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***FOUR DECADES OF RESEARCH ON THE  
LOWER  
COLORADO RIVER***

**By:**

**Bertin W. Anderson**

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# Table of Contents

<b>ABSTRACT .....</b>	<b>1</b>
<b>INTRODUCTION .....</b>	<b>5</b>
<b>CLASSIFYING AND MAPPING VEGETATION.....</b>	<b>6</b>
<i>Phenology.....</i>	<i>12</i>
<b>BIRD POPULATION STUDIES.....</b>	<b>15</b>
<i>Bird Densities.....</i>	<i>17</i>
<i>Bird Species Richness.....</i>	<i>26</i>
<b>MAMMALS .....</b>	<b>53</b>
<b>INSECTS .....</b>	<b>65</b>
<b>AVIAN DIETS .....</b>	<b>77</b>
<i>Size of Dietary Items .....</i>	<i>84</i>
<i>Cicadas, Fire, and Insectivorous Birds.....</i>	<i>85</i>
<b>AUTECOLOGICAL STUDIES OF PLANTS .....</b>	<b>87</b>
<b>ARE SCREWBEAN DISAPPEARING? .....</b>	<b>95</b>
<i>Effect of Screwbean Demise on Some Bird Species .....</i>	<i>102</i>
<b>NESTING PLATFORMS AND WOLFBERRY .....</b>	<b>111</b>
<b>MANAGEMENT PHILOSOPHY.....</b>	<b>119</b>
<b>THINKING ABOUT THE FUTURE.....</b>	<b>123</b>
<i>Salinity .....</i>	<i>123</i>
<i>Lateral Roots.....</i>	<i>125</i>
<i>Fire.....</i>	<i>128</i>
<b>BIRDS WITH POPULATION INCREASES.....</b>	<b>131</b>
<b>ACKNOWLEDGEMENTS .....</b>	<b>134</b>
<b>BIBLIOGRAPHY .....</b>	<b>137</b>
<b>INDEX .....</b>	<b>145</b>



## Abstract

When we began biological studies on the lower Colorado River one of the first tasks was to classify the vegetation. This resulted in recognition of 7 variations by dominant vegetation and 6 by variation in vertical configuration of the foliage. This led to recognition of 25 vegetation types. The distribution of these vegetation types was then mapped. We also recognized 6 variations in marsh vegetation. Vegetation work continued with a detailed study of the phenology of the major dominant tree species.

The next task was to begin determining the densities and diversities of wildlife, namely birds and nocturnal rodents, associated with each of these vegetation types. We conducted 19,258 bird censuses over the period from 1973-1984. Most of the vegetation types were censused year around for 5 years and many for 6-10 years. Cottonwood/willow vegetation types 1-4 showed above average densities 85% of the time; CW5-6, 10%; honey mesquite 3-6, 5%; saltcedar 1-4, 7%; SC5-6, 0; screwbean mesquite 2-6, 8%, and arrowweed 6, 0%. Below average densities did not occur in cottonwood willow; in honey mesquite, 30% of the time; saltcedar1-4, 30%; saltcedar 5-6, 80%; screwbean2-6 32%; arrowweed 100%. Species richness showed much the same pattern.

We also conducted detailed studies on the Yuma clapper rail, white-cheeked geese, Gambel's quail, coyote, phainopepla, Abert's towhee, sage sparrow, and ruby-crowned kinglet. Cottonwood/willow bird communities, including the yellow-billed cuckoo and summer tanager, received special attention. The ecology of the duck community was also studied in detail. Duck numbers have increased substantially since Grinnell recorded their numbers in 1910. While Grinnell found 8 species we regularly detected 18 species. We conducted detailed studies of white-cheeked geese, mainly at the Cibola National Wildlife Refuge for 6 years. Our studies of this group led to the discovery of many new subspecies in the Rocky Mountain area and 4 of these dominate the wintering population in the LCR valley.

Various methodologies involving rodent trapping and bird censusing were studied in detail. In addition we also studied statistical aspects including methods for analyzing data with principal components analysis, and the use of discriminant function analysis in uncovering bird-vegetation relationships and the identification and evolution of white-cheeked geese. We also developed a method for calculating foliage diversity in the horizontal and vertical planes simultaneously. The formula is as follows:

$$HDI = s^2 = \frac{\sum_{i=1}^n k_i^2 - (\sum k_i)^2}{n-1}$$

where HDI = horizontal diversity index;  $k_i$  = foliage density,  $n$  = sample size. We conjectured that birds may respond to various characteristics of the vegetation in a nonlinear fashion and developed statistical procedures for uncovering this potential.

Habitat relationships of the Yuma clapper rail were studied and the ecological physiology of the Gambel's quail reproductive cycle. Several aspects of community ecology were studied in detail, namely competition theory, social regulation, species turnover, habitat overlap between species, and statistical investigations of diversity.

Rodents were considered to be an important component that could be fairly easily investigated. We employed both snap-trapping and life trapping in determining rodent associations with the various vegetation types. Over the 6 year rodent trapping effort we had more than 330,000 trap nights in riparian vegetation. Almost all habitat types had 6-8 rodent species. Rodent densities reached highest levels in the denser saltcedar habitats, although they also sometimes reached relatively high numbers in cottonwood/willow habitats. In 1910 when Grinnell and his party floated the LCR from Needles to Yuma they found the desert pocket mouse (*Perognathus penicillatus*) to be the most common rodent. We found that by far the most common rodent 3 decades ago to be the cactus mouse (*Peromyscus eremicus*). We attributed their increase in numbers to the cessation of flooding. Anthony Andersen disagrees with this on the basis of a two-season study in about 5 ha that he conducted. We studied thousands of ha in all seasons

for multiple years and found that on a small scale any number of explanations might be brought in to play, but we concluded that on the large scale the absence of flooding is the only one that works consistently.

Most of the bird species of the LCR are insectivorous. With this in mind and in order to learn something about the food base available for this divergent group we investigated insect numbers associated with the various vegetation types. For this study, which spanned about 3 years, we collected just short of a million individual insects. These were all identified to family, weighed and measured. Insect densities peaked in May and the peak occurred in saltcedar and cottonwood/willow. Insect diversity was greatest in cottonwood/willow habitats. We discovered that insect numbers peaked in May. This was an important discovery with respect to studies of social regulation in birds. It was the study of insect numbers and diversity that led to learning that insects in the family Psyllidae reach peak numbers in May in honey mesquite habitats. This ultimately proved to be useful in revegetation projects because species of this family of sap-sucking insects attack honey mesquite and the attacks are often lethal. The lesson learned was that one should not plant honey mesquite until psyllid numbers drop. The most abundant insects were in the family Cicadellidae (leaf hoppers) and they reached peak densities in saltcedar, with cottonwood/willow a far second. We found that the number of species and individuals that consume cicadas increase in density after fire.

With acquisition of data concerning insect numbers in the various habitats we also began collecting information about what birds eat by collecting specimens and identifying stomach contents. This effort extending over a 3 year period that led to the collection of about 4,000 birds. These studies were conducted on a seasonal basis. We found that most species of insectivores and seedeaters have a significant degree of non-overlap. Where there is extensive overlap in diet the species usually are separable by habitat, foraging methodology or both. These observations mesh well with competition theory as an explanation, but there are myriad other explanations which probably also come into play such as predator-prey relations, symbiosis, social regulation, sexual selection. The overall result is that the system cannot be understood in terms of any individual species or even a small group of species.

These animal studies occurred over a period of about 11 years. At that point we turned to questions associated with revegetation. From the onset it was clear that information about the flora and fauna would be the basis for revegetation studies. Our first effort at doing revegetation was mostly involved library work. At the conclusion of that endeavor we realized that very little was known about what makes the native plant species grow. We spent the next 25 years investigating the autecological factors surrounding growth and survival of riparian plant species native to the LCR.

We found that cottonwood and willow are relatively salt sensitive species that grow best under conditions where depth to the water table or permanently wet soil is less than 2 m. Honey mesquite and screwbean tolerate moderately saline conditions. Species such as quail bush (*Atriplex lentiformis*) are somewhat more salt tolerant. Even more salt tolerant are inkweed (*Suaeda torreyana*) and pickleweed (*Allenrolfia occidentalis*).

Soil density is also important with cottonwood, willow and screwbean normally doing best in sandy soils. Honey mesquite is tolerant of denser soils. Inkweed is tolerant of soil with significant amounts of clay. Saltcedar tolerates a range of soil types and salinity levels. We found that it does not aggressively displace native species such as mesquite, cottonwood and willow and is found most extensively in those portions of the habitat that are now unsuitable or marginal for native species. It is the damming of the river that has converted the LCR into a habitat less suitable for native species and more suitable for saltcedar. The dams have led to drying of the soil, increased salinity levels and increased depth to the water table.

In the LCR we have, indeed, a sick, perhaps terminally ill, subject. Revegetation is one means of temporary life support. Since salinity levels have increased and the Colorado River water has salt, life support systems should have a shunt or method of filtering some of these toxins. We learned early on that deep tillage falls into the category of an ancillary procedure promoting longevity of the life support system. Another is leaching. Tillage is the base upon which leaching depends and the whole life support operation is dependant upon the proper combination for long term survival. Roots and salts follow water to the water table. Without deep tillage, when water encounters soil layers it moves laterally thus hindering leaching and contributing to build up of soil salts. We demonstrated this with controlled experimental projects involving thousands of cottonwood, willow, screwbean, and honey mesquite. Life support systems can function for a while with doing nothing more than merely irrigating. Of course tillage and leaching should occur before

planting, but if one forgets to do that it must also be born in mind that to successfully leach an area an amount of water in excess of consumptive use by the trees must be applied.

Life support systems on the LCR are in jeopardy because of the potential for the lack of adequate water to irrigate in perpetuity. Let us hope that those in charge of the life support systems are carefully considering the future of the system's own life expectancy. We have an ever increasing demand for Colorado River water in metropolitan areas and we are faced with global warming both of which are likely to result in less water for the Colorado River. Increasing population with greater demands for energy in the face of declining fossil fuels and a less than inspiring economic situation are also factors that should be considered in planning the life support systems. Planting should include a large proportion of plant species more drought tolerant than cottonwood and willow. This list would include wolfberry (*Lycium* sp) palo verde (*Cercidium* sp) and Jerusalem thorn (*Parkinsonia aculeata*) and patch size should be on a scale much smaller than hectares. Diversity on a scale of, say, 0.25 ha where drought tolerant species are interspersed with cottonwood/willow would still leave a viable habitat just in case irrigating could not take place in perpetuity, yet heterogeneity at that level will still be attractive to species such as the yellow-billed cuckoo (*Coccyzus americana*).

In 2004 our attention was drawn by CDFG to areas where screwbean were dying. We investigated and found that, indeed, screwbean that we planted were dying. So were indigenous screwbean in the immediate vicinity. Since the areas were seemingly well suited for growth of screwbean we found this decrease in health enigmatic. At the time we were initiating another plot that involved planting 4,000 screwbean so we were concerned, but trees adjacent to the new site seemed to be thriving. In 2005 we noticed a reduction in health of some of these indigenous trees, but planted trees seemed to fine. By the end of summer 2005 we noticed that the screwbean in the vicinity of our planting site were degrading rapidly. This degradation persisted into 2006 when it became so severe that I did a survey of screwbean from Bullhead City to Yuma. Trees that had produced 18,000 grams of pods in 2005 were largely dead by season's end in 2006. This situation has only gotten worse; so much worse that I now consider indigenous SB-2, -3, and -4 to be extinct in the LCR. A stretch of the imagination might lead to a conclusion that some SB5 and -6 still exist on a scale of 20 ha, but this may be unwarranted optimism.

The potential effect of the demise of screwbean on birds has now been partially documented. Ash-throated flycatcher, Verdin, black-tailed gnatcatcher, and Lucy's warbler populations in an area that included SB2 and -4 habitats have decreased by 80% since 2005. Frugivorous bird populations have been entirely eliminated in these areas. Saltcedar and arrowweed are expanding into the opening created by the death of screwbean. This raises questions concerning our philosophy of management.

Current management philosophy prescribes that we manage for species that are currently endangered or which have already been eliminated. Let's apply this philosophy to the situation as it existed in 1910 when Grinnell and his party studied the LCR. At that time the 8 most common species in riparian habitats included yellow warbler, Bell's vireo, vermilion flycatcher, black-tailed gnatcatcher, song sparrow, Abert's towhee, and ash-throated flycatcher. Applying our current philosophy we would conclude that none of these species were in need of any management. Now, however, the first 6 of these have undergone population reductions and 3 or 4 of them are included in the management plans. One of them, the yellow warbler is probably extinct as a breeding bird in the LCR, but we still make management efforts designed for its benefit. But what about the Verdin, black-tailed gnatcatcher, and Lucy's warbler which are now undergoing population reductions—at least in screwbean habitats. Should we wait until they are gone or nearly gone before we take any action? That would, in fact, be business as usual. The LCRMSCP projects illuminate the entrenchment of the current wrong-headed philosophy. These projects do virtually nothing for these and other species such as cavity nesters. In some areas such as at the Cibola NWR management plans are more encompassing.

After studying the autecological factors affecting growth of native plant species for 25 years I began in about 2005 to again make bird surveys. I have been giving serious thought to comparisons of the recent data with wildlife data collected in the period 1973-1984. Much of this thought will be laid bare in a book that I am currently writing.

From casual observation I believe that deep tillage has not been provided on many, or even any, of the current major revegetation efforts. This means that it will be difficult, at best, for any leaching to take place. Salts will build up will slowly but inexorably.

Another consequence of failing to provide deep tillage is that trees will develop lateral roots. This is of little consequence if irrigation can be provided in perpetuity. But if, for any of the reasons explicated above, irrigation cannot be provided there may be a mortality rate of 60% or so in the first 5-8 years after irrigation stops. If irrigation stops and many of the trees die this doesn't necessarily equate with a disaster for wildlife if there is a plethora of patches planted with more drought tolerant species. That trees on one project did not get deep tillage is readily apparent from the number of trees that the wind has blown over thus exposing their lateral roots. If water cannot be supplied at least to the extent of consumptive use many of these trees will die.

A final point to consider is the possibility of fire. It was mentioned to me that the threat of fire is reduced because of the ability to flood the area. A moment's reflection reveals that this ability provides approximately zero protection from fire. In the first place water delivery often has to be scheduled. Once scheduled it would take hours for the water to reach the site and become fully distributed over it. If the fire began at night or on a weekend or holiday it might not be noticed until much damage is done. Finally, even if the area is flooded in time there is much fuel for a fire in the upper story. I grew up not far from bog country in Minnesota. Bogs, of course, have plenty of water, but that didn't stop fires from racing through the upper canopy.

## INTRODUCTION

The prairies and the riparian vegetation along the meandering streams of western Minnesota and South Dakota were the setting in which I grew up. When I was awarded a research assistantship at the University of Minnesota my work in riparian vegetation began by collecting birds in riparian habitats for the research collection at the James Ford Bell Museum of Natural History. I have conducted research in riparian vegetation every year since then. In this report I will begin with my exit from the prairie scene to take up residence in the desert setting of the arid southwest.

I came to the Southwest in 1973 to conduct and direct research in riparian vegetation along the lower Colorado River (that portion from Davis Dam to the International Boundary with Mexico). This work was initially funded by the U. S. Bureau Reclamation. The Bureau is often accused of making poor decisions, but from my point of view, the decision to fund our work certainly did not fall into that category. It was the beginning of a dream come true with respect to my desire to be a field biologist.

The objectives of this report are threefold: (1) to provide a broad summary of research that we conducted on the lower Colorado River from 1973-present, (2) discuss current approaches to management, and (3) make a brief consideration of the future.

In this summary I deviate from tradition in that all literature cited in the text occurs in the terminal *Bibliography* rather than in a *Literature Cited* section. However, not all of the papers in the bibliography occur in the text.

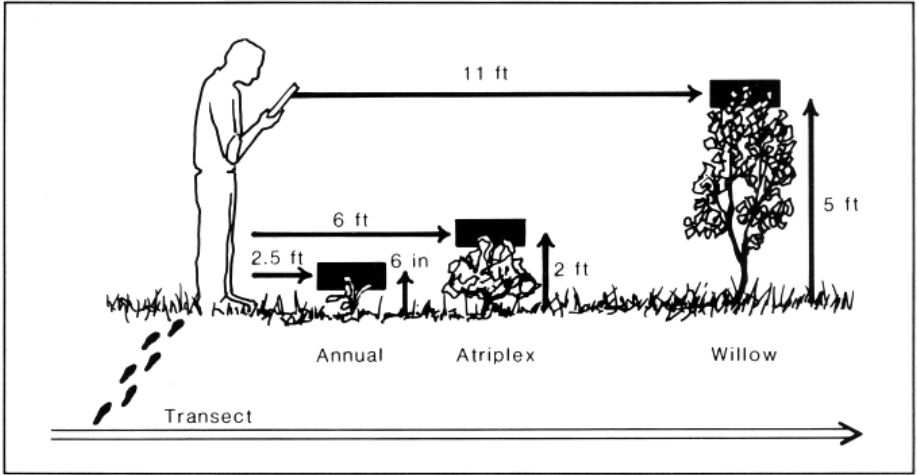


## CLASSIFYING AND MAPPING VEGETATION

When I arrived little work had been done on the lower Colorado River. The most extensive was that done by Joseph Grinnell (1914). He and his crew floated the river beginning in mid-February at Needles and ending in mid-May 1910 at Yuma. They took notes on the vegetation associations and photographed several of them. They collected 1,374 bird specimens of 132 species and 1,272 mammals of 37 species.

Our first job was to classify the vegetation. This was accomplished by obtaining estimates of the foliage volume at various heights (Fig. 1) and from this calculating the diversity of the foliage in the vertical dimension. This was done in stands no smaller than about 15 ha. Since we also wanted to survey the various vegetation stands for birds we made an effort to determine the smallest stand that, by itself, would yield reliable bird density estimates. This search led to selection of stands no smaller than 15-20 ha (Engel-Wilson et al. 1981.) These data were divided into 6 different structural types on the basis of cluster analysis of the foliage at the various levels (Fig. 2). The interpretation of the dendrogram could have resulted in fewer or more structural types. Decisions were made on the basis of frequency and biological importance of potential structural types (Anderson and Ohmart 1985, 1986, Anderson, Russell, and Ohmart 2004, Ohmart, Anderson, and Hunter 1985, Rosenberg, et al 1991, Anderson In prep.,). The difference in the distribution of the foliage in these structural types is shown in a statistical sense in Fig. 3 and in a cartoon depiction in Fig. 4.

Figure 1. An index to foliage volume was obtained using the MacArthur (MacArthur & MacArthur) board technique at various levels within a stand.



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Figure 2. Using the foliage volume at various heights as determined in dozens of stands of vegetation a dendrogram was created with a cluster analysis. The stems of the dendrogram were the basis for defining structural types.

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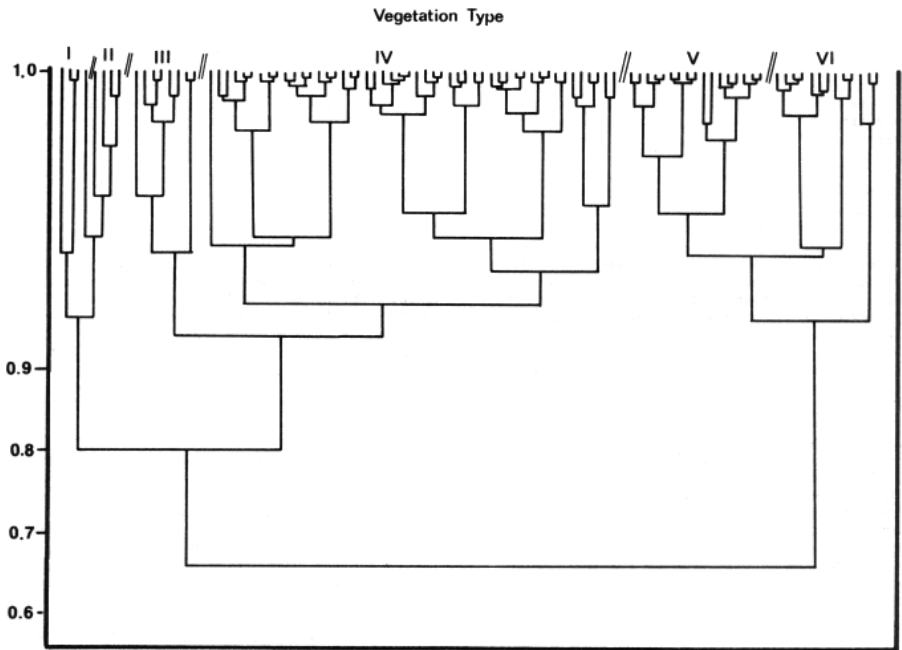


Figure 3 Statistical differences among the structural types. The horizontal bar represents the mean; vertical open rectangles, plus and minus 1 standard deviation, and the black rectangles, 2 standard errors of the mean; A, foliage at 0-0.06 m; B, 0.64-4.5 m; C, > 4.5 m.

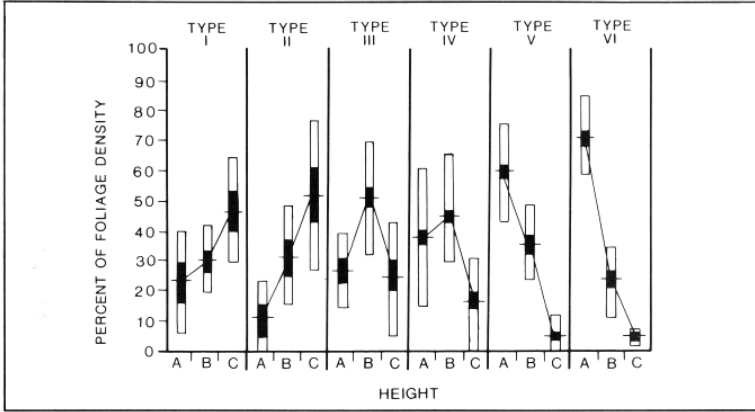
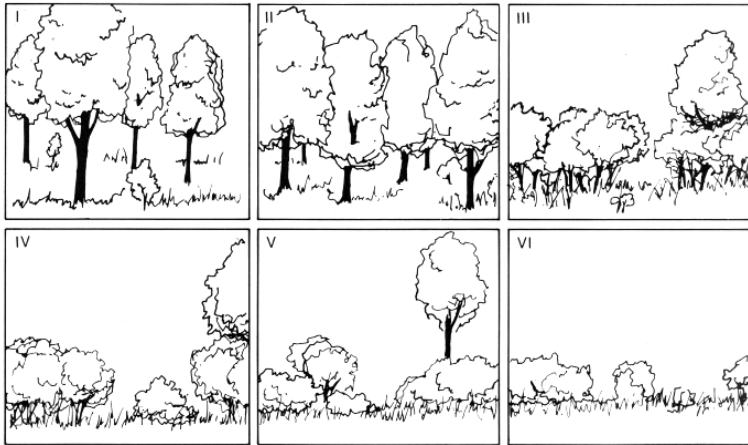


Figure 4. A cartoon depiction of the vertical distribution of the foliage in various vegetation structural types.



The vegetation was further divided on the basis of the dominant vegetation within each stand. We found relatively pure stands of arrowweed (*Pluchea sericea*), saltcedar (*Tamarix ramosissima* or *T. aphylla*), and honey mesquite (*Prosopis glandulosa*). There were also large tracts where the dominants were mixed, including cottonwood/willow (*Populus fremontii*/*Salix gooddingii*), saltcedar/screwbean mesquite (*Prosopis pubescens*), and saltcedar/honey mesquite. Desert washes included a variety of dominant trees including ironwood (*Olneya tesota*) and palo verde (e.g. *Cercidium floridum* and *C. microphyllum*). This totals 7 types of stands determined by dominant vegetation. Since there are 6 structural types each hypothetically including the 6 variants with respect to vertical distribution of the foliage, the potential is for 42 vegetation types differing by dominant species present, vertical configuration of the foliage or both. In reality there were 6 structural types of cottonwood/willow, 6 types of saltcedar (including *T. aphylla*), 5 types of screwbean mesquite, 4 types of honey mesquite, 1 type of saltcedar/honey mesquite, 1 type of arrowweed, and 2 types of desert wash, bringing the total to 25 vegetation types other than marshes which were classified differently (see below). There were stands of some vegetation types such as *Atriplex* but these were always smaller than 20 ha. We concluded that we could determine the value of *Atriplex* and some other taxa to wildlife when they were mixed with the other dominant tree species mentioned above. In all stands we made tree and shrub counts annually.

The next step was to map the distribution of the various vegetation types (Fig. 5). We did this in 1976 and 1983 (Anderson and Ohmart 1976, 1984d). The mapping was repeated by Younker and Andersen 1986. Our earlier efforts and those of Younker and Andersen (1986) and were evaluated by Ohmart, Anderson and Hunter (1988). The inclusive analysis suggested that over the decade in which analyses were done saltcedar and arrowweed increased in abundance, while most of the other vegetation types decreased in abundance.

Marshes were also classified but according to a different system (Anderson et al 1984). That classification system resulted in recognition of 8 Marsh types. The types were:



## Phenology

Interest in the perpetuation and management of Southwestern riparian habitats led to studies determining which vegetation components are most important in supporting highest numbers of species and densities of wildlife. As shown below trees species composition and density, foliage volume, and vegetation structure have been correlated with avian densities and numbers of species. Differential seasonal use of plant communities was documented for birds and some mammalian species. These consumers are dependent directly or indirectly upon the primary production of the plant species in the various habitats. It was believed that the phenological events of these riparian plants exerted an important annual influence on vertebrate populations relative to movement and timing of reproduction. To examine this influence data concerning five species of dominant phreatophytic trees on the lower Colorado River were gathered from 1975 through 1978 on transects from Davis Dam south to the Mexican Boundary. Cottonwood, willow, honey mesquite, screwbean mesquite and saltcedar trees were sampled at monthly intervals. Fifty-seven individuals of each of these species were marked to provide phenological data on a monthly basis. Twenty new branches, spikes, pods, and leaves were measured on each tree monthly during 1975 and 1976. A wire hoop of 0.1 m was placed at the outer perimeter of the canopy of the tree and the number of leaves, spikes, and pods occupying an imaginary cylinder from that point to a depth of 0.3 m were counted. This was repeated 15 times and from this the mean number per  $9.5 \text{ m}^3$  was extrapolated to a cubic meter. Trees on transects were evaluated August through December 1976-1978 for volume, coverage, and pod productions.

The cottonwood growth cycle started in February, with shoot growth and new leaves appearing on all trees checked in both years. Cottonwood had the shortest flowering period of the 5 trees species studied, with flowers appearing in March and disappearing by mid-April. Stem growth continued through September, and terminal growth of marked branches averaged 25 cm/season. Leaf length averaged 6.5

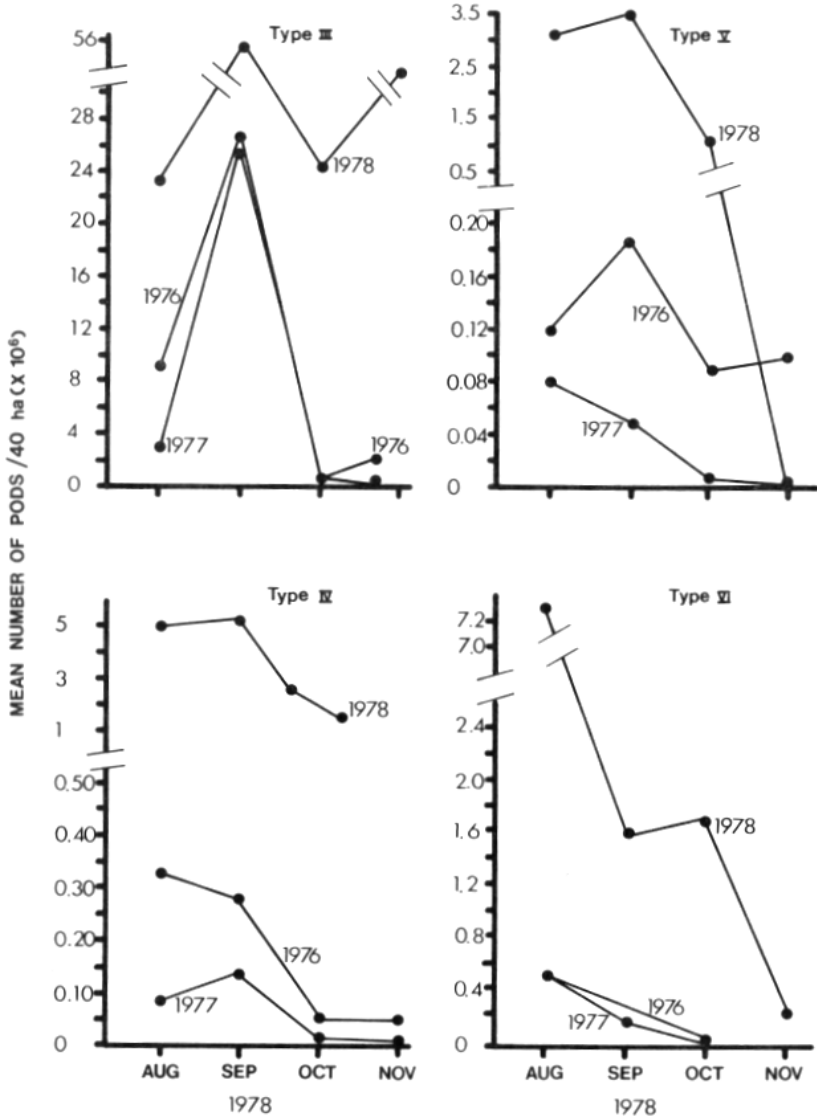
cm and leaf density started changing in September, and all trees were dropping leaves in December. Trees remained dormant only throughout much of December and January.

Willows also started their growth cycle in February, with new leaves, stem growth, and flowers appearing by the end of the month. Flowering continued through July, with fruits first appearing in May and persisting until late August.

As an example of phenological work I present pod production data for honey mesquite (Fig. 6). The mean number of honey mesquite pods was  $4.5 \times 10^6$  pods/40 ha. The maximum number was  $54.9 \times 10^6$  pods/40 ha (Fig. 5). The maximum number of pods was found in 1978. Also pod production in 1976 was greater than in 1997. The greatest number of pods was produced in HM3, but among HM4-5 there was little difference. This sort of information was obtained for all species.



Figure 6. Comparison of mean number of honey mesquite pods/40 ha by structural type and year.



## **BIRD POPULATION STUDIES**

The next objective was to determine the number of birds, mammals, and insects associated with the various vegetation types. To meet this objective we established 117 transects through relatively homogeneous stands of upland vegetation and 38 along the edge of marshes in addition to several transects in desert washes and in citrus orchards. We also conducted about 1,400 censuses in agricultural cropland, but this aspect will not be discussed in the volume.

The transects were censused with a modified version of the Emlen line transect technique (Emlen 1971, Anderson and Ohmart 1977). We tested the precision of the technique against spot map results, but the latter technique relies on territoriality as an indication of species presence, thus is good only in the breeding season for most species. At this time of year results from the 2 techniques corresponded fairly well. We also compared the results obtained with a circular plot or point count methodology and we found that these also produced comparable results (Anderson and Ohmart 1981). We believed that the circular plot/point count methodology censused only about half of the same area in the same amount of time as the transect method. Some workers use the circular shaped plots or point counts in order to get increased sample sizes. Results from a number of such studies were included in a symposium edited by Ralph, Sauer, and Droege (1995). In a review of that volume I discussed the methodologies in addition to problems associated with scale in the papers in this volume and it seems that the enormous variation associated with the technique is its most serious shortcoming (Anderson 1997). Problems associated with scale are discussed by Wiens (1989).

