factors contributing to its competitiveness must be understood to fully comprehend the nature and extent of this problem.

Salt Cedar and Cottonwood/Willow Phenology

Historically, cottonwoods and willows were the predominant trees occupying most typical riparian communities along the lower Colorado River before the advent of salt cedar (Grinnel, 1914 [53]). The relentless clearing of these riparian constituents and river control through damming aided the advance of salt cedar.

Table 1 shows a step-by-step comparison of these species' seed phenology and growth rates to aid in the understanding of the reasons for salt cedar's competitive edge in the establishment and domination of disturbed areas. Obviously, salt cedar has an added advantage over these native communities, even when riparian disturbance is minimal. Extremely prolific seed production of considerable duration, effective seed dissemination, dense growth, and early maturity all contribute to its success.

Impacts of Salt Cedar

Flood Stream Impediment.–Many studies document the problem caused by salt cedar's high density and foliage volume. Graf (1978) [30] noted that salt cedar tended to trap and stabilize sediments, thus reducing average channel width in areas along the Colorado River system. Johnson (1978) [31] discussed the increase in erosion and sedimentation rates along the lower Colorado River. In Safford

[1] Numbers in brackets refer to entries in the Bibliography.

Table 1. – Phenological comparison of salt cedar and cottonwood/willow.

	Salt Cedar	Cottonwood/Willow
Flowering period	Protracted; starting in early March, peaking occurred in May and June, still flowering in October (Everitt, 1980 [22]; Ohmart, 1983 [24] final draft).	Temporal; only in March and April to coincide with spring flows essential for establishment (Zimmerman, 1969 [25]; Ohmart [24]).
Seed production	In dense salt cedar during flowering season, viable seeds settled on soil surface at the rate of 100 seeds per square inch over the entire season (Warren and Turner, 1975 [81]). Seeds may be produced at the rate of 500,000 seeds per mature plant per season (Tomanek and Ziegler, 1962 [26]).	Seeds are abundantly produced by the flowers of both species (Elias, 1980 [17]), but not to the extent of salt cedar.
Seed dispersion	Small, lightweight seeds with a tuft of hair at one end; disseminated by wind and water enabling the seeds to be carried to new areas far from point of origin (Turner, 1974 [19]).	
Seed viability	Short-lived for only a few weeks (Horton, et al., 1960 [27]), although Merkel and Hopkins, (1957 [28], p. 363) report survival of seed of up to 1 year in cold storage, suggesting that seed can winter-over in temperate climates.	Equally short-lived for cottonwood [27] and willow [29].
Growth conditions	Bare, moist soil in well-lit openings appears to be the ideal seedbed for salt cedar and obligate riparian plants; interspecies competition for space is probably great during critical time of streamflows, prolonged periods of saturation may be the main force promoting establishment of seedlings.	
Salt tolerance	Very high salt tolerance; salt concentrating mechanism called "guttation" makes soils surrounding trees more saline.	Relatively low salt tolerance does not fair well with salinities above 2,000 p/m; tolerance also varies depending on soil composition (Bertin W. Anderson, per. comm.).
Natural growth rate	Very rapidly establishes itself in large numbers, thickly spaced. In cutoff stands, under favorable conditions, shoots can increase in length as much as 2 inches/day (van Hylckama, 1970 [11]). Only a few plants are reported to grow faster.	Fairly slow when compared to growth rate of salt cedar, slow establishment rate.
Sexual maturity	Seedlings often produce the first year [26, 28].	Several years or more
	Monecius; all mature plants in a stand produce seeds.	Dioecious; about half of sexually mature plants in a stand produce flowers that yield only pollen, the other half produces seeds.

Valley, Arizona, the general increase in salt cedar cover led to a decrease in width of the Gila River channel after 1917, with an accumulation of sediment in the flood plain (Burkham, 1972 [32]). A similar sequence of erosion and channel narrowing was documented by Turner (1974) [19] for the Gila River. Culler, et al. (1970) [1] state how salt cedar "produces a flood hazard by choking normal channels and reducing conveyance of flood flows".

Wildlife Habitat Value.–Numerous scientific studies have been conducted along several of the major southwestern riparian systems to assess vegetational requirements for wildlife. The CRP (Colorado River Project), funded in part by the Bureau of Reclamation and conducted through Arizona State University, has studied wildlife for more than 8 years along much of the lower Colorado River valley, and has statistically shown that salt cedar is of low value to birdlife (Anderson and Ohmart, 1981 [33], 1977 [34], 1977 [35]; Cohan, et al., 1978 [36]; Ohmart, 1983 [24] final draft). Native vegetation, such as cottonwood, willow, mesquite, and quailbush, were found to all have significantly higher densities for birds and were all, by far, best for wildlife. Revegetation efforts, with native vegetation by the

CRP, have further proven to be beneficial for wildlife. By selectively clearing salt cedar, the bird populations, in general, were enhanced even though the vegetation cover was reduced by more than 90 percent [33]. Rodent numbers likewise increased after salt cedar was cleared and native vegetation planted. Johnson (1971) [37] and Carothers, et al. (1974) [38] reported the highest concentrations of nesting birds in the cottonwood communities in central Arizona, and that thinning of the native cottonwoods reduced nesting bird populations. Doves have been found to use the taller salt cedar groves as nesting habitat (Shaw, 1961 [39] and Cohan, et al. 1978 [36]), but studies appear to show that lack of former native habitat may explain the present use of salt cedar vegetation.

Water Consumption.–As previously mentioned, salt cedar consumes large amounts of water and, with its prolific spread, presents a major problem for the arid southwest. Measuring consumptive water use by phreatophytes, especially salt cedar, has been a primary objective of most studies trying to ascertain if clearing phreatophytes would prove feasible in attaining a net gain in the water supply. The two most popular techniques used to estimate the difference in water use by phreatophytes have been to measure the hydrologic budget or the energy budget.

(a) *Hydrologic Budget*.–The hydrologic or water budget is a method used to quantitatively evaluate all water associated with a study area; that is, all water that enters, leaves, or becomes stored in the study area during a given period. This method has been used extensively and has resulted in a wide range of consumptive-use values. Despite the debate concerning exactly how much water is actually used by salt cedar (estimates range from 1 to 12 acre-feet per year), it is clear that salt cedar affects local water budgets and water quality (Gatewood, et al., 1950 [40], and cited by Graf, 1983 [41]). Woessner, et al. (1981) [42], measured salt cedar water use in the Lower Virgin River study area. They estimated an annual use rate of about 7.5 acre-feet with as much as 12 acre-feet in the lower section (Mormon Mesa area, close to the vegetation management study site). Phreatophytes were shown to transpire water in diurnal cycles, causing a rise and fall in the associated water table. By causing the water table to lower during the growing season (March to November), a partial loss in surface streamflow occurred in some areas. The water-budget method showed that surface water and ground-water inflow into the study area was 37 percent greater than outflow.

Gatewood, et al. (1950) [40] measured riparian vegetation consumptive water use in the lower Safford Valley of Arizona along the Gila River by using various hydrologic budget methods which, individually, resulted in limited accuracy. However, by combining the methods, a better overall estimate of water use by the vegetation on the 9,303-acre study site was calculated at 28,000 acre-feet per year, of which more than 75 percent was attributed to consumption by salt cedar. The annual computed use rate for salt cedar with 100 percent cover was about 7.2 acre-feet, and as high as 9.0 acre-feet in some areas. Robinson (1958) [9] reports an annual use rate of more than 7.0 acre-feet for salt cedar. Robinson (1965) [12] estimated the average rate for salt cedar in the Western States to be about 4.0 acre-feet. These differences in consumptive water use estimates are primarily due to problems in accurately measuring inflow and outflow from the study areas. Artesian wells, extremely high ground-water tables, and other factors can cause errors in effectively measuring the hydrologic dynamics of a study site based on these techniques. These possible errors along with the usually poor quantification of vegetation density and diversity of an area appear to be some of the major contributing factors in differences between consumptive water use estimates.

(b) *Energy Budget*.– Consumptive use values can also be determined by computing the amount of water that could potentially be transpired based on the available energy. The potential water use must then be adjusted for the plant species and stage of growth. Daily measurements must be repeated for this process during the growing season, and daily values totaled to determine consumptive water use over a season. Estimations of phreatophyte water use using the energy budget method has similarly resulted in a range of values. Evapotranspiration tanks and tents, lysimeters, and other equipment have been used to measure the water use by vegetation. For young salt cedar plants growing in two large tanks near Buckeye, Arizona, van Hylckama (1963) [10] measured consumptive water use at 8.25 acre-feet per year. Culler, et al. (1970) [1] cites van Hylckama (written comm., 1966) as measuring water use in these tanks at 7.0 acre-feet from April to August during 1964.

Probably the most accurate and current method of estimating consumptive water use by phreatophytes uses the energy budget approach; this method is currently being researched by Dr. Lloyd Gay at the University of Arizona in Tucson (Gay and Fritschen, 1979 [82]). This method, which has evolved from an experimental to an operational basis during the past two decades, has the advantages of precision and mobility when compared with the more traditional water budget method. The measuring equipment, though sophisticated, can be quite portable, making it possible to sample over different types of evaporating surfaces in a wide range of site and climate conditions. The method "budgets" the gains and losses of thermal energy at the evaporating surface. Only four forms of thermal energy are involved: (1) radiation, (2) convection, (3) change in thermal storage, and (4) latent energy that is used to evaporate water. Radiation and change in thermal storage are measured directly, and convection and latent energy are calculated from measurements of thermal radiation (primarily from the sun) and from the temperature and humidity gradients in the lowest part of the atmosphere. The quantity of latent energy is then converted to the depth of water that was vaporized in the ET (evapotranspiration) process. Results from the energy budget method have been repeatedly verified by comparison with lysimeter and water budget estimates. Estimates of ET can be obtained from vegetated surfaces without disturbing the natural condition, and for a much lower cost (cited from SRNR Research Newsletter, Gay–1981).

Recently developed techniques with more advanced equipment have resulted in ET measurements of unequaled precision. The energy budget system determined ET values with an error as small as 0.5 percent from two irrigated fields (Gay and Hartman, 1981 [43]). This is substantially better than the generally accepted estimates of about 15 to 20 percent precision for the water budget and for applications of the energy budget made elsewhere. This large increase in precision has resulted from improvements in sensors, data acquisition and processing, and design of the field experiments.

Along the lower Colorado River, riparian salt cedar about 23 feet tall with an underlying water table 11 feet below the surface was determined to use an average of 5.68 acre-feet of water during the growing season using this method (Gay and Hartman, 1982 [44]). Current studies involve testing agriculture and other types of riparian vegetation.

(c) *Potential Factors Influencing Budget Estimates.*–In addition to the variables usually considered in the hydrologic and energy budget methods, other factors appear to influence the consumptive use rate of salt cedar. Attempts have been made to study water use by salt cedar with varying water tables, primarily during the period of highest water consumption (March–October), see table 2. These studies, with one exception, appear to show that salt cedar uses more water with a higher water table. Theoretically, water consumption might be substantially reduced by lowering the water table.

Horton and Campbell (1974) [16] and cited by Gay and Hartman (1982) [44] showed that elevation was an important factor in determining water consumption by salt cedar. In low-desert, dense salt cedar stands on the Gila River near Phoenix, 6 to 7 acre-feet per year was used. On somewhat higher elevation sites in Safford, Arizona, and Carlsbad, New Mexico, 5 to 6 acre-feet was lost annually. Even the high-desert elevation Bernardo site near Albuquerque used less water, which was measured at 4 to 4.5 acre-feet per year. It appears that an elevation variable should also be considered in determining consumptive use values.

Salinity Concentration.–Salt cedar can grow and thrive in areas with saline water by excreting a fairly concentrated solution of salt through the leaf surfaces, a process known as "guttation," or through "salt glands" (Hem, 1950 [49], p. 80, and cited by Laney, 1977 [3]). One sample of this exudate contained 41,000 p/m of dissolved solids, with

Table 2.–Water use by salt cedar using varying water tables.

Reference	Depth to water table, feet	Water use by salt cedar, acre-feet	Time period measured
Blaney, et al. (1942) [45]	2	5.1	Aug.–Oct.
	4	4.4	Aug.–Oct.
Turner and Halpenny (1941) [46]	2	5.1	May–Dec.
	4	4.0	May–Dec.
Malder (1966) [47]	3	2.7	Annually
	5	3.5	Annually
van Hylckama (1974) [48]	5	7.0	Annually
	7	5.0	Annually
	9	3.3	Annually

18,300 p/m of chlorine and 13,800 p/m of sodium being the main salt constituents [49]. The removal of the exuded water and salt from the leaves and stems by dew, precipitation, and wind may cause large concentrations of salt to accumulate in the upper part of the soil [3].

As previously discussed, salt cedar consumes large quantities of water, primarily through evapotranspiration. Consumptive use is so great in most areas that movement of ground water is influenced by phreatophytes (Culler, et al., 1970 [1]), especially by salt cedar. Therefore, when salt cedar translocates water along its root systems, salts are also translocated and concentrated in the root zone. This salt-concentrating mechanism, along with the salts concentrated in surface soils by guttation, results in abnormally high salinity levels in both the saturated and unsaturated zones of the soil. As a result, the underlying ground water is also affected. Woessner, et al., (1981) [42] described this phenomenon through their study along the Lower Virgin River basin. The salt budget showed that salt input from inflow of surface water and ground water was 35 percent more than the salt outflow. Salt losses tied up in the study site were attributed to an annual storage of 189,000 tons, derived from consumptive use by phreatophytes [142,500 tons (75%)] and agriculture [46,600 tons (25%)]. They also found that salt concentrations through consumptive water use had reached levels ranging from 7,000 to 11,000 mg/L within a zone estimated to extend about 10 feet below the water table. Laney (1977) [3] reports dissolved solids concentrating under a phreatophyte study area along the Gila River of 400 to 19,000 mg/L in the saturated zone and 600 to 14,000 mg/L in the unsaturated zone. The SCS (Soil Conservation Service) (1981) [50] also states consumptive use by phreatophytes (primarily salt cedar) as a major contributing factor for increased salt concentrations.

Economic Value.–The *Tamarisk* family is of minor economic importance and of little value to wildlife. Although the pungent bark of salt cedar has been used for tanning and dyeing (Elias, 1980 [17]), it currently has no marketable value as forage or timber [1]. However, larger woodlands are being considered as a potential source of paper pulpwood (Everitt, 1980 [22]). Beekeepers along the central Rio Grande in Trans-Pecos, Texas, have recently been receiving a higher price for salt cedar honey than for honey from other sources.

Discussion

The introduction of the exotic salt cedar may be compared with other familiar yet unfortunate introduced species such as the house sparrow, Norway rat, and European carp. The net result of each introduction has been a considerable annual expense in damages and control. Effective control in the case of salt cedar potentially offers substantial economic benefits directly through water and salinity control and indirectly through the enhancement of wildlife habitat.

After discussing salt cedar's history of successful establishment and subsequent impacts, it is apparent that interdisciplinary studies of riparian systems are becoming a necessity. Environmental problems and subsequent water management needs will continue to grow in extent and complexity without appropriate action. Salt cedar's phenologic advantages and hence, its present dominance over formerly native vegetated areas, can only be reversed with man's help. The ironic part is that salt cedar's "boast" as the most common riparian vegetative element along many Southwest waterways is the fault of man's own progress. The spread of salt cedar would never have been so rapid or so successful based solely on the phenology characteristics reviewed. Authors that have summarized historical changes along Southwest rivercourses point out the timing and sequence of events that have occurred. The extensive clearing and plowing of riparian floodplains during the 19th century in the Western States eliminated large tracts of the established native vegetative community (Harris, 1966, p. 421, and cited by Everitt, 1980 [22]). The construction of dams further disrupted the natural state of spring flood flows critical for seed germination by many native species, especially cottonwood.

Salinity increases associated with outflow from agricultural areas further prevented the native, low salt-tolerant vegetation from reestablishment. At the same time, salt cedar was introduced and used for bank protection, erosion control, and windbreakers. Compiling this information, it would certainly appear, as stated by Everitt [22], that "the present dominance of salt cedar along certain watercourses is related to a complex of changing physical and hydrologic factors, together with the historical accident that seeds were made available at the very time development in the Western States was disrupting the native plant communities of flood plains."

Based on the literature search of phreatophyte studies, it would appear that the salt cedar problem is a complex issue, as numerous projects have shown, based on a wide array of ecological and hydrological variables associated with each study site. Therefore, in assessing water consumption by salt cedar, or any vegetation type, methods of identifying the hydrologic and environmental variables should be *clearly* and *completely* explained. Standardization of procedures would ease the difficulty in determining applicability and give a more thorough understanding in determining the most important factors and how much they influence water consumption.

The most important study factors to consider, especially during the growing season, would be:

- vegetation cover — to encompass percent species composition
  - — percent bare ground
  - — foliage density/unit area
  - — total study area
- water table — average depth from surface
- water quality — salinity levels of water underlying vegetated area
- soil composition — soil type, density, and salinity
- elevation — height above mean sea level
- climate (preferably obtained during study duration by a weather station located onsite) — average temperature range
  - — relative precipitation
  - — average wind speed
  - — cloud cover

The above factors should be considered to be common for most energy or water budget methods applied in determining consumptive water use values for vegetation. This will hopefully yield more accurate results and a better understanding of how water consumption is affected by the combination of these particular influencing factors. Research should also continue to determine a biological control for salt cedar. Preferably, this control would consist of replacing salt cedar with a low-water use, salt-tolerant vegetation type that would benefit man and enhance wildlife. The possibilities are available to successfully achieve this objective if careful planning and experimentation are pursued.

The intent of the Lower Virgin River Vegetation Management Study was to consider these factors in determining consumptive water use by salt cedar. The details of methodology and results of the consumptive use studies are to be published in the future by the Bureau of Reclamation. The remainder of this report is concerned with wildlife aspects of the study and selection of suitable replacement vegetation.

BIOLOGICAL INVENTORY RESULTS ALONG LOWER VIRGIN RIVER

Introduction

The Lower Virgin River Vegetation Management Study was initiated in 1982 with the primary objective of determining if clearing phreatophytic vegetation and replacing it with less water consumptive vegetation would result in measurable water savings. For this study, it was believed that the prior inconsistencies in evaluating consumptive water use could be reduced by using a combination of reliable energy budget and hydrologic methods. An environmental assessment of the area was made to evaluate the present habitat value. The main objectives were:

- Gather baseline data on vegetation and wildlife use of the study site.

- Determine relative habitat value of site for wildlife through comparison to previous related work in similar habitats.

- Based on study results and literature search, formulate alternative revegetation plans that would best meet the objectives of increasing water savings while maintaining or enhancing wildlife community.

The second phase of the study involved clearing 300 acres, half the study area. The primary objectives for this phase were:

- Gather baseline data on vegetation and wildlife from the cleared (experimental) area and noncleared (control) area.

- Determine if replacing existing vegetation with a less water consumptive vegetation was feasible, and determine impact on vegetation and wildlife.

This section discusses and summarizes the results obtained on the above objectives. Alternative vegetation plan recommendations will be discussed in the next section, and objectives for the second phase of the study will be summarized if vegetation clearing is implemented.

Methods

Site Location and Description.-Vegetation and wildlife studies were conducted along the Lower Virgin River, about 6 miles southwest of Bunkerville, Nevada (fig. 1). The site consists of 600 acres of remote riparian habitat composed predominantly of the exotic, salt cedar (*Tamarix chinensis*). A portion of the adjacent desert wash habitat, composed of a creosote bush community (primarily *Larrea divaricata* with *Ambrosia dumosa*), was also included in the study.

Study Time Frame.-The biological study period lasted from June 1982 through December 1983. Full-time field work, 3 to 5 days per week and 4

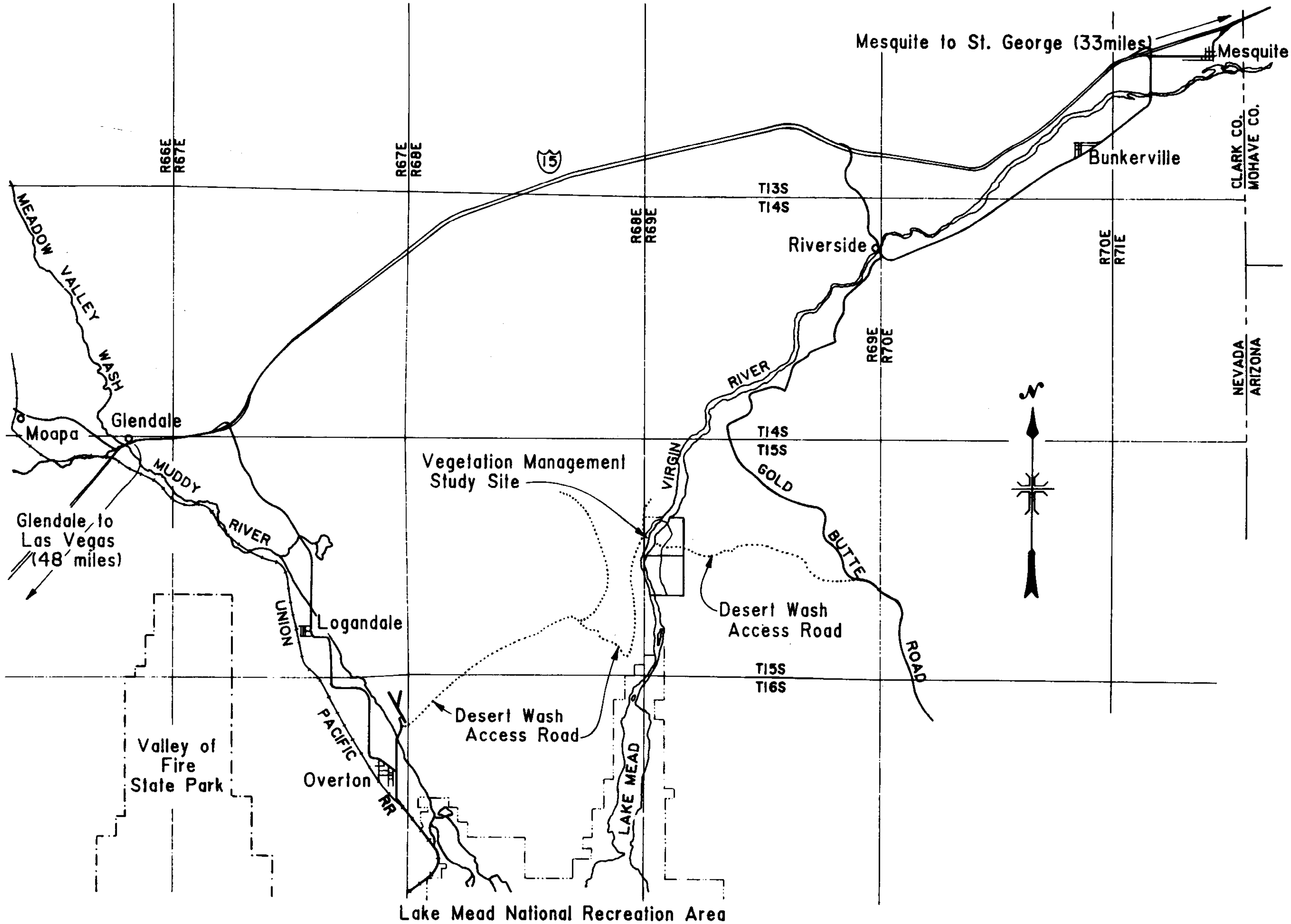


Figure 1. – Lower Virgin River Vegetation Management Study site.

weeks per month, ran from June 1982 through May 1983. The remaining time frame from June through December 1983 was spent conducting half-time field work, 3 to 5 days per week and 2 weeks per month.

Home Base Station and Equipment.–All studies were conducted from a 15-foot field trailer located at the midpoint of the site overlooking the riparian vegetation. A portable generator was housed nearby to power the trailer as necessary. This onsite homebase was essential for carrying out early morning studies, primarily because of the site's remoteness.

Sampling Methodology.–Various applicable surveying techniques that appeared most suitable for site characteristics and manpower limitations were used. Sampling was then scheduled accordingly to maximize available field time and to collect a more comprehensive data base. The most labor intensive categories of the biological studies were directed at the major site constituents: birds, small mammals, insects, and vegetation. Insects, though initially sampled, were chosen as the category to be dropped due to the excessively large sample size needed and time required to process samples. Data on reptiles, amphibians, and large mammals were recorded as general observations. Since the major study emphasis was placed on the riparian salt cedar community, desert sampling data were regarded more as secondary information. The categories sampled and the techniques used are listed and described in the following subsections.

(a) *Bird Censusing.*–The bird censusing was conducted using a modified Emlem transect technique (Anderson and Ohmart, 1977 [34, 35]). A diagram showing the layout of bird transects along the bulldozed strips is shown on figure 2. A total of 14 transects, averaging 3,000 feet long and 12 feet wide, were established in the riparian (salt cedar) and desert wash (creosote-bush) communities. Each transect was subdivided into 500-foot intervals. The censuser, during hours of peak bird activity, slowly walked the transect estimating the lateral distance zone (e.g., 0 to 50, 50 to 100, 100 to 200, and 200 to 400 feet) of each detected bird species within each 500-foot interval. Each transect was censused 2 to 3 times per month (two exceptions were June 1983, one census, and September 1983, no data) to provide an adequate sample size for bird density derivations. Each 500-foot section was categorized based on the main vegetation types, as either desert wash or salt cedar communities, for bird density calculations. The 12-foot-wide bulldozed transects did not appear to influence the effectiveness of the sampling technique. For a more detailed explanation of this technique, see Emlen (1971, 1977) [51, 52] and [34, 35].

Densities were grouped according to the seasonal occurrence of each species within the riparian salt cedar. Individuals of a species were classified as primarily occurring during all seasons (permanent residents), summer season (summer visitors), winter season (winter visitors), or the spring and fall seasons (migrants). Desert wash birds were not split in this manner because density calculations were too small to put into these categories. Therefore, bird density estimates for the desert wash are presented by species only, not by season.

Each of the four groups were then split into two categories for a total of eight divisions to compare bird density and vegetation relationships. The two categories were wetland and riparian. Typical wetland (ducks, herons, and marsh birds) and, to a lesser extent, grassland (meadowlarks and pipits) species were grouped together into the wetland category to represent the atypical habitat within the study site. An extremely high water table and river inundation across the site were conducive to the formation of a more diverse habitat of marsh plant species and thick, salt grass (*Distichlis spicata*) ground cover within the salt cedar. Species selection for this category was on the conservative side, using only representatives typically associated with marsh or grassland habitat not normally found in salt cedar. All other species were regarded as riparian (salt cedar) bird densities.

(b) *Small Mammal Live Trapping.*–The small mammal live trapping was conducted using the assessment line technique (O'Farrell, et al., 1977 [88] and O'Farrell and Maza, 1984 [89]). Figure 3 shows the layout of the small mammal trap configuration. Since future clearing efforts were being considered for the area north or south of strip 10 (i.e., strip 10 was the midpoint of the total site area), configurations were cut and established abutting one another on either side of this strip. This format would best show the change in rodent populations before and after clearing. Configurations were also placed midway down the strip to sample more homogeneous salt cedar habitat without influence from the river or desert wash borders.

Figure 4 shows the numbering sequence for the line trap configuration selected. Each dot and dash represents a trap station 50 feet apart where a collapsible Sherman live-trap was placed. This interstation distance was selected based on the species and relative numbers of rodents expected [89]. The two parallel lines were called basic lines, which were 174 feet apart, with a total of 20 trap stations per line. These stations were trapped for three consecutive nights. After a lapse of 3 to 5 days, the four diagonal assessment lines were

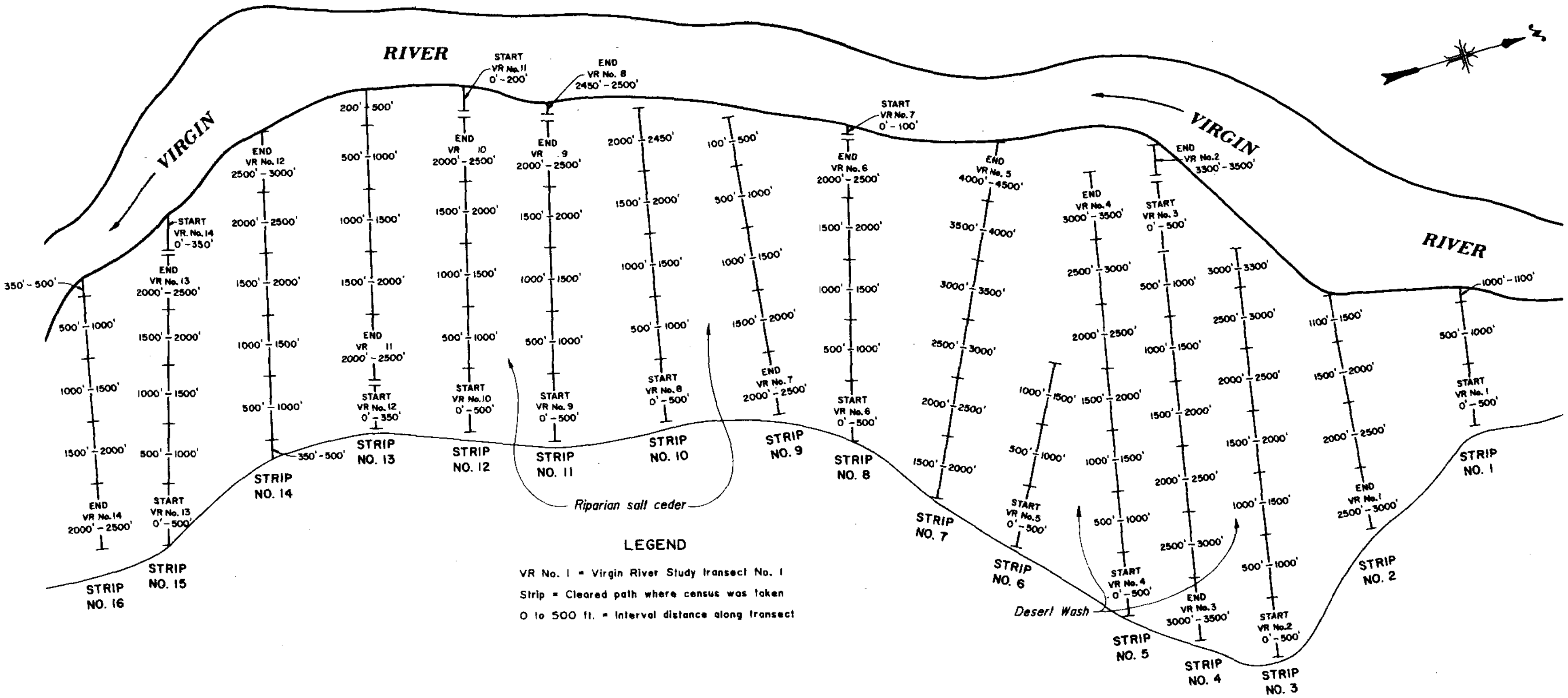


Figure 2. - Bird and vegetation transect format.

