VEGETATION MANAGEMENT STUDY
for the enhancement of wildlife along the LOWER COLORADO RIVER

1984

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by

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for the
Bureau of Reclamation
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FINAL REPORT

A VEGETATION MANAGEMENT STUDY FOR THE ENHANCEMENT OF WILDLIFE ALONG THE LOWER COLORADO RIVER

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July 1984

In fulfillment of

U.S. Bureau of Reclamation

Contract No. 7-07-30-V0009

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CHAPTER 1

INTRODUCTION

In 1972 we began studying the riparian vegetation of the lower Colorado River and the vertebrate species associated with it. At that time, the ultimate purpose was to acquire the capacity to recommend ways in which the vegetation could be managed so that three objectives could be realized: (1) reduced water loss caused by evapotranspiration, (2) reduced total vegetation at heights of 4 to 6 ft in the floodplain so that flood flows could pass unhindered by the damming effect of dense vegetation, and (3) explore the economic and technical feasibility of revegetating areas. Ultimately these objectives had to be blended with wildlife enhancement.

Initially it seemed that wildlife enhancement was mutually exclusive of the removal of vegetation to reduce evapotranspiration losses and to permit free passage of flood waters. But because the exotic salt cedar is the dominant riparian vegetation, has dense foliage at lower levels, which significantly impedes flood flows, has a potential for large water losses due to evapotranspiration, and does not have high wildlife use values, it is a good candidate for replacement. Native plants, such as quail bush, honey mesquite, and palo verde, all having evolved various adaptations for water conservation, could conceivably use less water per unit area than does salt cedar. Some of these native plant species support much higher densities and number of species of wildlife than does salt cedar. Water salvage and increased flood flow could be acquired in two ways: replace salt cedar with native plant species that have lower evapotranspiration rates, and in the replacement process, design reduced total foliage volumes to curtail water loss. Passage of flood flows could be achieved by removing dense stands of salt cedar in the floodplain and replacing these with plant species that have little vegetation at the 0 to 6-ft level. Although native tree species, such as cottonwood and willow, formerly the numerically dominant vegetation in the valley (Ohmart et al. 1977), have high evapotranspiration rates, they are so attractive to wildlife that a smaller total volume of these species would be needed to replace salt cedar. Thus wildlife enhancement, water salvage, and unimpeded flood flows would be accomplished.

This report specifically relates to the analysis and conclusions of the major data sets that we have collected over the life of the Vegetation Management Study. Other reports should be consulted for detailed information on directly related subjects dealing with the plant community and structural types along the river and wildlife use values of these various communities. For example, all natural riparian vegetation from Davis Dam south to the Mexican Boundary has been mapped and classified as to community and structural type (Anderson and Ohmart 1976). Densities and number of species of birds and small mammals in these various communities on a seasonal basis over a number of years is also available (Anderson and Ohmart 1977). The herpetofauna found along the lower Colorado River, along with past specimens collected in the area, has been reported (Vitt and Ohmart 1978). Changes in wildlife

numbers during the conversion of natural habitats to agricultural settings and the importance of edge between these two ecosystems has been documented (Anderson and Ohmart 1982). And lastly, the success in converting salt cedar communities to more productive wildlife habitats and revegetating barren dredge-spoil areas along with costs are well documented (Anderson and Ohmart 1982). This report stands alone as an analysis of data concerning a number of major topics in the Vegetation Management Study. It also provides a basic data foundation and should help the reader to better understand our efforts to meet the three initial objectives. The other reports can be referred to in order to bring the total accomplishments into focus.

Some people have questioned and criticized our approach relative to the emphasis that we have placed on birds and vegetation as ecological indicators of environmental health. This was not planned nor intended in our initial efforts, but as the study progressed and as our knowledge of the ecosystem increased it became quite apparent that birds and the vegetation would be the major data set with small mammals and herps playing lesser roles. Our revegetation efforts supported this assumption in that by fulfilling the habitat requirements of a large number of species of birds the needs of numerous species of small mammals, deer, coyotes, rabbits, and herps were also addressed; they were present on the revegetated areas in high numbers (Anderson and Ohmart 1982, pers. obs.) Birds are so important a group that they obviously cannot be eliminated from detailed consideration. Expense and duration of effort required to study all species or species groups (insects, herps, deer, skunks, coyotes, etc.) clearly made an in-depth study of these species or groups of species impractical or impossible. However. since bird densities and diversities can be used to indicate the general health of the native riparian vegetation we feel confident that if management for birds is adequate one can be reasonably confident that species in other animal groups will also be present in reasonably good numbers. This assumption is bolstered by data for noctural rodents and coyotes, detailed in Chapters 10-12 in this report, personal observation and copious notes made by various staff members over the past decade, and by data and observations on our revegetation sites (Anderson and Ohmart 1982).

In Table 1-1 we list the general problems in assessing each of the three vertebrate groups. Granted there are specific problems with different species in each group, but these broad generalizations hold for each group. Unquestionably, special attention should be given to any species in either of the three groups if it is listed as endangered by either federal or state agencies.

Snakes and lizards might approach the importance of birds in assessing plant community health situations except for three reasons: (1) they are highly capricious and may not appear for any reasonable length of time or even for a year or more unless climate is favorable; (2) they are cryptically colored, which makes them difficult to detect in the field, and they offer virtually no vocalizations as an aid in census detection; and (3) because they are heterothermic, portions of the population may not surface in poor years, making habitat perturbation assessments even more problematical.

Table 1-1. General characteristics associated with assessing the status of terrestrial vertebrates.

Life history parameters related to censusing	Birds	Small mammals	Herpetofauna
Activity patterns	Primarily diurnal	Primarily nocturnal	Primarily diurnal
Aids in censusing	Fly, may be brightly colored and are vocal	Cryptic and nonvocal	Cryptic and nonvocal
Movement	Residents and migrants	Local	Local
Annual behavior	Residents and migrants	Aestivate and hibernate	Hibernate
Census methods	Sight and auditory	Snap-trap or live-trap	Can-trap or sight
Ease of censusing	Good to excellent	Questionable	Questionable
Availability to census	Good to excellent	Capricious	Highly capricious
Response to major habitat perturbations	Within weeks	May take months and possibly up to a year	Within weeks but could be extended

Small mammals are the most unreliable of the three groups relative to assessing population responses to major plant community change. Because small mammals are primarily nocturnal, cost effective census methods that can be used are few in number. Combined with this problem is the question of how each species responds to the type of bait (usually a mixture of peanut butter and oatmeal) used in the trapping effort. Are all species equally attracted to this type of bait throughout the year and does the availability of natural foods overpower the temptation to eat oatmeal and peanut butter? The answer is probably no to the first question and yes to the second, but even more frustrating is, how do you collect reliable data sets to support either response? This major problem, combined with estivation and hibernation in some species, an apparently low response of small mammals to perennial plant community structure and species composition, the strong relationship of some species to soil texture and structure and coupled with the many unanswered questions involving behavioral and cyclical responses makes small mammals poor interpretative indicators of man-caused habitat changes. Certainly a major factor of concern is the time lag between habitat change and the small mammal community in reaching a new equilibrium.

In studies of rodent communities in recently cleared areas along the lower Colorado River, we have observed a lag period of at least two months before a noticeable difference in trapping response is apparent. After 10 months, populations of some species appear to have reached lowest densities and are possibly beginning to stabilize. Others are continuing to decline. How does one assess mitigation for these losses without 5 to 10 years of monitoring, and more important, how do we mitigate, since many of the habitat needs of small mammals remain unresolved? Some researchers have advocated live trapping as an approach, but we are still faced with most of the above problems and with added costs and other problems not inherent in snap-trapping studies. As recommended, live trapping should be conducted for at least a week to insure total catch. In our climate, traps should be monitored at least every three hours to avoid death of small mammals due to either heat or cold, which would introduce further problems in estimating population numbers. Diurnal rodents seem to be hesitant to enter solid panel folding traps, which are most easily carried in large numbers. A tractor and trailer are needed to carry an adequate number of traps that are constructed of wire and cannot be folded. Sampling an area requires a labor force to clear vegetation, place traps, check traps, and mark animals individually. Incidents of individual mice or rats defending a specific trap that supports a bountiful food supply are commonplace in live-trapping efforts. Finally, once the trapping operation has been completed and the soils and vegetation have been trampled repeatedly (eight times a day for 7-10 days), can the data ever be duplicated, since the area has been highly disturbed by the repeated trampling process?

Avian censusing methods are not without problems, as is evident in a recent publication (Ralph and Scott 1981). But with repeated sampling (three times in each community and structural type monthly), many problems can be overcome. More important, most bird species appear to respond directly to habitat change. Although numbers and species may

fluctuate on a seasonal and annual basis, the optimum habitats identified for each species hold year after year. As habitats change quickly or slowly, the avian population changes in density and species composition. In major habitat alterations the avian response is relatively rapid as compared with other vertebrate groups.

We are not advocating that future studies should exclude censusing efforts of herps or small mammals. Information on herps and small mammals provides insight as to optimum habitat conditions for these groups and this information may or may not be the same as those habitats indicated by avian population parameters. In general the information is the same for the most productive vertebrate habitats along the lower Colorado River. In our studies the most reliable criteria for plant community productivity and health (if abundance of thriving native plant species is the criterion) have been the number of bird species present and the densities of these species. Relative densities and species richness in herps and species richness in small mammals serve as supporting criteria in this judgment. Further, at least some evidence indicates that if one designs and builds new plant communities optimum for a large number of avian species, the habitat will also support numerous species of reptiles as well as small mammals (Anderson and Ohmart 1982, Chapter 13 this report, and unpublished data and observations of field biologists).

In the Vegetation Management Study one of our first objectives was to classify the vegetation in the valley, quantify its areal extent, and then determine quantitatively what wildlife species were associated with each of the vegetation types present. With this information we would then know which plant communities along the lower Colorado River were most important to wildlife. Analysis of the vegetation-wildlife data should then identify the most important vegetation components (vegetation structure, plant species, tree densities, etc.) being selected by the wildlife that inhabit these communities. For wildlife enhancement, these important vegetation components have to be designed and implemented into existing communities or into newly vegetated communities. Further, the initial baseline data would allow us to determine the response of each species to any habitat perturbation so that we could judge if the response was toward enhancement or toward degradation of the habitat.

Data for the study are from July 1972 through February 1981. Field techniques used in collecting the data are numerous. Chapter 2 explains the main field techniques, as well as a few of the most widely applied analytical techniques. The more specialized analytical approaches are explained in detail as encountered in subsequent chapters. Common names of plants and animals are used in the text where possible. Appendix 1-1 lists the common and scientific names for plants, mammals, reptiles and amphibians. Common and scientific names of birds are in Chapter 4.

Following the explanation of techniques and a chapter on phenological events in riparian vegetation are seven chapters analyzing avian use of the Colorado River valley. The lead chapter in this series is a general introduction to the birds of the lower Colorado River (Chapter 4), including their distribution, period when they are present in the study

area, breeding status, and general comments about their food habits. The second chapter in this series (Chapter 5) is a careful, comprehensive analysis of how birds use riparian vegetation. In this chapter we considered both species richness and densities and how these varied spatially and temporally. This is one of the major sources of information about the stated objectives of the report. This is followed by a detailed analysis of avian use of a small but important area -- the Bill Williams Delta (Chapter 6). This area is important because it supports the largest remaining stand of cottonwood-willow in the vicinity of the lower Colorado River. This stand was severely damaged by high water flows during 1979-1980 and even as this report is being written, the area is threatened with more high water flows.

Brief consideration of various aquatic-based avian groups that use the river are the subject of Chapter 7. This chapter takes into account the potential impact on these groups of dredging, riprapping, and human recreational use of the river. Because of the economic importance of Gambel Quail, a separate chapter is devoted to this species (Chapter 8).

Chapter 9 considers the vegetational changes at various intervals of time following a disturbance such as fire. Emphasis is placed on the birds that are attracted to an area at various stages of redevelopment. This is potentially important in predicting the avian density and diversity at various times following revegetation efforts.

Chapters 10 and 11 summarize the use of riparian vegetation by nocturnal rodents. Chapter 10 is the second chapter with substantial information directly relating to the objectives of the report.

Chapter 12 summarizes four years of the collection and analysis of contents in coyote scats along avian census routes. The knowledge of food habits of coyotes on a seasonal and annual basis, combined with abundance data on prey species such as rodents and birds, has allowed an in-depth assessment of the ecological role played by the coyote in riparian habitats along the lower Colorado River and helps identify the habitats most preferred in the hunting activities of this large carnivore.

The final chapter (Chapter 13) represents an effort to synthesize the entire report. This chapter not only evaluates the extent to which we were successful in meeting the four objectives, but it also references the data most pertinent to those objectives.

The majority of the plans concerning field and basic analytical methodologies were developed by both authors during 1974. Both worked full time toward achieving the objectives from that time forward. The project was such an enormous undertaking that it was not likely that two people of modest ability could successfully attain the intended objectives without the intellectual input, to say nothing of the field effort, from a large number of other interested and capable biologists. Many of these individuals deserve special mention.

The chapter concerning techniques (Chapter 2) is a by-product of a paper first published by Anderson et al. (1977) and later revised by Dr. Julie K. Meents. The illustrations were done by Brian Woodbridge.

The work done by Kenneth V. Rosenberg on Chapters 4, 6, and 8 and by Alton Higgins on Chapter 9 was so extensive that they have been listed as authors of these chapters. Both of these astute biologists also assisted with field work for several years. Without them, our success would be much less than it is.

Dan Cohan assisted with writing Chapter 5, Kenneth V. Rosenberg with Chapter 7, Dr. Meents with Chapter 2, and Kathleen Conine with Chapters 10 and 12. These biologists also assisted with field work, and we are grateful for their dedication to the project.

Dr. Meents' editorial work was also aided extensively by Susan M. Cook, Jane R. Durham, and Cindy D. Zisner.

We are grateful to Beatrice Anderson, Marcelett Ector, and Cindy D. Zisner for typing the numerous drafts of chapters. Melodie Carr, Elaine Hassinger, Stephanie Lewis, Rodney H. Ohmart, Duna Strachan, and Cindy D. Zisner kindly prepared the graphs.

We are grateful to Dr. Jake Rice for advice concerning data analysis and to A. Kurt Webb for computer programming. We also thank the many field biologists who assisted with field work and data analysis and helped in various other ways. We also thank all those who sorted, coded, and keypunched data, especially Linda C. Richardson.

Finally we wish to thank the U.S. Bureau of Reclamation for its long-term funding of this project. Many members of that organization deserve thanks, especially Phillip Sharpe, Herbert Guenther, William Butler, and Mildred Elkins.

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Appendix 1-1. List of scientific names of plants, mammals, reptiles and amphibians.

Common name	Scientific name
	PLANTS
Arrowweed	Tessaria sericea
Buckwheat	Eriogonum spp.
Bulrush	Scirpus spp.
Cat-tail	Typha spp.
Cottonwood	Populus fremontii
Four-wing salt bush	Atriplex canescens
Goosefoot	Chenopodium spp.
Hackberry	Celtis spp.
Honey mesquite	Prosopis glandulosa
Mistletoe	Phoradendron californicum
Palo verde	Cercidium spp.
Prickly pear	Opuntia spp.
Quail bush	Atriplex lentiformis
Sago pondweed	Potamogeton pectinatus
Salt bush	Atriplex spp.
Salt cedar	Tamarix chinensis
Sand-bur	Xanthium spp.
Screwbean mesquite	Prosopis pubescens
Sedge	Carex spp.
Willow	Salix gooddingii
Wolfberry	Lycium spp.
Yerba-mansa	Anemopsis californica
	MAMMALS
Antelope ground squirrel	Spermophilus spp.
Bighorn sheep	Ovis canadensis
Cactus mouse	Peromyscus eremicus
Coyote	Canis latrans
Deer mouse	Peromyscus maniculatus
Desert cottontail rabbit	Sylvilagus audubonii
Desert kangaroo rat	Dipodomys deserti
Desert pocket mouse	Perognathus penicillatus
Desert shrew	Notiosorex crawfordii
Desert woodrat	Neotoma lepida
Harris antelope squirrel	Ammospermophilus harrisii
Hispid cotton rat	Sigmodon hispidus
House mouse	Mus musculus
Jackrabbit	Lepus spp.
Merriam kangaroo rat	Dipodomys merriami
Mule deer	Odocoileus hemionus
Muskrat	Ondatra zibethicus
Porcupine	Erethizon dorsatum
Skunk	Mephitis spp.
Southern grasshopper mouse	Onychomys torridus
Southern pocket gopher	Thomomys umbrinus
Western harvest mouse	Reithrodontomys megalotis

Appendix 1-1. (cont.)

Common name	Scientific name
White-tailed antelope squirrel	*Ammospermophilus leucurus*
White-throated woodrat	*Neotoma albigula*
Valley pocket gopher	*Thomomys bottae*
REPTILES AND AMPHIBIANS	
Rattlesnake	*Crotalus* spp.
Spiny lizard	*Sceloporus* spp.

CHAPTER 2

FIELD TECHNIQUES AND DATA ANALYSES

INTRODUCTION

A community consists of a group of populations that occur in the same area and interact with one another. The delimitation of a community is arbitrary to some extent because individual species distributions are geographically variable.

Plant communities are generally described by the visibly most common or dominant plant species. Finer-grained studies usually subdivide recognized plant communities into smaller units based on secondary characteristics such as structure (density, height) or the presence of other, less common, plant species. Animal communities are frequently studied in association with recognized plant communities for the obvious reason that animals tend to be closely associated with plant community characteristics. Differences at some level between animal communities can be expected wherever there are significant differences between plant communities.

The vegetation of the lower Colorado River valley has been classified into six major community types, based on the dominant tree species (arrowweed is the sixth type, but since it is not a tree it is not included in the table; Table 2-1). Each of these community types is further subdivided into structural types, based on distribution of the foliage at various heights (Fig. 2-1). Animal communities of the lower Colorado River valley are studied in conjunction with these community-structural types. (For a greater in-depth discussion of the vegetation classification system consult Anderson et al. 1983, Anderson and Ohmart 1984).

Most communities are too large and/or too complex for every component to be individually measured or counted. Even if this were possible, the information obtained would probably be no more useful than a good representative data set obtained with an appropriate sampling technique. The following procedures have been developed for sampling desert riparian communities on the lower Colorado River.

ESTABLISHING TRANSECTS

Purpose

A transect is a sampling strip extending through a stand of relatively homogeneous vegetation. Data obtained along the transect are representative of the entire vegetation stand. Permanent transects allow comparisons to be made in a recognized plant community through time.

Table 2-1. Average number of trees (±1 SD) per subplot in each of 23 recognized riparian habitat types along the lower Colorado River.

Vegetation type and number of subplots		Number of trees per 150-X-50-m subplot										Percent of subplots with no trees of dominant species
		Salt cedar		Cotton-wood		Willow		Screw-bean mesquite		Honey mesquite		
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Salt cedar												
I	18	95	20	0	0	0	0	0	0	2	20	0
II	8	47	19	0	0	0	0	0	0	0	0	0
III	28	74	25	0	0	0	0	7	13	0	0	0
IV	32	163	105	0	0	0	0	0	0	0	0	0
V	109	133	146	0	0	0	0	1	3	0	0	1
VI	20	31	50	0	0	0	0	0	0	0	0	0
Salt cedar-cottonwood/willow												
I	18	52	13	59	27	87	23	0	0	0	0	0-0
II	10	129	46	38	22	49	34	0	0	0	0	0-0
III	62	130	147	19	44	54	66	13	23	6	7	0-6
IV	52	38	53	0	0	29	17	7	15	0	0	3-8
V	30	44	49	0	0	17	21	0	0	0	0	0-0
VI	22	19	32	1	1	1	26	0	0	0	0	0-50
Salt cedar-screwbean mesquite												
II	10	63	24	2	4	1	1	96	17	0	0	0-0
III	40	49	43	0	0	0	0	18	15	0	0	0-8
IV	78	60	58	0	0	4	25	39	31	0	0	1-6
V	84	45	39	0	0	0	0	44	62	0	0	0-8
VI	18	45	55	0	0	0	0	6	6	0	0	0-22
Salt cedar-honey mesquite												
IV	38	41	53	0	0	0	0	0	0	35	68	2-6
Honey mesquite												
III	24	0	0	0	0	0	0	<1*		93	50	0
IV	122	0	0	0	0	0	0	0	0	31	42	1
V	56	0	0	0	0	0	0	0	0	12	7	2
VI	52	0	0	0	0	0	0	<1*		9	7	2

*Standard deviation not calculated where $\bar{x}<1$.

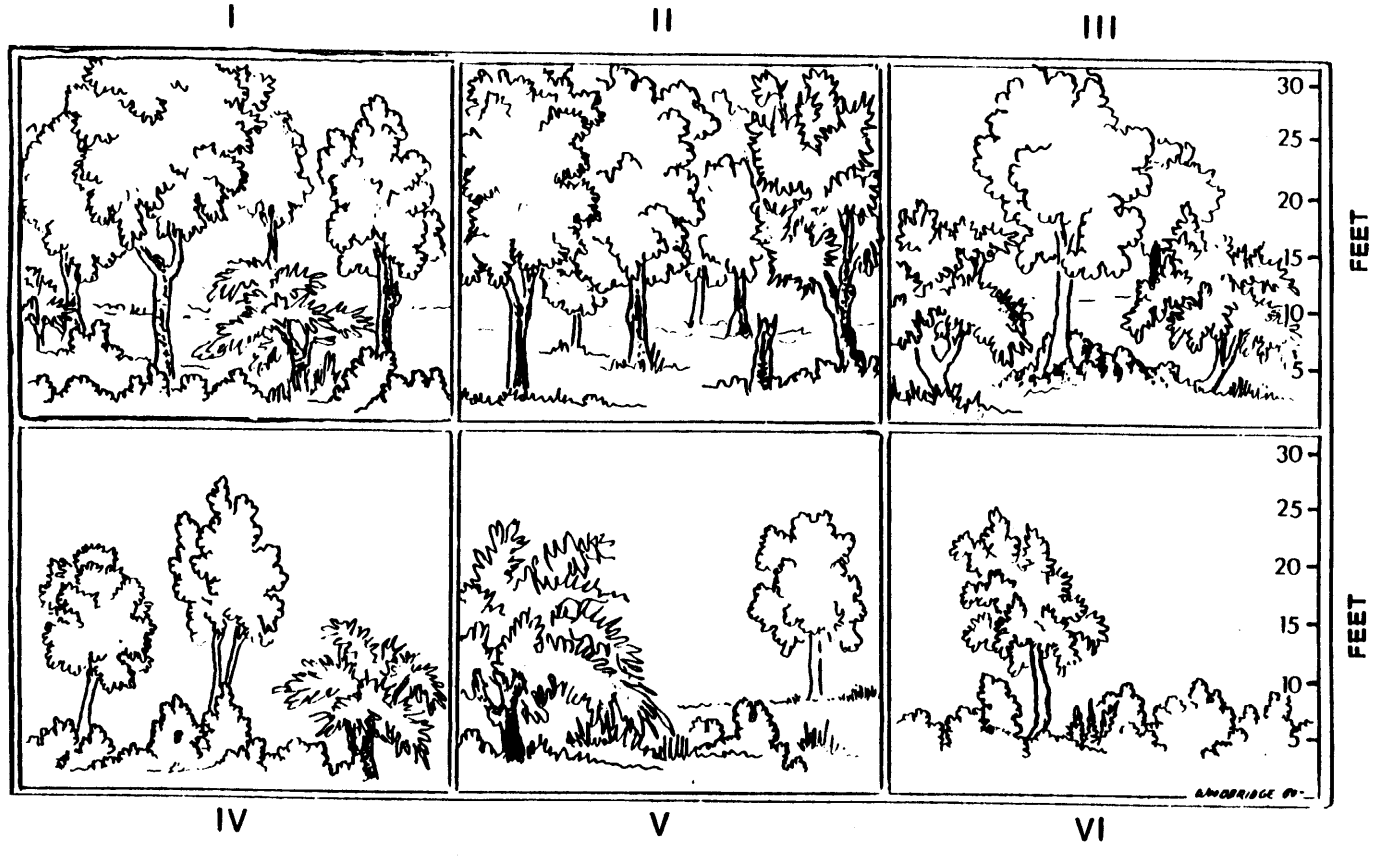


Figure 2-1. Vegetation structural types based on foliage density at various heights.

Procedure

As noted, transects are established through stands of relatively homogeneous vegetation. The plant community-structural types shown in Table 2-1 serve as the basis for defining homogeneous stands of vegetation; a stand suitable for a transect is one that represents only one community-structural type. In the field, the identification of a stand may not be clear-cut because vegetation types tend to be patchy or to intergrade with other types. Extensive reconnaissance is necessary before transects are established to ensure that the best representative vegetation is chosen and that it is of adequate areal extent to accommodate a transect.

In order to provide an adequate sample, transects should be between 0.8 and 1.6 km (0.5 and 1.0 mi) long, the general rule being that long transect lines are better than short ones. The maximum sampling area extends up to 124 m (412 ft) from the center line on each side. The area encompassed is 20 ha (50 a) on a 0.8-km transect and 40 ha (100 a) on a 1.6-km (1.0-mi) transect of maximum width. When a transect is established, a line 1-1.5 m (3-5 ft) wide is cleared to facilitate traversing the area and to ensure that the same area is always sampled. A typical transect is illustrated in Figure 2-2.

Each transect line is numbered and designated as oriented in a specific compass direction and begins and ends with three red flags. A stake marked with the transect number and direction sampled is also present at each end of the line. Each 150-m (500-ft) interval of the line is marked with a numbered stake and two red flags. The transect path is marked with single red flags at 15-m (50-ft) intervals.

A transect that is 750 m (2500 ft) long has five 150-m intervals, each of which has two sides. This yields a total of ten 150 X 124-m plots (Fig. 2-2). All data are recorded in relation to a specific plot.

VEGETATION MEASUREMENTS

Purpose

Vegetation measurements are made to determine the composition and structure of each community sampled by a transect.

Procedures and Data Analysis

Tree Counts. Tree counts are conducted only once on each transect. Counting is not affected by the amount of foliage present and can be done at any time of the year.

Each individual tree and shrub in a strip 15 m wide on either side of each 150-m interval is counted and categorized by species, presence of mistletoe, and size (less than or greater than 3 m [10 ft]). A sample data sheet is shown in Figure 2-3. It is sometimes easier to divide the counting into 30-m (100-ft) intervals because the large diversity of tree and/or shrub species may make it difficult to keep track of the number of each species.

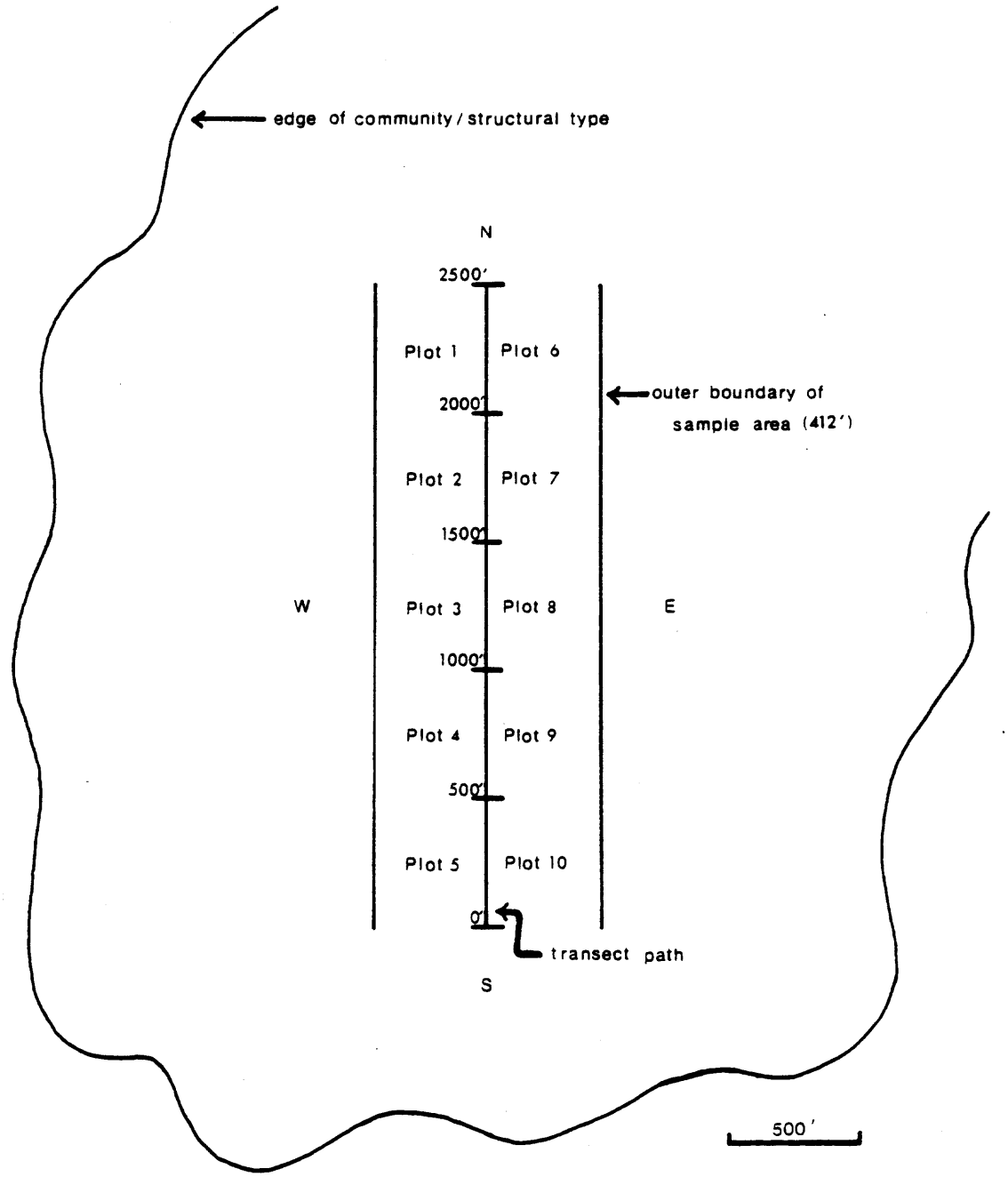


Figure 2-2. Typical transect showing individual plots and outer boundaries.

TREE COUNT

PAGE 1 OF 1

TRANSECT PA25 STARTING DIRECT E DATE 6/2 READER DB

DIRECTION S DIRECTION N

SC = Salt Cedar
SAL = Salix

INTERVAL	SPECIES			SPECIES		
	SC <10	SC ≥10	SAL ≥10	SC <10	SC ≥10	SAL ≥10
0-500	80	140	3	50	160	2
500-1000	12	95	2	50	200	0
1000-1500	110	250	0	75	320	0
1500-2000	40	200	4	60	250	3
2000-2500	10	150	1	5	100	1

Figure 2-3. Tree count data sheet.

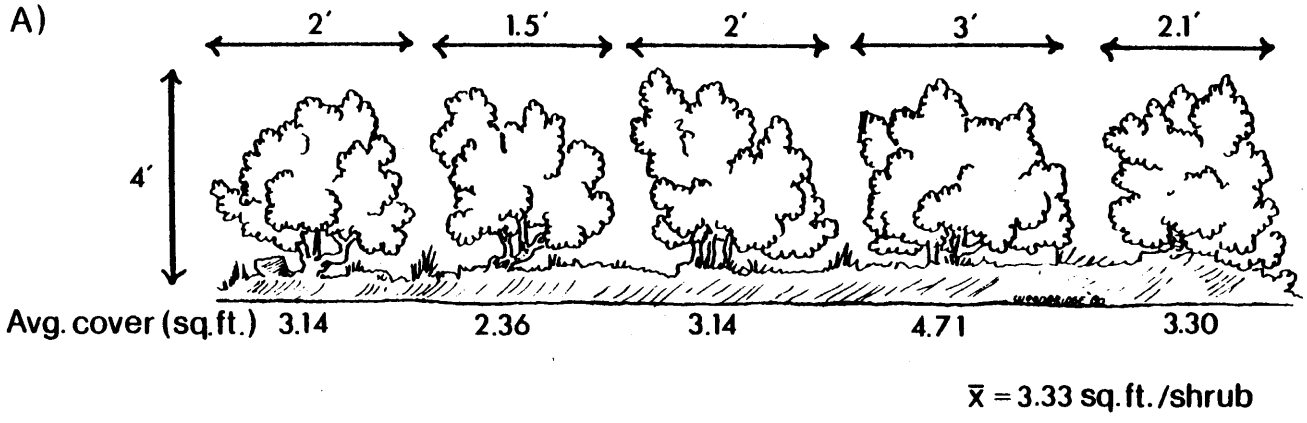
Some shrubs that grow in large clumps are difficult to count as individuals. In these cases, a reference sample of individual shrubs is measured for foliage diameter and foliage height (Fig. 2-4A). The average amount of ground cover per shrub can then be determined for each height class. During actual transect counts, the percent ground cover of this shrub in each 15 X 30-m strip is estimated by the observer. This estimate is converted to the minimum number of shrubs for the area by dividing by the average cover per shrub (Fig. 2-4B). This method may also be applied to all trees and shrubs to determine ground cover for a given species of plant in the area.

Foliage Density. Mature plant communities are sampled annually between May and July; plant communities undergoing succession are measured at the beginning and end of each growing season to quantify growth changes.

Relative foliage density is estimated using the board technique of MacArthur and MacArthur (1961). Sampling is done at three points on each side of each 150-m interval. These sampling points are at 15 m (50 ft), 75 m (250 ft), 135 m (450 ft), 165 m (550 ft), 225 m (750 ft), 285 m (950 ft), 315 m (1050 ft), and so on, for the entire length of the transect. Stopping points were selected on a stratified random number basis. For example, on a 750-m transect there are 15 points per side, or a total of 30 points for the entire transect.

At each sample point on the transect the observer moves seven steps perpendicular to the transect, taking the first step at the edge of the vegetation bordering the transect path (Fig. 2-5). The nearest green leafy vegetation that will cover half of a foliage board (a board approximately 22.5 X 40 cm [9 X 16 in]) centered at 15 cm (6 in) above ground level is then selected (Fig. 2-6). This may be a single plant or a series of plants of differing distances from the observer that in total cover only half of the board. The distance to the board is then measured using a measuring tape or range finder. All measurements are rounded to the nearest foot, except that 5 inches is not called 0, as 5 inches represents very dense vegetation; 0 means vegetation is absent. Thus any distance greater than 0 but less that 5 inches is called 1 foot. This is done because it is difficult to obtain agreement between two observers for distances less than 1 foot, yet the difference in the density estimate between 2.5 cm (1 in) and 5 cm (2 in) is large. This results in a conservative estimate of foliage density but yields results that are reproducible by other observers. The same procedure is repeated at height levels of 0.6 m (2 ft), 1.5 m (5 ft), 3 m (10 ft), 4.5 m (15 ft), 6 m (20 ft), 7.5 m (25 ft), 9 m (30 ft), 12 m (40 ft), 15 m (50 ft), etc. until no vegetation is present. The distance from the observer and the type of plant are recorded at each level. As heights increase it becomes more difficult to make the measurements. In theory, one should use a ladder or climb a tree to the various heights. This was impractical; therefore, we used a range finder to locate a point, say to 25 ft, then estimated as carefully as possible the distance to vegetation which would cover half of the board.

Distances should be measured very accurately within the first 3 m because the foliage density index is more sensitive to near vegetation. Measurements beyond 10 ft may be estimated or determined using a range



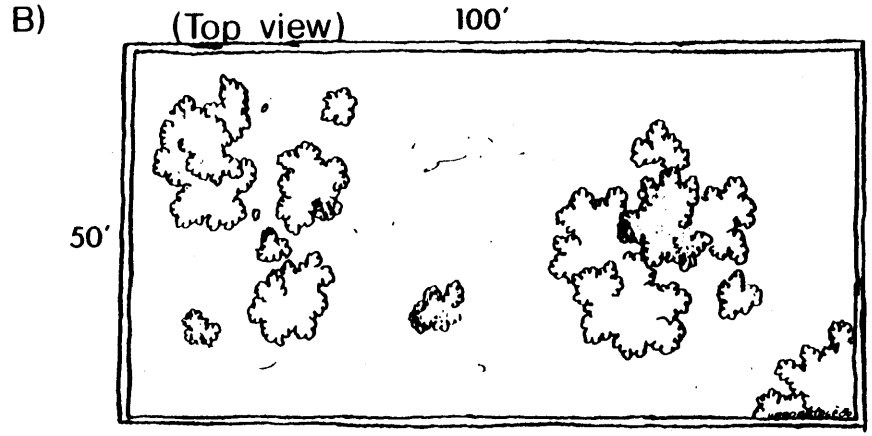


Figure 2-4. A. Reference sample of Atriplex.

B. Sample area with approximately 30 percent cover of Atriplex.

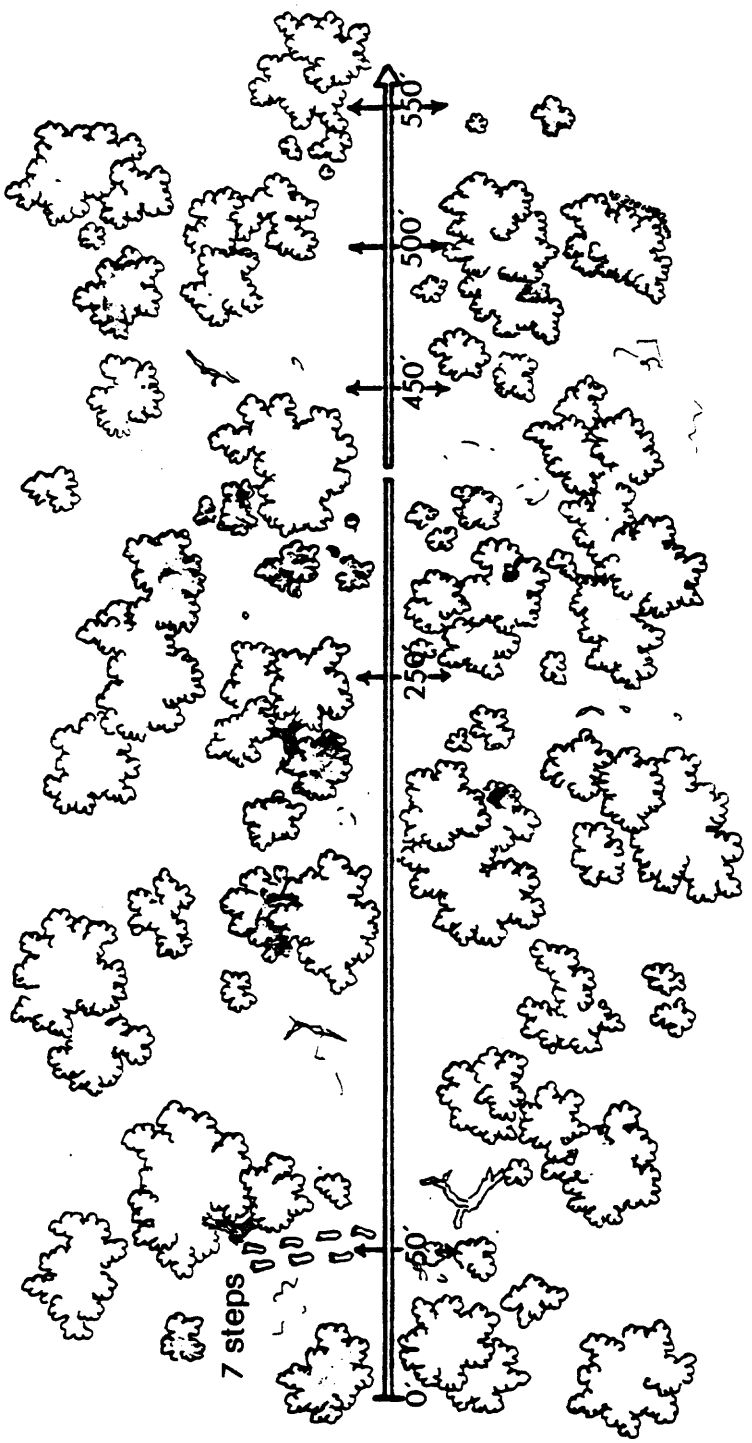


Figure 2-5. Sampling points for foliage density measurements.

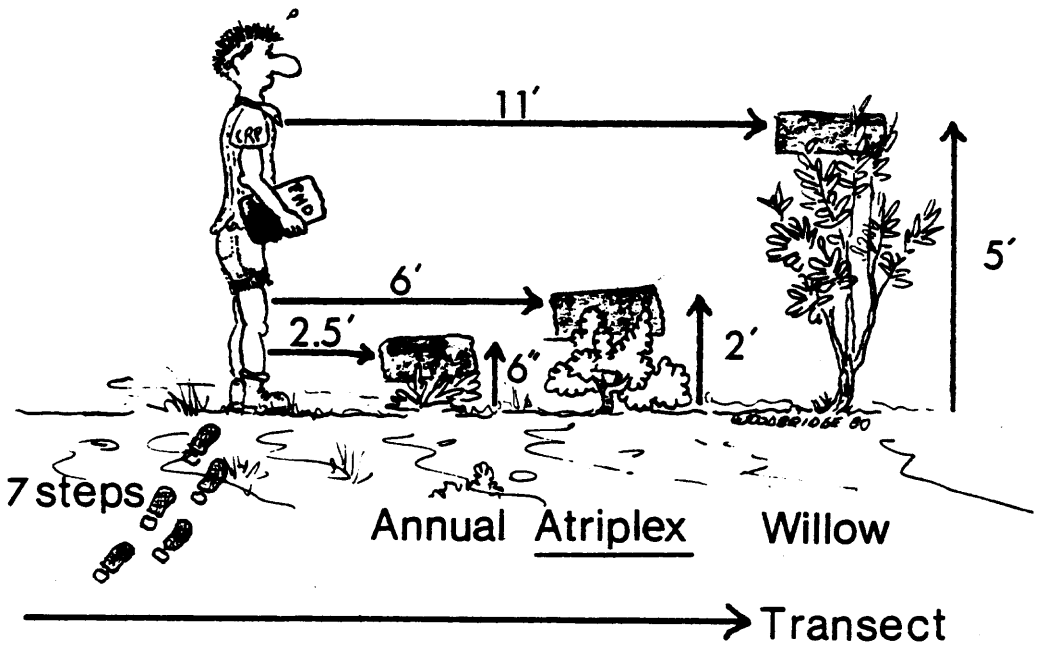


Figure 2-6. Selection of vegetation for foliage density measurements.

finder. The maximum distance considered is 124 m, or the outer boundary of the transect. A specific individual plant may be used only once in foliage measurements. Thus if a plant was used at a previous point, or will be used for an estimate from a subsequent point, it should not be included at any other point. Each plant species and distance measurement is recorded separately according to distance along the transect, side of transect, and height interval, as shown on the sample data form (Fig. 2-7).

Each plant species distance measurement is converted to ft^2 of leaf surface per ft^3 of space using the formula

$$K = \frac{\log_e 2}{D} = \frac{0.693}{D}$$

where K is the foliage density and D the measured distance. The three foliage densities for each plot are then averaged to obtain the plot foliage density. All of these measurements were done in feet. Since conversions would create cumbersome numbers, we retain the original measurements in all of the following calculations.

For example, foliage density for the first plot of the sample data shown in Figure 2-7 is calculated from measurements taken at 15, 75, and 135 m on the south side. The three plant distance measurements are first converted to foliage density estimates using the formula given above. Foliage density for the first plot is then calculated:

$$\frac{0.0770 + 0.0462 + 0.3465}{3} = 0.1556$$

If no green vegetation could be measured at a particular point, a zero should be used in calculations. Foliage densities for all plots in Figure 2-7 are shown in Table 2-2.

Patchiness. Vegetation patchiness is a structural feature of a habitat that describes the regularity of vegetation distribution in the horizontal and vertical dimensions of space. For example, a lemon orchard that has trees of equal size that are evenly spaced (Fig. 2-8A) is less patchy than a honey mesquite-Atriplex community that has irregularly spaced trees and shrubs of different heights (Fig. 2-8B). A quantitative measure of patchiness can be calculated from foliage density data.

Foliage density measurements at different heights are pooled to represent layers of vegetation. Four layers (0-0.6 m, 1.5-3.0 m, 4.5-6.0 m, $\geq$7.5 m) appear to relate best to avian data in the lower Colorado River valley (Anderson and Ohmart, ms.). Mean foliage density for each layer is the average of the sum of foliage densities measured at the appropriate heights in each plot. The measure of patchiness is simply the variance associated with the mean total foliage density at each level.

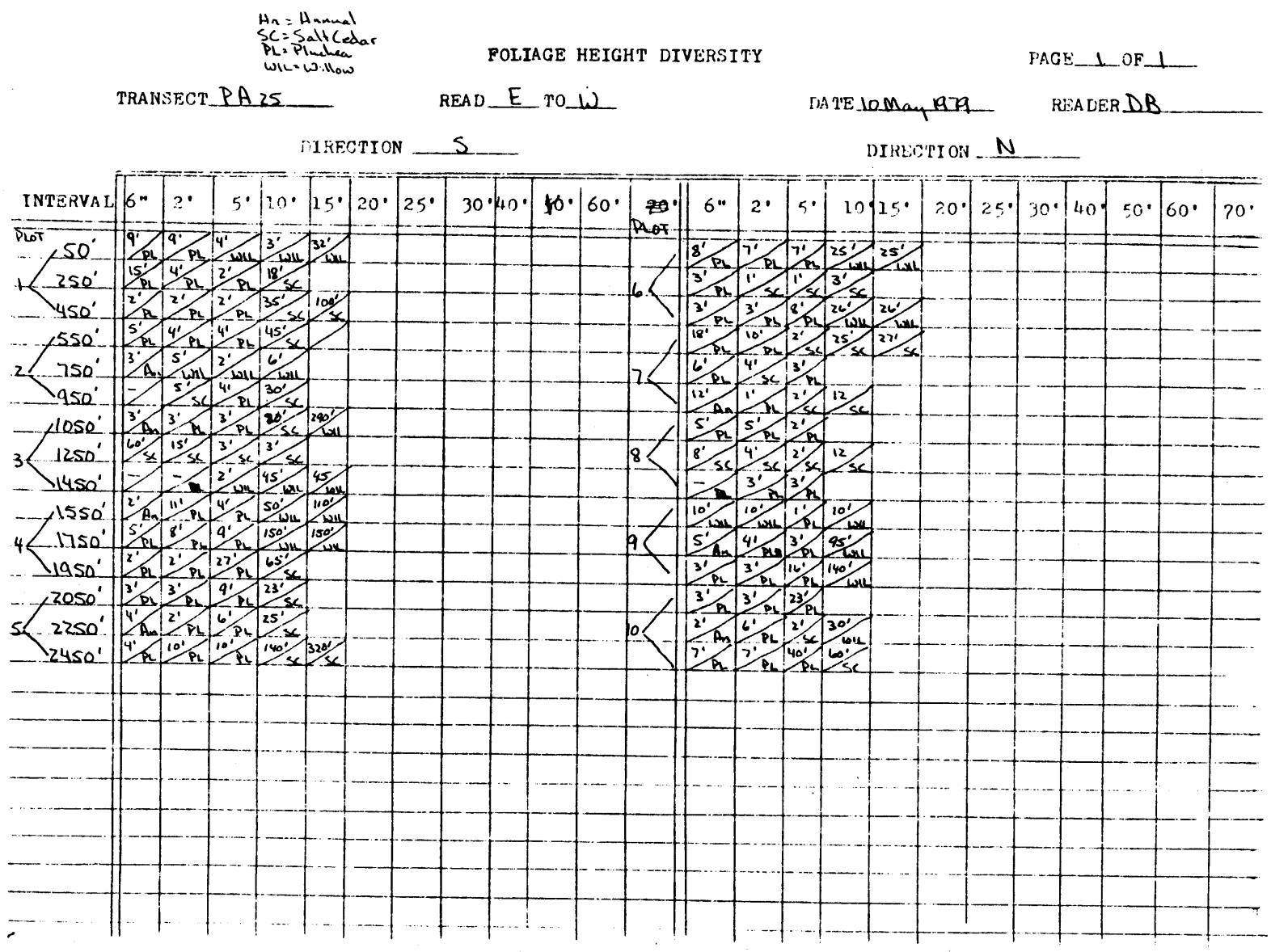


Figure 2-7. Foliage Height Diversity (FHD) data form.

Table 2-2. Foliage density, patchiness, and foliage height diversity calculations for the sample vegetation data in Figure 2-7.

	Foliage density				
Plot	0.15 m	0.6 m	1.5 m	3.0 m	4.6 m
1	0.157	0.199	0.289	0.096	0.010
2	0.123	0.150	0.231	0.055	-
3	0.081	0.092	0.270	0.085	0.006
4	0.277	0.147	0.092	0.010	0.004
5	0.193	0.216	0.087	0.021	0.001
6	0.183	0.341	0.293	0.095	0.018
7	0.071	0.312	0.308	0.029	0.009
8	0.075	0.181	0.308	0.019	-
9	0.146	0.158	0.322	0.027	-
10	0.226	0.149	0.131	0.012	-

	Patchiness				
	0.15-0.6 m	1.5-3.0 m	4.6-6.0 m	$\geq$7.5 m	Total
$\bar{x}$ Total density	0.348	0.278	0.004	-	
PI(s^2)	0.010	0.013	0.000	-	0.023

Table 2-2. (cont.)

	Foliage height diversity				
	0.15-0.6 m	1.5-3.0 m	4.6-6.0 m	≥7.5 m	Total
$\bar{x}$ Total density	0.348	0.278	0.004	0	0.630
p_i	0.552	0.441	0.006	0	
$\log p_i$	-0.258	-0.355	-2.197	0	
$p_i \log_{10} p_i$	-0.142	-0.157	-0.013	0	FHD=0.312

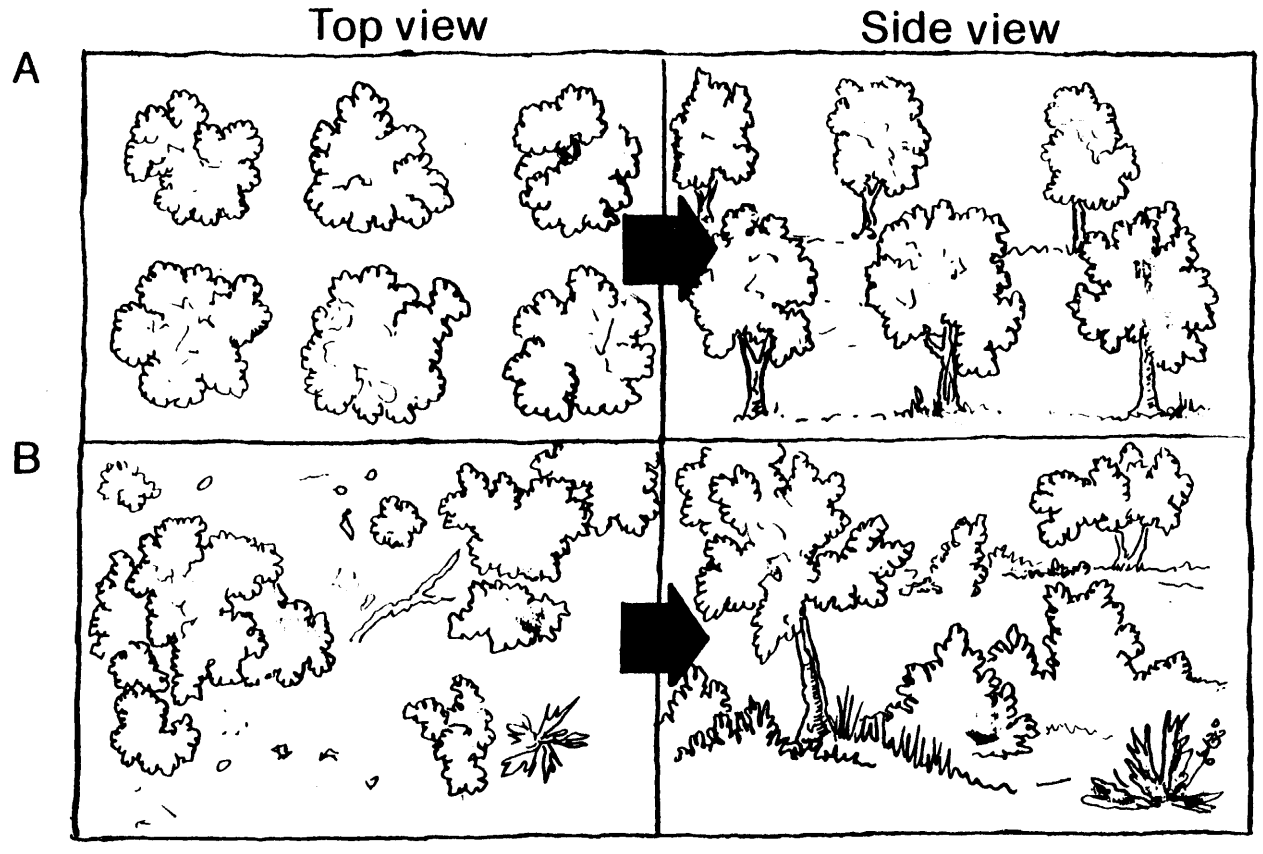


Figure 2-8. A. A lemon orchard with evenly spaced trees of equal height exhibits relatively low patchiness.

B. A honey mesquite-Atriplex community with irregularly spaced trees and shrubs of different heights exhibits relatively high patchiness.

For example, the summed foliage densities for 15 cm and 0.6 m in each plot in Table 2-2 are averaged to obtain the mean foliage density for 0-0.6 m (0.348). Patchiness is the variance associated with the mean total foliage density. The same procedure is used to determine patchiness at the other levels. Total patchiness is the sum of the variances for all layers.

Foliage Height Diversity. Foliage height diversity is computed according to information theory (Shannon and Weaver 1949):

$$H = -\sum_{i=1}^{n} p_i \log p_i$$

where H equals foliage height diversity and p_i equals the proportion of the total foliage density contributed by the density at height level i. Calculations for determining H from the example in Figure 2-6 are shown in Table 2-2.

Litter Height Diversity. The presence or absence of litter is recorded every 30 m along a transect within a 1.5-m (5-ft) radius from the observer at the same height intervals used in foliage density measurements. Information theory is also used for calculating litter height diversity; p_i is the proportion of total points with litter occurring in the ith layer.

RODENT POPULATIONS

Purpose

Rodent populations are sampled in each community type to determine relative densities, habitat preference, and reproductive patterns of each species. Small mammal population data are grouped into two seasons: winter (November through March) and summer (April through October).

Procedure

Setting Out a Grid. Rodent populations are sampled with a snap-trap grid consisting of two parallel lines 15 m apart; each line is made up of 15 stations, 15 m apart (Fig. 2-9). Each station has two museum-special mouse traps and one Victor rat trap. Each grid is trapped for three consecutive days. Evidence indicates that nearly all of the rodents within effective range (200-300 ft) of the traps are caught in three nights (see Chapter 11 for more information concerning movements of rodent species).

Because snap-trapping removes animals from the population, a particular area should not be sampled too frequently. Rodent trapping is generally used to describe populations in particular community-structural types rather than those on a particular transect. Trapping is rotated between different transects representing the same community type in order to allow mammal populations to recover between samples. In general, the same transect is not sampled more than once per season. If a transect

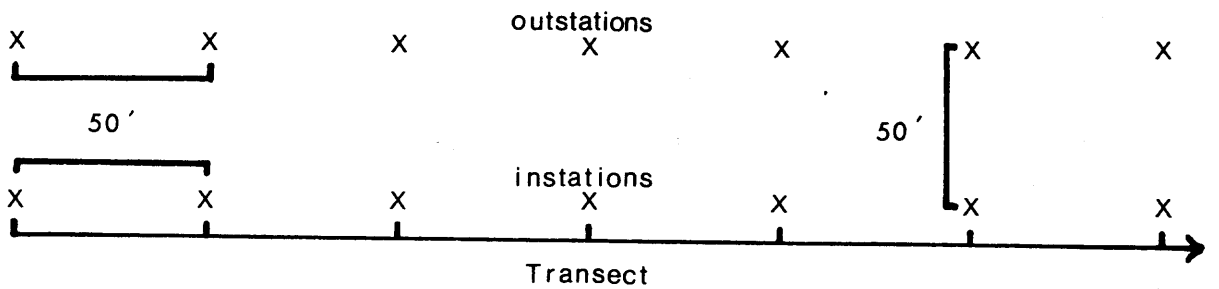


Figure 2-9. Small mammal trapping grid, showing placement of in-stations and out-stations.

must be sampled more than once in a season, the portion of the transect trapped should be changed each time the transect is sampled.

Traps are placed in the portion of the transect that is most representative of the community-structural type and the side of the transect to be sampled is randomly selected. Stations of one line of the grid are placed at the 15-m interval flags along the transect. These are termed "in-stations" (Fig. 2-9). The in-station traps are placed in the vegetation on the appropriate side of the transect. If the grid is placed along a road, cut, or edge, the traps are placed in adjacent vegetation, not on the edge of the road or cut.

Traps placed in a line parallel to those along the transect are termed "out-stations." Out-stations are placed 15 m from in-stations, perpendicular to the transect (Fig. 2-9). All trap stations are marked with blue flagging.

The three traps at each station are placed within a 0.9-m^2 (3-ft^2) area according to the pattern illustrated in Figure 2-10. The traps are placed 0.2-0.3 m (8-12 in) apart so that an animal caught in one trap will not set off the other traps. All traps are nailed to the ground to prevent them from being dragged off by animals that have not been immediately killed. Traps are baited with peanut butter and rolled oats, combined with an ant repellent (Table 2-3; Anderson and Ohmart 1977a). Fresh bait is used on traps each day.

A maximum/minimum thermometer is placed in the shade near one of the stations. Traps are checked each morning after being set out and left overnight.

Daily Trapping Procedure. A sample small mammal field data form is shown in Figure 2-11. This form is used for all three days of trapping. Vegetation data are taken on the first day to describe the microhabitat in which each station is placed.

Microhabitat data are collected at three height intervals, including 0-0.2 m (GR), 0.2-0.6 m, and >0.6 m. An imaginary square, about 0.9 m on each side, is visualized around the three traps, with the rat trap at the center. The percent cover of each plant species, litter, and dead vegetation in the square is estimated for each vegetation level (Fig. 2-11). These estimates are made in 25% increments, except for annual plants, which are recorded in 1% increments. A vegetation level may have more than 100% cover if several species overlap in cover.

Weather and maximum/minimum temperatures are recorded daily. Each mammal captured in a trap is recorded according to its location and species. Key characteristics of common rodent species in the lower Colorado River valley are listed in Table 2-4. The status of each trap (snapped, unbaited, etc.) is also recorded. Traps are reset and rebaited. Mammals are then processed to obtain reproductive information.

A sample small mammal processing form is shown in Figure 2-12. Weight, body measurements, and measurements and status of reproductive organs are recorded for each individual.

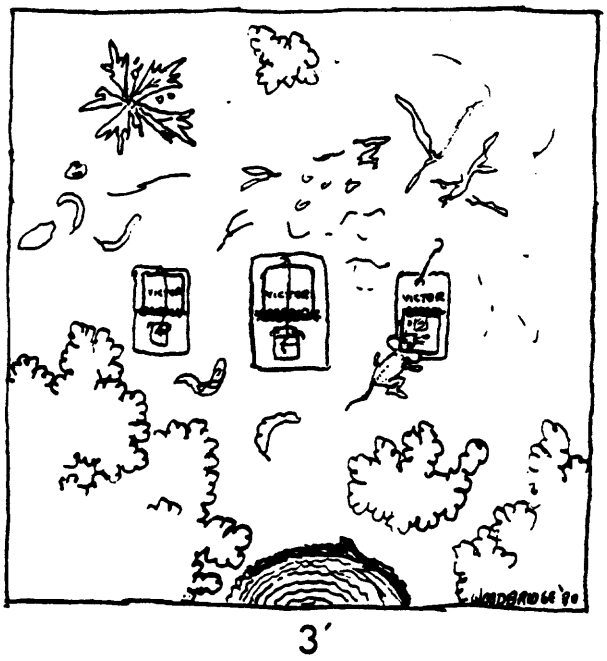
Table 2-3. Procedure for making bait for small mammal trapping.

Ingredients:

1. Peanut butter - 2-1/2 cups
2. Rolled oats - 2-1/2 cups
3. Dimethyl pthalate - 1:24 ratio of dimethyl pthalate to bait

Mixing directions:

1. Measure peanut butter, oats and dimethyl pthalate into separate containers.
2. Place oats into mixing container.
3. Add a small baby food jar (6 oz.) of hot water to oats. Mix well.
4. Mix in peanut butter thoroughly with hands.
5. Add dimethyl pthalate. Mix thoroughly with hands.
6. If mixture is too moist, add small amounts of oats until mixture is of proper consistency.



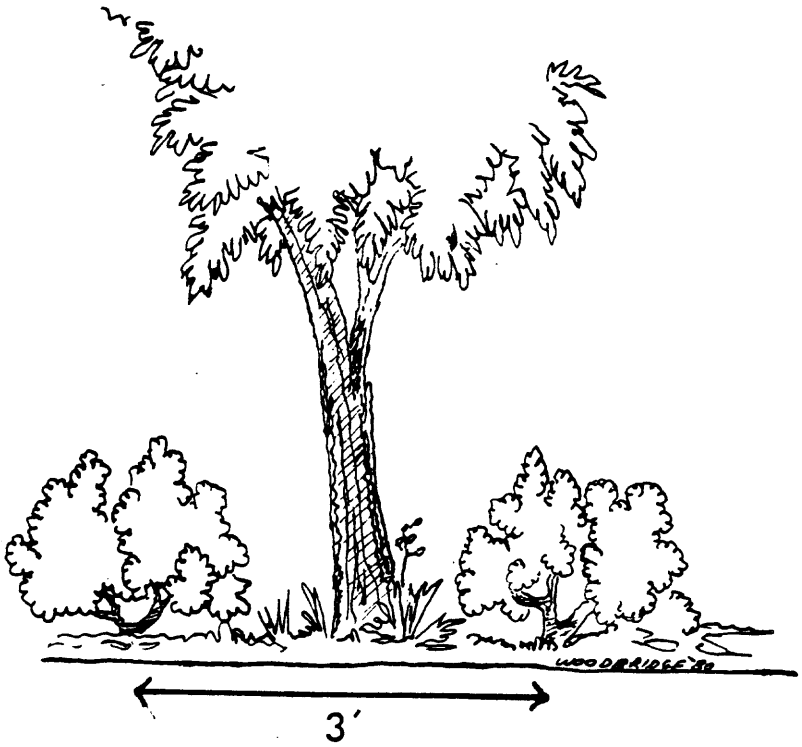


Figure 2-10. Placement of small mammal traps in the vegetation.

MAMMAL PICK-UP FIELD FORM

SNAP - 2 X 15 - 50 ft.

Transect: _____

Distance Along Transect: _____

Nailed: _____

Date Full Moon: _____

Night-1(date: _____

Temp _____

Weather _____

Night-2(date: _____

Temp _____

Weather _____

Night-3(date: _____

Temp _____

Weather _____

Remarks: _____

SUMMARY:
Night-1

Total
Night-2

Total
Night-3

Total

SUM:

Night-1			Vegetation				Night-1			Vegetation		
1-A			GR	0-2'	2' +		1-B			GR	0-2'	2' +
2.							2.					
3.							3.					
4.							4.					
5.							5.					
6.							6.					
7.							7.					
8.							8.					
9.							9.					
10.							10.					
11.							11.					
12.							12.					
13.							13.					
14.							14.					
15.							15.					

Night-2				Night-3			
1-A			1-B	1-A			1-B
2.			2.	2.			2.
3.			3.	3.			3.
4.			4.	4.			4.
5.			5.	5.			5.
6.			6.	6.			6.
7.			7.	7.			7.
8.			8.	8.			8.
9.			9.	9.			9.
10.			10.	10.			10.
11.			11.	11.			11.
12.			12.	12.			12.
13.			13.	13.			13.
14.			14.	14.			14.
15.			15.	15.			15.

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Figure 2-11. Small mammal field data form.

Table 2-4. Key characteristics of small mammals in the lower Colorado River valley.

Scientific name	Two-letter code	Six-letter code	Common name	Characteristics
Peromyscus eremicus	PE	PERERE	Cactus mouse	Most common of all rodents. Tail longer than head and body. No cheek pouches. No tuft on tail. No clear dorsal tail stripe.
Peromyscus maniculatus	PM	PERMAN	Deer mouse	Similar to PE, except tail shorter than head and body. No tuft on tail. Dorsal tail stripe extremely evident.
Perognathus penicillatus	PP	PERPEN	Desert pocket mouse	Yellowish-gray color. Tail longer than head and body. Cheek pouches present. Tuft on tail. Head and body length 2-2.8 in.
Neotoma albigula	NA	NEOALB	White-throated woodrat	Head and body length 7.5-8.5 in. Hairs of throat white to base. Tail white below.
Dipodomys merriami	DM	DIPMER	Merriam kangaroo rat	Cheek pouches present. Head and body length 4 in. Tail longer than head and body. Pale yellow to dark brown above. Large hind foot with 4 toes.

Table 2-4. (cont.)

Scientific name	Two-letter code	Six-letter code	Common name	Characteristics
Mus musculus	MM	MUSMUS	House mouse	Head and body 3.2-3.6 in. Small grayish-brown mouse with gray or buffy belly and a scaly tail about the same color above and below; fur short. Upper incisors not grooved.
Sigmodon hispidus	SH	SIGHIS	Cotton rat	Head and body 5-8 in; long coarse body fur mixed buff and black above, whitish below.
Reithrodontomys megalotis	RM	REIMEG	Western harvest	Head and body 2.8-3 in; like a small PM or PE (wt. 10 g). Upper incisor with a distinct groove down the front, lengthwise.

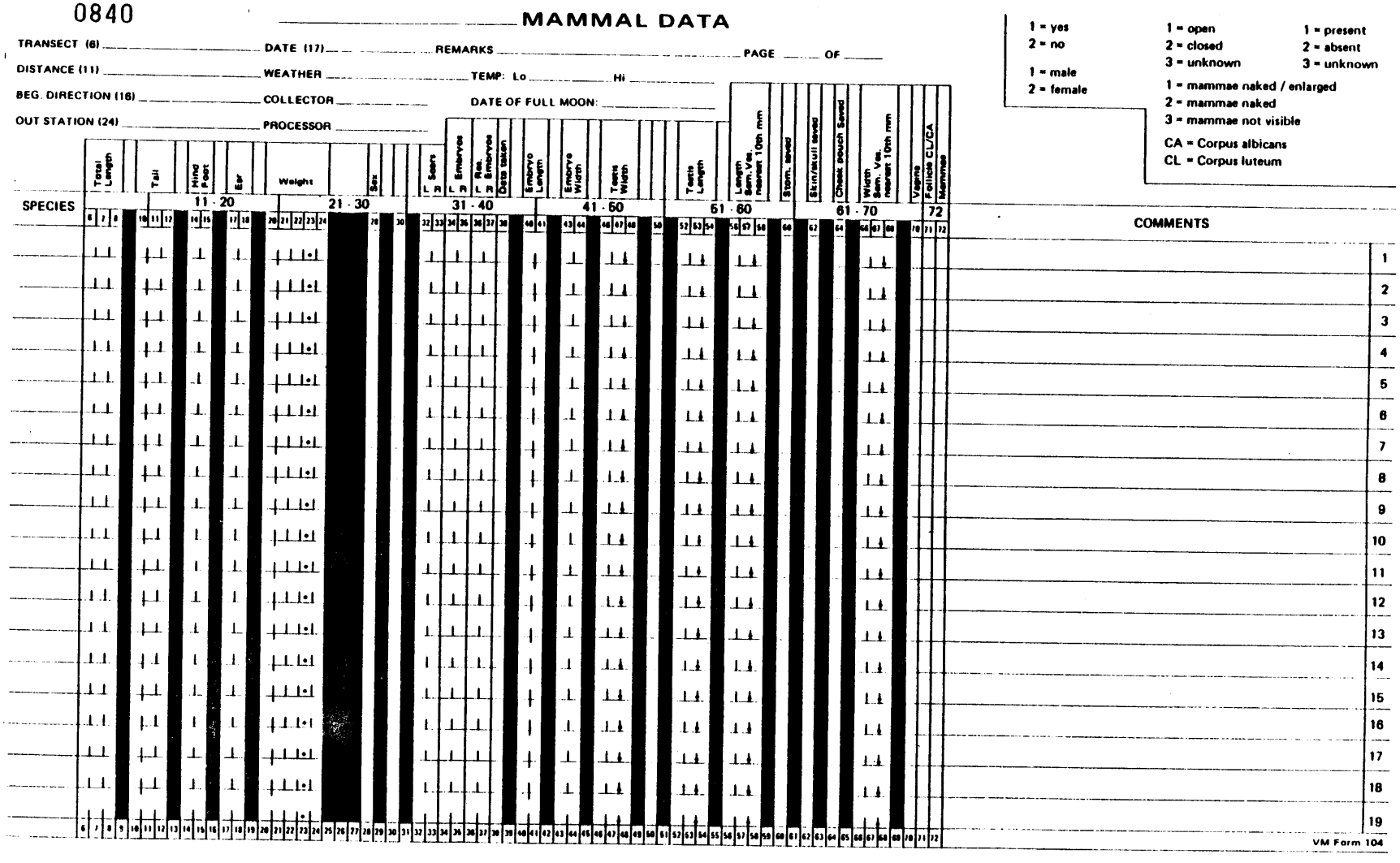

Figure 2-12. Small mammal processing form.

AVIAN POPULATIONS

Purpose

Bird populations are sampled to determine distribution, habitat preference, and abundance of each species. The data also provide information on avian community characteristics.

Procedure

The technique used for sampling birds is based on a method described by Emlen (1971, 1977). As an observer walks the transect line, birds are recorded as they are detected in one of four distance categories perpendicular to the line: 0-15 m (0-50 ft), 15-30 m (50-100 ft), 30-60 m (100-200 ft), and 60-124 m (200-412 ft). Detections are recorded according to side of the transect line, distance from the transect within each 150 X 124-m plot, and whether the detection was made by sight or sound. A sample data form is illustrated in Figure 2-13.

Assigning bird detections to a particular 150-m plot is not necessary for determining population density but is an attempt at fine-grain analysis of the preferred habitat of each species. When a bird is recorded in the 0-15-m distance category, its presence can be correlated with the vegetation parameters that have been measured in that particular 150 X 15-m plot. These parameters include tree densities, foliage density, foliage height diversity, and patchiness.

Censusing a transect two to three times per month provides an adequate analysis of bird populations in most cases (Anderson and Ohmart 1977b). To eliminate sampling biases, the same observer usually does not census the same transect more than once in a single month. Also, the three censuses are evenly spaced throughout the month whenever possible. Censusing is postponed if there is heavy precipitation or strong wind.

Data Analysis

Avian population parameters are determined on a monthly and seasonal basis for individual transects and for community-structural types. The seasons are defined as summer (May-July), late summer (August-September), fall (October-November), winter (December-February), and spring (March-April).

Bird Density. The Emlen (1971, 1977) technique for bird censusing assumes that birds are approximately randomly distributed in a homogeneous habitat. If all birds in a particular strip of vegetation have been counted, their density can be extrapolated to the entire habitat.

To determine the density of birds from a transect count, one first summarizes the number of detections for each species according to the distance from the center line. The detections for Mourning Doves in Figure 2-13 would be summarized as:

0-15 m	15-30 m	30-60 m	60-124 m
6	7	3	2

READ E TO W CRP **BIRD DATA** PAGE 1 OF 1

TRAN Pv6 DATE 20 March 80 TIME 0800- CLOUDS Clear WIND Calm TEMP 70 READER JFS

DIRECTION: S DIRECTION: N

SPECIES	INT.	0-5	5-10	+	++	0-5	5-10	+	++	BIRD HT	TREE HT	TREE SP	POS
AURFLA	1		E (1)										
POLMEL							E (1)						
PIPABE				ESB (1)				2E (2)					
DENSCA	2	2T (2)	E (1)							15'	20'	HM	F
ZENMAC		2T (2)	E,E (2)		E (1)		E (1)						
SPIBRE							GR (1)	2T (2)		2'	4'	ATA	F
PIPABE	3		E (1)					E (1)					
COLGAM		GR (6)											
THRBEW							ESB (1)						
ZENMAC			2T (2)	E (1)		E (1)		E (1)					
PHANIT	4	♂ (1)		E (1)					E (1)				
CAMBRU				E (1)									
ZENMAC		2T (2)											
AURFLA	5	E (1)				T (1)				8'	4'	HM	F
ZENMAC			2E (2)	E (1)		T (1)			E (1)				
PIPABE									E (1)				

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Figure 2-13. Bird census data form.

The distribution of detections shows a peak at one of the intervals lateral to the center line, after which detectability of the species declines. The distribution peak is chosen by selecting the number of detections in a given distance category that, when summed with all detections in distance categories closer to the center line of the transect and multiplied by a lateral distance conversion factor, yields the highest population estimate. These conversion factors serve to extrapolate the number of detections over the entire sample area. The conversion factors for the distance categories of 0-15 m, 0-30 m, 0-60 m, and 0-142 m are 8.24, 4.12, 2.06, and 1.00, because these distances represent 1/8, 1/4, 1/2, and 1/1 of the censused area, respectively. The resulting population estimate is then adjusted, if necessary, to reflect the number of birds per 40 ha (100 a). This procedure is conducted separately for each bird species and the species totals are then summed to yield a total bird density.

The distributional peak of Mourning Doves in the example occurs in the 0-30-m category because the sum of 6 + 7, multiplied by the lateral distance conversion factor for 0-30 m (4.12), yields the highest population estimate (54 birds). If this were a transect with five 150-m intervals (750 m), the population estimate would be 53 birds per 18.6 ha (47.3 a), or 115 birds per 40 ha.

A demonstration that these calculations are realistic is illustrated in Figure 2-14. The figure shows a hypothetical transect with each possible detection point numbered in sequence. A population of 50 birds is assumed to be present in the 41.6-ha (104-a) area. The location of each bird (circled numbers) is randomly determined. If all birds in the first distance category are observed (6 birds), we would obtain a density estimate of 49.4 birds/41.6 ha (6 X 8.24 = 49.4). Estimates for the 0-30-m, 0-60-m, and 0-124-m distance categories would be 45.3, 53.6, and 51.5 birds/41.6 ha, respectively, if each of the circled numbers is counted as one detection. In all cases, the estimates are within 10% of the actual number of birds present. Bird densities are computed on a monthly basis on the basis of the total detections on three separate censuses conducted on the transect during that month.

Bird Species Diversity. Bird species diversity (BSD) is determined using information theory (Shannon and Weaver 1949), where p_i is the proportion of the total bird density contributed by the i^{thi} species. BSD's are calculated on a monthly and seasonal basis for each transect as well as for each community-structural type.

Habitat Breadth. Habitat breadth (HB) indicates the extent to which a species' population is evenly distributed throughout the habitat. It is determined from the species' distribution among the categories of dominant vegetation and structural types (Fig. 2-15).

Habitat breadth is also calculated from information theory; p_i represents the proportion of a species' total population contributed by its density in community-structural type i. When expressed as the percent of maximum habitat breadth:

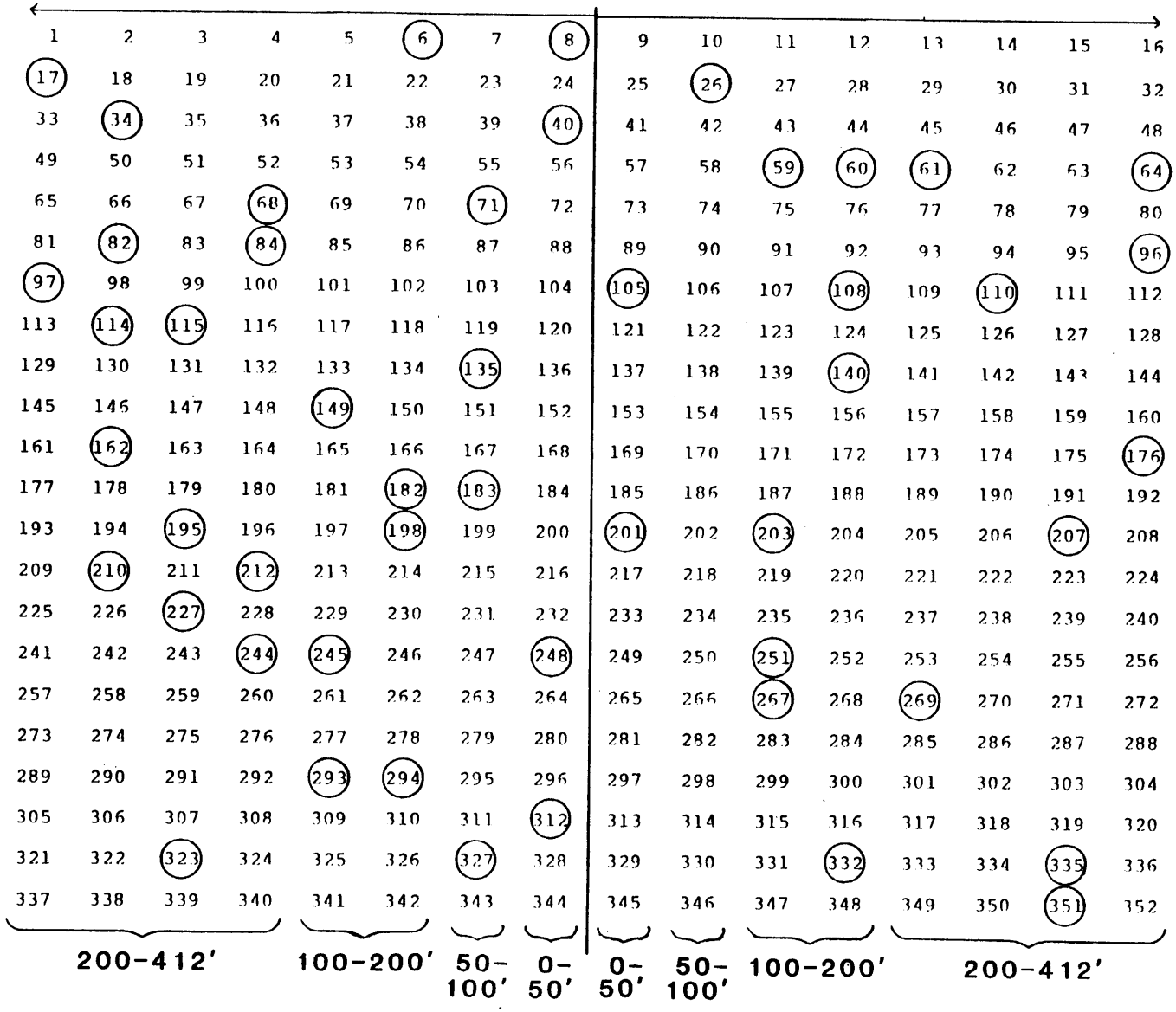

Figure 2-14. Hypothetical transect with randomly distributed birds.

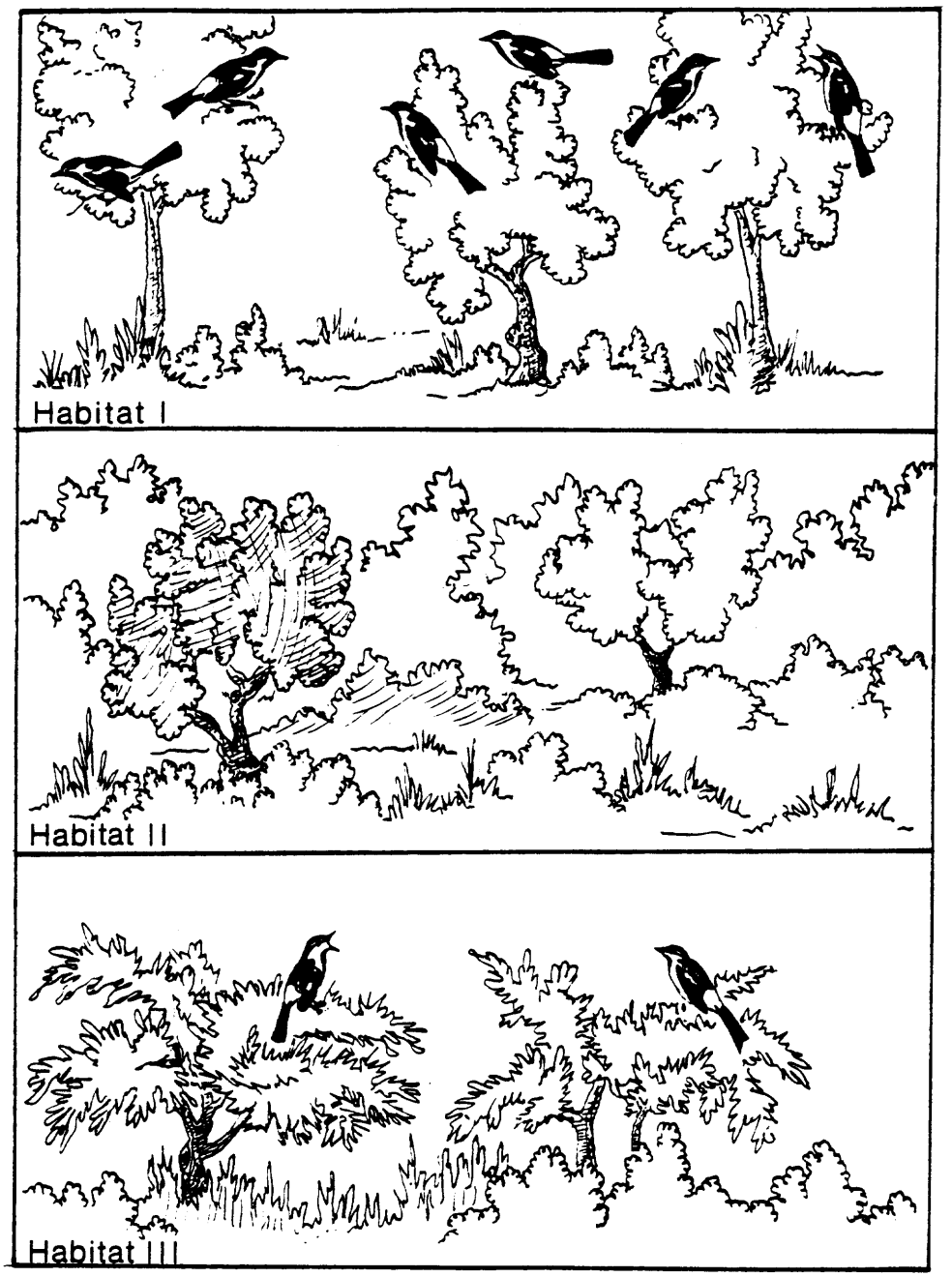

Figure 2-15. Presence of a species at varying densities in three habitat types.

$$J = \frac{HB}{\ln n}$$

(n = number of community types), habitat breadth can be used to designate species as generalists or specialists. Species having a high percentage of maximum habitat breadth are generalists compared to those occurring in a more limited number of habitat types.

Habitat Overlap. Habitat overlap is a measure of the extent to which two species use the same community and/or structural type (Fig. 2-16). It is calculated using Horn's (1966) formula for ecological overlaps:

$$R_o = \frac{\Sigma(x_i + y_i)\log(x_i + y_i) - \Sigma x_i \log x_i - \Sigma y_i \log y_i}{(X + Y)\log(X + Y) - X\log X - Y\log Y}$$

where x_i and y_i represent the density of bird species x and y in community or structural type i, and X and Y represent the sum of the x_i and y_i values. High overlap is indicated by a relatively high R_o value.

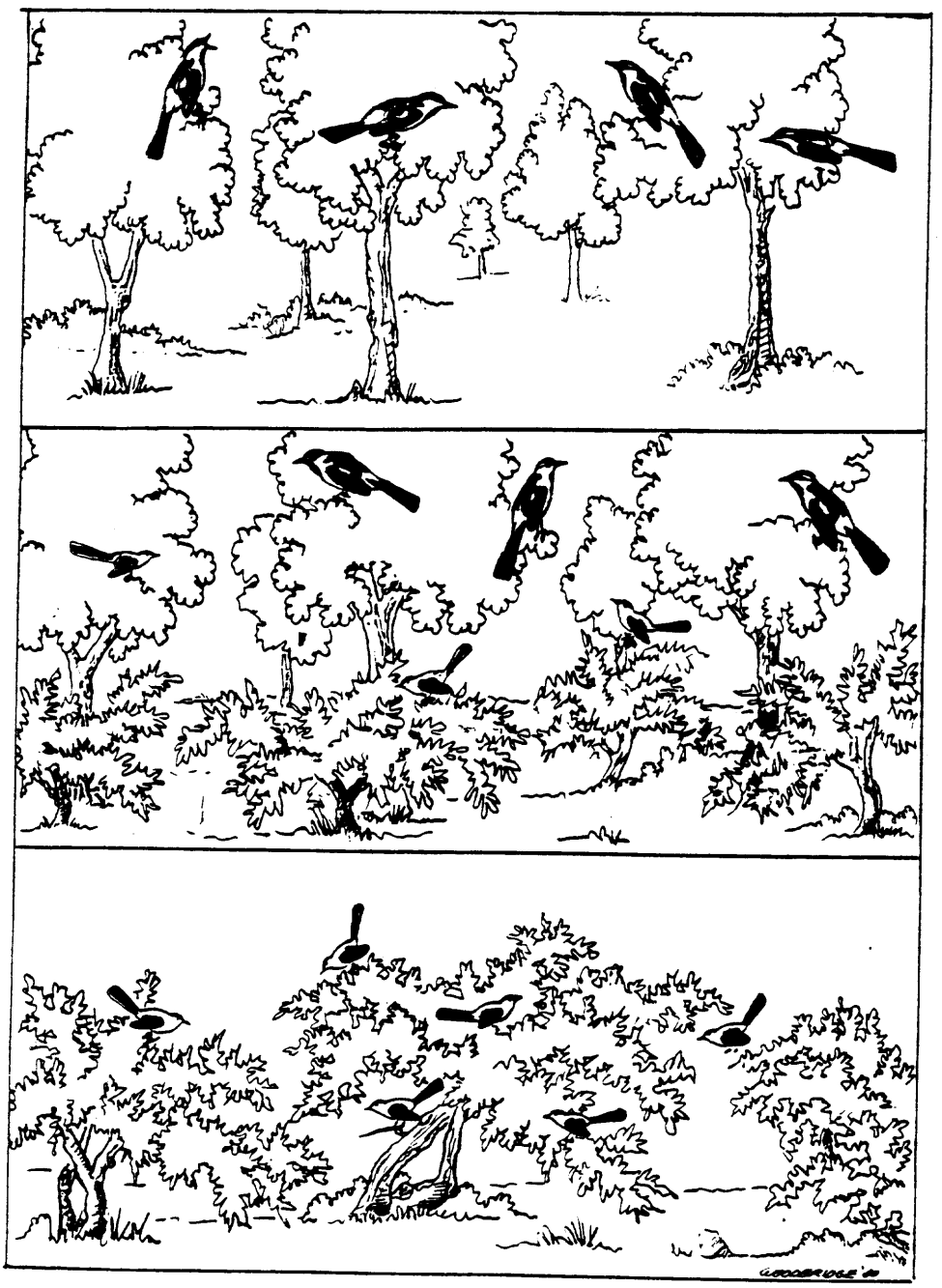

Figure 2-16. Two species overlap in use of one habitat but do not share other types.

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CHAPTER 3

PHENOLOGY

INTRODUCTION

Interest in the perpetuation and improved management of Southwestern riparian habitats has led to numerous studies examining which vegetation components are most important in supporting highest numbers of species and densities of wildlife. Along the lower Colorado River, tree species composition and density, foliage volume, and vegetation structure have been highly correlated with avian densities and numbers of species (Anderson and Ohmart 1977). Seasonal use of the various plant communities by wildlife is related to the phenology of the plants in these communities.

Differential seasonal use of plant communities has been 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 is believed that the phenological events of these riparian plants exert 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, a distance of approximately 440 km (273 mi). Cottonwood, willow, honey mesquite, screwbean mesquite, and salt cedar trees were sampled at monthly intervals for a number of growth and developmental features (see Anderson et al. 1977). Results of the data collected on phenological events are presented in this chapter.

METHODS

Phenological Data

Fifty-seven individuals of each species of the five dominant tree species (above) were marked to provide phenological data on a monthly basis during the years 1975 and 1976. Only mature trees were used. Transects with marked trees were representative of all divisions (Mohave, Parker, etc.) and of nearly all structural and community types.

Twenty new branches, spikes, pods, and leaves were measured on each tree monthly (Fig. 3-1), from which a mean was computed and used in data analysis. A wire hoop of 0.1 m^2 (1.1 ft^2) was placed at the outer perimeter of the canopy of the tree and the numbers of leaves, spikes, and pods occupying an imaginary cylinder from that point to a depth of 0.3 m (1 ft) were counted. This was repeated 15 times to give the mean number per 0.45 m^3 (15.9 ft^3), which was extrapolated to a cubic meter.

Fifteen honey or screwbean mesquite trees along each of 34 transects were sampled at regular intervals for volume, coverage, and pod production. Transects were censused from August through December at one

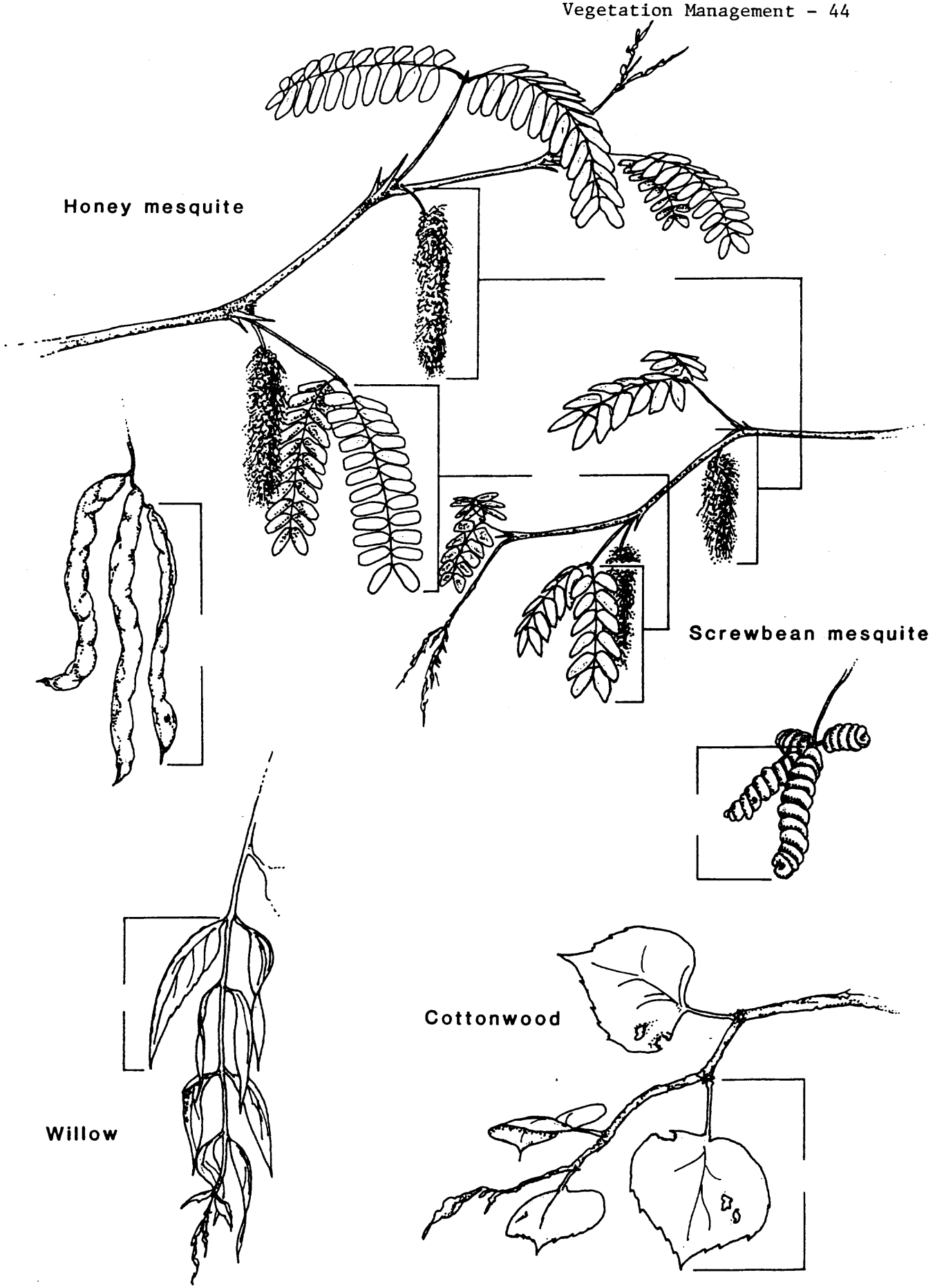


Figure 3-1. Representation of plant parts measured in 1975 and 1976.

month intervals 1976, 1977, and 1978. In 1978, only totals of pods on the ground under trees were recorded.

Average ground coverage per tree was determined by averaging the north-south diameter by two and using that figure as the radius in the formula for the area of a circle. For volumetric considerations, both species of mesquite were assumed to possess approximately geometric shapes: a hemi-oblate spheroid for honey mesquite and an oblate spheroid for screwbean mesquite. Furthermore, both were assumed to have a "shell" of pod-producing foliage surrounding a relatively unproductive interior. Depth of this "shell" was measured along with tree height, foliage diameter, and height from ground level to the lowest foliage. Using the general formula for an oblate spheroid, it was possible to estimate the volume of tree space available for pod growth. This was obtained for each transect by calculating the average tree's total foliage volume and subtracting from it the volume not occupied by pods (Fig. 3-2). With this treatment, the average volume per tree was extended over an entire transect.

The 15 trees were sampled for number of pods on and below the tree. For measurement of number of pods per tree, the wire hoop previously described was used (Fig. 3-3A). Pods below the tree were sampled by placing a hoop on the ground at the base of the trunk, counting the pods inside the hoop, then flipping the hoop over and away from the tree trunk. This process was repeated until the edge of the canopy was reached (Fig. 3-3B). Numbers of pods per hoop from ground samples were averaged, then extrapolated to pods per m^2 and multipled by the average tree's ground cover (m^2) to estimate average pod fall beneath a mesquite tree on a given transect.

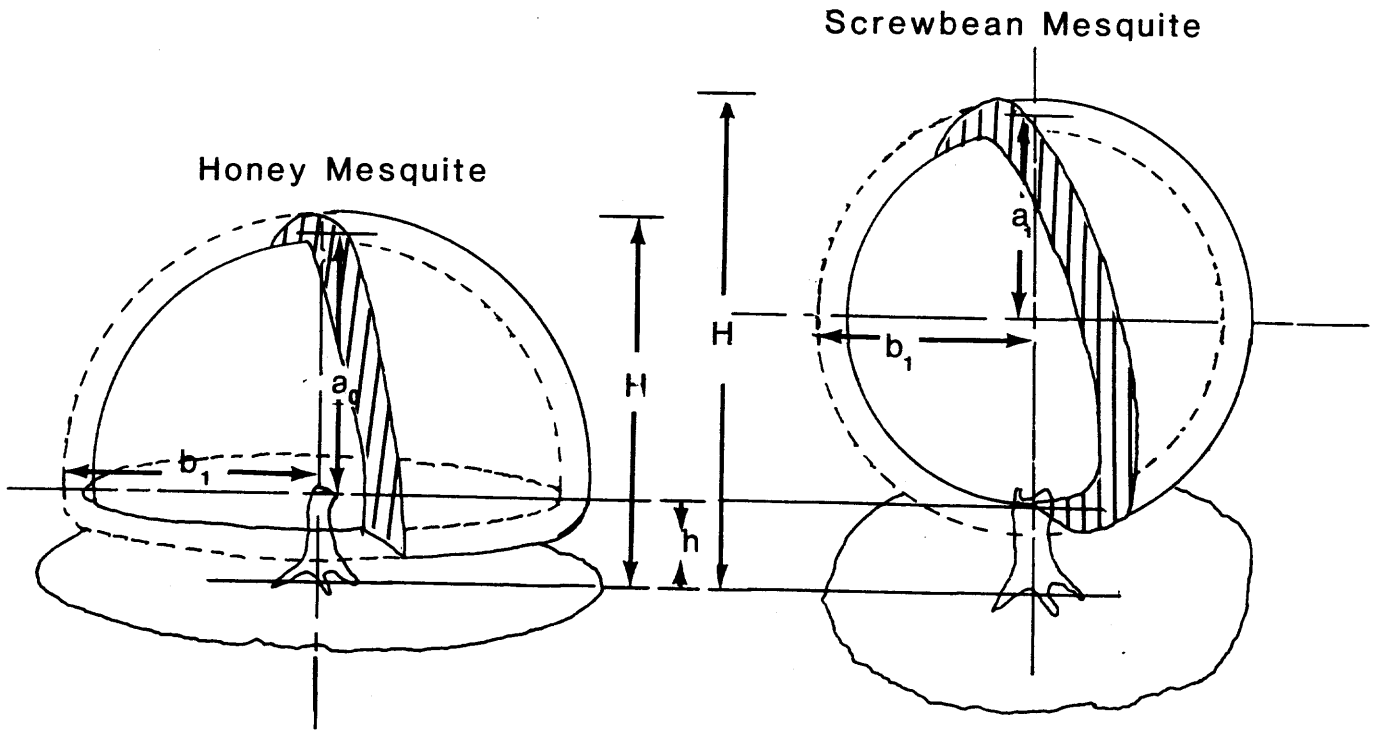
The total estimated ground plus foliage counts gave the estimated pod production per tree. This figure multipled by estimated trees per 40 ha (100 a) yielded pod production per 40 ha.

The nonparametric Kruskal-Wallis one-way analysis of variance test and Dunn's Multiple Comparison test (Hollander and Wolfe 1973) were used to determine difference in pod production between different structural types and years. Tests were run on mean number per 40 ha for both honey mesquite and screwbean mesquite and on mean number per tree for honey mesquite. All means were transformed by converting to natural logs.

RESULTS

Cottonwood

Annual growth cycle for cottonwood started in February, with shoot growth and new leaves appearing on all trees checked in both years (n = 8). Cottonwoods had the shortest flowering period of all five tree species, with flowers appearing in March and disappearing by mid-April. Stem growth continued until September, and terminal growth of marked branches averaged 25 cm/season (10 in). Leaf length averaged 6.5 cm (2.6 in) and leaf density was approximately $170/m^3$ ($5/ft^3$). Leaf color first started changing in September, and 100% of the trees (n = 4) were dropping leaves in December. Trees remained dormant throughout much of December and January.



$V = \frac{2}{3}\pi\left[a_0 b_1^2 - a_2 b_2^2\right]$

$V = \frac{4}{3}\pi\left[a_1 b_1^2 - a_2 b_2^2\right]$

▥ = pod producing foliage

h = height to lowest vegetation

H = overall height (ft.)

$a_0 = H - h$ $\qquad$ $a_1 = (H - h)/2$

$a_2 = a_0$ or $a_1 - 0.984$ (ft.)

$b_1 = D/2$ $\qquad$ $b_2 = b_1 - 0.984$ (ft.)

Figure 3-2. Diagrams showing measurements taken of mesquite trees to determine area and volume.

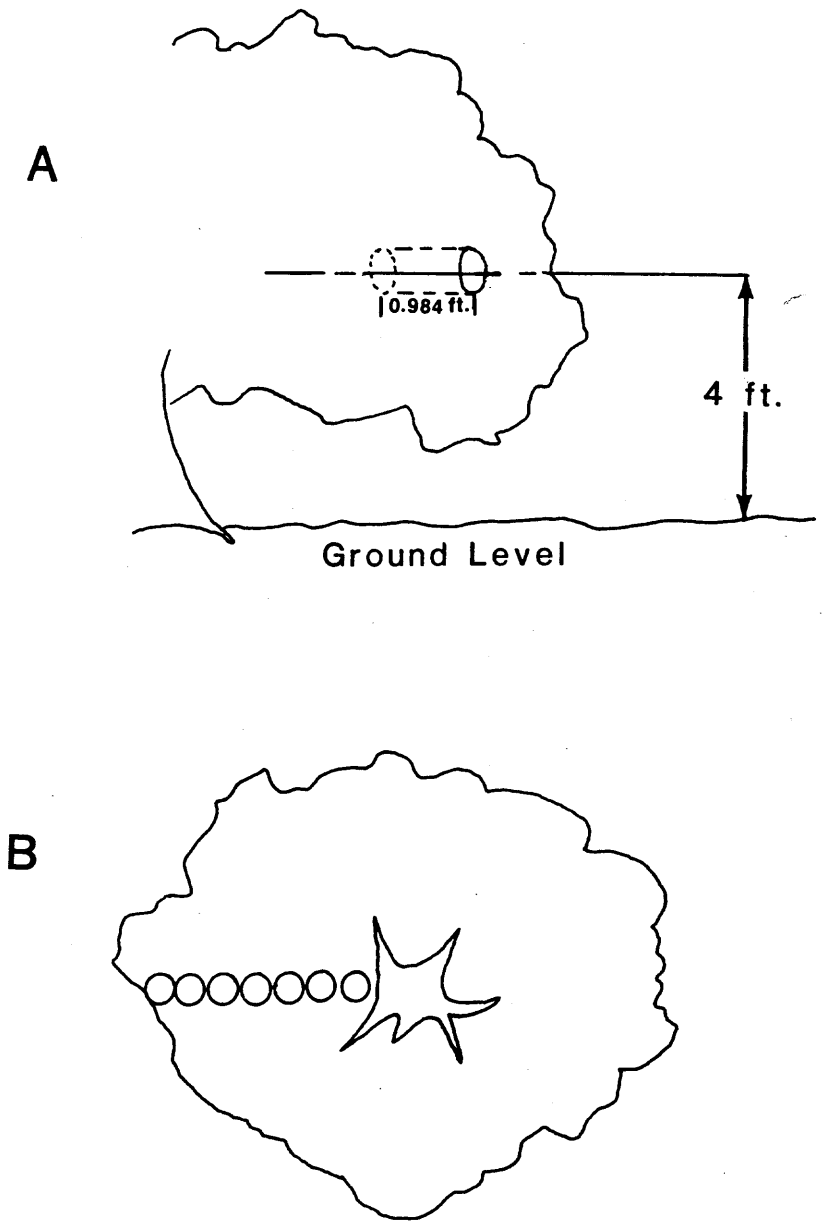


Figure 3-3. Diagrams showing method used in determining pod numbers. Fig. 3-3 A depicts the determination of pod numbers on the tree. Fig. 3-3 B indicates hoop placement under the tree for determination of pod numbers on the ground.

Willow

Willows also started their growth cycle in February, with new leaves, stem growth, and flowers all appearing by the end of the month. Flowering continued through July, with fruits first appearing in May and persisting until late August. Terminal growth continued until September and averaged 37.4 cm (14.7 in). Leaf length averaged 9.0 cm (3.5 in) and mean leaf density was 225/m^2 (20/ft^2). Catkins averaged 5.0 cm (2 in) and at their peak averaged a density of 75/m^2 (7/ft^2). In November leaves started to change color, and by December there was a 100% change and leaves began dropping. In January, the trees were bare. Data are from 13 trees.

Honey Mesquite

Honey mesquite began its growing season in late March and early April (Fig. 3-4). Trees were usually fully leafed out by the first of May; average leaf length was 6.0 cm (2.4 in). New stem growth increased rapidly between March and April (Fig. 3-5) and then slowed, but growth continued until late September or early October. Annual new stems averaged 30.6 cm (12 in).

Flowers first appeared in abundance in April, with 100% (n = 16) of the marked trees flowering. Honey mesquite trees continued to flower through November, although the peak was from April to June. Spikes averaged 7 cm (2.8 in) long. Mean density for the peak (April-June) season was 125.7/m^2 (11.4/ft^2). Density in the latter part of the season (October-November) was only 27.8/m^2 (2.5/ft^2). Data are from 15 trees.

Trees started to bear pods in May and continued to do so until November. Although most trees bore fruit in July, August, and September, there was no single month in which all trees had pods; this suggests variable seeding.

Leaves on honey mesquite started changing color in September and began to drop in early November. By the end of December most of the trees were bare, and they were dormant in January and February.

Honey Mesquite Pod Production

The mean number of honey mesquite pods was 4.5 X 10^6 pods/40 ha. The maximum number was 54.9 X 10^6 pods/40 ha. The majority of pods dropped in August and September. Pod drop was similar to that of screwbean mesquite in that by November most trees were bare (70%), and in December pods were absent on most transects.

Unlike screwbean mesquite, honey mesquite showed significant differences in pod production between years ($P<0.049$; Table 3-1; Fig. 3-6). The maximum number of pods was found in 1978 (which was greater [$P<0.05$] than 1977 or 1976). Also pod production in 1976 was greater ($P<0.05$) than in 1977. Structural types also showed some variation ($P<0.1$) in both pods/40 ha and pods produced per tree. Structural type III produced more pods ($P<0.05$) than types IV, V, and VI, but among types IV, V, and VI there was no difference (Table 3-2; Fig. 3-7).

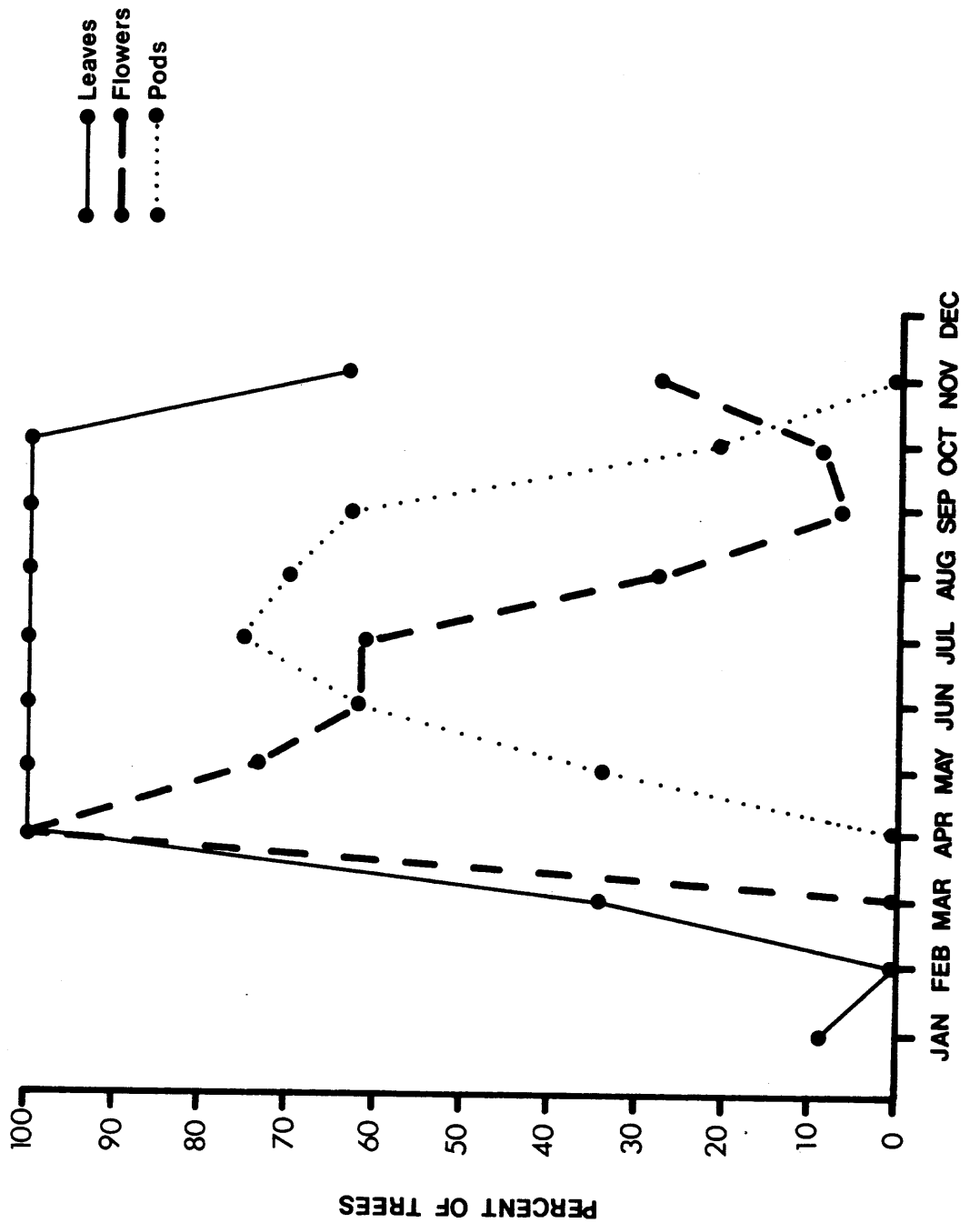


Figure 3-4. Percent of honey mesquite trees bearing leaves, flowers, and pods at monthly intervals during 1976.

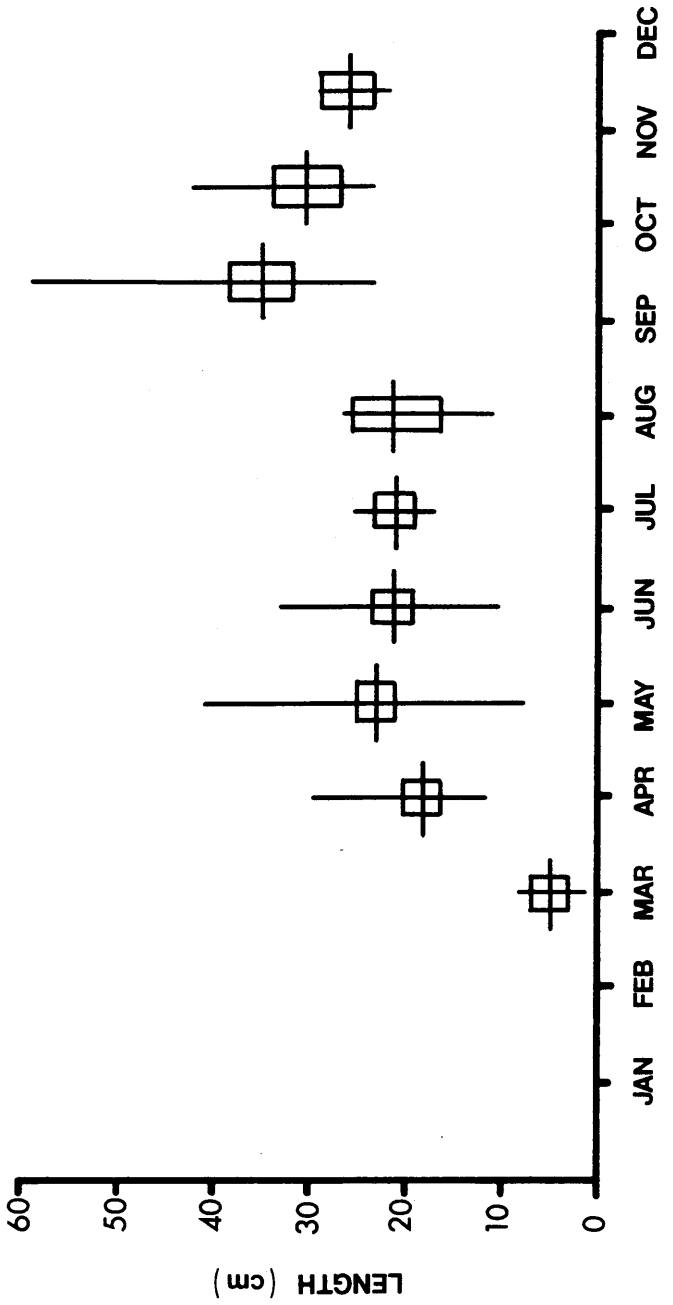


Figure 3-5. New stem growth in honey mesquite trees in 1976. Vertical lines are range, horizontal lines are the means, and rectangular boxes represent standard deviations.

Table 3-1. Mean number of honey mesquite pods/40 ha (100 a) (X 10^6) by year, 1976-1978 across all structural types.

	Month			
Year	August	September	October	November
1976				
Mean	1.25	3.5	0.18	0.36
SD	3.6	2.6	0.38	0.86
N	19	17	11	14
1977				
Mean	0.436	2.6	0.06	0.06
SD	1.0	10.7	0.2	0.3
N	21	21	19	21
1978				
Mean	9.7	16.3	7.95	9.3
SD	9.2	25.7	12.3	17.3
N	4	4	4	4

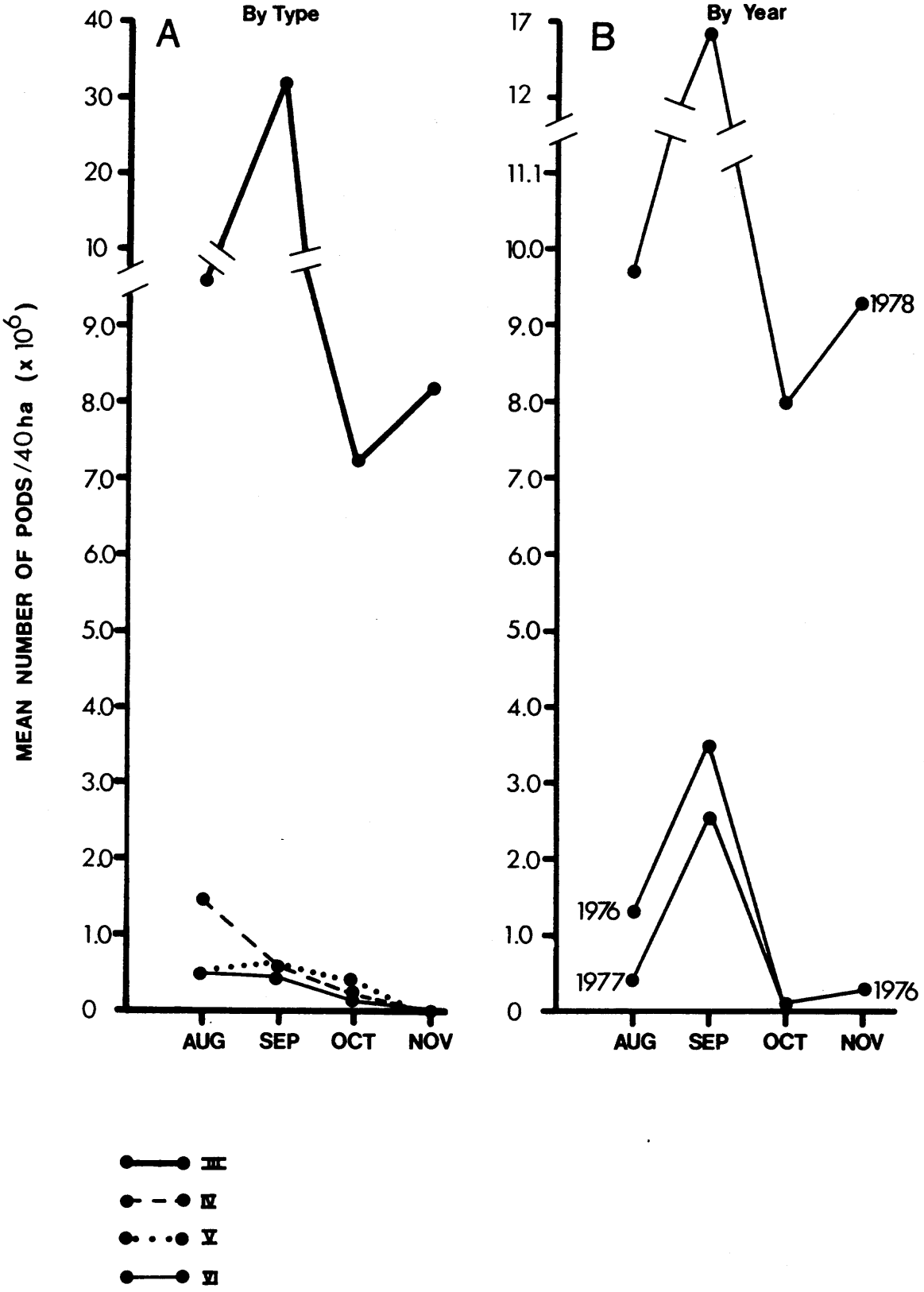


Figure 3-6. A. Mean number of honey mesquite pods/40 ha by structural type. B. Mean pod production/40 ha for all structural types for three years.

Table 3-2. Mean number of honey mesquite pods/40 ha (100 a) (X 10^6) by structural type.

	Month			
Type	August	September	October	November
III				
Mean	9.58	32.0	7.23	8.2
SD	9.57	26.9	12.7	15.1
N	5	5	4	5
IV				
Mean	0.43	0.41	0.15	0.09
SD	1.05	1.07	0.57	0.34
N	23	23	20	24
V				
Mean	0.42	0.49	0.17	0.01
SD	1.04	1.13	0.36	0.03
N	9	9	9	9
VI				
Mean	1.44	0.53	0.34	0.03
SD	2.6	0.72	0.74	0.08
N	7	5	5	7

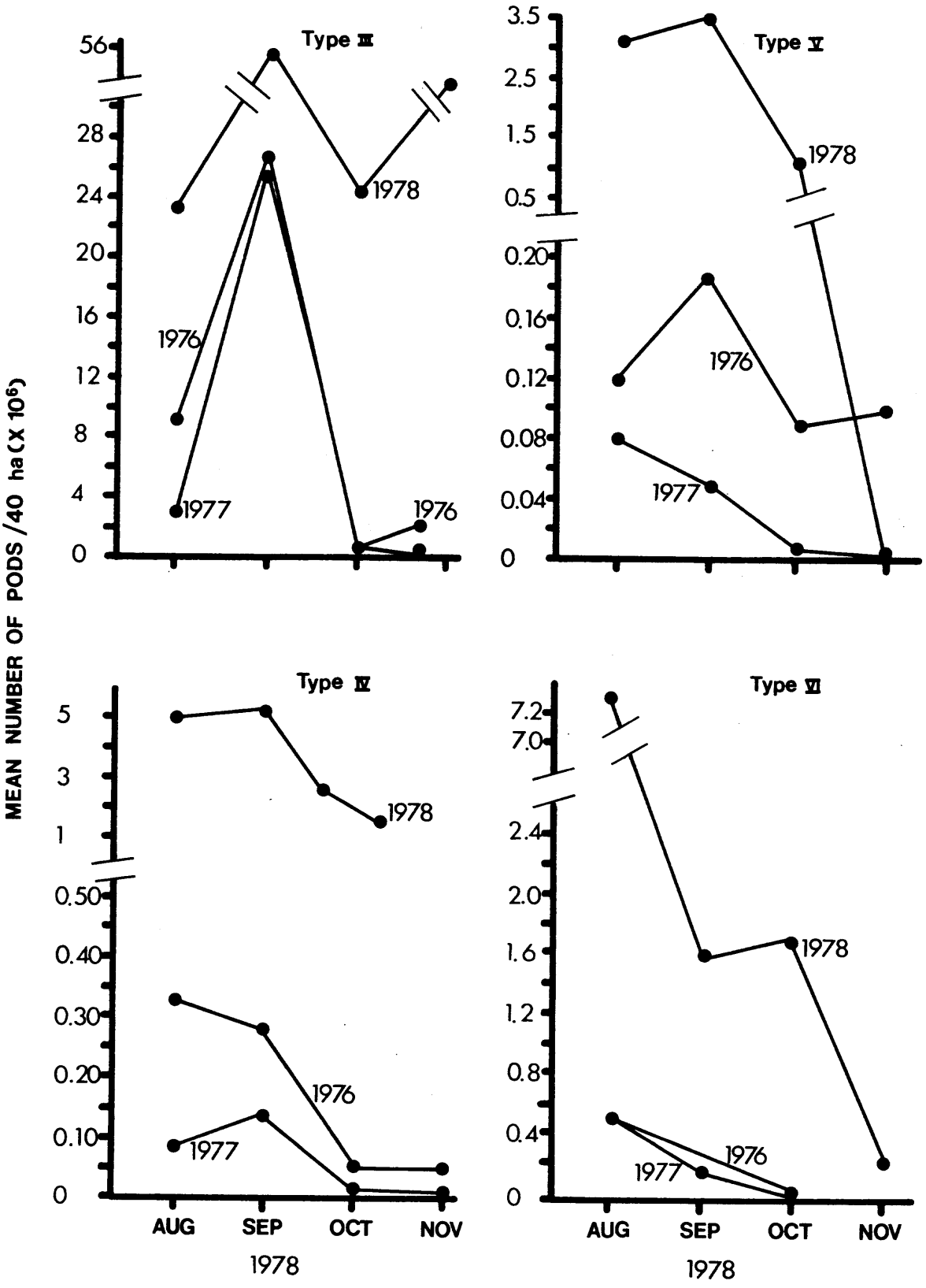


Figure 3-7. Comparison of mean number of honey mesquite pods/40 ha by structural type by year.