Between 1974 and 1984 we conducted 19,258 censuses in various vegetation types, not including censuses in agricultural habitats (Table 1). Not all vegetation types were censused equally over

the census period. In several instances transects were lost because of clearing or fire. In some years censusing had to be curtailed because of the lack of adequate funding.

Five vegetation types (cw4, sc3, -4, sb4, sh4) were censused 8-10 years; 12 were censused for 5-6 years. This means that 10 vegetation types were censused for fewer than 5 years. Notably this included desert washes, which were censused for only 1 year. Similarly marshes were censused for 3 years and orchards for about 3.5 years (Fig. 7).

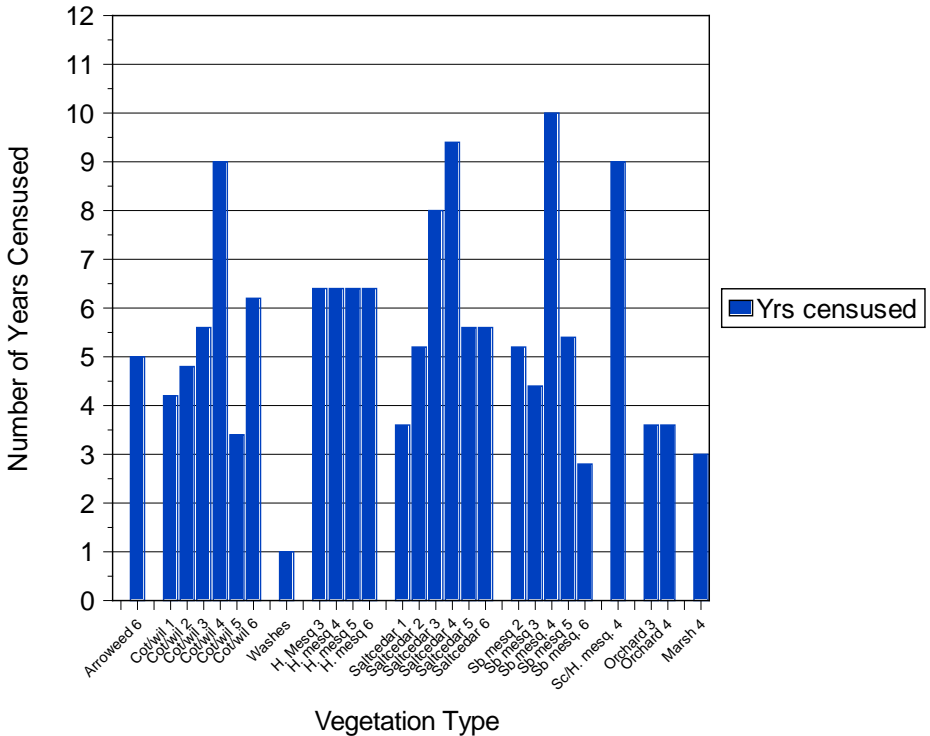
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Table 1. Number of bird censuses in various habitats from 1974-1984

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	Censuses
<b>Cottonwood/Willow</b>	<b>4693 (24.4%)</b>
<b>Arrowweed</b>	<b>366 (1.9%)</b>
<b>Desert Wash</b>	<b>384 (2.0%)</b>
<b>Honey Mesquite</b>	<b>4382 (22.8%)</b>
<b>Marshes</b>	<b>878 (4.6%)</b>
<b>Orchards</b>	<b>1080 (5.6%)</b>
<b>Saltcedar (incl <i>T. aphylla</i>)</b>	<b>4373(22.7%)</b>
<b>Saltcedar/Honey mesquite</b>	<b>564 (2.9%)</b>
<b>Screwbean Mesquite/Saltcedar</b>	<b><u>2538(13.3%)</u></b>
<b>Total</b>	<b>19258 (100%)</b>

Figure 7. Number of years of censusing done in various vegetation types.



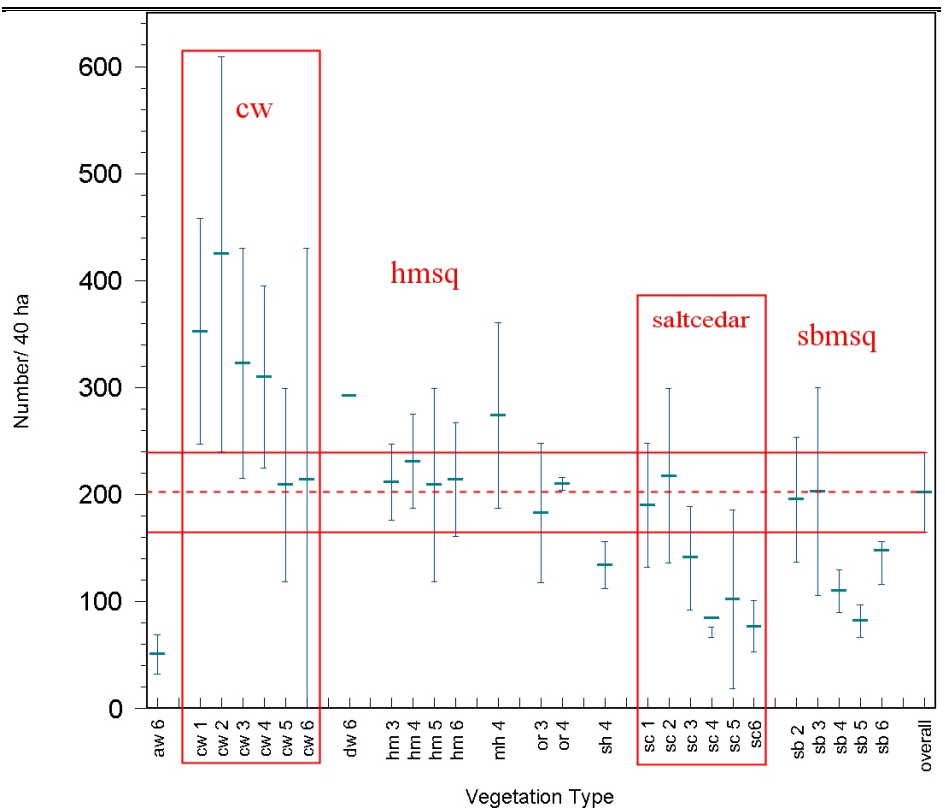
**Bird Densities**

Densities for birds were collected and are available by vegetation types on a monthly or seasonal basis during the period 1974-1984. In Figs. 8-12 densities are shown for 27 upland vegetation types on a seasonal basis.

In spring average bird densities were highest in cottonwood/willow habitats of structural types 1-4. However using a two-way test only CW 1 had significantly larger densities (Fig. 8). Honey mesquite densities were slightly above average, but not

significantly so. Saltcedar vegetation types were significantly below average for types -4 and -6. Type 1 had an above average number of birds, but this was within the range of expected values for the overall average. Screwbean types -4, -5, and -6 were significantly below the overall average. The averages for the other 3 structural types hovered around the overall mean. The greatest density was in CW 2 at 425 birds/40 ha. Winter visitors such as yellow-rumped warbler, ruby-crowned kinglet, and white-crowned sparrow were typically still present in relatively large numbers in spring.

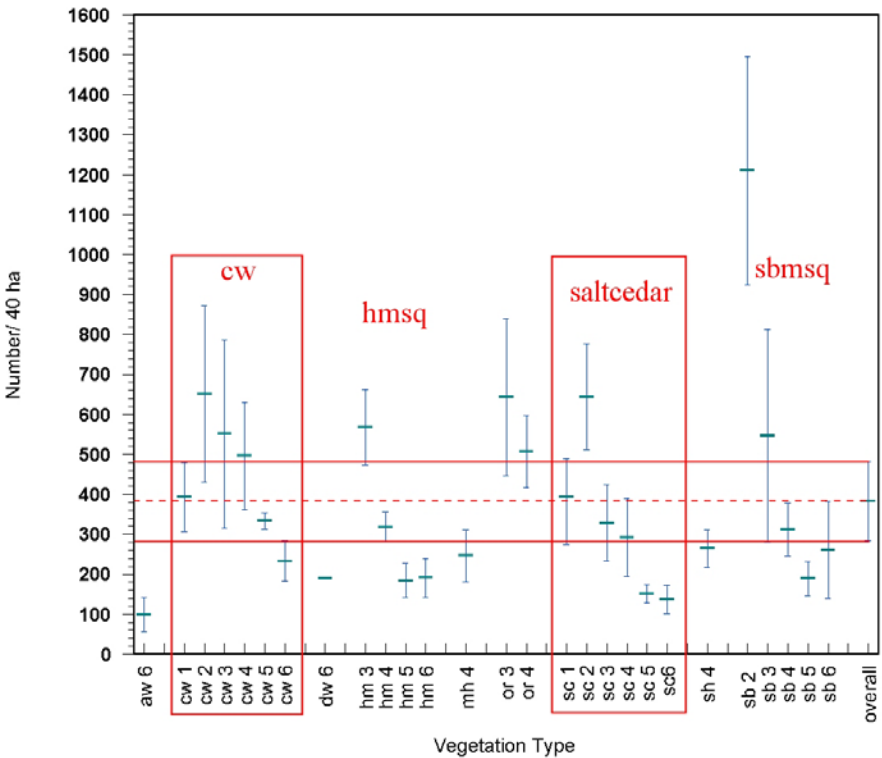
Figure 8. Bird densities in spring by vegetation type. cw=cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc=saltcedar. Numbers refer to structural types (the vertical distribution of foliage). Sc 1 refers to *Tamarix aphylla*. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors.



Overall densities increased from about 200 birds/40 ha in spring to twice that (Fig. 9) in summer, mainly due to the influx of white-winged and mourning doves. While densities in CW tended to be higher than the overall average they were significantly larger only in CW 2. Densities in HM 5 and 6 were below average, but greater than average in the denser HM3. SC2 had densities significantly greater than average largely due to the large numbers of nesting doves. SC 5 and SC 6 had densities significantly smaller than the overall mean. The greatest densities of all were found in SB 2—a habitat type now extinct, as are most, perhaps, all other screwbean habitat types, on the LCR. In some years densities in SB 2 attained 1,500 per 40 ha. SB-4, -5 and -6 all had densities below the overall mean. Arrowweed had the lowest densities in summer as it did in all seasons. Orchard densities were above average in most years, this, as in several other habitats, was due to the relatively high densities of doves. Marshes in summer had below average densities.

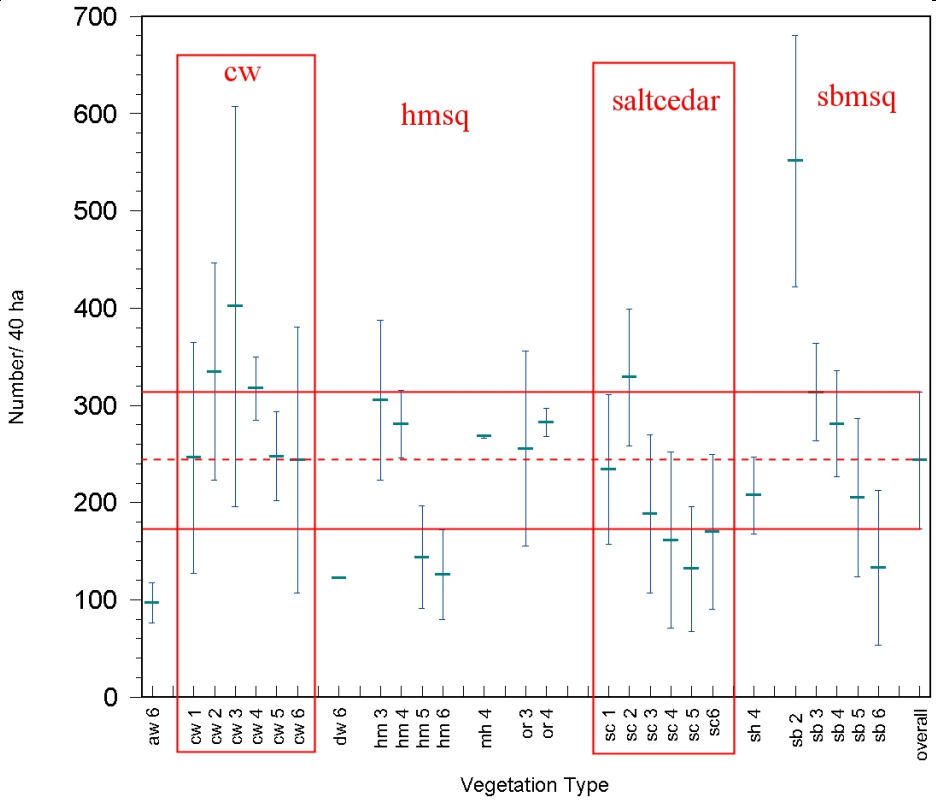
Typically species such as ladder-backed woodpecker (*Picoides scalaris*), gila woodpecker (*Melanerpes uropygialis*), yellow-billed cuckoo (*Coccyzus americana*), Bullock's oriole (*Icterus bullockii*), yellow-breasted chat (*Icteria virens*), Abert's towhee (*Pipilo aberti*), and summer tanager (*Piranga rubra*) reached peak densities in fairly dense, mature cottonwood/willow habitats. Summer tanager reached relatively high numbers in SC1. Peak densities of Lucy's warbler were reached in honey mesquite and saltcedar habitats. Blue grosbeak (*Guiraca caerulea*) densities peaked in cottonwood/willow habitats and saltcedar habitats were in second place for this species. Ash-throated flycatcher reached peak densities in honey mesquite and brown-crested flycatchers in cottonwood/willow.

Figure 9. Mean bird densities (horizontal bar) with 2 standard errors in summer. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq to honey and screwbean mesquite, respectively; Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.



In late summer (August-September) densities in CW tended to be greater than the overall average, and this was significant for CW-3 and -5 (Fig. 10). The overall average dropped to about 240 birds per 40 ha largely because after the September opening of the dove season dove numbers drop dramatically. HM 3 and HM 4 had averages slightly

Figure 10. Bird densities in late summer (August-September). Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.





above the overall average, but HM5 and HM6 had average densities significantly below average. These sparse, quite open habitats are apparently not attractive to birds in the extreme heat of August and September. Densities in SB2 remained relatively high in late summer—averaging about 550 per 40 ha. SB6 had significantly below average densities. Orchards and marshes were about average. SC2 had densities significantly above average. All other SC habitats were somewhat below the overall average.

In fall overall densities dropped from about 250 in late summer to 220 per 40 ha in fall (Fig. 11). This is due to the exodus of white-winged and mourning doves. Fall densities in CW habitats tended to be greater than the overall mean, but this was significant only in CW-4 and -6. The increase in bird numbers in sparse habitats was also seen in HM and SB. It is due primarily to the influx of sparrows in fall. Seed eaters find more seeds in the open habitats than in the dense vegetation dominated by trees. If by chance it had rained the preceding winter or spring there can be a large seed crop produced by various grasses and other annuals that become abundant in these open habitats.

Marshes in fall had the greatest average density at about 450 birds per 40 ha (Fig. 11). SC -5 and -6 averaged significantly below the overall average.

Figure 11 . Bird densities in fall. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.

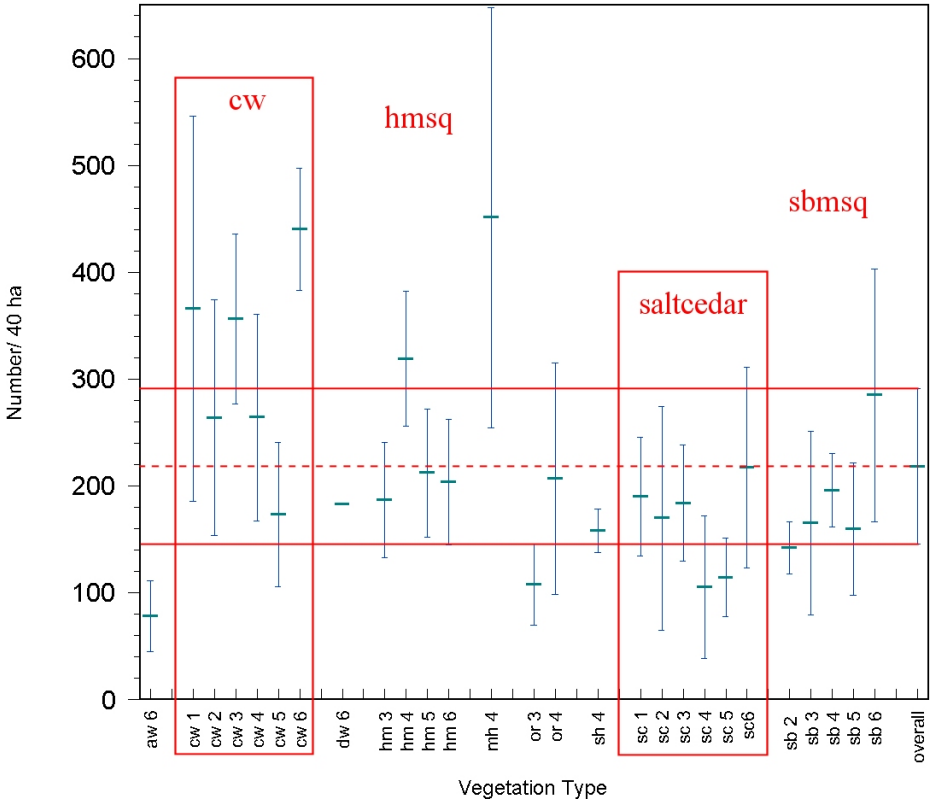
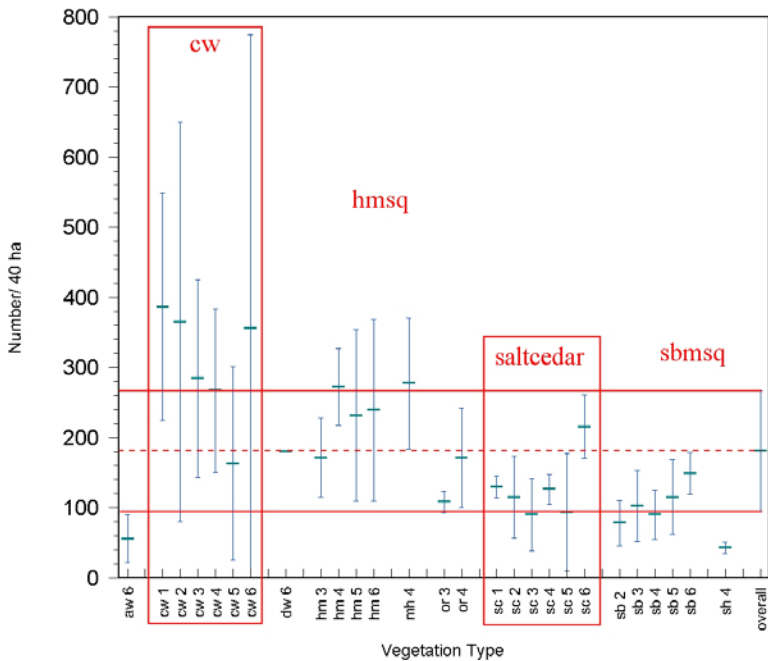


Figure 12. Bird densities in winter. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.



In winter overall densities dropped to about 180 birds per 40 ha. Averages in CW were generally above the overall average (Fig. 12), but this was significant only for CW1. Densities in HM also tended to be larger than average and this was significantly true for HM 4. Above average densities in HM are in large part due to the fact that these habitats tend to frequently have mistletoe (*Phoradendron californica*), wolfberry (*Lycium*), and inkweed (*Sueada torreyana*). The berries of mistletoe are consumed by several species (e.g. gila woodpecker,

phainopepla, quail, cedar waxing, robin, mockingbird, western bluebird, house finch). Most of these species also eat the berries of wolfberry. In addition, wolfberry produces flowers in the spring that attract hummingbirds, insects and insectivorous bird species. Marshes had average densities above the overall average. This usually included marsh wren, and several species of sparrows.

The total number of birds present in a habitat provides an indication of the value of those habitats to birds. Not including a species by species account obscures much valuable information, but it would take a book length account to adequately cover this aspect and that was our intent with *Birds of the lower Colorado River* (Rosenberg et al 1992). I attempt no reiteration of that information here.

To summarize, the account of densities did reveal that arrowweed had significantly below average densities in all seasons when averaged over 5 years of censusing. Cottonwood/willow habitats on the other hand showed significantly greater than average densities 6 times while only once were these vegetation types significantly below the overall average (CW6), Honey mesquite was significantly above average 3 times, mostly in fall and winter when frugivores such as phainopepla are present or in summer when doves are present. Saltcedar 2 showed above average densities twice, both in summer and both involving high densities of doves. Saltcedar 1-4 were average or above across 18 of 20 seasonal comparisons. Saltcedar 5-6 combined were significantly below average 7 out of 10 seasons. Orchards and marshes were in the range of the overall average most of the time. Screwbean 2 and -3 had, collectively, above average 3 out of 10 times, but were significantly below average a similar number of times. Screwbean 4-6 were, collectively, significantly below the overall average 8 of 15 times. SH 4 was within the range of the variation of the overall average in 3 of 5 seasons and was significantly lower than the average twice.

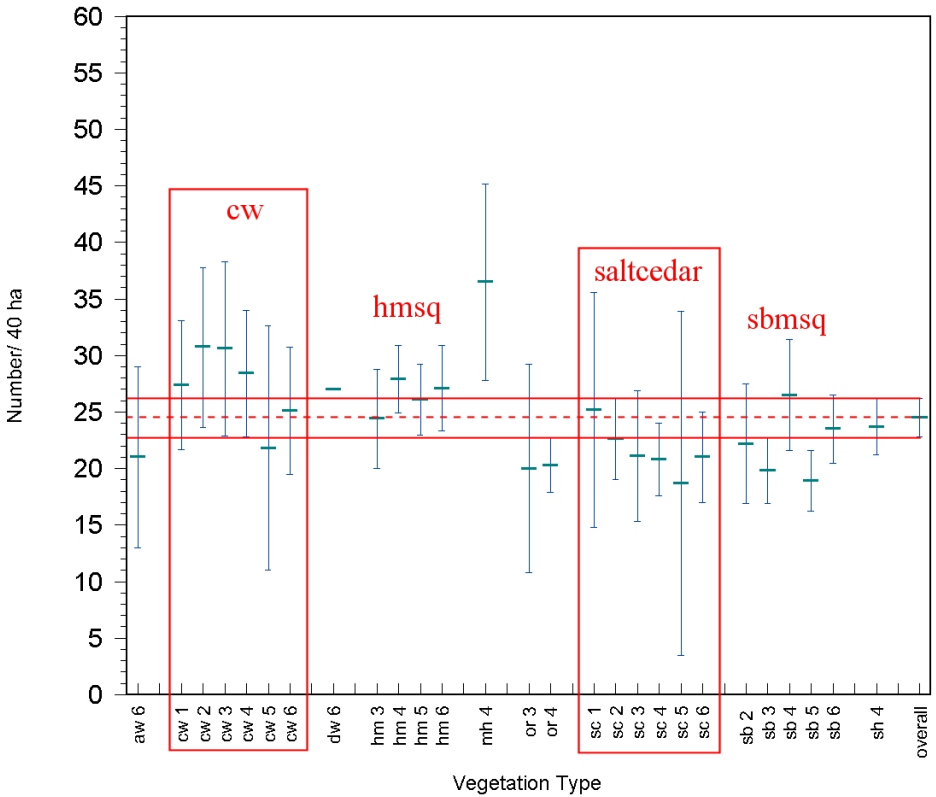
### **Bird Species Richness**

High densities were often due to the presence of doves in spring, summer, and late summer. In winter high densities were due to the presence of frugivorous birds in honey mesquite and seedeaters, including quail, in the sparser habitats. Densities of seedeaters varies with the production of seeds by annual plants.

Another evaluation of the various habitat types involves species richness as reflected in the number of species present. In spring Arrowweed was below the overall mean, but was within the range of 2 standard errors of the overall average number of species. (Fig. 13). Cottonwood/willow 1-4 were above average, but none of these values were outside of 2 standard errors of the overall average. Species richness in honey mesquite was average across all structural types. Marsh 4 had a significantly greater species richness with about 36 species. Orchards 3 and 4 were below the overall average and this was significant for OR4 and marginal for OR3. Saltcedar structural types were mostly on the low side of average species richness, and this was significant for sc4. Screwbean -2, -4, and -6 had average richness values, but SB-3 and -5 had significantly below average richness with about 19 species. The overall average was about 24 species.

Several granivorous and frugivorous species present in winter are still present in spring. For this reason spring has the greatest number of species. A grand total of 130 species were recorded in riparian habitats in spring, but many of these were present in very small numbers. Only 38 species occurred at densities of one bird or more per 40 ha across all cottonwood/willow, arrowweed, marsh, and honey mesquite habitats. In those habitat types where saltcedar was co-dominant (saltcedar, saltcedar/honey mesquite, saltcedar screwbean) had 17 species with densities of 1 or more.

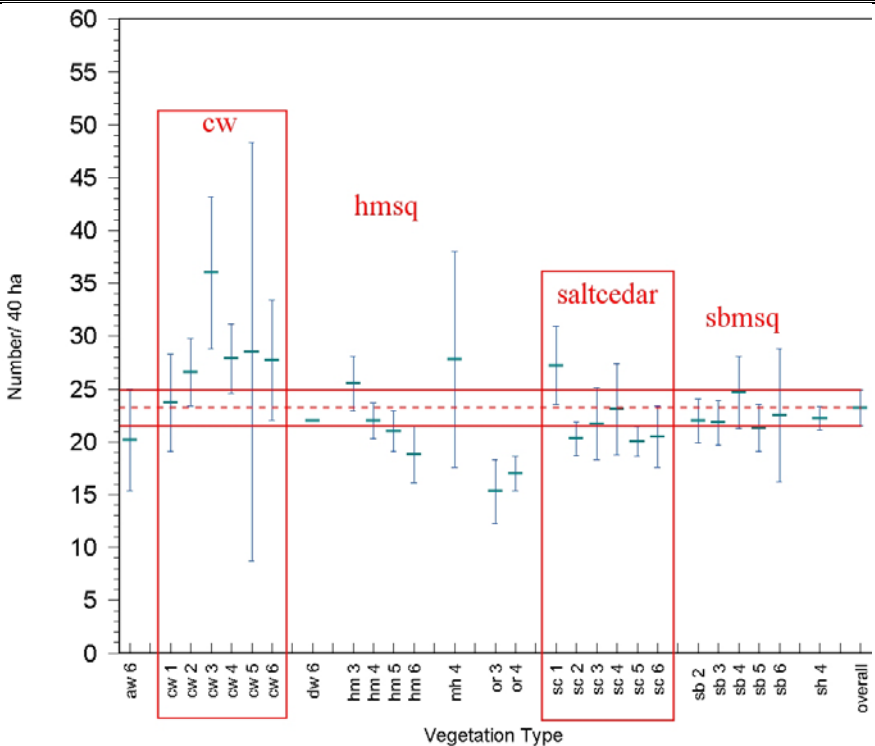
Figure 13. Species counts for spring. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.



In summer arrowweed was again below average with just over 20 species on average. Species richness was significantly greater than average in CW2-4 (Fig. 14). The greatest number of species (35) occurred in CW3. HM3 and -4 had average, species richness values but HM5 and -6 were significantly below average each with about 19 species. Orchards included species richness values (15 and 17 species) well below the overall mean of about 23 species. Marshes averaged

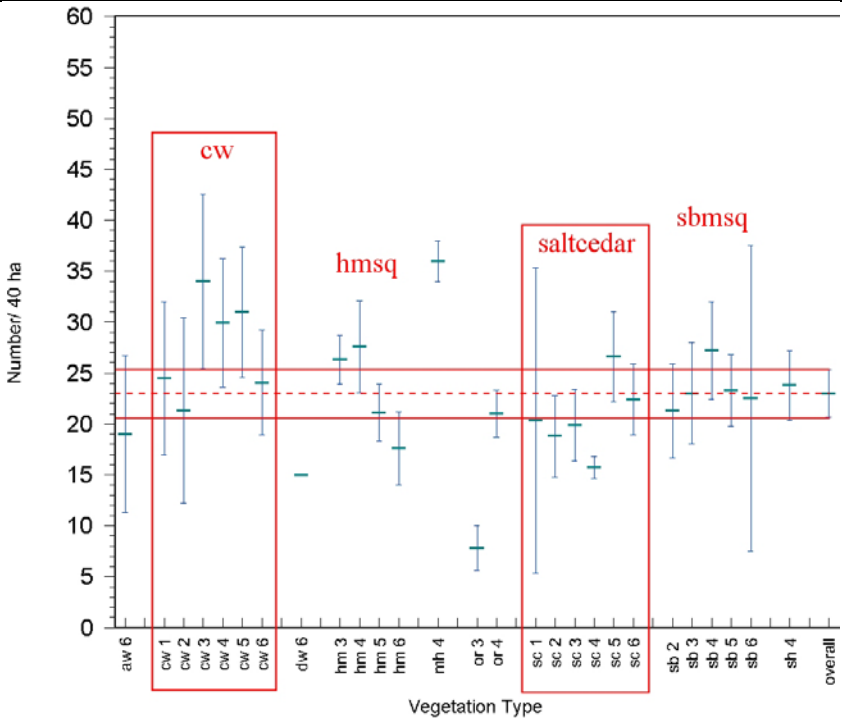
above the overall mean, but the variation from year to year was considerable and therefore the deviation from the overall mean was not significant. SC1, with 27 species, was significantly above the overall mean. Other SC structural types were on the low side of the overall average (Fig. 14). This was also true for SB and SH structural types.

Figure 14. Species counts for summer. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.



In late summer (Fig. 15) species richness in arrowweed was below the overall average. CW-3, -4, and -5 had above average number of species with 34, 30, and 31 species, respectively. Desert washes were relatively species poor with 15 species in the single year that censusing was done. Marsh 4, with 36 species, was significantly above the overall average. Species numbers in HM3 (26) and HM4 (29) were significantly greater than the overall mean (23). HM6, averaged 18 species across the 6 years that censuses were made in late summer. Screwbean and saltcedar structural types were about equal to the overall mean.

Figure 15. Species counts for late summer. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.