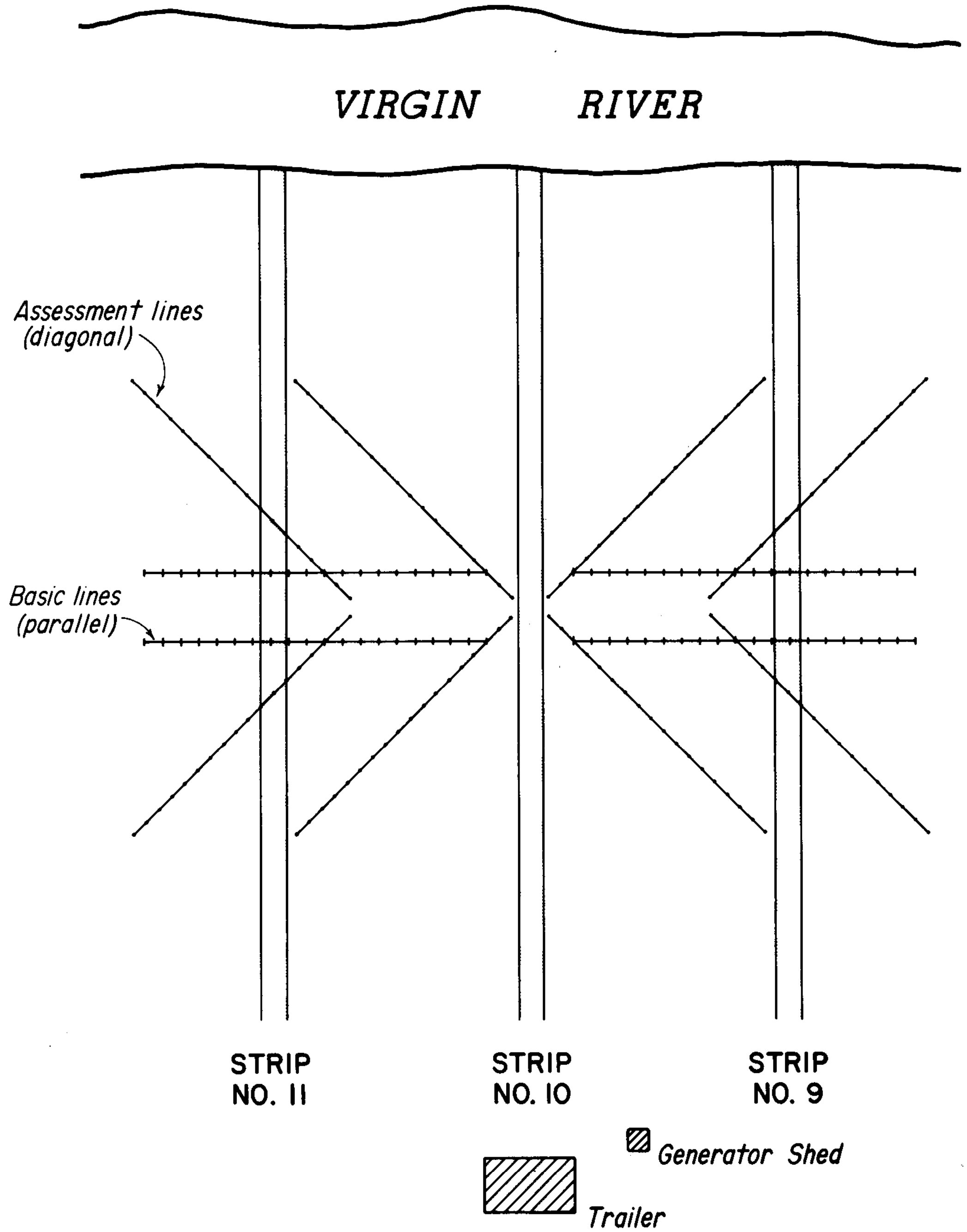


Figure 3. – Layout of small mammal trap configuration.

trapped for three consecutive nights. These lines also had an interstation space of 50 feet with a total of 18 trap stations per line. All trapping was scheduled as near to the new moon (no moon) as possible to sample during nights of highest rodent activity. Monthly rodent densities in number per acre and number per hectare and rodent biomass in ounces per acre and grams per hectare were calculated for each species for plot No. 1 (grid north of strip 10) and plot No. 2 (grid south of strip 10). Community indices were also calculated monthly for each plot. The "species richness" represents the total number of species occurring within the rodent community. At the other end of the population parameters is "evenness," which is the contribution of each species to the total number. That is, how evenly distributed each species is within the community. A more "even" or homogeneous distribution of individuals per species would yield a higher

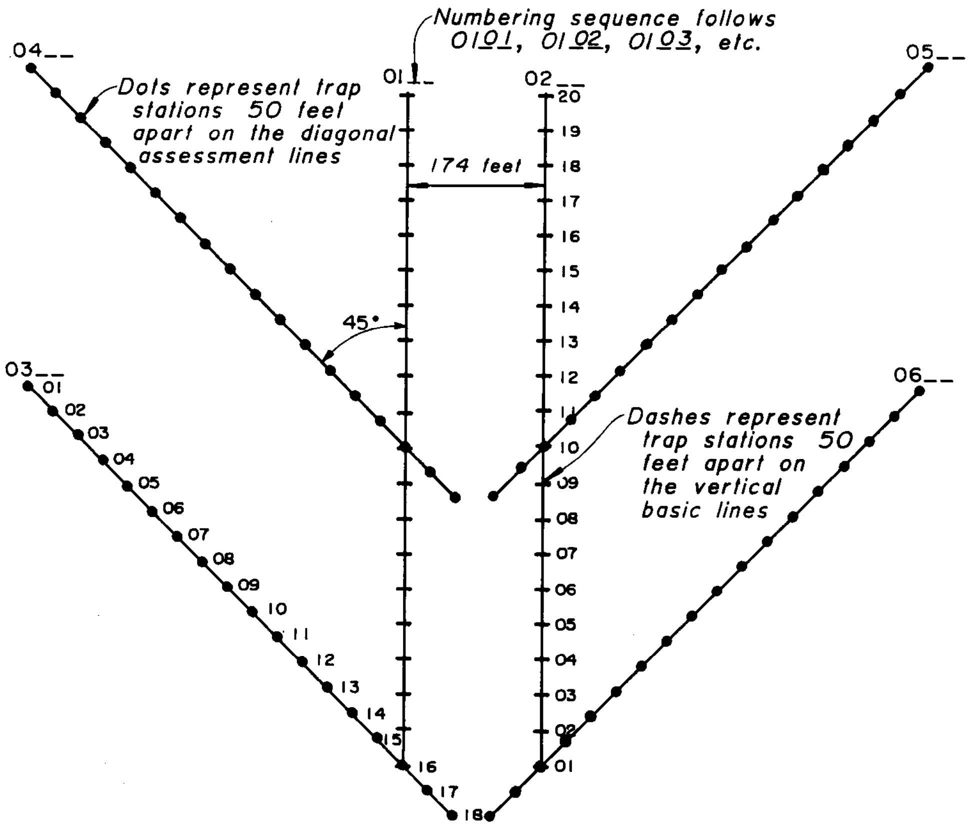


Figure 4. - Numbering sequence and format for small mammal trap configurations.

evenness value. "Species diversity" represents, more or less, the midpoint between richness and evenness. The species diversity value was based on the combined contribution of species richness and evenness. High species richness and evenness values will yield the highest species diversity value and should reflect a more stable population.

The predominant rodent species were grouped together monthly by sex ratio (number of males/females), age structure (number of adults/juveniles), and reproductive condition. The reproductive condition category represents the number of males (scrotal) and females (estrus, pregnant, lactating) that were at these points of sexual activity each month. Each individual was represented by the most advanced stage of sexual activity reached each month.

(c) *Vegetation Measurements*.-The FHD (foliage height diversity) is a measure of the vertical distribution of foliage in a community, and was calculated from foliage volume measurements collected using the board technique (MacArthur and MacArthur, 1961 [83]) taken at heights of 6 inches, and 2, 5, 10, 15, etc., feet. Measurements were taken at three points on either side of the transects within each 500-foot interval (e.g., 50, 250, and 450 feet). Vegetation measurements were also taken 50 feet around each rodent trap station recording the number of trees and shrubs, percent cover, density of understory, and range of tree height. The tree counts were simply a measure of the number of trees within 50 feet of each side of the transect and along the 500-foot intervals. The counts were categorized by tree (or shrub) species and heights greater than or less than 10 feet.

(d) *Amphibians, Reptiles, and Large Mammals*.-General sightings were recorded during early morning bird censuses and while performing other daily site activities. From these sightings, the relative frequency and habitat use were established.

Results

Bird Species Checklist.-An alphabetized checklist of all bird species observed over the entire study area from June 1982 to December 1983 is found in table 3. A total of 169 species were observed.

Bird Densities by Species.-Table 4 shows the calculated monthly bird species densities for all individuals observed along the riparian salt cedar transects during scheduled censuses. Bird species detected during each month on the study site, but not during census time, are designated by an asterisk. Table 5 shows the same information for the desert wash transects, except that species recorded within the entire study area that were never seen in the desert wash habitat are omitted.

Seasonal occurrences and density estimations in salt cedar are found in table 4. The highest monthly density for a particular bird species belonged to the Marsh Wren (*Cistothorus palustris*) during late fall and early winter. The most consistently occurring species having relatively stable populations and moderately high densities were, in order of decreasing overall density, Song Sparrow (*Melospiza melodia*), Bewick's Wren (*Thyromanes bewickii*), and Abert's Towhee (*Pipilo aberti*). The avian density summary and bird species totals at the end of table 4 portray the monthly changes in the total bird population and relative species number over time. Totals were highest primarily during spring and fall and lowest during late summer of the first year. The second year density totals for summer are double those of the previous summer. Probable reasons for this increase are related to the wetness of the site during the second year, as discussed in the next section.

Bird species density and diversity in the desert wash habitat are found in table 5. Compared to the salt cedar habitat, species diversity was substantially lower across all months in the desert wash and bird density was higher than salt cedar in only 2 months.

Bird Densities for Riparian and Wetland Categories.-Table 6 shows the monthly density and species totals of riparian and typical wetland birds for the four seasonal categories. General trends for the time categories were:

- *Permanent residents*.-Wetland species density estimates were higher than riparian species densities for 15 of 18 months, with the largest differences occurring during the winter months. Second year summer month densities (July, August) were the reverse of the first year, with wetland figures dominating.

- *Summer visitors*.-Riparian species densities were higher than wetland species densities for 9 of 9 months where the combined densities were large enough for comparison. The differences were less during the second year.

- *Winter visitors*.-Riparian species densities were higher than wetland species densities for 12 of 13 months; differences were extremely high during fall to early winter and lower during late winter and spring of the first year. Second year data showed the same relative trend.

- *Migrants*.-Riparian species densities made up the entire migrant category for the 8 months recorded. Density totals were relatively high for the 3 months during which most bird migrations occur in the area. All other density totals were low.

The density summary at the bottom of table 6 gives the overall picture by showing what percent of the total monthly density was contributed by riparian and wetland species. Riparian density totals were higher during June-December 1982. However, for the entire 1983 sampling period, wetland density totals were higher for all months except May. Total densities for both categories combined were higher in the second year than in the first year where replicate data were available for comparison.

Small Mammals.-Rodent community composition differed between plots as well as from month to month, see tables 7, 8, 9, and 10. Although grids were established in adjacent salt cedar communities, plot No. 1 represented an overall denser and drier salt cedar habitat; plot No. 2 was generally wetter and more open with a prevalent salt grass understory. Plot No. 1 (tables 7 and 9) averaged higher in both species composition and density. *Dipodomys merriami*, absent from plot No. 2 (tables 8 and 10), was only caught in the sandy areas of plot No. 1. The highly mobile *Onychomys torridus* was caught on plot No. 2 only once. *Reithrodontomys megalotis* and *Mus musculus* were the primary rodent community constituents in both plots with the two *Peromyscus* species usually forming a much lower secondary role. Species richness was slightly higher for plot No. 1 because of the presence of *D. merriami* and *O. torridus*.

Seasonal peaks generally occurred in July-August or October-November, and were similar between plots. The highest total densities for both plots occurred during October-November with a decline in December; however, species richness remained constant. Species evenness was lowest for plot No. 1 in November and December due to *R. megalotis* constituting a large portion of the density distribution. The lowest evenness value for plot No. 2 occurred a month earlier for the same reasons. The highest evenness occurred on plot No. 2 between March and July, reflecting relatively low, yet consistent densities for all species.

Density-based diversity averaged higher for plot No. 1 than for plot No. 2 with a wider range of values. The lowest value occurred in April for plot No. 1, which declined due to the absence of three species. For plot No. 2, October was lowest because of very skewed density distributions.

The total monthly biomass was usually well below 7.0 ounces per acre for both plots, except during December on plot No. 2 when *Neotoma lepida* accounted for nearly two-thirds of the entire biomass. Seasonal trends were similar to those for density values.

Sex ratios did not differ significantly from 1:1 except in the case of *Reithrodontimys megalotis* where males predominated generally by 2:1 or 3:1, see tables 11, 12, and 13. Sex ratios for all other species tended to slightly favor males.

Juveniles tended to be first caught in June, with larger numbers appearing by fall. *R. megalotis* juveniles were caught in good numbers later into the year than other species. Sex ratios were similar to the discussion presented for adults.

Reproductive activity occurred throughout the year for males of the regularly occurring species, with the lowest sexual activity occurring during December and January and, surprisingly, during June and July. Females were active for all months except December and January. Female *R. megalotis* were as sexually active as females of other species, but juveniles were detected later in the year. Sexual activity was summarized for the three low-density species only for plot No. 1 due to similar trends and even lower numbers found on plot No. 2, see table 13. General trends followed the same pattern as previously described for the more common species.

Vegetation Measurements.–The total foliage volume across the study site was highest at the south end (figs. 5 and 6), especially between strips 9 and 12. Total foliage volume along the more predominant salt cedar south end tended to be similar at the desert and river edges; however, the volume varied greatly at the five height layers. Salt grass contributed a good portion of the foliage volume at the 6-inch level, especially at the south end of the site.

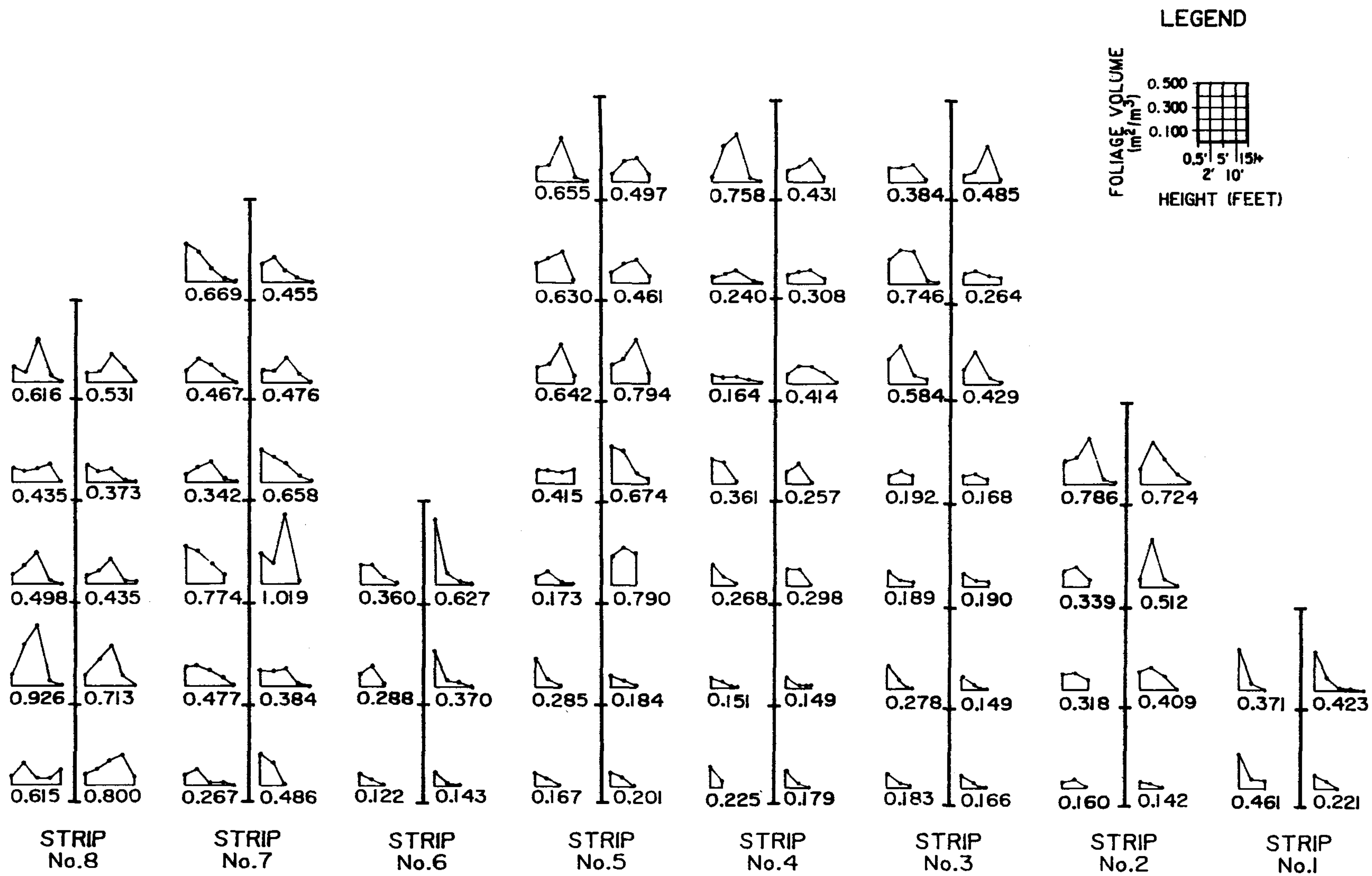
Salt cedar was the major vegetation type measured along the study strips, as shown by matching tree count results (figs. 7 through 22) to the overall map of the study area (fig. 2). The north end (strips 1-8) was characterized by a greater mixture of shrubs (arrowweed, pickleweed) within the salt cedar as opposed to the more monotypic south end (strips 9-16). The larger, mature salt cedars, that appeared to be more widely used by wildlife, tended to be found closer to the drier desert wash (east side) rather than the wetter river channel (west side). Salt cedar was restricted almost exclusively to the riparian floodplain, and desert wash counts at the north end indicated a decrease or absence of salt cedar where the width of the riparian vegetation narrowed. Quailbush, highly favored as a wildlife habitat, was also a minor constituent of the vegetative community. The presence of this shrub in moderate numbers indicated that the site conditions were conducive to survival, but some limiting factors preventing its spread are involved. This is probably partially due to inefficient seed dissemination and direct competition from established salt cedar.

Amphibians, Reptiles, and Large Mammals.–Table 14 is a species checklist of the amphibians, reptiles, and large mammals identified on the study site. Five species of amphibians were identified, and all were found within the Virgin River floodplain, primarily in the wetter, marshy situations close to the river. Meandering wet channels through thick, shady salt cedar were also frequented. *Bufo woodhousei* was the most common amphibian found throughout the wet riparian vegetation. *B. microscaphus*, which hybridizes with *B. woodhousei* along this portion of the Virgin River, appeared to be the second most common species. *Rana catesbeiana* were present in fair numbers, confined primarily to marshy islands and edges along the river. The remaining species were infrequently present in the salt cedar.

There were 18 different species of reptiles identified in the study area. *Trionyx spiniferus* was observed once in the Virgin River, and *Gopherus agassizi*, though never sighted in the actual study area, was encountered along the desert wash road leading down to the site. This protected species was recorded twice in May 1983, once at the upper end of the access road near the junction with Gold Butte Road, and once about 2 miles down from the first location.

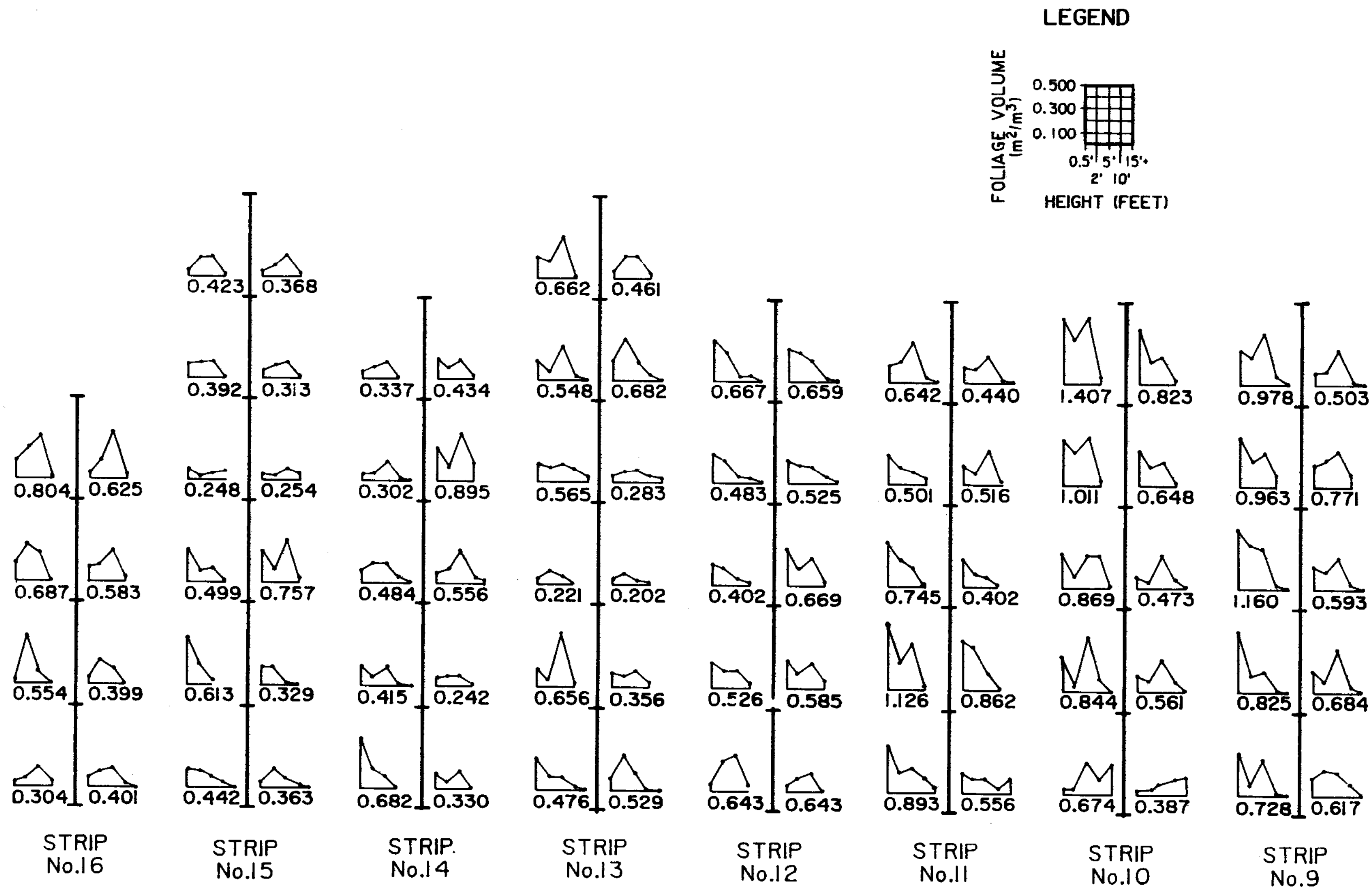
The 10 lizard species identified were primarily found in the desert wash habitat. Those observed in salt cedar always inhabited the drier, sandier areas found along the desert wash, salt cedar margin, or on sandy dune areas scattered throughout the site. *Urosaurus ornatus* and *Sceloporus magister* were the only species found more often in salt cedar than in the desert wash. *Callisaurus draconoides* and *Cnemidophorus tigris* were the most commonly seen lizards in the creosote bush community. *Uta stansburiana* was fairly common, primarily near desert-riparian margins. All other species were infrequently observed in the desert wash.

Six species of snakes were identified. *Pituophis melanoleucus* and *Masticophis flagellum* were observed the most frequently, usually at the desert wash-salt cedar border, with the former being observed on two occasions rapidly moving along salt cedar branches before making its escape into adjacent trees. *Crotalus cerastes* were sighted occasionally, but only in the sandier desert wash habitat. *Crotalus scutulatus* were seen a few times along the upper and lower parts of the desert wash



Note : Numbers under diagrams represent total foliage volume for all layers, in square meters per cubic meter.

Figure 5. – Foliage volume and distribution across Virgin River site for strip numbers 1 through 8.



Note: Numbers under diagrams represent total foliage volume for all layers, in square meters per cubic meter.

Figure 6. – Foliage volume and distribution across Virgin River site for strip numbers 9 through 16.

access road, acting very aggressive on two occasions. *Rhinocheilus lecontei* and *Lampropeltis getulus* were noted only twice along the desert-riparian border next to denser vegetated areas.

Only two species of bat, *Myotis californicus* and *Pipistrellus hesperus*, were positively identified. Both were commonly seen feeding on insects along the entire Virgin River floodplain and the adjacent desert. The five other species listed have been previously mist netted in the vicinity of the Lower Virgin River by Dr. Michael J. O'Farrell (pers. comm.).

Lepus californicus were commonly observed in the desert wash and particularly along the margins. Some were also found in the drier salt cedar areas. *Sylvilagus audubonii* were regularly encountered in the desert wash and margin habitat. Individuals were also frequently seen in the salt cedar; however, like the jackrabbit, mostly in drier, sandy situations. Some were observed eating salt cedar.

Castor canadensis, though never seen, left signs of its presence by cutting down some of the few large willows along the river edge. Of the mammals more typically regarded as rodents, 12 species were identified. A discussion of the species found in salt cedar is presented as results from the live-trapping studies. Of the nine species identified in the desert wash habitat, only *Dipodomys merriami* and, to a much lesser extent, *Perognathus longimembris* were found in any numbers. *Dipodomys deserti* and *Ammospermophilus leucurus* were found in small isolated colonies or in a few pairs, respectively.

The highly mobile *Onychomys torridus* appeared sporadically across the wash. *Peromyscus crinitus*, found only once in the wash, is probably more common in the adjacent rock hills, which is its preferred habitat. The two remaining *Peromyscus* species were found primarily at the riparian-wash margin, especially *Peromyscus eremicus*. *Spermophilus tereticaudus* was frequently heard along the desert wash road leading to the site.

Six species of carnivores were found on the site. The most common was undoubtedly *Canis latrans*, which was often heard howling in numbers from all habitat types. Tracks were common along the transect strips and along the river, and numerous individuals were seen hunting. Scats contained a wide variety of food items from cattails to rabbits to exclusively red-legged grasshoppers. *Vulpes macrotis* tracks were frequently found primarily in the desert wash. The remaining species were detected by tracks alone on rare occasions, except for *Taxidea taxus*. The sole occurrence for this species was of an individual seen unexpectedly in a sandy salt cedar area in June 1982.

Of the three species of hoofed mammals, *Odocoileus hemionus* was the rarest. Two sets of tracks leading from the Virgin River edge to the desert wash were recorded during April 1983. Individual tracks were also noted in 1982. *Equus asinus* were few in numbers but traversed the entire study area through all habitats, browsing on cacti, annuals, and salt cedar. Range cattle also browsed on similar plants but were much more abundant, especially in salt cedar and along the river. Cattle caused many problems for conducting the field studies, including disturbance during bird transect readings, damage to stakes and flagging, and crushing traps.

Conclusions

Birds.–Before discussing the conclusions, it should be noted that the densities recorded are estimations for a given species population size during a segment of time. Densities are often referred to as the "actual number" of birds although the number only represents a sample of the population that is used for estimating the actual density. In reference to bird species that tend to flock together, such as sparrows or quail, densities are calculated based on how far from the transect the birds are first detected. As a result, such flocking species tend to cause somewhat overinflated density estimates. This is especially relevant when the flocks are not evenly distributed across a habitat or are exploiting a highly productive food resource that happens to fall near the transect. Similar problems arise when vegetation types found along the transect are not representative of the overall habitat type, as in the case of our wetland vegetation, that increased in area along certain transects during the second year. These problems are discussed in the following section.

Based on the density/diversity tables, the salt cedar habitat appears to be far superior to the native desert wash community. In this case, salt cedar should harbor more species and numbers of birds simply because it is a wet riparian habitat that possesses a much greater foilage volume and structure. Therefore, to more accurately assess the relative importance of the salt cedar habitat for birds, comparisons should be made with other riparian communities. The dry desert wash habitat in this area characteristically has low foilage volume and is generally frequented by more ground-foraging bird species such as quail and sparrows.

Bird densities found in the salt cedar community along the Lower Virgin River were compared with bird density results found in similar habitat along the Lower Colorado River near Blythe, California (Anderson and Ohmart, 1974 [34]). Before making comparisons, it should be noted that the salt cedar study area on the Lower Virgin is a much wetter, less vertically diverse habitat than is found in typical situations along the Lower Colorado. The July 1982 Lower Virgin density total was over 20 birds per 100 acres lower than Lower Colorado densities. Subtracting the wetland species densities from the Lower Virgin total in July (table 6) reduces the number to almost half that of the Lower Colorado. However, the December 1982 densities for the Lower Virgin (minus wetland densities) were three times greater than the Lower Colorado. Therefore, the wetter salt cedar environment appears to be more favorable for winter bird populations. This is especially pronounced when comparing the Lower Virgin density totals in December 1982 with the December 1983 totals.

To gauge the significance of the salt cedar bird density estimates, comparisons should be made with other vegetation communities' estimates using the same methods of censusing. Data taken from Anderson and Ohmart, 1984 [84] compare the relationships between salt cedar and other native vegetation types similar to those found in the study area, see table 15. The native tree species shown in table 15 were found to have higher bird densities in all cases, especially in the cottonwood/willow and honey mesquite communities. Salt cedar's value as a bird habitat was even lower than the native tree species with the lowest bird densities.

The categorized bird density results appeared to show some interesting within habitat relationships between the riparian and wetland categories. Major density differences appeared to be due to habitat change and will be discussed by the seasonal categories:

- *Migrants*.-This category groups the bird species that breed to the north and normally winter to the south of the Virgin River. Based on the observations, migrant bird habitat use of the study site appeared to be a short-term stopover that was used to find food or to rest. Birds passing through this area, especially those with low fat reserves, have little choice of other native raparian tree species where food is typically obtained. Compared to the cottonwood/willow habitat upriver at Beaver Dam Wash, relative numbers of migrants found in the Virgin River salt cedar appear to be substantially less on days when migration was evident.

  The Virgin River data show a fairly large migratory bird density for only 1 month. Migrant bird densities can only be generally related to vegetation types primarily because of climatic variables influencing movement, and hence, density and diversity. Censusing 1 day before the passage of a weather front and 1 day after during the migration season (fall or spring) can yield totally different results. However, some species may have a more general and steady migratory passage, showing wide variations in numbers primarily when weather conditions are very conducive to or very much against migration. The Yellow Warbler (*Dendroica petechia*) was one such species on the site and was also the most common migrant, contributing to the majority of the monthly density total. In May, which yielded the highest migrant density (77.9 birds per 100 acres), the density consisted of 77 percent Yellow Warblers (60.0 birds per 100 acres), leaving a relatively small density spread among the remaining 16 species.

  The 100-percent contribution of riparian migrants during all months does not imply there were no migratory wetland species. Again, migrants found along the salt cedar transects were exclusively migratory. Migratory wetland species tend to winter and/or summer on the site or are observed as fly-overs along the river, uninfluenced by the vegetation.

- *Summer Visitors*.-This grouping includes bird species that normally breed on the site and winter to the south. Most summer visitors are present for a relatively short time span (about 4 months). Total density patterns for this category are sometimes difficult to interpret because of early or late arrivals or departures, and increases in numbers by juvenile birds. One example is Lucy's Warbler (*Vermivora luciae*), an early breeder that arrives in March, and Indigo Bunting (*Passerina cyanea*) that does not arrive until May or June. Some warblers may be feeding young when some buntings are just arriving.

Riparian densities during the summer were four times larger than wetland densities. Even though densities fluctuated for both categories, relative proportions remained virtually the same. An interesting comparison between June–July summer and January–February winter riparian versus wetland densities reveals nearly equal numbers and proportions, perhaps reflecting some general carrying capacity for the habitat when populations are somewhat stable. Comparing the summer of 1982 with 1983 shows a rather large change in the riparian-wetland density categories. Ratios for June–August 1982 riparian-wetland habitat averaged 4:1 in favor of riparian whereas June–August 1983 data resulted in proportions averaging less than 2:1. Total densities also increased in 1983 by an average of 12 birds per 100 acres each month. Wetland densities more than doubled for each month and species diversity increased. Riparian densities averaged 5 birds per 100 acres higher over the 3 months. A density increase in riparian and wetland birds could be due to annual fluctuations in the population, but this seems unlikely by the way the density totals favored a different category in 1983.

Considering the vegetation characteristics from the observations, it would appear the site has indeed undergone some changes. The winter of 1982 was characterized by excessively high flood flows of the Virgin River across the site. River inundation formed new channels and also deepened existing channels, eroding the study area even more. The riverbed and site typically dried up during the latter part of the summer of 1982, whereas the summer of 1983 was never completely dry. Strips 15 and 16, in particular, actually became regular avenues of streamflow. Cattails, bulrushes, marsh plants, and even grasses more than doubled the area they covered the previous year. Hence, wetland species had more available wetland habitat. Even riparian birds appeared to be influenced in a positive manner. The few, more monotypic salt cedar areas that were dry appeared to have extremely low numbers of birds relative to the wetter areas. It appeared that the salt cedar habitat value for birds was enhanced simply by the presence of water alone instead of only by the increase in marsh vegetation.

- *Winter Visitors.*–This category usually includes species that breed to the north and winter in the area of the study site. Some studies indicate that wintering grounds are extremely important to birds. Food supply and climate highly influence a bird's survival rate and will, in part, regulate the numbers that will be able to return north to breed. Overall numbers for these species may be governed more by winter food availability rather than by breeding success.

Densities for winter visitors were similar for the latter part of fall and early winter of the first year. Wetland densities only represented about 10 percent of the total density during this period. January densities showed a drastic decline in riparian birds of well over 50 percent, whereas wetland birds dropped little. The decreases in March, and also possibly for February, could be due to earlier departing individuals. However, the drops in January seem to indicate dispersion or mortality. As previsouly discussed, flocking species may yield inflated densities if encountered along the transect in large numbers. However, seed eaters such as the White-crowned Sparrow (*Zonotrichia leucophrys*) and the Dark-eyed Junco (*Junco hyemalis*), that accounted for most of the decrease, maintained low numbers after January. By January, *Atriplex* seeds, found in scattered areas along the site, were fairly well depleted. Also, the insectivore Ruby-crowned Kinglet (*Regulus calendula*) dropped to one fifth of the previous months totals, further indicating that the salt cedar habitat does not support the winter food requirements for these species. Salt cedars' potential food supply for birds could be very limited by January, and competition for the remaining food supply would probably be high. Options available are to move to a better habitat or risk starvation. Some studies have suggested that the less experienced, first-year birds are first to suffer from the food shortage. One would expect local resident species (adult and immature) to have an advantage over wintering visitors, where niche overlap is concerned, because they are more familiar with habitat resources. Declines from December to January for riparian permanent residents and winter visitors were 37 and 65 percent, respectively.

Wintering birds during November and December of the second year show a dramatic increase in numbers. Riparian density nearly doubled while wetland density more than tripled. Diversity was slightly higher for riparian species while the diversity for wetland species more than doubled. This is apparently a reflection of the enhanced habitat conditions due to the wetter circumstances characterizing the second year.

- *Permanent Residents.*–This category made up the largest proportion of the overall monthly densities, averaging 69 percent of the total per month. Permanent resident refers to the bird species present during most summer and winter months. Densities for a particular species may vary greatly, particularly during migration when individuals that breed further north or winter further south pass through and temporarily increase their numbers. Hypothetically, breeding individuals could be entirely replaced by wintering birds of the same species from the north. The rate and the amount of species turnover can only be determined through banding studies or by collecting specimens.

Most permanent resident species are probably more indicative of intrinsic habitat value than any of the groups previously mentioned. Numbers of these year-round residents are likely to be governed more by vegetative characteristics of the site, and may be more readily affected by change.

The relationship between permanent resident riparian and wetland densities is evident in table 6. Wetland densities were higher 87 percent of the time, with the greatest differences occurring during winter when densities more than doubled riparian. In particular, the Marsh Wren (*Cistothorus palustris*) and the Virginia Rail (*Rallus limicola*) accounted for most of the increase, two species that are closely tied to emergent marsh vegetation. The wetter environment in 1983 and cleared unshaded transect lines promoted emergent growth that provided more habitat for these species. The summer of 1982 showed riparian densities averaging higher than wetland, whereas the summer of 1983 showed wetland densities averaging nearly twice riparian densities. This drastic change between years appears to dramatically reflect the wetter conditions during the second year as previously discussed. Also, as with summer visitors, riparian permanent resident densities increased in June–August 1983 by an average of 20 birds per 100 acres each month.

Comparing the 1982 total riparian versus wetland densities with duplicate months in 1983 (June–December, excluding September) shows riparian densities averaging higher in 1982 by a proportion of 2:1. However, in 1983, wetland densities had the edge, averaging 1.3:1. Total densities also increased in 1983 by an average of 170 birds per 100 acres each month. Relationships between density change and marsh vegetation area certainly appear to be present.

Small Mammals.–The small mammal population studies in salt cedar vegetation have been few, with the only major work consisting of snap trapping conducted in vegetation communities along the Lower Colorado River Valley (Ohmart 1983, work draft).