Screwbean Mesquite

Leaves first appeared on screwbean mesquite in late March and early April, and by the end of April the trees were usually in full leaf (Fig. 3-8). New stem growth closely followed the beginning of leaf production, and stems continued to grow until September, when they reached an average length of 29.9 cm (11.8 in). Flowers first appeared in May, and in June all trees examined were flowering. By August the number of trees flowering generally decreased, and by November no trees were flowering. Pods first appeared in June, and 100% of all trees (n = 8) examined from June through August bore fruit. Pod drop began in August and continued until November, when no trees contained pods. In November leaves started to change color and drop, and by January and February the trees were dormant.

Screwbean Mesquite Pod Production

Screwbean mesquite along the Colorado River produced an extremely large number of pods. The average number of pods produced per year along the transects was 41.9 X 10^6 pods/40 ha. The maximum number found on any transect was 240 X 10^6 pods/40 ha.

The majority of pods dropped in August, except during 1978 when most dropped in September (Fig. 3-9). By November trees were usually bare of pods and only a fraction remained on the ground. By December no pods were found on most transects.

Pod productivity remained much the same (not significant at $P>0.1$; Table 3-3) over the three years. However, different structural types produced a significantly ($P<0.01$) different number of pods/40 ha. Structural types II and III showed no differences ($P<0.1$) but both produced more pods ($P<0.05$) than types IV or V (Table 3-4; Fig. 3-10), and type VI produced significantly more pods than type V.

Salt Cedar

In late February and early March new growth, leaves, and flowers appeared on some salt cedar trees (16%). New stem growth continued until November, with the average stem measuring 56.6 cm (22.3 in). The largest increase in new stem growth occurred during May (Fig. 3-11). Salt cedar started to flower in March; peak flowering occurred in May and June. Seven of the 17 trees were still flowering in October (Fig. 3-12), but no flowers were recorded in November or December. Density of flowers during the peak flowering period (May-June 1976) was 416/m^2 (38/ft^2). Average leaf length was 8.2 cm (3.2 in). Leaves started changing color in October and were dropping by November. By the end of December almost all the leaves had dropped, and the trees were dormant in January and early February.

DISCUSSION

Although there was some intraspecific variability in growing seasons, differential trends were observed between tree species. Three of the dominant phreatophytic species (cottonwood, willow, and salt cedar)

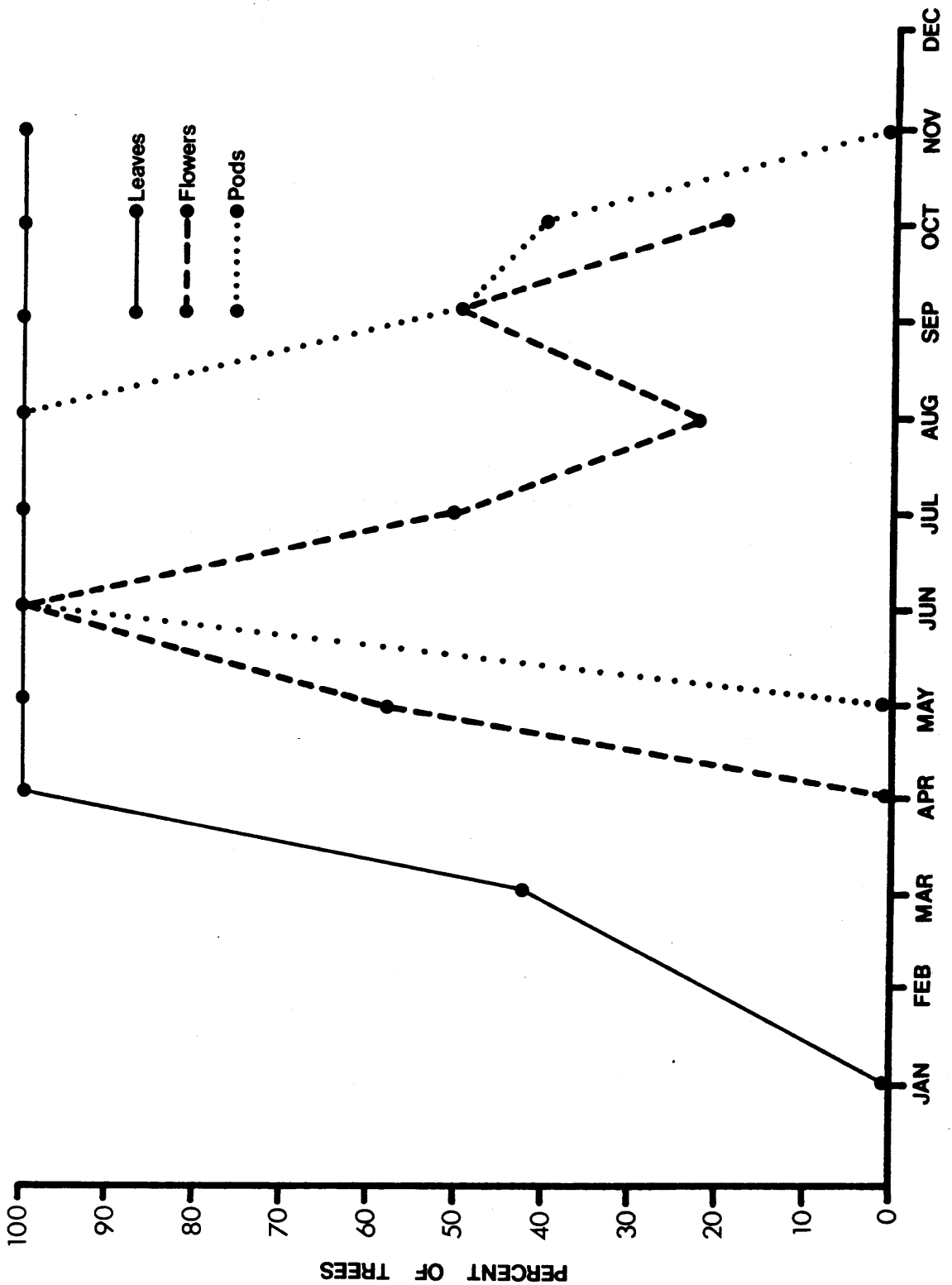


Figure 3-8. Percent of screwbean mesquite trees bearing leaves, flowers, and pods at monthly intervals during 1976.

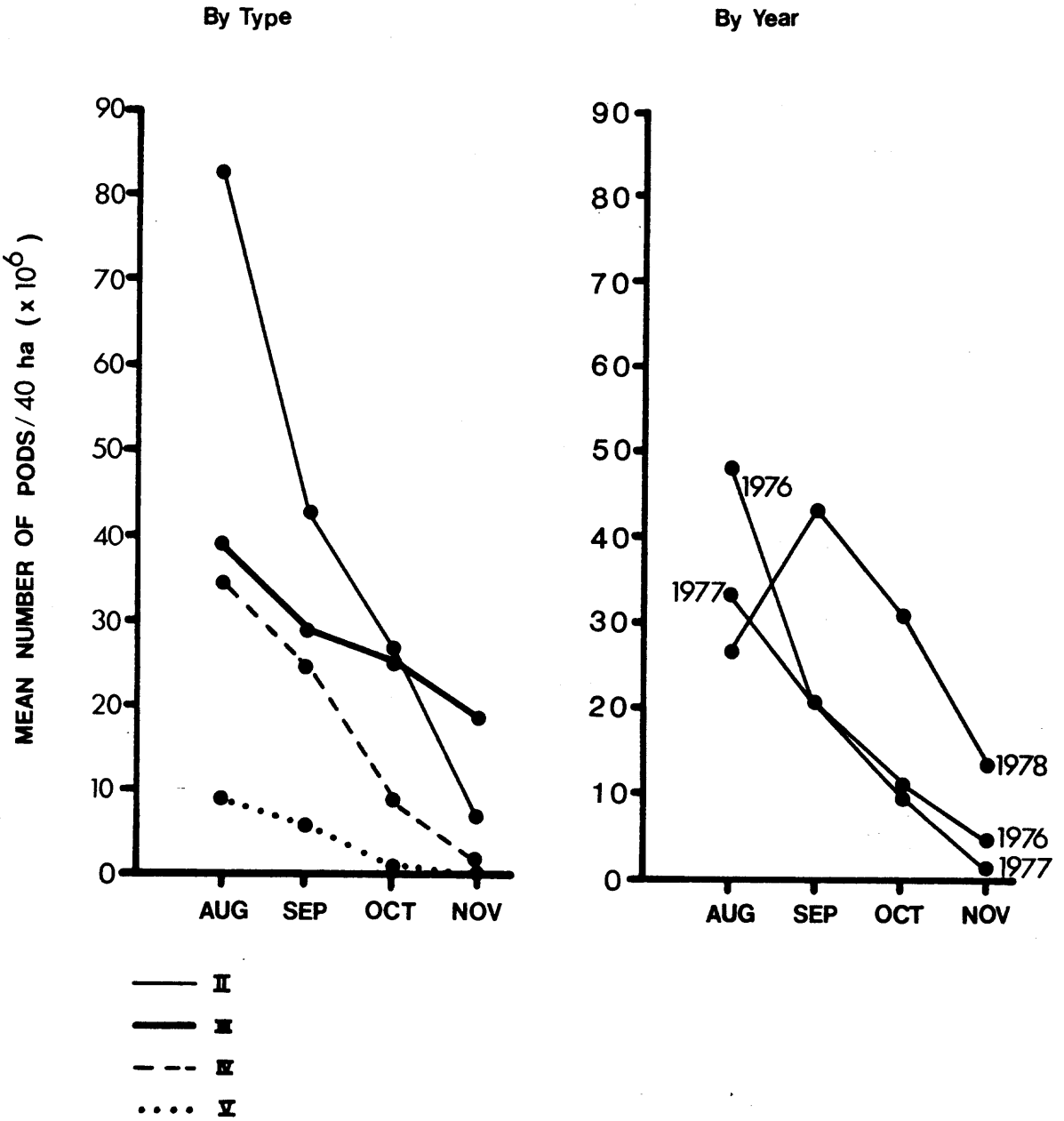


Figure 3-9. Comparison of mean number of screwbean mesquite pods/40 ha by structural type and sampling year (1976-1978).

Table 3-3. Mean number (X 10^6) of screwbean mesquite pods/40 ha (100 a) by year, 1976-1978.

	Month			
Year	August	September	October	November
1976				
Mean	48.4	21.36	10.7	1.89
SD	61.2	21.9	13.7	3.3
N	11	11	11	9
1977				
Mean	32.9	20.4	11.02	5.2
SD	41.7	21.0	9.04	10.8
N	12	13	10	9
1978				
Mean	26.4	43.9	30.33	13.5
SD	29.8	26.8	18.52	13.2
N	4	4	4	4

Table 3-4. Mean number (X 10^6) of screwbean mesquite pods/40 ha (100 a) by structural type.

Type	Month			
	August	September	October	November
II				
Mean	83.06	43.04	27.4	6.7
SD	62.6	18.1	14.8	10.2
N	5	5	5	3
III				
Mean	38.7	28.9	24.9	18.3
SD	17.9	15.8	13.8	15.4
N	5	5	4	4
IV				
Mean	34.65	24.6	10.8	2.7
SD	52.9	27.3	10.1	3.8
N	11	11	10	8
V				
Mean	9.2	6.4	1.3	0.57
SD	4.4	6.3	1.4	0.5
N	5	7	5	6

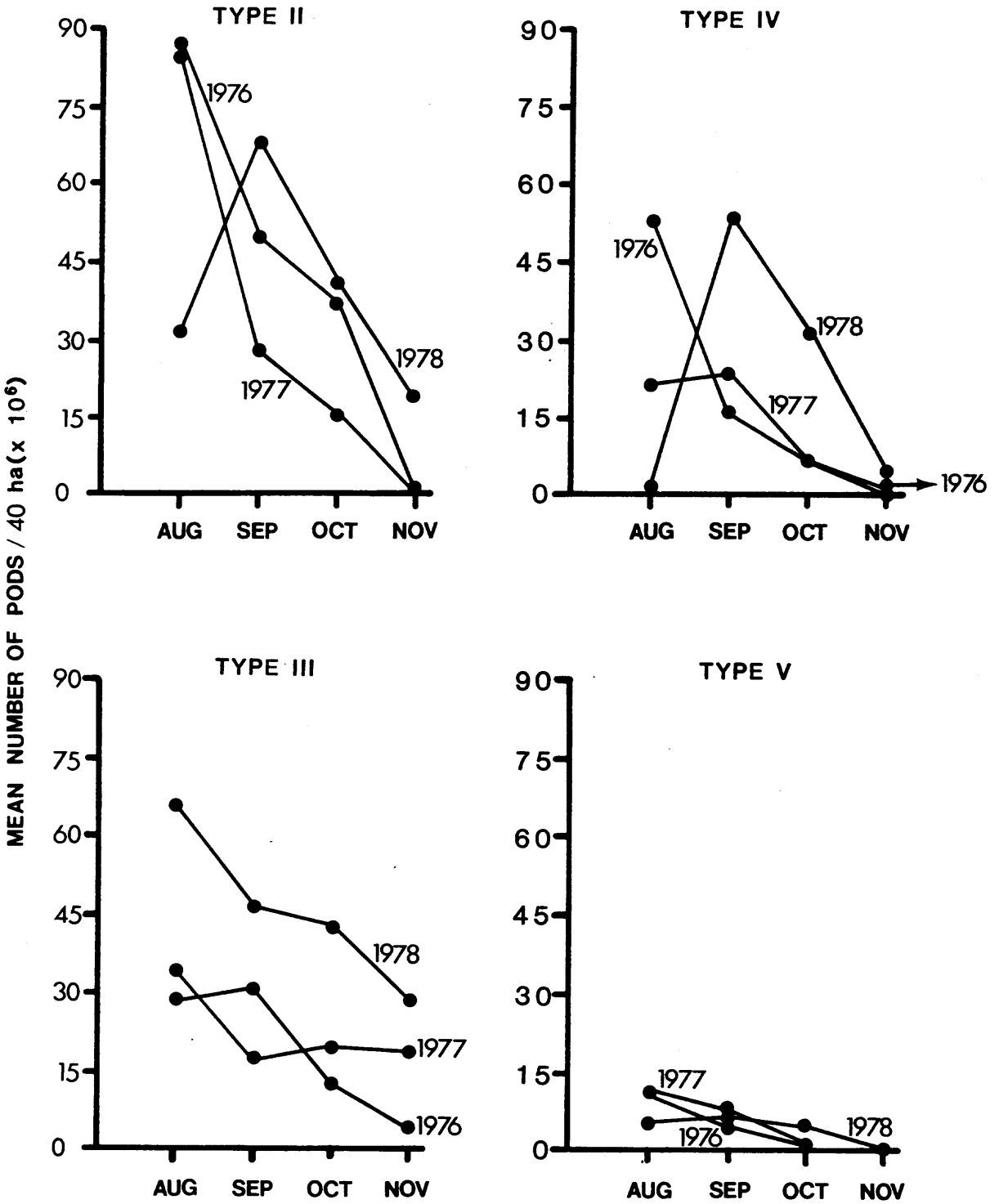


Figure 3-10. Comparison of mean number of screwbean mesquite pods/40 ha by structural type and year.

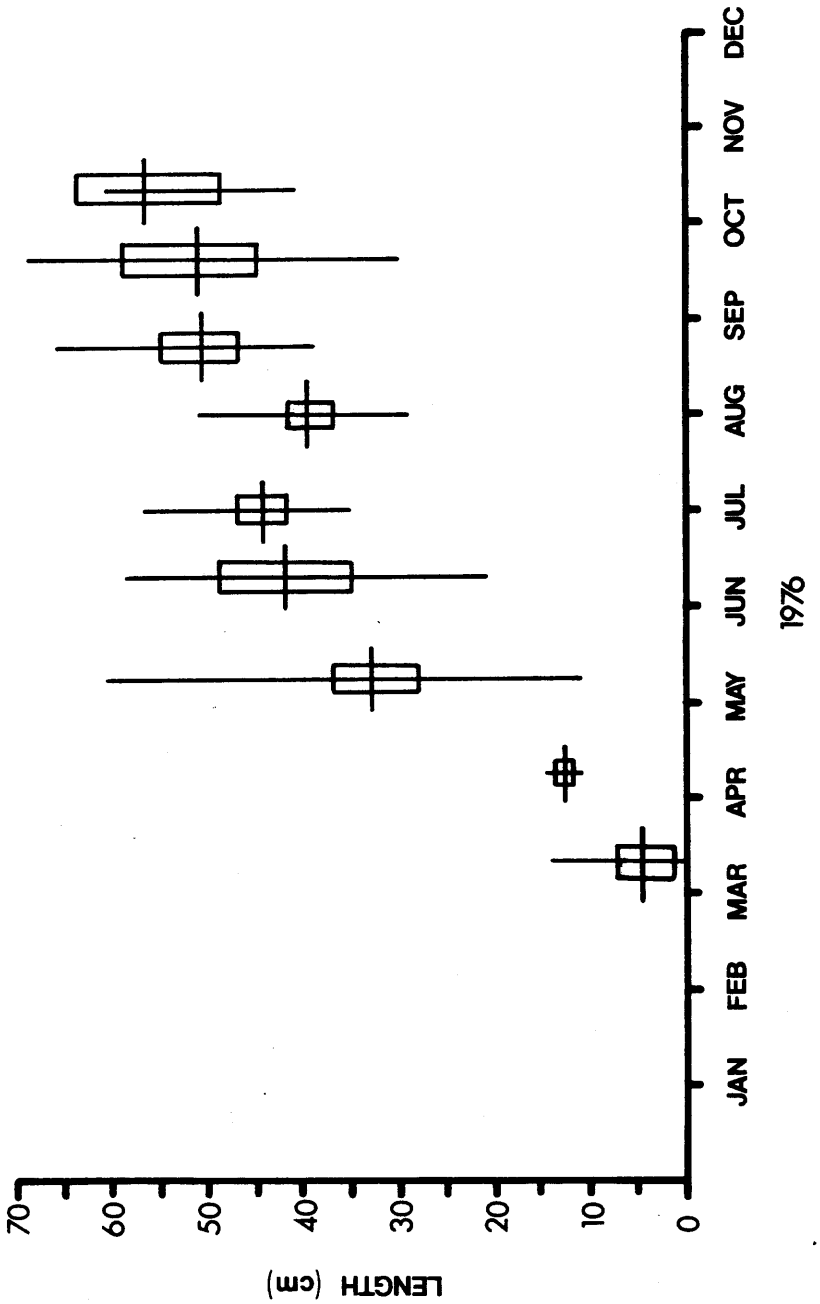


Figure 3-11. New stem growth in salt cedar trees in 1976. Explanation of diagrams as in Figure 3-5.

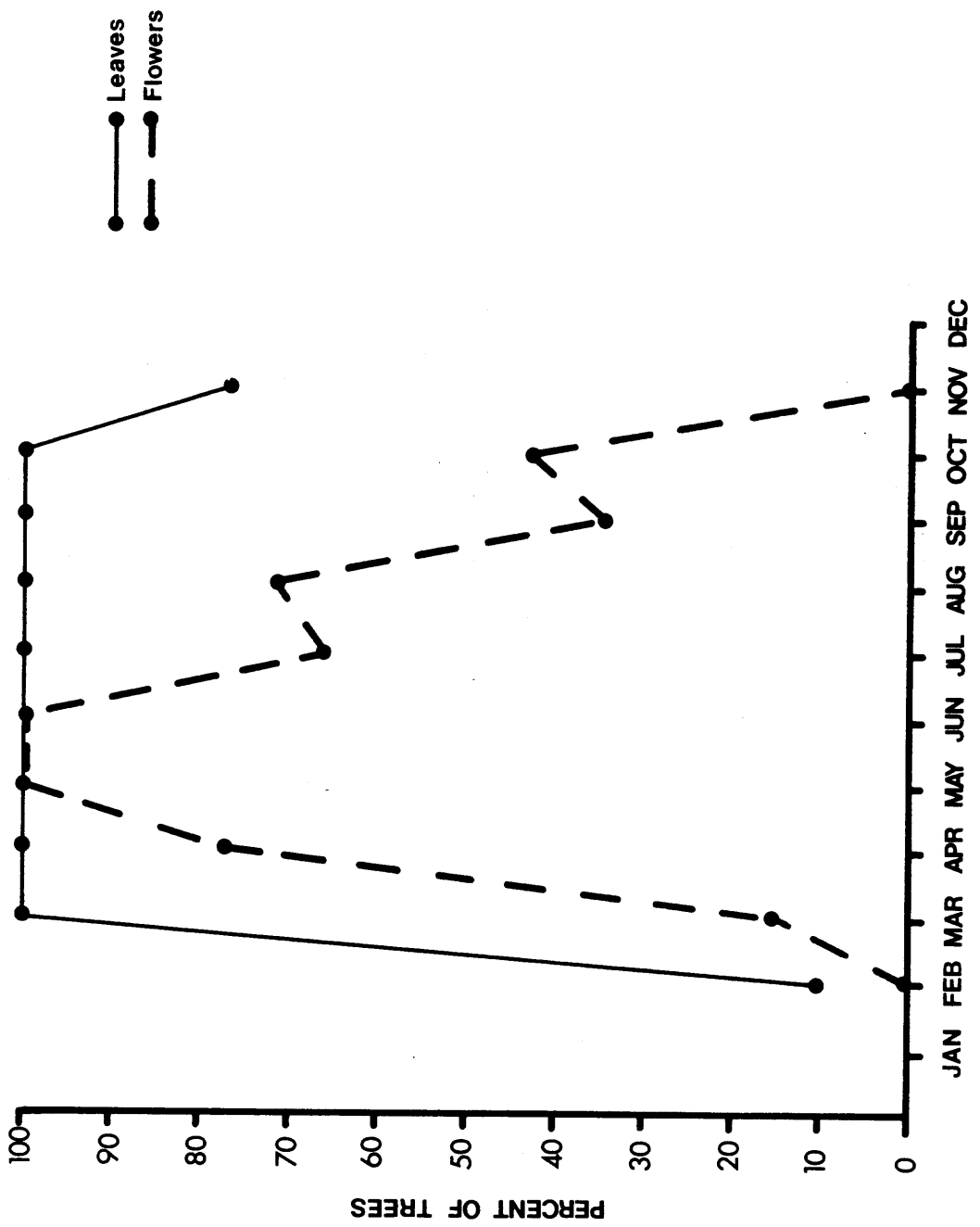


Figure 3-12. Percent of salt cedar trees bearing leaves and flowers at monthly intervals during 1976.

began their growing season in February during both years (1975 and 1976). The genetically determined growing season of mesquite (McMillan and Peacock 1964, Peacock and McMillan 1965) started in late March and April, the same time the other three tree species were in flower. Cottonwood and willow were the first to finish fruiting. The two species of mesquite and salt cedar flowered and fruited late into the year (November) and these three were the last to become dormant. This difference in the growing seasons of the five dominant tree species occupying the banks of the Colorado River are influencing faunal use of various habitats and use of specific tree species within communities.

In our area, all 57 of the individual trees studied dropped the growth attained during the growing season; thus they were the same size at the end of the growing season as at the beginning. It seems that new growth on mature trees is dropped at the end of the growing season (Simpson 1977). Many parasites attack young growth, thus shedding this growth may be a protective mechanism (Simpson 1977).

The two species of mesquite also showed variation in growing seasons. Honey mesquite began to grow a little earlier and was about a month ahead of screwbean mesquite in all stages of growth. Honey mesquite tended to flower earlier, but both species flowered about 1.5 to 2 months before the summer rains. Timing of flowering in mesquite is initiated by changing day length and normally occurs about 1.5 to 2 months previous to the rainy season. This assures that many of the seeds are dropped when the ground is moist, allowing for higher germination rates and for the developing root system to reach a sustaining moisture supply (Simpson et al. 1977). About 3% of mesquite flowers initiate fruit development and only one-half to one-third of these produce fruits (Solbrig and Contino 1975). Although honey mesquite flowered for a longer period of time, it did not produce pods for a longer period. In fact, during the summer of 1976, when all screwbean mesquite trees observed bore pods, only 65% of the honey mesquite trees had pods. Leaf change and leaf drop occurred earlier in honey mesquite, but both mesquite species were dormant in January and February. There was also considerable variation between years and from tree to tree within each species. Mooney et al. (1977) observed intra-population variation in physiology of honey mesquite and attributed this to differences in the attractiveness of inflorescences to insect visitors during the flowering season.

It is not known how old a mesquite tree is when it first flowers and produces fruit. On our revegetation plots nearly all of the mesquite trees provided with tillage to 3 m produced flowers and fruit in the third growing season.

As the season progresses, mesquite pods form, drop, and are subsequently removed by animals or occasionally by flooding. Readings at the beginning of the season showed high tree counts and low pod numbers on the ground. Pods began to drop, accumulating under trees until pod production ceased. Ground totals dominated until all the pods on the ground were depleted by wildlife. This means that during midseason some pods on the ground (under the average tree) were undoubtedly counted twice. Also, pods were being removed by animals from the time they

became available until they were depleted. Monthly figures for pods per 40 ha is a cumulative one. To get an approximation of absolute production from these totals, the month with the highest pod count can be considered as the least amount of pods produced in a particular vegetation type for that season.

Along the Colorado River, screwbean mesquite trees produced a much larger number of pods/40 ha (41.9×10^6 vs. 4.5×10^6) than did honey mesquite trees. Screwbean mesquite trees also tended to drop the majority of their pods slightly earlier than did honey mesquite (August-September) trees. Screwbean mesquite did not differ in productivity between years; however, it did differ significantly between structural types. This is because structural types II and III consist of older, larger, or healthier trees than types IV and V. Presumably maturity was not a factor, since we studied only mature trees.

Trees of smaller stature indicate stress conditions such as high salinity or low water availability. For example, Type V vegetation is often located adjacent to desert areas or in highly saline areas (Anderson and Ohmart unpubl. data). Water shortage or saline conditions seems to result in reduced survival and diminutive stature of trees which do survive.

Honey mesquite varied both in vegetation structural type and in annual production. We believe the difference in structural types can be explained also by differences in size, maturity, and health of trees. The annual production difference, though, appears to be related to climatological factors, and particularly to precipitation. In 1976 and 1978 when there were heavy winter rains (Fig. 3-13), honey mesquite had much higher pod productivity than in 1977. In 1978, which had the highest winter precipitation, honey mesquite had the greatest pod productivity. We believe the reason that honey mesquite is affected by rainfall and screwbean mesquite appears not to be so affected is because honey mesquite tends to be located farther from the river on higher terraces. Furthermore, honey mesquite trees not only have a long taproot (up to 50 m; Phillips 1963), but they also have an extensive lateral root system to collect surface water when it is available (Simpson 1977). When surface water is in low supply or absent, trees must bring water up from the water table, which may be 4 m or more beneath the soil surface. Screwbean mesquite occurs along or more proximal to the river and probably has a more stable water supply. It also has to expend less energy to transport water to the growing part of the tree.

Mesquite is the dominant phreatophyte of the New World deserts (Simpson and Solbrig 1977). Therefore it is an important part of the desert ecosystem and is used by many species of plants and animals. Simpson et al. (1977) found more animal species associated with mesquite than any other desert scrub plant. Mesquite's large number of flowers and fruits provide an excellent food resource, but also other features such as its tall, leafy habit, its complex branching pattern, and its distribution along watercourses or in areas with a shallow water table provide other important habitat parameters for desert scrub organisms.

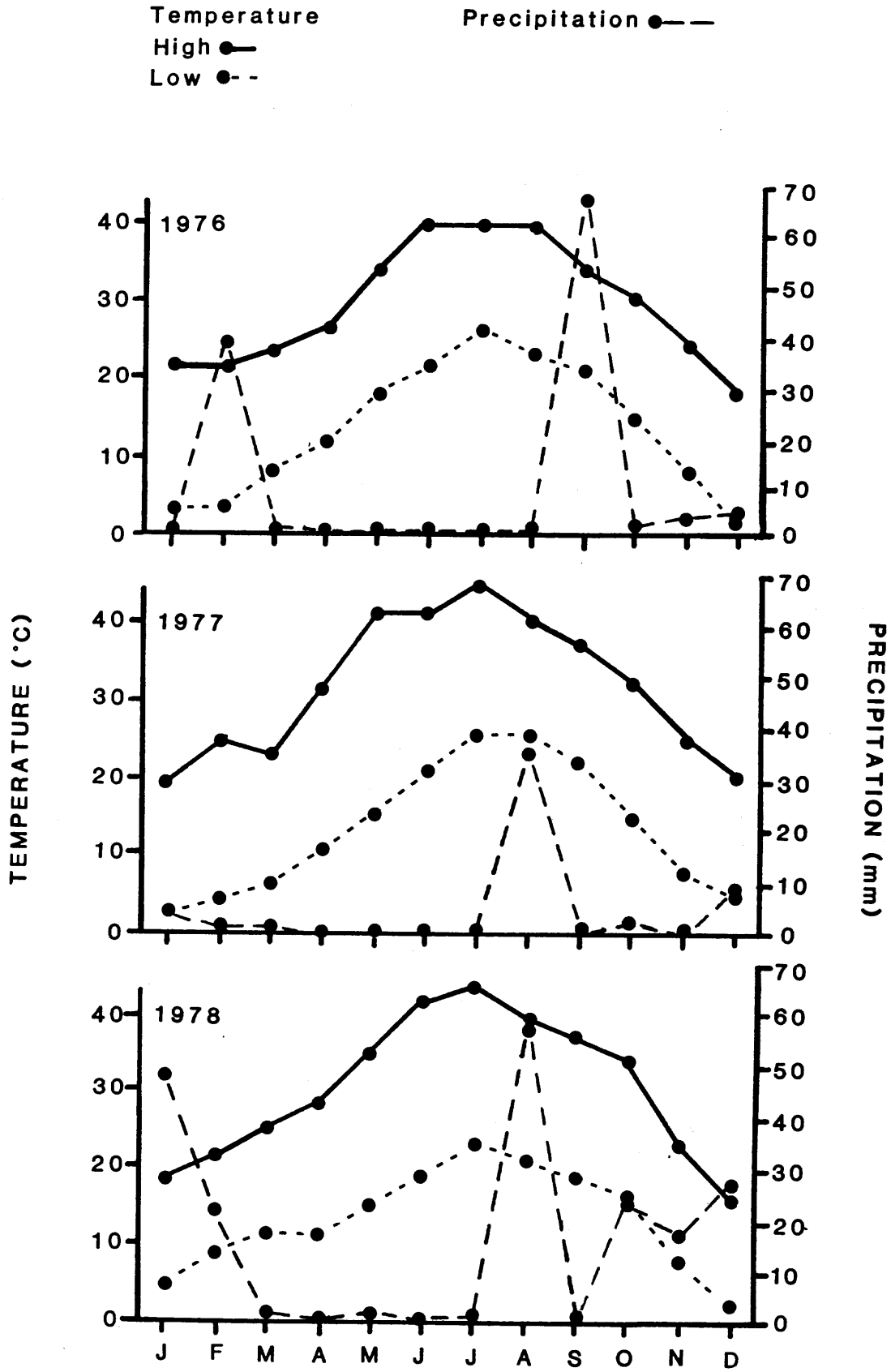


Figure 3-13. Temperature and precipitation from 1976 to 1978 on the lower Colorado River (Blythe).

The canopy of mesquite is important for many vascular plants in desert scrub communities. It provides shelter from the sun, soil drought, and in some cases shelter from grazing animals (Mares et al. 1977). Mares et al. (1977) found a distinct difference in numbers and species composition under the canopy of mesquite in the full sun. They found that annual grasses grew more in full sunlight but that forbs (herbaceous plants) preferred the shaded canopy. Forbs provide an ample supply of seeds for granivorous birds and small mammals. Mesquite also provides the necessary requirements for the parasite, mistletoe, which is important to many bird species.

Mesquite provides an excellent food resource for literally thousands of insects. Leaf feeders, flower visitors, fruit feeders, and spiders all use mesquite. Mesquite flower units provide an extremely high sugar source ($\bar{x}$ = 2.4 mg/day; Simpson et al. 1977) for many invertebrates. Some of the more common orders of insects are Diptera, Coleoptera, Lepidoptera, and Hymenoptera. In the southwestern United States more than 160 species of solitary bees have been recorded using mesquite inflorescences, 96 of which are specific (Simpson et al. 1977). Both invertebrate external and internal feeders of mesquite fruits are common. The most abundant are the hemipteran leaf-footed bug (Mozena obtusa, Ueckert 1973) lepidopteran larvae, and members of the family Bruchidae (Coleoptera, Kingsolver 1972).

In our studies of the foraging behavior and food habits of numerous insectivorous birds we have found that Ruby-crowned Kinglets (Laurenzi et al. 1982), Yellow-rumped Warblers (Anderson et al. ms) and a host of other bird species are greatly attracted to the pollen, nectar, and insects which are present when cottonwoods, willows, and honey mesquite are in bloom. Pods of honey and screwbean mesquite are extremely important to Gambel Quail (Chapter 8), coyotes (Chapter 12), and numerous rodents (Howell 1976), which depend mainly on this resource during the fall and winter months when food supplies and diversity of food items are often severely restricted.

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CHAPTER 4

BIRD SPECIES OF THE LOWER COLORADO RIVER VALLEY: AN ANNOTATED CHECKLIST

INTRODUCTION

This chapter consolidates distributional, seasonal, and abundance data on the 385 bird species known to have occurred in the Lower Colorado River valley from Davis Dam to the Mexican border. Information was gathered from a variety of sources. In addition to records obtained from the avifaunal censuses during 1974-1981, a simultaneous record of data on migration and of birds detected away from immediate study plots was kept in the form of personal field notes and a centralized file on Colorado River birds. This file now serves as the basis for the present checklist. It was kept current by the efforts of biologists Kenneth V. Rosenberg, Alton E. Higgins II, Bret M. Whitney, Sharon Goldwasser, Richard Martin, and Mark Kasprzyk.

Most past knowledge of the valley's avifauna was gleaned from the published work of Phillips A., J. Marshall, and G. Monson. 1964. The Birds of Arizona, University of Arizona Press, Tucson, and from the exhaustive personal notes and knowledge of Gale Monson. Other published records were taken from the seasonal reports in American Birds and its predecessor, Audubon Field Notes, from 1953 to the present.

The format of each species account is in three or four parts. First, the seasonal status is described in terms consistent with the bar graphs that follow. Abundance terms are defined in the "Introduction to the Bar Graphs" below. Specific information on records of many rare or casual species is listed in this section (as well as significant maximum counts of some species).

The "Habitat" section provides a breakdown of the broad vegetation types considered suitable for each species. Detailed data are provided for species under study (see also Chapters 5 and 6), and more general information is given for other rare or poorly known species. A habitat code is also presented with the bar graphs.

The "Food" and "Breeding" sections (where appropriate) similarly supply detailed information from field study, if available. General accounts for other species were taken largely from the life history publications of Arthur Cleveland Bent (1923-1968, U.S. Nat. Mus. Bull. Nos. 107, 113, 126, 130, 135, 142, 146, 162, 167, 170, 174, 179, 191, 196, 197, 203, 211, 237. Washington, D.C.).

INTRODUCTION TO THE BAR GRAPHS

Bar graphs are a pictorial representation of the seasonal status of each species. In general, the length of each line corresponds to a species' period of occurrence in the lower Colorado River valley and the width of the line signifies the species' abundance at that time. In many cases,

the graphs are an oversimplification and the text should be consulted for species of interest.

Along with the abundance designations are codes for the major habitats used by each species. For very rare species, the code may represent the habitat in which particular records were obtained and not necessarily all habitats of potential use. The habitat codes are as follows:

O = open water, mainly artificial lakes and reservoirs.

R = river; flowing channel, exposed bars and shoreline.

M = marsh; emergent vegetation along river channel, backwaters, lakes, etc.

V = riparian vegetation; includes all natural plant communities within floodplain.

D = desert; includes washes and flats immediately adjacent to river or floodplain.

A = agricultural land; includes cultivated crops, bare fields, orchards, canals, and rural residences.

U = urban or suburban residential communities.

The following abundance codes indicate a species' "average" status in its preferred habitat(s). It may be more numerous locally, or less common in other habitats. For species whose abundance varies geographically within the river valley, this is clearly stated in the text.

COMMON, or locally abundant; always present in moderate to large numbers in proper habitat.

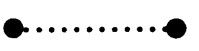
FAIRLY COMMON, or locally common; always present but usually in small numbers, in proper habitat.

UNCOMMON; occurs locally or patchily and in small numbers at the given season.

RARE; occurs annually during the period indicated but generally in very small numbers, or extremely locally and in small numbers.

CASUAL; records are too numerous to show individually, but occurrence is sporadic and generally unexpected.

INDIVIDUAL RECORD; for species recorded only a few times overall or in a given season.



Individual record, showing a prolonged stay by the individual(s).

When a species occurrence or status varies from year to year this is indicated by a broken abundance graph. In those cases, the wider bar represents the greatest potential abundance and the narrower connecting bar represents the least common state. As examples:

Irregularly common; common in some years, uncommon (or fairly common) in others.

---------- Rare and irregular; may be absent some years, but not unexpected at that time.

*Indicates breeding species.

ANNOTATED CHECKLIST

Common Loon (Gavia immer)

Status: Uncommon winter visitor and migrant, October to early May. Individual birds rarely remain through the summer months. Sometimes seen in small groups on Lake Havasu and Lake Mohave in November and April. May be increasing as a wintering species. Max: 24, 10 April 1954, at Lake Havasu.

Habitat: Deep water areas such as the spillways of dams or their reservoirs.

Food: Primarily fish, but also crustaceans, amphibians, and aquatic insects; some vegetation.

Arctic Loon (Gavia arctica)

Status: Recently a rare but regular winter visitor and transient, primarily in the northern parts of the valley. Most records are from Davis Dam and upper Lake Havasu from November through March. Individuals have lingered through the summer months.

Habitat: Deep water of spillways and reservoirs.

Food: Similar to Common Loon.

Red-throated Loon (Gavia stellata)

Status: Casual transient or winter visitor; may prove to be of regular occurrence. Sight records 21 November 1947 and 8-15 June 1948, one photographed on lower Lake Havasu 31 March-2 April 1978; and one present on upper Lake Havasu from 23 December 1980 to at least 21 February 1981.

Habitat: Open water.

Food: Similar to Common Loon.

Red-necked Grebe (Podiceps grisegena)

Status: Casual visitor; one in breeding plumage photographed 23 March 1981 on lower Lake Havasu.

Habitat: Open water.

Food: Mainly aquatic invertebrates, small fish.

Horned Grebe (Podiceps auritus)

Status: Rare but regular winter visitor and transient, mid-November to mid-April. Most often seen at Davis Dam, Parker Dam, and Lake Havasu, but also as far south as Imperial Dam.

Habitat: Reservoirs and deep spillways of dams; occasionally along other parts of the river during migration.

Food: Mainly small fish, aquatic invertebrates, and amphibians.

Eared Grebe (Podiceps nigricollis)

Status: Common winter visitor and transient, November to April; fairly common to uncommon during spring and fall months. Individuals in breeding plumage occasionally seen during June and July, but breeding does not occur. Large flocks of several thousand may be present on Lake Havasu in winter, with scattered individuals in nearly every section of the river at that time.

Habitat: Most numerous on large reservoirs; less so on main river channels; occasionally in marshes, backwaters, and sewage ponds.

Food: Mainly aquatic insects and larvae.

Least Grebe (Podiceps dominicus)

Status: Casual visitor from Mexico; nested at West Pond near Imperial Dam in 1946. Also seen there 14 May-22 June 1955. A few may have been resident there throughout that period.

Habitat: Marshes, ponds.

Food: Mainly aquatic insects and larvae.

Western Grebe (Aechmophorus occidentalis)

Status: Recent local breeder on Lake Havasu. Numbers augmented by transient and wintering birds from late August to March. Large winter concentrations occur north of Parker Dam; uncommon farther south, to Imperial Dam and Mittry Lake. This species has increased dramatically as a wintering bird since the 1950's; breeding was first noted in 1966.

Habitat: Cat-tail marshes required for nesting. Otherwise prefers larger lakes and reservoirs, rarely in main river channels.

Breeding: Nest a floating mass of dead reeds, usually anchored to bulrushes, usually 3-4 eggs. Courtship begins in March and young birds are seen in July and August.

Food: Fish, other aquatic animals.

Pied-billed Grebe (Podilymbus podiceps)

Status: Locally common throughout the year. Breeds commonly in marshes throughout the valley. Numbers augmented during the nonbreeding season (August-March) by northern migrants. Max: 74, 20 December 1980, Yuma Christmas Bird Count (CBC).

Habitat: Marshes required for breeding; any open water at other times. Occurs on large lakes, main river channels, backwaters, and rarely small ponds and agricultural canals.

Breeding: Nest is a floating mat of vegetation anchored to emergent marsh vegetation. Eggs average from 5-7; young noted as early as late March (1958).

Food: Fish, frogs, tadpoles, aquatic invertebrates.

Laysan Albatross (Diomedea immutabilis)
- Status: Casual visitor. One found alive on a Yuma street on 14 May 1981. The bird was nursed to health, photographed, and released in the Pacific Ocean.
- Habitat: Normally, open ocean.
- Food: Fish.

Leach Storm-Petrel (Oceanodroma leucorhoa)
- Status: Hypothetical. A storm-petrel with a white rump, probably this species, was seen on Lake Havasu 2 September 1977.
- Habitat: Normally, open ocean.
- Food: Small marine invertebrates.

Least Storm-Petrel (Halocyptena microsoma)
- Status: Accidental visitor. One seen 17 September 1976 at Davis Dam after hurricane Kathleen, which deposited this species at Salton Sea and several other inland Southwest localities.
- Habitat: Open water.
- Food: Tiny marine invertebrates.

White Pelican (Pelecanus erythrorhynchos)
- Status: Uncommon transient (but sometimes in large flocks) primarily from March through May and late September to October. Individuals or small groups rarely seen during summer months. A flock of 250 noted in July 1958. Rare and irregular in winter with most from the southern sector, but up to 100 have wintered at Cibola Lake. Max: 3200, 4 October 1956 near Laguna Dam.
- Habitat: Most often seen migrating over the river or lakes; occasionally rests in marshes or on sandbars in the river.
- Food: Primarily fish; also other aquatic vertebrates like tadpoles.

Brown Pelican (Pelecanus occidentalis)
- Status: Annual post-breeding wanderer from Mexico in late summer and early fall in very small numbers. Most frequent around Imperial Dam but has occurred north to Davis Dam and even Lake Mead. Occasionally individuals linger through the winter and following spring. All records are of immatures. The closest breeding colonies are in the Gulf of California.
- Habitat: Prefers large open water areas, such as near dams. Occasionally frequents marinas.
- Food: Primarily fish.

Blue-footed Booby (Sula nebouxii)
- Status: Casual post-breeding wanderer from Mexico in late summer and early fall. Recorded in 1953, 1954, 1959, 1971, and 1977, north to Lake Havasu. At least two individuals have remained through the winter.
- Habitat: Open water, such as reservoirs of dams.
- Food: Primarily fish and aquatic invertebrates are taken occasionally.

Brown Booby (Sula leucogaster)

Status: Casual post-breeding wanderer from Mexico in late summer and early fall. Recorded in 1953, 1958, 1973, and 1977, north to Lake Havasu. One individual remained at Martinez Lake from September 1958 to October 1960.

Habitat: Open water.

Food: Same as the preceding species.

Double-crested Cormorant (Phalacrocorax auritus)

Status: Common transient and winter resident, often observed in large flocks. Fairly common local breeder at Topock Marsh and on Imperial National Wildlife Refuge. Winter numbers vary greatly from year to year. Max: 1802, 20 December 1977, Yuma CBC.

Habitat: Requires flooded snags or live riparian trees for nesting, usually in secluded backwaters. Occasionally seen on small ponds and on agricultural canals.

Breeding: Nests composed of small sticks in dead flooded trees. Usually 3-4 eggs laid from April-May.

Food: Primarily fish.

Olivaceous Cormorant (Phalacrocorax olivaceus)

Status: Casual visitor from Mexico. Recorded 22-23 April 1972 near Imperial Dam, 27 January 1978 at Cibola Lake, and 20 December 1979 to late January 1980 at Mittry Lake.

Habitat: Open water, backwater lakes.

Food: Mainly fish.

Anhinga (Anhinga anhinga)

Status: Hypothetical. Old sight records such as Laguna Dam, 9 February 1913, not substantiated.

Magnificent Frigatebird (Fregata magnificens)

Status: Rare summer visitor from Mexico. Recently of annual occurrence (1974-1981), with most records occurring from late June to mid-September, north to Davis Dam.

Habitat: Open water; most often seen flying high overhead.

Food: Primarily fish and other aquatic animals.

Great Blue Heron (Ardea herodias)

Status: Fairly common year-round resident throughout the valley. Usually seen singly or in small groups, except when at rookeries and rarely as migratory flocks. Breeding population apparently augmented by migrants from the north and west. Max: 96, 15 December 1979, Yuma CBC.

Habitat: Requires tall riparian trees for nesting. Occurs on riverbanks, mudflats, marshes, and occasionally on agricultural canals.

Breeding: Rookeries form in late February and nesting continues through May and June. About 10-12 known rookeries between Topock Marsh and Yuma, usually in isolated cottonwood stands. Numbers range from 10 to 15 nests per colony, except at Topock Marsh where up to 75 nests have occurred.

Food: Mainly fish, rodents, and other vertebrates.

Green Heron (Butorides striatus)

Status: Fairly common summer resident from March through September in southern half of the valley, less common farther north. In winter, uncommon in the south, rare but regular farther north. Max: 14, 18 December 1978, Parker CBC.

Habitat: Requires riparian trees near water for nesting. Nonbreeding birds occur on riverbanks, in marshes, backwaters, and agricultural canals.

Breeding: Not colonial; builds stick nests in trees over or near water.

Food: Small fish, amphibians, various invertebrates.

Little Blue Heron (Florida caerulea)

Status: Casual visitor from Mexico in spring and summer. Recorded 9 May 1979 in Dome Valley and 19 July 1979 at Andrade. An odd heron at Bill Williams Delta 14-15 August 1976 may have been a hybrid between this species and the Louisiana Heron.

Habitat: Riverbank, marsh.

Food: Small fish, amphibians, various invertebrates.

Cattle Egret (Bubulcus ibis)

Status: Uncommon and irregular year round but occasionally in large flocks. Most numerous in southern parts of the valley, especially near Yuma. First recorded in 1970; numbers are increasing slowly. Presence of large numbers in breeding plumage near Yuma in 1980 and breeding colonies in the nearby Imperial Valley suggests that breeding is imminent. Max: 500, 7 July 1980, northeast of Yuma.

Habitat: Agricultural fields, riverbanks.

Food: Various vertebrates and insects.

Reddish Egret (Dichromanassa rufescens)

Status: Casual visitor from Mexico. Five records: 30 September 1954 to 3 March 1955 above Imperial Dam; 9 September 1954 at Lake Havasu (sp. - MVZ); 19 November 1955 at Ferguson Lake; 2 September 1960 30 miles north of Imperial Dam; and 11 February to mid-March 1979 at Imperial Dam (photo).

Habitat: Riverbank, mudflats in shallow water.

Food: Mainly fish, amphibians, and aquatic invertebrates.

Great Egret (Casmerodius albus)

Status: Fairly common year-round resident throughout the valley. Concentrations usually near breeding sites but occasionally flocks elsewhere, especially in spring. Max: 191, 22 December 1975, Yuma CBC.

Habitat: Riparian trees required for nesting. Riverbank, mudflats, marshes, spillways of dams, and occasionally agricultural fields.

Breeding: Nests in mixed rookeries with Great Blue Herons and may displace that species from specific nest sites.

Breeding begins in March, later than in the Great Blue Heron. Fewer than 10 known rookeries, with 2 to 16 nests, except at Topock Marsh where as many as 144 have nested.

Food: Mainly frogs, fish, snakes, rodents, and grasshoppers.

Snowy Egret (Egretta thula)

Status: Irregularly fairly common in small numbers throughout the valley, mainly as transients in spring and early fall. Generally most numerous from Imperial Dam south, where flocks up to 60 have been recorded. Recently uncommon to rare in winter in northern sectors. Formerly more numerous. Breeds sporadically at Topock Marsh, Imperial National Wildlife Refuge, and possibly elsewhere. Max: 450, 31 July 1958, Imperial National Wildlife Refuge.

Habitat: Requires riparian trees for nesting. Seen most frequently in marshy backwaters in spillways of Imperial and Laguna dams; occasionally along main river channels and rarely in agricultural fields.

Breeding: Usually in mixed colony with other herons. Large colony at Topock Marsh built up to 141 nests in 1950 but disbanded in 1953.

Food: Mainly fish, amphibians, and large insects.

Louisiana Heron (Hydranassa tricolor)

Status: Casual visitor from Mexico in fall. Recorded 13 October 1954 at Martinez Lake and 8-30 September 1955 at Imperial Dam.

Habitat: Shoreline, marshes.

Food: Small fish, aquatic invertebrates.

Black-crowned Night Heron (Nycticorax nycticorax)

Status: Uncommon to fairly common year-round resident throughout the valley. Usually occurs singly or in small groups and rarely in large concentrations. Nocturnal habits make the status of this species difficult to monitor. Max: 200, December 1953 at Topock Marsh.

Habitat: Riparian trees required for nesting and diurnal roosts. Feeds in marshes and along main river channels and lakeshores.

Breeding: Nests in colonies in trees. Usually flimsy nests of branches and twigs contain 3-5 eggs. Breeds April-July.

Food: Mainly fish and amphibians, some aquatic invertebrates.

Yellow-crowned Night Heron (Nyctanassa violacea)

Status: Probably a casual visitor from Mexico. One sight record, a near adult 17 April 1973 at Imperial Dam.

Habitat: Marsh, riverbanks.

Food: Mainly crayfish, fish, and other vertebrates.

Least Bittern (Ixobrychus exilis)

Status: A locally common breeder from April through September, in extensive marshes, such as at Topock Marsh and

Imperial Dam. Less numerous elsewhere throughout the valley. Uncommon in winter around Imperial Dam south to Yuma; rare farther north. Max: 41, July 1978, Imperial National Wildlife Refuge.

Habitat: Prefers cat-tail and bulrush marshes, but may be present in a variety of marsh or pond situations.

Breeding: Breeds in densities up to 40/100 acres in cat-tail marshes. Nests are hidden in dense marsh vegetation. Many fledged young seen in July.

Food: Mainly small fish and amphibians; also insects and rodents.

American Bittern (Botaurus lentiginosus)

Status: Uncommon winter visitor from late August to early May, throughout the valley. This species is not gregarious. Recent summer records might suggest breeding. Max: 11, 20 December 1976, Parker CBC.

Habitat: Dense marsh and wet riparian areas.

Food: Mainly amphibians, fish; also rodents, reptiles, insects.

Wood Stork (Mycteria americana)

Status: Rare but regular post-breeding visitor from Mexico in summer and early fall, north to Bill Williams Delta. Local concentrations at Cibola National Wildlife Refuge and in the Palo Verde Valley, suggest a dispersal from the Salton Sea in California. Formerly more widespread and numerous and occurring all year. Max: 230, 16 July 1959, near Laguna Dam.

Habitat: Agricultural fields and marshes.

Food: Tadpoles, aquatic insects, some fish and seeds.

White-faced Ibis (Plegadis chihi)

Status: Uncommon to fairly common transient in small flocks, March through May and July through October. Rare as a transient in June and as a winter visitor from November to February in the southern sectors. An exceptionally large concentration of 5000 roosted in the Dome Valley, east of Yuma on 9 September 1979. Max: 5,000, 9 September 1979, in Dome Valley.

Habitat: Marshes, irrigated fields, and shallow backwaters.

Food: Crayfish, other invertebrates, small fish.

White Ibis (Eudocimus albus)

Status: Casual visitor from Mexico. Two records: March 1914 at Palo Verde and 4-5 April 1962 at Martinez Lake (photo).

Habitat: Marsh, backwaters.

Food: Mainly crayfish, other invertebrates.

Roseate Spoonbill (Ajaia ajaja)

Status: Very rare and erratic visitor from Mexico in summer and fall. Recorded at least in 1942, 1959, 1969, 1973, and 1977. At least one bird remained through winter until 21 March 1974 at Palo Verde. Max: 21, 18 June 1973, northeast of Yuma.

Habitat: Marshes and backwater channels.
Food: Fish, aquatic insects and other invertebrates.

Whistling Swan (Olor columbianus)
Status: In recent years a rare but regular winter visitor and transient in very small numbers, from late October to mid-March. Formerly, more numerous. Max: 47, 13-25 February 1957, at Martinez Lake.
Habitat: Protected river channels, marshes, and rarely agricultural fields.
Food: Mainly vegetation; some aquatic animals.

Canada Goose (Branta canadensis)
Status: Fairly common winter resident from mid-October to late February; occasionally flocks are observed outside these dates. Most numerous at Cibola National Wildlife Refuge where supplemental grain is provided, however flocks are scattered throughout the valley.
Habitat: Protected river channels and sandbars, marshes, and agricultural fields, especially on national wildlife refuges.
Food: Mainly seeds, other vegetation.

Brant (Branta bernicla)
Status: Casual or very rare winter visitor and spring transient. About seven records always of single birds or of several mixed with other geese.
Habitat: River, agricultural fields, national wildlife refuges.
Food: Aquatic vegetation.

White-fronted Goose (Anser albifrons)
Status: Uncommon transient in small numbers in late September and early October; rare but probably regular winter resident, often associated with other geese. Formerly much more numerous (until 1950's), when it occurred as an early spring transient as well. One recent spring record, 28 March 1981 at Parker. Max: 577, 28 September 1943, Bill Williams Delta.
Habitat: River, agricultural fields, national wildlife refuges.
Food: Mainly seeds, other vegetation.

Snow Goose (Chen caerulescens)
Status: Uncommon or locally fairly common winter resident and transient, sometimes in large flocks, from mid-October to mid-March, occasionally occurs in very small numbers outside that period. Most numerous at Topock Marsh, especially in November. There are four records of the "Blue" form, all from Topock Marsh.
Habitat: Agricultural fields, marshes and sandbars, primarily on national wildlife refuges.
Food: Mainly grain, other seeds and vegetation.

Ross Goose (Chen rossii)

Status: Rare but probably regular winter resident from November to March, in very small numbers, usually associated with Snow Geese. Max: 7, winter 1979-80, Cibola National Wildlife Refuge.
Habitat: Agricultural fields, marshes, river.
Food: Mainly grain, other seeds and vegetation.

Fulvous Whistling-Duck (Dendrocygna bicolor)

Status: In recent years, a very rare and irregular visitor in spring, summer and fall. Formerly more common, even in winter. All recent records are from the southern half of the valley, north to Cibola National Wildlife Refuge. Max: 27, 16 November 1961, Martinez Lake.
Habitat: Marsh, backwaters, irrigated fields.
Food: Mainly seeds, other vegetation.

Mallard (Anas platyrhynchos)

Status: Uncommon to fairly common between early August and mid-April; irregularly common during winter months. Rare in late April and May, casual in June and July. May have bred formerly, but there are no recent records. Most often occurs in small flocks.
Habitat: Unchannelized river, backwaters, marshes.
Food: Seeds, vegetation, aquatic invertebrates.

Gadwall (Anas strepera)

Status: Uncommon to fairly common from mid-September to early April. Rare in late April and May and casual in summer months. Has bred locally, such as at West Pond, July 1957 (2 females with 15 young), and at Topock Marsh in 1949, 1951, and 1970.
Habitat: Unchannelized river, marshes and ponds; sometimes on larger lakes.
Breeding: Nests are hollows in ground, lined with reeds and down. Ten, 11, or 12 eggs laid from April-July.
Food: Mainly aquatic vegetation.

Pintail (Anas acuta)

Status: Common to abundant early fall transient primarily from mid-August through September, with first arrivals occurring in late July. Fairly common to common in late fall and winter, with most concentrations on Cibola and Imperial National Wildlife Refuges. Rare by May, with small flocks rarely seen during June and July.
Habitat: Agricultural fields, marshes, unchannelized river.
Food: Mainly agricultural and aquatic seeds and vegetation.

Green-winged Teal (Anas crecca carolinensis)

Status: Common to abundant early fall transient in late August and September, often occurring in large flocks. Irregularly common through fall and winter, with the greatest numbers wintering at Cibola National Wildlife Refuge. Rare by late April, with a few records from May through July.

Habitat: Marshes, agricultural fields, unchannelized river.
Food: Mainly seeds and aquatic vegetation, some invertebrates.

Blue-winged Teal (Anas discors)
Status: Rare to uncommon transient from February through October, generally in pairs or small flocks with other teal. The majority occur from late February to mid-May. Rare and irregular from November through January, however fall status is uncertain due to difficulty in separating eclipse plumaged birds from Cinnamon Teal.
Habitat: Marshes, unchannelized river, ponds.
Food: Mainly aquatic vegetation, seeds, and invertebrates.

Cinnamon Teal (Anas cyanoptera)
Status: Uncommon and local summer resident, occasionally breeding (1979,1981). Fairly common transient from early February through mid-May and from late July through September, generally in small flocks. The first migrants arrive by early January and fall birds regularly linger through October. Rare but regular in November and December. Max: 600, 26 August 1979, northeast of Yuma.
Habitat: Marshes, unchannelized river, ponds, agricultural fields and canals.
Breeding: Nests varied. Some on dry ground, others in reeds. Nests usually consist of reeds lined with down. Usual set 10-12 eggs.
Food: Mainly seeds, some aquatic invertebrates.

European Wigeon (Anas penelope)
Status: Casual transient or winter visitor. Three records: 18 December 1947 at Topock, 28 September 1974 near Poston, and 20-28 March 1981 at Parker (photo). This species usually occurs among flocks of American Wigeons.
Habitat: River channels, marshes.
Food: Mainly aquatic vegetation, some seeds, and insects.

American Wigeon (Anas americana)
Status: Fairly common to common winter resident, from November through February. Uncommon transient in September, October, and March; rare in April, May, and August. There are several records from June and July.
Habitat: Unchannelized river, marshes, ponds.
Food: Mainly aquatic vegetation, some seeds, and insects.

Northern Shoveler (Anas clypeata)
Status: Uncommon transient and winter resident from late August to early April. Rare in May and early August; there are several mid-summer records.
Habitat: Unchannelized river, marshes, agricultural fields.
Food: Mainly aquatic vegetation and seeds, some molluscs.

Wood Duck (Aix sponsa)

Status: Rare but regular visitor from October to early March. Small flocks have wintered on ponds along lower Bill Williams River. The several June records are anomalous. Max: 14, 24 December 1977, Bill Williams Delta CBC.

Habitat: Wooded ponds, protected backwaters, rarely open river and agricultural canals.

Food: Seeds.

Redhead (Aythya americana)

Status: Uncommon to fairly common transient and winter resident from mid-October to mid-April, generally in small flocks. Rare but regular in August, September, and May; irregular in June and July, but has bred.

Habitat: Open lakes, channelized river, marshes, and ponds.

Breeding: Nests made of rushes lined with down, found in wet marshes. Ten to fifteen eggs laid from April-May.

Food: Aquatic vegetation.

Ring-necked Duck (Aythya collaris)

Status: Uncommon to fairly common from mid-October to mid-April, generally in small flocks. The largest concentrations have occurred near Imperial Dam. Virtually absent from the valley outside that period. Max: 984, 20 December 1977, Yuma CBC.

Habitat: Ponds, open lakes, and river channels, marshes.

Food: Primarily musk grass, other vegetation, some invertebrates.

Canvasback (Aythya valisineria)

Status: Rare to locally uncommon from October through April. The latest spring occurrence is 15 May 1954. Areas of regular occurrence include Imperial Dam and Topock Marsh. Max: 65, 22 December 1975, Yuma CBC.

Habitat: Ponds, open lakes, river channels.

Food: Mainly crustaceans, shellfish, and aquatic vegetation.

Greater Scaup (Aythya marila)

Status: Rare but regular winter visitor from mid-November to mid-April. Usually associated with Lesser Scaup. Occurs regularly at Imperial Dam and below Parker Dam. Max: 23, 19 December 1978, Bill Williams Delta CBC.

Habitat: Spillways of dams, lakes, rarely agricultural canals.

Food: Aquatic invertebrates and vegetation.

Lesser Scaup (Aythya affinis)

Status: Uncommon to common winter visitor from November to April, often in large local concentrations. The earliest arrivals occur in early October, and some individuals rarely linger into May. There are few summer records, most of which probably involve injured birds. Areas of frequent concentration include Imperial Dam and Parker Dam. Max: 383, 15 December 1979, Yuma CBC.

Habitat: Spillways of dams, lakes, river channels.

Food: Aquatic invertebrates, some vegetation.

Common Goldeneye (Bucephala clangula)

Status: Fairly common to common from mid-November through February in the northern half of the valley, decreasing in abundance to the south. Numbers decrease through the spring; a few individuals rarely linger into May. June and July records probably are of injured birds. Max: 1860, 21 December 1979, Bill Williams Delta CBC.

Habitat: Open lakes, channelized rivers, spillways of dams.

Food: Mainly insects, other invertebrates.

Barrow Goldeneye (Bucephala islandica)

Status: Since 1974, a rare but regular winter visitor from mid-November to early April. Usually occurs with flocks of Common Goldeneye below Davis and Parker dams, with scattered records south to Imperial Dam. Max: 57, 17 December 1974, Davis Dam.

Habitat: Spillways of dams, lakes, channelized rivers.

Food: Mainly insects, other invertebrates, some fish.

Bufflehead (Bucephala albeola)

Status: Uncommon to fairly common from November to March in the northern half of the valley; less numerous farther to the south. Most individuals depart in April, but rarely a few linger into May. June records are probably of injured birds. Sometimes occur in large flocks during cold winters. Max: 464, 23 December 1977, Parker CBC.

Habitat: Channelized river, lakes, spillways of dams, ponds.

Food: Primarily insects, some molluscs.

Oldsquaw (Clangula hyemalis)

Status: Rare and irregular winter visitor to northern parts of the valley from late November through February. Most records are from Davis Dam and Lake Mohave. Max: 8, 20 January 1977, Davis Dam.

Habitat: Open water.

Food: Mainly molluscs, crustaceans, and insects.

White-winged Scoter (Melanitta deglandi)

Status: Casual winter visitor. Singles occurred at Davis Dam in November 1975 and at Imperial Dam from November 1976 to April 1977. Two on Lake Havasu, 8 January through February 1981.

Habitat: Open water.

Food: Mainly molluscs, small fish, other invertebrates.

Surf Scoter (Melanitta perspicillata)

Status: Rare and irregular late fall visitor, with most records from Parker Dam, Lake Havasu, and Davis Dam. Max: 4, late November 1975, Davis Dam.

Habitat: Open water.

Food: Mainly molluscs, small fish, other invertebrates.

Black Scoter (Melanitta nigra)

Status: Casual winter visitor. One immature male present from 8 January to 31 March, 1981 below Parker Dam.
Habitat: Open water.
Food: Mainly molluscs, small fish, other invertebrates.

Ruddy Duck (Oxyura jamaicensis)

Status: Uncommon transient and winter resident from mid-August to mid-May. Rare but regular through the summer months, occasionally breeding (e.g., 1943, 1946, 1978, 1979). Max: 173, 17 December 1973, Yuma CBC.
Habitat: Marshes for breeding; backwaters, lakes and occasionally agricultural canals.
Breeding: Nests are baskets of interwoven reeds, usually built above water. 6-10 eggs laid from April-August.
Food: Mainly seeds, other plant materials, some aquatic invertebrates.

Hooded Merganser (Mergus cucullatus)

Status: Rare but regular winter visitor from November to mid-March. Max: 13, 12 January 1950, Topock Marsh.
Habitat: Ponds, lakes, spillways of dams.
Food: Small fish.

Common Merganser (Mergus merganser)

Status: Uncommon to common winter visitor from November through February, decreasing rapidly by April. Occasionally occurs in large flocks during colder winters. Small numbers recorded during summer months at Parker Dam; may be injured. Max: 1863, 21 December 1979, Bill Williams Delta CBC.
Habitat: River channels, lakes, and spillways of dams.
Food: Small fish.

Red-breasted Merganser (Mergus serrator)

Status: Rare but regular in any month of the year. Irregularly fairly common as a transient from February through May and again in November;. Max: 244, 8 November 1958, Imperial National Wildlife Refuge.
Habitat: Lakes, spillways of dams, and river channels.
Food: Small fish.

Turkey Vulture (Cathartes aura)

Status: Fairly common summer resident with large movements into and out of the valley in March and October, respectively. Uncommon in winter, but occasionally absent from areas north of Parker. Usually occurs singly or in small groups, except when in large migratory flocks. Max: 350, 15 March 1977, Imperial National Wildlife Refuge.
Habitat: Primarily agricultural land, but individuals forage over all habitat types. Roosts in tall trees or on cliffs.
Food: Carrion.

Black Vulture (Coragyps atratus)
- Status: Hypothetical. One sighted below Parker Dam, in California, on 5 September 1977. This would have represented a first record for California if substantiated. Black Vultures are locally common in south central Arizona, and throughout northern Sonora.
- Habitat: Tall trees or cliffs, agricultural lands.
- Food: Carrion.

White-tailed Kite (Elanus leucurus)
- Status: Casual visitor, probably from California. Three sightings to date: 22 February 1979, and 22 March 1980, both at Cibola National Wildlife Refuge; and 13 November 1980 near Poston.
- Habitat: Agricultural land and brushy vegetation.
- Food: Mainly rodents, small birds, reptiles, and insects.

Goshawk (Accipiter gentilis)
- Status: Casual fall transient. Palo Verde 1916; one photographed 29 November 1972 at Topock Marsh; and one seen 15 October 1978 at Ehrenberg.
- Habitat: Riparian and other woods.
- Food: Mainly birds and rodents.

Sharp-shinned Hawk (Accipiter striatus)
- Status: Fairly common transient and winter resident throughout the valley. Migration is mainly from late March to early April, and in September, but records occur from the end of August to mid-May. Max: 26, 23 December 1977, Parker CBC.
- Habitat: Riparian vegetation, brushy agricultural margins.
- Food: Mainly birds and rodents.

Cooper Hawk (Accipiter cooperii)
- Status: Fairly common transient and winter resident from late August to mid-May. Generally more numerous than the previous species. Summer breeding was noted at Parker in 1946 and 1948 and in Bill Williams Delta in 1953 and 1954, but this species does not presently breed in the valley. Max: 24, 23 December 1977, Parker CBC.
- Habitat: Riparian vegetation, agricultural land, and desert washes.
- Food: Mainly birds and rodents.

Red-tailed Hawk (Buteo jamaicensis)
- Status: Uncommon summer resident and breeder, primarily along the edges of the valley. Common transient and winter resident from late September to early April, when many races and color phases occur. Max: 77, 22 December 1980, Parker CBC.
- Habitat: Large trees or cliffs required for breeding; in winter, agricultural lands, open desert, riparian vegetation.
- Breeding: Often nests in saguaro or cottonwoods, sometimes in cliffs. 2-3 eggs laid from February-June.
- Food: Mainly rabbits and rodents.

Red-shouldered Hawk (Buteo lineatus)
- Status: Casual visitor from the west but has bred in the valley. Nest with young found in 1968 at Mittry Lake. Other records are 16 February 1962 at Yuma, 29 October 1977 to 31 January 1978 at Bill Williams Delta, 12 March to 23 April 1978 at Yuma, and two on 21 January 1978 north of Needles.
- Habitat: Cottonwood-willow groves.
- Food: Rodents, reptiles, amphibians, and insects.

Broad-winged Hawk (Buteo platypterus)
- Status: Hypothetical. Two sighted high over Bill Williams Delta on 5 August 1980.
- Habitat: Riparian woodland.
- Food: Mainly rodents.

Swainson Hawk (Buteo swainsoni)
- Status: Uncommon transient from mid-August to mid-October and from late March through April, in very small numbers. One dark-phase bird was north of Ehrenberg on 29 June 1976 and there is one careful sighting, 5 January 1974 at Bard.
- Habitat: Agricultural land, riparian vegetation, desert.
- Food: Mainly rodents and insects.

Zone-tailed Hawk (Buteo albonotatus)
- Status: Rare and irregular summer resident in Bill Williams Delta where nests were found in 1943, 1946, and 1947, and a pair was courting in 1977. Two records of migrants: 3 April 1949 south of Parker and 25 April 1953 along Lake Havasu; and one old winter specimen, 23 January 1902.
- Habitat: Tall riparian vegetation, especially near cliffs.
- Breeding: Nests in tall trees near water and cliffs.
- Food: Mainly lizards, frogs, and small fish.

White-tailed Hawk (Buteo albicaudatus)
- Status: Hypothetical. One adult repeatedly sighted by refuge manager at Imperial National Wildlife Refuge during the winters of 1977 and 1978.
- Habitat: Open country, dry woods.
- Food: Mainly rabbits and rodents.

Rough-legged Hawk (Buteo lagopus)
- Status: Rare but regular in winter from November through February, primarily in the northern half of the valley.
- Habitat: Agricultural land.
- Food: Mainly rodents.

Ferruginous Hawk (Buteo regalis)
- Status: Uncommon transient and winter resident from mid-October to the end of March; most numerous in the northern half of the valley. A few migrants may arrive by late September and linger into early April. Max: 12, 29 November 1981, Blythe.
- Habitat: Agricultural lands.
- Food: Mainly rabbits and rodents.

Harris Hawk (Parabuteo unicinctus)

Status: Formerly a fairly common resident and breeder in many parts of the valley, although not noted by Grinnell in 1910. Extirpated by 1961 except at Topock Marsh, where a population persisted into 1964. Probably still occurs as a casual winter visitor or transient but status confused by accidental releases from falconers in the region and by recent attempts to reestablish a breeding population in the valley.

Habitat: Cottonwood-willow, mesquite, and saguaro associations.

Food: Mainly reptiles, rodents, and other animals.

Black Hawk (Buteogallus anthracinus)

Status: Casual transient and summer visitor. One bird seen repeatedly between 23 March and late June 1979 at Bill Williams Delta, exhibited courtship behavior. Also recorded 25 August 1946 south of Parker and 11 April 1978 at Ehrenberg. An immature seen near Ehrenberg on 5 May 1979 may have been a Great Black Hawk (Buteogallus urubitinga).

Habitat: Mature cottonwood-willow associations near water.

Food: Mainly fish, amphibians, and other small animals.

Golden Eagle (Aquila chrysaetos)

Status: Rare and irregular visitor to the immediate river valley throughout the year.

Habitat: Wide ranging in open country; could occur almost anywhere.

Food: Mainly rabbits, rodents, carrion.

Bald Eagle (Haliaeetus leucocephalus)

Status: Rare in early winter, uncommon in late winter. The first birds may arrive by mid-October and virtually all are gone by late March. One pair attempted unsuccessfully to breed at Topock each spring from 1975 to 1977. An unseasonal immature at Cibola National Wildlife Refuge on 19 May 1978 may have been a wanderer from Arizona breeding populations.

Habitat: Riverbanks, marshes; prefers tall cottonwoods for roosting and nesting.

Food: Mainly fish, birds, mammals, and carrion.

Marsh Hawk (Circus cyaneus)

Status: Common transient and winter resident throughout the valley from October through March, with numbers increasing steadily in September and decreasing in April. Rare in August and May; casual through summer months. In light of a recent breeding record in western Arizona, summer birds should be watched more closely. Max: 97, 22 December 1980, Parker CBC.

Habitat: Agricultural land, sparse riparian vegetation, marsh, desert.

Food: Mainly rodents and other mammals.

Osprey (Pandion haliaetus)

Status: Uncommon transient from mid-August through September and from early March to early May. Rare but regular winter visitor from October through February; rare and irregular in midsummer. Most records outside the migration period are from the Imperial Dam area.

Habitat: River, lakes, dams.

Food: Mainly fish.

Caracara (Caracara cheriway)

Status: Now a casual visitor. One sighting from near Tacna, about 35 miles east of Yuma, on 5 December 1978, and one seen 8 December 1980 at Cibola National Wildlife Refuge. Historically, a resident at Yuma, with the last record 15 January 1905.

Habitat: Riparian vegetation, agricultural land.

Food: Mainly carrion.

Prairie Falcon (Falco mexicanus)

Status: Uncommon transient and winter visitor from September to late March. Also, rare but regular from May through August, most likely as a post-breeding visitor. May breed occasionally at Bill Williams Delta. Max: 5, 18 December 1979, Parker CBC.

Habitat: Agricultural land, sparse riparian vegetation, desert.

Food: Mainly small mammals and birds.

Peregrine Falcon (Falco peregrinus)

Status: At present, a rare and irregular transient, winter resident, and post-breeding visitor. Recorded recently in every month except May. Nested near Parker Dam at least until 1954 and probably also at Imperial National Wildlife Refuge (1942) and Topock Gorge (1953).

Habitat: Wide ranging, occurring in almost any habitat.

Food: Mainly birds, small mammals.

Merlin (Falco columbarius)

Status: Rare but regular transient and winter visitor from mid-September to mid-April, throughout the valley. Formerly more common. Max: 4, 20 December 1979, Parker CBC.

Habitat: Agricultural land, riparian vegetation.

Food: Small birds and large insects.

American Kestrel (Falco sparverius)

Status: Locally uncommon summer resident and breeder; common transient and winter resident from mid-September to mid-May. Max: 177, 22 December 1980, Parker CBC.

Habitat: Requires tall trees or snags for nesting in riparian vegetation or agricultural areas. Primarily in agricultural areas during nonbreeding season.

Breeding: Nests in woodpecker holes or natural cavities in tall trees or snags.

Food: Mainly insects, sometimes rodents and small birds.

Gambel Quail (Lophortyx gambelii)

Status: Common to abundant permanent resident throughout the valley, with population peaks in late summer. Often occurs in large coveys. Max: 1206, 18 December 1979, Parker CBC.

Habitat: Widely distributed; most numerous in screwbean mesquite habitats in summer and fall, and in honey mesquite and desert washes in winter and spring.

Breeding: From late February through August, with broods present from May to September.

Food: Mainly agricultural or annual plant seeds in winter and spring, and mesquite seeds in late summer and fall. Ants and other insects also eaten. Annual cycle varies according to precipitation.

Ring-necked Pheasant (Phasianus colchicus)

Status: Periodically introduced for hunting. A few persist year round, with recent sightings at Yuma, Parker, and Cibola National Wildlife Refuge.

Habitat: Agricultural land.

Food: Grain and other seeds.

Sandhill Crane (Grus canadensis)

Status: Locally fairly common in winter between early October and late February, with a few lingering into early March. Occurs in flocks near Poston, Bullhead City, and on Cibola National Wildlife Refuge.

Habitat: Feeds in agricultural fields and requires protected sandbars as roosts.

Food: Mainly plant materials, some animals.

Clapper Rail (Rallus longirostris)

Status: Locally fairly common summer resident and breeder between April and September, north to Topock Marsh. Rare but regular in winter, at least north to Imperial Dam.

Habitat: Extensive marsh, particularly cat-tails and bulrushes.

Breeding: Nests are clumps of marsh grass in dry portions of marshes, 9-12 eggs laid from March-June.

Food: Aquatic invertebrates, insects, amphibians.

Virginia Rail (Rallus limicola)

Status: Recently, a locally fairly common breeder, and common to abundant winter resident. Present in most marshes throughout the year. Apparently has increased substantially in recent years. Max: 90, 21 December 1979, Bill Williams Delta CBC.

Habitat: Marshes, flooded riparian vegetation.

Breeding: Only one definite breeding record, a downy young seen 1 April 1978 at Bill Williams Delta, but doubtless breeds more commonly.

Food: Mainly worms, insect larvae, other invertebrates.

Sora (Porzana carolina)

Status: Common winter resident and transient throughout the valley between August and early May. Although there are summer records for Topock Marsh, there are no definite breeding records. Max: 81, 21 December 1979, Bill Williams Delta.

Habitat: Marshes, small ponds and agricultural canals.

Food: Molluscs, other invertebrates, aquatic seeds and vegetation.

Black Rail (Laterallus jamaicensis)

Status: Permanent resident in small numbers only in vicinity of Imperial Dam, first noted in 1969. Total population has been estimated at about 100, between Mittry Lake and West Pond. One northerly record, 18 April 1979 at Bill Williams Delta.

Habitat: Primarily marshes containing three-square bulrush (Scirpus americanus).

Breeding: Nest composed of fine grass, found in marshes. 6-10 eggs laid from March-May.

Food: Mainly insects, some plant materials.

Common Gallinule (Gallinula chloropus)

Status: Locally fairly common permanent resident and breeder, but decreasing in abundance in the northern half of the valley in winter. Max: 66, 20 December 1979, Parker CBC.

Habitat: Marshes, agricultural canals.

Breeding: Nests made of reeds and usually placed on the edges of water in various marsh grasses. 10-12 eggs are laid from May-July.

Food: Mainly seeds, vegetation, some invertebrates.

American Coot (Fulica americana)

Status: Locally common breeder and abundant winter resident throughout the valley. Often occurs in large flocks on lakes. Max: 50,000, December 1953 at Havasu National Wildlife Refuge.

Habitat: Marshes for breeding; any open water at other times.

Breeding: Nests, usually concealed in rushes, are floating structures which are sometimes attached to reeds. 8-12 eggs laid from April-August.

Food: Mainly aquatic vegetation, some seeds, invertebrates.

Semipalmated Plover (Charadrius semipalmatus)

Status: Uncommon transient in small numbers in late April and early May, and from early August to late October. One seen 22 June 1968 at West Pond.

Habitat: Agricultural fields, mudflats.

Food: Mainly insect larvae, grasshoppers, and other insects.

Piping Plover (Charadrius melodus)
- Status: Hypothetical. One seen (bright orange legs noted) with Snowy Plovers at Blythe on 11 August 1979. A few winter regularly at Puerto Penasco, Sonora, not far to the south.
- Habitat: Agricultural fields, mudflats.
- Food: Crustaceans, insects and larvae.

Snowy Plover (Charadrius alexandrinus)
- Status: Uncommon transient in small numbers from late March to early June and from July to early November. Rare and irregular in winter. Max: 27, 22 July 1954, Topock Marsh.
- Habitat: Agricultural fields, mudflats.
- Food: Mainly flies, beetles, other insects and larvae.

Killdeer (Charadrius vociferus)
- Status: Fairly common summer breeder throughout the valley. Also, common to abundant transient and winter resident from September through May, often seen in large flocks. Max: 1248, 23 December 1977, Parker CBC.
- Habitat: Anywhere near water; especially agricultural fields, mudflats.
- Breeding: Nests in fields and on bare gravelly ground. Usually lays 4 eggs. Breeds from March-July.
- Food: Mainly insect larvae, grasshoppers, and beetles.

Mountain Plover (Eupoda montanus)
- Status: Uncommon transient and winter resident in small flocks, between early November and early April. Most frequently seen near Poston and Parker. Max: 200, 27 November 1981, Blythe.
- Habitat: Bare, plowed agricultural fields.
- Food: Mainly grasshoppers, beetles, flies, and larvae.

American Golden Plover (Pluvialis dominica)
- Status: Very rare or casual transient. Three definite records: 12 October 1977 south of Blythe, 6 May 1978 (photo), and 18 October 1979, both near Parker.
- Habitat: Plowed agricultural fields, riverbank.
- Food: Mainly grasshoppers, other insects, and larvae.

Black-bellied Plover (Pluvialis squatarola)
- Status: Uncommon transient in very small numbers from late March to late May, and from mid-July through mid-September. Occasional birds may linger into late fall.
- Habitat: Agricultural fields, mudflats.
- Food: Mainly grasshoppers, beetles, insect larvae.

Ruddy Turnstone (Arenaria interpres)
- Status: Casual fall transient. Three records from Lake Havasu: 16 September 1952, 21 August 1953, and 3 September 1977.
- Habitat: Shoreline.
- Food: Mainly molluscs, crustaceans, and insects.

Black Turnstone (Arenaria melanocephala)

Status: Casual visitor. One record, 21 May 1978 at Lake Havasu. Wintering birds in the Gulf of California are a potential source of such strays.
Habitat: Shoreline.
Food: Mainly molluscs, crustaceans, and insects.

Common Snipe (Capella gallinago)

Status: Fairly common transient and winter resident in wet areas throughout the valley from September to late April. First birds arrive in early August and late transients are recorded into early May. One bird photographed on 18 July 1979 at Poston was unseasonal for the region. Max: 100, Bill Williams Delta, 17 December 1957.
Habitat: Irrigated fields, marshes, wet riparian vegetation.
Food: Mainly worms, insect larvae, and insects.

Long-billed Curlew (Numenius americanus)

Status: Uncommon to fairly common transient between mid-March and late September, with the peak migration occurring in April and again from mid-July through early September. Occasionally seen in large flocks at those times; early summer records are usually of singles or pairs. Max: 190, 28 September 1974, San Luis.
Habitat: Plowed or grassy agricultural fields, sandbars.
Food: Various insects, larvae, and worms.

Whimbrel (Numenius phaeopus)

Status: Uncommon transient from late March to late May, and from July to mid-September. Most regularly seen near Blythe and Poston in early August. Max: 8, 2 August 1976, Ripley, CA.
Habitat: Plowed agricultural fields, sandbars.
Food: Mainly grasshoppers, beetles, spiders, other invertebrates.

Upland Sandpiper (Bartramia longicauda)

Status: Casual fall transient. Two sight records: 11 September 1952 at Lake Havasu and 9 September 1978 at Imperial National Wildlife Refuge.
Habitat: Agricultural fields, shorelines.
Food: Mainly grasshoppers, beetles, and bugs.

Spotted Sandpiper (Actitis macularia)

Status: Common transient and winter resident between September and April. Present in very small numbers through summer, increasing steadily in fall and decreasing in spring. No breeding records. Max: 84, 23 December 1977, Parker CBC.
Habitat: Riverbanks, sandbars, agricultural canals.
Food: Various insects, larvae, crustaceans, and small fish.

Solitary Sandpiper (Tringa solitaria)
- Status: Uncommon fall transient from early August to mid-October. An extremely early bird was at Topock, 8 July 1953. Rare in spring from early April to early May, and one winter record, 26 December 1950 near Yuma.
- Habitat: Irrigated fields, marshes, riverbanks.
- Food: Various insects, larvae, crustaceans.

Greater Yellowlegs (Tringa melanoleuca)
- Status: Fairly common transient from mid-March through late April and from early August to late September. Uncommon in July with an extremely early bird at Parker, 22 June 1953. Also an uncommon winter resident locally throughout the valley.
- Habitat: Irrigated fields, marshes, riverbanks.
- Food: Aquatic insects, larvae, some fish.

Lesser Yellowlegs (Tringa flavipes)
- Status: Rare but regular spring transient in April and early May, and uncommon fall transient from early July (extreme date 30 June 1953) to late September.
- Habitat: Irrigated fields, mudflats.
- Food: Aquatic insects, larvae, and crustaceans.

Willet (Catoptrophorus semipalmatus)
- Status: Fairly common transient in moderate numbers from early April to mid-May and again in July. Uncommon in small flocks through most of June and in August; rare in early September. There is one later record: four on 26 October 1979, near Yuma. Max: 260, 30 July 1953, Topock Marsh.
- Habitat: Marshes, sandbars, irrigated fields.
- Food: Aquatic insects, crustaceans, molluscs, small fish.

Red Knot (Calidris canutus)
- Status: Casual or very rare fall transient. Five records: 23 July 1952 at Topock, 9 August 1950 at Lake Havasu, 2 October 1959 near Imperial Dam, 6 October 1979 east of Yuma, and 28 November 1975 near Davis Dam. Also one spring sighting: 1 May 1975 near Davis Dam.
- Habitat: Irrigated fields, marshes, mudflats.
- Food: Mainly crustaceans and insect larvae.

Pectoral Sandpiper (Calidris melanotos)
- Status: Uncommon fall transient from mid-September to early November, rarely appearing as early as late August. Two reliable spring sight records: 9 April 1975 (2) near Davis Dam, and 15 April 1979 at Blythe, and one winter sighting, 30 December 1957 at Martinez Lake.
- Habitat: Irrigated fields, marshes.
- Food: Mainly flies, amphipods, other insects, and vegetable matter.

Baird Sandpiper (Calidris bairdii)
- Status: Uncommon fall transient in September; rare in August, October, and early November. Two seen 8 July 1953 at Topock Marsh were very early. Four spring sight records: 13 March, 8 April (8), and 1 May (4) 1975 near Davis Dam, and 2 May 1979 at Blythe.
- Habitat: Irrigated fields, mudflats, marshes.
- Food: Insects, larvae, and amphipods.

Least Sandpiper (Calidris minutilla)
- Status: Common to abundant transient and winter resident from August through April, but very rare by mid-May. An early fall record is for 29 June 1977, but this species remains uncommon through July.
- Habitat: Riverbanks, sandbars, mudflats, agricultural fields.
- Food: Various insects and larvae.

Dunlin (Calidris alpina)
- Status: Rare but regular late fall transient and winter visitor from mid-October to mid-March. Only one earlier record, 16 September 1955 at Imperial National Widllife Refuge. Also a few records of spring transients in April and early May. Max: 21, 28 January 1978, Bill Williams Delta.
- Habitat: Mudflats, sandbars.
- Food: Molluscs, worms, crustaceans, insects, and spiders.

Semipalmated Sandpiper (Calidris pusilla)
- Status: Casual transient. One record, 31 August 1980 at Lake Havasu (photo). There are numerous recent records of this species elsewhere in Arizona and southern California.
- Habitat: Mudflats.
- Food: Mainly beetles, flies, bugs, and insect larvae.

Western Sandpiper (Calidris mauri)
- Status: Fairly common spring transient from April into early May. Fall migration is more protracted; fairly common in August, uncommon in July, September, and early October. A few records in December and January indicate that this species may winter irregularly.
- Habitat: Irrigated fields, sandbars, mudflats.
- Food: Mainly insects, larvae, and other invertebrates.

Sanderling (Calidris alba)
- Status: Rare but regular fall transient from late August to late September. One later record, 28 November 1975 near Davis Dam. Rare and irregular in spring, from early April to late May. Usually seen singly, but note maximum. Max: 60, 22 September 1980, south of Blythe.
- Habitat: Lakeshore, sandbars, agricultural fields.
- Food: Crustaceans, insects, and larvae.

Short-billed Dowitcher (Limnodromus griseus)
- Status: Rare but regular fall transient throughout August and September. One additional early record: three on 1 July 1973 northeast of Yuma.
- Habitat: Irrigated plowed fields, marshes.
- Food: Mainly insects and larvae.

Long-billed Dowitcher (Limnodromus scolopaceus)
- Status: Uncommon in small flocks from mid-July through the winter into early May, fairly common transient in April and August. Rare in mid-May and early again in July; one June record: 15 June 1978 at Martinez Lake. Max: 200, 29 January 1957, Imperial National Wildlife Refuge.
- Habitat: Irrigated fields, marshes, mudflats.
- Food: Insects, larvae, other invertebrates.

Stilt Sandpiper (Micropalama himantopus)
- Status: Casual transient. One record, two seen 17 August 1979 near Bard. This species' regularity at Phoenix and the Salton Sea suggests it may be overlooked along the Colorado River.
- Habitat: Agricultural fields, probably river and marsh.
- Food: Primarily insect larvae, some vegetation.

Marbled Godwit (Limosa fedoa)
- Status: Uncommon spring transient from late March to early May, and fairly common fall transient in small flocks from mid-July to mid-August. Rare as a transient or lingerer outside the main migration period, between mid-June and mid-November. Max: 180, 29 April 1952, Topock Marsh.
- Habitat: Shorelines, sandbars, agricultural fields.
- Food: Molluscs, crustaceans, insects, and larvae.

American Avocet (Recurvirostra americana)
- Status: Fairly common transient from mid-March to late May and from late July through September. Fall migration often extremely protracted with records from late June occasionally into December. Rare and irregular through winter months. Usually seen in small flocks. Max: 2500, 21 September 1959, Topock Marsh.
- Habitat: Marshes, shorelines, irrigated fields.
- Food: Aquatic plant seeds, insects, and larvae.

Black-necked Stilt (Himantopus mexicanus)
- Status: Rare and local breeder in some years (e.g., 1956, 1980). Fairly common transient in small flocks from mid-March to the end of May and from mid-July to mid-September. Uncommon transient in late June, and early October. One winter record; two seen at Parker, 20 December 1979.
- Habitat: Marshes, irrigated fields, sewage ponds.
- Breeding: Nests in fields and along margins of ponds. Breeds April to August. Lays 4 eggs.
- Food: Mainly aquatic insects, larvae, and other invertebrates.

Red Phalarope (Phalaropus fulicarius)
- Status: Rare and irregular fall transient from mid-September to late November. One earlier record, 4 August 1946 at Parker, and one spring record, 1 April 1977 at Lake Havasu.
- Habitat: Large lakes.
- Food: Crustaceans, insects, tiny fish.

Wilson Phalarope (Steganopus tricolor)
- Status: Uncommon spring transient in late April and early May, with an exceptionally early record, 27 March 1959 at West Pond. Fall migration more protracted; fairly common in August, and uncommon in July and September. Flocks seen occasionally in mid- or late June are probably also southbound migrants. Max: 346, 2 September 1961, Imperial National Wildlife Refuge.
- Habitat: Irrigated fields, marshes, ponds.
- Food: Mainly flies, aquatic bugs, and beetles.

Northern Phalarope (Lobipes lobatus)
- Status: Uncommon fall transient, but sometimes in large flocks on large reservoirs, from mid-August to mid-October. Has been recorded as early as late July. Rare and irregular in spring; recorded 16 May 1952 at Bill Williams Delta (24), 19 May 1952 at Lake Havasu, 8 May 1961 at Imperial National Wildlife Refuge (4), and 26 May 1979 at Lake Havasu (photo). Max: 644, 18 August 1954, Topock Marsh.
- Habitat: Large lakes; occasionally river channels, irrigated fields.
- Food: Aquatic insects and larvae.

Pomarine Jaeger (Stercorarius pomarinus)
- Status: Casual transient. Two records from Lake Havasu: 26 September 1950 and 3-5 September 1977 (2).
- Habitat: Open water.
- Food: Live or dead fish and other animals, often steals food from other seabirds.

Long-tailed Jaeger (Stercorarius longicaudus)
- Status: Casual transient. Two adults photographed at Lake Havasu 4 September 1977, and an immature carefully identified there on 14 September 1977.
- Habitat: Open water.
- Food: Same as Pomarine Jaeger.

Parasitic Jaeger (Stercorarius parasiticus)
- Status: Rare but possibly regular fall transient in September and early October. Recorded on Lake Havasu at least in 1947, 1953, 1977, and 1980, and at Davis Dam 17 September 1976.
- Habitat: Open water.
- Food: Same as other jaegers.

Glaucous-winged Gull (Larus glaucescens)
- Status: Casual winter visitor. Four records: 4-24 February 1954 on Lake Havasu, 17 November 1956 at Imperial National Wildlife Refuge, all winter 1975-76 at Davis Dam, and 19 December 1977 at Imperial Dam.
- Habitat: Open water.
- Food: Omnivorous; fish, other animal foods, garbage.

Western Gull (Larus occidentalis)
- Status: Casual winter visitor. One immature collected on 12 December 1946 at Parker Dam, identified as the nominate race L. o. occidentalis.
- Habitat: Open water.
- Food: Omnivorous: fish, other animal foods, garbage.

Herring Gull (Larus argentatus)
- Status: Rare but regular winter visitor between mid-November and mid-April. Most records are from Lake Havasu.
- Habitat: Open water, rarely flooded fields.
- Food: Omnivorous: fish, other animal foods, garbage.

Thayer Gull (Larus thayeri)
- Status: Casual winter visitor. Three records: 13 December 1946 at Lake Havasu, 12 December 1974, 18 February 1975 (1-2 immatures) at Davis Dam, 17 January 1976 (3) at Davis Dam, and 26 November 1978 at Imperial Dam.
- Habitat: Open water.
- Food: Omnivorous: fish, other animal foods, garbage.

California Gull (Larus californicus)
- Status: Uncommon early fall transient from late July to early September, and uncommon to fairly common spring transient in April. Rare to uncommon in winter, occasionally in local concentrations at Davis Dam; rare but regular through summer and in late fall.
- Habitat: Open water, sandbars, marinas.
- Food: Omnivorous: fish, other animal foods, garbage.

Ring-billed Gull (Larus delawarensis)
- Status: Fairly common to locally common in winter from November through early March. Uncommon fall transient in small flocks beginning in late July. Also, uncommon spring transient through April. Rare but regular in small numbers through summer.
- Habitat: Lakes, river, dams, agricultural fields.
- Food: Fish, insects, other animal foods, garbage.

Mew Gull (Larus canus)
- Status: Casual winter visitor or transient. One adult and three immatures present 20 March-3 April 1979 at Davis Dam (photos) and a probable adult seen 25 January 1978 above Davis Dam.
- Habitat: Open water.
- Food: Mainly fish, other animal foods.

Black-headed Gull (Larus ridibundus)
Status: Hypothetical. A worn-plumaged gull seen and photographed 14-16 June 1978 at Imperial National Wildlife Refuge may have been this species.
Habitat: Marshes, sandbars.
Food: Insects, small fish and crustaceans.

Laughing Gull (Larus atricilla)
Status: Casual transient. Three records: one collected 3 September 1960 near Imperial Dam, one photographed 17-20 March 1979 at Davis Dam, and an adult seen 12 June 1981 at Cibola National Wildlife Refuge.
Habitat: Open water.
Food: Mainly insects, small fish.

Franklin Gull (Larus pipixcan)
Status: Rare and irregular fall transient in October and November, and in spring from late March to early June. Also three seen 25 August 1978 at Lake Havasu.
Habitat: Open water, sandbars.
Food: Mainly insects, small fish.

Bonaparte Gull (Larus philadelphia)
Status: Rare transient and winter visitor with records for every month of the year; but regular only in November. A large flight occurred in late spring 1977 with over 30 seen between 22 April and 1 July.
Habitat: Open water, sandbars.
Food: Mainly insects, small fish, and crustaceans.

Heermann Gull (Larus heermanni)
Status: Very rare but possibly regular fall transient in recent years. Recorded 17 September 1976 at Davis Dam, 15 October 1977 near Parker, 28 October 1977 south of Blythe, 10 November 1978 (2 adults) at Imperial National Wildlife Refuge, 12 November 1980 - one at Lake Havasu and one at Ehrenberg, and 13 November 1955 at Imperial National Wildlife Refuge.
Habitat: Open water.
Food: Mainly fish, other seafood.

Black-legged Kittiwake (Rissa tridactyla)
Status: Casual transient and winter visitor. Recorded: 11-19 November 1978 at Parker Dam (adult), 24 November 1973 at Martinez Lake (immature), 28 November to 5 December 1980 at Lake Havasu (2 immatures, one collected), with two more immatures at Parker Dam until late February 1981, 18-20 February 1975 at Davis Dam, and 10 December 1975 to 25 February 1976 (1 adult and 2-3 immatures) at Davis Dam.
Habitat: Open water.
Food: Mainly fish and garbage.

Sabine Gull (Xema sabini)

Status: Rare but regular fall transient from mid-September through October. At least 20 individuals have been recorded in 10 different years between 1948 and 1980. Also a flock of seven was seen at Martinez Lake on 13 April 1956, with one lingering to 27 April, and one was seen 22-23 June 1974 at Imperial Dam.
Habitat: Open water.
Food: Mainly insects, small fish, crustaceans.

Gull-billed Tern (Gelochelidon nilotica)

Status: Casual visitor. One collected from two seen on 24 May 1959 at Imperial National Wildlife Refuge. This species is fairly common at the Salton Sea in southern California in summer, and future records are to be expected.
Habitat: River, marsh.
Food: Mainly insects, some other aquatic animals.

Forster Tern (Sterna forsteri)

Status: Uncommon transient from early April through September, except from mid-July to late August when it is fairly common. Rare in March and October, with a few records as late as December. Northbound and southbound migrants apparently occur in June, as with some other Great Basin nesting species. Max: 54, 30 July 1953, Topock Marsh.
Habitat: River, lakes, marshes.
Food: Mainly insects, other aquatic animals.

Common Tern (Sterna hirundo)

Status: Uncommon to fairly common fall transient from mid-August to late September, rarely until mid-October. This species has recently been found to greatly outnumber S. forsteri on Lake Havasu in late August and early September. Two spring sight records: 18 April 1977 and 22 May 1979 near Parker.
Habitat: Lake, river, sandbars.
Food: Primarily small fish.

Least Tern (Sterna albifrons)

Status: Casual transient or post-breeding visitor; four records: 18 June 1953 at Lake Havasu (spec.), 30 July 1959 and 1 July 1973 at Imperial Dam, and 19-20 June 1980 at Cibola National Wildlife Refuge.
Habitat: Open water, marsh.
Food: Mainly small fish.

Caspian Tern (Sterna caspia)

Status: Uncommon transient in late March and April and from early June through September. Rarely lingers into late fall and even through winter (1977-78 at Imperial Dam). Max: 34, 11 September 1953, Bill Williams Delta.
Habitat: River, marsh, sandbars.
Food: Mainly fish.

Black Tern (Chlidonias niger)
- Status: Uncommon transient from late April through mid-September, with north- and southbound migrants occurring in June. Max: 66, 11 September 1959, near Yuma.
- Habitat: River, marsh, lakes, agricultural fields.
- Food: Mainly insects, small fish.

Black Skimmer (Rynchops niger)
- Status: Casual transient or post-breeding visitor. Three records: 12 June 1977 near Martinez Lake (photo), 2-4 September 1977 at Lake Havasu (photo), and 30 August 1979 at Cibola National Wildlife Refuge. This species now breeds at the Salton Sea in southern California, and more records are expected.
- Habitat: River, sandbars.
- Food: Mainly small fish, crustaceans.

Band-tailed Pigeon (Columba fasciata)
- Status: Casual straggler from higher elevations; about four records: Yuma (specimen at University of Arizona sensu Monson), 29 October 1977 at Bill Williams Delta, 10 July 1978 north of Blythe, and 22-31 May 1979 at Blythe (photo).
- Habitat: Tall trees in riparian or agricultural areas.
- Food: Seeds, fruit.

Rock Dove (Columba livia)
- Status: Locally common resident and breeder throughout the valley wherever human habitations occur.
- Habitat: Cities, trailer parks, farm houses, feedlots.
- Food: Seeds, human refuse.

White-winged Dove (Zenaida asiatica)
- Status: Locally abundant summer resident and breeder throughout the valley from April to mid-August. First migrants arrive in early March. Most birds leave the valley before the September hunting season, but small numbers are seen until October and a few have wintered in the Yuma area.
- Habitat: Most abundant in dense riparian woodlands, especially tall screwbean mesquite and salt cedar stands, also citrus orchards, less so in desert and urban areas. Feeds extensively in agricultural fields.
- Breeding: Nests in mesquite and salt cedar. Nests are loosely constructed of sticks. Breeds from May-June. Lays 2 eggs.
- Food: Primarily agricultural crop seeds.

Mourning Dove (Zenaida macroura)
- Status: Abundant spring and summer breeder; less numerous but still common in fall and winter throughout the valley.
- Habitat: Breeds in most riparian habitats as well as in citrus orchards; feeds in agricultural lands. Also present in desert and urban areas.

Breeding: Builds loosely constructed stick nests in mesquite and salt cedar. Breeds April-September. Lays 2 eggs.
Food: Weed and agricultural seeds.

Ground Dove (Columbina passerina)
Status: Locally fairly common resident, though more so in the southern half of the valley.
Habitat: Agricultural land and sparse riparian vegetation; prefers sandy areas.
Breeding: Nests are well built, consisting of small twigs and grass. Nests are located near open water in willows and mesquite. Lays 2 eggs between May and October.
Food: Seeds.

Inca Dove (Scardafella inca)
Status: Locally fairly common resident around Blythe, Parker, Needles, and Bullhead City; rare in the Yuma area.
Habitat: Human habitations.
Breeding: From February to October. Nests are flattened platforms of twigs, grass, and rootlets, constructed in cottonwoods, mesquite, and cactus. Lays 2 eggs.
Food: Seeds, fruit, and other plant materials.

Yellow-billed Cuckoo (Coccyzus americanus)
Status: Locally fairly common summer breeder from June through August; rare in late May and early September. One late record, 3 October 1959 at Imperial National Wildlife Refuge. The largest remaining population is at the Bill Williams Delta; decreasing elsewhere.
Habitat: Mature cottonwood-willow associations, rarely in tall mesquite stands where scattered cottonwood trees remain.
Breeding: Mainly in July and August. Nest, a platform of sticks on horizontal branch in dense foliage, 5-15 m above ground, usually near water. One brood of 2-3 young raised per season.
Food: Mainly large insects such as cicadas, grasshoppers, and caterpillars; occasionally takes lizards and treefrogs.

Roadrunner (Geococcyx californianus)
Status: Common resident throughout the valley.
Habitat: Agricultural edges, riparian vegetation, desert.
Breeding: Breeds April to June. Nest, compact, 12 in diameter and 6-8 in high, usually 3-15 ft above ground in thickets. Lays 3-5 eggs.
Food: Mainly insects such as grasshoppers, cicadas and beetles; also takes reptiles, rodents, and birds.

Barn Owl (Tyto alba)
Status: Fairly common resident throughout the valley. Max: 18, 20 December 1980, Yuma CBC.
Habitat: Roosts and nests in tall trees, buildings, and cliffs; feeds over agricultural land.
Breeding: Breeds January to June. Nests in cavities in trees, cliffs, or banks. One brood of 5-7 young raised per season.
Food: Mainly rodents and birds.

Screech Owl (Otus asio)
- Status: Fairly common resident throughout the valley.
- Habitat: Dense riparian vegetation, tall trees, desert washes.
- Breeding: Nests in cavities in tall trees or saguaro cacti.

Flammulated Owl (Otus flammeolus)
- Status: Casual visitor. One heard calling repeatedly from March to April 1979 at Bill Williams Delta. Early spring migrants are known to linger in lowlands elsewhere in Arizona and California.
- Habitat: Riparian woodland.
- Food: Mainly insects.

Great Horned Owl (Bubo virginianus)
- Status: Fairly common resident throughout the valley.
- Habitat: Riparian woodland, desert wash.
- Breeding: Nests in small caves, on ledges, in cottonwoods and saguaros, and in old raptor nests. Usually lays 2 eggs, February-May.
- Food: Rodents, birds, other vertebrates.

Elf Owl (Micrathene whitneyi)
- Status: Very local and rare summer resident between early March and early September. Small populations exist at Bill Williams Delta, near Needles and Bullhead City (Fort Mohave area), and possibly near Yuma and Blythe.
- Habitat: Tall riparian trees, adjacent desert.
- Breeding: Nests in cavities in trees or saguaro cacti.
- Food: Mainly insects.

Burrowing Owl (Athene cunicularia)
- Status: Fairly common resident and breeder in agricultural areas throughout the valley.
- Habitat: Agricultural land, sparse sandy riparian habitat.
- Breeding: Nests in burrows in the ground, usually in canal banks.
- Food: Insects, rodents, other small animals.

Long-eared Owl (Asio otus)
- Status: Rare but probably regular transient and winter visitor; recorded between late November and late April. Also, possibly a sporadic summer breeder; recorded 9 July 1948 at Lake Havasu, 6 June 1960 at Imperial National Wildlife Refuge, 29 May 1978 at Topock Marsh (fledgling photographed), 30 June 1979 across from Needles (adult photographed), and 11 June 1981 north of Blythe (remains of immature found). Large roosts and breeding have been noted in desert areas to the east and west of the river valley.
- Habitat: Riparian woods, desert washes.
- Food: Mainly rodents.

Short-eared Owl (Asio flammeus)
- Status: Uncommon winter resident from November through March, usually singly but occasionally in small communal roosts. Max: 9, 1 January 1959, near Yuma.

Habitat: Agricultural fields, riparian edges, marshes.
Food: Mainly rodents.

Saw-whet Owl (Aegolius acadicus)
Status: Casual visitor in winter. One found dead at Bill Williams Delta, 21 December 1979. This notorious wanderer has been recorded elsewhere in the western Arizona deserts and even at Puerto Penasco, Sonora.
Habitat: Riparian woodland.
Food: Mainly small rodents.

Poor-will (Phalaenoptilus nuttallii)
Status: Fairly common summer resident along the edge of the river valley between mid-March and mid-October. Occasionally migrants are found closer to the river.
Habitat: Desert, cliffs; feeds in adjacent habitats.
Food: Various flying insects.

Common Nighthawk (Chordeiles minor)
Status: Casual transient in late spring; one heard at Bill Williams Delta 13 June 1979.
Habitat: Aerial; feeds over many habitat types.
Food: Flying insects such as ants and mosquitos.

Lesser Nighthawk (Chordeiles acutipennis)
Status: Common summer resident and breeder between mid-April and mid-September. Numbers increase gradually after the first migrants arrive in early March, and decrease sharply through October. Some have lingered as late as December in mild years, and there are even a few mid-winter records, such as 31 January-1 February 1977 at Blythe (2).
Habitat: Sparse or burned riparian areas, desert washes, towns; forages over agricultural fields, river, and marsh.
Breeding: Nests on ground.
Food: Beetles, moths, ants, and other insects.

Black Swift (Cypseloides niger)
Status: Casual transient. Two reliable sightings: two on 1 April 1974 at Lake Havasu, and one 9 May 1977 south of Ehrenberg (flying low with a large flock of Vaux Swifts for direct size comparisons). This species is undocumented in Arizona.
Habitat: River.
Food: Flying insects.

Chimney Swift (Chaetura pelagica)
Status: Casual transient. One specimen, 6 May 1930 at Bard, and one other sighting 23 July 1974 at Laguna Dam. This species has been recorded regularly in recent years in many parts of the Southwest.
Habitat: Forages over vegetation, water, or towns.
Food: Flying insects.

Vaux Swift (Chaetura vauxi)

Status: Fairly common but irregular spring migrant from mid-April through mid-May. Uncommon fall migrant from mid-August through mid-September. Max: 220, 9 May 1977, Parker to Ehrenberg.

Habitat: Forages over river, marsh, riparian vegetation.

Food: Flying insects.

White-throated Swift (Aeronautes saxatalis)

Status: Fairly common but irregularly seen resident in the northern half of the valley, rare in the south; occasionally in large foraging flocks in winter. Max: 1210, 20 December 1979, Parker CBC.

Habitat: Breeds at desert cliffs. Ranges widely to forage over river, agricultural and riparian habitats.

Food: Flying insects.

Black-chinned Hummingbird (Archilochus alexandri)

Status: Common summer resident and breeder from mid-March to mid-September. The first migrants (usually adult males) arrive in late February and late birds linger at feeders through October.

Habitat: Widespread in riparian vegetation, especially dense salt cedar and around human habitations.

Breeding: Nest is composed of willow, down, and spider webs, built in cottonwood and willow trees. Usually 2 eggs are laid, April-September.

Food: Nectar, small insects, spiders.

Costa Hummingbird (Calypte costae)

Status: Uncommon or locally fairly common spring breeder, arriving in early January and generally departing by mid-May. A few may linger through summer, fall, and early winter at feeders.

Habitat: Desert washes and adjacent riparian vegetation; also at human habitations.

Food: Nectar, insects.

Anna Hummingbird (Calypte anna)

Status: At present, a fairly common winter resident and uncommon spring breeder throughout the valley. Apparently has increased substantially, both in numbers and duration of stay, during the past 20 years. Records occur throughout the year, primarily at feeders. Definite nesting has been noted at Yuma, Blythe, and Parker Dam.

Habitat: Mainly around human habitations; also in riparian woodland.

Breeding: Breeds December-August. Nests are made of plant material, down, and cobwebs. Nest site is variable. Two eggs are laid.

Food: Nectar, insects.

Broad-tailed Hummingbird (Selasphorus platycercus)
- Status: Casual migrant. A male seen and heard on 29 April 1979 at Bill Williams Delta.
- Habitat: Riparian woodland.
- Food: Nectar.

Rufous Hummingbird (Selasphorus rufus)
- Status: Uncommon spring migrant from early March through mid-May. The first fall migrants arrive in mid-July, becoming fairly common by late August and September, and uncommon in early October. A female Selasphorus seen 27 December 1977 at Parker Dam, was probably this species.
- Habitat: Flowering plants around human habitations and in riparian woodland.
- Food: Nectar.

Allen Hummingbird (Selasphorus sasin)
- Status: Probably a very rare early spring and early fall transient. Sightings of apparent adult males include: 27 July 1953 at Parker, 28 August-9 September 1960 at Yuma, 17 February 1975 at Sommerton, 12 July 1978 north of Blythe, and 6-10 July 1979 at Blythe.
- Habitat: Flowering plants and feeders.
- Food: Nectar.

Calliope Hummingbird (Stellula calliope)
- Status: Rare and irregular spring migrant from mid-April to early May. One fall record: a male seen 2 September 1976 at Ehrenberg.
- Habitat: Flowers or feeders.
- Food: Nectar.

Broad-billed Hummingbird (Cynanthus latirostris)
- Status: Very rare and irregular fall or winter visitor. Four records: a male 6-8 September 1979 east of Yuma, a female 30 September 1979 at Bill Williams Delta (photo), an immature male north of Blythe late September through November 1979, and a male December through February 1975-76 at Blythe.
- Habitat: Flowers or feeders. This species is attracted to blooming tree tobacco (Nicotiana) here and elsewhere in Arizona in fall.
- Food: Nectar.

Belted Kingfisher (Megaceryle alcyon)
- Status: Fairly common winter resident from September through March, uncommon in late August and April. Early arrivals rarely occur in late July and some individuals have lingered through May; a few records for June.
- Habitat: Riverbanks, ponds, agricultural canals.
- Food: Mainly small fish.

Common Flicker (Colaptes auratus)

Status: Locally fairly common permanent resident and breeder, although rarer in the southern parts of the valley (Gilded form). Numbers are greatly augmented in winter by migrants of the Red-shafted form. Thus, the species overall is common throughout the valley between early October and early April. At least part of the breeding population are intergrades between these two forms. The Yellow-shafted form is a rare but regular winter visitor and a few Red-shafted X Yellow-shafted intergrades have been noted. Max: 279, December 1978, Parker CBC.

Habitat: Breeds in mature riparian woodland containing cottonwood or willow trees, also desert washes with saguaro cacti. More widespread in winter.

Breeding: Nests in cavities in tall trees or saguaro cacti. Breeding begins in February. Two broods are raised, with young fledging in late May and early July.

Food: Mainly ants and other small insects taken from the ground or trunks of large trees.

Gila Woodpecker (Melanerpes uropygialis)

Status: Locally common resident and breeder throughout the valley where tall trees occur.

Habitat: Mature riparian woodland, usually with cottonwoods or willows; also desert washes with saguaro cacti, and around human habitations.

Breeding: Nests in cavities in tall trees or saguaro cacti. Two broods are raised, fledging in May and July.

Food: Mainly insects and insect larvae, also mistletoe berries and cactus fruit.

Acorn Woodpecker (Melanerpes formicivorus)

Status: Casual visitor. Three records: 23 October 1950 at Bill Williams Delta, 23 November 1977 at Ehrenberg, and 25 June 1977 near Poston.

Habitat: Tall trees.

Food: Seeds, ants, and other insects.

Lewis Woodpecker (Melanerpes lewis)

Status: Rare to uncommon fall and winter visitor from higher elevations during "flight years." May also be a regular fall migrant in very small numbers. Recorded from October through March.

Habitat: Tall trees, especially orchards.

Food: Grasshoppers, beetles, and other insects.

Yellow-bellied Sapsucker (Sphyrapicus varius)

Status: Locally fairly common winter resident and transient from mid-October to mid-March; uncommon as early as mid-September and as late as early April. Nearly all birds are the Red-naped form (S. v. nuchalis). The Eastern form (S. v. varius) has been noted several times in fall and winter and on 26 April 1977 at Parker. The Red-breasted form (S. v. daggetti) is a rare but regular

visitor; one bird seen southwest of Parker on 28 January 1978 was either S. v. ruber or an intergrade with S. v. daggetti.

Habitat: Tall riparian trees, especially cottonwoods and willows; also ornamental trees in urban areas.

Food: Tree sap, also ants, beetles, larvae.

Williamson Sapsucker (Sphyrapicus thyroideus)

Status: Casual visitor from higher elevations. Three sight records: 12 March 1861 at Ft. Mohave, a female 7 December 1946 at Bill Williams Delta, and a male 7 December 1978 in the Dome Valley northeast of Yuma.

Habitat: Tall trees.

Food: Tree sap, ants, and other insects.

Ladder-backed Woodpecker (Picoides scalaris)

Status: Common resident and breeder throughout the valley.

Habitat: Riparian woodland, desert washes.

Breeding: Nests in cavities in tree trunks or large branches. Only one brood is raised, with 3-4 young fledging in late May or early June. Family groups remain together in summer, then disperse.

Food: Bark-dwelling insects and larvae, such as termites, beetles, and ants.

Eastern Kingbird (Tyrannus tyrannus)

Status: Casual fall transient. About six records: 4-11 September 1949 at Parker, late August 1967 at Topock, 16 August 1976 at Davis Dam, 4-5 September 1976 north of Blythe, 7-8 September 1977 near Poston (specimen), and 4 September 1979 at the same location near Poston.

Habitat: Tall trees, agricultural land.

Food: Flying insects, larvae, some fruit.

Tropical Kingbird (Tyrannus melancholicus)

Status: Casual visitor in fall and recently in early summer. Recorded: 1 October 1947 at Topock, 16 August 1954 at Bill Williams Delta, 5 June 1978 at Bill Williams Delta, May 1980 at Davis Dam, 6 June 1980 in the Dome Valley, and also 10 June 1973 at Tacna, east of Yuma. One additional record: 23 March 1957 at Palo Verde.

Habitat: Tall trees.

Food: Aerial insects and larvae, some fruit.

Western Kingbird (Tyrannus verticalis)

Status: Common summer breeder and transient between April and mid-September. Fairly common after initial arrival in mid-March, and also in late September and early October; casual after mid-October. No winter records.

Habitat: Tall trees in agricultural areas and riparian woodland, also around inhabited areas; telephone wires.

Breeding: Nests in canopy of tall trees, usually cottonwoods.

Food: Aerial insects, such as beetles, grasshoppers, moths, and cicadas.

Cassin Kingbird (Tyrannus vociferans)

Status: Rare fall transient in very small numbers, September through October; Kingbirds seen in November are most likely this species. Also a casual spring transient, recorded: 31 March 1952 at Parker, 17 May 1950 at Topock, and 19 May 1977 near Poston. Five summer records between 1950 and 1955 from Bill Williams Delta, Parker, and Imperial National Wildlife Refuge, plus one at Bard 8 June 1976, are enigmatic.

Habitat: Tall trees in riparian or agricultural areas.

Food: Grasshoppers, bees, and other insects.

Thick-billed Kingbird (Tyrannus crassirostris)

Status: Casual post-breeding and winter visitor. Four records within six years: 17 December 1972 at Laguna Dam (photo), 2 December 1977 at Parker (spec.), 5 August to 16 September 1978 north of Blythe (photo), and late November to 23 December 1979 southwest of Parker (photo).

Habitat: Tall trees.

Food: Wasps, beetles, and other insects.

Scissor-tailed Flycatcher (Muscivora forficata)

Status: Recently a very rare but consistent transient or straggler from mid-May to mid-October. About 10 records between 1974 and 1980, including a female that paired with a Western Kingbird and built a nest at Needles 26 May to 16 July 1979 but raised no young.

Habitat: Tall trees, telephone wires, mainly in agricultural areas.

Food: Wasps, beetles, grasshoppers, and other insects.

Wied Crested Flycatcher (Myiarchus tyrannulus)

Status: Locally fairly common summer breeder from late April through mid-August; a few linger into early September.

Habitat: Mature cottonwood-willow woodlands, occasionally in other riparian habitats with scattered cottonwood trees or snags.

Breeding: Nests in woodpecker cavities in tall trees. One brood of three or four is fledged around the first of July.

Food: Large insects, particularly cicadas and grasshoppers; occasionally small lizards.

Ash-throated Flycatcher (Myiarchus cinerascens)

Status: Common summer breeder from April through September; fairly common by March and in October. Also, an uncommon to rare winter resident, mainly in peripheral parts of the valley such as desert washes.

Habitat: Riparian woodland, particularly mesquite; also desert washes.

Breeding: Nests in woodpecker or natural cavities in trunks or large branches. Breeding begins in March; two broods fledge in late May and early July.

Food: Mainly beetles, cicadas, caterpillars, grasshoppers, and wasps.

Olivaceous Flycatcher (Myiarchus tuberculifer)

Status: Casual straggler. One record, 9-14 November 1977 at Cibola National Wildlife Refuge. Two individuals may be involved, as the specimen was collected 5 miles from where the bird was first seen.

Habitat: Riparian woodland.

Food: Mainly flies, beetles, and insect larvae.

Eastern Phoebe (Sayornis phoebe)

Status: Rare but regular transient and winter visitor from late September through late March, always singly.

Habitat: Riverbanks, agricultural canals.

Food: Mainly wasps, bees, beetles, and grasshoppers.

Black Phoebe (Sayornis nigricans)

Status: Common winter resident and recently a locally fairly common summer breeder throughout the valley, near water. An influx of nonbreeding birds begins in July and these birds leave in March. This species was not recorded as breeding in the 1950's.

Habitat: Riverbanks, agricultural canals, other water areas including temporary pools.

Breeding: Nests low above water on overhanging tree trunks, branches, or rocks, or frequently under bridges. Breeding begins in March and up to three broods may be raised in May, June, and July.

Food: Aerial, terrestrial, and semi-aquatic insects, such as flies, ants, dragonflies, and beetles.

Say Phoebe (Sayornis saya)

Status: Common winter resident throughout the valley. Fairly common spring breeder along the periphery of the river valley. Numbers drop markedly in late May with only a few individuals (mostly juveniles) remaining through summer. Wintering birds begin to arrive in late August and are common by late September.

Habitat: Mainly agricultural and sparse riparian areas in fall and winter; rocky desert and human habitations for breeding.

Breeding: Nest, of mud, plastered to rock face or manmade structure. Two or three broods raised in May and June.

Food: Mainly grasshoppers, flies, wasps, beetles, and earwigs.

Willow Flycatcher (Empidonax traillii)

Status: Uncommon late spring migrant from late May through mid-June; rare earlier. Uncommon to fairly common fall transient from early August to mid-October with a peak in early September. Two singing males at Bill Williams Delta 23 May through 20 June 1977 suggest local breeding in suitable habitat. Historical breeding is suspected but not documented, and this species was formerly more common as a transient as well.

Habitat: Riparian woodland, especially near water; also other trees and shrubs.

Food: Mainly wasps, bees, beetles, and flies.

Hammond Flycatcher (Empidonax hammondii)

Status: Fairly common spring migrant from early April to mid-May, uncommon in late May; rare but regular fall migrant from mid-August to mid-September. Also a rare and irregular winter resident, several sight records and one specimen: 12 February to 21 March 1977 at Bill Williams Delta.

Habitat: Riparian woodland, other trees and shrubs.

Food: Small flying insects.

Dusky Flycatcher (Empidonax oberholseri)

Status: Apparently a casual or very rare spring migrant, one specimen 9 April 1977 at Bill Williams Delta and three careful sight records: 13 April 1978 at Bill Williams Delta, 21 April 1978 at Yuma, and April 1979 at Andrade. May prove to be regular. Also a rare and irregular winter resident with specimens 19 February 1910 near Needles, 6 December 1953 at Parker, 16 December 1978 at Cibola National Wildlife Refuge, and a careful sighting 24 December 1977 at Bill Williams Delta.

Habitat: Riparian woodland.

Food: Small flying insects.

Gray Flycatcher (Empidonax wrightii)

Status: Uncommon transient from March to early May and from mid-September to mid-October; also a local winter resident in very small numbers. Max: 12, 9 May 1977 in Parker area.

Habitat: Sparse riparian woodland, desert washes.

Food: Small flying insects.

Western Flycatcher (Empidonax difficilis)

Status: Uncommon to fairly common migrant from early March to early June, and late July through late October. Multiple records in late June and July probably represent both late spring and early fall migrants. Also, a rare but regular winter resident in very small numbers, especially at Bill Williams Delta. Max: 32, 9 May 1977 at Parker and Bill Williams Delta.

Habitat: Dense riparian woodland, especially willow groves in winter; other dense vegetation.

Food: Mainly wasps, flies, and beetles.

Coues Flycatcher (Contopus pertinax)

Status: Very rare winter visitor, at least in recent years. About five records: 13 January 1972 at Yuma, 15 December 1977 at Cibola National Wildlife Refuge, 24 December 1977 to 9 March 1978 and probably the same individual December 1978 through mid-January 1979 at Parker Dam, and 28-29 November 1979 at Blythe.

Habitat: Tall trees, riparian woodland.

Food: Flying insects.

Western Wood Pewee (Contopus sordidulus)

Status: Common spring migrant from late April through early June, rarely later. Uncommon to fairly common fall migrant from early August through mid-October. Max: 68, 18 May 1977, Parker area.
Habitat: Riparian woodland, other trees.
Food: Mainly flies, wasps, bees, and beetles.