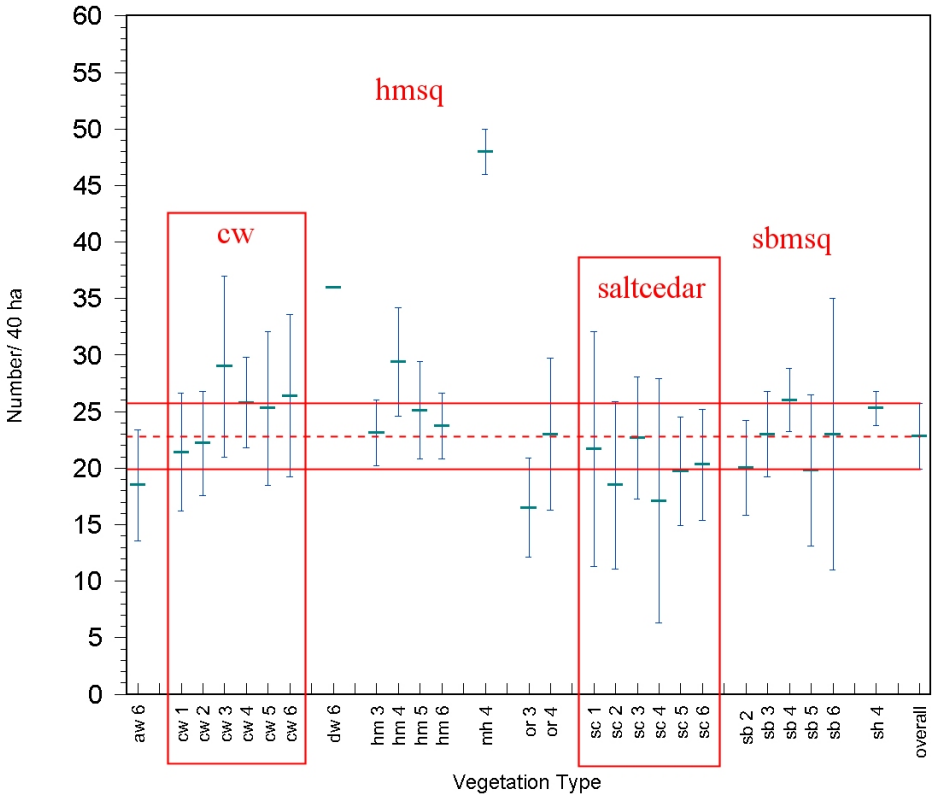




In fall arrowweed was below average with only 19 species (Fig. 16). Species richness in cottonwood/willow habitats hovered mostly slightly above the overall average. Surprisingly desert washes were well above the average with 36 species detected in the single year that washes were censused. The mouth of washes, although somewhat sparse, often have a diversity of trees and shrubs that are attractive to a variety of birds. Marsh 4 showed an even more spectacular 48 species and this was a fairly constant number across the 4 years that this marsh type was censused. Orchard 3 was below average while OR 4 was about average with respect to species number. Species richness in saltcedar hovered on the low side of the overall average of 23 species. Saltcedar/honey mesquite 4 was slightly above average, consistently hovering between 24 or 25 species across the 9 years that this vegetation types was censused.

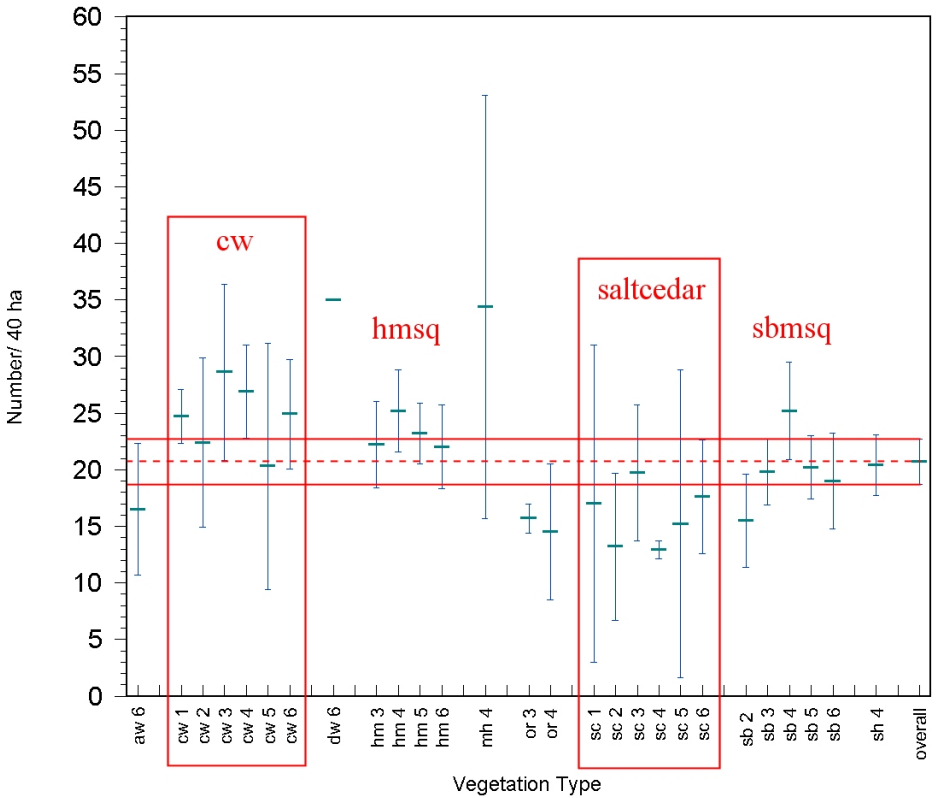
Fall is somewhat like the mirror image of spring—summer residents often linger into fall when winter immigrants are beginning to arrive. Across cottonwood/willow, honey mesquite, arrowweed, and marsh habitats a total of 115 species were detected in fall—15 species fewer than in spring. A total of 36 species occurred in densities of 1 or more per 40 ha. This is only 2 fewer than in spring. In habitats where saltcedar is dominant or co-dominant 32 species attained a density of 1 or more per 40 ha. A total of 100 species were detected in these habitats in fall.

Figure 16. Species counts for fall. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.



In winter the overall average across all vegetation types was about 21 species. Arrowweed was below this average (Fig. 17). Among the 6 structural types of CW structural types -1, -3, and -4 were significantly above the overall mean and it was close for CW6. All 4 honey mesquite structural types had above average species numbers. Marsh 4 had well above the overall average number in some years, with as many as 55 species having been recorded. However, annual and seasonal fluctuations were dramatic with a low of about 20 species having been recorded in one year. Species richness in orchards was significantly below average for both OR-3 and -4. All saltcedar structural types were below average and this was significant for SC2 and SC4. The latter structural type was censused for 9.5 years and during that time the number of species in winter was consistently between 13 and 15 species. Screwbean structural types were mostly on the low side of the overall average with the exception of SB4. This structural type, with 25 species, was significantly above the overall mean. Recall that densities in this structural type were below the overall average, thus it appears that several species wander into screwbean habitats only in small numbers. Perhaps this habitat type, which includes much saltcedar as well as screwbean, affords about as much feeding potential as saltcedar does.

Figure 17. Species counts for winter. Cw, cottonwood/willow; sb, screwbean; hm, honey mesquite; aw, arrowweed, sc, saltcedar. Numbers refer to structural types, i.e. the vertical distribution of foliage. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. Short horizontal bars indicate means; vertical lines, 2 standard errors of the mean; dashed horizontal line, overall mean; long horizontal lines, 2 standard errors of the overall mean.



In summary, arrowweed was below average, but not significantly so, with respect to species richness in all 5 seasons. Cottonwood/willow, with 6 structural types, across 5 seasons has 30

estimates of species richness. Eight of these estimates were significantly above average. One would expect by chance alone, assuming an even number of species in each of the vegetation and structural types, about 1 to 2 times. CW structural types were significantly below average only once when 1 or 2 would be expected by chance. Clearly CW habitats are the home for the greatest number of species. There were 4 honey mesquite structural types so across 5 seasons there are 20 opportunities to be above the overall mean with respect to species richness. HM structural types were significantly above average 3 times, when 1 would be expected by chance alone. The difference is not significant. A similar number were below average, thus honey mesquite is average with respect to species richness. Saltcedar, with 6 structural types, like CW, had 30 different estimates of species richness. Only SC 2 was above the overall average and this happened twice. Eight times average species richness was below the overall average when 1 or 2 would be expected by chance. Structural types 4-6 accounted for 5 of the 8 totals that were significantly below average.

The question “Why are there so many SC4-6 habitat type parcels?” comes to mind. In 1983 SC 4-6 accounted for about 955 saltcedar patches and about 48% of all riparian habitat in 1986 (Ohmart, Anderson, and Hunter 1986). The question of why there is so much of this habitat type will be addressed later in this report.

Screwbean/saltcedar mixes, with 5 structural types, had 25 estimates of species richness across the 5 seasons. They were significantly greater than average 3 times, all of these involving SB2 and -3. SB had significantly below average number of species 3 times when about 1 would be expected. Saltcedar/honey mesquite 4 had about average species richness across the 5 seasons (Figs. 13-17).

Over the years we discovered many interesting aspects of avian ecology. I will briefly summarize some of what seems to me to be the most salient among these findings.

We did relatively intensive studies of several species, including clapper rail, Gambel’s quail (Plate 1), Abert’s towhee, sage sparrow, and ruby-crowned kinglet, phainopepla (Plate 2). The phainopepla study documented their extensive use of honey mesquite habitats with mistletoe. Their numbers were found to decrease substantially after frost

reduced the number of berries present. In some years frosts were so severe that the mistletoe was killed. This altered the structure of the bird community for years. In fall and winter densities of these species were associated with the presence of mistletoe, but in spring they were correlated significantly with wolfberry. In spring the mistletoe berries are largely gone, but wolfberry is producing copious amounts of berries by then. Phainopepla also eat insects to a significant extent in spring.

Abert's towhees numbers tended to be correlated with various vegetation characteristics during most seasons of most years, but not in fall. This would be expected with a socially regulated species. Birds of the year that have been evicted by their elders occur in other habitat types in a more or less random order. Towhees were significantly associated positively with the number of cottonwood/willow present, diversity of the vegetation in the horizontal dimension, and foliage density. They were also significantly positively associated with the proportion of trees that were saltcedar 23 of 48 months (Meents, Anderson and Ohmart 1981).

We found that sage sparrows were significantly associated with honey mesquite areas with inkweed (*Suaeda torreyana*). This association was proven with vegetation manipulation (Meents, Anderson, and Ohmart 1982). We planted *Sueada* in dense, moderately dense and sparse numbers on separate plots. The results showed an overwhelming preference of this species for inkweed at a scale of at least 20 ha. However, at a different (smaller) scale of 150 m X 130 m sage sparrow occurrence was not statistically associated with those plots with the most inkweed. We have also noted that on a small scale cuckoos were not significantly associated with the number of cottonwood/willow. Phainopepla were not associated with the small plots with the most mistletoe in winter when they ate nothing but mistletoe berries. Many more examples varying by scale could be given.

An important species is the endangered Yuma clapper rail (*Rallus longirostris yumanensis*). We found that habitat breadth of this taxon was greatest in summer and narrowest in winter. The primary feature of the marshes with greatest rail densities was density of the vegetation (Anderson and Ohmart 1984).

We also reported on 4 years of wintering population data for ruby-crowned kinglets (*Regulus calendula*). During this time we found that their numbers were significantly related to climatic conditions. Analysis of these data emphasizes the selective importance of the nonbreeding season ecology to kinglets and implies that some bird species are winter limited (Laurenzi, Anderson, and Ohmart 1982) and management considerations should take this into account.

Social regulation in birds, a hypothesis put forward by Steve Fretwell (1972), is a behavioral mechanism by which parents expel the young of the year from the parental territory. This expulsion occurs at the time of, or slightly before, a crash in the major food source. This expulsion preserves the most favorable portions of the habitat for that segment of the population that has just completed a successful breeding effort. The young are forced to search for new areas that are suitable or to fill holes in the primary habitat where adult pairs have been eliminated by predation or disease. At this time observers should find individuals of species exhibiting this behavior in habitats or sub-habitats in which they are typically not found. Species that are not socially regulated typically remain in or near the most favored areas and undergo a rather sudden and substantial decrease in their populations shortly after the food supply (i.e. insects and other arthropods for insectivorous species) crashes.

Since we had a large number of transects and each of them was subdivided into units 150 m long X 125 m wide on each side of the transect, it seemed that we were in a good position to evaluate the reality of this hypothesis. We could test only fairly abundant, non-migratory species. We found (Anderson, Ohmart, and Fretwell, 1982) that Abert's towhee, crissal thrasher, Gila woodpecker, and ladder-backed woodpecker displayed the most important characteristics associated with species that are socially regulated, while verdin, cactus wren, and Gambel's quail were not. These species are regulated by predation, disease, and starvation.

We investigated seasonal variation in use of specific habitats by birds using monthly census data from 110 transects within riparian vegetation. We generally found support for the hypothesis that habitat breadth narrows in seasons of supposed resource restriction, and that the

narrowing occurs before the winter season. Habitats preferred in the breeding season were found not to be consistently preferred in other seasons, implying that conclusions on habitat optimality might not be appropriate from studies during only part of a year (Rice, Anderson, and Ohmart 1980).

We found that the scale of investigation was important. For example, vegetation density and diversity were both important predictors of avian community measures at the habitat level with plots totaling at least 80 ha, but accounted for little of the variation in bird communities at the transect level (<40 ha). We also found that, in addition to structural components of communities (horizontal and vertical distribution of the vegetation), tree species played an important role. This was contrary to popular conjectures voiced at the time by such influential investigators as Robert MacArthur (1961). Our findings supported findings of Rotenberry and Wiens (1980) which they reported at about the same time as we reported ours.

The high variances seen in the graphs of bird densities was particularly noticeable at the transect level. We examined 4 years of census records for 72 line transects in contiguous riparian vegetation. The proportion of avian species in a community changing between years was lower in summer than in other seasons, but was similar between years for any specific season. Locally breeding species showed slightly more stable communities than did nonlocally breeding species. The high rates of turnover in bird community composition between years brought into question assumptions underlying theories of avian habitat selection, as well as assumptions essential when competition theory is used as the framework to account for community organization. Furthermore there were substantial empirical similarities between these species turnover in contiguous habitats and species turnovers on island and island-like patches of habitat (Rice, Ohmart, and Anderson 1983).

If we are going to manage vegetation for wildlife we must know what attributes associated with the vegetation are most important to the various species. The variables we investigated included foliage density and 3 levels, foliage diversity in the horizontal and vertical dimensions, the number of honey mesquite, honey mesquite plus mistletoe, screwbean mesquite screwbean with mistletoe, saltcedar, willow, and



cottonwood and other (e.g *Atriplex* sp., *Sueada*, *Lycium*). We found that all of these variables were positive for some species with density at 0-0.6 m, 1.5-3.0 m, and 4.5<sup>+</sup>m, patchiness index, number of honey mesquite, honey mesquite with mistletoe, saltcedar, willow, cottonwood, and “other”, being most prominent among those with positive correlations with bird densities on a species by species basis. Some variables were often associated negatively with species abundances. This included foliage density at 0-0.6 m, density and >4.5 m, number of screwbean mesquite. Among 203 events saltcedar was a significant factor 43 times and these associations were negative with species abundances 21 times (Rice, Anderson, and Ohmart 1984, Rice, Ohmart, and Anderson 1983). By comparison number of cottonwood trees contributed about 55 times of which 42 were positive; willow 44 times, 22 positive; honey mesquite, 49 times, 33 positive, foliage height diversity, 92 times, 77 positive. Clearly diversity of the foliage is the single most important variable when birds are selecting habitats.

From these studies we concluded that studies of avian habitat use must be designed to encompass realistic portions of these annual seasonal, and spatial sources of variation in habitat use characteristics of the community under study. Within the limits of biological reality, studies should include as comprehensive a set of measures as possible, rather than relying heavily on either a few measures recommended from studies on other areas or even ones shown useful for a few species in the community under study. Studies testing large-scale ecological hypotheses or providing data for environmental management plans, especially habitat modification projects, with impacts on substantial portion of the avian communities must be based on data bases adequate for a thorough description of the system. Had we selected subsets of our species, transects, time period or habitat attributes we could have undoubtedly produced results supporting quite a wide range of invalid proposals. Such actions are neither ecologically wise nor do they lead to effective management.

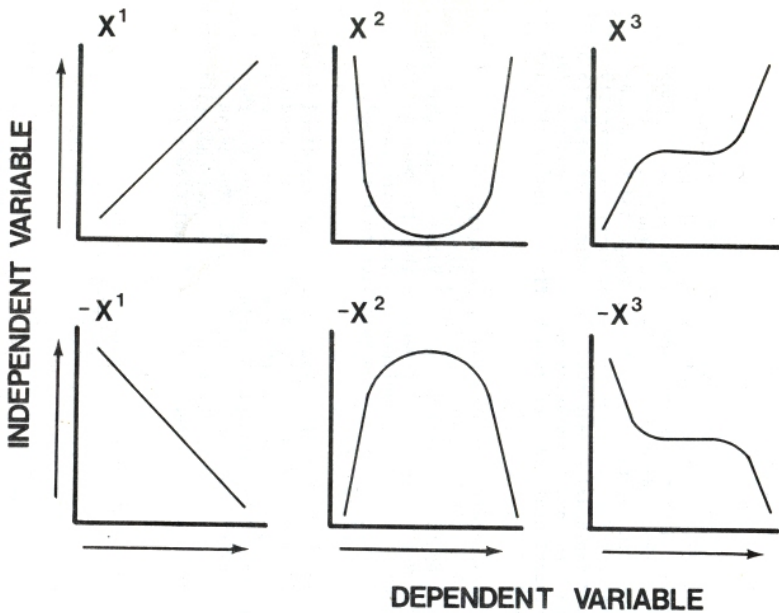
We also discovered that the response of birds to community variables can be complex. We investigated a number of potential curvilinear relationships and found that polynomials were selected in 36% of first steps and 45% of second steps using multiple linear

regression. Consideration of curvilinear responses by species to vegetation community characteristics offers a more comprehensive examination of responses to environmental gradients (Meents et al 1983). Examples of curvilinear relationships are presented in Fig. 18.

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Figure. 18. The graphs on the left show linear relationships, those to the right of these show various curvilinear relationships.

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From 1975-1982 I was interested in food and habitat relationships of the 18 species of ducks commonly occurring along the 400 km of the lower Colorado River to determine the extent, if any, to which congeneric species might be ecologically separated spatially. I also considered separation through time within each year. Dabbling ducks tended to be associated with areas of high-standing crop of submerged aquatics and emergent aquatic vegetation. Most diving ducks

were associated with the areas immediately downstream from hydroelectric dams.

We detected an average of 17,800 ducks of 18 species each year in the same stretch of river studied by Grinnell in 1910. From Grinnell's account (1914) we estimate that his party saw about 1,000 ducks of 8 species between Needles and Yuma. Common goldeneye were the most common species every year in our study. Grinnell reports seeing no goldeneyes or buffleheads. These species accounted for 40% of the detections in our study. One of Grinnell's objectives was to list all species that occurred in the area. The fact that he identified only 8 species, whereas we detected 18 species of ducks each year, attests to the current increase in the species richness relative to 1910 (Anderson and Ohmart 1988).

The association of diving ducks with dams was related to large numbers of hydropsychid insects and the Asiatic clam (*Corbicula fluminea*), the major food of the bufflehead and common goldeneye. Pochards (*Aythya* sp.) were also associated with areas immediately downstream from hydroelectric dams but not as strongly as *Bucephala* sp. (Plate 1 p.49); they also overlapped in diet and habitat with dabbling ducks. Ecological separation between species was apparent for nearly all congeneric species pairs. That could reflect competition for food, but other processes, including a difference in habitat use patterns are probably more important. The hypothesis (Hutchinson 1959, Nudds 1980, 1983, Nudds et al. 1981). that the size ratio of the largest-to-the-next-largest congener should be 1.25 was not supported, either statistically or biologically, for dabblers or pochards, but was supported for goldeneye and bufflehead. The ability of dabbling ducks to shift from high-protein diets in summer to seed and plant diets in winter and to opportunistically forage on locally superabundant food resources also contributed to the observed lack of structure of the wintering duck community.

When I began my studies on the LCR white-cheeked geese (formerly known as Canada geese *Branta canadensis*, Plate 1 p.49) were scarce. Many of them wintered around the Salton Sea, but as the Cibola National Wildlife Refuge was developed it became attractive to geese. In 1974 perhaps 250 geese wintered on CNWR but by 1990 this

had ballooned to more than 20,000. I became interested in the geographic origin of the geese wintering at CNWR. The American Ornithologist's Union declared that a single subspecies (*moffitti*) of *Branta canadensis* occupies the western portion of the United States. Brief study of a topographical map revealed that there are many isolated pockets of water in the west where geese are known to breed. It seemed unlikely that a genetically plastic species on the rest of the continent would develop only a single subspecies in the ecologically diverse western half of the continent. We decided to look into this further.

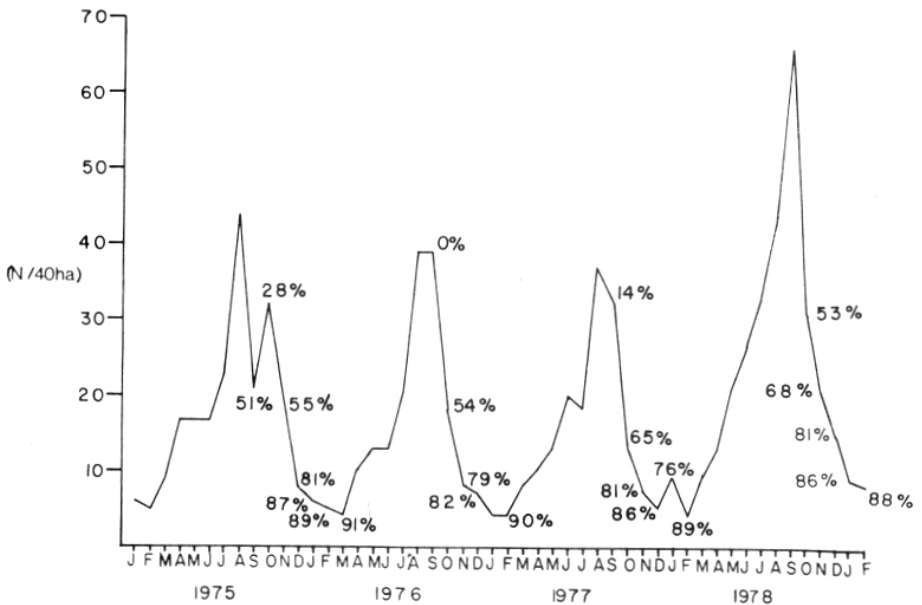
We first were able to discern that the geese at CNWR hailed from 4 major areas—the Salt Lake Basin in Utah (35%), southwestern Wyoming east of the Uinta Mountains (40%), the Yellowstone Park areas (10%) and the prairies of southern Alberta (5%). The other 10% included geese from a wide variety of places (e.g. Idaho, Montana, central Wyoming). In time, in collaboration with Dr. H. C. Hanson at the University of Illinois, we were able to conclusively show that all of these sources of geese were represented by a diagnosable taxon (Hanson 2007, 2007, Anderson 2010).

Another species that we decided to study in greater detail than most species was the Gambel's quail. This is an important species because of its value as a game species and the species is of interest to physiologists and ecologists, as well as to game managers. From 1973-1978 a large-scale ecological study of this species was undertaken. Goals of the study were to: (1) understand seasonal and local population fluctuations, (2) identify essential aspects of preferred quail habitat; (3) determine timing and duration of breeding cycles, (4) assess dietary components, (5) compare Gambel's quail in the LCRV with other populations previously studied, (6) discuss management implications as they pertain to habitat change and population regulation. Information concerning these details was presented in Anderson, Ohmart, and Fretwell 1982, Rice, Anderson, and Ohmart 1983, Anderson and Ohmart 1984, Ohmart, Anderson and Hunter 1988, Rosenberg et al 1991. All I can do here is to present a smattering of the information acquired.

One of the aspects of quail ecology that was and is of interest to me is their great seasonal and annual fluctuations in population densities

(Fig. 19). As expected with a non-socially regulated species and in contrast to socially regulated species, quail numbers fluctuated wildly, Their numbers frequently decreasing by 80-90% at lowest levels that were observed in January-March. Of course hunting is a factor affecting quail numbers, but we found that in portions of Cibola NWR that were closed to hunting exhibited almost identical levels of population decrease, suggesting that hunting merely substitutes for other natural causes of mortality.

Figure 19. Average monthly densities (N/40 ha) of Gambel's quail in all riparian vegetation in the lower Colorado River valley. Mortality is given as percent decrease from population peak.



Quail showed a preference for mesquite communities, and densities were lowest in cottonwood/willow and pure stands of saltcedar. Quail densities were correlated with the number of mesquite trees, saltbush, and patchiness of ground vegetation in all seasons except

summer. Numbers were enhanced by the presence of an agricultural border, but agricultural land alone supported few quail.

These population fluctuations are also probably affected by the weather. In one particularly wet September their numbers dropped dramatically before the onset of the hunting season.

Another interesting aspect of quail ecology is the physiological aspects of the annual reproductive cycle. The reproductive cycle begins when males start “cow” calling—their way of advertising for female companionship. Cow calls of male Gambel’s quail were heard for a six-month period each year between February and August. Calling peaked in May and June and was greatest in honey mesquite habitats.

Quail broods were detected from mid-May through August; young less than one-quarter grown were seen throughout that period. After August, older broods coalesced to form large coveys that persisted through the fall. Based on all field observations, the extent of the breeding season was at least 6 months, from February through August.

During the study 401 male and 314 female quail were collected for studies of their reproductive biology. Annual testis cycles (Fig. 20) revealed that the first histological changes occurred by early February, with an increase in testicular weight by mid-February. Full sperm production lasted a total of 18-19 weeks, beginning as early as 15 March and continuing as late as 7 August. No differences in testis recrudescence or regression among years were observed, so the data were pooled to represent the general cycle observed during the study.

Annual cycles of ovary and oviduct weight are shown in Fig. 21. Females with mature eggs were first detected about 20 March, with laying activity lasting at least 16 weeks. This estimate was thought to be conservative because no female specimens were taken during late July when the termination of egg laying would have been apparent. Data from ovaries and oviducts gave similar results. In general, female reproductive activity lagged several weeks behind that of the male, with increased ovarian and oviduct weights noted from 1 March to early September.

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Figure 20. Annual testis weight cycle of Gambel's quail in the lower Colorado River valley. Dots represent combined samples for the period: 1974-1977. Note that weight is on a logarithmic scale. N=401

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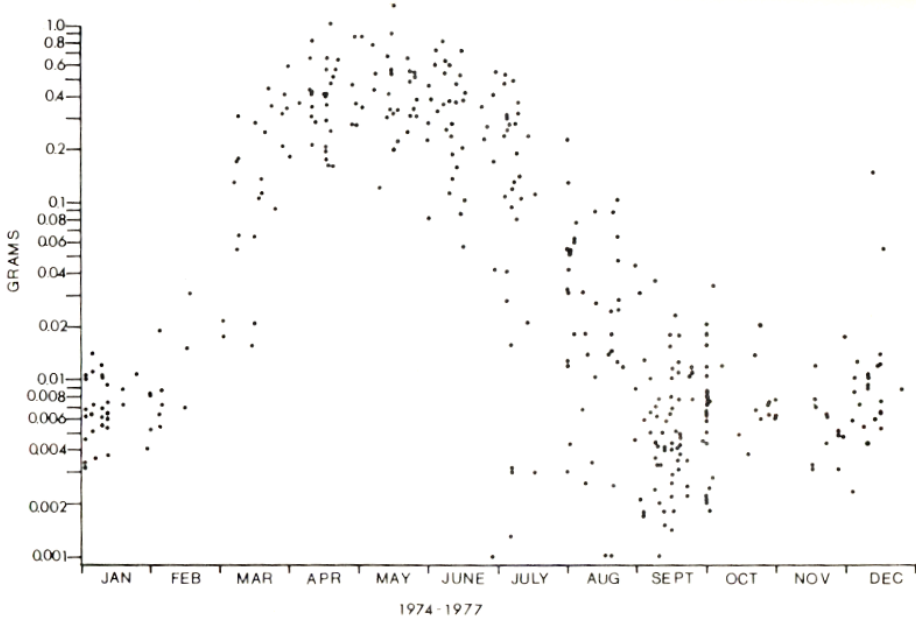
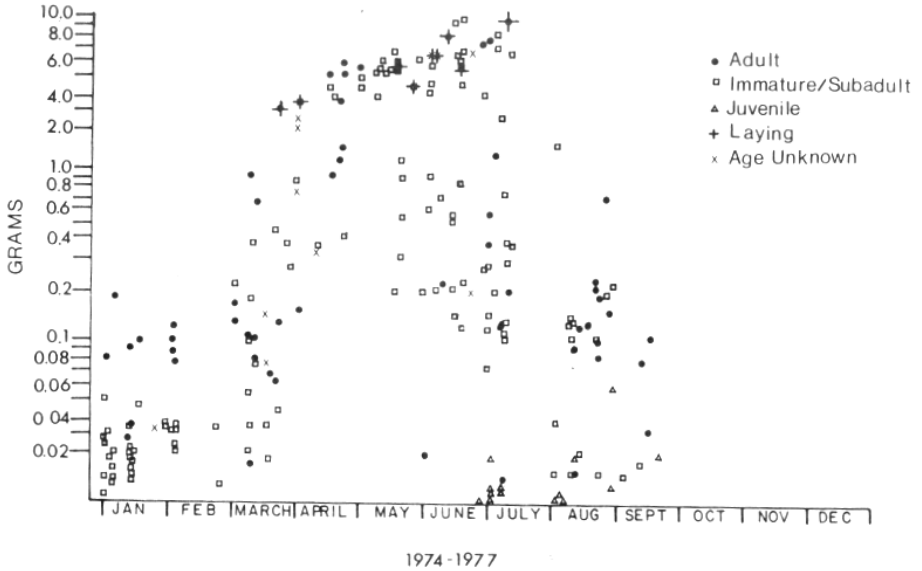


Figure 21. Annual cycle of ovarian weight (log10) in Gambel's quail in the lower Colorado River valley (combined samples 1974-1977, N=314)



We studied one large mammal in detail, that being the food habits of the coyotes *Canis latrans*. For this purpose coyote scats were collected over a five-year period (1974-1978) in riparian habitats along the lower Colorado River. Scats were collected along transects. All scats were first cleared from the transects. Then they were collected 2 or 3 times each month from 1975-1978 along these transects after bird censusing. Scats were collected on a less regular basis in 1974.

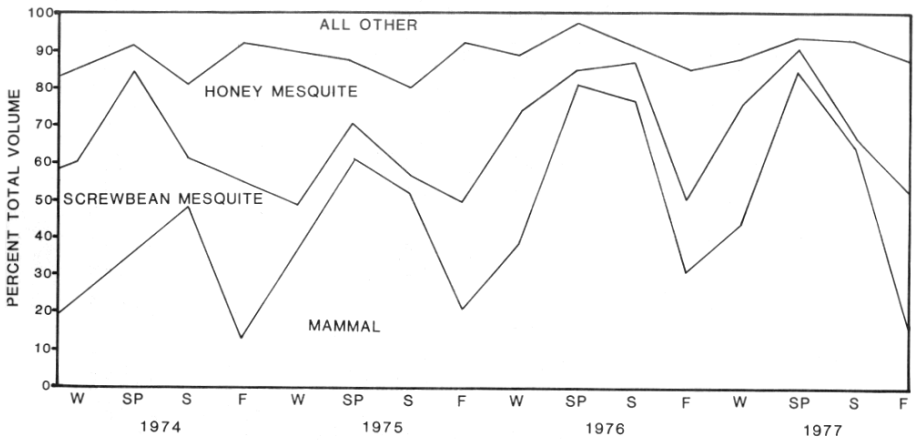


The purpose of this study was to: (1) identify food items consumed by coyotes in this region, (2) determine which items made up the major portion of the diet of coyotes, (3) examine whether coyotes showed a response in food habits to food availability, and (4) ascertain if certain riparian habitat types were more attractive to coyotes than others, based on food habits and resource abundance (Anderson and Ohmart 1984).

The following items were found in coyote scats over the five-year period: 19 mammalian species, 20 plant species, 2 bird species, two reptilian species, eggshell remains, nine orders of arthropods, charcoal, gravel, and shot. Compared with food frequencies in other coyote studies percent frequency of occurrence of rabbits, rodents, deer, and livestock was lower in our study. Rabbits and rodents were the most frequently identified mammals. Plants were more frequent in our study relative to other studies. An idea of the seasonal variation in food items can be seen in Fig. 22. Mammals tended to be most numerous in diets in spring and summer. Honey mesquite pods tended to constitute a large proportion of the diet in fall. Rodent abundance in the various habitats tended to be correlated with their occurrence in coyote diets.