On the Virgin River site, *Mus musculus* and *Reithrodontomys megalotis* were the highest density rodent species caught. This is contrary to the low density estimates found along the Lower Colorado for these species. Likewise, high numbers of *R. megalotis* were trapped in open salt cedar areas with a dense salt grass cover along the Lower Virgin River, whereas along the Lower Colorado this species was correlated to high density in the upper foliage layers ($\geq$ 16.4 feet). Within the salt cedar,wetter areas with an understory would appear to be more preferred by this species. The seemingly odd sex-ratio predominance found in male *R. megalotis* along the Lower Virgin is, in fact, concurrent with the literature (Fisler, 1971 [54]). Little information appears to be available on *M. musculus* as occurring in salt cedar other than in reference [54]. An introduced species, *M. musculus* tends to be associated with more populated areas where it is well recognized as a pest. It is interesting to note that this species is native to Eurasia, where it commonly occurs in a salt cedar habitat. Future small mammal population studies conducted in salt cedar may reveal this species as being more prevalent than expected, especially in riparian vegetation near inhabited areas.

Both *P. eremicus* and *P. maniculatus* were caught in relatively low densities along the Lower Virgin with numbers reaching two mammals per acre only once. These species were normally associated with foliage density at the higher layers. The Lower Colorado studies showed highest density estimates for these species occurring in salt cedar; *P. eremicus* correlated to salt cedar with little low-level vegetation, and *P. maniculatus* in all salt cedar structure types.

Rodent densities in the wet salt cedar habitat were higher than expected when compared to drier salt cedar areas. This could possibly be accounted for by a higher production of annuals and grasses to support a much larger rodent population. Drier, more mature salt cedar stands are normally devoid of understory due to excessive leaf litter that prevents ground cover from becoming established.

One of the most interesting aspects of trapping was the rodents' ability to cope with excessively high flood flows. The months of December 1982, January 1983, and May 1983 were characterized by 1 to 3 days of flooding that nearly covered the entire study area by up to 3 feet of water. The May 1983 trapping session had to be cancelled due to lack of dry areas available to place the traps. Once the high river flows started, traps were set at the periphery of the riparian salt cedar at the desert wash edge to determine if this area was being inhabited by the rodents until flooding subsided. Not a single toe-clipped individual was caught. Subsequent trapping on the configurations revealed no dramatic change in the rodent community. As a result of these observations, it appeared the small rodents had to have climbed the salt cedar to escape the flood flow. This apparent periodic arboreal habit is a behavior necessary for survival and successful establishment in such a dynamic environment. The extremely dense salt cedar would probably allow adequate protection from predators during these high flood-flow periods. The apparent lack of predators on the site should also be noted. *Canis latrans* and *Vulpes macrotis* tracks were found along the strips, but dense areas appeared to discourage access.

Since there has been little done with small mammal live trapping in salt cedar vegetation, the results along the Lower Virgin were important in that baseline information is provided on the rodent community.

Vegetation.–The vegetative studies conducted along the Lower Virgin River test site portrays an accurate assessment of the general layout for foliage volume structure and plant species distribution. This should contribute to determining relationships between well-data results and the associated vegetation characteristics. Interpreting the vegetation data into the type mapping classification of vegetative structure used along the Lower Colorado River (Anderson and Ohmart, 1977 [34,35]), the measurements predominantly fall into structure type V. Vegetation characteristics of this structure type have little volume above 10 feet, generally rather sparse with trees, and moderately dense volume particularly from 6 inches to 2 feet. Some locations fell into type VI (very sparse areas, little volume above 10 feet) and type IV (little volume above 15 feet, generally moderately dense) categories. Type VI tended to be characterized primarily at the south end of the study site while type IV was found primarily along the riparian/desert wash border. These differences in vegetation structure are probably attributable to the water table, soil, and salinity factors as indicated in the literature. Therefore, consideration of the plant species and relative vigor alone would provide helpful information in determining replacement vegetation types for the Lower Virgin River site.

Amphibians, Reptiles, and Large Mammals.- Habitat use by these wildlife groups, although judged only through general observations, still appears to favor the desert wash community. Also, native riparian communities in the Southwest States generally have a much richer fauna association than salt cedar, especially with mammals, and, to a lesser extent, reptiles. Scattered higher, drier sandy areas long the floodplain appeared to be the primary reason for reptile use in salt cedar. Again, all the species listed for these three groups were recorded as general observations, and is by no means a complete list. This applies especially to the more nocturnal reptile species in the desert wash habitat.

Amphibians along the Lower Virgin River Valley were studied by Blair in 1955 [55], and represents one of the few works conducted in this area. Blair showed *Bufo microscaphus* hybridizing with *B. woodhousei* downriver from Mesquite, Nevada. Dr. Melodie Serena, who visited the test site in 1983 to assess the current hybridization tendency between these species, found mostly intermediate toads with primarily *B. woodhousei* characteristics. Dr. Serena's conclusions were basically the same as those found by Blair over 25 years ago. It was postulated that characteristics favored *B. woodhousei* because slower flowing river channels and sandier areas provided more favorable habitat for this species. *B. microscaphus* tends to favor more rocky, faster flowing streams.

Table 3. – Bird species checklist for June 1982 – December 1983.

1. Abert's Towhee (*Pipilo abertii*)
2. American Avocet (*Recurvirostre americana*)
3. American Bittern (*Botaurus lentiginosus*)
4. American Coot (*Fulica americana*)
5. American Crow (*Corvus brachyrhynchos*)
6. American Goldfinch (*Carduelis tristis*)
7. American Kestrel (*Falco sparverius*)
8. American Robin (*Turdus migratorius*)
9. American White Pelican (*Pelecanus erythrorhynchos*)
10. Ash-throated Flycatcher (*Myiarchus cinerascens*)
11. Band-tailed Pigeon (*Columba fasciata*)
12. Bank Swallow (*Riparia riparia*)
13. Barn Swallow (*Hirundo rustica*)
14. Bell's Vireo (*Vireo bellii*)
15. Belted Kingfisher (*Ceryle alcyon*)
16. Bewick's Wren (*Thyromanes bewickii*)
17. Black and White Warbler (*Mniotilta varia*)
18. Black-bellied Plover (*Pluvialis squatarola*)
19. Black-crowned Night Heron (*Nycticorax nycticorax*)
20. Black-headed Grosbeak (*Pheucticus melanocephalus*)
21. Black-necked Stilt (*Himantopus mexicanus*)
22. Black Phoebe (*Sayornis nigricans*)
23. Black-tailed Gnatcatcher (*Polioptila melanura*)
24. Black Tern (*Chlidonias niger*)
25. Black-throated Gray Warbler (*Dendroica nigrescens*)
26. Black-throated Sparrow (*Amphispiza bilineata*)
27. Blue-gray Gnatcatcher (*Polioptila caerulea*)
28. Blue Grosbeak (*Guiraca caerulea*)
29. Brewer's Blackbird (*Euphagus cyanocephalus*)
30. Brewer's Sparrow (*Spizella breweri*)
31. Broad-tailed Hummingbird (*Selasphorus platycercus*)
32. Brown-crested Flycatcher (*Myiarchus tyrannulus*)
33. Brown-headed Cowbird (*Molothrus ater*)
34. Bushtit (*Psaltriparus minimus*)
35. Cactus Wren (*Campylorhynchus brunneicapillus*)
36. California Gull (*Larus californicus*)
37. Canada Goose (*Branta canadensis*)
38. Canyon Wren (*Catherpes mexicanus*)
39. Caspian Tern (*Sterna caspia*)
40. Cassin's Kingbird (*Tyrannus vociferans*)
41. Cedar Waxwing (*Bombycilla cedrorum*)
42. Chipping Sparrow (*Spizella passerina*)
43. Cinnamon Teal (*Anas cyanoptera*)
44. Cliff Swallow (*Hirundo pyrrhonota*)
45. Common Barn-Owl (*Tyto alba*)
46. Common Poorwill (*Phalaenoptilus nuttallii*)
47. Common Raven (*Corvus corax*)
48. Common Snipe (*Gallinago gallinago*)
49. Common Yellowthroat (*Geothlypis trichas*)
50. Cooper's Hawk (*Accipiter cooperii*)
51. Costa's Hummingbird (*Calypte costae*)
52. Crissal Thrasher (*Toxostoma dorsale*)
53. Dark-eyed Junco (*Junco hyemalis*)
54. Double-crested Cormorant (*Phalacrocorax auritus*)
55. Eared Grebe (*Podiceps nigricollis*)
56. European Starling (*Sturnus vulgaris*)
57. Forster's Tern (*Sterna forsteri*)
58. Gadwall (*Anas strepera*)
59. Gambel's Quail (*Callipepla gambelii*)
60. Golden Eagle (*Aquila chrysaetos*)
61. Gray Flycatcher (*Empidonax wrightii*)
62. Great Blue Heron (*Ardea herodias*)
63. Great Egret (*Casmerodius albus*)
64. Great Horned Owl (*Bubo virginianus*)
65. Greater Roadrunner (*Geococcyx californianus*)
66. Greater Scaup (*Aythya marila*)
67. Greater Yellowlegs (*Tringa melanoleuca*)
68. Great-tailed Grackle (*Quiscalus mexicanus*)
69. Green-backed Heron (*Butorides striatus*)
70. Green-tailed Towhee (*Pipilo chlorurus*)
71. Green-winged Teal (*Anas crecca*)
72. Hammond's Flycatcher (*Empidonax hammondii*)
73. Hermit Thrush (*Catharus guttatus*)
74. Horned Lark (*Eremophila alpestris*)
75. House Finch (*Carpodacus mexicanus*)
76. House Sparrow (*Passer domesticus*)
77. House Wren (*Troglodytes aedon*)
78. Inca Dove (*Columbina inca*)
79. Indigo Bunting (*Passerina cyanea*)
80. Killdeer (*Charadrius vociferus*)
81. Ladder-backed Woodpecker (*Picoides scalaris*)
82. Lark Sparrow (*Chondestes grammacus*)
83. Lazuli Bunting (*Passerina amoena*)
84. Least Bittern (*Ixobrychus exilis*)
85. Least Sandpiper (*Calidris minutilla*)
86. Lesser Goldfinch (*Carduelis psaltria*)
87. Lesser Nighthawk (*Chordeiles acutipennis*)
88. Lincoln's Sparrow (*Melospiza lincolnii*)
89. Little Blue Heron (*Egretta caerulea*)
90. Loggerhead Shrike (*Lanius ludovicianus*)
91. Long-billed Curlew (*Numenius americanus*)
92. Long-eared Owl (*Asio otus*)
93. Lucy's Warbler (*Vermivora luciae*)
94. MacGillivray's Warbler (*Oporornis tolmiei*)
95. Mallard (*Anas platyrhynchos*)
96. Marbled Godwit (*Limosa fedoa*)
97. Marsh Wren (*Cistothorus palustris*)
98. Mountain Bluebird (*Sialia currucoides*)
99. Mourning Dove (*Zenaidura macroura*)
100. Nashville Warbler (*Vermivora ruficapilla*)
101. Northern Flicker (*Colaptes auratus*)
102. Northern Harrier (*Circus cyancus*)
103. Northern Mockingbird (*Mimus polyglottos*)
104. Northern Oriole (*Icterus galbula*)
105. Northern Pintail (*Anas acuta*)
106. Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)
107. Northern Shoveler (*Anas clypeata*)
108. Orange-crowned Warbler (*Vermivora celata*)
109. Osprey (*Pandion haliaetus*)
110. Phainopepla (*Phainopepla nitens*)
111. Pine Siskin (*Carduelis pinus*)
112. Prairie Falcon (*Falco mexicanus*)
113. Red-breasted Merganser (*Mergus serrator*)
114. Red-tailed Hawk (*Buteo jamaicensis*)
115. Red-winged Blackbird (*Agelaius phoeniceus*)
116. Ring-billed Gull (*Larus delawarensis*)
117. Ring-necked Pheasant (*Phasianus colchicus*)
118. Rock Dove (*Columba livia*)
119. Rock Wren (*Salpinctes obsoletus*)
120. Rose-breasted Grosbeak (*Pheucticus ludovicianus*)
121. Rough-legged Hawk (*Buteo lagopus*)
122. Ruby-crowned Kinglet (*Regulus calendula*)
123. Rufous-sided Towhee (*Pipilo erythropthalmus*)
124. Sage Sparrow (*Amphispiza bellii*)
125. Sandhill Crane (*Grus canadensis*)

Table 3. - Bird species checklist for June 1982 - December 1983. - Continued

126. Savannah Sparrow (*Passerculus sandwichensis*)
127. Say's Phoebe (*Sayornis saya*)
128. Scott's Oriole (*Icterus parisorum*)
129. Scrub Jay (*Aphelocoma coerulescens*)
130. Semipalmated Plover (*Charadrius semipalmatus*)
131. Sharp-shinned Hawk (*Accipiter striatus*)
132. Snow Goose (*Chen caerulescens*)
133. Snowy Egret (*Egretta thula*)
134. Solitary Vireo (*Vireo solitarius*)
135. Song Sparrow (*Melospiza melodia*)
136. Sora (*Porzana carolina*)
137. Spotted Sandpiper (*Actitis macularia*)
138. Summer Tanager (*Piranga rubra*)
139. Swainson's Hawk (*Buteo swainsonii*)
140. Swamp Sparrow (*Melospiza georgiana*)
141. Townsend's Solitaire (*Myadestes townsendi*)
142. Townsend's Warbler (*Dendroica townsendi*)
143. Tree Swallow (*Tachycineta bicolor*)
144. Turkey Vulture (*Cathartes aura*)
145. Verdin (*Auriparus flaviceps*)
146. Vesper Sparrow (*Pooecetes gramineus*)
147. Violet-green Swallow (*Tachycineta thalassina*)
148. Virginia Rail (*Rallus limicola*)
149. Virginia's Warbler (*Vermivora virginiae*)
150. Warbling Vireo (*Vireo gilvus*)
151. Water Pipit (*Anthus spinoletta*)
152. Western Flycatcher (*Empidonax difficilis*)
153. Western Kingbird (*Tyrannus verticalis*)
154. Western Meadowlark (*Sturna neglecta*)
155. Western Sandpiper (*Calidris mauri*)
156. Western Tanager (*Piranga ludoviciana*)
157. Western Wood-Pewee (*Contopus sordidulus*)
158. White-crowned Sparrow (*Zonotrichia leucophrys*)
159. White-faced Ibis (*Plegadis chihi*)
160. White-throated Swift (*Aeronautes saxatalis*)
161. Willet (*Catoptrophorus semipalmatus*)
162. Willow Flycatcher (*Empidonax traillii*)
163. Wilson's Warbler (*Wilsonia pusilla*)
164. Winter Wren (*Troglodytes troglodytes*)
165. Yellow-breasted Chat (*Icteria virens*)
166. Yellow-bellied Sapsucker (*Sphyrapicus varius*)
167. Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)
168. Yellow-rumped Warbler (*Dendroica coronata*)
169. Yellow Warbler (*Dendroica petechia*)

Table 4. – Bird densities[1] for the salt cedar transects for June 1982-December 1983.

Bird Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1. Abert's Towhee	9.2	18.3	17.8	24.2	24.7	13.8	10.7	6.4	11.4	10.9	10.0	13.8	(20.8)	21.3	57.9	ND	30.1	20.5	13.9
2. American Avocet	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	ND	–	–	–
3. American Bittern	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	ND	–	–	–
4. American Coot	–	–	–	–	–	–	*	–	–	–	–	–	–	*	–	ND	–	–	–
5. American Crow	–	–	–	–	*	*	*	–	–	–	–	–	–	–	–	ND	–	*	*
6. American Goldfinch	–	–	–	–	–	*	*	*	*	–	*	*	–	–	–	ND	*	*	*
7. American Kestrel	–	*	*	0.4	–	–	–	–	–	*	0.1	*	–	–	*	ND	*	–	–
8. American Robin	–	–	–	–	*	*	*	0.1	*	–	–	–	–	–	–	ND	–	0.1	–
9. American White Pelican	–	–	–	*	–	–	–	–	–	*	*	*	–	–	–	ND	*	–	–
10. Ash-throated Flycatcher	0.1	*	0.9	1.5	1.0	–	–	–	–	–	*	0.3	–	0.4	2.2	ND	0.2	–	–
11. Band-tailed Pigeon	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
12. Bank Swallow	–	–	*	–	–	–	–	–	–	–	–	*	–	*	–	ND	–	–	–
13. Barn Swallow	*	*	*	*	*	–	–	–	–	–	*	*	–	–	–	ND	*	–	–
14. Bell's Vireo	1.0	0.4	1.5	0.3	–	–	–	–	–	*	0.7	1.0	(0.7)	0.9	0.3	ND	–	–	–
15. Belted Kingfisher	–	–	–	*	–	–	–	–	–	–	*	–	–	–	–	ND	–	–	–
16. Bewick's Wren	17.5	13.8	15.8	23.2	33.1	22.3	26.6	16.8	12.6	16.8	17.2	27.0	(8.9)	22.7	16.9	ND	36.7	46.9	28.6
17. Black and White Warbler	–	–	–	–	–	–	–	–	–	–	–	0.3	–	–	–	ND	–	–	–
18. Black-bellied Plover	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	ND	*	–	–
19. Black-crowned Night Heron	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	ND	–	–	–
20. Black-headed Grosbeak	–	–	0.1	–	–	–	–	–	–	–	–	0.5	–	–	–	ND	–	–	–
21. Black-necked Stilt	–	–	*	–	–	–	–	–	–	–	*	*	–	–	–	ND	–	–	–
22. Black Phoebe	–	–	–	–	–	0.5	0.4	–	0.5	–	–	*	(*)	*	–	ND	–	–	0.7
23. Black-tailed Gnatcatcher	0.2	2.0	6.9	5.4	2.5	5.4	7.4	4.4	1.0	1.2	0.7	0.7	(*)	1.1	1.5	ND	1.1	2.2	2.2
24. Black Tern	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	ND	–	–	–
25. Black-throated Gray Warbler	–	–	*	–	–	–	–	–	–	–	–	0.5	–	–	–	ND	–	–	–
26. Black-throated Sparrow	–	*	–	–	–	–	–	–	–	*	*	0.5	(1.5)	0.4	*	ND	–	–	–
27. Blue-gray Gnatcatcher	5.3	4.8	6.4	1.5	0.1	0.5	–	–	–	–	5.3	5.4	(4.4)	3.3	*	ND	0.4	0.4	0.7
28. Blue Grosbeak	6.0	3.5	6.4	4.7	0.5	–	–	–	–	–	0.1	2.5	(3.0)	8.1	6.6	ND	–	–	–
29. Brewer's Blackbird	–	–	–	*	*	*	*	*	*	*	*	*	–	–	–	ND	*	*	*
30. Brewer's Sparrow	–	–	–	11.4	0.5	–	–	–	–	–	*	0.3	–	–	–	ND	–	–	–
31. Broad-tailed Hummingbird	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	ND	–	–	–
32. Brown-crested Flycatcher	–	–	0.5	–	–	–	–	–	–	–	–	–	–	–	*	ND	–	–	–
33. Brown-headed Cowbird	3.8	2.0	*	–	*	*	–	–	–	–	1.0	5.4	(8.9)	4.4	0.7	ND	*	*	–
34. Bushtit	–	–	–	–	3.1	21.0	12.5	11.4	11.1	1.5	–	–	–	*	–	ND	–	2.0	9.35
35. Cactus Wren	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	ND	–	–	–
36. California Gull	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	ND	–	–	–
37. Canada Goose	–	–	–	–	–	*	*	*	*	–	–	–	*	–	–	ND	–	–	*
38. Canyon Wren	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
39. Caspian Tern	–	–	–	–	–	–	–	–	–	–	*	*	*	–	–	ND	–	–	–
40. Cassin's Kingbird	–	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	ND	–	–	–
41. Cedar Waxwing	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	ND	–	–	–
42. Chipping Sparrow	–	–	1.0	0.5	1.2	–	–	–	–	–	0.1	0.5	–	–	–	ND	*	–	–
43. Cinnamon Teal	–	–	–	–	–	–	–	–	–	*	0.2	0.8	*	0.2	0.1	ND	–	–	–
44. Cliff Swallow	*	*	*	–	–	–	–	–	–	*	*	*	*	*	*	ND	–	–	–
45. Common Barn-Owl	*	*	*	*	*	–	–	*	*	*	–	–	–	–	–	ND	*	–	–

Table 4. – Bird densities[1] for the salt cedar transects for June 1982-December 1983. — Continued

Bird Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
46. Common Poorwill	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
47. Common Raven	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	ND	*	*	*
48. Common Snipe	–	–	–	0.5	*	0.5	*	1.5	1.5	2.0	2.4	0.5	–	–	–	ND	*	*	2.2
49. Common Yellowthroat	9.7	5.9	7.4	7.9	1.0	–	–	–	–	–	9.1	21.1	(7.4)	14.7	15.4	ND	9.5	0.7	1.8
50. Cooper's Hawk	–	–	–	–	–	*	*	*	*	–	–	–	–	–	–	ND	*	0.1	–
51. Costa's Hummingbird	–	–	–	–	–	–	–	–	–	*	0.5	*	–	–	–	ND	–	–	–
52. Crissal Thrasher	3.2	1.6	1.2	1.5	2.2	0.9	2.9	0.9	2.0	1.4	3.8	2.7	(1.5)	2.9	2.2	ND	2.2	0.7	1.0
53. Dark-eyed Junco	–	–	–	–	1.0	6.4	23.6	0.1	0.5	0.5	*	–	–	–	–	ND	–	1.5	5.1
54. Double-crested Cormorant	–	–	–	*	–	–	–	–	–	*	*	–	*	–	–	ND	*	–	–
55. Eared Grebe	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	ND	–	–	–
56. European Starling	–	–	–	–	*	1.2	0.7	1.0	–	–	–	–	–	–	–	ND	*	*	0.7
57. Forster's Tern	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	ND	–	–	–
58. Gadwall	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	ND	–	–	–
59. Gambel's Quail	1.8	0.1	*	*	–	0.3	–	–	–	*	0.2	0.2	*	5.1	0.7	ND	0.7	*	1.7
60. Golden Eagle	–	–	–	*	–	*	–	–	–	*	–	–	–	–	–	ND	–	–	–
61. Gray Flycatcher	–	–	–	1.5	–	*	–	–	–	–	0.2	0.1	–	–	–	ND	–	–	0.2
62. Great Blue Heron	*	*	*	–	*	*	–	–	–	*	*	*	*	*	*	ND	*	*	0.3
63. Great Egret	–	*	*	–	–	–	–	*	–	–	*	–	–	*	–	ND	*	–	–
64. Great Horned Owl	*	*	*	*	*	–	*	*	*	*	–	–	–	–	*	ND	*	*	*
65. Greater Roadrunner	0.1	0.4	0.2	1.2	0.5	–	*	*	0.1	0.3	*	0.5	*	0.2	0.7	ND	0.7	0.2	*
66. Greater Scaup	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–	ND	–	–	–
67. Greater Yellowlegs	–	–	–	*	*	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
68. Great-tailed Grackle	–	*	–	–	–	–	–	–	–	–	*	–	–	*	–	ND	–	–	–
69. Green-backed Heron	*	*	–	–	–	–	–	–	–	–	–	*	–	–	–	ND	0.4	–	0.7
70. Green-tailed Towhee	–	–	–	1.0	0.5	–	–	–	–	–	*	*	–	–	–	ND	–	–	–
71. Green-winged Teal	–	–	–	–	–	*	–	–	–	*	*	–	–	–	–	ND	*	*	1.1
72. Hammond's Flycatcher	–	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
73. Hermit Thrush	–	–	–	–	0.3	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
74. Horned Lark	*	–	–	*	*	*	*	–	*	*	*	–	–	–	*	ND	*	*	*
75. House Finch	*	*	0.7	0.1	*	*	*	–	*	*	*	0.3	–	1.5	*	ND	1.1	*	*
76. House Sparrow	–	–	–	–	*	*	–	–	–	–	*	*	–	–	–	ND	–	*	–
77. House Wren	–	–	–	2.5	3.2	0.5	2.6	1.5	1.5	0.3	0.2	0.5	–	–	–	ND	5.9	7.3	4.4
78. Inca Dove	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
79. Indigo Bunting	0.6	0.4	–	–	–	–	–	–	–	–	–	0.1	–	*	–	ND	–	–	–
80. Killdeer	–	*	*	*	*	*	–	–	*	*	*	*	–	–	*	ND	*	*	–
81. Ladder-backed Woodpecker	–	–	–	–	–	–	–	–	–	–	–	–	–	*	*	ND	–	–	–
82. Lark Sparrow	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	ND	–	–	–
83. Lazuli Bunting	–	–	0.1	0.1	*	–	–	–	–	–	*	5.9	*	*	–	ND	–	–	–
84. Least Bittern	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
85. Least Sandpiper	–	–	*	*	–	–	–	–	–	–	*	–	–	*	*	ND	–	–	–
86. Lesser Goldfinch	–	–	*	*	*	–	–	–	–	*	*	–	–	–	–	ND	*	–	*
87. Lesser Nighthawk	0.9	2.5	1.0	–	–	–	–	–	–	–	*	*	–	1.5	3.7	ND	–	–	–
88. Lincoln's Sparrow	–	–	–	0.5	4.0	8.9	8.1	3.5	0.5	0.7	1.2	0.3	–	–	–	ND	8.8	37.4	22.0
89. Little Blue Heron	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–	ND	–	–	–
90. Loggerhead Shrike	0.1	0.6	2.2	3.0	2.5	1.0	0.4	1.0	0.5	1.0	–	–	*	0.7	2.9	ND	3.7	0.9	1.5

Table 4. - Bird densities[1] for the salt cedar transects for June 1982-December 1983. — Continued

Bird Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
91. Long-billed Curlew	–	–	*	*	–	–	–	–	–	–	*	*	–	*	*	ND	–	–	–
92. Long-eared Owl	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	*
93. Lucy's Warbler	4.2	2.5	0.1	0.5	–	–	–	–	–	*	0.1	2.5	(7.4)	4.4	0.4	ND	–	–	–
94. MacGillivray's Warbler	–	–	0.5	1.5	0.5	–	–	–	–	–	–	1.5	–	–	–	ND	*	–	–
95. Mallard	*	–	–	–	–	0.1	*	1.1	0.9	0.7	*	0.2	*	–	–	ND	*	*	1.8
96. Marbled Godwit	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	ND	–	–	–
97. Marsh Wren	1.4	0.2	–	4.0	50.9	79.6	80.4	68.7	59.3	32.1	5.7	7.9	(7.4)	5.4	5.9	ND	82.1	239.1	179.7
98. Mountain Bluebird	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	ND	–	–	–
99. Mourning Dove	1.2	1.5	0.5	2.0	*	–	–	–	–	*	1.1	8.8	(3.0)	2.9	13.2	ND	–	–	–
100. Nashville Warbler	–	–	0.2	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
101. Northern Flicker	–	–	–	0.1	4.0	5.0	2.9	4.0	3.0	2.0	–	–	–	–	–	ND	2.2	1.65	1.5
102. Northern Harrier	0.1	0.1	*	0.1	0.1	0.2	0.1	0.2	0.5	1.2	0.3	0.6	(0.6)	0.4	–	ND	0.2	0.4	0.3
103. Northern Mockingbird	–	–	0.5	0.4	–	–	–	–	0.1	–	*	–	*	2.9	1.5	ND	–	–	–
104. Northern Oriole	*	–	0.4	*	–	–	–	–	–	–	*	0.9	–	–	0.7	ND	–	–	–
105. Northern Pintail	–	–	–	–	–	–	–	–	–	*	–	–	–	*	–	ND	*	–	*
106. Northern Rough-winged Swallow	1.4	*	*	–	–	–	–	–	*	0.1	*	0.1	(0.4)	1.5	*	ND	–	–	–
107. Northern Shoveler	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	ND	–	–	0.3
108. Orange-crowned Warbler	–	–	2.0	2.2	3.5	1.5	0.7	*	0.1	–	*	2.0	–	–	–	ND	4.8	6.6	6.6
109. Osprey	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
110. Phainopepla	–	–	–	–	–	0.1	0.2	0.2	0.1	–	–	*	–	–	–	ND	–	*	0.2
111. Pine Siskin	–	–	–	–	*	*	–	–	–	–	–	*	–	–	–	ND	*	*	–
112. Prairie Falcon	–	–	–	–	–	*	–	–	–	–	*	–	–	–	–	ND	–	–	–
113. Red-breasted Merganser	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	ND	–	–	–
114. Red-tailed Hawk	*	–	*	–	–	*	–	–	*	–	*	–	–	*	–	ND	*	–	*
115. Red-winged Blackbird	*	*	*	*	*	2.5	2.2	5.4	1.0	21.3	10.0	14.8	(17.8)	44.0	49.1	ND	*	9.5	2.3
116. Ring-billed Gull	–	*	–	–	–	*	–	–	*	*	*	*	–	–	–	ND	–	–	*
117. Ring-necked Pheasant	0.5	0.1	0.1	0.1	1.0	0.5	*	0.5	1.0	0.6	1.0	1.2	(0.4)	*	*	ND	1.5	2.2	5.1
118. Rock Dove	*	*	–	–	*	–	–	–	–	–	–	–	–	*	–	ND	*	–	–
119. Rock Wren	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	ND	*	*	*
120. Rose-breasted Grosbeak	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	ND	–	–	–
121. Rough-legged Hawk	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	ND	–	–	–
122. Ruby-crowned Kinglet	–	–	–	0.5	12.4	26.2	25.8	5.4	5.0	4.9	2.9	0.5	–	–	–	ND	13.9	42.5	57.9
123. Rufous-sided Towhee	–	–	–	0.5	1.5	2.5	0.9	1.5	0.7	*	–	–	–	–	–	ND	2.9	1.1	3.7
124. Sage Sparrow	–	–	–	*	0.5	1.0	*	0.5	0.5	0.5	–	–	–	–	–	ND	0.7	0.7	1.5
125. Sandhill Crane	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
126. Savannah Sparrow	–	–	–	*	*	0.1	0.4	*	0.5	*	*	–	–	–	–	ND	0.2	0.2	*
127. Say's Phoebe	0.1	0.4	*	0.1	0.2	0.5	0.7	0.1	0.1	*	*	*	*	*	*	ND	0.2	0.1	*
128. Scott's Oriole	–	–	–	–	–	–	–	–	–	–	–	0.7	–	–	–	ND	–	–	–
129. Scrub Jay	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	0.7	*
130. Semipalmated Plover	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
131. Sharp-shinned Hawk	–	–	–	–	0.1	0.1	–	0.1	0.1	*	*	–	–	–	–	ND	0.1	0.7	0.3
132. Snow Goose	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	ND	–	–	–
133. Snowy Egret	0.2	*	*	–	–	–	–	–	–	–	*	0.2	(12.0)	0.2	*	ND	*	–	–
134. Solitary Vireo	–	–	–	–	–	–	–	–	–	–	–	0.5	–	–	–	ND	–	–	–
135. Song Sparrow	39.7	27.7	19.3	31.1	40.5	41.5	34.7	12.4	19.3	25.2	27.2	54.6	(60.8)	59.4	66.7	ND	68.9	65.3	52.8

Table 4. – Bird densities[1] for the salt cedar transects for June 1982-December 1983. — Continued

Bird Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
136. Sora	–	–	–	0.1	–	0.1	0.4	0.3	1.0	0.3	0.1	–	–	–	–	ND	3.3	2.4	0.7
137. Spotted Sandpiper	–	*	*	–	–	–	–	–	–	–	–	*	–	–	*	ND	–	–	–
138. Summer Tanager	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	ND	–	–	–
139. Swainson's Hawk	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
140. Swamp Sparrow	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	0.7
141. Townsend's Solitaire	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	*	–	–
142. Townsend's Warbler	–	–	0.5	–	*	–	–	–	–	–	–	1.0	–	–	–	ND	–	–	–
143. Tree Swallow	–	*	*	*	–	–	–	–	–	*	*	*	–	–	–	ND	*	–	–
144. Turkey Vulture	–	–	–	*	–	–	–	–	–	*	*	*	–	*	*	ND	–	–	*
145. Verdin	7.3	11.9	12.9	14.1	12.9	8.4	8.9	6.1	6.9	5.7	5.1	5.9	(11.9)	12.8	12.5	ND	10.6	7.3	7.3
146. Vesper Sparrow	–	–	–	–	–	–	–	–	–	*	*	–	–	–	–	ND	–	0.7	–
147. Violet-green Swallow	–	–	–	*	–	–	–	–	–	*	*	*	–	–	–	ND	–	–	–
148. Virginia Rail	1.8	3.0	3.0	6.9	10.9	7.4	7.7	8.0	7.4	6.9	8.8	12.3	(16.3)	21.8	12.5	ND	45.5	42.5	38.9
149. Virginia's Warbler	–	–	–	–	–	–	–	–	–	–	0.2	0.2	–	–	–	ND	–	–	–
150. Warbling Vireo	0.5	0.1	–	–	–	–	–	–	–	–	–	1.2	–	–	–	ND	–	–	–
151. Water Pipit	–	–	–	*	*	4.0	5.2	2.5	0.7	0.1	*	*	–	–	–	ND	*	1.5	0.7
152. Western Flycatcher	–	–	0.5	–	0.5	–	–	–	–	–	–	–	–	–	*	ND	–	–	–
153. Western Kingbird	–	0.5	*	–	–	–	–	–	–	–	–	*	–	0.7	0.1	ND	*	–	–
154. Western Meadowlark	–	–	–	0.5	8.4	4.5	5.9	4.0	3.5	0.5	–	–	–	–	–	ND	0.7	8.1	30.1
155. Western Sandpiper	–	–	*	*	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
156. Western Tanager	0.1	–	0.1	0.5	–	–	–	–	–	–	–	*	–	–	*	ND	–	–	–
157. Western Wood-Pewee	–	–	1.0	–	–	–	–	–	–	–	–	0.5	–	–	–	ND	–	–	–
158. White-crowned Sparrow	–	–	–	2.6	33.1	6.7	5.9	3.5	0.5	1.7	1.4	0.1	–	–	–	ND	19.1	12.5	22.0
159. White-faced Ibis	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
160. White-throated Swift	*	–	–	–	–	–	–	–	*	*	–	*	*	–	–	ND	*	–	*
161. Willet	–	*	–	–	–	–	–	–	–	–	*	–	–	–	–	ND	–	–	–
162. Willow Flycatcher	0.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
163. Wilson's Warbler	–	–	3.0	1.5	1.5	–	–	–	–	–	0.5	8.9	–	–	–	ND	–	–	–
164. Winter Wren	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	ND	0.7	1.5	0.7
165. Yellow-breasted Chat	12.9	7.9	10.9	3.5	–	–	–	–	–	–	2.6	8.8	(7.4)	7.3	8.1	ND	0.2	–	–
166. Yellow-bellied Sapsucker	–	–	–	–	0.5	0.5	–	*	*	–	–	–	–	–	–	ND	–	–	*
167. Yellow-headed Blackbird	–	*	*	*	–	–	–	–	–	–	*	0.5	*	–	0.4	ND	–	–	–
168. Yellow-rumped Warbler	–	–	–	1.5	31.6	15.8	11.1	*	0.1	1.5	1.2	4.4	–	–	–	ND	17.6	48.4	37.4
169. Yellow Warbler	–	–	2.5	1.0	–	–	–	–	–	–	0.1	60.0	(0.2)	*	*	ND	–	–	–
AVIAN DENSITY TOTALS	131.1	112.2	128.2	168.2	296.5	292.0	290.0	173.1	155.5	141.9	121.4	292.5	(202.7)	253.1	282.9		407.2	616.5	550.6
AVIAN SPECIES TOTALS	49	50	69	72	67	63	47	45	52	65	89	92	42	53	52		69	56	63

[1] Density values shown are number of birds per 100 acres of riparian salt cedar. A dash indicates there were no individuals recorded for that month.