Olive-sided Flycatcher (Nuttallornis borealis)

Status: Uncommon migrant from late April to mid-June, and from late August through mid-September.
Habitat: Riparian woodland, other trees.
Food: Mainly bees, wasps, and winged ants.

Vermilion Flycatcher (Pyrocephalus rubinus)

Status: Uncommon and local resident and breeder throughout the valley. Slightly more widespread in winter.
Habitat: Riparian woodland, human habitations, margins of agricultural fields.
Breeding: Nests on horizontal branch of mesquite, willow, or cottonwood, 6 to 35 feet above ground. Breeding begins in March, with two or three broods raised in May, June, and July.
Food: Mainly bees, wasps, and flies.

Horned Lark (Eremophila alpestris)

Status: Locally fairly common summer breeder and common to abundant transient and winter resident from August to April. Nonbreeding birds often in large flocks. Max: 3950, 18 December 1978, Parker CBC.
Habitat: Agricultural lands, especially bare plowed fields.
Breeding: Nest built in a rounded hollow in the ground, usually located in open desert or cultivated land. Breeds March-July. Clutch 3-4 eggs.
Food: Mainly weed and other seeds; also beetles and other insects.

Violet-green Swallow (Tachycineta thalassina)

Status: Very local breeder in small colonies, at least at Bill Williams Delta and Parker Dam. Uncommon to fairly common transient from mid-January to late March, and again from early August through October. Rare through mid-November and casual in December. Max: 400, 13 October 1954 at Imperial National Wildlife Refuge.
Habitat: Nests on cliffs, forages and migrates over river, riparian vegetation and marsh.
Food: Mainly bugs, flies, and winged ants.

Tree Swallow (Iridoprocne bicolor)

Status: Common to abundant transient and winter resident between late July and early April; sometimes in huge flocks. Numbers decrease rapidly through April with the last birds seen in early May. First fall arrivals are in the first week of July; a few individuals have been noted in June.

Habitat: Forages over river, marshes, and agricultural fields; roosts at night in marshes.
Food: Mainly flies, beetles, and ants.

Bank Swallow (Riparia riparia)
Status: Uncommon to fairly common transient in April and early May, and from mid-July to early October; rare in late March, late May, early July, and late October. Three careful winter sightings: 16 February 1974 (2) at Imperial Dam, 23 December 1977 at Parker, and possibly the same individual seen there 1 March 1978, and 24 January 1980 at Mittry Lake. Max: 40, 3 May 1972, Imperial Dam.
Habitat: Forages over river, marshes, and fields.
Food: Mainly flies, ants, and beetles.

Rough-winged Swallow (Stelgidopteryx ruficollis)
Status: Common transient and breeder from late January through early September. Uncommon resident through fall and early winter, with numbers increasing in late December. This species was rare in winter in the 1950's.
Habitat: Riverbanks and agricultural canals for breeding; forages over water, marshes, and fields.
Breeding: Nests in burrows excavated in banks or irrigation ditches of clay, sand, or gravel. Breeds from April-July. Lays 6-7 eggs. One brood raised in a season.
Food: Mainly flies, ants, and beetles.

Barn Swallow (Hirundo rustica)
Status: Common to abundant spring and fall transient; migrations are extremely protracted, but large numbers occur only from mid-April to mid-May, and from mid-September to mid-October. Small numbers are seen consistently from mid-February through March, in early June, throughout August, and to mid-November. Several December records at least in 1973, 1974, 1979, and 1980. Max: 18,000, 30 September 1955 at Martinez Lake.
Habitat: Forages over agricultural fields, water, and marshes.
Food: Mainly flies, wasps, ants, and beetles.

Cliff Swallow (Petrochelidon pyrrhonota)
Status: Common transient and breeder from March through August with the first birds arriving in mid-February. Breeding colonies are vacated in late August, but migrants remain uncommon until early October. One bird seen 27 January 1980 east of Yuma was probably a very early spring migrant.
Habitat: Breeds at cliffs, dams, and bridges over water; forages widely over water, agricultural areas, and even desert.
Breeding: Nest is a cylinder of mud plastered to vertical wall of cliff or structure, often in large colonies.
Food: Mainly beetles, bugs, and flies.

Purple Martin (Progne subis)

Status: Rare but annual migrant, usually occurring singly, from mid-April to mid-May, and from July to early October. One female was at Martinez Lake 22 June 1954. Usually seen with other swallows.

Habitat: Forages over river, marsh, other vegetation.

Food: Mainly wasps, ants, bees, and flies.

Steller Jay (Cyanocitta stelleri)

Status: Casual straggler during flight years. Recorded 23 February 1935 at Blythe (50), winter of 1950-51 at Imperial Dam and Bill Williams Delta, 10 October 1957 at Bill Williams Delta, and 21 November 1957 at Martinez Lake.

Habitat: Riparian woodland.

Food: Mainly seeds, nuts, some insects.

Scrub Jay (Aphelocoma coerulescens)

Status: Rare and irregular transient and winter visitor, primarily during flight years, from September through April. Occasionally individuals may take up residence and remain all year.

Habitat: Riparian woodland, inhabited areas.

Food: Seeds, nuts, some insects.

Common Raven (Corvus corax)

Status: Fairly common resident and local breeder in the northern parts of the valley but rare south of Blythe. More widely dispersed in winter; almost never in flocks.

Habitat: Desert cliffs for breeding; ranges widely at other times.

Breeding: Nests on desert cliffs and rarely in large trees. Nest a platform, loosely constructed. Breeds March through June. Lays 4 to 7 eggs.

Food: Omnivorous: seeds, insects, other animals and carrion.

Common Crow (Corvus brachyrhynchos)

Status: Until recently, a rare or casual straggler in winter. Since about 1976, a large winter roost containing 500-1000 individuals has formed at Cibola National Wildlife Refuge. This flock is present from November through late February. Flocks have also occurred near Topock Marsh where another winter roost may have formed; e.g., 300 on 23 February 1979, and 180 on 6 December 1980. Also, three to eight birds wintered at Parker in 1947-48. Records of migrants away from these locations are: 17 November 1960 (2) at Imperial Dam, 7 October 1974 at Poston, 28 October 1977 south of Blythe, 8 November 1977 (20) at Bill Williams Delta, 16 November 1977 (5) south of Poston, and 1 March 1978, flock of 32 flying north at Parker.

Habitat: Agricultural fields and riparian margins.

Food: Omnivorous: seeds, fruits, insects, and carrion.

Pinyon Jay (Gymnorhinus cyanocephalus)
- Status: Casual fall straggler during flight years. Recorded 25 September 1952 (3) at Topock Marsh, recorded 8 October 1955 (2) at Imperial Dam, 28 October 1955 at Imperial National Wildlife Refuge, 9 October 1978 at Bill Williams Delta, and 23 November 1978 (6) near Parker Dam.
- Habitat: Riparian vegetation.
- Food: Seeds and nuts.

Clark Nutcracker (Nucifraga columbiana)
- Status: Casual straggler during flight years. Recorded 9 October 1955 near Imperial Dam and in 1972 on 28 August at Needles, 14 September at Topock Marsh, 15 September at Bullhead City, 23 November northeast of Yuma, and 17 December at Laguna Dam.
- Habitat: Riparian vegetation, human habitations.
- Food: Seeds, nuts, and fruit.

Mountain Chickadee (Parus gambeli)
- Status: Casual fall and winter visitor. Two seen 14 November 1976 at Bill Williams Delta - one remained until 19 March 1977 (spec.); one was at Cibola National Wildlife Refuge 26 September 1977, with two there on 8 and 13 December 1977.
- Habitat: Riparian woodland.
- Food: Small insects, spiders, and seeds.

Bridled Titmouse (Parus wollweberi)
- Status: Casual winter visitor. One first seen on 17 February 1977 at Bill Williams Delta, was collected 20 March 1977.
- Habitat: Riparian woodland.
- Food: Mainly insects, larvae, and eggs.

Verdin (Auriparus flaviceps)
- Status: Common resident and breeder throughout the valley. Populations peak in August and may be greatly reduced after severe winters.
- Habitat: Widespread in riparian woodland, desert washes, and around human habitations.
- Breeding: Nest is a covered dome of sticks fastened to a tree or shrub. Breeding season extends from March through August with 2-3 broods raised.
- Food: Mainly small caterpillars, bugs, and spiders.

Bushtit (Psaltriparus minimus)
- Status: Rare but regular winter visitor in small numbers, at least at Bill Williams Delta from late October to early March. Recorded south to near Ehrenberg; a flock of 10, 25 February to 2 March 1977 (2 specimens).
- Habitat: Riparian woodland, adjacent desert scrub.
- Food: Mainly small bugs, larvae, and spiders.

White-breasted Nuthatch (Sitta carolinensis)
- Status: Casual winter visitor during flight years; a few present during 1950-51 (specimen, 10 November) and 1975-76 (specimen, 31 January) until 18 March, all at Bill Williams Delta. Also one specimen from Imperial National Wildlife Refuge 4-26 November 1961 and one seen 20 December 1979 southwest of Parker.
- Habitat: Riparian trees.
- Food: Bark-inhabiting insects and spiders; some seeds.

Red-breasted Nuthatch (Sitta canadensis)
- Status: Rare but possibly regular transient in September and October, and again in late February and March. A few individuals winter irregularly.
- Habitat: Riparian woodland, other tall trees.
- Food: Bark-inhabiting insects and spiders.

Pygmy Nuthatch (Sitta pygmaea)
- Status: Casual visitor, one old specimen from Yuma 30 September 1902.
- Habitat: Riparian or other trees.
- Food: Bark-inhabiting insects and spiders.

Brown Creeper (Certhia familiaris)
- Status: Uncommon winter resident at Bill Williams Delta between late October and early April. Rare and local elsewhere in the valley, with records from Topock Marsh, Parker, Ehrenberg, Cibola National Wildlife Refuge, and Imperial National Wildlife Refuge.
- Habitat: Tall riparian trees.
- Food: Bark-inhabiting bugs, insects, and spiders.

Dipper (Cinclus mexicanus)
- Status: Casual straggler from higher elevations; one seen 22 October 1980 at Parker.
- Habitat: Rocky riverbank.
- Food: Aquatic insects and other invertebrates.

House Wren (Troglodytes aedon)
- Status: Fairly common transient and winter resident between late August and the beginning of May.
- Habitat: Dense riparian woodland, other brush, margins of agricultural fields.
- Food: Mainly beetles, insect larvae and pupae, bugs, and ants.

Winter Wren (Troglodytes troglodytes)
- Status: Rare but regular winter resident in very small numbers between late October and early April. Most frequent at Bill Williams Delta, but records extend from Topock Marsh to Yuma.
- Habitat: Dense riparian woodland, other dense brush.
- Food: Mainly small beetles, bugs, and ants.

Bewick Wren (Thryomanes bewickii)

Status: At present, a fairly common and local summer breeder from the Bill Williams Delta (a few pairs) northward. Virtually absent farther south between April and September, except one record 4 August 1946 at Parker and a pair 15 miles north of Blythe in June-July 1981. Fairly common in winter throughout the valley. Formerly absent as a breeding species, and rarely recorded during the 1950's, even in winter.

Habitat: Riparian woodland, desert washes, other brush.

Breeding: Nests in cavities in stumps, snags, or live trees. Birds begin singing in February (even wintering birds), but breeding is somewhat later. Young fledge in May and June.

Food: Mainly spiders, ants, beetles, and bugs.

Cactus Wren (Campylorhynchus brunneicapillus)

Status: Fairly common resident and breeder throughout the valley, becoming local in the northern parts. Winter numbers are irregular and possibly represent periodic influxes from other regions.

Habitat: Riparian woodland, especially mesquite; also desert washes, and inhabited areas.

Breeding: Nest is a covered dome of sticks placed in tree, shrub or cactus.

Food: Mainly flies, beetles, grasshoppers, and spiders; occasionally lizards.

Long-billed Marsh Wren (Cistothorus palustris)

Status: Locally common summer breeder in extensive marshes. Common to abundant winter resident throughout the valley.

Habitat: Marshes, wet riparian woodlands, wet agricultural fields and canals.

Breeding: Breeds in marshes from March to July. Nest is a compact ball of vegetation intertwined with stems or reed blades. Lays 5-6 eggs. One to two broods raised.

Food: Mainly beetles, insect larvae, bugs, and spiders.

Canyon Wren (Catherpes mexicanus)

Status: Locally common resident and breeder at Bill Williams Delta, Parker Dam, and Topock Gorge. Very rare and irregular elsewhere.

Habitat: Rocky cliffs for breeding; birds move down into dense riparian vegetation from August through March.

Breeding: Nest usually on cliff ledges or crevices. Lays 5-6 eggs in a set. April-June.

Food: Mainly beetles, ants, and spiders.

Rock Wren (Salpinctes obsoletus)

Status: Locally fairly common resident and breeder along the drier edges of the valley. Slightly more widespread in winter.

Habitat: Desert, washes, occasionally in agricultural areas in winter.

Breeding: Nest usually on rocky cliffs and arroyos; often placed in cavities under and among loose rocks. Lays 5-6 eggs. April-July. Two broods in a season.
Food: Ground-dwelling insects and larvae.

Mockingbird (Mimus polyglottos)
Status: Fairly common summer breeder and common winter resident, with an influx of birds into the valley between October and April. Max: 165, 23 December 1977, Parker CBC.
Habitat: Riparian woodland with mistletoe berries; also in inhabited areas and other trees. More widespread in winter.
Breeding: Builds nests in bushes, small trees, or tangles of vines, including cactus. 3-6 eggs in a set. Breeds from April to August. Two broods raised in a season.
Food: Mistletoe and other berries; also beetles.

Gray Catbird (Dumetella carolinensis)
Status: Casual transient. One seen 26 September 1978 at Bill Williams Delta.
Habitat: Riparian woodland.
Food: Various insects, fruit, and seeds.

Brown Thrasher (Toxostoma rufum)
Status: Casual or very rare transient and possibly winter visitor. Two sight records: 15-17 November 1978 at Ehrenberg and 22 December 1980 near Poston. Also, distinctive call heard twice; 20 December 1976 near Parker and 30 September 1979 at Bill Williams Delta.
Habitat: Riparian woodland, other brush.
Food: Various insects and berries.

Bendire Thrasher (Toxostoma bendirei)
Status: Very rare and irregular visitor from adjacent desert mountains, mainly to the east. Recorded: 17 December 1973 to 1 February 1974 at Bard, 21 March 1977 at Bill Williams Delta, 20 May 1977 north of Needles, 12 June 1978 north of Ehrenberg (family group), 20 August 1978 near Poston, 21 January 1979 northeast of Yuma, and 16 July 1979 at Bill Williams Delta (immature). These represent post-breeding wanderers, migrants, and wintering individuals.
Habitat: Desert wash, sparse riparian woodland, agricultural land.
Food: Mainly beetles, ants, and insect larvae.

Curve-billed Thrasher (Toxostoma curvirostre)
Status: Rare and irregular visitor from deserts to the east, primarily in fall and winter. Has been recorded between August and February with most records from the Yuma area.
Habitat: Desert, riparian woodland.
Food: Mainly beetles, ants, and insect larvae.

Le Conte Thrasher (Toxostoma lecontei)

Status: Possibly resident or transient along the periphery of the valley; very few records in the immediate floodplain. These include one at Imperial Dam 8 December 1973, one collected 13 November 1979 in a harvested cottonfield near Poston, and two seen 22 December 1980 near Parker.

Habitat: Desert, adjacent open country.

Food: Mainly beetles, ants, and insect larvae.

Crissal Thrasher (Toxostoma dorsale)

Status: Common but secretive resident and breeder throughout the valley. Max: 106, 18 December 1978, Parker CBC.

Habitat: Riparian woodland, especially on sandy soil.

Breeding: Nest is of twigs, placed 3 to 10 feet high in a tree, well concealed. Breeding activity begins in February; two broods are raised in April through August, two to four young per brood.

Food: Mainly beetles, ants, and insect larvae.

Sage Thrasher (Oreoscoptes montanus)

Status: Rare fall transient and early winter resident from early September through December. Uncommon to fairly common late winter and spring transient from mid-January through March, occasionally in large numbers.

Habitat: Most numerous in honey mesquite woodland with mistletoe berries; also in desert washes and other open habitats.

Food: Mistletoe and other berries, beetles, ants, and earwigs.

American Robin (Turdus migratorius)

Status: Uncommon to common transient and winter visitor from October to March. In some years, large numbers arrive in the valley during mid-winter. Also, recently a rare but regular summer breeder at inhabited areas such as Blythe, near Needles, and near Yuma.

Habitat: Riparian woodland with mistletoe berries in winter, inhabited areas, especially for breeding.

Breeding: Nests in tall trees in parks or near houses; young have been noted in late May and June.

Food: Mistletoe, beetles, and insect larvae.

Rufous-backed Robin (Turdus rufopalliatus)

Status: Casual straggler from Mexico. One found 17 December 1973 to 6 April 1974 at Imperial Dam (photo).

Habitat: Park with lawn and tall trees.

Food: Various insects and fruit.

Varied Thrush (Ixoreus naevius)

Status: Rare and irregular winter visitor from the northwest in flight years. At least 10 individuals found between mid-October 1977 and early April 1978, including one specimen 29 November 1977 at Bill Williams Delta. Other records include 12 April 1972 north of Blythe, and in December 1973 near Yuma.

Habitat: Tall riparian woodland, especially willows.
Food: Ground-dwelling insects, spiders, and worms.

Hermit Thrush (Catharus guttatus)
Status: Uncommon to fairly common transient and winter resident. Present from early October until mid-April. A few individuals appear in late September and stay until mid-May. Number of wintering birds fluctuates from year to year. Max: 188, 24 December 1977, Bill Williams Delta.
Habitat: Riparian woodland, especially willow; other dense vegetation.
Food: Mainly beetles, ants, and insect larvae.

Swainson Thrush (Catharus ustulatus)
Status: Uncommon transient in May, rarely in very early June. Casual in fall; one seen 20 September 1953 at Parker.
Habitat: Dense riparian woodland, especially cottonwood-willow associations.
Food: Mainly beetles, ants, insect larvae, and berries.

Western Bluebird (Sialia mexicana)
Status: Uncommon to fairly common winter visitor in the north half of the valley, from mid-October to mid-March, rarely to mid-April. Numbers vary from year to year; usually seen in small nomadic flocks.
Habitat: Honey mesquite woodland with mistletoe, also desert washes, other riparian woods.
Food: Mainly mistletoe berries, a few insects.

Mountain Bluebird (Sialia currucoides)
Status: Uncommon to fairly common winter visitor from October to mid-March, usually in nomadic flocks. Numbers vary from year to year. Max: 155, 22 December 1980, Parker CBC.
Habitat: Agricultural fields, especially grass or pastures; also in mesquite woods and desert washes with mistletoe.
Food: Mainly grasshoppers, beetles, other insects; also mistletoe berries.

Townsend Solitaire (Myadestes townsendi)
Status: Rare to uncommon and irregular transient and winter visitor between late September and April. Always seen singly.
Habitat: Riparian woodland with mistletoe.
Food: Mistletoe berries, some insects.

Blue-gray Gnatcatcher (Polioptila caerulea)
Status: Fairly common winter resident from September through March; uncommon transient in late August and April. Max: 70, 20 December 1979, Parker CBC.
Habitat: Prefers screwbean mesquite woodland close to the river; also widely dispersed in other riparian and desert vegetation.
Food: Mainly bugs, flies, beetles, spiders, and insect larvae.

Black-tailed Gnatcatcher (Polioptila melanura)

Status: Common resident and breeder throughout the valley. Found in pairs or family groups year round. Max: 142, 22 December 1980, Parker CBC.

Habitat: Widely distributed in all but the densest riparian habitats; also in desert washes.

Breeding: Nest is an elaborate cup in branch fork or mistletoe clump. Breeding begins in March; 2-3 broods are raised. This species is a frequent host of the Brown-headed Cowbird.

Food: Mainly insect larvae, bugs, beetles, and spiders.

Golden-crowned Kinglet (Regulus satrapa)

Status: Rare but regular visitor from late October through December; irregular in January and February. Usually occurs in very small flocks.

Habitat: Riparian woodland, especially willows.

Food: Mainly bugs, beetles, insect larvae and eggs.

Ruby-crowned Kinglet (Regulus calendula)

Status: Common to abundant winter resident from early October to mid-April. Uncommon transient in late September and in May. Occurs singly and in small flocks.

Habitat: Riparian woodland, especially cottonwood-willow associations; other trees and shrubs.

Food: Mainly bugs, beetles, and flies.

Water Pipit (Anthus spinoletta)

Status: Common to abundant winter resident from October through mid-April. A few individuals arrive by mid-September and linger rarely until late May. Often seen in large flocks. Max: 6723, 18 December 1978, Parker CBC.

Habitat: Agricultural fields, riverbanks, sandbars.

Food: Mainly bugs, beetles, flies, and insect larvae.

Sprague Pipit (Anthus spragueii)

Status: Rare but probably regular winter visitor from late September through March, in very small numbers.

Habitat: Agricultural fields, especially tall alfalfa mixed with dry Bermuda grass.

Food: Mainly grasshoppers, beetles, bugs, and some seeds.

Bohemian Waxwing (Bombycilla garrulus)

Status: Casual visitor in late winter and spring, with records from only the northernmost parts of the valley.

Habitat: Berry-producing shrubs and trees.

Food: Various berries and fruit.

Cedar Waxwing (Bombycilla cedrorum)

Status: Erratic transient and winter visitor; rare to uncommon from the end of August through December, uncommon to common from January through May. A few individuals linger into early June, and at least one stayed at Parker until 12 July 1953. Often found in large nomadic

flocks, but numbers and timing of occurrence vary greatly from year to year.

Habitat: Riparian woodland with mistletoe; also human habitations with pyracantha and other berries.

Food: Mistletoe and other berries.

Phainopepla (Phainopepla nitens)

Status: Common to abundant winter resident and early spring breeder from late September through early May. Numbers increase and decrease rapidly in October and May, respectively. A few individuals, usually immatures, can be found all summer but the majority of the population is absent between early June and early September. The number of breeding individuals may be reduced in years when mistletoe berries freeze. Max: 798, 23 December 1977, Parker CBC.

Habitat: Primarily honey mesquite woodland and desert washes with mistletoe. Occur elsewhere mainly as transients; summering individuals often found adjacent to the river.

Breeding: Nest is placed in mistletoe clump. One brood raised in March and April.

Food: Mistletoe, other berries, also aerial insects, such as beetles and flies.

Northern Shrike (Lanius excubitor)

Status: Casual straggler in winter. One immature seen 21 November 1977 and one collected 9 January 1978, both near Poston.

Habitat: Agricultural land, riparian edge.

Food: Mainly rodents, birds, and large insects.

Loggerhead Shrike (Lanius ludovicianus)

Status: Common winter resident throughout. Fairly common spring breeder in the drier parts of the valley. Numbers increase in July after breeding.

Habitat: Breeds mainly in sparse riparian woodland and desert washes; widespread in winter in other open habitats, especially agricultural land.

Breeding: Breeds from March to June, usually in shrubby to open areas, often in cholla and mesquite. Lays 4-7 eggs. Two broods often raised.

Food: Mainly rodents, small birds, beetles, grasshoppers, and wasps.

Starling (Sturnus vulgaris)

Status: Now, a common breeder and abundant winter resident throughout the valley; often found in large flocks. This species was first recorded in the valley at Parker in 1946 and was only a winter visitor until 1960. Probably is still increasing in numbers.

Habitat: Riparian woodland, other tall trees, saguaros for breeding; widespread in agricultural and urban areas at other times.

Breeding: Nests in cavities in trees, saguaro cacti, or buildings. Very aggressive at nest holes, often usurping other cavity-nesting species. 2-3 broods.
Food: Seeds, beetles, grasshoppers, and millipedes.

Hutton Vireo (Vireo huttoni)
Status: Casual or very rare fall transient and winter visitor in November and December, with four records from Bill Williams Delta and one from near Imperial Dam. Also, one seen 5 May 1980 in the Dome Valley northeast of Yuma.
Habitat: Tall riparian woodland.
Food: Mainly bugs, insect larvae, and beetles.

Bell Vireo (Vireo bellii)
Status: At present, an uncommon and local summer resident and breeder between late March and late September. The earliest arrival date is 8 March and the latest departure dates are from late November. Two winter records: 7 February to 7 March 1951 at Topock Marsh and 18 December 1978 at Parker. This species was formerly quite abundant and more widespread (until 1950's). Breeding during 1979-80 occurred only in the vicinity of Needles, Topock Marsh, Bill Williams Delta, and Cibola National Wildlife Refuge, with a few scattered pairs near Parker and Poston. A few transients still appear in other areas such as at Laguna Dam and Yuma.
Habitat: Breeds only in tall honey mesquite with scattered willows and well-developed understory, near water. May prefer willows, but willows have been virtually extirpated from the valley.
Breeding: Nest is a hanging cup in mesquite or understory shrub. Two broods are raised from May to August. This species is a frequent host of the Brown-headed Cowbird, which may be partially responsible for its demise.
Food: Mainly bugs, insect larvae, grasshoppers, and beetles.

Gray Vireo (Vireo vicinior)
Status: Casual transient. Recorded: 29 April 1952 south of Needles, 6 September 1976 near Yuma, and 1 October 1977 north of Ehrenberg.
Habitat: Riparian woodland, desert washes.
Food: Mainly bugs, beetles, and insect larvae.

Yellow-throated Vireo (Vireo flavifrons)
Status: Casual transient. One specimen collected 10 October 1953 at Bill Williams Delta.
Habitat: Riparian woodland.
Food: Mainly insect larvae, moths, and bugs; some fruit.

Solitary Vireo (Vireo solitarius)
Status: Fairly common transient from mid-March to mid-May and from mid-August through October, uncommon until mid-November. One seen 2 June 1975 at Imperial National

Wildlife Refuge was probably a late spring migrant. Also a rare but regular winter resident, primarily at Bill Williams Delta. Two races, V. s. plumbeus and V. s. cassinii, occur in roughly equal proportions in both migration and winter.
Habitat: Tall riparian woodland, other tall trees.
Food: Mainly insect larvae, moths, and bugs.

Red-eyed Vireo (Vireo olivaceus)
Status: Casual or very rare transient and summer visitor. About five records: 28 May 1956 at Imperial National Wildlife Refuge, 5 June 1964 at Imperial Dam, a singing male at Blythe 23 June to 6 July 1976, 7-10 September 1977 at Blythe, and 28 June 1978 at Bill Williams Delta.
Habitat: Riparian woodland, other tall trees.
Food: Mainly insect larvae, beetles, bugs, and fruit.

Philadelphia Vireo (Vireo philadelphicus)
Status: Hypothetical. One seen but not substantiated, 16 September 1976 near Poston. This species occurs every year in Arizona and southern California and is to be expected as a casual transient.
Habitat: Riparian woodland.
Food: Mainly insect larvae, beetles, wasps, and flies.

Warbling Vireo (Vireo gilvus)
Status: Spring and fall transient with very protracted migration periods. Occurs between mid-March and mid-June, and from mid-July to mid-November, but common only from April to mid-May, and from early August to mid-October. Unseasonal sightings include: 28 June 1977 near Poston; 17 June 1978 at Cibola National Wildlife Refuge, and 19 December 1978 at Bill Williams Delta.
Habitat: Riparian woodland, other tall trees.
Food: Mainly beetles, insect larvae, and bugs.

Black-and-white Warbler (Mniotilta varia)
Status: Rare but regular transient in May and September; rare and irregular winter resident and transient from October through April and in June.
Habitat: Riparian woodland, especially willows.
Food: Mainly beetles, larvae, ants, and spiders.

Prothonotary Warbler (Protonotaria citrea)
Status: Casual transient. Two records: 10 May 1977 at Bill Williams Delta and 8-16 October 1979 north of Blythe (photo).
Habitat: Tall riparian trees near water.
Food: Ants, other insects, and larvae.

Worm-eating Warbler (Helmitheros vermivorus)
Status: Casual transient. Two records: a singing male seen 10 May 1977 at Bill Williams Delta, and one photographed near Parker Dam 5 September 1981.

Habitat: Dense riparian vegetation.
Food: Insect larvae, beetles, ants, and spiders.

Golden-winged Warbler (Vermivora chrysoptera)
Status: Casual transient. One male seen 8 October 1978 at Bill Williams Delta.
Habitat: Riparian woodland.
Food: Various small insects and larvae.

Blue-winged Warbler (Vermivora pinus)
Status: Casual transient. One taken 5 September 1952 at Bill Williams Delta.
Habitat: Riparian woodland.
Food: Various small insects and larvae.

Orange-crowned Warbler (Vermivora celata)
Status: Fairly common to common transient and winter resident from late August to early May. Uncommon in early August and late May; one seen 1 July 1957 at Imperial National Wildlife Refuge. Max: 352, 18 December 1978, Parker CBC.
Habitat: Riparian woodland, especially willows; other trees.
Food: Mainly bugs, beetles, and insect larvae.

Nashville Warbler (Vermivora ruficapilla)
Status: Uncommon to fairly common transient from late March to early May, and from mid-August to early October.
Habitat: Riparian woodland.
Food: Mainly beetles, insect larvae and eggs.

Virginia Warbler (Vermivora virginiae)
Status: Rare but regular transient from mid-April through mid-May, and from early August through mid-September. One taken 23 July 1946 at Topock Marsh and one seen 2 November 1977 at Cibola National Wildlife Refuge, were unseasonal.
Habitat: Riparian woodland.
Food: Various insects and larvae.

Lucy Warbler (Vermivora luciae)
Status: Locally common spring breeder from mid-March to mid-July; numbers then decrease rapidly, but a few always linger into September. Due to habitat destruction this species is becoming scarce in some areas, such as near Yuma. However, the large mesquite bosques remaining near Ehrenberg and Poston are estimated to support as many as 750 pairs (1976-80). This species decreased rapidly throughout the valley in the 1950's and was virtually absent between 1954 and 1960.
Habitat: Most numerous in dense honey mesquite woodlands, widespread in other riparian woods and desert washes.
Breeding: Nests in cavities or behind slabs of bark or debris in mesquite or other trees. Two to three broods. Lays 3-7 eggs, April to June.
Food: Mainly insect larvae, beetles, and bugs.

Northern Parula (Parula americana)
Status: Rare but probably regular transient and winter visitor with records between mid-October and early June. About 15 records to date: 3 in fall, 6 in spring, and 5 of probably wintering birds. Also, one definite breeding record, a female discovered north of Blythe on 9 June 1981 was subsequently found feeding 2 fledglings.
Habitat: Riparian woodland.
Food: Beetles, flies, insect larvae, and spiders.

Yellow Warbler (Dendroica petechia)
Status: Fairly common transient from mid-April to early June and from early August to early October. Also, a rare but regular winter resident in very small numbers. Formerly a common breeder in the valley (until 1952 or 1953), but local extinction has probably been caused by cowbird parasitism and destruction of willow habitats. A few singing males are irregularly present in June or July but breeding was not suspected from 1975-1980, even in suitable habitat such as at Bill Williams Delta.
Habitat: Riparian woodland, other trees.
Food: Mainly ants, beetles, bugs, and larvae.

Magnolia Warbler (Dendroica magnolia)
Status: Casual transient and winter visitor. Four records: 5 October 1949 at Bill Williams Delta, 11 November 1951 at Topock, 12 October 1968 at Imperial Dam, and 24 December 1977 to 24 January 1978 at Bill Williams Delta (photo).
Habitat: Riparian woodland.
Food: Mainly beetles, flies, and insect larvae.

Cape May Warbler (Dendroica tigrina)
Status: Casual transient. One taken 23 September 1924 at Laguna Dam.
Habitat: Riparian and other trees.
Food: Mainly wasps, flies, larvae, and beetles; also fruit.

Black-throated Blue Warbler (Dendroica caerulescens)
Status: Casual transient and winter visitor. Three records: a male was near Davis Dam 15 October 1975, a female was seen 10 October 1978 at Bill Williams Delta, and another adult male spent at least two weeks until 23 December 1978 at Yuma.
Habitat: Riparian woodland, other trees.
Food: Mainly flies, beetles, bugs, and larvae.

Yellow-rumped Warbler (Dendroica coronata)
Status: Common to abundant transient and winter resident between late September and mid-April. A few individuals arrive as early as late August and linger to late May. Sometimes occurs in large flocks. The Myrtle Warbler (D. c. coronata) is a rare but regular visitor, usually associating with large concentrations of D. c. auduboni. Max: 3981, 23 December 1977, Parker CBC.

Habitat: Riparian woodland, other tall trees, agricultural land, and inhabited areas.
Food: Mainly bugs, beetles, insect larvae, flies, and wasps.

Black-throated Gray Warbler (Dendroica nigrescens)
Status: Uncommon transient in April, early May and August; fairly common in September to mid-October. Also, a rare but regular winter resident, primarily at Bill Williams Delta.
Habitat: Riparian woodland, especially cottonwoods; other tall trees.
Food: Mainly insect larvae and various insects.

Townsend Warbler (Dendroica townsendi)
Status: Uncommon to fairly common transient from early April through May and August through mid-October. Five winter records: 22 December 1975 north of Yuma, 13 January 1977 at Imperial National Wildlife Refuge, two on 23 December 1977 near Vidal, California, and 26 January 1978 at Parker.
Habitat: Riparian woodland, other tall trees.
Food: Mainly bugs, ants, wasps, and beetles.

Black-throated Green Warbler (Dendroica virens)
Status: Casual or very rare fall transient. Six records: 30 October 1952 at Bill Williams Delta, 21 October 1952, and 18 October 1953 at Parker; 23 October 1978 at Cibola National Wildlife Refuge; 11 November 1978 at Bill Williams Delta; and 14 October 1979 at Blythe.
Habitat: Riparian woodland, other trees.
Food: Mainly insect larvae, beetles, and bugs.

Hermit Warbler (Dendroica occidentalis)
Status: Uncommon transient from mid-April to late May and late July to mid-October.
Habitat: Riparian woodland, other trees.
Food: Small spiders, larvae, beetles, and other insects.

Grace Warbler (Dendroica graciae)
Status: Casual winter visitor. One seen 27 February 1977 at the south tip of Nevada.
Habitat: Riparian vegetation.
Food: Insect larvae and various insects.

Chestnut-sided Warbler (Dendroica pensylvanica)
Status: Casual transient. Recorded 11 October 1978 north of Blythe and 18 December 1978 near Poston.
Habitat: Riparian woodland.
Food: Mainly beetles, wasps, insect larvae, and spiders.

Bay-breasted Warbler (Dendroica castanea)
Status: Casual transient. One seen 9 October 1978 at Bill Williams Delta.
Habitat: Riparian woodland.
Food: Various insects and larvae.

Blackpoll Warbler (Dendroica striata)
Status: Casual transient. Four records: one at West Pond 15 May 1955, a female 23 June 1977 at Imperial National Wildlife Refuge, a singing male 10 May 1979 at Blythe, and one 11 October 1980 at Parker.
Habitat: Riparian woodland, other trees.
Food: Beetles, wasps, ants, and insect larvae.

Palm Warbler (Dendroica palmarum)
Status: Casual transient. Three records: 22 September 1942 north of Imperial Dam, 9 October 1979 south of Davis Dam, Nevada, and 22 December 1980 south of Parker.
Habitat: Riparian woodland, brush.
Food: Various insect larvae and insects.

Ovenbird (Seiurus aurocapillus)
Status: Casual transient and winter visitor. Five records: 10 May 1977, 5 September 1977, 14 October 1977, and 13 June 1979 all at Bill Williams Delta, and 23 December 1977 near Parker.
Habitat: Riparian woodland, other dense vegetation.
Food: Mainly beetles, ants, larvae, spiders, and other invertebrates.

Northern Waterthrush (Seiurus noveboracensis)
Status: Rare but regular transient from mid-August through mid-September; irregular in late fall, winter, and spring. Max: 4 on 20 August 1977 at Bill Williams Delta.
Habitat: Wet riparian woodland, marsh.
Food: Mainly aquatic insects, beetles, and larvae.

Louisiana Waterthrush (Seiurus motacilla)
Status: Casual transient. One careful sight record 31 July to 15 August 1977 at Bill Williams Delta.
Habitat: Flooded riparian woodland.
Food: Aquatic insects, beetles, and larvae.

Kentucky Warbler (Oporornis formosus)
Status: Casual transient. One caught 20 June 1976 north of Yuma.
Habitat: Dense vegetation.
Food: Various insects, larvae, and spiders.

MacGillivray Warbler (Oporornis tolmiei)
Status: Fairly common transient in April, May, and in September; uncommon in late March, early June, mid-August, October, and early November. One was seen 27 November 1971 at Laguna Dam and a bird identified only to genus on 20 December 1976 at Parker was most likely O. tolmiei.
Habitat: Riparian woodland, other dense vegetation.
Food: Mainly beetles, other insects, and larvae.

Common Yellowthroat (Geothlypis trichas)

Status: Locally common summer breeder and fairly common transient and winter resident. May be found year round in extensive marshes, and occurs at other breeding sites, such as Bill Williams Delta, from April through September.

Habitat: Marsh, wet riparian woodland.

Breeding: Nests on or near ground in emergent vegetation. Two broods are raised in June and July.

Food: Small insects, aqautic larvae and spiders.

Yellow-breasted Chat (Icteria virens)

Status: Locally fairly common summer breeder from late April to early September; a few lingering individuals or transients appear through mid-October.

Habitat: Tall riparian woodland, especially willows, with well-developed shrub layer.

Breeding: Nests usually low in thickets of willows or other shrubs, often overgrown with tangles. Eggs 3-5 in a set. Breeding season is April to August.

Food: Small and large insects, including ants, grasshoppers, and cicadas.

Red-faced Warbler (Cardellina rubifrons)

Status: Hypothetical. One seen but not documented, 19 April 1975 at Imperial National Wildlife Refuge.

Habitat: Riparian woodland.

Food: Various insects and larvae.

Hooded Warbler (Wilsonia citrina)

Status: Casual transient or summer visitor. One female seen 29 June 1979 at Bill Williams Delta.

Habitat: Riparian woodland.

Food: Various insects, spiders, and larvae.

Wilson Warbler (Wilsonia pusilla)

Status: Common transient in April, May, late August, and September; uncommon in March, early June, early August, and early October. Rare but probably regular in winter in the southern parts of the valley. Max: 109, 10 May 1977, at Parker and Bill Williams Delta.

Habitat: Riparian woodland, other trees and shrubs.

Food: Various insects and larvae.

American Redstart (Setophaga ruticilla)

Status: Rare but regular transient and winter resident in very small numbers, with records for every month except July and perhaps March. Max: 3, 16 September 1978, Bill Williams Delta.

Habitat: Riparian woodland, other tall trees.

Food: A wide variety of insects and larvae.

Painted Redstart (Myioborus pictus)
- Status: Casual or very rare transient and winter visitor. Several records: all winter until 27 February 1976 at the south tip of Nevada (photo), 16 April 1976 at Bill Williams Delta, 14-16 September 1978 at Ehrenberg, and 31 August 1979 at Imperial Dam.
- Habitat: Riparian woodland, other tall trees.
- Food: Various insects and larvae.

House Sparrow (Passer domesticus)
- Status: Common to abundant resident and breeder in all developed parts of the valley, often in large concentrations.
- Habitat: Towns, other inhabited areas, agricultural land.
- Breeding: Nest is either a bulky dome of grass or sticks, or in a cavity of a tree or building.
- Food: Seeds, insects, garbage.

Bobolink (Dolichonyx oryzivorus)
- Status: Casual transient. Three sightings: 14 September 1954 at Bill Williams Delta, 29 May 1975 (male) at Katherine's Landing, Lake Mohave, and 8 June 1977 (singing male) near Poston.
- Habitat: Agricultural land, marsh.
- Food: Mainly insects and larvae; also grain and weed seeds.

Eastern Meadowlark (Sturnella magna)
- Status: Status uncertain. One specimen collected "by accident" 17 March 1979 north of Ehrenberg, and a few unsubstantiated sight records such as 25 November and 20 December 1979 (2) near Parker. This species could be a regular winter visitor to the valley and would represent a new species for California if found on that side of the river.
- Habitat: Agricultural fields, especially tall alfalfa and grass.
- Food: Mainly insect larvae, beetles, and grasshoppers.

Western Meadowlark (Sturnella neglecta)
- Status: Locally fairly common summer breeder and common winter resident in all grassy situations.
- Habitat: Agricultural fields, especially alfalfa, sparse riparian or desert areas with grass, marshes.
- Breeding: Nest in low grass, in ground depression or concealed in thick grass, particularly in pasturelands. Eggs: 3-7, usually 5. Breeding season is February-July. Two broods per season.
- Food: Mainly beetles, earwigs, insect larvae, and seeds.

Yellow-headed Blackbird (Xanthocephalus xanthocephalus)
- Status: Locally common summer breeder throughout the valley between March and September. Uncommon in winter, but large concentrations occasionally occur in the southern parts of the valley. Max: 20,000 (all male), 1 January 1955, northeast of Yuma.
- Habitat: Marshes for nesting and roosting; agricultural fields for feeding.

Breeding: Nest built in reeds and cat-tails, 1-3 ft above water. Eggs 3-5, usually 4. Breeding season is April-June.
Food: Insect larvae, beetles, grasshoppers, and various seeds.

Red-winged Blackbird (Agelaius phoeniceus)
Status: Common to abundant year round throughout the valley, but local status varies due to the differential breeding, wintering, and migration of various populations. Often occurs in large flocks.
Habitat: Marshes for nesting and roosting; feeds in agricultural land, occasionally in riparian woodland or at human habitations.
Breeding: Nests usually built in marshes, connected to blades of cat-tails. Lays 3-5 eggs; 2 broods normally raised. Breeding season is April-July.
Food: Mainly seeds, insect larvae, and beetles.

Orchard Oriole (Icterus spurius)
Status: Casual transient and winter visitor. Four records: 20-21 February 1974 at Imperial Dam, 23 April 1978 at Earp, California, 20 May 1979 near Yuma, and 1 October 1979 at Laguna Dam.
Habitat: Riparian woodland, other trees.
Food: Insects, larvae, spiders, and fruit.

Hooded Oriole (Icterus cucullatus)
Status: Locally fairly common summer breeder from mid-March through September, with a few lingering as late as November.
Habitat: Towns and inhabited areas, particularly with ornamental palms and hummingbird feeders; less numerous in riparian woodland.
Breeding: Nest is a woven basket in a palm or other tree.
Food: Insects, nectar, and fruit.

Northern Oriole (Icterus galbula)
Status: Fairly common to common summer breeder between mid-March and late July. Most breeding individuals depart in early August, but lingerers and transients remain until late September or rarely later. One winter specimen; 1 January-1 February 1947 at Parker, and two other possible winter records: a male, 28 February 1956 at Bard, and two noted in February 1966 at Yuma. The eastern form, I. galbula galbula is a casual transient: seen 22 September 1956 at Imperial National Wildlife Refuge and in May 1980 north of Ehrenberg. A male I. g. galbula mated with a female I. g. bullocki north of Blythe in 1977 and produced a local hybrid population as the offspring returned to breed in subsequent years.
Habitat: Tall riparian woodland, other tall trees.
Breeding: Nest is a woven basket suspended from a branch. Two broods are raised in May and June.
Food: Mainly caterpillars and large insects such as cicadas and grasshoppers.

Scott Oriole (Icterus parisorum)
- Status: Casual straggler or transient. Three records: 3 August 1954 at Bill Williams Delta, 7 May 1977 and 20 July 1978 north of Ehrenberg.
- Habitat: Riparian woodland, desert washes.
- Food: Mainly grasshoppers, beetles, insect larvae, and fruit.

Rusty Blackbird (Euphagus carolinus)
- Status: Casual transient or winter visitor. Specimens taken 17 February 1950 at Bill Williams Delta and 6 November 1952 at Topock Marsh; females seen 21 November 1951 at Bill Williams Delta, and 26 February 1959 at Imperial National Wildlife Refuge, and a flock of three females and two males seen 10 March 1977 at Bill Williams Delta.
- Habitat: Wet riparian woodland.
- Food: Mainly beetles, grasshoppers, other insects.

Brewer Blackbird (Euphagus cyanocephalus)
- Status: Common to abundant winter resident between October and mid-April, often in large flocks. Uncommon in September and until early May. One summer specimen; a female 12 June 1947 at Lake Havasu.
- Habitat: Agricultural fields, feedlots, inhabited areas, shoreline.
- Food: Mainly seeds, earwigs, beetles, and bugs.

Great-tailed Grackle (Quiscalus mexicanus)
- Status: Locally fairly common resident and breeder throughout the valley. This species was first recorded along the Colorado River in 1964 at Imperial Dam with the first evidence of breeding there in June 1968. It has been increasing and spreading continually since then. In 1975, small colonies existed at Blythe and Needles, and the first small flock was at Parker in December 1976. One was noted at Bill Williams Delta in 1977, and it was common there in 1978. By 1980, this species had filled in many gaps in its distribution and was very common around Parker. This species is predicted to become an abundant resident throughout the valley.
- Habitat: Agricultural land, marshes, inhabited areas, shorelines.
- Breeding: Nests in colonies near water; often associated with heron rookeries. 3-4 eggs per clutch. Breeding season April-June.
- Food: Mainly grasshoppers, earwigs, beetles, and wasps.

Common Grackle (Quiscalus quiscula)
- Status: Casual visitor. One careful sighting 19 June-9 July 1979 north of Blythe.
- Habitat: Farmyard.
- Food: Mainly seeds, various insects, and some vertebrates.

Brown-headed Cowbird (Molothrus ater)
- Status: Common year-round resident throughout the valley, but local distributions vary seasonally. Occurs primarily

in flocks in developed areas in fall and winter. Breeding birds enter native habitats in late March.
Habitat: Agricultural land, riparian woodland, inhabited areas, marsh.
Breeding: A brood parasite of other species; known hosts include Black-tailed Gnatcatcher, Bell Vireo, Lucy Warbler, Common Yellowthroat, Northern Oriole, Abert Towhee, and Song Sparrow. Eggs are laid from May to July.
Food: Mainly seeds; also insect larvae, bugs, other insects.

Bronzed Cowbird (Molothrus aeneus)
Status: Recently, a rare but regular summer resident and breeder locally throughout the valley. Areas of occurrence include Davis Dam, Parker Dam, Earp, Blythe, Ehrenberg, Laguna Dam, and Yuma. This species was first recorded in 1950 and was regular by 1952.
Habitat: Inhabited areas, especially with lawns.
Breeding: A brood parasite of other birds; its most frequent host is the Hooded Oriole.
Food: Mainly grain, other seeds, a few insects.

Western Tanager (Piranga ludoviciana)
Status: Fairly common transient from April through early June and in August and September. Early birds arrive by mid-March or early July and late individuals occur into late October. At least one individual male was present through summer at Parker.
Habitat: Riparian woodland, other tall trees.
Food: Mainly wasps, bugs, beetles, and fruit.

Scarlet Tanager (Piranga olivacea)
Status: Casual transient. One banded and photographed 18 October 1970 at Bard, California.
Habitat: Riparian vegetation.
Food: Mainly wasps, bees, beetles, insect larvae, and fruit.

Hepatic Tanager (Piranga flava)
Status: Casual transient and winter visitor. Recorded: 18 November 1960 at Imperial National Wildlife Refuge, 19 December 1973 at Imperial Dam, and 2-5 April 1979 at Blythe.
Habitat: Riparian woodland, other tall trees.
Food: Mainly insects, some fruit.

Summer Tanager (Piranga rubra)
Status: Locally fairly common summer breeder from late April to early October. There are a few late fall and winter records such as 19 December 1977 to 8 February 1978 at Bill Williams Delta, and possibly 9 April 1966 at Bard.
Habitat: Tall riparian woodland, especially cottonwood-willow associations.
Breeding: Nest is a cup 25 to 40 feet high in a cottonwood or willow. Two broods are raised in June and July.
Food: Large insects such as wasps, cicadas, and grasshoppers.

Cardinal (Cardinalis cardinalis)

Status: Rare and local resident between Ehrenberg and Bill Williams Delta and more recently at Needles, Laguna Dam and Yuma. Apparently spreading gradually. Max: 5, 23 December 1977, Parker CBC.

Habitat: Riparian woodland, other brush.

Food: Insects, seeds, and fruit.

Pyrrhuloxia (Cardinalis sinuatus)

Status: Casual summer visitor. A male was caught at Palo Verde on 14 July 1974, and a singing male was north of Ehrenberg on 4 July 1981. Also, a pair nested in Chemehuevi Wash, 15 miles west of Lake Havasu in 1977.

Habitat: Riparian brush, desert wash.

Food: Insects, seeds, and fruit.

Rose-breasted Grosbeak (Pheucticus ludovicianus)

Status: Rare but regular transient from mid-May through late June; casual in summer, fall, and early winter. This species was exceptionally numerous in June 1977 (about 10 reports), and a pair is reported to have nested at Lost Lake Resort near Vidal, California that summer.

Habitat: Riparian woodland, other trees, margins of agricultural fields.

Food: Seeds, fruit, and insects.

Black-headed Grosbeak (Pheucticus melanocephalus)

Status: Fairly common transient in April, May, and August; uncommon in late March, early June, late July, and September. A few individuals noted in late June and early July may be non-breeding summer residents.

Habitat: Riparian woodland, other trees and shrubs.

Food: Seeds, fruit, and insects.

Blue Grosbeak (Guiraca caerulea)

Status: Common breeder from early May through August. First migrants appear in mid-April and the latest migrants occur through mid-October.

Habitat: Riparian woodland, particularly burned or other open areas.

Breeding: Nest 5 to 10 feet high in a dense shrub; 4 eggs in a clutch, 2 broods. Breeding season is from May-August.

Food: Large insects, particularly grasshoppers and cicadas; also seeds.

Indigo Bunting (Passerina cyanea)

Status: Uncommon and local summer breeder from May through August; rare transient in late April and September. Breeding areas shift from year to year following burns or disturbance. Over 40 singing males were noted between Topock Marsh and Imperial National Wildlife Refuge in July 1977.

Habitat: Burned or other open riparian woods, orchards, other edge situations.

Breeding: Definite breeding has been noted at Topock Marsh, north of Needles, and Bill Williams Delta, with fledged young being fed in July.
Food: Grasshoppers, other insects, and seeds.

Lazuli Bunting (Passerina amoena)
Status: Fairly common transient from mid-April through May, and again from August through September. Uncommon in early April, early June, and late July. The status of singing males noted through June and July at Topock Marsh and Blythe is unknown. One winter sighting: 18 December 1978 at Parker.
Habitat: Riparian woodland, agricultural margins, citrus orchards, other brush.
Food: Various seeds and insects.

Varied Bunting (Passerina versicolor)
Status: Casual transient or winter visitor; a flock of 15 seen at Blythe (2 collected) 8-9 February 1914, and one seen 20 September 1952 at Bill Williams Delta.
Habitat: Riparian woodland.
Food: Various seeds and insects.

Painted Bunting (Passerina ciris)
Status: Casual visitor. One specimen, an immature female, collected 6 November 1976 north of Ehrenberg. Another female-plumaged bird seen 13 November 1978 near Vidal, California.
Habitat: Riparian woodland.
Food: Various seeds and insects.

Dickcissel (Spiza americana)
Status: Casual transient. Three records: 26 September 1949 and 19 September 1954 (2) at Parker, and 18 September 1952 at Topock Marsh.
Habitat: Riparian vegetation, agricultural land.
Food: Seeds.

Evening Grosbeak (Hesperiphona vespertina)
Status: Rare and irregular fall visitor in October and November. Two spring records: 6 May 1902 at Yuma and 7 May 1973 near Vidal, California (two males).
Habitat: Riparian woodland, tall trees near human habitations.
Food: Seeds.

Purple Finch (Carpodacus purpureus)
Status: Rare and irregular fall and winter visitor, with records from mid-October through January. A female Carpodacus, seen 9 April 1978 at Ehrenberg, was probably this species.
Habitat: Riparian woodland, other trees and shrubs.
Food: Seeds.

Cassin Finch (Carpodacus cassinii)
- Status: Casual fall visitor. One seen and heard, October 1979 at Andrade near the Mexican border, and a female carefully identified as this species was seen 9 November 1980 north of Blythe.
- Habitat: Riparian woodland, desert.
- Food: Seeds.

House Finch (Carpodacus mexicanus)
- Status: Common to abundant year-round resident, but with large shifts in local distribution. Often found in large flocks except during the spring breeding season.
- Habitat: Breeds in desert and sparse riparian woodland. Found year round in agricultural areas and around human habitations.
- Breeding: Breeds from March-July. Nests can be found in almost any situation, usually near a source of seeds. Clutch size 2-6.
- Food: Almost entirely seeds and other plant parts.

Pine Siskin (Carduelis pinus)
- Status: Uncommon fall visitor in October and November, and irregular winter visitor through April; a few have lingered to early June.
- Habitat: Riparian woodland, agricultural margins.
- Food: Seeds.

American Goldfinch (Carduelis tristis)
- Status: Uncommon winter resident in small flocks between mid-October and mid-April, rarely to early or mid-May. One adult male seen 4 July 1977 at Bill Williams Delta was unseasonal.
- Habitat: Margins of agricultural fields, riparian woodland.
- Food: Seeds.

Lesser Goldfinch (Carduelis psaltria)
- Status: Locally uncommon spring and summer breeder; fairly common but irregular in winter. For example, large flocks move into and out of the cottonwood-willow forest at Bill Williams Delta when the trees flower in February and March, but only a few remain there to breed.
- Habitat: Riparian woodland, margins of agricultural fields, citrus orchards, human habitations.
- Breeding: Usually nests in large trees (e.g., cottonwoods and willows). 4-5 eggs per clutch. Breeding season from April-August.
- Food: Seeds.

Lawrence Goldfinch (Carduelis lawrencei)
- Status: Highly irregular. Uncommon to fairly common transient and winter resident in flocks from October to April during flight years, but absent in other years. Also a rare but possibly regular summer breeder locally; breeding has been confirmed at Parker (1952), north of Blythe (1978), and Bill Williams Delta (1978, 1979).

Habitat: Margins of agricultural fields, riparian woodlands; attracted to areas with inkweed (Suaeda torreyana).
Breeding: Usually nests in large trees. 3-6 eggs per clutch. Breeds from April-July.
Food: Seeds.

Red Crossbill (Loxia curvirostra)
Status: Casual visitor. Recorded 23 August 1953 at Parker (flock of 5), 16 November 1976 at Bill Williams Delta, 20 December 1976 at Parker (2), and 27 November 1979 near Yuma.
Habitat: Tall trees.
Food: Seeds.

Green-tailed Towhee (Pipilo chlorurus)
Status: Fairly common transient and uncommon winter resident, with the largest influx occurring in September and early October, and from mid-April to late May. Somewhat more numerous in the southern half of the valley, especially in relatively mild winters.
Habitat: Riparian woodland, other dense brush.
Food: Various seeds and insects.

Rufous-sided Towhee (Pipilo erythrophthalmus)
Status: Uncommon winter resident from mid-September through late March.
Habitat: Dense riparian woodland, especially willows, other dense brush, marshes.
Food: Mainly beetles, insect larvae, and some seeds.

Abert Towhee (Pipilo aberti)
Status: Common permanent resident and breeder throughout the valley. Often occurs in small family groups from late summer through early winter. Max: 594, 18 December 1978, Parker CBC.
Habitat: Most riparian woodlands; less common in desert washes, marshes, agricultural and urban habitats.
Breeding: Nests low in dense shrubs or trees. Breeding activity begins in late January with young fledging between March and September. This species is frequently parasitized by Brown-headed Cowbirds.
Food: Mainly beetles, seeds and insect larvae year round; grasshoppers and cicadas in summer.

Lark Bunting (Calamospiza melancorys)
Status: Rare and irregular transient or winter visitor from October through February. Single birds are often in the company of sparrows, but flocks have occurred in some years. Max: 450, 19 December 1951, west of Lake Havasu.
Habitat: Agricultural land, desert flats.
Food: Grasshoppers, other insects, and seeds.

Savannah Sparrow (Passerculus sandwichensis)
- Status: Common to locally abundant winter resident from mid-September to mid-April. First individuals arrive in late August and a few linger to mid-May. Max: 4965, 22 December 1980, Parker CBC.
- Habitat: Agricultural fields, especially alfalfa; also marshes.
- Food: Mainly weed seeds; also insect larvae and other insects.

Grasshopper Sparrow (Ammodramus savannarum)
- Status: Rare but probably regular transient and winter resident from mid-October to mid-April or possibly early May. This species is extremely secretive and easily overlooked.
- Habitat: Agricultural fields and weedy margins.
- Food: Grasshoppers, beetles, insect larvae, and seeds.

Sharp-tailed Sparrow (Ammospiza caudacuta)
- Status: Casual transient. One seen 29 March 1975 at West Pond.
- Habitat: Marshes.
- Food: Insects, larvae, and seeds.

Vesper Sparrow (Pooecetes gramineus)
- Status: Common winter resident from mid-September through mid-April. Initially arrives in late August and may linger to early May. Max: 1064, 18 December 1978, Parker CBC.
- Habitat: Weedy agricultural fields and margins, sparse riparian woodland, desert flats.
- Food: Mostly seeds; a few beetles and bugs.

Lark Sparrow (Chondestes grammacus)
- Status: Uncommon transient and winter resident from late August to May. A few remain to breed in summer in citrus orchards at Blythe and Yuma, and locally near Parker. Max: 121, 23 December 1977, Parker CBC.
- Habitat: Orchards for breeding; also inhabited areas, other agricultural land.
- Breeding: First noted in 1976 at Blythe. Copulation has been observed in May and recently fledged young were noted in June.
- Food: Mainly grasshoppers, other insects, and seeds.

Cassin Sparrow (Aimophila cassinii)
- Status: Casual visitor or transient. A male was singing and "skylarking" near Poston 26 April 1981.
- Habitat: Grassy fields, sparse mesquite.
- Food: Various seeds and insects.

Black-throated Sparrow (Amphispiza bilineata)
- Status: Uncommon and local spring and summer breeder from mid-February through August along the sparser periphery of the valley. A few migrants have been noted elsewhere in September. Rare or irregular in fall and early winter in the immediate river valley.

Habitat: Sparse riparian woodland, desert washes.
Breeding: Singing males appear at breeding sites in February; young fledge in May. Nests on or near ground in desert shrub or mesquite.
Food: Mainly seeds; some insects and larvae.

Sage Sparrow (Amphispiza belli)
Status: Uncommon to locally fairly common winter resident from early September to early April. Often occurs in small flocks.
Habitat: Honey mesquite woodland or desert wash with flats of inkweed (Suaeda torreyana) or salt bush (Atriplex spp.).
Food: Mainly seeds; some beetles, bugs, and grasshoppers.

Dark-eyed Junco (Junco hyemalis)
Status: Uncommon winter resident from mid-October to mid-April, primarily in small flocks. This species exhibits marked geographic variation and several races have been identified. Among these the northwestern races, "Oregon Juncos," are the most numerous; the more easterly "Slate-colored" and Rocky Mountain "Pink-sided" forms are rare but regular visitors.
Habitat: Riparian woodland, weedy margins of agricultural fields, other brush.
Food: Seeds, bugs, and other insects.

Gray-headed Junco (Junco caniceps)
Status: Rare but regular transient and winter visitor in very small numbers from mid-October to early April, and exceptionally to 11 May (1957) at Cibola National Wildlife Refuge. Occasionally in mixed flocks with other juncos.
Habitat: Riparian woodland, brush near inhabited areas, parks.
Food: Like other juncos.

Tree Sparrow (Spizella arborea)
Status: Casual winter visitor. One seen 23 November 1968 at Bard, two seen at a marsh south of Parker, 11 February 1977, and one seen 28 January 1981 at Hunter's Hole, south of Yuma.
Habitat: Marsh-riparian mix.
Food: Mainly weed seeds.

Chipping Sparrow (Spizella passerina)
Status: Uncommon to fairly common transient and winter resident from late July to mid-May. Often in small flocks with other sparrows.
Habitat: Riparian woodland, agricultural margins, other brush.
Food: Mainly seeds, insect larvae, bugs, and other insects.

Clay-colored Sparrow (Spizella pallida)
Status: Casual transient. One seen in a mixed flock, 4 September 1981 near Parker Dam. This species is regularly recorded elsewhere in the Southwest and may be overlooked here.

Habitat: Margins of agricultural fields, other brush.
Food: Various seeds and insects.

Brewer Sparrow (Spizella breweri)
Status: Common winter resident from September to mid-April. The first migrants arrive in mid-August, and some linger rarely to late May. Often in large mixed flocks with other species of sparrows.
Habitat: Open riparian woodland, desert wash, margins of agricultural fields.
Food: Mainly seeds, insect larvae, bugs, and beetles.

Black-chinned Sparrow (Spizella atrogularis)
Status: Casual transient or winter visitor. Three records: 30 August 1955 at Imperial Dam, 17 December 1973 at Mittry Lake (3), and September 1975 north of Ehrenberg.
Habitat: Riparian brush, desert edge.
Food: Various insects and seeds.

Harris Sparrow (Zonotrichia querula)
Status: Rare and irregular winter visitor. Recorded from October through April. Occurs individually in large flocks of White-crowned Sparrows.
Habitat: Margins of agricultural fields, riparian brush.
Food: Mainly weed seeds.

White-crowned Sparrow (Zonotrichia leucophrys)
Status: Abundant winter resident from late September to early April. Numbers build slowly in early September and decrease in April and May. Migrants in May and September are dark-lored, whereas white-lored individuals comprise the large wintering flocks. An unseasonal bird at Parker 8 July 1978 had white lores. Max: 19,529, 22 December 1980, Parker CBC.
Habitat: Widespread in riparian and agricultural habitats; also in marshes, desert and urban areas.
Food: Seeds, other plant materials, ants, other insects and larvae.

Golden-crowned Sparrow (Zonotrichia atricapilla)
Status: Rare to uncommon winter resident, occurring singly in large flocks of White-crowned Sparrows, from October to early May. Immatures are easily overlooked due to their resemblance to immature White-crowned Sparrows.
Habitat: Mostly in sparse riparian and desert habitats, but may be anywhere White-crowned Sparrows occur.
Food: Seeds and other plant materials.

White-throated Sparrow (Zonotrichia albicollis)
Status: Rare but regular winter resident from October to early May. Usually in flocks of White-crowned Sparrows or juncos.
Habitat: Usually in dense or marshy riparian areas; also inhabited areas, margins of agricultural fields.
Food: Mainly seeds, ants, beetles, bugs, and insect larvae.

Fox Sparrow (Passerella iliaca)
- Status: Rare but regular transient or winter resident from mid-September to early April.
- Habitat: Dense or marshy riparian woodland; also inhabited areas, especially with feeders.
- Food: Weed seeds, fruit, and some insects.

Lincoln Sparrow (Melospiza lincolnii)
- Status: Common winter resident from September through March. Lesser numbers occur in late August and again from April into early May.
- Habitat: Dense riparian woodland, marshes, agricultural margins.
- Food: Mainly seeds, bugs, flies, and spiders.

Swamp Sparrow (Melospiza georgiana)
- Status: Locally uncommon winter resident from November to mid-April.
- Habitat: Marshes, wet riparian groves.
- Food: Mainly beetles, wasps, and seeds.

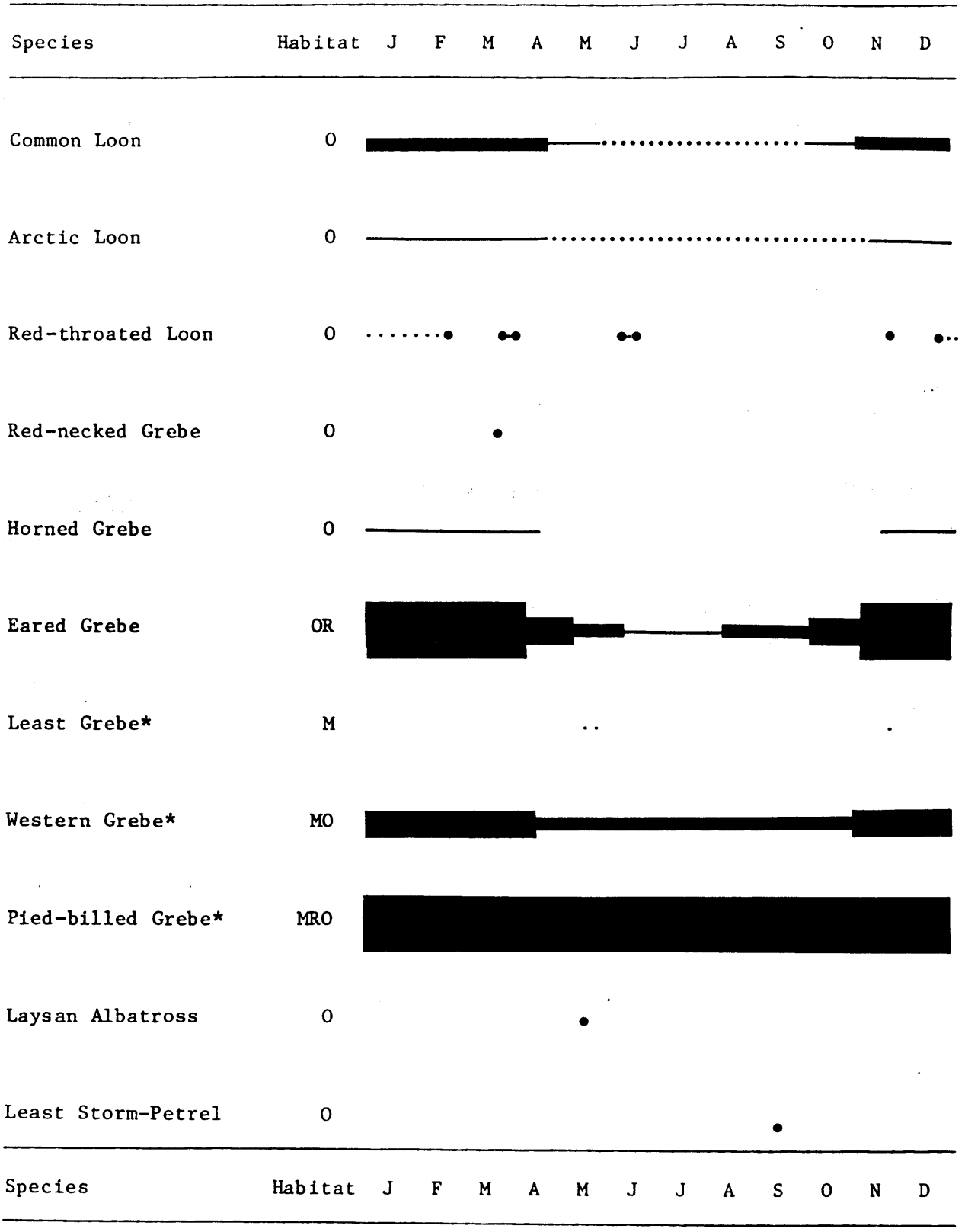
Song Sparrow (Melospiza melodia)
- Status: Common year round; local as a spring and summer breeder, more widespread in winter and during migrations.
- Habitat: Restricted to marshes and flooded riparian woods for breeding; also in other dense riparian and agricultural habitats at other times.
- Breeding: Nests near ground in marsh vegetation or shrub, usually above water. Breeding begins in February; young fledge from May through July.
- Food: Mainly insect larvae, beetles, earwigs, and seeds.

McCown Longspur (Calcarius mccownii)
- Status: Casual winter visitor. One record of two birds seen along lower Bill Williams River 24 December 1978.
- Habitat: Agricultural fields.
- Food: Seeds.

Lapland Longspur (Calcarius lapponicus)
- Status: Rare and irregular transient and winter visitor from November to early March. Usually found in flocks of Horned Larks.
- Habitat: Agricultural fields, especially those recently plowed.
- Food: Seeds.

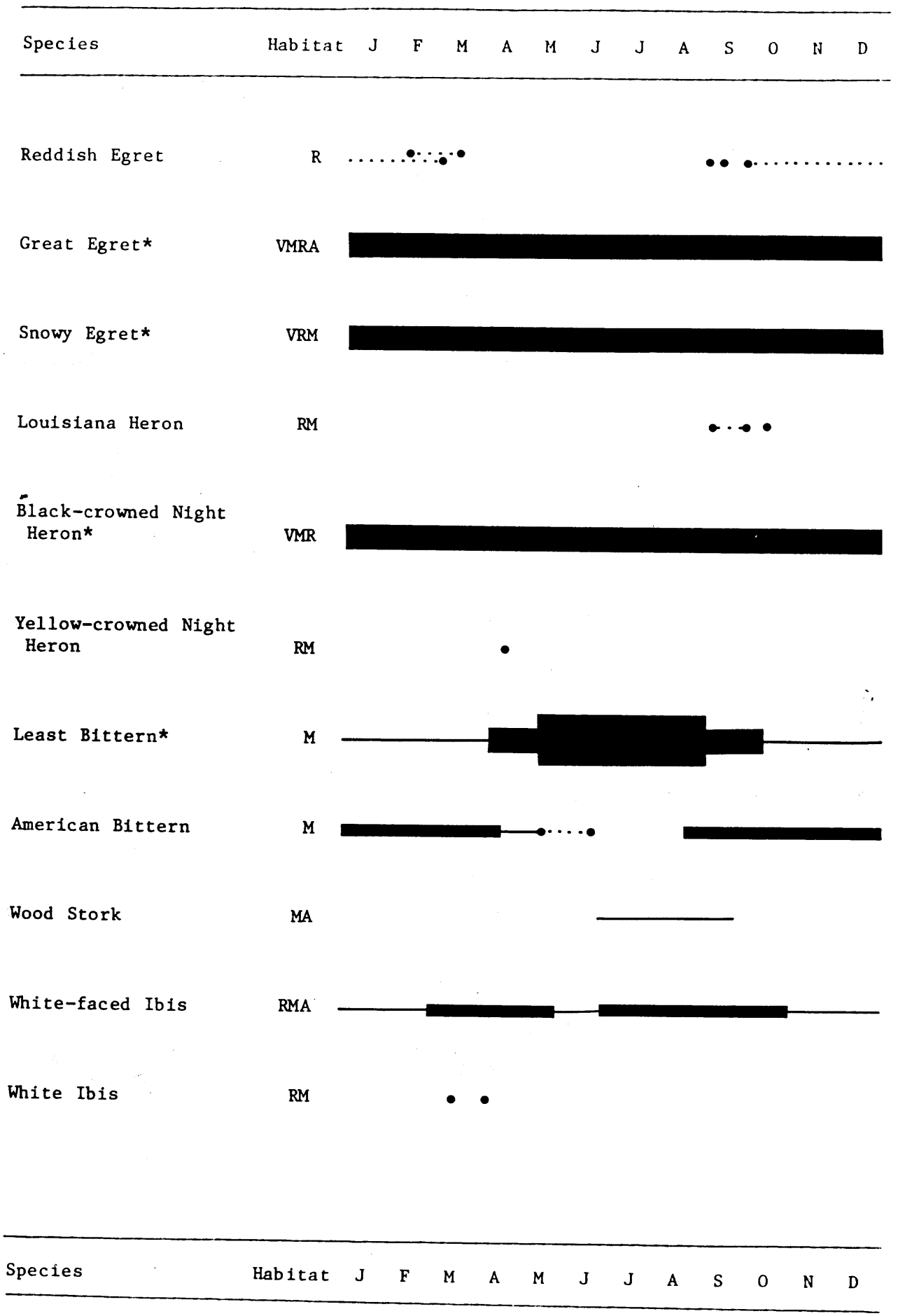
Chestnut-collared Longspur (Calcarius ornatus)
- Status: Rare or irregularly uncommon winter resident from late October to early April. Occurs primarily as singles or in small groups with larks and pipits.
- Habitat: Agricultural fields, especially dry Bermuda grass.
- Food: Seeds.

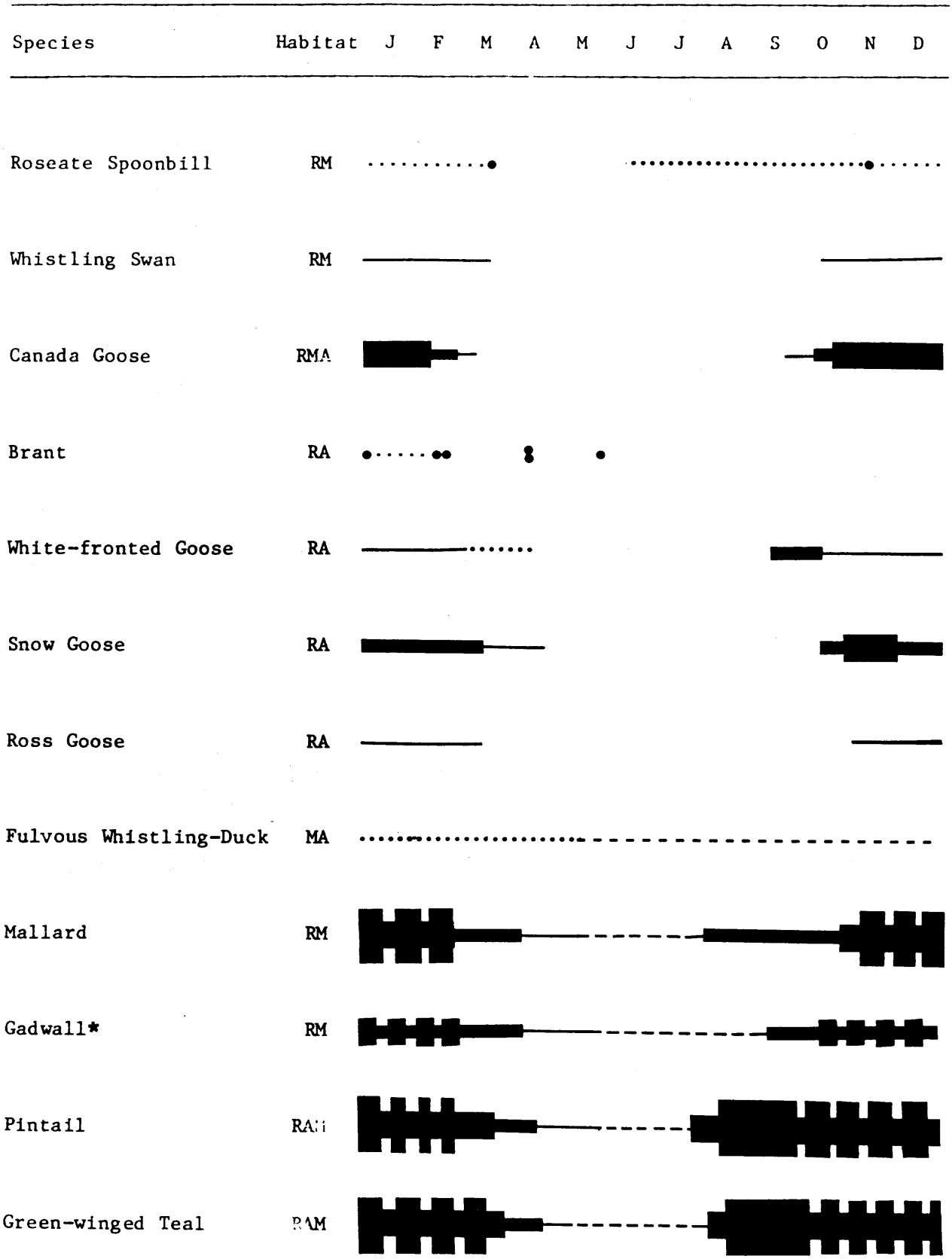
BIRDS USING LOWER COLORADO RIVER



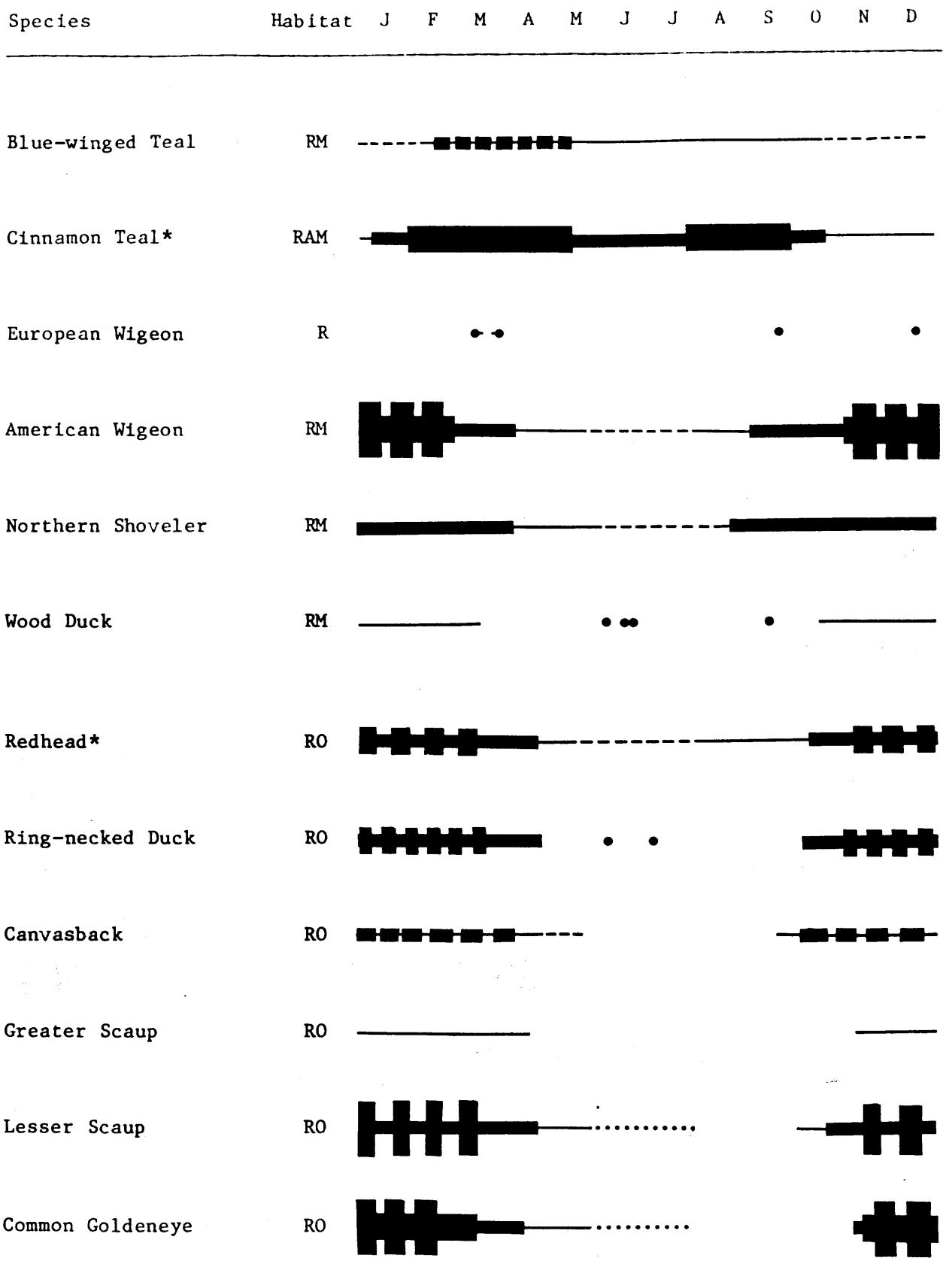
Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Leach Storm-Petrel	O								o				
White Pelican	OR			▬	▬	▬	▬	▬	▬	▬			
Brown Pelican	OR	·····	·····	·····	·····	·····	·····	———	———	———	·····	·····	·····
Blue-footed Booby	O	·····•								·····•·····			
Brown Booby	O	·····	·····	·····	·····	·····	·····	·····	·····	·····	·····	·····	·····•
Double-crested Cormorant*	RO	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬
Olivaceous Cormorant	R	··•·•			•	••							•··
Magnificent Frigatebird	OR						———	———	———				
Great Blue Heron*	VMR	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬
Green Heron*	VRM	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬
Little Blue Heron	AM					••		•	o				
Cattle Egret	AR	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬

Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D


Species
Habitat
J F M A M J J A S O N D
Reddish Egret
R
Great Egret*
VMRA
Snowy Egret*
VRM
Louisiana Heron
RM
Black-crowned Night Heron*
VMR
Yellow-crowned Night Heron
RM
Least Bittern*
M
American Bittern
M
Wood Stork
MA
White-faced Ibis
RMA
White Ibis
RM
Species
Habitat
J F M A M J J A S O N D

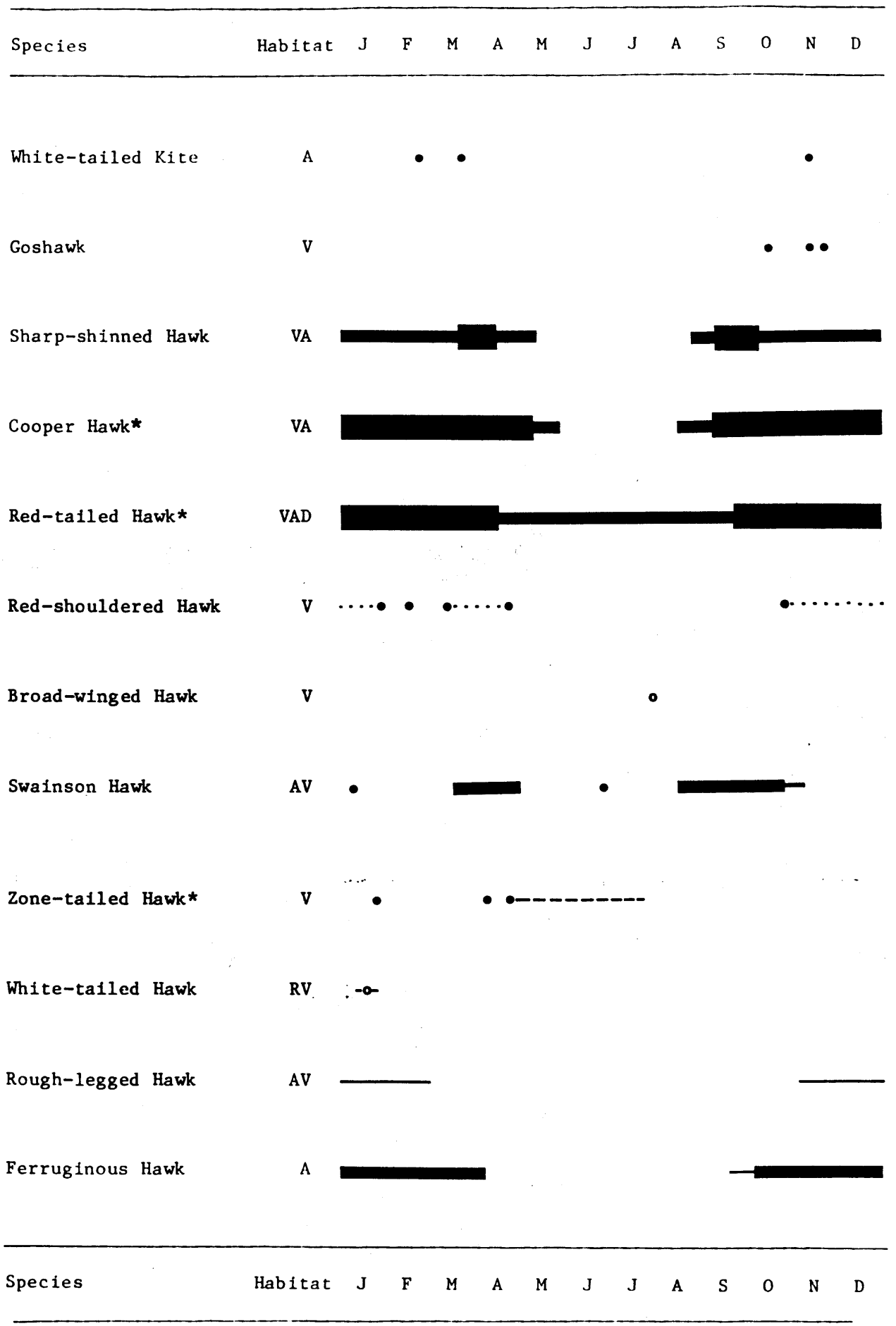


Species Habitat J F M A M J J A S O N D


Species
Habitat
J F M A M J J A S O N D
Blue-winged Teal RM
Cinnamon Teal* RAM
European Wigeon R
American Wigeon RM
Northern Shoveler RM
Wood Duck RM
Redhead* RO
Ring-necked Duck RO
Canvasback RO
Greater Scaup RO
Lesser Scaup RO
Common Goldeneye RO
Species
Habitat
J F M A M J J A S O N D

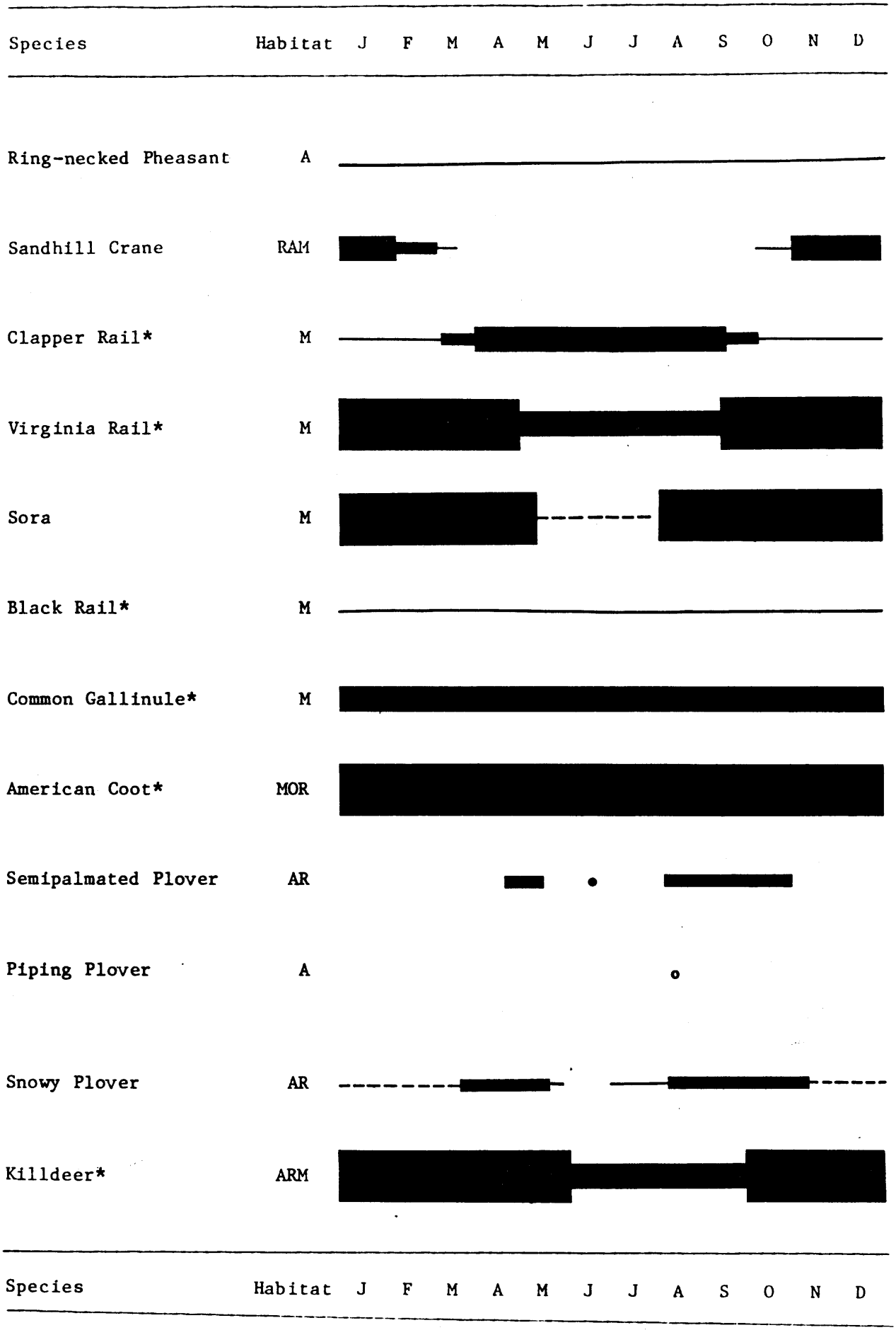
Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Barrow Goldeneye	RO												
Bufflehead	RO												
Oldsquaw	OR												
White-winged Scoter	OR												
Surf Scoter	OR												
Black Scoter	R												
Ruddy Duck*	MRO												
Hooded Merganser	RO												
Common Merganser	RO												
Red-breasted Merganser	RO												
Turkey Vulture*	AVD												
Black Vulture	VD												

| Species | Habitat | J | F | M | A | M | J | J | A | S | O | N | D |


Species
Habitat
J F M A M J J A S O N D
White-tailed Kite A
Goshawk V
Sharp-shinned Hawk VA
Cooper Hawk* VA
Red-tailed Hawk* VAD
Red-shouldered Hawk V
Broad-winged Hawk V
Swainson Hawk AV
Zone-tailed Hawk* V
White-tailed Hawk RV
Rough-legged Hawk AV
Ferruginous Hawk A
Species
Habitat
J F M A M J J A S O N D

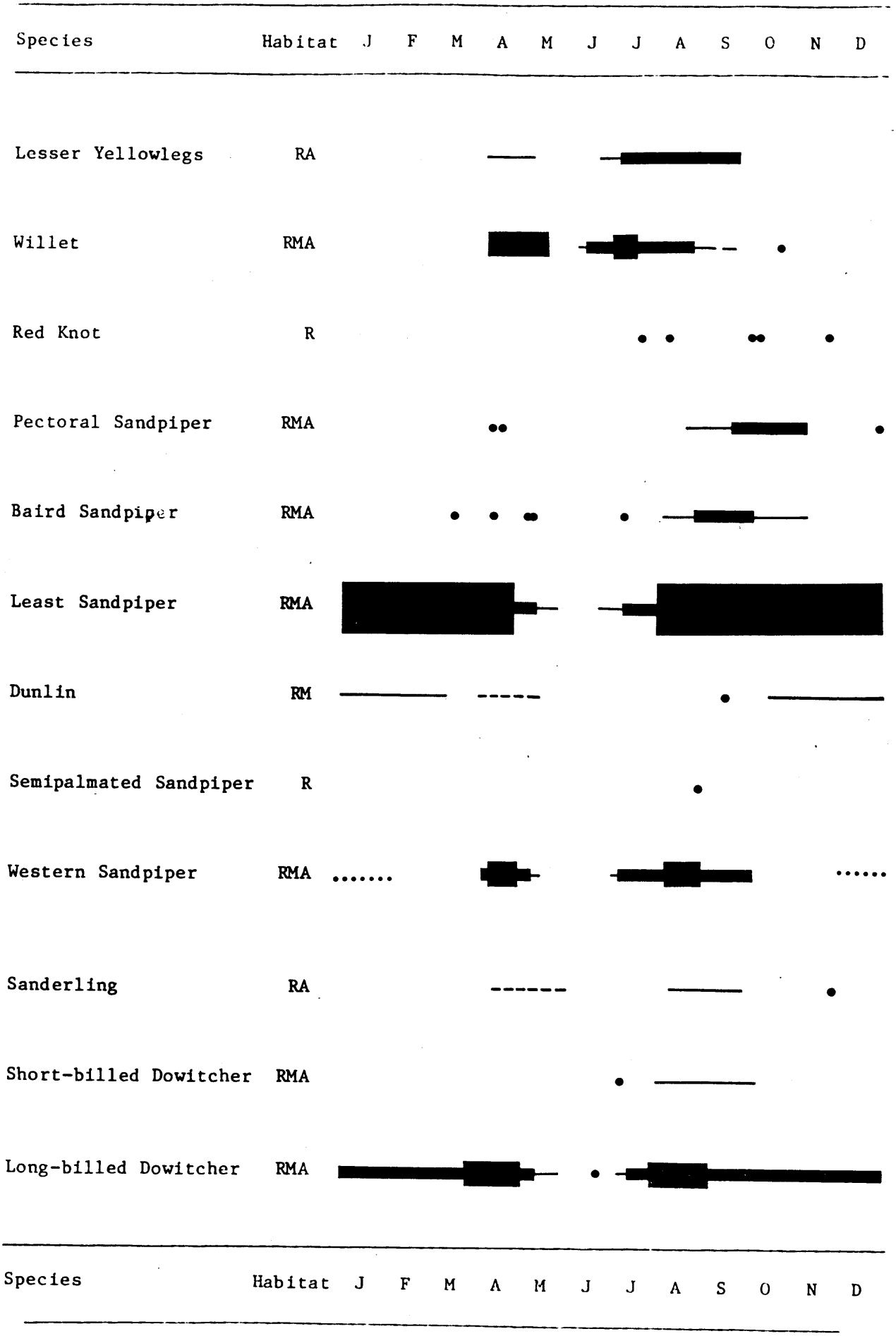
Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Harris Hawk*	VD												
Black Hawk	V												
Golden Eagle	DVA												
Bald Eagle	RM												
Marsh Hawk	MVA												
Osprey	RM												
Caracara	VA												
Prairie Falcon	VAD												
Peregrine Falcon*	RMA												
Merlin	VA												
American Kestrel*	VAD												
Gambel Quail*	VD												

Species Habitat J F M A M J J A S O N D


Species
Habitat
J F M A M J J A S O N D
Ring-necked Pheasant
A
Sandhill Crane
RAM
Clapper Rail*
M
Virginia Rail*
M
Sora
M
Black Rail*
M
Common Gallinule*
M
American Coot*
MOR
Semipalmated Plover
AR
Piping Plover
A
Snowy Plover
AR
Killdeer*
ARM
Species
Habitat
J F M A M J J A S O N D

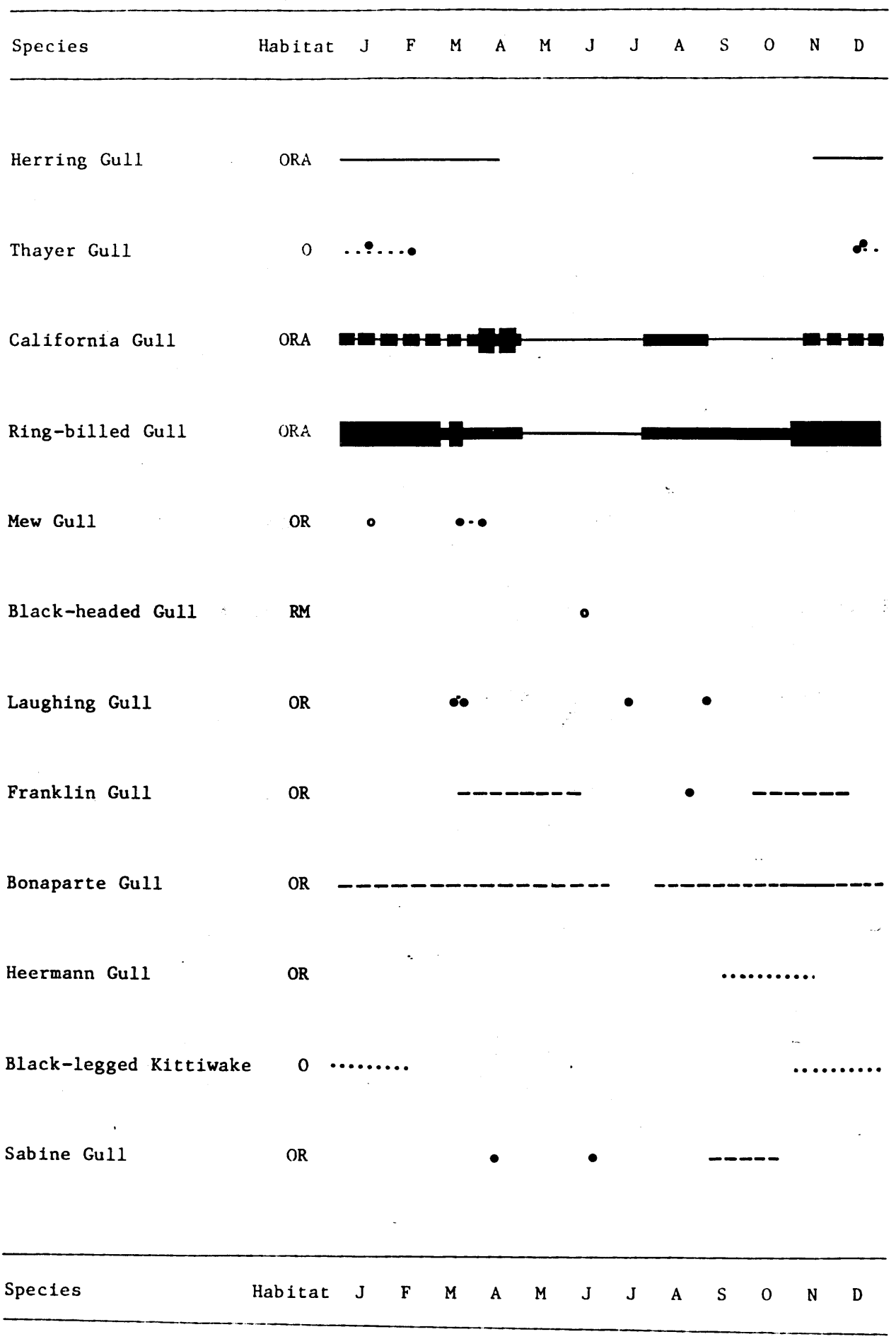
Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Mountain Plover	A												
American Golden Plover	AR												
Black-bellied Plover	AR												
Ruddy Turnstone	R												
Black Turnstone	R												
Common Snipe	RMVA												
Long-billed Curlew	RA												
Whimbrel	RA												
Upland Sandpiper	AR												
Spotted Sandpiper	RM												
Solitary Sandpiper	RA												
Greater Yellowlegs	RA												

| Species | Habitat | J | F | M | A | M | J | J | A | S | O | N | D |

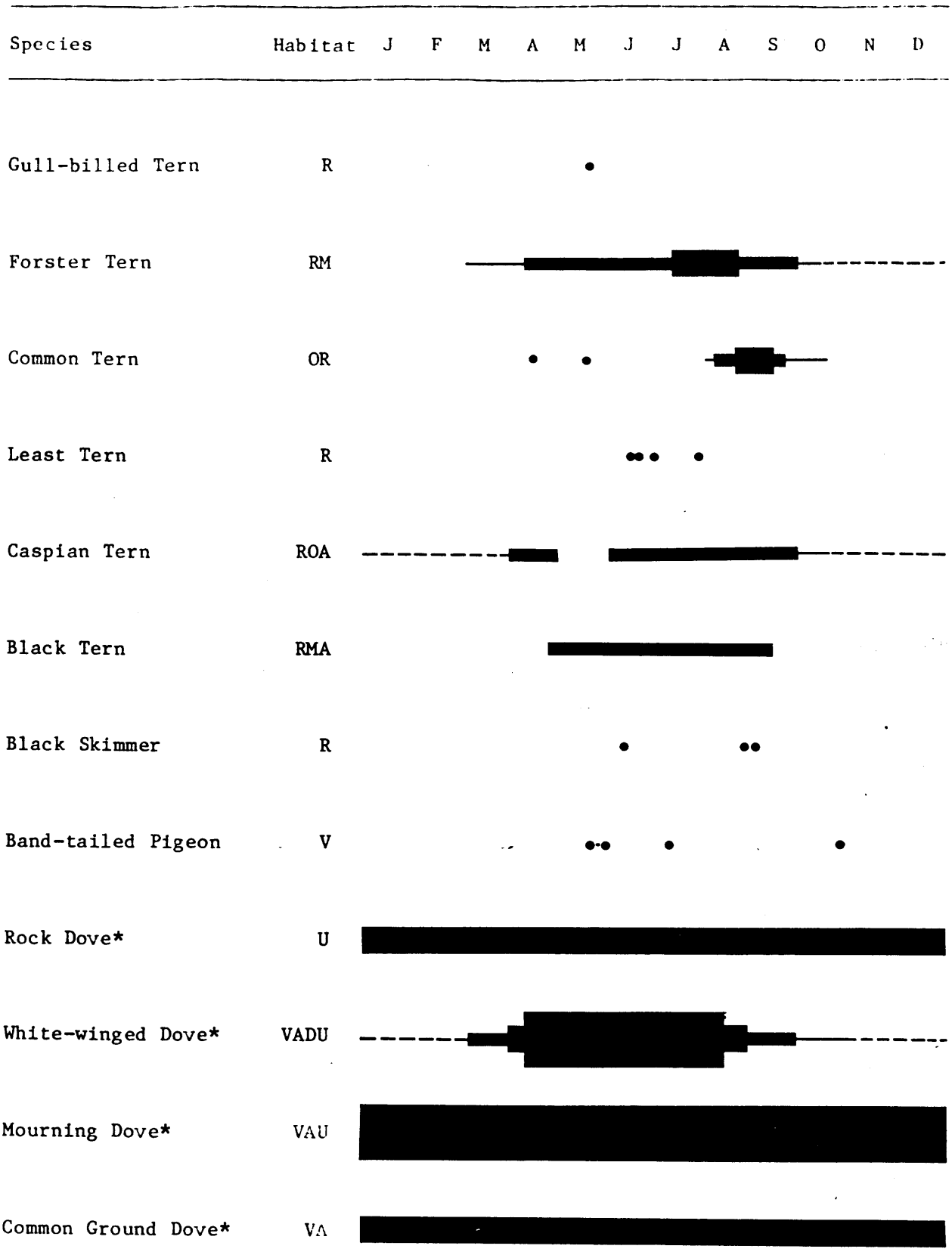

Species
Habitat
J F M A M J J A S O N D
Lesser Yellowlegs RA
Willet RMA
Red Knot R
Pectoral Sandpiper RMA
Baird Sandpiper RMA
Least Sandpiper RMA
Dunlin RM
Semipalmated Sandpiper R
Western Sandpiper RMA
Sanderling RA
Short-billed Dowitcher RMA
Long-billed Dowitcher RMA
Species
Habitat
J F M A M J J A S O N D

Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Stilt Sandpiper	RA								•				
Marbled Godwit	RA				▬		▬	▬	▬	▬			
American Avocet	MRA	·····	·····	·····	▬	▬	▬	▬	▬	▬	▬	▬	····
Black-necked Stilt*	MRA			▬	▬	▬	▬	▬	▬	▬	▬		•
Red Phalarope	OR			•					•	- - - - -	- - - - -	- - - - -	
Wilson Phalarope	RA			•	▬			▬	▬	▬			
Northern Phalarope	OR					- - -			▬	▬	▬		
Pomarine Jaeger	O									• •			
Long-tailed Jaeger	O									•			
Parasitic Jaeger	O									▬ ▬ ▬			
Glaucous-winged Gull	OR	····	····	····	····	····	····	····	····	····	····	····	····
Western Gull	O												•

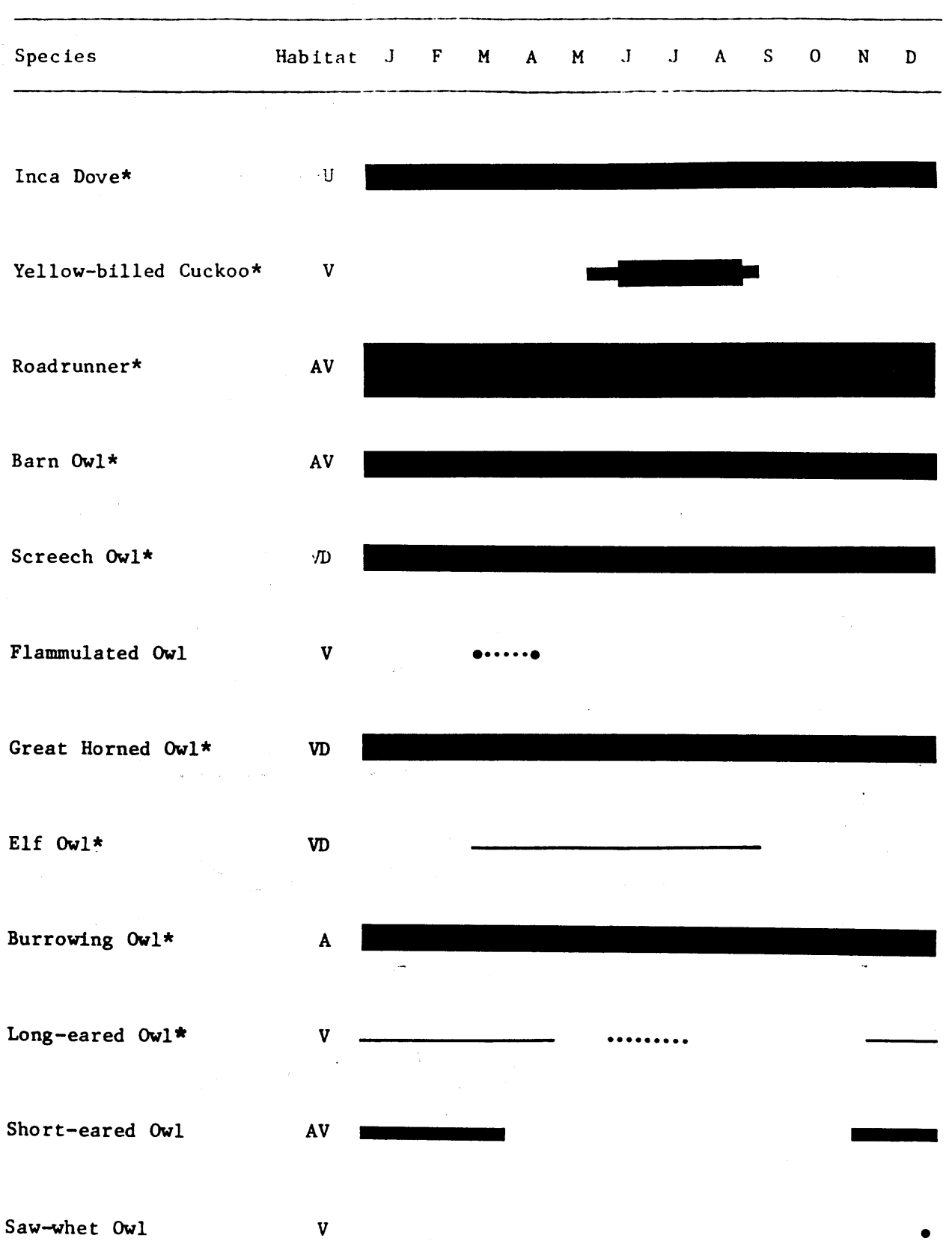
| Species | Habitat | J | F | M | A | M | J | J | A | S | O | N | D |



Species Habitat J F M A M J J A S O N D



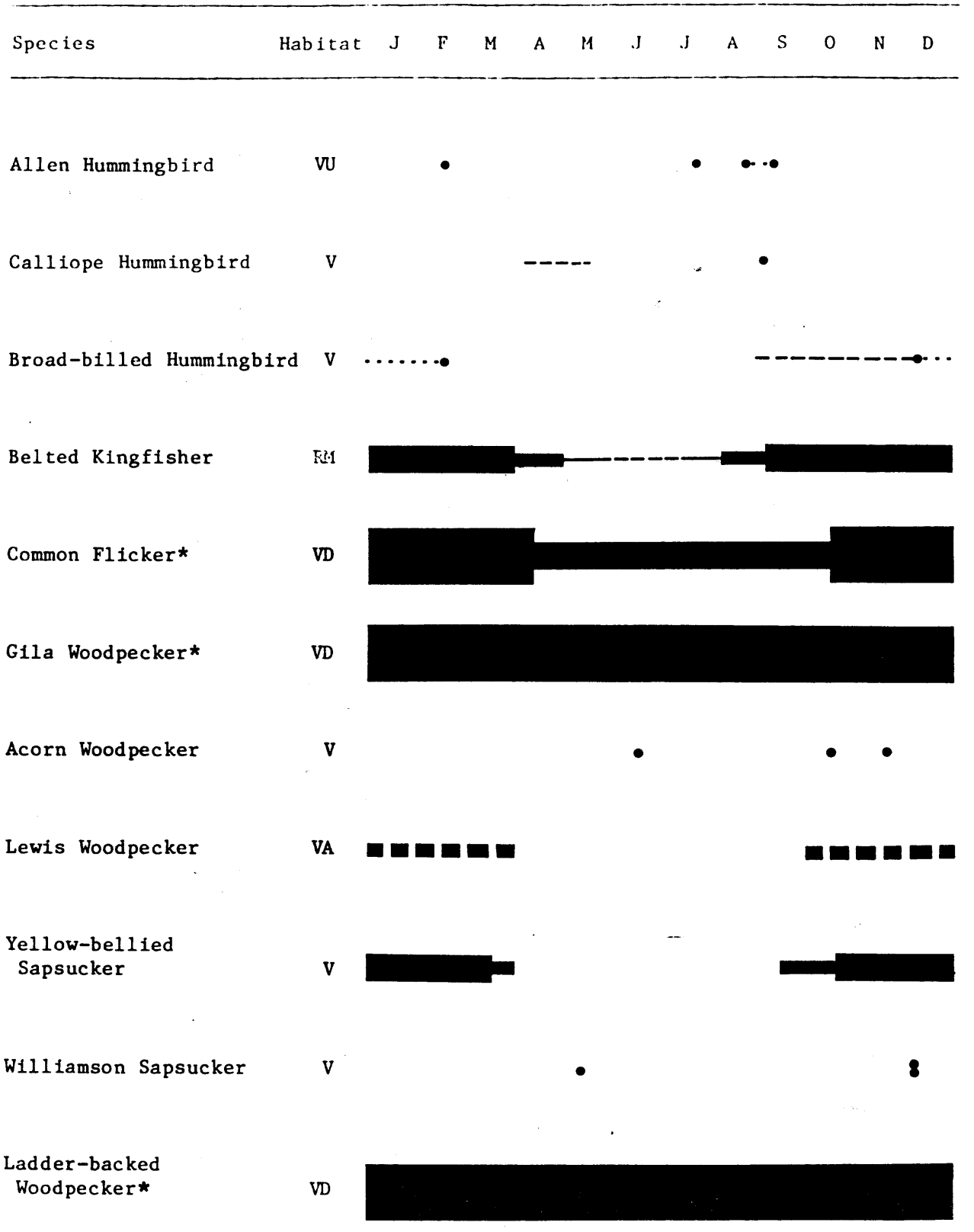
Species Habitat J F M A M J J A S O N D



Species Habitat J F M A M J J A S O N D

Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Poor-will*	D												
Common Nighthawk	VD												
Lesser Nighthawk*	VDRA												
Black Swift	R												
Chimney Swift	R												
Vaux Swift	RV												
White-throated Swift*	DR												
Black-chinned Hummingbird*	VU												
Costa Hummingbird*	DV												
Anna Hummingbird*	VU												
Broad-tailed Hummingbird	V												
Rufous Hummingbird	VU												

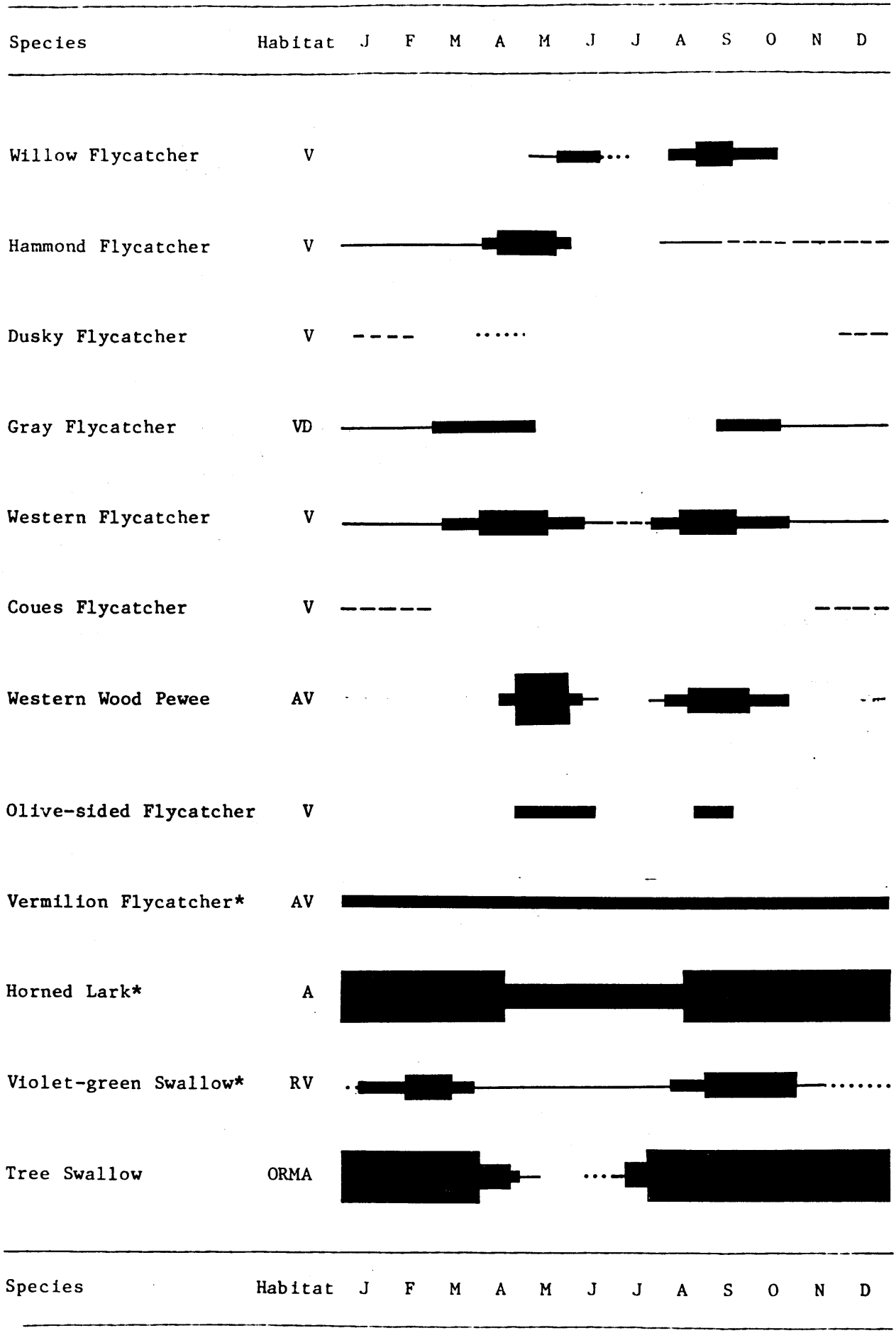
Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D

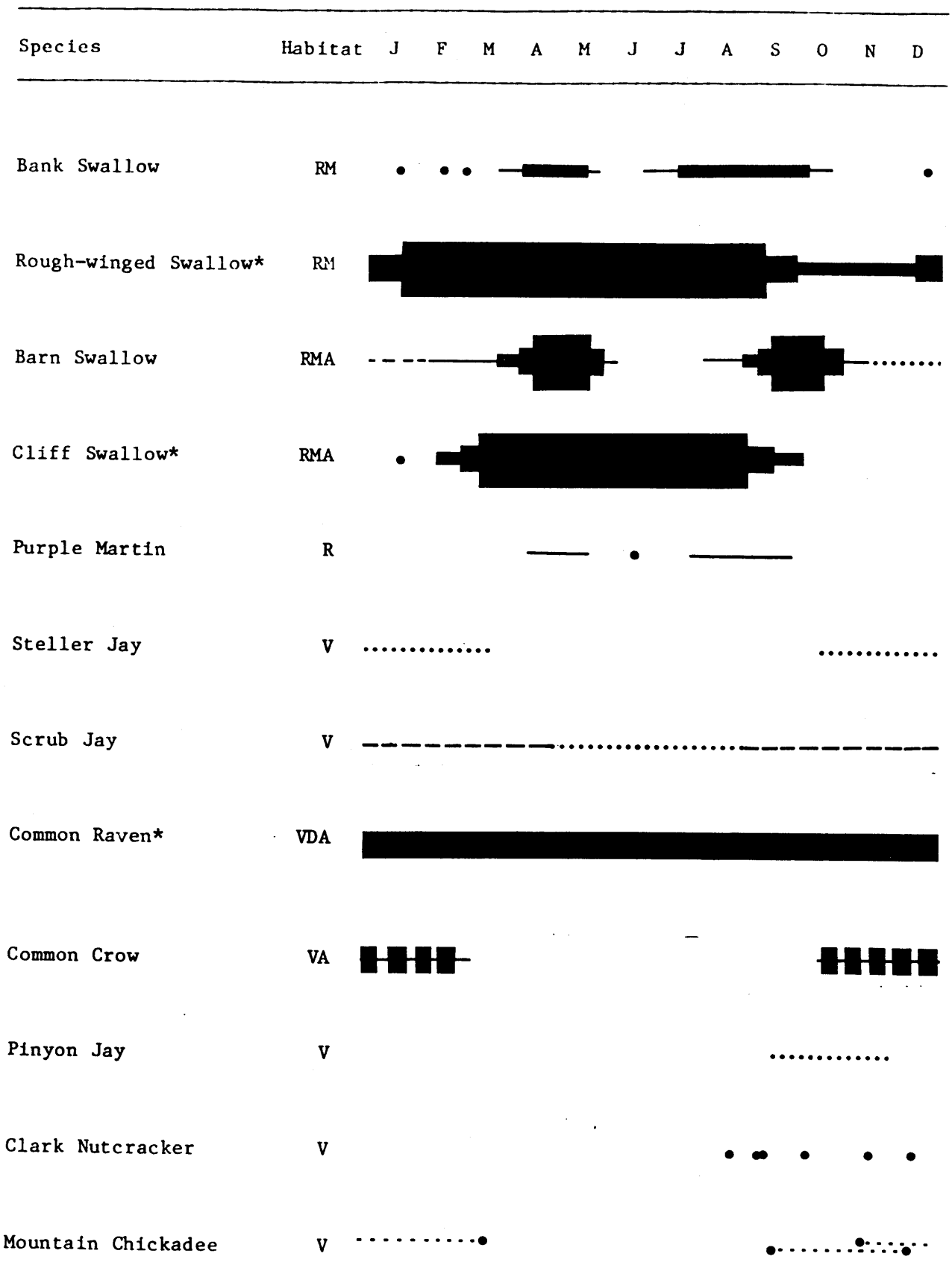


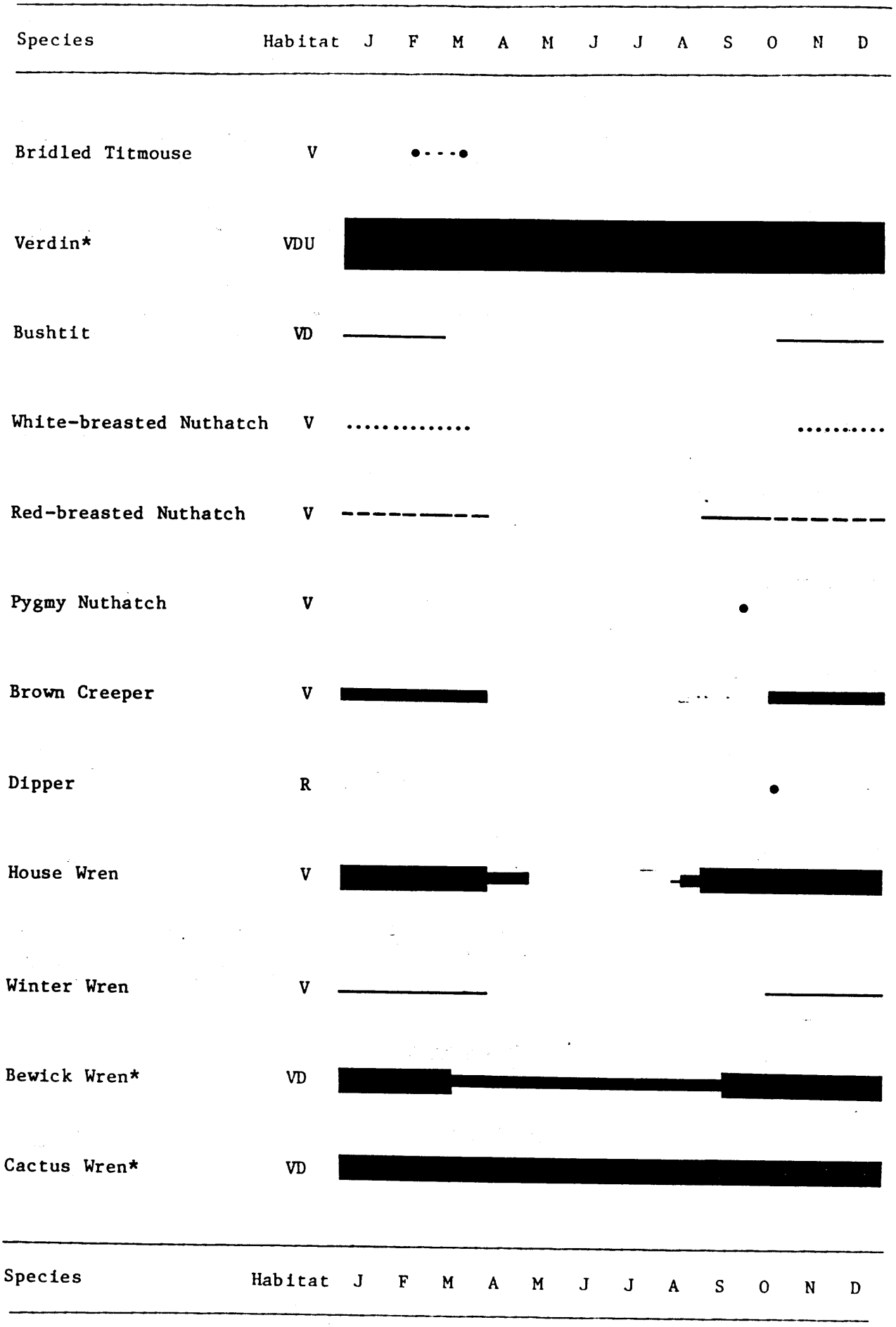
Species Habitat J F M A M J J A S O N D

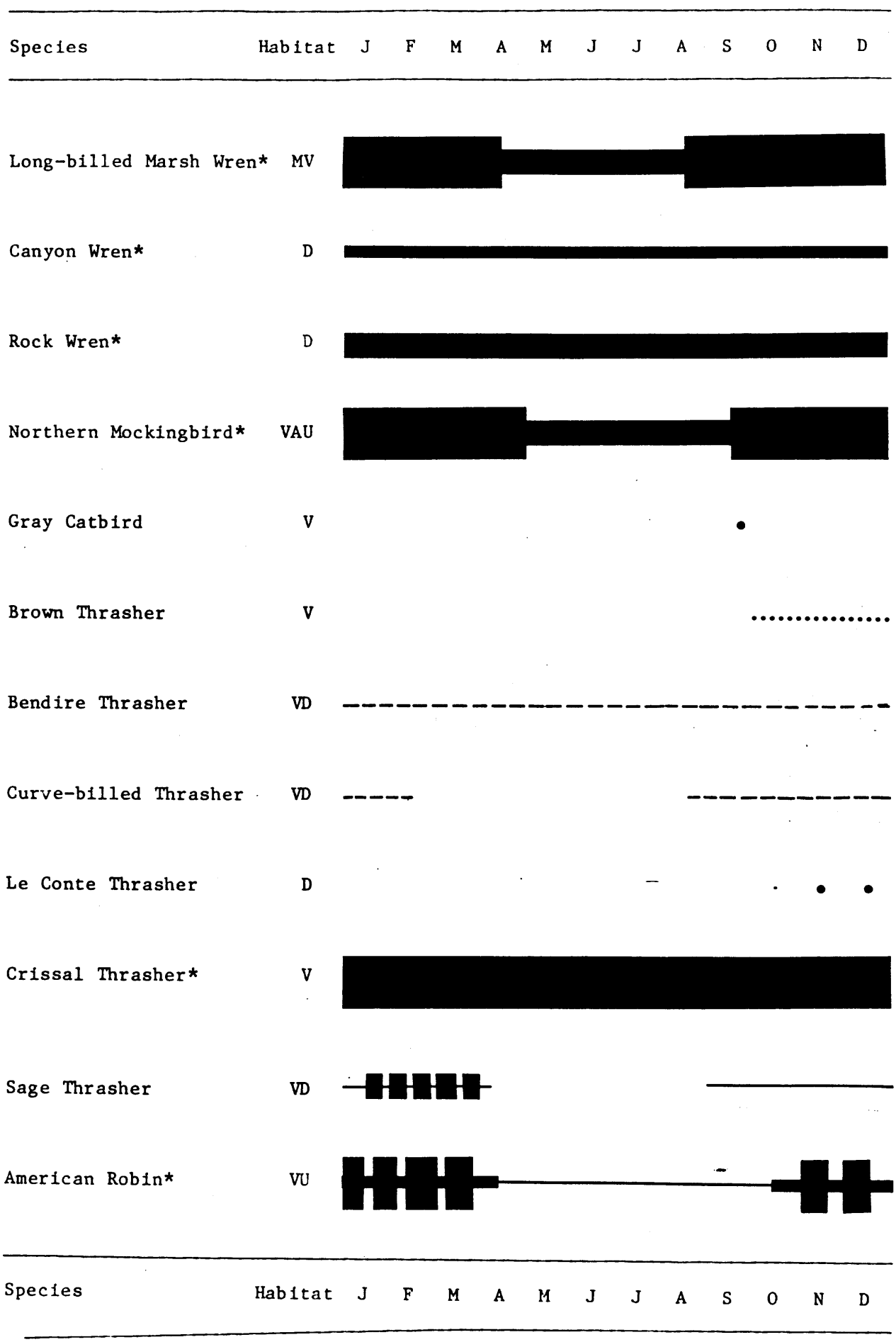
Species	Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Eastern Kingbird	VA								·····				
Tropical Kingbird	V			•			••		•		•		
Western Kingbird*	AV												
Cassin Kingbird	AV			·····						———			
Thick-billed Kingbird	V								•····•			·····	
Scissor-tailed Flycatcher	AV					— — — — — — — — — —							
Wied Crested Flycatcher*	V												
Ash-throated Flycatcher*	VD												
Olivaceous Flycatcher	V											••	
Eastern Phoebe	V			———						———			
Black Phoebe*	VR												
Say Phoebe*	AVD												