Major foods for coyotes were ones which were abundant in the region. Stands of honey mesquite were previously much more extensive and mesquite pod production was prolific (millions of pods/40 ha) in the LCR, and small rodents and cottontail rabbits showed an extended breeding period (due probably to the mild regional climate). Native riparian habitats harbor these foods. Therefore, if adequate native habitat is preserved, coyote populations could be sustained in those areas and would present little threat to farms or livestock.

Figure 22. Seasonal variations in percent total volume of coyote food found in scats in 1974-1977. For a given season, the total percentages (on the left) are a cumulative figure such that for all seasons, mammal + screwbean + honey mesquite + "other" equals 100%. W refers to winter; SP, spring; S, summer; F, fall.



Flooding is an unusual event on the LCR and its tributaries, but in 1983-1984 the Colorado River reservoirs were full and releases from the hydroelectric dams were much greater than normal. These high-water flows, unlike natural flooding, which usually lasts only a month or only a few months, these high flows lasted month on end for more than 2 years. Effects of flooding on the vegetation and avian communities of the Bill Williams River, Arizona, were evaluated from 1976 to 1983. High water flows there in 1978 through 1980 caused the death of 99% of all Fremont cottonwoods and 64% of all Goodding willow on a 120-ha areas near the confluence with the Colorado River. By 1982, cattails (*Typha* sp.) had become the dominant vegetation. Ground- and canopy-dwelling avian insectivores and cavity nester decreased, whereas

passerine marsh insectivores and rail-like species increased. Water released from Alamo Dam resulted in loss of the last remaining large stand of mature cottonwood-willow habitat in the lower Colorado River valley, causing declines in numbers of some bird species possibly threatened with local extirpation. Need for flood management procedures to conserve vegetation was considered to be of paramount importance given the beleaguered habitats involved (Hunter, Anderson, and Ohmart 1987).

Use of saltcedar (*Tamarix ramosissima*) by birds was compared with data from the Rio Grande, middle Pecos, and LCR (Hunter, Ohmart, and Anderson 1988). Use of saltcedar ranked high among all bird groups in all seasons on the middle Pecos River. In contrast, many species do not occur in saltcedar on the LCR, while few species winter in saltcedar on the lower Rio Grande. Occurrence of granivores and insectivores during winter in saltcedar on the Pecos River may be explained by seed-producing shrubs and annuals within or adjacent to these habitats. Most breeding birds on the Pecos River are summer visitors. These breeding species, though present, do not occur in saltcedar on the Colorado River despite abundant food resources and occur in intermediate abundances on the Rio Grande. Densities of several summer-visiting insectivores have declined markedly on the Colorado River since the construction of hydroelectric dams which created the conditions suitable for saltcedar expansion, whereas they have remained relatively stable in other river valleys to the east. The trend for fewer birds in saltcedar in the west to many more to the east seemed to correlate with an elevational gradient (Hunter 1988a).



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Plate 1. We studied the ecology of ducks and the Yuma clapper rail (*Rallus longirostris yumanensis*, upper right) on the lower Colorado River. We also studied the evolution and taxonomy of white-cheeked geese (*Branta canadensis*) throughout the valley. We studied the population dynamics and reproductive biology of Gambel's quail (*Callipepla gambelli*). Common goldeneye (*Bucephala clangula*, upper right), bufflehead (*Bucephal albeola*), lower right.

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Plate 2. We studied the ecology of some species more intensively than most, including (from left to right and top to bottom) the Ruby-crowned kinglet (*Regulus calendula*), phainopepla (*Phainopepla nitens*), sage sparrow (*Amphispiza belli*), and Abert's towhee (*Pipilo aberti*).

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Plate 3. Food habits of coyotes were determined from their scats. Small mammals were a significant food item. Top left, wood rat *Neotoma albigula*, Merriam's kangaroo rat *Dipomys merriami*, cactus mouse *Peromyscus eremicus*.

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Birds are not only an important indicator of the health of an ecosystem but they are relatively easy to observe and count. Density estimates can be made over relatively large areas. However nocturnal rodents are also a significant component of riparian ecosystems. We will discuss their distribution across the vegetation types next.



## MAMMALS

We began trapping rodents in the various riparian habitats in 1973 and continued on a monthly basis through summer 1979, but the trapping effort was not equal in all years, being notably less intensive in 1973. Neither was trapping equally intensive in all vegetation types, abundance of a vegetation type being the variable most affecting trapping intensity—scarce vegetation types were trapped less than abundant ones. Marshes and desert washes were trapped less intensively because a lack of funds for extending effort into these habitats. For purposes of analysis we divided the year into the warm season (April-September) and the cool season (October-March). The results are based on 340,000 trap nights and 18,067 captures across 15 species (Table 2).

A trap grid consisted of 2 parallel lines 15 m apart and 225 m long. Along each line 3 traps were placed every 15 m for a total of 30 stations on the 2 lines and a total of 90 traps. The grid was operated for 3 consecutive nights so there were 270 trap nights per grid. In the warm season the average 5.4 species per 1,000 tn (Fig.23). In the winter season the greatest number of species (8) occurred in SB5 while 7 species were found in HM4, SB4 and SC6.



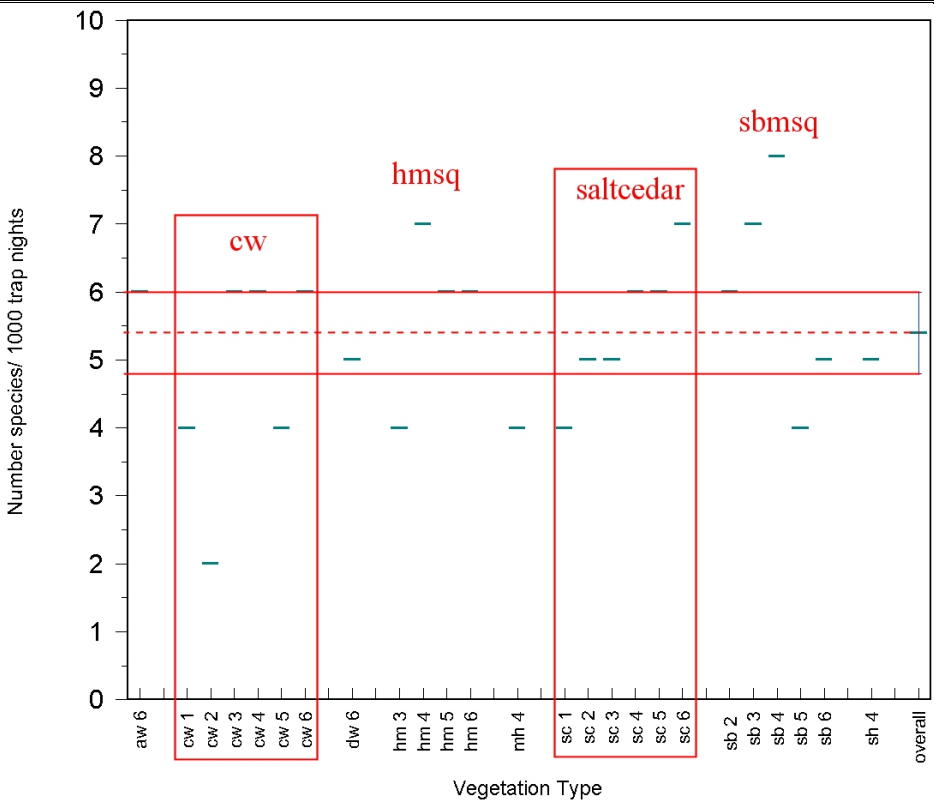
Table 2. Trapping intensity by (trapnights) vegetation and structural type.

Veg	Winter	%total	Summer	%total	sum	%total
AW6	5940	3.8	3510	1.9	9450	2.8
CW1	4320	2.8	430	1.3	6750	2.0
CW2	1350	0.9	810	0.4	2160	0.6
CW3	2970	1.9	6210	3.4	9180	2.7
CW4	8100	5.2	5130	2.8	13230	3.9
CW5	4050	2.6	4320	2.4	8370	2.5
CW6	7020	4.5	4320	2.4	11340	3.3
DW	5130	3.3	2160	1.2	7290	2.1
HM3	5940	3.8	3510	1.9	9450	2.8
HM4	22410	14.3	18630	10.1	41040	12.1
HM5	3780	2.4	4590	2.5	8370	2.5
HM6	8910	5.7	6210	3.4	15120	4.4
Marsh	810	0.5	0	0.0	810	0.2
SC1	2700	1.7	1350	0.7	4050	1.2
SC2	10804	6.9	16206	8.8	27010	7.9
SC3	4050	2.6	3240	1.8	7290	2.1
SC4	6750	4.3	5870	3.2	12620	3.7
SC5	8100	5.2	8370	4.6	16470	4.8
SC6	3510	2.2	3240	1.8	6750	2.0
SB2	3510	2.2	2700	1.5	6210	1.8
SB3	6210	4.0	2970	1.6	9180	2.7
SB4	13500	8.6	12690	6.9	26190	7.7
SB5	6210	4.0	56750	30.9	62960	18.5
SB6	2700	1.7	1080	0.6	3780	1.1
SH4	7830	5.0	7290	4.0	15120	4.4
Total	156604	100	183586	100	340190	100

We found only 2 species in CW2. SC4 had 6 species. Screwbean and honey mesquite averaged 5.8 species per 1,000 tn; saltcedar, 5.5, and cottonwood/willow 4.7. The relatively large number of species found in screwbean and honey mesquite habitats is probably related to the large seed pods produced in these habitats. Three cottonwood/willow habitat types had significantly below average numbers of species (CW1, -2, -5),

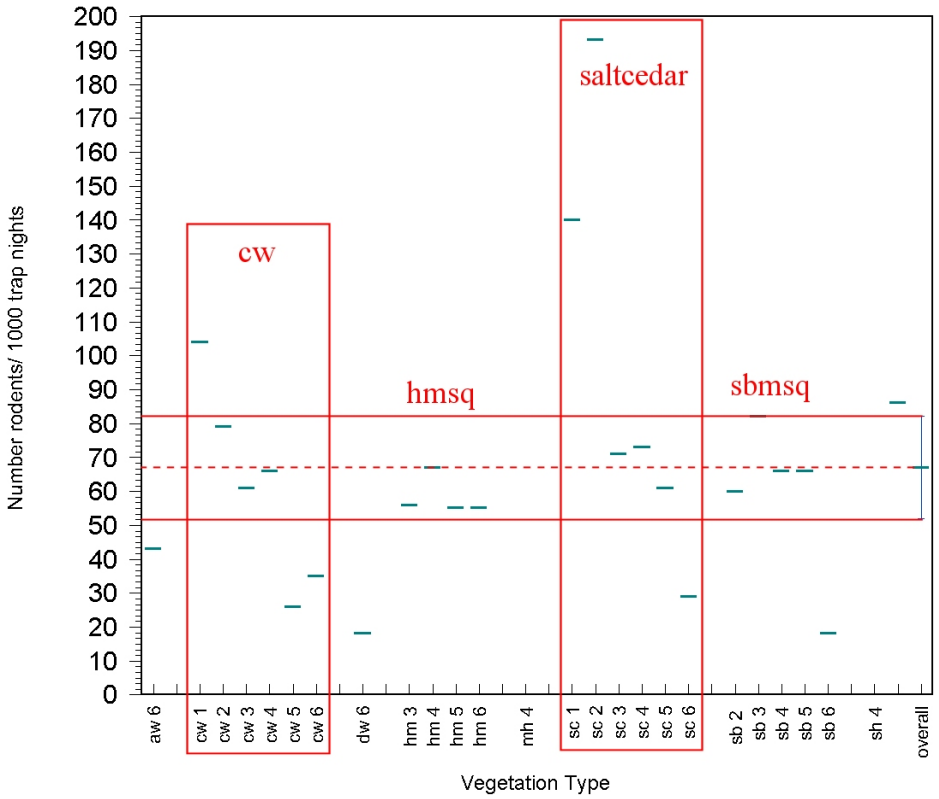
while saltcedar had only 1 (SC1, athel saltcedar). Sparse habitats tend to have more species because these habitats are often at the periphery of the riparian zone. At this juncture there is a greater tendency for there to be sand dunes and therefore desert kangaroo rats (*Dipodomys deserti*) which are absent in more typical riparian habitats. The more open country is also home to species such as antelope ground squirrels and round-tailed ground squirrel.

Figure 23. Number of species of rodents by vegetation type in the warm season. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. The mean number of species is represented by the short horizontal lines. The 2 horizontal solid lines represent plus and minus 2 standard errors of the overall mean number of species/1,000 trap nights. The dashed horizontal lines represents the overall mean.



Rodent densities in the warm season were greatest in SC1 (140/1,000 TN) and SC2 (193/1,000 TN). Although there were 4 or 5 species in SC1, -2, and -3, the cactus mouse (*Peromyscus eremicus*) made up 71-89% of the total catch in these vegetation types (Fig. 24). This dominance by a single species was equally true in CW1-3 where this species comprised 71-86% of the total catch. In HM3 they made up 70% of the total and in SB2 and -3 they made up 70% and 60% of the total captures, respectively. In sparser habitats densities tended to decrease, but the number of species tended to increase. Total densities tended to be significantly below average in types 5 and 6, this being true in 6 of 10 cases (Fig. 24). Type 4 vegetation had mostly average densities.

Figure 24. Number of rodents per 1,000 TN in the warm season. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. The mean number of rodents is represented by the short horizontal lines. The 2 horizontal solid lines represent plus and minus 2 standard errors of the overall mean number of species/1,000 trap nights. The dashed horizontal line represents the overall mean.



In the cool season overall average number of species of rodents was about the same as in summer (Fig. 25) hovering around 5 species per 1,000 tn. As in summer the sparser vegetation types tended to have the most species with 6 of 10 vegetation types with structures of 5 or 6 had significantly above average number species. The greatest number of species in any vegetation type was in HM6. Average number of species were found in CW4, HM4, SC4, and SB4.

Densities in the cool season did not differ significantly from those observed in summer (Fig. 26). Above average densities were obtained in CW2 and CW3, SC1-3, and SB2-4. Below average densities, as in summer, tended to occur in the sparser type 5 and 6 habitats. Type 4 habitats tended to be about average. The cactus mouse decreased in abundance, but the desert pocket mouse increased substantially in numbers from the cool to the warm season. While no harvest mice were collected in the cool season they were present in the warm season.

Figure 25. Number of rodent species in the cool season by vegetation type. Sc 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. The mean number of species of rodents is represented by the short horizontal lines. The 2 horizontal solid lines represent plus and minus 2 standard errors of the overall mean (dashed line) number of species/1,000 trap nights.

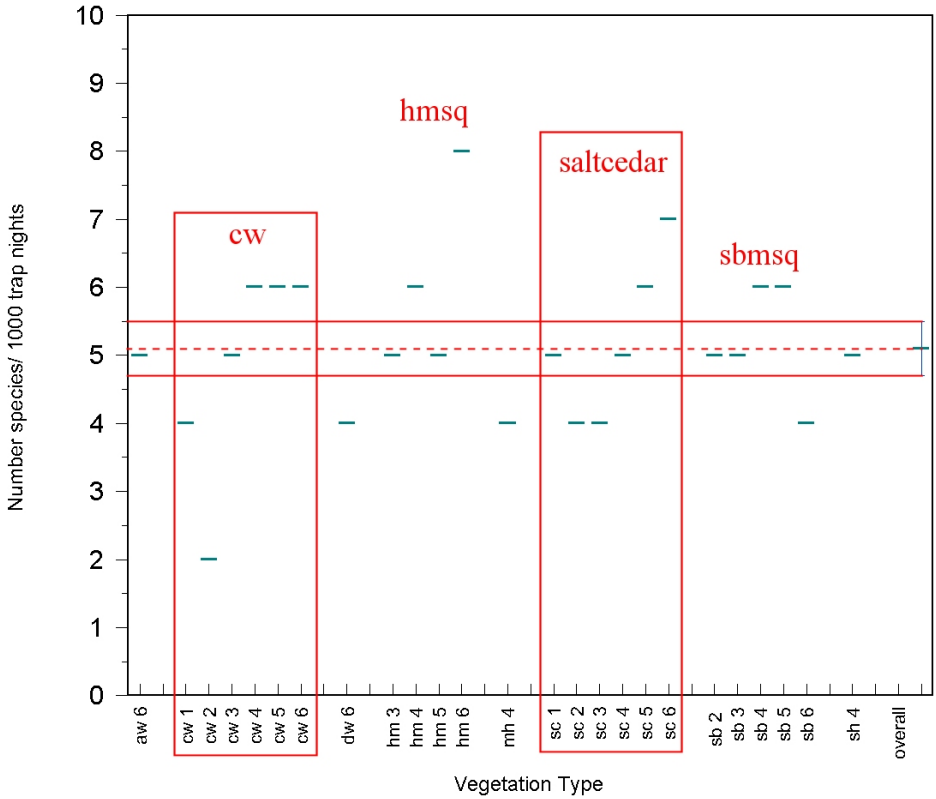
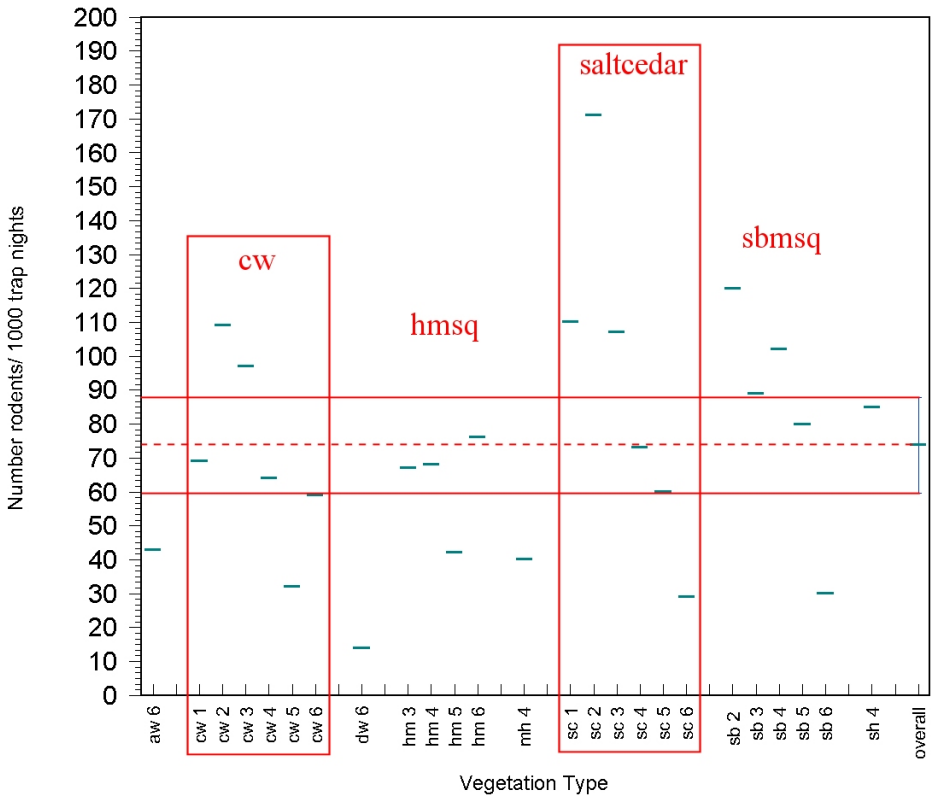


Figure 26. Number of rodents per 1,000 trap nights in the cool season Number of rodent species in winter by vegetation type. SC 1 refers specifically to *Tamarix aphylla*. Hmsq and sbmsq refer to honey and screwbean mesquite, respectively; cw, cottonwood/willow. The mean number of species of rodents is represented by the short horizontal line. The 2 horizontal solid lines represent plus and minus 2 standard errors of the overall mean (dashed line) number of species/1,000 trap nights.



The five most common rodents in the 1910 collection made by Grinnell and his party are the same as in the warm and cool seasons in 1973-1979 (Table 3). However, this glosses over some major differences. In the earlier collection the cactus mouse accounted for 15% of the total sample across 13 species. This species accounted for

56% of the sample in the warm season and 68% in the cool season in the period 1973-1979. In 1910 the desert pocket mouse accounted for the largest proportion (27%) of the collection, but only 18% in the warm season and 7% in the cool season 1973-1979. The white-footed mouse accounted for similar proportions at both times. The Grinnell collection was made from 15 February to 15 May, thus including some of what we called the cool time of year and some of the warm season. The harvest mouse was present at 2-3% in both collections, but we caught none of them during the cool season. Our collection included the grasshopper mouse on a regular basis, if in small numbers. Grinnell's party collected none of this species. Ground squirrel and desert kangaroo rat are more numerous in the 1910 collection, but the Grinnell party might have spent more time trapping in marginal situations than we did.

Table 3. Most commonly trapped rodents by species in 1910 compared those trapped in 1973-1979.

Species	Grinnell 1910		Warm 1973-79		Cool 1973-79	
	N	%	N	%	N	%
Desert pocket mouse	196	26.6	319	18.2	122	7.0
Merriam's kangaroo rat	168	22.8	122	7.0	139	7.9
Cactus mouse	109	14.8	971	55.5	1197	68.4
White-throated woodrat	68	9.2	130	7.4	121	6.9
White-footed mouse	65	8.8	122	7.0	152	8.7
Desert kangaroo rat	39	5.3	5	0.3	4	0.2
Harris' ground squirrel	26	3.5	0	0.0	0	0.0
Harvest mouse	21	2.9	36	2.1	0	0.0
Antelope ground squirrel	17	2.3	1	0.1	1	0.1
Round-tailed ground squirrel	15	2.0	21	1.2	0	0.0
Cotton rat	12	1.6	16	0.9	0	0.0
House mouse	0	0.0	2	0.1	5	0.3
Grasshopper mouse	0	0.0	6	0.3	8	0.5
Total	736	100	1751	100	1749	100

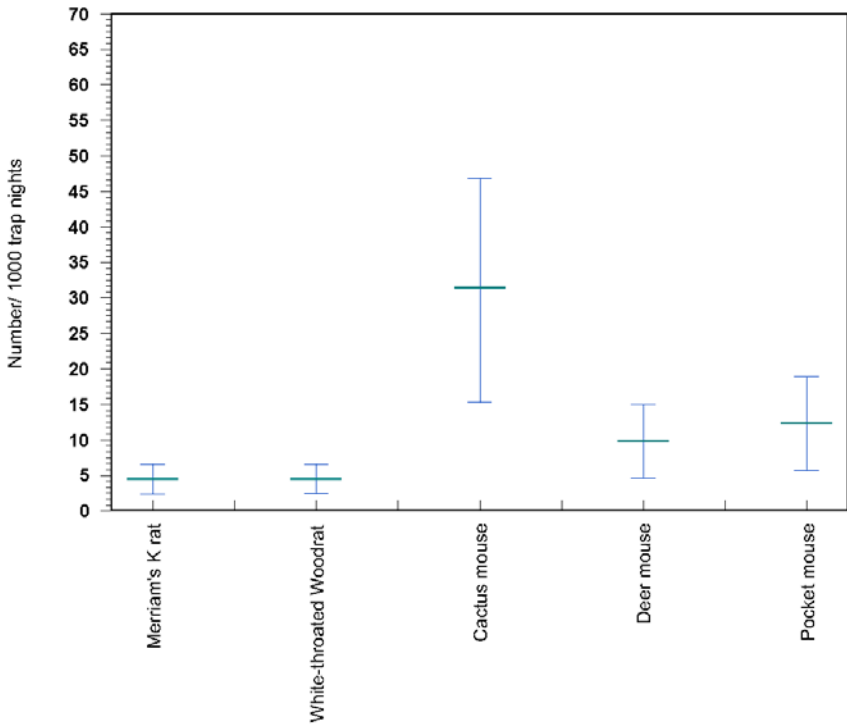


For the 5 most common rodents in our trapping effort the cactus mouse was the most abundant in both the cool and warm seasons (Fig. 27, 28). Densities were greater in the cool season than in the warm season, suggesting a cessation of breeding during the hottest, driest times of year (Anderson and Ohmart 1984). Cactus mouse densities were relatively high in CW1-3, SC1-3 and HM3 suggesting that they prefer relatively dense vegetation. Since there was dense vegetation in 1910, but fewer cactus mice, I conjecture that it is the absence of annual flooding that has led to their numeric dominance. Andersen (1993) disputes this and presents some data from a 4.5 ha plot that seem to not be in line with the possibility that cactus mouse densities may not be affected by flooding. Our work, of course, included thousands of hectares. Variation was so great on a small scale such as 4.5 ha that a plethora of different explanations for the increase in cactus mice might be possible, but the only one that fits the overall general pattern is the current absence of flooding.

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Figure 27 . Numbers of various rodent species (n/1,000 tn) in the warm season across all vegetation types. The short horizontal lines represent the mean and the vertical lines, 2 standard errors of the mean.

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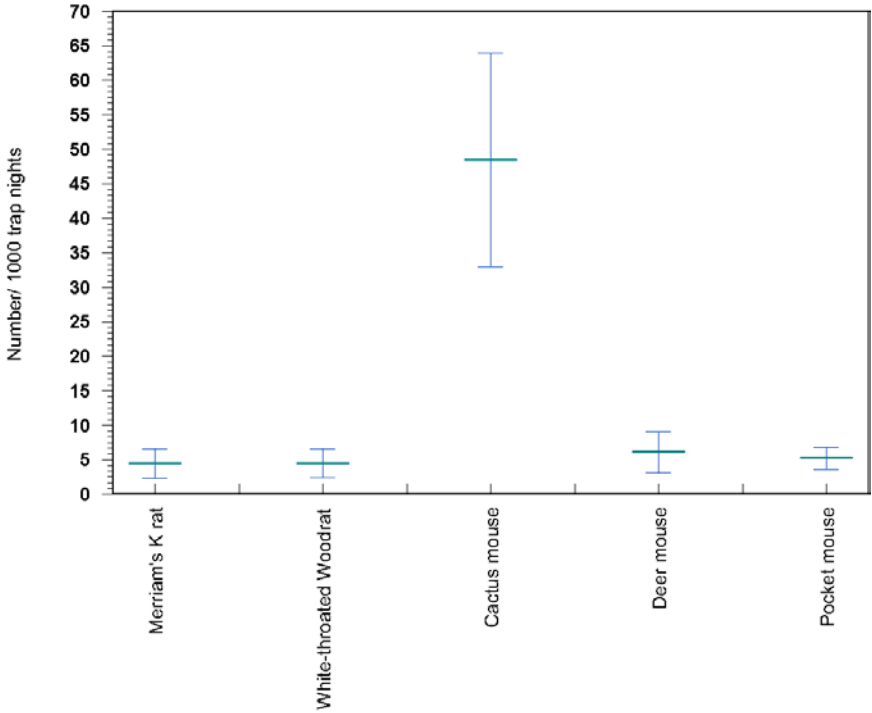
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Figure 28. Numbers of various rodent species (n/1,000 tn) in the cool season across all vegetation types. The short horizontal lines represent the mean and the vertical lines, 2 standard errors of the mean.

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## INSECTS

We collected insects in arrowweed type 6, and in structural type 4 in cottonwood/willow, honey mesquite, screwbean/saltcedar, honey mesquite/saltcedar, and saltcedar. Arrowweed and the type 4 habitats account for about 64% of the riparian vegetation, in the main part of the LCR.

Dr. Ed Minch, an entomologist, developed the sampling protocol which, briefly stated, consisted of making 4,000 sweeps with an insect net along transects about 900 m long. This sampling was done on a monthly basis for 30 months. The insects captured were identified by Dr. Minch and his small staff to the family level.

Only a smattering of data from this study can be presented here. The first data set (Fig. 29) provides a picture of the number of insects in the various habitats. The cottonwood/willow habitat ranked first in terms of total number of insects captured from March through July and is near the top with respect to biomass from August through December. Saltcedar was a close second. This was true in May even though a single sample from saltcedar included more than 500,000 cicadellids (Homoptera, Cicadellidae). This was such an inordinately large number and, even though the other vegetations types sampled also included saltcedar, none had cicadellids in numbers remotely like this. This sample of cicadellids was considered an anomaly and was therefore omitted and the average for May from other years was substituted for it. It has been stated repeatedly in the literature that saltcedar has few insect. Our insect sampling suggests that such statements deviate from the truth. Both cottonwood/willow and saltcedar had 50-60% more insects than honey mesquite habitats (see note, p.74).

It is also clear that there is a peak in overall insect abundance that occurs in May and that this peak occurs in all vegetation types. Insect abundance is fairly high in honey mesquite and much of this is due to an abundance of psyllids at that time (see below). The trend for insects to drop rather dramatically in numbers from June to August is an

occurrence that is in line with the dispersal of the socially regulated birds mentioned above.

The diversity of insects was relatively high in all vegetation types with 20 or more families occurring from May through June (Fig. 30). Cottonwood/willow was represented by more than 20 families of insects in all seasons and more than 60 families in April and May, more than 40 families in June, July, August, and September. In terms of diversity saltcedar/honey mesquite had about 50 families of arthropods from April through June, but this vegetation type also had the smallest diversity of families in January, February and March. Although insect numbers were generally low in arrowweed, in April and May that vegetation type had a greater diversity of families than saltcedar or saltcedar/honey mesquite. Honey mesquite had about 40 families April through June.

Figure 29 . Insect densities (number of individuals) captured in 6 vegetation types by month.