* Indicates there were individuals recorded, but not during scheduled census.

( ) Numbers in parentheses indicate only one census (June 1983).

ND indicates that no data were collected.

Table 5. – Bird densities[1] for the desert wash transects for June 1982-December 1983.

Bird Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1. Abert's Towhee	*	*	*	*	1.7	*	0.6	*	*	*	0.4	*	(*)	1.3	1.9	ND	10.2	2.5	0.6
2. American Kestrel	–	*	*	0.4	–	–	–	–	–	*	*	*	–	–	*	ND	*	–	–
3. Ash-throated Flycatcher	*	*	0.4	*	*	–	–	–	–	–	*	*	–	*	*	ND	*	–	–
4. Band-tailed Pigeon	–	–	–	–	0.4	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
5. Bewick's Wren	*	*	0.4	3.4	7.2	6.0	5.1	2.6	5.1	1.3	*	0.8	(*)	1.3	*	ND	10.2	10.2	6.4
6. Black-tailed Gnatcatcher	6.8	1.4	0.9	*	*	1.7	*	3.4	3.4	0.4	0.4	1.7	(*)	3.8	2.5	ND	1.3	1.3	0.3
7. Black-throated Sparrow	–	1.9	–	–	–	–	–	–	–	5.1	18.8	5.1	(1.2)	*	1.3	ND	–	–	–
8. Blue-gray Gnatcatcher	*	*	*	1.7	*	*	–	–	–	–	0.6	*	(*)	*	*	ND	*	*	*
9. Blue Grosbeak	*	0.5	*	*	*	–	–	–	–	–	*	*	(*)	*	*	ND	–	–	–
10. Brewer's Sparrow	–	–	–	11.9	1.7	–	–	–	–	–	13.6	3.4	–	–	–	ND	–	–	–
11. Bushtit	–	–	–	–	1.1	4.3	*	*	0.6	*	–	–	–	10.2	–	ND	–	*	*
12. Cassin's Kingbird	–	–	–	–	–	–	–	–	–	–	0.4	–	–	–	–	ND	–	–	–
13. Chipping Sparrow	–	–	0.4	*	*	–	–	–	–	–	6.8	0.4	–	–	–	ND	*	–	–
14. Costa's Hummingbird	–	–	–	–	–	–	–	–	–	2.6	*	*	–	–	–	ND	–	–	–
15. Crissal Thrasher	0.4	0.9	0.2	1.7	1.3	3.4	*	0.4	*	3.4	1.7	0.4	(1.2)	0.3	*	ND	0.6	*	*
16. Dark-eyed Junco	–	–	–	–	*	*	0.6	*	5.1	*	*	–	–	–	–	ND	–	5.1	*
17. Gambel's Quail	3.4	*	25.6	1.3	–	0.4	–	–	–	4.3	13.6	6.8	(0.6)	*	29.4	ND	*	*	*
18. Gray Flycatcher	–	–	–	0.2	–	*	–	–	–	–	0.8	0.8	–	–	–	ND	–	–	*
19. Greater Roadrunner	0.4	*	*	*	*	–	*	*	*	*	*	*	(*)	*	0.6	ND	*	*	2.5
20. Green-tailed Towhee	–	–	–	*	*	–	–	–	–	–	1.7	*	–	–	–	ND	–	–	–
21. House Finch	*	*	*	*	1.7	*	*	–	*	*	0.4	*	–	*	*	ND	*	*	*
22. Lark Sparrow	–	–	–	–	–	–	–	–	–	–	0.8	*	–	–	–	ND	–	–	–
23. Lazuli Bunting	–	–	*	*	*	–	–	–	–	–	*	0.4	(*)	*	–	ND	–	–	–
24. Lesser Nighthawk	*	0.9	*	–	–	–	–	–	–	–	*	*	–	*	*	ND	–	–	–
25. Lincoln's Sparrow	–	–	–	*	*	*	2.6	*	*	0.4	*	*	–	–	–	ND	*	*	*
26. Loggherhead Shrike	*	5.6	5.1	0.4	0.6	*	0.6	0.9	0.4	*	1.7	–	(*)	0.6	1.6	ND	*	0.6	2.5
27. Lucy's Warbler	*	*	*	*	–	–	–	–	–	*	*	0.2	(*)	*	*	ND	–	–	–
28. MacGillivray's Warbler	–	–	*	*	*	–	–	–	–	–	–	0.8	–	–	–	ND	*	–	–
29. Marsh Wren	*	*	–	*	*	*	*	*	*	*	*	*	(*)	*	*	ND	*	1.3	*
30. Mourning Dove	*	*	3.4	*	*	–	–	–	–	*	1.7	0.4	(*)	*	1.9	ND	–	–	–
31. Northern Flicker	–	–	–	*	0.9	*	*	*	*	*	–	–	–	–	–	ND	*	*	*
32. Northern Harrier	*	*	*	*	*	*	*	*	*	0.4	*	*	(*)	*	–	ND	*	*	*
33. Northern Mockingbird	–	–	*	*	–	–	–	–	*	–	0.4	–	(1.2)	*	2.5	ND	–	–	–
34. Northern Oriole	*	–	*	*	–	–	–	–	–	–	*	0.4	–	–	*	ND	–	–	–
35. Northern Rough-winged Swallow	0.2	*	*	–	–	–	–	–	*	*	*	*	(1.2)	*	*	ND	–	–	–
36. Orange-crowned Warbler	–	–	*	*	*	*	*	*	*	–	*	0.4	–	–	–	ND	*	*	*
37. Rock Wren	1.7	*	*	1.7	0.2	*	*	*	*	*	*	*	(*)	*	*	ND	*	*	0.6
38. Ruby-crowned Kinglet	–	–	–	*	1.3	2.6	3.8	1.3	1.7	*	*	*	–	–	–	ND	2.5	2.5	2.5
39. Rufous-sided Towhee	–	–	–	*	0.4	1.7	*	*	*	*	–	–	–	–	–	ND	*	*	*
40. Sage Sparrow	–	–	–	6.8	39.2	19.6	32.0	23.9	30.7	1.7	–	–	–	–	–	ND	51.1	81.7	30.6
41. Savannah Sparrow	–	–	–	*	*	0.2	*	*	*	*	*	–	–	–	–	ND	*	*	*
42. Say's Phoebe	*	0.9	*	*	0.4	*	*	*	*	*	*	*	(2.5)	*	*	ND	*	0.3	*
43. Song Sparrow	*	*	*	*	*	0.4	2.6	0.9	0.2	*	*	*	(*)	1.3	*	ND	*	*	0.6

Table 5. – Bird densities[1] for the desert wash transects for June 1982-December 1983. — Continued

Bird Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
44. Verdin	6.8	2.3	2.6	1.7	1.7	3.4	2.6	2.6	3.4	2.6	1.3	0.4	(*)	4.5	3.2	ND	2.5	2.5	0.6
45. Vesper Sparrow	–	–	–	–	–	–	–	–	–	0.4	*	–	–	–	–	ND	–	*	–
46. Western Kingbird	–	*	1.7	–	–	–	–	–	–	–	–	0.4	–	*	*	ND	*	–	–
47. Western Meadowlark	–	–	–	*	*	*	*	*	*	*	–	–	–	–	–	ND	7.7	*	*
48. Western Wood-Pewee	–	–	*	–	–	–	–	–	–	–	–	0.4	–	–	–	ND	–	–	–
49. White-crowned Sparrow	–	–	–	1.1	13.7	13.7	16.0	17.1	65.7	138.2	35.8	*	–	–	–	ND	418.9	97.1	79.2
50. Yellow-breasted Chat	*	0.5	*	*	–	–	–	–	–	*	*	*	(*)	*	1.3	ND	*	–	–
51. Yellow-rumped Warbler	–	–	–	*	0.9	0.4	0.3	*	*	0.9	*	*	–	–	–	ND	5.1	*	1.3
52. Yellow Warbler	–	–	*	*	–	–	–	–	–	–	0.4	0.4	(*)	*	*	ND	–	–	–
AVIAN DENSITY TOTALS	19.7	14.9	40.7	32.3	74.4	57.8	66.8	53.1	116.3	161.7	101.3	23.6	(7.9)	23.3	46.2		510.1	205.1	127.7
AVIAN SPECIES TOTALS	23	25	31	40	35	27	25	24	27	32	43	40	23	28	27		31	28	28

[1] Density values shown are number of birds per 100 acres in the desert wash transects. A dash indicates there were no individuals recorded for that month.
* Indicates there were individuals recorded, but not during scheduled census.
( ) Numbers in parentheses indicate only one census (June 1983).
ND indicates that no data were collected.

Table 6. – Monthly density and number of species for riparian and typical wetland birds for June 1982 – December 1983.

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Permanent Residents																			
Riparian Density (No./100 acres)	40.1	49.3	57.8	73.0	79.7	53.3	57.7	36.4	36.1	39.1	38.3	52.9	43.5	68.3	95.3	ND	78.8	81.4	61.5
Number of Species	(11)	(11)	(9)	(11)	(10)	(10)	(8)	(9)	(10)	(9)	(8)	(10)	(5)	(9)	(8)		(12)	(10)	(9)
Wetland Density (No./100 acres)	42.9	30.9	22.3	42.0	102.3	131.5	125.4	94.5	87.5	85.5	51.7	89.6	102.3	130.6	134.2	ND	196.5	356.4	274.4
Number of Species	(3)	(3)	(2)	(3)	(3)	(5)	(5)	(4)	(5)	(4)	(4)	(4)	(4)	(4)	(4)		(3)	(4)	(5)
Total Density	83.0	80.2	80.1	115.0	182.0	184.8	183.1	130.9	123.6	124.6	90.0	142.5	145.8	198.9	229.5		275.3	437.8	335.9
Summer Visitors																			
Riparian Density (No./100 acres)	37.3	25.5	26.9	12.6	0.6	0.5	–	–	–	0.1	11.4	41.0	37.3	35.1	33.0	ND	0.6	0.4	0.7
Number of Species	(10)	(9)	(8)	(7)	(2)	(1)	(–)	(–)	(–)	(1)	(8)	(11)	(10)	(11)	(7)		(2)	(1)	(1)
Wetland Density (No./100 acres)	9.9	5.9	7.4	7.9	1.0	–	–	–	–	–	9.3	22.6	19.4	15.1	15.9	ND	9.5	0.7	1.8
Number of Species	(2)	(1)	(1)	(1)	(1)	(–)	(–)	(–)	(–)	(–)	(2)	(4)	(2)	(3)	(3)		(1)	(1)	(1)
Total Density	47.2	31.4	34.3	20.5	1.6	0.5	0.0	0.0	0.0	0.1	20.7	63.6	56.7	50.2	48.9		10.1	1.1	2.5
Winter Visitors																			
Riparian Density (No./100 acres)	–	–	2.0	10.4	98.5	97.4	95.0	32.8	23.7	13.6	6.9	7.8	–	–	–	ND	76.7	164.7	173.3
Number of Species	(–)	(–)	(1)	(8)	(13)	(15)	(12)	(13)	(13)	(9)	(5)	(6)	(–)	(–)	(–)		(11)	(16)	(15)
Wetland Density (No./100 acres)	–	–	–	1.1	8.4	9.3	11.9	9.4	8.1	3.6	2.5	0.7	–	–	–	ND	4.6	12.2	38.6
Number of Species	(–)	(–)	(–)	(3)	(1)	(6)	(4)	(5)	(6)	(5)	(2)	(2)	(–)	(–)	(–)		(4)	(4)	(10)
Total Density	0.0	0.0	2.0	11.5	106.9	106.7	106.9	42.2	31.8	17.2	9.4	8.5	0.0	0.0	0.0		81.3	176.9	211.9
Migrants																			
Riparian Density (No./100 acres)	0.9	0.6	11.8	21.2	6.2	–	–	–	0.1	–	1.3	77.9	0.2	4.0	4.5	ND	0.2	0.7	0.2
Number of Species	(4)	(2)	(15)	(11)	(8)	(–)	(–)	(–)	(1)	(–)	(7)	(17)	(1)	(3)	(4)		(1)	(1)	(1)
Wetland Density (No./100 acres)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	ND	–	–	–
Number of Species	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)		(–)	(–)	(–)
Total Density	0.9	0.6	11.8	21.2	6.2	0.0	0.0	0.0	0.1	0.0	1.3	77.9	0.2	4.0	4.5		0.2	0.7	0.2
Density Summary and Percent Total																			
Riparian Density (No./100 acres)	78.3	75.4	98.5	117.2	185.0	151.2	152.7	69.2	59.9	58.8	57.9	179.6	81.0	107.4	132.8		156.3	247.2	235.7
Percent	(60)	(67)	(77)	(70)	(62)	(52)	(53)	(40)	(39)	(40)	(48)	(61)	(40)	(42)	(47)		(42.6)	(40.1)	(42.8)
Wetland Density (No./100 acres)	52.8	36.8	29.7	51.0	111.7	140.8	137.3	103.9	95.6	89.1	63.5	112.9	121.7	145.7	150.1		210.6	369.3	314.8
Percent	(40)	(33)	(23)	(30)	(38)	(48)	(47)	(60)	(61)	(60)	(52)	(39)	(60)	(58)	(53)		(57.4)	(59.9)	(57.2)

ND Indicates no data.
– indicates no detection for particular category.

Table 7. – Density-based species diversity and evenness indices for plot No. 1, salt cedar north.[1]

Small Mammal Species	Jan.	Feb.	Apr.	June	July	Aug.	Oct.	Nov.	Dec.
Reithrodontomys megalotis	1.27	0.81	0.83	4.76	1.61	3.28	5.30	8.07	6.17
Peromyscus eremicus	1.29	0.70	0.46	0.98	1.40	1.78	1.12	1.11	1.23
Peromyscus maniculatus	0.72	0.16	0.11	0.51	0.15	1.55	1.11	0.51	1.14
Onychomys torridus	1.12	0.64	—	—	—	0.14	1.02	0.87	0.22
Neotoma lepida	—	0.44	—	0.44	0.87	0.05	0.46	0.32	0.31
Mus musculus	2.62	1.81	1.04	3.62	2.46	4.11	3.28	2.76	2.47
Dipodomys merriami	0.22	0.44	—	—	—	—	—	—	—
Totals	7.24	5.00	2.44	10.31	6.49	10.91	12.28	13.64	11.54
Species richness	6	7	4	5	5	6	6	6	6
Species diversity	1.61	1.74	1.18	1.31	1.40	1.38	1.48	1.22	1.31
Species evenness	0.90	0.89	0.85	0.81	0.87	0.77	0.83	0.68	0.73

[1] Density is in number per acre.

Table 8. – Density-based species diversity and evenness indices for plot No. 2, salt cedar south.[1]

Small Mammal Species	Jan.	Mar.	June	July	Aug.	Oct.	Dec.
Reithrodontomys megalotis	0.87	0.82	0.91	1.27	3.16	15.86	5.72
Peromyscus eremicus	0.34	1.33	0.92	1.53	0.77	0.95	0.11
Peromyscus maniculatus	0.27	0.37	0.54	0.44	0.65	0.39	0.70
Onychomys torridus	0.22	—	—	—	—	—	—
Neotoma lepida	—	—	—	0.44	0.45	0.33	1.31
Mus musculus	3.52	0.96	0.91	1.19	2.44	1.68	2.23
Totals	5.22	3.48	3.28	4.87	7.47	19.21	10.07
Species richness	5	4	4	5	5	5	5
Species diversity	1.03	1.30	1.37	1.49	1.34	0.94	1.16
Species evenness	0.64	0.94	0.99	0.93	0.83	0.58	0.72

[1] Density is in number per acre.

Table 9. – Biomass-based species diversity and evenness indices for plot No. 1, salt cedar north.[1]

Small Mammal Species	Jan.	Feb.	Apr.	June	July	Aug.	Oct.	Nov.	Dec.
Reithrodontomys megalotis	0.41	0.25	0.32	0.95	0.63	1.58	1.68	2.61	1.98
	(28.68)	(17.63)	(22.19)	(66.77)	(43.93)	(110.57)	(117.52)	(182.54)	(138.48)
Peromyscus eremicus	0.93	0.58	0.40	0.69	0.83	1.35	0.74	0.64	0.79
	(65.04)	(40.43)	(27.82)	(48.60)	(58.20)	(94.60)	(51.90)	(44.56)	(55.31)
Peromyscus maniculatus	0.53	0.11	0.08	0.29	0.11	1.06	0.67	0.25	0.72
	(37.06)	(7.86)	(5.92)	(20.62)	(7.44)	(74.48)	(47.19)	(17.42)	(50.31)
Onychomys torridus	0.63	0.42	—	—	—	0.11	0.53	0.55	0.10
	(44.19)	(29.21)	—	—	—	(7.61)	(36.93)	(38.35)	(6.95)
Neotoma lepida	—	1.48	—	1.45	3.26	0.22	1.51	1.11	1.06
	—	(103.38)	—	(101.57)	(228.16)	(15.66)	(105.70)	(77.44)	(74.07)
Mus musculus	1.53	1.01	0.64	2.12	1.00	2.03	1.81	1.41	1.23
	(107.07)	(70.72)	(44.79)	(148.45)	(70.09)	(142.26)	(127.10)	(98.90)	(86.07)
Dipodomys merriami	0.25	0.67	—	—	—	—	—	—	—
	(17.43)	(46.67)	—	—	—	—	—	—	—
Totals	4.27	4.51	1.44	5.50	5.82	6.35	6.94	6.55	5.87
	(299.47)	(315.90)	(100.72)	(386.01)	(407.82)	(445.18)	(486.34)	(459.21)	(411.19)
Species richness	6	7	4	5	5	6	6	6	6
Species diversity	1.63	1.72	0.97	1.44	1.22	1.53	1.69	1.56	1.69
Species evenness	0.91	0.88	0.70	0.89	0.76	0.85	0.94	0.87	0.94

[1] Top value shown for biomass is in ounces per acre, bottom value shown (in parentheses) is in grams per hectare.

Table 10. – Biomass-based species diversity and evenness indices for plot No. 2, salt cedar south.[1]

Small Mammal Species	Jan.	Mar.	June	July	Aug.	Oct.	Dec.
Reithrodontomys megalotis	0.28	0.28	0.41	0.53	1.18	2.95	1.73
	(19.83)	(19.42)	(28.60)	(37.04)	(82.43)	(206.34)	(121.43)
Peromyscus eremicus	0.24	1.11	0.62	1.07	0.47	0.58	0.08
	(16.82)	(78.01)	(43.74)	(74.84)	(32.96)	(40.96)	(5.83)
Peromyscus maniculatus	0.18	0.30	0.28	0.24	0.27	0.26	0.37
	(12.45)	(20.83)	(19.79)	(17.07)	(18.94)	(18.42)	(25.79)
Onychomys torridus	0.13	—	—	—	—	—	—
	(8.94)	—	—	—	—	—	—
Neotoma lepida	—	—	—	1.53	1.83	1.38	5.84
	—	—	—	(106.95)	(128.09)	(96.96)	(408.94)
Mus musculus	1.88	0.53	0.49	0.61	1.45	0.84	1.01
	(131.48)	(37.12)	(34.60)	(42.96)	(101.61)	(58.78)	(71.04)
Totals	2.71	2.22	1.81	3.98	5.20	6.02	9.04
	(189.52)	(155.38)	(126.73)	(278.86)	(364.03)	(421.46)	(633.03)
Species richness	5	4	4	5	5	5	5
Species diversity	1.03	1.22	1.35	1.45	1.43	1.33	1.02
Species evenness	0.64	0.88	0.97	0.90	0.89	0.82	0.63

[1] Top value shown for biomass is in ounces per acre, bottom value shown (in parentheses) is in grams per hectare.

Table 11. – Number of rodents grouped according to sex, age, and reproduction classification for highest density species in plot No. 1 (salt cedar north).

Species	Month	Total No.	Sex Ratio/Age Structure: Adult Male	Sex Ratio/Age Structure: Adult Female	Sex Ratio/Age Structure: Juvenile Male	Sex Ratio/Age Structure: Juvenile Female	Reproductive Conditions: Male Scrotal	Reproductive Conditions: Female Estrus	Reproductive Conditions: Female Pregnant	Reproductive Conditions: Female Lactating
Reithrodontomys megalotis	Jan.	42	30	12	-	-	8	-	-	-
	Feb.	39	33	6	-	-	30	5	-	-
	Apr.	28	22	6	-	-	22	1	4	-
	June	24	18	5	1	-	19	1	-	4
	July	37	22	12	1	-	23	-	3	9
	Aug.	34	18	12	2	2	20	3	4	6
	Oct.	46	18	5	17	6	35	4	-	3
	Nov.	99	40	18	26	15	66	8	2	8
	Dec.	69	46	18	4	1	50	-	-	1
Peromyscus eremicus	Jan.	14	11	3	-	-	10	-	-	-
	Feb.	17	11	6	-	-	11	5	1	-
	Apr.	11	8	3	-	-	8	-	2	1
	June	11	5	4	2	-	7	-	1	3
	July	10	4	3	2	1	6	1	-	3
	Aug.	9	2	3	3	1	5	2	-	2
	Oct.	22	11	10	1	-	12	6	1	3
	Nov.	32	14	9	5	4	19	6	1	3
	Dec.	23	13	9	-	1	13	-	-	-
Mus musculus	Jan.	21	10	11	-	-	7	1	-	-
	Feb.	21	11	10	-	-	11	3	1	-
	Apr.	28	16	12	-	-	16	6	3	-
	June	19	5	10	3	1	8	-	2	8
	July	17	2	6	6	3	6	-	5	1
	Aug.	30	7	8	5	10	12	3	4	1
	Oct.	46	14	12	10	10	22	4	1	2
	Nov.	42	17	18	1	6	18	8	8	-
	Dec.	20	4	8	5	3	7	-	-	2

Table 12. – Number of rodents grouped according to sex, age, and reproduction classification for highest density species in plot No. 2 (salt cedar south).

Species	Month	Total No.	Sex Ratio/Age Structure: Adult Male	Adult Female	Juvenile Male	Juvenile Female	Reproductive Conditions: Male Scrotal	Female Estrus	Female Pregnant	Female Lactating
Reithrodontomys megalotis	Jan.	30	10	11	–	–	7	–	–	–
	Mar.	27	19	8	–	–	19	7	1	–
	June	15	11	4	–	–	11	–	3	1
	July	18	14	4	–	–	14	–	1	3
	Aug.	20	14	3	2	1	16	1	–	2
	Oct.	41	20	12	10	9	29	8	–	11
	Dec.	72	43	21	6	2	48	1	–	–
Peromyscus eremicus	Jan.	11	4	7	–	–	4	–	–	–
	Mar.	7	4	3	–	–	4	1	2	–
	June	5	2	1	–	2	2	2	1	–
	July	8	4	3	1	–	5	–	1	2
	Aug.	6		3	1	2	1	2	–	3
	Oct.	8	2	5	1	–	3	5	–	–
	Dec.	7	5	2	–	–	5	–	–	–
Mus musculus	Jan.	25	11	13	–	1	8	–	–	–
	Mar.	22	11	11	–	–	11	10	–	–
	June	14	6	6	2	–	8	2	2	2
	July	9	4	3	1	1	4	–	2	1
	Aug.	20	8	6	1	5	8	3	2	–
	Oct.	44	14	9	12	9	24	3	2	–
	Dec.	27	9	7	5	6	13	–	1	1

Table 13. – Number of rodents grouped according to sex, age, and reproduction classification for low-density species in plot No. 1 (salt cedar north).

Species	Month	Total No.	Sex Ratio/Age Structure: Adult Male	Adult Female	Juvenile Male	Juvenile Female	Reproductive Conditions: Male Scrotal	Female Estrus	Female Pregnant	Female Lactating
Onychomys torridus	Jan.	5	2	3	–	–	1	–	–	–
	Feb.	3	1	2	–	–	1	1	–	–
	Apr.	–	–	–	–	–	–	–	–	–
	June	–	–	–	–	–	–	–	–	–
	July	–	–	–	–	–	–	–	–	–
	Aug.	1	–	1	–	–	–	–	–	1
	Oct.	5	1	2	2	–	3	1	–	1
	Nov.	2	–	2	–	–	–	–	–	–
	Dec.	1	–	–	1	–	1	–	–	–
Peromyscus maniculatus	Jan.	5	3	2	–	–	2	–	–	–
	Feb.	6	4	2	–	–	4	2	–	–
	Apr.	7	5	2	–	–	5	–	2	–
	June	6	2	2	1	1	3	1	–	2
	July	7	4	3	–	–	4	1	2	–
	Aug.	12	7	3	1	1	8	1	1	2
	Oct.	11	6	4	1	–	7	1	–	3
	Nov.	14	5	6	1	2	6	2	–	5
	Dec.	13	3	5	5	–	8	–	–	1
Neotoma lepida	Jan.	–	–	–	–	–	–	–	–	–
	Feb.	2	–	2	–	–	–	–	1	–
	Apr.	–	–	–	–	–	–	–	–	–
	June	2	1	–	1	–	2	–	–	–
	July	2	2	–	–	–	2	–	–	–
	Aug.	1	1	–	–	–	1	–	–	–
	Oct.	2	1	–	–	1	1	1	–	–
	Nov.	3	2	–	–	1	2	–	–	–
	Dec.	2	1	–	–	1	1	–	–	–

Table 14. - Species checklist for amphibians, reptiles, and large mammals identified on study site.

Bullfrog (*Rana catesbeiana*)	Brazilian Free-tailed Bat (*Tadarida brasiliensis*)
Southwestern Toad (*Bufo microscaphus*)	Big Free-tailed Bat (*Tadarida macrotis*)
Western Toad (*Bufo boreas*)	Blacktail Jackrabbit (*Lepus californicus*)
Woodhouse's Toad (*Bufo woodhousei*)	Desert Cottontail (*Sylvilagus audubonii*)
Desert Tortoise (*Gopherus agassizi*)	Beaver (*Castor canadensis*)
Spiny Softshell (*Trionyx spiniferus*)	Cactus Mouse (*Peromyscus eremicus*)
Brush Lizard (*Urosaurus graciosus*)	Canyon Mouse (*Peromyscus crinitus*)
Desert Horned Lizard (*Phrynosoma platyrhinos*)	Deer Mouse (*Peromyscus maniculatus*)
Desert Iguana (*Dipsosaurus dorsalis*)	Desert Kangaroo Rat (*Dipodomys deserti*)
Desert Spiny Lizard (*Sceloporus magister*)	Desert Woodrat (*Neotoma deserti*)
Desert Whiptail (*Cnemidophorus tigris*)	House Mouse (*Mus musculus*)
Long-nosed Leopard Lizard (*Gambelia wislizenii*)	Little Pocket Mouse (*Perognathus longimembris*)
Side-blotched Lizard (*Uta stansburiana*)	Merriam's Kangaroo Rat (*Dipodomys merriami*)
Tree Lizard (*Urosaurus ornatus*)	Round-tailed Ground Squirrel (*Spermophilus tereticaudus*)
Western Banded Gecko (*Coleonyx variegatus*)	Southern Grasshopper Mouse (*Onychomys torridus*)
Zebra-tailed Lizard (*Callisaurus draconoides*)	Western Harvest Mouse (*Reithrodontomys megalotis*)
Bullsnake (*Pituophis melanoleucus*)	White-tailed Antelope Squirrel (*Ammospermophilus leucurus*)
Coachwhip (*Masticophis flagellum*)	Badger (*Taxidea taxus*)
Common Kingsnake (*Lampropeltis getulus*)	Bobcat (*Lynx rufus*)
Longnosed Snake (*Rhinocheilus lecontei*)	Coyote (*Canis latrans*)
Mohave Rattlesnake (*Crotalus scutulatus*)	Gray Fox (*Urocyon cinereoargenteus*)
Sidewinder (*Crotalus cerastes*)	Kit Fox (*Vulpes macrotis*)
California Myotis (*Myotis californicus*)	Striped Skunk (*Memphitis memphitis*)
Western Pipistrel (*Pipistrellus hesperus*)	Burro (*Equus asinus*)
Silver-haired Bat (*Lasionycteris noctivagans*)	Mule Deer (*Odocoileus hemionus*)
Lappet-eared Bat (*Idionycteris phyllotis*)	Range Cattle (*Bos taurus*)
Pallid Bat (*Antrozous pallidus*)	

Table 15.–Comparison of bird density and bird species estimates for different vegetation communities. From [90]

Community	Average density (avg. No. of species) per 100 acres	
	July	December
Salt cedar	134 (11)	43 (7)
Salt cedar and screwbean	273 (16)	67 (9)
Screwbean	185 (9)	62 (6)
Honey mesquite	305 (16)	185 (13)
Honey mesquite and salt cedar	219 (13)	45 (7)
Cottonwood and willow	346 (17)	169 (12)

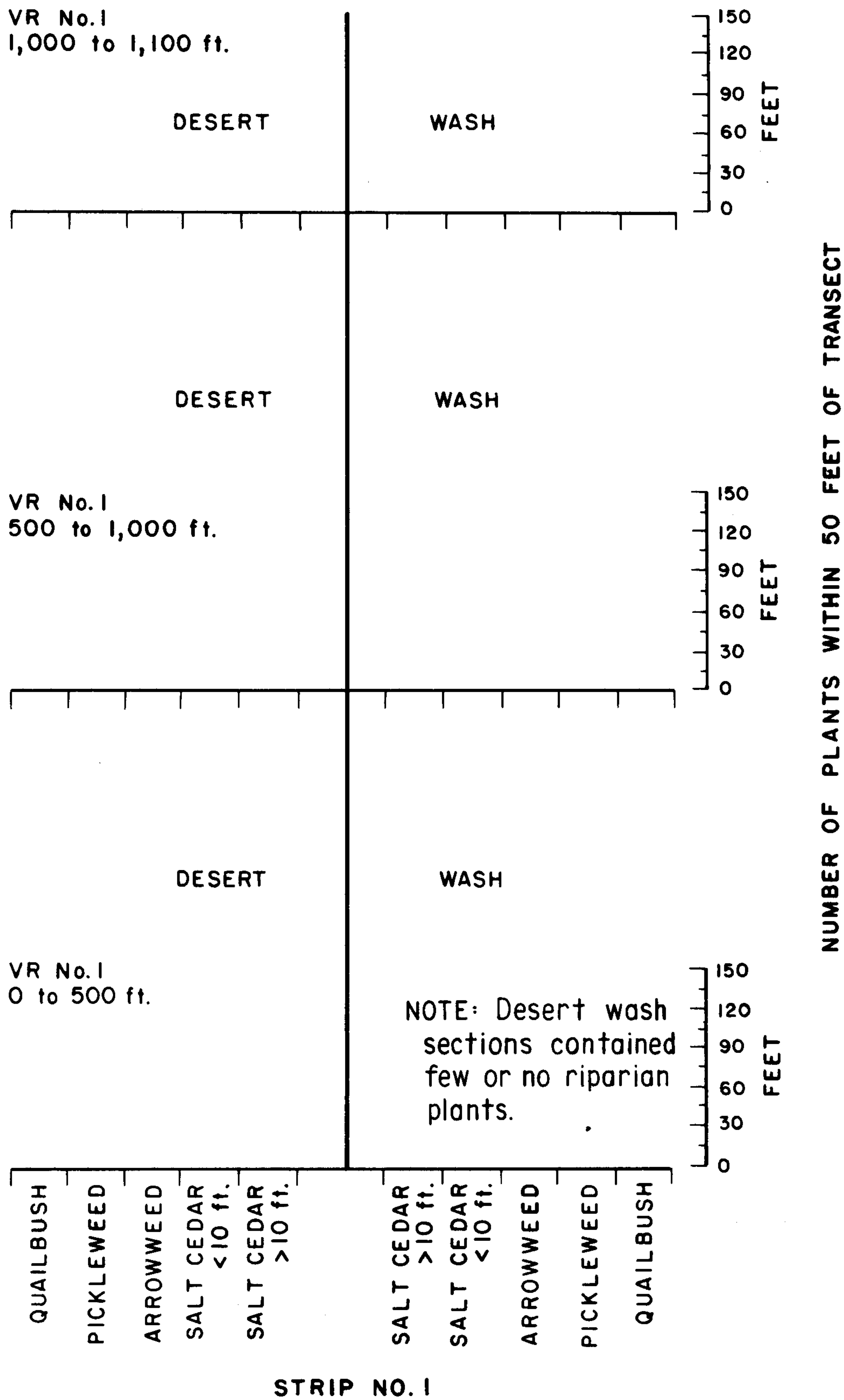


Figure 7. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 1.