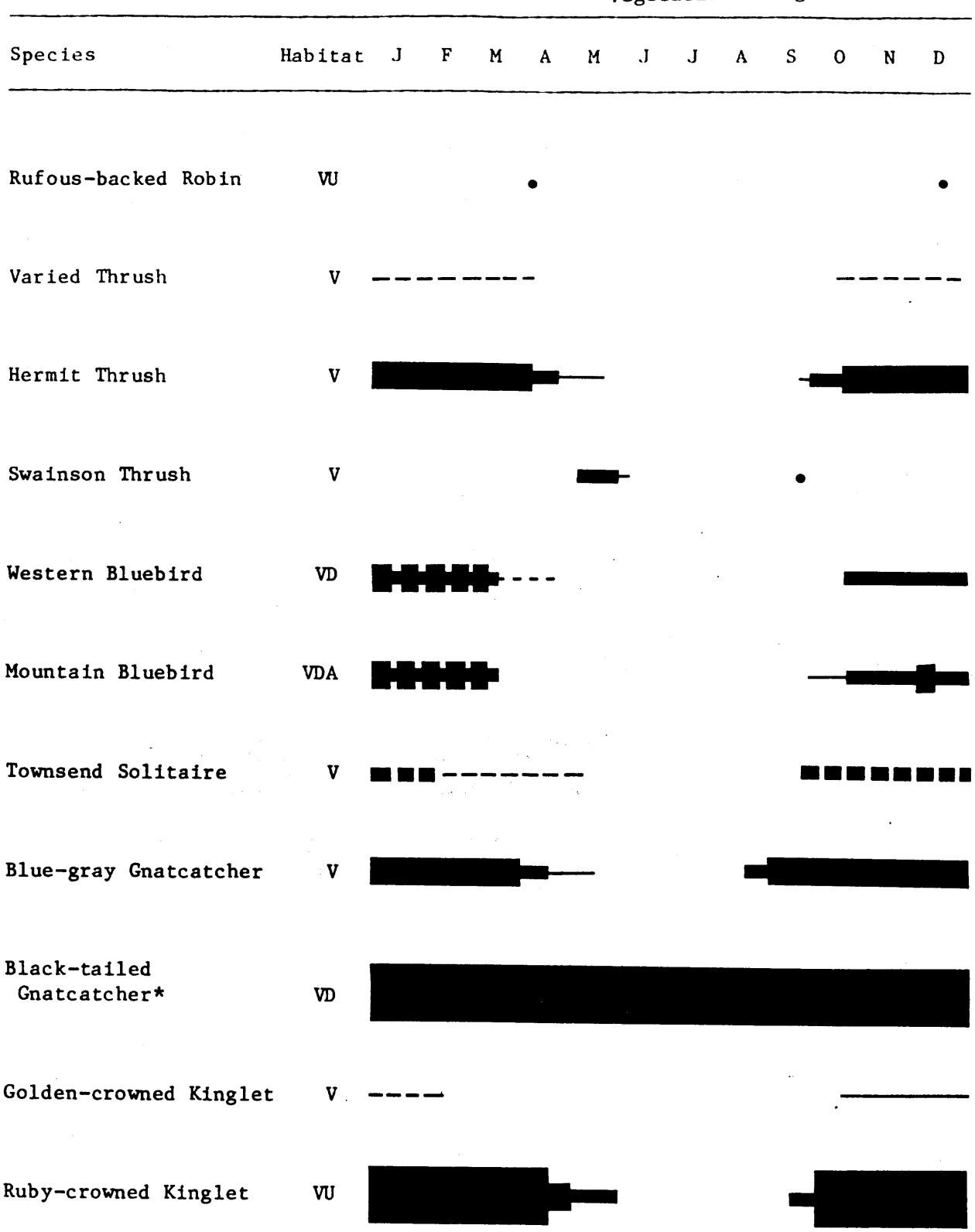
| Species | Habitat | J | F | M | A | M | J | J | A | S | O | N | D |


Species
Habitat
J F M A M J J A S O N D
Willow Flycatcher V
Hammond Flycatcher V
Dusky Flycatcher V
Gray Flycatcher VD
Western Flycatcher V
Coues Flycatcher V
Western Wood Pewee AV
Olive-sided Flycatcher V
Vermilion Flycatcher* AV
Horned Lark* A
Violet-green Swallow* RV
Tree Swallow ORMA
Species
Habitat
J F M A M J J A S O N D

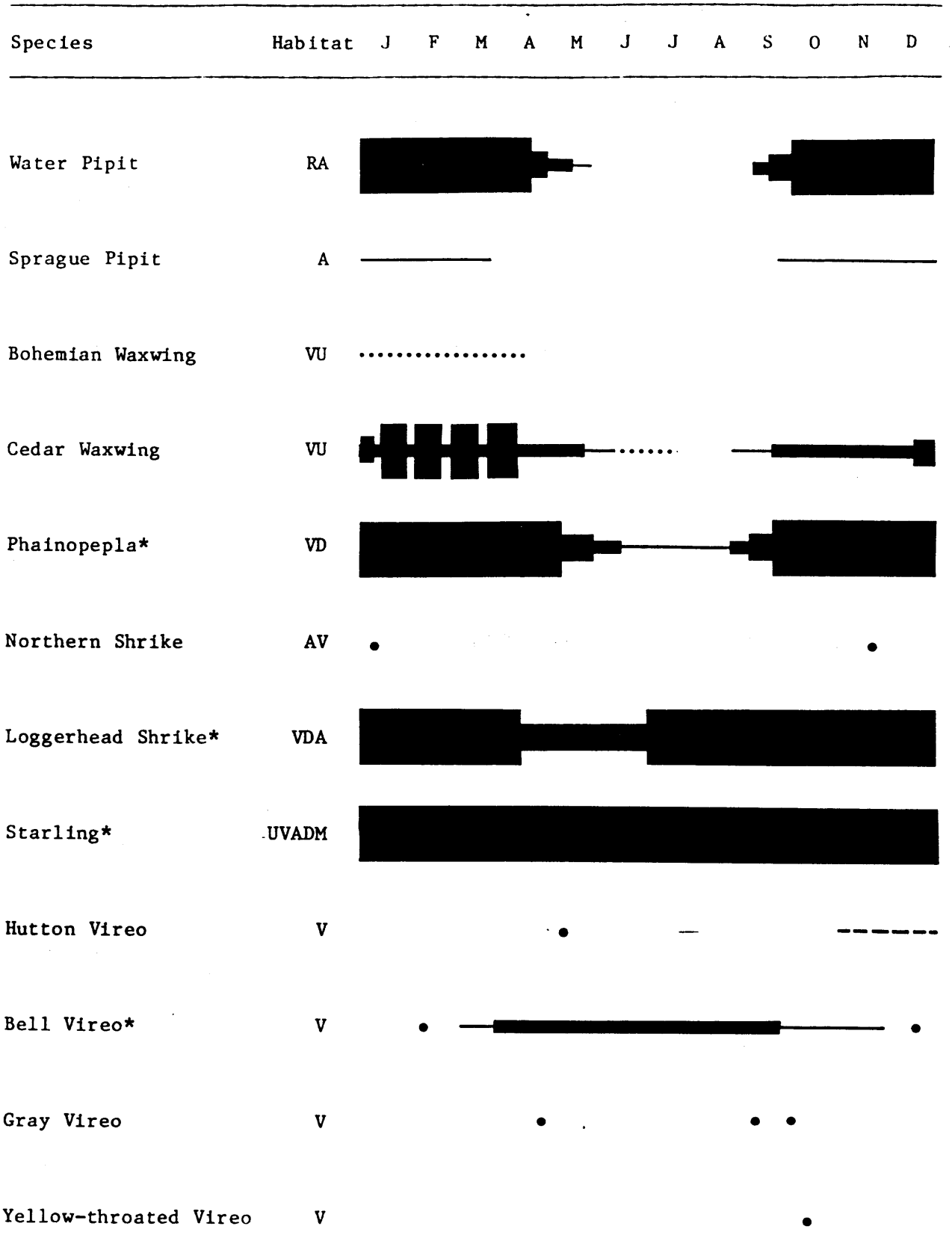

Species
Habitat
J F M A M J J A S O N D
Bank Swallow
RM
Rough-winged Swallow*
RM
Barn Swallow
RMA
Cliff Swallow*
RMA
Purple Martin
R
Steller Jay
V
Scrub Jay
V
Common Raven*
VDA
Common Crow
VA
Pinyon Jay
V
Clark Nutcracker
V
Mountain Chickadee
V
Species
Habitat
J F M A M J J A S O N D


Species
Habitat
J F M A M J J A S O N D
Bridled Titmouse V
Verdin* VDU
Bushtit VD
White-breasted Nuthatch V
Red-breasted Nuthatch V
Pygmy Nuthatch V
Brown Creeper V
Dipper R
House Wren V
Winter Wren V
Bewick Wren* VD
Cactus Wren* VD
Species
Habitat
J F M A M J J A S O N D

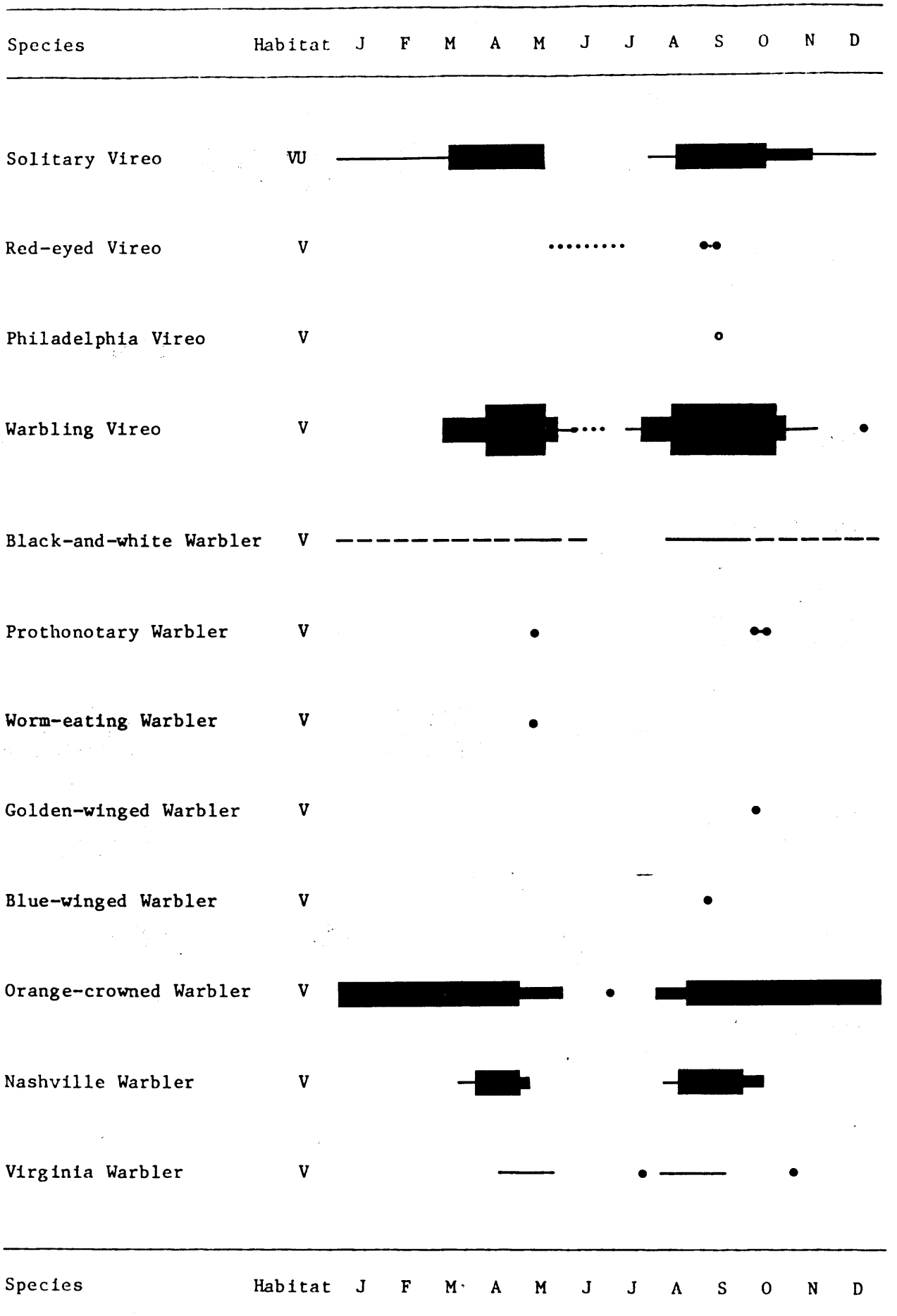

Species
Habitat
J F M A M J J A S O N D
Long-billed Marsh Wren* MV
Canyon Wren* D
Rock Wren* D
Northern Mockingbird* VAU
Gray Catbird V
Brown Thrasher V
Bendire Thrasher VD
Curve-billed Thrasher VD
Le Conte Thrasher D
Crissal Thrasher* V
Sage Thrasher VD
American Robin* VU
Species
Habitat
J F M A M J J A S O N D



Species Habitat J F M A M J J A S O N D



Species Habitat J F M A M J J A S O N D


Species
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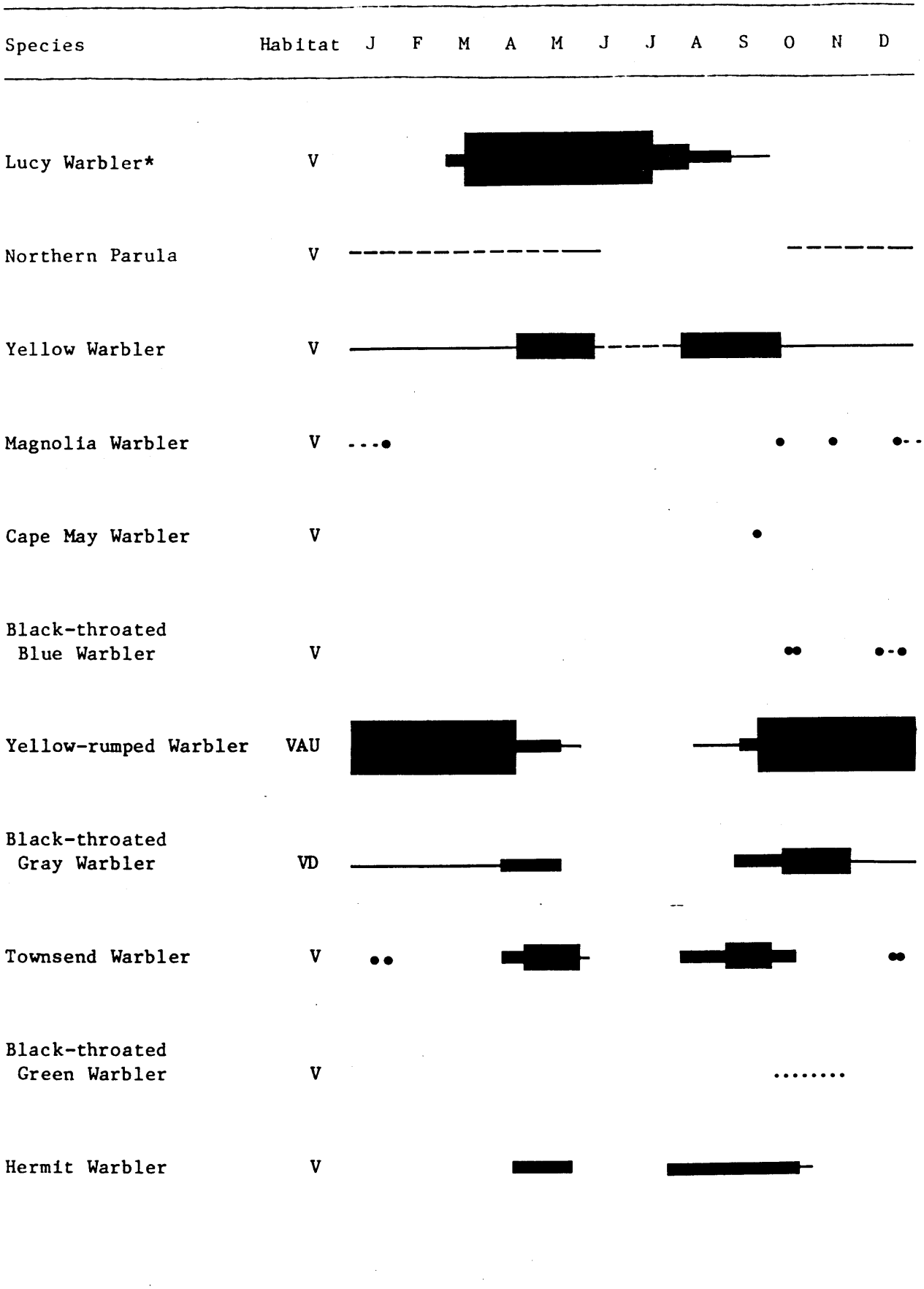
J F M A M J J A S O N D
Solitary Vireo VU
Red-eyed Vireo V
Philadelphia Vireo V
Warbling Vireo V
Black-and-white Warbler V
Prothonotary Warbler V
Worm-eating Warbler V
Golden-winged Warbler V
Blue-winged Warbler V
Orange-crowned Warbler V
Nashville Warbler V
Virginia Warbler V
Species
Habitat
J F M A M J J A S O N D


Species
Habitat
J F M A M J J A S O N D
Lucy Warbler*
V
Northern Parula
V
Yellow Warbler
V
Magnolia Warbler
V
Cape May Warbler
V
Black-throated Blue Warbler
V
Yellow-rumped Warbler
VAU
Black-throated Gray Warbler
VD
Townsend Warbler
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Black-throated Green Warbler
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Hermit Warbler
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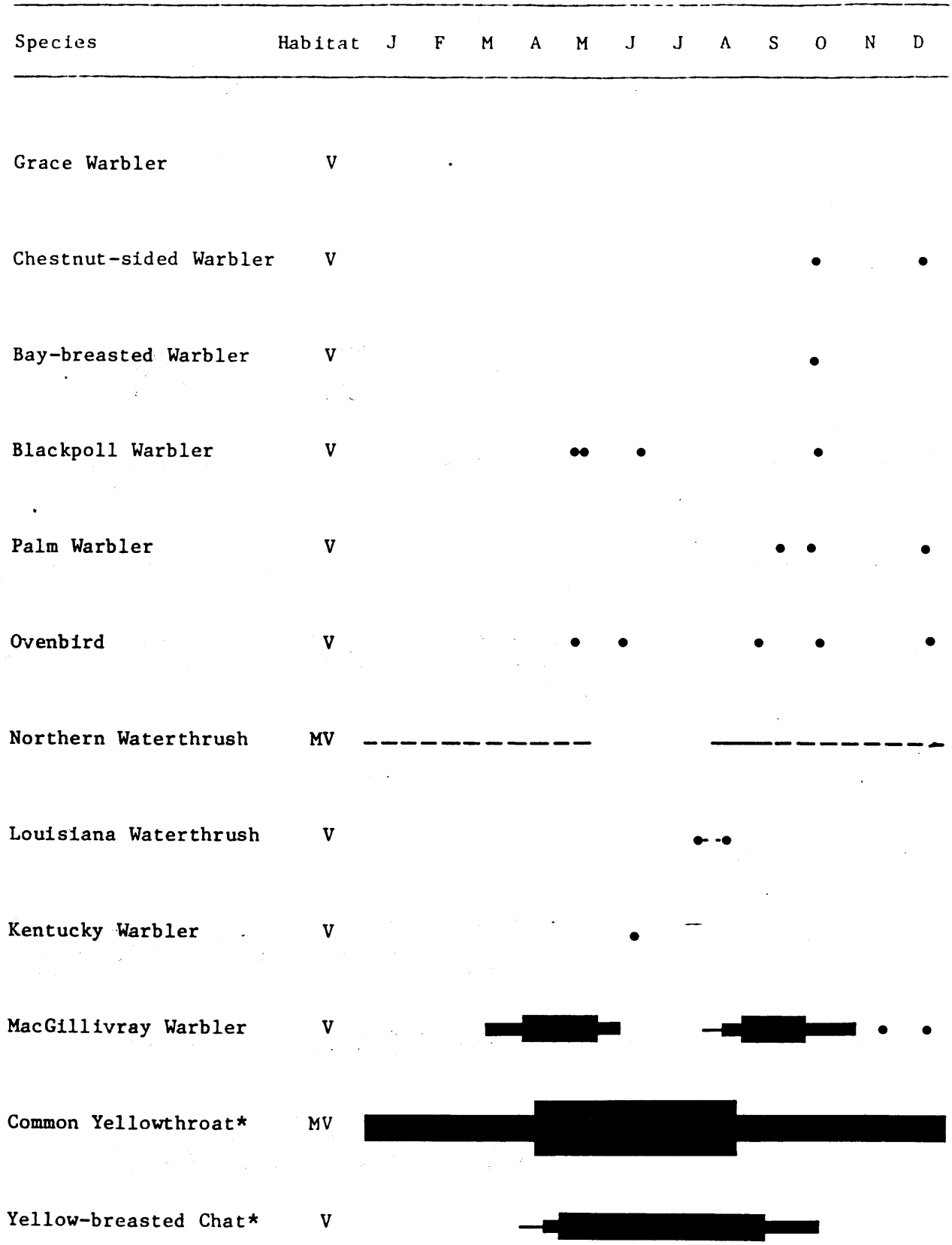
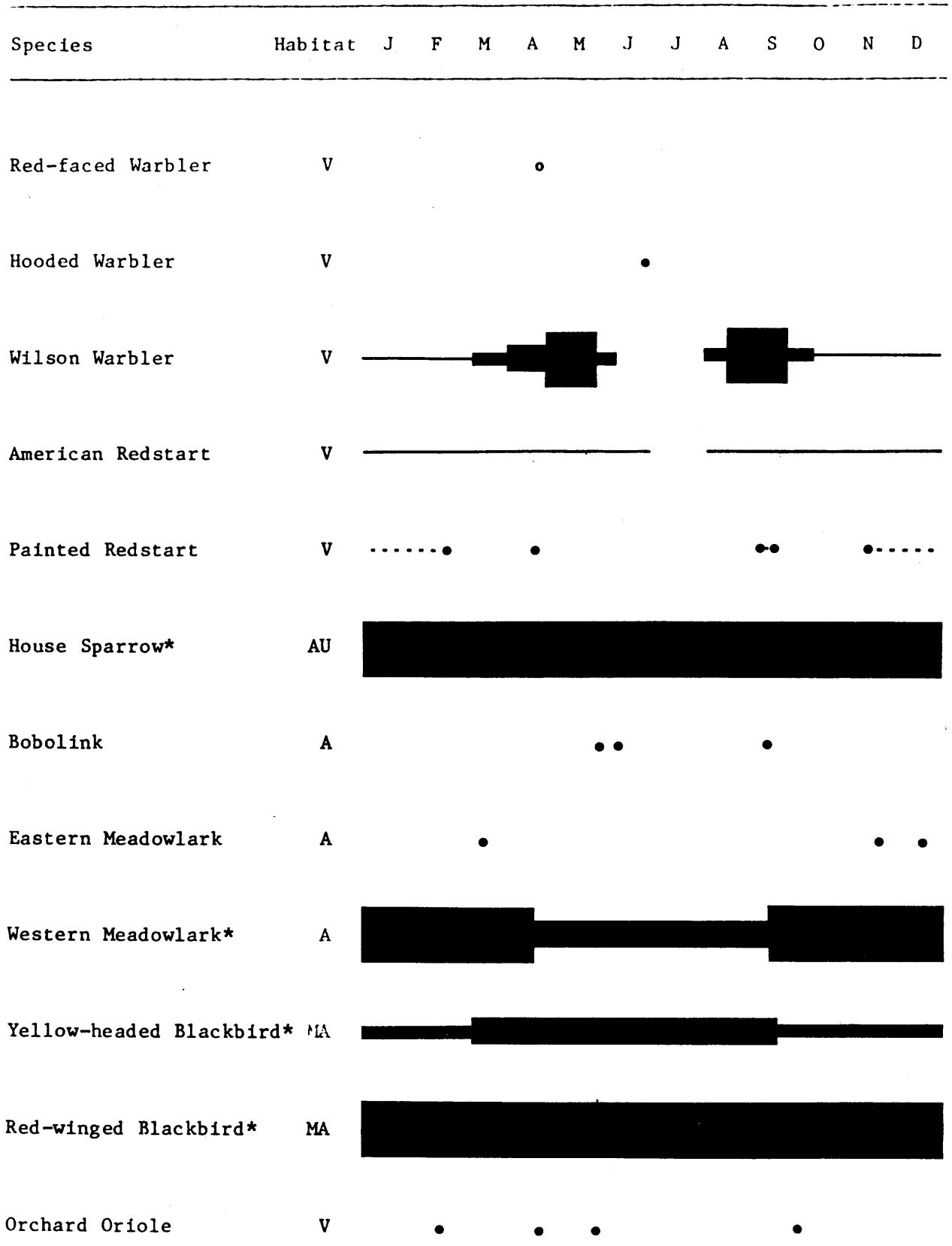
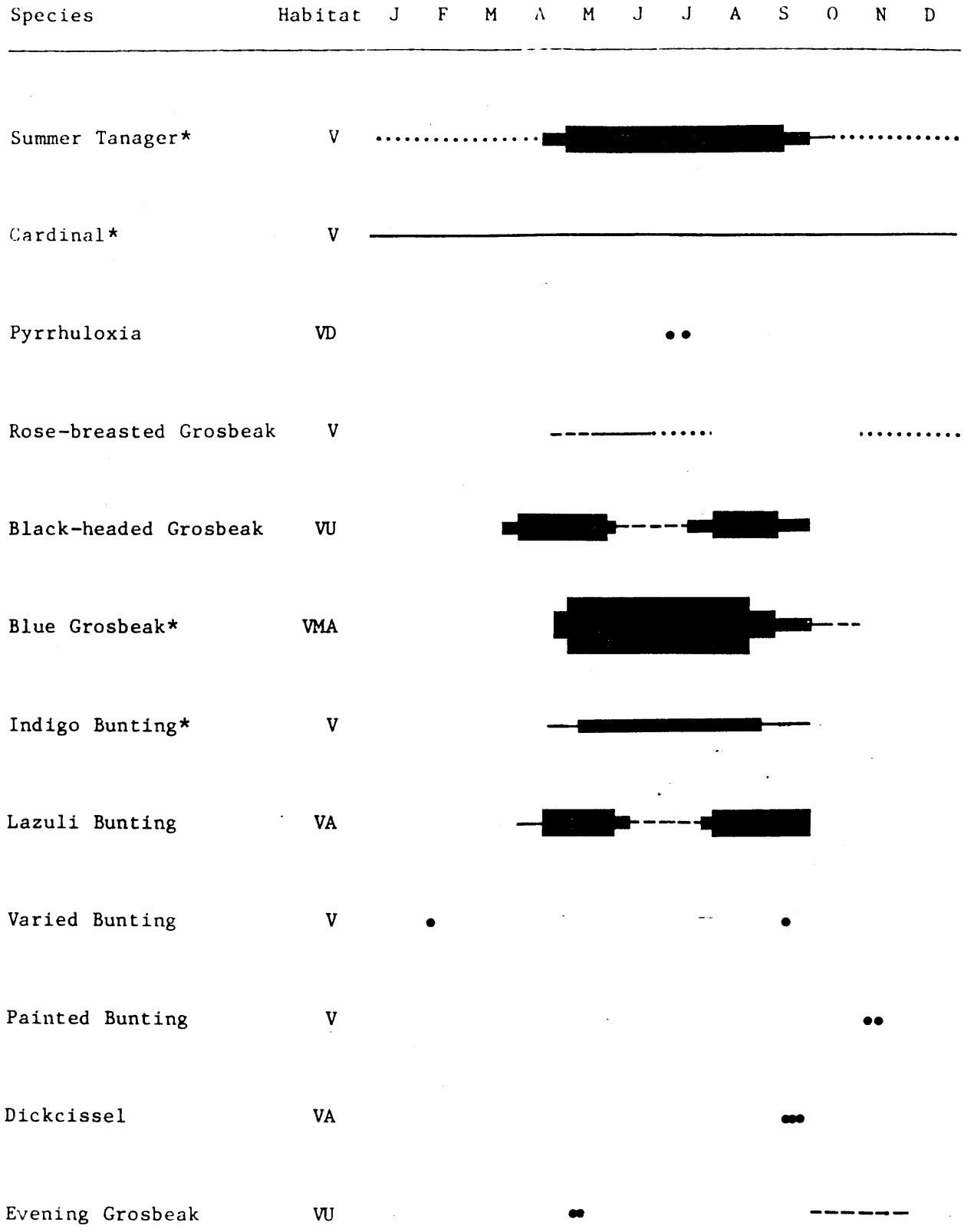
Species
Habitat
J F M A M J J A S O N D


Species
Habitat
J F M A M J J A S O N D
Grace Warbler V
Chestnut-sided Warbler V
Bay-breasted Warbler V
Blackpoll Warbler V
Palm Warbler V
Ovenbird V
Northern Waterthrush MV
Louisiana Waterthrush V
Kentucky Warbler V
MacGillivray Warbler V
Common Yellowthroat* MV
Yellow-breasted Chat* V
Species
Habitat
J F M A M J J A S O N D

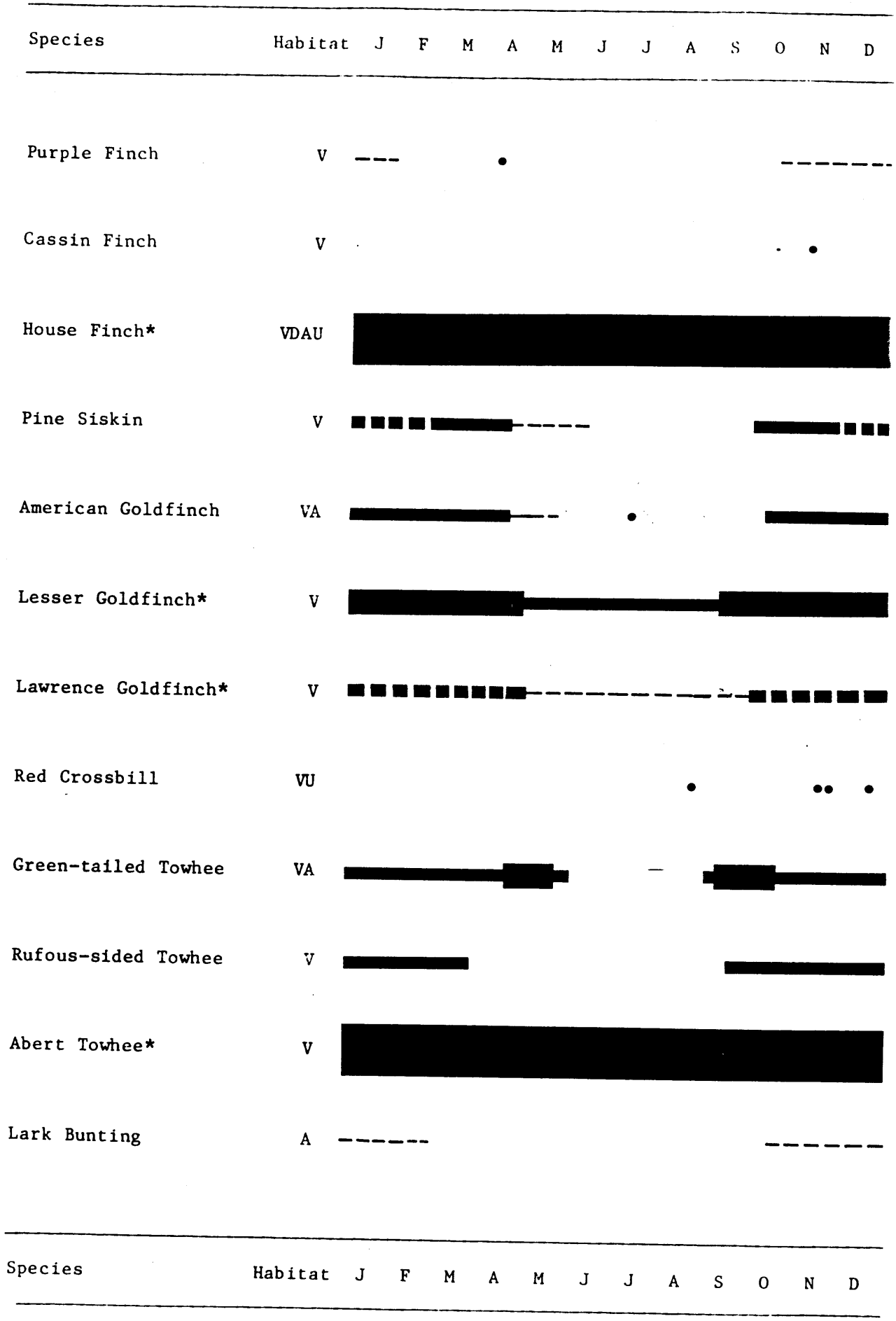


Species Habitat J F M A M J J A S O N D

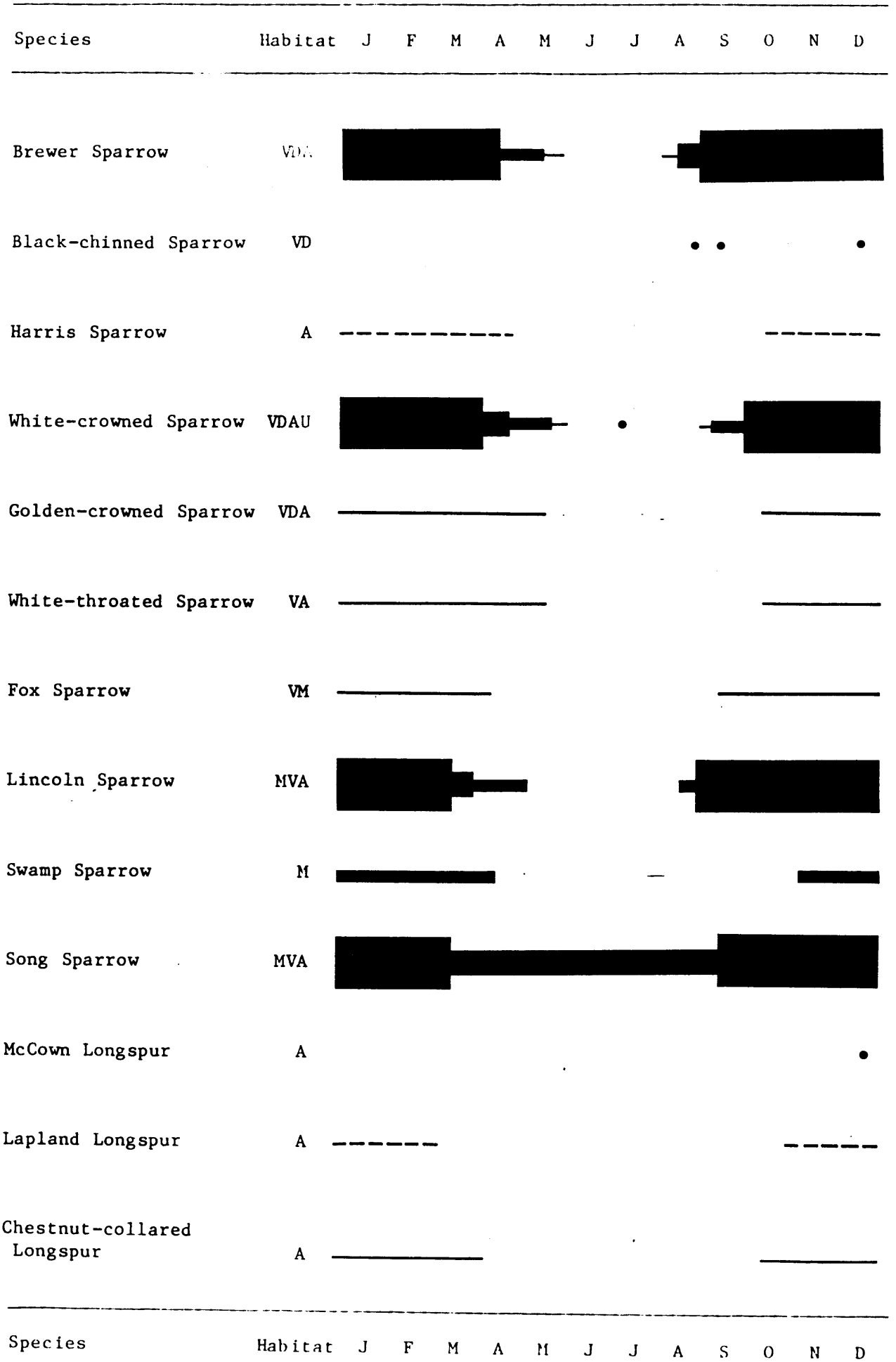
Species
Habitat
J F M A M J J A S O N D
Hooded Oriole* VU
Northern Oriole* VU
Scott Oriole D
Rusty Blackbird V
Brewer Blackbird AUV
Great-tailed Grackle* MAU
Common Grackle AV
Brown-headed Cowbird* VAU
Bronzed Cowbird* U
Western Tanager VD
Scarlet Tanager V
Hepatic Tanager V
Species
Habitat
J F M A M J J A S O N D



Species Habitat J F M A M J J A S O N D


Species
Habitat
J F M A M J J A S O N D
Purple Finch V
Cassin Finch V
House Finch* VDAU
Pine Siskin V
American Goldfinch VA
Lesser Goldfinch* V
Lawrence Goldfinch* V
Red Crossbill VU
Green-tailed Towhee VA
Rufous-sided Towhee V
Abert Towhee* V
Lark Bunting A
Species
Habitat
J F M A M J J A S O N D

Species Habitat J F M A M J J A S O N D


Species
Habitat
J F M A M J J A S O N D
Brewer Sparrow
VDA
Black-chinned Sparrow
VD
Harris Sparrow
A
White-crowned Sparrow
VDAU
Golden-crowned Sparrow
VDA
White-throated Sparrow
VA
Fox Sparrow
VM
Lincoln Sparrow
MVA
Swamp Sparrow
M
Song Sparrow
MVA
McCown Longspur
A
Lapland Longspur
A
Chestnut-collared Longspur
A
Species
Habitat
J F M A M J J A S O N D

CHAPTER 5

AVIAN USE OF RIPARIAN VEGETATION

INTRODUCTION

The conclusions regarding management of riparian communities for birds were derived from monthly censuses for four consecutive years (1976 to 1979) in all major riparian vegetation types along the lower Colorado River. Censusing data were supported by three years (1978 to spring 1981) of work involving vegetation manipulation that included revegetation plots designed to satisfy the habitat needs of some of the most sensitive or lowest density species in the lower Colorado River valley. Other data sets such as food habits, foraging behavior, and individual species studies are included to aid land managers in making habitat management decisions. In all, 84 months of continuous data collection on birds were used in compiling the information in this chapter and the attendant management conclusions.

Even with a large data base, incomplete analysis could lead to erroneous conclusions. To avoid this problem we have analyzed the data in several different ways and used the information from the revegetation plots to confirm or refute our conclusions. As an aid to understanding and following the analyses, which may at times seem complex, we have provided a description in Figure 5-1.

Management conclusions are based on the associations between each of nine avian community components and sixteen riparian vegetation characteristics. Avian community components are species or groups of species that tend to have similar vegetation and seasonal relationships. First, we present a summary of characteristics of vegetation most highly associated with avian use. This step introduces the reader to the vegetation variables and provides the first insight into how management might proceed. The next step is to show seasonal variation in vegetation use, again disregarding differences between avian variables and annual variation. This illustrates the distinct seasonal variation in habitat use by birds. Next we indicate differences in association with the vegetation among the various avian components. At this point we arrive at some tentative management conclusions. The conclusions are basically accurate in identifying vegetation characteristics to be enhanced in order to increase bird populations, but the picture is complex and it is not clear how to overcome problems caused by seasonal shifts in avian habitat preference. Some habitats are extremely important to some bird species during certain seasons and may not be heavily used during other seasons. Unfortunately we cannot move habitats in and out of an area between seasons in order to accommodate seasonal changes in preferences by birds.

The range, average, and standard deviation of correlation coefficients, disregarding seasonal variation, indicate the average strength and variability of the association between each avian variable and the vegetation. This is important because if the response of a particular

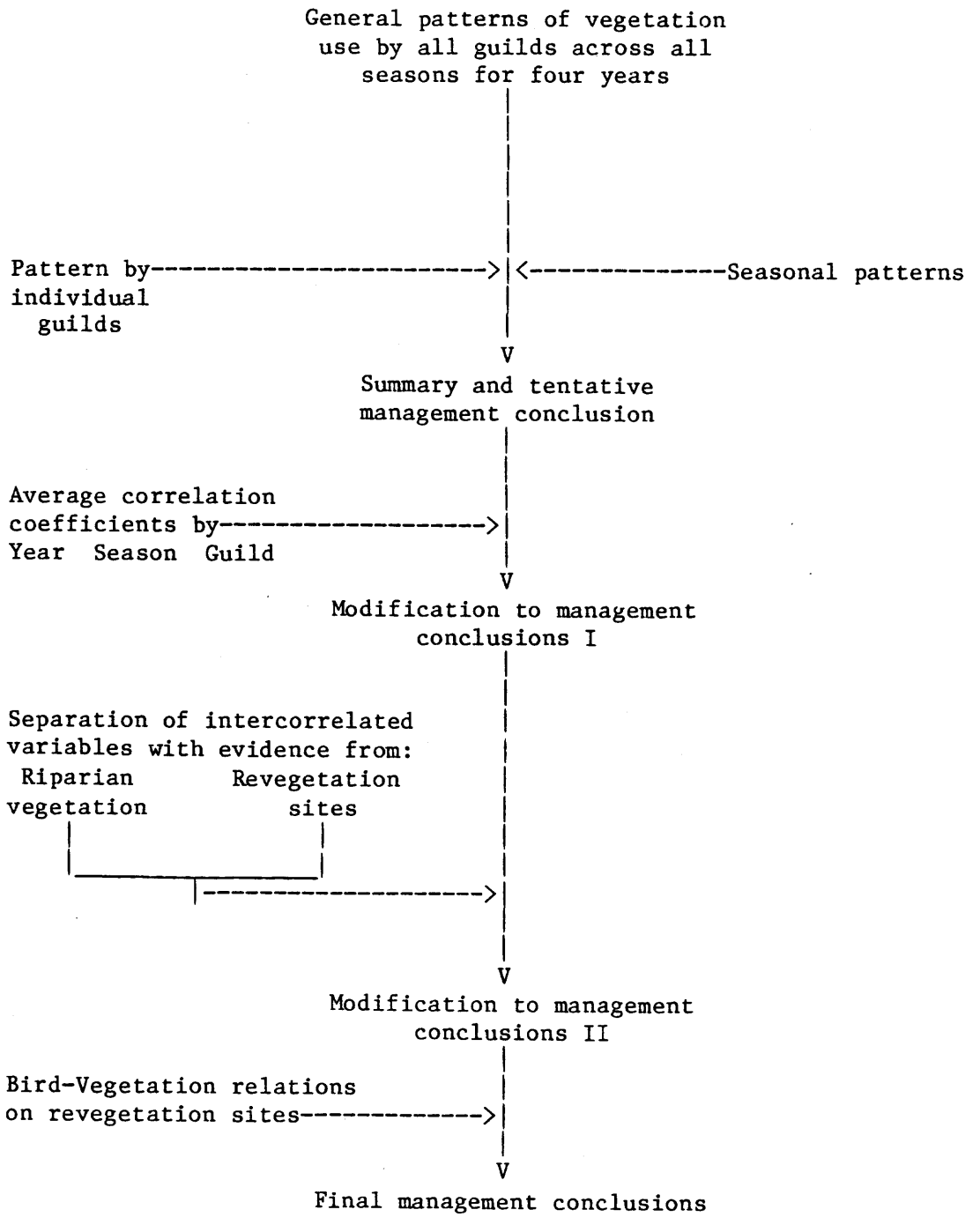


Figure 5-1. Flow diagram showing the steps involved in reaching recommendations for managing habitats for enhancement of birds.

bird species or group of species to some aspect of vegetation is consistently strong, as indicated by a high average coefficient of correlation and low variance, the needs of this group must be provided with relative precision. On the other hand, those avian groups with low average coefficients of correlation and high variances have more general associations with vegetation, although each species within a group may have fairly explicit associations with vegetation.

This analysis of avian correlations with vegetation is repeated for seasons, disregarding variation introduced by different avian groups. This is important because in a given season if all species composing a group react to the same element of the vegetation (species overlap is high), the coefficient of correlation is likely to be much higher than if each species reacts to a different aspect of the vegetation (species overlap is low). The mean coefficient of variation for a given season is higher in groups in which all bird species react to the same element of the vegetation. This analysis is supplemented with conclusions from previous reports.

Finally, the mean coefficients of correlation and their associated variances from year to year are presented. If more members of an avian group share habitat preferences for more than one season (i.e., they have more habitat overlaps across seasons), the mean correlation coefficients will be higher. If several groups show this response, the mean for the year will be higher. At this point, tentative management recommendations are modified.

Since the vegetation variables used in the analysis are really principal components (see Methods), each including several intercorrelated vegetation variables, it may be unclear precisely with which vegetation characteristics the birds are associated. Of course, the more complicated the network of variables that seem to attract birds, the more complicated the actual management procedures become. Significant progress in understanding groups of intercorrelated variables was possible using data from sites where the vegetation was manipulated in various ways. These results are potentially important because they further narrow the range of variables to which birds are particularly attracted. This knowledge can simplify management efforts.

Finally, the association between the vegetation and each avian group on the manipulated sites was considered. This analysis was made within the context of variation found within riparian vegetation in general. Final management recommendations were made on the basis of refinements arrived at through this analysis.

The included information should be used in making management decisions and designing enhancement projects. If predictions concerning the outcome of habitat modifications are desired, the predictive model that we have developed should be used (Rice et al. 1982).

METHODS

Avian Variables

Nine variables were used to describe the avian community: (1) total species richness (TSP), (2) number of species of permanent resident insectivores (SPRI), (3) number of species of visiting insectivores (SVI), (4) density of permanent resident insectivores (DPRI), (5) density of visiting insectivores (DVI), (6) density of Gambel Quail (DGQ), (7) density of doves (DO), (8) density of passerine granivores (DGR), and (9) density of frugivorous species (DFR). These categories represent the major avian components of the riparian vegetation system we studied. Another group might have included hawks and owls, but density data for birds of prey were so scanty that few, if any, valid conclusions concerning their associations with the vegetation could have been reached. The number of species of doves, passerine granivores, and frugivores was not analyzed because, although densities of these groups varied substantially from one vegetation type to another, the number of species varied little.

There are some potential dangers associated with analyzing avian groups such as those described above, especially in determining density associations with vegetation. First, if the density of one bird species was much greater than that of other species, the analysis is likely to reflect vegetation associations of dominant species rather than of the group. However, if the distributions of the various species were highly intercorrelated, this should not be a problem.

Second, when one or two bird species were numerically much more abundant than one or more other species, management recommendations based on analysis of entire groups could lead to elimination of the scarcer species, unless their distribution was positively correlated with the abundant species. This problem was avoided by considering species richness as well as densities. Management recommendations made with the aim of maximizing species richness as well as densities should decrease the likelihood of eliminating scarce species.

Gambel Quail and doves were often present in relatively large densities, but the two species had different habitat preferences. Analysis of census data for these two species was done separately from one another and from other granivores. Densities of passerine granivorous species were considered as a single group because only a small number of granivorous species occurred in any one vegetation type, and this number was fairly constant across all vegetation types. Since many granivorous species reach maximum densities in agricultural land and occur only occasionally in riparian vegetation, a clear characterization of habitat associations was difficult.

Vegetation Variables

The 16 vegetation variables included foliage density and patchiness at 0.2-0.6 m, 1.5-3.0 m, >4.5 m, and total; FHD; and n/acre of shrubs, honey mesquite, honey mesquite with mistletoe, screwbean mesquite, cottonwood and willow; and proportion of total trees which were salt

cedar (see Chapter 8, Table 8-3). Many of these were intercorrelated; i.e., as the value of one variable increased, there were parallel increases in other variables. This can confound attempts to evaluate avian response to each separate variable. This problem was overcome by using principal components analysis (PCA) of the vegetation data.

PCA reduces a large set of intercorrelated variables to a set of uncorrelated components. These components are essentially a new set of derived variables that are statistically independent of each other. Although each of the derived components is often more complex than any single variable from the original set, it is usually readily interpreted. Each habitat type was given a single value for each derived variable; thus, the principal components (PC's) could be used as continuous variables in subsequent analyses.

With PCA each vegetation type receives a factor score on each PC. The variance explained by each PC = ΣFS^2, where FS is the factor score for each variable on a given PC. The variables with the highest factor scores on each PC are used to define that PC, which may be considered a newly derived variable. The derived variables from the PCA were: (1) the first PC was defined as number of cottonwood-willow trees and foliage density and diversity (DD); (2) PC 2 positive was defined as density and proportion (number SC divided by total trees present) of salt cedar (SC and PSC) present; (3) PC 2 negative was defined as number of honey mesquite, honey mesquite trees with mistletoe, and shrubs (HS) per acre; (4) PC 3 was defined as foliage density and diversity at 0 to 0.6 m (0 to 2 ft; DL 0-0.6 m); and (5) the fourth PC was defined as number of screwbean mesquite trees (SB) per acre. Familiarity with the vegetation was helpful in interpreting data analyzed with PCA. This PCA was conducted for each year separately. With all years combined the results were fundamentally the same (Chapter 8, Table 8-3). When more than one variable was combined in a single component, it was usually not possible to decide to which variable the birds were responding when there was a significant correlation, unless we had special insight. Frugivorous birds, for example, were associated with the derived variable which included honey mesquite, mistletoe, and shrubs. In this case, we know it was the fruit of the mistletoe that attracted these birds, a fact readily confirmed by observation. But when a group was associated with DD, it was not clear which of the four major variables associated with that PC the birds preferred. The factor scores on each principal component for each plant community type, each year are presented in Appendix 5-1.

Avian-Vegetation Associations

Associations between avian variables and the derived vegetation variables were determined with stepwise multiple linear regression analyses. Multiple regression was used because it seemed possible for birds to be associated with more than one of the vegetation variables (PC's). The first variable to enter the stepwise analysis was the derived variable having the largest simple correlation coefficient (r) with the particular avian variable being considered. The square of the correlation coefficient (r^2) represents the proportion of the variance in the avian variable which was accounted for by its association with

the derived variable. The remaining unexplained variance is called the residual. The next vegetation variable to enter the analysis was the one having the largest correlation with the residual. This was repeated for up to four steps, as long as the newly added variable explained an additional 5% of the variance. We felt that these restrictions (only 4 steps and at least 5% of variance explained), while arbitrary, were most likely to result in the inclusion of only those variables which were biologically interpretable.

Nonlinear Associations. Some avian associations with particular vegetation characteristics were readily apparent from field observation. For example, frugivorous birds occurred wherever mistletoe berries occurred, and the more mistletoe, the greater the number of birds. A linear regression model was clearly appropriate for quantitative confirmation or denial of such an association.

Early in our field work, we observed that Yellow-rumped Warblers were abundant in certain sparse habitats as well as in certain dense habitats. Black-tailed Gnatcatchers increased in numbers as the number of shrubs and mesquite trees increased to a certain density. After that, further increases in vegetation density corresponded to reduced numbers of gnatcatchers. These, and other similar examples, normally would be inadequately explained by any method assuming a strictly linear relationship between birds and the vegetation. One may often establish simple patterns of relationship in such data by first standardizing and then transforming the data.

Standardization of data merely indicates that we assigned the value of zero to the sample mean. Other values are standardized by subtracting the mean and dividing by the standard deviation. Values larger than the mean take on positive values, while those smaller than the mean assume negative values. When this is done, nonlinear relationships can often be detected by transforming the vegetation variables to the second, third, and fourth powers (Fig. 5-2).

To illustrate this, assume that in five locations the standardized data for a vegetation variable were 2, 1, 0, -1, and -2; the corresponding avian densities were 0, 2, 4, 2, and 0. Clearly, a linear model will not detect any meaningful relationship. Squaring the values for the vegetation variable yields values of 4, 1, 0, 1, and 4. The avian values corresponding to this new set of values for the environmental variable can now be described by a negative linear model (lower left illustration, Fig. 5-2).

Since many nonlinear associations can be imagined, an analysis cannot include an evaluation of all possible nonlinear relationships. The nonlinear relationships we examined were based on their likelihood of occurrence, which were derived from our observations and past data interpretations. Other nonlinear relationships may exist. We feel that a search for these curvilinear relationships allows us to detect at least some of the nonlinear relationships that might not be detected by considering only linear relationshps. We have presented more methodological detail elsewhere (Meents et al. 1983).

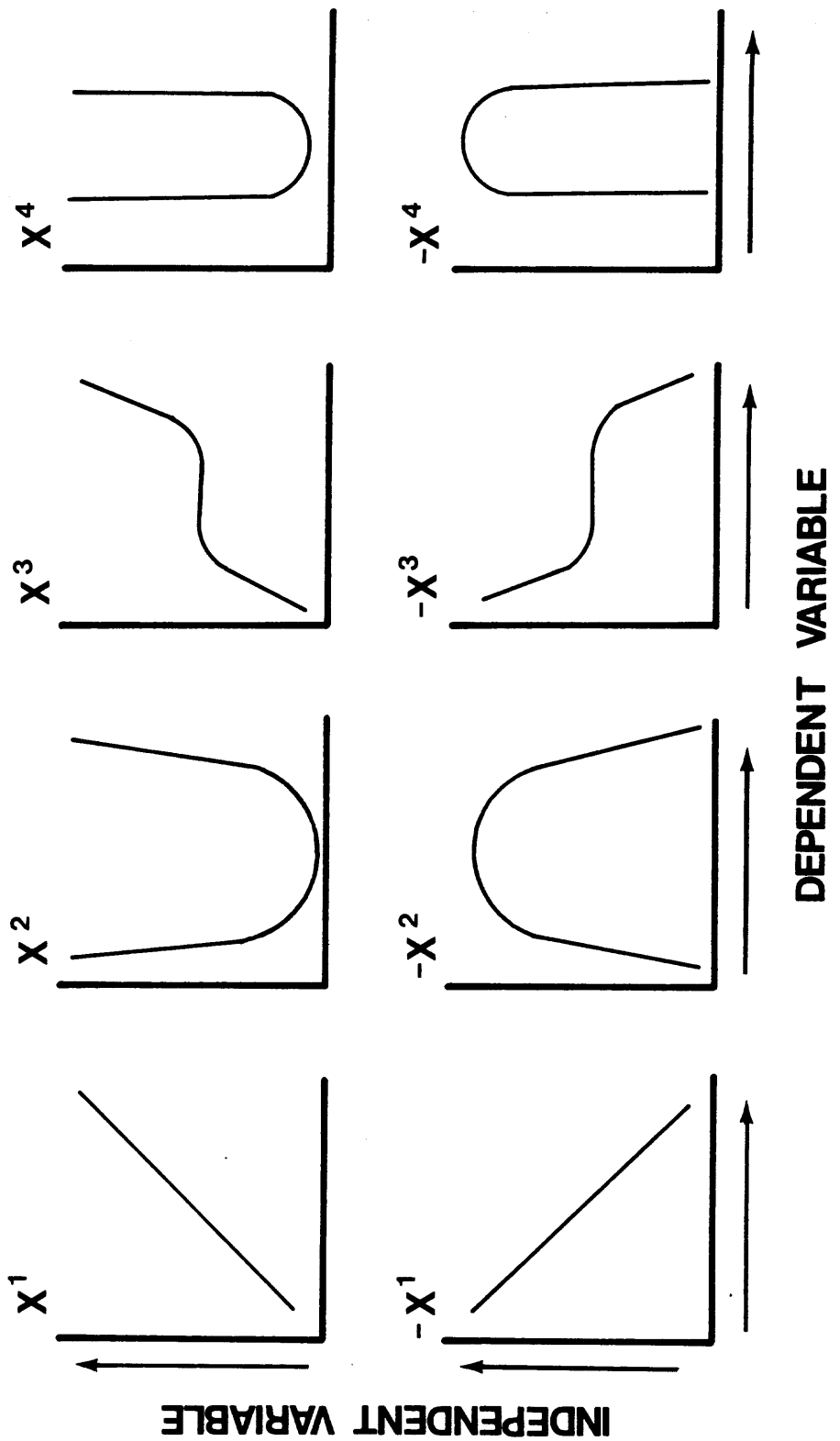


Figure 5-2. Some linear and nonlinear relationships.

Other Assumptior Correlation Analyses. Parametric correlation analyses, including PCA, assume that the data of both the independent and dependent variables fit normal distributions. To help insure that this assumption was met, we used square-root transformations for independent and dependent variables with values <1.0, and $\log_{10}(N + 1)$ transformation for variables with values $\geq$1.0.

RESULTS AND DISCUSSION

General Pattern of Avian-Vegetation Associations

The general pattern of avian use of the riparian vegetation was determined by tabulating the number of times that a vegetation variable occurred as a step in a significant regression equation across all seasons and years. The tabulation was subdivided into bird-vegetation associations that were more or less linear (independent variable raised to the first or third power) and either positive or negative. Highly curvilinear associations ($\pm x^2$ and $\pm x^4$) were also tabulated.

This analysis revealed that foliage density and diversity and the number of cottonwood and willow trees (DD), and numbers of honey mesquite trees, mistletoe, and shrubs (HS) were included in significant equations far more frequently than were other vegetation variables (Fig. 5-3). The contributions were primarily positive, with a significantly greater proportion of positive contributions by DD. DD was more important than HS because it had more positive contributions; this indicates that DD was more frequently positively associated with the bird density and diversity variables than was HS. Although screwbean mesquite had a high proportion of positive contributions, it was selected far less frequently than DD or HS. This indicated that screwbean mesquite trees were important to one or a few of the avian groups or were important to more than one group at restricted times of the year.

Negative contributions to equations explaining a significant portion of the variance in the avian variables most frequently included salt cedar (Fig. 5-3). In addition, salt cedar seldom made positive contributions. Overall, birds seemed to avoid vegetation that included a large number of salt cedar trees.

Nonlinear contributions were common, ranging from 26% of the total contribution by DD to 46% of the contribution by foliage density and diversity at 0 to 0.6 m (0 to 2 ft; DL 0-0.6 m). Curvilinear contributions can be of two types: (1) intermediate values of the vegetation variable are associated with larger values of the avian variables (x^2 or x^4, Fig. 5-2), or (2) intermediate values of the vegetation variables are associated with the smallest values for avian variables ($-x^2$ or $-x^4$, Fig. 5-2). Failure to consider curvilinear relationships would mean missing one-third to one-half of the total significant bird-vegetation relationships.

For those involved in management and mitigation decisions, the results so far indicate that bird-vegetation relationships are complex. Although DD and HS were important to birds, some groups avoided areas with high values of these variables (negative contributions), and some

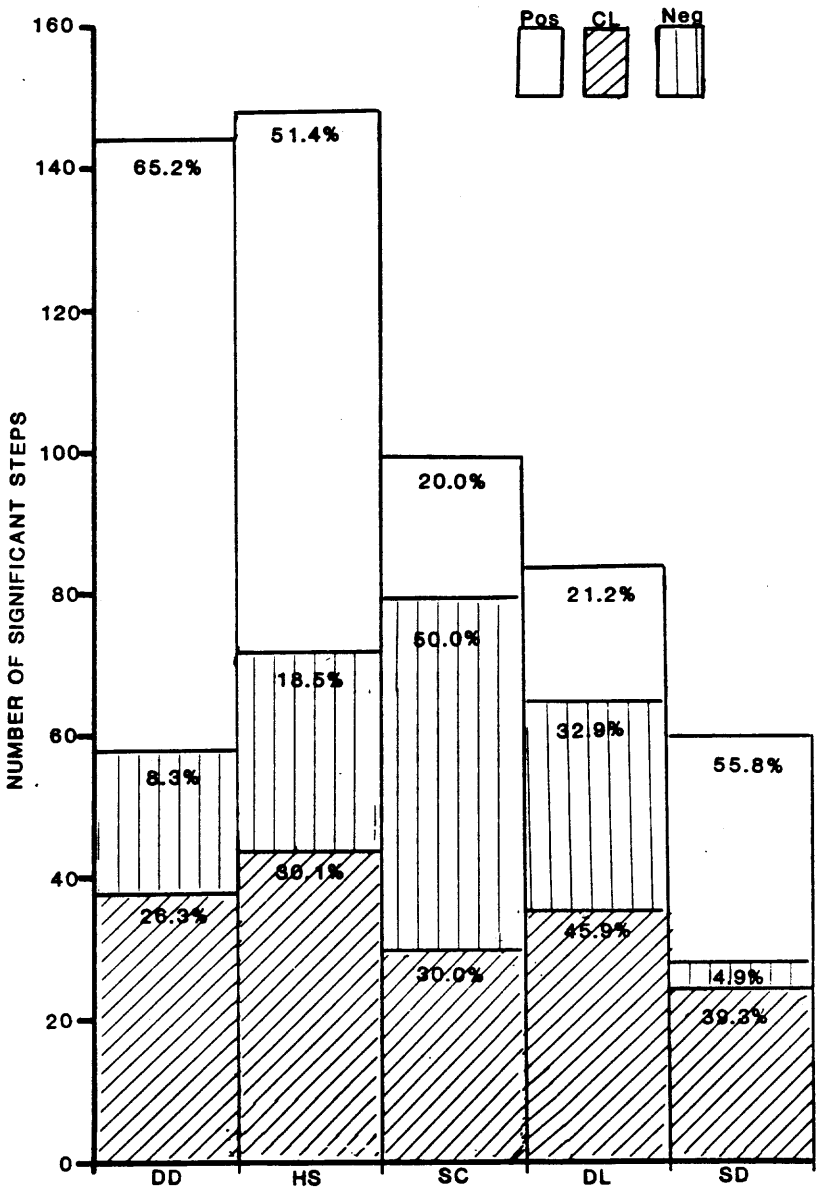


Figure 5-3. General pattern of avian association with the riparian vegetation. Percentages indicate the proportion of each type of relationship. Pos = positive linear relationship, CL = positive or negative curvilinear relationship, Neg = negative linear relationship. DD = total foliage density and diversity and the number of cottonwood and willow trees; HS = densities of honey mesquite trees, mistletoe, and shrubs; SC = salt cedar; DL = foliage density and diversity 0-0.6 m; SB = density of screwbean mesquite trees.

were associated with intermediate values (nonlinear contributions) of these variables. Screwbean mesquite was important for certain seasons, generally to only one or a small number of the groups studied.

Seasonal Variations in the General Pattern of Avian-Vegetation Associations

In spring, summer, and late summer, DD made more positive contributions to the regression analyses than any other variable (Fig. 5-4). In fall and winter, HS was the most important vegetation variable in explaining the variance in the avian variables. Screwbean mesquite was a more important positive contributor in summer and late summer than at other seasons.

Salt cedar was the most important negative variable in spring, fall, and winter. In summer, HS was the most frequent negative variable, and it was a common negative variable in spring and fall, indicating that it was important to some of the avian groups studied but was avoided at certain times of the year by some birds. DD, in contrast, was seldom a negative variable. In late summer, DD was the most frequent negative variable. This variable was seldom positive in the equations; it seemed to be basically neutral or avoided by the groups studied.

In assuming that an even distribution of curvilinear reactions between seasons (i.e., about 20% of the total each season) is expected by chance, we found that curvilinear reactions to the vegetation were significantly ($P \leq 0.02$) more abundant in spring (47%) and less abundant in fall (22%) than expected (33% for each). Separate evaluation of each of the derived variables revealed that DD was involved in significantly ($P \leq 0.05$) more curvilinear reactions than expected in late summer and fewer curvilinear reactions than expected in fall. Salt cedar had the greatest number of curvilinear reactions in spring and fewest in fall. HS was involved in significantly ($P \leq 0.05$) fewer curvilinear reactions in late summer relative to other seasons, but no season had significantly ($P \leq 0.05$) more curvilinear associations. The distribution of curvilinear responses among the seasons did not deviate from an even distribution for DD 0-0.6 m or for screwbean mesquite. Thus, avian-vegetation relationships tended to vary between seasons and, in general, were more complex in spring and least complex in fall.

These results indicate that conclusions about habitat requirements for one season are not applicable to all seasons. Thus the avian-vegetation relationships discussed in the first section become more complex when seasonal variation is considered. Management for a large segment of the avifauna is clearly not a simple goal. The avifauna as a whole not only responds to different environmental characteristics in different ways (linear or curvilinear), but these responses vary seasonally. With this in mind, the associations of each of the avian groups with the vegetation will be discussed.

Patterns of Use by Avian Groups

Total Species. Total species richness was associated with DD more frequently than with any other variable; HS was second (Fig. 5-5). Salt

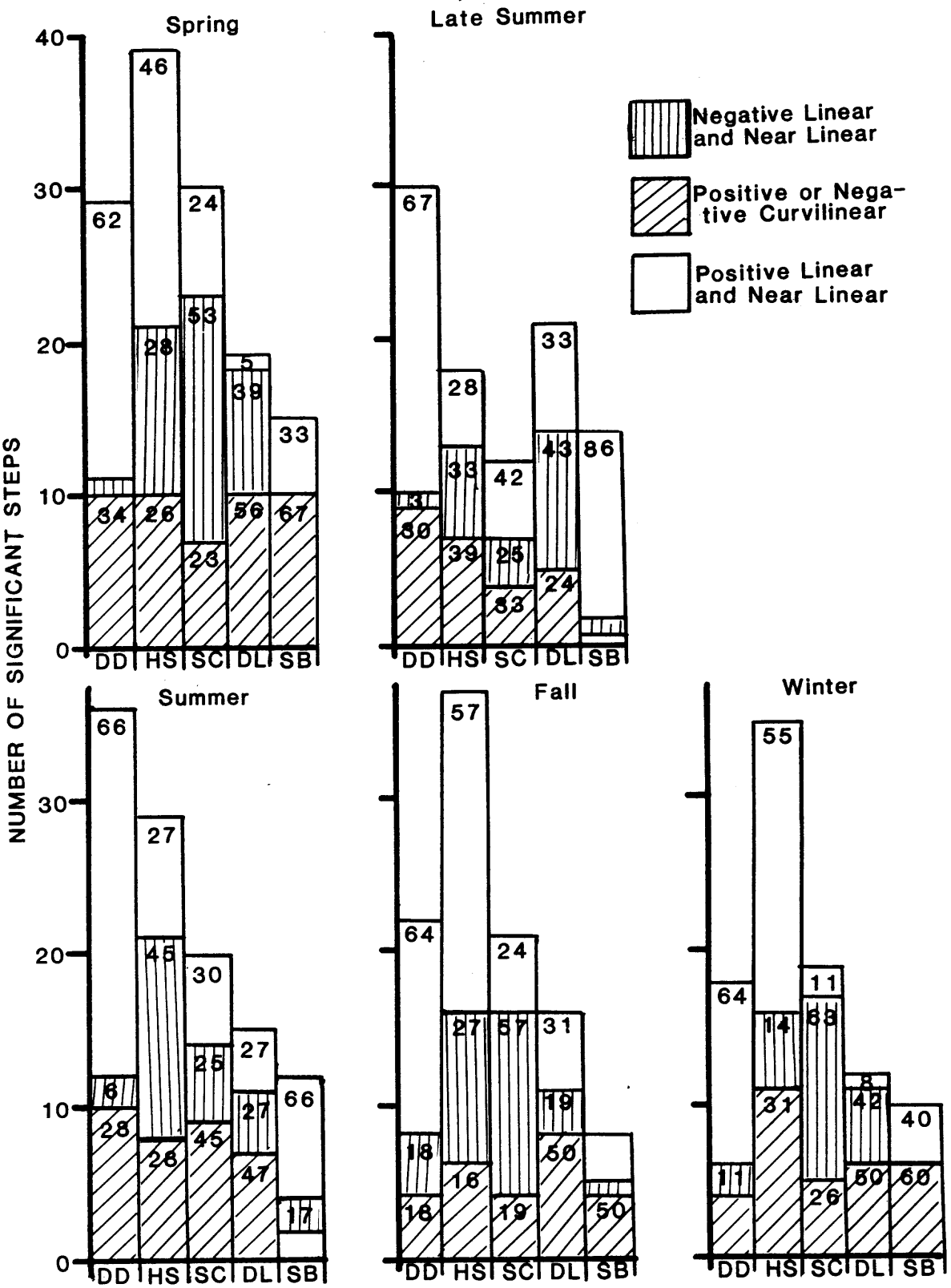


Figure 5-4. Pattern of avian associations with the riparian vegetation by season. Numbers in each graph indicate the percent of each type of relationship. Abbreviations as in Figure 5-3.

Figure 5-5. Pattern of association between avian guilds and the derived vegetation variables. SPRI = number of species of permanent resident insectivores, SPVI = number of species of visiting insectivores, DVI = density of visiting insectivores, DPRI = density of permanent resident insectivores, DDOVES = density of doves, DGQ = density of Gambel Quail, DGR = passerine granivores, DFR = density of frugivores. Open bar refers to positive linear relationships including positive reactions to the third power; stippled bar refers to negative relationships including negative reactions to the third power; diagonally striped bar = highly curvilinear reactions (positive and negative), variables were raised to the second or fourth power. Abbreviations of vegetation variables as in Figure 5-3.

cedar was the variable most frequently negatively associated with species richness. DD and HS were most frequently involved in curvilinear reactions, indicating that relationships were not simple. Screwbean mesquite was not often an important variable, but it was most often positive when it was selected.

Each species was placed into one of several rather broad guilds on the basis of their length of stay in Colorado River habitats and on the basis of diet. The dietary designations were based on stomach contents of more than 8,000 specimens collected by us (Anderson, Gabaldon, and Ohmart unpubl. data). Insectivores ate primarily insects; granivores ate seeds and plant parts; and frugivores ate mostly mistletoe berries.

Species of Permanent Resident Insectivores. The number of species of permanent resident insectivores was most frequently associated with DD and HS (Fig. 5-5). It was negatively associated with salt cedar. Curvilinear associations were uncommon and fairly evenly distributed among the vegetation variables.

Species of Visiting Insectivores. The number of species of visiting insectivores was by far most frequently associated with DD (Fig. 5-5). Negative associations were most common with HS, but positive associations with this variable were almost equally as common.

Density of Visiting Insectivores. Densities of visiting insectivores increased as DD increased (Fig. 5-5). Screwbean mesquite was associated with large densities of visiting insectivores less often than expected by chance. There were fewer positive associations of visiting insectivores with screwbean mesquite than expected by chance.

Density of Permanent Resident Insectivores. There was a tendency for densities of permanent resident insectivores to increase as DD increased (Fig. 5-5). Associations with HS and screwbean mesquite were significantly more common than expected by chance. Densities of permanent resident insectivores decreased as foliage density and diversity 0-0.6 m (DL) increased.

Density of Doves. Dove densities tended to decrease as DL increased (Fig. 5-5). Positive associations were significantly more frequent with screwbean mesquite than expected by chance.

Density of Gambel Quail. Gambel Quail numbers tended to increase as HS increased; quail numbers decreased as salt cedar increased (Fig. 5-5). When DL was important, it tended to be nonlinear. There were fewer negative associations with DL than expected by chance.

Density of Passerine Granivores. Density of granivores was related to HS; this relationship was primarily positive or curvilinear (Fig. 5-5). Granivore numbers generally decreased as the amount of DL increased.

Density of Frugivores. Frugivore densities increased as HS increased, although this relationship was frequently curvilinear (Fig. 5-5). Frugivores had almost all negative associations with salt cedar.

Summary Analysis

Two-thirds of the avian groups showed increasing numerical values as HS increased, and five-ninths of the groups increased as DD increased. No avian group increased as salt cedar increased, but four-ninths of the avian groups decreased as salt cedar density increased. The number of species of visiting insectivores showed some tendency to decrease as HS increased, and the density of permanent resident insectivores decreased as DL increased.

A management plan designed to enhance DD and HS would enhance eight of the nine avian variables over a period of years. Adopting such a plan could, however, result in lowered habitat values for some groups at certain seasons. It is clear, however, that DD and HS are important to birds of the lower Colorado River and that salt cedar is apparently avoided by some species.

Association with DD, SC, and HS. The avian groups studied were associated with foliage density and diversity to a greater extent than with other vegetation variables. This derived variable explained more of the variance in the avian data than did other vegetation variables. DD was particularly important in attracting large numbers of species, species of visiting insectivores, and densities of visiting and permanent resident insectivores. Areas of high DD were, however, avoided by frugivores and Gambel Quail. In some seasons, areas of high DD were avoided by granivores and had reduced numbers of species of permanent resident insectivores. Birds tended to have the greatest association with DD in spring and summer.

Salt cedar tended to have low associations with the number of species of permanent resident insectivores, granivores, and Gambel Quail. These groups were apparently attracted to stands of honey mesquite with mistletoe and shrubs.

Curvilinear Associations. Some groups were associated with certain salt cedar/honey mesquite/shrub stands and avoided others. Such reactions were of two basic types: (1) some avian groups were attracted to dense or sparse vegetation and avoided intermediate areas, or (2) they were attracted to intermediate stands of vegetation and avoided very dense or sparse stands (- reactions). These curvilinear relationships were typical of species of visiting insectivores and densities of permanent resident insectivores and, in some seasons, passerine granivores and Gambel Quail. Such associations tended to be strongest in spring.

Screwbean Mesquite. In spring, summer, and late summer, screwbean mesquite supported particularly large densities of doves. Screwbean mesquite was avoided by doves in winter, by granivores and Gambel Quail in spring, and by visiting insectivores in fall.

DL. DL attracted doves and quail and a variety of species of permanent resident insectivores in some seasons. In other seasons, quail and visiting insectivores were attracted to areas of moderate foliage density and diversity but avoided areas of either high or low foliage densities at low levels. During some seasons, areas with well-developed

low level vegetation were avoided by several species of permanent resident insectivores and, in general, they supported low species richness, especially in summer and late summer.

Average Correlation Coefficients

Thus far, we have emphasized the number of times the derived variables were involved in significant correlations. Nothing has been mentioned about the strength of the correlations. In this section, we discuss the multiple correlation coefficients resulting from the avian associations with the derived vegetation variables. This will be done in three ways. First, we present the average, range, and standard deviation of correlations with vegetation variables for each of the nine avian groups for all seasons and years combined. As an indication of how precise the mean is, relative to the sample sizes involved, we present the range within which the true mean could be expected to fall 95% of the time; i.e., two standard errors of the mean. Second, we present this information for each season. The data within a season will include correlations for the nine avian variables for the four years. Finally, correlations were averaged across all seasons and avian variables for each of the four years.

Average Correlation Coefficients for Each Avian Group. Those avian variables with the greatest average correlations with the vegetation variables (Fig. 5-6) are the ones requiring special attention, for they are the groups which consistently have highly specific requirements across seasons and years. The top three groups in this category were frugivores and density and species richness of visiting insectivores. In each of these three groups, an average of more than 60% of the variance (variance = R^2) was explained by relationships to vegetation. Densities of permanent resident insectivores and Gambel Quail had intermediate associations with vegetation. Density of doves, total species richness, density of granivores, and species of permanent resident insectivores were least consistently associated with the derived vegetation variables. This means that the vegetation characteristics that attracted groups with the most specific requirements probably also attracted at least a moderate number of those birds that had low average correlations with vegetation. However, since the last four groups were not strongly related to the vegetation, it is tempting to conclude that members of this group are generalists. This may not be true in that we might get the same results if each species within a group tended to seek a specific element of the vegetation, and this element was different for each species. Management for the top groups would, in that case, also include moderate values for the other groups, but some species might be eliminated altogether. This will be considered in more detail later.

Average Correlation by Season. Average correlations with the vegetation were highest in summer, followed by fall, spring, winter, and late summer (Fig. 5-7). This could mean that the species composing all groups were attracted about equally by the same feature in the vegetation in summer, but at other seasons the species composing the avian groups tended to be associated with separate vegetation characteristics. A lower mean value in late summer could indicate that

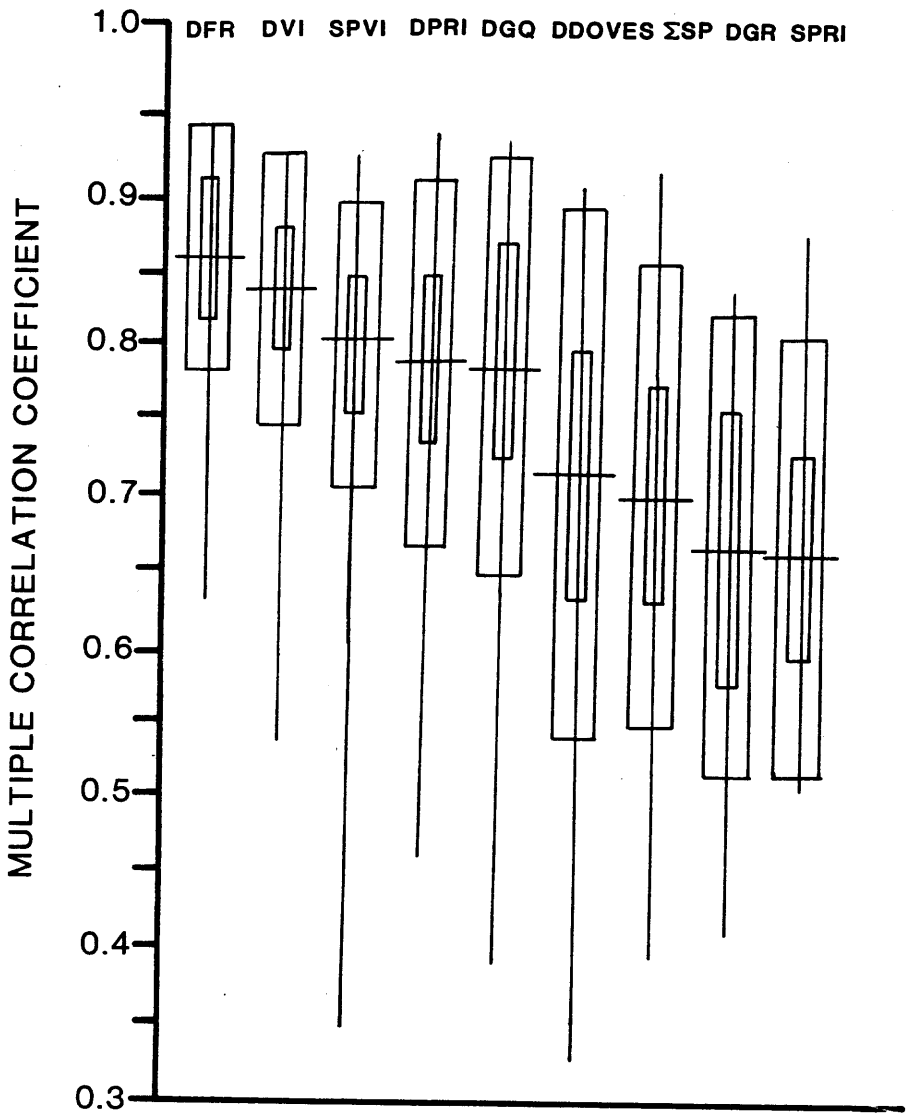


Figure 5-6. Mean coefficients for avian guild correlations with the derived variables. Abbreviations as in Figure 5-5. The horizontal line represents the mean; the vertical line, the range; the large rectangle, one standard deviation; the small rectangle, two standard errors of the mean. Each season represented a case. Since there were five seasons and four years, the statistics are based on a sample of 20 for each guild. The guilds are arranged from the largest to the smallest mean.

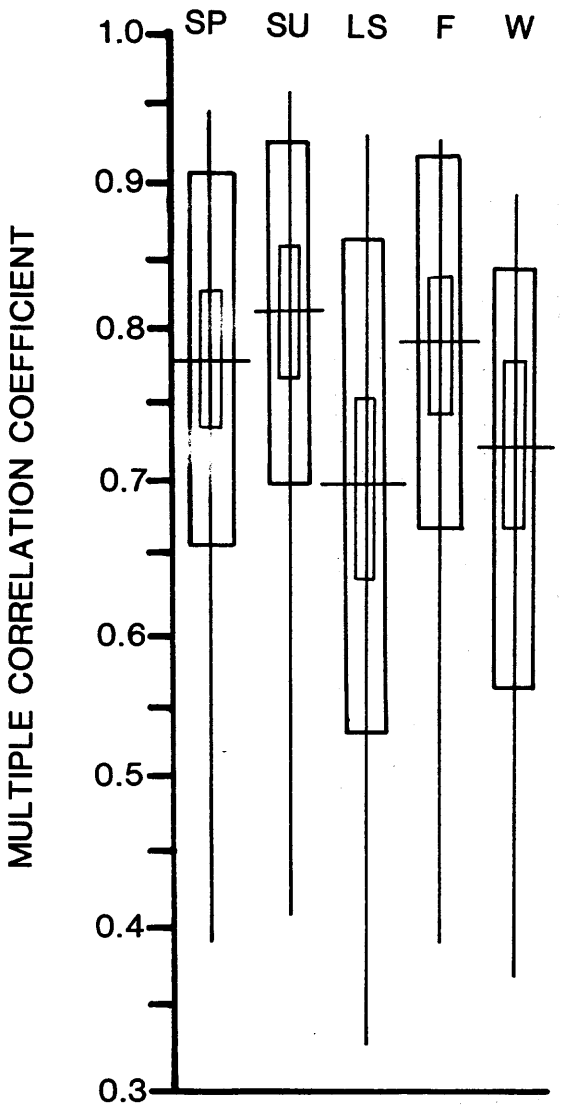


Figure 5-7. Mean coefficients of correlations between avian guilds and derived vegetation variables by season. SP = spring, SU = summer, LS = late summer, F = fall, W = winter. Symbols as in Figure 5-6. A correlation coefficient for one guild for a given year constituted one case for a season. Since there were nine guilds and four years, the statistics are based on a sample of 36 in each season.

all species within each group were generalists. If this were true, it would make management easier, because it would mean that the vegetation characteristic selected at one time of year by all avian groups would also attract reasonable numbers of birds in other seasons. We have tested this concept and detailed results have been presented elsewhere (Anderson and Ohmart 1980, Rice et al. 1980). Our results indicated that species overlaps and habitat breadths were greatest in summer and smallest in winter, but specific habitat preferences were greatest in winter. The tendency for habitat breadths and overlaps to be low in winter was more pronounced in harsh winters than in mild winters.

In a management context, the high correlation coefficients found in summer plus the information above shows that, in general, birds composing the various groups were found in the same habitat types at that season and that they were fairly general in their selection of habitats.

The low correlation coefficients in winter are explained by the fact that habitat breadths or overlaps are small in winter. It would be a mistake to assume that birds were not habitat selective in winter. In fact, winter is the time of greatest habitat specialization. Greater attention must be given to habitat preferences at this time of year. Failure to do so could result in elimination of several species, even if summer habitat conditions were met.

Average Correlation by Year. Although significant differences did occur, associations with vegetation across avian groups and seasons were fairly similar from year to year (Fig. 5-8). The implication is that the findings in one year may be fairly similar to those during another year. The danger of only one year of data is that management based on conclusions drawn during a good year, when many species select more generalized habitats, might lead to elimination of species during poor years, when species habitat requirements are more specialized.

Management Conclusions

We know that, with the exception of frugivores, densities and numbers of species of visiting insectivores were more strongly associated with the vegetation than were any other avian groups (Fig. 5-6), and that vegetation relationships are stronger in summer than in other seasons (Fig. 5-7). We also know that densities and species of visiting insectivores were associated most often with DD (Fig. 5-5). In order to insure larger numbers for this guild, a management plan must include above-average foliage density and diversity and above-average numbers of cottonwood and willow trees compared to the average for riparian vegetation in the lower Colorado River valley. This action would also contribute to increases in total species richness and densities of permanent resident insectivores (Fig. 5-5).

Frugivores were found in riparian vegetation in fall, winter, and spring, when they were associated with mistletoe. Thus, in order to enhance presence and abundance of frugivores, management plans must include mistletoe. Management for the variables associated with mistletoe (honey mesquite and shrubs) would also enhance densities of

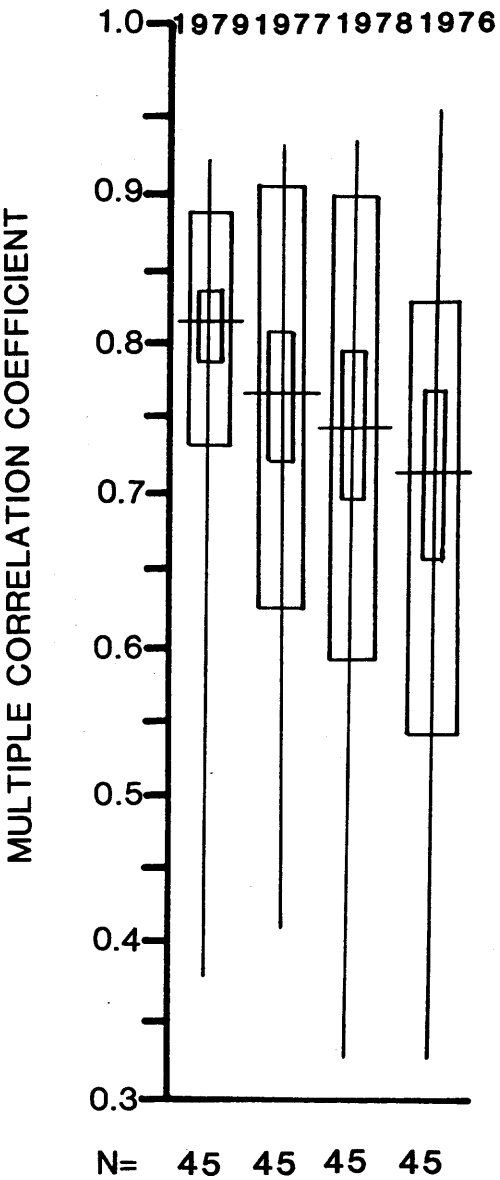


Figure 5-8. Mean coefficients of correlation between avian guilds and derived vegetation variables for each of four years. Symbols as in Figure 5-6. A correlation for one guild for one season constituted one case for a given year. Since there were nine guilds and five seasons, the statistics are based on a sample of 45 for each year. The years are arranged from the largest to the smallest mean.

granivores, quail, doves, and permanent resident insectivores, and species richness. This management recommendation and the first one, to include above-average numbers of cottonwood and willow trees, are not mutually exclusive; it is possible to have shrubby areas with mesquite and mistletoe that are dense as well as vertically and horizontally diverse. Avian species richness would apparently be sacrificed somewhat if the number of cottonwood and willow trees was reduced in order to increase honey mesquite, mistletoe, and shrubs (Fig. 5-5). However, a management plan designed to increase DD and HS theoretically would provide some benefits for most of the major avian groups considered.

The third management conclusion is that the effect of the first two recommendations can be enhanced by eliminating salt cedar. Five of the nine avian groups were negatively associated with salt cedar in one or more seasons (Figs. 5-2 and 5-5). Only the density of visiting insectivores was enhanced at any time by the presence of salt cedar. It is probable, though unproven, that removal of salt cedar from a mixed stand would enhance the area in terms of avian use (Anderson and Ohmart 1982; Chapter 3).

Separating Intercorrelated Variables

The derived variables from the PCA consisted of groups of highly intercorrelated variables. It would be useful to be able to separate these variables to determine if all or only one of the intercorrelated variables was associated with avian densities and diversities. It would also simplify management requirements if only one or two of a series of intercorrelated variables were important. Separate PCA's of the vegetation variables for each year helps clarify this.

Evidence from Riparian Vegetation Analysis. In most years, foliage height diversity (FHD), total foliage patchiness and density, and the number of cottonwood and willow trees were all combined into a single derived variable. However, in 1977, FHD and the number of cottonwood and willow trees were separated from the other variables. In 1977, cottonwood and willow trees and FHD contributed negatively to a separate derived variable that also included foliage density 0-0.6 m. In the other three years, foliage density and diversity 0-0.6 m were the only variables loading >0.5 on this derived variable (PC). This meant that areas with high FHD and numbers of cottonwood and willow trees had little foliage density at 0-0.6 m. Therefore, if the number of negative bird responses to this derived variable increased in 1977, it would suggest that increasing FHD and greater numbers of cottonwood and willow trees attracted more birds. If, at the same time, the number of positive responses to foliage density and patchiness (the remaining variables associated with the first derived variable) dropped, it would suggest that total foliage density and patchiness were not very important to birds. In 1977, there were 14 negative associations with the variable that included FHD and the number of cottonwood and willow trees. Based on the other three years, when negative reaction to this variable occurred at a rate of 0.246, we expected 6.9 of the 28 total reactions to be negative. The observed represents a significant (χ^2= 9.8, 2 df, $P<0.01$) deviation from expected, indicating that either FHD or the number of cottonwood and willow trees, or both of these

variables, were important to birds. On the other hand, there was no significant change ($\chi^2 = 1.31$, 2 df, $P>0.05$) for the overall responses to the first derived variable; thus patchiness and total foliage density were also important. Although this advanced our understanding of this complex of variables, it remained unknown if birds responded to both or only one member of these pairs of data. Further insight was gained from examining the results from the revegetation site.

Standardization of Variables on Revegetation Sites. Because data for less than three years were available, avian data from the revegetation sites were standardized for each season; i.e., densities for each season were adjusted to reflect their relationship to the average bird density, which was assigned a value of zero. Densities greater than the mean became positive values and densities lower than the mean became negative values. The mean for a given season was the average density for all riparian vegetation censused by us in the lower Colorado River valley for 1978 and 1979.

The standardized range for any given season was roughly -3 to +3. Standardization has the advantage of allowing us to pool the data for all seasons and years, thus allowing more effective use of data from only three transects on revegetated areas. Since there are five seasons for each of the three years, we have the potential for 15 data points per year (3 transects X 5 seasons). Actually, there were 14 points for one site, 15 for a second, and 20 for the third and oldest site.

The vegetation data from the revegetation transects were similarly standardized. Collection of revegetation data began when the sites were virtually bare areas and continued through spring 1981.

Separation of Variables on the First Derived Variable. The first derived variable from the original PCA of riparian vegetation included FHD, the number of cottonwood and willow trees, total patchiness, and total foliage density. On the revegetation plots, over all seasons and years, total patchiness and total foliage density were highly intercorrelated (Table 5-1). However, there is a fundamental difference between this correlation and the correlation in the riparian vegetation analysis. On the revegetation sites, total foliage density was correlated with the foliage density at 0-0.6 m (Table 5-1); in the original analysis these variables were not significantly correlated. On the revegetation sites, total foliage density and foliage density at 0-0.6 m were not significantly correlated with the number of cottonwood and willow trees. FHD was significantly correlated with the number of cottonwood and willow trees on the revegetation sites.

Separation of Variables on the Second Derived Variable. In the original analysis, honey mesquite trees and shrubs were intercorrelated on the second derived variable. On the revegetation sites, there were no honey mesquite trees >3 m (>10 ft) tall but, at various times, there were many shrubs. Thus, these variables were fully separated.

Among shrubs, only quail bush and inkweed were highly intercorrelated (Table 5-1), but both were also significantly correlated with smotherweed. Total foliage density and total patchiness were also significantly correlated with shrubs.

Table 5-1. Correlations of variables on the revegetation sites which were intercorrelated on various derived variables in the riparian vegetation analysis. Correlations $\geq$0.65 are significant at $\geq$0.05.

A. First derived variable

	Total patchiness	Cottonwood-willow trees	FHD
Total density	0.933	0.203	-0.311
Total patchiness	-	0.064	-0.436
Cottonwood-willow trees	-	-	0.663

B. Shrubs

	Inkweed	Smotherweed	Russian thistle	Total shrubs
Quail bush	0.927	0.752	-0.103	0.585
Inkweed	-	0.697	-0.096	0.518
Smotherweed	-	-	-0.176	0.589
Russian thistle	-	-	-	0.525

C. Third derived variable and intercorrelations with selected additional variables

	Patchiness 0-0.6 m	Total patchiness	Total foliage density	Total shrubs
Foliage density 0-0.6 m	0.941	0.936	0.995	0.821
Patchiness 0-0.6 m	-	0.976	0.845	0.490
Total patchiness	-	-	0.933	0.699
Total foliage density	-	-	-	0.731

Variables Associated on the Third Derived Variable. Foliage density and patchiness at 0-0.6 m were highly intercorrelated and each was highly correlated with shrubs.

Bird-Vegetation Relationships for 1981 on Revegetation Sites

Density of Passerine Granivores. The number of granivorous birds was strongly associated with shrub densities. When granivore densities were three to four standard deviations (SD) above the mean, the number of shrubs averaged more than two SD's above the mean (Fig. 5-9). When densities were between two and three SD's above the mean, shrubs averaged about 1.3 SD's above the mean. When granivore densities were 0.5 to 2 SD's above the mean, the number of shrubs was about average. Finally, when granivore densities were below average, the number of shrubs was significantly ($P<0.05$) below average.

A comparable series of graphs, showing how foliage density 0-0.6 m changed as granivore densities changed, could have been presented. This would have little or no biological meaning, however, because in the correlation for riparian vegetation (Fig. 5-5), granivores avoided foliage density of 0-0.6 m. In that analysis, arrowweed and salt cedar communities contributed heavily to foliage density of 0-0.6 m. When foliage density at 0-0.6 m was made up of shrubs, it became valuable to granivores. Thus, plant species and not foliage density attracted the birds. Granivores did not seem to be associated with any particular species of shrub on the revegetation sites. Number of species of granivorous passerines was also associated with the number of shrubs (Fig. 5-9).

Management conclusion: To attract high densities and diversities of passerine granivores, large numbers of shrubs must be present.

Gambel Quail. When densities of quail were larger than average, quail bush was present in significantly larger numbers than average (Fig. 5-10). The original analysis indicated an association between quail and shrubs (Fig. 5-5). With this additional analysis, we have achieved additional insight. Quail were consistently present in above-average densities only when quail bush was abundant; above-average quail densities were erratically associated with other shrubs.

Quail were also associated with foliage density and diversity on the revegetation sites. In the original analysis of the riparian vegetation, quail were associated only weakly with DL. The stronger association between quail and foliage density at 0-0.6 m on the revegetation plots occurred because quail bush made up a large proportion of the foliage density at this level.

Management conclusion: To increase quail numbers, especially around agricultural areas, dense stands of quail bush should be planted in close proximity to cultivated fields. See Chapter 8 for an in-depth discussion of quail habitat needs.

Permanent Resident Insectivores. Densities of permanent resident insectivores averaged higher than the average for riparian vegetation

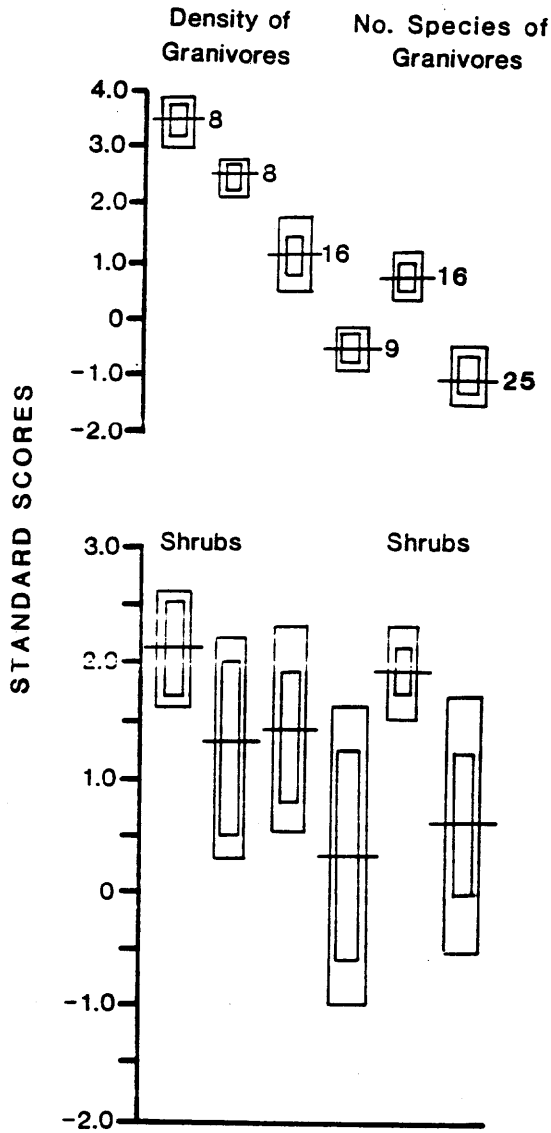


Figure 5-9. The relationship between density and species richness of passerine granivores with the number of shrubs on the revegetation sites. The bird variables are expressed in terms of standard deviation units relative to the average for riparian vegetation along the lower Colorado River. The number of shrubs is expressed as standard deviations of the mean for riparian vegetation. The numbers adjacent to the mean represent sample sizes. Standard scores for density and species richness of granivores are given on the top graph. The associated standard score for number of shrubs is given on the bottom graph. A significant relationship between granivores and shrubs is indicated when a shift in shrubs (up or down the standard score scale) is reflected by a similar shift in the granivore variable.

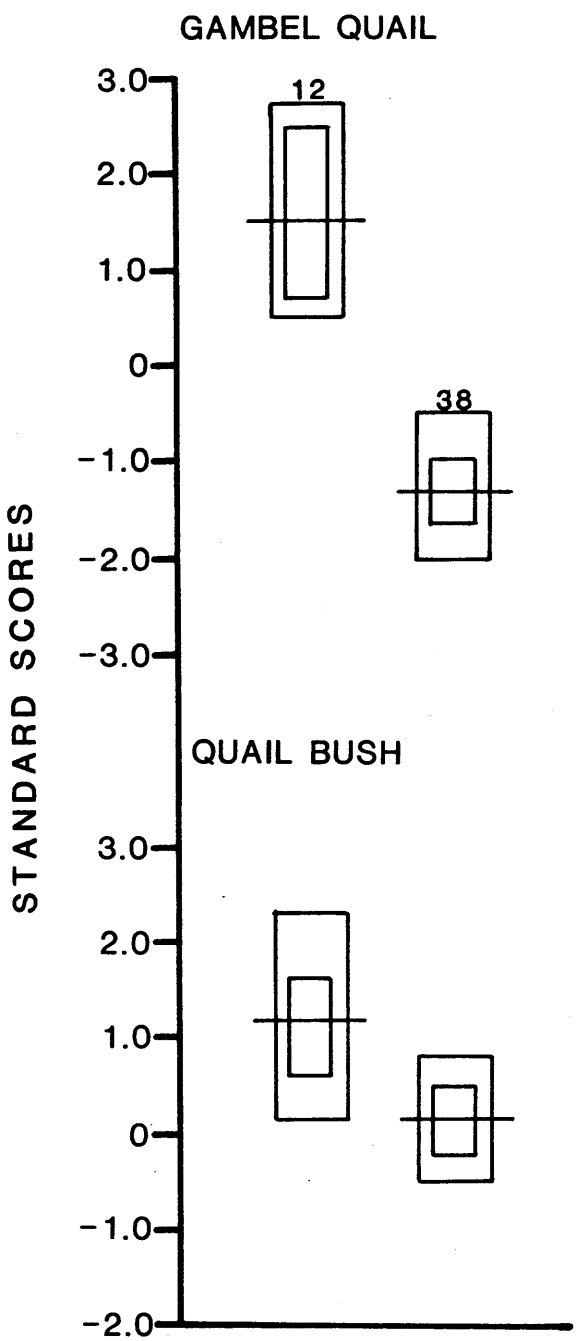


Figure 5-10. Changes in Gambel Quail densities when quail bush densities were above and below the average for riparian vegetation. Symbols as in Figure 5-6. See Figure 5-9 for further explanation.

when quail bush and cottonwood and willow trees were present in relatively large numbers (Fig. 5-11). Since these two variables were not highly correlated with each other, it is apparent that both attract permanent residents.

In the analysis of riparian vegetation, total foliage density and diversity, cottonwood, willow, and honey mesquite trees, and shrubs were associated with densities of permanent resident insectivores (Fig. 5-5). Analysis of the revegetation site data showed that foliage density did not attract this group. In the analysis for all riparian habitats, neither total foliage density nor permanent resident insectivores were correlated with DL (Fig. 5-5). On the revegetation sites, DL was strongly correlated with total foliage density (Table 5-1), and so were the birds. Foliage density was largely related to shrub density on the revegetation sites. In the original analysis, high foliage density was associated with high densities of cottonwood and willow trees; on the revegetation plots, this association was not significant. We also know, then, that it was the trees and not foliage density that attracted permanent resident insectivores. (One can have high foliage density without having these tree species present.) FHD was associated with the number of cottonwood and willow trees and total foliage density in the original analysis, but not on the revegetation plots. However, densities of resident insectivores on the revegetation sites were high when FHD was below average but the number of cottonwood and willow trees was above average. Thus, FHD was not important to resident insectivores. Horizontal patchiness was also implicated as an important factor in the first analysis (Fig. 5-5) because of its intercorrelation with foliage density and the number of cottonwood and willow trees. Although patchiness may be important, it is probably not patchiness, per se, that attracts permanent resident insectivores, but rather areas with high densities of quail bush and cottonwood and willow trees. Relatively high patchiness is the inevitable result when there are large numbers of quail bush and cottonwood and willow trees in an area.

Management conclusion: High densities of permanent resident insectivores will be attracted if there are alternating patches of cottonwood and willow trees and quail bush.

Density of Visiting Insectivores. In the original analysis, across all habitats density of visiting insectivores was strongly associated with DD (Fig. 5-5). We can eliminate FHD and total foliage density as the primary variables affecting visiting insectivores, using the same logic as for permanent resident insectivores. (It is possible to have high FHD and/or high foliage density without having cottonwood and willow trees.) The number of cottonwood and willow trees was presumably an important factor (Fig. 5-12). But patchiness, rather than shrubs, appeared to be more important to visiting insectivores. It seems likely that at least some visiting insectivores (Blue Grosbeak) were attracted to low-level vegetation (a tall tree can have vegetation at low levels) other than shrubs and perhaps to a patchy situation itself. This point needs further research, but it seems likely that salliers, such as the Western Kingbird and Ash-throated Flycatcher, may prefer patchy areas. Some visiting insectivores were attracted to quail bush (Anderson et al. 1978).

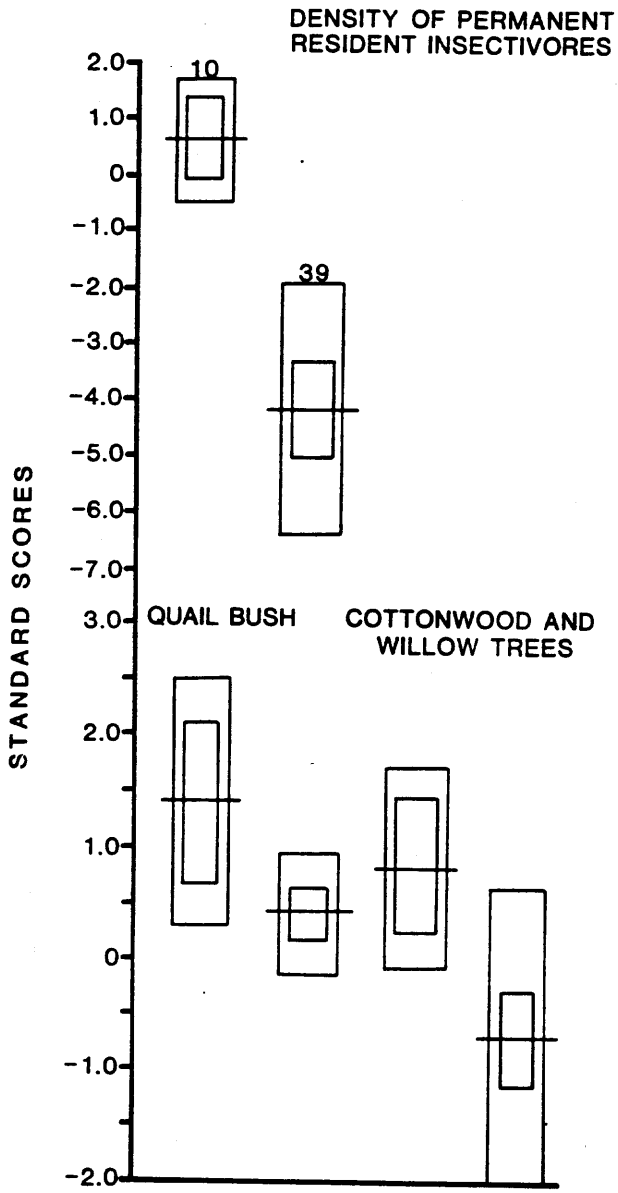


Figure 5-11. Changes in densities of permanent resident insectivores when densities of cottonwood and willow trees and quail bush were above and below the average for riparian vegetation. Symbols as in Figure 5-6. Here when standard scores for PRI were highest, scores for quail bush and cottonwood-willow trees were also highest. It cannot be determined from these data whether the birds were responding to one or both of these vegetation variables.

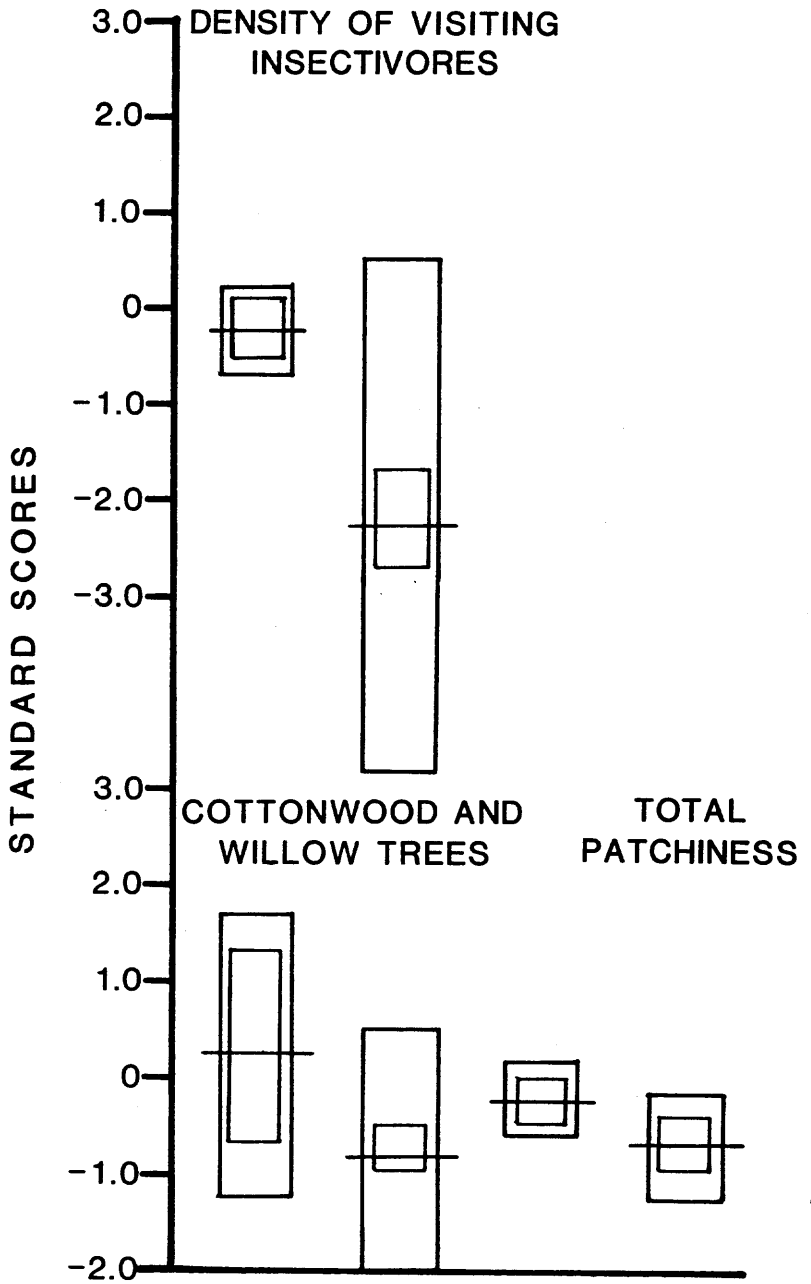


Figure 5-12. Changes in density of visiting insectivores when the number of cottonwood and willow trees and total patchiness was near average and below average for riparian vegetation. Interpretation of this graph follows the logic presented in Figures 5-9 and 5-11.

Management conclusion: To attract visiting insectivores, develop areas in such a way that cottonwood and willow trees and quail bush are present in patches in above-average densities per unit area (Table 2-1).

Doves. Doves were attracted to the trees on the revegetation plots (Fig. 5-13). Doves were present in above-average numbers when there were trees and no shrubs or trees and many shrubs, but not when there were shrubs alone. Although our data do not address this point, our personal observations lead us to believe that a rather open stand of trees, or dense patches of trees mixed with patches of shrubs, or even rather sparsely vegetated patches of trees might consistently attract the greatest numbers of doves across all seasons. Although dense stands of trees supported large breeding densities of doves, they did not attract doves in fall or winter.

Management conclusion: To attract doves, plant trees in varying densities. We cannot determine from our data precisely how tall the trees must be. Personal observation suggests 15-25 ft as adequate. Trees taller than 40 ft could have a negative influence.

Total Densities. Total bird densities were best explained by the amount of quail bush, which attracted granivores, permanent resident insectivores, and quail, and by the number of cottonwood and willow trees, which attracted resident and visiting insectivores and doves (Fig. 5-14). Bird densities also were greater when patchiness was greater, but if there are dense patches of quail bush, as well as dense patches of trees, the area will, of course, be horizontally patchy at one or more vertical layers. Patchiness, by itself, may not be particularly important; it is the specific plant species that attracts the birds.

Data from the revegetation sites do not allow a clear evaluation of whether other tree species are as valuable as cottonwood and willow, but the initial analysis indicates that cottonwood and willow trees are better, in general, than other tree species (Fig. 5-5). Since mistletoe primarily attacks honey mesquite, this species of tree has the greatest potential for attracting frugivores.

Management conclusion: To attract the greatest number of birds, an area must have shrubs (preferably quail bush) and trees (preferably cottonwood and willow). Some additional enhancement might be possible by designing the area so that there are alternating patches (150 X 150 m [400 X 400 ft]) of trees and shrubs. Inkweed should be included to enhance populations of Sage Sparrows (Anderson et al. 1978, Meents et al. 1981). The presence of honey mesquite increases the likelihood of mistletoe being present; mistletoe is an essential habitat component for frugivores (Anderson and Ohmart 1978).

Total Species. Designing an area to maximize densities will also maximize species richness. A horizontally patchy environment might be more important for maximizing richness than it is for maximizing densities (Fig. 5-15).

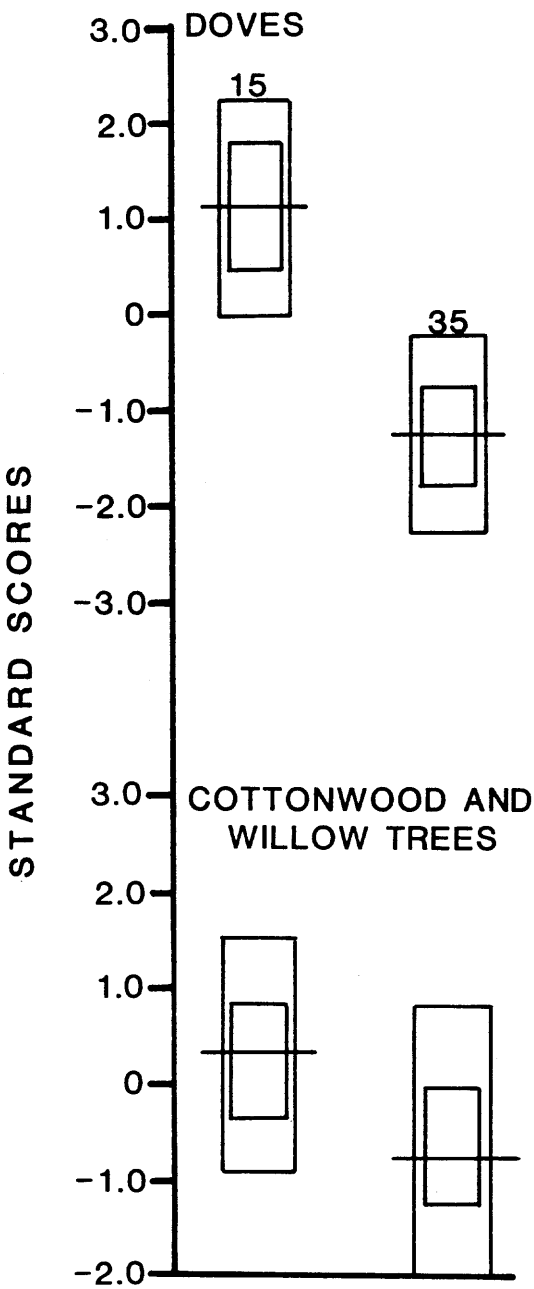


Figure 5-13. Changes in the number of doves when the number of cottonwood and willow trees was above and below average for riparian vegetation. Symbols as in Figure 5-6. Interpretation of this graph follows the logic presented in Figure 5-9.

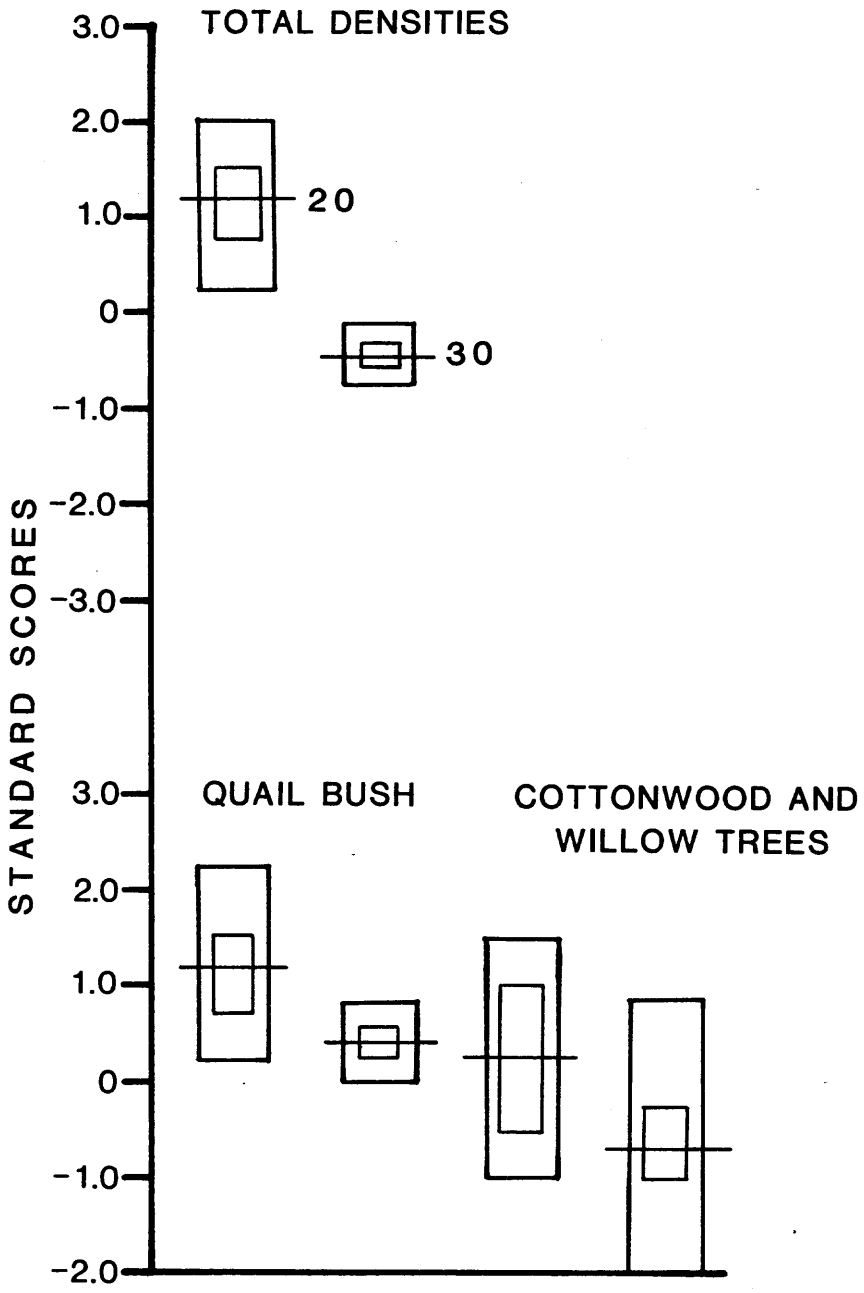


Figure 5-14. Changes in the total bird density when density of quail bush and cottonwood and willow trees was above and below average. Symbols as in Figure 5-6. Interpretation of this graph follows the logic presented in Figures 5-9 and 5-11.