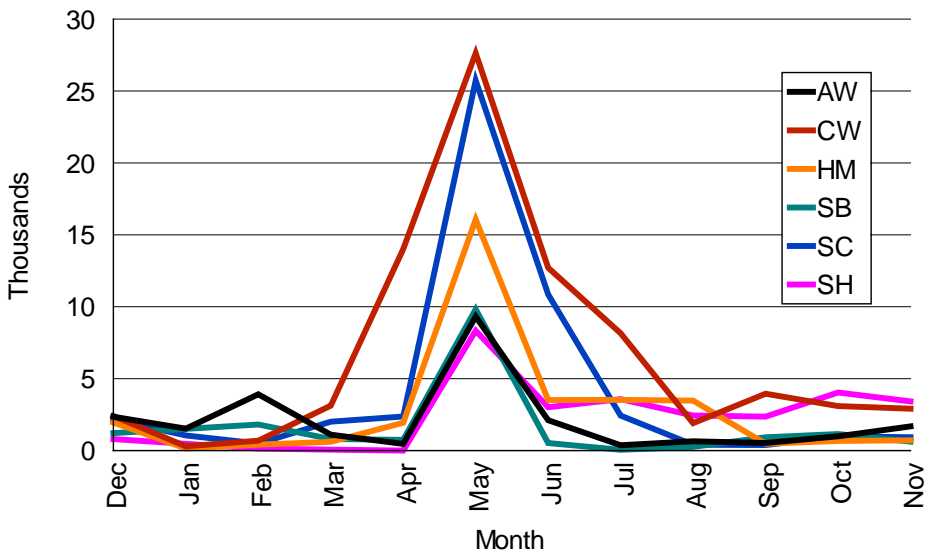
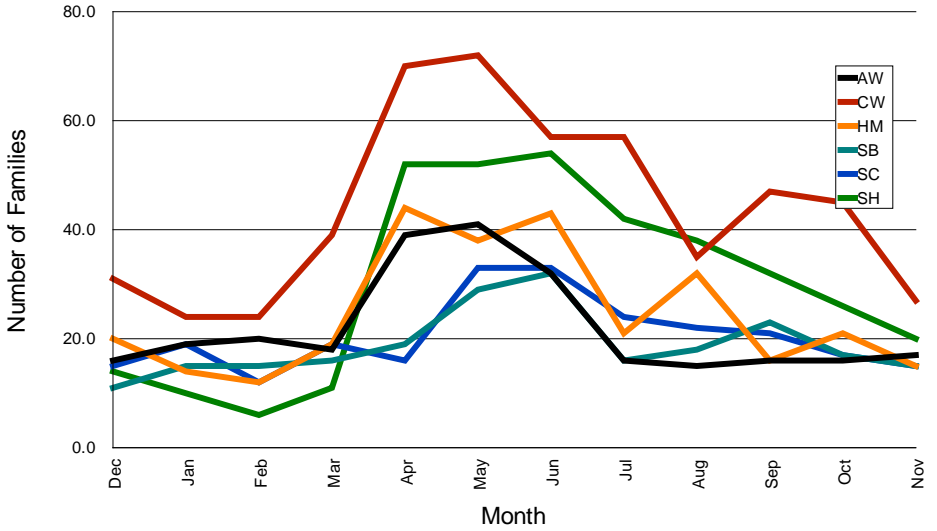


Figure 30. Number of families of insects by month and vegetation type



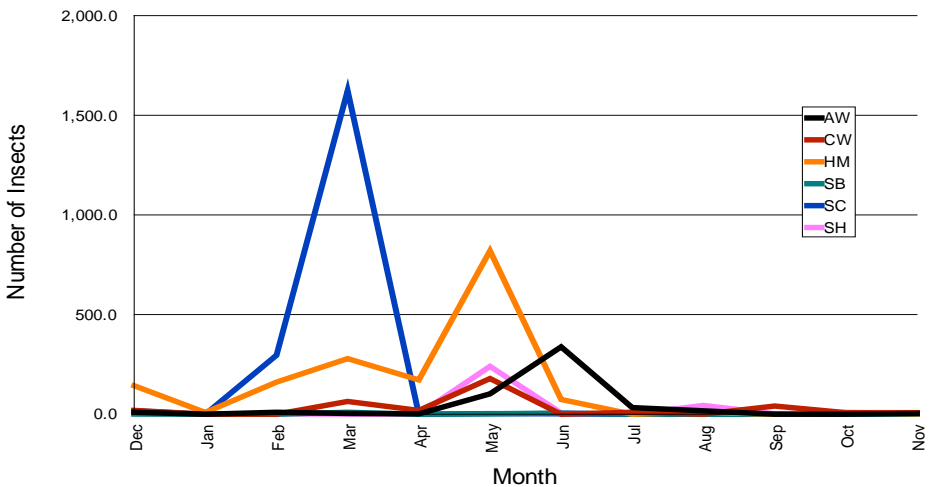
Even though the overall peak in insect abundance occurred in May this was not true for all individual families. For example species in the family Miridae (leaf or plant bugs) reached peak numbers in March (Fig. 31). This is the largest family of bugs in North America with several hundred species. They occur on vegetation and are often abundant. All are rather soft-bodied, many are brightly colored. One might suspect that they are a significant dietary item for insectivorous birds, but this did not turn out to be true, this taxon being a minor dietary item.

They reached peak numbers in saltcedar in March but had a second peak later in May in honey mesquite. They had a third, smaller, peak in arrowweed in June.

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Figure 31. Number of insects in the family Miridae (leaf or plant bugs) captured in various vegetation types by month.

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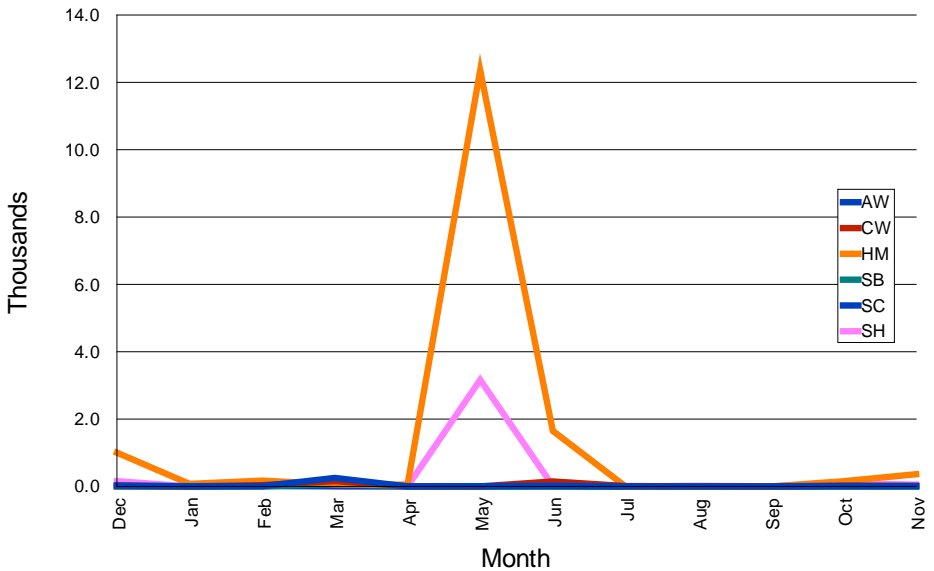


The family Psyllidae is important because it affects revegetation projects that include honey mesquite. On the basis of the bird specimens we collected they are also a dietary item of negligible importance for insectivorous birds. Species in this family reached peak numbers in May in honey mesquite and saltcedar/honey mesquite mixes. This fact suggests that honey mesquite should be planted after May. Psyllids were virtually absent in all other vegetation types (Fig. 32).

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Figure 32. Number of insects in the family Psyllidae (psyllids) captured in various vegetation types by month.

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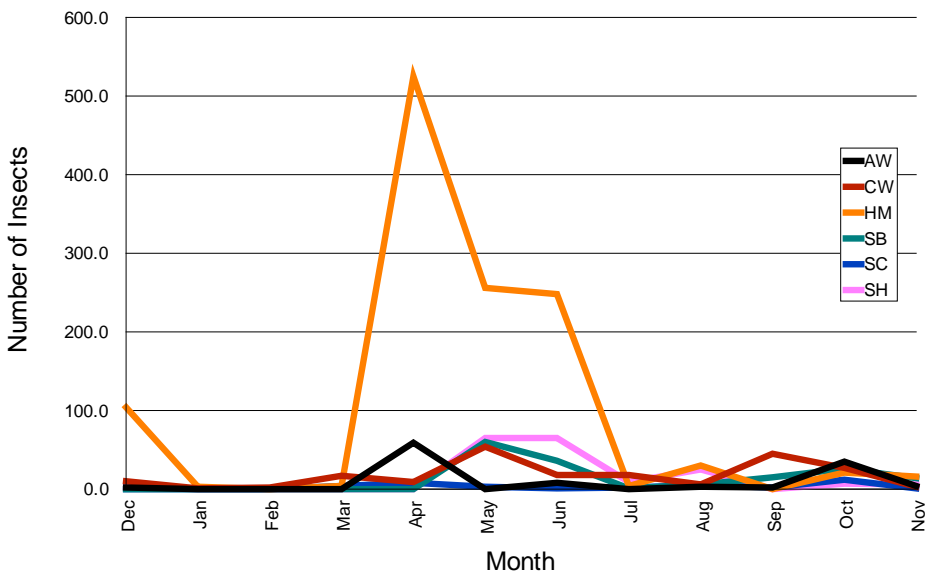


The family Lepidoptera (moths and butterflies) reached peak numbers in April in honey mesquite, but their numbers remained relatively high through June (Fig. 33). This is an important group for insectivorous birds as will become apparent below. Adult lepidopterans were consumed by 7 species; larvae by 19 species; pupae by 2 species.

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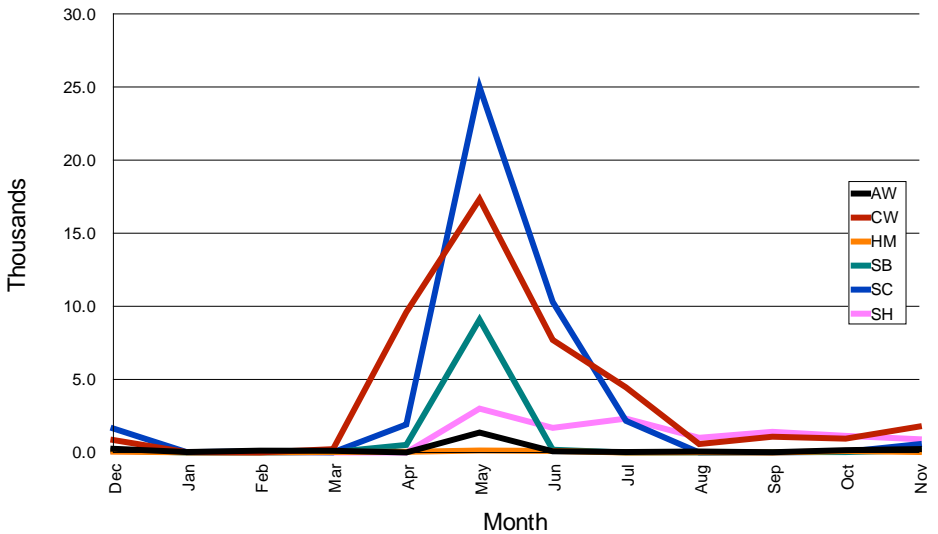
Figure 33. Number of insects in the family Lepidoptera (butterflies and moths) captured in various vegetation types by month.

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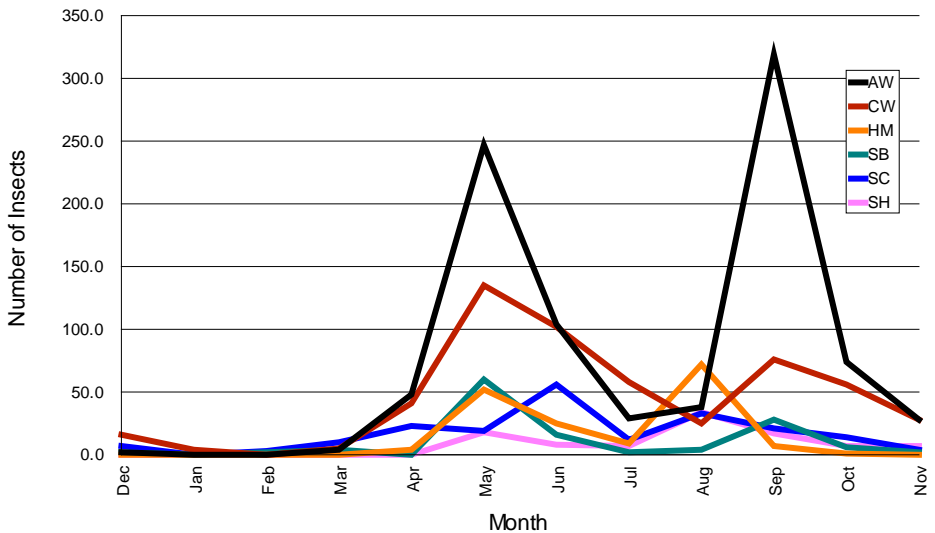
Insects in the family Cicadellidae (leaf hoppers, cicadellids) reached peak densities in May in all habitats, but this group was found in relatively small numbers in saltcedar/honey mesquite, honey mesquite, and arrowweed (Fig. 34). This is a very large group with several species being abundant. Some species are not native to North America. As will be shown below, they are an important dietary item of insectivorous birds. Insects in this family reached peak densities in saltcedar and next greatest in cottonwood/willow. In summer this taxon was found to have been consumed by 12 species.

Figure 34. Number of insects in the family Cicadellidae captured across 6 vegetation types by month.



The order Orthoptera includes crickets and grasshoppers. These insects were found in peak numbers in arrowweed where they had one peak in May and a second peak in September in arrowweed (Fig. 35). They were also relatively abundant in cottonwood/willow in May. Members of this order included some of the largest insects captured. Across all seasons species in the family Acrididae (short-horned grasshoppers), were consumed by 23 bird species, including yellow-billed cuckoo and summer tanager. Crickets were consumed by Bullock’s oriole, western kingbird, and Abert’s towhee in summer; in late summer by blue grosbeak, Abert’s towhee, and western kingbird. Species in the family Grillidae (camel crickets, etc.) were prominent in the diet of the roadrunner.

Figure 35. Number of insects in the order Orthoptera (crickets and grasshoppers) captured across 6 vegetation types by month.



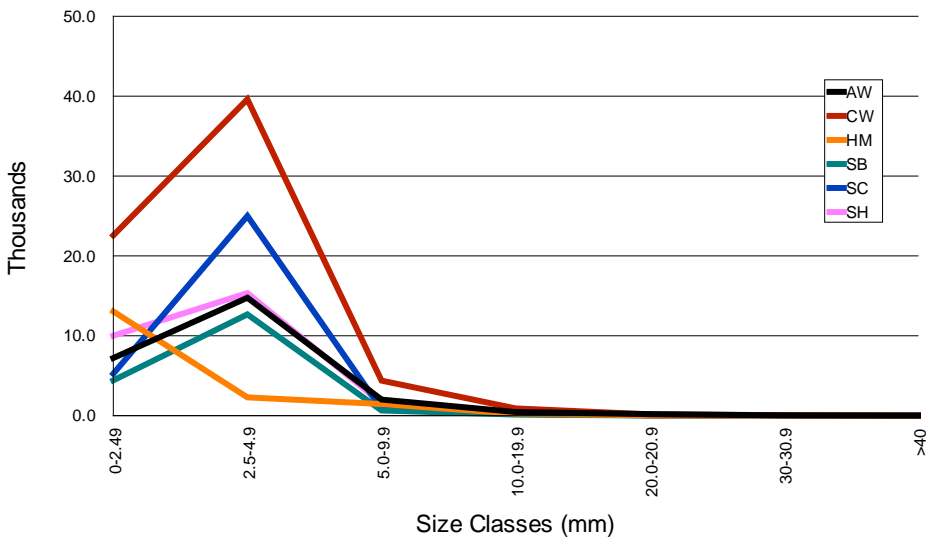
The size of arthropods was also determined. Size can be an important variable with respect to their importance to insectivorous birds. The majority of insects captured in our sampling fell between 2.5 and 9.9 mm. The exception was honey mesquite, where most insects sampled were between 0-2.49 mm (Fig. 36). There were more in this size category in cottonwood/willow vegetation types than in any other.

Aphids, chironomids, curculionids, and mirids were among the families in the smallest size category, while spiders, cicadellids, and lygaeids were in the category 2.5-4.9 mm. Orthopterans were relatively large with many falling in the size categories 5-9.9 mm and 10-19.9 mm.

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Figure 36. Size of insects captured across all months of the study.

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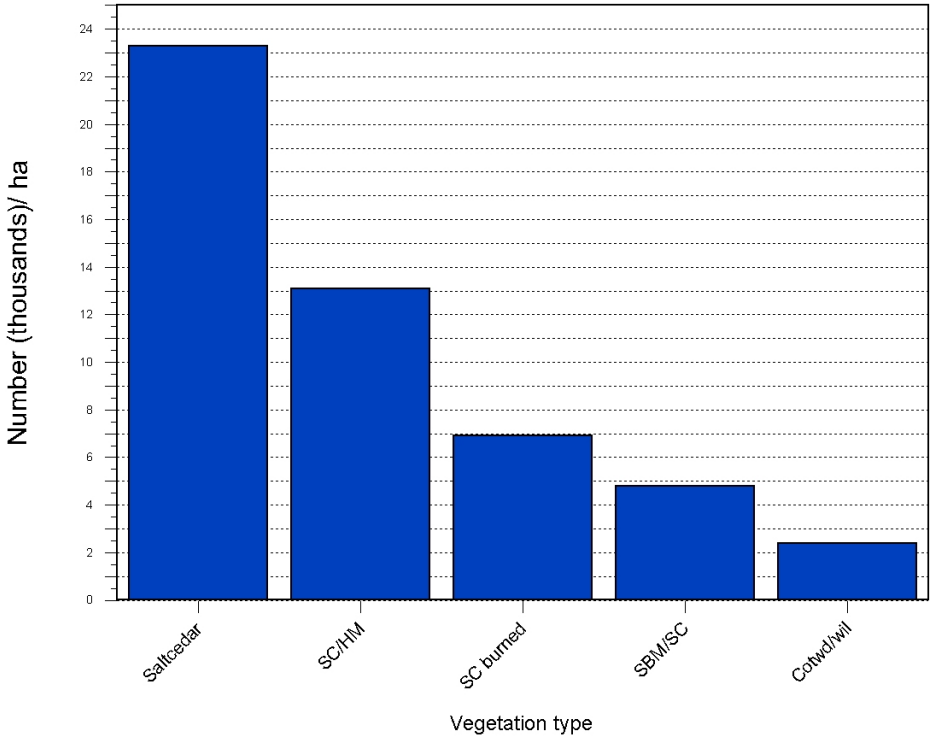


Of all the terrestrial invertebrates found on the lower Colorado River, the Apache cicada ranks as one of the most important food items to birds. This cicada emerges annually beginning in mid-June in riparian vegetation. Tremendous numbers of them were found in the 1970s and 1980s, but my impression is that they might now be declining. Cicada densities were abundant in saltcedar, saltcedar/honey mesquite mixes, screwbean, and cottonwood/willow habitats. The timing of cicada emergence coincides closely with the peak fledging period for many bird species in cottonwood/willow communities. Most breeding birds in cottonwood and willow forage primarily for cicadas.

Interestingly, cicada are most abundant in saltcedar habitats. Glinski and Ohmart (1984) conjectured that saltcedar provides greater surface area for cicada egg-laying because of the intricate branching of leaves compared with that of native riparian trees (Fig 37).

Note: Since writing this report I uncovered additional insect data for some habitat types. Time did not permit re-writing this section, but alterations are mostly a matter of number changes—overall conclusions are little altered by the additional information. A more inclusive re-write will occur in a forthcoming book. (Anderson, in prep).

Figure 37. Number of Cicadas (*Diceroprocta apache*) in 1983 in various vegetation types. SC/HM refers to saltcedar/honey mesquite; sc, saltcedar; sbm/sc, screwbean mesquite/saltcedar; cotwd/wil. Cottonwood/willow.





## AVIAN DIETS

Diets were analyzed on a seasonal basis. The effort focused on the most abundant bird species because it was for these that credible samples could be obtained. Although data were collected over a 3 year period (1976-1980), samples within a season in any given year were likely to be small for a majority of species, precluding meaningful analysis on an annual basis. For this reason samples were lumped across years for each season. Presentation of all of the data would require a book length manuscript, thus here I present only enough data to give a flavor of the overall analyses.

*Winter.* The winter collection included 367 individuals of 14 species. Among these 14 species of insectivorous bird species ants (Formicidae) were consumed by 13 of them (Table 4). Those eating greater than 30% ants are mostly larger species, such as the red-shafted flicker (*Colaptes auratus*). Beetle (Coleoptera) were the second most common in bird diets having been consumed by 12 species. This insect order includes a large number of species—just how many of them occur in the LCR is not known to me. Leaf hoppers (Cicadellidae) were not very abundant in winter, but were nonetheless included in the diets of 7 of the 14 species collected for dietary analysis. Those species that consumed leaf hoppers were very small species (blue-gray and black-tailed gnatcatcher, ruby-crowned kinglet, yellow-rumped and orange-crowned warblers). These species each weigh less than 10 grams.

Moths and butterflies and their eggs, pupae, and larvae are popular bird dietary items. Even in winter lepidopterans were consumed by 9 of 14 species.

In winter there is extensive non-overlap in taxa consumed by the most abundant insectivorous species, just as anticipated if you have recently read an introductory ecology text. The reason for the overlap, according to many ecologists, is that competition for food through time has led to diversification in order to avoid competition for food.



Although this is no doubt true to some extent, all observed differences in diets of species pairs are probably not exclusively due to competition for food. Many dietary differences may have been ancillary developments resulting from, for example, intraspecific competition for mates. It also seems to me that many differences are due to chance developments that have nothing to do with competition. It is also likely in this study that some apparent differences are due simply to accidents of sampling—namely small samples.

The 5 insect taxa included in Table 4 made up, on average, 70.4% of the total diet of these 14 species.

Table 4. Major insect taxa consumed in winter by birds in collected in riparian vegetation in the lower Colorado River valley. Dietary taxa making up significant proportions of diets for the various species are highlighted to show dietary differences among the bird species collected. Cicade refers to Cicadellidae; Lepidop, Lepidoptera; Coleop, Coleoptera; Formicid, Formicidae.

Species	N	Cicade	Lepidop	Coeleop	Formicid	Araneae	Total
Northern flicker	8	0.0	0.0	0.0	<b>100.0</b>	0.0	100.0
Black phoebe	6	0.0	0.0	25.0	<b>57.1</b>	0.0	82.1
Sage thrasher	6	0.0	0.0	<b>43.1</b>	<b>56.9</b>	0.0	100.0
Hermit thrush	8	0.0	10.4	<b>30.4</b>	<b>44.4</b>	0.0	85.2
Abert's towhee	32	2.1	<b>27.0</b>	16.2	<b>44.0</b>	3.0	92.3
Cactus wren	4	0.0	0.0	0.0	<b>40.0</b>	<b>26.0</b>	66.0
Crissal thrasher	12	0.0	<b>23.2</b>	<b>34.8</b>	34.8	0.0	92.8
Yellow-rumped warbler	103	14.7	9.3	13.9	13.9	1.0	52.8
Loggerhead shrike	7	0.0	0.0	<b>36.4</b>	9.0	0.0	45.4
Orange-crowned warbler.	30	<b>19.5</b>	3.5	14.7	5.0	2.2	44.9
Blue-grey gnatcatcher	7	15.8	8.8	12.3	3.5	14.0	54.4
Black-tailed gnatcatcher	39	18.9	8.3	11.1	2.8	3.8	44.9
Ruby-crowned kinglet	56	<b>43.0</b>	0.9	25.7	2.1	7.3	79.0
Verdin	49	1.3	20.7	7.2	0.0	<b>17.0</b>	46.2
Number sp >0 or sum	367	7	9	12	13	8.0	70.4

*Spring.* The spring collection included 301 specimens of 14 species. The 5 insect taxa included in the Table made up 77% of the diets of the species sampled. Among this group all 14 included beetles (Coleoptera) in their diets. Sixty-three percent of western kingbird diet was made up of beetles (Table 5). Hymenopterans (bees, wasp, and ants) were consumed by 12 species; cicadellids by 8 species. Lepidopterans were consumed by 9 of the 14 species.

Table 5. Major insect taxa consumed in spring by birds in collected in riparian vegetation in the lower Colorado River valley. Dietary taxa making up significant proportions of diets for the various species are highlighted to show dietary differences among the bird species collected. Cicadel refers to Cicadellidae; Homop, Homoptera; Hymen, Hymenoptera; Lepidop, Lepidoptera; Coleop, Coleoptera.

Species	N	Cicade	Homopt	Hymen	Lepidop	Coleop	sum
Verdin	38	3.4	<b>35.9</b>	0.7	34.0	14.6	88.6
Crissal thrasher	3	0.0	0.0	<b>58.8</b>	23.5	14.7	97.1
Ash-throated flycatcher	31	0.0	9.1	8.4	<b>39.0</b>	18.7	75.2
Bullock's oriole	9	0.0	0.0	4.8	<b>47.6</b>	19.1	71.4
Abert's towhee	21	4.2	3.6	18.8	<b>38.2</b>	21.9	86.8
Lucy's warbler	30	8.8	11.0	4.4	<b>43.4</b>	23.2	90.8
Black-tailed gnatcatcher	26	<b>10.1</b>	5.9	16.0	16.0	26.9	74.8
Orange-crowned warbler	9	<b>24.6</b>	19.7	18.0	0.0	27.9	90.2
Cactus wren	5	0.0	0.0	2.7	0.0	32.5	35.1
Yellow-rumped warbler	57	6.1	3.7	<b>31.0</b>	9.7	<b>39.3</b>	89.9
Ladder-backed woodpecker	4	0.0	0.0	0.0	8.2	<b>40.8</b>	49.0
Ruby-crowned kinglet	16	2.5	10.0	17.6	0.0	<b>41.9</b>	72.0
Phainopepla	47	1.8	<b>26.3</b>	3.5	0.0	<b>43.9</b>	75.4
Western kingbird	5	0.0	0.0	17.2	0.0	<b>62.5</b>	79.7
No. species>0 or sum	301	8	9	12	9	14	76.85

*Summer.* In summer, data are presented for all species for which samples included 4 or more stomachs. This included 20 species found in riparian habitats. These 20 species accounted for about 75% of all riparian insectivores. Agricultural and marsh species are not included. The major dietary items for these species and the size of prey items are points now discussed.

Since cicadellids are the most abundant insects in the LCR it is of interest to learn that in summer 11 of the 20 major insectivorous

species include this taxa in their diets. (Table 6). Among these species cicadellids accounted for between 2% and 20% of their total diets. Study of the data in Table 6 reveals that there is a significant degree of non-overlap in dietary items among species. Since beetles were consumed by 18 of the 20 species the data in Table 6 are arranged by increasing proportion of beetles. Lucy's warbler and crissal thrasher both consumed over 40% beetles, but Lucy's warbler consumed 11% leaf hoppers and the thrasher consumed none. In addition, the warbler is much smaller than the thrasher and the thrasher forages on the ground and the warbler in trees and shrubs.

Closer dietary similarities are seen for Lucy's warbler and black-tailed gnatcatcher. These 2 small insectivores also consumed leafhoppers and lepidopterans. They also forage similarly in similar habitats. Lucy's warbler occurred in dense saltcedar and honey mesquite habitats to a greater extent than gnatcatchers. It is also perhaps significant that when insect numbers begin to drop at the end of May, Lucy's warblers begin to leave the area. Remember, too, that even though both of these species consume large numbers of beetles, there is an inordinately large number of species in this order; these 2 species could be specializing on different species of beetles that, themselves, use the habitats in somewhat different ways.

The yellowthroat and phainopepla differ from the others in that they ate mostly items other than those listed. The phainopepla consumed berries of mistletoe and wolfberry in addition to insects. When the berries disappear in late May phainopepla leave the area. The 10 species eating cicada are taking advantage of a superabundant food source. Even if cicada presence lasts for only a month or so, they reach peak numbers at a time when other insect populations have crashed. Species of concern such as the gila woodpecker, yellow-breasted chat, and summer tanager, consumed 28% or more cicadas.

Table 6. Major insect taxa consumed in summer by birds in collected in riparian vegetation in the lower Colorado River valley. Dietary taxa making up significant proportions of diets for the various species are highlighted to show dietary differences among the bird species collected. Cicade refers to Cicadellidae; Lepidop, Lepidoptera; Coleop, Coleoptera; Orthop, Orthoptera.

Species	N	Cicade	Cicada	Lepidop	Coelop	Orthop	Sum
Yellow-breasted chat	4	0.0	<b>40.0</b>	0.0	0.0	20.0	60.0
Yellow-billed cuckoo	6	0.0	<b>33.3</b>	6.1	0.0	<b>60.6</b>	100.0
Abert's towhee	41	2.9	20.4	15.5	2.9	14.6	56.3
Song sparrow	6	<b>16.1</b>	0.0	9.7	3.2	0.0	29.0
Cactus wren	11	0.0	0.0	19.6	3.3	0.0	22.9
Verdin	86	7.8	0.0	<b>55.1</b>	4.1	0.0	67.0
Bullock's oriole	47	0.0	24.7	<b>30.2</b>	4.3	19.2	78.4
Phainopepla	14	11.1	0.0	16.7	5.6	0.0	33.4
Yellowthroat	7	6.3	0.0	0.0	6.3	0.0	12.6
Northern roadrunner	7	0.0	8.4	0.0	7.5	<b>41.8</b>	57.7
Blue grosbeak	16	1.6	<b>40.0</b>	8.6	8.6	28.6	87.4
Gila woodpecker	15	0.0	<b>56.6</b>	0.0	11.1	0.0	67.7
Summer tanager	7	0.0	28.6	0.0	14.3	14.3	57.2
Brown-crested flycatcher	11	0.0	<b>41.9</b>	0.0	19.4	9.7	71.0
Lesser nighthawk	21	<b>14.5</b>	8.4	6.8	21.2	0.0	50.9
Ash-throated flycatcher	84	<b>20.0</b>	20.0	14.1	21.6	3.2	78.9
Black-tailed gnatcatcher	65	<b>14.2</b>	0.0	22.0	<b>33.0</b>	0.3	69.5
Western kingbird	23	2.1	12.5	6.2	<b>35.4</b>	18.8	75.0
Lucy's warbler	37	11.2	0.0	22.8	<b>41.8</b>	0.0	75.8
Crissal thrasher	10	0.0	0.0	18.4	<b>47.4</b>	0.0	65.8
No. species>0 or sum	518	11	13	13	18	11.0	60.8

*Late summer.* In late summer (August and September) 145 specimens of 12 species were collected for dietary analysis. Again, beetles were consumed by most species, in this season by 11 of the 12 species represented. However, again there is significant non-overlap in diets and or in the method of foraging (Table 7). For example, the crissal thrasher and northern mockingbird both consumed more than 40% beetles, but the former forages on the ground and the latter in trees. The animal portion of the diet of Gambel's quail included 63% beetles as did that of the lesser nighthawk, but the 2 species obviously feed in

different way and, in addition, quail consume primarily plant material. Lesser nighthawk and Wilson's warbler both consumed significant numbers of beetles, but this pair forage differently, the nighthawk being a crepuscular aerial forager while the warbler forages at low levels of vegetation in daylight.

Leaf hoppers (Cicadellidae) were consumed by 4 species and were a major dietary item of the black-tailed gnatcatcher and Wilson's warbler, but the Wilson's warbler diet included 56% Hymenoptera and Coleoptera, but these taxa were not represented in the diet of the gnatcatcher.

Table 7. Major insect taxa consumed in late summer by birds in collected in riparian vegetation in the lower Colorado River valley. Dietary taxa making up significant proportions of diets for the various species are highlighted to show dietary differences among the bird species collected. Cicade refers to Cicadellidae; Homop, Homoptera; Hymen, Hymenoptera; Lepidop, Lepidoptera; Coleop, Coleoptera.

Species	N	Other					sum
		Cicade	Homop	Lepido	Hymen	Coleop	
Black-tailed gnatcatcher	8	<b>39.1</b>	8.7	13.0	0.0	0.0	60.9
Abert's towhee	8	0.0	<b>18.2</b>	0.0	22.7	4.6	45.5
Gambel's quail	50	8.8	16.3	0.0	<b>62.5</b>	6.3	93.8
Verdin	14	0.0	13.0	<b>50.0</b>	0.0	10.4	73.4
Western kingbird	33	0.0	33.3	13.3	24.8	10.5	81.9
Yellowthroat	3	0.0	0.0	8.3	0.0	16.7	25.0
Song sparrow	8	0.0	0.0	12.8	16.7	22.6	52.0
Lesser nighthawk	5	1.5	4.4	5.1	<b>63.0</b>	24.6	98.6
Wilson's warbler	4	<b>19.4</b>	2.8	5.6	<b>30.6</b>	25.0	83.3
Ash-throated flycatcher	5	0.0	15.8	<b>26.3</b>	0.0	26.3	68.4
Crissal thrasher	3	0.0	8.3	0.0	12.7	<b>42.3</b>	63.4
Northern mockingbird	4	0.0	0.0	0.0	<b>35.0</b>	<b>55.0</b>	90.0
No. species >0 or sum	145	4	9	8	8	11	69.7

*Fall.* In fall we collected 424 specimens of 11 species in riparian habitats. One major change from previous seasons is that, although beetles were consumed by 10 of the 11 species, butterflies and moths were also consumed by 10 species (Table 8). Sage sparrows, white-crowned sparrows, and Gambel's quail consumed much plant material in addition to animal matter. Two similar-sized species, yellow-rumped warbler and orange-crowned warbler, both consumed significant numbers of lepidopterans (moths and butterflies). The orange-crowned warbler stomachs contained 25% beetles, but this taxon accounted for only 9% of the diet of the yellow-rumped warbler. In addition the orange-crowned warbler specimens had consumed 14% leafhoppers, but this taxon accounted for only about half of that amount for yellow-rumped warbler specimens.