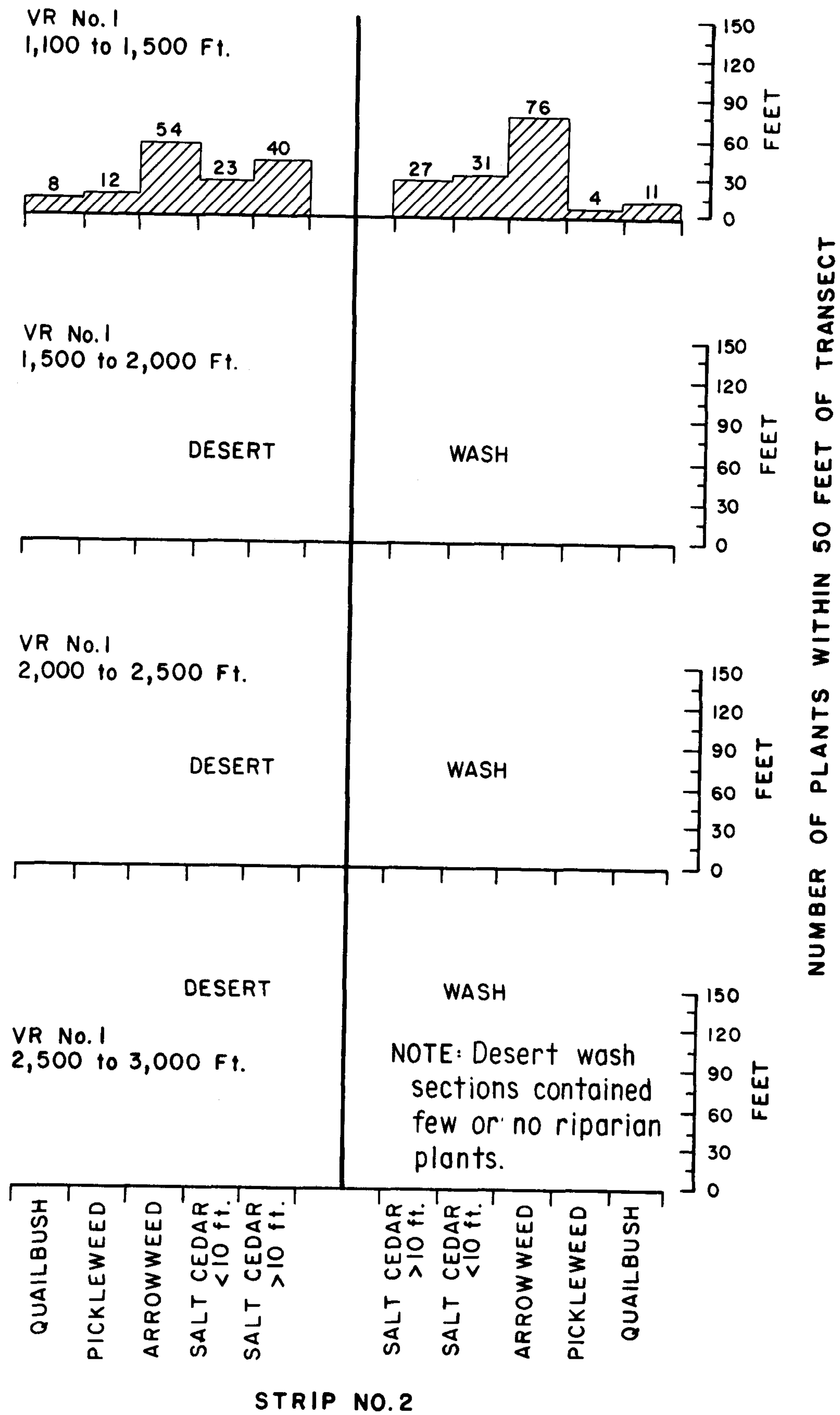


Figure 8. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 2.

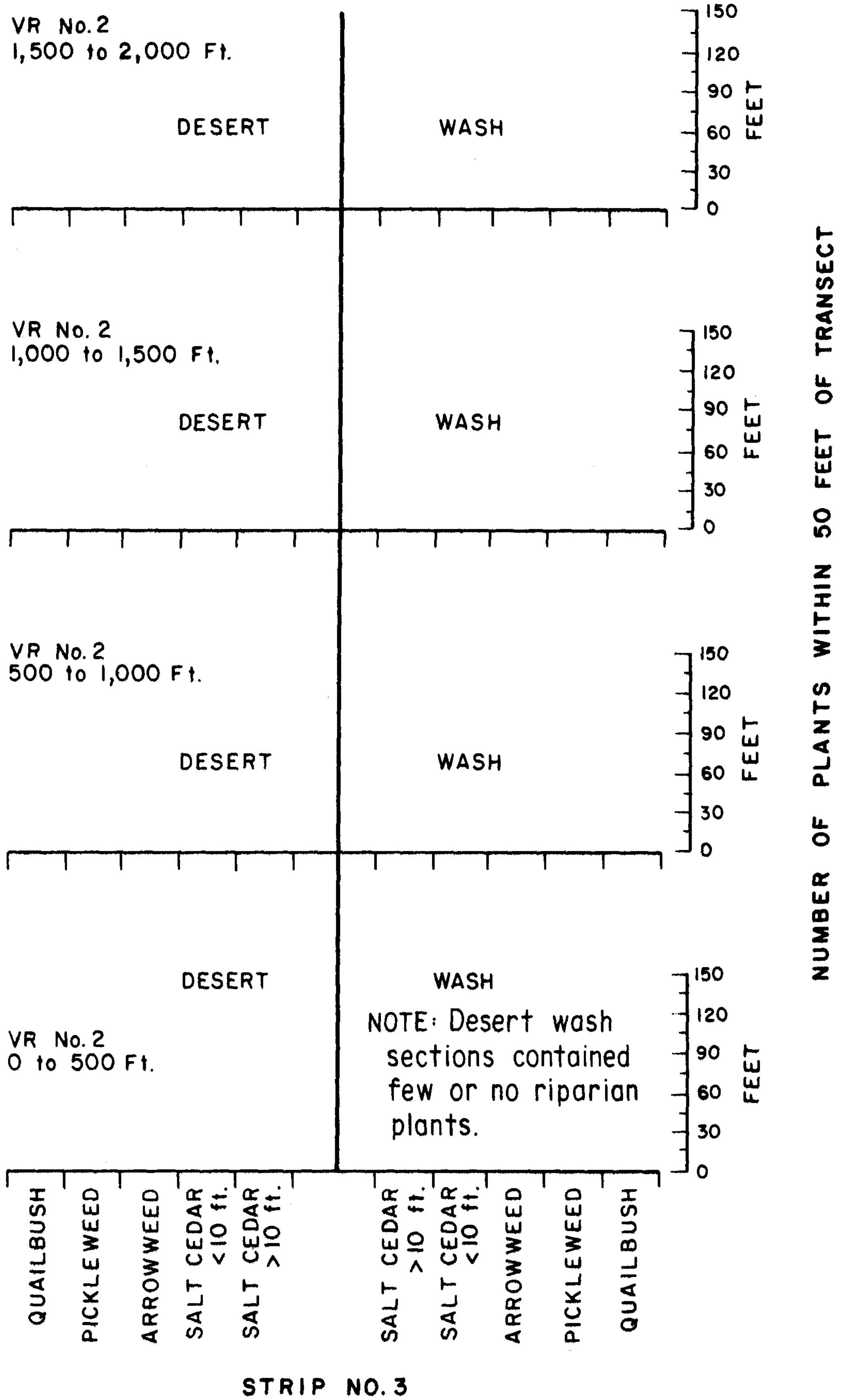


Figure 9. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 3 (sheet 1 of 2).

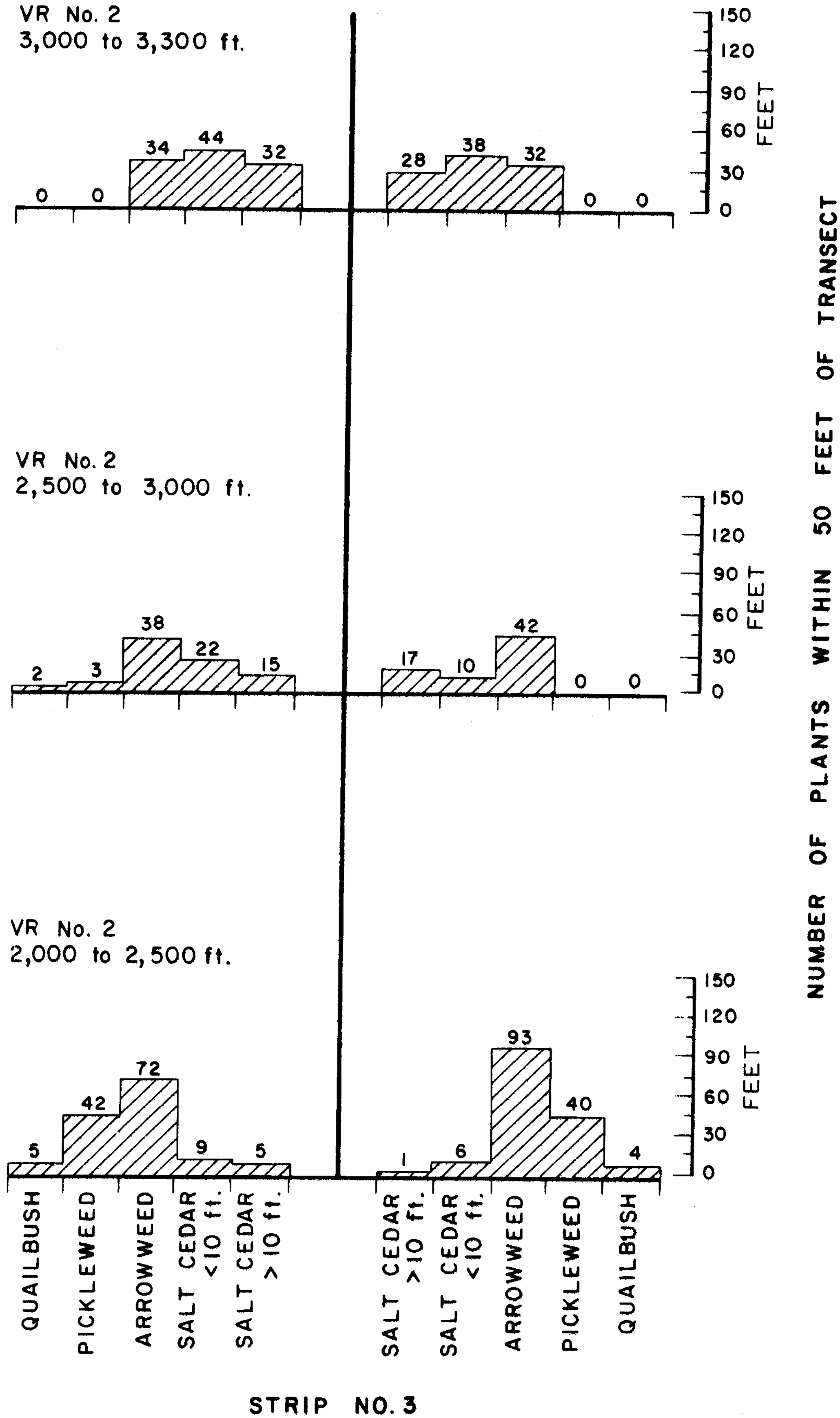


Figure 9. - Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 3 (sheet 2 of 2).

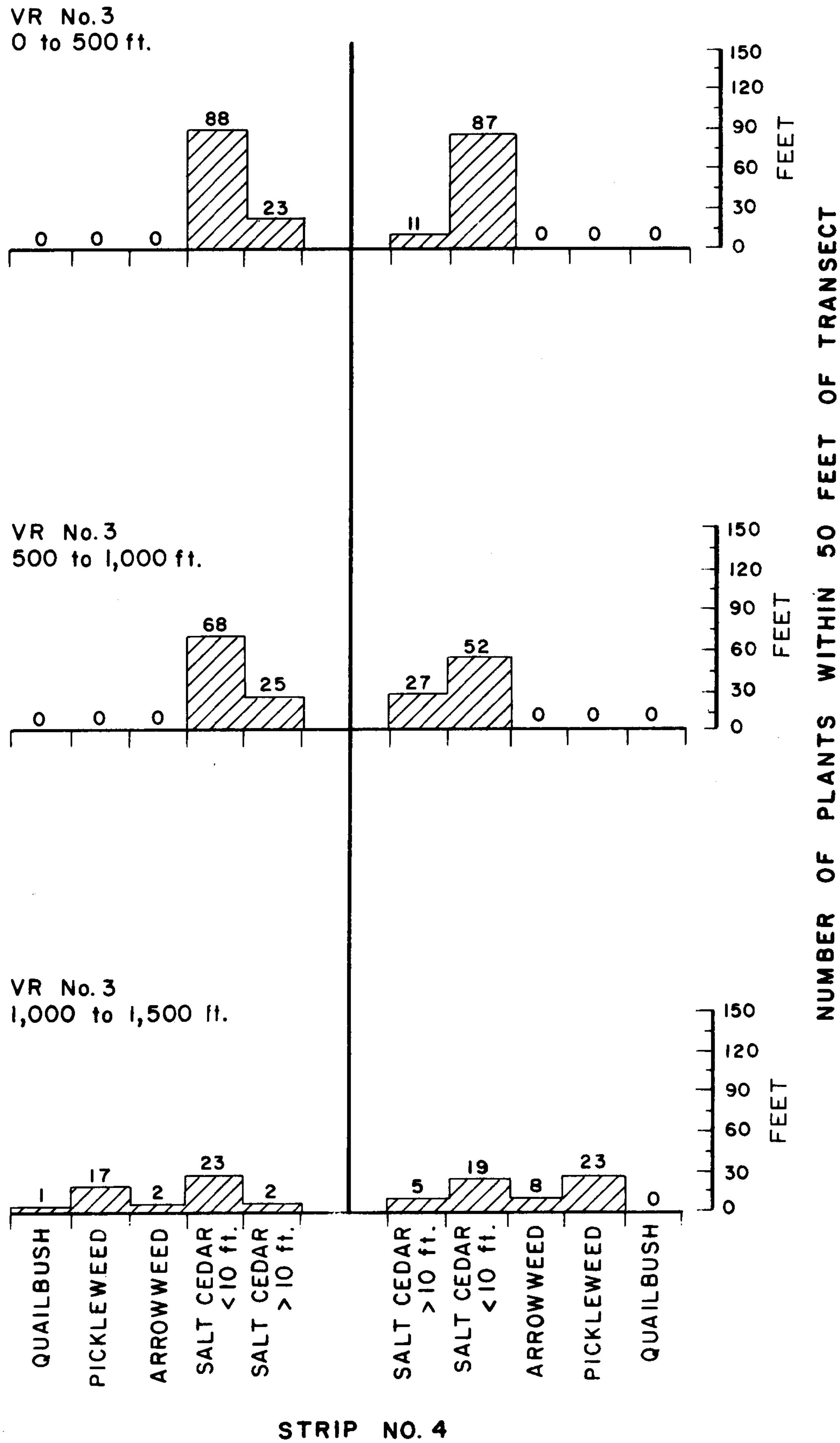


Figure 10. - Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 4 (sheet 1 of 2).

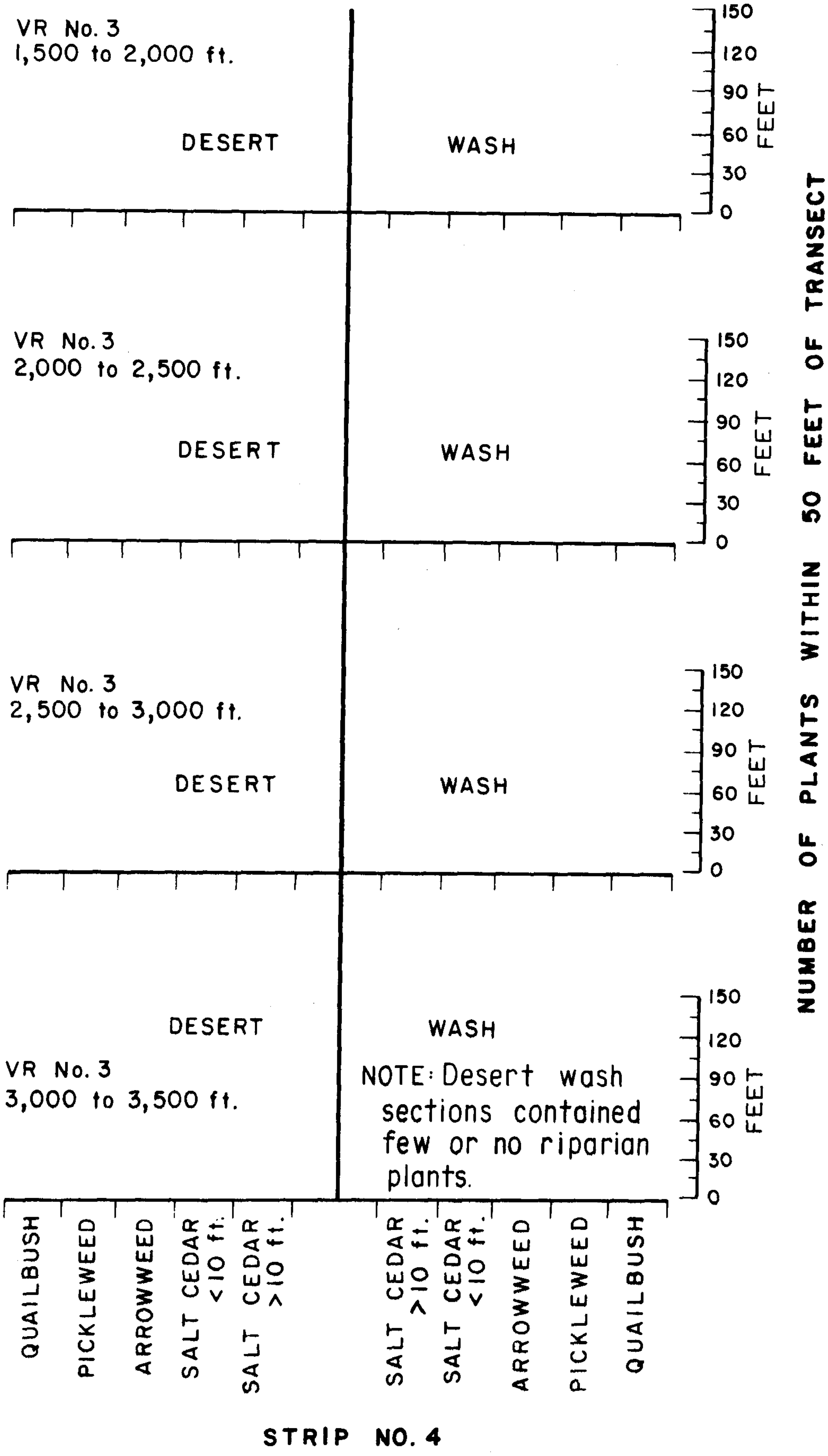


Figure 10. - Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 4 (sheet 2 of 2).

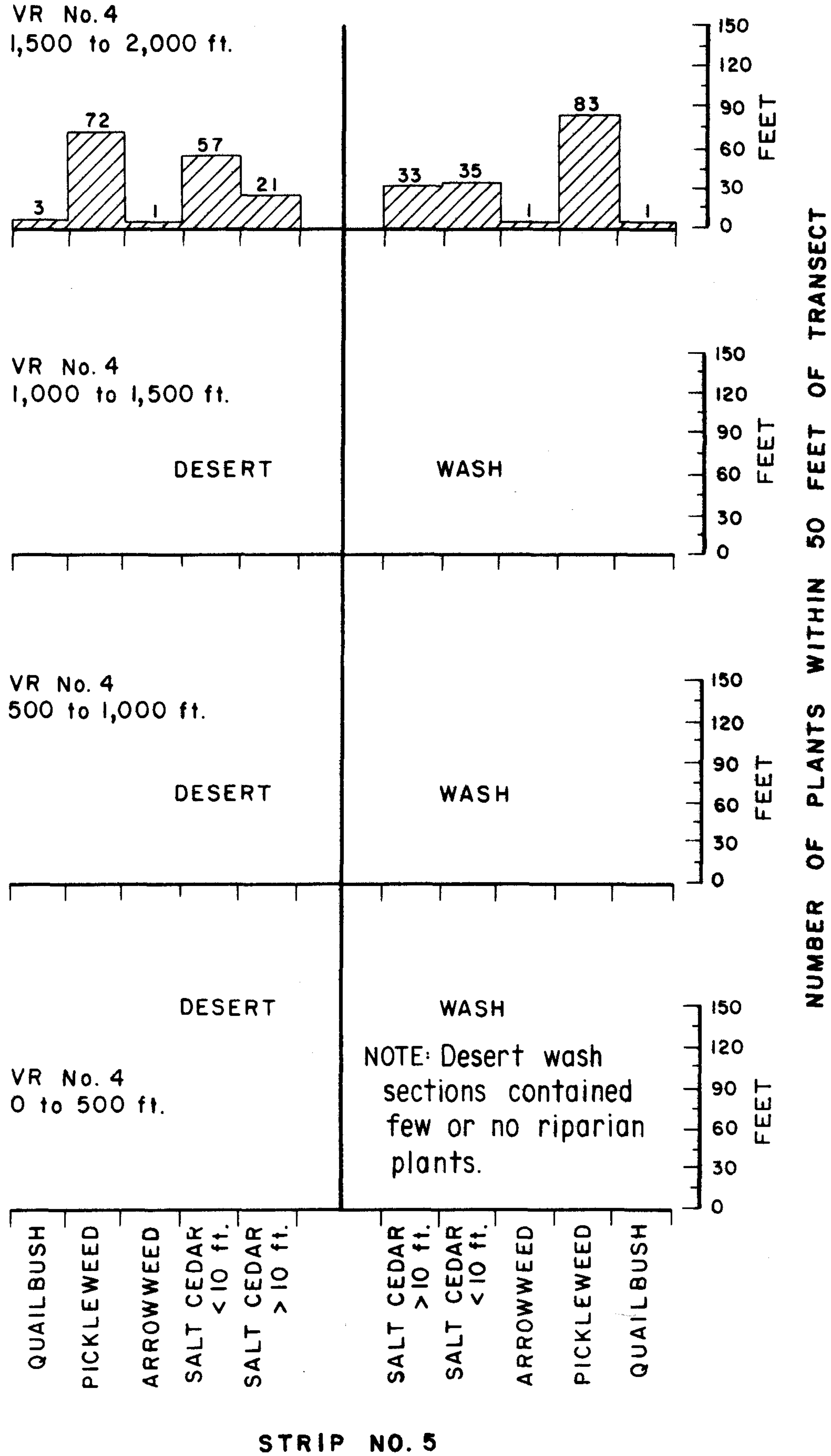


Figure 11. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 5 (sheet 1 of 2).

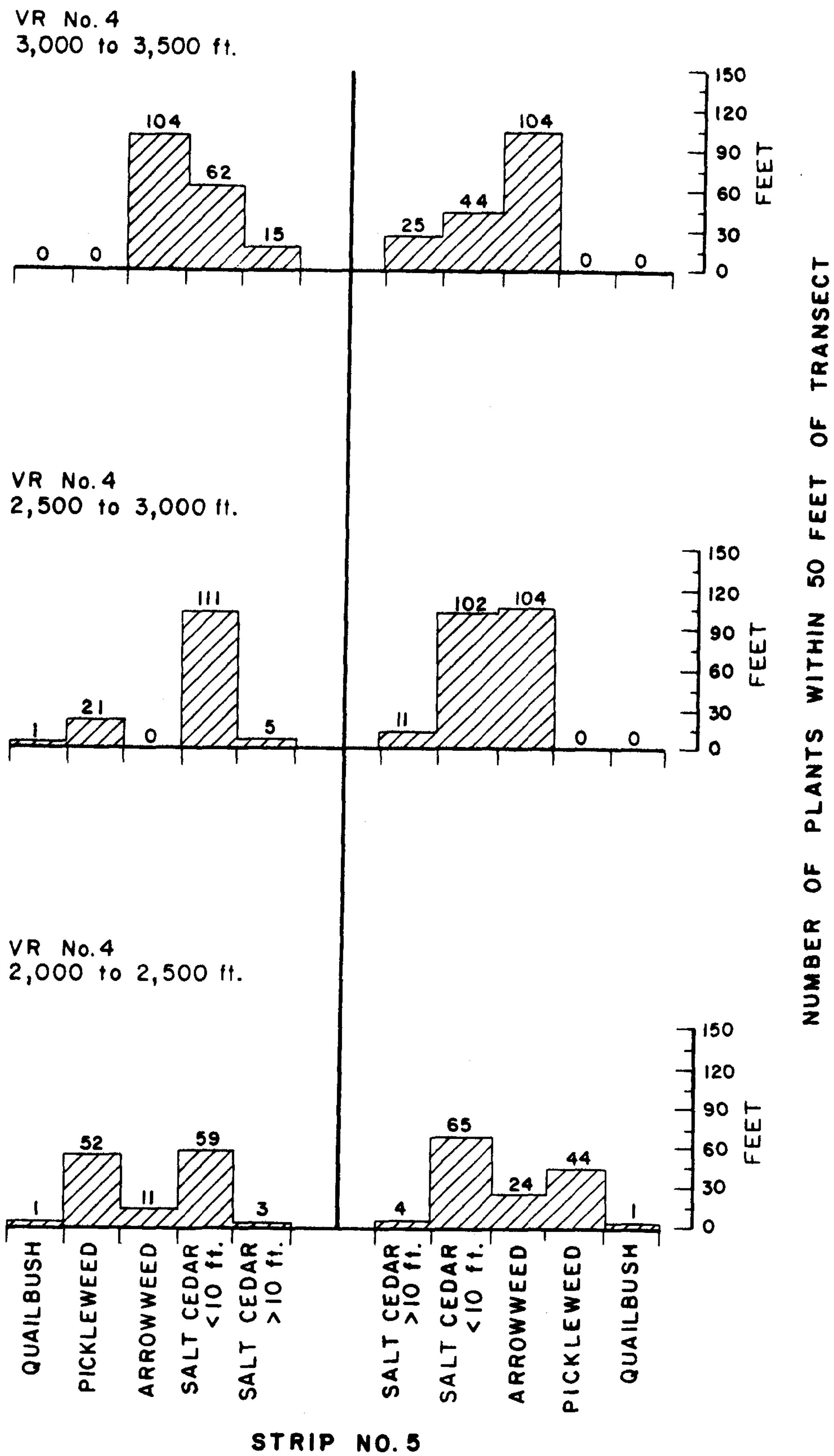


Figure 11. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 5 (sheet 2 of 2).

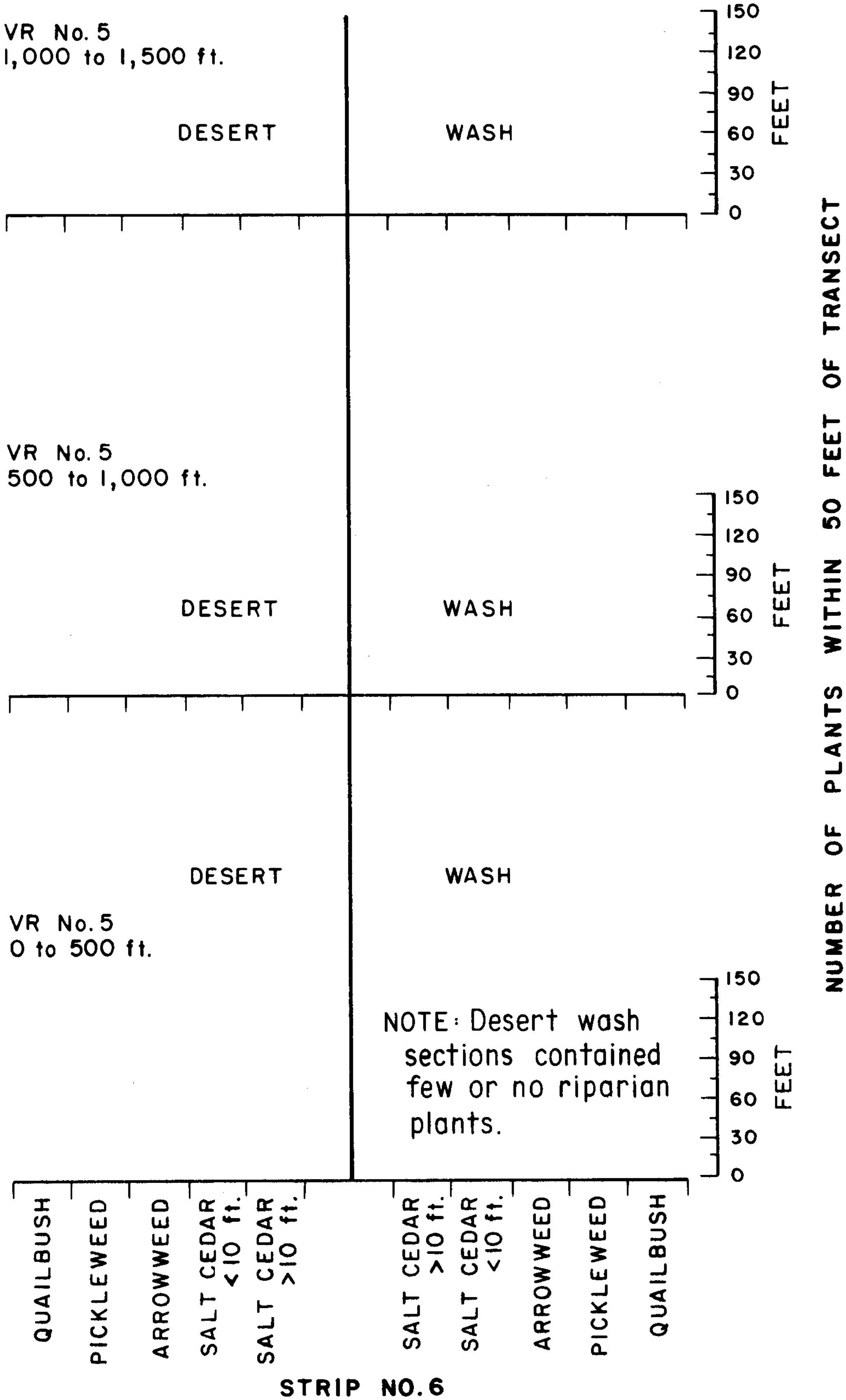


Figure 12. - Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 6.

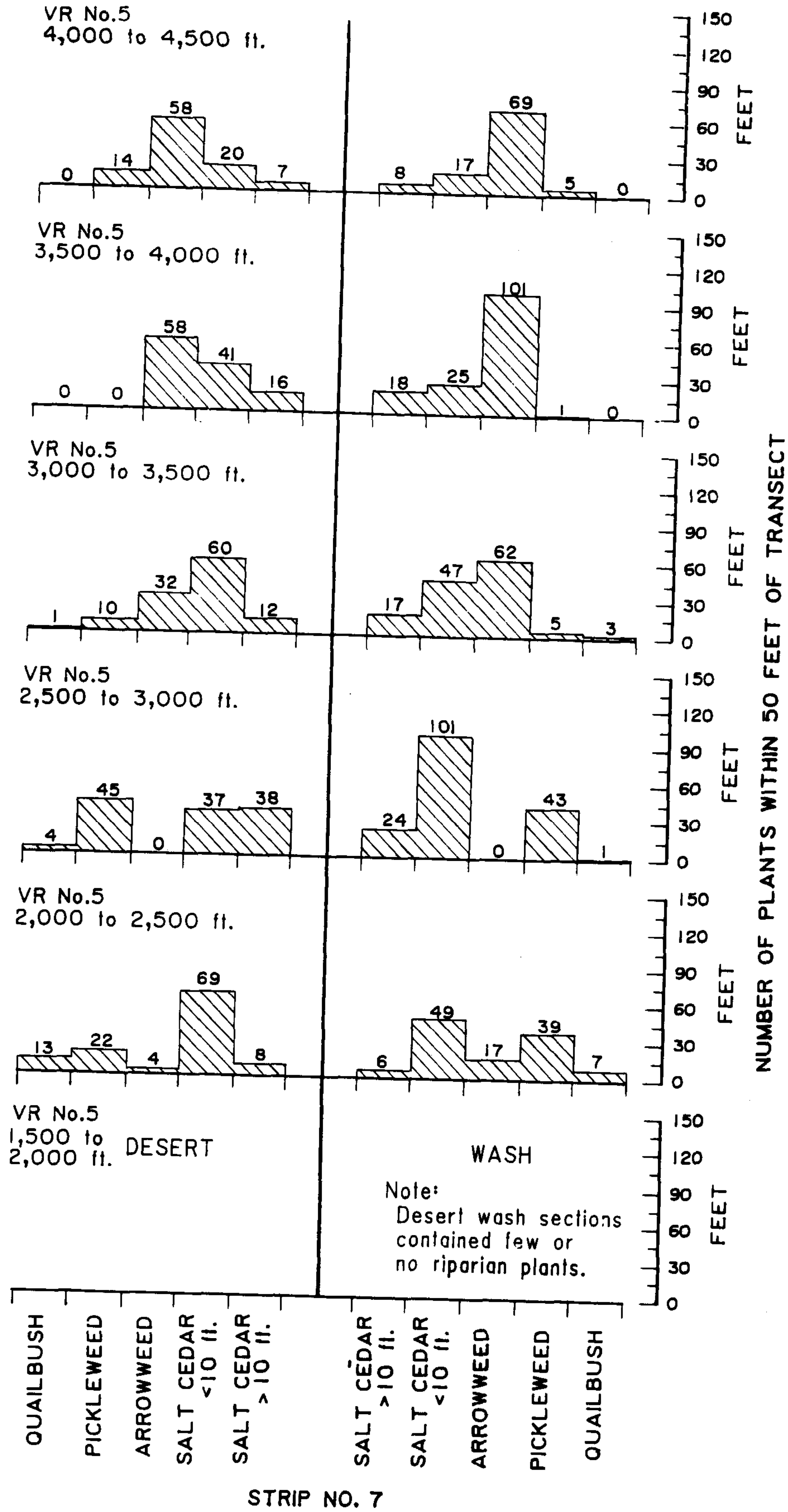


Figure 13. - Tree counts for predominant riparian vegetation species along lower Virgin River transects for strip No. 7.