Figure 5-15. Changes in total species richness when total patchiness and density of cottonwood and willow trees were above and below average for riparian vegetation. Symbols as in Figure 5-6. Interpretation of this graph follows the logic presented in Figures 5-9 and 5-11.

The results in this chapter using guilds and pooled habitat types have also been analyzed with transect-by-transect considerations of species-by-species distributions (Rice et al. 1983, in press). The two approaches have yielded essentially the same results (Anderson et al. 1983).

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Appendix 5-1. Factor scores for each plant community type for each year. The four principal components were derived from a principal components analysis. SB = screwbean mesquite, CW = cottonwood-willow, SC = salt cedar, HM = honey mesquite, AW = arrowweed, SH = salt cedar/honey mesquite.

Community type		VPC1			
		1976	1977	1978	1979
SB	II	1.35	0.71	1.63	1.63
	III	-0.09	0.03	-0.19	-0.18
	IV	0.25	0.31	0.26	0.26
	V	-0.47	-0.56	-0.84	-0.84
	VI	-1.83	-0.90	-1.07	-1.07
CW	I	1.53	3.19	3.27	3.27
	II	0.19	0.32	0.32	0.32
	III	1.63	1.62	1.26	1.24
	IV	0.59	0.59	0.46	0.74
	V	0.07	0.06	0.01	-0.01
	VI	-1.25	-1.01	-0.44	-0.43
SC	I	0.21	0.29	1.28	1.28
	III	-0.43	-0.50	0.02	-0.09
	IV	-0.07	-0.01	0.00	-0.20
	V	-0.97	-1.02	-1.03	-1.29
	VI	-1.58	-0.32	-0.46	-0.94
HM	III	0.93	0.87	0.17	0.08
	IV	0.04	-0.14	-0.37	-0.55
	V	-0.62	-0.71	-0.79	-0.81
	VI	-1.21	-1.23	-0.87	-0.57
AW	VI	-0.89	-0.85	-0.89	-0.60
SH	IV	-0.17	-0.17	-0.18	-0.42

Appendix 5-1. (cont.)

Community type		VPC2			
		1976	1977	1978	1979
SB	II	-0.68	-0.53	-0.40	-0.40
	III	0.30	-0.25	-0.24	-0.24
	IV	0.29	0.20	0.16	0.16
	V	-0.47	-0.35	-0.40	-0.40
	VI	-0.92	-0.80	-0.72	-0.72
CW	I	0.44	0.15	0.16	0.16
	II	0.33	0.29	0.29	0.29
	III	0.12	0.05	-0.17	0.02
	IV	-0.85	-0.36	-0.31	-0.22
	V	-0.66	-0.75	-0.90	-0.90
	VI	-0.73	-0.71	-0.61	-0.61
SC	I	-1.02	-1.02	-0.77	-0.77
	III	-0.27	-0.45	-0.51	-0.55
	IV	-1.30	-1.22	-1.31	-1.37
	V	-0.54	-0.80	-0.91	-0.98
	VI	-0.92	-0.96	-1.14	-1.28
HM	III	2.06	2.04	1.38	1.80
	IV	2.19	2.19	2.08	2.03
	V	1.65	1.65	1.61	1.61
	VI	1.70	1.70	1.73	1.83
AW	VI	-0.19	-0.05	0.02	0.22
SH	IV	0.71	0.71	0.68	0.68

Appendix 5-1. (cont.)

Community type	VPC3 1976	1977	1978	1979
SB II	-1.49	-1.41	-1.31	-1.31
III	-1.25	-1.80	-1.42	-1.42
IV	-0.58	-0.57	-0.36	-0.36
V	-0.17	-0.09	-0.64	-0.64
VI	-0.62	1.41	0.24	0.24
CW I	0.37	1.97	1.94	1.94
II	-1.93	-2.16	-2.16	-2.16
III	-0.20	-0.12	-1.05	-0.41
IV	1.64	0.22	0.23	0.37
V	0.38	0.46	0.93	0.93
VI	0.24	0.58	0.26	0.26
SC I	-0.99	-1.12	0.39	0.39
III	-1.24	-0.79	-0.79	-0.84
IV	0.16	0.31	0.31	0.21
V	0.06	0.13	0.10	-0.03
VI	0.44	3.00	1.87	1.64
HM III	0.03	0.13	-0.23	-0.32
IV	0.20	0.55	0.55	0.40
V	0.26	0.41	0.46	0.44
VI	-0.16	-0.11	0.61	0.91
AW VI	2.11	0.63	0.68	0.45
SH IV	-0.03	-0.03	-0.03	0.08

Appendix 5-1. (cont.)

Community type		VPC4			
		1976	1977	1978	1979
SB	II	1.66	1.41	1.68	1.68
	III	0.83	0.75	0.74	0.74
	IV	1.35	1.34	1.40	1.40
	V	0.94	0.79	0.36	0.36
	VI	-0.07	0.01	-0.04	-0.04
CW	I	-1.21	-0.43	-0.44	-0.44
	II	-1.66	-1.62	-1.62	-1.62
	III	-0.76	-0.63	0.73	-0.83
	IV	1.04	0.78	0.64	-0.72
	V	-0.42	-0.27	-0.01	-0.01
	VI	-1.14	-1.09	-1.04	-1.04
SC	I	-0.91	-0.91	0.13	0.13
	III	0.11	0.34	0.22	0.18
	IV	0.73	0.63	0.73	0.66
	V	0.01	0.30	0.39	0.30
	VI	-0.76	-0.21	-0.17	-0.32
HM	III	0.72	0.75	-0.20	-0.37
	IV	0.50	0.49	0.14	-0.17
	V	0.03	0.02	-0.10	-0.15
	VI	-0.62	-0.62	-0.24	-0.34
AW	VI	-0.52	-0.72	-0.81	-0.45
SH	IV	0.56	0.56	0.56	0.34

CHAPTER 6

AVIAN COMMUNITY ORGANIZATION IN MATURE COTTONWOOD-WILLOW HABITAT

INTRODUCTION

Avian inventories in the lower Colorado River valley have provided much information on patterns of abundance and distribution that are described in this report. These patterns have generally involved large-scale comparisons of plant communities, species' habitat preferences, and seasonal and year-to-year community dynamics. These results paint a broad picture of avian relationships that is essential for the proper evaluation and management of desert riparian communities.

The fine details of individual species ecology are not described in this report. Knowledge of the microhabitat preferences, behavioral repertoires, and dietary needs of a single community of birds can provide much insight on the interpretation of large-scale patterns of abundance and distribution. In the lower Colorado River valley, we have shown that mature cottonwood-willow communities support extremely high densities and diversities of avian species, compared with most other vegetation types (see Chapter 5). Cottonwood-willow associations once dominated the valley but now persist only in small remnant stands (Ohmart et al. 1977). However, these communities are important to several rare or specialized breeding birds.

To better understand the needs and tolerances of wildlife species, and to describe the breeding bird community organization of the remaining cottonwood-willow habitats, we chose to examine a study plot in a mature stand of cottonwoods and willows in the Bill Williams River delta. The general approach of the study was to record in detail the densities, microhabitat preferences, foraging behavior, and diets of all diurnal insectivorous species breeding on the plot. In the following analyses, each set of ecological measures is used separately to test for differences among the species and to identify the most important components of these ecological differences.

Specifically, analyses of habitat measures were designed to answer the following questions:

1. Do individual avian species have preferences for specific microhabitats within the study plot?

2. Are there associations between specific bird species and specific plant species?

3. Are there negative associations among avian species at specific points in the habitat (e.g., are they dividing horizontal space)?

4. Which habitat factor or factors are most important in contributing to the structure of the bird community?

Similarly, analyses of avian foraging behavior and diet were designed to answer the following questions:

1. Do bird species differ significantly in their patterns of foraging behavior or diet (e.g., are they dividing vertical space)?

2. How much actual ecological overlap is associated with these relationships?

3. Which variables are most important in separating pairs or groups of bird species?

4. How does the entire bird community exploit existing foraging opportunities and available resources?

METHODS

Study Area and General Methods

This study was conducted over two complete breeding seasons, from January through July 1977 and from February through August 1978. The 20-ha study plot was along the Bill Williams River, about 3 km from its delta at Lake Havasu in Yuma County, Arizona (Lat. 34°18'N, Long. 114°07'W, elevation 100 m). The study area was part of a continuous forest stand of about 100 ha and was bordered abruptly on one side by Sonoran Desert scrub. This stand lies within the Havasu National Wildlife Refuge and is the largest remaining tall forest stand in the lower Colorado River valley.

The dominant tree species were cottonwood and willow with a patchy understory of the exotic salt cedar. The soil was wet throughout the year, although water level on the study plot did not fluctuate with the main river channel. Cat-tails, bulrushes, and a perennial herb, yerba-mansa, formed a dense but patchy ground cover in summer, and much of the stand was littered with decayed and rotting wood. A narrow, linear strip of honey mesquite and arrowweed occurred along the riparian forest-desert edge. The forest stand has been typed as cottonwood-willow I, and constitutes virtually the only mature vegetation of this type in the valley.

Precipitation, as measured at Parker, Yuma County, was consistently low, totaling 2 cm during the 1977 nesting season and 11.5 cm during the year 1978. Temperature varied from -6°C to 33°C in early spring, and from 8°C to 43°C in summer. Temperature exceeded 38°C nearly every day after June 1. The weather both years was similar, and the resulting phenology of the vegetation was nearly identical.

The study area was visited 63 days in 1977 and 40 days in 1978; visits varied from 4 to 11 days per month. Several assistants were present on most visits. An estimated total of 1,000 man-hours was spent on data collection for this chapter.

Line transect censusing, spot-mapping, and observations of avian foraging behavior were usually conducted simultaneously during the morning hours. Habitat measurements and data transcription were undertaken during periods of minimal bird activity.

The general design of data analysis was to examine variables in three major sets: microhabitat use, foraging behavior, and diet and morphology. Within each set, individual species patterns were identified and compared, using a variety of univariate techniques.

Density and Breeding Phenology

Two line transects, each approximately 0.8 km long, traversed the study plot and adjacent forest. Birds were censused three to four times per month using a variable-distance line census (Emlen 1971, 1977). All censuses were conducted shortly after sunrise. Censuses from January through July 1977 and from February through August 1978 were considered in the present study.

In addition, the 20-ha plot was gridded at 20-m intervals with surveyor's tape, and each grid point was marked with a coordinate number. Detections of all territorial breeding species were recorded on daily field maps, with special attention given to locating nests, following known pairs, and determining territorial boundaries. The grid was walked randomly, except during strip censuses, with all parts receiving approximately equal coverage. Number of pairs and relative territory size were determined from the composite of field maps for each season. Final estimates of breeding bird densities were taken from both spot map data and line transect censuses.

The following data on breeding biology were recorded: date of first arrival (for summer visitors), nest location and height, parental behavior such as nest building and feeding young, date of fledging for each located nest, number of fledglings observed, and observations of post-nesting dispersal. No attempt was made to quantify fledging success at individual nests.

Microhabitat

At each of 281 numbered grid points, measurements of relative foliage density (MacArthur and MacArthur 1961) were taken at 11 height intervals: 0-0.02 m, 0.6 m, 1.5 m, 3.0 m, 4.5 m, 6.0 m, 9.0 m, 12.0 m, 15.0 m, 18.0 m, and 21.0 m (Anderson et al. 1977a). By facing in four perpendicular directions, four samples were obtained for each grid point. These data were used to construct a foliage density profile for each point. Dominant canopy and understory plant species, as well as distance from the desert-riparian edge, were also recorded for each point. In addition, direct counts of all trees within 15 m of the line transects were made to determine relative density of each tree species in the study plot.

Each bird detection was assigned its closest grid coordinate number from the daily field maps. Males and females were treated equally because activities of all individuals were considered important indicators of a species' microhabitat preference.

For each bird species, foliage density measurements were weighted by that species' frequency of occurrence at each grid point. The weighted mean foliage densities at all heights were then used to construct a foliage density profile for that species. A significant difference between any species' profile and the average foliage profile for the 281 points on the plot would indicate selection of a portion of the habitat by that species. A total of 1,482 bird detections in 1977 and 1,800 detections in 1978 of 12 species were used in this analysis. Data from the two years were analyzed both separately and combined.

To test for differences among species' use of vertical foliage layers, a Kruskal-Wallis nonparametric one-way analysis of variance (Hollander and Wolfe 1973) was performed separately for each foliage layer as well as for distance from the desert edge. Observations were the weighted measurements of foliage density at each grid point, and treatments were the 12 bird species (flickers were present in densities too low to warrant statistical analysis for habitats). For those variables that yielded significant ($P<0.05$) H statistics, a Dunn's Multiple Comparison (Hollander and Wolfe 1973) was performed on the Kruskal-Wallis rank sums for each species to identify those species pairs that differed significantly. The Kruskal-Wallis H test was executed by subroutine KRUWAL in statistical package BMDP (Dixon 1975), and the Dunn's Multiple Comparison was executed by a Fortran program (Webb 1979).

To test for association between bird species and plant species, a Cramer's V statistic was calculated based on the presence or absence of each bird species and each dominant plant species at each of the 281 points on the study plot (Pielou 1977:208-211). Because willow was a dominant tree at nearly every point, associations between bird species and willow were assumed and not tested.

Similarly, associations between pairs of bird species were tested separately for each season based on frequency of co-occurrence at each of the 281 points. The V statistic is essentially a correlation coefficient and its significance was tested by simultaneously computing "X^2," which approximates a chi-square distribution with 1 degree of freedom (Pielou 1977:207).

A rough measure of the relative dispersion of each species' distribution on the plot was obtained by dividing the total number of points where a species occurred by that species' density (n/40 ha). Thus, it was assumed that a common species had a higher probability of being detected at more points than did a rare species with a similar distribution.

Foraging Behavior

Foraging by birds was observed on the study plot and in similar forest stands along the Bill Williams River. A foraging observation was defined as an actual attempt to procure prey, and for each observation the following data were recorded: bird species, location, date, time of day, air temperature, wind speed, percent cloud cover (by estimation), foraging method (glean, hover, hawk, peck, or probe), height of bird in tree, tree species, tree height, branch diameter, shade or exposed sun, portion of tree (inner or outer), substrate from which prey was captured

(leaf, bark, ground, air), and type of prey (if observed). In addition, any birds close to or associated with the foraging individual were noted, as well as any instances of aggression. Definitions of foraging measures and the states of each measure are listed in Appendix 6-1.

An attempt to observe foraging was made whenever a bird was seen, with additional effort concentrated on low-density bird species and those present for a short breeding period. Nearly all observations were made during the morning, because bird activity declined sharply in the hot part of the day. No attempt was made to record sequential maneuvers by a bird, and no more than five observations were recorded for any individual at one time. Too few observations of Blue Grosbeak were obtained to warrant analysis.

Frequencies and proportions of all states of all foraging measures were computed by subprogram CROSSTABS in SPSS (Nie et al. 1975). These were computed for each year separately and for the two seasons combined.

From the distribution of proportions of each foraging measure, a diversity or niche breadth value was calculated for each species using $B = (\Sigma p_i^2)^{-1}$ where p_i is the proportion of the ith state of the measure (Levins 1968). B varies from 0 to n, with n states of a measure, and indicates degree of specialization apparent along that niche axis (Karr and James 1975).

The degree of overlap between species pairs (i, j) for each foraging measure was calculated as:

$$O_a = \frac{\Sigma P_{ia} P_{ja}}{(\Sigma p_{ia}^2)(\Sigma p_{ja}^2)}$$

where p_{ia} and p_{ja} are the proportional use of resource state (vegetation variable, food item abundance, etc.) "a" by species i and j, respectively (Pianka 1974, May 1975).

To test for actual differences between species for each foraging measure, the distributions of the state of frequencies of each measure were compared for goodness-of-fit using G_H (Sokal and Rohlf 1969:575-577). When the statistical significance associated with different degrees of overlap between species are compared directly, the biological relevance of each approach can be assessed.

Diet and Morphology

During July and August 1978, 110 birds of 15 species were collected from riparian forest stands similar to the study plot, and their stomachs were immediately preserved. Age, sex, weight, bill size (exposed culmen, depth and width), wing chord, fat condition, and condition of molt were recorded for each specimen. A reference series of skins was prepared.

Stomach contents were dried and weighed, and their volumes were determined. Length, frequency, and percent-volume of each individual prey item were recorded. All arthropod prey were identified to order and many were identified to family. Identifiable insect parts contributed to the percent-volume of that category, but not to its frequency. Unidentified parts were not included in volumetric analysis.

The importance of selecting relevant categorical divisions in the computation of diet diversity and overlaps has been emphasized by Hespenheide (1975) and others. Since a majority of insect orders show consistent features of form, habit, and catchability, this level was used in most cases to group prey items in this study. A few families (e.g., Cicadidae) that were frequently identified and that were considered sufficiently different from others in their order comprised distinct categories. Soft-bodied larvae of several orders and all spiders were considered as two groups.

For each bird species, niche breadth values were computed for both frequency and percent-volume of prey categories using $B = (\Sigma p^2 i)^{-1}$, as described for foraging measures. The proportion and frequency of each category for a species was the mean of the proportion and frequency in each stomach. Overlap matrices were prepared for all species pairs, as described above. Prey items were also grouped into 10-mm size classes for computation of prey size diversities and overlaps, as above. The G_H statistic was used to test for differences in the mean prey size and prey taxa frequency distributions of each species pair, as was done for foraging measures. Percent-volume data were not appropriate for such comparisons.

From morphological measurements, the ratio of the values of each measure for any pair of species was used as an index of similarity. Overall morphological similarity for each species pair was the average of the similarity values for each measure. Group average clustering was performed on the matrix of similarity values, as for foraging overlaps.

Insect Availability

Although resources were not sampled on the study plot, insect sweep samples were available (Anderson and Ohmart unpubl. data) for the two breeding seasons in a forest stand about 4 km from this study area. These samples consisted of 4000 sweeps with a standard 40-cm-diameter net in understory foliage along a 0.8-km transect, on one morning per month.

Samples were frozen for storage. After insects were separated from vegetational matter, they were identified to family and sorted into size categories, and then stored in 70% alcohol. Frequency, average length, and total dry weight for each family-size grouping were recorded. Total frequency and dry weight of the sample were the sums of the individual groupings. Percent-frequency and percent-weight were then recorded.

From these sweep samples, a rough estimate of resource availability in cottonwood-willow-salt cedar habitat was obtained. Limitations and biases of sweep sampling were discussed by Whittaker (1952) and Davis and Gray (1966).

RESULTS

Density and Breeding Phenology

Table 6-1 lists the breeding densities (N/40 ha) and summarizes the breeding biology for the 13 species considered in this community analysis. Densities were nearly identical both seasons and are presented as a range of values, representing breeding adults. Five species were permanent residents on the plot. The Verdin is a resident in the region but was only a summer visitor to the riparian forest plot. All species except Common Flickers nested on the plot. Flickers used saguaro cactus in the adjacent desert for nesting but regularly foraged in the riparian forest.

In addition to these species, Cactus Wrens, Crissal Thrashers, Bell Vireos, Yellow-breasted Chats, and Indigo Buntings nested along the desert-riparian edge but rarely penetrated into the riparian forest. Diurnal predators visiting the plot included the Red-tailed Hawk, Zone-tailed Hawk, and American Kestrel. The Screech Owl, Elf Owl, and Great Horned Owl were nocturnal visitors.

Finally, both White-winged and Mourning doves were abundant breeders on the plot. However, doves foraged in agricultural areas outside of the riparian vegetation, were not territorial, and did not appear to interact behaviorally with the other species studied.

Microhabitat

Of 12 species for which average vegetation profiles were constructed, only the Common Yellowthroat and Blue Grosbeak showed any significant departure from the average profile for the plot. As illustrated in Figure 6-1, the Common Yellowthroat used areas with greater than average foliage density at 0.02 m and 0.6 m and less than average density above 12 m. These areas corresponded to openings in the forest canopy that supported dense patches of cat-tails or bulrushes. The Blue Grosbeak avoided areas with a canopy layer above 12 m and showed a tendency to use areas with dense vegetation at 4.5 m. The profile of the Ash-throated Flycatcher was similar to that of the Blue Grosbeak, but it did not differ significantly from the average at any particular height layer. Profiles of all other species were nearly identical to the average for the plot, indicating little or no microhabitat selection on the basis of foliage layers.

Kruskal-Wallis tests indicated that four foliage height layers were selected differentially by some species pairs (Table 6-2). With respect to foliage density at 0.02 m, the Common Yellowthroat occurred at significantly denser points than did all other species except the Wied Crested Flycatcher and the Blue Grosbeak. The Wied Crested Flycatcher and the Northern Oriole also selected areas that had significantly denser ground cover than those chosen by the Ash-throated Flycatcher.

The Blue Grosbeak's tendency to use areas with dense foliage at 4.5 m was significantly different from the low use of this layer by the Wied Crested Flycatcher and the Summer Tanager. Ash-throated Flycatchers

Table 6-1. Densities and breeding characteristics of 13 species of birds on a riparian forest plot. Species names are followed by abbreviations used in subsequent tables and figures. Density is based on estimates from two breeding seasons. Dispersion index is calculated as number of grid points where present/density (see text). Nest heights are the mean height of values of nests found on or near plot; C = cavity-nester. I-III indicate timing of fledging of three broods. J - A = January through August, respectively. Lines denote duration of breeding activities.

Species	Density N/40 ha	Dispersion index	Nest height (m)	Breeding chronology J F M A M J J A
Yellow-billed Cuckoo (YC)	28-30	4.87	9.5	——— I
Common Flicker (CF)	2-4			——— I II
Gila Woodpecker (GW)	36-40	4.88	11.1,C	——— I II
Ladder-backed Woodpecker (LW)	28-36	5.72	11.7,C	——— I ———
Wied Crested Flycatcher (WF)	20-24	7.16	10.2,C	——— I ———
Ash-throated Flycatcher (AF)	4-6	6.00	6.2,C	——— I II
Verdin (VN)	20-24	3.22	5.8	- - - - ——— I II
Common Yellowthroat (YT)	80	1.49	0	——— I II
Northern Oriole (NO)	64-80	2.81	11.1	——— I II II
Summer Tanager (ST)	24	7.71	11.7	——— I II
Blue Grosbeak (BG)	4	3.00	1.2	——— I ———
Abert Towhee (AT)	50-56	1.83	1.8	——— I I II II III?
Song Sparrow (SS)	80-100	1.65	0	——— I II

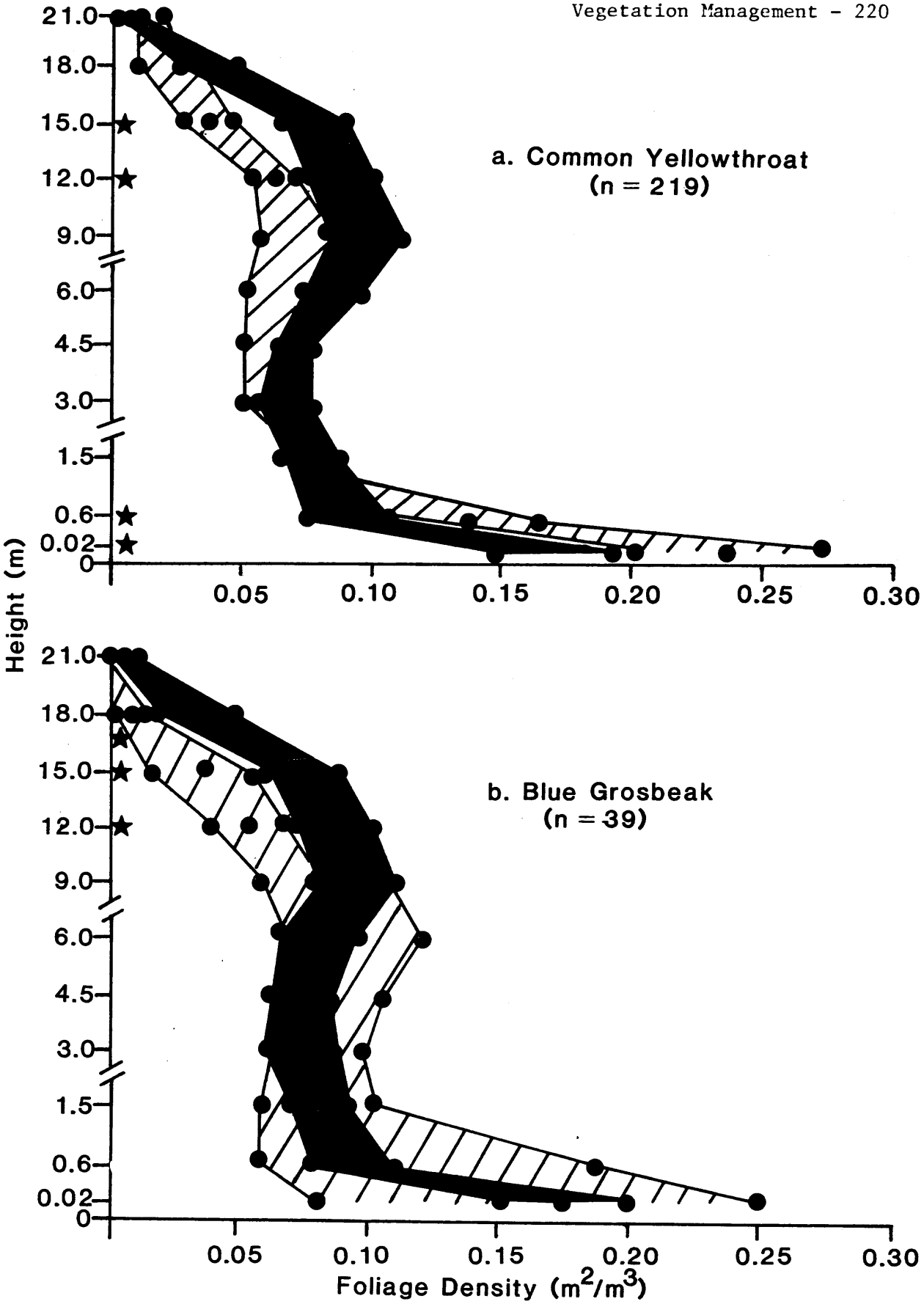


Figure 6-1. Foliage density profile for two birds on a riparian forest plot. Solid band is average profile with 95% confidence limits for entire plot (281 pts.). Cross-hatched band is average for all occurrences (n) of bird species. * indicates significant difference between profiles.

Table 6-2. Vegetation measures selected differently by 12 riparian bird species. H statistic from Kruskal-Wallis test. Species pairs tested with Dunn's Multiple Comparison Test ($P<0.05$, $n = 66$). DEDGE = distance from riparian-desert edge. Species codes from Table 6-1.

Vegetation measure	H	Probability	Significantly different pairs
Foliage density at:			
0.02 m	63.89	<0.001	YT with YC, GW, LW, AF, VN, NO, ST, AT, SS AF with WF, NO
0.6 m	30.22	<0.002	YT with GW, LW, VN, ST
4.5 m	29.51	<0.002	BG with WF, ST
18.0 m	51.43	<0.001	AF with YC, GW, LW, WF, NO, ST, SS
DEDGE	142.48	<0.001	BG with YC, GW, LW, WF, NO, ST, AT, SS AF with YC, GW, LW, WF, YT, NO, ST, AT, SS NO with YC, GW, WF, VN ST with YC, GW, WF, VN VN with SS

occurred in areas with significantly sparser canopy cover at 18 m than all other species except Abert Towhee, Verdin, Common Yellowthroat, and Blue Grosbeak. The rarity, and consequently the small sample, of Blue Grosbeak detections, was in part responsible for difficulty in statistically separating this species from others.

The greatest separation of species occurred in relation to distance from the riparian edge (DEDGE). The Ash-throated Flycatcher and Blue Grosbeak were most highly associated with edge (Fig. 6-2). Each was significantly different from most other species except the Verdin, which also tended to occur close to the edge. Summer Tanagers and Northern Orioles were least associated with the edge and differed significantly from several intermediate species.

Associations among bird species and patchily distributed plant species (Table 6-3) show that salt cedar was negatively associated with the other plant species tested. The Verdin, Blue Grosbeak, Abert Towhee, and Song Sparrow were not associated with any plant. The Ash-throated Flycatcher was negatively associated with cottonwood and yerba-mansa, probably due to the rarity of these plants along the edge of the plot. All other species were negatively associated with salt cedar, which is an exotic invader into riparian areas. Only the Ladder-backed Woodpecker and Summer Tanager were positively associated with cottonwood trees. The strongest positive association was between the Common Yellowthroat and cat-tail/bulrush patches. Yellow-billed Cuckoos and Northern Orioles also occurred in these areas more frequently than expected by chance.

If bird species were dividing space so that they were avoiding or in some way excluding one another, then one might expect species pairs to have occurred together less frequently than by chance in a given season. No significant negative associations were found for any species pair in either year (Table 6-4). However, 9 significant positive associations were found in 1977 and 16 in 1978. With 66 comparisons, as many as four positive and four negative associations would be expected, even if the species were distributed at random with respect to one another (Kirk 1968). It can be concluded, then, that there was a tendency for species to be clumped together on the plot.

The presence of significant associations between species pairs was not consistent from year to year. Of the four pairs that were positively associated in both years, two were between cavity-nesting species. The Verdin and Ash-throated Flycatcher also consistently used the same points within a season. Both of these species tolerated salt cedar and occurred close to the edge of the forest. The occurrence of Summer Tanagers and Common Yellowthroats at the same points in both years is more difficult to interpret based on microhabitat measures.

From a summary of all significant species associations (Table 6-5), it can be concluded that two segments of the bird community behaved differently with respect to habitat. The Ash-throated Flycatcher, Verdin, Blue Grosbeak, Abert Towhee, and Song Sparrow all showed little or no association with plant species except that all tolerated salt cedar. The first three of these were found close to the forest edge, and the Ash-throated Flycatcher and Verdin tended to occur at the same points.

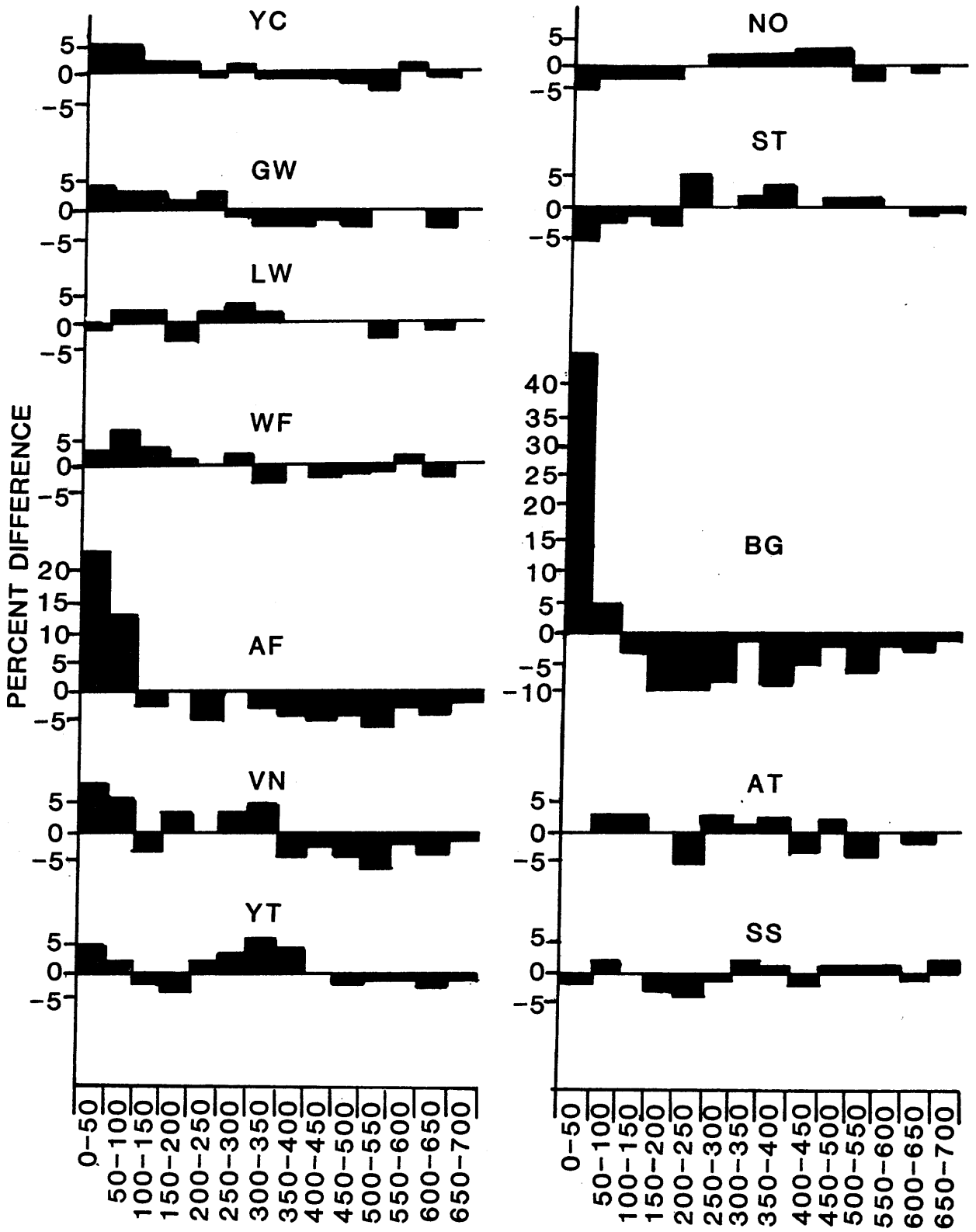


Figure 6-2. Distribution of 12 riparian birds with respect to distance from desert-riparian edge. Bars indicate differences between percentage of bird occurrences at each distance and percentage of grid-points at that distance. Species codes from Table 6-1.

Table 6-3. Associations between bird species and patchily distributed plant species. Bird species codes from Table 6-1. Plant species codes are SC = salt cedar; CW = cottonwood; CT = cat-tail; BR = bulrush; YB = yerba-mansa. V statistic after Pielou (1977:208-211). * = significant at 0.05; ** = significant at 0.01.

Species	Total points	Number of points in common with:				Association with (V):			
		SC	CW	CT/BR	YB	SC	CW	CT/BR	YB
SC	142		46	6	32		-0.125*	-0.447**	-0.148*
CW	108			30	30			0.094	-0.024
CT/BR	64				18				-0.013
YB	82								
YC	146	57	61	41	42	-0.239*	0.072	0.132*	-0.009
GW	205	94	75	49	57	-0.154*	-0.062	0.044	-0.049
LW	183	83	80	37	51	-0.142*	-0.148*	-0.089	-0.039
WF	172	73	70	46	55	-0.203*	0.058	0.118	0.077
AF	60	36	15	10	9	0.099	-0.144*	-0.076	-0.162*
VN	71	29	24	11	22	-0.112	-0.055	-0.101	0.023
YT	119	39	49	46	39	-0.305*	0.048	0.325**	0.067
NO	197	85	78	52	57	-0.226*	0.037	0.132*	-0.008
ST	185	85	84	48	49	-0.127*	0.199*	0.105	-0.082
BG	30	17	7	10	5	0.013	-0.107	0.087	-0.095
AT	99	52	35	21	26	0.029	-0.047	-0.027	0.047
SS	165	85	66	38	50	0.023	0.038	0.007	0.029

Table 6-4. Spatial associations among 12 riparian bird species during the breeding season. Along the diagonal are a number of points where a species occurred in a season. Above are a number of points where two species co-occurred; below are V statistics (Pielou 1977:208-211). * = significant at 0.05; ** = significant at 0.01. Species codes from Table 6-1.

A. 1977

	YC	GW	LW	WF	AF	VN	YT	NO	ST	BG	AT	SS
YC	108	63	37	49	15	17	21	64	62	11	8	30
GW	0.067	152	62	68	22	26	26	81	80	20	13	42
LW	-0.016	0.126*	99	45	5	16	14	58	55	6	13	27
WF	0.077	0.132*	0.101	109	8	25	26	50	60	11	14	30
AF	0.093	0.148*	-0.128	-0.100	29	10	8	15	16	5	2	8
VN	0.013	0.026	-0.004	0.141*	0.166*	46	12	26	23	4	6	8
YT	0.042	-0.005	-0.064	0.135*	0.091	0.101	49	28	33	7	4	17
NO	0.164*	0.106	0.075	-0.040	0.022	0.072	0.120	136	77	9	15	36
ST	0.103	0.038	0.068	0.066	0.046	-0.008	0.151*	0.117	143	17	10	39
BG	0.046	0.179*	-0.065	0.044	0.104	-0.007	0.094	-0.067	0.075	24	0	7
AT	-0.041	-0.013	0.098	0.136*	-0.024	0.065	-0.012	0.074	-0.070	-0.095	25	9
SS	0.039	0.050	-0.084	0.079	0.015	-0.039	0.095	0.019	0.038	0.025	0.076	72

Table 6-4. (cont.)

B. 1978	YC	GW	LW	WF	AF	VN	YT	NO	ST	BG	AT	SS
YC	72	39	41	40	13	12	35	42	32	3	26	31
GW	0.038	144	79	75	23	19	62	90	56	9	49	78
LW	0.113	0.155*	133	60	22	15	54	81	51	7	43	70
WF	0.179*	0.240**	0.087	114	19	18	45	70	44	4	40	67
AF	0.077	0.073	0.084	0.062	38	9	16	25	14	4	12	21
VN	0.098	0.058	-0.003	0.114	0.153*	32	13	21	11	1	10	17
YT	0.193*	0.217**	0.151*	0.112	0.076	0.057	93	66	40	5	32	48
NO	0.066	0.202**	0.156*	0.146*	0.104	0.094	0.258**	148	55	7	53	82
ST	0.132*	0.110	0.091	0.084	0.025	0.060	0.136*	0.074	95	3	36	48
BG	0.008	0.123	0.066	-0.017	0.135	0.015	0.053	0.044	-0.027	11	4	6
AT	0.079	0.092	0.050	0.094	0.014	0.011	0.069	0.136*	0.125	0.029	84	40
SS	-0.061	0.118	0.080	0.172*	0.054	0.034	0.045	0.148*	0.030	0.025	-0.010	136

Table 6-5. Summary of spatial associations among riparian bird and plant species 1977/1978. + = significant positive association; - = significant negative association; blank = no association. Species codes from Tables 6-1 (birds) and 6-3 (plants).

	YC	GW	LW	WF	AF	VN	YT	NO	ST	BG	AT	SS	SC	CW	CT	YB
YC																
GW																
LW		+/+														
WF	/+	+/+														
AF		+/														
VN				+/	+/+											
YT	/+	/+	/+	+/												
NO	+/	/+	/+	/+			/+									
ST	/+						+/+									
BG		+/														
AT				+/				/+								
SS				/+				/+								
SC	-	-	-	-			-	-	-							
CW			+		-				+				-			
CT	+						+	+					-			
YB					-								-			

The other group consisted of the woodpeckers and the other summer visitors. All avoided salt cedar and occurred away from the edge, and most showed a positive association with either cottonwoods or cat-tails. Of this group, only the Common Yellowthroat can be considered a microhabitat specialist, selecting dense cat-tail/bulrush patches to a much greater degree than any other species.

Foraging Behavior

Species-specific use patterns for each foraging measure are illustrated in Figure 6-3. Qualitatively, three major functional groupings of species can be recognized. These groups may be termed foraging guilds (Root 1967).

The two species of woodpeckers foraged primarily on bark, on larger branches (e.g., trunks), and in the inner portion of trees. Abert Towhees and Song Sparrows foraged on the ground. The Common Flicker mostly foraged like other woodpeckers, but it also fed on the ground.

The remaining seven species can be generally grouped into a canopy-feeding guild. All tended to use leaves as a substrate and to feed on the outer portions of trees. This group can be divided further into specialist gleaners (Verdin, Common Yellowthroat, and Northern Oriole) and those that tended to hover or hawk for prey (Yellow-billed Cuckoo, two flycatchers, and Summer Tanager).

The niche breadth or behavioral diversity (B) of each species for each measure is shown in Figure 6-3. With respect to foraging method, the Gila Woodpecker, Summer Tanager, and Common Flicker were the most diversified, whereas most other species were specialists, predominantly using a single method. The Summer Tanager, Ash-throated Flycatcher, and Verdin used the vertical canopy strata most evenly, whereas many other species tended to avoid the zone below 6.2 m. The ground foragers and the Common Yellowthroat were foraging height specialists.

The Common Flicker showed the highest diversity in use of tree species because of its usage of dead trees. The Ash-throated Flycatcher and Abert Towhee were tree species generalists that tended to use salt cedar. The woodpeckers used the widest range of branch sizes and thus had the largest niche breadths along this axis. The Summer Tanager was also extremely generalized in this respect, whereas most of the other canopy feeders were specialists on the smallest branches.

With respect to portion of tree, most species used either the inner or outer portion exclusively. Only the Common Yellowthroat used both portions equally. For ground feeders, inner portions were directly under the cover of an understory canopy and outer portions were in open areas away from direct cover. In this regard, the Song Sparrow was more generalized than the Abert Towhee.

Nearly all species specialized on a particular substrate. The Common Flicker, Common Yellowthroat, and Song Sparrow used two substrates almost equally, but the Summer Tanager was most generalized and had the largest niche breadth.

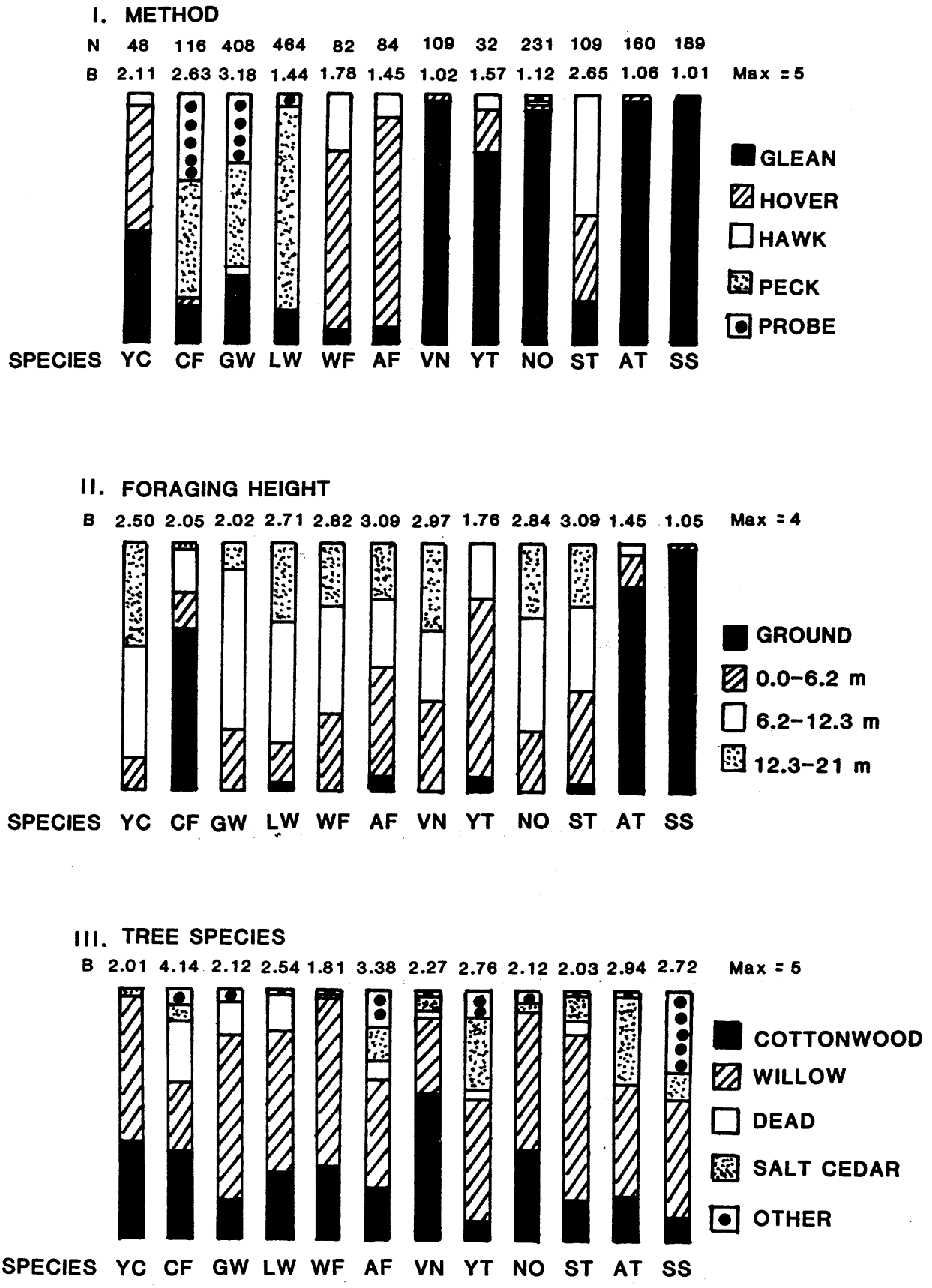
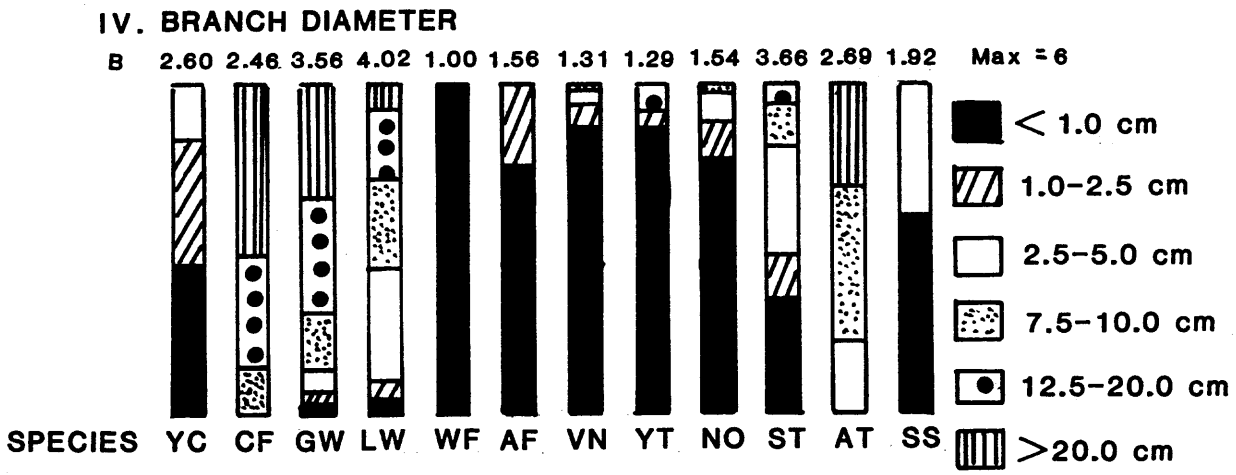
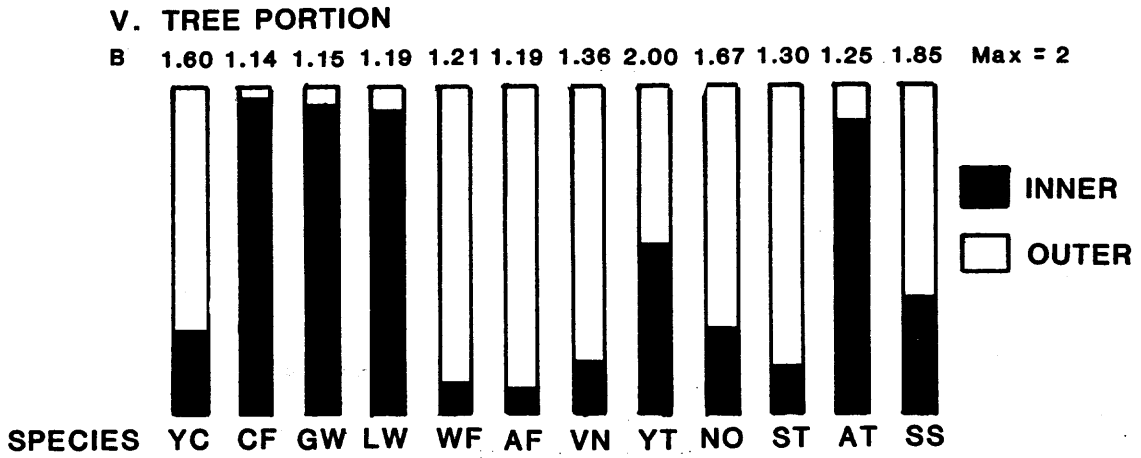
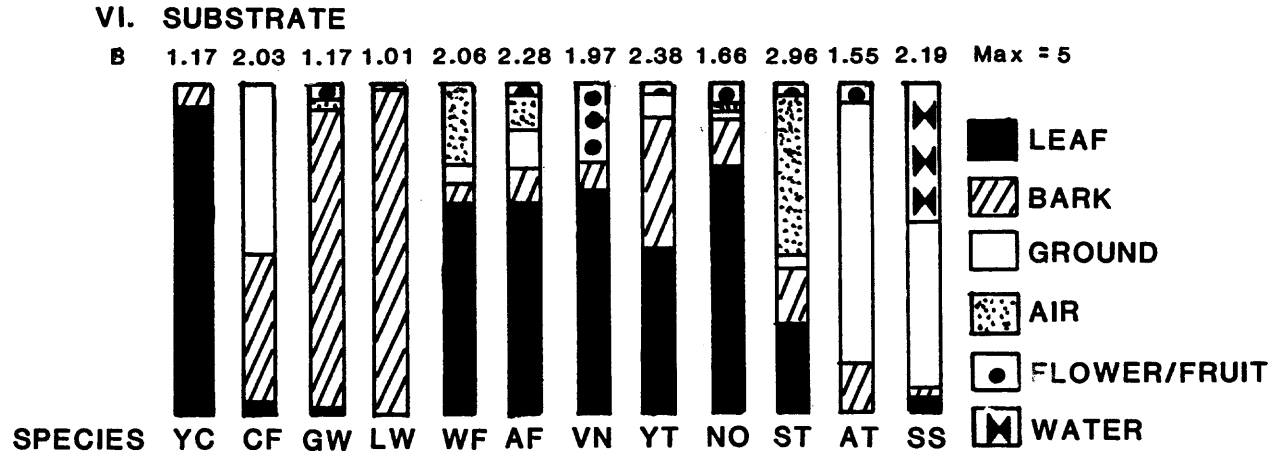


Figure 6-3. Foraging behavior patterns of 12 riparian birds. Items I-VI are foraging measures, bars indicate proportion of observations. Niche breadth (B) = $(\Sigma pi^2)^{-1}$, total niche size (in VII.) = ΣB. Sample size (N in I.) is the same for all measures except branch diameter (IV.). Species codes from Table 6-1. Definitions of measures and states in Appendix 6-1.







G. TOTAL NICHE SIZE

YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	AT	SS
11.99	14.45	13.20	12.91	10.68	12.95	10.90	11.76	10.95	15.69	10.94	10.74

Figure 6-3. (Continued).

To summarize the overall specialization in foraging by each species, the sum of niche breadths for each measure may be considered as a total niche size (Ulfstrand 1977) and compared among species (Fig. 6-3). The Summer Tanager was the most generalized forager in the community. Woodpeckers were generalists in most respects but were extreme substrate specialists. In general, the specialist gleaners tended to be specialized in other respects as well and exhibited smallest total niche sizes.

With guilds defined in a general sense, it was important to know how much overlap existed between guild members and which foraging measures were most important in separating species. Average niche overlaps and their associated levels of statistical significance between all species pairs for each measure are in Table 6-6. In order to minimize the Type I error rate with 66 pair-wise comparisons in each matrix, the G_H statistic was tested against a critical value of chi-square$_{0.001}^{df=n-1}$, where n equaled the number of states in a measure. The lack of a significant difference between two species (NS in Table 6-6) may be defined as a significant overlap.

In general, the highest calculated overlaps in each matrix were significant, and most significant overlaps were greater than 0.900. Exceptions to this generality were due to the extremely different properties of the overlap measure and the test of significance relating to sample size, number of states in a measure, etc.

Of the six foraging measures, substrate usage differed among the 12 bird species. This matrix (Table 6-6) contained the fewest number of species pairs (10) overlapping more than 0.900, and 10 pairs that were not significantly different in their use of the five substrates. Nine of these significant overlaps were within the canopy-feeding guild.

Foraging method and branch diameter (Table 6-6A and D) were next in their degree of species differences, each with 13 pairs overlapping more than 0.900. Thirteen pairs overlapped significantly with respect to method, and 16 overlaps in branch diameter were significant. Song Sparrows almost never foraged from branches, so their overlaps with other species on this measure were not considered. Only seven of the significant overlaps in foraging method were between guild co-members.

There was a greater degree of overlap in foraging height among most species pairs, with 21 pairs overlapping more than 0.900 and 15 of them being significant. Eight were between guild co-members, all within the canopy-feeding guild.

Results for tree species were equivocal; many species pairs (31) overlapped more than 0.900, but only 12 were significant. The relatively small choice of tree species available to the birds on the plot may have resulted in the high degree of overlap, but the meaning of statistically significant differences between these species is unclear. However, it is unlikely that this measure is important in separating many species within this community.

Table 6-6. Overlaps and associated significance between 12 riparian bird species for six foraging measures. Overlap values from 0 (no overlap) to 1.000 (complete overlap), see text. Significance (*) tested using G_H. Nonsignificant results (NS) are interpreted as "significant overlaps." Species codes from Table 6-1.

A. FORAGE METHOD

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	AT	SS
YC		0.178	0.346	0.113	0.765	0.818	0.709	0.804	0.705	0.661	0.724	0.711
CF	*		0.972	0.859	0.031	0.034	0.281	0.257	0.275	0.080	0.278	0.283
GW	*	NS		0.901	0.047	0.055	0.591	0.530	0.584	0.167	0.583	0.592
LW	*	*	*		0.011	0.013	0.171	0.165	0.169	0.050	0.170	0.171
WF	*	*	*	*		0.997	0.077	0.275	0.087	0.833	0.099	0.073
AF	*	*	*	*	NS		0.097	0.291	0.101	0.728	0.120	0.094
VN	*	*	*	*	*	*		1.000	1.000	0.322	1.000	1.000
YT	NS	*	*	*	*	*	NS		0.995	0.467	0.999	0.979
NO	*	*	*	*	*	*	NS	NS		0.334	0.995	0.999
ST	*	*	*	*	*	*	*	*	*		0.333	0.321
AT	*	*	*	*	*	*	NS	NS	NS	*		0.997
SS	*	*	*	*	*	*	NS	NS	NS	*	NS	

Table 6-6. (cont.) B. FORAGING HEIGHT

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	AT	SS
YC		0.251	0.843	0.980	0.921	0.768	0.880	0.405	0.967	0.867	0.090	0.007
CF	*		0.320	0.324	0.317	0.399	0.276	0.345	0.306	0.353	0.983	0.945
GW	*	*		0.935	0.946	0.793	0.766	0.761	0.940	0.868	0.126	0.011
LW	NS	*	NS		0.968	0.824	0.888	0.530	0.989	0.910	0.124	0.050
WF	NS	*	NS	NS		0.925	0.889	0.728	0.991	0.976	0.139	0.017
AF	*	*	*	*	NS		0.964	0.922	0.663	0.983	0.267	0.146
VN	NS	*	*	*	NS	NS		0.771	0.932	0.982	0.134	0.021
YT	*	*	*	*	*	NS	*		0.631	0.839	0.236	0.114
NO	NS	*	NS	NS	NS	NS	NS	*		0.953	0.142	0.030
ST	NS	*	*	NS	NS	NS	NS	*	NS		0.199	0.077
AT	*	NS	*	*	*	*	*	*	*	*		0.985
SS	*	*	*	*	*	*	*	*	*	*	NS	

Table 6-6. (cont.) C. TREE SPECIES, Chi-square$_{.001}$ = 18.467, df = 4.

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	AT	SS
YC		0.950	0.924	0.976	0.981	0.948	0.878	0.771	0.996	0.936	0.824	0.750
CF	*		0.838	0.927	0.899	0.858	0.960	0.678	0.937	0.835	0.765	0.669
GW	*	*		0.974	0.974	0.945	0.649	0.844	0.941	0.980	0.950	0.853
LW	NS	*	NS		0.980	0.929	0.795	0.788	0.982	0.964	0.800	0.777
WF	NS	*	*	*		0.976	0.776	0.835	0.991	0.983	0.840	0.820
AF	*	*	*	*	*		0.769	0.927	0.956	0.977	0.906	0.917
VN	NS	*	*	*	*	*		0.526	0.890	0.677	0.680	0.511
YT	*	*	*	*	*	NS	*		0.789	0.910	0.959	0.855
NO	NS	*	*	*	NS	*	*	*		0.951	0.824	0.791
ST	NS	*	*	*	NS	NS	*	*	NS		0.888	0.851
AT	*	*	*	*	*	*	*	NS	*	*		0.734
SS	*	*	*	*	*	*	*	*	*	*	*	

Table 6-6. (cont.) D. BRANCH DIAMETER

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	AT	SS
YC		0.000	0.109	0.302	0.831	0.921	0.851	0.816	0.877	0.843	0.084	0.765
CF	*		0.956	0.486	0.000	0.000	0.006	0.052	0.004	0.100	0.597	0.000
GW	*	NS		0.879	0.062	0.071	0.078	0.288	0.083	0.274	0.623	0.126
LW	*	*	*		0.103	0.123	0.153	0.061	0.186	0.688	0.777	0.471
WF	NS	*	*	*		0.978	1.000	1.000	1.000	0.834	0.000	0.875
AF	NS	*	*	*	NS		0.983	0.968	0.985	0.799	0.000	0.799
VN	*	*	*	*	NS	NS		0.993	0.999	0.835	0.019	0.867
YT	NS	*	*	*	NS	NS	NS		0.991	0.879	0.000	0.844
NO	NS	*	*	*	NS	NS	NS	NS		0.846	0.046	0.872
ST	NS	*	*	*	*	*	*	*	*		0.431	0.959
AT	*	*	*	*	*	*	*	*	*	*		0.000
SS	+											

+ = Song Sparrows rarely used branches; their overlaps on this measure were not tested.

Table 6-6. (cont.) E. INNER/OUTER

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	AT	SS
YC		0.388	0.388	0.410	0.984	0.986	0.991	0.900	0.999	0.989	0.435	0.988
CF	*		1.000	1.000	0.176	0.163	0.240	0.788	0.431	0.223	1.000	0.541
GW	*	NS		1.000	0.176	0.163	0.240	0.788	0.431	0.223	1.000	0.541
LW	*	NS	NS		0.203	0.189	0.266	0.798	0.452	0.248	0.997	0.559
WF	NS	*	*	*		1.000	0.995	0.803	0.976	0.995	0.231	0.949
AF	NS	*	*	*	NS		0.995	0.798	0.978	0.998	0.218	0.944
VN	NS	*	*	*	NS	NS		0.840	0.988	0.998	0.294	0.961
YT	NS	*	*	*	*	*	NS		0.918	0.825	0.813	0.955
NO	NS	*	*	*	NS	NS	NS	NS		0.986	0.477	0.996
ST	NS	*	*	*	NS	NS	NS	NS	NS		0.277	0.959
AT	*	NS	NS	NS	*	*	*	*	*	*		0.581
SS	NS	*	*	*	NS	NS	NS	NS	NS	NS	*	

Table 6-6. (cont.) F. FORAGING SUBSTRATE

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	AT	SS
YC		0.074	0.093	0.087	0.965	1.000	0.971	0.873	1.000	0.574	0.016	0.052
CF	*		0.696	0.716	0.104	0.244	0.087	0.497	0.134	0.256	0.851	0.576
GW	*	*		0.996	0.090	0.195	0.196	0.671	0.200	0.345	0.186	0.025
LW	*	*	NS		0.078	0.187	0.139	0.685	0.191	0.348	0.184	0.026
WF	NS	*	*	*		0.970	0.873	0.771	0.937	0.792	0.085	0.101
AF	NS	*	*	*	NS		0.933	0.865	0.985	0.543	0.209	0.022
VN	NS	*	*	*	*	*		0.807	0.968	0.526	0.053	0.048
YT	NS	*	*	*	*	*	*		0.891	0.583	0.217	0.125
NO	NS	*	*	*	*	NS	NS	NS		0.593	0.052	0.060
ST	*	*	*	*	*	*	*	*	*		0.127	0.080
AT	*	*	*	*	*	*	*	*	*	*		0.759
SS	*	*	*	*	*	*	*	*	*	*	*	

Portion of tree was useful in separating guilds but not in separating members of a guild. As mentioned above, most species were specialized on either inner or outer portions, and 22 of 25 species pairs within guilds overlapped significantly.

Table 6-7 summarizes the significant overlaps within and between various ecological groups of species. Not surprisingly, there was always greater similarity within a guild than between guilds. The summer visitor species, which were the only members of the canopy-feeding guild in this community, overlapped much more among themselves than did the permanent residents. There was a very low degree of significant overlap between the residents and visitors.

Morphology

Table 6-8 lists the means and standard deviations of all morphological measures for the 13 species used in this study. The smallest species was the Verdin (6.5 gm, 8.4 mm bill length) and the largest was the Common Flicker (110 gm, 32.7 mm bill). Seven species were between 27 and 46 gm, with bill lengths varying from 15.7 mm to 23.8 mm.

Overall morphological similarity based on ratios of the measures is illustrated in Figure 6-4. In general, species were arrayed by body size and bill length, with three major size groupings formed. The seven medium-sized species differed primarily with respect to bill width and depth. The Ladder-backed Woodpecker, Northern Oriole, and Ash-throated Flycatcher had relatively narrow or flattened bills; the Wied Crested Flycatcher and Summer Tanager had the widest bills, and the Abert Towhee and Blue Grosbeak had very deep as well as wide bills.

Diet

The contents of 106 stomachs, representing midsummer diets of 13 species, were analyzed for the present study. In July, all species had raised at least one brood, the largest number of birds occurred on the plot, and, according to ecological theory, potential competition for food would have been greatest. Sample sizes were small, ranging from 2 to 13; however, these are believed to be adequate for most species, based on the small variation in individual diets and their correspondence with field observations. Wiens and Rotenberry (1979) similarly justified small samples as being reasonable inventories of avian diets. The small sample for Common Flicker and Ladder-backed Woodpecker prevent conclusive analysis; however, they were included for completeness.

The distribution of size classes of insects in the diets are shown in Figure 6-5. The largest and smallest avian species (Common Flicker and Verdin, respectively) were specialists on the smallest size class of insects, illustrating the danger of inferring prey size indirectly from bill measurements. The most frequently eaten size class of insects among the larger avian species was 21-30 mm. All of these birds except the Yellow-billed Cuckoo ate very small insects as well.

Table 6-7. Degree of foraging overlap within and between "ecological" groupings of bird species. Significant overlaps based on G_H-test (see Table 6-6, text), with six tests for each species pair.

Ecological group	Number of pair-wise comparisons	Number of significant overlaps per pair (max = 6)
Woodpecker guild	3	2.66
Ground-feeding guild	1	2.00
Canopy-feeding guild	21	3.40
Foliage-gleaners	3	4.00
Hawkers and hoverers	6	3.83
Between guilds	41	0.61
Permanent residents	10	1.40
Summer visitors	21	3.40
Residents versus visitors	35	0.60
Entire community	66	1.60

Table 6-8. Morphological measurements of 13 species of riparian birds. Means and standard deviations are given in parentheses. Bill length is exposed culmen; width and depth measured at nares. Species codes from Table 6-1.

Species	N	Weight (gm)	Wing (mm)	Bill length (mm)	Width (mm)	Depth (mm)
YC	6	66 (4.8)	149 (4.0)	29.3 (0.9)	7.8 (0.3)	8.9 (0.8)
CF	2	110	145	32.7 (2.7)	9.2 (0.1)	8.0 (0.3)
GW	11	62 (6.9)	128 (1.8)	27.4 (2.8)	7.2 (0.6)	7.3 (0.5)
LW	2	33 (3.0)	106 (8.5)	20.0	6.5	5.7
WF	11	38 (11.6)	108 (5.8)	23.8 (2.5)	9.7 (0.6)	8.1 (0.6)
AF	13	27 (1.8)	93 (3.4)	19.0 (0.7)	7.5 (0.4)	6.3 (0.3)
VN	12	6.5(0.4)	49 (3.1)	8.4 (0.4)	3.7 (0.4)	3.9 (0.4)
YT	10	10 (0.7)	54 (1.3)	11.9 (0.7)	3.6 (0.3)	3.6 (0.4)
NO	10	31 (2.7)	95 (3.0)	18.1 (0.5)	5.7 (0.5)	6.9 (0.4)
ST	7	33 (3.3)	100 (3.7)	20.3 (0.8)	9.4 (0.4)	9.7 (0.4)
BG	9	27 (1.9)	85 (3.6)	16.3 (0.9)	8.5 (0.8)	11.3 (0.8)
AT	10	46 (3.8)	89 (2.8)	15.7 (0.4)	6.7 (0.5)	8.8 (0.4)
SS	10	19 (2.4)	64 (2.1)	11.9 (0.5)	5.4 (0.4)	6.2 (0.3)

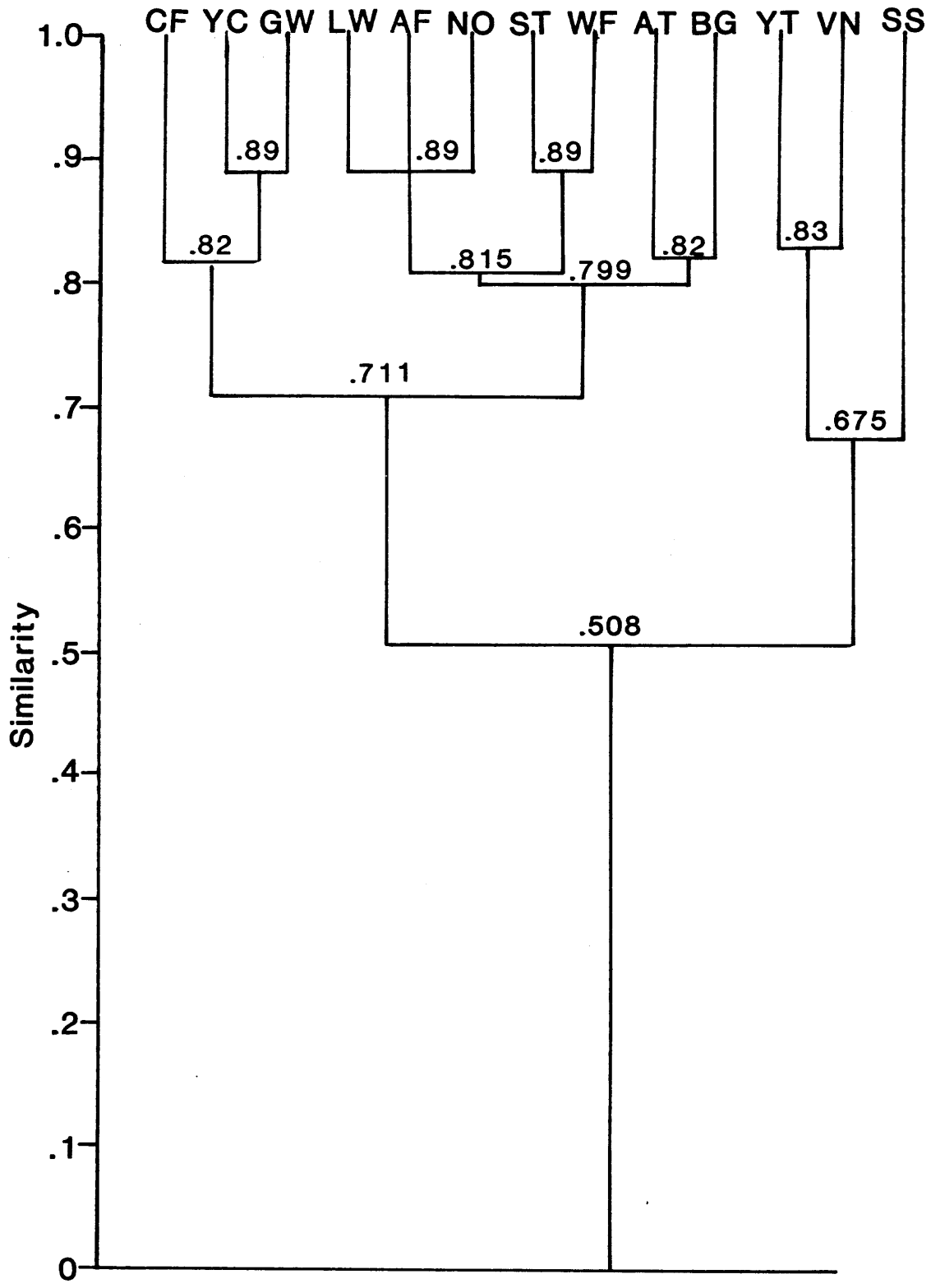


Figure 6-4. Morphological similarity among 13 riparian birds. Represents average of ratios of five measures for each species pair. Species codes from Table 6-1.

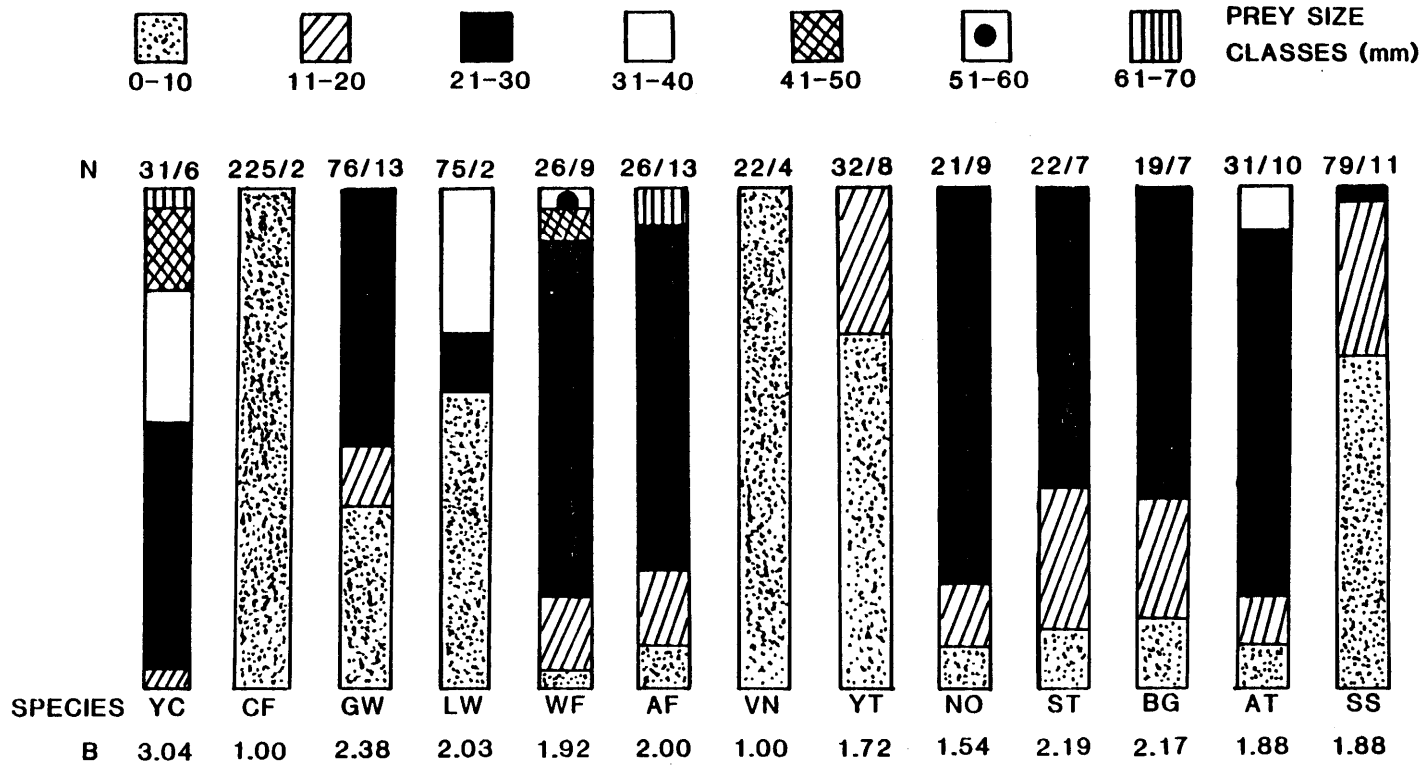


Figure 6-5. Prey size (mm) use by 13 riparian birds. Niche breadth (B) = $(\Sigma pi^2)^{-1}$. N represents number of food items/number of stomachs. Species codes from Table 6-1.

Prey size diversity (B) for each avian species is also shown in Figure 6-5. The Yellow-billed Cuckoo had the highest diversity, and the Common Flicker and Verdin were completely specialized. The remaining species differed little, varying from 1.54 to 2.38. The maximum possible value of B was 7.00.

Overlap in prey size distributions among bird species is illustrated as a dendrogram in Figure 6-6. Two major clusters separate species that feed on large insects from those taking only small prey.

Actual overlaps among avian species pairs and their accompanying levels of statistical significance are listed in Table 6-9. Because seven insect size classes were used by the entire community, the G_H statistics were compared with a chi-square$_{0.001}$ distribution with 6 degrees of freedom. This critical value was necessary to minimize Type I errors with 78 simultaneous comparisons. Alternatively, the actual number of size classes used by the two species in each comparison determined the degrees of freedom of that particular test. Thus, the critical value of chi-square$_{0.001}$ would also vary for each test. Species comparisons whose significance differed with the two approaches are shown in Table 6-9 and may be interpreted as being marginally significant overall.

The two flycatchers, Northern Oriole, Summer Tanager, Blue Grosbeak, and Abert Towhee all overlapped very highly in prey size distribution, and all of these overlaps were significant. The Gila Woodpecker overlapped significantly with the Northern Oriole and Blue Grosbeak, and marginally with the Ash-throated Flycatcher and Abert Towhee. The Yellow-billed Cuckoo overlapped significantly only with the Wied Crested Flycatcher.

Among smaller species, the Common Yellowthroat and Song Sparrow had nearly identical prey size distributions and their overlap was significant. The Verdin and Common Flicker overlapped completely with respect to prey size. The Verdin could not be separated statistically from the Common Yellowthroat and was only marginally different from the Song Sparrow. These species were retested using 0-5 mm and 5-10 mm as distinct insect size classes, and in no case did the results change.

In summary, there was a great amount of overlap among both the larger and smaller avian species. Within each group, the canopy-foraging summer visitor species were nearly inseparable statistically. Among permanent residents and the other two foraging guilds, the only overlap that was even marginally significant was between the Gila Woodpecker and the Abert Towhee.

The distribution of prey types in the diets of the 13 avian species is shown in Figure 6-7. These are expressed as both percent-volume and percent-frequency, each weighted to represent the average of the individual stomachs for each species. In general, volume and frequency distributions were very similar. Volume measures tend to emphasize larger insect taxa and may better represent the relative importance of food items to the bird. Frequency measures emphasize smaller food items which can occur in larger numbers and may better correspond to the foraging efforts of the bird. The weighted averaging technique employed reduced the latter bias among the frequency measures.

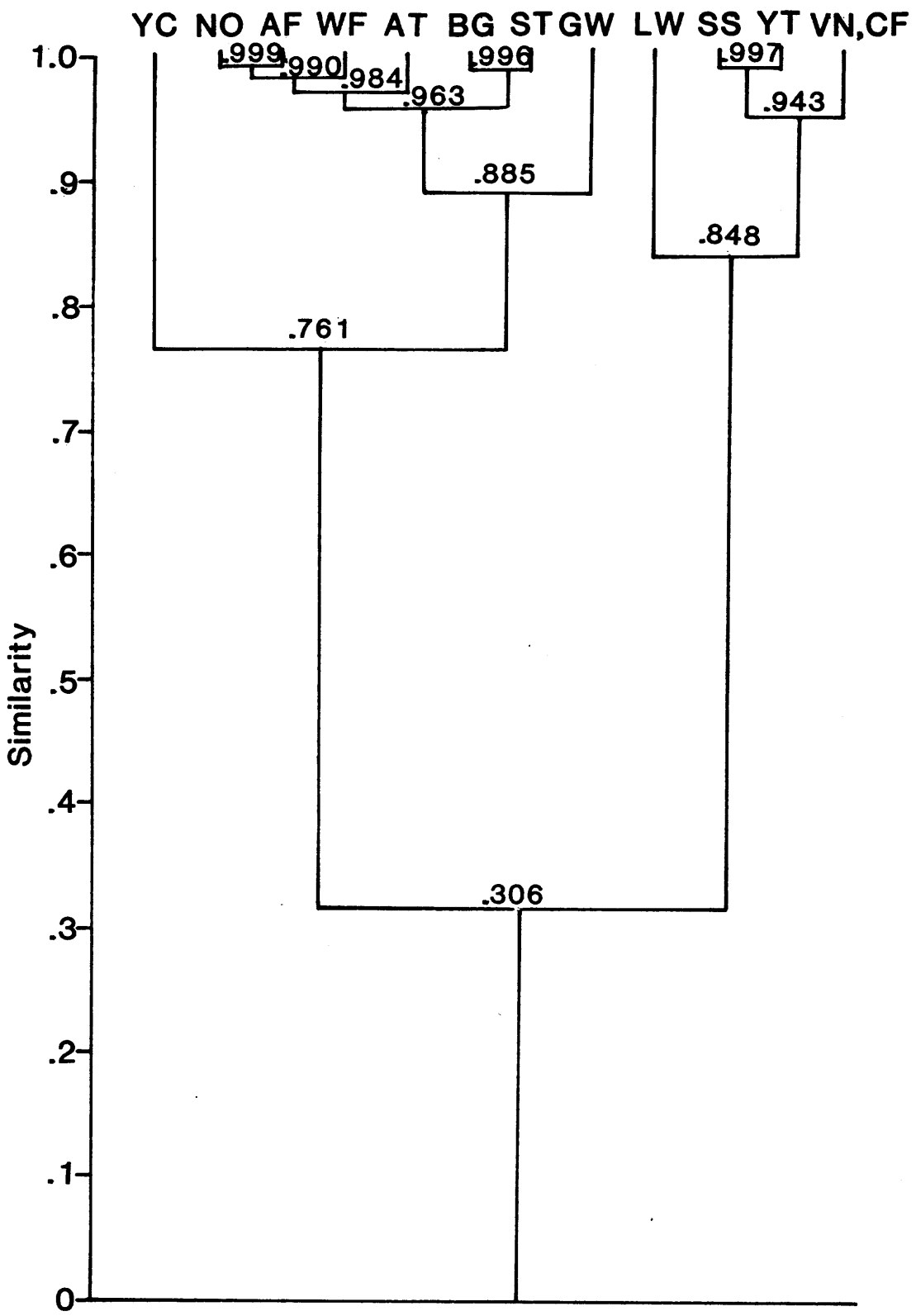


Figure 6-6. Prey size overlap among 13 riparian birds. Overlaps from Table 6-12. Species codes from Table 6-1.

Table 6-9. Overlap in use of prey size classes among 13 species of riparian birds. Overlap and significance tests as in Table 6-6. NS (*) indicates marginally significant overlap (see text). Species codes from Table 6-1.

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	BG	AT	SS
YC		0.000	0.691	0.344	0.880	0.846	0.000	0.036	0.882	0.791	0.806	0.850	0.064
CF	*		0.625	0.905	0.059	0.135	1.000	0.950	0.102	0.176	0.222	0.130	0.935
GW	*	*		0.604	0.850	0.885	0.625	0.599	0.890	0.879	0.911	0.881	0.612
LW	*	*	*		0.186	0.246	0.905	0.813	0.225	0.266	0.307	0.313	0.767
WF	NS	*	*	*		0.982	0.059	0.133	0.998	0.959	0.972	0.980	0.170
AF	*	*	NS(*)	*	NS		0.110	0.201	0.999	0.967	0.980	0.981	0.236
VN	*	NS	*	NS(*)	*	*		0.950	0.102	0.262	0.222	0.130	0.935
YT	*	*	*	*	*	*	NS		0.155	0.321	0.330	0.168	0.997
NO	*	*	NS	*	NS	NS	*	*		0.971	0.985	0.993	0.189
ST	*	*	*	*	NS	NS	*	*	NS		0.996	0.947	0.365
BG	*	*	NS	*	NS	NS	*	*	NS	NS		0.963	0.370
AT	*	*	NS(*)	*	NS	NS	*	*	NS	NS	NS		0.199
SS	*	*	*	*	*	*	NS(*)	NS	*	*	*	*	

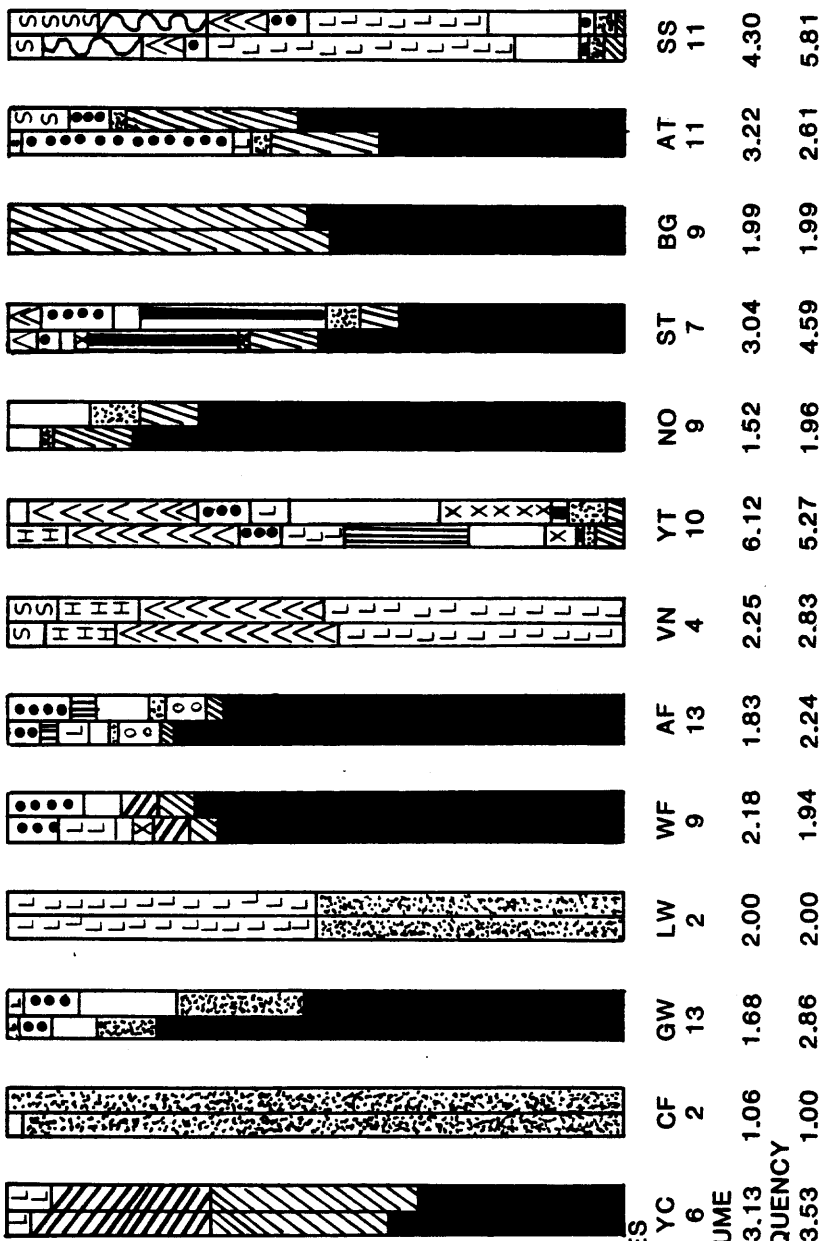


Figure 6-7. Diets of 13 riparian birds in summer. Bars indicate weighted percent volume (left) and percent frequency (right). Niche breadth (B) for volume and frequency = $(\Sigma pi^2)^{-1}$. Species codes from Table 6-1.

Eight species preyed heavily on cicadas. Grasshoppers were an important food for the Yellow-billed Cuckoo, Blue Grosbeak, Abert Towhee, and possibly the Northern Oriole. Summer Tanagers were the only birds to feed on bees and wasps, and Gila Woodpeckers ate many ants. Abert Towhees fed heavily on beetles, and the two flycatchers took a wide variety of food items in addition to cicadas.

The smaller bird species fed on a variety of soft-bodied prey, primarily spiders and larvae of several insect orders. The small samples of Common Flicker and Ladder-backed Woodpecker stomachs suggest that their diets may have been very different from most other species. Of the three species sometimes referred to as granivores, the Song Sparrow and Abert Towhee ate very few seeds, and the sample of Blue Grosbeak stomachs contained no seeds.

Diet diversities (B) for volume and frequency are also shown in Figure 6-7. These two measures generally showed the same patterns among the species. The Common Yellowthroat and Song Sparrow had the most diverse diets. Among the larger birds, the Summer Tanager, Yellow-billed Cuckoo, and Abert Towhee had the most generalized diets, while the two flycatchers, Northern Oriole, and Blue Grosbeak were more specialized.

Overlaps in diet are illustrated in Figures 6-8 and 6-9 for both percent-frequency and percent-volume distributions. Both result in very similar groupings of species.

Table 6-10 lists overlap values and associated significance for the diet distributions of all species pairs, using percent-frequency. Because there were 78 simultaneous comparisons and 15 prey categories, the G_H statistic was compared with chi-square$_{0.001}$ distribution with 14 degrees of freedom. The alternative of varying the degrees of freedom for each comparison is presented as for prey size.

In the tight cluster in Figure 6-8, the two flycatchers, Northern Oriole, and Gila Woodpecker all overlapped >0.900; all overlaps were significant. The Yellow-billed Cuckoo, Blue Grosbeak, and Abert Towhee also overlapped significantly among themselves. The Summer Tanager overlapped significantly with all these species except the Gila Woodpecker. Altogether, among the eight species which preyed upon cicadas, 23 of 28 overlaps in diet were statistically significant, although seven of these were marginal.

Insect Availability

As can be seen from Figure 6-10, insect biomass varied seasonally, even within the breeding season. Furthermore, it is suggested that the availability of large insects increased through the summer months, while small insects and total biomass were decreasing from a peak in May. This trend is especially noteworthy, considering the difficulty in sampling large mobile insects with sweep nets.

Figure 6-11 shows the relative contribution of major arthropod orders to the samples. Consistent in both years was a peak of homopterans (mainly tiny cicadellids) in May and an increase in orthopterans until July. A

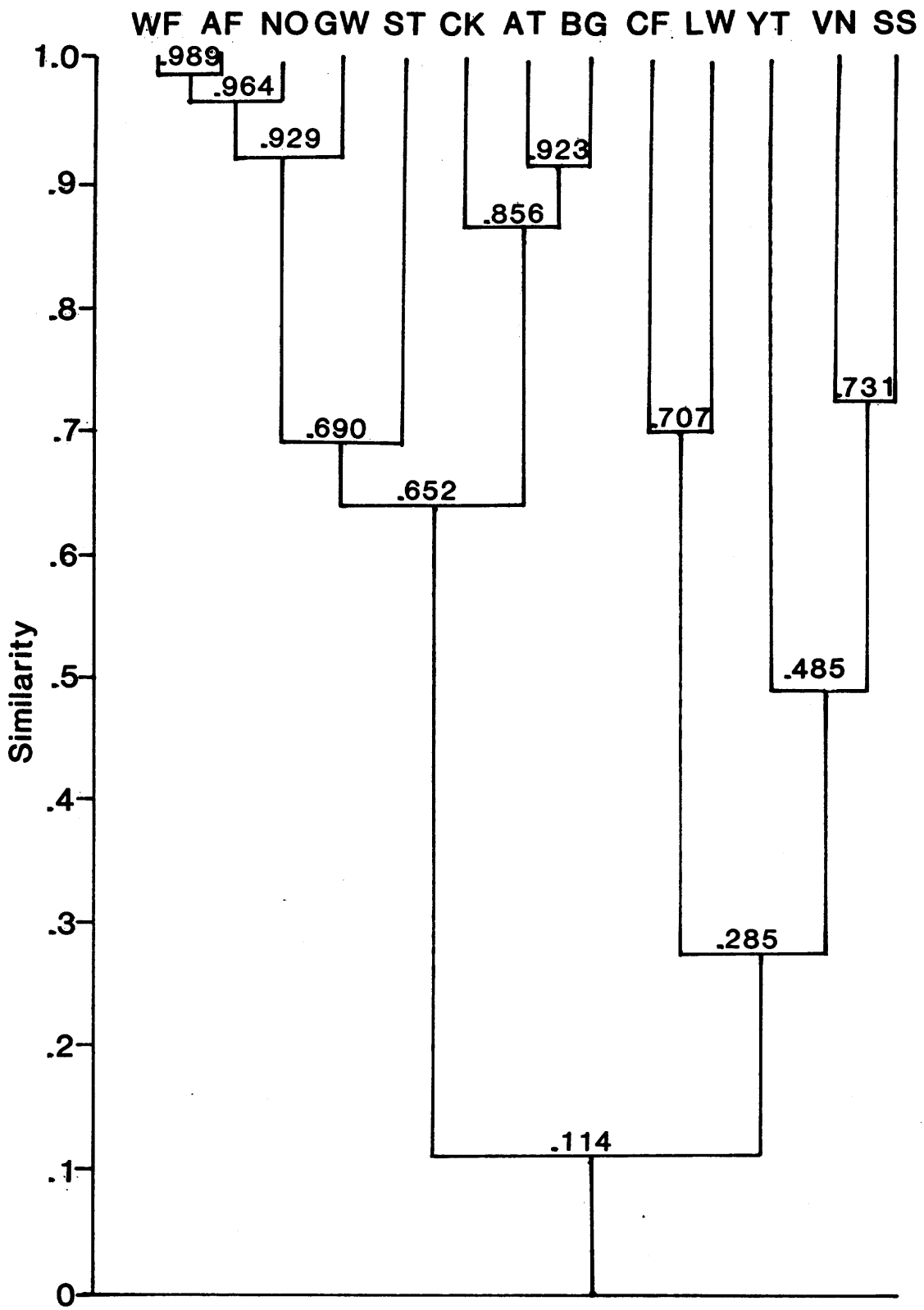


Figure 6-8. Diet overlap among 13 riparian birds-percent frequency. Overlaps from Table 6-13. Species codes from Table 6-1.

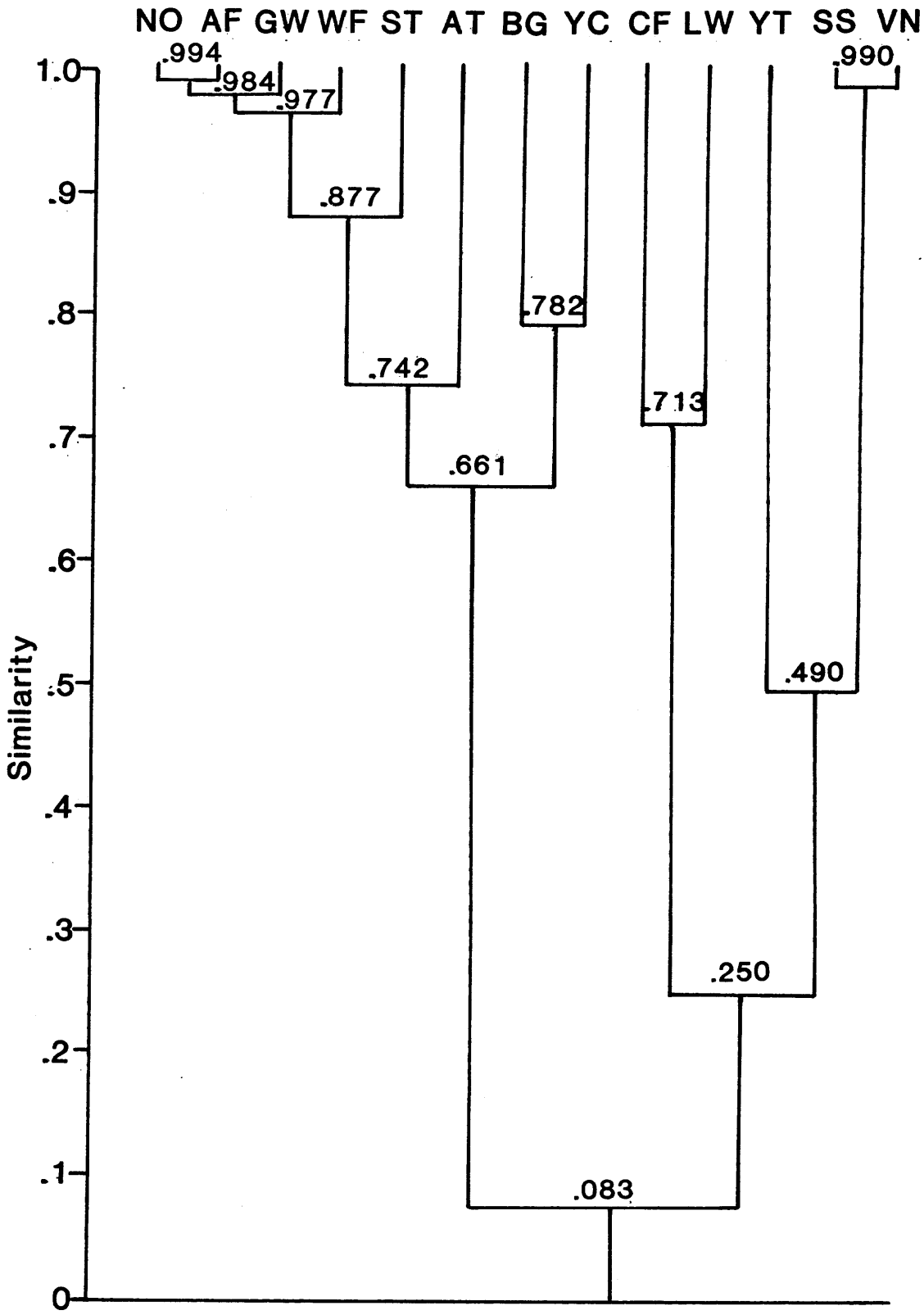


Figure 6-9. Diet overlap among 13 riparian birds-percent volume. Species codes from Table 6-1.

Table 6-10. Diet overlap among 13 species of riparian birds, based on weighted average frequency of prey categories. Overlap and significance tests as in Table 6-6. NS(*) indicates marginally significant overlap (see text). Species codes from Table 6-1.

	YC	CF	GW	LW	WF	AF	VN	YT	NO	ST	BG	AT	SS
YC		0.000	0.545	0.130	0.766	0.632	0.145	0.082	0.688	0.562	0.888	0.829	0.016
CF	*		0.355	0.707	0.000	0.064	0.000	0.140	0.178	0.195	0.000	0.055	0.092
GW	*	*		0.263	0.908	0.929	0.000	0.229	0.939	0.683	0.595	0.801	0.131
LW	*	*	*		0.000	0.046	0.582	0.264	0.126	0.138	0.000	0.039	0.494
WF	NS(*)	*	NS	*		0.987	0.000	0.143	0.968	0.700	0.721	0.904	0.114
AF	*	*	NS(*)	*	NS		0.000	0.206	0.959	0.706	0.659	0.889	0.149
VN	*	*	*	*	*	*		0.472	0.000	0.030	0.000	0.000	0.731
YT	*	*	*	*	*	*	NS(*)		0.154	0.270	0.062	0.072	0.497
NO	NS(*)	*	NS	*	NS	NS	*	*		0.691	0.757	0.911	0.115
ST	NS(*)	*	*	*	NS(*)	NS	*	*	NS		0.624	0.708	0.190
BG	NS	*	*	*	NS	NS	*	*	NS	NS		0.923	0.020
AT	NS(*)	*	*	*	NS	NS	*	*	NS	NS(*)	NS		0.093
SS	*	*	*	*	*	*	NS(*)	*	*	*	*	*	

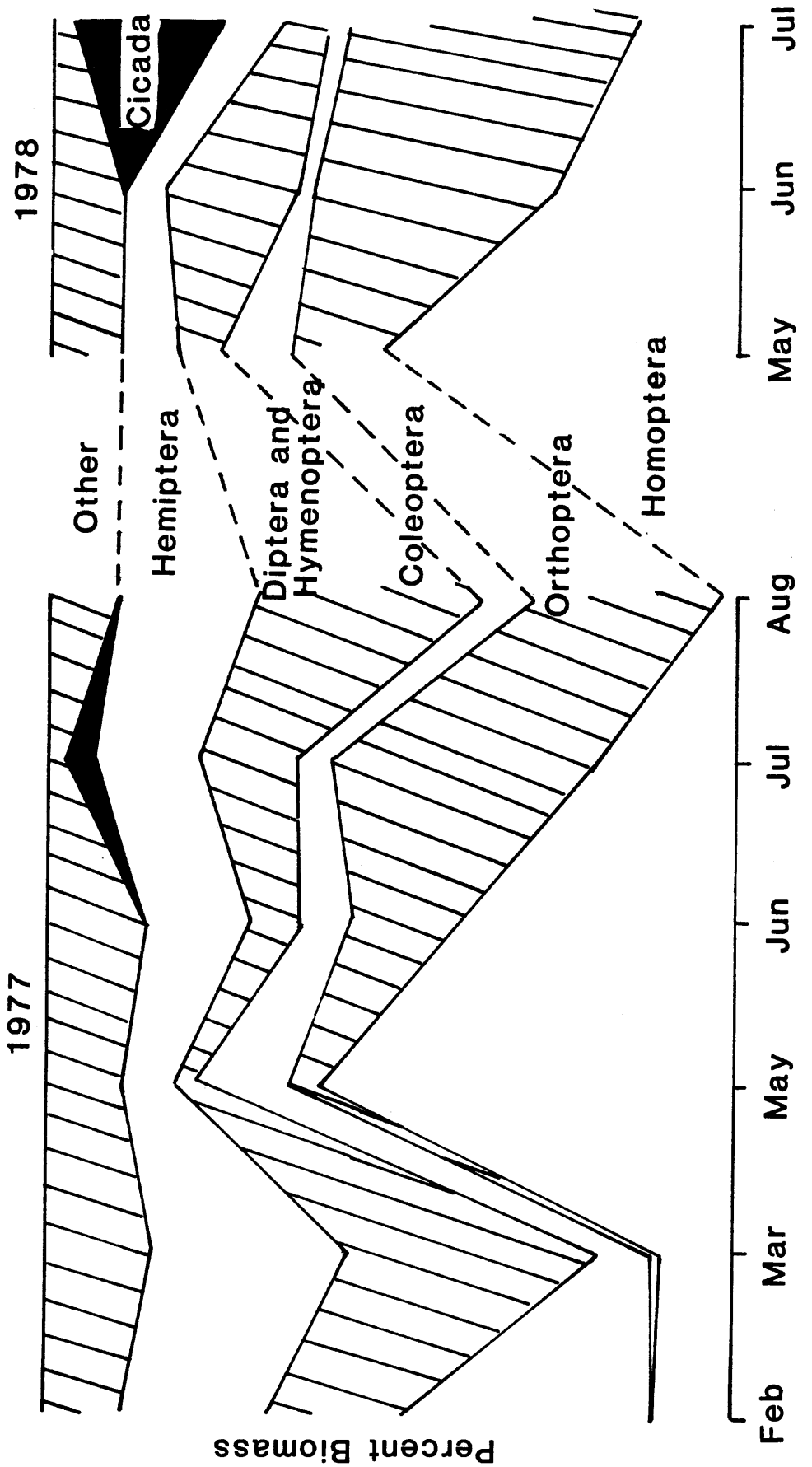


Figure 6-10. Biomass of arthropod size classes in cottonwood-willow habitat in two summers.

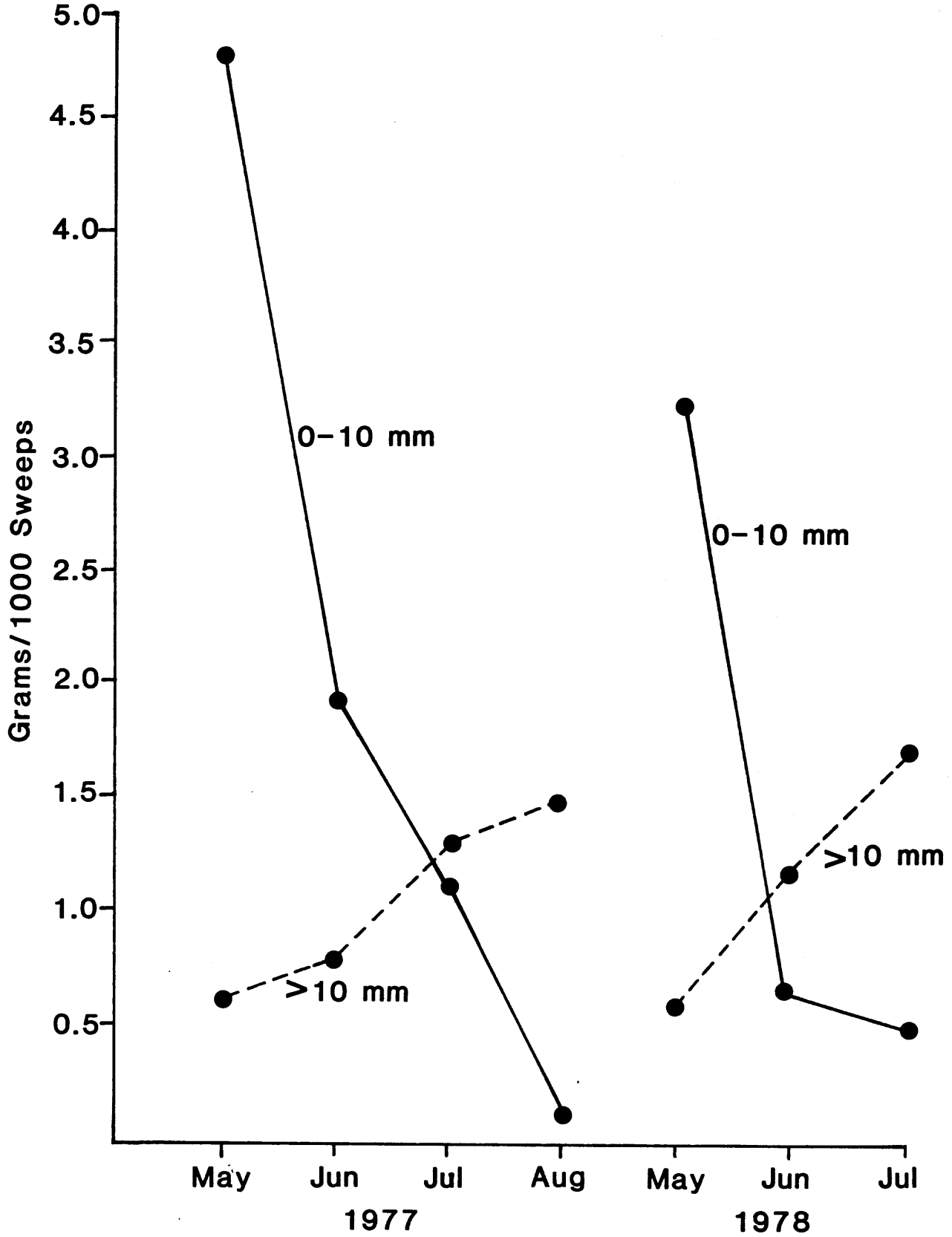


Figure 6-11. Taxonomic breakdown of arthropod samples in cottonwood-willow habitat.

few cicadas in the July 1978 sample contributed greatly to its biomass, but in general a huge population of cicadas was not represented at that time.

To estimate cicada numbers, data from R. Glinski (pers. comm.) were used as representative of cottonwood-willow-salt cedar habitat in Arizona (Fig. 6-12). These were successive weekly counts of exuvia on plots along the San Pedro River in southeastern Arizona during the summer of 1978. The species of cicada was the same as on the present study plot, and a qualitative comparison of habitat and cicada populations (noise levels) suggests that these data are relevant to this study.

Cicada numbers peaked at nearly 700,000 per 40 ha on 21 July and declined steadily until late August. Average number of adult cicadas emerging through the sampling period was 250,000 per 40 ha per week. These numbers, superimposed on the sweep samples, indicate availability of large insects to birds in mid-summer, and this was certainly represented in the diets of many species (see Figs. 6-5 and 6-7).

DISCUSSION

Community organization in this riparian forest was complex. Many of the measured variables were important determinants of bird species patterns, and these variables were highly correlated when considered simultaneously. In addition, it is clear that sets of species responded differently to patterns of habitat and resource availability. Relationships between measured niche axes and the ecological groups that made up this bird community will be discussed in the following sections.

Species usage patterns indicated a high degree of overlap with respect to both space and food and also that partitioning was not well developed within this community. How this can be reconciled in light of theories that predict optimal mechanisms for avoiding competition will also be discussed.

Habitat Selection

Within the riparian ecosystem of the Colorado River valley, cottonwood-willow forest stands provide virtually the only tall trees required by several canopy- and cavity-nesting species. This structural component of the habitat was a prerequisite for the coexistence of many species in this study. However, within the relatively homogeneous riparian forest studied, microhabitat (within-habitat plots) separation was minimal, suggesting that habitat selection may be only coarse-grained in most riparian species. There was, of course, separation by foraging method. A few trends within the community are of interest.

Those species showing no association with any plant species (Table 6-5), thus indicating at least a tolerance of salt cedar, were typically habitat generalists within the overall riparian system. Nearly all attained higher densities away from the cottonwood-willow forest, and all occurred in pure stands of salt cedar (Anderson and Ohmart 1977). Other habitat generalists, including most other local permanent resident species, were absent from this forest plot. The Ash-throated

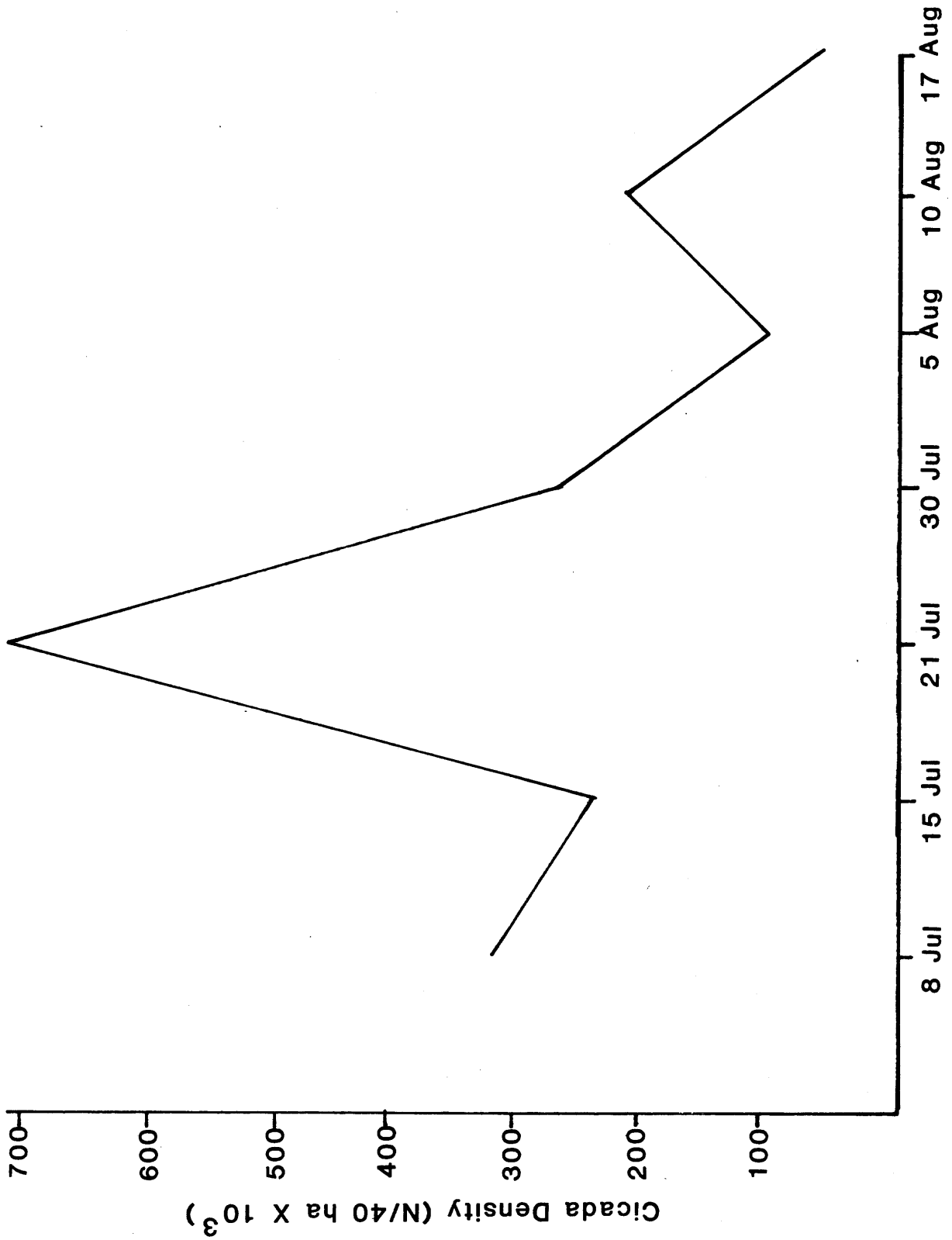


Figure 6-12. Density of emerging cicadas in cottonwood habitat during summer 1978. Data from R. Glinski.

Flycatcher, Verdin, and Blue Grosbeak showed an affinity for the edge of the plot, suggesting that they were only marginal members of this bird community.

The two ground foragers did not show this avoidance of the interior of the plot. Abert Towhees occur in all habitats along the lower Colorado River where there is dense understory, whereas the Song Sparrows' distribution appears to depend on the presence of surface water and not on any plant community. Ground foragers in general may view vegetation mainly as cover and therefore may not respond to changes in the upper canopy of forests (Stiles 1980).

The remaining species were woodpeckers and summer visitor insectivores. All preferred mature cottonwood-willow stands in the Colorado River valley, and nearly all were absent from pure stands of salt cedar. This was reflected in their unanimous avoidance of salt cedar areas on the plot. The problems that this exotic invader impose on riparian bird species in the region are well documented (Anderson et al. 1977b, Cohan et al. 1978).

Only the Common Yellowthroat showed a distinct preference for specific portions of the plot. This species is typically associated with emergent marsh vegetation throughout its range and was among the few microhabitat specialists on a high elevation riparian plot (Eckhardt 1979).

Both primary and secondary cavity-nesting species tended to occur at the same points on the plot, indicating both a shared habitat preference and a failure to exclude each other from preferred areas. However, aggression and direct competition for actual nest cavities was observed. Counts of snags indicated only a 30% usage of potential sites (T. Brush, unpubl. MS thesis), and without manipulative experiments it is difficult to assess to what extent such competition may be limiting populations of these species.

Thus, in general, overall habitat preferences of the species throughout their ranges were reflected in their microhabitat selection on the study plot. Failure of species to avoid or exclude one another suggests that for each species this process was independent of the other species present. An assumption of interspecific competition is not necessary to explain the observed spatial distribution of the species.

A consistent relationship existed between density, degree of clumping, and the preferred vegetation strata for the bird species. High density species tended to be clumped and to occur in the understory layers, whereas low density species occurred in the canopy and tended to be dispersed over the plot. Both dense salt cedar and emergent cat-tails and bulrushes were patchily distributed, and these largely determined the clumped distribution of the three understory species. Furthermore, total foliage density in the lower strata was much greater than in the canopy and was correlated with the close packing among the high density species.

An exception to this generality was the Northern Oriole, which attained a higher density than other canopy species. Pleasants (1979) showed that Northern Orioles exhibit a cline from strict territoriality to semicoloniality, concomitant with extended feeding trips outside the riparian nesting zones. Northern Orioles on this plot may have exhibited this weakening of territorial behavior. Furthermore, territories on the plot often contained more than two birds; typically a subadult male accompanied each pair. No other species on the plot showed this tendency, and this situation merits further study.

Fretwell (1972) suggested that breeding density within a habitat may be limited more by factors related to nest sites than to food supply. If density-dependent nest mortality was important, then the abundant presence of open dove nests on this plot would have affected open-nesting species more than their own individual nest densities. Plots with and without doves were not available to test this hypothesis. Moreover, there were no consistent differences between cavity- and canopy-nesters in terms of distribution pattern.

The results of this study cannot elucidate the mechanism of population regulation. However, it seems possible that social behavior such as territoriality may serve to limit population densities even when not mediated by local resource levels (Franzblau and Collins 1980).

Resource Exploitation Pattern

The relationship between morphology, behavior, and diet has received much theoretical and empirical attention (e.g., Emlen 1966, Schoener 1971, Pulliam 1974). Virtually all considerations of optimal foraging concern the coexistence of species, with special attention given to potential competitive interactions.

The grouping of species into guilds (Root 1967) has allowed a meaningful examination of these patterns among species. In the riparian forest community, some guilds were clearly defined (woodpeckers, ground foragers), whereas the large canopy feeding group was behaviorally less homogeneous. Although no true salliers were present in this community, a gradient did exist between specialist gleaners and more active hoverers and hawkers, corresponding in part to the "active" and "passive" searchers of Eckhardt (1979). The Summer Tanager, being the closest species to a passive searcher in this study, exhibited the most diverse foraging behavior and diet. This is in agreement with Eckhardt's empirical findings, which contradicted a major prediction of optimal foraging theory, that such predators should specialize.

Also pertinent was Eckhardt's (1979) finding that specialist gleaners exploited a smaller total foraging space than did flycatching species. This may have contributed to the clumped distribution and high density of Northern Orioles, compared with other canopy species in this study.

Hovering as a prey-capture maneuver requires a set of adaptations intermediate between those predicted for the extremes of purely active or passive searching. Prey may be located during either stationary or active periods in the bird's behavioral sequence and although capture in

flight probably involves a large energy expenditure relative to searching, actual pursuit of prey is not necessary. Although these measures were not quantified in the present study, it is of interest that hovering is a predominant behavior among the canopy species. It is likely that the dense and continuous canopy foliage in this stand minimized the opportunities for aerial hawking of insects; indeed, true salliers (e.g., Western Kingbird) were common in other more open or patchy forest stands near the study site.

Since hovering maneuvers involved prey capture on a foliage substrate, diets of species exhibiting this behavior might not be expected to differ greatly from those of more specialized foliage gleaners. In both cases, insects were sought whose main predator defense was concealment rather than escape (Root 1967). Indeed, the actual diets of all medium-sized foliage insectivores were very similar, and the finer splitting of the canopy-feeding guild seems unjustified.

If three foraging guilds, reflecting major foraging opportunities, were the functional units of this bird community, then interspecific relationships within these guilds should ultimately determine the species composition of the community. Both the ground foraging and woodpecker guilds were small and made up of morphologically divergent species. In fact, adjacent pair size and bill length ratios within these guilds were nearly identical to those predicted by Hutchinson (1959) to permit coexistence. Diets within these guilds were also divergent.

A simplistic explanation based on competition for limited resources is inviting, but closer examination reveals a more complex picture. Systematic differences in body size among the woodpeckers were not paralleled by similar differences in diet; the largest species (Common Flicker) ate the smallest prey. Furthermore, interguild overlap in diet between the Gila Woodpecker and the Abert Towhee was higher than in any intraguild comparison, and both these species overlapped significantly with several members of the canopy-feeding guild.

In contrast, the canopy-feeding guild was much more tightly packed and consistently showed a high degree of overlap in both behavior and diet. Although large size differences resulted in major differences in diet, more subtle differences in bill morphology or body size were not reflected in either prey size use or diet composition differences. Furthermore, divergent behavior most often did not result in different diets.

Detailed explanations of these patterns and their relevance to theoretical ecology are beyond the scope of this chapter and are presented by Rosenberg (1980) and Rosenberg et al. (1982). However a summary of our conclusions is relevant to the management recommendations that follow.

First, it can be reasonably argued that this bird community is not limited by food supply during the breeding season. The high degree of dietary overlap, the convergence of summer breeding with a peak in cicada numbers, and the lack of spatial segregation, together suggest:

(1) that interspecific competition is not an important force in organizing this bird community, and (2) that the community may have evolved in response to an annual resource peak. This is discussed in more detail in Rosenberg et al. (1982). Competition could be more acute if a "bad" year for cicadas was experienced.

Second, it is apparent that the seasonal nature of the food supply differentially affects various subgroups within the community. Guilds of species exploiting bark and ground substrates presumably find a relatively stable food supply year round and are thus permanent residents on the plot. Guilds exploiting foliage and aerial insects in the canopy are exposed to a highly seasonal food supply and are thus present only where these foods are abundant in summer. Various seasonal groups (residents vs. visitors) and foraging guilds may then be under very different long-term natural selective forces and the application of any single theory to the entire community may be impossible.

Management Implications

The overall goals of this study were to provide information essential for the maintenance of an intact and diverse ecosystem in the lower Colorado River valley, in the face of future proposed developments and for enhancement of the valley's fauna through vegetation management. A forceful conclusion of this report is the disproportionately high value of native cottonwood-willow habitats to birds. It is hoped that this chapter will aid in incorporating a cottonwood-willow enhancement approach into the overall management plan.

Our finding that various subgroups within the bird community respond differently to portions of habitat and food availability identifies the need to consider several aspects of habitat management simultaneously. Large changes in bird species diversity associated with large structural differences between habitats (MacArthur and MacArthur 1961) are often due to the addition or subtraction of entire foraging or nesting guilds (Holmes et al. 1979, Stiles 1980). Within each guild, number of species may be determined by the absolute abundance and seasonal nature of the specific food resources. What this means in terms of management is the necessity to preserve or create a diversity of foraging substrates and nest sites.

We have shown that tree foliage, bark, and ground litter are all heavily used as foraging substrates. In addition, nesting occurred in tree canopies, snags, and dense understory foliage. To maintain all components of the present bird community and to reestablish missing elements in areas under intensive vegetation management, the following guidelines are presented: (1) maintain a viable population of mature, living cottonwood and willow trees, preferably forming a continuous canopy; (2) allow or encourage the presence of dead snags and branches, both standing and fallen; (3) maintain a patchy understory of shrub and emergent plant species (a continuous understory of salt cedar is <u>not</u> encouraged); and (4) allow for the accumulation of leaf and wood litter, at least in part of the habitat.

Perhaps our most important conclusion is the need to preserve remaining cottonwood-willow habitat in the lower Colorado River valley. The Bill Williams delta is now an essential stronghold for breeding species that are rare or declining elsewhere along the river. This area can serve as a constant source of birds that can disperse into other areas as habitat conditions improve. The existence in this study of "edge" and "interior" forest species implies that small remaining stands may attract only a subset of the complete bird community. However, many areas can benefit from the kinds of habitat improvement (irrigation, planting, salt cedar control) that are demonstrated in the revegetation report (Anderson and Ohmart 1982).

LITERATURE CITED

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Appendix 6-1. Definitions of foraging measures and states.

Measure	State	Definition
Method	1. Glean	Bird is perched; prey is captured from surface of substrate.
	2. Hover	Bird is in flight; prey is attached to substrate surface.
	3. Hawk	Both bird and prey are in flight.
	4. Peck	Bill is struck against substrate to expose prey below the surface.
	5. Probe	Bill enters substrate to capture prey below the surface.
Foraging hieght	1. Ground	Ground and litter.
	2. 0-6.2 m	Understory.
	3. 6.2-12.3 m	Midcanopy.
	4. 12.3-21.0 m	Upper canopy.
Tree species	1. Cottonwood	Populus fremontii
	2. Willow	Salix gooddingii
	3. Dead	Dead cottonwood or willow.
	4. Salt cedar	Tamarix chinensis
	5. Other	Honey mesquite, cat-tails, etc.
Branch diameter	1. $\leq$1 cm	
	2. 1-2.5 cm	
	3. 1.5-5 cm	
	4. 7.5-10 cm	
	5. 12.5-20 cm	
	6. >20 cm	

Appendix 6-1. (cont.)