Table 8. Major insect taxa consumed in fall by birds in collected in riparian vegetation in the lower Colorado River valley. Dietary taxa making up significant proportions of diets for the various species are highlighted to show dietary differences among the bird species collected. Cicade refers to Cicadellidae; Homop, Homoptera; Lepidop, Lepidoptera; Coleop, Coleoptera; Hymen, Hymenoptera.

Species	N	Other					sum
		Cicade	Homopt	Lepido	Coleop	hymeno	
Sage sparrow	31	0.00	0.00	0.00	<b>100.00</b>	0.00	100.00
Ruby-crowned warbler	32	12.94	<b>28.16</b>	2.91	<b>43.04</b>	2.58	89.63
White-crowned sparrow	90	6.75	<b>23.60</b>	5.08	5.47	<b>55.05</b>	95.95
Gambel's quail	158	5.36	3.57	7.15	1.79	<b>69.64</b>	87.51
Black-tailed gnatcatcher	18	<b>25.88</b>	10.59	<b>15.29</b>	<b>29.41</b>	9.42	90.59
Verdin	22	0.63	<b>72.40</b>	<b>18.38</b>	0.00	0.08	91.49
Orange-crowned warbler.	14	13.70	<b>22.75</b>	<b>18.87</b>	<b>25.33</b>	3.11	83.76
Abert's towhee	6	<b>18.37</b>	4.08	<b>20.40</b>	2.04	8.16	53.05
Yellow-rumped warbler	35	6.85	<b>28.77</b>	<b>30.14</b>	9.13	10.86	85.75
Crissal thrasher	15	0.00	0.00	<b>40.00</b>	13.33	13.33	66.66
Northern mockingbird	3	0.00	<b>36.59</b>	<b>40.65</b>	4.07	2.44	83.75
No. species>0 or sum	424	8	9	10	9	10	84.38

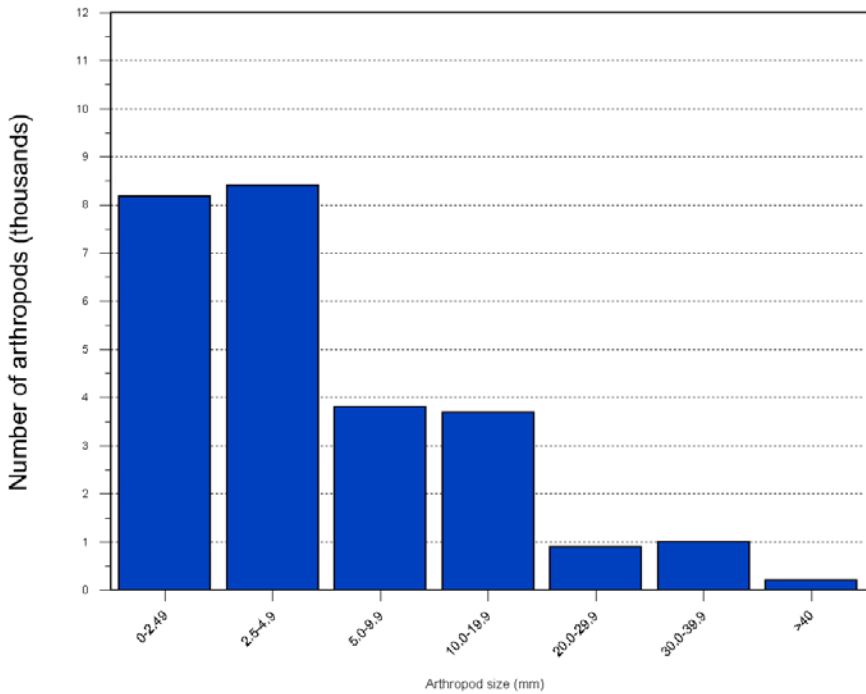
### Size of Dietary Items

It was shown in Fig. 36 (p. 73) that the predominant size of insects in the insect collections was 0-4.9 mm. This is also the predominant size of insects in the diets of riparian birds in summer (Fig. 38). This is also true for other seasons.

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Figure 38. Size of insects eaten by insectivorous birds.

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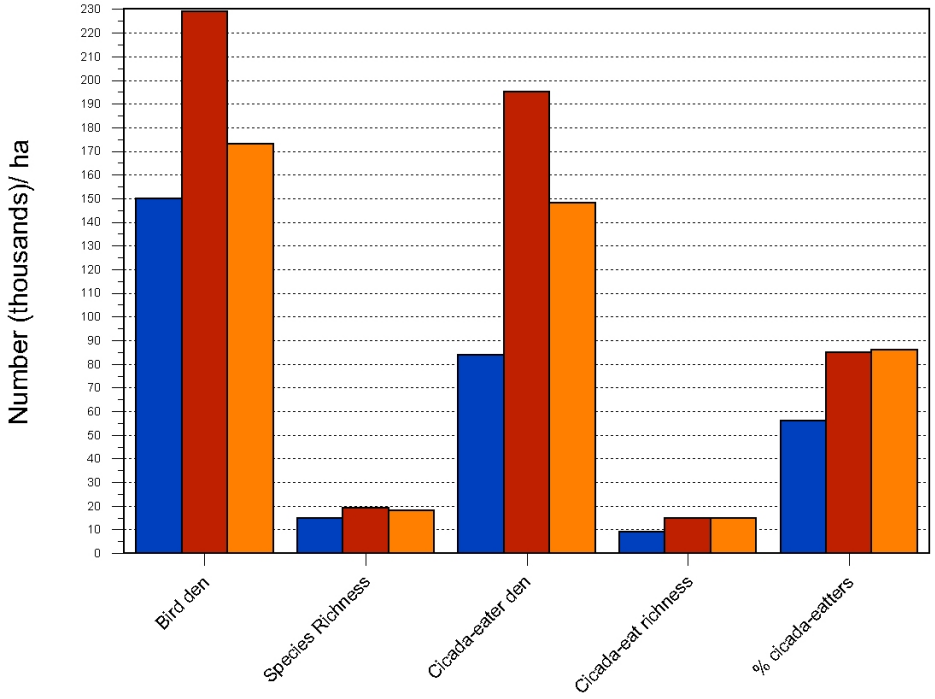


### **Cicadas, Fire, and Insectivorous Birds**

It was shown above that saltcedar habitat had a multitude of cicada (*Cicada diceroprocta*). In 1982 fire burned a 30 ha SC3 habitat on the Cibola NWR. We had bird density and diversity data before the fire and we decided to see what the effect of fire might have on the density of cicada-eating birds. In the summer after the fire the total number of species in summer in this area increased from 15 to 19 species and cicada-eating species rose from 9 to 15 species (Fig. 39). Prior to the fire the bird density was 150 birds. In the first year after the fire the density rose to 229 birds. Much of this increase was due to the increase in cicada-eating birds which rose from 84 to 195. As the saltcedar began to recover from this fire the number of birds began to again decrease. In the second season after fire there were 173 birds, a decrease of about 24%, but this was still 15% greater than the year before the fire. The density of cicada-eating birds decreased from 195 to 148—a decrease of 24% relative to the first year after fire, but it was still 76% greater than in the year before the fire. Many of the birds that feed on cicada are rare or absent in saltcedar. However, after saltcedar stands burn, the emerging cicada attract many bird species which become abundant in the burned habitat.



Figure 39. Cicada eating birds in saltcedar before and after fire.



## AUTECOLOGICAL STUDIES OF PLANTS

One feature of the LCR riparian vegetation is that it is patchy. If we were to define habitats on the basis of dominant vegetation we would have to incorporate some measure of patchiness into our scheme. For this reason I developed the patchiness index (Anderson and Ohmart 1986a). The reason for this patchiness is probably related to the horizontal variation in soil characteristics including soil moisture, soil density, and salinity. The variation is exemplified by that found on a plot of about 40 ha on the Cibola NWR (Fig. 40). The suitability of the soil on that plot for various native plant species is based on differences in the soil salinity, depth to the water table, and soil texture. We studied the effects of these variables on growth and survival of Cottonwood, Goodding willow, sandbar willow, screwbean mesquite, honey mesquite, quibush, four-winged saltbush, desert holly, allscale, wolfberry, inkweed, pickleweed, Emory baccharis, fan palm, arrowweed, and saltcedar in the LCR valley. Three specific examples of these sorts of data will be discussed here (Anderson, Russell, and Ohmart 2004, Anderson 2012, In prep.).

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Figure 40. Map of an area of about 40 ha located on the Cibola National Wildlife Refuge. The suitability for various species of native vegetation is based on the tolerance of these species of soil texture and salinity, and depth to the water table. Cottonwood/willow, for example, are least tolerant of soil salinity.

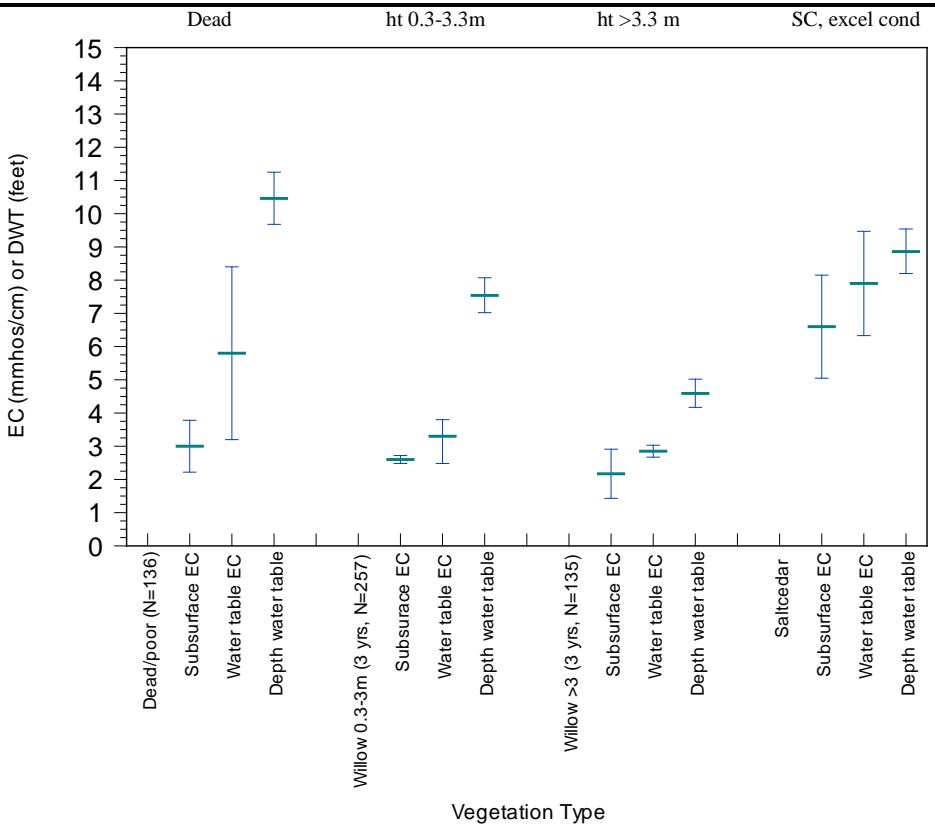
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Goodding willow were found to be particularly sensitive to the depth from the surface to the water table and to soil salinity (Anderson 2012). In a project where Goodding willow were planted where the

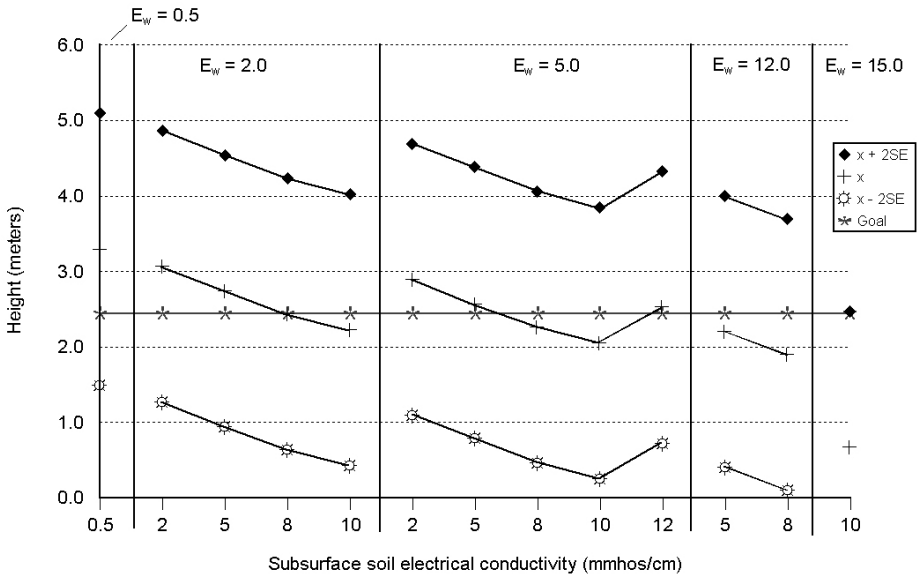
depth to the water table was more than 3 m and soil and water table salinity levels were greater than 3.0 mhos/cm 136 trees were dead or near dead after 3 years even with irrigation at about 30 liters per day (Fig. 41). In a second group where height after 3 years was 0.3-3.3 m depth to the water table was nearly 2.4 m; electrical conductivity (ec) levels were marginal, but significantly lower than in the previous group. In the final group where ec levels were about the same, but DWT was reduced to about 1.5 m growth for 136 trees was > 3 m at the end of 3 years. In contrast, 139 saltcedar that were randomly selected throughout the LCR and which seemed to be thriving (condition judged to be good or excellent), the subsurface ec was more than 7 mmhos/cm and DWT was more than 2.7 m. This indicates the relatively great ability of saltcedar to tolerate conditions that willow cannot tolerate. Unfortunately about two-thirds of current riparian zone is unsuitable for Goodding willow and cottonwood (Anderson 1995). Across 9 drainages in the arid southwest with a sample of 4,714 data points only about 20% were below the threshold of tolerance for cottonwood/willow, 50% for screwbean, 43% for honey mesquite, but 80% for saltcedar (Anderson 1995). This estimate does not include land currently under agriculture where conditions are distinctly better with respect to soil salinity levels, although DWT is still a major problem. This problem can possibly be overcome with irrigation in perpetuity, but even then salts may accumulate if irrigation is not accompanied by leaching

Figure 41. Conditions involving 3 groups Goodding Willow. Tree height for these trees is given at the top of the graph. Conditions for a sample of 149 randomly selected saltcedar trees in the lower Colorado River valley are shown for comparative purposes. SC refers to saltcedar; excel. cond., excellent condition



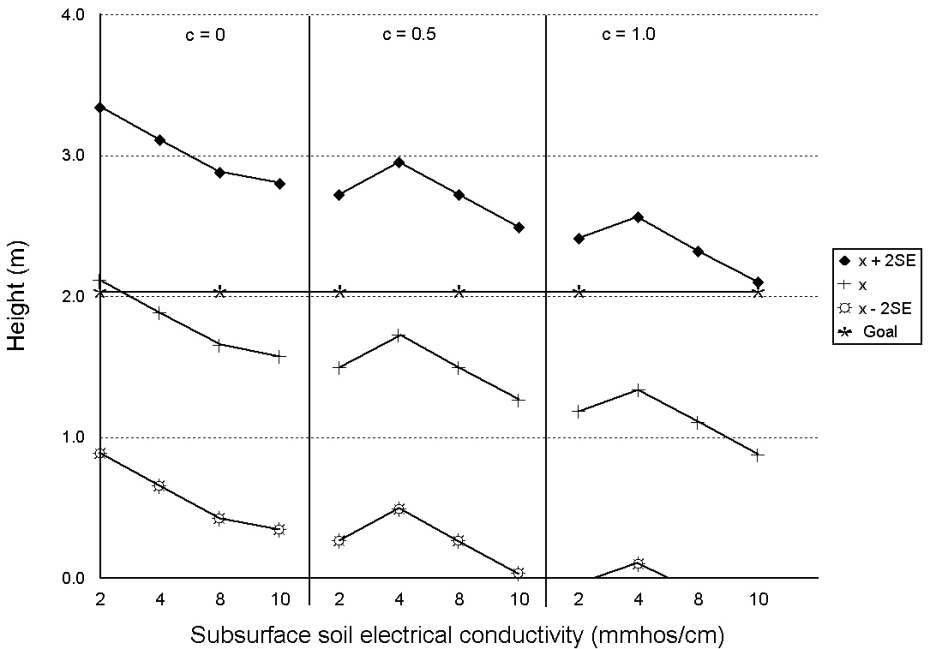
Screwbean mesquite are usually found growing in sandy areas. In such areas salinity levels tend to be lower than in denser soils (Anderson 2011, p. 75). Although water penetrates sand very well and there is little or no loss by capillary action, with limited precipitation and lack of flooding to recharge this soil type with water, it becomes deficient in soil moisture relatively quickly. The lack of soil moisture can limit growth of species such as screwbean. With the passage of time salinity levels have increased, even in sandy areas so that in addition salinity levels as well as low soil moisture may curtail the growth of screwbean. Growth is best when salinity levels are low. If a goal height after 3 years is 2.6 m we see that average growth begins to fall below this level at ec levels between 5 and 8 mmhos/cm (Fig. 42) in subsurface soil and 5 mmhos/cm at the water table.

Figure 42. Growth of screwbean mesquite under varying electrical conductivity levels in the subsurface soil and at the water table. X refers to the mean.



Honey mesquite will grow in denser soils than screwbean and this species probably has greater tolerance of dry soil conditions. In addition to salinity tolerance we also evaluated the effects of competition from weeds. If we assume that a goal of 2 m after 3 seasons of irrigation is desirable then we see that in a competition free environment average growth after 3 years begins to fall below this level when ec levels are between 3-5 mmhos/cm (Fig. 43). With moderate or severe competition from weeds such as Bermuda grass, height is less than 2 m even when salinity levels are low.

Figure 43. Relationships between subsurface soil electrical conductivity levels and competition from weeds ( $C$ ) with growth of honey mesquite in the first 3 growing seasons. The goal height of about 2 m is a typical goal on many projects for this species after 3 growing seasons. As the mean calculated height associated with the stated conditions drops further below the goal the odds of achieving the goal become increasingly slender. When  $C=0$ , no competition; 0.5, intermediate competition; 1, extensive competition.

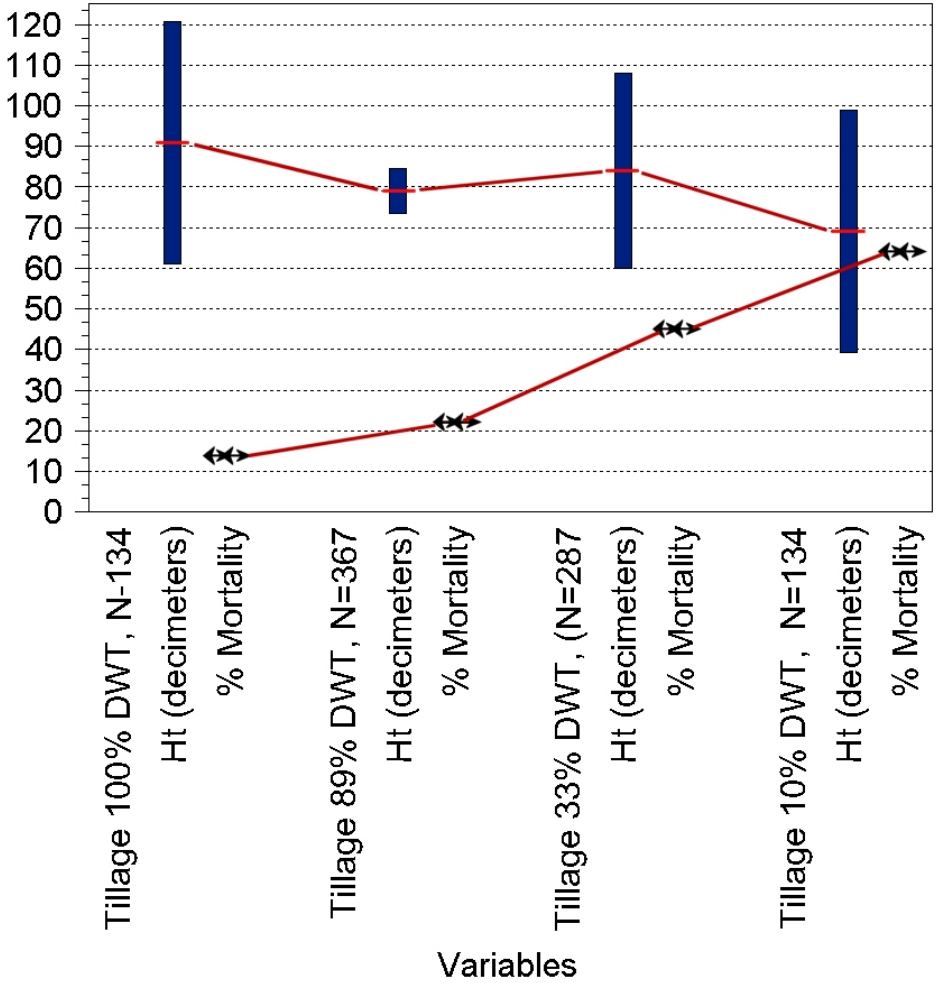


In addition to the response of trees to autecological variables found in the riparian zone we were also interested in studying the effect of deep tillage on growth. In about 1979 it was pointed out to us by several people, namely Les Ead and Dr. Jule Meyer, University of California Agricultural Extension Service, that tillage facilitated deep penetration of roots. The physics of water flow through soil was clearly explained in an article by Shoji (1977) and he made it clear that water added to the surface will spread laterally before filtering through a newly encountered soil layer, even if the second layer is less dense than the soil just penetrated. Since roots follow water (they don't go to water through dry soil.), they, too, will spread laterally when a soil layer is encountered. These advisors recommended deep tillage. We asked how deep we should till? They responded that they didn't know, so we conducted experiments to find out.

To investigate this question we had 4 major groups of cottonwoods: those with tillage 100%, 89%, 33% and 10% of the distance from the surface to the water table, where the water table fluctuated around 3 m below the surface. These trees were irrigated at a rate of 32 gallons per day from March through October for 2 growing seasons. Here I report on results obtained 6 years after irrigation stopped. The height of live trees at this time was 9.1 m, 7.9 m, 8.4 m and 6.9 m, for the 4 groups, respectively (Fig. 44). The difference in height of live trees between several of those involved in pairwise comparisons is statistically significant. Those with the deepest tillage were tallest (9.1 m) and those with tillage only 10% of the total distance from the surface to the water table were shortest (6.9 m, Fig. 44). But it is the differential in mortality that is most striking. Those with tillage to the water table had suffered 14% mortality in the 8 year growing period; those with tillage only 10% of the distance to the water table displayed a 64% mortality rate. The relationship between tillage expressed as the percent of the surface to water table distance is nearly a straight line (Fig. 34).



Figure 44. Effects of depth to the water and tillage on growth cm of cottonwood about 8 years after irrigation stopped. The data represent the mean (horizontal red bar) with 2 standard deviations of the mean (blue vertical bars).



## **ARE SCREWBEAN DISAPPEARING?**

In 2004 our attention was drawn to a site in which screwbean trees that we had planted seemed to be dying. We were surprised at this because a significant portion of the trees had been planted where it was only about 1.5 m to the water table, salinity levels were relatively low and the soil was sandy. On the rest of the site conditions were the same except for DWT which averaged about 3 m. However, reasonably vigorous, healthy looking screwbean were already established on a portion of this site, thus we were optimistic about the odds that our planted screwbean would perform satisfactorily. In fact these trees were planted for a mitigation project and they passed the 5-year height and survival requirements. When we observed this situation about 7 years after planting, not only were the trees doing poorly where the distance to ground water was greatest, but those planted closer to the water table were also apparently dying. Further observation revealed that the indigenous screwbean on the site were less than verdant and were also dying.

Since we had just planted about 4,000 screwbean for a project not far away, we were very much concerned about what we had just observed. In spring 2005 we noticed that some of the established screwbean on this site looked less than healthy, the leaves displaying a distinctly yellow color. At first we thought that the roots of the sickly looking trees had been damaged by the bulldozer blade at the time of clearing. Soon, however, we began to notice many other screwbean unaffected by the clearing process were developing these yellowish colored leaves. By mid-summer we knew that something was drastically wrong.

In the vicinity of our planting site there were thousands of indigenous screwbean. By mid-summer in 2005 many of them looked obviously afflicted with something. A pattern was becoming apparent. First they would acquire the tell-tale yellowish color (Fig. 45), and then they would degrade, often rapidly; sometimes they declined slowly, but inexorably.

The affliction was unevenly distributed across stands of screwbean; one would look very bad while the adjacent tree looked reasonably good (Fig. 46), but as the season progressed the healthier looking trees also deteriorated. Strangely, in some stands the decline was faster and evenly distributed, but in other stands decline was slower and more patchy in distribution.



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Figure 45. Once screwbean show the tell tale yellow leaf color (photograph) they typically degrade rapidly over two-three months.

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Figure. 46. In both of these photographs the screwbean mesquite on the left appear more or less normal or lightly infected, while those on the right are seriously affected. These photographs were taken in June 2006; by September 2007 the screwbean on the left had an appearance similar to those on the right.

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The effects of this malady on the ecosystem are at least two-fold. Screwbean are often parasitized by mistletoe (*Phoradendron californicum*) (Fig. 47). While this parasitism seems to be well tolerated by the screwbean, it (the mistletoe) adds an additional dimension to the vegetation that is attractive to a significant array of birds, namely frugivorous species. But as the screwbean degrade the mistletoe tends to die, thus we see a two-pronged assault on the ecosystem. One tree produced 18 kilograms of pods in 2006, but none in 2007 and by 2008 it was dead (Fig. 47). This tree was also quite heavily infested with mistletoe.

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Figure 47. Screwbean mesquite is often a home for mistletoe (*Phoradendron californicum*). This parasite provides fruit for frugivorous species. Since the mistletoe also dies as the tree dies, frugivorous birds will be negatively impacted. This particular tree produced 18 kilograms of pods in 2006, but no pods in 2007.

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By 2006 it seemed that the handwriting was on the wall—our 4,000 recently planted screwbean were in jeopardy. Throughout the 2006 season they weathered the onslaught (Fig. 48), but by 2007 it was clear that the results would be devastating. Although some of them as of 2011 still have some live limbs the screwbean that we planted look much like the tree in Fig. 47.

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Figure 48. Screwbean planted for revegetation projects typically do not become afflicted in the earliest years. The photograph shows screwbean in June of their third growing season in 2006. By August of 2007 they had an appearance similar to afflicted trees in Fig. 45.

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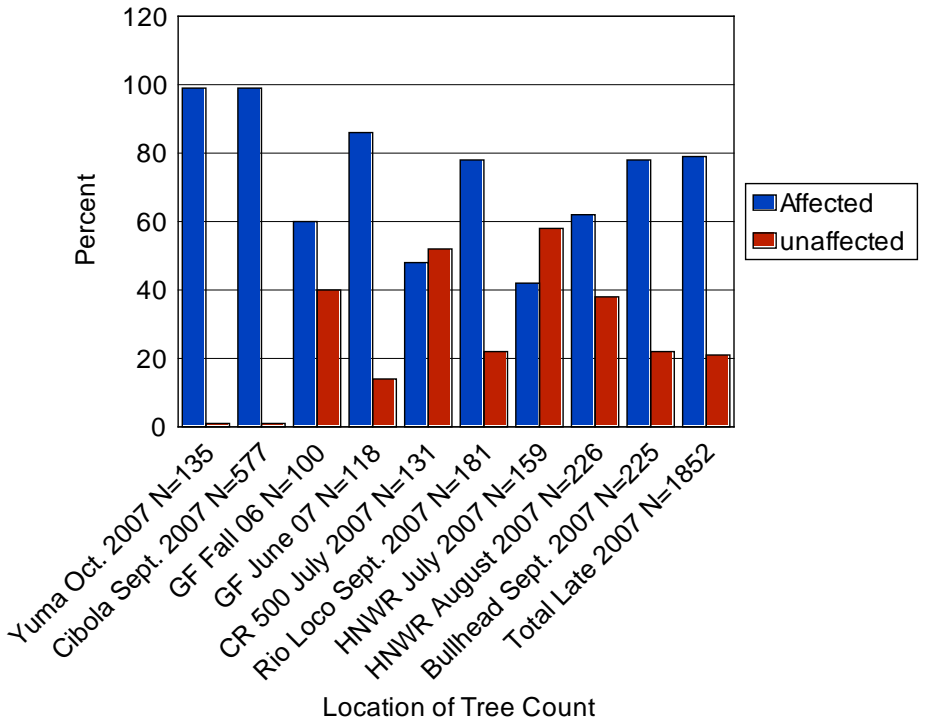
The apparent demise of screwbean in the Blythe area prompted me to make a survey on a larger scale. I have long been familiar with many stands of screwbean from Davis Dam to the border with Mexico so I decided to make observation throughout the LCR. The findings were interesting and grim. Apparently this malady started in the south because virtually all of the screwbean in the Yuma area were afflicted in 2007. The picture was similar in Cibola. On the Cibola NWR I found a

couple of small stands that had been a part of revegetation projects that were still not fully afflicted, but all of the indigenous stands that I was familiar with were in sharp decline (Fig. 50). I skipped over the Imperial National Wildlife Refuge and now I am told that the trees there are relatively unaffected, but I have not verified this. Only a few kilometers north of the I-10 Bridge across the Colorado River at Blythe I found in 2006 that about half of the trees were affected. This changed dramatically with 90% or more affected in that area by 2007. About 30 km north of Blythe (Rio Loco) 80% were afflicted in 2007 and I have not visited that site since then. In the Bullhead City area nearly 80% were affected in September 2007. Overall just under 80% of the screwbean that I surveyed in the LCR were affected.

I believe that screwbean revegetation types-2, -3, and -4 are now extinct in the LCR. Some stands may still be called SB5 or -6 in areas where most of the trees have died thus reducing the overall foliage density and height but those that remain are affected and the higher limbs have died. Fortuitously I started censusing birds in one area in 2005 before the malady became visually manifest. These areas were censused 3 times per month starting in December 2004 through 2005 and then 3 times per month from December 2007 to the present. These data are not fully analyzed at this point, but some highlights are presented below.

We should now be collecting and propagating seeds in greenhouses from the still extant screwbean. These trees may have a modicum of genetically based resistance to whatever this strange malady might be. We should also be conducting plant pathological studies involving this disease.

Figure 50. Proportion of affected and unaffected trees on 9 occasions at 7 different locations along the lower Colorado River. GF refers to Goose Flats; CR 500 is the name of a development project east of Blythe, California, and HNWR refers to the Havasu National Wildlife Refuge. Rio Loco is located about 40 km north of Blythe. See Fig. 1.





### **Effect of Screwbean Demise on Some Bird Species**

The decrease of Lucy's warbler in screwbean type 2 has been rather dramatic (Fig. 51). This species is a rather early arrival becoming relatively numerous by the end of March. They immediately become territorial, produce young, and are largely gone by the end of June.

Densities of Lucy's warbler in screwbean type 2 prior to infection was 25.3 birds per 40 ha in spring 2005. By 2011 this had decreased to 5 per 40 ha with none having been detected in 2010 (Fig. 51). Their densities in summer had decreased by 95% according to the comparative data collected in the same area. However, the census area is rather small (<20 ha) and in such small areas it is possible to get ballooned population estimates. In the decades of the 70s and 80s Lucy warbler densities were 14.1 per 40 ha with an error rate of 2.3. This result, based on censuses conducted over a 6 year period, still indicates a loss of 80% after subtracting 2 times the error rate from the mean. Reduction of Lucy's warbler numbers in screwbean type 4 in the area was more extensive.