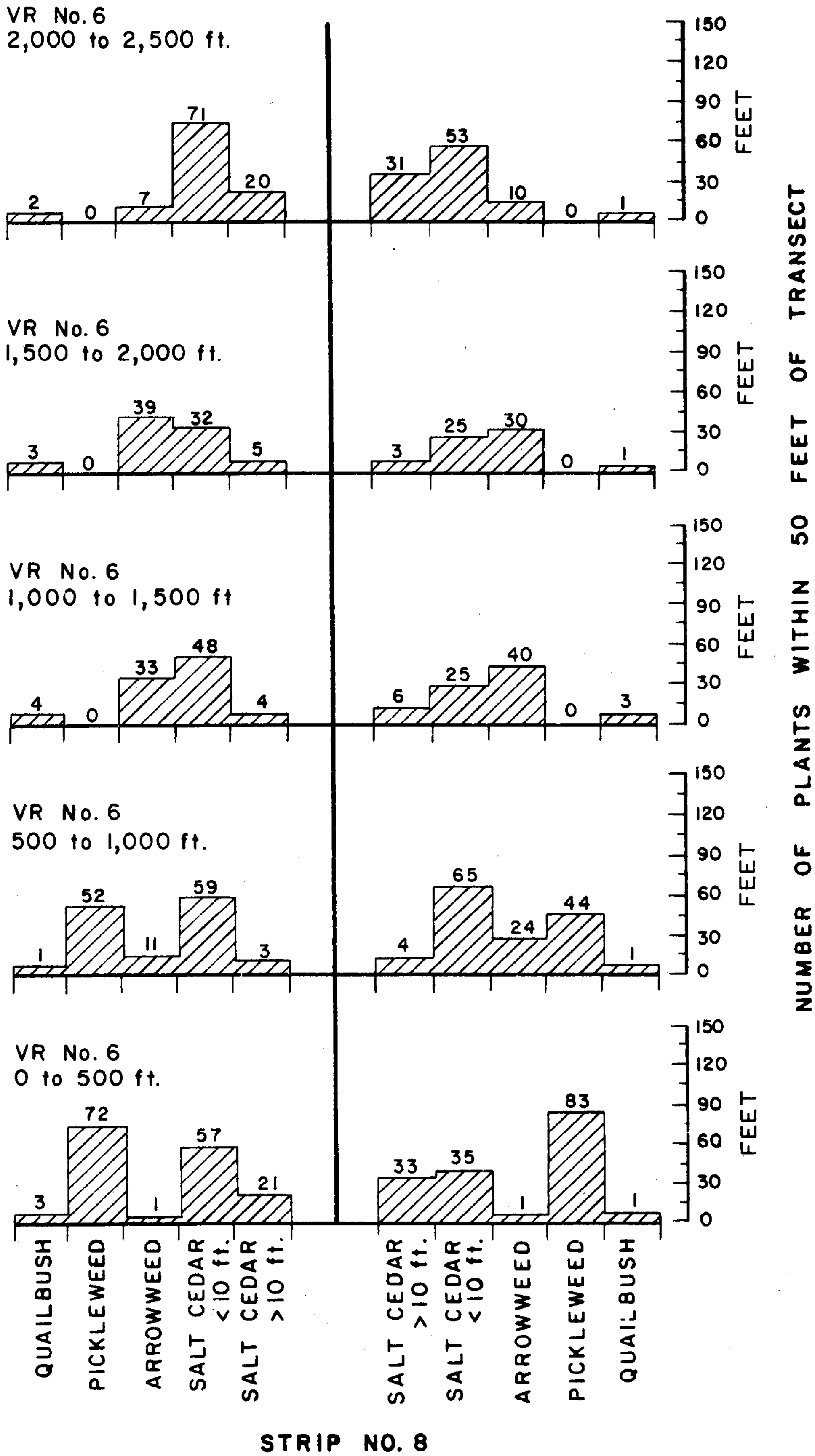


Figure 14. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 8.

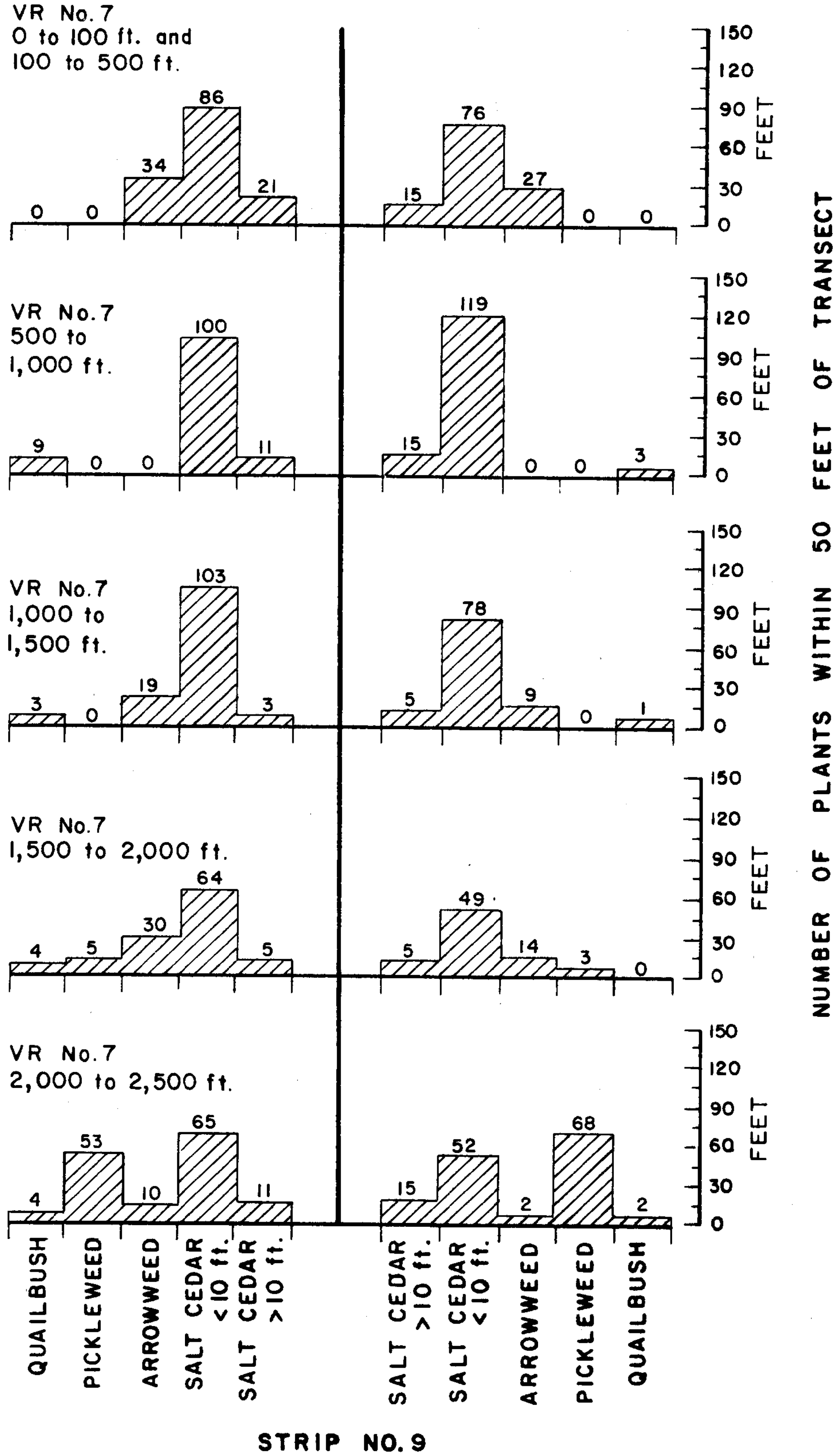


Figure 15. – Tree counts for predominent riparian vegetation species along Lower Virgin River transects for strip No. 9.

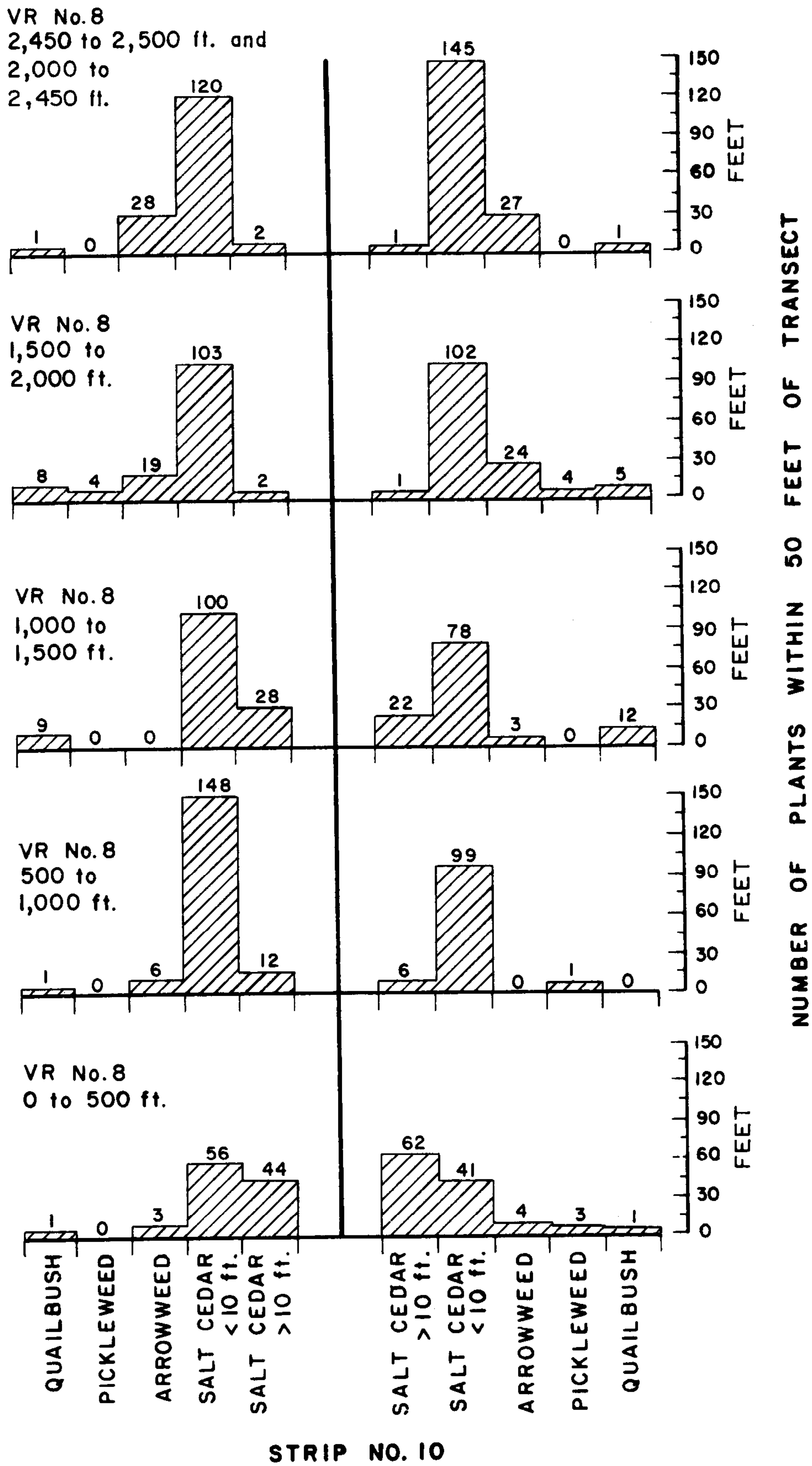


Figure 16. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 10.

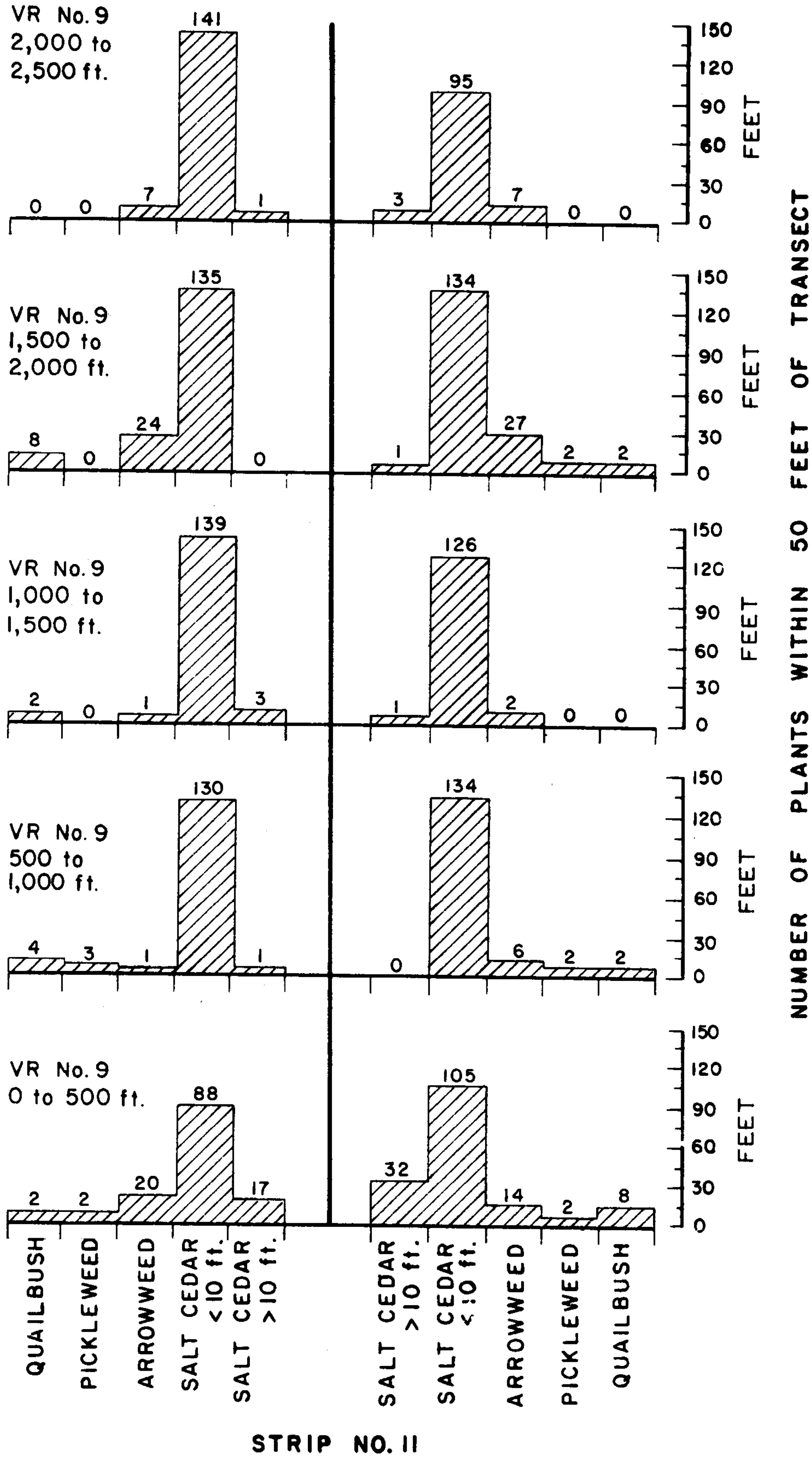


Figure 17. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 11.

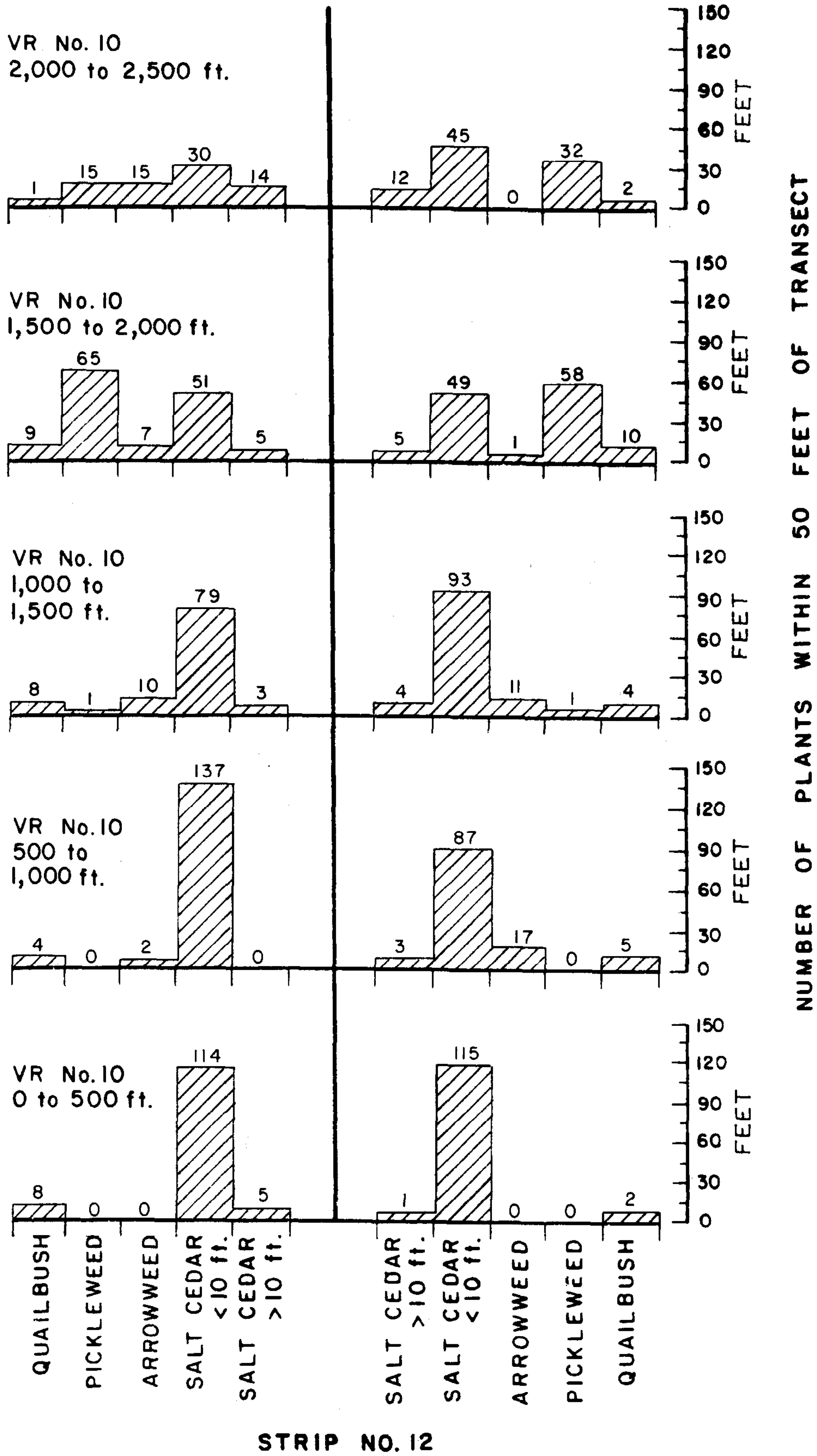


Figure 18. - Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 12.

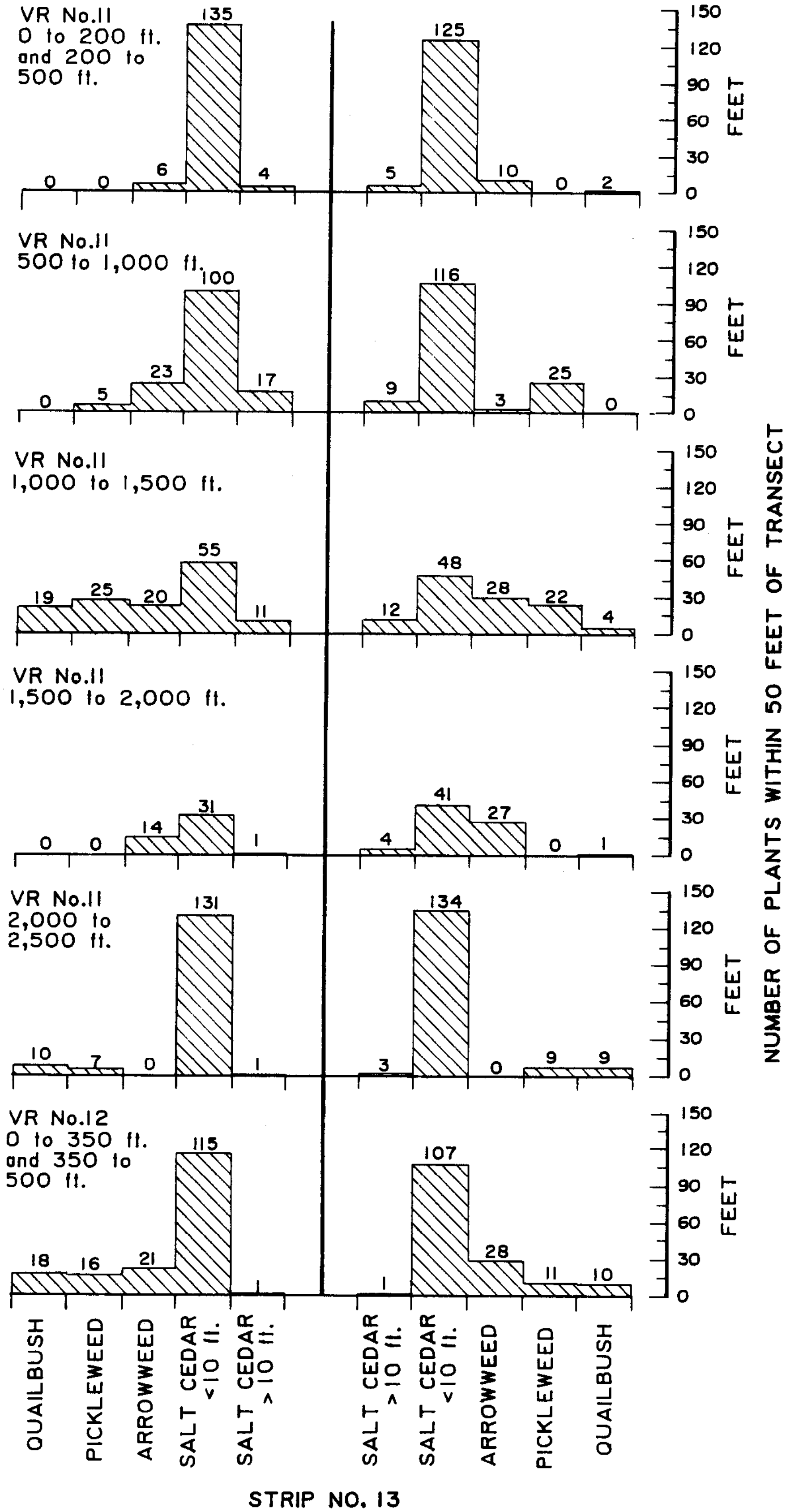


Figure 19. - Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 13.

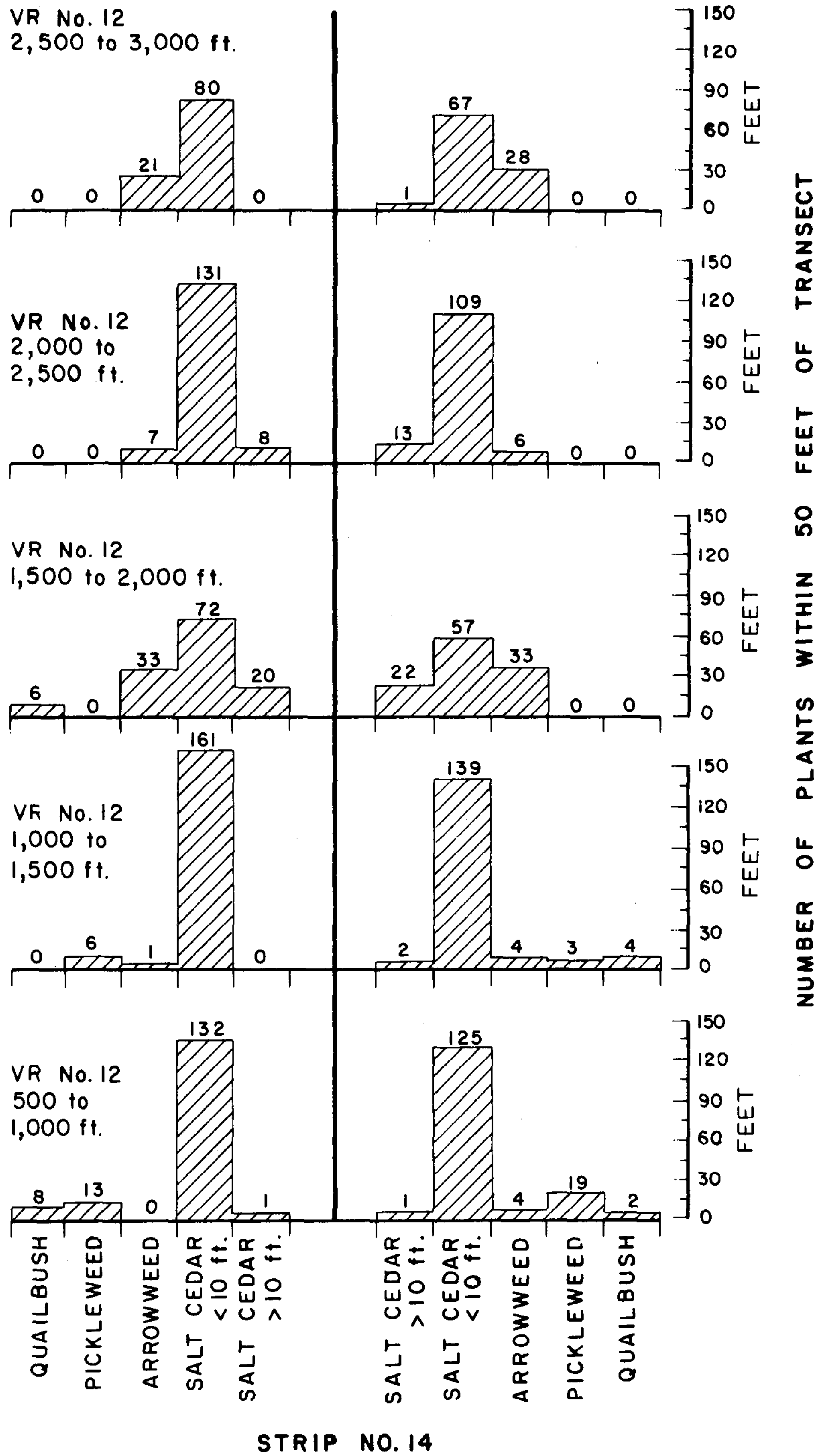


Figure 20. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 14.

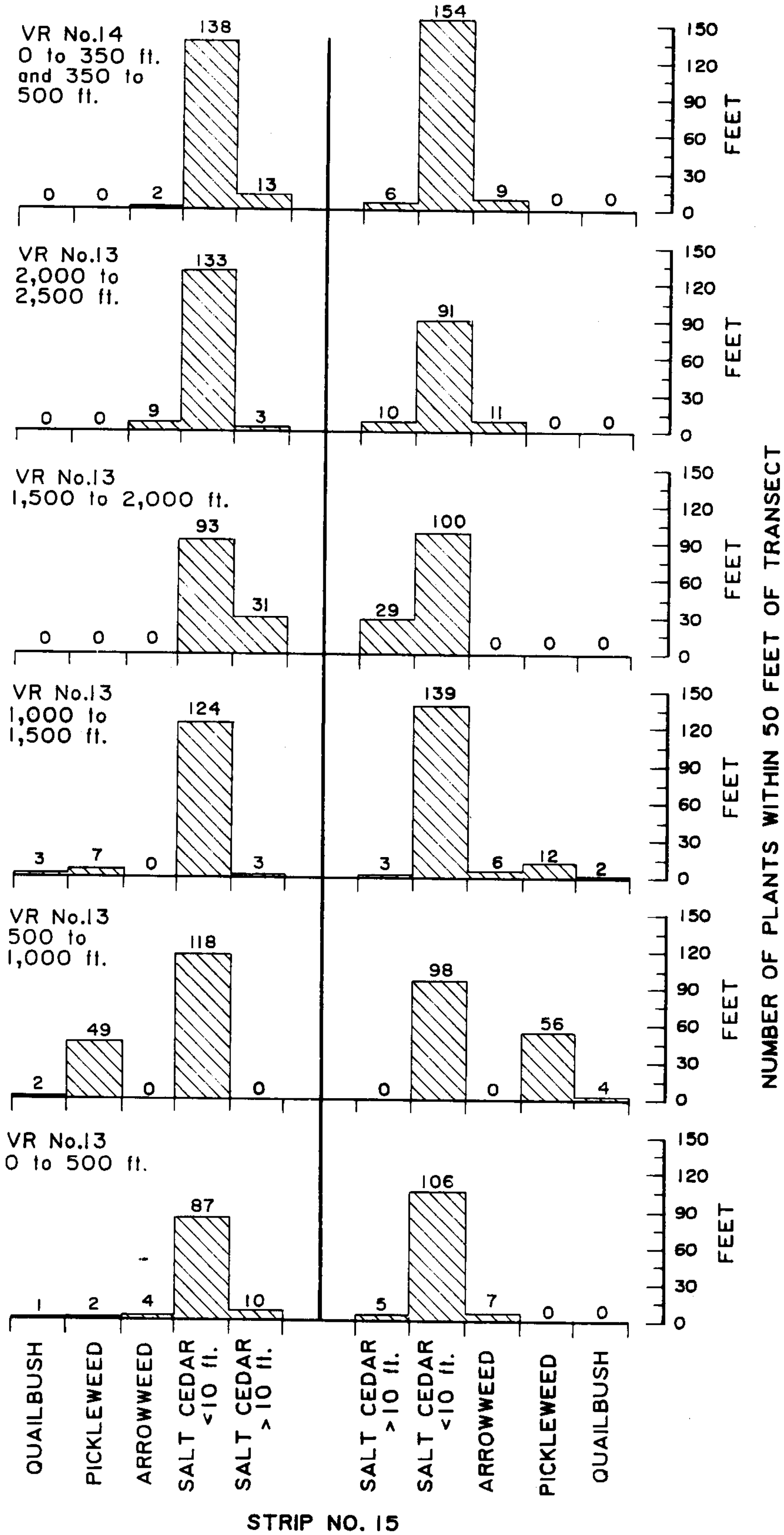
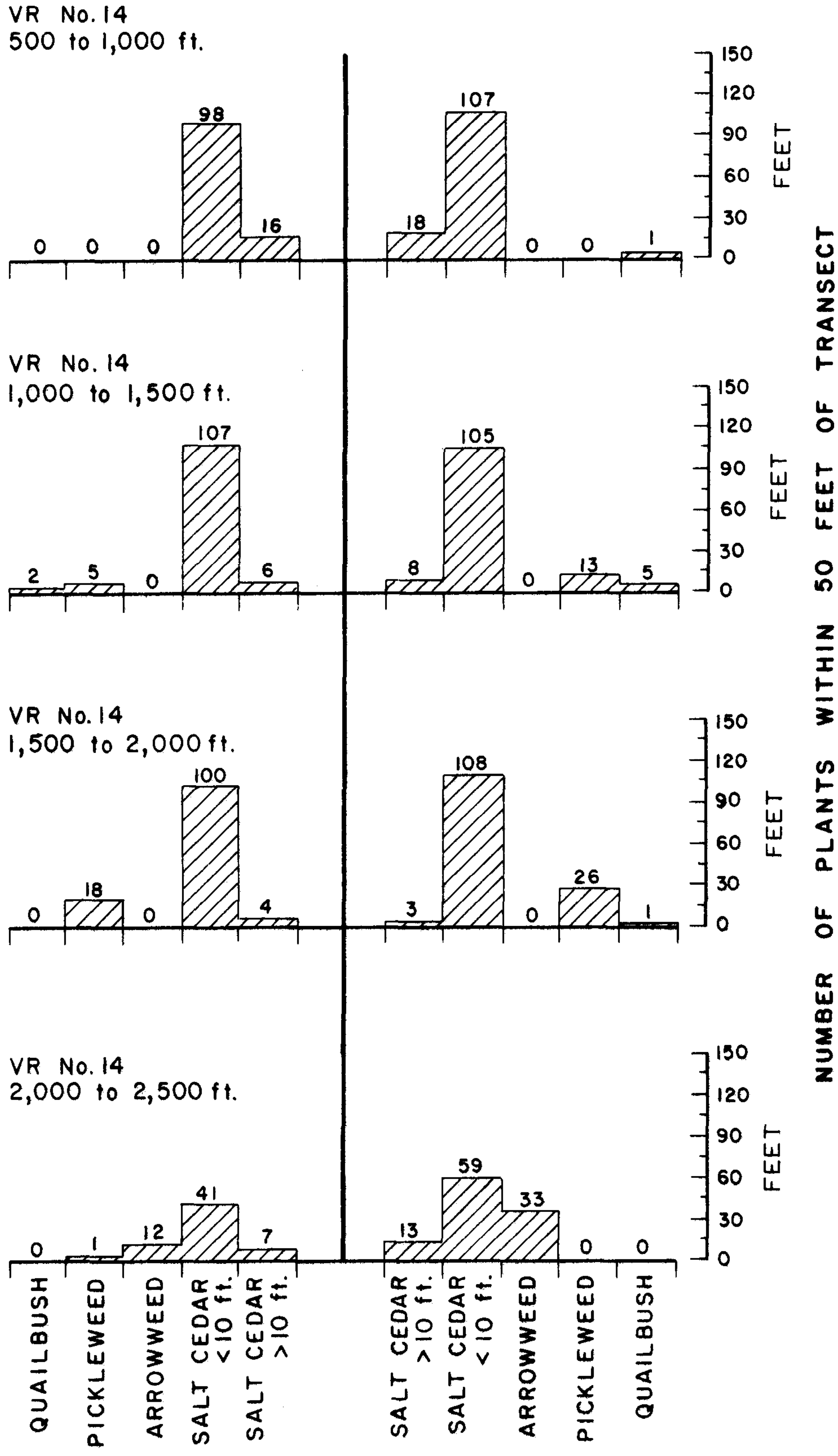


Figure 21. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 15.



STRIP NO. 16

Figure 22. – Tree counts for predominant riparian vegetation species along Lower Virgin River transects for strip No. 16.

RECOMMENDATIONS FOR REVEGETATION IMPLEMENTATION ALONG LOWER VIRGIN RIVER

Based on previous discussions, it is apparent that a need exists to control salt cedar. The negative impacts of salt cedar on both man and wildlife have been well documented, and evidence of its negative aspects continues to grow. Replacing salt cedar with a beneficial vegetation type has been proposed in many manuscripts as a potentially successful control method. Planting of revegetation sites with certain native species, and agricultural lands with hardy crop types, has shown promise as an effective technique.

Plant Selection Methods

The main criteria for such a study would be water salvage efficiency and socioeconomic benefits through wildlife enhancement and/or agricultural production. The Bureau of Reclamation is considering this potential approach. Table 16 shows the crops and native vegetation that were evaluated after initial appraisal of site potential and limitations.

When considering the species that would be most suitable for the project site, three basic factors must be considered: (1) must be compatible with physical/environmental properties of site, (2) be a strong competitor with salt cedar, and (3) be available in quantities large enough for an extensive area.

Investigations were made into the characteristics of the species shown in table 16 through the review of scientific journals, project reports, pertinent publications, and consultations with vegetation professionals. Successful revegetation is accomplished by understanding the potential negative factors working against the optimum growth of each species, and comparing these factors to on-site conditions to determine the probability of success. Salinity, depth to the water table, and soil density are all important examples of physical factors regulating plant growth.

The vegetation type from each category that appeared to be best suited to conditions on the Virgin River was then compared to the specific qualities of the site to determine which vegetation type would be most feasible.

Table 16.-Potential revegetation for replacing salt cedar.