Measure	State	Definition
Tree portion	1. Inner	Larger branches close to and including trunk.
	2. Outer	Smaller branches and twigs, containing most foliage
Substrate	1. Leaf	
	2. Bark	
	3. Ground	
	4. Air	
	5. Flower or fruit	
	6. Surface of water	

CHAPTER 7

WATER BIRD USE OF NATURAL AND MODIFIED PORTIONS OF THE LOWER COLORADO RIVER

INTRODUCTION

Natural habitats along the lower Colorado River have undergone dramatic alterations by man since about 1870. The need for flood control, water storage, hydroelectric power, and development of agriculture in the riparian floodplain has promoted impoundments, straightening, dredging, and bank reinforcement along much of the lower Colorado River since the early 1900's (Ohmart et al. 1977).

There are few quantitative data on how alterations of desert rivers affect water birds using these rivers. In this report we examine relationships between human use of the river, bank and channel modifications, abundance of food resources, and water bird densities and diversities.

We studied the water birds of the lower Colorado River between Yuma, Arizona and Mohave Lake, Nevada-Arizona border, from January 1977 through February 1979. We compared bird populations in areas having river channel and bank alterations with those in relatively undisturbed areas, and then examined the reactions of six major water bird groups to environmental variables. We also analyzed the importance of exposed islands to water birds. For additional information on these subjects see Anderson and Ohmart 1977, 1978).

METHODS

One to three census areas were established in channelized, undisturbed, and canyon-embanked portions of the lower 443 km (275 mi) of the Colorado River during January 1977 (Table 7-1). In addition, two census areas on reservoirs and two river areas directly downstream from dams were established during November 1977. Census areas were from 48 to 500 ha (120 to 1250 a; $\bar{x}$ = 176 ha = 440 a) in area and ranged in length from 0.3 to 2.9 km (0.2 to 1.7 mi; $\bar{x}$ = 0.8 km = 0.5 mi).

Birds using the river (feeding, swimming, or resting) were censused by direct count of the birds present made from a boat along pre-defined reaches of the river. These reaches were identical for all censuses. Birds occurring in large flocks were sometimes difficult to count. In such cases, we used our best estimate. We assumed a mean river width of 500 ft. This figure multiplied by the length of the reach and divided by 43,560 gave an approximation of acreage censused. Backwaters were eliminated from censuses and were not included in river width estimates. The mean of three censuses each month provided density (n/40 ha [100 a]) and species richness (number of different species) estimates. Species with an average monthly density of 0.5/40 ha or less were not included in overall density and species richness estimates. Data for winter 1977 (January and February 1977), winter 1977-78 (October 1977-February

Table 7-1. Biological features and descriptions of the study areas on the lower 443 km of the Colorado River. Dashes (-) indicate datum not provided.

Habitat type and transect name	Length (m)	Area (ha)	Bank modification (%/km)[a]	Invertebrates (N/m^3)[b]	Human usage (N/km)[c]	Latitude	Description of habitat
Channelized river							
Rv 1	6,450	600	65.4	409	642	34° 59′	Banks are riprapped[d]. Limited meandering of river. Deep, swift-moving water[e]. Sparse riparian vegetation along riverbanks. Inhabited by people to a large extent.
Rv 4	4,840	450	58.0	121	373	33° 34′	
Rv 5	6,450	600	86.0	176	1,088	33° 21′	
Undisturbed river							
Rv 2	6,450	600	50.0	-	608	34° 06′	Many adjacent backwaters and marshes. Extensive stands of riparian vegetation along river-banks. Slow, shallow, meandering water[e]. Rv 3 receives effluence of an agricultural wasteway.
Rv 3	6,450	600	4.0	-	608	33° 58′	
Backwater							
Rv 6	3,220	300	4.0	759	328	33° 17′	Pristine river. Slow, shallow, meandering water. Extensive natural riparian vegetation along banks. Extensive stands of benthic vegetation. More exposed islands, mudflats, sandbars and peninsulas than any other study area.

Table 7-1. (cont.)

Habitat type and transect name	Length (m)	Area (ha)	Bank modification (%/km)[a]	Invertebrates (N/m^3)[b]	Human usage (N/km)[c]	Latitude	Description of habitat
Canyon embanked							
Rv 7	29,030	2,700	35.0	136	579	33° 00′	Generally banks consist of steep, rocky canyon walls with little vegetation. Water is deep and swift. Many adjacent lakes and backwaters away from river.
Below dams							
Rv 8	3,220	300	50.0	-	643	35° 06′	Directly downstream from dams.
Rv 10	4,032	375	65.4	328	2,376	34° 17′	Very swift, cool water[e].
Reservoirs							
Rv 9	8,062	2,125	100.0	-	-	35° 09′	Major reservoirs.
Rv 10	12,900	2,425	100.0	2	1,521	34° 17′	Has coves and beaches. Little riparian vegetation along shore.

[a]Banks modified with riprap and/or dirt fill per km of river.

[b]The number of invertebrates per cubic meter of river (Minckley 1979).

Table 7-1. cont.

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[c]The average number of people per km using the river for recreational purposes (skiing, fishing, boating, etc.) during the months of January, February, October, November and December, 1976-79 (Greey et al. 1976-78).

[d]Banks reinforced with rocks.

[e]Minckley 1979.

1978), and winter 1978-79 (October 1978-February 1979) were analyzed for this report. Data for spring and summer months were not included because bird densities decreased to such low values during those seasons that statistical analyses were meaningless. If riverine habitats are critical to those species present in the summer, it seems likely that the high flows at that time render the river an almost worthless habitat for them.

Food resource information, including number of invertebrates (n/m^2), number of invertebrate taxa, invertebrate biomass (kg/ha x 10^4), and aquatic plant standing crop (g/m^3) are from Minkley (1979). Number of people (n/km/month) using the river for recreational purposes (swimming, fishing, hunting, tubing, boating) on our census areas is from Greey et al. (1976-1978).

Simple linear regressions were used to indicate the extent of colinearity between independent variables. Problems of multiple colinearity among independent variables were reduced by using only those independent variables which correlated less than $r = 0.8$.

Two-way analysis of variance (ANOVA) and regression analysis were used to test differences in densities and species richness from month to month and area to area. Only areas designated Rv 1 through Rv 7 (Table 7-1) were used for analysis of variance, since data had been collected during fewer months on the remaining census areas (designated Rv 8 through 11). Relationships between independent variables and total avian densities and diversities were evaluated with simple product-moment linear regressions and stepwise multiple linear regression. ANOVA was used to determine significance levels.

Six groups of water birds collectively constituted 90% or more of the total avian density. These groups included: (1) loons (Gaviidae) and grebes (Podicipedidae), (2) diving ducks (Aythyinae), (3) puddle ducks (Anatinae), (4) coots and gallinules (Rallidae), (5) shorebirds (Scolopacidae) and avocets and stilts (Recurvirostridae), and (6) gulls (Laridae). Density of each of these six groups was compared with the independent variables to determine if groups responded to food resource and habitat variables in similar ways. Since water bird densities varied considerably from a normal curve, and because distributions could not be normalized, we used nonparametric statistics for this analysis.

Number of water birds, people (n/km/month), bank modification (percent/km), and food resource base per census area were ranked across all census areas. The Spearman-rank test (Siegel 1956) was used to derive correlation coefficients (r_s) between ranks of water bird densities and ranks of independent variables. Results indicate the amount of habitat used relative to its availability. The available habitat is represented by independent variables associated with each census area represented. Use of habitat is represented by distribution of water bird populations in relation to the independent variables.

A significant positive r_s suggests that water bird densities were higher wherever a particular habitat feature was present. On the other hand, a significant negative r_s indicates that the feature of the habitat in

question was avoided by water birds. An r_s of near zero indicates that water bird densities were independent of the environmental variable in question.

The Kolmogorov-Smirnov One Sample test (Sokal and Rohlf 1969) was used to determine the amount of the habitat which was being used, based on the relative breadth of habitat potentially available for use (i.e., the breadth of the habitats we studied). If there were more negative than positive expected values, and the maximum habitat used (KS "D") was significant, the portion used was narrower than the total extent of the habitat feature and may or may not have overlapped it. When there were more positive than negative expected values and the maximum D was significant, the habitat used was broader than and overlapped the distribution of the habitat variable over the area we studied in question.

Numbers of mudflats and sandbars (islands), which vary considerably from time to time because of river level fluctuations, were recorded during each census and were averaged for the study period. Combined densities of water birds characteristically associated with islands (puddle ducks, shorebirds, coots and gallinules, and herons) were also averaged for the entire study. Dividing water bird density by the number of islands resulted in the number of birds per island per census area.

RESULTS AND DISCUSSION

Correlation of Habitat Characteristics with Water Bird Densities and Diversities

Densities and Species Richness. A two-way ANOVA indicated significant differences in water bird densities (n/40 ha) and species richness among years and areas (Table 7-2). During the second year, densities were lower than during the first year in five of seven census areas. Densities during the last year exceeded those of the first year in five of seven census areas, and exceeded those of the second year in eight of 11 areas. Within-year differences in densities from month to month in each area were not significant ($P = 0.25$), but differences between areas were significant ($P<0.005$), suggesting that an analysis of factors varying from area to area might be useful in explaining the observed differences in density.

During the second season, species richness (Table 7-2) was lower than in the first season for five of seven census areas. Species richness during the last year exceeded that of the first year in four of six areas, and that of the second year in six of 11 areas. Differences in species richness were significant ($P<0.001$) from month to month but were not significant from area to area ($P = 0.16$), suggesting that an analysis of factors varying from area to area would not be useful in explaining between-area differences in species richness.

There were more birds below dams and in undisturbed areas (Table 7-2). The fact that differences in bird densities occurred between areas, rather than between months for a given area, indicates that something other than temporal factors may have been responsible for these

Table 7-2. Average water bird densities (D = birds/40 ha) and species richness (R), winter 1977 to winter 1978-79. Analyses of variance resulted in n (sample size), F-statistic, and P (statistical significance) by rows (season differences) and columns (area differences). Rv 1, Rv 2, etc. are study area designations.

	Winter							
	1977		1977-1978		1978-1979		$\bar{x}^*$	
Study area	D	R	D	R	D	R	D	R
Channelized river								
Rv 1	91	14	33	9	20	7	37	9
Rv 4	32	9	33	5	34	9	34	7
Rv 5	55	6	3	2	18	6	18	4
Undisturbed river								
Rv 2	167	11	128	12	186	14	159	13
Rv 3	121	18	150	14	226	14	192	14
Backwater								
Rv 6	503	22	169	14	828	34	500	24
Canyon embanked								
Rv 7	13	4	36	9	34	9	33	8
Below dams								
Rv 8	-	-	200	14	162	15	177	14
Rv 10	-	-	281	19	384	20	346	20
Reservoirs								
Rv 9	-	-	13	6	34	4	26	5
Rv 11	-	-	58	7	74	6	61	7
$\bar{x}^*$	153	9	94	10	181	13		

Table 7-2. (cont.)

	n	F-statistic	P den	P R
Rows**	83	7.73-11.82	0.25	0.001
Columns**	83	1.32-2.08	0.005	0.16

*Since the winter of 1977 had fewer months than succeeding winters and data from Rv 8-11 were not acquired until the second year of censusing, averages vary from the number derived by simply averaging data from the three winters.

**Analyses of average densities and species richness in rows and columns are taken from Rv 1-7 only.

Table 7-3. Correlation matrix (r) indicating extent of co-linearity between biological characteristics of study areas of the lower Colorado River.

	Invertebrate			Plant standing crop	Human use
	Density	Biomass	Taxa		
Invertebrate (n/m^3) density					
Invertebrate biomass (kg/m^3)	0.687				
Number of invertebrate taxa (n/km)	0.117	0.720			
Plant standing crop (g/m^3)	0.546	0.503	0.502		
Human use (n/km)	-0.314	-0.416	-0.690	-0.920	
Bank modification (%/km)	-0.555	-0.509	-0.652	-0.852	0.585

differences. Regression analysis of water bird densities and various other biological features associated with the areas was useful in explaining water bird density differences.

Simple Linear Regressions. Independent variables which showed low colinearity included human use, percent bank modification, and number of invertebrates (Table 7-3). Aquatic plant standing crop showed a significant positive correlation with the number of invertebrate taxa, indicating that as the number of invertebrates varied, so did standing crop. Therefore these variables were not treated independently; the number of invertebrates and aquatic plant standing crop combined seemed representative of the food resource base. The variables human use, percent bank modification, and food resource base were used in the correlation with avian densities.

Food resource base-avian density correlations were positive for all months and were significant ($P<0.05$) during six months (Fig. 7-1). In contrast, avian density correlated negatively with the number of people in seven of the 12 months, negatively with percent bank modification in all months, and was significant for three months (Fig. 7-1).

In general the results suggest that food resources affect water bird densities positively and that bank modification, and perhaps human use, affect bird densities negatively. In order to better resolve all significant correlations in the data, stepwise multiple linear regression analyses were calculated for all months.

Stepwise Multiple Linear Regression. A stepwise multiple linear regression of water bird densities with the above three independent variables revealed correlations with significant ($P<0.05$) F values for six of the 12 months (Fig. 7-2). Food resource base was involved in each of the six significant correlations, human use was involved in four, and bank modification in three. Food resource base was related positively to water bird densities, but bank modification and human use influenced water bird densities negatively. The relationship between bank modification and food resource was not significant (Table 7-3).

Responses of Water Bird Groups to Habitat Variables

Response to Food-Resource Base. When ranked, the density of birds in each of the six water bird groups was positively correlated with food abundance in the 11 areas but was significant only for the group containing coots and gallinules (Table 7-4). Thus, bird use was not significantly related to the amount of available food for five of the six major water bird groups. The K-S tests indicated that the range of food-resource density used was narrower ($P<0.01$) than the total range available (more negative than positive deviations from expected) for each of these five groups (Table 7-4). Areas with a larger than average food resource base had more water birds than expected for four of the groups. Shorebirds used a greater range of areas with different levels of food abundance (more +'s than -'s) than any other group (Table 7-4). Gulls, loons and grebes had the narrowest food use breadth. They also had relatively high densities in areas where the food resource base was relatively low. These groups probably used, at least partly, a different resource base than the one measured; water birds within these groups consume fish to varying degrees.

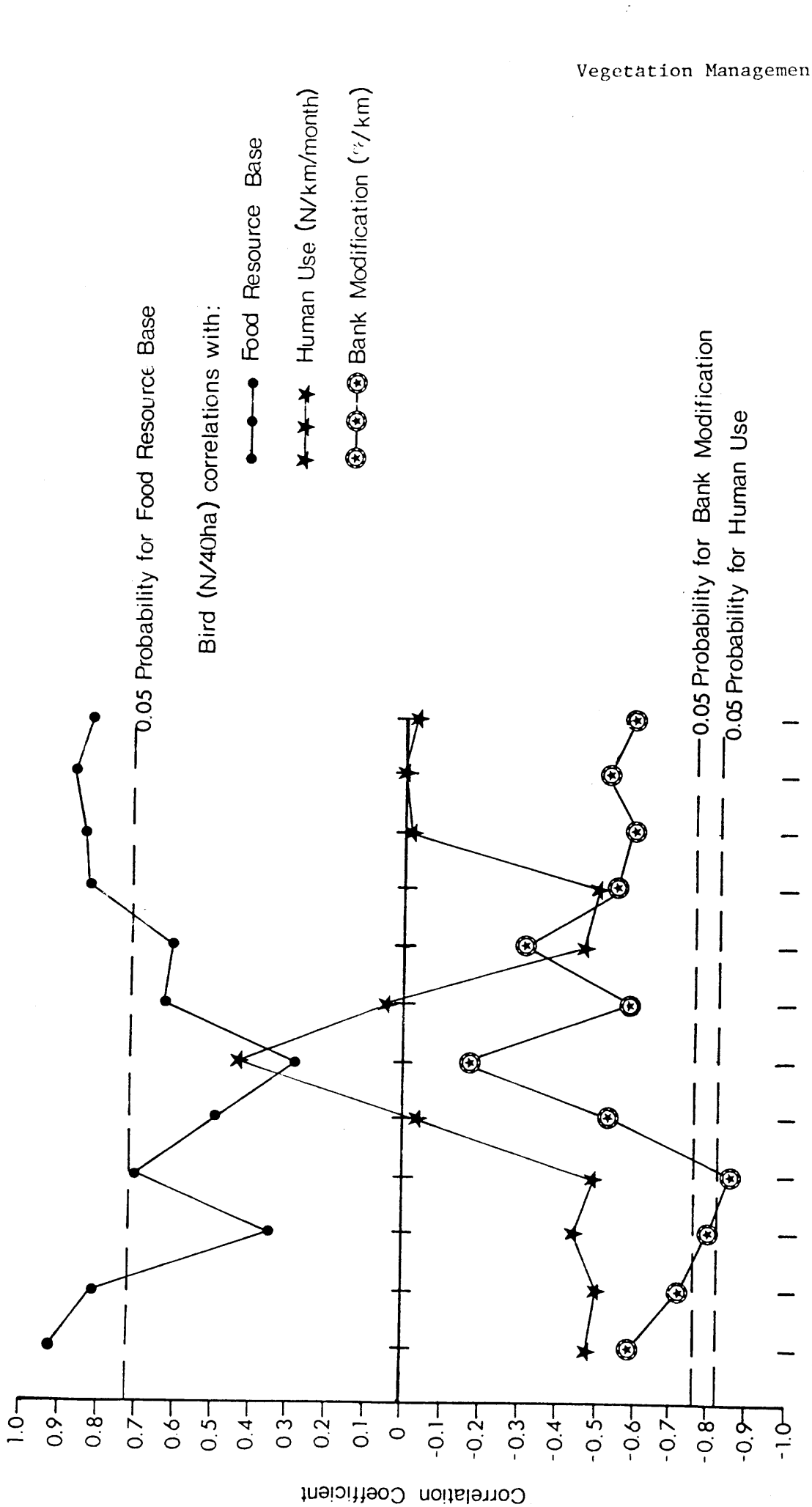

Figure 7-1. Correlation between three independent environmental variables and bird densities over a 12-month period on the lower Colorado River.

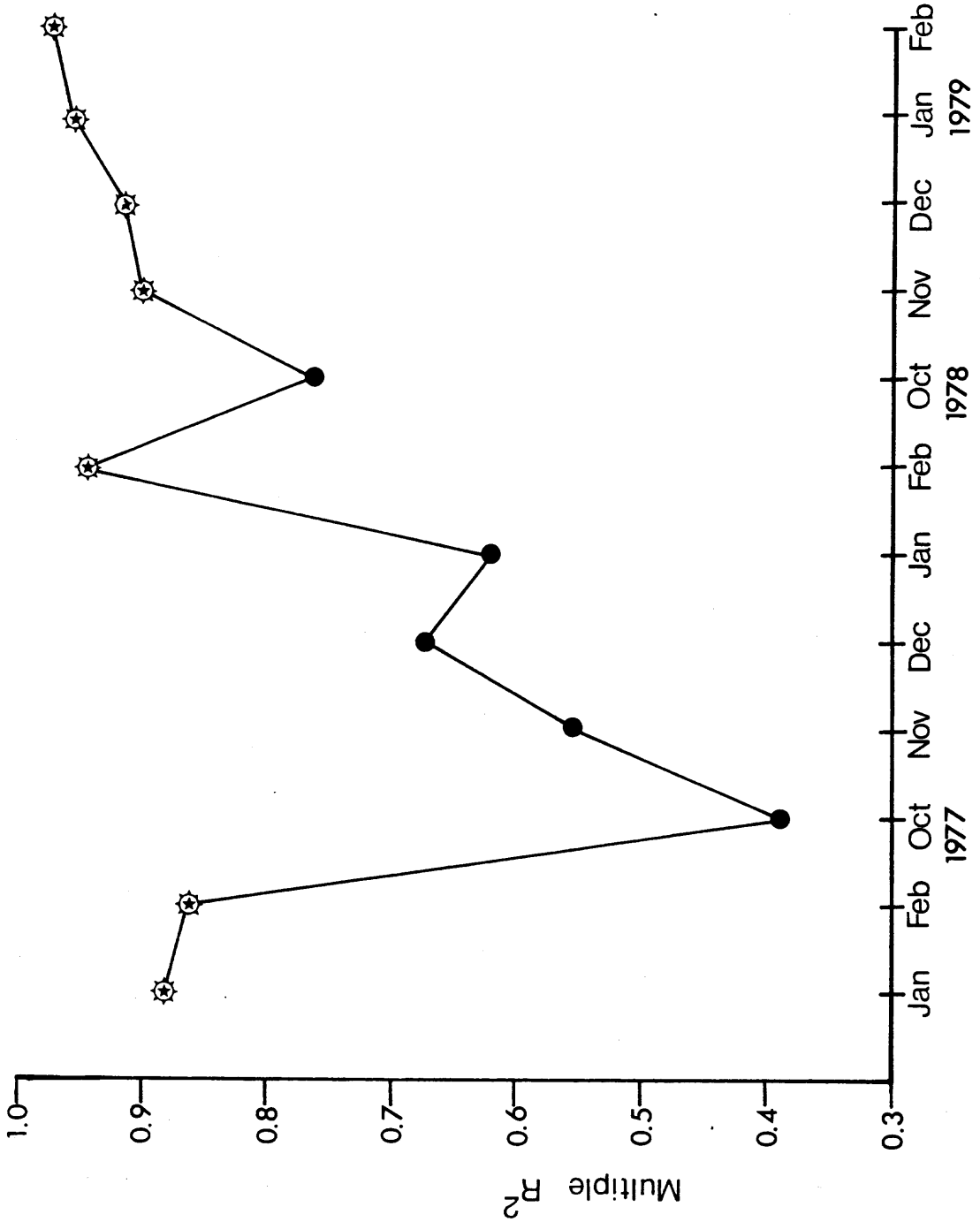

Figure 7-2. Results of multiple correlation analysis of water bird densities and three environmental variables. Significant correlations indicated with a star.

Table 7-4. Analysis of densities of avian groups in relation to differences in the food resource base in various areas along the lower Colorado River.

	r_s	Number of observations >expected	Number of observations <expected	KS "D"	Max[1]	Densities of birds > expected when food abundance was: <average	Densities of birds > expected when food abundance was: >average
Diving ducks	0.477	3	5	0.204	0.116	1	2
Puddle ducks	0.569	3	6	0.557	0.115	1	2
Coots	0.720[2]	3	5	0.288	0.079	1	2
Shorebirds	0.225	5	4	0.346	0.122	1	4
Loons and grebes	0.525	1	7	0.525	0.259	1	0
Gulls	0.427	1	8	0.522	0.199	1	0

[1]When Kolmogorov-Smirnov "D" value is greater than max, $P \leq 0.01$.

[2]Spearman-rank correlation significant at $P \leq 0.05$.

Response to Bank-Channel Modifications. None of the six water bird groups used all portions of the channel (Table 7-5). Use of channel-bank area was not significantly different ($P<0.05$) only for puddle ducks (Table 7-5). The K-S tests revealed that the habitat used was significantly narrower ($P<0.01$) than the available habitat for all water bird groups. This was due to the occurrence of greater than expected numbers of water birds in areas with below-average bank-channel modifications (Table 7-5). Only loons and grebes had above-average populations in any area with greater than average modification. The ranks for food resource base were independent of bank modification (r_s near 0). In areas where the bank was modified, water birds of several groups showed reduced populations, not because of the absence of food, but apparently because of the riverbank structure. It should be noted, however, that food resources were above average only where bank modifications were below average (Table 7-6). This indicates that even though channel modification was negatively associated with the food resource base the relationship with water birds is not simple.

Human Use. We considered the extent of human use as another dimension of the available habitat and found that densities of diving ducks and gulls were postively related to human use but shorebirds were negatively affected (Table 7-6). The K-S tests revealed that for every water bird group, the utilized habitat was narrower than the available habitat. For puddle ducks, coots, and shorebirds, densities were lower than expected in places where human use was greater than average (Table 7-6). Larger than average numbers of diving ducks, loons, grebes, and gulls were related to human use of an area.

Puddle ducks, coots, and shorebirds are adversely affected by both human use of an area and bank modification. Diving ducks and gulls responded negatively to bank and channel modifications but not to human use, at least not if food was abundant.

Use of Islands. The average densities of water birds which characteristically used islands (Table 7-7) were different between each area ($P\leq0.05$), even though the number of islands was not different ($P\geq0.05$) between census areas. Mean numbers of water birds per island in channelized and canyon-embanked river were lower ($P\leq0.01$) than mean numbers of water birds per island in other areas. It is not clear whether low numbers of water birds per island in some areas were due to generally low densities of water birds or to other factors. Channelized and canyon-embanked river areas generally had moderate to high human use and bank modification, and moderate to low food availability, which may explain the low numbers of birds. For further discussion on bird use of islands see Anderson and Ohmart (p. 92-93, 1977; 1982).

CONCLUSIONS

Areas having extensive channel and bank modifications and/or relatively heavy human use supported fewer water birds. Food resources seemed to be the most important variable related to water bird densities. Areas below dams and reservoirs supported the largest densities of some water birds. Food was most abundant in these areas, but the areas also had the heaviest human use and the greatest amount of stream modification.

Table 7-5. Analysis of densities of avian groups and food abundance in relation to differences in human use of various areas along the lower Colorado River.

	r_s	Number of observations		K-S "D"	Max[1]	Density>expected when human use was:	
		>expected	<expected			<average	>average
Diving ducks	0.579[2]	2	7	0.274	0.087	1	1
Puddle ducks	-0.285	3	7	0.028	0.671	3	0
Coots	-0.075	3	7	0.550	0.071	3	0
Shore-birds	-0.706[2]	4	6	0.663	0.119	4	0
Loons and grebes	0.537	2	7	0.390	0.236	1	1
Gulls	0.616[2]	2	8	0.300	0.170	1	1
Food resource	0.110	5	4	0.266	0.030	3	2

[1]When Kolmogorov-Smirnov "D" value is greater than max, $P \leq 0.01$.

[2]Spearman-rank correlation significant at $P \leq 0.05$.

Table 7-6. Analysis of densities of avian groups, food abundance, and human use in relation to differences in the extent of bank and channel modification of various areas along the lower Colorado River.

	r_s	Number of observations >expected	Number of observations <expected	K-S "D"	Max[1]	Density>expected when bank-channel modification was: <average	Density>expected when bank-channel modification was: >average
Diving ducks	-0.263	4	6	0.693	0.090	4	0
Puddle ducks	-0.678[2]	3	8	0.884	0.111	3	0
Coots	-0.534	4	7	0.639	0.870	4	0
Shore-birds	-0.904[2]	3	8	0.800	0.120	3	0
Loons and grebes	0.333	5	6	0.639	0.209	3	2
Gulls	0.362	2	9	0.659	0.020	2	0
Food resource	-0.079	4	5	0.420	0.001	4	0
Human use	0.628[2]	4	6	0.220	0.028	4	0

[1]When Kolmogorov-Smirnov "D" values is greater than max, $P \leq 0.01$.

[2]Spearman-rank correlation significant at $P \leq 0.05$.

Table 7-7. Mean number of birds characteristically using areas such as exposed sandbars, mudflat islands, and peninsulas, the observed densities (N/40 ha) of such exposed areas, and the density of birds per exposed area for each transect. All numbers represent the mean for 12 months over 3 winters.

	Transect								
	Rv 1	Rv 2	Rv 3	Rv 4	Rv 5	Rv 6	Rv 7	Rv 8	Rv 10
Average density (N/40 ha) birds characteristic of exposed areas	24	122	173	22	12	446	21	58	148
Average density (N/40 ha) of exposed areas	3.2	3.7	3.4	2.6	2.3	11.0	3.5	3.7	3.5
Birds/exposed area	8	33	51	8	5	41	7	16	42

Undisturbed areas supported the largest densities of most water birds, since there were fewer people and less bank modification, as well as larger quantities of food.

MANAGEMENT IMPLICATIONS

Species Richness and Overall Densities

If high overall water bird densities and diversities are the management objective, it is important to have a large food resource base. This includes a variety of invertebrate taxa, a large invertebrate biomass, and a large aquatic plant standing crop. Since all of these variables are negatively correlated with stream alterations and/or increased human use (Table 7-3), when such alterations of the river are planned, mitigation in the form of enhancement in other areas should also be planned if species richness and total densities are to be maintained. When alterations of the river are unavoidable, it is possible to reduce the overall impact by enhancing the altered area for those water bird species which are not negatively affected.

Diving Ducks

This group of ducks showed a significant tolerance of human use and some disregard for bank modification if food supply was abundant. Thus this group can be enhanced in altered areas if resources such as aquatic plant standing crop and invertebrate biomass can be increased.

Loons and Grebes

This group may require relatively large fish populations and nonflowing water such as that occurring in reservoirs. More research on this group is necessary before explicit management recommendations can be made.

Gulls

Gulls used the reservoirs and areas below dams. They seemed to be independent of the food resource base and showed tolerance of human encroachment. Although gulls reached peak densities in highly altered stretches of the river, they had below-average numbers in other modified stretches. More study of this group is required before specific management proposals can be made.

Coots and Gallinules

Coot densities were reduced by bank-channel modifications and human encroachment. Coots reached maximum population levels where the food resource base was large. Management for these birds would probably involve some combination of increasing plant standing crop and decreasing human encroachment. Coots and gallinules will tolerate humans if the disturbance is not of certain types, such as shooting, extensive boating, etc. If retirement developments, such as the Blue Water Marina, are established, coots and people can live compatibly. The human inhabitants often derive pleasure from the presence of the birds.

Puddle Ducks

Puddle ducks are apparently unable to cope with bank-channel modifications or human encroachment. Management should involve increasing plant standing crop in unaltered areas with low human use. If disturbance is minimal and food is abundant, it is possible to have human developments along the river and still have puddle ducks as well as coots. Again, the Blue Water Marina is a classic example. The channel adjacent to the marina has been little altered, there are ample sandbars for resting, and food is apparently abundant.

Shorebirds

Shorebirds are apparently the most intolerant of river alterations and human encroachment. Judging from the data we have collected, management for this group will involve the creation or maintenance of unaltered areas with high invertebrate biomass and low human encroachment.

A Comment on Reducing Human Use

It is sometimes assumed that keeping human use at minimal levels is synonymous with creating wildlife refuges. Nothing could be farther from the truth. Our study area designated RV 3 is open to hunting, fishing, and boating. Similarly, area RV 6, the old river channel, although on a refuge, is open to public use. Yet these areas had the greatest densities and diversities of birds. Other areas, for example the stretch of river from the bridge at Parker south to Deer Island Lake, should attract relatively large water bird populations, yet numbers are lower than expected (Ohmart and Anderson 1978). The difference is that in the RV 3 and RV 6 areas, access is restricted to relatively few areas. In contrast, hardly any area of the river from Parker to Deer Island Lake, on both sides of the river, is inaccessible from the road paralleling the river. Eliminating or reducing vehicular traffic along the river would almost certainly increase water bird use along this reach of the river. On the other hand, reducing access does not mean closing the area altogether; it merely means that the area will be restricted to those who most want to use it--only those people with the greatest interest in hunting, fishing, or hiking will make the effort necessary to gain access. With reduced disturbance, water bird use will increase.

MANAGEMENT RECOMMENDATIONS

1. The jetties along the river south of Parker create potentially good water bird habitat as cat-tails and other aquatic vegetation develop. When stretches of the river must be altered, construction of jetties should be included in the plans as a mitigation feature.

2. Access to areas should be kept to a minimum by restricting vehicular traffic into the areas during the time of peak avian populations (between November and March).

3. For puddle ducks, many diving ducks, coots and gallinules, primary productivity should be maintained at high levels. This may mean

fertilizing the water to encourage the growth of cat-tails and submerged aquatic vegetation such as Sago pondweed (Potamogeton pectinatus).

4. For shorebirds and some diving ducks, secondary productivity should be high. This will occur naturally as primary productivity increases.

5. Many water birds, including puddle ducks, coots, gallinules, shorebirds, and gulls, require mud flats and sandbars for resting and feeding. To maximize water bird use, an area of high primary and secondary productivity must have exposed mud flats and sandbars.

6. When areas are developed for human habitation, use by water birds will be discouraged unless activities such as shooting and extensive boating are sharply curtailed in winter. If productivity is high and mud flats and sandbars are developed, the area may be used extensively by birds.

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CHAPTER 8

BIOLOGY OF GAMBEL QUAIL ON THE LOWER COLORADO RIVER WITH MANAGEMENT RECOMMENDATIONS

INTRODUCTION

The Gambel Quail is an abundant and successful gallinaceous species in most of the arid lands of the southwestern United States and northwestern Mexico. This species is considered an important game bird and is currently being managed and hunted in at least five states. Because this quail is a permanent resident in harsh desert environments, its biology is of interest to physiologists and ecologists, as well as to game managers.

Although state game agencies have sponsored much research on Gambel Quail management, published literature on its biology is meager. The more thorough studies have dealt with water economy, food, and habitat requirements of southern Nevada populations (Gullion 1960, 1962, Gullion and Gullion 1964) and food habits of southern Arizona populations (Hungerford 1962). Reproductive cycles were studied in detail along the Rio Grande River in New Mexico (Raitt and Ohmart 1966). In addition, parallel studies of the closely related Scaled and California quail offered data for comparison. Based on past research, Gambel Quail appear to thrive most successfully in riparian habitats with dense cover, abundant food, and high humidity. However, there is a lack of long-term studies of food and habitat requirements of the Gambel Quail that examine seasonal patterns and annual trends.

The lower Colorado River valley from southern Nevada to the Colorado River delta in Mexico historically contained some of the most extensive tracts of native riparian vegetation in the Southwest (Ohmart et al. 1977). Large-scale agricultural clearing, inundation of areas by water storage reservoirs, and invasion by exotic plant species have severely reduced and degraded native riparian communities in the valley. However, where tracts of native vegetation remain, species such as Gambel Quail are abundant and are maintaining relatively stable populations. Current land use patterns in the valley provide an excellent opportunity to study Gambel Quail in their natural riparian habitats and to evaluate their response to altered environments, which may become more widespread in the future.

From 1973 to 1978 a large-scale ecological study of the lower Colorado River valley was undertaken, dealing in part with the biology of the Gambel Quail. Goals of this study specifically pertaining to quail were:

1. To understand seasonal and local quail population fluctuations in the valley;

2. To identify essential aspects of preferred quail habitat;

3. To determine timing and duration of breeding cycles;

4. To assess dietary preferences and needs on a seasonal and annual basis;

5. To compare Gambel Quail in the Colorado River valley with other populations previously studied;

6. To discuss management implications as they pertain to habitat changes and population regulation.

Some additional information not repeated here can be found in earlier Vegetation Management annual reports (Anderson and Ohmart 1976, 1977).

METHODS

General Methods and Study Area

In June 1973, a large-scale ecological study of the lower Colorado River valley was begun. Efforts were concentrated in the remaining 50,000 ha (125,000 a) of riparian vegetation along a 425 km (264 mi) stretch of the river from the Mexican boundary, north to Davis Dam in southern Nevada. Since Gambel Quail occurred in all parts of the study area, general methods of study can be applied specifically to the present report. These are described in detail by Anderson et al. (1977) and are only summarized here.

Riparian vegetation was categorized as belonging to one of six vegetation types, based on either the numerically dominant tree or shrub species (i.e., honey mesquite, salt cedar, honey mesquite/salt cedar, and arrowweed), or the ecologically dominant species (i.e., cottonwood-willow and screwbean mesquite; Table 8-1 in Anderson et al. 1977). The six vegetation types were further subdivided into as many as six structural types based on foliage density at various levels. Structural Type I was most dense overall; remaining types were progressively less dense at the upper levels (above 9 m [29.5 ft]). Vegetation-structural types are referred to as communities. An effort was made to sample each community in proportion to its total area in the valley. Over 100 study sites were established, each consisting of a line transect 0.8 or 1.6 km (0.5 or 1 mi) in length and sampling 20 or 40 ha (50 or 100 a), respectively.

A series of vegetational measurements was made in a strip 15 m (49 ft) wide on either side of each transect line. These measurements included direct counts of all tree and shrub species, estimates of relative foliage density using the board technique (MacArthur and MacArthur 1961), and the presence of mistletoe. In addition, phenology measurements, including mesquite pod production, were made throughout the year on representative transects in each community type. Each transect was segmented every 150 m (492 ft), with the resultant 150 x 15 m (0.23 ha [0.6 a]) strips along each side of the transects referred to as plots. Vegetation measurements for each plot were kept distinct for later, fine-grained analysis. From the relative foliage density measurements for each study site, a foliage height diversity (FHD) value

was obtained using information theory (Shannon and Weaver 1949). Patchiness (horizontal foliage diversity) was determined as the variance in foliage measurements for various layers among the plots of a study site. This index of patchiness was calculated according to the equation:

$$\frac{\sum_{i=1}^{k}\sum_{j=1}^{n} V_{ij}^2 - \frac{\sum_{j=1}^{n} V_{ij}^2}{n}}{n-1}$$

where V_{ij} represents the foliage density in vertical layer i, of plot j; k is the number of layers; and n is the number of plots (see Anderson et al. 1978).

The resulting framework of sampling was designed so that all vegetation and wildlife measurements could be analyzed on the level of the plot or the study site, or averaged for each specific plant community type or for all riparian vegetation. In addition, similar sampling was conducted in agricultural areas to provide comparative quail population data for these habitats.

Quail Populations

Gambel Quail and other resident bird species were censused along each transect using a variable strip census similar to that developed by Emlen (1971). Quail were censused by recording all detections in parallel strips at various lateral distances from the transect, to 120 m (394 ft). After each census a lateral strip was selected in which the maximum number of detections had occurred and beyond which the number of detections decreased. The method assumes that all quail within that lateral distance were detected; the number of detections was then extrapolated to number of quail per 40 ha. This method provides a built-in coefficient of detectability that allows for the great variation in detectability of species such as quail and is nearly identical to Emlen's own modification for cue attenuation (Emlen 1977).

Each transect was censused 2-4 times per month, from December 1974 through December 1978. Density estimates from all censuses on each transect were averaged each month and season. Five seasons were defined: winter (December-February), spring (March-April), summer (May-July), late summer (August-September), and fall (October-November).

In analyses, quail populations were examined on the level of study site, community type, and total riparian vegetation for each month, season, or year.

Habitat Analysis

As part of the regular census, quail detections were recorded in the specific plots (0.23 ha units along each transect) in which they occurred. This information was then used to determine a preferred vegetation profile.

The relative density of quail among the various community types gives the most general view of habitat preference for this species. The extent to which birds are evenly distributed, or the extent to which they are habitat specific, is defined as habitat breadth and is calculated using information theory ($HB = - \Sigma \ p_i \log_{10} p_i$, where p_i is the proportion of the total population within vegetation type i). This is often expressed as a percent of maximum ($J = \log_{10}$ of the total number of vegetation types), which yields a relative value that can be compared between months or seasons.

Analytical Technique

Sixteen vegetation variables were used to describe the 22 types of riparian vegetation. Some of these variables were intercorrelated, so a principal components analysis (PCA) was performed to reduce the variables to a set of truly independent trends in the data (the principal components). These principal components were then treated as a new set of variables. Principal components (PC's) were those with eigenvalues ≥ 1. The first PC accounts for more of the variance in the data than successive ones, which in turn account for successively less of the variance. Each type of vegetation receives a factor score which ranks it along the PC axes.

Several transects were lost or added during the first year. Fewer and mostly minor changes were made thereafter. In order to base our conclusions concerning habitat preference on the best possible data set, we decided to include only the last four years of data.

Monthly quail density data from each community were also analyzed with PCA. This procedure grouped months in which quail were similarly distributed throughout the types of riparian vegetation. Instead of analyzing quail-vegetation relationships for each month, this procedure allowed us to analyze a smaller data set and arrive at conclusions about quail habitat preferences for all months when quail were similarly distributed.

Following the PCA's, stepwise multiple regression analyses were employed to determine the amount of variance in quail density data that could be explained by significant, systematic associations with vegetation. Independent variables were the vegetation principal components (VPC's) and dependent variables were the quail PC's. The first VPC selected for the analysis was the one that correlated highest with the dependent variable being considered. The second VPC entered correlated highest with the residual variance remaining after taking out the variance explained by the first VPC. The process continued until the next variable added in the stepwise procedure failed to explain at least 5% of the variance, or when the fourth step had been included.

There is no reason to assume that quail habitat preferences will always be represented by linear relationships. A variety of nonlinear relationships can be tested by raising the independent variables to the second, third, and fourth powers (Fig. 8-1). Although other nonlinear relationships may occur, those we included in the analysis allowed us to detect most quail-vegetation relationships.

On a finer scale, the quail detections in each plot were related to vegetation in that plot in order to describe a preferred vegetation profile. This was examined on a seasonal basis by noting any temporal changes in vegetation preference. This correlative approach does not yield direct information about causes of quail responses to vegetation; however, when performed with large enough samples over several years and supplemented with observations on behavior and diet, this method was useful in determining habitat characteristics associated with variation in quail density at different localities in the lower Colorado River valley.

Reproductive Cycles

During the breeding season, male Gambel Quail produce a loud and incessant "cow" call, often from an exposed perch. This provides a convenient measure of the duration and intensity of breeding activity and has been used by game managers as an index of reproductive success and subsequent hunter success (Smith and Gallizioli 1965). During regular censusing in the present study, the number of "cow" calls was recorded along each transect.

In addition to this indirect measure, quail were collected and their gonads examined throughout the study period. An attempt was made to collect a random monthly sample from all community types. Birds were processed as soon as possible after collection; gonads and other organs were stored in a mixture of ethylalcohol, formalin, and glacial acetic acid (AFA) for later examination. Methods of examination were similar to those of previous studies (Lewin 1963, Raitt and Ohmart 1966) in order to facilitate comparisons.

For all males, length and largest diameter of the left testis was measured with a dial caliper. The testis was then weighed. Several transverse sections from each testis were prepared as slides from which histological changes in the cycle of spermatogenesis were noted (Lewin 1963: 252-255). For females, both the ovary and oviduct were measured and weighed.

As a final measure of reproductive activity, all quail broods were noted wherever they were encountered in the Colorado River valley. Number in the brood and approximate age (less than one-quarter grown, half to three-fourths grown, more than three-fourths grown) of the young quail were recorded.

Diet

Crops from all quail collected were stored in AFA and later analyzed. Before examination, the contents of each crop were flushed with tap

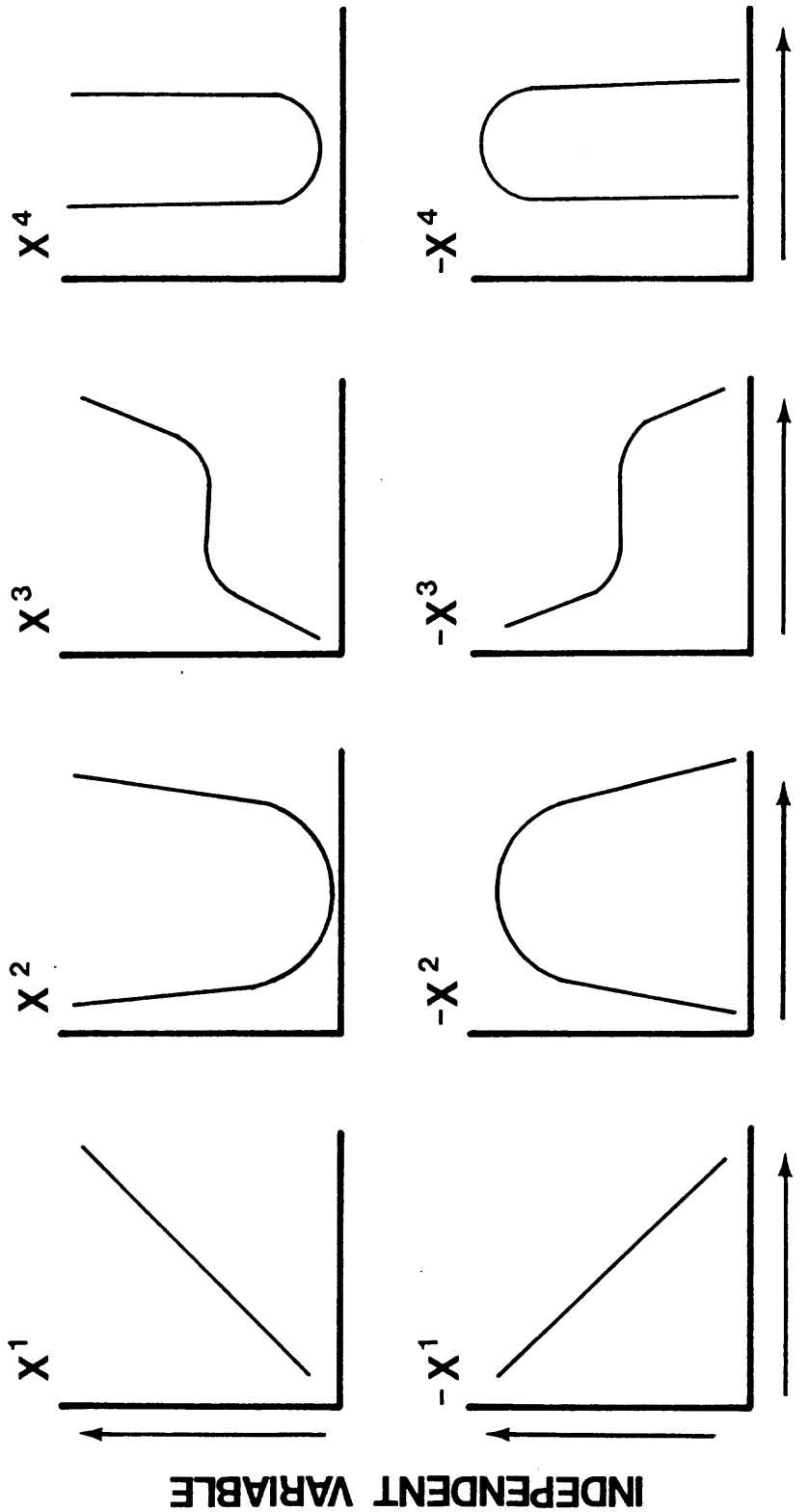


Figure 8-1. Generalized relationships between dependent and independent variables detected by transforming the independent variables to second, third, and fourth powers.

water and then dried. Samples were sorted and all plant and animal parts identified. Each item was weighed on a Mettler H6T analytical balance. Volume measurements were obtained by water displacement after food items had been resoaked for four days. From the combined crop contents for each month, a diet diversity index was calculated in the same manner as for habitat breadth (see Habitat Analysis). Overall diet diversity was calculated from the combined contents of all crops.

RESULTS

Tables 8-1 and 8-2 list the monthly precipitation and temperatures in the lower Colorado River valley for the years immediately preceding and during the study period. Precipitation was erratic, with August 1973 and September 1976 showing relatively large amounts of precipitation. Production of annual grasses and forbs, particularly in winter and early spring, was significantly affected by moisture. In general, 1973 and 1976 were wetter than average, 1975 and 1977 were drier than average, and 1974 was a normal year for precipitation.

Although summer temperatures were relatively consistent, winter temperatures showed great daily and annual differences. The winter of 1974-75 was considered an unusually cold winter, the winter of 1975-76 was average, and subsequent winters were warmer than the 30-year average.

Populations

Average monthly quail densities for all riparian communities combined are shown in Figure 8-2. The percent of decrease from the population peak is shown as an estimate of mortality; this includes both actual mortality and dispersal out of riparian vegetation. In most years, the population was lowest in February and then steadily increased until a peak was reached either in August or September. Quail numbers usually decreased 54% by November and 71% by December, coinciding with peak hunting activity in the lower Colorado River valley. An additional 19% mortality occurred during the winter months; approximately 10% of the previous year's summer population survived to breed the following March. Lower populations in winter could reflect reduced detectability in winter. However, this effect is probably very small. Emlen-census technique automatically adjusts for reduced detectability as long as all birds within 50 ft of the observer are being detected (see Chapter 2, Figs. 2-14).

Habitat Preference

Figure 8-3 shows the distribution of quail among the six riparian communities and the mean habitat breadth during the four-year study period. Quail densities (n/40 ha) in all seasons were usually highest in honey mesquite habitats and much lower in cottonwood and salt cedar habitats. Quail were fairly well distributed (largest habitat breadth) in summer, indicating both a dispersal of some birds out of honey mesquite habitats after breeding and a later reproductive effort in other habitats. By late summer, peak densities of quail shifted to screwbean mesquite habitats, paralleling pod production in those

Table 8-1. Rainfall in the lower Colorado River valley.

Month	Precipitation (cm)						
	1973	1974	1975	1976	1977	1978	Twenty-year average
January	0.12	1.60	0.13	0.00	0.48	1.89	0.76
February	3.07	0.00	0.08	3.66	0.02	0.82	0.81
March	1.85	0.94	0.69	0.05	0.13	0.14	0.71
April	0.00	1.50	1.75	0.00	0.00	0.00	0.33
May	0.12	0.00	0.00	0.00	0.20	0.10	0.03
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	2.06	0.00	0.00	0.00	0.01	0.50
August	5.84	1.78	0.00	0.00	3.60	2.37	1.68
September	0.00	0.00	2.44	6.45	0.00	0.00	0.84
October	0.00	0.61	0.05	0.25	0.09	0.95	1.17
November	0.28	0.00	0.00	0.38	0.00	0.70	0.66
December	0.00	1.24	0.00	0.43	0.36	1.09	1.17
TOTAL	11.30	8.23	4.89	12.97	4.88	8.07	8.75

Table 8-2. Temperatures for the lower Colorado River valley.

Month	Mean high and low tempertures (°C)													
	1973		1974		1975		1976		1977		1978		Twenty-year average	
January	18.0	3.0	18.2	4.8	20.8	2.3	21.4	3.0	19.8	3.6	18.9	5.6	20.1	3.7
February	20.9	7.6	22.3	5.1	21.6	3.9	21.8	3.3	25.4	4.7	21.7	7.2	22.8	6.5
March	21.7	8.4	26.4	9.9	23.7	7.8	24.5	8.5	23.6	6.2	26.7	11.1	25.9	9.0
April	29.1	11.4	30.0	12.2	25.1	9.7	27.5	11.2	31.9	11.3	28.9	11.7	29.8	12.3
May	37.2	17.5	35.1	17.8	33.8	14.9	35.4	18.0	35.8	18.2	34.4	15.6	34.8	16.9
June	41.3	22.9	43.2	23.3	39.6	20.6	40.2	20.9	41.3	18.4	42.2	20.0	39.8	21.5
July	42.7	25.6	41.2	26.2	42.2	26.3	40.5	25.7	43.5	21.7	43.3	23.9	42.3	26.0
August	41.2	24.3	41.5	23.9	42.2	24.6	40.6	23.0	40.2	20.5	41.1	21.7	41.4	25.5
September	38.3	19.3	38.8	23.3	38.3	22.8	34.6	21.4	38.4	16.2	37.8	19.4	38.4	25.5
October	32.8	13.2	32.1	15.8	31.1	14.0	31.0	14.7	33.9	15.6	35.0	17.2	31.8	14.6
November	23.9	7.8	24.7	8.5	25.8	8.7	26.2	8.0	26.7	7.8	23.3	8.9	24.5	8.1
December	21.3	4.2	18.2	3.3	20.9	5.1	19.7	2.6	21.7	6.1	17.2	2.8	19.9	4.0

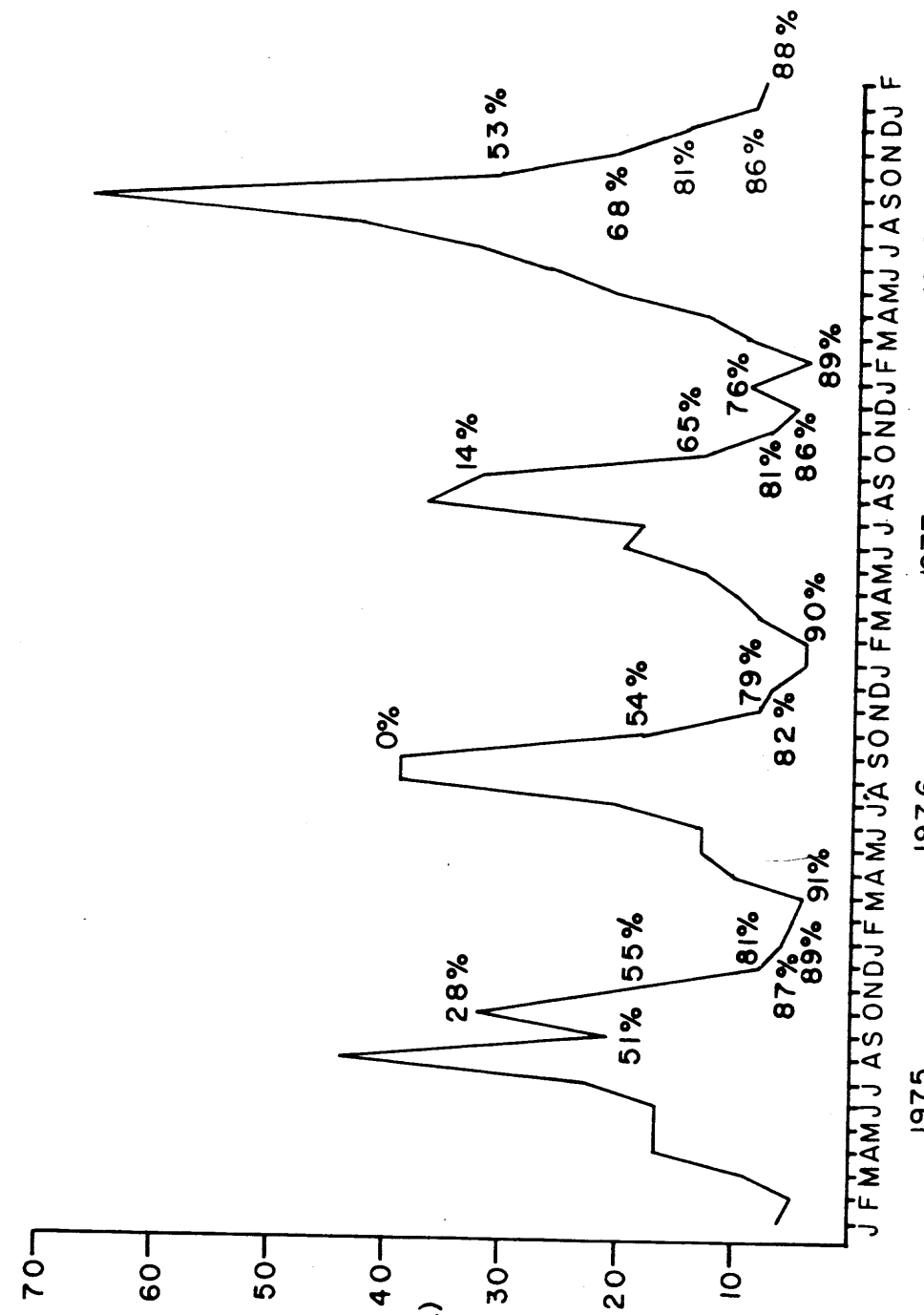


Figure 8-2. Average monthly densities (N/40 ha) of Gambel Quail in all riparian vegetation in the lower Colorado River valley. Mortality is given as percent decrease from population peak.

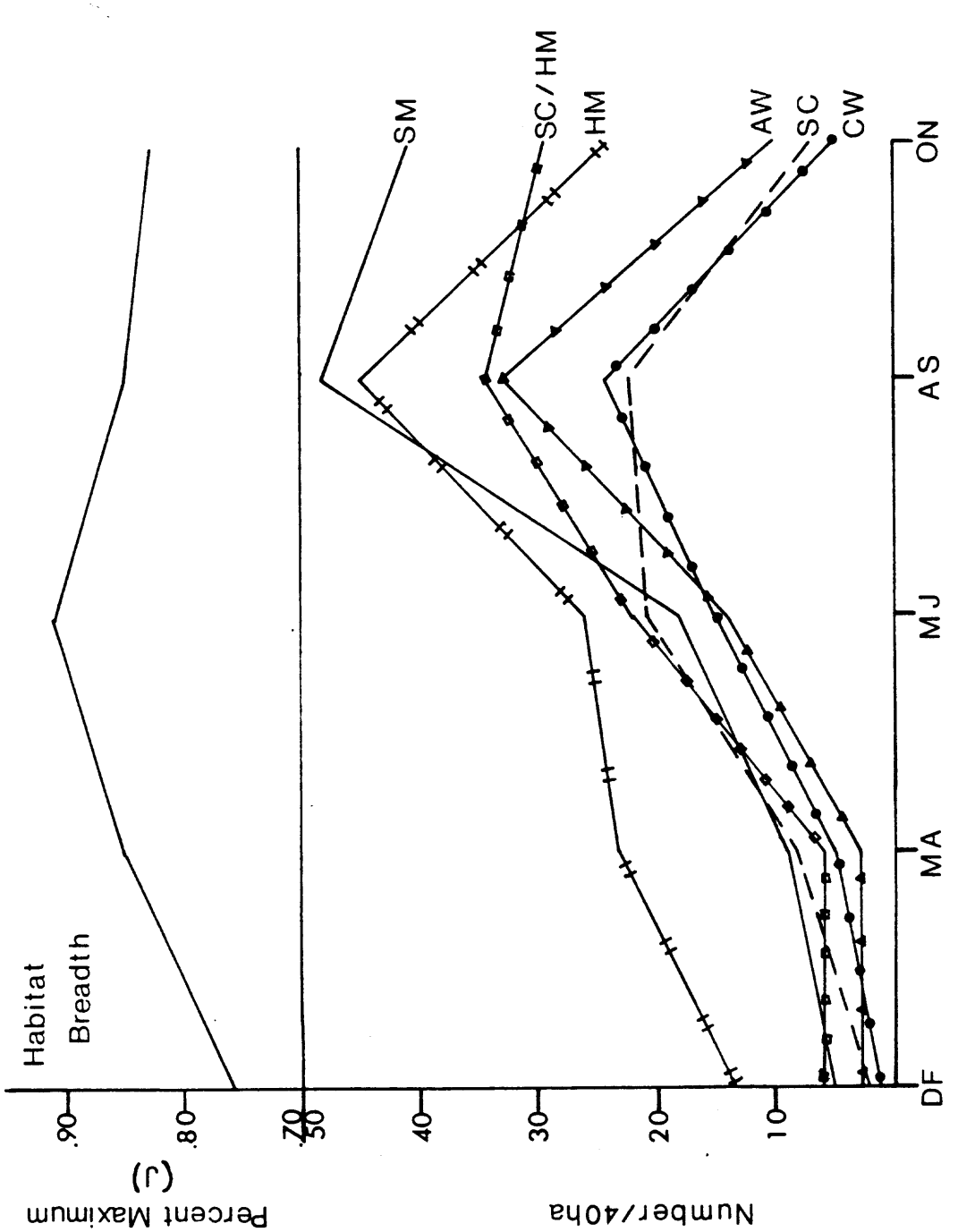


Figure 8-3. Average seasonal densities (N/40 ha) in six plant communities and habitat breadth for Gambel Quail for 1975-1978. Plant communities were: SM = screwbean mesquite, SC/HM = salt cedar-honey mesquite, HM = honey mesquite, AW = arrowweed, SC = salt cedar, CW = cottonwood-willow. DF = December, January, February; MA = March, April; MJ = May, June, July; AS = August, September; ON = October, November.

habitats, but densities of quail still remained very high in honey mesquite habitats. Although densities of quail in autumn were variable from year to year, occasionally higher than average quail densities persisted in screwbean mesquite habitats.

Relationships to Vegetation

Four vegetation principal components (VPC's) accounted for a total of 69% of the variance in the four years of pooled vegetation data. Variance explained for single variables (communality) ranged from 54% for the number of screwbean mesquite trees to 88.9% for patchiness >4.5 m (>15 ft) (Table 8-3).

The first VPC accounted for 35% of the total variance. It represents a continuum from low foliage density and diversity to high foliage density and diversity. The second VPC, accounting for 21% of the total variance, was a trend from many honey mesquite trees, many shrubs, and few salt cedar trees to areas where honey mesquite trees and shrubs were absent and salt cedar trees were numerically dominant. The third VPC accounted for 13% of the variance and was an axis from high foliage density and patchiness at 0 to 0.6 m (0 to 2 ft) to little or no low level foliage. The fourth and final VPC accounted for 7% of the variance and represented an axis with many screwbean mesquite trees and few cottonwood and willow trees at one end and many cottonwood and willow trees and few screwbean mesquite trees at the other end. Each vegetation type was positioned on the continuum represented by each VPC and received a factor score based on its position on each axis. Factor scores for each type of vegetation each year appear in Appendix 5-1.

A second PCA was executed using the community types across years as cases and quail density per month as variables. The objective was to detect population trends within a year, and/or a period which spanned more than one year. There were three major trends in the monthly quail density data that collectively accounted for 69.4% of the variance in the data. The first of these accounted for nearly half of the variance (49.4%) and included summer and late summer densities, which are the months of relatively large quail populations when broods are evident (Table 8-4). Factor scores on this component averaged lowest in 1976 and 1977 and highest in the final two years (Fig. 8-4). This means that quail populations were higher the last two years. Had quail populations been the same during all years, the factor scores for each year would have been about zero.

The second PC included fall densities of quail (October, November and December) and accounted for 11.3% of the variance (Fig. 8-5). A final component accounted for an additional 8.5% of the variance in the population data and included winter and spring densities, when the population was lowest (Fig. 8-6). Although there are other ways that quail could conceivably react to the vegetation, it was felt that these eight patterns would allow us to detect the linear and most of the nonlinear relationships between quail and the vegetation.

Habitat types preferred by quail are indicated in Figures 8:4-6 by positive scores; those habitats that supported low numbers of quail had

Table 8-3. Principal components (eigenvalues ≥1.0) from an analysis of four years of vegetation data from 22 types of riparian vegetation in the lower Colorado River valley.

	Factors loading on principal components*				
	I	II	III	IV	Communality
Patchiness					
0.2-0.6 m	0.146	-0.049	<u>0.846</u>	0.027	0.741
1.5-3.0 m	<u>0.701</u>	0.095	0.338	0.272	0.688
>4.5 m	<u>0.918</u>	-0.122	-0.132	-0.117	0.889
Total	<u>0.887</u>	0.068	0.219	0.033	0.841
Foliage density					
0.2-0.6 m	0.028	0.076	<u>0.899</u>	-0.129	0.832
1.2-3.0 m	<u>0.891</u>	-0.083	0.160	0.033	0.827
>4.5 m	<u>0.837</u>	-0.218	-0.205	-0.156	0.815
Total	<u>0.879</u>	-0.093	0.059	-0.252	0.848
FHD	<u>0.708</u>	-0.246	-0.514	-0.020	0.827
Shrubs/ha	-0.258	0.666	-0.008	0.194	0.548
Honey mesquite/ha	0.047	<u>0.900</u>	-0.094	-0.040	0.823
Honey mesquite with mistletoe	-0.226	<u>0.895</u>	0.075	0.118	0.872
Salt cedar/ha	0.158	<u>-0.754</u>	-0.106	0.319	0.707
Proportion of salt cedar	0.160	<u>-0.812</u>	-0.111	0.090	0.705
Screwbean mesquite/ha	0.123	-0.180	-0.381	<u>0.587</u>	0.538
Cottonwood-willow/ha	0.307	-0.060	-0.093	<u>-0.707</u>	0.606
Percent variance explained	35.0	20.9	12.8	7.0	68.7

*Underlined factor loadings indicate significant contribution to the principal component.

Table 8-4. Principal components (eigenvalues ≥ 1.0) from an analysis of four years of monthly Gambel Quail population data from 22 types of riparian vegetation in the lower Colorado River valley. High factor loadings on a particular principal component (underlined) indicate months when quail were distributed similarly among the 22 types of vegetation.

	Factor loadings on principal components			
Month	I	II	III	Communality
January	0.149	0.423	0.569	0.525
February	0.071	0.238	<u>0.776</u>	0.664
March	0.223	0.114	<u>0.817</u>	0.731
April	0.496	0.041	<u>0.643</u>	0.661
May	<u>0.768</u>	0.147	0.382	0.757
June	<u>0.826</u>	0.138	0.283	0.781
July	<u>0.679</u>	0.462	0.064	0.678
August	<u>0.699</u>	0.513	0.131	0.769
September	<u>0.644</u>	0.518	0.080	0.689
October	0.289	<u>0.804</u>	0.121	0.744
November	0.334	<u>0.743</u>	0.204	0.705
December	0.095	<u>0.693</u>	0.364	0.622
Percent variance explained	49.6	11.3	8.5	69.4

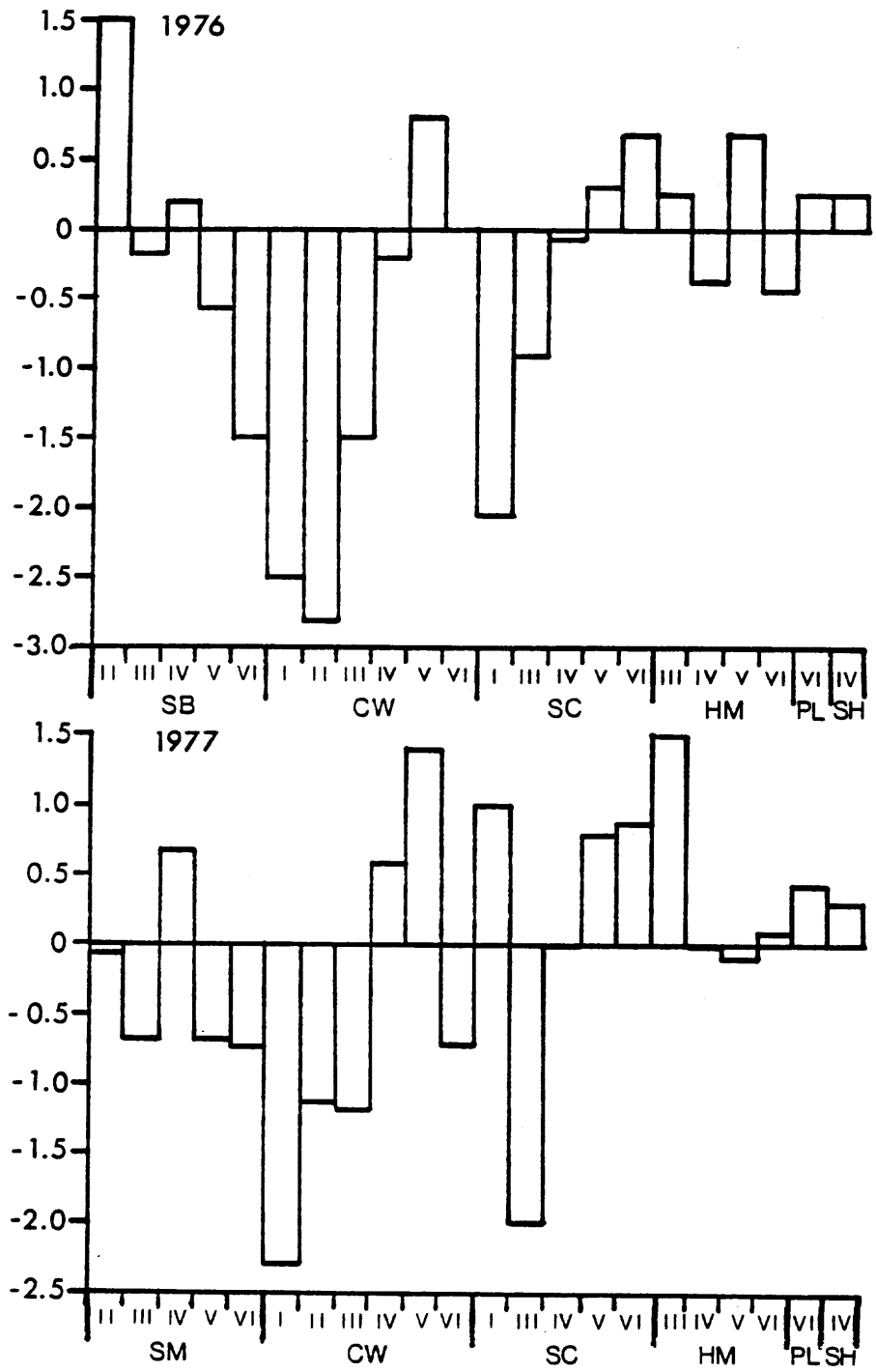


Figure 8-4. Factor scores of plant community types on the first quail principal component, representing the distribution of quail in the community types during summer for each of four years.

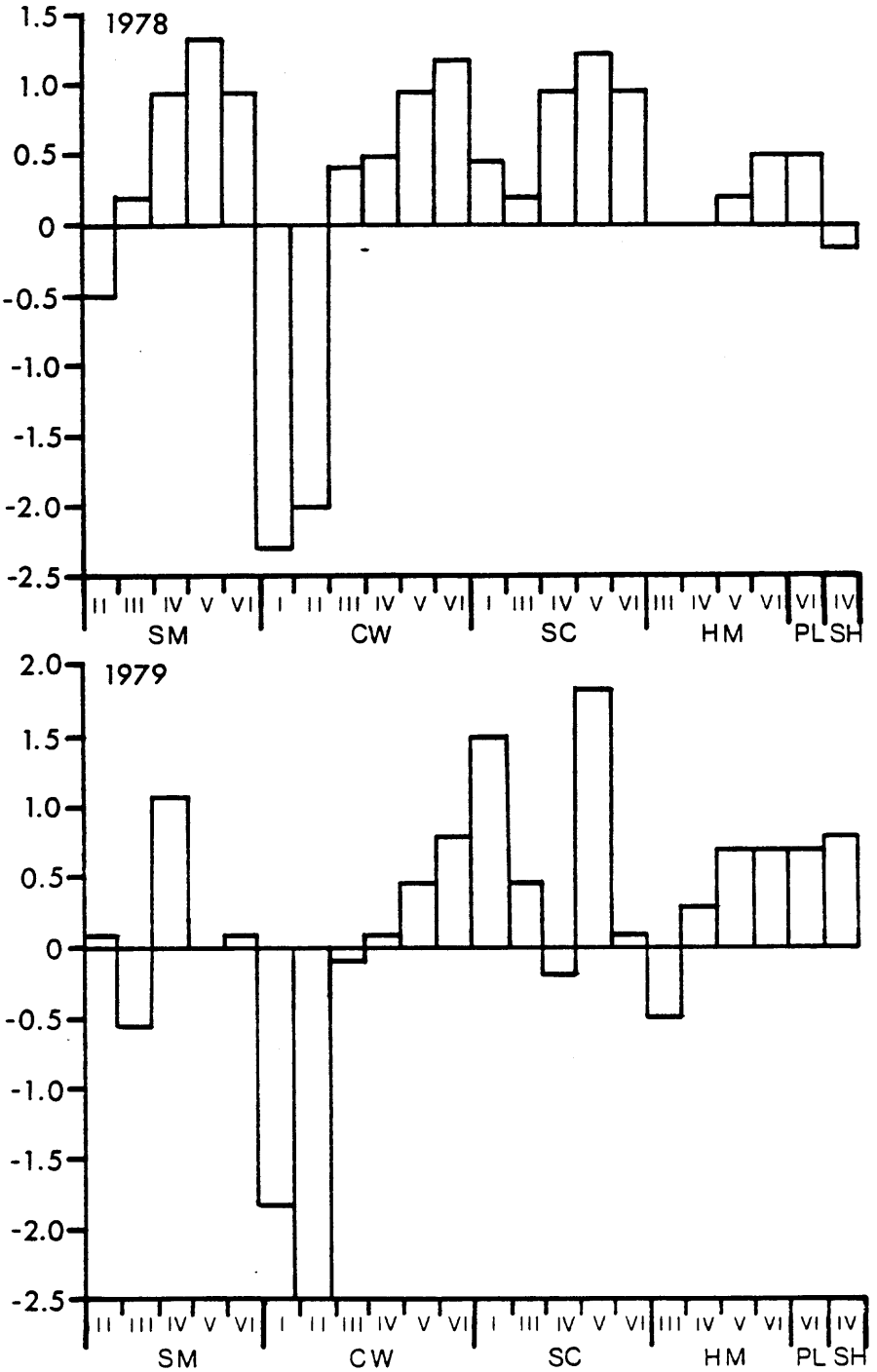


Figure 8-4. (Continued)

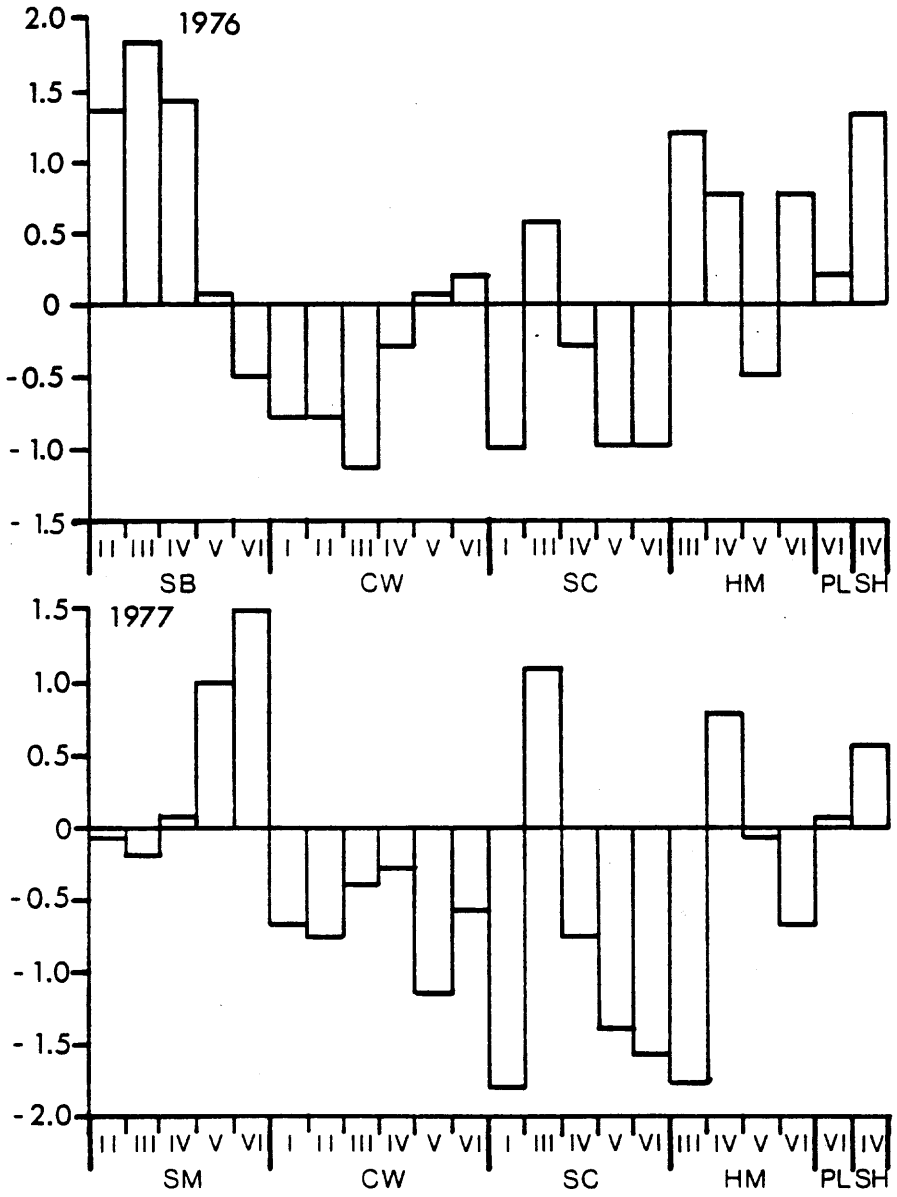
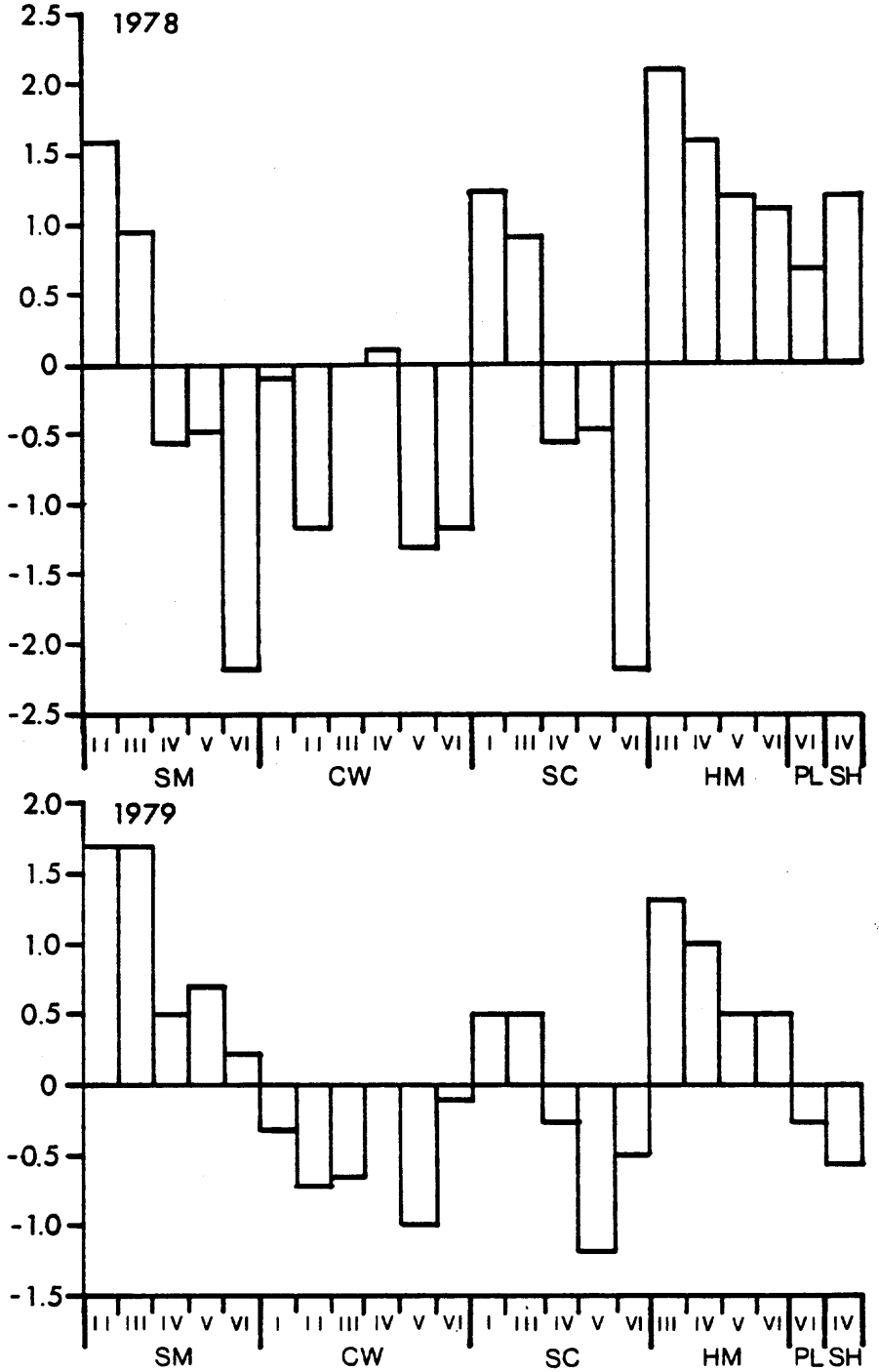


Figure 8-5. Factor scores of plant community types on the second quail principal component, representing quail distribution in the communities during the fall for each of four years.



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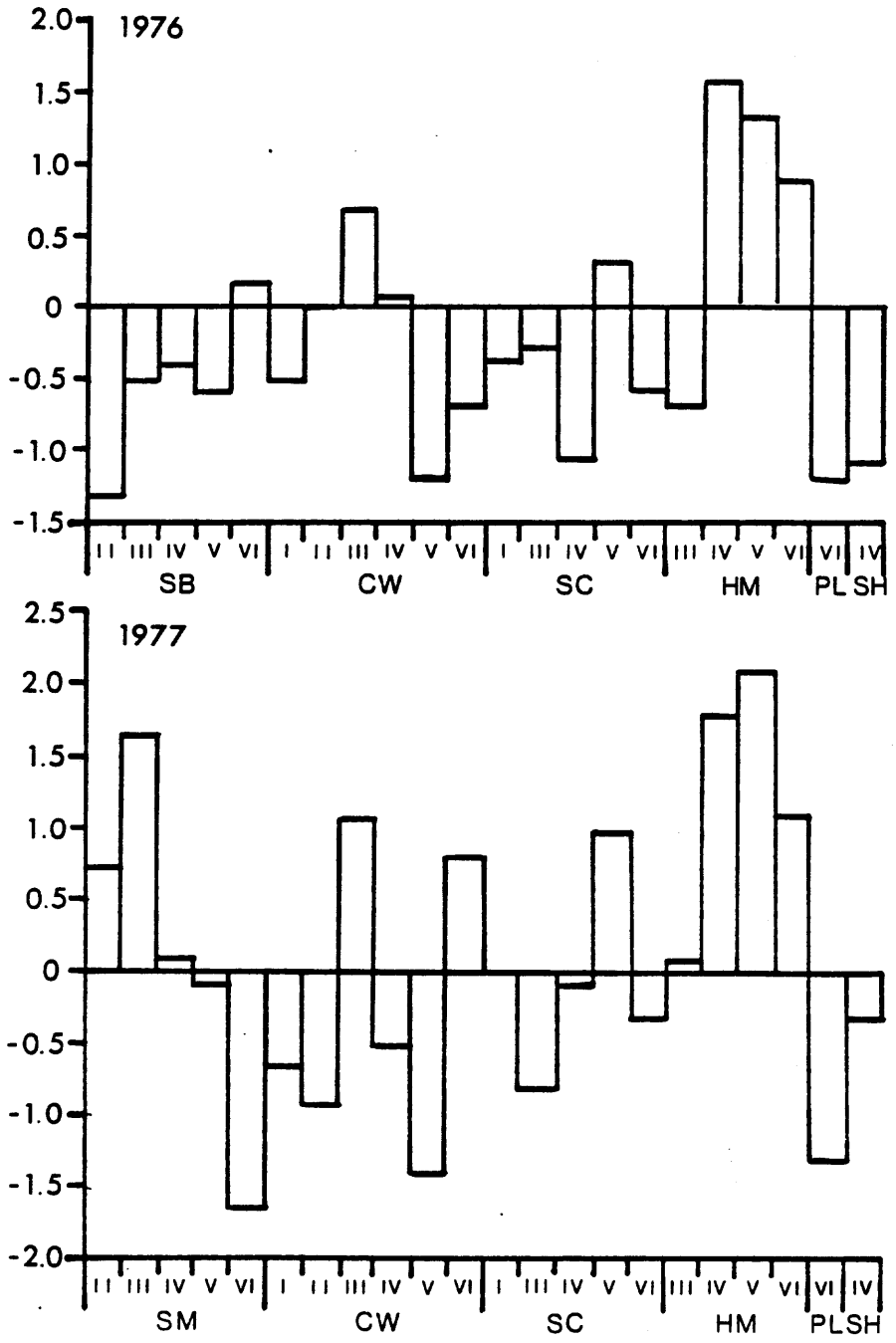

Figure 8-6. Factor scores of plant community types on the third quail principal component, representing quail distribution in the communities in winter and spring for each of four years.

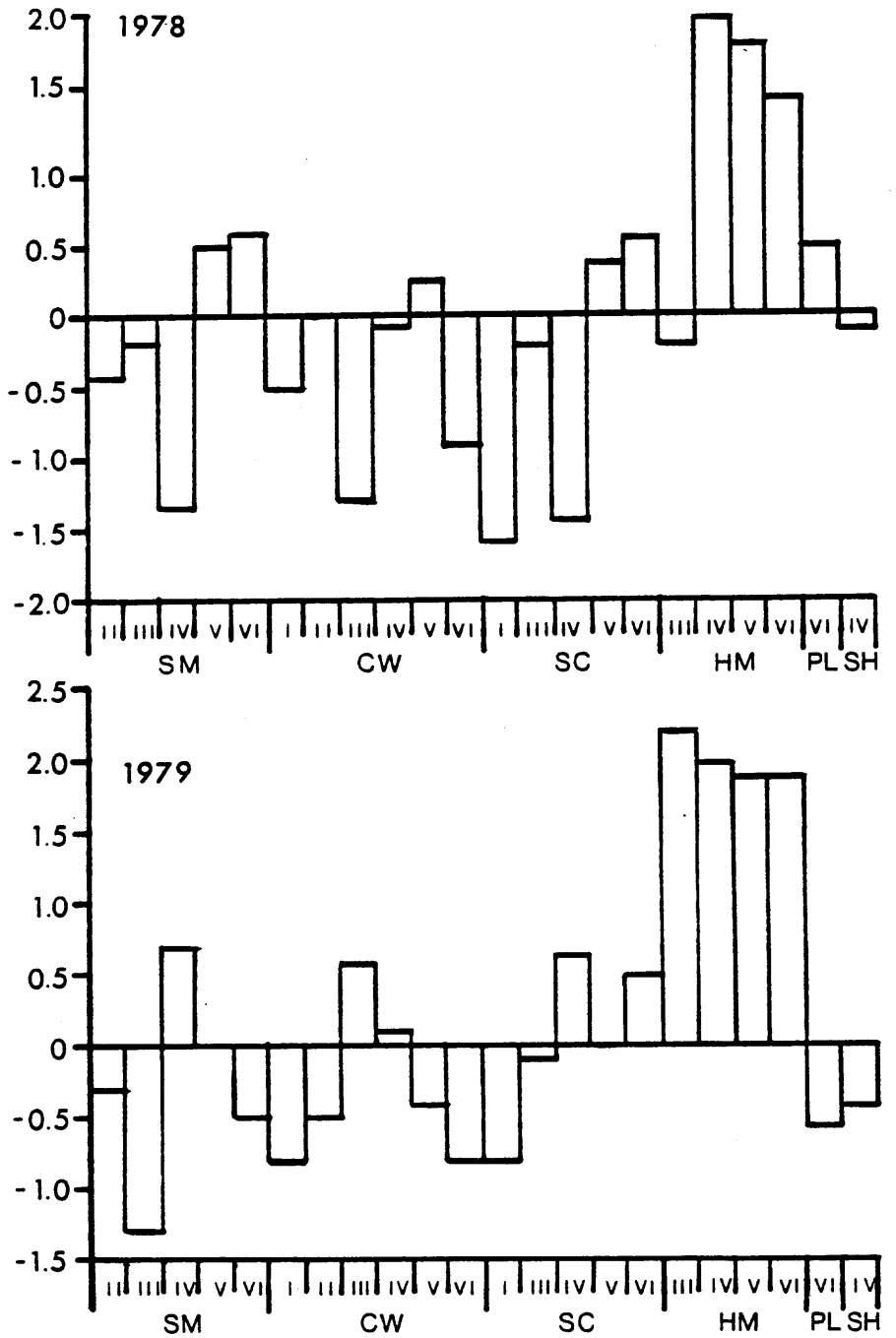

Figure 8-6. (Continued)

negative scores. Cottonwood-willow I and II always supported low numbers, while vegetation structural types V and VI, in general, supported higher densities. It is apparent that preferred vegetation varies from season to season and even from year to year (Figs. 8:4-6). In order to systematically quantify these relationships, we performed a series of stepwise multiple linear regression analyses.

Overall, a greater proportion of the variation in quail numbers (64%) was explained in summer than in fall (49%) or winter-spring (47%) by relationships with vegetation (Table 8-5). In summer, winter, and spring, the quail-vegetation relationships were primarily nonlinear, whereas in fall, relationships were predominantly linear.

The third VPC, representing foliage patchiness and density at 0.0-0.6 m, generally showed a positive relationship with quail densities in summer. The number of screwbean mesquite trees also had a positive relationship. VPC1 (total foliage density and diversity) always had a negative relationship, indicating that quail tended to avoid areas with dense foliage in the upper levels (cottonwood-willow and some salt cedar communities).

Densities of honey mesquite and screwbean mesquite trees were important in explaining quail distribution in fall. VPC3 had minor negative contributions, indicating that vegetation preferred by quail in summer tended to be avoided in fall.

In winter and spring, areas with honey mesquite trees and shrubs (VPC2) were preferred by quail. As in summer, areas with high foliage density and diversity (VPC1) were avoided.

Figure 8-7 shows preferred vegetation profiles for four community types, constructed from the specific 0.8 ha (2 a) plots in which quail occurred. Quail were always associated with dense vegetation in the lower layers (<5 m [16 ft]) and with relatively sparse vegetation in the upper canopy (>8 m {>26 ft]). This profile was nearly identical to the average vertical distribution of vegetation within the two mesquite communities, indicating that the birds were not selecting specific portions of those communities. However, in cottonwood-willow and salt cedar habitats, where only occasional openings in the canopy permit growth of a dense understory layer, the preferred profiles for quail differed significantly ($P<0.05$) from the average profiles for those communities. Quail avoided areas with tall, dense vegetation. The degree to which birds must select or avoid portions of a plant community may account, in part, for their density in that community. It should be noted that plots with dense vegetation increase the patchiness of a stand if not all the plots within the stand are dense. Thus quail may respond simultaneously to both dense and patchy vegetation in the ground layer.

In Figure 8-8, populations in honey mesquite are compared with those in agricultural edge habitats. Agricultural edge is riparian vegetation that is bordered on one side by agricultural fields. It is clear that the agricultural edge tends to concentrate quail; densities of quail were always higher in edge areas than in any other riparian vegetation.

Table 8-5. Proportion of variance explained by nonlinear and linear steps in significant multiple linear regressions at various seasons for four years. The independent variables were factor scores for each of four principal components from an analysis of 16 of 22 riparian vegetation types along the lower Colorado River. The dependent variables were factor scores representing Gambel Quail densities at various seasons.

	Percent variance explained		
Season	Nonlinear	Linear	Total
Winter-spring	42.3	5.0	47.2
Summer	53.6	10.2	63.8
Fall	9.6	39.7	49.3
Mean	35.2	18.3	53.4
SD	21.4	22.8	22.5

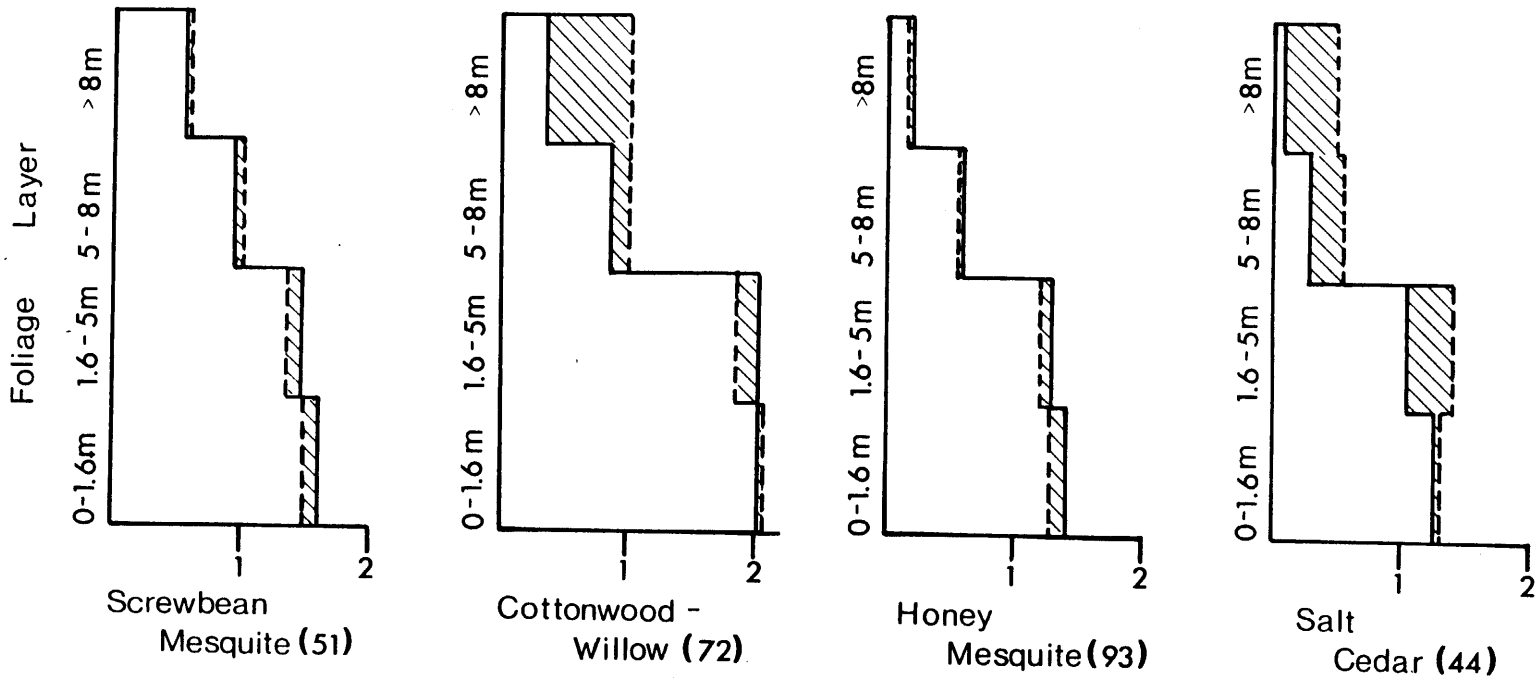

Figure 8-7. Preferred vegetation profiles for Gambel Quail in four plant communities in the lower Colorado River valley. Average profiles for each community are given by dashed outline and shaded areas represent the difference between the quail's preferred profile and the average. Four height layers of foliage density were used. Number in parentheses is the number of 0.08-ha plots in each community where quail occurred.

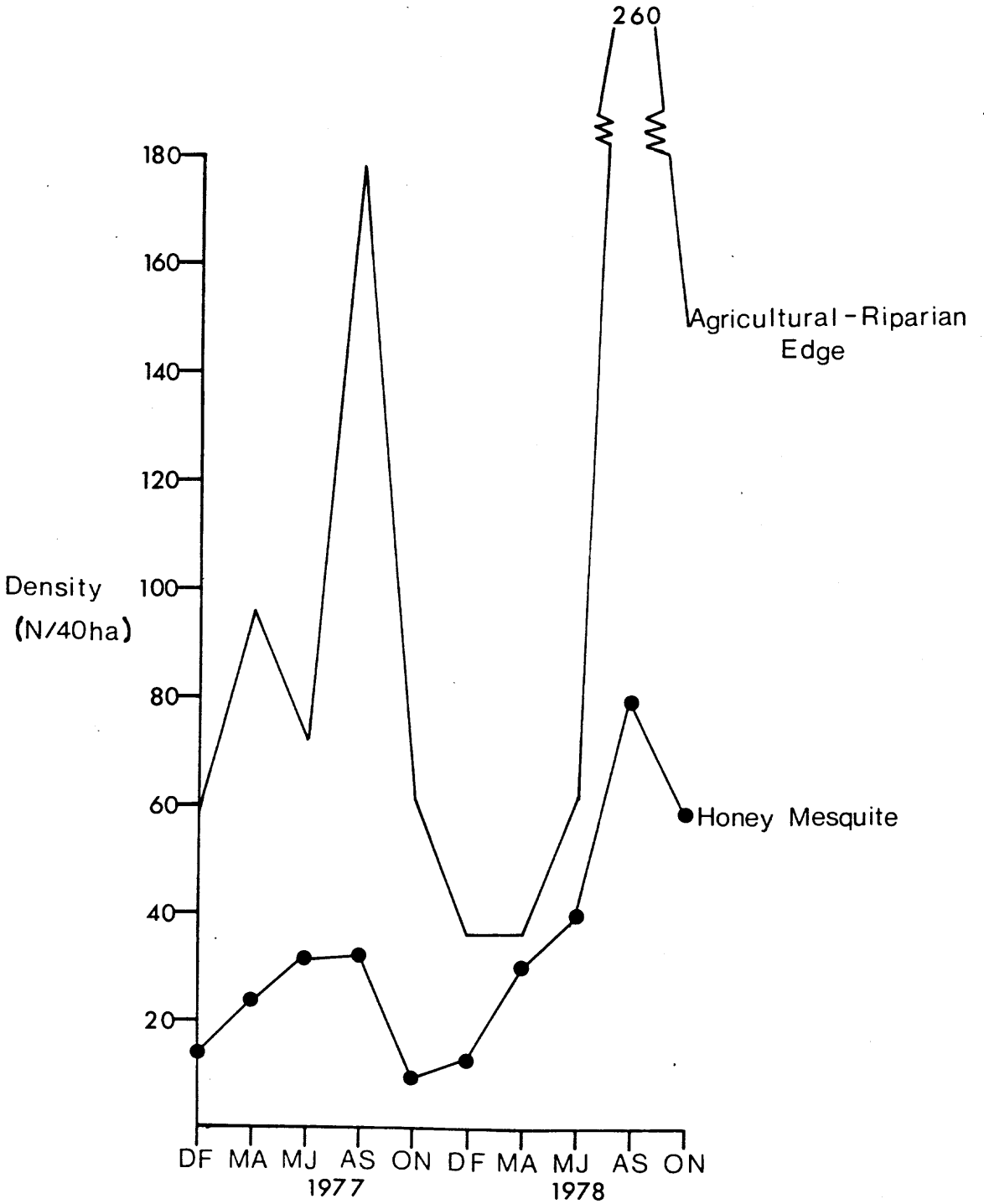

Figure 8-8. Density (N/40 ha) of Gambel Quail in honey mesquite and agricultural-riparian edge habitats in the lower Colorado River valley. Seasons are defined in the text.

This is due, in part, to the dense salt bush typically present along the agricultural border, but it is also a function of the abundant food supply provided by the cultivated crops (see diet section). In agricultural land away from riparian vegetation, quail densities were low, never exceeding 2 birds/40 ha in any season. Quail were not found farther than 0.4 km (0.2 mi) from the riparian-agricultural edge (Conine et al. 1978).

In summary, quail showed a preference for mesquite communities, and densities were lowest in cottonwood and pure salt cedar stands. Quail density was correlated with the number of mesquite trees, salt bush, and/or 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.

Reproductive Cycle

"Cow" calls of male Gambel 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. Due to variation in recording effort, comparisons of total numbers of "cow" calls from year to year are not possible.

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 six months, from February through August.

During the study period, 401 male and 314 female quail were collected and examined. Annual testis cycles (Figs. 8-9 and 8-10) revealed that the first histological changes occurred by early February, with an increase in testicular weight by mid-February. Full sperm production (Stage 5) lasted a total of 18 to 19 weeks, beginning as early as 15 March and continuing as late as 7 August. The longest period of full sperm production in any single year was 16.5 weeks in 1976. 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 weights are shown in Figures 8-11 and 8-12. Females with mature eggs were first detected about 20 March, with laying activity lasting at least 16 weeks. This estimate is 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. Oviducts showed gradual recrudescence and regression and a clear separation of adult and immature weights. 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.

All reproductive measures confirm a long breeding season of 21 to 24 weeks for Gambel Quail in the Colorado River valley. This is longer than other previously reported breeding periods for this or any closely related species.

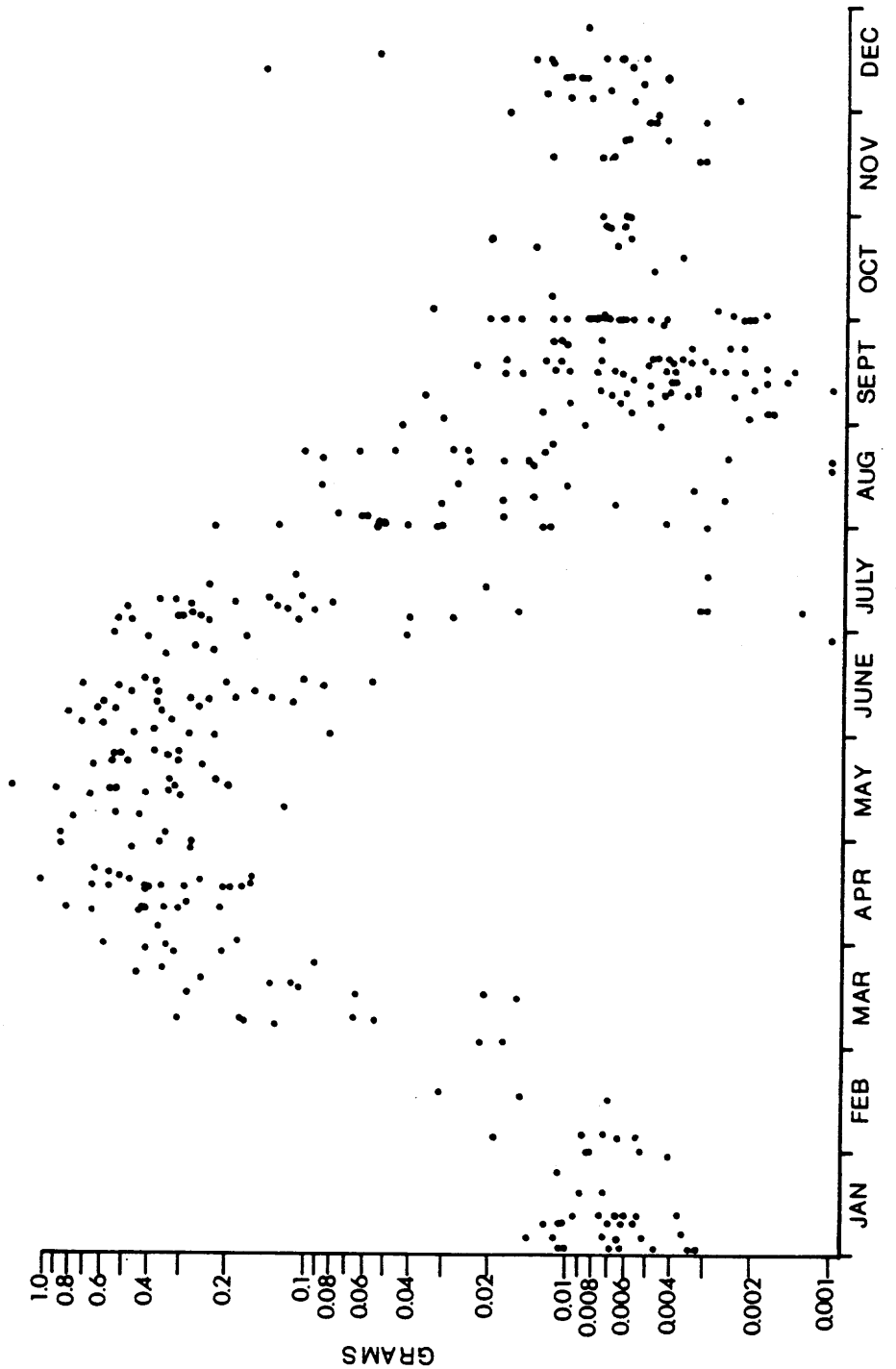

Figure 8-9. Annual testis weight cycle of Gambel Quail in the lower Colorado River valley. Dots represent combined samples for period: 1974-1977. Note that weight is on a logarithmic scale.

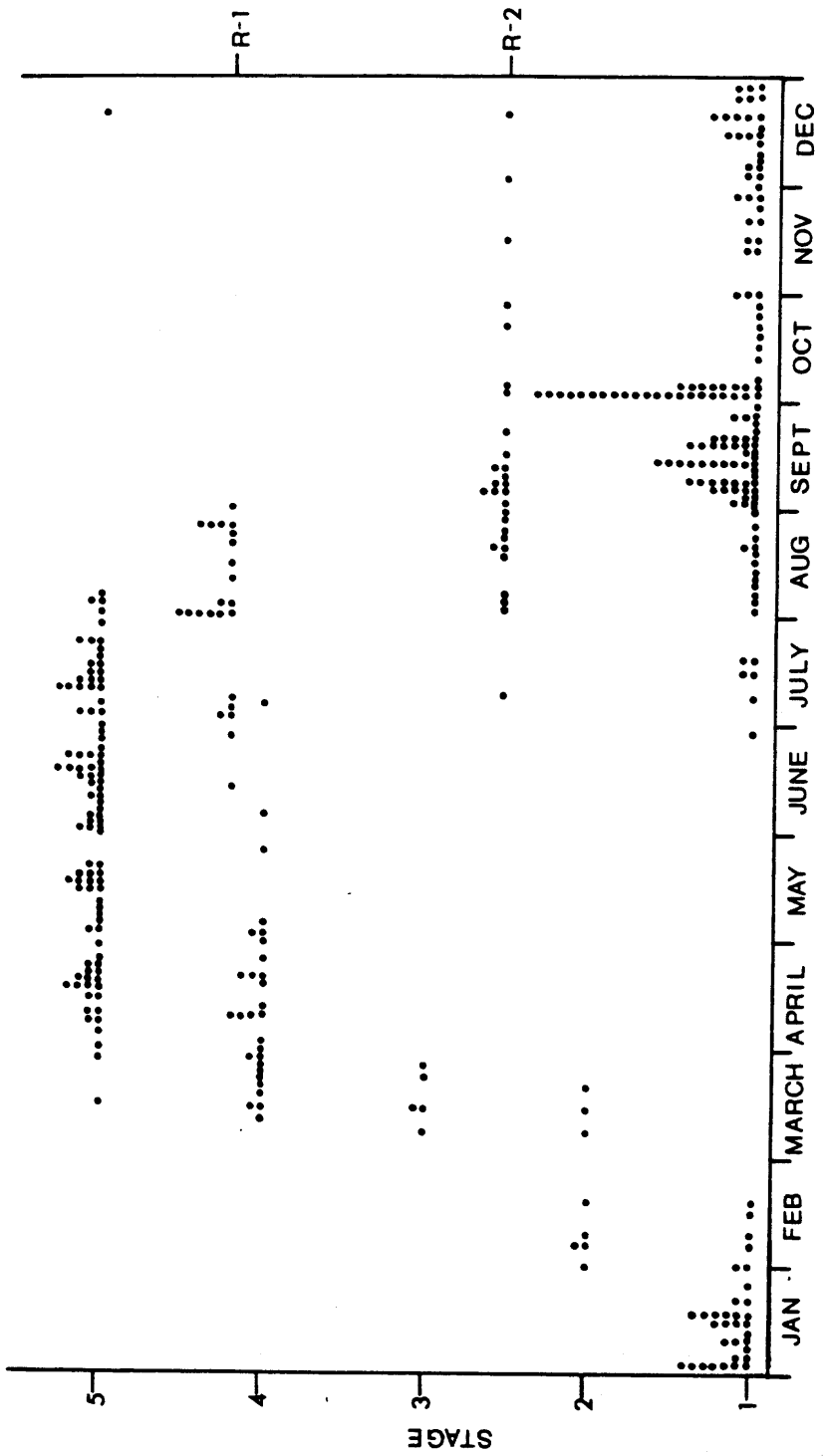

Figure 8-10. Cycle of spermatogenesis for Gambel Quail in the lower Colorado River valley. Stages are after Lewin (1963, pp. 252-255). R-1 and R-2 are stages of testis recrudescence. Samples were combined for 1974-1977.

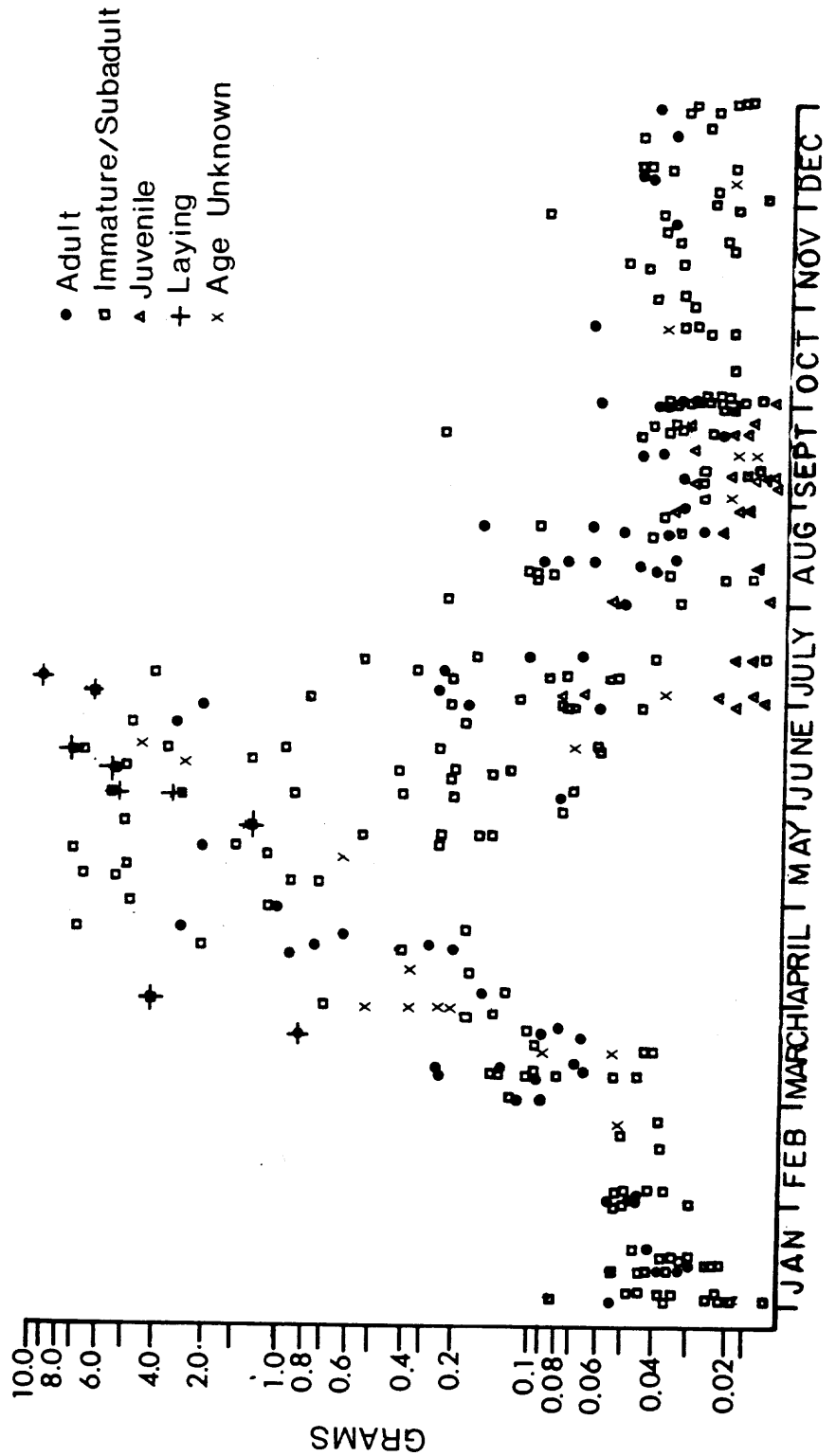

Figure 8-11. Annual cycle of ovarian weight (log_{10}) in Gambel Quail in the lower Colorado River valley (combined samples 1974-1977).

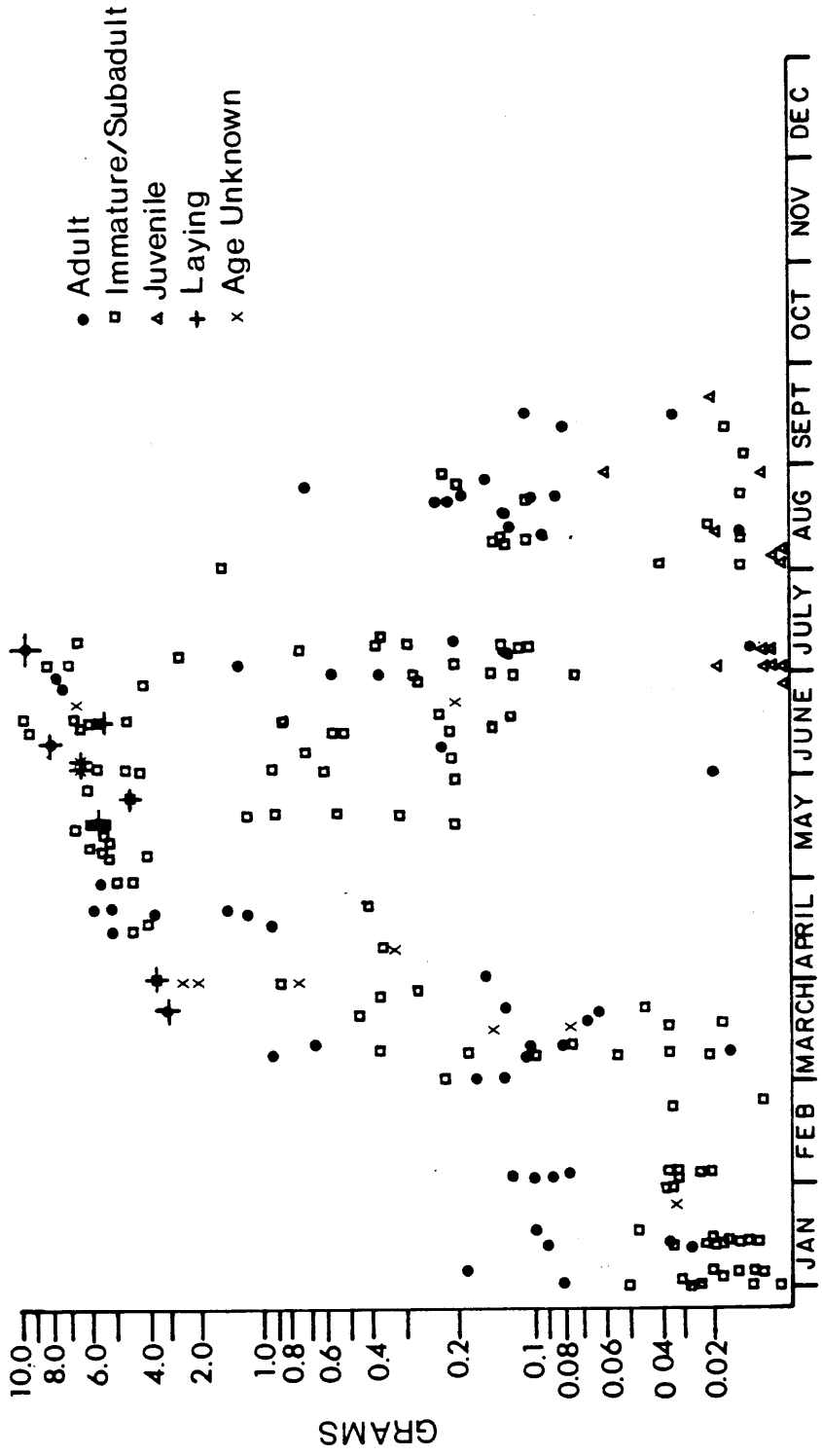

Figure 8-12. Annual cycle of oviduct weights (log_{10}) in Gambel Quail in the lower Colorado River valley (combined samples 1974-1977).

Diet

About 900 quail crops containing a total of 2,188 food items were examined between 1974 to 1978. Table 8-6 shows the frequency and percent volume of food items comprising at least 1% of the diet for the four years of study. About 100 plant species and 45 arthropod taxa were represented in the total sample. Major food categories were cultivated crops, mesquite beans, annual seeds and plants (including mistletoe), and animal matter. A general seasonal pattern of food preferences was apparent (Fig. 8-13), with mesquite pods a major food item in late summer and fall, annuals or cultivated crops most important in winter, and animal material (mainly ants and rodent feces) taken largely in summer.

This pattern varied greatly from year to year. Both 1974 and 1977 showed a high percentage of annuals in the diet (winter 1974, spring 1977). In each case this occurred five to six months after major rains (Fig. 8-13). In 1976, following a very dry year, annuals were not very important in the diet, and cultivated crops remained the major food source through most of the year. In 1975, following a year of intermediate rain, three major food items shared importance, with a switch from annuals to cultivated crops in spring and a shift to mesquite pods in late summer. Overall diet diversity was highest in summer and lowest in winter and was higher after wet years than after dry years (Table 8-7).

DISCUSSION

Examination of all data from the present study suggests two important topics for further discussion. One is the highly seasonal nature of all aspects of Gambel Quail biology. The other is the great influence that agricultural areas have on quail in the Colorado River valley.

The importance of the winter season to bird populations was stressed by Fretwell (1972); however, most bird studies have been conducted exclusively during the breeding season. The fact that quail consistently experience heavy mortality in fall and winter suggests that this is the time of population limitation. Winter quail densities were nearly identical each year, whereas winter temperatures, precipitation, and summer quail densities varied markedly. Thus, quail densities seemed independent of winter weather; however, temperature and rainfall probably affected subsequent reproductive success in some way.

The fact that the distribution of quail among plant communities (i.e., habitat breadth) became narrower with the onset of each winter implies that this was a period of active habitat selection. The consistent preference for honey mesquite at this time relates to both food and cover. Honey mesquite stands are generally quite patchy, with more salt bush in open areas. The nondeciduous salt bush is a predictable winter cover for quail where foliage is otherwise lacking. Openings also support growth of annual plants in late winter and early spring. In addition, enough mesquite pods probably remain on the ground to supply a dependable food source through at least part of the winter, and mistletoe seeds become available in late winter.

Table 8-6. Diet of Gambel Quail in lower Colorado River valley from 1974-1978.

Category	Percent frequency	Percent volume
Animal material		
Rodent feces	6.03	1.50
Formicidae (ants)	9.14	1.10
Coleoptera (15 families)	3.94	1.24
Homoptera (7 families)	2.15	0.75
Hemiptera (7 families)	1.51	0.35
Eruciform larvae	1.28	1.38
Elateriform larvae	1.10	0.87
16 other orders and families	1.60	1.01
Miscellaneous insect parts	2.56	0.58
Total	29.31	8.79
Mesquite seeds		
Screwbean mesquite	11.81	19.95
Honey mesquite	4.49	4.26
Total	16.30	24.21
Cultivated crop seeds		
Triticum aestivum (Wheat)	8.01	19.76
Medicago sativa (Alfalfa)	2.61	4.95
Sorghum vulgare (Milo)	1.88	2.10
Total	12.50	26.81
Annual and other seeds		
Phoradendron californicum (Mistletoe)	3.84	8.54
Chenopodium (spp.)	3.38	3.10
Oligomeris linifolia	2.88	2.24
Rumex (spp.)	2.60	0.90
Panicum (spp.)	1.82	4.89
Sorghum halepense (Johnson grass)	1.24	0.89
Salsola kali (Russian thistle)	0.73	3.61
Capsella bursa-pastoris (Shephard's purse)	0.59	1.13
85 other plant species	12.80	7.91
Total annual seeds	29.88	33.21
Total seeds	58.68	84.23

Table 8-6. (cont.)

Category	Percent frequency	Percent volume
Plant material		
Medicago sativa	2.38	3.66
Prosopis (spp.)	1.33	0.48
Other species	4.94	3.01
Total	8.65	7.15

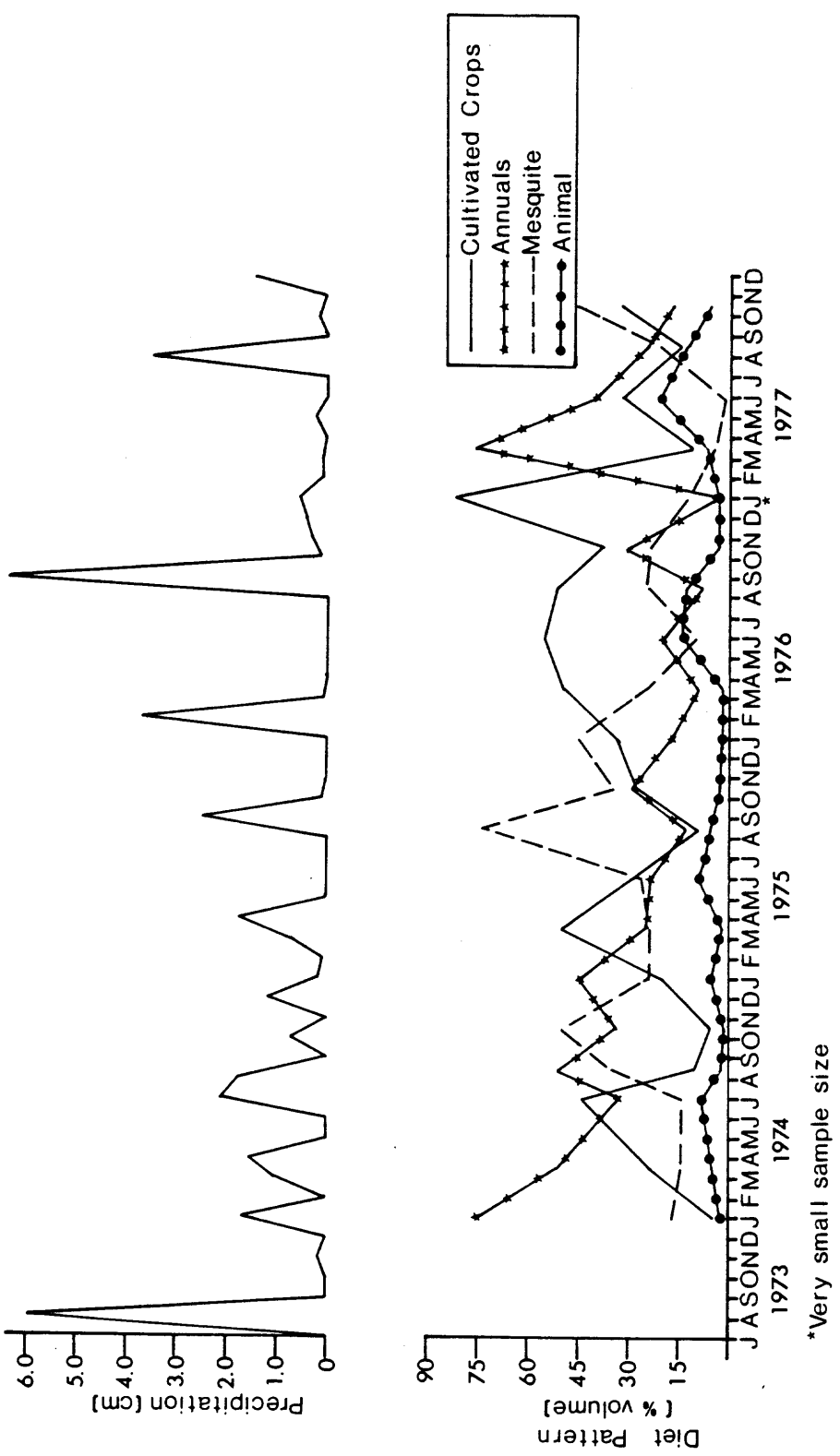

Figure 8-13. Relationship between timing and amount of rainfall and annual plant material in the diet of Gambel Quail in the lower Colorado River valley.