In screwbean type 4 the density estimate of Lucy's Warbler in spring 2005, before any extensive affliction of screwbean, in spring was 15.5 birds per 40 ha. In contrast in 2011 the density was 0 (Fig. 52). In summer 2005 the density estimate was 69.4 per 40 ha, which seems high. The census results from 3 decades earlier indicated a mean population level of 12.2 per 40 ha with an associated error estimate of 2.5 birds per 40 ha. These data were the result of a decade-long censusing effort (1975-1983). A population level of 1.4 per 40 ha in 2011 indicates a loss of 89% relative to the earlier 10 year results and a loss of 98% relative to 2005. We could ignore this, but would that be a wise decision?

Figure 51. Lucy's warbler densities before and after death of screwbean mesquite in Screwbean mesquite type 2 in spring (spr, left) and summer (su).

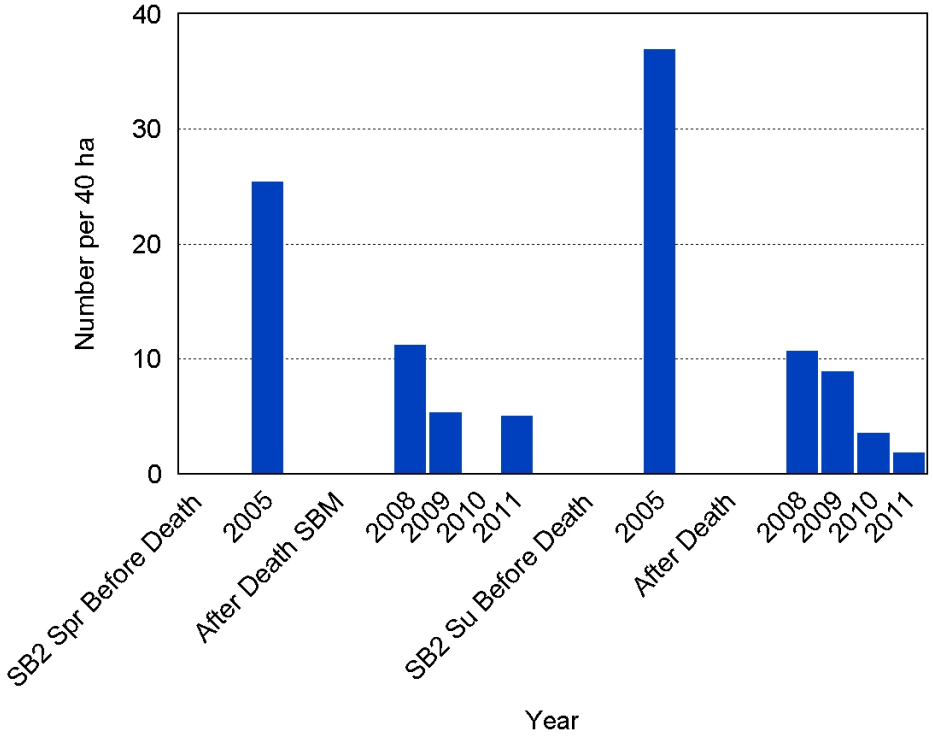
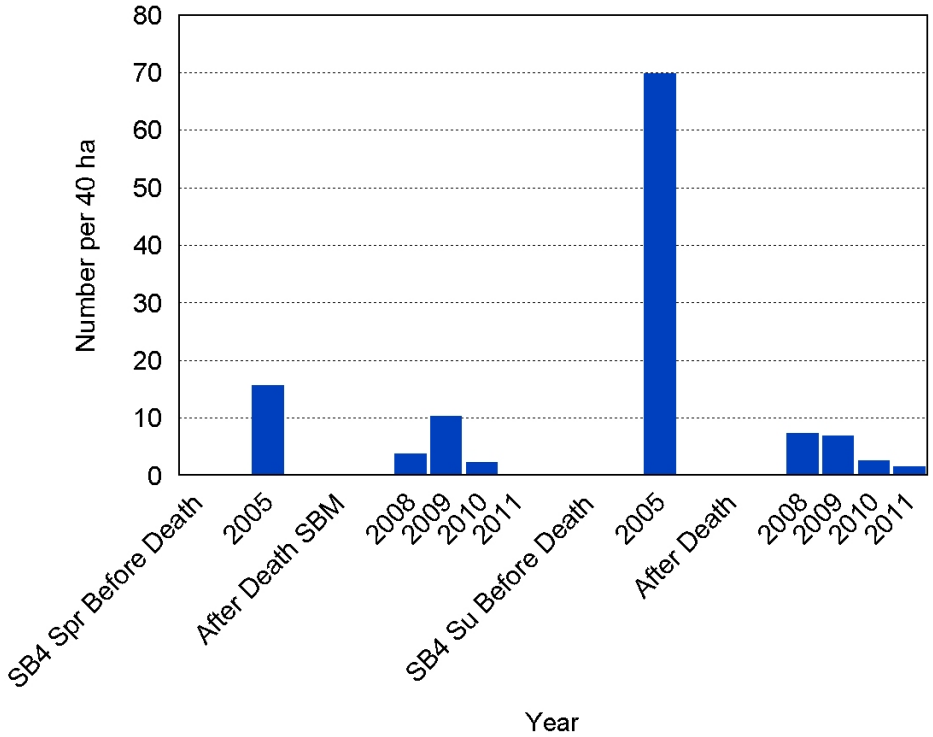


Figure 52. Lucy's warbler before and after death of screwbean mesquite in Screwbean type 4 in spring (spr, left) and summer (su)



Unfortunately Lucy's warbler is not the only species that has declined in these stands of screwbean mesquite. The density of verdins (*Auriparus flaviceps*) dropped from 10.1 per 40 ha in screwbean type 2 in spring 2005 to 8 in 2008 to 5.3 in 2009 to none in 2010 and 2011 (Fig. 53).

This indicates a decrease of over 50% considering the observed mean. Subtracting 2 standard errors from the mean obtained 3 decades earlier we get a density estimate of 7.8 birds per 40 ha, still a decrease of about 42%. In summer in SB 4 (Fig. 54) the verdin density was estimated to be 45.6 per 40 ha, this decreasing to 3.6 in 2009 and 2010, but rebounding slightly to 7.2 in 2011. This indicates a loss of about 84%. Three decades ago the estimate was 19.6 birds per 40 ha over a decade of censusing. The error rate was 3.8 per 40 ha. This indicates rather large variance for this species, but this might be expected since it was found to not be socially regulated (Anderson and Ohmart and Fretwell 1982). Non-socially regulated species are controlled by population levels relative to resource availability. Population fluctuations are greater in lean years and less in years of resource abundance. Even with the most optimistic information from these data, i.e. 19.6 birds per 40 ha minus 7.68 to get the density estimate at minus 2 standard errors, we obtain 11.9 birds per 40 ha. This would still suggest population reduction of 35%.

Figure 53. Decreases in verdin populations corresponding to the death of screwbean mesquite type 2 in spring (spr, left) and summer (su).

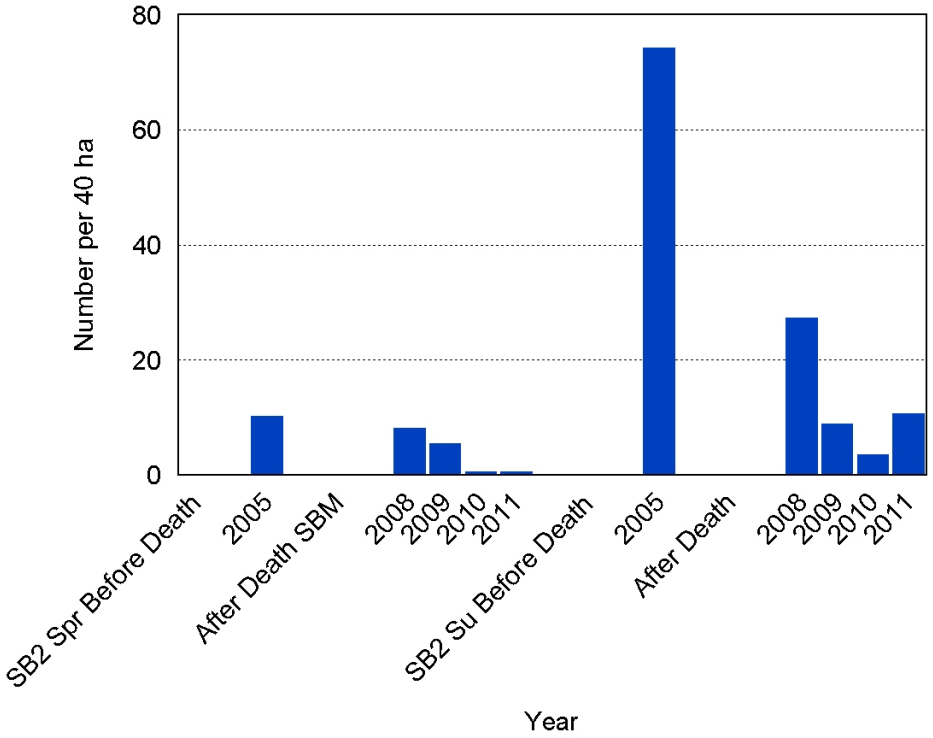
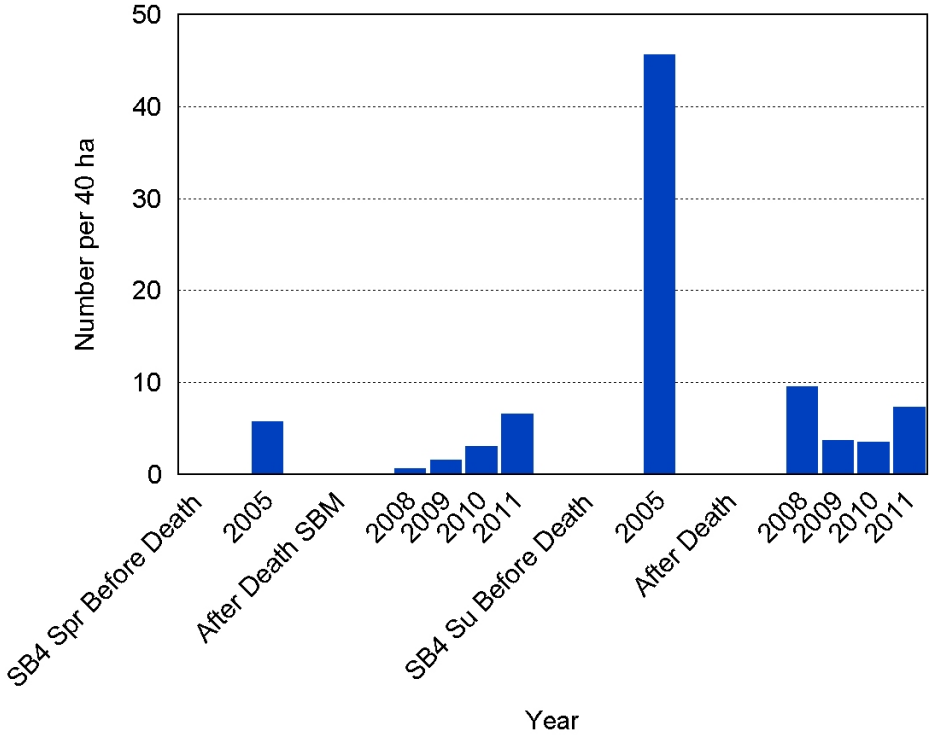


Figure 54. Decreases in verdin populations corresponding to the death of screwbean mesquite type 4 in spring (spr, left) and summer (su).



A similar decrease was observed for the black-tailed gnatcatcher (*Polioptila melanura*). In SB2 in spring black-tailed gnatcatcher was 5 in 2005 and in spring 2008 but was less than 1.0 in 2009-2011—a decrease indicating a decrease of at least 90% (Fig. 55). In summer the density was 12.5 in 2005, but decreased by 75% in 2008, 2009, and 2011 and by 86% in 2010.

In screwbean type 4 the observed density in spring 2005 was 5.6 per 40 decreasing to none in 2008 but rebounding thereafter to 1.5 in 2009, 2.9 in 2010 and 6.5, an increase of 16%, in 2011 (Fig. 56). Again resorting to the data from 3 decades earlier we find that the density then was 9.8 with an error estimate of 1.0 bird per 40 ha. The black-tailed gnatcatcher density estimate in screwbean 4 in 2005 was 14.4 birds per 40 ha. This compares quite well with the estimate, obtained 3 decades earlier, of 12.5 (se 2.0) birds per 40 ha. Their numbers dropped to 5.8 in 2008, rebounded to 9.6 in 2009, dropped to 2.4 in 2010 and registered 8.1 in 2011. Even the higher figure of 8.1 per 40 ha in 2011 suggests a loss of 44%. Using the mean obtained from decades earlier a loss of 35% is indicated.

Figure 55. Decreases in black-tailed gnatcatcher populations corresponding to the death of screwbean mesquite type 2 in spring (spr, left) and summer (su).

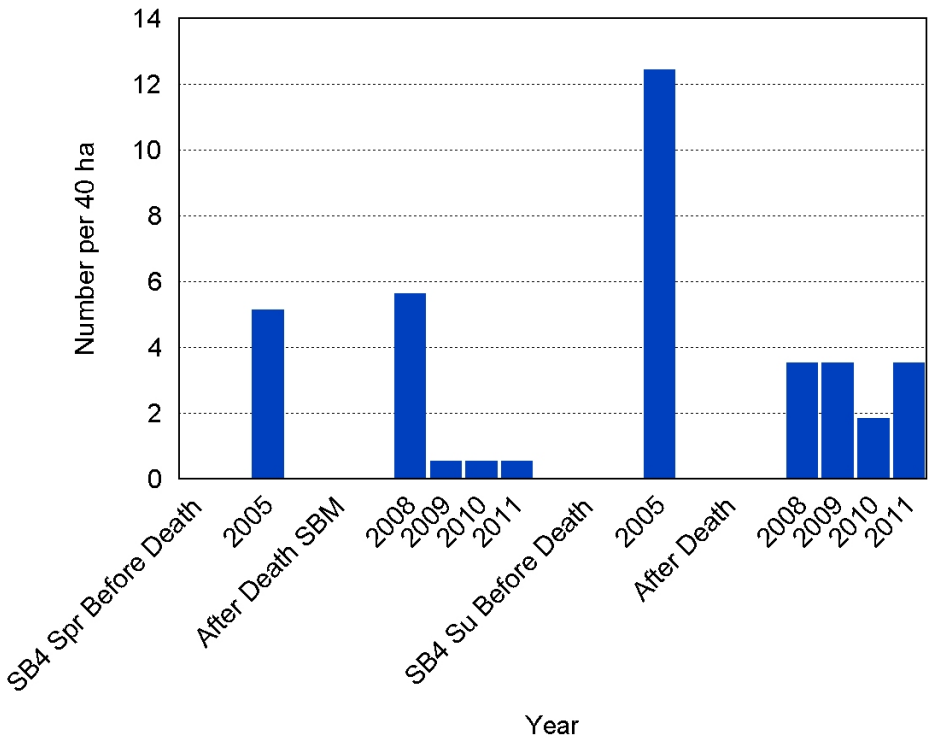
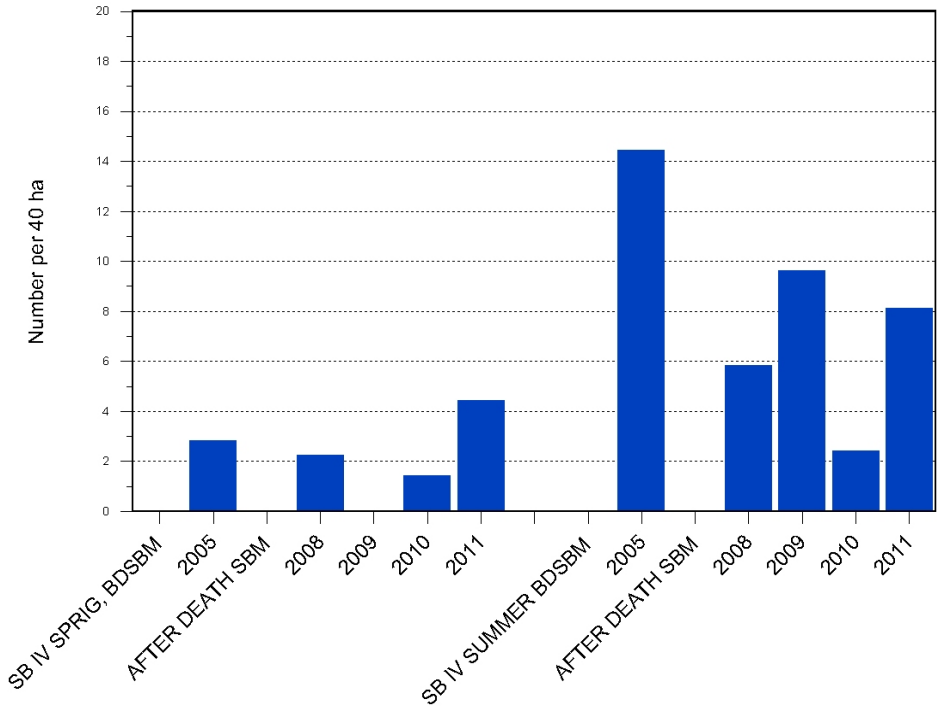


Figure 56. Decreases in black-tailed gnatcatcher populations corresponding to the death of screwbean mesquite type 4.



Other species have also probably declined. The ladder-backed woodpecker (*Picoides scalaris*) may have benefited from the increased number of dead trees, but the data at this point do not definitively or consistently lead to this conclusion due to extensive variance. Cactus wren seems to have totally disappeared from these 2 screwbean vegetation types if we are to give any credence to the data obtained decades ago. Dove densities have remained about the same—highly variable. I have found doves nesting in dead screwbean trees. Abert’s towhees have remained about the same in SB 2, but have decreased in



SB 4. Birds that have increased are mainly winter visitors that do not breed here, including yellow-rumped warbler, white-crowned sparrow, savanna sparrow, and chipping sparrow. The presence of the sparrows may be related to the fact that the screwbean areas are immediately adjacent to agriculture.

## NESTING PLATFORMS AND WOLFBERRY

In 1989-1990 we did some revegetation a Goose Flats, located about 2 km downstream from the Interstate 10 Bridge across the Colorado River east of Blythe. The soil at this site consists primarily of dredge spoil sand. This area is highlighted by a number of backwaters (actually representing the old river channel, the current river channel being straight, rip-rapped dry cut). In the early 1980s this area was flooded by the highest water levels recorded since the construction of Parker Dam, flow velocities reaching 40,000 cfs in the area. This high water level persisted for more than 2 years and the most obvious effect was to drown the cottonwood trees that rimmed the backwaters. Now decimated, the decision was made to revitalize the area with a revegetation effort. Consultation with members of the California Department of Fish and Game led to the conclusion that the planting effort should not involve planting any trees near the water's edge. That is, no planting where conditions would normally be assumed to be the most appropriate for species such a cottonwood and willow. The reasoning was that the high-water levels just witnessed would return every 3 to 5 years. If that was to be the case, reasoning went, it would be folly to plant cottonwood trees where the surface to the water was only a meter or so, even though this would normally be the best place to plant them. But if high water flows were to return such an effort would have been in vain. Thus cottonwood and willow trees were planted where the depth to water in summer was 2.7 to 3 m or so. Just in case the prediction for high water levels failed to come to pass we decided to plant species that might survive the harsher low soil moisture levels associated with the sandy soil dominating the area. So we included honey and screwbean mesquite, palo verde, and wolfberry (*Lycium torreyana*) in the effort. Since 1989 there have been no flows down the river remotely similar to the conditions seen in, for example, 1983. Still, a significant portion of the area was planted with cottonwood and willow and most evaluations of this effort would have probably

concluded that it was a failure with respect to the cottonwood/willow planting effort.

In 2010 I surveyed the area to see what had happened on this 20 ha site in the ensuing 21 years since planting. All of the willow, 72% of the 1,336 cottonwood and all of the 549 screwbean were dead. Most of the palo verde and honey mesquite had survived and about a third of the honey mesquite had become parasitized by mistletoe. A total of 34 palm trees (*Washingtonia filifera*), and 100 or so seep willow (*Baccharis*) had invaded the area naturally or were left intact at the time of clearing. In addition about 1,600 arrowweed clumps measuring 1.5 X 1.5 m and about 800 saltcedar had come back since clearing. Most astounding was the performance of the wolfberry. We originally planted 646 of them and now the number has increased to 1,825. This is a desert wash shrub that spreads by stolons. The fact that it has thrived in this situation, and others native species have not, indicates that the area is no longer a typical riparian type situation.

We planted trees using variation in depth from the surface to the water table as a guide. Since the surface of the area is highly uneven, DWT varying from about 2 to 4 m, the result was a highly heterogeneous area with respect to plant species, tree height, and the presence of shrubs. The scale of the diversity was about 0.25 ha. As it turned out this scale of heterogeneity is remarkably good for birds. Mesquite or cottonwood trees are often near patches of wolfberry. Most patches that include mesquite or palo verde also include arrowweed, palm trees or wolfberry. The site is remarkably patchy. This is the antithesis of areas such as the Palo Verde Ecological Reserve, which are remarkably homogenous with little patchiness in the horizontal plane. Plants differing in height from cottonwood or willow are found mainly on the margins—the patchiness is on a scale involving multiples rather than fractions of hectares. The foliage volume at Goose Flats is fairly sparse above 5 m, moderate at 2-5 m. At the PVER foliage volume is densest at levels greater than 5 m and sparse at 2-5 m. The foliage is so dense (Fig. 57) in many portions that even though nesting platforms may be present for doves, for example, they are present in only moderate numbers perhaps because the birds can't fly through the dense

foliage. At any rate dove densities at Goose Flats are more than 5 times the number found at the PVER in summer (Fig. 58).

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Figure 57. Palo Verde Ecological Preserve showing dense planting that leads to tall, thin trees.

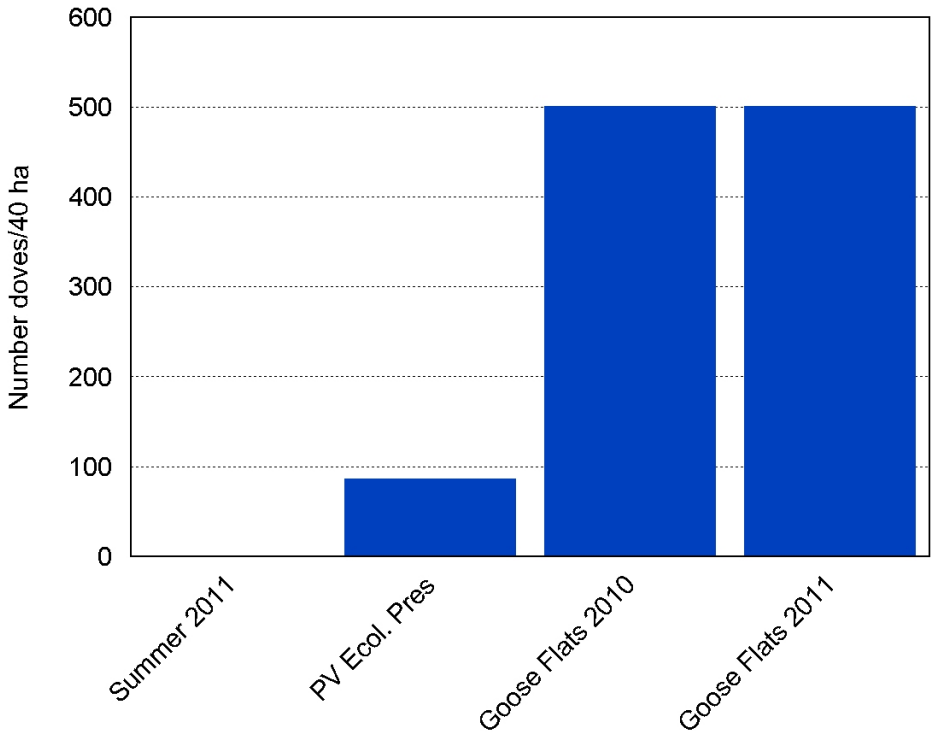
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Figure 58. Total mourning and white-winged doves at the Palo Verde Ecological Preserve and Goose Flats in summer 2010 and 2011

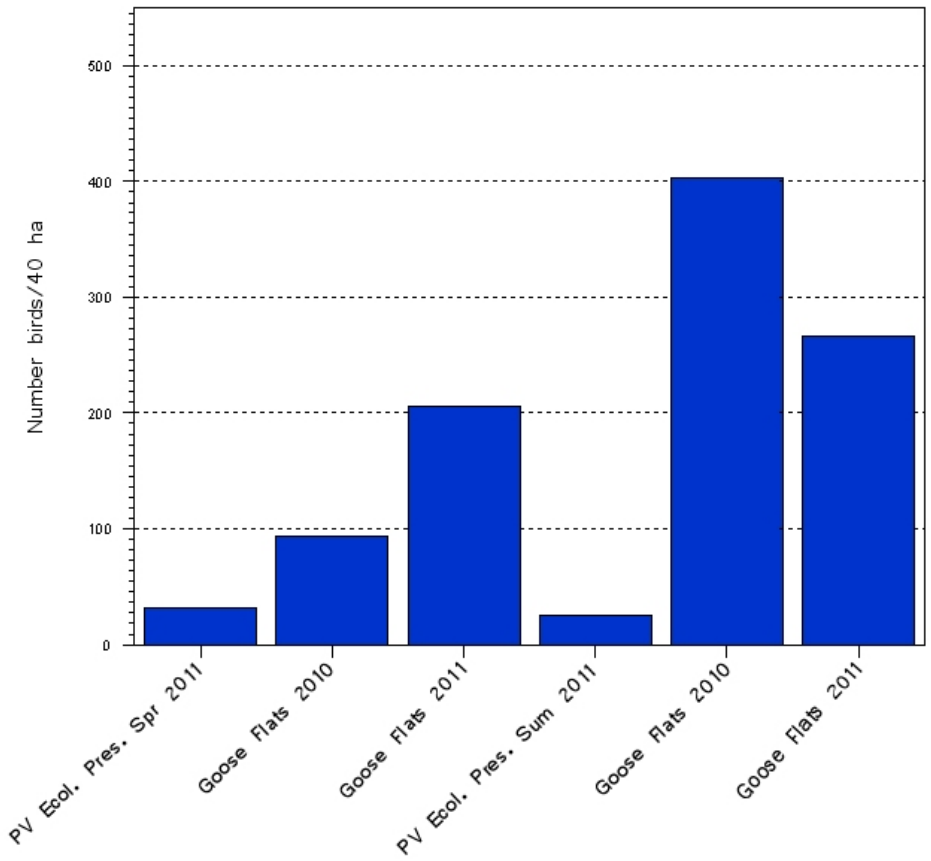
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Another contingent of species specifically takes advantage of the presence of wolfberry, including phainopepla (*Phainopepla nitens*), house finch, (*Carpodacus mexicanus*), and mockingbirds (*Mimus polyglottis*). These species feed extensively on the berries that are produced in April and May. By June the berries are largely eaten or begin drying up with the advance of hot, dry weather. These berries are a major food source for the young of phainopepla. This species, (*Phainopepla*) begins breeding in February. Other species either eat the berries (white-crowned sparrow, gila woodpecker, northern

mockingbird, and house finch) or the insects and nectar associated with the flowers of wolfberry (hummingbirds, phainopepla). These bird species are virtually absent at the PVER, but have numbered in the hundreds in spring and summer over the past 2 years at Goose Flats (Fig. 58).

Figure 58. Combined densities of phainopepla, house finch, and northern mockingbird at Goose Flats and at Palo Verde Ecological Preserve in spring and summer. These data show the use of an area with wolfberry (Goose Flats) relative to one without (PVER).

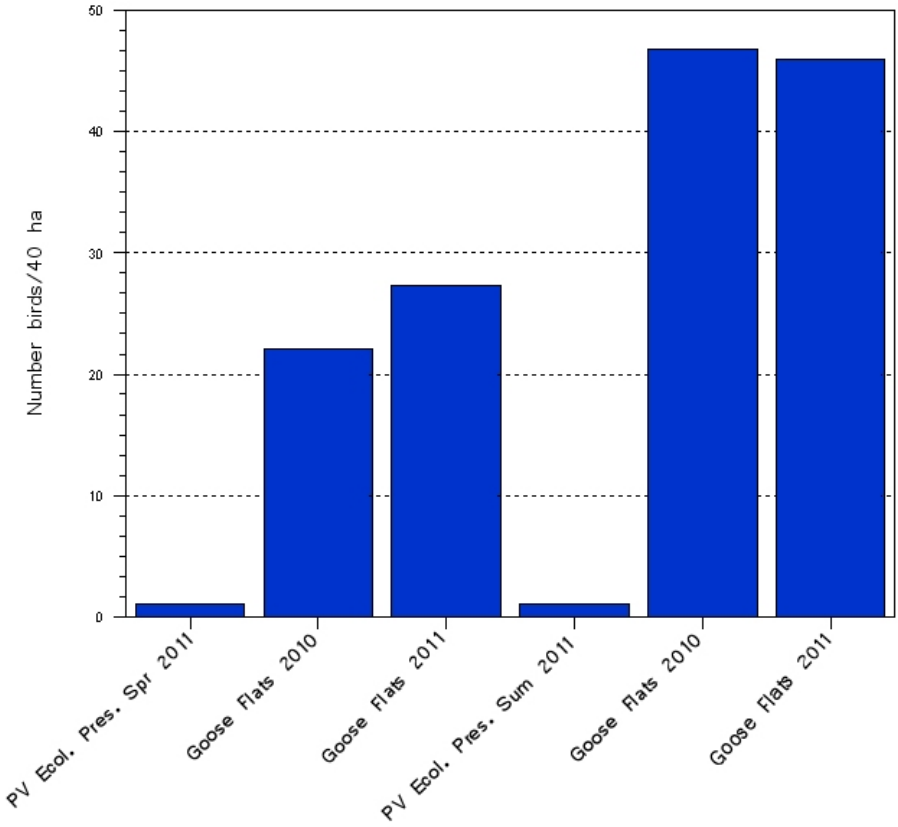


The PVER was created mainly for a few scarce species that are or were associated with cottonwood and willow, but the total density of these species at PVER in summer 2011 was less than 5 per 40 ha. The total density of the same list of species at Goose Flats was about twice this suggesting that passive management for these species is at least equally effective. The density of verdins, black-tailed gnatcatcher at the PVER in 2011 was 0; 91 and 103 in 2010 and 2011 at Goose Flats. As we stated above, these species are declining in number due to loss of screwbean. Imagine what the situation would be if saltcedar viability were also significantly reduced over a relatively short period of time—say a decade.

Another important group is cavity nesting species (Fig. 59). The trees at PVER are tall and thin and are crowded close together (Fig. 57). Woodpeckers actively dig out holes in trees. Other cavity nesting species such as the brown-crested and ash-throated flycatchers nest in holes made by woodpeckers. Other species, such as Lucy's warbler will nest behind big chunks of bark in mesquite trees or in dense litter that accumulates in the crotches of trees such as saltcedar. The PVER plots have relatively little litter accumulated in the crotches. The density of cavity nesters at Goose Flats was 22 to 56 per 40 ha but only around 5 per 40 ha at PVER (Fig. 59).