Agricultural Crops	Native Species
Grain Barley (*Hordeum vulgare*)	Quailbush (*Atriplex lentiformis*)
Tall Wheatgrass (*Agropyron elongatum*)	Saltbush (*Atriplex canescens*)
Fairway Wheatgrass (*Agropyron cristatum*)	Screwbean Mesquite (*Prosopis pubescens*)
Altai Wildrye (*Elymus angustus*)	Inkweed (*Suaeda torreyana*)

Selected Vegetation

For the agricultural crops considered, all choices use relatively similar low amounts of water. However, grain barley was considered foremost because it is slightly more salt tolerant and there is more information available on this crop. The native species of vegetation also use similar amounts of water. Quailbush and inkweed stand out in particular because of their high salt tolerance. Due to the lack of information on inkweed and the difficulty of seed acquisition for the species, quailbush will only be considered here as the primary candidate for native species.

The logical choice based on survival probability and cost effectiveness would appear to be quailbush due to its extremely high salt tolerance and relatively low cost implementation. Agricultural areas along the Lower Virgin River between the study site and Riverside Bridge are few in number, with grasses and alfalfa the main crop type. Patchy fields reveal problems of high salts and/or high water tables, and salt cedar reestablishment is evident within some fields. Farmers attempting agriculture in the lower lying areas assume the risk of poor crop productivity and hence low profits to cover initial establishment costs. The Nevada Department of Wildlife at the OWMA (Overton Wildlife Management Area) has cited the high costs involved in simply maintaining crops to attract waterfowl. Also, the alfalfa and grass fields along the Lower Virgin River are virtually devoid of wildlife, harboring occasional waterbirds primarily when irrigation is ongoing and some wintering granivorous birds. The OWMA, located along Lake Mead, is more attractive to waterfowl, with marsh and grain crops providing an ample food supply and cover.

As a result of the literature search, quailbush and grain barley were finally selected. The comparative reasoning leading to this selection is presented in table 17.

Recommendations

Quailbush was the logical choice for vegetation management along the Lower Virgin River. The balance of this section is therefore concerned with the establishment of quailbush.

Revegetation With Quailbush

Introduction.-The foundation for the revegetation procedures that follow was based on our prior

Table 17. – Comparison of potential revegetation species characteristics with study site.

	Lower Virgin River Test Site Characteristics	Native Vegetation Quailbush (*Atriplex lentiformis*) Most Suitable	Agricultural Crop Grain Barley (*Hordeum vulgare*) Most Suitable
Soil salinity	Ranges from 403 to 28,177 p/m (Woessner, et al., 1981 [42]).	Tolerance from 200 to 60,000+ p/m (Anderson, 1983, unpubl.). Test site along Lower Colorado River with hand-planted seeds that grew under a wide salinity range, determined through soil samples. Extreme halophyte growth occurred in soils with 3 to 4 percent total soluable salts (Osmond, et al., 1980 [56]). Las Vegas Wash soil samples show *Atriplex lentiformis* growing in areas with saturation extract of dissolved solids up to 171,300 p/m in top 2 feet of soil.	Tolerance of up to 5,200 p/m (Maas and Hoffman, 1977 [57]). Above this level, initial yield decreases 5 percent per 650 p/m unit increase in salinity of soil. During emergence and seedling stage, salt content should not exceed 2,500 to 3,250 p/m.
Ground-water salinity	Average salinity across site was 11,150 p/m, based on an incomplete hydrological data set.		
Water table	Ranges from 1.5 to 6.0 feet. Average water table across Virgin River site was approximately 3.0 feet, based on an incomplete hydrological data set.	Test site along Lower Colorado grew quailbush over a 12-foot water table (Anderson, 1983, unpubl.). Quailbush is present on Virgin River test site (general observations) in areas with a high water table. A dominant, shallow-rooted species (Osmond, et al., 1980 [56]).	Fields of barley grown at OWMA determined a minimum of 3- to 4-foot water table needed; even problems at this level (personal comm., Nevada Dept. of Wildlife).
Soil profile	Primarily a silty clay to 6 inches, and silty clay, clay loam, or clay from 7 to 29 inches. Below this to 60 inches, stratified fine sand to fine sandy loam.	On Virgin River test site, this species grows in areas with a thick clay loam to sand composition (general observations). Along Lower Colorado, test site showed *Atriplex* growing well in a wide range of soils from sand to clay (Anderson, 1983, unpubl.).	Principal soil types on Virgin River test site have severe limitations that generally make them unsuitable for cultivation (soil profile prepared by Val Carter from existing data).
Water consumption	Phreatophytic (salt cedar) water consumption estimated along Virgin River to be between 7.5 and 12.0 ft/yr (Woessner, et al., 1981 [42]). Current studies show the hydrologic estimate to be very similar.	Minimal work has been done on quailbush consumptive use. Present values range from 2.5 to 4.0 ft/yr (McDonald and Hughes, 1968 [58] and Hughes and McDonald, 1966 [59]). Proven consumptive use decreases with maturity of stand (same as above, also [56]).	Barley has been determined to use about 2 ft/yr.

Table 17. - Comparison of potential revegetation species characteristics with study site. — Continued

	Lower Virgin River Test Site Characteristics	Native Vegetation Quailbush (*Atriplex lentiformis*) Most Suitable	Agricultural Crop Grain Barley (*Hordeum vulgare*) Most Suitable
Wildlife values	Based on previous studies on similar stands of salt cedar vegetation and on vegetation management wildlife studies conducted on study site. This vegetation type is generally poor for wildlife (Anderson and Ohmart, 1981 [33]; Ohmart, 1983 [24]; Anderson, et al., 1977 [85]; Cohan, et al., 1978 [36]).	Revegetation of a 50-acre site with this species of *Atriplex* greatly enhanced certain bird and rodent species. Native occurring stands have also been shown to harbor high wildlife densities [33, 24, 85]. Provides an important food supply for some species of game birds and other granivorous birds.	Grain crops have been shown to produce food and nesting habitat for some species of birds (Anderson and Ohmar, 1982 [60]) and to provide a winter food supply for waterfowl in some areas (personal comm., Nevada Dept. of Wildllife). Under proposed winter planting scheme, habitat for breeding birds would be unavailable during summer. Benefit would be to some waterfowl only during late winter.
Competition	The influence of man on waterways and salt cedar's prolific characteristics have been the primary reasons for the success of this species.	Once established, quailbush competed successfully against salt cedar on a revegetation site along the Lower Colorado [33].	Must be maintained to prevent salt cedar from competing. Poor soil and high salinities result in restricted yields and salt cedar encroachment. Take 2 to 3 years before salt cedar is suppressed (personal comm., Nevada Dept. of Wildlife).
Cost considerations	Cost should be based on: • 300-acre area • Moderately dense salt cedar, average height 5 to 7 feet • High water table, fairly wet and mucky areas • From main highway: about 13 miles of winding paved road, then 4.5 miles of rugged dirt road down a desert wash to river. Possible, through unlikely, access via Overton depending on river flow.	Cost should be based on: • Cutting vegetation with a bulldozer • Raking and piling vegetation • Root ripping (plowing to remove root crown) • Herbicide application* • Seed costs • Fertilizer costs* • Short-term investment: once established, should out-compete salt cedar indefinitely unless stand is destroyed by fire or flood	Cost should be based on: • Cutting vegetation with a bulldozer • Raking and piling vegetation • Root ripping (plowing to remove root crown) • Herbicide application* • Seed costs • Fertilizer costs • Discing rows • Leveling soil surface • Irrigation preparations: installation of canals or pipes for sprinkler irrigation • Water costs • Long-term, annual investments: seeds, fertilizer, water, harvesting, etc.

* May be optional.

experience on the Virgin River site, revegetation conducted along the Lower Colorado River, and involvement in the Cibola vegetation strip-clearing project. Consultation with regional experts and further literature research will affirm and add to the proposed plans.

Obtaining a fairly high biomass production for quailbush can best be accomplished by maximizing the knowledge of potential negative factors against its growth and treating them accordingly. Some factors that will ultimately influence the percent growth or germination success can be indirect from obvious problems such as those related to soil or water quality. Therefore, the information presented is an attempt to identify some potential concerns and approaches to formulate a more successful planting format through more fundamental research on the biological aspects of quailbush.

Successful competition against salt cedar will ultimately depend upon the relative degree of biomass production by quailbush. The greater the biomass, the greater the chance for outcompeting salt cedar. This is basically achieved by "smothering" or shading out salt cedar growth. In fact, native species have been documented to compete well with salt cedar under certain circumstances. However, evidence appears to suggest that the primary limiting factor is the water quality. Nearly all native trees are unable to compete under even moderately saline conditions but, under low salinity conditions, native trees have been shown to outcompete salt cedar. One example is Beaver Dam Wash in Arizona, about 25 miles north of the Virgin River site, which remains a cottonwood/willow community with little salt cedar encroachment. At the confluence of Beaver Dam Wash and the Virgin River, the effect of water quality on vegetation is obvious.

Site Selection and Location.-Phase 1 of the Lower Virgin River Vegetation Management Study has been completed, and biological and hydrological studies have been conducted across the 600-acre salt cedar dominated site. The wildlife habitat value and consumptive water-use estimates were determined under existing conditions. Phase 2 is to clear half (300 acres) of the study area and establish selected vegetation types that consume less water and are more beneficial to wildlife. Monitoring would continue over the entire site, using the revegetated area as the experimental plot and the uncleared salt cedar as the control plot. Success in achieving project objectives can then be tested by comparing collected data from control and experimental plots, using the sampling studies before clearing as baseline material. The study area selected for clearing will be based primarily on floodplain conditions.

Based on available water table and ground-water salinity data, plus the geographic and vegetative characteristics of the site, revegetation success would probably be best achieved by clearing the north end of the site (strips 1-10). The following facts support this recommendation:

- Depth to water table is shallower and the amount of area with surface water is, on the average, greater at the south end (strips 10-16).

- General observations presently show existence of many channeled areas inundated with high ground water and/or streamflow. Extensive riverbank degradation at the south end and subsequent erosion could cause serious problems when considering the feasibility of deterring flood flows. The river currently flows across portions of the site using strips No. 13, 15, and 16, in particular, as part of the channel, even during low flows. This feature, coupled with the river channel's eastward migration (presently abutting the west banks of strips 8-16), points towards continued erosion in this section; therefore, revegetation does not appear feasible here.

- The average ground-water salinity is lower at the north end, a factor that would increase the probability of having a successful revegetation effort. Also, salt grass appears to be more abundant in the south sector. Anderson and Ohmart, 1984 [87] have shown this species to be strongly competitive in revegetative situations that might outcompete the species the Bureau is trying to establish.

- The north end (strips 1-10) of the site could be structurally protected from flooding, which could drown out or wash away plantings. Figure 23 shows a general overview of the major vegetative and physical features of the site. Sandy soil covers more total area at the north end than at the south end, and these areas are usually higher above the floodplain and contain fewer salt cedars, making clearing and bank protection more feasible. Also, more low water-use screwbean mesquites still exist in scattered locations at the north end, offering increased wildlife enhancement if these trees are left uncleared.

Planting Season.-The success of a revegetation effort using quailbush depends highly on the planting season. Planting should take place during October or November because of three primary factors:

(1) *Salt Cedar Competition*.-If cleared during its growing season (March-October), salt cedar will reestablish itself either through new seedlings or regrowth from remnant root systems. The objective is to clear as close as possible to the

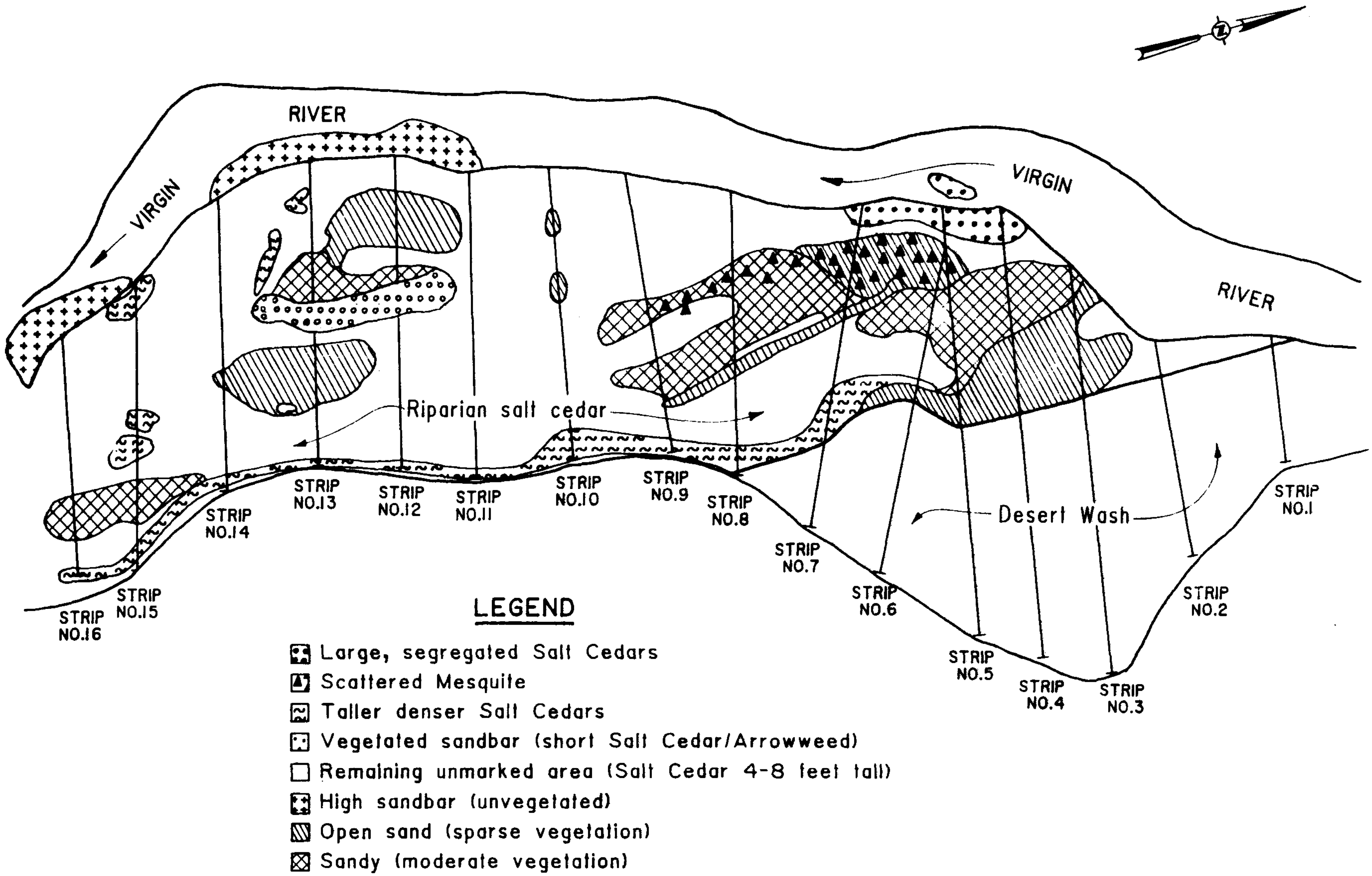


Figure 23. – Major vegetation and physical features along Lower Virgin River study site.

period of salt cedar dormancy to reduce part of its competitive advantage.

(2) *Winter Germination.*–Quailbush is a shrub that germinates during the winter months. Fall sowing would give quailbush a head start for initial establishment before the onset of salt cedar growth in April. Planting too close to spring would likely result in reduced growth establishment and therefore, reduced success in competing with salt cedar. Revegetation studies have shown spring planting to be detrimental; fragile seedlings were unable to survive the hot summer temperatures and dry conditions (Anderson and Ohmart, 1979 [86]).

(3) *Dry Season.*–The Virgin River is usually driest during mid-late summer and into early fall. The site can be extremely wet during the late fall, winter, and spring months, causing potential costly problems in pulling out heavy equipment that may become bogged down in the muck.

If clearing were to begin too soon (July - September) before the winter dormancy of salt cedar, action would probably be necessary to limit reestablishment. A possible solution could be to apply a short-term herbicide to kill off the seedlings prior to sowing the quailbush. Care should be taken not to destroy the quailbush or native plants left after clearing. A second alternative would be to reclear after the initial clearing effort.

Clearing Methodology and Site Preparation

(a) *Clearing Vegetation Using Bulldozers.*–Chaining is inappropriate in this case because the vegetation is too short and the scarcity of substantial trunks would result in the chain simply pulling over the flexible branches. Bulldozing would at least partially disrupt the root system.

(b) *Selective Clearing.*–A few stands of screwbean mesquite and individual large willows exist on the site. Leaving these trees would be extremely beneficial to wildlife through the creation of a more diverse habitat (Anderson and Ohmart, 1977 [33,34,35]; Ohmart, 1983 [24]). The water consumption of screwbeans is about the same as or less than that of quailbush, and its presence would not hinder the spread of the shrub.

(c) *Rake and Pile Vegetation.*–The cleared vegetation can be pushed towards the river and left in piles. A possible alternative to aid in stabilizing the site and preventing erosion would be to bury the vegetation along the riverbank. The cleared vegetation could be burned before burying or buried without burning; however, with the latter, regeneration would probably occur to some extent. The feasibility of this option needs to be discussed with experienced engineers who would be able to determine if buried vegetation would remain stabilized; i.e., if flood flows would actually be held back. Another option would be to leave the piles for wildlife to use as shelter and nesting habitat, which would greatly enhance wildlife in creating a more diverse habitat feature.

(d) *Root Plowing.*–Root plowing, or grubbing, involves the use of a series of chisel-like prongs mounted on a tractor or grader. The prongs penetrate the soil to a depth of as much as 3 feet, which will cut off salt cedar root crowns well below the surface. Failure to follow this procedure will often result in abundant regrowth from the root systems the following spring.

(e) *Discing.*–After root plowing, the large root systems pulled up should be cleared away. If the ground is rough or uneven, discing will enhance quailbush germination because the rough areas will collect water and keep the seeds moist. If large holes and pockets are created after root plowing, discing or selective earth moving is beneficial in preventing deep pools from being formed. Discing may not be required in all situations.

(f) *Aeration.*–This method could probably be used in place of discing. An elongated drum with numerous peg-like projections is mounted on a tractor and pulled over the site. The result is the formation of shallow, evenly-spaced holes that trap the planted seeds and any precipitation, which protects the seeds from drying out. The holes also prevent the seeds from being carried away by strong winds that would, in turn, result in patchy areas with no plants.

Seed Germination Characteristics and Requirements

(a) *Seed Site Selection.*–Variations in the salt tolerance of seeds from closely related plant species or varieties and from different populations or ecotypes within a particular plant species have been reported in the literature (Dewey, 1960 [61]; Workman and West, 1967 and 1969 [62, 63]; Bazzaz, 1973 [64]; Kingsbury, et al., 1976 [65]; and cited by Ungar, 1982 [66]). Data indicate that the source from which seed were obtained may be very critical in determining the germination response when exposed to saline conditions. Therefore, seeds should be selected from areas as near to the Virgin River site as possible or from an area where conditions are similar. The problems of salinity and disease would then be less important variables to contend with.

(b) *Seed Age.*-Most *Atriplex* species produce some seeds that are genetically programmed to germinate only after a minimum of about 10 months (Osmond, et al., 1980 [56]). The older the seeds, the greater the percent of seed germination expected.

(c) *Temperature.*-Investigations have found a significant decrease in germination when seeds were transferred from colder to warmer locations [56]. Plants of *A. lentiformis* from desert habitats acclimate when grown at higher temperatures by developing higher carbon dioxide uptake rates (Pearcy, 1977 [67]). However, winter temperatures (60 °F or colder) are required by seeds before germination can occur. The cold stratification apparently induces the potential for germination. Ungar (1978) [68] indicated that interactions between temperature, salinity, and seed germination exist in halophytes. Recent work with the halophyte *Crithmum maritimum* indicates that alternating temperatures of 5 and 15 °C, 5 and 25 °C, and 15 and 25 °C produced significantly higher germination percentages at all salinities tested than did constant temperatures. No seeds germinated at a constant temperature treatment of 5 or 25 °C. Zohar, et al., 1975 [69], and cited by Ungar [66] found an interaction between temperature and osmotic stress on the level of germination of *Eucalyptus occidentalis* seed. The results support other earlier data reporting temperature-salinity effects on the germination of halophyte seeds (Binet and Combes, 1961 [70]; Langois, 1961 and 1966 [71, 72]; Malcolm, 1964 [73]; Binet, 1964 and 1968 [74, 75]; Ungar, 1965 [76]; Springfield, 1966 and 1970 [77, 78]; and Ungar and Hogan, 1970 [79], all cited by Ungar [66]).

Seed Supply

(a) *Sources.*-At least two companies are available for supplying quailbush seeds: Hubbs Brothers in Phoenix, Arizona, and Native Plants, Inc., of Salt Lake City, Utah. Another possibility would be to collect the seeds inhouse. Quailbush seed production in 1983 was excellent and large quantities of seed could be gathered in a short period. Prime locations in the area are Las Vegas Wash, the outskirts of Las Vegas, Nevada, and the Overton Wildlife Management Area.

(b) *Seed Collection Timing.*-Seeds are available for collection from November to March; therefore, revegetation needs must be determined in advance so seeds can be acquired at the proper time of year, either locally or through other channels. Perhaps the most important aspect of timing to consider is the initiation of seed collection as soon as they are ripe. During early fall, seeds are green and well formed, but by late fall, depending on the latitude/elevation, they are already turning to their characteristic pinkish to reddish color. Soon after, the seeds will turn tan or brownish, and this is the best time for collection. Insects, particularly beetles, will take a heavy toll on the season's seed production, especially during wetter years. Care should also be taken once the seeds are ready for storage to ensure they are insect free. Insect problems also vary with latitude.

(c) *Quantity.*-Data used by seed companies for various species of native shrubs were obtained to determine the quantity of seeds required for revegetating the proposed 300 acres along the Lower Virgin River. For quailbush, 2.5 to 3.0 pounds per acre was recommended by the Hubbs Brothers Seed Company in Phoenix, Arizona, who have successfully planted this species. This quantity was based on what is known as "pure life seed", which is calculated by multiplying the percent purity by the percent germination. With any seed collection, a certain percentage of the harvest will be infertile, or consist of empty seed casings. The resulting pure-life seed quantity hypothetically assures 100 percent germination per acre. Therefore, the recommended amount of pure-life seed for the 300-acre site was 900 pounds. Approximately 18 sacks (30 pounds each) of seed (non pure-life) were collected during February and March 1983, and were purchased in anticipation of future revegetation needs. Some of these seeds are being stored in the Bureau warehouse, but the majority were given to OWMA to test plant after the Lake Mead water level dropped low enough to allow their submerged fields to dry. In the meantime, the germination potential of the seeds should increase with age.

(d) *Cost.*-The cost of pure-life quailbush seed is currently about $5.72 per pound. This is apparently one of the cheapest native seeds available due to the relative ease of collection and the high percentage of viable seeds. The estimated cost for the 300-acre site, at 3 pounds per acre, would be $5,148, excluding the cost of the seed previously collected.

Implementation

(a) *Fertilizer.*-The use of fertilizer has been suggested by the seed companies for quicker and more healthier growth; however, this may not be necessary, as shown by previous revegetation work with quailbush. If considered, the fertilizer recommended is 16-20-0 ammonium phosphate. The cost would be expensive based on the 250 lbs/acre suggested, at $350/ton; and for a 300-acre site, the total cost would be about $13,125.

(b) *Planting.*–Some of the same equipment used in sowing agricultural crops could be used in planting the site. This would ensure more even seed distribution and a better use of manpower. Once the seeds are planted, nature should take care of the rest. A sprinkler irrigation system should only be necessary in the event of a dry winter, and even then may be of no consequence due to the high water table. Follow-up procedures for monitoring the site are recommended, keeping a watchful eye for salt cedar encroachment, disease, or any other problems.

(c) *Revegetation Completion.*–Figure 24 shows how the site would appear after revegetion procedures are completed and establishment is successful. Quailbush will be the primary vegetative component, forming a dense cover intermixed with the scattered screwbeans and willows that were selectively uncleared. Spaces between shrubs represent cut areas through the quailbush. Higher foliage diversity and better wildlife access would be created as a result. This diversity would be performed once quailbush growth is lush and establishment complete.

Revegetation for Maximum Wildlife Value

Introduction.–Revegetation for maximum water salvage has been proposed for the study area using quailbush, which was the most suitable choice based on its low water use and ability to grow in a wide range of soil densities and salinities. The revegetation directives proposed in this section are only for the purposes of enhancing habitat value for wildlife. This information will serve as a guideline towards any measures taken for mitigation.

As previously discussed, revegetation with certain native plant species is the best way to reach the objectives of enhancing wildlife habitat (Johnson, 1971 [37]; Carothers, et al., 1974 [33]; Anderson and Ohmart, 1977 [33,34,35]; Cohan, et al., 1978 [36]; and Ohmart, 1983 [24]). Therefore, the recommendations that follow consider these species of trees and shrubs proven to be valuable to wildlife. Plans and procedures are based on clearing half the study area and taking into account the existing site conditions. Physical features of water table depth, soil composition, and water/soil salinity for the site are considered where information is available. The recommended format and ideas should also be applicable to clearing on a much greater scale along the Lower Virgin River.

Methods

(a) *Vegetative and Physical Features.*–After clearing, the study area should be relatively free of all vegetative debris. The only remaining vegetation will be the larger stands and taller individual screwbean mesquites and willows. These trees will add diversity to the vegetative community once the new plants start to grow. Two important points should be considered with respect to these trees: (1) low vegetation surrounding the trees that was not cleared by bulldozers must be removed to ensure that it does not reestablish itself, and (2) chicken wire should be placed around the base of the willow tree trunks so that beavers will not cut down or girdle the trees as they have done in some locations.

(b) *Tree and Seed Site Selection.*–Figure 25 shows a general planting scheme for native vegetation within the cleared area. Factors affecting the planting segregation for the three main plant types are:

- *Trees.*–The trees should be planted in the lowest salinity areas possible due to their low salt tolerance. Higher, drier, and sandier areas would probably be best. Sands have better drainage than other soils and would permit salt leaching. Salinity contour data for the site indicates that areas closest to the river have the lowest salinities. A higher ground-water table would be advantageous for more rapid tree establishment. The largest existing stands of willows on the site are located along the river edge.

- *Shrubs.*–Dessert shrub species can be planted across the entire site, particularly in the high saline locations where trees are ruled out. Quailbush would especially be useful because of its lush vegetative growth that competes against salt cedar reestablishment. Dense soils would likewise be more suitable for desert shrubs. As previously discussed, quailbush has been shown to grow in a wide variety of soil types. Growing stands of shrub species adjacent to one another would create a more diverse habitat.

- *Marsh Plants.*–Emergents are grown best in shallow water conditions. Ponds 2 and 3 (fig. 25) are made shallow along the backwater areas and perimeters to facilitate establishment of alkali bulrush. Sufficient water levels must be maintained to ensure survival.

(c) *Plant Species and Sources.*–The following is a list of native plant species documented as important wildlife habitat and found in the locality of the study area:

Fremont Cottonwood (*Populus fremontii*)
Goodding Willow (*Salix gooddingii*)
Glandular Mesquite (*Prosopis glandulosa*)

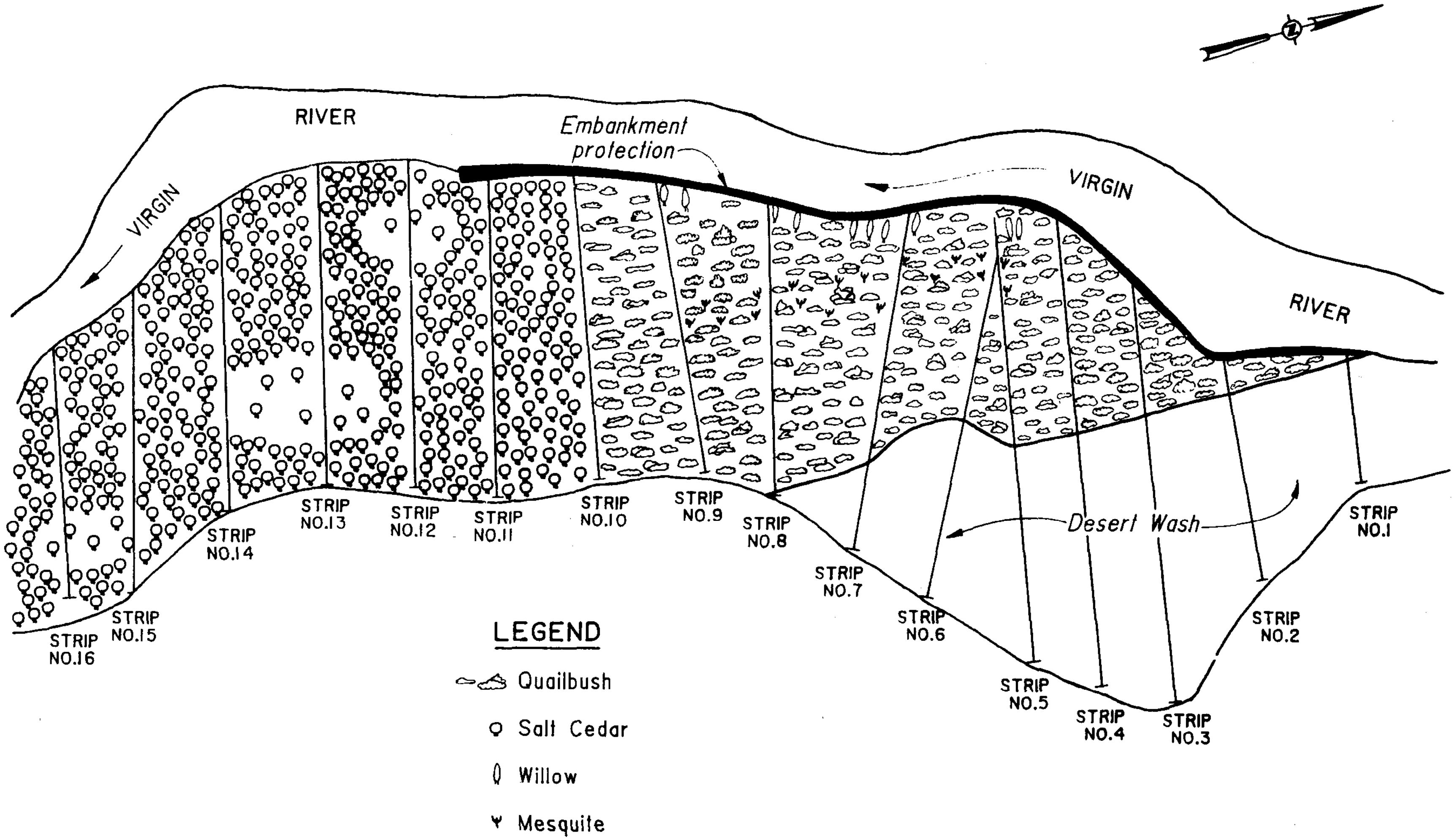


Figure 24. – Proposed revegetation scheme for maximum water salvage on strip numbers 1 through 10.

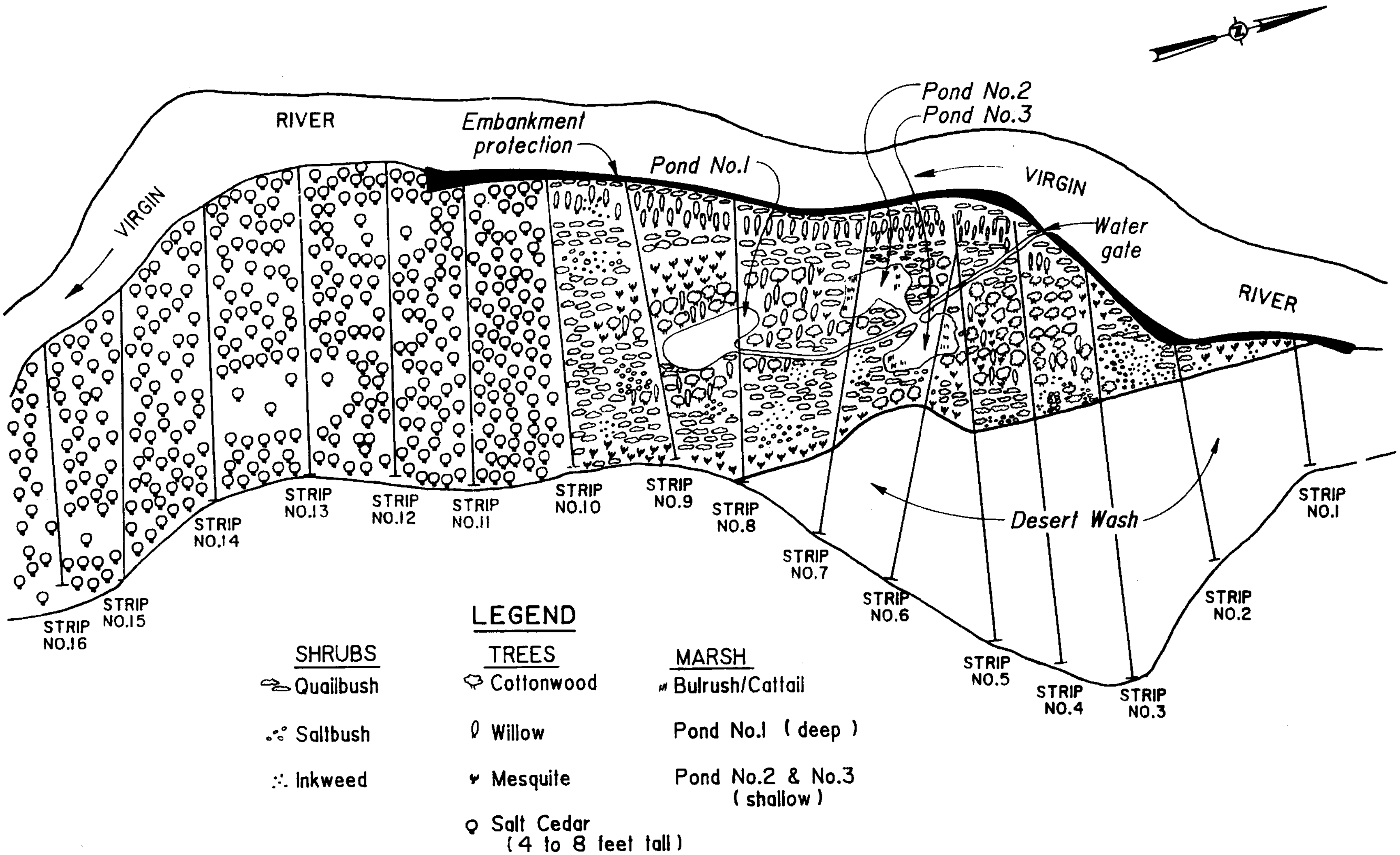


Figure 25. - Proposed revegetation scheme for maximum wildlife habitat value on strip numbers 1 through 10.