Table 8-7. Diet diversity index for Gambel Quail in the lower Colorado River valley. Index calculated ($H = -\Sigma\ p_i \log_{10} p_i$) for each month and for combined samples for months and years (see text) where p is the proportion of dietary item i. * = very small sample; blank signifies no data.

Month	1974	1975	1976	1977	Total
January	1.163	2.194	1.150	1.263	2.340
February	0.044*	-	0.783*	-	1.404
March	1.374	1.416	0.020*	1.134	2.126
April	1.933	1.409	1.689	1.866	2.679
May	2.589	1.487	2.105	2.492	2.979
June	1.857	1.684	2.316	2.791	2.828
July	-	1.638	2.284	2.301	2.617
August	2.128	0.931*	2.262	2.091	2.611
September	-	-	1.733	1.504	2.115
October	1.455	2.282	2.417	1.525	2.553
November	1.555	1.359	1.633	0.484	1.795
December	1.580	1.981	1.500	0.857	2.431
TOTAL	2.759	2.673	2.709	3.079	3.152

Screwbean mesquite stands appear superficially similar to honey mesquite, but they support almost no quail in winter. Screwbean mesquite is usually denser and less patchy than honey mesquite, lacks salt bush, has few mistletoe, and has little bare ground for annual plant production. The presence of seed pods is apparently not sufficient to attract wintering quail, and high autumn densities decline by December.

It has been suggested that choice of winter habitat by birds may directly affect subsequent breeding season survival and reproduction (Fretwell 1972). It would be advantageous for birds to winter in habitats where they can breed. They would thus gain experience in foraging and reduce the time and energy necessary to establish breeding sites. Since most spring breeding by quail takes place in honey mesquite and seems related to winter production of annual plants, quail that successfully winter in honey mesquite would have an advantage at that time.

The quail hunting season opened every year on 1 October. Hunting pressure tapered off as quail dispersed and the population declined. In fall, when hunting pressure is greatest, quail habitat preferences are linear. At that time, they are forced out of the open areas into the more dense areas where hunters and their dogs cannot penetrate.

Year-to-year variation in quail habitat preference can best be explained by food availability which is influenced by precipitation. In late summer and fall, quail densities in mesquite communities paralleled pod production. In 1975 and 1978, both pod availability and quail densities remained high through November; both years followed wet winters. The single most important factor governing quail productivity appears to be the presence of annuals in winter and early spring. The annuals provide the bulk of the diet at those critical periods when mesquite pods are absent, particularly at the beginning of the breeding cycle. During March-April 1977, six months after major rains, annuals were predominant in the diet. At that time, only a low correlation ($r = 0.461$) existed between quail numbers and the important vegetation variables (see Chapter 5); the widespread appearance of annuals allowed a relaxation of the quail's usually more rigid habitat preferences.

Precipitation and production of annual plants are extremely variable, and it is this variability that highlights the importance of agriculture to quail in the Colorado River valley. As shown in Figure 8-10, the proportions of annuals and cultivated crops in the diet were inversely related throughout the study period. Annuals predominated during the winter and spring following the major rains of August 1973 and September 1976. After the dry year of 1975, cultivated crops replaced annuals in quail diets almost completely. Thus, the alternative food source provided by agricultural land may help to mitigate winter losses caused by starvation and insure ample food to stimulate early spring reproduction.

The Gambel Quail is one species showing a classical edge effect; that is, it attains a higher density on the agricultural-riparian edge than in either pure agricultural areas or riparian communities. Laudenslayer

and Balda (1976) did not find typical edge birds in natural ecotonal areas of northern Arizona. However the effect of agricultural-riparian edge on several southwestern desert species is now becoming apparent (Conine et al. 1978). The response of quail to this edge is, again, related to both food and cover. The dense salt bush strip that is typically present provides ideal cover, and the readily available alternative food sources alleviate food shortages in riparian habitats.

The extremely long breeding season recorded in this study is probably related to the above mentioned factors. Because quail do not socially regulate their numbers before the onset of winter (Anderson et al., ms.), young produced late in the season are not at a disadvantage in fall coveys. Therefore, there is a selective advantage for breeding pairs to produce as many young as possible over as long a period as possible. The consistently dependable food supply from agricultural crops assures relatively favorable conditions in late winter for the initiation of early breeding and extension of breeding through late summer. If agricultural areas were not present in the valley, breeding might be delayed or even curtailed in years when food is limited.

In summary, the presence of agricultural land in the Colorado River valley seems to moderate quail population fluctuations by alleviating winter food shortages. Agricultural land also contributes to higher numbers of quail year-round because of the particular benefits of agricultural-riparian edge. However, the benefits of agriculture must be viewed with caution. It must be stressed that pure agriculture habitat supports very few quail. At present, quail populations are dependent upon native mesquite communities for breeding and foraging. A mosaic of riparian and altered habitats must be maintained in order to support healthy quail populations. As the balance of this mosaic shifts toward pure agriculture, the enhancing effect of the edge will be lost and isolated areas of natural habitat will become refugia for quail populations struggling to survive. If the entire valley is converted to agriculture, some quail may persist in pockets of nonarable land or in desert washes adjacent to the Colorado River valley, but Gambel Quail will be lost as a gamebird resource.

CONCLUSIONS

Addressing the goals outlined in the introduction, the main conclusions of this study are as follows:

1. Quail density fluctuates by 90% annually, with peaks attained in late summer and lows reached in February; winter is the season when the population is limited.

2. Quail depend on native honey mesquite during most seasons; preferred stands are dense but patchy, with salt bush and annuals present. Quail densities are highest along the interface between agricultural areas and riparian habitats.

3. The long breeding season (21-24 weeks) extends from late February through August; favorable precipitation and subsequent winter annual plant production are important for the initiation of early breeding.

4. Quail feed primarily on honey mesquite pods in late summer and fall and prefer seeds of annual plants in winter and spring. When dry conditions prevent growth of annuals, cultivated crops become more prevalent in the diet of quail.

5. Factors such as extensive mesquite habitats and adjacent agricultural areas probably contribute to increased winter survival and a longer breeding season, making this population consistently denser and more stable than nonriparian populations.

6. A mosaic of agricultural and riparian vegetation will adequately support healthy quail populations, provided that future conversion to agriculture is limited.

With these facts in mind, the following specific management recommendations can be made:

A. Maintain a diversity of natural plant communities, since most community types are used during some period throughout an annual cycle.

B. Preserve extensive tracts of honey mesquite or mixed honey mesquite communities. Fruits of honey mesquite are an important dietary component in late summer and fall. Soils supporting extensive tracts of mixed or mesquite-dominated communities also support varying amounts of annual plants, the leaves and seeds of which comprise the main dietary items of quail in the absence of agricultural crops. Presence of extensive mesquite habitats adjacent to agricultural areas may lengthen the quail breeding season and mitigate winter mortality.

C. Irrigate 2 to 5 ha (5 to 12.5 a) plots of honey mesquite habitats, where possible, once monthly in November, December, and January, to encourage growth of annuals and salt bush. This would maintain a higher carrying capacity of quail throughout the winter (the limiting season), and ensure a higher density of breeding pairs at the beginning of the breeding season. Irrigation tailings from agricultural areas could be diverted into mesquite habitats for this purpose. Summer waterings would promote less desirable plant species and extensive tracts of dense vegetation, which are not preferred by quail.

D. Maintain cover species such as quail bush and wolfberry, as well as other seed and fruit-bearing species such as mistletoe, in tracts of honey mesquite. Quail bush and wolfberry could be seeded in low areas if irrigation waters were provided.

E. Encourage the development of hedgerows of quail bush in the natural plant communities adjacent to agricultural areas. This would serve as escape cover for quail and provide benefits to the farmer by reducing wind erosion of top soil (boundary layer effect). Excess water from fall irrigations could be used to establish the hedgerows of quail bush.

F. Convert pure salt cedar stands to mesquite or mixed communities and develop patchy dense ground cover (<3 m [<10 ft]) using quail bush and wolfberry shrubs. This management capability is possible where irrigation is available.

G. Encourage rectangular development of agricultural blocks in remaining honey mesquite habitats that are to be cleared. A strip of mesquite habitat 200 to 300 m (656 to 984 ft) wide should be left between adjacent fields. Rectangular blocks of agricultural lands can be as long as possible, but the width should not exceed 1 km (0.6 mi) for minimum natural habitat loss for quail.

H. Promote better understanding between the water managers, local residents, and wildlife agencies as to both the value of Gambel Quail as an aesthetic and economic resource, and the harmony that is possible between population growth, agricultural development, and wildlife conservation in the future.

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CHAPTER 9

AVIAN SUCCESSION IN BURNED RIPARIAN VEGETATION

INTRODUCTION

Currently in the United States a large proportion of upland habitat destruction or disturbance is a result of clearcutting for lumber and natural and man-caused fires. Economic and aesthetic losses sustained as a consequence of fires are great -- destruction of wildlife often has been portrayed as similarly large. Nevertheless, there is little information available on the impact of fire on wildlife.

The recovery of plant communities after various types of disturbances has been observed and documented (Shantz 1917, Booth 1941, Launchbaugh 1955, Judd 1974). Changes in plant community composition are consistent and predictable in many areas. Rapidity of recovery varies as a function of type, size, severity of disturbance, and the type of plant community involved.

Among the trends characterizing successive stages (seres) occurring after disturbance is a progressive increase in the vertical complexity of vegetation, continuing until some stable, climactic plant community is established. The relationship between the diversity of various community components and stages of development can be expressed in general probabilities. That is, early stages generally will have a lower diversity of plants, insects, birds, etc., than the last stage or stages (Odum 1971). But specific observations of early and intermediate stages of development and diversity of community components (particularly avian indices of diversity) have not always lent themselves to ready interpretation or provided reliable or consistent data for predictive purposes.

A number of studies have reported concurrent increases in the number of bird species (bird species richness) and the number of birds (density) with increasing age of developmental stages (Kendeigh 1944, Odum 1950, Johnston and Odum 1956, Shugart and James 1973, and others). However, closer examination of the data (Odum 1950, Johnston and Odum 1956), for example, indicates early or intermediate stages of development in which species richness and/or density was higher than in later stages.

A tendency toward increasing values of bird species diversity with advancing seres, as reported by Shugart and James (1973) and Zimmerman and Tatschl (1975), was not confirmed by the observations of Milne (1974) or Conner and Adkisson (1975). This contradicts predictions that have been made possible by the development of a technique (MacArthur and MacArthur 1961) for quantifying the structural characteristics of plant communities in a manner more refined than merely determining the age of an area in years. The MacArthurs' view of avian responses to vegetation involved the demonstration of correlations between foliage height diversity (FHD) and bird species diversity (BSD). By assuming that the key variable was vertical vegetation structure (and not other attributes

such as plant species richness or composition), the comparison of foliage and avian indices of diversity obtained from various types of habitats or plant associations was possible (MacArthur and MacArthur 1961). But it seemed logical to assume that intercommunity differences in bird populations existed; as pointed out by Willson (1974:1021), "Simple similarity of foliage profile...does not predict similarity of avian communities; different habitats have different relationships." By accepting the Willsonian logic (and without attempting to discredit the confirmations that have accumulated in support of MacArthur and MacArthur 1961), it should not be surprising, and perhaps one should expect, to find dissimilar avian communities characterizing different habitats, especially those with unequal FHD's.

Other studies have been restricted to one plant community or association (Meslow and Wight 1975, Conner and Adkisson 1975) in which the number and/or diversity of birds did not reach their peak in concert with the development of a mature or climax stand of vegetation, again in contrast to what would have been predicted via FHD and BSD correlations (Conner et al. 1979). Presumably the nonconformity of some of the above-mentioned bird communities to various plant community developmental stages was a response to some factor or factors other than foliage height diversity per se. In our study, data are presented from a single community type in order to reduce variation due to differential responses to the presence or absence of certain species of vegetation that could potentially affect avian population characteristics.

Most studies examining the relationship of avian populations and seral stages have been conducted in the eastern United States. Of the few western studies, none has investigated the response of bird populations to regenerated riparian vegetation. The present study was designed to determine which of several previously reported patterns (if any) was exhibited by the avifauna of such a habitat type, and to determine the relationship of bird species richness, density, and daily energy expenditure (DEE) to various indices of vegetation structure and complexity. Specifically, the assumption was that no significant relationship would exist between FHD and the avian community attributes.

This study includes data only for summers. It would have been more informative to have included data from all seasons. Ultimately it was time and logistical support which placed constraints upon us. Our choices were to present one season only or to present no information on succession at all. Obviously we though that some information was better than none at all in this case. The results we present in this chapter cannot necessarily be considered representative of other seasons. They do, however, represent four summers, thus conclusions for summer are based on a substantial data base.

THE STUDY AREA

The study was conducted in the lower Colorado River valley of extreme western Arizona at an elevation of approximately 100 m (328 ft). Some of the most dramatic habitat changes that have occurred in Arizona have taken place in the riparian ecosystem associated with the lower Colorado River (Ohmart et al. 1977). The construction of dams, starting in the

1930's, has resulted in the control of spring flooding, an integral part of the establishment and maintenance of riparian habitats, particularly those of the cottonwood-willow community. Patterns of succession were therefore observed under conditions where natural means of succession as affected by flooding were precluded.

The climate of the lower Colorado River valley is one of extremes. Rainfall is sparse. Scattered, sometimes violent, but brief late-summer thunderstorms and gentle winter rainfall combine to contribute an average of less than 10 cm (3.9 in) of moisture per year. Winter temperatures are comparatively mild, but summers are consistently hot, with daily highs often exceeding 40°C (104°F).

Six areas of riparian habitat were studied (Fig. 9-1). Two of the areas (A and B) were on the Havasu National Wildlife Refuge near Topock, Arizona. These areas burned early in 1976. Area C, which burned in the summer of 1974, was located northwest of Poston, Arizona, on the Colorado River Indian Reservation. Area D, located southwest of Poston, was burned in August 1973. Area E, which burned in 1959, was located approximately 15 km (9.3 mi) north of Blythe, California, and was used as a representation of an intermediate stage of redevelopment. Data from relatively mature vegetation (area F) were obtained from the lower Bill Williams River, about 25 km (15.5 mi) northeast of Parker, Arizona (Fig. 9-1). This area had not been burned previously.

The study areas were established within what had been cottonwood-willow-salt cedar associations. Cottonwood proved to be very susceptible to the effects of fire, and few trees survived the holocaust. Resulting associations were dominated by willow and salt cedar. Also present were screwbean mesquite and the shrubs arrowweed and four-wing salt bush. Area A contained approximately 24 willows per ha (2.5 a); area B had 59 willows per ha; area C had 154 willows per ha; area D had 252 willows per ha; area E had 374 willows per ha; and area F had approximately 219 cottonwoods and 355 willows per ha.

METHODS

Transects

Pathways 0.75 m (2.5 ft) wide and 800 m (2625 ft) long were established through the study areas. Each pathway, or transect, was divided into 160-m (525-ft) units, yielding five subplots on each side of the transect. All data were obtained from the transects and within the subplots, except temperature information, which was procured from U.S. weather stations in the Colorado River valley.

Vegetation Measurements

Foliage height diversities were measured for each transect using the board technique of MacArthur and MacArthur (1961). From each of the four most recently burned areas (A through D), FHD's were recorded during each of the four summers. Foliage measurements were taken from three predetermined points located within each subplot, each approximately 4.6 m (15 ft) from the transect (Anderson et al. 1977).

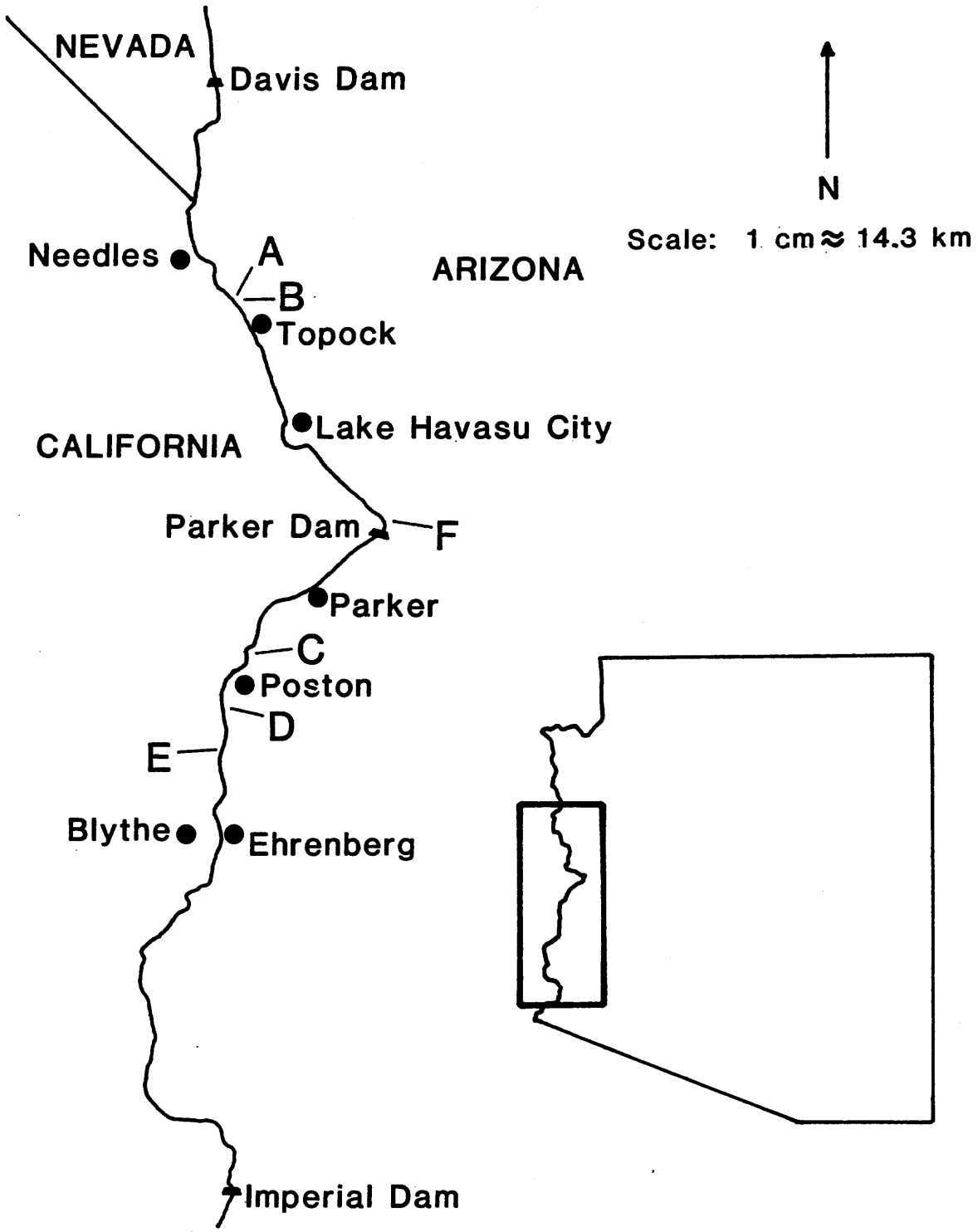

Figure 9-1. Location of study sites.

The same points were used each year; measurements were made during May. The factor measured was the distance from each point at which a board (approximately 25 X 38 cm [10 X 15 in]), held vertically to the ground and perpendicularly to the observer, was half covered with foliage (not dead stems or limbs) when centered at heights of approximately 15 cm (6 in), 60 cm (2 ft), 1.5 m (5 ft), 3.0 m (10 ft), 4.6 m (15 ft), 6.0 m (20 ft), 7.6 m (25 ft), and each 3.0-m interval thereafter, above the ground. These values were converted into an estimate of leaf surface area per cubic unit of measure (see MacArthur and MacArthur 1961), and the average value for each height category was computed. These relative foliage density values were then grouped into layers consisting of the sums of the averages obtained at 15 cm and 60 cm, at 1.5 m and 3.0 m, and at 4.6 m and above, representing, respectively, the theoretical grass layer, shrub layer, and tree layer. The term "grass layer" is descriptive of the height interval involved and is not meant to imply that only grass was measured, or that grass even existed. The same was true of the other two layers measured. Foliage height diversity was calculated by means of information theory (Shannon and Weaver 1949), $-\Sigma\ p_i \ln p_i$, where p_i represents the proportion of the total estimated foliage density contributed by the foliage at height level i, producing an index of vertical complexity.

The means of the foliage measures obtained were used as indices of foliage density in the three layers mentioned above. The sum of these values was used as an index to overall community foliage density.

Horizontal complexity in the three layers was also thought to have a potential influence on the avian community (MacArthur 1964, Willson 1974). An index to this component of the habitat was derived using the average value for a given layer within each 160-m subplot and calculating the variance of the subplots. The sum of the variances was used as an indication of total horizontal complexity (Anderson et al. 1978).

The average number of cottonwood and willow trees per ha was included as a final community measure (NTC). Only live trees were counted. This measure did not change each year as did the other vegetation parameters.

Avian Density

A modified version of the Emlen (1971) census technique was used to estimate bird densities (Anderson et al. 1977). Transects were censused three or four times each month during May, June, and July, here defined as the breeding season. Several species, however, commence and/or cease breeding two to three months prior to and after this period in the Colorado River valley. Each area was censused within two or three hours following sunrise. Data were gathered from areas A-D for four consecutive summers, commencing with the first summer after the date of disturbance. Data from areas E and F, obtained during four summers (1976-1979), were averaged.

Total bird density estimates for each area included only 10% of the estimate for White-winged Doves and Mourning Doves. These species obtained but a small fraction of their food requirements from their

nesting habitat and commonly occurred in large numbers in riparian situations, particularly those near agricultural areas (Anderson and Ohmart 1975).

Species Richness

Estimates of numbers of species of birds in each study area for each year were limited to species known to breed within the riparian habitat, as determined by collection and dissection, and by observations of nests and young. Species observed only as flyovers (hawks, swallows) and those occurring only as migrants were not included. In addition, the more uncommon species whose densities were <0.5 per 40 ha (100 a) were not included in species richness totals. Migrants were omitted because of their irregular occurrence. If one study area did not happen to be censused on the day when a large wave of migrants passed through but another area was censused on that day, differences in species richness would merely reflect the vagueries of timing associated with migration rather than environmental features which characterize the sites.

Daily Energy Expenditure (DEE)

Estimates of the total avian DEE per 40 ha were derived by use of the following regression equation for bird species which do not feed exclusively on the wing,

$$\log DEE = \log 8.96 + 0.653 \log W$$

where DEE is expressed in kJ/day and W is body mass in grams (Walsberg 1980). Weights for most species were obtained from specimens collected in the Colorado River valley during the study period (Appendix 9-1). DEE values for each species, multiplied by that species' density, were summed to yield an estimate of the energy consumption occurring within each area each summer. These community DEE values do not include data for Gambel Quail, White-winged Doves, or Mourning Doves. Each of these species is large (average weight 167 g [5.8 oz], 150 g [5.3 oz], 117 g [4.1 oz], respectively); Gambel Quail may occur in large coveys, which results in large differences in DEE estimates between areas otherwise similar. White-winged and Mourning doves were present in large numbers in riparian habitat near agriculture; these species, in addition to the Gambel Quail, differ from the rest of the avian community in foraging primarily as granivores and herbivores. Energy used by a bird or any other animal is a direct result, directly or indirectly, of the ability of the vegetation to carry on photosynthesis. Thus DDE is frequently thought to be related to characteristics (foliage density and diversity, etc.) of the vegetation.

Analysis

Statistical analyses used included the Dunn multiple comparison test (Dunn 1964) and correlation matrices. The Dunn test was used to test for differences among the most recently disturbed sites (A through D), which were the areas of greatest structural similarity. The technique was used to compare combined sets of data observed during years one through four. Correlation matrices were created from the plant

community measures to search for colinearity. Correlation coefficients were also obtained for the three dependent variables and the plant community measures.

A data description program was employed to determine the normality of the distribution of the independent variables. Those variables not normally distributed in terms of both skewness and kurtosis at the 5 percent level of significance were not used in predictive analyses. Since it is desirable in statistical analyses to refrain from using highly correlated variables, a principal components analysis was also used to aid in the separation and determination of suitable variables. A multilinear regression analysis was used to test avian community parameters (species richness, bird density, and DEE) against the applicable quantified variables of the plant community.

The deviations produced by subtracting the observed Y's from the Y's predicted by the equations resulting from regression analysis are logically considered to be the result of numerous unmeasured biotic and abiotic variables, including sampling error and assumption bias. Since the length of time after disturbance of the study areas was known (and is measurable in many plant communities), age (AGE) was included as a variable to help account for some of the cumulative or successive ecological changes that can be known but not easily measured. Some of these variables might include such factors as changing community respiration and production, plant biomass, total organic matter, role of detritus in nutrient regeneration, capacity of community to conserve nutrients, and food chain and biochemical diversity (Odum 1969).

RESULTS

Vegetation

In the four most recently disturbed areas (A through D), FHD values were, as expected, lowest during the first summer (Table 9-1). FHD's were similar in areas A through C during the first three years, changing from an average of 0.31 the first summer to an average of 0.55 the second summer, and stabilizing near 0.70 in years three and four. The vegetation of study site D was more evenly distributed than at sites A through C in years one and two but was similar during the third summer. FHD's in areas A, C, and D decreased slightly during year four, whereas area B increased from 0.70 to 0.79 (Table 9-1). The FHD of study site E was 0.98; the FHD for area F was 1.01.

Foliage density measures exhibited strong and predictable general patterns in the three layers of vegetation considered (Table 9-2). Foliage density was greatest in the grass layer (FDG) during the first summer after disturbance and was observed at its lowest values in the two most mature areas. Foliage density in the intermediate or shrub layer (FDS) demonstrated a trend opposite to that observed at the lowest layer. Values were smallest during the first summer, subsequently peaking in areas A and B during the third summer, and in areas C and D during the fourth summer. The foliage density value at the shrub layer in area D was higher in the fourth summer (0.51) than the foliage density values in areas E (0.24) or F (0.41). Very small amounts of

Table 9-1. Foliage height diversities (FHD) of the most recently disturbed study sites.

Year following burn	Study site			
	A	B	C	D
1	0.327	0.296	0.315	0.697
2	0.550	0.570	0.544	0.793
3	0.712	0.702	0.690	0.750
4	0.698	0.793	0.686	0.740

Table 9-2. Foliage density in grass (FDG), shrub (FDS), and tree (FDT) layers, and total plant community estimator (FDC).

Study site	Year	FDG	FDS	FDT	FDC
A	1	0.549	0.061	0.000	0.611
	2	0.315	0.099	0.000	0.414
	3	0.238	0.340	0.004	0.582
	4	0.364	0.236	0.003	0.603
B	1	0.648	0.060	0.001	0.708
	2	0.289	0.092	0.001	0.383
	3	0.240	0.252	0.001	0.493
	4	0.259	0.208	0.013	0.480
C	1	0.612	0.063	0.000	0.675
	2	0.281	0.085	0.000	0.366
	3	0.303	0.176	0.003	0.482
	4	0.286	0.365	0.000	0.651
D	1	0.374	0.195	0.004	0.573
	2	0.279	0.291	0.012	0.582
	3	0.376	0.370	0.009	0.755
	4	0.342	0.509	0.013	0.864
E	20	0.121	0.241	0.420	0.782
F	40	0.185	0.415	0.574	1.174

foliage occurred in the highest or tree layer (FDT) in areas A through D during the first four summers. This height interval contained the greatest foliage density in areas E and F. The index to relative total community foliage density (FDC) arrived at by combining the foliage density estimates of the three major vegetation layers presented no obvious pattern. Lowest FDC values were observed during the second summer at sites A through C; the highest value was that of area F (Table 9-2).

Estimates of horizontal complexity did not fall into patterns as obvious as those just described, but the same trends existed (Table 9-3). Horizontal complexity was greatest in the grass layer (HCG) in areas A through D during the first year. In the shrub layer (HCS) values were low in areas A through C during the first and second summers. Values greatly increased in areas A and B during the third summer and in area C in the fourth year. Study site D exhibited relatively high values each year. Horizontal complexity values in the tree layer (HCT) were almost nonexistent until the stage of growth and recovery exhibited by areas E and F were obtained (Table 9-4). The index of total community horizontal complexity (HCC) was high in areas A through D during the first year, in D during the second year, in B and D (A was moderately high) in the third year, and in C and D during the fourth year. Values were high in areas E and F also (Table 9-4).

A matrix of the correlation coefficients of the 10 plant community measures used in this study indicated a number of variables that appeared to exhibit colinearity (Table 9-5). In terms of biological significance we believe that some of the significant correlations were merely coincidental and should not be interpreted as indicating multiple measurement of the same community features. The correlations appearing most likely to represent interrelatedness were foliage density and horizontal complexity measures.

Avian Community

A total of 36 species of birds was detected on the sites in sufficient densities to be included as a part of the study (Table 9-6). Of those species observed on the study sites each summer, nine species were recorded in all of the areas each year (Table 9-7). These nine species (Gambel Quail, Mourning Dove, Ladder-backed Woodpecker, Ash-throated Flycatcher, Lucy Warbler, Northern Oriole, Brown-headed Cowbird, Blue Grosbeak, and Abert Towhee) represent a basic avifauna of the cottonwood-willow-salt cedar community, although only three of the nine species (Northern Oriole, Blue Grosbeak, Abert Towhee) are considered obligate riparian species.

Interesting trends were also exhibited in the year-to-year data. During the first summer the fewest number of species were observed in each of the four most recently disturbed sites (A through D). Species richness peaked in these areas during the third summer, averaging 21 species, the same as that observed in area E (which had burned nearly 20 years earlier; Table 9-8). The difference between the first and third years was significant at the 5% level.

Table 9-3. Horizontal complexity in grass (HCG), shrub (HCS), and tree (HCT) layers in the most recently disturbed sites.

Study site	Year	HCG	HCS	HCT
A	1	0.057	0.002	0.000
	2	0.014	0.003	0.000
	3	0.005	0.029	0.000
	4	0.001	0.006	0.000
B	1	0.045	0.000	0.000
	2	0.014	0.002	0.000
	3	0.027	0.024	0.000
	4	0.004	0.008	0.001
C	1	0.052	0.001	0.000
	2	0.003	0.001	0.000
	3	0.012	0.004	0.000
	4	0.028	0.024	0.000
D	1	0.023	0.036	0.000
	2	0.019	0.042	0.000
	3	0.016	0.038	0.000
	4	0.019	0.029	0.000

Table 9-4. Community horizontal complexity (HCC).

	Age of study areas (AGE) (years)					
Study site	1	2	3	4	20	40
A	0.059	0.017	0.034	0.007	-	-
B	0.045	0.016	0.051	0.013	-	-
C	0.053	0.004	0.016	0.052	-	-
D	0.059	0.061	0.054	0.048	-	-
E	-	-	-	-	0.054	-
F	-	-	-	-	-	0.068

Table 9-5. Correlation coefficients of the natural log of plant community measures.* Abbreviations as in Tables 9:1-4.

Plant community measure	Plant community measure					
	ln HCG	ln HCS	ln HCT	ln FHD	ln FDC	ln FDG
ln HCG	1.000					
ln HCS	-0.083	1.000				
ln HCT	-0.306	-0.165	1.000			
ln FHD	-0.756	0.439	0.570	1.000		
ln FDC	0.107	0.209	0.648	0.330	1.000	
ln FDG	0.791	-0.238	-0.520	-0.885	-0.016	1.000
ln FDS	-0.382	0.706	0.288	0.752	0.591	-0.519
ln FDT	-0.305	-0.136	0.995	0.579	0.680	-0.512
ln AGE	-0.531	-0.022	0.903	0.779	0.630	-0.701
ln HCC	0.532	0.485	0.349	0.082	0.687	0.118
ln NTH	-0.128	0.216	0.582	0.480	0.592	-0.305

Plant community measure	Plant community measure				
	ln FDS	ln FDT	ln AGE	ln HCC	ln NTH
ln FDS	1.000				
ln FDT	0.325	1.000			
ln AGE	0.567	0.912	1.000		
ln HCC	0.365	0.364	0.191	1.000	
ln NTH	0.457	0.595	0.561	0.440	1.000

* NTH = number of broadleaf trees per ha; other variable abbreviations as identified in Tables 9:1-4. 1% level of significance = 0.59.

Table 9-6. Avian species occurrence (no/40 ha) in riparian habitat recovering from disturbance, lower Colorado River valley.

Study site	Bird species	1976	1977	1978	1979
A, burned in 1976	American Kestrel	-	1	-	-
	Gambel Quail	13	1	6	6
	White-winged Dove	3	1	2	-
	Mourning Dove	7	4	3	7
	Roadrunner	-	3	7	2
	Lesser Nighthawk	1	5	1	-
	Gila Woodpecker	15	-	6	-
	Ladder-backed Woodpecker	1	1	5	6
	Ash-throated Flycatcher	9	5	17	8
	Say Phoebe	-	-	3	2
	Verdin	-	5	13	6
	Bewick Wren	-	-	1	-
	Crissal Thrasher	-	1	4	4
	Black-tailed Gnatcatcher	-	-	10	2
	Loggerhead Shrike	-	5	1	2
	Lucy Warbler	1	18	28	31
	Yellow-breasted Chat	-	-	1	1
	Northern Oriole	2	2	2	7
	Brown-headed Cowbird	4	2	8	3
	Blue Grosbeak	16	19	55	20
	Indigo Bunting	-	7	10	-
	Lazuli Bunting	-	2	-	7

Table 9-6. (cont.)

Study site	Bird species	1976	1977	1978	1979
	House Finch	1	-	-	-
	Abert Towhee	5	15	52	26
	Song Sparrow	-	-	2	2
B, burned in 1976	American Kestrel	-	1	1	2
	Gambel Quail	16	7	5	17
	White-winged Dove	2	-	7	2
	Mourning Dove	2	4	4	6
	Roadrunner	-	-	3	7
	Lesser Nighthawk	1	-	1	-
	Common Flicker	-	1	-	-
	Gila Woodpecker	5	3	2	1
	Ladder-backed Woodpecker	2	4	9	3
	Ash-throated Flycatcher	12	7	9	8
	Verdin	14	3	23	6
	Bewick Wren	-	-	1	2
	Mockingbird	-	-	2	-
	Crissal Thrasher	-	1	2	4
	Black-tailed Gnatcatcher	-	-	2	4
	Loggerhead Shrike	-	-	2	1
	Starling	-	-	1	1
	Lucy Warbler	8	19	6	9
	Common Yellowthroat	-	1	-	-
	Northern Oriole	4	2	5	6

Table 9-6. (cont.)

Study site	Bird species	1976	1977	1978	1979
	Brown-headed Cowbird	5	5	6	1
	Blue Grosbeak	38	22	60	22
	Indigo Bunting	2	16	3	-
	Lazuli Bunting	1	-	-	2
	Abert Towhee	7	20	29	20
	Song Sparrow	-	4	-	-
		1975	1976	1977	1978
C, burned in 1974	Gambel Quail	33	22	18	8
	White-winged Dove	15	40	14	32
	Mourning Dove	9	41	56	24
	Roadrunner	-	9	1	4
	Common Flicker	-	-	-	2
	Gila Woodpecker	-	-	1	-
	Ladder-backed Woodpecker	1	2	2	2
	Western Kingbird	6	7	3	-
	Wied Crested Flycatcher	-	-	2	-
	Ash-throated Flycatcher	8	10	12	13
	Verdin	1	5	4	10
	Cactus Wren	-	-	1	-
	Mockingbird	-	2	-	3
	Crissal Thrasher	4	6	2	8

Table 9-6. (cont.)

		1975	1976	1977	1978
	Black-tailed Gnatcatcher	-	-	3	3
	Loggerhead Shrike	2	-	-	-
	Lucy Warbler	3	13	4	3
	Common Yellowthroat	-	-	1	-
	Northern Oriole	6	6	9	3
	Brown-headed Cowbird	11	18	20	13
	Blue Grosbeak	2	9	8	10
	House Finch	-	4	3	6
	Abert Towhee	15	17	90	37
		1974	**1975**	**1976**	**1977**
D, burned in 1973	Gambel Quail	14	45	67	51
	White-winged Dove	4	30	19	22
	Mourning Dove	33	96	135	103
	Roadrunner	-	1	2	7
	Lesser Nighthawk	14	3	7	2
	Common Flicker	-	-	1	-
	Gila Woodpecker	-	2	-	-
	Ladder-backed Woodpecker	3	3	4	2
	Western Kingbird	-	4	4	11
	Ash-throated Flycatcher	8	17	13	23
	Verdin	-	6	6	31
	Cactus Wren	-	1	-	-

Table 9-6. (cont.)

	1974	1975	1976	1977
Mockingbird	1	-	-	1
Crissal Thrasher	-	3	-	3
Loggerhead Shrike	-	3	1	3
Lucy Warbler	3	6	14	19
Common Yellowthroat	-	-	1	-
Northern Oriole	3	15	7	12
Brown-headed Cowbird	5	17	16	64
Blue Grosbeak	1	5	7	5
Lazuli Bunting	-	-	1	-
House Finch	3	1	2	15
Abert Towhee	8	17	25	38

Species	Site E (burned in 1959)	Site F (undisturbed)
Gambel Quail	15	4
White-winged Dove	39	5
Mourning Dove	88	2
Yellow-billed Cuckoo	1	6
Roadrunner	2	-
Lesser Nighthawk	2	-
Common Flicker	1	7
Gila Woodpecker	4	19
Ladder-backed Woodpecker	13	21
Western Kingbird	-	2
Wied Crested Flycatcher	3	10

Table 9-6. (cont.)

Species	Site E (burned in 1959)	Site F (undisturbed)
Ash-throated Flycatcher	16	15
Verdin	18	10
Bewick Wren	-	5
Cactus Wren	7	7
Crissal Thrasher	7	2
Black-tailed Gnatcatcher	10	2
Loggerhead Shrike	3	-
Bell Vireo	-	1
Lucy Warbler	11	2
Common Yellowthroat	-	13
Yellow-breasted Chat	-	16
Northern Oriole	10	21
Brown-headed Cowbird	30	35
Summer Tanager	-	12
Blue Grosbeak	4	12
House Finch	-	2
Abert Towhee	28	35
Song Sparrow	-	12

Table 9-7. Birds observed each year on study sites.

Bird Species	Study Site					
	A	B	C	D	E	F
Gambel Quail	*	*	*	*	*	*
White-winged Dove			*	*	*	*
Mourning Dove	*	*	*	*	*	*
Yellow-billed Cuckoo						*
Lesser Nighthawk				*		
Common Flicker						*
Gila Woodpecker		*			*	*
Ladder-backed Woodpecker	*	*	*	*	*	*
Wied Crested Flycatcher						*
Ash-throated Flycatcher	*	*	*	*	*	*
Verdin		*	*		*	
Bewick Wren						*
Crissal Thrasher			*	*	*	*
Black-tailed Gnatcatcher					*	
Lucy Warbler	*	*	*	*	*	*
Common Yellowthroat						*
Yellow-breasted Chat						*
Northern Oriole	*	*	*	*	*	*
Brown-headed Cowbird	*	*	*	*	*	*
Summer Tanager						*
Blue Grosbeak	*	*	*	*	*	*

Table 9-7. (cont.)

Bird Species	Study Site A	B	C	D	E	F
House Finch				*		*
Abert Towhee	*	*	*	*	*	*
Song Sparrow						*

Table 9-8. Avian population characteristics of study sites.

Study site	Year following burn	Species richness	Density (birds/ 40 ha)	Daily energy expenditure (kJ/40 ha)
A	1	13	69	5,311
	2	18	92	7,512
	3	22	232	19,011
	4	18	136	9,764
B	1	15	115	7,213
	2	17	116	8,176
	3	22	173	13,828
	4	20	117	9,717
C	1	14	94	5,534
	2	16	138	9,532
	3	20	110	7,225
	4	17	130	11,467
D	1	14	69	4,897
	2	20	170	10,026
	3	20	201	10,787
	4	19	308	21,311
E	20	21	198	14,684
F	40	26	272	28,364

Areas A through D added three to seven species (mean = 5.5) during the second summer and lost one or two (mean = 1.5) of the species that had been present the first summer. During the third summer, areas A through D added an average of 5.5 species (range 3-8) and lost one to three (mean = 2.25) species that had been present the previous year. The average net increase in species richness during the second and third summers was 3.5 species per study area. Site D did not exhibit a net increase in species richness from the second to the third summer, probably because species richness had reached a relatively high level in this area after the first summer. This is probably related to the fact that site D developed vegetationally much more rapidly, especially with respect to variables most associated with species richness (Tables 9:2-4), than sites A-C.

Species additions followed a similar pattern on the four recently burned sites. A large species of woodpecker (Common Flicker or Gila Woodpecker) was added during the second (area B) or third summer (areas A, C, D), in addition to a pair of small insectivores in the third summer -- Black-tailed Gnatcatcher and Bewick Wren in area A, Black-tailed Gnatcatcher and Bewick Wren in area B, Black-tailed Gnatcatcher and Common Yellowthroat in area C, and Black-tailed Gnatcatcher (year two) and Common Yellowthroat in area D.

During the fourth summer the trend toward increased species richness was reversed; three to five species were lost (mean = 3.75), and none to two (mean = 1.25) were gained, for an average net decrease of 2.5 species per area. This decrease, though not statistically significant, was nonetheless notable because of its consistency. No such decrease occurred in area E, which averaged 21 species during the summers of 1976-1979.

The increase in bird species richness during the first three years (particularly in areas A through C) was strongly correlated with increasing FHD values (Table 9-8). There was no change in FHD in the fourth summer in areas A, C, and D, although the FHD of area B continued to increase. Interestingly enough, as noted above, species richness values declined compared to the third year.

Numbers of birds per 40 ha were not as strongly related to changing FHD's as were species richness totals ($r = 0.64$ vs. 0.80), nor were the trends as consistent. Area A reached its highest level of bird density in the third year (232 birds), decreasing by 96 individuals per 40 ha in the fourth year (Table 9-8). Densities in area B were virtually identical during the first, second, and fourth summers, averaging 116 birds per 40 ha. The peak density observed during the third summer was only 57 birds per 40 ha more than had been observed previously. No marked changes in bird density occurred in site C during the four summers, the greatest change occurring after the first summer when 44 birds per 40 ha were added. However, density in area D increased each summer, from a low of 69 birds per 40 ha the first year to an estimated 308 birds per 40 ha in year four, a total higher than that observed in areas E and F (Table 9-8).

Estimates of DEE exhibited the same patterns demonstrated by density values (Table 9-8). There were several situations, however, in which the avifauna of a particular site during a particular year expended 2000 to 7000 more kJ's than in other areas (or the same site in a different year) possessing densities similar to or greater than its own. Peak DEE's occurred in areas A and B during the third summer (19,011 and 13,828 kJ's, respectively) and in areas C and D the following year (11,467 and 21,311 kJ's, respectively). DEE was greatest in area F (28,364 kJ's; Table 9-8).

Analysis

The null hypothesis, that no relationship existed between FHD and species richness, density, or DEE, was rejected for all three variables. The correlation coefficient for each was significant at the 1% level (df = 16; r = 0.80, 0.64, and 0.70 for species richness, density, and DEE, respectively). It should be noted, however, that significance merely indicates linear relations with nonzero slopes. The r's from above indicate that 36, 59, and 51% of the observed variation of the three dependent variables were not explained through their respective relationships with FHD.

Other parameters of the plant community were also highly significantly correlated with the three attributes of the avifauna under consideration (Table 9-9). However, descriptive statistics indicated that three of the variables were not normally distributed. These variables (HCT, FDT, AGE) were therefore excluded from multilinear regression analysis. The equations also excluded all highly correlated ($r \geq 0.8$) and associated independent variables.

The equation for species richness,

$$\ln\text{Species Richness} = 2.997 + \ln(\text{HCS} + 1)(0.283) + \ln(\text{FDC} + 1)(0.751) + \ln(\text{FDG} + 1)(-1.131) + \ln([\text{HCC}\cdot 10] + 1)(-0.369)$$

($F = 8.09$, df = 4 and 13, $P<0.002$), explained 71% of the observed variation.

Seven X variables were significantly correlated with density of birds (Table 9-9). One of the usable variables, foliage density in the shrub layer (FDS), was more strongly correlated (r = 0.80) than was FHD (r = 0.64). The sorting of the variables in the multiple regression analysis resulted in an equation explaining 73% of the observed variation. Four of the measures were incorporated:

$$\ln\text{Density} = 4.301 + \ln(\text{FDC} + 1)(1.520) + \ln(\text{FDG} + 1)(-0.989) + \ln(\text{FDS} + 1)(2.092) + \ln([\text{HCC}\cdot 10] + 1)(-0.658)$$

($F = 8.67$, df = 4 and 13, $P<0.001$).

The third dependent variable, DEE, was even more predictable via multiple regression than was species richness or density of birds. Due to the existence of possibly interrelated X variables, several combinations of the plant community measures resulted in equations

Table 9-9. Correlations of avian community parameters and plant community measures. Abbreviations as in Tables 9:1-5. NTC = average number of cottonwood and willow trees/ha. * = 5% level of significance; ** = ≥1% level of significance. - indicates negative correlations.

Plant community measure	Species richness	Density	DEE
HCG	-**	-*	-*
HCS	NS	NS	NS
HCT	*	NS	*
HCC	NS	NS	NS
FDG	-**	-*	-**
FDS	**	**	**
FDT	*	*	*
FDC	NS	*	*
FHD	**	**	**
AGE	**	**	**
NTC	NS	NS	NS

explaining similar percentages of the observed variation of avian community energy expenditure. Of these,

$$\ln DEE = 8.994 + \ln(FDC + 1)(2.449) + \ln(FDG + 1)(-2.293) + \ln(FDS + 1)(1.624) + \ln([HCC \cdot 10] + 1)(-0.688) + \ln(NTC + 1)(-0.084),$$

explained 82% of the variation ($r^2 = 0.82$, $F = 10.89$, $df = 5$ and 12, $P<0.0004$).

Successive breeding season increases and/or decreases in DEE were successfully predicted, as were the relative positions of the study sites with each other. The variable NTC explained only 1% of the variation, the minimum contribution allowed for the purpose of this study.

DISCUSSION

Patterns of bird species richness and density have been studied in some depth (Johnston and Odum 1956, MacArthur and MacArthur 1961, Pianka 1966, Terborgh 1967, Balda 1967, 1975, MacArthur 1975). Factors producing these patterns have been interpreted in terms of community age, structural complexity of vegetation, latitude, elevation, plant species diversity, resource availability, and climatic harshness. The structural complexity agent has been most intensively examined, particularly by means of comparing avifaunas in the dramatically altered habitat characteristic of secondary successional stages (Lack 1933, Odum 1950, Johnston and Odum 1956, Karr 1968, Ferry and Frochot 1970, Shugart and James 1973, Glowacinski and Jarvenin 1975, Bock et al. 1978).

We believe the factors involved in the production of avian community characteristics in the area studied can be partly identified, if not fully comprehended. But first some thoughts related to other factors possibly affecting the avian community will be discussed.

Climatic Influence

The numbers of individuals in the different species of an avifauna change. Various biotic and abiotic forces have been proposed as the agents controlling bird community structure. The effort to understand the population fluctuations of avian guilds or communities has been examined by numerous workers and has resulted in many theories attempting to explain the structures therein. One of these theories suggests that changes in breeding bird populations occurring in the same area between years may not be related to changing vegetation characteristics but, rather, to conditions existing during the nonbreeding season (Fretwell 1972). Specifically, the postulate holds that competition for food is the primary force shaping winter avian populations, and that this force is lessened as climatic factors ameliorate, thereby reducing competitive interactions and increasing survivorship. Theoretically, unusually mild winters should permit higher rates of survival during the nonbreeding season, resulting in higher population levels during the following breeding season.

A rough check for such climatic influences was possible as a result of the study design. Initiation of study in the four most recently burned sites was staggered (first-summer data were obtained in 1976 for areas A and B, in 1975 for area C, and in 1974 for area D), making possible the comparison of within-year as well as between-year trends. Population data from the study sites during the same calendar year revealed that during the summer of 1977, bird density increased in areas A and D by 23% and 107 birds per 40 ha from the previous summer, and that areas A, B, C, and E increased in density by 140, 57, 20, and 51 birds per 40 ha, respectively, during the summer of 1978. Both of the winters preceding these two summers were milder than normal, particularly the winter of 1977-78, when the minimum daily temperature averaged about seven degrees warmer (^{o}F) than the 30-year norm (Sellers and Hill 1974). The observed population changes lend support to Fretwell's (1972) hypothesis. Data from areas similar in vegetation structure but which had not been burned serve as controls and confirm this interpretation.

The climatic explanation of population control may not apply, however, for the following reasons: (1) not all of the study sites exhibited population increases during the summers referred to above (area B, year 2; area C, year 3), and (2) nonresident breeding species (44% of the species richness totals) accounted for seemingly inordinate percentages of the observed population increases. Nonresident birds accounted for an average of 53% of the population increase observed during the summer of 1978 (in areas A, B, C, D, E), 100% of the increase observed in area A in 1977, and 70% of the increase observed in 1977 in area D. Differences in breeding densities may well reflect winter survival, but resident species should be more affected than the migratory breeding contingent. It seems more logical that the birds were responding to changing characteristics of the vegetation, and in fact the asynchronous nature of the study did result in consistent or readily explainable population levels during the various stages of redevelopment examined.

Habitat Measures

Few studies have addressed the subject of habitat selection through the use of more than one habitat variable, a situation producing observations in conflict with predictions, or observations which fit habitat measures of limited applicability (Balda 1975). Some workers have reported avian biomasses or densities in grassland, shrub, and forest seres that remained unchanged or actually decreased in the later stages of succession, these measures acting independently of species diversity indices (Willson 1974, Zimmerman and Tatschl 1975). Studies in other areas have revealed closer correlations between species richness, density, and succession, as has the present study. But later plant community stages or habitats in which decreases in avian population characteristics occurred have been observed as well (Adams 1908, Odum 1950, Johnston and Odum 1956, Ferry and Frochot 1970, Milne 1974, Meslow and Wight 1975, Bock et al. 1978). It is possible that in all of these situations some of the same circumstances or principles have prevailed, resulting in population reductions.

Specifically, it appears that subtle shifts in the amount and percentage of vegetation in different layers, and in the horizontal complexity of

foliage, represent the primary factors influencing use by bird populations in the lower Colorado River valley. Measures of foliage height diversity are unaffected by the relationship of the distribution of foliage; but it is this relationship (obscured in FHD values) that is important. For example, bird species richness was highly negatively correlated with increasing foliage density and horizontal complexity in the lowest foliage layer measured in this study. Species richness was highly significantly correlated with foliage density in the intermediate or shrub layer and significantly correlated with foliage density in the tree layer (Table 9-9).

Densities and daily energy expenditures of breeding bird populations exhibited more readily observed relations than did species richness, resulting in more accurate predictions. Perhaps species richness estimates were more greatly affected by interspecific incompatibilities, specific responses to nuances of vegetation structure, climate, or behavioral unknowns. Regardless, the relationship between the dependent variables (density and DEE) and the foliage measures was such that in two areas having similar FHD's and foliage volumes, the area with the greater percentage of foliage in the shrub layer would have the greater avian density or DEE. None of the foliage measures employed in this study emerged as a criterion superior to FHD in predicting bird species richness. Bird density and DEE fluctuated independently of species richness, in response to different parameters of the plant community than those affecting species richness. Despite coincidental correlations of density and DEE with FHD, the measures of density and DEE were more strongly affected by foliage volume or complexity in different layers.

Species-Specific Responses

Avian preference for a certain breeding locality (and wintering locality) has been demonstrated under changing environmental conditions resulting in drastically altered habitats (Evans 1978). Three species not observed within the intermediate stage (area E) that inhabited the mature area (F) each summer were present in the most recently disturbed sites (A through D). Site tenacity cannot be positively ruled out, but two lines of evidence suggest that site preference was not responsible for these occurrences. Most important, none of the species (Bewick Wren, Common Yellowthroat, Song Sparrow) was detected in sites A through D during the first summer after disturbance. In addition, these three species are most typically observed within the grass and shrub layer of area F, reinforcing the thought that their occurrence during the early stages of recovery was in response to structural attributes of the plant community. The presence of the Song Sparrow and Common Yellowthroat also may have been due in part to the presence of water, although in some of the areas the nearest known water was at least 320 m (1050 ft) from the censused area.

In considering the responses of specific species or guilds of birds after disturbance by fire, dramatic increases in avian densities (particularly woodpeckers) in the early years of vegetation recovery have been reported (Blackford 1955). Evidently these increases in avian densities have occurred as a result of insect infestations in dead or

weakened trees, a phenomenon observed during the course of this study but not quantified. Estimated woodpecker densities were quite low in areas A through D (Table 9-6). On only one occasion, while we were collecting in a burned locality adjacent to area D, did we observe a large mixed-species flock of woodpeckers foraging among the blackened and damaged remains of a mesquite bosque. This would indicate that woodpeckers do at least occasionally congregate in burned areas of the lower Colorado River valley, but they are perhaps not as common during the breeding season, or at later times of the day than when censusing was conducted. At any rate, a large species of woodpecker (Gila Woodpecker or Common Flicker) was added to the avifauna of each of the four most recently disturbed sites during the second or third summer, only to disappear the next breeding season. Various factors may have interacted to produce such observations. Since large woodpeckers were not consistently observed in sites A through D, it must be presumed that at least part of the reason was because of inappropriate vegetation structural characteristics. The presence of a temporary superabundance of food (i.e., woodboring beetles or their larvae) may override such drawbacks, resulting in an association of birds that would not otherwise be expected.

If our observations and data construct a true reflection of what actually occurred, then it would appear that perhaps two years were required for large numbers of beetles to become established. During this same period of time a progressively smaller number of dead limbs and trunks remained each summer because of high winds and other factors. This may have reduced suitable foraging substrate or potential cavity nest sites to the point where exploitation of the increased food supply was no longer profitable. Unfortunately, food-supply and snag-density data were not collected in our study areas.

Two species would appear to qualify as burn specialists in the lower Colorado River valley: the Indigo Bunting and the Lazuli Bunting. These species were observed only during the early stages of recovery. Typical habitat for these buntings has been described variously as "brush, sproutland" and "burns" (Peterson 1969), apt descriptions of sites A through D. The Blue Grosbeak (an overgrown bunting), although one of the nine most consistently observed species, nevertheless occurred in greatest numbers in the most recently burned sites. The presence of the Indigo and Lazuli buntings and their contribution to species richness, density, or DEE totals, however, are rather limited, not affecting any of the trends or relationships that would exist otherwise.

The occurrence of a number of the remaining 27 avian species detected on the study sites can be understood in simple mechanical terms. The two species of doves, for example, are nesting specialists. Dense vegetation between 1.5 and 6 m is required for occurrence of high densities of White-winged and Mourning doves (Anderson and Ohmart 1977a).

Cavity-nesting species are slightly more complex but basically fall into two groups: primary and secondary cavity nesters. Primary cavity nesters (woodpeckers) excavate their own nest sites, whereas secondary

cavity nesters use previously existing sites. Woodpeckers require nest trees of suitable size. As the number of potential nest sites increases, woodpecker densities increase. An average of about six woodpeckers occurred in the most recently disturbed sites, compared with 18 in area E and 47 in the most mature area (F; Table 9-6). A yearly average of about 23 secondary cavity nesters in areas A, B, C, and D compared more favorably with the more mature areas E and F, which each supported approximately 30 secondary cavity nesters (Table 9-6). The proportion of the secondary cavity-nesting population made up of the tiny Lucy Warbler was greatest in areas A through D (mean = 47%), whereas this species was a mere 6% of the total secondary cavity-nesting population in area F. If secondary cavity nesters are considered a guild, it appears that they respond more strongly to an area in terms of nest site availability than do primary cavity nesters (see the account for Wied Crested Flycatcher in Phillips et al. 1964). In other words, a burned area will continue to support a greater percentage of secondary cavity nesters than primary cavity nesters, indicating that vegetation structure is more important to primary cavity nesters such as woodpeckers, than it is to secondary cavity nesters. In summary, the long-term effects of disturbance upon cavity-nesting species are: (1) reduced densities and species richness of primary cavity-nesting species; (2) reduced diversity of secondary cavity nesters; (3) reduced overall density of secondary cavity-nesting species, but to a lesser degree than that of primary cavity nesters; and (4) reduced average body size of secondary cavity nesters.

Another common riparian species, the Crissal Thrasher, was not consistently observed in the most recently burned areas. This species is found in shrubby areas with well-developed deposits of leaf litter. After these areas burned, suitable substrate for foraging was greatly reduced, thus depressing the level of occurrence of the Crissal Thrasher.

In conclusion, it would appear that those of us interested in predicting levels of species occurrence are still far from unifying thoughts and approaches into a formula of widespread palatability or practicability. The basic ingredients in the lower Colorado River valley are the nine avian species found in the cottonwood-willow-salt cedar community, whose numbers vary with different vegetational structural characteristics. Additional more restricted species include low-foliage inhabitants (e.g., Bewick Wren, Common Yellowthroat, Song Sparrow) and upper-canopy dwellers (e.g., Yellow-billed Cuckoo and Summer Tanager), species whose presence is closely tied to the occurrence of vegetation in specific layers (Anderson and Ohmart 1977b). The remaining species constitute a reservoir which makes up the balance of the avifauna.

Avian species richness, density, and daily energy expenditure can be predicted fairly precisely (r^2 = 0.71, 0.73, 0.82, respectively), but the composition of the avifauna, whether the result of competition, response to specific ecological conditions, or pure chance, cannot be determined by the plant community attributes quantified in this study. Correlations between these attributes and variation of avian community parameters cannot be construed as evidence of causality. Identification of factors responsible for the occurrence of any species at any location

must come from other sources, such as studies relating the structural complexity of areas to actual use by specific species (Balda 1975). These sorts of data will be required if designers and managers of wildlife sanctuaries are to deal successfully and pragmatically with species packing and community assembly problems, or if, in an ever-shrinking natural world, we hope to duplicate or improve upon existing plant communities via manipulation or the creation of new habitats.

SUMMARY

Seeming contradictions between expected avian community-habitat relationships and observed parameters have prompted widespread efforts to determine the features used by birds in habitat selection. It was argued that the identification of vegetation complexity components affecting avian communities can best be made when observations are limited to the same plant community. This procedure was observed in documenting the birds found in burned riparian vegetation. Nine foliage measures, in addition to age (in summers since disturbance) and number of broadleaf trees, were used to characterize six study sites in the cottonwood-willow-salt cedar community. Data were obtained for the four most recently disturbed sites during four consecutive summers. The data were interpreted as indicating that observed species richness totals resulted primarily as a response to FHD, whereas avian density and daily avian community energy expenditure (DEE) were more strongly related to and affected by such vegetation attributes as foliage density or complexity in the shrub layer. Multiple regression analysis resulted in a highest r^2 (0.94) for DEE, indicating possible food resource limitation of the avifauna. Rapid turnover of bird species, characteristic of many redeveloping plant communities, was not observed. An assemblage of nine bird species, inhabiting all of the study sites during the first summer after burning occurred, remained throughout successive stages. Additional species were added as the avifauna responded to the redeveloping plant community, but more data will be needed to predict the occurrence of most of the additional 27 species observed.

MANAGEMENT RECOMMENDATIONS

A number of management recommendations can be made, but their feasibility and practicality remain to be determined.

1. Controlled burning. This tool has been used effectively for wildlife management purposes in national forests. It has potential in salt cedar communities along the lower Colorado River where river management has essentially eliminated flooding. Flood waters carried the leaf litter accumulations downstream from the plant communities, which then reduced the probability of extensive stands of salt cedar being burned because the fuel (litter) had been removed. Controlled burning could be beneficial to both water managers and wildlife.

Intuitively, it appears that young actively growing salt cedar communities would have a greater evapotranspirative water loss than a mature community with little understory and a dense overstory to shade

the soil and produce a boundary layer effect. For most species of wildlife, and certainly for the White-winged Dove, the mature salt cedar community provides better habitat for both foraging and nesting than does a young, developing community.

Salt cedar communities along the lower Colorado River have a high probability of burning about every 12 to 15 years. It takes about 15 years for a newly burned community to reach maturity. Consequently, the mature community may only exist for about 2 to 5 years before reentering a fire cycle. The fuel which carries the fire comes from the annual leaf drop and the death of lower limbs as the canopy develops to shade out the more horizontal branches. After about 12 or more years, the litter accumulation is more than adequate to carry a fire, and the heat produced is sufficient to kill the cambium in the trunks of the trees. Fires are either intentional or accidental, but once the area burns, the root crowns quickly sprout new branches and the cycle repeats itself. When willows, mesquites, and cottonwoods are mixed with salt cedar they burn as well. Willows resprout fairly well, depending upon their health, and 80 to 100% may form new trees. Some mesquite trees also resprout from the root crown, but generally only a few persist. Fire usually kills all cottonwoods, which results in a rapid elimination of this species from mixed communities that tend to undergo fire cycles.

Data are needed on temperatures that the cambium in the trunks of willows, mesquites, and salt cedar can withstand without being killed. Once this is known, along with the fuel/heat production factor, then these communities could be control-burned periodically to maintain them in a mature stage. If small groves of cottonwoods were present they could be cleared around to prevent a killing heat load.

It was mentioned previously, but it should be reemphasized, that water and wildlife managers would both benefit from salt cedar communities being in a mature state. Because both would benefit from this action, it is incumbent on the responsible agencies to explore this management recommendation for both water salvage and wildlife benefits. Certainly it should be explored before any consideration is given to vegetation removal strictly for water salvage purposes.

2. Fire lanes. Salt cedar communities could be blocked off into manageable-sized units by 50-ft fire lanes. This would prevent extensive areas from being burned when fires do occur. Though the data are not complete on the responses of this action to wildlife, it would certainly be beneficial to some species, and the tree removal in the 50-ft lanes would have some water salvage value. Once the clearing study is completed, a more comprehensive understanding of the impacts on wildlife will be available.

If such an action were ever undertaken, we would recommend selectively removing salt cedar in the fire lanes and leaving any lone trees or clumps of native trees. If fire lanes were periodically mowed, these remaining trees would present no problems to the mowers, as we have observed in the case of the International Boundary and Water Commission's action on the lower Rio Grande Boundary Preservation Project.

Operational enhancement features are also possible simply by revegetating a narrow strip of quail bush along each side of the tree fringe. This evergreen shrub has tremendous wildlife value, especially for quail, and would enhance the area for wildlife. Fire lanes might have to be wider, but a strip of quail bush would offset any wildlife losses from a wider cleared strip. The cleared area would also provide growing sites for annual plants, which would also provide additional food resources for quail, other avian granivores such as doves, and rodents. During fires the quail bush would reduce crown fires to lower levels and would also reduce the probability of the fire jumping the fire lane. The evergreen nature of the shrub would curtail the moving fire.

The fire lane concept could also be integrated with the controlled burn effort to more effectively manage fires. Once a block burned, the area could be put under a controlled burning management plan.

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Appendix 9-1. Some mean weights (gms) for insectivorous birds breeding in the lower Colorado River valley[a]. n = number of specimens.

Species	Weight	n
American Kestrel[b]	188.8	12
Yellow-billed Cuckoo	64.2	6
Roadrunner	239.0	5
Lesser Nighthawk	46.5	12
Common Flicker	118.0	2
Gila Woodpecker	62.4	14
Ladder-backed Woodpecker	32.7	3
Western Kingbird	39.3	40
Wied Crested Flycatcher	39.8	11
Ash-throated Flycatcher	27.0	40
Say Phoebe	22.5	7
Verdin	6.5	40
Bewick Wren	8.8	2
Cactus Wren	40.3	18
Mockingbird	48.8	13
Crissal Thrasher	62.8	15
Black-tailed Gnatcatcher	5.2	40
Loggerhead Shrike	43.3	4
Starling[b]	79.0	35
Lucy Warbler	6.8	40
Common Yellowthroat	9.4	9
Yellow-breasted Chat	23.6	3
Northern Oriole	31.0	40

Appendix 9-1. (cont.)

Species	Weight	n
Brown-headed Cowbird	37.0	40
Summer Tanager	112.0	4
Blue Grosbeak	26.8	18
Indigo Bunting[b,c]	14.6	33
Lazuli Bunting[c]	15.3	38
House Finch	18.0	40
Abert Towhee	47.3	40
Song Sparrow	18.9	9

[a]Weights of specimens collected along lower Colorado River, except American Kestrel, Starling, and Indigo and Lazuli buntings.

[b]Data from Stewart and Skinner (1967).

[c]Data from Kroodsma (1975).

CHAPTER 10

LIFE HISTORY AND POPULATION DATA OF SMALL MAMMALS IN RIPARIAN VEGETATION

INTRODUCTION

Rodents are an important component in ecosystems in that they are relatively numerous, harvest large quantities of seeds and other plant parts, consume some insects, and are the prey base for numerous carnivores. Population dynamics, reproductive characteristics, and behavioral attributes of all organisms are intricately related to their food resources. Therefore knowledge of rodent populations is not only important in itself, it is also a contribution to the knowledge of entire faunal communities.

This report summarizes small rodent census data from 1974 through 1979 along the 450 km (275 mi) of the lower Colorado River valley from Davis Dam south to the Mexican border. A total of 219,780 trap nights were employed in censusing the six riparian vegetation community types.

The information reported includes: identification of species trapped, their numbers and distribution in nine defined divisions of the study area, a brief physical description of each species, reproductive characteristics, population characteristics, species habitat associations, and species movements and home ranges.

METHODS

Rodents were sampled on transects in representative riparian vegetation of the lower Colorado River valley. See Chapter 2 (Table 2-1) for an explanation the vegetation classification system.

Snap Trapping

Snap trapping methods are detailed in Chapter 2. The same area was never trapped consecutively within a six-week period. Trapping was organized so that all structural and vegetation types were sampled on a basis proportional to their presence in the valley.

Capture data were reported on a seasonal basis; winter extended from November to March, summer from April to October. Seasonal population sizes were determined for the vegetation and structural types by averaging the n/270 trap nights for transects sampled within that season.

External measurements and reproductive data were taken for each captured rodent. Presence or absence of embryos and their number were noted.

Live Trapping

Two hundred Sherman live traps were set 15 m (49 ft) apart for ten consecutive nights in March or April 1975 in two Type IV honey mesquite

stands. Captured animals were toe clipped for identification. Home range areas were calculated according to the exclusive boundary strip method. In a computer-simulated study of determining home ranges, the exclusive boundary strip method was reported to be most accurate (Stickel 1954). A boundary strip equal in width to one-half the distance between traps was laid off around the minimum area and the area enclosed was measured. Home range estimates were usually based on three to five captures. Van Vleck (1969) stated that three to ten captures are commonly used for range estimates, and the higher the minimum number of captures the greater the mean size of the home range estimate. He suggested that range estimates be reported according to the number of different stations at which an individual was caught, as well as the number of individuals at that many stations, so that comparisons of range estimates could be more accurate. This recommendation was followed.

We also examined movement distances by calculating the adjusted range length and distances between captures of species. To measure adjusted range length, the distance between the most widely separated capture sites was measured and one-half the distance to the next trap was added to each end of the line drawn (Stickel 1954). This method was used because Stickel (1954) found that compared to computer simulations of home range length, the adjusted range length values were 3% larger than actual versus observed range lengths, which were 25% smaller than actual. Distance between captures was recorded as an average of that measure for all individuals of a species.

Live trapping was not a continuous effort. Because trap grids were set in only one month, in only one community type, results cannot be considered necessarily representative for the species, but they can be examined relative to those of other species. The low number of recaptures per individual makes the area estimates of home range conservative and variable. Home range can be calculated whenever the data offer more than one point of recapture, but estimates of range are more realistic with greater numbers of recaptures (Van Vleck 1969). The sample sizes for distance between capture and range length were larger; thus they may be examined with more assurance.

Statistical Methods

We used the Kruskal-Wallis test (Siegel 1956) to examine differences in proportion of pregnant females between years. Chi-square statistic was used to test for differences between proportions of pregnant females in sequential months. Differences between seasons in relative population size, percent maximum habitat breadth, and overlap were tested with the Mann-Whitney U test (Siegel 1956). The association between seasonal population size and ($\bar{x}$ and SD) seasonal rainfall was tested with the Kendall rank correlation coefficient (r; Siegel 1956).

Habitat breadth was calculated using the formula: $-\Sigma p_i \ln_{10} p_i$, where p_i represented the proportion of a species population occurring in the ith vegetation or structural type. Percent average habitat breadth was the percentage contribution to the habitat breadth measure by each vegetation or structural type. Percent maximum habitat breadth equals

habitat breadth divided by lnN, where N = the number of vegetation or structural types in the analysis. Habitat breadth measures a species' distribution among habitat types. Maximum habitat breadth occurs when a species is equally abundant in all habitat types. Percent of maximum habitat breadth (J) measures how evenly a species is distributed among habitats.

Spatial overlaps between species were calculated with Horn's formula (1966). Habitat (spatial) overlap indicates the degree to which two species were captured together in proportion to the degree to which they were captured separately (see Chapter 2, p. 27).

We used Kendall's coefficient of concordance W test (Siegel 1956) to examine among-year and between-season habitat associations of rodent species. We tested the difference in the number of males and females with the Chi-square test. Significance was accepted at the 0.05 level.

The above analyses were applied to data on the five numerically dominant rodent species in the Colorado River valley. Data from 1979 were not included in the statistical analyses because trap effort in that year was not proportionate to the occurrence of vegetation and structural types.

RESULTS

Trapping Summary

Summary of the numbers of rodents captured per 270 trap nights (Table 10-1) reveals the five numerically dominant species to be: (1) cactus mouse, (2) deer mouse, (3) white-throated woodrat, (4) Merriam kangaroo rat, and (5) desert pocket mouse. Seasonal and annual samples of these species were adequate to permit examination of reproductive and population characteristics.

Cactus Mouse

Description

Mean weight 17.7 gm (0.62 oz).

> Upper parts...dull, pale gray; underparts white or whitish suffused with buff or tawny; tail faintly bicolor, dusky above, whitish below....Tail markedly longer than head and body, but slightly pencilled, covered with short, fine hairs; ears relatively large and thin...(Hall and Kelson 1959:605).

Distribution

The cactus mouse was captured in all six habitat types: cottonwood-willow, honey mesquite, screwbean mesquite, salt cedar, salt cedar-honey mesquite, and arrowweed, at sites ranging from the Mohave Division south to the Limitrophe Division (Fig. 10-1).

Table 10-1. Number of rodents caught in summer and winter during the study, 1974 to 1979 is expressed in the upper portion of the table. Number of trap nights in various habitats is expressed in the lower portion of the table.

Species	Number caught		
	Summer	Winter	Total
Cactus mouse	4128	4430	8558
Deer mouse	720	555	1275
White-throated woodrat	568	471	1039
Merriam kangaroo rat	873	533	1406
Desert pocket mouse	1573	209	1782
Southern grasshopper mouse			119
Western harvest mouse			70
House mouse			22
Hispid cotton rat			6
Desert kangaroo rat			65
Round-tailed ground squirrel			96
Harris antelope squirrel			7
White-tailed antelope squirrel			7

Vegetation type	Structural type					
	I	II	III	IV	V	VI
Cottonwood-willow	7290	4320	7290	12,150	2970	10,530
Honey mesquite	---	---	7020	32,400	9990	10,800
Screwbean mesquite	---	4590	9450	20,790	13,770	2430
Salt cedar	3420	2970	5130	11,610	16,740	6750

Table 10-1. (cont.)

Vegetation type	Structural type					
	I	II	III	IV	V	VI
Salt cedar-honey mesquite	---	---	---	8640	---	---
Arrowweed	---	---	---	---	---	8910

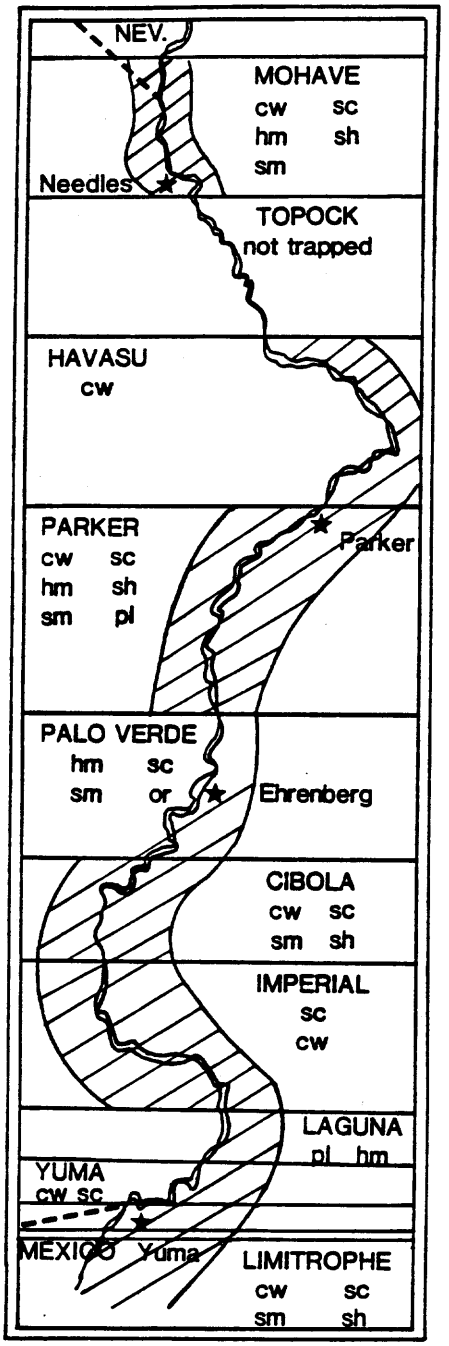

Figure 10-1. The Bureau of Reclamation has divided the lower Colorado River into nine divisions for engineering purposes. These are named and outlined on the map. The major vegetation types found in each division are given under the name of the division. cw = cottonwood and willow, hm = honey mesquite, sm = screwbean mesquite, sc = salt cedar, sh = salt cedar-honey mesquite mixes. Cross-hatching indicates areas where trapping was done.

Breeding Activity

Each month, in all years, a proportion of females was pregnant, except in 1975 when no pregnant females were captured in November and December (Table 10-2). Highest proportions of females with embryos generally occurred from March to July or August (Table 10-2). In 1974 and 1976 the season of greatest breeding activity extended from March to July; in 1977 greatest breeding activity extended from March to August. In 1978 breeding activity was sporadic; February, March, May, June, and August were the months of greatest breeding activity. There was no significant difference between years in the proportion of pregnant females.

There is some evidence for a decrease in reproductive rate functioning as a controlling mechanism of population size in some species of Peromyscus (Terman 1968). Although differences in population sizes existed among years (Fig. 10-2), the data did not demonstrate an associated response in reproductive effort in terms of the proportion of pregnant females, although litter size may have differed among years.

Litter Size and Gestation

The mean number of embryos per litter was 3 (n = 265). Stamp and Ohmart (1979) reported 2.7 embryos per litter (extremes of 1 and 5, n = 57). Asdell (1964) reported 3.7 embryos per litter (extremes 1 and 4).

Layne (1968) reported that the average duration of gestation for the cactus mouse is 21 days. He noted that in most species of Peromyscus there is a prolongation of gestation ranging from 2 to 7 days in females experiencing post-partum estrus and that weaning occurs between 3 and 4 weeks of age. Svihla (1932) reported prolonged weaning in the cactus mouse. First estrus in females and mature spermatozoa in males marks sexual maturity and is reached by cactus mice at a mean age of 39 days (Clark 1938). Stickel (1968) and Terman (1968) stated that young of the year disperse to establish their own home range as early as the onset of sexual maturity.

Relative Population Size

Relative population sizes were determined on a winter/summer seasonal basis. There was no statistical difference in population size between seasons. Numbers of cactus mice declined steadily from 1974 through 1977 (Fig. 10-2). During 1978 and 1979 populations were seasonally cyclic with winter highs and summer lows. The correlation of relative population size with ($\bar{x}$ and SD) seasonal rainfall was not significant (Table 10-3).

Habitat Breadth and Overlap

There was no significant difference in average overlap among vegetation types (Table 10-4) or structural types (Table 10-5) or in percent maximum habitat breadth (Table 10-6) between summer and winter (Tables 10:4-6). Values were $\geq$0.80 among vegetation and structural types both seasons (Table 10-6). There was a trend for changes in percent maximum habitat breadth (J) among vegetation types to be opposite the changes in

Table 10-2. Percent of pregnant females of four rodent species in each month. Sample size in parentheses. Asterisk indicates significant ($P \leq 0.05$) difference from preceding month.

Species/month	Year									
	1974		1975		1976		1977		1978	
Cactus mouse										
January	20	(20)	1*	(188)	7	(73)	0	(40)	18*	(11)
February	13	(106)	18*	(124)	13	(32)	7	(72)	35*	(40)
March	57*	(54)	23	(53)	42*	(140)	24*	(54)	62*	(50)
April	64	(56)	51	(156)	41	(17)	43*	(65)	--	(0)
May	49	(67)	47	(77)	45	(65)	42	(31)	30	(20)
June	65	(17)	43	(44)	58	(24)	27	(26)	27*	(11)
July	54*	(26)	41	(61)	47*	(30)	43	(49)	14*	(14)
August	8*	(25)	23	(22)	23*	(35)	35*	(29)	33*	(43)
September	--	(0)	--	(0)	8*	(36)	7*	(29)	13*	(63)
October	18	(80)	14	(21)	1*	(96)	19*	(32)	6	(87)
November	16	(25)	0	(26)	5	(102)	5*	(150)	2	(42)
December	14	(21)	0	(13)	--	--	2	(49)	8	(75)
Deer mouse										
January	17	(6)	7*	(30)	0*	(12)	0	(14)	0*	(5)
February	25*	(8)	38*	(8)	27*	(11)	0*	(6)	33*	(3)
March	71*	(7)	50	(12)	54*	(13)	17*	(6)	75*	(12)
April	43*	(7)	52	(25)	0*	(3)	0*	(2)	--	(0)
May	25*	(12)	40	(5)	17*	(12)	50*	(12)	--	(0)
June	50*	(2)	--	(1)	45*	(11)	50*	(2)	--	(0)
July	63*	(8)	38	(8)	40	(5)	25*	(4)	33	(3)
August	100*	(4)	--	(1)	--	(1)	--	(0)	--	(0)
September	--	(0)	--	(0)	0	(2)	25*	(4)	18*	(11)
October	25	(4)	--	(0)	--	(1)	50*	(2)	0*	(7)
November	33*	(6)	--	(1)	0	(21)	6*	(33)	0	(7)
December	0*	(3)	--	(0)	--	(0)	13	(8)	0	(4)
Desert pocket mouse										
January	--	(1)	0*	(4)	--	(0)	--	(1)	--	(0)
February	0	(6)	13*	(8)	--	(1)	--	(1)		
March	0*	(10)	0*	(5)	0	(7)	0	(2)	--	(1)
April	15*	(23)	4*	(26)	0*	(5)	0*	(6)	--	(0)
May	50*	(28)	22*	(32)	28*	(18)	50*	(8)	0*	(3)
June	42*	(12)	27	(56)	13*	(23)	36*	(11)	50*	(2)
July	63*	(32)	39	(56)	56*	(9)	14*	(7)	--	(1)
August	20*	(10)	29	(17)	6*	(18)	21*	(14)	0*	(3)
September	--	(0)	--	(0)	0	(3)	0*	(11)	9*	(11)
October	0	(52)	0	(4)	0	(14)	0	(6)	0*	(7)
November	0	(7)	0	(2)	0	(11)	0	(10)	0	(3)
December	0	(9)	--	(0)	--	(0)	0	(2)	--	(1)

Table 10-2. (cont.)

Species/month	Year									
	1974		1975		1976		1977		1978	
Merriam kangaroo rat										
January	0	(17)	3	(29)	0	(5)	6	(17)	--	--
February	50*	(2)	31*	(13)	22*	(9)	11	(9)	--	--
March	58	(12)	0*	(3)	67*	(6)	30*	(10)	--	--
April	87*	(15)	33*	(15)	14*	(7)	33	(15)	--	--
May	70	(10)	86*	(17)	60*	(5)	88*	(8)	--	--
June	83	(6)	20*	(5)	50	(4)	29*	(7)	--	--
July	66	(9)	19	(21)	43	(7)	0*	(13)	--	--
August	100*	(2)	20	(5)	--	(0)	13*	(8)	--	--
September	--	(0)	--	(0)	0	(2)	0*	(5)	--	--
October	0	(13)	--	(0)	0	(3)	0	(10)	--	--
November	0	(3)	--	(1)	0	(3)	7	(15)	--	--
December	0	(4)	--	(1)	--	(0)	0	(13)	--	--

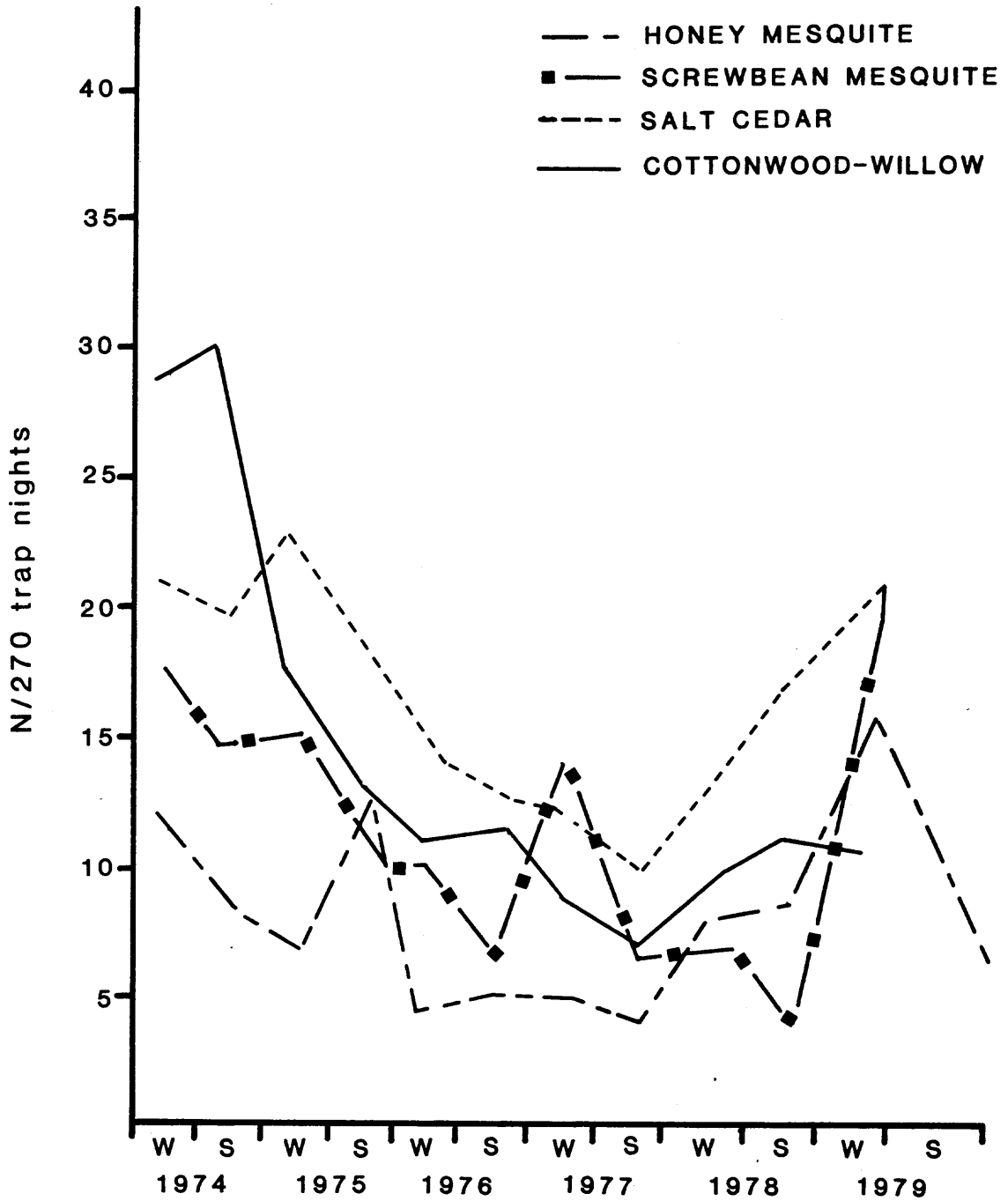

Figure 10-2. Capture rates (N/270 trap nights) for the cactus mouse in four vegetation types along the lower Colorado River. W = winter, S = summer.

Table 10-3. Correlation (Kendall τ) of population size with ($\bar{x}$ and SD) inches of rainfall. Rainfall data from Parker, Arizona. NS = not significant ($P>0.05$), S = significant ($P<0.05$).

	Rainfall ($\bar{x}$ and SD)		
	Year	Summer	Winter
	1974	0.044	0.273
	1975	0.019	0.079
	1976	0.079	0.113
	1977	0.141	0.689
	1978	0.170	0.798
Species			
Cactus mouse		-0.22	NS
Deer mouse		-0.067	NS
White-throated woodrat		-0.36	NS
Merriam kangaroo rat		-0.33	NS
Desert pocket mouse		-0.56	S

Table 10-4. Average overlap among vegetation types for the five numerically dominant rodent species. Averages for 1974-1978. Standard error of the mean is in parentheses.

Species/ season	Species			
	Deer mouse	White-throated woodrat	Merriam kangaroo rat	Desert pocket mouse
Cactus mouse				
Summer	0.765(0.077)	0.906(0.025)	0.783(0.030)	0.880(0.022)
Winter	0.654(0.046)	0.919(0.022)	0.751(0.051)	0.807(0.068)
Deer mouse				
Summer		0.740(0.037)	0.704(0.065)	0.805(0.035)
Winter		0.648(0.054)	0.735(0.072)	0.602(0.041)
White-throated woodrat				
Summer			0.816(0.037)	0.872(0.023)
Winter			0.712(0.074)	0.757(0.056)
Merriam kangaroo rat				
Summer				0.914(0.019)
Winter				0.796(0.028)

Table 10-5. Average overlap among structural types for the four numerically dominant rodent species. Averages for 1974-1978. Standard error of the mean is in parentheses.

Species/ season	Species			
	Deer mouse	White-throated woodrat	Merriam kangaroo rat	Desert pocket mouse
Cactus mouse				
Summer	0.735(0.090)	0.940(0.028)	0.606(0.068)	0.799(0.064)
Winter	0.864(0.033)	0.957(0.016)	0.627(0.022)	0.810(0.055)
Deer mouse				
Summer		0.581(0.084)	0.729(0.072)	0.888(0.027)
Winter		0.516(0.120)	0.723(0.051)	0.716(0.053)
White-throated woodrat				
Summer			0.571(0.106)	0.686(0.083)
Winter			0.542(0.040)	0.740(0.085)
Merriam kangaroo rat				
Summer				0.752(0.096)
Winter				0.800(0.018)

Table 10-6. Percent maximum habitat breadth (J) across vegetation types (A) and structural types (B) for the numerically dominant rodent species of the lower Colorado River valley. S = summer, W = winter.

(A)

	Species/season									
	Cactus mouse		Deer mouse		White-throated woodrat		Merriam kangaroo rat		Desert pocket mouse	
Year	S	W	S	W	S	W	S	W	S	W
1974	0.823	0.890	0.753	0.728	0.853	0.855	0.788	0.763	0.879	0.830
1975	0.851	0.901	0.782	0.727	0.784	0.815	0.804	0.746	0.813	0.736
1976	0.940	0.932	0.733	0.741	0.840	0.866	0.552	0.784	0.957	0.811
1977	0.905	0.926	0.831	0.710	0.879	0.842	0.652	0.679	0.962	0.851
1978	0.800	0.849	0.531	0.726	0.788	0.800	0.733	0.790	0.979	0.683

(B)

	Species/season									
	Cactus mouse		Deer mouse		White-throated woodrat		Merriam kangaroo rat		Desert pocket mouse	
Year	S	W	S	W	S	W	S	W	S	W
1976	0.872		0.775		0.811		0.652		0.880	
1977	0.860	0.862	0.724	0.647	0.757	0.823	0.616	0.750	0.885	0.798
1978	0.864	0.821	0.784	0.708	0.814	0.624	0.651	0.608	0.823	0.448

population size. In three of four cases where relative population size decreased, J increased, and in two cases where relative population size increased, J decreased (Fig. 10-3).

Habitat Association

The proportion of the total captures in each vegetation type identifies the proportionate contribution of each habitat type to the total abundance. For example, if the largest number caught was in salt cedar (regardless of structural type) among the six vegetation types, the greatest proportion of cactus mice were captured there. We assumed that a high proportion of animals captured in a habitat indicated a high rank on a habitat preference scale.

We ranked the six vegetation (regardless of structural type) and structural (regardless of vegetation type) types by percent of numbers for each season each year (Table 10-7) and examined the consistency of ranks between seasons and among years to determine if the cactus mouse showed a habitat preference and if the preferences were the same between seasons. The ranks for vegetation and structural types were consistent in winter and summer among years (Table 10-8). Ranks in summer were consistent with ranks in winter. Statistically this implies that the cactus mouse showed a preference for certain vegetation and structural types and this preference did not change between seasons.

Friedman's two-way analysis of variance indicated that the distribution of ranks among the vegetation types (regardless of structural type) was not random in either summer (χ^2 = 18.8, 4 df, P<0.001) or winter (χ^2 = 13.2, 4 df, P<0.02). In both seasons, salt cedar and salt cedar-honey mesquite mixes were among the highest ranked (the most rodents were caught there) across years, while arrowweed and honey mesquite were among the lowest ranked each year. This indicates that salt cedar may be a more preferred habitat by cactus mice than arrowweed or honey mesquite. This is discussed further in the following chapter.

Kendall's coefficient of concordance W values were between 0.635 and 0.653 (on a 0 to 1.0 scale), reflecting some fluctuation in ranks. Salt cedar and salt cedar-honey mesquite were of first and second rank significantly more often than other vegetation types. Salt cedar was first ranked in summer, salt cedar-honey mesquite ranked first in winter, cottonwood-willow was third ranked both seasons, screwbean mesquite was third or fourth ranked, and honey mesquite and arrowweed ranked fifth and sixth, respectively, in both seasons (Table 10-8).

Friedman's two-way analysis of variance indicated that the distribution of ranks across years and structural types of vegetation deviated significantly from random in both summer (χ^2 = 22.7, 4 df, P<0.001) and in winter (χ^2 = 21.8, 4 df, P<0.001). Vegetation of structural types I or II tended to be ranked highest, and structural types V and VI tended to be ranked lowest. This suggests that areas with tall vegetation and little understory may be preferred by cactus mice more than areas of low vegetation.

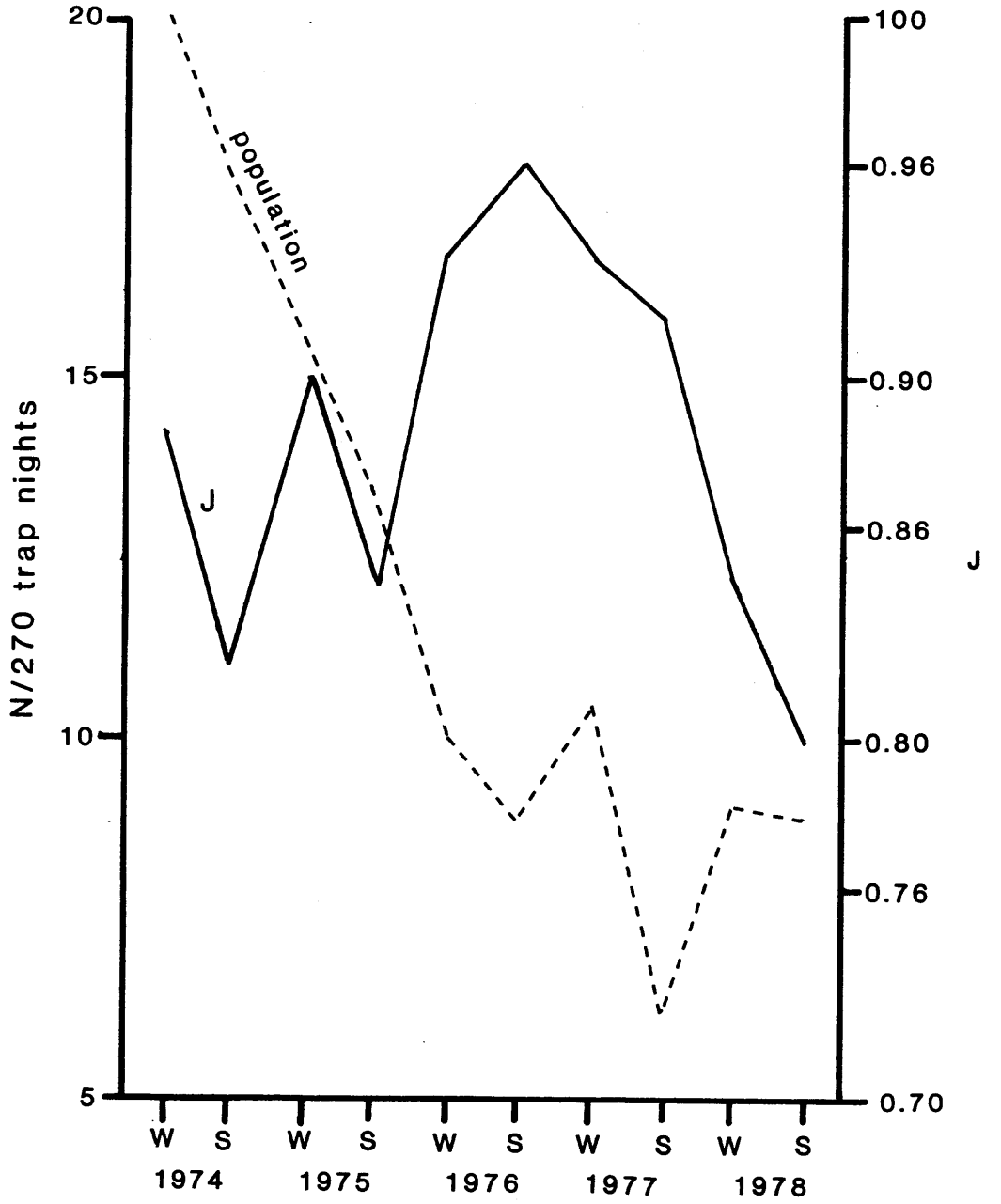

Figure 10-3. Changes in population level (dashed line) and percent maximum habitat breadth (J, solid line) of the cactus mouse. Abbreviations as in Figure 10-2.

Table 10-7. Rank of the proportion of cactus mice caught among (A) vegetation type and (B) structural type. SM = screwbean mesquite, CW = cottonwood-willow, SC = salt cedar, HM = honey mesquite, PL = arrowweed, SH = salt cedar-honey mesquite.

(A) Vegetation type

	Summer						Winter					
Year	SM	CW	SC	HM	PL	SH	SM	CW	SC	HM	PL	SH
1974	4	2	3	5	6	1	4	2	3	5	6	1
1975	5	3	1	5	6	2	4	3	2	5	6	1
1976	4	3	1	5	6	2	4	3	2	6	4	1
1977	2	3	1	5	6	4	1	3	2	5	6	4
1978	5	6	2	3	4	1	4	6	2	3	5	1
TOTAL	20	17	8	23	28	10	17	17	11	24	27	8

(B) Structural type

	Summer						Winter					
	I	II	III	IV	V	VI	I	II	III	IV	V	VI
1974	1	2	3	4	5	6	1	2	3	4	5	6
1975	3	1	2	4	6	5	4	1	3	2	5	6
1976	2	1	3	4	5	6	2	1	4	3	5	6
1977	3	1	2	4	5	6	3	1	2	4	5	6
1978	1	2	3	4	5	6	2	1	3	4	5	6
TOTAL	10	7	13	20	26	29	12	6	15	17	25	30

Table 10-8. Results of Kendall's coefficient of concordance W test (Siegel 1956) for analysis of vegetation type and structural type. W = the degree of concordance (0 to 1.0). * is significant at $P<0.05$. First analysis (A) was among years within a season. Second analysis (B) was between seasons for those significant in the first analysis.

(A)	Vegetation type		Structural type	
	Summer	Winter	Summer	Winter
	W	W	W	W
Cactus mouse	0.648*	0.653*	0.909*	0.872*
Deer mouse	0.643*	0.760*	0.379	0.383
White-throated woodrat	0.661*	0.305	0.451*	0.496*
Merriam kangaroo rat	0.635*	0.485*	0.837*	0.877*
Desert pocket mouse	0.224	0.510*	0.614*	0.510*

(B)	Vegetation type	Structural type
	Summer vs. Winter	Summer vs. Winter
	W	W
Deer mouse	0.588*	0.363
Cactus mouse	0.635*	0.879*
White-throated woodrat	0.518*	0.467*
Merriam kangaroo rat		0.848*
Desert pocket mouse		0.554*

Kendall's coefficient of concordance (W) among structural types (Table 10-8) was higher than among vegetation types (0.879 to 0.909). The structural type preference of cactus mice rarely changed from season to season or year to year. Dense, more closed structural types were preferred over open structural types. Structural type II ranked first both seasons; structural types I and III fluctuated between second and third rank. Structural types IV, V, and VI were fourth, fifth, and sixth ranked, respectively, both seasons. Vegetation and structural types were probably interactive factors in selection of habitat by the cactus mouse; salt cedar and cottonwood-willow (rank 1 or 2, 3, respectively) were the habitats with structural types I and II (rank 2, 1, respectively). Yet there is a suggestion that vegetation type was an independent factor in selection because salt cedar-honey mesquite ranked first or second even though all salt cedar-honey mesquite areas were structural type IV, a low-ranking structural type. This is discussed further in Chapter 11.

Movement and Home Range

Eighty cactus mice, 38 females and 42 males, were marked with an individualized toe-clip sequence. Seventy-eight of these were recaptured; 19 were recaptured only once. For those mice captured more than once, the mean number of recaptures was 2.75 for females and 3.35 for males (Table 10-9). There was a greater number of males than females caught at a greater number of different stations. The mean home range area was 0.066 ha (0.165 a) among females, and 0.105 ha (0.263 a) among males (Table 10-10). Adjusted range length for females was 58.8 m (193 ft), and 61.9 m (203 ft) for males. Average distance between captures of females was 31.4 m (103 ft) and of males was 32.6 m (107 ft) (maximum/minimum distance, 91.4/0 m [299.9 ft] and 116.1/0 m [380.9 ft], respectively).

In summary, although movement distances were not significantly different between males and females, males were caught in a greater number of different traps than females. Van Vleck (1969) has interpreted such conditions as an indication that males travel more. The mean number of recaptures between males and females was similar enough to conclude that the likelihood of catching a male or female was equal. Neither sex was more "trap happy" or "trap shy" than the other.

Sex Ratio

Most species of Peromyscus are reported to have a higher number of males than females, although some species show no difference in sex ratio (Terman 1968). Skewed sex ratio in Peromyscus populations has sometimes been attributed to greater catchability of males, influenced by their greater wandering and larger home ranges (Terman 1968). Yet, Terman (1968) reported a greater number of males than females in deer mice born and raised in the laboratory. Thus, skewed sex ratio may not be an artifact of capture.

In winter in two years there were significantly higher numbers of males than females, in two other years there was no significant difference, and in one year there was a significantly higher number of females than

Table 10-9. Live trap information.

	Species				
	Cactus mouse	Deer mouse	Desert Pocket mouse	Merriam kangaroo rat	White-throated woodrat
Total marked	80	21	58	18	21
Marked recapture	78	19	57	18	21
Number dead	14	1	9	2	1
Number captured once	19	8	38	7	16
Number females marked	38	10	23	9	10
Number males marked	42	11	35	9	11
Mean number recaptured females	2.75	1.86	1.74	3.56	1.30
Mean number recaptured males	3.35	2.44	1.50	1.44	1.27

Table 10-10. Estimates of home range and movements of the cactus mouse. Area in hectares by the boundary strip exclusive method (Stickel 1954). Movements in meters. ARL = adjusted range length (Stickel 1954). DBC = distance between captures. Sample size in parentheses.

	Minimum number of different stations					
	2	3	4	5	7	$\bar{x}$
Males						
Area	0.115 (4)	0.109 (11)	0.112 (8)			0.112 (23)
ARL	16.76 (8)	58.70 (11)	63.61 (9)	111.56 (1)	83.52 (1)	(30)
DBC						
Mean	37.06 (9)	26.15 (28)	31.79 (33)	44.65 (8)	44.41 (6)	32.58 (84)
Max/min	76/15	116/0	91/0	96/15	68/15	
Females						
Area	0.047 (8)	0.058 (7)	0.12 (2)	-	-	0.075 (17)
ARL	58.52 (9)	59.16 (11)	58.22 (1)	57.91 (3)	-	58.73 (24)
DBC						
Mean	38.95 (10)	29.17 (27)	37.09 (3)	29.41 (13)		31.52 (53)
Max/min	91/0	76/0	43/34	48/0		

males (Table 10-11). In summer in two years there was a significantly higher number of males than females; in three years there was no significant difference between numbers of males and females.

The sex ratio in cactus mouse populations was not influenced by a difference between sexes in catchability, since male and female recapture averages were similar. Sex ratio was variable between years and did not show a consistent trend of being either skewed or equal.

Deer Mouse

Description

Mean weight 18.0 gm.

> Upper parts...usually varying...from pale grayish buff to deep reddish brown overlaid in varying degree by dusky; underparts white; tail clothed with short hairs, slightly penicillate, sharply bicolor, dark above, light below (Hall and Kelson 1959:612).

Distribution

The deer mouse was captured in all six vegetation types: cottonwood-willow, honey mesquite, screwbean mesquite, salt cedar, salt cedar-honey mesquite, and arrowweed, at sites ranging from the Mohave Division to the Limitrophe Division (Fig. 10-1).

Breeding Activity

During the study period, pregnant females were captured in each month, January through December (Table 10-2). In February a quarter to a third of the females were pregnant. The highest proportion of pregnant females occurred from March through July or August. There was no significant difference among years in the proportion of pregnant females.

Litter Size and Gestation

The mean number of embryos per litter was 4.2 (n = 49). Terman (1968) reported mean litter size of >4 in deer mice. Hall and Kelson (1959) reported the mean number of embryos per litter as 5 (extremes of 1 and 8). Gestation period in the deer mouse has been reported as 23 days (Layne 1968) and 21 to 27 days (Hall and Kelson 1959). Weaning has been reported to occur at 22 to 37 days (Layne 1968), and sexual maturity to occur at 49 days of age in females (Layne 1968) and by 60 days of age in males (Clark 1938). Terman (1968) stated that Peromyscus individuals select a home site or area at about the time of sexual maturity; individuals then remain relatively sedentary.

Relative Population Size

The relative population size of the deer mouse was seasonally cyclic, with highs in winter and lows in summer, except in 1976 (Fig. 10-4).

Table 10-11. The numbers of males and females captured, by season, with vegetation and structural types combined. * = Chi-square significant at $P<0.05$.

	Cactus mouse	Deer mouse	White-throated woodrat	Merriam kangaroo rat	Desert pocket mouse
Winter					
1974					
Males	41	10	0	6	10
Females	76*	11	4	11	15
1975					
Males	529*	92*	50	96	66*
Females	419	62	75*	92	35
1976					
Males	286	72*	108	50*	28*
Females	250	35	108	22	9
1977					
Males	417*	95*	28	--	16
Females	339	57	54*	--	11
1978					
Males	238	41*	20	30	10*
Females	204	24	23	28	1
Summer					
1974					
Males	84	10	6	14	59
Females	101	12	3	16	72

Table 10-11. (cont.)

	Cactus mouse	Deer mouse	White-throated woodrat	Merriam kangaroo rat	Desert pocket mouse
1975					
Males	556*	120*	51	177*	301
Females	487	67	40	142	267
1976					
Males	185*	51*	--	53*	59
Females	138	27	--	22	51
1977					
Males	205	53*	39	--	75
Females	197	23	36	--	63
1978					
Males	343	50*	41	28	38
Females	315	26	59	32	45

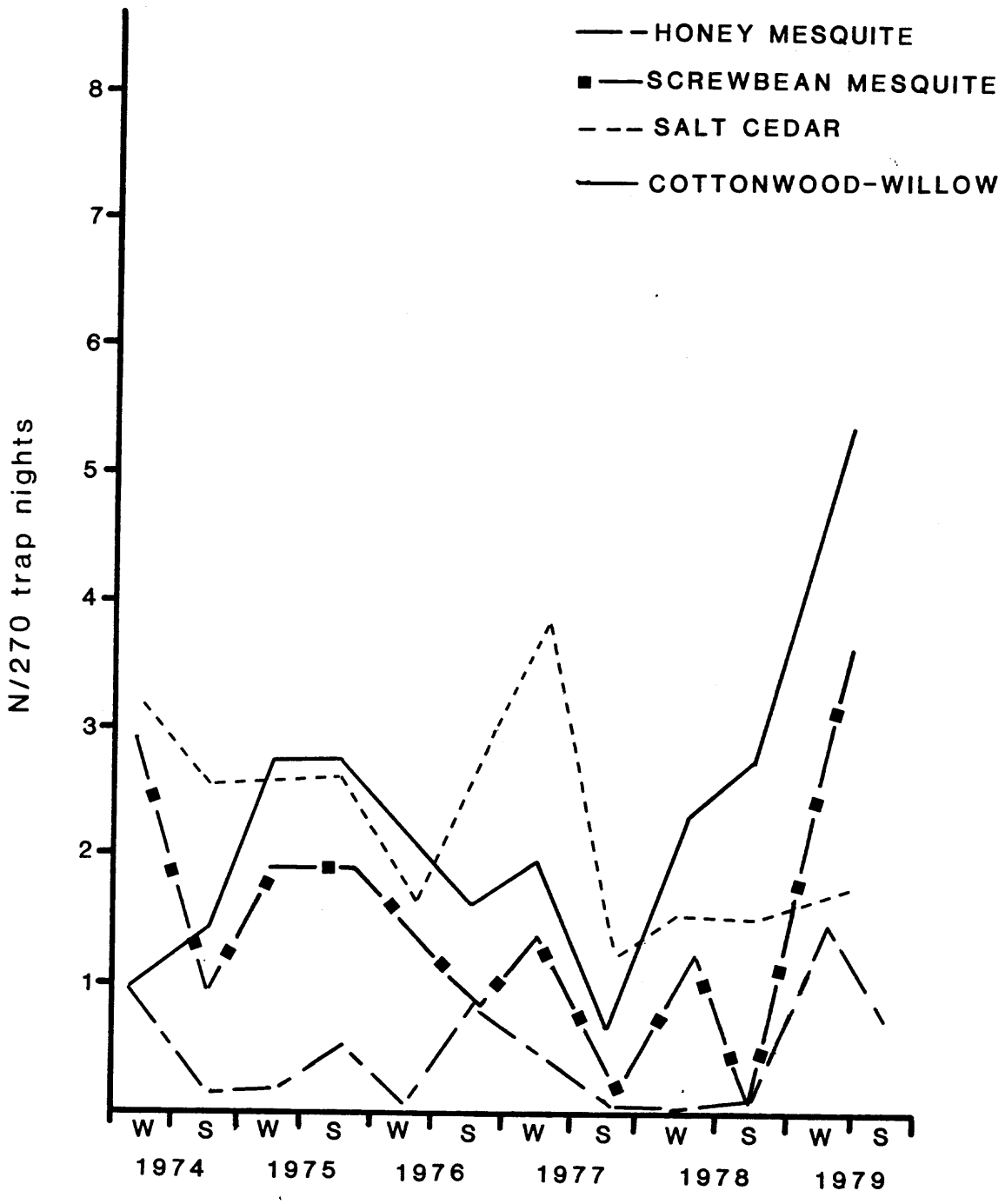

Figure 10-4. Capture rates (N/270 trap nights) for the deer mouse in four vegetation types along the lower Colorado River. Abbreviations as in Figure 10-2.

There was no significant difference between summer and winter population sizes. The correlation between relative population size and ($\bar{x}$ and SD) seasonal precipitation was not significant (Table 10-3).

When population size increased, the vegetation types which showed increases generally were higher ranking (types which showed high proportion of species abundance; Table 10-12 and Fig. 10-4). Vegetation types which showed no change or a decrease in relative population size when there was an overall population increase generally were lower ranking types.

Habitat Breadth and Overlap

There was no significant difference between seasons in average overlap among structural types (Table 10-5) or in percent maximum habitat breadth (Table 10-6). Average overlap among vegetation types was significantly lower in the winter (Table 10-4). J values were mostly $\geq$0.71 among vegetation and structural types both seasons (Table 10-2). There was a trend for changes in percent maximum habitat breadth to oppose changes in population size. In three of five cases when population size decreased, J increased, and in all four cases when population size increased, J decreased (Fig. 10-5).

Habitat Association

We ranked the six vegetation and structural types (separately) by proportion of rodents caught within each season each year (Table 10-13) and examined the consistency among years and between seasons (Table 10-8). Ranks for vegetation types were significantly consistent among years in summer and winter. Ranks were also consistent between seasons. Yet the between season W value was less than that of summer or winter separately, indicating that there was more fluctuation in rank between seasons than within seasons among years. The W values were between 0.588 and 0.760 (on a 0 to 1.0 scale). Salt cedar ranked first in summer and second in winter significantly more often than other vegetation types. Arrowweed ranked first in winter. Salt cedar-honey mesquite and screwbean mesquite changed rank slightly, varying from fourth to fifth, between seasons. Honey mesquite was lowest ranking in both seasons. Ranks for salt cedar, cottonwood-willow, screwbean mesquite, and honey mesquite were similar for the deer mouse and the cactus mouse. Arrowweed and salt cedar-honey mesquite were at opposite ends of the scale between the two species in the winter.

The ranks of structural type for the deer mouse were not significantly consistent in winter or summer among years (W = 0.383, 0.379). This indicates that the deer mouse did not show a preference for a particular structural type. But the higher structural types (IV, V, and VI) generally were in the top three ranks, whereas lower structural types (I, II, and III) generally were in the lower three ranks. This was the reverse of structural type preference of the cactus mouse, for which V and VI ranked fifth and sixth, and II, I, III ranked first, second or third, respectively.

Table 10-12. Periods of population increase in the white-throated woodrat, deer mouse, kangaroo rat, and pocket mouse and the vegetation types which showed density increases and decreases during the overall population increase. Abbreviations as in Table 10-7. Rank values are from Tables 10-7, 10-13, 10-15, and 10-16.

Species	Population increase	Vegetation type rise	Rank	Vegetation type fall	Rank
Deer mouse	S 1974 to W 1975	SM, CW	2, 4	None	
	W to S 1976	SC, HM	1, 5	SC, SM	2, 4
	S 1976 to W 1977	SC, CW, SM	2, 3, 4	HM	6
	S 1977 to W 1978	SC, CW, SM	2, 3, 4	HM	5.5
White-throated woodrat	W to S 1975	SM, HM, CW	1, 2, 3	SC	4
	W to S 1976	SM, HM	1, 4	SC, CW	2, 3
	S 1977 to W 1978	SC, HM	1, 2	SM	5
	W to S 1978	All			
Merriam kangaroo rat	W to S 1974	All		None	
	W to S 1975	SC, CW	1, 5	SM, HM	2, 3
	S 1976 to W 1977	All		None	
Desert pocket mouse	W to S 1974	All		None	
	W to S 1975	All		None	
	W to S 1976	All		None	
	W to S 1977	All		None	
	W to S 1978	All		None	

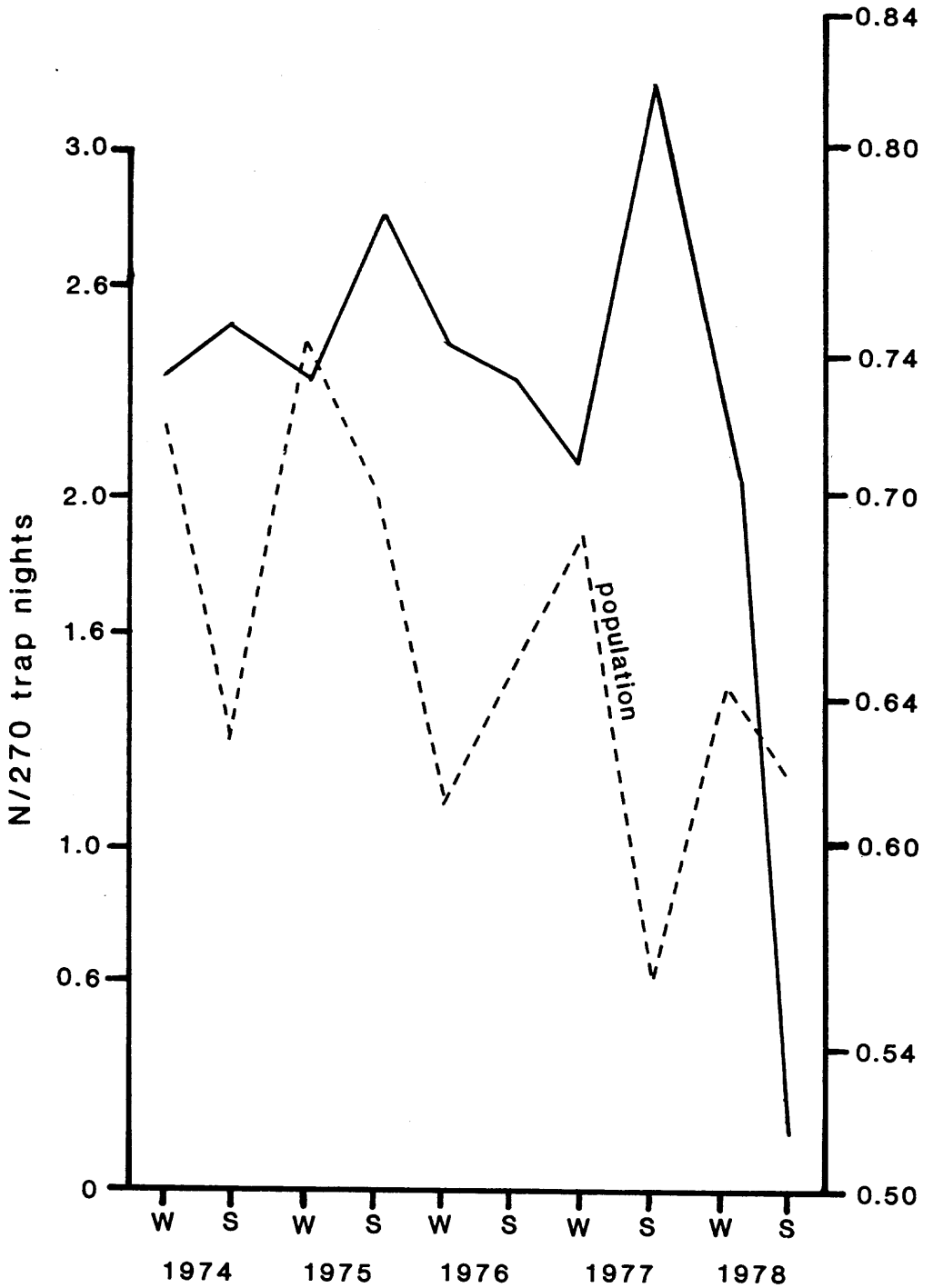

Figure 10-5. Changes in population level and percent maximum habitat breadth of the deer mouse. Abbreviations as in Figures 10-2 and 10-3.

Table 10-13. Rank of the proportion of total captures of deer mice among vegetation (A) and structural (B) types. Abbreviations as in Table 10-7.

(A) Vegetation type

	Summer						Winter					
Year	SM	CW	SC	HM	PL	SH	SM	CW	SC	HM	PL	SH
1974	4	3	1	6	2	5	2.5	4.5	2.5	4.5	1	6
1975	5	3	1	4	6	2	4	2	3	6	1	5
1976	4	2	1	5	3	6	3	1	2	5.5	4	5.5
1977	5	2	1	6	4	3	4	3	2	6	1	5
1978	5	1	2	4	3	6	4	3	2	5.5	1	5.5
TOTAL	23	11	6	25	18	22	17.5	13.5	11.5	27.5	8	27

(B) Structural type

	Summer						Winter					
Year	I	II	III	IV	V	VI	I	II	III	IV	V	VI
1974	5.5	5.5	3	2	4	1	5.5	5.5	2	3	4	1
1975	6	2	5	3	4	1	6	2	5	4	3	1
1976	6	5	4	2	3	1	5.5	5.5	4	3	2	1
1977	1	6	5	4	2	3	1	6	5	3	4	2
1978	2	5	6	4	1	3	1	6	5	4	2	3
TOTAL	20.5	23.5	23	15	14	9	19	25	21	17	15	8

The Kendall coefficient of concordance W tests indicated that vegetation type was a more important factor than structural type in habitat selection by deer mice. These tests also showed that the factors distinguishing the difference in habitat preference between the cactus mouse and deer mouse were changes in winter vegetation preference (arrowweed vs. salt cedar-honey mesquite) and structural type.

Movement and Home Range

Twenty-one deer mice (10 females, 11 males) were toe clipped with an individualized sequence. Nineteen deer mice were recaptured. The mean number of recaptures of females was 1.86 and of males was 2.44 (Table 10-9). Data were insufficient to examine home range size and average movement distance according to sex.

The average home range area was 0.23 ha (0.13 a; Table 10-14). Home range area estimated from the maximum number of different stations at which an individual was caught was 0.43 ha (1.08 a). The average adjusted range length was 87.6 m (288 ft) and the mean distance between captures was 61.5 m (202 ft) (maximum/minimum = 138/15 m [453/49 ft). The average adjusted range length and distance between captures were significantly greater in the deer mouse than in the cactus mouse ($P<0.005$, $t = 30.46$, 65 df; $t = 47.63$, 144 df, respectively).

Blair (1958) recorded a frequency table of movement distances for the deer mouse in 152.4-m (500-ft) categories. Of 123 recordings, 110 were in the 0- to 152.4-m (500-ft) category. We concluded that deer mice mostly travel distances less than 152.4 m (500 ft). Our findings of adjusted range length and distance between captures (87.6 m [288 ft], 61.5 m [202 ft]) agree with his findings. Storer et al. (1944) in California and Blair (1958) in Texas reported that the deer mouse kept fairly stable home ranges from month to month.

Sex Ratio

There was a significantly higher number of males than females in both winter and summer during four of five years (Table 10-11). The difference probably was not an artifact of biased capture because males and females showed statistically equal average numbers of recaptures. As mentioned previously, Terman (1968) reported a skewed sex ratio in favor of males in laboratory-raised populations of deer mice. Blair (1953) noted that the sex ratio remained even within the limits of chance variation in his study of deer mice in Texas.

White-throated Woodrat

Description

Mean weight 200 gm (7.05 oz).

> Upper parts grayish washed with fulvous to ochraceous mixed with dusky; underparts white or grayish, individual hairs plumbeous basally except on throat where they are white to the base; tail brownish or even dusky above, whitish below (Hall and Kelson 1959:686).

Table 10-14. Live trap estimates of home range and movements of the deer mouse. Sample sizes in parentheses. See Table 10-7 for abbreviations.

	Minimum number of different stations			
Measure	2	3	4	$\bar{x}$
Area	0.063 (2)	0.072 (3)	0.432 (4)	0.230 (9)
ARL	80.5 (4)	56.6 (4)	119.3 (4)	87.6 (12)
DBC				
Mean	65.2 (3)	39.3 (8)	73.3 (14)	61.5 (25)
Max/min	97.2/48.2	82.0/15.2	138/34.1	

Distribution

The white-throated woodrat was captured in all six vegetation types: cottonwood-willow, honey mesquite, screwbean mesquite, salt cedar, salt cedar-honey mesquite, and arrowweed, at sites ranging from the Mohave Division to the Limitrophe Division (Fig. 10-1).

Breeding Activity

An insufficient sample (n = 22) of reproductively active female woodrats was collected; therefore we could not determine the onset and duration of breeding. Hall and Kelson (1959) reported that the white-throated woodrat breeds from April to September and possibly year round in southern latitudes.