Common wisdom has it that as projects such as PVER age trees will die thus rendering the vegetation more sparse. As this occurs there will be an influx of many of the species I have just mentioned. But can we really count on that occurring? What will the vegetation be in the shrub layer? Maybe, without irrigation in perpetuity, there will be only bare ground. Dead or decadent cottonwood/willow trees in combination with bare ground make for relatively poor habitat for not only the scarce target species, but for all species. Death or decadence can occur rapidly (8 to 10 years) where depth to the water table is relatively great (>3 m) and water is no longer amply applied.

Figure 59. Sum of cavity nesting birds (Gila woodpecker, ladder-backed woodpecker, Lucy's warbler, ash-throated flycatcher) at Goose Flats and Palo Verde Ecological Reserve in spring (spr) and summer (su) 2011.





In addition to the bad news there was also some good news. At the PVER some species were found to be unusually abundant. Most obvious was the great density of red-winged blackbirds (*Agelaius phoenicius*) in sandbar willow. Their numbers reached densities greater than 750 per 40 ha in summer 2011. Blue grosbeak (*Guiraca caerulea*) numbers were greater in this habitat than any density of this species that I have observed. Since this habitat is established in an area where it is 3 m or more to the water table I did not anticipate the presence of species such as the yellowthroat or song sparrow because these species are typically found at points of interdigitation between marsh and cottonwood/willow habitats. However, the persistent irrigation is apparently great enough to fool individuals of these 2 species into thinking that the habitat is at the edge of a marsh. Song sparrow densities were low (1/40 ha) in summer 2011, but yellowthroat densities were 9/40 ha.

## MANAGEMENT PHILOSOPHY

Presently management target species are those that are endangered with management of other species being passive, meaning the other species are coincidentally attracted to the same habitat as the target species. Is this the correct approach or is it too narrow? I believe that it is too narrow. Planting cottonwood and willow in great densities, as shown above attracts few of even target species. Some target species, such as yellow warbler, may never be attracted because the taxon associated with the LCR is probably extinct. These dense stands also attract few other major categories of birds such as cavity nesters and doves and species such as Lucy's warbler, verdin, black-tailed gnatcatcher, and ash-throated flycatcher. Perhaps, with time, as these stands open up they will support these species, but is this wishful thinking? Will the tall thin trees get thicker trunks as their neighbors die or will they just be blown over by the wind? When many cottonwood and willow trees began to die along the lower Bill Williams River we thought that the number of cavity nesting species would increase dramatically, but this expectation was not realized. Within a year of death the wind had blown over almost all of the dead trees (Hunter, Anderson, and Ohmart 1987). If this happens what plant species will invade the vacated ground? Since areas such as PVER have been in agriculture for decades the process of reinvasion by native species will likely be slow.

On the Colorado River Indian Reservation about 25 km north of Ehrenberg there is some land on the east side of Mojave Road that was honey mesquite until about 1978 when it was cleared. Efforts were then made to put this land into agricultural production. This effort extended over more than a decade or so, but for the last decade more than 500 ha have been lying fallow. Almost no species of native plants such as honey mesquite, palo verde, *Atriplex* sp, *Lycium*, or *Sueada* have invaded this fallow ground (Fig. 60). Wildlife use is probably low although I have not conducted any surveys in this area, but since there are virtually none of the plant species just mentioned, bird densities are

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Figure 60. These photographs shows an area on the Colorado River Indian Reservation that was honey mesquite habitat until it was cleared in the late 1970s. The area was under agriculture for about a decade and not it had been bare ground for about a decade, illustrating the fact that native species do not reinvade areas quickly.

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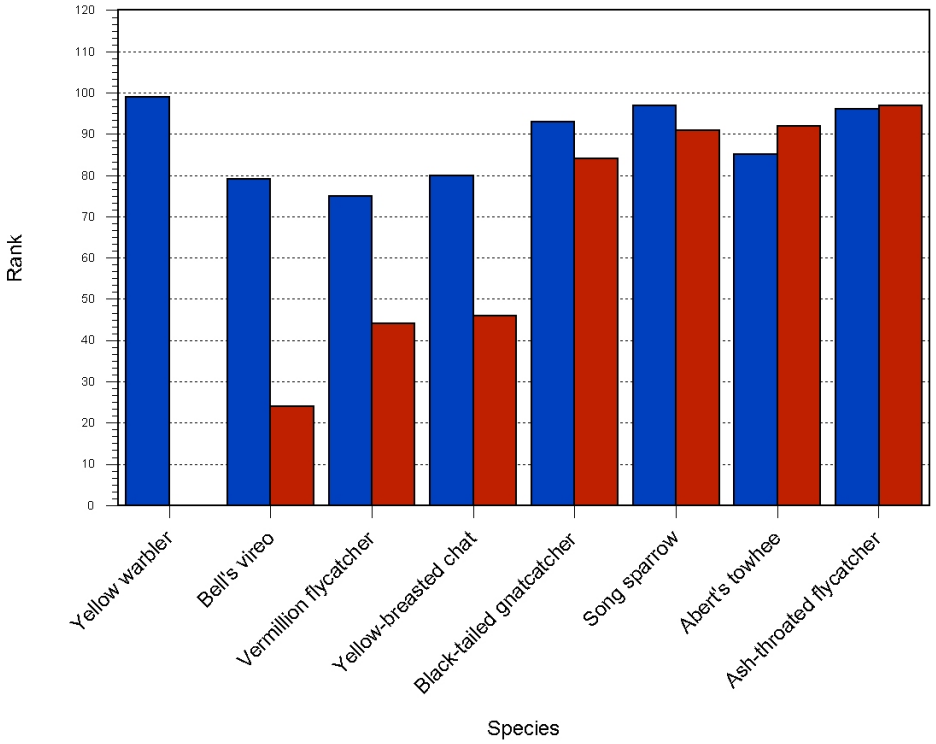


bound to be low. On this basis I suspect that as the trees are thinned on PVER a lot of bare ground will develop; the area might degrade with respect not only to currently targeted species, but almost all of the most typical species of the riparian zone in the LCR. But such a conclusion can probably be circumvented with a new philosophical approach. Such an approach does a turnabout in that if we target the major species that are still currently relatively abundant such as Gambel's quail, Abert's towhee, verdin, black-tailed gnatcatcher, white-winged and mourning doves, the species currently targeted will also benefit as long as some cottonwood/willow thrive. If unforeseen events cause reduction in cottonwood/willow numbers the area will remain a good wildlife

habitat. We would then be adopting a policy aimed at preventing more species from becoming threatened while still supporting currently targeted species .

Consider the species that were not threatened in 1910 when Grinnell surveyed the riparian zone of the LCR (Fig. 61). Yellow-warbler was perhaps the most numerous birds at that time (Grinnell 1915). Other common birds included Bell's vireo, vermilion flycatcher, yellow-breasted chat, black-tailed gnatcatcher, song sparrow, Abert's towhee, and ash-throated flycatcher. Currently the rank of the first 4 mentioned species is 45th or less where the most abundant is ranked 100. A rank of 40 corresponds to a density of less than 1 bird per 40 ha where the 40 ha include equal amounts of cottonwood/willow, honey mesquite, marsh, desert wash, and arrowweed habitats. In 1910 if we were to apply today's management philosophy of actively managing for only the threatened species we would have concluded that nothing needs to be done for any of these species. But today half of these species are now so scarce that they are considered "threatened". Clearly application of today's management philosophy to the situation in 1910 would have been wrong. Is it also wrong to only passively manage for the verdin, gnatcatcher, song sparrow, Abert's towhee, ash-throated flycatcher, and several other species which are still common today? If we were to direct management efforts at birds which are not yet threatened we would also provide critical habitat for those species currently considered threatened. The key is to create habitat diversity on a smaller scale, that is, create diversity of a scale of about 0.25 ha. This diversity should involve plant species such as wolfberry, inkweed, *Atriplex canescens* and *A. polycarpa*. There are other compelling reasons for developing greater diversity in projects such as the PVER and these will be discussed next.

Figure 61. Comparison of relative species abundance in 1910 relative to the 1970s and 1980s. Blue=1910, Red=1970-1980. A rank of 40 corresponds to less than 1 bird per 40 ha across an equal amount of cottonwood/willow, honey mesquite, arrowweed, marsh, and desert wash habitats.



## THINKING ABOUT THE FUTURE

As has been made crystal clear by Daniel Kahneman (2011) we humans are less in control of our thought processes than we think, i.e. we have less free will than we suppose. Kahneman, a Nobel Prize winner for his work on how the human mind works, develops the notion that we humans have minds analogous to 2 systems. System 1 involves quick intuitive thinking that works fast and saves us, for example, if our car begins to skid on a slippery surface or in interpreting the body language of a person walking toward us. This system will also quickly fill in marginal, but often significant, information that is needed for spur of the moment decisions. The second system becomes involved when the initial solution is not intuitively obvious such as multiplying  $28 \times 72$  or committing the sequence 3, 5, 8, 6 to memory and then adding 3 to each number while reciting the results. Sometimes, however, system 1 is invoked when system 2 is required. We tend to be lazy thinkers, and accept what system 1 tells us even though this is wrong. For example, answer the following as fast as you can: Suppose that a bat and ball cost \$1.10 and that the bat costs \$1 more than the ball. How much does the bat cost? Most of you will almost reflexively—intuitively—say that the bat costs \$1. Reflecting on that intuitive response, i.e. calling upon system 2 for a moment, you realize that the bat costs \$1.05 and the ball \$0.05, the difference between which is \$1. Now, with system 2 engaged we'll move on.

### Salinity

Are we using the reflexive intuitive system 1 type of thinking too much when we plan projects such as the PVER? We do it once and initially the results are visually terrific so we intuitively apply the same

plan over and over again without invoking system 2. What could go wrong?

Well, the first thing we might ponder is the fact that Colorado River water used for irrigation has salt in it. Nor is the land itself free of salt. We found that, on average, the electrical conductivity (ec) of the soil in agricultural fields is about 2.1 mmhos/cm. Let us assume that the ec in, say, the PVER is at about that mean level. We found that at the Coachella Canal (which carries Colorado River water) the seepage adds about 52 ppm annually or about 0.08 mmho/cm, but that estimate includes some runoff. In 11 years, under these conditions, we would have brought the soil ec up to about 3.0 mmhos/cm—the upper tolerance limit for cottonwood and willow. In the next 11 years the level would nearly reach 4.0. At this level we can expect no natural germination of most native plant species. But if there is little or no drainage the increase in salt on the surface will be even greater.

Some would be quick to point out that with irrigation we would have leaching. But is that really the case? For there to be leaching 2 factors must be taken into account. First, is the soil layered? It almost certainly is. This complicates the situation because water moving down through the soil will begin to spread laterally when it encounters a soil layer. If the top layer is not very thick and the soil is moderately dense the water will begin to move to the surface by capillary action, leaving its salt on the surface. This can be fairly easily and quickly remedied by ripping the soil prior to planting. Even if the soil was ripped years ago, after years of heavy equipment driving across the surface, it will have become compacted. Ripping, at least to a depth of 1-2 m will greatly increase the extent of leaching (Anderson 2004, 2011). But even if we leach to the water table we have then increased the salinity there—we still have the salt. Without annual flooding electrical conductivity in the area can only go up.

The second factor to take into account is the consumptive use of water by the trees. For leaching to take place after planting has occurred the water applied must exceed consumptive use. We obtained reasonably good leaching results by first ripping then sprinkling on 2 m of water before any planting was done. Cottonwood and willow use a great deal of water—in the heat of the summer they could use 1.7 acre

feet per month, assuming a planting density of about 250 trees per ha. Denser planting will not result in greater water use because more than 1 tree begins to occupy the space than a single tree would normally occupy.

### **Lateral Roots**

The trees on projects such as the PVER are so dense that birds can't even fly through the interior (Fig. 57). Some have pointed out to me that with the passage of time some trees will die thus making canopy openings, the dead trees themselves becoming potential sites for cavity nesting species to develop some cavities. However, as pointed out above, if the area has not been deep tilled, thus preventing deep penetration of water, it might be that the roots, too, will have developed laterally and will be readily blown over by the wind. At the PVER many of the trees have already been blown over and the roots have been partially exposed. They are developed laterally to a significant degree (Fig. 62, 63).



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Figure 62 . Trees on the Palo Verde Ecological Reserve showing a tree blown over by wind. Lateral roots of this tree are shown in the lower photograph.

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Figure 63. Tree on the Palo Verde Ecological Reserve showing a tree blown over by wind. Lateral roots are apparent in both photographs.

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## Fire

The threat of fire at revegetation sites like PVER is large. Someone suggested that if a fire starts one need only turn on the irrigation water to stop it. I'm afraid that this is wishful thinking. In the first place irrigation must often be scheduled. If this hurdle is overcome actually getting the water to the site uses up valuable time. It would take hours for water to become distributed over the site. Getting water to the site in time to be beneficial would be even more problematic if the fire started at night, on a weekend, or on a holiday. A fire on the site would spread rapidly and would likely be out of control by the time irrigation water got to the site. Even if the threat of fire were in some adjacent vegetation and the water did get to the site and was well distributed the fact is that much of the fuel in these project sites is well above the few centimeters of water that cover the ground (Fig. 64). Fire would sweep rapidly through the upper canopy in spite of a few centimeters of water on the surface. At best, the presence of irrigation water would quell fire at the surface. If your house is on fire water in the basement wouldn't help at all with the fire on the roof.

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Figure 64. Even if this site is irrigated it is likely that fire would quickly sweep through such a stand because of the large amount of fuel in the upper branches. Cottonwood are likely to be killed by fire.

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## BIRDS WITH POPULATION INCREASES

It is of interest to compare census results from 30 years ago with more recent censuses. As of this writing extensive comparisons have not been made for all species. However, details are available for 3 species for which the changes over this time period are spectacular.

When I arrived in the LCR the great-tailed grackle (*Quiscalus mexicanus*) was scarce. In the Blythe vicinity the only population was at the KOA campground south of the Port of Entry into California on I-10. Censusing from 1973 through 1984 uncovered only wandering small groups or individuals of this species. The largest density during this time was found in CW4, but even in that habitat occurrence was sporadic, having registered a density of 7 one season and a density of 5 in another in 8 years of censusing. I considered 1 habitat type for 1 season in 1 year to be the unit for making assessments. This yielded a total of 719 independent cases that could include grackles. However, grackles actually occurred in only 12 (1.7%) of them (Fig. 65). Grinnell and his party did not record seeing any grackles in 1910.

In more recent years grackles have been detected in 33 (39%) of the 50 census units (Fig. 65). The maximum number found was 74 in SB2 in summer and 39 in SB4. These habitats are both located immediately adjacent to agricultural fields and this may have been a factor influencing their presence. A density of 17 was recorded in summer at Goose Flats. This species is now abundant throughout the LCR.

The second type of bird showing a large change from the censusing done 1973-1984 is hummingbirds. Three species (black-chinned *Archilochus alexandri*; Annas' *Calypte anna*; Costa's *Calypte costae*) are included in this analysis of changes in hummingbird

numbers. The first mentioned breeds in the area in spring and summer, the last 2 species breed in late winter and spring with some overlap in spring between the first and the last 2 mentioned. Hummingbirds were present in 72 (10.2%) habitat types over the years and seasons in early census work (Fig. 65). In those years they had a mean density of 1.2 birds/40 ha in CW1 in summer, 1.6 in CW2 in summer, 3.4 in CW3, and 2.6 in SC 1. The largest densities and consistency of occurrence was in SC2 where they were found in all 5 springs censused and had a mean density of 14.6 per 40 ha. Between 2005 and the present they occurred in 47% of the 50 possible opportunities as defined above. Maximum density was 69 per 40 ha in spring 2011 at Goose Flats where there is a large amount of wolfberry. At Goose Flats they occurred at a density of 9 per 40 ha in winter and 21 in summer.

The final species that I consider is the collared dove (*Streptopelia decaocto*). This species was not present in the period 1973-1984. We saw the first one in about 2000. They were not detected in any riparian vegetation on formal censuses until 2010. Peak density, (35 per 40 ha) was reached in an area with many grasses and *Atriplex polycarpa* that was also adjacent human inhabited areas. This species may actually be 2 species: *S. decaocto* and *S. risoria*. The latter is considered to be a separate species by some, but others think that it is derived in captivity (Babtista, Trail, and Horbitt 1992). The potentially derived form occurs but in much smaller numbers, perhaps 1-2%, of *S. decaocto* numbers.

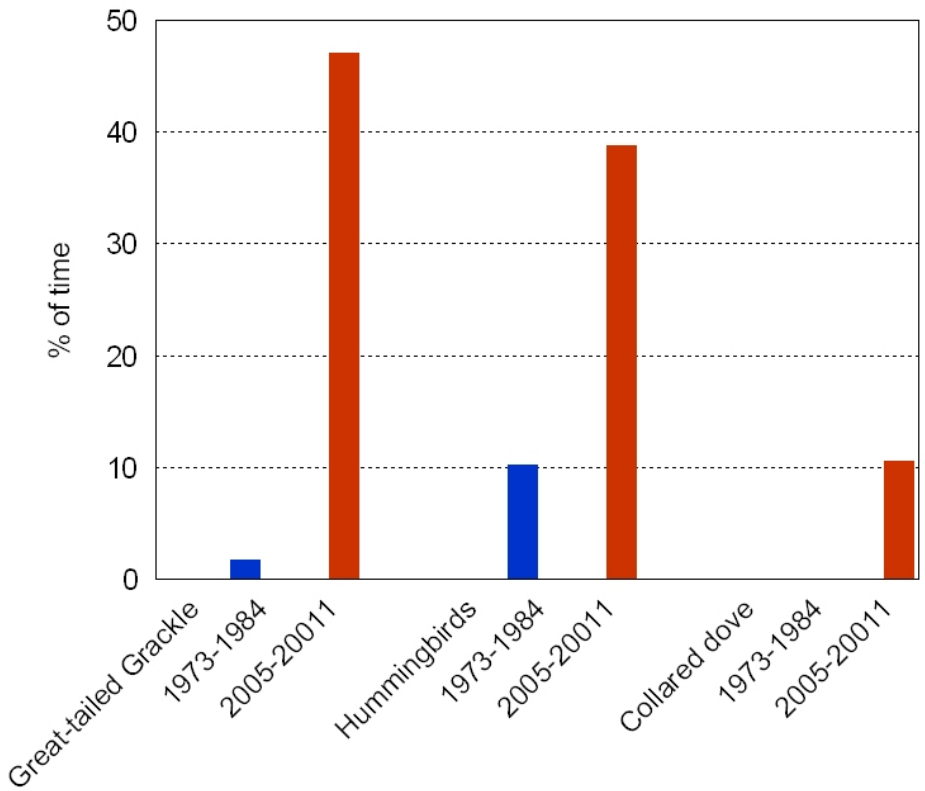
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Figure 65. Observed increase in density of some bird species in the lower Colorado River valley.

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## INDEX

### A

Abert towhee, 19, 50  
Acrididae, 72  
agriculture, 89, 110, 119, 120  
allscale, 87, 132  
ants, 77, 79  
Arizona, 47, 134, 135  
arrowweed, 1, 3, 10, 18, 20, 21, 23, 24, 25,  
26, 27, 28, 29, 30, 31, 33, 65, 66, 68,  
71, 72, 87, 112, 121, 122  
ash (from fires), 3, 116, 119, 121  
*Atrilplex*  
  *polycarpa*, 132  
*Atriplex*, 2, 10, 38, 119, 121, 132  
  *cansescens*, 87, 121  
  *hymenolytra*, 87  
  *lentiformis*, 2

### B

baccharis, 87  
bare ground, 116, 120  
  lower Colorado River valley, 42, 44, 45,  
  48, 78, 79, 81, 82, 83, 90, 133  
bees, 79  
beetles, 79, 80, 81, 83  
Bermuda grass, 92  
birds, 1, 2, 3, 5, 6, 12, 15, 17, 18, 19, 20,  
22, 24, 25, 26, 30, 36, 38, 48, 66, 68,  
69, 70, 71, 73, 74, 78, 79, 81, 82, 83,  
84, 85, 86, 98, 100, 102, 105, 108, 112,  
117, 119, 121, 125, 132, 133, 135  
Blythe, California, 0, 99, 101, 111, 131  
bufflehead, 40, 49  
Bullhead City, Arizona, 3, 100, 134  
Bureau of Reclamation, 134

### C

California, 0, 11, 93, 101, 111, 131, 134  
*Canis latrans*, see coyote, 45

*Carpodacus mexicanus*, see finch, house,  
114  
cattail, 11  
cavities (in trees), 125  
cavity  
  nesters, 3, 116, 119  
  nesting, 116, 117, 119, 125  
chat, 121  
chat, yellow-breasted, 19, 80, 121  
Cibola National Wildlife Refuge, 1, 3, 40,  
42, 85, 87, 88, 99  
Cicada, 74, 75, 85, 86  
Cicadellidae, 2, 65, 71, 77, 78, 79, 81, 82,  
83  
clearing, 16, 95, 112  
cluster analysis, 6, 8  
Coachella Canal, 124  
*Colaptes auratus*, see flicker, 77  
Coleoptera, 77, 78, 79, 81, 82, 83  
Colorado River Indian Reservation, 119,  
120  
competition, 1, 2, 37, 40, 77, 92  
cottonwood, 1, 2, 3, 10, 12, 17, 18, 19, 20,  
21, 23, 24, 26, 27, 28, 29, 30, 31, 33,  
35, 38, 42, 48, 54, 55, 57, 59, 60, 65,  
71, 72, 73, 74, 89, 94, 111, 112, 116,  
118, 119, 120, 121, 122, 124  
coyote, 1, 45, 46, 47  
cuckoo, yellow-billed, 1, 3, 19, 72  
curvilinear relationships, 38, 39

### D

Davis Dam, 5, 12, 99  
decline, of screwbean, 96, 100  
deep  
  tillage, 2, 3, 4, 93  
deer, mule, 46  
density, 1, 2, 6, 12, 13, 17, 18, 19, 20, 21,  
22, 23, 24, 25, 26, 30, 32, 35, 37, 38,  
41, 42, 56, 58, 62, 66, 71, 74, 85, 87,  
100, 102, 103, 104, 105, 108, 109, 113,

115, 116, 118, 119, 121, 125, 131, 132, 133  
desert, 1, 5, 10, 15, 16, 30, 53, 55, 58, 61, 87, 112, 121, 122  
wash, 10, 15, 16, 30, 53, 112, 121, 122  
desert holly, 87  
*Diceroprocta apache*, see cicada, 75  
disease (affecting screwbean), 36, 100  
dove, 20, 113, 132  
mourning, 19, 22, 120  
white-winged, 114  
ducks, 39, 40, 49

## E

Emory baccharis, 87

## F

finch, house, 25, 114, 115  
fire, 2, 4, 16, 85, 86, 128, 129  
flicker, northern, 77  
flooding, 1, 47, 62, 91, 124  
flycatcher, 3, 19, 119, 121  
brown-crested, 19  
vermillion, 3, 121  
foliage, 1, 6, 7, 8, 9, 10, 12, 18, 21, 23, 24, 27, 28, 29, 31, 33, 35, 37, 100, 112  
density, 35, 37, 100  
foliage volume, 6, 7, 8, 12, 112  
Formicidae, 77, 78

## G

geese, 1, 40, 41, 49  
gnatcatcher, black-tailed, 3, 77, 80, 82, 107, 108, 109, 116, 119, 120, 121  
goldeneye, common, 40, 49  
Goose Flats, California, 101, 111, 112, 114, 115, 116, 117, 131, 132  
grackle, great-tailed, 131  
Grinnell, Joesph, 1, 3, 6, 40, 60, 121, 131  
grosbeak, blue, 19, 72, 118

## H

habitat, 1, 2, 3, 5, 12, 15, 16, 17, 19, 22, 24, 25, 26, 30, 32, 34, 35, 36, 37, 38, 39, 40, 41, 43, 45, 46, 48, 53, 54, 56, 58, 65, 71, 74, 79, 80, 83, 85, 87, 116, 118, 119, 120, 121, 122, 131, 132  
Homoptera, 65, 79, 82, 83  
Hummingbird, 132  
Hymenoptera, 79, 82, 83

## I

*Icteria virens*, see chat, yellow-breasted, 19  
*Icterus bullocki*, see oriole, Bullock's, 19  
Imperial National Wildlife Refuge, 100  
inkweed, 2, 24, 35, 87, 121  
insectivorous birds, 68, 69, 70, 71, 73, 84  
insects, 2, 15, 25, 35, 36, 40, 65, 66, 67, 68, 69, 70, 71, 72, 73, 79, 80, 84, 115  
irrigation, 4, 89, 92, 93, 94, 116, 118, 124, 128, 134

## K

kangaroo rat, desert, 55  
kingbird, western, 72, 79  
kinglet, ruby-crowned, 1, 18, 34, 36, 50, 77

## L

leaching, 2, 3, 89, 124  
leaf hoppers, 2, 71, 77, 80  
Lepidoptera, 70, 78, 79, 81, 82, 83  
Los Angeles, California, 134  
*lower Colorado River*, 1, 2, 3, 5, 6, 11, 12, 19, 25, 39, 40, 42, 44, 45, 46, 47, 48, 49, 65, 74, 77, 78, 79, 81, 82, 83, 87, 89, 90, 99, 100, 101, 119, 120, 121, 131, 133  
Lower Colorado River Multiple Species Conservation Plan, 3

## M

malady (affecting screwbean), 98, 99, 100  
mammals, 6, 15, 46, 51  
mapping, 10  
    mapped, 1  
marsh, 1, 11, 25, 26, 30, 48, 79, 118, 121, 122  
*Melanerpes uropygialis*, see woodpecker, Gila, 19  
mesquite, 1, 2, 10, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 42, 43, 46, 47, 54, 55, 57, 59, 60, 65, 66, 68, 69, 70, 71, 73, 74, 80, 87, 89, 91, 92, 97, 98, 103, 104, 106, 107, 108, 109, 111, 112, 116, 119, 120, 121, 122  
    honey, 1, 2, 10, 12, 13, 14, 18, 19, 20, 21, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 43, 46, 47, 54, 65, 66, 68, 69, 70, 71, 73, 74, 80, 87, 89, 92, 112, 119, 120, 121, 122  
    screwbean, 1, 10, 12, 20, 21, 23, 24, 27, 28, 29, 31, 33, 37, 55, 57, 59, 60, 87, 91, 97, 103, 104, 106, 107, 108, 109, 111  
Mexico, 5, 99  
Miridae, 68  
mistletoe, 24, 34, 35, 37, 80, 98, 112  
mitigation, 95  
mockingbird, northern, 25, 81, 115  
mouse, 1, 51, 56, 58, 61, 62  
    cactus, 1, 51, 56, 58, 60, 62  
    grasshopper, 61  
    pocket, 1, 58, 61

## N

*Neotoma albigula*, see woodrat, white-throated, 51  
nesting platforms, 112  
nighthawk, lesser, 81

## O

orchards, 15, 16, 32  
oriole  
    Bullock's, 19  
Orthoptera, 72, 81  
ovarian weights, 43, 44, 45

## P

palm, fan, 87, 112  
Palo Verde Ecological Reserve, 112, 117, 126, 127  
palo verde, blue, 3, 10, 111, 112, 119  
parasite, 98  
Pecos River, 48  
*Perognathus penicillatus*, see mouse, pocket, 1  
*Peromyscus eremicus*, see mouse, cactus, 1, 51, 56  
Phainopepla, 35, 114  
phenology, 1  
philosophy, management, 3, 121  
pickleweed, 2, 87  
*Picoides scalaris*, see woodpecker, ladder-backed, 19, 109  
*Pipilo aberti*, see Abert towhee, 19, 50  
*Piranga rubra*, see tanager, summer, 19  
plant community, 12  
*Polioptila melanura*, see gnatcatcher, black-tailed, 107  
*Populus fremontii*, see cottonwood, 10  
preparation, 135  
*problem*, 89  
*Prosopis*  
    *glandulosa*, see mesquite, honey, 10  
    *pubescens*, see mesquite, screwbean, 10  
*Prosopis*, see mesquite, 10  
Psyllidae, 2, 69  
psyllids, 65, 69

## Q

quail, Gambel, 41, 49

quailbush, 2

## R

*Regulus calendula*, see kinglet, ruby-crowned, 36, 50  
requirements, 95  
revegetation, 2, 3, 69, 99, 100, 111, 128, 134  
  projects, 2, 99, 100  
Rio Grande, 48  
ripping, 124  
roadrunner, greater, 72  
rodents, 1, 46, 51, 53, 55, 57, 58, 59, 60, 61, 62  
roots, 4, 93, 95, 125, 126, 127

## S

salinity, 2, 87, 88, 91, 92, 95, 124, 134  
*Salix gooddingii*, see willow, Gooddingii, or black, 10  
*Salix*, see willow, 10  
saltbush, 42, 87  
  four-winged saltbush, 87, 121  
saltcedar, 1, 2, 10, 12, 18, 19, 20, 21, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 42, 48, 54, 65, 66, 68, 69, 71, 74, 80, 85, 86, 87, 89, 90, 112, 116  
  athel, 55  
salts, 2, 89  
screwbean, 1, 2, 3, 10, 12, 18, 19, 20, 21, 23, 24, 26, 27, 28, 29, 31, 32, 33, 37, 47, 54, 55, 57, 59, 60, 65, 74, 87, 89, 91, 92, 95, 96, 97, 98, 99, 100, 102, 103, 104, 106, 107, 108, 109, 111, 112, 116  
  birds in, 2, 25, 36, 46, 48, 74, 77, 78, 79, 81, 82, 83, 85, 115, 133  
  healthy stands of, 95  
soil, 2, 87, 88, 91, 92, 93, 95, 111, 124  
  moisture, 87, 91, 111  
  texture, 87, 88  
sparrow, 1, 3, 34, 35, 50, 110, 114, 118, 121

savanna, 110  
  song, 3, 118, 121  
  white-crowned, 18, 83, 110, 114  
species richness, 26, 27, 29, 33, 34, 40  
spiders, 73  
structural type, 6, 8, 9, 10, 14, 17, 18, 20, 21, 23, 24, 26, 27, 28, 29, 31, 32, 33, 34, 54, 65

## T

*Tamarix ramosissima*, see saltcedar, 10, 48  
tanager, summer, 1, 19, 72, 80  
thrasher, crissal, 36, 80, 81  
tillage, 2, 3, 4, 93, 94, 134  
Topock, 11  
  Marsh, 11  
trapping, 1, 53, 61, 62

## U

US Fish and Wildlife Service, 134

## V

*vegetation types*, 1, 2, 10, 15, 16, 17, 18, 25, 30, 32, 51, 53, 56, 58, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 75, 109  
verdin, 36, 104, 105, 106, 107, 119, 120, 121

## W

warbler  
  lucy, 102  
  yellow-rumped, 18, 83, 110  
water, 2, 3, 4, 11, 41, 47, 87, 88, 91, 93, 94, 95, 111, 112, 116, 118, 124, 125, 128  
  consumptive use of, 3, 4, 124  
weather, 43, 114  
willow, 1, 2, 3, 10, 12, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 35, 37, 42, 48, 54, 55, 57, 59, 60, 65,

66, 71, 72, 73, 74, 87, 88, 111, 112,  
116, 118, 119, 120, 121, 122, 124  
Goodding, 10, 47, 87, 88  
sandbar or coyote, 87, 118  
wolfberry, 3, 24, 35, 80, 87, 111, 112, 114,  
115, 121, 132  
woodpecker, 19, 24, 36, 80, 109, 114  
Gila, 19, 36  
ladder-backed, 19, 36, 109

woodrat, white-throated, 51  
wren, 25, 36, 109  
cactus, 36

## Y

Yuma, 1, 3, 6, 35, 40, 49, 99  
Yuma clapper rail, 1, 35, 49