Screwbean Mesquite (*Prosopis pubescens*)
Quailbush (*Atriplex lentiformis*)
Four-winged Saltbush (*Atriplex canescens*)
Inkweed (*Sueada torreyana*)
Wolfberry (*Lycium sp*)
Alkali Bulrush (*Scirpus paludosus*)

Nurseries in Las Vegas, Phoenix, and southern Utah are areas most likely to carry the desired tree stock. Revegetation efforts with many of these species have shown that cuttings from wild stock started in a nursery have the highest survival and growth rates (Anderson and Ohmart, 1981 [33]). Trees planted as saplings are the logical choice. Dormant log cuttings using cottonwood and willows have been shown to be successful along the Gila River near Bylas, Arizona [80]. Beaver Dam Wash in Arizona, about 9 miles from Mesquite, Nevada, might provide a local source for both logs and saplings. If so, care should be taken only to remove trees from densely wooded areas or saplings from along the normal course of the river floodplain. Regardless of where trees are purchased, advanced planning must be considered to ensure that adequate tree stock will be available for the proper planting time (late fall, early winter). It should also be stressed that using stock from unknown origins or from areas outside the general study area to be revegetated will probably result in a low survival rate.

For shrubs, all species should be planted from seed stock because establishing shrubs from seed is cheaper, easier, and more successful. Only the largest nurseries that supply a wide variety of plant types can provide adequate seed quantities. Marsh plant seeds could also be purchased from recommended seed companies or from an agricultural seed supplier.

(d) *Planting and Irrigation Procedures*.–Numerous types of irrigation systems are available, varying in cost as much as they vary in design. In deciding on the most appropriate irrigation system for revegetation, the type of vegetation being planted must initially be considered, then select the method that will best meet the plant's water requirements. Low water waste and reasonable cost should also be researched. The following information for planting vegetation and selecting the appropriate irrigation system was considered:

- *Trees*.–Augering holes to plant trees has been shown to greatly increase growth and survival rates (Anderson and Ohmart, 1981 [33]). Augering serves to break up and mix the soil (tillage), permitting rapid root penetration into the water table. This process also serves to leach salts downward or laterally along the column. Holes should be augered at least to the water table.

  In this case, the cheapest and most efficient irrigation system for watering trees would be to use drip irrigation. Main irrigation lines should consist of buried PVC pipe, and lateral lines should be of black polyethylene tubing. Pressure-compensating emitters should be installed off the lateral lines and run to each augered hole. For more information on technique and costs, see [33].

  Once the irrigation system is installed and trees planted in the augered holes, seeds from the salt tolerant shrub species (especially quailbush) should be liberally spread between saplings. This will serve to keep out salt cedar encroachment and add diversity to the vegetative community.

  Every tree planted should be encircled with chicken wire at its base. This is a very justifiable cost as it serves as a preventative measure in keeping rodents, rabbits, and other wildlife from gnawing on the saplings. Saplings that become girdled will inevitably die. Each wire basket should be securely set around each sapling to ensure it stays in place.

- *Shrubs*.–The same irrigation measures previously discussed for quailbush apply here. Sprinkler irrigation is best for watering the abundantly spread seed, but there is doubt whether any irrigation would be necessary. Late fall and early winter rains, coupled with a very high water table, may result in a high germination rate without irrigation. However, installation of an irrigation system would guarantee a more successful germination.

  Planting methods are also the same as those discussed for quailbush. The salt tolerant shrub seeds should be applied liberally to all bare ground areas as best possible, while attempting to create monotypic species patches of considerable size. What appears to be overplanting seeds will provide better salt cedar competition and result in higher germination per unit area. If shrubs eventually get too dense and start crowding the trees, the shrubs can always be cut, and with much less effort than it takes to eradicate salt cedar.

- *Marsh Plants*.–Emergents, in this case alkali bulrush, require a very wet soil to grow. Therefore, ponds 2 and 3 (fig. 25) are made shallow to establish emergent vegetation along the edges. To create the ponds, a canal system with gates will have to be installed to regulate water depth. Planting is a relatively simple procedure. The seeds are first soaked for about 24 hours in a detergent to induce germination, rinsed, then distributed across the area to be planted.

A safety measure would be to plant quailbush along the wet banks, just beyond the bulrush. The quailbush can then take over what would otherwise be an ideal seedbed for salt cedar. If the ponds accidently dry and the bulrush dies, quailbush would have a better chance of reclaiming the lost ground.

(e) *Care and Monitoring*-Successful revegetation under this study requires careful attention. Identifying problems as soon as they occur and addressing them accordingly can be critical towards achieving success. Trees will suffer the most adverse affects if neglected, especially during summer months. Irrigation lines should be periodically checked for proper water pressure. Too many holes chewed into the polyethylene lines will result in low water pressure and a substantial reduction of water going to the saplings. Plugs for small holes and tubing slips for large holes can quickly and easily remedy any of these problems. Emitters should also be checked to ensure they lead to the base of each sapling and not to the path. The bowl or dish surrounding each plant should be adequately concave and built up around the perimeter to hold in water and permit sufficient penetration to the root zone. Small salt cedar seedlings may become established in the moist bowl surrounding the sapling, and these seedlings must be scooped out so that the water and nutrients will not be lost to the salt cedar. This can be accomplished by using a large spoon and removing the seedlings before their roots penetrate too deeply, making complete root removal extremely difficult. Ensure that each sapling is properly enclosed and protected with a wire basket. Strong winds can tilt over baskets that are not secured into the ground. Small rodents and rabbits are quick to discover the exposed sapling and take advantage. Insect infestion and disease should also be watched for and attended to as soon as possible to prevent tree stress and potential mortality. Trees should be watered to as near a daily basis as possible for an extended period. This will keep the ground moist in the root zone and prevent plant stress due to lack of water.

The above are all "little" problems that can greatly increase tree mortality in a relatively short time. Manpower devoted to curbing tree mortality because of these problems is a very necessary and justifiable expense. The rewards will more than exceed the expenditure in the long run.

Monitoring shrubs is much less involved. As with the trees, growth should be monitored, at least initially, to be sure germination is plentiful and establishment complete. Some areas may require reseeding or extra watering. Preventive measures must be taken early to increase competitive success against salt cedar. Once establishment is initiated and becomes extensive, relatively little care is needed to maintain the site.

A final recommendation is based on problems with range cattle during the baseline biological investigations when cattle were numerous and represented a considerable nuisance. Native revegetation attempts will undoubtedly run into problems with plants being trampled or browsed upon unless efforts are made to keep cattle out of the area. Erecting a sturdy barbed wire fence around the revegetation site would probably be the best solution to this problem. Removing the cattle is another possibility.

Impacts of Ground-Water Reduction on Revegetation

Introduction.-The State of Nevada and the Nevada Power Company are seeking to have the Bureau of Reclamation develop a firm water supply from the Virgin River Basin to supply industrial cooling water to the proposed Harry Allen Powerplant and other projects within Las Vegas Valley. Ground water flowing through the Virgin River alluvium is being considered for removal by a series of pumping wells, and would basically use the Virgin River aquifer as a storage reservoir. As a result, water-table levels are likely to be lowered considerably, especially when the river is dry. Periods of typically low river flow would be dry as surface flows drain underground to replenish the depleted ground-water storage. Therefore, any future revegetation efforts planned for the Virgin River study area should take the potential impacts of ground-water reduction into consideration before implementation. The following subsections discuss how this impact may influence the proposed revegetation plans and procedures previously discussed.

(a) *Revegetation for Water Salvage and Ground-water Impacts*.-Quailbush was the vegetation type selected for this study. As previously discussed, the experimental portion would consist almost exclusively of quailbush intermixed with scattered screwbean mesquite and willow trees that remain after clearing. The degree of impact will vary depending primarily on the vegetation type, magnitude of ground-water drawdown, speed of ground-water drawdown, and season of year.

Vegetation types that essentially derive their water from the ground-water table (saturated zone) would probably be most affected. Salt cedar and willow are two examples of plants that are able to withstand a high degree of water saturation in their root system. Conversely, quailbush and screwbean mesquite root systems appear to occupy the area above the ground-water table (unsaturated zone).

The amount of ground-water drawdown affects each species differently. A 2- to 3-foot drop would probably have no impact. Riparian vegetation has to cope with seasonal fluctuations of this magnitude due to changes in river flows. A 10- to 20-foot drawdown would likely have an impact. Species which rely heavily on ground water in particular would have to keep pace with the retreating water table or perish.

The speed of ground-water drawdown comes into play as a deciding factor influencing impacts on trees. Most species root systems can follow a slowly sinking water table to maintain a sufficient water supply, but a rapid 10- to 20-foot drop would probably have serious adverse affects.

Plant species occupying the saturated zone would probably die from the abrupt change. Rapid ground-water drawdown has been previously recommended as a possible method for killing salt cedar. The season in which the drawdown occurred would also influence the impact to a lesser degree.

The time of year would be a final factor. The hot summer season is the maximum growth period for all vegetation types, both above and below ground. Foliage growth and development is supplied with water and nutrients from the roots. The roots are supplied by the products of photosynthesis to promote growth of a more extensive root system able to meet greater foliage growth demands. Total tree growth above the ground is approximately equal to the root system below the ground.

Rapid ground-water drawdown during the summer period of high vegetative growth would almost certainly adversely affect the species relying heavily on ground water. A drop in ground water of considerable magnitude (10 to 20 ft) would interrupt the balance between photosynthesis above ground and water nutrient uptake below ground. Water nutrients leading to the foliage would decrease and the photosynthetic rate would be slower and less efficient with water requirements well below normal. This, in turn, would result in less energy return to promote root growth for reaching the much lower ground-water table. Plants would be stressed and probably would die.

The overall impact on the entire vegetative community, for a rapid ground-water table drawdown of 10 to 20 feet during the summer, would probably be detrimental to all species concerned. As a result, all plant species would be getting less water. Each species ability to adjust to this form of stress is not equal, and may even vary depending on physical characteristics. Native trees in particular are relatively slow growers and would have difficulty producing enough root growth to bridge the rather large water gap. Conversely, quailbush appears to be adapted for growing under a large variety of circumstances. Along the Lower Colorado River, quailbush was successfully revegetated over a ground-water table 12 feet deep. Along the Lower Virgin River, quailbush is growing over a water table as high as 2 feet deep. Because of its ability to grow in such a wide variety of soil types, salinities, and ground-water table depths, quailbush would probably survive a 10- to 20-foot drop in the water table. Plants would probably suffer some foliage die-back, but would more than likely survive once adjusted to the new condition. The total amount of water consumption would probably be somewhat reduced as a result.

The screwbeans and willows scattered through the quailbush stand would almost inevitably die. Willows can withstand and survive long periods of flooding, but a large, rapid drop in the water table would probably result in death. Screwbean mesquites are already stressed across the site, probably due to high salinities and possibly high ground water. Chances are the sudden change would stress, then kill the trees. Any net survival gains achieved by the trees through a lower water table would probably be lost by an increase in soil salinity.

In conclusion, the greatest mortality in the vegetative community would occur under the condition of a substantial and rapid drop in the ground-water table during the summer. A slow ground-water drop would result in many species' root growth keeping pace with the retreating water table. A rapid drop during the winter might result in the root systems eventually reaching their ground-water destination. Roots would need to supply nutrients to maintain woody parts without the taxing energy demands of the foliage; however, winter is the time when root growth for most plants is minimal.

(b) *Revegetation for Wildlife Habitat Value and Ground-Water Impacts.*–Various species of native plants important to wildlife were selected for this study. The resulting revegetation site would have high foliage density and diversity, which are vegetation characteristics that attract wildlife.

Ground-water drawdown impacts on the native plant species selected would be virtually the same as those previously discussed. Cottonwoods, willows, and mesquite species would all be adversely affected. Shrub species would probably react in a similar fashion as that discussed for quailbush. Plant reactions to this type of stress are difficult to predict due to little comparative data available. Plant reactions and impacts should be based on their individual phenology. Most desert plants are adapted to arid conditions, but it also appears that some can adapt to a wet environment, consumptively using more water if available.

While a 10- to 20-foot ground-water drawdown would certainly appear to influence vegetation negatively, some positive impacts could also occur. Maintaining a 10-to 20-foot-deep ground-water table would hypothetically result in nearly complete tree mortality for the riparian floodplain. Water consumptive salt cedar would no longer be transpiring excessive amounts of water or concentrating salts into the soil. Revegetation attempts would probably benefit from an increase in salt leaching potential. Augered holes to the water table would likely result in successful tree growth for more species. Shrub seeds would require irrigation but, like the trees, would successfully grow and consumptively use less water.

Therefore, drawing the water table down before revegetation is implemented appears to indicate that impacts would be beneficial. Conditions would be similar to areas where revegetation attempts have been successful. Lowering soil salinities would be the primary goal; however, it must be noted and emphasized that lowering the water table 10 to 20 feet and maintaining that level is very important if revegetation is considered. Fluctuations of ±3 to 5 feet could probably occur without adverse affects, but raising the water table any higher for an extended period of time would probably start drowning the root systems of most tree species. The unusually high river levels in the Lower Colorado River in 1983 is a good example of high tree mortality as a direct cause of flooding.

Future vegetation attempts for any portion of the Lower Virgin River should be thoroughly investigated before proceeding. If all factors are accurately assessed and addressed, successful revegetation implementation should be possible for most conditions. Indifferent attempts that only address some of the negative revegetation factors should be discouraged. For example, if all of the recommendations for planting quailbush are implemented except one (e.g., planting during proper season), then all other efforts and expenses are wasted. Chances for successful revegetation can only be achieved through careful planning and preparation that maximizes the replacement vegetations growth potential and minimizes competition.

Biological Studies and Procedures For Monitoring Site After Clearing

Introduction

After half of the Lower Virgin River site is cleared and the replacement vegetation planted, biological studies will resume to test conditions after clearing. The biological field techniques and format that follow are the recommended procedures for comparing wildlife habitat value before and after clearing. Sampling frequency, estimated manpower/equipment and potential problems will also be discussed to assess project costs and prevent study set-backs.

Biological Studies

Birds.–The sampling technique used for birds should be the modified Emlen censusing method that was previously discussed in the second section of this report. The transect format should reestablish the previously censused transect numbers 1 through 14 (fig. 2) used to obtain the baseline data as close as possible along the old bulldozed strips.

Mark each 500-foot segment with a clearly numbered, brightly colored 4-foot stake. These points should also be double-flagged (yellow) on both sides of the transect. Transects can be reestablished by placing a large, sturdy stake at the ends of each strip. Once clearing and planting is completed, a surveying instrument can be used to guide the individual as he repaces the 500-foot intervals. These cleared transects should also be renamed to avoid confusion and allow easy reference; e.g., VR No. 8 becomes CL (cleared) No. 8. Stakes should also be placed at the start or end of each transect. Some bird transects stop or start before the end of the strip. Care should be taken during clearing so that these stakes are not removed. Establishing stakes at either end may not be necessary if strip lines can be accurately reestablished by surveying from an original point. Interval stakes could be coated with varnish to preserve writing and prevent color-fading. Vegetative regrowth, range cattle, and rodents all cause problems in maintaining interval markers. These markers should be placed in a cleared area just within the vegetation edge in plain view, which will prevent damage to the stakes whenever strips are recut.

(a) *Censusing Period.*–To accurately assess the post-clearing conditions, three censuses per month along riparian salt cedar transects and two to three censuses per month along desert wash transects should be required for a minimum of 2 years.

The three censuses should be spread throughout the month (e.g., beginning, middle, end) as best possible. The direction should be switched with each reading to prevent time-of-day bias (i.e., VR No. 6,7, and 8 read first. then VR No. 8,7, and 6 read on next census). Transects should be censused starting 1/2 hour before sunrise (summer) or 1 hour after sunrise (winter). Starting and ending times will vary depending on seasonal temperatures and wind, and good judgement should be used to ensure census is valid. Morning censuses should be completed in about 3 hours and encompass three to four transects.

The study emphasis should be initially concentrated on the riparian salt cedar zone. If some transects can not be censused during a month due to inclimate weather, then the number of desert wash censuses should be reduced. Since the number of salt cedar transects will be reduced by half once cleared, these transects must be censused three times to maintain a large enough sample size.

(b) *Estimated Manpower*.-The estimated manpower requirements would be 15 separate early mornings per month at 3 hours per morning for a minimum of 45 man hours per month.

Rodents.-The sampling technique for rodents should be the census line configuration method for live trapping that was discussed in the second section of this report. The trapping format should reestablish the live-trapping configurations north and south of strip No. 10 (figs. 3 and 4) in the riparian salt cedar and cleared areas. Trap stations should be marked with a 2-foot, clearly numbered, brightly colored lathe or stake. Entrances to trap grids, paths between trap lines, and individual trap stations should be well marked with brightly colored flags. One collapsible Sherman live-trap with galvanized doors and treadle should be placed at each trap station number (fig. 4).

Since clearing will take place north or south of strip No. 10, trap grid reestablishment should be fairly easy by using the uncleared salt cedar grid as a basepoint. Once the clearing/planting is implemented, all trap lines in the uncleared salt cedar should be rechopped and remarked, using a compass or surveyor if necessary. To locate the former lines of the cleared trap grid, a surveying instrument should be placed at the edge of the uncleared grid's 01 basic line entrance on strip No. 10 and lined up. The instrument can then be "flipped" to maintain a straight line in the opposite direction that will be directly on line with the cleared grid. The first trap station for the cleared grid (0201) can then be located by measuring 102 feet (width of strip plus distance through salt cedar to first station) from instrument location. This technique can also be applied to establish the 0102 basic line. For assessment lines, the surveying instrument is placed at the station that bisects the basic line (0101,0110, 0201, 0210) and a 45° angle taken.

The color of the flagging used to mark the trap lines should be different from the color used to mark the bird transects (yellow) to avoid misinterpretation where rodent lines intersect the strip. Red (trap station) and orange (between traplines) show up well. Care should be taken to ensure the trap grid in the cleared area is reestablished as near to the original lines as possible. Individuals setting the trap station stakes should frequently check to be sure they are on line. The 50 feet between trap stations should be established using a tape measure. However, actual trap placement can be up to 5 feet on either side of the numbered stake if there is poor vegetative cover in the vicinity of the stake. Traps should be placed under vegetation if possible to increase trapping success and prevent rodents from overheating during the hot summer months. An effort should be made to place the trap at the same location for each trap session.

The Sherman live traps should preferably have galvanized steel doors and treadles. Aluminum traps can be gnawed by the rodents, particularly if they remain in the traps for extended periods. Completely galvanized Sherman live traps are much heavier and more cumbersome than the collapsibles, making trap placement along the trap lines even more difficult. These steel traps also have an upraised lip at the entrance that tends to scrape a person's hands when rodents are removed.

(a) *Trapping Period*.-Trap grids in cleared and uncleared areas should be trapped monthly, for a minimum of 2 years. The grids should be trapped as close to the time of the new moon (period of highest rodent activity) as possible. To even out the work load for processing rodents, one grid could be initiated on a Monday and the other on Tuesday. This would allow the grids to be set out Monday and Tuesday and picked up on Thursday and Friday. This is especially helpful when trapping the more labor intensive assessment lines. It should be noted that, during the hot summer months, rodents will not survive if the traps heat up. During the colder winter nights, rodents will become torpid and, in some cases, will die if temperatures become too low. Since this technique is based on recapturing population members, fatalities can be critical and would influence density estimates. Therefore, some important precautions must be followed:

- Keep traps under vegetation and in the shade.
- Start checking trap grids as early as possible in the morning, even before sunrise if necessary.
- Nightly winter temperatures below 20 °F may result in rodent mortality. During these cold nights, this can be prevented by checking the grid twice. The first processing should be conducted at least 2 hours after sunset when rodent activity is at its highest. Headlamps are recommended rather than hand-held flashlights. Traps should then be rebaited and set to be checked again after sunrise.
- Process rodents quickly but carefully to reduce the time rodents spend in the traps.
- Two experienced people could split up and each do a trap grid; however, this should be weighed against the added speed of having two people process the same grid.
- Traps should be baited as late in the day as possible to reduce the chances of traps being set off by range cattle or the bait being eaten by ants.

(b) *Estimated Manpower.*–The estimated manpower requirements would be 6 to 8 separate early mornings per month at 1 to 4 hours per morning, depending on basic or assessment lines processing, for a minimum of 35 to 40 man hours per month, (two persons processing trap grids). The individual running the trap grid is unavailable for bird censusing.

Vegetation.–The sampling technique for vegetation should be the MacArthur and MacArthur board method for foliage height diversity plus tree counts, as discussed in the second section of this report. The transect format would include taking measurements and counts along reestablished bird transects (fig. 2) by pacing the proper distances between intervals. Preferably, the same two people should conduct the vegetation assessment. Trial counts should be run to ensure sampling techniques are correct and vegetation estimates are in agreement. Points where vegetation measurements need to be taken should be paced rather than flagged because flagging, in this case, is too time consuming and usually only lasts for a short period.

Sampling "styles" should be standardized. When counting trees that are clumped together, individual trunks are difficult to discern and are counted as the height squared. For example, if trees are 8 feet tall, one tree would cover an area of 64 square feet (8 by 8 feet). If a 500-square foot area is covered by an 8-foot-high group of trees, the group would be counted as approximately 8 separate trees. Trees must be at least 5 feet tall to be counted as an individual. Shrubs must cover an area of 3 by 3 feet to be separate individuals. Clumps of shrubs are divided into the number of 3- by 3-foot areas that they encompass.

(a) *Censusing Period.*–The FHD (foliage height diversity) and tree counts should be conducted across the entire site along each strip. Measurements should be completed during the May through July time frame. Sampling in the uncleared salt cedar area and desert wash can be conducted once every 2 years due to little vegetative change. However, the cleared area should be sampled annually to document progress of revegetative growth. It should be noted that two to three strips can be sampled by two people per day for tree counts or foliage height diversity. Hot summer temperatures will lead to erroneous estimations if more than three strips are attempted in a day. This is especially true when dealing with diverse salt cedar intermingled with shrubs. A better choice, if necessary, would be to split up the sampling during the day.

(b) *Estimated Manpower.*–Based on 16 strips with an average length of 2,500 to 3,000 feet and with people completing 2 strips per day for about 3.5 hours per day, 56 man hours per year would be required.

Equipment

The equipment list that follows stems from the biological field work conducted out of a trailer along the Lower Virgin River. Any future wildlife studies being considered for the site would best be accomplished in the same manner that the baseline data was gathered to make comparisons before and after. Early morning hours, long field days, and a remote study area are the principal reasons for maintaining an onsite base station rather than driving to and from Mesquite, Nevada. For the baseline studies, project costs were found to be much less than commuting from town. In fact, the total savings achieved by working from the study site more than paid for the initial investment for the trailer. This also takes into account all extraneous costs such as moving the trailer to and from the site, maintenance, generator, fuel, etc. The equipment list would include:

Base Station Trailer
- large enough for two people
- twin propane tanks
- refrigerator
- air conditioner
- trailer water pump and storage tank

Generator
- gas or diesel (powerful enough to work air conditioner)

- fuel supply tank (extended periods of use)
- cans of oil (frequent oil change with gas generator)

Shed.-Preferably sealed for protection from wasps, scorpions, and black widows taking up residence. Should be large enough to house and protect a large amount of equipment and contain adequate shelf space. Some items to consider would include:

- generator
- fuel tank
- boxes of traps
- tools
- shovels
- stakes and flagging
- brush axes
- files
- assorted materials

ATC/Hauler Motorcycle

- workable under future field conditions
- flat-bed with edges

The time and energy expended just walking down the transects would be substantially reduced. Boxes of traps, stakes, brush axes, shovels, and plants could be brought to most places along the site without "burning out." Under revegetation conditions, frequent monitoring of the planted area would be necessary to check for any problems, especially if an irrigation system is installed.

4-Wheel Drive Truck

- enclosed
- heavy-duty tires
- should always have oiled truck jack, canteen/water jug, two thick planks, shovel, flashlight, extra can of oil, and odd tools.

Biological Equipment

Bird Censusing studies will require:

- binoculars
- waterproof notebooks (2)
- bird censusing forms (70 per month)
- black pen/thin, dark-lead mechanical pencil
- bulldog clamps (1 to 2 large clamps/notebook)
- numbered stakes (100)
- box of flagging (yellow)

Rodent Trapping studies will require:

- Sherman live-traps (115 per trap grid), aluminum with steel doors
- wooden boxes for transporting traps
- 100-gram (2) and 300-gram (2) pesolas
- small, pointed, heavy-duty scissors (3)
- 100-pound bag crimped oats per year
- waterproof storage can for oats
- numbered lathes or stakes (115 per grid)
- red and orange flagging
- measuring tape
- compass or surveying instrument
- headlamps (2)
- rodent processing board(s) or notebook
- rodent forms (30 per month for 2 grids)
- rodent species toe numbering cards (max. of 10 per grid)
- thin, dark-lead mechanical pencils
- bulldog clamps (2 medium, 4 small processing boards)

Vegetation Measurements will require:

- waterproof notebooks (2)
- tree count, foliage height diversity forms (20 each per year)
- FHD sticks or measuring rod (2)
- bulldog clamps (1 to 2 large clamps per notebook)

Other Necessary Miscellaneous Materials

Trailer items to be stored for use include:

- box of rags
- plastic trash bags
- box of matches
- broom
- waterproof notebooks (4)
- bulldog clamps (small, medium, large)
- pen/pencil holder
- box of black pens/thin, dark-lead mechanical pencils
- correcting fluid, erasers
- clear plastic bags (notebook size)
- portable water pump
- water jugs (for transporting water to trailer)

Field equipment items to be stored for use include:

- brush axes, replacement blades, and handles
- machetes
- files
- shovels
- assorted tools
- work gloves

REPORT SUMMARY

Salt cedar (*Tamarix chinensis*) has been identified as the most widespread phreatophyte in the Western States. Introduced in the early 1800's as a horticultural plant from Eurasia, salt cedar rapidly established itself along riparian floodplains. An estimated 5 million acre-feet of water was lost through consumptive use in the Western States during 1970. As a result, serious problems for effective water and habitat management programs exist today.

Salt cedar's competitive edge over the native riparian communities has aided its establishment and domination of disturbed areas. Increased salinities in riparian river channels have benefited the highly salt-tolerant salt cedar's competition and hurt the low salt-tolerant native trees. Extremely prolific seed production of considerable duration, effective seed dissemination, dense growth, and early maturity contribute further to salt cedar's success.

Numerous studies have documented salt cedar's detrimental impacts. Major problems identified include:

- flood stream impediment
- poor wildlife habitat value
- extremely high water consumption
- salinity concentration
- low economic value

Water consumption is regarded as the most pressing problem for the arid Southwest. Many studies have attempted to measure consumptive water use to ascertain if clearing salt cedar would prove feasible in attaining a net gain in the water supply. Two often used techniques for estimating consumptive water use values for riparian communities are evaluation of (1) hydrologic budget or (2) energy budget. Results vary in consumptive use estimates, from 1 to 12 acre-feet per year. A wide array of complex hydrological and ecological variables associated with riparian study areas has been the major cause for disagreement in consumptive use estimates.

All hydrological and environmental variables associated with a study area should be clearly and completely defined, and the procedures must be standardized to determine the applicability between similar studies. Important factors that will potentially influence consumptive water use and that should be accurately assessed include:

- vegetative cover
- water table
- water quality
- soil composition
- elevation climate

An environmental assessment was conducted from June 1982 to December 1983 on a 600-acre study plot along the Lower Virgin River to evaluate the riparian salt cedar habitat value for wildlife. Small mammal trap grids, bird, and vegetation transects were established in the salt cedar community and intensively sampled.

A total of 169 bird species were recorded during the study period. Song Sparrow, Bewick's Wren, and Abert's Towhee were the three most consistently occurring, highest bird density species in salt cedar. Permanent resident birds represented the highest density seasonal category for all months. Typical riparian bird species yielded higher densities than typical wetland bird species for all months in 1982 but, in 1983, the trend was reversed. An extremely wet study site in 1983, which resulted in a three-fold increase in marsh vegetation and area covered by water, was believed to the major cause for the increase in bird densities. The salt cedar habitat for the birds appeared to be greatly enhanced just by the presence of water.

Seven small rodent species were caught on the trap grids. *Mus musculus* and *Reithrodontomys megalotis* were by far the highest density rodent species with *Peromyscus eremicus* and *P. maniculatus* constituting a lower density secondary role. All regularly occurring rodent species were closely associated with the denser salt cedar growth. *R. megalotis* was also commonly found in open salt cedar stands with a moderate salt grass understory. Sexual activity was apparent during all months for nearly all species. Rodents were believed to exhibit arboreal habits in salt cedar to escape excessively high flood flows. Salt cedar's dense foliage and multistemed structure provided ample cover and protection from predators. Virtually no other live-trapping studies of small rodent communities in salt cedar exist.

Vegetation measurements taken along the Lower Virgin River represent an accurate assessment of foliage volume/structure and plant species distribution. Vegetation characteristics of the predominantly salt cedar study area are best described as having little foliage volume above 10 feet, rather sparse with trees and having moderately dense foliage volume, particularly at the 6-inch to 2-foot level. Salt cedar's structural differences are probably attributable to water, soil, and salinity factors as indicated in the literature. Other vegetative species subcomponents, which made up a very small proportion of the total vegetative community, were heavily used by wildlife.

General observations of reptiles and larger mammals indicated larger numbers and more species inhabiting the adjacent desert wash community. *Bufo microscaphus* hybridization with *B. woodhousei* was found to favor *B. woodhousei* characteristics, which is similar to conclusions reached over 25 years ago in the same vicinity.

Planting revegetation sites with certain native species, and agricultural lands with hardy crop types, has shown promise as an effective measure for controlling salt cedar. Native vegetation and crop types were evaluated after initial appraisal of site potential and limitations along the Lower Virgin River. Half of the 600-acre study area is being considered for clearing to determine if the replacement vegetation will use less water than the highly water consumptive salt cedar vegetation.

Criteria for species selection would be for water salvage efficiency and socio-economic benefits through wildlife enhancement and/or agricultural production. Selected species must also be compatible with physical/environmental properties of the site and a strong competitor with salt cedar.

Quailbush (*Atriplex lentiformis*) was selected as the vegetation choice for revegetation purposes:

- low water consumption (about 2.4 to 40 feet per year, use decreases with maturity)
- high salt tolerance (successful revegetation accomplished on soils ranging from 200 to 60,000+ p/m)
- soil compatibility (grows on soils ranging from sand to clay)
- successful competitor against salt cedar

Appraisal of the Virgin River study area features indicated that the "north end" (strips 1-10) would be better suited for revegetation due to a lower ground-water table, lower salinities, less river inundation, and more higher drier areas.

Quailbush is a winter germinating shrub. Planting should be implemented in late fall to ensure adequate shrub growth for competition against salt cedar. Planting before winter dormancy of salt cedar will result in rapid seedling reestablishment of salt cedar.

Clearing the revegetation site should be conducted with bulldozers to appropriately cut down vegetation. Larger native trees beneficial to wildlife on the site, such as screwbean mesquites and willows, should be selectively left uncleared. Cleared salt cedar should be pushed into piles and burned. Root plowing, or grubbing, will serve to penetrate deep into the soil and sever the salt cedar root crowns well below the surface. An elongated drum with numerous peg-like projections is mounted on a tractor and pulled across the site to create small holes that will entrap seeds and precipitation.

Quailbush seeds should be selected from the general vicinity of the Virgin River Valley or from areas where conditions are similar. Disease and difference in salinity tolerances may influence germination response. Most *Atriplex* species have been found to produce seeds genetically programmed to germinate after a minimum of 10 months. Older seeds will usually have a greater germination potential. Cold stratification of quailbush seed appears to be necessary to induce germination.

Atriplex seeds can be purchased from seed companies or gathered by hand. Timing is critical for seed collection and to ensure that adequate seed stock will be available in advance of planting. Quailbush seed is relatively inexpensive and has a high germination potential. Fertilizer for growing quailbush is expensive and probably unnecessary. A sprinkler irrigation system should be used to water the seeds and to guarantee an appropriate germination response. The resulting revegetation site will be relatively salt cedar free, more beneficial to wildlife, use less water, and require little maintenance.

Revegetation for maximum wildlife value is best achieved by selecting a variety of native plants important to wildlife, then planting to create a vegetative community with high foliage density and diversity. Establishing ponds would further enhance wildlife and vegetation diversity. Clearing methodology should be selective, preserving as many of the native tree species already established as possible. Physical features of water-table depth, soil composition, and water/soil salinity are important factors that will govern the planting scheme of vegetation distribution across the study area.

Trees should be planted only in low salinity areas. Sandy soil allows for better water drainage and salt leaching. Holes must be augered to the water table to permit easier root penetration to ground water and a greater salt leaching potential. A drip irrigation system using PVC main lines and polyethylene lateral lines installed with pressure controlling emitters would be the most appropriate method of irrigation. All uncleared trees and saplings should be circled with wire mesh to prevent damage from rodents and rabbits. Desert shrub seeds, particularly quailbush, should be planted around saplings to prevent salt cedar encroachment. Carefully monitoring the saplings is a very justifiable expenditure that is important for achieving a high survival rate.

Desert shrub seeds should be liberally spread to increase germination rates, and should definitely be used in areas containing saline soils. The planting scheme to strive for is one that will create a high density and wide variety of shrubs. A sprinkler irrigation system would be the most suitable for watering shrubs, and would require short term watering and monitoring.

Emergents can be easily established at the shallow edges of the ponds. Water gates, along with a canal system, must be constructed to maintain pond levels for marsh vegetation.

Ground water from the Lower Virgin River aquifer is being considered for removal by a series of pumping wells to be used as industrial cooling water for the proposed Harry Allen Powerplant. If implemented, ground-water levels could potentially be lowered considerably, which would affect any revegetation work in that area. Assuming a substantial drawdown of 10 to 20 feet, the degree of impact on existing vegetation or considered revegetation will vary depending primarily on four factors: (1) vegetation types, (2) magnitude of ground-water drawdown, (3) speed of ground-water drawdown, and (4) season of year. The impacts would probably be greatest on plant species that rely heavily on ground water; e.g., salt cedar. Native tree species (e.g., cottonwood) would also be seriously affected because of slower growth and low salt tolerance. Desert shrub species, in particular quailbush, would probably be least affected.

Biological studies that serve to monitor the experimental (revegetated) and control (salt cedar) areas of the Virgin River site after clearing should be conducted in a similar manner to baseline data collection. Proper bird, mammal, and vegetation transect establishment is initially critical for conducting future comparative work. Likewise, all relevant equipment should be prepared in advance and be readily available before conducting any field study.

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