Litter Size and Gestation

The mean number of embryos per litter was 2.3 (n = 22). Stamp and Ohmart (1979) reported a mean of 1.9 embryos per litter (extremes of 1 and 3, n = 21). Hall and Kelson (1959) reported litter sizes of 1 to 3 after a gestation period of about 30 days.

Relative Population Size

Relative population size in the white-throated woodrat was asynchronous among the various habitat types (Fig. 10-6). There was no significant difference between winter and summer population sizes. The correlation between population size and ($\bar{x}$ and SD) seasonal precipitation was not significant (Table 10-3).

When population size increased, the vegetation types which showed increases generally were higher ranking (Table 10-15, Fig. 10-6). Vegetation types which had no change or decreased population size when there was an overall population increase generally were lower ranking vegetation types.

Habitat Breadth and Overlap

There was no statistical difference between seasons in percent maximum habitat breadth or average overlap among vegetation or structural types (Tables 10:3-5). J values were mostly >0.76 among vegetation and structural types in both seasons (Table 10-3). There was a trend for changes in percent maximum habitat breadth to be opposite changes in population size. In two of three cases when population size dropped, J increased; in all four cases in which population size increased, J decreased. In both cases in which the population size stayed the same, J stayed the same (Fig. 10-7).

Habitat Association

We ranked the vegetation and structural types (separately) by proportion of total rodents caught in each type for each season, each year (Table 10-15). The ranks of vegetation types were significantly consistent in summer but were not significantly consistent in winter (Table 10-8).

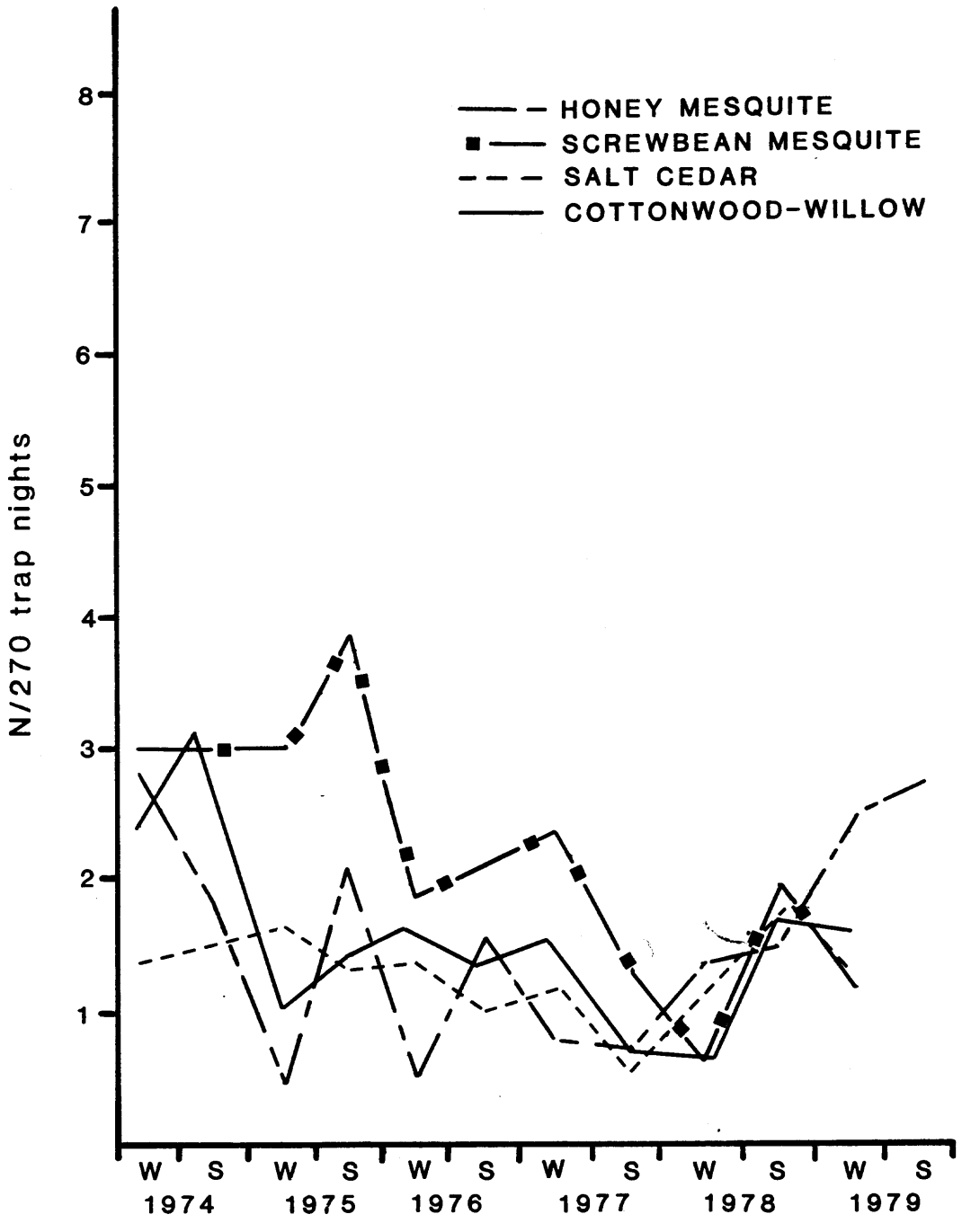

Figure 10-6. Capture rates (N/270 trap nights) for the white-throated woodrat in four vegetation types along the lower Colorado River. Abbreviations as in Figure 10-2.

Table 10-15. Rank of proportion of total captures for the white-throated woodrat among vegetation (A) and structural (B) types. See Table 10-7 for abbreviations.

(A) Vegetation type

	Summer						Winter					
Year	SM	CW	SC	HM	PL	SH	SM	CW	SC	HM	PL	SH
1974	2	1	5	3	6	4	1	3	5	2	6	4
1975	1	3	4	2	6	5	1	5	3	6	2	4
1976	1	3	2	4	6	5	1	2	4	5	3	6
1977	2	1	4	3	6	5	2	1	3	4	6	5
1978	3	4.5	1	2	4.5	6	5	3	1	2	6	4
TOTAL	9	12.5	16	14	28.5	25	10	14	16	17	23	23

(B) Structural type

	Summer						Winter					
Year	I	II	III	IV	V	VI	I	II	III	IV	V	VI
1974	1	2	3	4	6	5	1	3	2	5	4	6
1975	3	2	5	4	1	6	6	1	2	3	5	4
1976	3	1	2	4	5	6	2	1	6	3	4	5
1977	6	1	3	2	5	4	3	1	2	4	6	5
1978	6	1	2	4	3	5	5.5	1	2	3	4	5.5
TOTAL	17	7	15	18	20	26	17.5	7	14	18	23	25.5

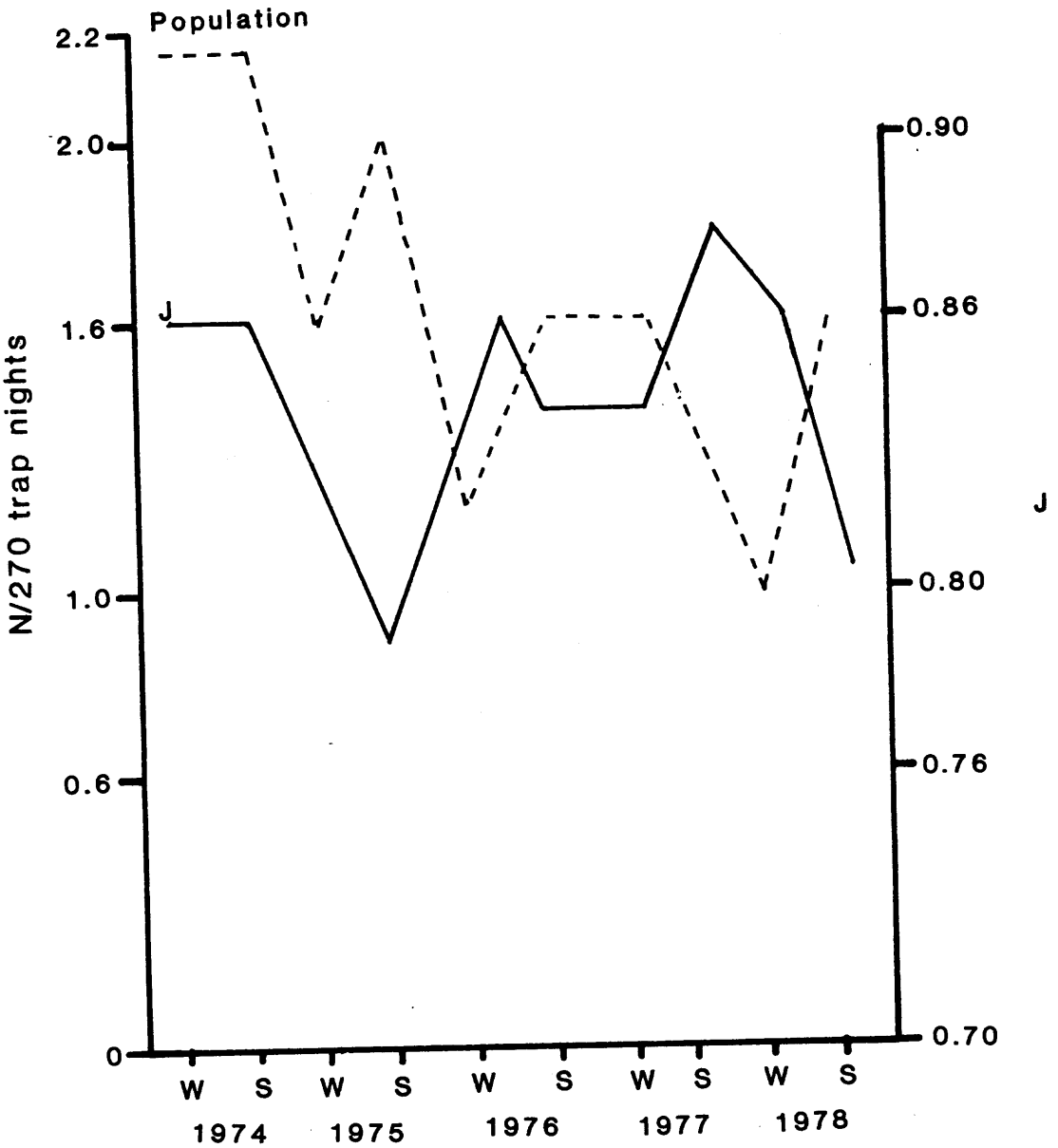

Figure 10-7. Changes in pouplation level and percent maximum habitat breadth of the white-throated woodrat. Abbreviations as in Figures 10-2 and 10-3.

This indicated that white-throated woodrats exhibited a preference for certain vegetation types in summer but not in winter. The W value for summer was 0.661, so there was some fluctuation in the rank of vegetation types. But screwbean mesquite was consistently of highest rank, cottonwood-willow ranked second, honey mesquite third, salt cedar fourth, salt cedar-honey mesquite fifth, and arrowweed ranked sixth in summer.

Ranks by structural type were significantly consistent in winter and summer among years, and between winter and summer (Table 10-8). This indicated that white-throated woodrats showed a structural type preference. W values were low (0.451-0.496), indicating that the rank of structural types fluctuated quite a bit. Type II consistently ranked first both seasons. Type III consistently ranked second in winter but was less consistently second in summer. Types V and VI were low ranking (4th, 5th, 6th) both seasons. According to these data, white-throated woodrats in summer considered mesquite and cottonwood-willow habitats with relatively dense canopy to be optimal habitats, and arrowweed and relatively open habitats to be less preferable. Vegetation type was not an important factor in habitat selection in winter, whereas structural type was, although it was not as important a factor as with the other rodent species.

Movement and Home Range

Twenty-one woodrats (10 females and 11 males) were toe clipped with an individualized sequence. All 21 were recaptured; the average number of recaptures was 1.30 for females and 1.27 for males (Table 10-9). We were unable to calculate home range area and distance traveled because of the low recapture success.

Sex Ratio

In summer among all years there were statistically equal numbers of males and females (Table 10-11). In winter the sex ratio was variable. One year had a significantly greater number of females, another year had a significantly greater number of males, and other years showed statistically equal numbers of males and females. The mean number of recaptures showed that neither sex was biased over the other in catchability.

Merriam Kangaroo Rat

Description

Mean weight 38.0 gm (1.34 oz).

> ...[F]orefeet and antiplantar faces of hind feet white; white stripe extending from flank to base of tail and isolating patch of pigmented hair on each hind leg, this patch being some shade of buff or brownish like upper parts; tail white all around at base and having white stripes for entire length on each side; dark stripe extending down top of tail...tail tufted...; fur silky, plumbeous basally on upper parts and white to base on

underparts....Hind legs large and 5th toe on large hind feet vestigial or [lacking]....short neck (Hall and Kelson 1959:511).

Distribution

The Merriam kangaroo rat was captured in all six vegetation types: cottonwood-willow, honey mesquite, screwbean mesquite, salt cedar, salt cedar-honey mesquite, and arrowweed, at sites ranging from the Mohave Division to the Limitrophe Division (Fig. 10-1).

Breeding Activity

Pregnant kangaroo rats were captured as early as January in some years (Table 10-2). In February, 10 to 30% of the females had embryos. The highest proportion of females with embryos occurred from March to July in 1974 and 1976, from February to May in 1975, and from March to May in 1977. Pregnant females were rarely captured from September through December. There was no significant difference among years in the proportion of pregnant females.

Reynolds (1960) noted first pregnancies in March, peak numbers of pregnancies in May and again in September, and observed no pregnancies from November through February in Merriam kangaroo rats in southern Arizona. Stamp and Ohmart (1979) reported that more than 60% of females were reproductively active from February through July and that no reproductively active females were caught in December and January in their study area 40 km (25 mi) northeast of Phoenix, Arizona.

Litter Size and Gestation

The mean number of embryos per litter was 2.1 (n = 37). Reynolds (1960) reported a mean of 2.02 embryos per litter (extremes 1 and 3). Hall and Kelson (1959) reported a mean of 3 embryos per litter (extremes 1 and 5).

Relative Population Size

The relative population size of the Merriam kangaroo rat was asynchronous over the seasons studied (Fig. 10-8). Reynolds (1960) stated that Merriam kangaroo rat abundance varied widely with the season and year and that no predictable cyclic changes were apparent. Our data were consistent with those findings. Population size was not significantly different between seasons. The correlation between population size and ($\bar{x}$ and SD) seasonal rainfall was not significant (Table 10-3). When population size increased, all vegetation types showed increased abundances of kangaroo rats in two of three cases (Table 10-12, Fig. 10-8).

Habitat Breadth and Overlap

There was no significant difference in percent maximum habitat breadth or average overlap among vegetation or structural types between seasons (Tables 10:3-5). J values were mostly >0.70 among vegetation types both

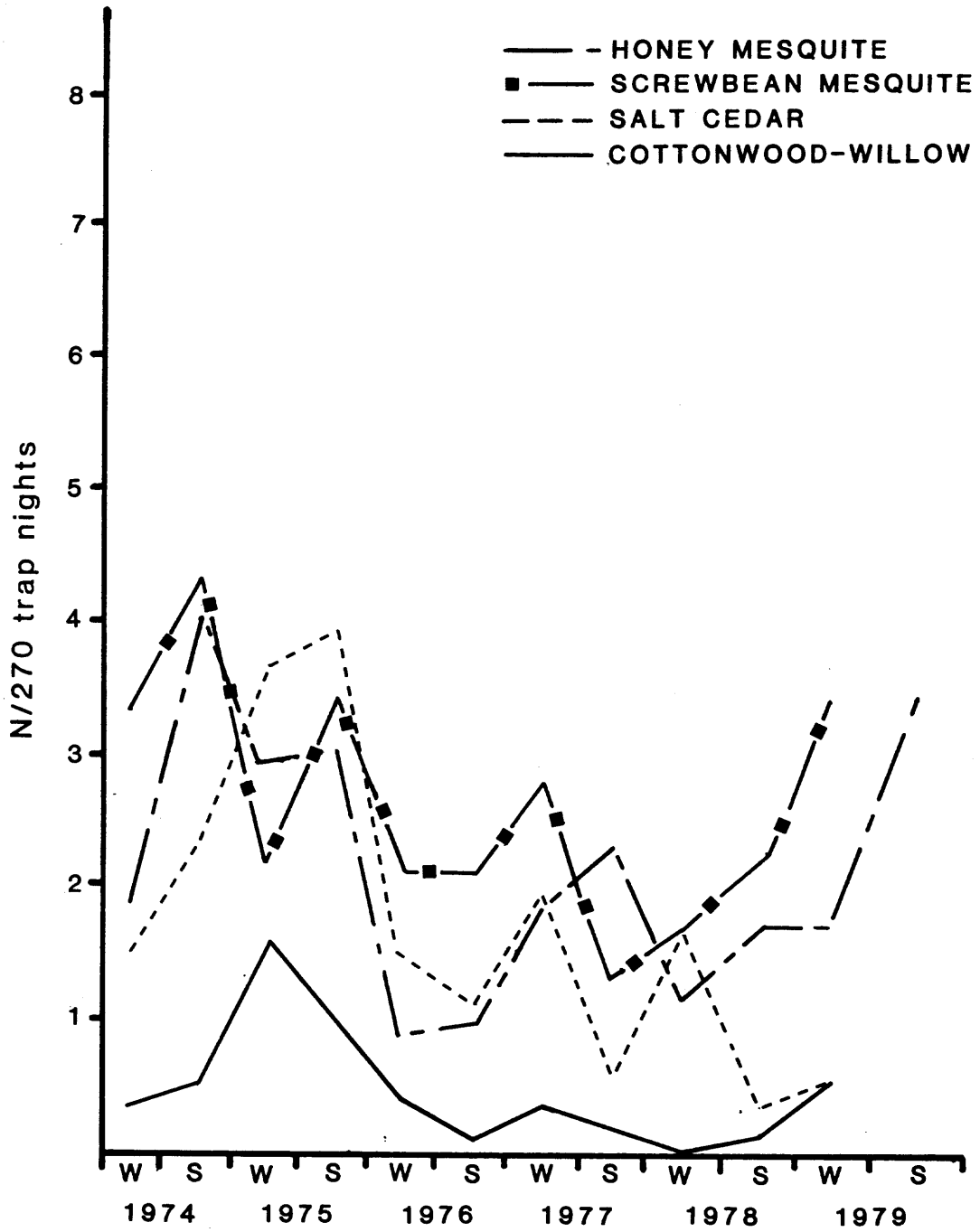

Figure 10-8. Capture rates (N/270 trap nights) for the Merriam kangaroo rat in four vegetation types along the lower Colorado River. Abbreviations as in Figure 10-2.

seasons but were mostly between 0.62 and 0.65 among structural types (Table 10-3). There was a trend for the changes in J values to follow changes in population size. In all three cases in which population size decreased, J decreased (Fig. 10-9). In all three cases in which population size increased, J increased.

Habitat Association

When we ranked vegetation and structural types by proportion of total captures in each habitat for each season each year (Table 10-16), we found that ranks were significantly consistent for both vegetation and structural type in winter and summer among years and between winter and summer (Table 10-8). W values for vegetation type (0.635, 0.485) showed that ranks fluctuated more in winter than in summer. Screwbean mesquite ranked first in summer and winter; honey mesquite and arrowweed ranked high in both summer and winter, although ranks varied among years. Salt cedar-honey mesquite ranked lowest in winter and had a similarly low status to cottonwood-willow in summer.

The Kendall's coefficient of concordance W values (Table 10-8) for structural type were relatively high (0.837, 0.877), implying that the optimality of structural types changed very little between years and seasons. Type V was the optimum structural type, Type VI was second, Type IV was third, and Type III was fourth in both seasons. Types I and II ranked sixth and fifth in winter and were nearly tied for last rank in summer.

In summary, the sparseness of vegetation was an important factor in selection of habitat by Merriam kangaroo rats. Mesquite vegetation and sparse structural types were optimal; cottonwood-willow and salt cedar-honey mesquite vegetation types and denser structural types were less preferable. Preference in vegetation type was more consistent in winter than in summer. Fidelity to structural type was quite high. Substrate type may also be an important habitat component for this species, but we did not collect data concerning the nature of the substrate.

Movement and Home Range

Eighteen kangaroo rats were toe clipped with an individualized sequence. Eighteen were recaptured at least once; the mean number of recaptures for females was 3.56 and for males 1.44 (Table 10-9). Data were insufficient to examine home range area and movement distances according to sex.

Home range area was 0.06 ha (0.15 a; Table 10-17). Home range estimate was based on a small sample. The average adjusted range length was 65.4 m (214.6 ft) and the mean distance between captures was 36.9 m (121 ft) (maximum/minimum, 130/15 m [427/49 ft]). Reynolds (1960) reported home range area as 0.17 ha (0.43 a) for adult males, 0.15 ha (0.38 a) for adult females, and 0.10 ha (0.25 a) for immatures.

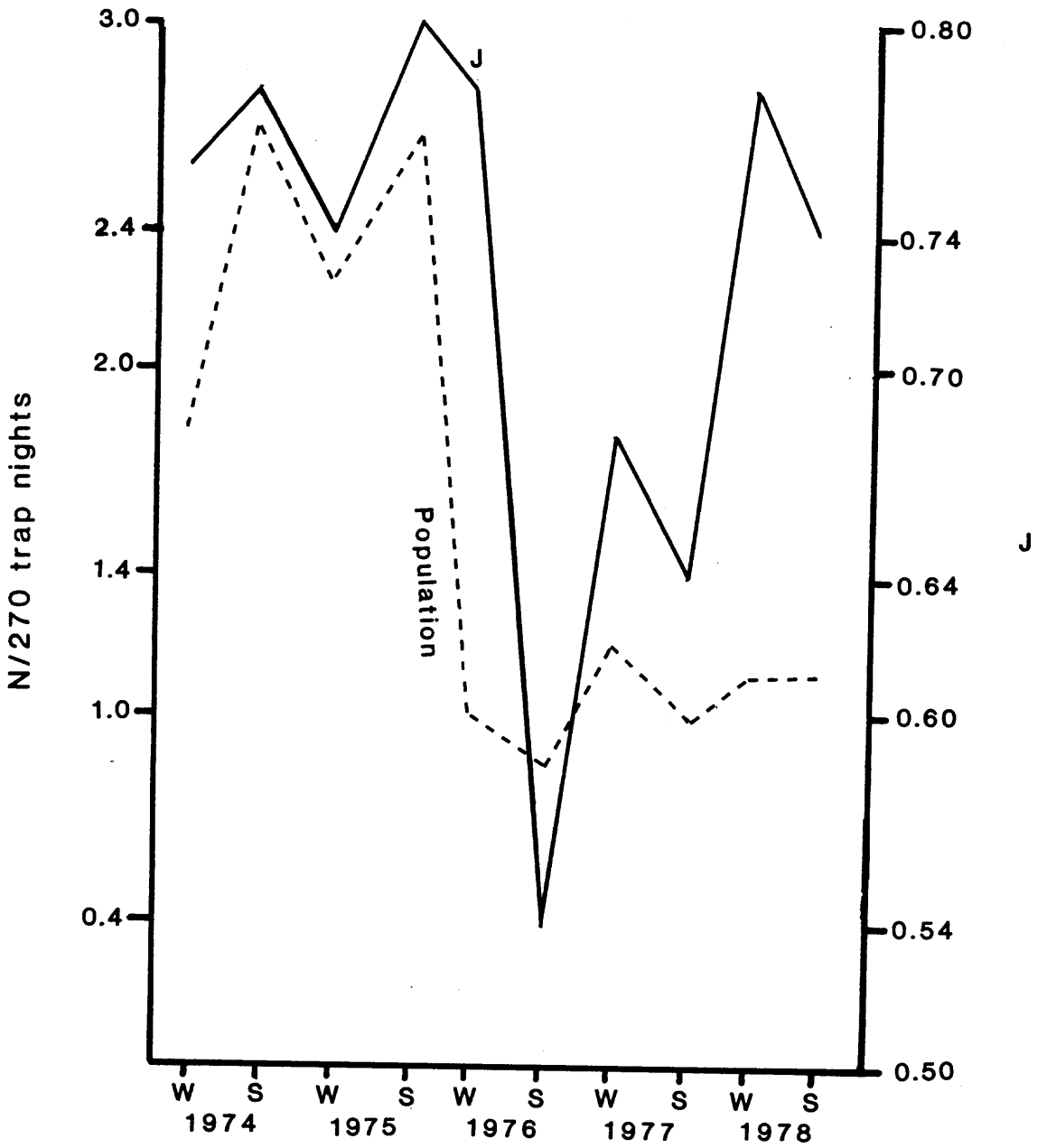

Figure 10-9. Changes in population level and percent maximum habitat breadth of the Merriam kangaroo rat. Abbreviations as in Figures 10-2 and 10-3.

Table 10-16. Rank of percent average habitat breadth for the Merriam kangaroo rat among vegetation (A) and structural (B) types. Abbreviations as in Table 10-7.

(A) Vegetation type

	Summer						Winter					
Year	SM	CW	SC	HM	PL	SH	SM	CW	SC	HM	PL	SH
1974	1	5.5	3	2	4	5.5	2	5	4	3	1	6
1975	2	5	1	3	4	6	3	4	1	2	5.5	5.5
1976	2	5	4	3	1	6	1	5	3	4	2	6
1977	3	6	4.5	1	2	4.5	1	5	4	2	3	6
1978	1	4	6	3	2	5	2	1	3	4	6	5
TOTAL	9	25.5	16.5	12	13	27	9	20	15	15	17.5	28.5

(B) Structural type

	Summer						Winter					
Year	I	II	III	IV	V	VI	I	II	III	IV	V	IV
1974	6	5	3	2	1	4	6	5	3	4	1	2
1975	5	5	5	3	1	2	5.5	5.5	4	3	1	2
1976	5.5	5.5	4	3	1	2	6	5	4	3	1	2
1977	5.5	5.5	4	3	2	1	6	4	5	3	1	2
1978	5.5	5.5	4	3	2	1	5.5	5.5	3	2	1	4
TOTAL	27.5	26.5	20	14	7	10	29	25	19	15	5	12

Table 10-17. Live trap estimates of home range and movements of the Merriam kangaroo rat. Sample sizes in parentheses. Abbreviations as in Table 10-7.

	Minimum number of different stations		
Measure	2	3	$\bar{x}$
Area	0.075 (5)	0.053 (5)	0.064 (10)
ARL	79.6 (5)	53.6 (6)	65.4 (11)
DBC			
Mean	64.3 (5)	26.4 (13)	36.9 (18)
Maximum/minimum	130.1/30.5	82.0/15.2	

Sex Ratio

There was a statistically equal number of males and females captured in three of four years in winter and in two of four years in summer (Table 10-11). The other years showed a significantly greater number of males than females. The average number of recaptures of females was greater than that of males. If females were more "trap happy" than males, they may have masked the true sex ratio.

Desert Pocket Mouse

Description

Mean weight 17.5 gm (0.62 oz).

> Upper parts yellowish-brown to yellowish-gray; underparts white to buffy; lateral line obscure or absent; tail long, markedly crested, penicillate, white below proximal to tuft, upper side of tail and tuft dusky (Hall and Kelson 1959:497).

Distribution

The desert pocket mouse was captured in all six vegetation types: cottonwood-willow, honey mesquite, screwbean mesquite, salt cedar, salt cedar-honey mesquite, and arrowweed, at sites ranging from the Mohave Division to the Limitrophe Division (Fig. 10-1).

Breeding Activity

High proportions of females with embryos occurred from April or May to July or August (Table 10-2). Generally, the highest proportion occurred in May. No pregnant females were captured from October through January, nor in March. There was no significant difference among years in the proportion of pregnant females. Stamp and Ohmart (1979) reported peak breeding activity in spring (April, May) and early summer (June, July).

Litter Size and Gestation

The mean number of embryos per litter was 4.5 (n = 65). Stamp and Ohmart (1979) reported a mean of 3.8 embryos per litter (n = 16).

Relative Population Size

The population size of the desert pocket mouse was seasonally cyclic, with highs in summer and lows in winter. There was a significant difference in population size between seasons. The correlation between population size and ($\bar{x}$ and SD) seasonal precipitation was significant and negative (Table 10-3). As precipitation increased, population size decreased. Based on Brown's (1973) findings, the opposite result would be expected. When relative population size increased, all vegetation types showed a greater abundance of pocket mice (Table 10-12, Fig. 10-10).

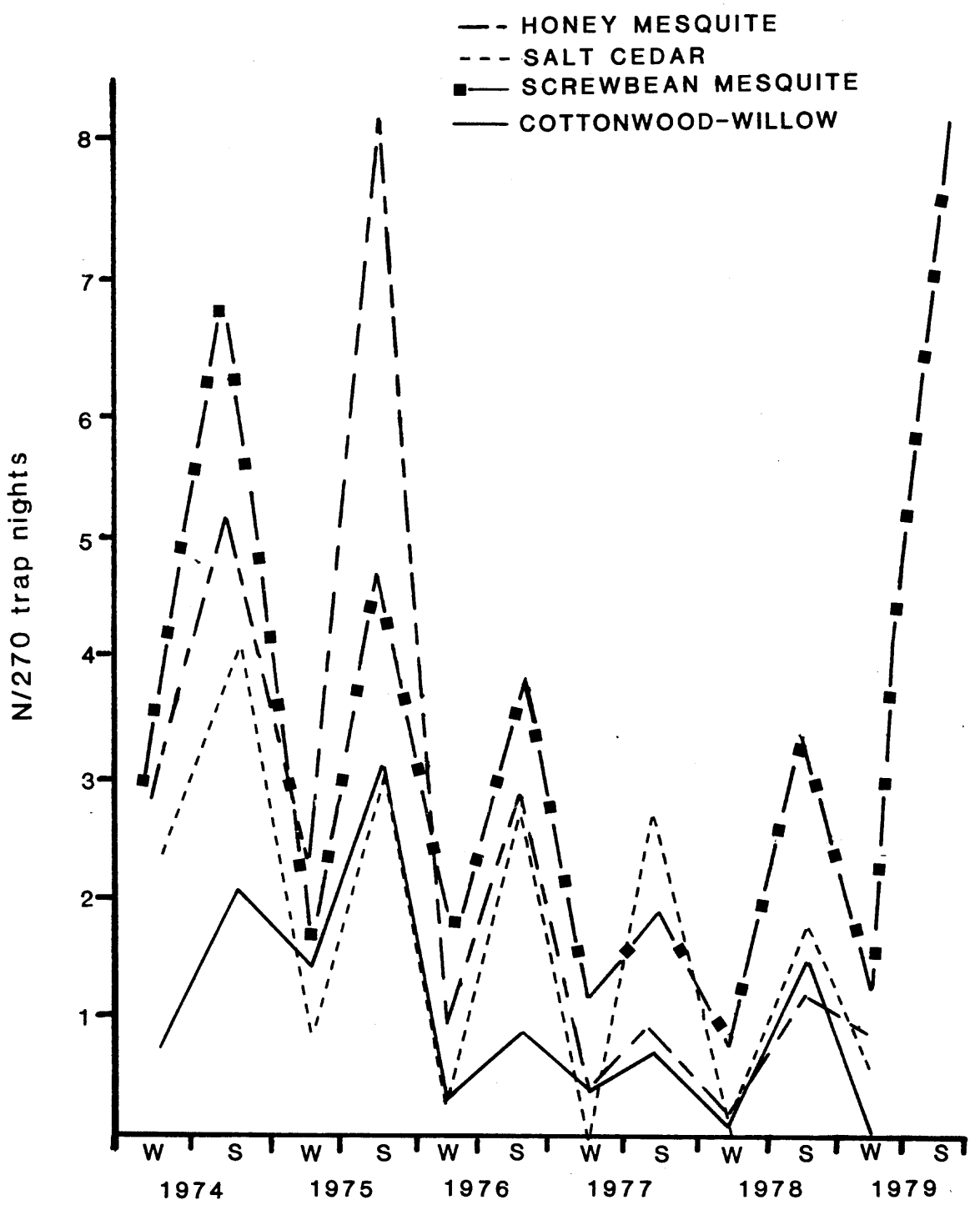

Figure 10-10. Capture rates (N/270 trap nights) for the desert pocket mouse in four vegetation types along the lower Colorado River. Abbreviations as in Figure 10-2.

Habitat Breadth and Overlap

The percent maximum habitat breadth and average overlap among vegetation types were significantly different between summer and winter (Tables 10:3-5). Both measures were higher in summer than in winter. There was no statistical difference in average overlap among structural types between seasons (Table 10-5). J values among vegetation and structural types were mostly >0.88 in summer and >0.74 in winter (Table 10-16). Changes in percent maximum habitat breadth followed changes in relative population size. In all three cases in which population size decreased, J decreased, and in all five cases when population size increased, J increased (Fig. 10-11).

In summary, when population size increased, distribution of desert pocket mice among habitats became more even, and the occurrence of desert pocket mice with the other small mammal species among vegetation types increased.

Habitat Association

When we ranked vegetation and structural types by percent average habitat breadth (Table 10-18), summer and winter structural type and winter vegetation type were significantly consistent among years (Table 10-8); summer vegetation type was not. This indicated that the desert pocket mouse did not show a vegetation preference in summer. Kendall's coefficient of concordance W values were higher for structural type than for vegetation type, but all values (0.510 to 0.614) showed that there were fluctuations in rank.

In winter screwbean mesquite ranked first (according to the sums of ranks), honey mesquite and salt cedar-honey mesquite ranked second, and cottonwood-willow, salt cedar, and arrowweed ranked third, fourth and fifth, respectively.

Structural Types IV and V consistently ranked first and second, respectively, in both seasons. Type VI changed from fourth to third rank from summer to winter, exchanging places with Type III, which moved from third to fourth rank. Types I and II were low ranking in winter and summer; Type II ranked lower in winter than in summer.

Kendall's coefficient of concordance W tests showed that in summer, vegetation type was not a significant factor in habitat selection, but structural type was. In winter, both vegetation and structural type were significant factors in habitat selection. The desert pocket mouse preferred mesquite and mesquite mix vegetation (in winter) and more open habitats and avoided arrowweed and salt cedar and more closed, dense habitats. These attributes of habitat selection were similar to those of the Merriam kangaroo rat, except that desert pocket mice preferred salt cedar-honey mesquite habitat.

Home Range and Movement

Fifty-eight pocket mice (23 females and 35 males) were toe clipped with an individualized sequence. Fifty-seven were recaptured at least once;

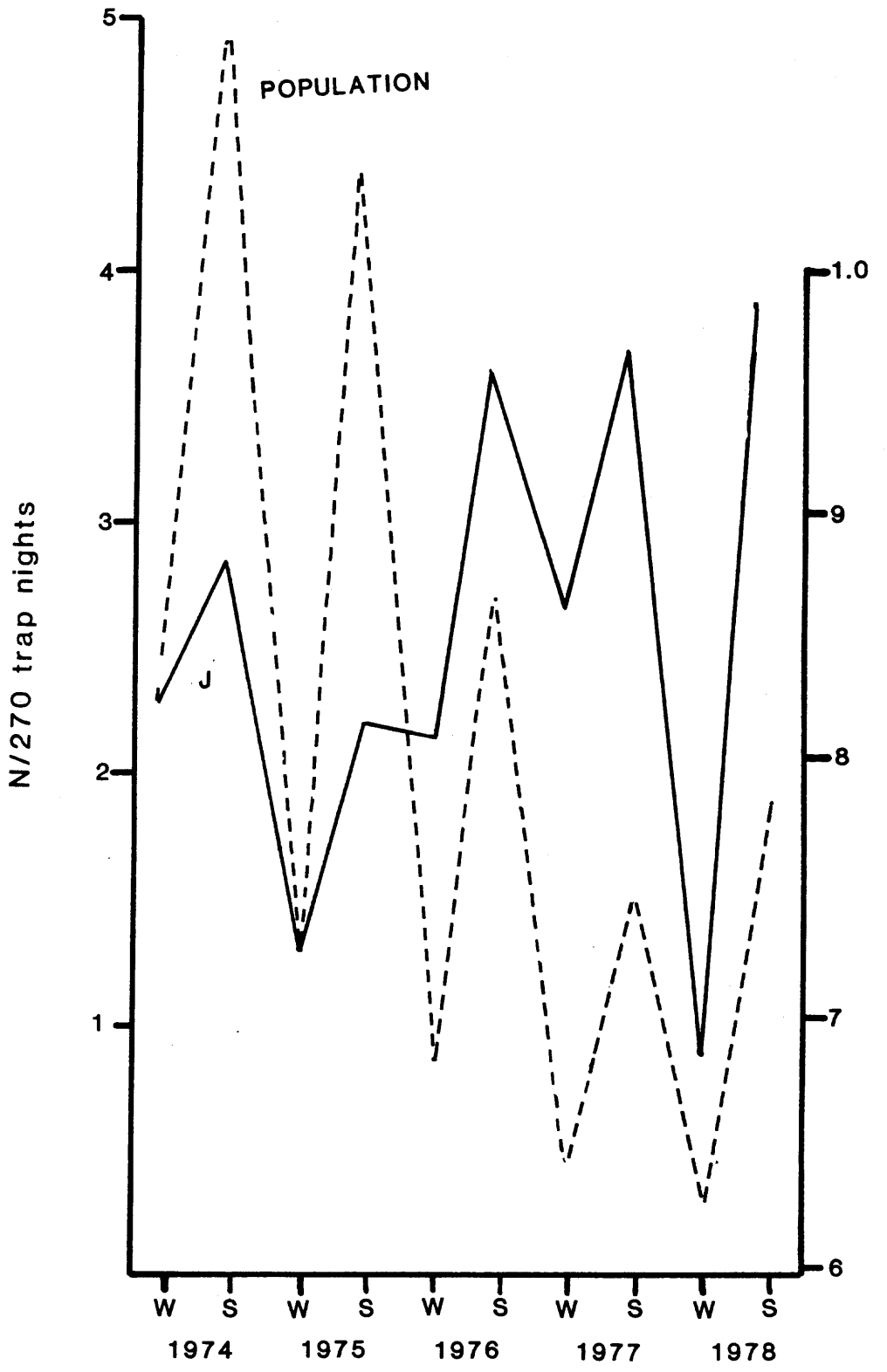

Figure 10-11. Changes in population level and percent maximum habitat breadth of the desert pocket mouse. Abbreviations as in Figures 10-2 and 10-3.

Table 10-18. Rank of proportion of total captures for the desert pocket mouse among vegetation (A) and structural (B) types. Abbreviations as in Table 10-7.

(A) Vegetation type

	Summer						Winter					
Year	SM	CW	SC	HM	PL	SH	SM	CW	SC	HM	PL	SH
1974	2	6	5	3	4	1	1	5	3	2	6	4
1975	3	4.5	4.5	1	2	6	2	3	5	1	6	4
1976	1	6	4	5	2	3	1	4.5	4.5	2	6	3
1977	3	6	4	1	5	2	2	5	3	6	4	1
1978	4	1	5	6	3	2	2	1	5	4	6	3
TOTAL	13	23.5	22.5	16	16	14	8	18.5	20.5	15	28	15

(B) Structural type

	Summer						Winter					
Year	I	II	III	IV	V	VI	I	II	III	IV	V	VI
1974	6	3	1	2	4	5	6	4.5	3	1	2	4.5
1975	6	4	3	2	1	5	6	5	4	1.5	1.5	3
1976	6	3	5	4	2	1	6	4	5	1	3	2
1977	4.5	4.5	3	1	2	6	5	6	4	1	3	2
1978	5	5	5	1	3	2	1	6	5	2	3	4
TOTAL	27.5	19.5	17	10	12	19	24	25.5	21	6.5	9.5	15.5

the mean number of recaptures was 1.74 for females and 1.50 for males (Table 10-9). Data were insufficient to examine range and movement according to sex.

Average home range area was 0.106 ha (0.27 a; Table 10-19). The average adjusted range length was 75 m (246 ft) and the mean distance between captures was 53 m (174 ft) (maximum/minimum, 183/15 m [600/49 ft]; Table 10-19). These movements were of significantly longer distance than those of the Merriam kangaroo rat ($P<0.005$, $t = 6.79$, 25 df; $t = =14.56$, 40 df, respectively).

Sex Ratio

In summer of all years the number of males was statistically equal to the number of females (Table 10-11). In winter, three of the five years had a significantly higher number of males than females. There was a seasonal difference in sex ratio, with males being more numerous in the winter. This was probably not because of differential catchability, since male and female mean numbers of recapture were similar.

Co-occurrence of Rodent Species

Overlap values among vegetation and structural types (Table 10-4) showed that the deer mouse and Merriam kangaroo rat co-occurred more frequently with the desert pocket mouse than with either the cactus mouse or the white-throated woodrat. The latter two species also co-occurred more frequently with the desert pocket mouse than with either the deer mouse or the Merriam kangaroo rat. There was a nearly perfect degree of co-occurrence between the cactus mouse and the white-throated woodrat among vegetation and structural types.

Overlap measures were relatively high among all species. Exceptions were overlaps of the deer mouse and the Merriam kangaroo rat with the white-throated woodrat, and the Merriam kangaroo rat with the cactus mouse.

Range of Rare and Uncommon Rodent Species

We trapped in six riparian vegetation types, each with one to six structural types. Consequently the observed range of uncommon species may be a function of our trapping procedure and the types of vegetation trapped; these species may actually show wider ranges.

Desert Shrew

Two specimens taken; one in salt cedar and one in salt cedar-honey mesquite mix in Cibola.

Harris Antelope Squirrel

Description

Upper parts in summer pinkish cinnamon more or less darkened with fuscous; in winter mouse gray; tail, above and below,

Table 10-19. Live trap estimates of home range and movements of the desert pocket mouse. Sample sizes in parentheses. Abbreviations as in Table 10-7.

	Minimum number of different stations			
Measure	2	3	4	$\bar{x}$
Area	0.088 (9)	0.309 (1)	0.066 (1)	0.106 (11)
ARL	65.9 (10)	113.8 (4)	58.2 (1)	75.2 (15)
DBC				
Mean	50.7 (10)	59.7 (11)	37.1 (3)	53.1 (24)
Max/min	140.5/15.2	183.5/15.2	43.0/34.1	

mixed black and white...; in both seasons having two white stripes down back (Hall and Kelson 1959:331).

Distribution

The Harris antelope squirrel was captured in honey mesquite and salt cedar-honey mesquite only in the Parker and Mohave divisions during 1974 through 1979.

White-tailed Antelope Squirrel

Description

Upper parts brownish or cinnamon; 2 white stripes on back extending from sides to hips; tail broadly white or whitish below, bordered with fuscous black; in winter pelage more grayish (Hall and Kelson 1959:332).

Distribution

The white-tailed antelope squirrel was captured only in salt cedar and only in the Parker Division.

Southern Pocket Gopher

Description

Color varies from black to almost white according to subspecies...; not sharply bicolored, but underparts paler than upper parts (Hall and Kelson 1959:413).

Distribution

The pocket gopher was captured in screwbean mesquite only in the Parker Division over the five-year period.

Reproduction

Hall and Kelson (1959) reported the average number of embryos per litter as 4.8 in Nevada (n = 63, extremes 2-11).

Desert Kangaroo Rat

Description

Upper parts pale ochraceous buff and remainder of body white; ventral dark stripe on tail lacking in most specimens; distal 3rd of tail crested; long hair forming crest dusky, except that distal 25 mm of tail white; 4 toes on hind foot...(Hall and Kelson 1959:534).

Distribution

The desert kangaroo rat was captured in honey mesquite, screwbean mesquite, salt cedar, and arrowweed only in the Mohave and Parker divisions.

Western Harvest Mouse

Description

> Upper parts of various shades of buffy mixed with dark brown or blackish that sometimes predominates middorsally; buffy tones purest on cheeks, shoulders, and flanks; underparts varying from dark buff to white; tail bicolored, darker above than below (Hall and Kelson 1959:584).

Distribution

The western harvest mouse was captured in cottonwood-willow, honey mesquite, screwbean mesquite, salt cedar, and arrowweed in the Mohave, Parker, Cibola, and Yuma divisions.

Reproduction

Hall (1946) reported that in Nevada pregnant females contained an average of four embryos (extremes of 1 and 6). Svihla (1932) reported a gestation period of 23-24 days.

Southern Grasshopper Mouse

Description

> Upper parts grayish or pinkish cinnamon; underparts white; tail above like upper parts in basal 2/3, white below and distally (Hall and Kelson 1959:665).

Distribution

The southern grasshopper mouse was captured in screwbean mesquite, salt cedar, and salt cedar-honey mesquite in the Mohave, Parker, Palo Verde, and Limitrophe divisions.

Hispid Cotton Rat

Description

> Upper parts coarsely grizzled; blackish or dark brownish hairs interspersed with buffy or grayish hairs...; sides usually only slightly paler; underparts usually pale to dark grayish...; tail coarsely annulated, sparsely haired...(Hall and Kelson 1959:671).

Distribution

The hispid cotton rat was captured in marshes, cottonwood-willow, screwbean mesquite, salt cedar, and salt cedar-honey mesquite in the Mohave, Palo Verde, Cibola, Yuma, and Limitrophe divisions. They were most abundant in marshy situations.

Reproduction

Hall and Kelson (1959) reported that litter size averaged 5 to 6 (extremes of 2 and 12). The gestation period was 27 days.

Desert Woodrat

Description

> Upper parts varying much according to subspecies but usually approximately buffy gray; underparts grayish or faintly buffy, all hairs plumbeous basally; tail bicolored, dark gray or dusky above, pale gray below (Hall and Kelson 1959:689).

Distribution

The desert woodrat was captured only in cottonwood-willow in the Mohave and Havasu divisions.

House Mouse

Description

> Upper parts light brown to black; underparts whitish, often with buffy wash. Tail not sharply bicolor, but lighter below than above (Hall and Kelson 1959:770).

Distribution

The non-native house mouse was captured in cottonwood-willow, honey mesquite, salt cedar, and salt cedar-honey mesquite in the Mohave, Havasu, Parker, and Yuma divisions.

DISCUSSION

The five rodent species closely examined were found in all six vegetation and structural types and co-occurred relatively regularly. We observed several similarities in characteristics among the species, including onset of breeding and peak of reproductive activity and population response to seasonality and precipitation. The desert pocket mouse was usually an exception. Differences among species occurred in litter size, distribution among habitats in relation to changes in population size, habitat association, sex ratio, and movement distances.

Population Structure

The peak reproductive activity of the rodents was between March and July or August. Desert pocket mouse reproduction peaked later (April or May), but reproductive activity also extended to July or August. Portions of populations of Peromyscus spp. were reproductively active for a longer period of time than heteromyid species. The species also showed a difference in number of young per litter. The desert pocket mouse and the deer mouse had larger litters (4.5 and 4.2 embryos, respectively) than did the Merriam kangaroo rat, cactus mouse, and white-throated woodrat (2.1, 3, and 2.3 embryos, respectively).

In addition to differences in natality, sex ratio differed among the rodents. Those species with more young per litter (desert pocket mouse, deer mouse) had a higher proportion of males in the population in at least one season of the year than did species producing fewer young. The deer mouse had a skewed sex ratio in favor of males year round. The desert pocket mouse showed a skewed ratio in favor of males in winter. The cactus mouse, white-throated woodrat, and Merriam kangaroo rat did not show this consistent trend in sex ratio. The desert pocket mouse and deer mouse, those species producing more young per litter and higher numbers of males, also showed greater average mobility than did species producing fewer young per litter and equal sex ratio.

Differences in natality, sex ratio, and movement lead to questions about population structure and life history of the species. Higher natality, a greater number of males, and greater movement may be indicative of a high juvenile-to-adult ratio and high dispersal and/or mortality. Excessive juvenile or first-year males have often been recorded in mammals and birds as dispersive and "floaters." Lower natality, an equalized sex ratio, and less extensive movements may be indicative of a population with few or no "floaters," a higher recruitment-to-dispersal ratio, and perhaps a less dispersive population.

Precipitation and Population Size

Brown (1973) investigated characteristics of desert rodent communities in the Great Basin, Mohave, and Sonoran deserts. He suggested that overall rodent density was associated with ($\bar{x}$ and SD) annual precipitation. He stated that the amount of precipitation in arid environments provides a good estimate of net primary productivity and seed production and that productivity determines both population size and diversity in desert rodent communities.

We tested the association of overall rodent density and total precipitation ($\bar{x}$ and SD) and it was not significant. (We used a nonparametric test, Brown used a parametric correlation test.) It should be kept in mind that our data are from riparian habitats where the perennial vegetation is phreatophytic. We tested the association between species seasonal density and seasonal precipitation ($\bar{x}$ and SD). No species, except the desert pocket mouse, showed significant correlations; the correlation of the desert pocket mouse was significantly negative. These data were not consistent with an hypothesis that rainfall and, consequently, productivity were directly

related to population size in a rodent community in riparian habitats of the lower Colorado River valley.

Beatley (1969) and Van De Graaff and Balda (1973) suggested a similar relationship between precipitation, winter annual productivity, and reproductive activity in the Merriam kangaroo rat. They concluded that autumn rainfall, through its effect on winter annual production, directly influenced the reproductive activity of the Merriam kangaroo rats. Although the level of rainfall varied among years (Table 10-20), the proportion of pregnant females among years was not significantly different. This was true for each species. Again our data are from riparian habitats, and we conclude that autumn precipitation was neither simply nor directly associated with reproductive activity among heteromyids or cricetids.

Rodent Community Structure

Brown (1973:324), in his comparative desert rodent study, stated:

> One of the most striking characteristics of desert rodent communities is that component species differ greatly in body size...in each of these areas (Sonoran, Mohave, Great Basin) the more diverse communities consist of five or six species that show a remarkably regular spacing in body size.

Of the five common rodent species in the lower Colorado River valley, three fall into the same size category. The others are either intermediate (Merriam kangaroo rat, 38 g [1.34 oz]) or large (white-throated woodrat, 200 g [7.05 oz]). The cactus mouse, deer mouse, and desert pocket mouse are all nearly the same size (17.7 g [0.62 oz], 18.0 g [0.63 oz], and 17.5 g [0.61 oz], respectively). Spatial overlap measures showed that these species co-occurred frequently among vegetation and structural types.

Brown (1973) reported a horizontal (spatial) foraging overlap between the deer mouse and the desert pocket mouse of 0.55. Our overlap measures ranged from 0.704 (average vegetation type summer/winter) to 0.802 (average structural type summer/winter). Brown's (1973) method of overlap measure differed from ours, but his inference was that there was low co-occurrence of the two species. That is, the two species used different microhabitats as a means of separation since they ate the same type of seeds. Our data indicate relatively high spatial co-occurrence with some separation by optimal habitat (habitats harboring the greatest proportion of a species abundance). The community of rodents in the lower Colorado River valley included three similarly small-sized rodents. But either optimal vegetation or optimal structural types, or both, in summer or winter were different among the three species. The three species co-occurred regularly, but habitat preferences resulted in greatest proportions of the species populations being separated in at least some portion of the year.

Table 10-20. Average rainfall in cm from August-December 1973-1978 at the Davis and Parker, Arizona weather stations.

	Average rainfall	
Year	Davis	Parker
1973	0.134	0.302
1974	0.476	0.244
1975	0.280	0.070
1976	1.184	0.766
1977	0.520	0.228
1978	0.784	1.108

Species Population Distribution

All species, with the exception of the desert pocket mouse, showed no significant seasonal difference in relative population size, evenness of distribution among habitat types, or average overlap among vegetation or structural types. The desert pocket mouse had higher values of these measures in summer than in winter.

Cyclic or asynchronous seasonal increases and decreases in population sizes were present even though seasonal differences in population size were not significant. Among the cricetid rodents, the changes in population size were opposite to the changes in percent maximum habitat breadth. This trend was clearer for the deer mouse and the white-throated woodrat than for the cactus mouse. For the heteromyid rodents, the changes in percent maximum habitat breadth followed that of population size. When cricetid population sizes showed an increase, their distribution among vegetation types became more restricted. Conversely, when heteromyid population sizes increased, their distribution among vegetation types expanded and they approached a more even distribution.

Fretwell (1972) advanced a theory of habitat distribution. It deals with ideal-free and ideal-despotic models and considers two assumptions: (1) animals select a habitat best suited to their survival and reproduction, and (2) an animal's chance of reproductive success is equal to that of other individuals when it is in habitats of equal suitability.

In the ideal-free distribution model, an individual selects a most suitable habitat (H_1). Those areas, then, are occupied first. As density increases, the suitability of that habitat (H_1) decreases, and eventually an unoccupied habitat previously of lower suitability (H_2) becomes equivalently or more suitable than H_1 and the animals move into the most suitable habitat, now H_2. This may occur through a series of habitats during increasing population density; the additional animals distribute in all $H_1 \ldots H_n$ habitats in proportions (not necessarily equal), so that all habitats remain equally suitable.

According to this model, we would expect an increase in percent maximum habitat breadth with an increasing population size. Densities in each habitat would not necessarily be equal. The heteromyid rodents showed changes in percent maximum habitat breadth that followed the same pattern as population size; thus, their distribution was consistent with the ideal-free distribution model.

If dominance or territoriality are despotic, an organism does not have a free choice in selecting a habitat. Distribution, therefore, follows a different model. If an animal selects a habitat as most suitable but must enter it at some risk, then the suitability is decreased. The animal is faced with the alternatives of entering at risk or selecting a less suitable habitat. Thus, the ideal-despotic model differs from the ideal-free model in that occupants of different habitats are not all enjoying equal chances of success. By mathematical means Fretwell

(1972:102) explained that suitability (chance of success) is higher in habitats of higher density if a population has an ideal-despotic distribution.

In an ideal-despotic model we would expect most suitable habitats to harbor the highest proportion of total density when the population increased. As population size increased, distribution would be restricted to high suitability habitats. When deer mouse and white-throated woodrat population sizes increased, their percent maximum habitat breadth decreased and distribution became restricted. During periods of increases, populations rose in high ranking (preferred) habitats and declined or showed no change in low ranking (less optimal) habitats. This was not the case with the heteromyids. When the desert pocket mouse and Merriam kangaroo rat populations increased, all habitat types (high and low ranking) showed a population increase. Therefore, distributions of deer mice and white-throated woodrats were consistent with the ideal-despotic model.

Correspondence with these theoretical models was based on trends in the data. To test Kendall's coefficient of concordance W, we need to examine the success (winter survival and reproductive success) of these rodents among the habitats. We would expect equal success among habitats in the heteromyids and unequal success among habitats in the cricetids. These theoretical distributional models relate to theories of density regulation, the role of dominance and territorial behavior, and predictions of distribution at different population sizes (Fretwell 1972). Therefore, if these rodent populations do correspond to these distributional models, much information could be gained from testing of hypotheses generated from the models.

Species Habitat Breadth

The five numerically dominant rodent species showed relatively high percent maximum habitat breadths in both seasons among vegetation and structural types. Species distributions were generally 70 to 90% of maximum. An exception was the Merriam kangaroo rat, whose distribution among structural types was $\leq$65% of maximum. The five species showed habitat preferences, but individuals were widely distributed and we did not consider them to be habitat specialists.

CONCLUSIONS

Management of small rodent communities is probably not a current objective of most wildlife managers. Yet an understanding of the fundamental characteristics of reproductive activity and populations of the rodent species is an important contribution to the natural history of riparian faunal communities. Small rodents are an important food resource for a number of animals, such as larger mammals and predatory birds and reptiles.

We have determined the period of greatest breeding activity and litter sizes for the common rodent species, and we know from the literature when young of the year are incorporated into the population. Other characteristics suggest that there may be differences in population structure among species.

Habitat associations were identified for the common species; these were relatively consistent between seasons. Species distributions among vegetation and structural types were generally 70 to 90% of maximum.

The distribution of species abundance among habitat types showed trends that were consistent with theoretical models. These models generate hypotheses which need further testing, because they contain predictive potential about distribution at different population sizes.

The relation of population size to precipitation was not consistent with previous findings in the literature. It may be that riparian habitats in desert climates influence rodent populations through factors different from those of desert scrub habitats. The relations between rainfall, productivity, and rodent populations need more intensive study as a consequence of the dichotomy of results.

In summary, we have identified some fundamental characteristics of rodent species in the lower Colorado River valley that will provide important reference information and that will also relate to research on community structure and population distribution.

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CHAPTER 11

RELATIONSHIPS OF RODENTS TO RIPARIAN VEGETATION

INTRODUCTION

The previous chapter discussed breeding biology and general habitat preferences of small mammals found in riparian vegetation. This chapter examines relationships between each small rodent species and specific vegetation characteristics. Vegetation variables considered in analyses are the same variables used in determining avian use of riparian vegetation (Chapter 5). Similarities in rodent habitat preference are examined and recommendations for management are proposed.

METHODS

Densities of several species of rodents were low each year, and often animals were not caught in all vegetation types. In these cases, densities were averaged over five years for each season. When rodents were even scarcer, it was necessary to average densities across seasons as well as across years. Average rodent densities were used as dependent variables in analyses. Vegetation variables (VPC's; see Chapter 2 and Appendix 5-1) were also averaged across years. These averages were used as independent variables. Vegetation variables were raised to the second, third, and fourth powers in order to detect certain curvilinear relationships between rodents and vegetation. (See Chapter 2 for discussion of Principal Components Analysis [PCA] and the use of polynomials to detect curvilinearity.) Because averaging eliminated much of the variance, other methods of assessing rodent species-vegetation relationships were employed, including analysis of variance.

A two-way analysis of variance examined differences in rodent densities between vegetation types; this analysis included densities of small mammals in each of the five vegetation types during each of the five years. This analysis indicated broad preferences for particular vegetation types without regard to foliage structure, except that various types of dominant vegetation were associated with particular foliage configurations. For example, arrowweed is highly associated with low-level foliage, cottonwood-willow habitats tend to have high foliage density and diversity, and honey mesquite is associated with sparser vegetation.

Another analytical technique employed calculated the probability of occurrence of each rodent species in each of the 23 habitat types. These probabilities were then correlated with the average vegetation factor scores for each habitat type (see Chapter 2 and Appendix 5-1). Results from such an analysis should be highly correlated with the results obtained using average densities in the correlation analysis if high densities are clearly associated with consistent occurrence. If rodent densities fluctuated from zero to some high density, the probability of occurrence would not be highly correlated with densities.

Considerable population fluctuation is indicated when the highest probability of occurrence in any vegetation type is substantially below 1.0 and when the results of correlation analysis using mean densities are different from results for probability of occurrence.

RESULTS AND DISCUSSION

Total Trapping Effort

Analyses in this chapter are based on monthly trapping over 63 months, in 23 habitat types (Table 11-1). In all, we set out 814 trap lines for a total of 219,780 trap nights. Among the rodents caught, one group, including five species, composed 98% of total captures (Table 11-1). Species in this group were relatively consistently caught in both the warm and cool seasons. The numerically dominant rodent in the group was the cactus mouse, which composed 60% of total captures.

A second group of five rodent species accounted for 2% of total captures (Table 11-1). These species were uncommon at all times; data were pooled across seasons and years in order to have a sufficient sample to make meaningful analyses. Even then, the best we could do was to list habitats where house mice and cotton rats occurred. Quantification beyond this was not meaningful.

Cactus Mouse

This species was associated with VPC1 (high foliage density and diversity) and VPC3 (low-level foliage) more frequently than with other derived variables (totals are from data in Table 11-2). Using binomial expansion, we concluded that VPC1 was selected significantly more frequently ($P<0.007$) and VPC2 less frequently ($P<0.001$) than expected by chance alone. Further, the chances of having nine positive associations with VPC1 were small ($P<0.0001$). The chances of getting eight negative scores for VPC3 were also small ($P<0.0001$). Therefore we concluded that the cactus mouse was attracted by dense and diverse foliage but tended to avoid areas with low, dense vegetation. This tendency was not quite significant ($P<0.071$).

The mean correlation coefficient between cactus mouse densities and the vegetation was $r = 0.620$, $SD = 0.142$ during the warm seasons of April-October (Table 11-2) and $r = 0.709$, $SD = 0.073$ in the cooler portion of the year (November-March; Table 11-2). This difference was not significant (4 df, $P>0.05$) but suggests a somewhat stronger tendency for cactus mice to select or survive in vegetation with greater foliage density and diversity at upper levels and to avoid or perish in areas with greater foliage density and diversity at low levels.

From Appendix 5-1, we can see that vegetation types SB II and IV, CW I, II, III, and IV, and SC I were consistently associated with high scores on VPC1, and that structural types V and VI and arrowweed were consistently associated with VPC3. Thus we would predict significant differences across habitat types in both dominant vegetation and structural types. High densities of cactus mice should occur in habitat types associated with VPC1 and low densities should occur in habitats

Table 11-1. Nocturnal rodents caught over a five-year period in riparian vegetation along the lower Colorado River.

Species	Number caught: Warm season (Apr-Oct)	Number caught: Cool Season (Nov-Mar)	Total	Percent of total	Cumulative percent
Common at all seasons					
Cactus mouse	4128	4430	8558	59.7	59.7
Desert pocket mouse	1573	209	1782	12.4	72.1
Merriam kangaroo rat	873	533	1406	9.8	81.9
Deer mouse	720	555	1275	8.9	90.8
White-throated woodrat	568	471	1039	7.2	98.0
Scarce at all seasons*					
Southern grasshopper mouse	---	---	119	0.8	98.8
Western harvest mouse	---	---	70	0.5	99.3
Desert kangaroo rat	---	---	65	0.5	99.8
House mouse	---	---	22	0.2	100.0
Hispid cotton rat	---	---	6	0.0	100.0

* Trap results not tabulated by season.

Table 11-2. Results of multiple linear regression analysis for cactus mouse densities (dependent variables) and vegetation principal components (independent variables) for the warm (April-October) and cool (November-March) times of year.

Season/year	Equation	Multiple R	F	df
Warm				
1974	$15.0 + 6.4VPC1^3 + (-3.4VPC4^3)$	0.674	8.3*	2/20
1975	$16.5 + (-5.5VPC3) + (-5.1VPC1^2)$	0.518	3.7*	2/20
1976	$10.0 + 4.9VPC1$	0.439	5.0*	1/21
1977	$11.4 + 1.5VPC4^4 + (-3.7VPC3) + 1.8VPC1^3 + (-4.7VPC1^2)$	0.790	7.5*	4/18
1978	$15.1 + 10.3VPC1 + (-3.5VPC4^3) + (-2.9VPC1^2)$	0.672	5.2*	3/19
Cool				
1974-75	$18.5 + 5.1VPC1 + (-5.1VPC1^2) + (-3.4VPC3)$	0.721	6.9*	3/19
1975-76	$10.7 + 3.7VPC1 + (-11.4VPC3) + 2.5VPC3^3 + (-2.7VPC2)$	0.715	4.7*	4/18
1976-77	$12.2 + (-8.2VPC3) + 3.4VPC1 + 1.6VPC3^2 + (-11.0VPC1^2)$	0.920	15.1*	4/18
1977-78	$11.4 + 1.5VPC4^4 + (-3.7VPC3) + 1.8VPC1^3 + (-4.7VPC1^2)$	0.790	7.5*	4/18
1978-79	$17.6 + (-8.3VPC3) + 4.4VPC1$	0.615	6.1*	2/20

*$P<0.05$

associated with VPC3; this difference in density may be greater in the cool time of the year. Two-way analysis of variance (ANOVA) revealed strong support for all of these predictions (Tables 11-3 and 11-4). One surprise, however, was that mixed communities of salt cedar and honey mesquite had more cactus mice than was predicted by the correlation analysis. It is also interesting to note that the exotic salt cedar, especially more mature stands, apparently supported largest populations of cactus mice.

Another point of interest is that for the cool time of year, there was a significant difference in cactus mouse densities between years (Table 11-4). There was a tendency for populations to be lower in the third or fourth year. This trend was also apparent in the warm time of year (Table 11-3), although it was not statistically significant ($P>0.05$).

Desert Pocket Mouse

This species was largely inactive in winter; during that time, the species was positively associated with honey mesquite or with honey mesquite mixed with salt cedar and shrubs (VPC2). Curvilinear associations were common, indicating that the desert pocket mouse favored moderate foliage densities; desert pocket mouse densities declined as vegetation became denser or sparser (Table 11-5). Desert pocket mice tended to avoid areas of high foliage density and diversity (VPC1) and thus were absent or occurred in low numbers in areas where the cactus mouse reached peak populations. Regression equations for each year are presented in Table 11-5.

Honey mesquite and mixed honey mesquite-salt cedar communities were the only variables loading relatively high on VPC2. We would predict populations of the desert pocket mouse to be smallest in cottonwood-willow and salt cedar communities. Negative curvilinearity of the relationship indicated that moderately dense vegetation supported greater numbers of this rodent species than either dense or sparse vegetation. The two-way ANOVA gave general support to the conclusion that Type IV (intermediate) vegetation supported the largest populations of the desert pocket mouse (Table 11-6). This trend was significant in three of the four vegetation types tested. Cottonwood-willow communities supported the smallest populations, but contrary to prediction, the largest numbers of desert pocket mice were trapped in arrowweed. Honey mesquite, predicted to have the largest density of desert pocket mice, was second to arrowweed.

Analysis of winter habitat associations was hampered by low populations. Densities at this time of year were averaged for all five years. Resulting averages were used in multiple regression analysis (Table 11-5). This indicated that the greatest number of desert pocket mice occurred in areas with screwbean mesquite, honey mesquite, and shrubs; desert pocket mice were least abundant in areas with high foliage density and diversity. Both relationships were linear and accounted for 61% of the variance. The desert pocket mouse often was not present in some vegetation types in the cool time of the year. We wished to see if there was a relationship between occurrence of this species and occurrence of some element of the vegetation. We first calculated the

Table 11-3. Analysis of variance for the cactus mouse for the warm season. CW = cottonwood-willow, HM = honey mesquite, SC = salt cedar, SB = screwbean mesquite, AW = arrowweed, SH = salt cedar-honey mesquite. $\bar{x}$ = mean, N/270 TN = number caught per 270 trapnights. A significant ($P<0.05$) F statistic indicated by an asterisk for structural types means that for the vegetation type listed at the top of the column there was a consistent tendency across years for more rodents to have been caught in one structural type and fewer in some other type. This structural type can be identified by studying the numbers in the column. A significant F statistic across years means that in one of the years rodents were consistently more abundant in a given vegetation type than in other years, regardless of structural type.

	Mean N/270 TN						
	CW	HM[a]	SC	SB[a]	AW[a]	SH[a]	$\bar{x}$ Annual N/270 TN
Structural Type							
I	26.3	-	20.0	-	-	-	
II	23.2	-	46.0	11.1	-	-	
III	10.9	12.0	19.5	15.3	-	-	
IV	11.3	8.1	12.1	6.3	-	18.1	
V	4.9	4.4	4.3	4.6	-	-	
VI	1.5	3.7	1.7	1.4	6.6	-	
F	4.0*	21.5*	38.1*	6.1*	-	-	
df	5/20	3/12	5/20	4/16	-	-	
Years							
1974	20.3	7.5	16.8	9.7	0.7	17.9	12.1
1975	12.1	7.5	19.2	8.4	3.0	34.3	14.1
1976	9.2	4.8	17.1	7.2	23.7	12.0	12.8
1977	7.7	5.3	12.0	9.3	0.8	5.4	6.8
1978	13.8	8.5	20.9	4.1	5.0	21.0	12.2

Table 11-3. (cont.)

	Mean N/270 TN						
	CW	HM[a]	SC	SB[a]	AW[a]	SH[a]	$\bar{x}$ Annual N/270 TN
F	1.61	4.4*	2.0	1.0	-	-	1.1
df	4/20	2/12	4/20	4/16			4/20
Vegetation $\bar{x}$N/270 TN[b]	12.6	6.7	17.2	7.5	6.6	18.1	

[a]Some structural types not available for study.

[b]$F = 3.3$, df = 5/20, $0.025>P>0.01$.

Table 11-4. Analysis of variance for the cactus mouse for the cool season (November-March). Abbreviations as in Table 11-3. Asterisk indicates $P<0.05$. Interpretations can be made as explained in Table 11-3.

	Mean N/270 TN						
	CW	HM[a]	SC	SB[a]	AW[a]	SH[a]	Annual $\bar{x}$ N/270 TN
Structural Type							
I	14.9	-	19.1	-	-	-	
II	24.1	-	47.6	27.1	-	-	
III	11.3	11.4	19.0	15.4	-	-	
IV	12.2	12.3	13.7	13.3	-	16.6	
V	1.0	7.4	6.8	10.5	-	-	
VI	5.5	3.6	1.0	1.0	6.0	-	
F	18.2*	1.7	29.0*	16.9*	-	-	
df	5/20	3/12	5/20	4/16	-	-	
Years							
1974-75	13.7	4.9	18.6	12.4	6.0	25.5	14.6
1975-76	9.4	4.8	17.7	10.7	10.3	14.3	11.2
1976-77	12.2	5.2	12.9	13.6	1.8	9.0	9.1
1977-78	10.2	7.4	15.7	10.4	6.0	18.0	11.3
F	1.4	1.5	2.6	3.0*	-	-	4.9*
df	4/20	4/12	4/20	4/16	-	-	4/20
Vegetation $\bar{x}$N/270 TN[b]	11.8	8.7	17.8	13.5	6.6	16.6	

[a]Some structural types not available for study.
[b]$F = 9.3$, df = 5/20, $P<0.001$.

Table 11-5. Results of multiple regression analysis for desert pocket mouse captures (dependent variable) and vegetation principal components (independent variables) for the warm (April-October) and cool (November-March) times of the year. Asterisk indicates $P \leq 0.05$. Interpret according to explanation in Table 11-3.

Season/year	Equation	Multiple R	F	df
Warm				
1974	$5.5 + (-2.33VPC1^2)$	0.537	8.5*	1/21
1975	$6.9 + 6.7VPC2 + (-2.4VPC2^3) + (-1.3VPC1^2) + (-5.0VPC1^3)$	0.882	15.8*	4/18
1976	$2.0 + (-0.48VPC1^3) + 0.73VPC1$	0.556	4.5*	2/10
1977	$11.4 + 1.5VPC4^4 + (-3.7VPC3) + 1.8VPC1^3 + (-4.7VPC1^2)$	0.790	7.5*	4/18
1978	$2.0 + (-0.52VPC3^2)$	0.470	5.9*	1/21
Cool				
All years	$0.16 + (-0.70VPC1) + 0.54VPC2 + 0.51VPC4$	0.755	8.4*	3/19

Table 11-6. Analysis of variance for the desert pocket mouse for the warm season (April-October). Abbreviations as in Table 11-3. Asterisk indicates $P<0.05$. See Table 11-3 for further explanation.

	Mean N/270 TN						
	CW	HM[a]	SC	SB[a]	AW[a]	SH[a]	$\bar{x}$ Annual N/270 TN
Structural Type							
I	0.08	-	2.0	-	-	-	
II	3.00	-	3.0	0.2	-	-	
III	0.10	1.78	2.3	3.5	-	-	
IV	2.74	6.50	3.9	6.5	-	4.2	
V	1.60	3.50	2.8	4.2	-	-	
VI	2.11	3.60	1.6	2.0	3.2	-	
F	7.2*	4.3*	1.2	4.2*	-	-	
df	5/20	3/12	4/20	4/16	-	-	
Years							
1974	2.0	5.2	0.1	5.8	4.3	0.7	3.5
1975	2.3	8.1	12.8	4.1	5.3	12.8	5.9
1976	0.9	2.2	5.0	2.5	3.2	5.0	2.3
1977	1.4	2.5	2.4	2.0	1.0	2.4	1.9
1978	1.4	1.2	2.5	2.0	2.3	2.5	2.0
F	1.7	6.9*	0.7	2.1	-	-	4.0*
df	4/20	4/12	4/20	4/16	-	-	4/20
Vegetation $\bar{x}$N/270 TN[b]	1.6	3.8	3.2	2.6	4.2	3.3	

[a]Some structural types not available for study.

[b]$F = 1.1$, df = 5/20, P is NS.

probability of occurrence of desert pocket mice within each habitat type as the number of times present divided by the five years of the study. We used these values in the same stepwise multiple linear regression analysis as we did for the average densities. This resulted in a significant equation:

$$\underline{P} \text{ of occurrence} = 0.35 + -0.23VPC1 + 0.23VPC4$$

(multiple R = 0.781, F = 15.7, df = 2/20, $\underline{P}<0.001$), which indicated that desert pocket mice had the least probability of being found in areas with greatest foliage density and diversity and were most likely to occur in areas with honey mesquite. Thus the vegetation characteristics important in predicting densities of desert pocket mice are similar to those used for predicting probability of occurrence.

The ANOVA indicated that desert pocket mouse densities were not significantly associated with any vegetation type in the cool time of the year, although the mean density was largest in screwbean mesquite habitats (Table 11-7). The analysis indicated a significant difference ($\underline{P}<0.05$) in densities between years, with smallest catches in 1977-1978 and largest in 1974-1975.

White-throated Woodrat

Densities of white-throated woodrats were relatively stable throughout the year; thus densities for this species were averaged for each season over the five years. These mean densities were found to be correlated with the vegetation in both seasons. The regression equations were as follows:

1. $\log_{10}$ (1 + N/270 TN in summer) = $0.24 + 0.47VPC3^2 + 0.22VPC4 + 0.17VPC2$

   (multiple R = 0.676, F = 5.3, df = 3/19, P<0.01).

2. $\log_{10}$ (1 + N/270 TN in winter) = $0.18 + (-0.61VPC3) + 0.35VPC1 + 0.18VPC2$

   (multiple R = 0.768, F = 9.1, df = 3/19, P<0.001).

In both the cool season and the warm season, low-level vegetation (VPC3) was avoided to at least some extent (negative and squared relationships to PC3). In summer, white-throated woodrats avoided places where low-level vegetation was moderately dense (negative PC3), but they were present where low vegetation was absent or very dense. In summer, white-throated woodrats were also associated with screwbean mesquite (positive PC4) and honey mesquite trees (positive PC2). In winter, they selected areas with high foliage density and diversity (positive PC1) and honey mesquite trees, but they preferred honey mesquite when foliage was very dense. White-throated woodrats were also present where honey mesquite was absent but salt cedar trees were very dense.

The ANOVA between white-throated woodrat densities in the various communities was significant ($\underline{P}\leq0.001$) and indicated that in the warm time of year greatest mean densities occurred in screwbean mesquite and cottonwood-willow and lowest densities occurred in arrowweed (Table

Table 11-7. Analysis of variance of desert pocket mouse captures in winter showing the vegetation effect and the annual effect. Asterisk indicates $P<0.05$.

Type of dominant vegetation	Mean density (N/270 TN)	By year	N/270 TN
SM	0.90	1974-75	1.12
CW	0.38	1975-76	0.84
SC	0.63	1976-77	0.53
SH	0.78	1977-78	0.19
HM	0.90	1978-79	0.49
AW	0.20		
F	1.82		3.36*
df	5/20		4/20
P	NS		*

11-8). This corresponds closely with results of the multiple linear regression analysis. In the cool time of year, the ANOVA revealed the same trend (Table 11-8), but it was not statistically significant because of wide fluctuations in numbers of woodrats caught from year to year.

Finally, equations for predicting the probability of occurrence (PO) were as follows:

1. Warm season PO = 0.72 + 0.16VPC2 + 0.12VPC4
   (R = 0.593, F = 5.4, df = 2/20, 0.05>P>0.025).

2. Cool season PO = 0.70 + (-0.16VPC3)
   (R = 0.469, F = 5.9, df = 1/21, 0.005>P>0.001).

Thus the probability of occurrence is not well predicted by the vegetation, even though it is statistically significant. In the warm season, white-throated woodrats tended to occur in greatest numbers in both honey mesquite habitat with shrubs and screwbean mesquite areas. In the cool season, white-throated woodrats were least likely to be present in areas with relatively dense vegetation at low levels. This, in general, supports the analysis using N/270 TN.

Merriam Kangaroo Rat

Merriam kangaroo rat densities were averaged across all five years for each season. During the warm season, the regression equation was as follows:

Standardized N/270 TN = -0.35 + (-1.1VPC1) + 0.42VPC4 + 0.25VPC2 (multiple R = 0.792, F = 6.8, df = 5/17, 0.005<P<0.001). Thus Merriam kangaroo rats avoided vegetation with high density and diversity (VPC1) and were attracted to areas with screwbean mesquite trees (VPC4) and honey mesquite trees with shrubs (VPC2).

From these results, we would predict the ANOVA to indicate a preference for screwbean mesquite and honey mesquite. There were too many communities with no measurable number of Merriam kangaroo rats to do an ANOVA by structural types, but since cottonwood-willow habitats tend to be above average on VPC1, low densities of Merriam kangaroo rats in these communities would be predicted. The ANOVA did, in fact, support the results of the correlation (Table 11-9).

Although differences among years were not sufficiently systematic to be statistically significant, average catches were greatest the first two years and lowest in 1977.

Probability of occurrence showed the following correlation with the vegetation:

PO in warm season = 0.42 + (-0.45VPC1) + 0.27VPC4 + 0.02VPC3 + $0.55VPC4^2$ (multiple R = 0.881, F = 15.7, df = 4/18, 0.005<P<0.001). This indicates that Merriam kangaroo rats were consistently absent from areas with high foliage density and diversity (VPC1), and that they were

Table 11-8. Analysis of variance of white-throated woodrat captures showing the vegetation effect and annual effect for the warm (April-October) and cool (November-March) times of year. Asterisk indicates $P<0.05$. Abbreviations as in Table 11-3.

Season	Type of dominant vegetation	Mean density (N/270 TN)	By year	
Warm	SM	1.94	1974	1.49
	CW	1.85	1975	1.44
	SC	1.04	1976	1.00
	HM	1.42	1977	0.93
	SH	0.42	1978	1.08
	AW	0.38		
	F	5.9*		1.0
	df	5/20		4/20
Cool	SM	1.39	1974-75	1.22
	CW	1.32	1975-76	0.84
	SC	1.09	1976-77	1.23
	HM	1.41	1977-78	0.76
	SH	1.00	1978-79	1.38
	AW	0.30		
	F	1.4		0.7
	df	5/20		4/20

Table 11-9. Analysis of variance of Merriam kangaroo rat densities showing the vegetation and annual effects for the warm (April-October) season. Asterisk indicates $P<0.05$. Abbreviations as in Table 11-3.

Type of dominant vegetation	Mean density (N/270 TN)	By year	
SM	2.52		
CW	0.37	1974	2.14
SC	1.72	1975	2.31
HM	2.11	1976	1.71
SH	0.34	1977	0.75
AW	1.87	1978	1.28
F	5.2*		2.7
df	5/20		4/20

consistently associated with screwbean mesquite. This agrees closely with the preceding analysis but varies in predicting occurrence of Merriam kangaroo rats in honey mesquite habitats with shrubs. This indicates that their presence in honey mesquite was inconsistent.

In the cool season, the regression equation was as follows:

$$\text{Standardized N/270 TN} = -0.22 + (-0.65\text{VPC1}) + 0.51\text{VPC4} + 0.52\text{VPC3} + 0.46\text{VPC4}^2$$

(multiple R = 0.742, F = 5.5, df = 4/18, $0.005<P<0.001$). This indicates that in the cool time of year, Merriam kangaroo rats were associated with screwbean mesquite (VPC4) and avoided areas with high foliage density and diversity (VPC1). Contrary to the warm season, however, they were not strongly associated with honey mesquite and shrubs (VPC2). Merriam kangaroo rats were also associated with low level foliage density and diversity (VPC3). This correlation accounted for 55% of the variance in the data.

Since there were too many habitats where there were no Merriam kangaroo rats, ANOVA by structural type could not be done. ANOVA by dominant vegetation did not lend significant support to the correlation analysis. Greatest numbers of Merriam kangaroo rats were caught in screwbean mesquite and salt cedar (loading was high on VPC4 and VPC3, respectively) and fewest were found in cottonwood-willow habitats (loading high on VPC1). The trend was not consistent enough across years to reach statistical significance. The regression equation for probability of occurrence is as follows:

$$\text{PO cool season} = 0.45 + (-0.11\text{VPC1}) + 0.35\text{VPC3} + 0.19\text{VPC4} + 0.54\text{VPC4}^2$$

(multiple R = 0.733, F = 5.2, df = 4/18, $0.01<P<0.005$).

This is in close agreement with the correlation analysis in that it indicates that Merriam kangaroo rats avoided areas with high foliage density and diversity (VPC1) and preferred screwbean mesquite (VPC4) and other habitats with low-level vegetation (VPC3). The correlation accounted for 54% of the variance in the data on occurrence of Merriam kangaroo rats.

Deer Mouse

The deer mouse was frequently absent in several habitat types or was caught in small numbers. Therefore the data for the correlation analyses are for average numbers caught over five years; seasons were not separated. The regression equation was as follows:

$$\text{Standardized N/270 TN} = 0.33 + (-0.83\text{VPC2}) + 0.22\text{VPC2}^2 + (-0.19\text{VPC4})$$

(multiple R = 0.717, F = 12.6, df = 3/42, $P<0.001$). This indicates that deer mice apparently avoid honey mesquite and are found in salt cedar (VPC2). The ANOVA for winter was not significant across vegetation types, but areas in which cottonwood-willow trees were dominant yielded the smallest capture rates, and salt cedar and screwbean mesquite yielded the largest capture rates. There were significant population changes across years, with the largest captures occurring the first two

years and the smallest in 1977-78. The equation for probability of occurrence was as follows:

$$PO \text{ cool season} = 0.72 + 0.16VPC2 + 0.12VPC4^2$$

(multiple R = 0.593, F = 5.4, df = 2/20, $0.05>\underline{P}>0.025$).

Vegetation accounted for only 35% of the variance in the probability data. This indicates that the greatest consistency of occurrence of deer mice was in areas with honey mesquite and shrubs (VPC2). Deer mice were also fairly consistently caught in stands with intermediate densities of screwbean mesquite ($VPC4^2$). Although deer mice occurred in low densities in areas with above-average foliage density and diversity, they were not consistently absent from such areas.

Southern Grasshopper Mouse

The southern grasshopper mouse was scarce, and captures were averaged over seasons and years. The regression equation was as follows:

$$\log_{10}(N/270 \text{ TN} + 1) = 0.26 + (-0.97VPC1)$$

(multiple R = 0.449, F = 5.3, df = 1/21, $0.05>\underline{P}>0.025$). This indicates that only foliage density and diversity (VPC1) showed any relationship to the mean number of southern grasshopper mice caught across seasons and habitat types for the five years of the study. Densities of southern grasshopper mice were lowest in arrowweed and were greatest in screwbean mesquite (Table 11-10). From the regression analysis, we would predict the largest populations of southern grasshopper mice to have occurred in screwbean mesquite and salt cedar, types V and VI, and in arrowweed. That arrowweed had small populations of southern grasshopper mice rather than large ones is one of the reasons the correlations analysis was not very successful in relating mean catches of this species to the vegetation. The equation for probability of occurrence was:

$$PO = 0.30 + 0.34VPC4 + (-0.16VPC4) + (-0.08VPC3)$$

(multiple R = 0.637, F = 4.33, df = 3/19, $0.025>\underline{P}>0.01$). This indicated that southern grasshopper mice occurred most consistently in screwbean mesquite (VPC4), and that this relationship involved two trends. The first trend was linear, with the probability of southern grasshopper mouse occurrence increasing as VPC4 increased. The other trend indicated a tendency for probability of occurrence to drop sharply in habitats loading high on VPC4 and to increase sharply in habitats with lower scores on VPC4. Finally, southern grasshopper mice were caught least consistently in areas with either much greater or much smaller than average foliage density and diversity at low levels (VPC3) and more consistently at intermediate low foliage density.

Western Harvest Mouse

The western harvest mouse was another scarce species, and capture data were analyzed in a way similar to that for the southern grasshopper mouse. The equation from the correlation analysis was as follows:

$$\log_{10}(N/270 \text{ TN} + 1) = 0.17 + 0.03VPC1 + 0.1VPC3$$

Table 11-10. Analysis of variance for southern grasshopper mouse densities showing the vegetation and seasonal effects. Asterisk indicates $P<0.05$. Abbreviations as in Table 11-3.

Type of dominant vegetation	Mean density (N/270 TN)	By season	
SM	0.90	Warm	0.10
CW	0.12	Cool	0.15
SC	0.13		
HM	0.09		
AW	0.03		
F	3.6*		0.4
df	5/5		2/5

(multiple R = 0.795, F = 17.4, df = 2/20, $P<0.001$). This analysis revealed a strong relationship between western harvest mice and total foliage density and diversity. Changes in western harvest mouse density were greater for very large or very small values of foliage density and diversity. Between the extremes, relatively large changes in foliage density and diversity resulted in small changes in the total catch. The second step in the equation indicated a preference for vegetation at low levels (VPC3).

Since cottonwood-willow habitats loaded relatively high on VPC1, it is not surprising that an ANOVA indicated that the largest average catches of western harvest mice were from cottonwood-willow (Table 11-11). Differences among the dominant vegetation types were not consistent enough to be statistically significant, however.

The equation resulting from the correlation of the probability of occurrence on the vegetation variables was:

$$PO = 0.12 + 0.013VPC1^2 + 0.088VPC3 + 0.086VPC1$$

(multiple R = 0.756, F = 8.4, df = 3/19, $P<0.001$). This indicates that the probability of occurrence of the western harvest mouse was also best accounted for by the total foliage density and diversity (VPC1) and foliage density and diversity at the lowest levels (VPC3), thus providing agreement with the results of abundance correlations.

Desert Kangaroo Rat

The multiple linear regression yielded the following predictive equation:

$$\log_{10}\text{Density} = 0.069 + (-0.053VPC1) + 0.036VPC2$$

(multiple R = 0.551, F = 4.3, df = 2/20, $0.05>P>0.025$). This suggests that desert kangaroo rats avoided dense vegetation (VPC1) and were associated with honey mesquite. From field work, it was obvious that this species was found only in areas with sand dunes. Since sand dunes were never present in dense vegetation, lack of association of the desert kangaroo rat with this type of vegetation was not surprising. Honey mesquite was found on the periphery of the floodplain, where conditions are drier and vegetation is sparser. It is here that sand dune formation is also most probable. Thus the correlation of the desert kangaroo rat with honey mesquite may not be a cause-effect relationship but probably reflects the greater likelihood of sand dunes occurring in stands where honey mesquite and shrubs are numerous.

The ANOVA (Table 11-12) indicated a significant difference in desert kangaroo rat densities in areas where the dominant trees are different. Desert kangaroo rats reached peak densities in honey mesquite and were absent from areas dominated by cottonwood-willow and salt cedar-honey mesquite. This is highly supportive of the linear regressions, since areas with cottonwood-willow have above-average foliage density and diversity, and honey mesquite contributes positively to VPC2.

Table 11-11. Analysis of variance of western harvest mouse captures showing the vegetation and seasonal effects. Abbreviations as in Table 11-3.

Type of dominant vegetation	Mean density (N/270 TN)	By season	
SM	0.01	Warm	0.09
CW	0.29	Cool	0.09
SC	0.03		
HM	0.03		
SH	0.06		
AW	0.12		
F	4.7		0.0
df	5/5		2/5

Table 11-12. Analysis of variance of desert kangaroo rat captures showing the vegetation and seasonal effects. Asterisk indicates $P<0.05$. Abbreviations as in Table 11-3.

Type of dominant vegetation	Mean density (N/270 TN)	By season	
SM	0.077		
CW	0.000		
SC	0.072		
HM	0.178		
SH	0.000	Cool	0.059
AW	0.100	Warm	0.083
F	5.49*		1.3
df	5/5		1/5

The regression equation predicting the probability of occurrence is:

$$PO = 0.12 + (-0.09VPC1) + 0.06VPC2$$

(multiple R = 0.607, F = 5.75, df = 2/20, $0.025 > P > 0.01$). This supports the conclusion that desert kangaroo rats avoid areas with dense vegetation and reflects the fact that captures were greatest in honey mesquite.

House Mouse

The house mouse was irregularly caught in a total of 10 habitat types. These habitat types had little in common. The species was caught in CW I half of the time, but dropped to an occurrence rate of 0.2 in CW IV and SC IV, and was lower in other habitat types (Table 11-13). Meaningful habitat relationships cannot be inferred with the paucity of data.

Hispid Cotton Rat

A total of six hispid cotton rats was caught in five habitat types (SM III, SM IV, CW III, SC V, and SH IV). Hispid cotton rats occurred in SM IV and SH IV in 2 of 10 seasons and were caught in only one season of one year in the other habitat types. This species occasionally wanders into riparian vegetation from marshy habitats, where it is reasonably abundant (Anderson and Ohmart unpubl. data).

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Habitats in which the greatest number of each rodent species was caught are shown in Figure 11-1. Assuming that capture rates represent rodent habitat preferences, some species clearly have widely differing preferences. These species can be separated into three major groups. One group, including the cactus mouse, white-throated woodrat, and western harvest mouse, reached greatest densities in areas with high foliage density and diversity. However, this was only a general similarity in habitat preference; the cactus mouse reached peak abundance in dense salt cedar, the white-throated woodrat was most common in mesquite vegetation, and the western harvest mouse reached greatest numbers in stands with a large amount of vegetation greater than 4.6 m (15 ft) tall.

Another group, including the desert pocket mouse, desert kangaroo rat, Merriam kangaroo rat, and southern grasshopper mouse, was characterized primarily by low numbers in areas with dense vegetation. This presumably indicates avoidance of these areas. The desert pocket mouse and desert kangaroo rat were primarily associated with fairly open stands of honey mesquite where shrubs were at least moderately abundant. The greatest numbers of Merriam kangaroo rats were caught in stands of moderately dense screwbean mesquite, although the species occurred elsewhere in reduced numbers. The southern grasshopper mouse occurred only within moderately dense vegetation but seemed to have no specific vegetation preference.

Table 11-13. Distribution of house mouse captures in riparian vegetation. Abbreviations as in Table 11-3.

Mean density (N/270 TN) across all seasons						
	Structural type					
Vegetation type	I	II	III	IV	V	VI
SM	-	0	0	0.01	0	0
CW	0.53	0	0	0.04	0	0
SC	1.00	0	0.14	0.03	0.06	0
HM	-	-	0	0.02	0.05	0
SH	-	-	-	0.03	-	-
AW	-	-	-	-	-	0

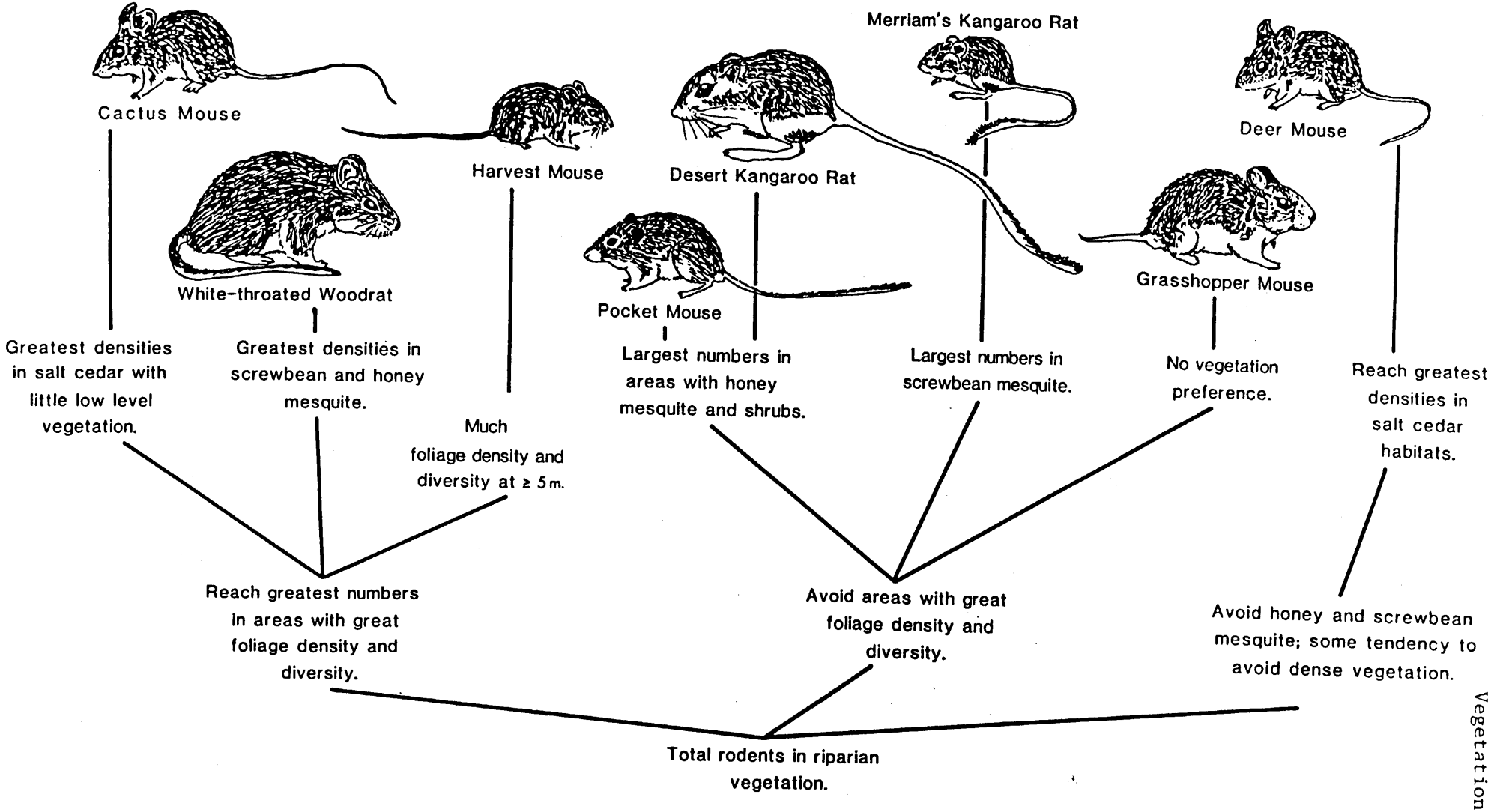

Figure 11-1. Summary of the vegetation relationships of eight species of rodents found in riparian vegetation along the lower Colorado River.

Finally, the deer mouse seemed to avoid mesquite and to some extent, very dense vegetation. It was always a numerically dominant species in disturbed areas such as burns. It was also the numerically dominant species in agricultural areas (Anderson and Ohmart 1982a: Chapter 18).

Obviously there is no simple way to manage for all of these rodents. The recommendation likely to benefit the most species is to create an area which is horizontally diverse. If salt cedar is absent from an area, the cactus mouse will probably not attain maximum densities. This species does, however, occur almost everywhere and reaches moderate densities in several vegetation types. An area with cottonwood-willow, honey mesquite, palo verde, and shrubs should attract fair numbers of this species. We captured 14 cactus mice/270 trapnights (TN) two years after clearing, by which time quail bush was the dominant vegetation present (Anderson and Ohmart 1982a:Chapter 18). Where cactus mice numbers were low, populations of Merriam kangaroo rats and desert pocket mice tended to be relatively larger. If an area is bare or has some bare ground, Merriam kangaroo rats and desert pocket mice might find it even more attractive.

Desert kangaroo rats will be present only if the area is sandy. If sand is present, proximity to the nearest desert kangaroo rat colony would determine the likelihood of pioneers moving into the area. If a colony is not nearby, live-trapping of desert kangaroo rats in one area and releasing them in the created habitat would probably be successful.

If a revegetated area initially involved clearing, the deer mouse would probably invade the area. This happened on our revegetation plot on the Cibola National Wildlife Refuge, where 16 deer mice were caught in 270 TN two years after clearing (Anderson and Ohmart 1982b:Chapter 5). It was the only species present (three were caught) two months after clearing, and one year after clearing three (75% of total) were caught in 270 TN.

The size and age of the vegetation may be important in determining whether the western harvest mouse or southern grasshopper mouse will establish themselves in a manipulated area. We did not capture any individuals of these species on the refuge revegetation site.

LITERATURE CITED

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CHAPTER 12

COYOTE FOOD HABITS ALONG THE LOWER COLORADO RIVER

INTRODUCTION

The relationship of an organism to its environment is based in part on the organism's food habits. A knowledge of these food habits, therefore, is valuable for the management of the species.

Many studies have shown that coyotes have a diverse diet (Sperry 1941, Murie 1945, Gier 1957, Korschgen 1957, Gipson 1974, Andrews and Boggess 1978, Berg and Chesness 1978, Kleiman and Brady 1978). The proportion of foods in the diet varies in relation to local and seasonal availability of foods (Sperry 1941, Fitch 1948, Ferrel et al. 1953, Fichter et al. 1955, Gipson 1972).

Coyote scats were collected over a five-year period (1974 through 1978), in riparian habitats along the lower Colorado River. Levels of certain food items were simultaneously censused in the same region. 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 abundances.

This report lists all items found in coyote scats over the study period. Typical foods (those which occurred each year) are listed, and principal foods (those which occurred with high frequency and volume displacement) are identified. The relation of some typical food abundances to coyote food habits and forage preferences for different habitats are discussed. Management implications are derived from these data.

METHODS

Transects of 800- or 1600-m (0.5- or 1-mi) lines were located in five habitat types of riparian vegetation along 475 km (295 mi) of the lower Colorado River, from Davis Dam to the Mexican border. Habitat types were: (1) cottonwood-willow, (2) honey mesquite, (3) screwbean mesquite, (4) salt cedar, and (5) salt cedar-honey mesquite (see Chapter 2 for community descriptions). In densely vegetated communities a path had to be cut (0.75 to 1 m wide [2.5 to 3.3 ft]) to allow unimpeded movement through the area. These transects were the same ones used for censusing birds.

All scats were first cleared from the transects. Then coyote scats were collected two or three times each month from 1975 to 1978 along these transects after bird censusing. Scats were collected on a less regular basis in 1974. Each scat was individually bagged and labeled with the transect number and date of collection. In the laboratory, scats were soaked in water until soft, then strained in a 1/16-inch mesh strainer

to remove mucous and soil particles. All food items were sorted and identified with the use of a reference collection. Animal remains were identified by feathers, scales, teeth, bones, and bone fragments. Fragments that could not be identified were grouped in an "unidentified rodent, mammal, or bird" category. Volumetric displacement (when measurable) and frequency of occurrence were determined for each food item.

Frequency (F) equals percent of all coyote scats examined per month in which a food item occurred. Volume (V) equals percentage of total volume displaced per month. Annual values were an average of months. V/F ratios were calculated for items occurring in coyote scats in each of the five years. Comparisons between years incorporate data for four years (1974 through 1977). Annual comparison of data for 1978 was not included because coyote scats were collected for only six months that year.

Relative densities of small rodents were determined seasonally in the five habitat types throughout the duration of the study. These results are reported in Chapters 10 and 11. Parallel lines with 15 stations in each line were used. Trap lines were 15 m apart and each contained two museum specials and a rat trap. Testes, seminal vesicles, and embryos were measured and reproductive conditions were noted for trapped specimens. The reproductive biology of rodent species is reported in Chapter 10. Birds were simultaneously censused along transects two to three times per month from 1975 to 1978 using a modified Emlen (1971) technique. Mammal trapping and bird censusing are discussed in detail in Chapter 2.

Seasons considered for coyote scat analysis were: winter (December, January, February); spring (March, April, May); summer (June, July, August); and fall (September, October, November). Seasons for rodent population analysis were: winter (November through March) and summer (April through October). Seasons for avian population analysis were: winter (December January, February); spring (March, April); summer (May, June, July); late summer (August, September); and fall (October, November).

Coyote scats per habitat type per year were divided by the total meters of transect in each habitat type to yield a standard measure of coyote scats/meter of habitat type per year. Each of the five habitat types had a different number of transects which were established along roads or cleared paths. The number of coyote scats/meter of road transect was compared to the number of coyote scats/meter of path transect in each habitat type, except in more open honey mesquite, where all transects were roads. Percent of difference between number of coyote scats on roads and paths was multiplied by the proportion of transects that were road transects in that habitat type. This value was used as a correction factor for removing bias caused by the appeal of road transects to coyotes. Coyote scats were not collected from each transect on a monthly basis in 1974, and in 1978 scats were collected for only six months; therefore data from 1974 and 1978 were not used in habitat comparisons.

Mesquite fruit drop was measured on 15 randomly selected trees along each of eight transects in both honey and screwbean mesquite habitats. Mesquite pods on the ground under the canopy were counted each month from August to December in 1976 and 1977. The number of pods encircled by a 0.1-m-diameter hoop was recorded as the hoop was flipped and moved from an outer canopy edge to the opposite outer canopy edge. Pod counts were extrapolated to a m^2 and then multiplied by the mean tree canopy coverage value (in m^2) to estimate average pod production per mesquite tree. Average tree canopy coverage was determined by halving the north-south diameter of the canopy and using that measure as the radius in the formula for the area of a circle. This approximated ground cover by a given tree. The average pod production per mesquite tree was multiplied by the average number of trees per 40 ha to estimate pod production per 40 ha. This value was multiplied by the average weight of a single pod to estimate weight of pods per 40 ha.

RESULTS

Coyote Diet Composition

The following items were found in coyote scats over the five-year period: 19 mammalian species, 20 plant species, two bird species, two reptilian species, eggshell remains, nine orders of arthropods, unidentified fish, and miscellaneous items such as trash, leather, charcoal, gravel, shot, etc. (Table 12-1). There were also nine unidentified categories of foods that may have included other items in addition to those identified.

Compared with food frequencies in other coyote studies (Table 12-2), percent frequency of occurrence of rabbits, rodents, deer, and livestock was lower in the present study. A majority of other studies (Table 12-2) identified all mammalian species; unidentified mammals, in studies with this category, represented a relatively small proportion. In the present study unidentified mammals composed the largest category of mammalian foods (33%). Rabbit and rodent remains probably were not as low in actuality compared to other studies because they may have been placed in the unidentified mammal group. Rabbits and rodents were the most frequently identified mammals. Deer and livestock were much less frequent. It is likely that rabbits and rodents were most frequent in the unidentified mammalian group. Plants were more frequent in the present study compared with other studies (Table 12-2).

Frequency and Volume Proportions Within Mammalian and Plant Groups

Mammals

Unidentified mammals had the greatest percent frequency of occurrence in coyote scats in all years (Fig. 12-1). Rodents were second and rabbits were third in three of four years (1976 was the exception when they exchanged rank). Categories labeled "domestic" (cattle and sheep) and "other" were always next to lowest and lowest, respectively. The pattern of change between years in rabbits corresponded oppositely to that of rodents.

Table 12-1. Summary of food items identified in coyote scats (1974-1978). Items are expressed in percent frequency and percent total volume.

Food item	1974 (N = 104) % Freq.	% Vol.	1975 (N = 405) % Freq.	% Vol.	1976 (N = 332) % Freq.	% Vol.	1977 (N = 706) % Freq.	% Vol.	1978 (N = 74) % Freq.	% Vol.
MAMMAL										
Antelope ground squirrel	-	-	0.5	0.1	0.3	0.1	1.0	1.0	-	-
Bighorn sheep	-	-	-	-	0.3	0.5	0.1	0.2	-	-
Cactus mouse	-	-	-	-	0.3	0.1	0.1	0.1	-	-
Cotton rat	1.0	1.0	0.7	1.0	1.2	1.1	0.4	0.3	-	-
Cottontail rabbit	7.7	7.7	10.9	12.1	22.3	28.0	8.7	11.0	6.8	10.0
Desert shrew	-	-	-	-	-	-	0.1	-	-	-
Domestic cattle	2.9	1.2	0.7	0.5	1.5	1.7	0.6	-	2.7	2.1
Domestic sheep	1.0	0.3	1.5	1.1	1.2	1.1	1.8	0.6	-	-
Grasshopper mouse	-	-	0.3	0.2	-	-	-	-	-	-
House mouse	-	-	-	-	-	-	0.1	-	1.4	0.4
Jackrabbit	-	-	0.3	0.0	-	-	-	-	-	-
Merriam kangaroo rat	4.8	1.0	3.9	2.2	2.7	1.4	0.3	0.2	-	-
Mule deer	1.0	1.4	0.7	0.6	-	-	0.4	-	-	-

Table 12-1. (cont.)

Food item	1974 (N = 104) % Freq.	% Vol.	1975 (N = 405) % Freq.	% Vol.	1976 (N = 332) % Freq.	% Vol.	1977 (N = 706) % Freq.	% Vol.	1978 (N = 74) % Freq.	% Vol.
Muskrat	1.9	0.8	2.7	2.6	0.9	0.8	0.7	0.9	-	-
Pocket mouse	-	-	-	-	1.5	0.8	0.7	0.3	-	-
Porcupine	-	-	0.3	0.0	-	-	-	-	-	-
Skunk	-	-	-	-	-	-	0.1	0.1	-	-
Unidentified canid	-	-	0.3	0.2	0.9	0.6	-	-	-	-
Unidentified leporid	1.0	1.0	0.5	1.2	-	-	-	-	-	-
Unidentified rodent	7.7	4.7	4.0	2.3	4.5	2.2	6.2	4.1	14.9	18.3
Unidentified small mammal	26.9	9.7	30.4	15.2	28.0	13.0	46.5	18.8	47.3	31.5
Woodrat	5.8	5.0	8.4	6.7	6.6	4.5	6.5	5.1	14.9	7.3
Valley pocket gopher	1.0	0.5	0.7	0.9	1.2	2.1	0.3	0.4	-	-
TOTAL MAMMALS	62.5	34.3	66.7	46.9	73.5	58.0	74.8	43.2	88.0	79.6
ARTHROPOD										
Ant	-	-	-	-	0.3	0.0	0.1	0.0	-	-
Wasp	-	-	-	-	0.3	0.1	0.1	0.0	-	-
Beetle	1.0	0.0	2.0	0.2	7.8	0.6	1.3	0.4	1.4	0.0

Table 12-1. (cont.)

Food item	1974 (N = 104) % Freq.	% Vol.	1975 (N = 405) % Freq.	% Vol.	1976 (N = 332) % Freq.	% Vol.	1977 (N = 706) % Freq.	% Vol.	1978 (N = 74) % Freq.	% Vol.
Botfly larvae	1.0	0.0	3.0	0.1	3.9	0.1	2.4	0.1	2.7	0.0
Cicada	-	-	-	-	0.3	0.0	0.1	0.0	-	-
True bug	-	-	-	-	0.6	0.0	0.1	0.0	-	-
Grasshopper	1.0	0.5	-	-	0.9	0.0	1.6	0.1	-	-
Lepidopteran	-	-	-	-	-	-	-	-	2.7	0.7
Scorpion	1.0	0.0	-	-	-	-	0.1	0.0	1.4	0.0
Crayfish	1.0	0.0	0.3	0.1	0.9	0.6	0.3	0.0	-	-
Unidentified insect	4.8	0.0	4.4	0.0	1.8	0.0	16.28	1.0	16.2	0.04
BIRDS										
Eggshell remains	1.0	0.0	2.5	0.1	4.2	0.3	1.4	0.0	1.4	0.0
Gambel Quail	-	-	0.3	0.0	0.3	0.0	-	-	-	-
Unidentified bird	26.9	3.7	26.7	4.4	25.6	2.6	29.5	2.5	28.4	1.7
Unidentified hawk	-	-	0.3	0.0	-	-	-	-	-	-
White-winged Dove	-	-	-	-	-	-	0.3	0.1	-	-

Table 12-1. (cont.)

Food item	1974 (N = 104) % Freq.	% Vol.	1975 (N = 405) % Freq.	% Vol.	1976 (N = 332) % Freq.	% Vol.	1977 (N = 706) % Freq.	% Vol.	1978 (N = 74) % Freq.	% Vol.
FISH										
Unidentified fish	1.0	0.1	3.5	0.2	4.5	0.2	5.2	0.3	2.7	0.2
REPTILES										
Rattlesnake	-	-	-	-	0.3	0.1	0.3	0.0	-	-
Spiny lizard	1.0	0.5	1.0	0.0	1.8	0.1	0.4	0.1	-	-
Unidentified lizard	-	-	0.3	0.0	0.3	0.0	1.2	0.1	2.7	0.04
Unidentified reptile	-	-	0.7	0.0	-	-	2.2	0.1	-	-
Unidentified snake	-	-	-	-	3.6	0.2	0.9	0.0	2.7	0.0
PLANT										
Arrowweed	-	-	5.9	0.1	16.3	0.0	5.2	0.0	6.8	0.04
Buckwheat	-	-	0.7	0.0	1.5	0.0	1.4	0.0	-	-
Date palm	2.0	0.4	-	-	1.8	0.8	0.7	0.0	-	-
Grape seeds	-	-	-	-	0.3	0.0	-	-	-	-
Grass	10.6	0.0	18.5	1.0	35.2	0.4	28.2	1.0	25.7	0.0
Goosefoot	-	-	4.2	0.0	3.1	0.0	0.1	0.0	4.1	0.0

Table 12-1. (cont.)

Food item	1974 (N = 104) % Freq.	1974 (N = 104) % Vol.	1975 (N = 405) % Freq.	1975 (N = 405) % Vol.	1976 (N = 332) % Freq.	1976 (N = 332) % Vol.	1977 (N = 706) % Freq.	1977 (N = 706) % Vol.	1978 (N = 74) % Freq.	1978 (N = 74) % Vol.
Hackberry	-	-	0.5	0.0	2.1	0.0	1.3	0.0	17.2	0.0
Honey mesquite	47.1	23.9	69.1	32.1	37.4	13.8	34.3	21.1	17.6	10.6
Pyracantha	-	-	-	-	-	-	0.1	0.0	-	-
Melon	5.8	0.9	2.0	0.3	2.1	0.0	2.4	0.2	2.7	1.2
Orange fruit	-	-	-	-	0.3	1.0	0.1	0.0	-	-
Prickly pear	-	-	0.3	0.2	0.6	0.2	1.0	0.3	-	-
Salt cedar	56.7	0.2	46.9	0.2	49.7	0.2	47.5	0.5	41.9	0.07
Saltbush	-	-	-	-	1.2	0.0	0.1	0.0	-	-
Sand-bur	-	-	0.3	0.0	0.3	0.0	-	-	-	-
Screwbean mesquite	57.7	34.5	23.5	12.8	33.7	19.4	38.5	25.8	12.2	5.1
Sedge	-	-	0.3	0.0	-	-	-	-	-	-
Sorghum	1.0	0.0	0.3	0.0	1.2	0.1	0.9	0.0	14.0	0.0
Unidentified mesquite	-	-	-	-	15.4	0.1	7.2	0.4	14.9	0.0
Unidentified plant matter	7.7	0.2	2.9	0.2	2.4	0.4	18.6	0.3	6.8	0.0
Unidentified seeds	0.4	0.0	4.9	0.0	0.6	0.0	0.1	0.0	1.4	0.0

Table 12-1. (cont.)

Food item	1974 (N = 104) % Freq.	1974 (N = 104) % Vol.	1975 (N = 405) % Freq.	1975 (N = 405) % Vol.	1976 (N = 332) % Freq.	1976 (N = 332) % Vol.	1977 (N = 706) % Freq.	1977 (N = 706) % Vol.	1978 (N = 74) % Freq.	1978 (N = 74) % Vol.
Wheat	5.8	0.3	8.6	0.7	5.7	0.3	3.8	0.1	9.4	0.04
Willow	-	-	-	-	0.6	0.0	0.1	0.0	1.4	0.07
TOTAL PLANT	194.8	60.2	188.9	47.6	211.5	36.7	191.5	49.7	158.6	17.1
MISCELLANEOUS ITEMS										
Charcoal	-	-	0.3	0.0	0.9	0.0	-	-	-	-
Fecal pellets	4.8	0.0	4.7	0.1	4.2	0.0	0.1	0.0	-	-
Lead shot	-	-	0.7	0.0	0.6	0.0	-	-	-	-
Leather	1.9	0.5	0.5	0.1	-	-	-	-	-	-
Parasitic worms	-	-	0.3	0.0	0.9	0.0	-	-	-	-
Rock or gravel	6.7	0.1	13.1	0.1	15.6	0.1	20.3	0.1	20.8	0.02
Trash	4.8	0.6	1.0	0.0	2.4	0.3	3.0	0.2	1.4	0.0

Table 12-2. Literature summary of the frequency of food groups found in coyote scats or stomachs.

Authority	Locality	n	Source	Percent frequency							
				Rabbit	Rodent	Deer	Livestock	Poultry	Bird	Plant	Invertebrate[a]
Richens and Hugie 1974	ME	51	Stomach	19.6	19.6	15.9	11.8[b]	-	19.6	88.4	17.7
Gipson 1974	AR	168	Stomach	7.0	13.0	5.0	13.0	34.0	10.0	36.0	11.0
Korschgen 1957	MO	770	Stomach	55.3	33.9	2.9	13.8	15.8	6.2	19.7	7.4
		326	Scat	80.4	28.5	-	2.7	2.8	9.5	35.3	10.4
Mathwig 1973	IA	-	Stomach	59.6	36.8	-	31.1	3.3	17.9	64.2	2.0
		147	Scat	40.8	38.4	3.4	20.4	1.4	19.7	85.7	34.7
Andrews and Boggess 1978	IA	246	Scat	42.3	35.4	-	33.7	3.3	29.2	80.8	37.4
Berg and Chesness 1978[c]	MN	670	Scat	50.7	25.5	24.6	9.0	-	15.7	48.1	-
Gier 1957	KS	1190	Stomach	57.1	36.4	-	-	15.7	9.4	4.8	1.8
Fichter et al. 1955	NE	2500	Scat	23.0	99.3	7.6	30.5	1.1	33.5	39.2	26.0
Murie 1940	WY	5086	Scat	3.9	59.6	1.0	0.05	0.17	3.0	2.0	9.5
Murie 1945	MT	286	Scat	31.2	39.8	1.1	-	-	1.6	0.3	1.6

Table 12-2. (cont.)

Authority	Locality	n	Source	Percent frequency							
				Rabbit	Rodent	Deer	Livestock	Poultry	Bird	Plant	Invertebrate[a]
Johnson and Hansen 1977	AZ	250	Scat	41.0	14.0	-	-	-	23.3	12.8	0.2
		125	Scat	13.1	63.8	-	-	-	11.4	5.7	1.7
Bond 1939	CA	282	Scat	38.8	65.7	26.1	8.8	-	16.2	16.9	7.4
Ferrel et al. 1953[d]	CA	2222	Stomach	32.4	47.8	16.7	23.0	3.9	18.3	11.1	17.9
Hawthorne 1972	CA	384	Scat	1.3	78.6	35.2	15.2	-	3.7	45.3	5.5
Sperry 1941	17 western states	8331	Stomach	43.0	32.0	6.0	20.0	3.0	10.0	6.0	6.0
This study[e]	AZ and CA	1621	Scats	11.3	21.4	0.7	2.8	-	27.7	188.9	16.6

[a]Invertebrates other than parasites.

[b]Includes poultry.

[c]Values are averages of January-July, 1973-1975 data (541 scats) and August-December, 1970-1973 data (129 scats).

[d]Values are averages of data from five regions in California.

[e]Unidentified mammal category is not included.

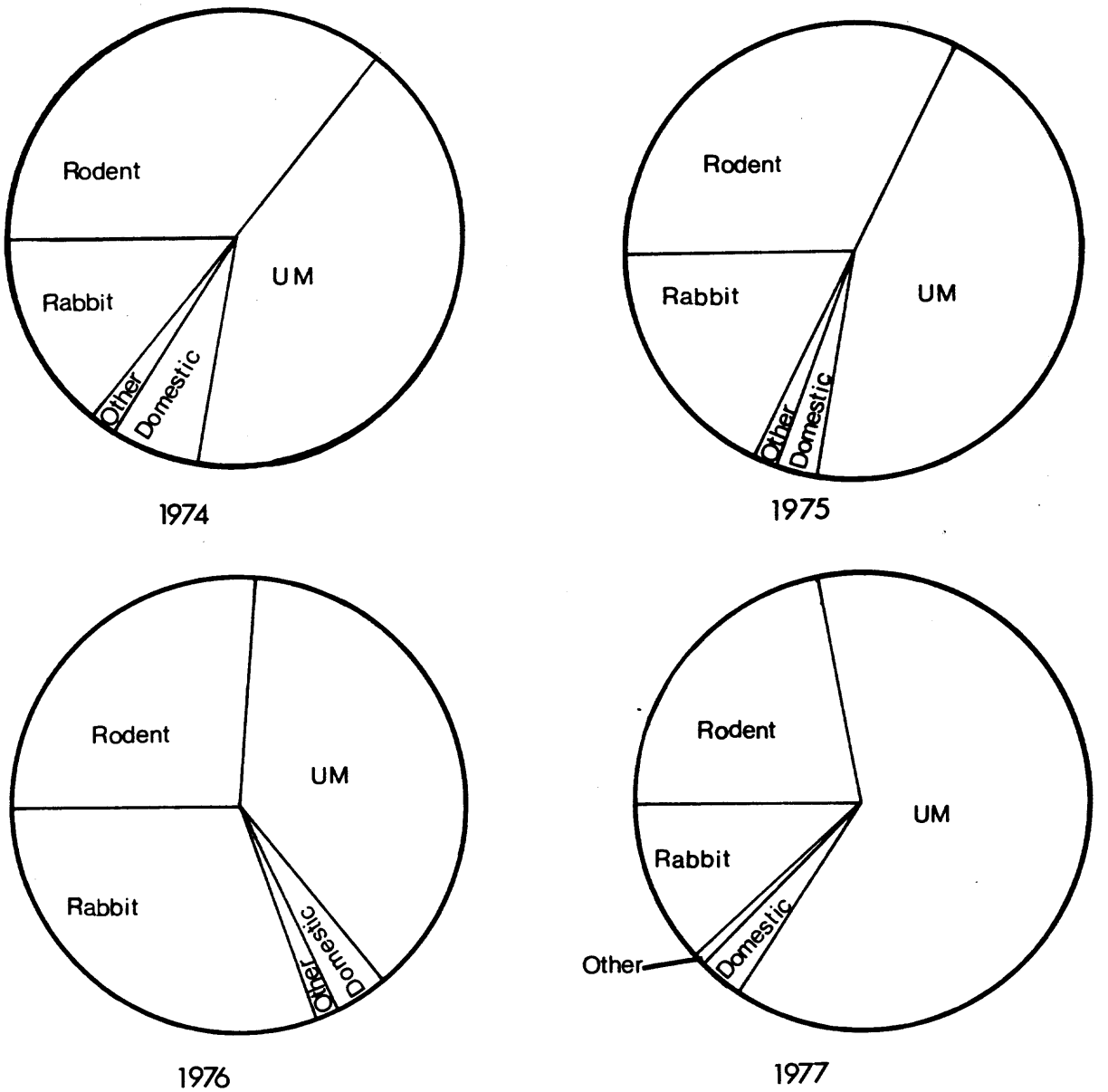

Figure 12-1. Proportion of mammal foods occurring in coyote scats (1974-1977). Domestic = cattle, sheep; Other = bighorn sheep, mule deer, skunk, desert shrew, unidentified canid; Rabbit = cottontail, black-tailed jackrabbit; UM = unidentified mammal; Rodent = all others listed in Table 12-1.

Percent volume among rabbits, rodents, and unidentified mammals in coyote scats was inconsistent (Fig. 12-2) although, as with percent frequency of occurrence, the pattern of change between years in rabbits corresponded oppositely to that of rodents. Percent volume of rabbits, rodents, and unidentified mammals in coyote scats in 1974 ranked as follows: (1) rodent, (2) rabbit and unidentified mammal. In 1975 they were nearly equivalent. In 1976 these were ranked: (1) rabbit, (2) rodent and unidentified mammal; in 1977 they were ranked: (1) unidentified mammal, (2) rabbit and rodent. "Domestic" and "other" were consistently the smallest proportions. Values for "domestic" were marginally higher than for "other."

Plants

Mesquite was the most frequently found plant in coyote scats, and salt cedar was the second most frequently encountered plant each year (Fig. 12-3). Grass ranked third in three years. "Other" and agricultural crops were fourth and fifth, respectively, in three years.

Mesquite displaced the most volume in coyote scats each year (Fig. 12-4). Salt cedar was lowest or next lowest in volumetric proportions. Agricultural crops were second in three of four years. "Other" fluctuated in fourth or fifth position. Grass fluctuated in rank.

V/F Values Within Mammalian and Plant Groups

Mammals

Volume/frequency (V/F) values for mammals in coyote scats showed rabbits consistently highest (Table 12-3). Values for domestic and other groups fluctuated widely, perhaps because of their more sporadic availability relative to rabbits or rodents. In three of four years rodents had equal or higher V/F ratios than domestic. Mammalian V/F measures were generally higher than plants.

Plants

Mesquite had highest plant V/F in coyote scats each year (Table 12-3). Agricultural crops were second, grass third, and salt cedar was fourth, except in 1974. Mesquite values were most similar to unidentified mammals.

Typical Foods

The complete composition of the coyote diet over all years and seasons differed from the typical diet. Some foods did not occur in the analysis in each of the four annual comparisons. Items which occurred in scats each year, 1974 through 1977, and appeared in volumetric displacement in most years, composed the typical foods of the coyote diet. These included 24 of 68 items, disregarding the miscellaneous category. By group classification, typical foods were:

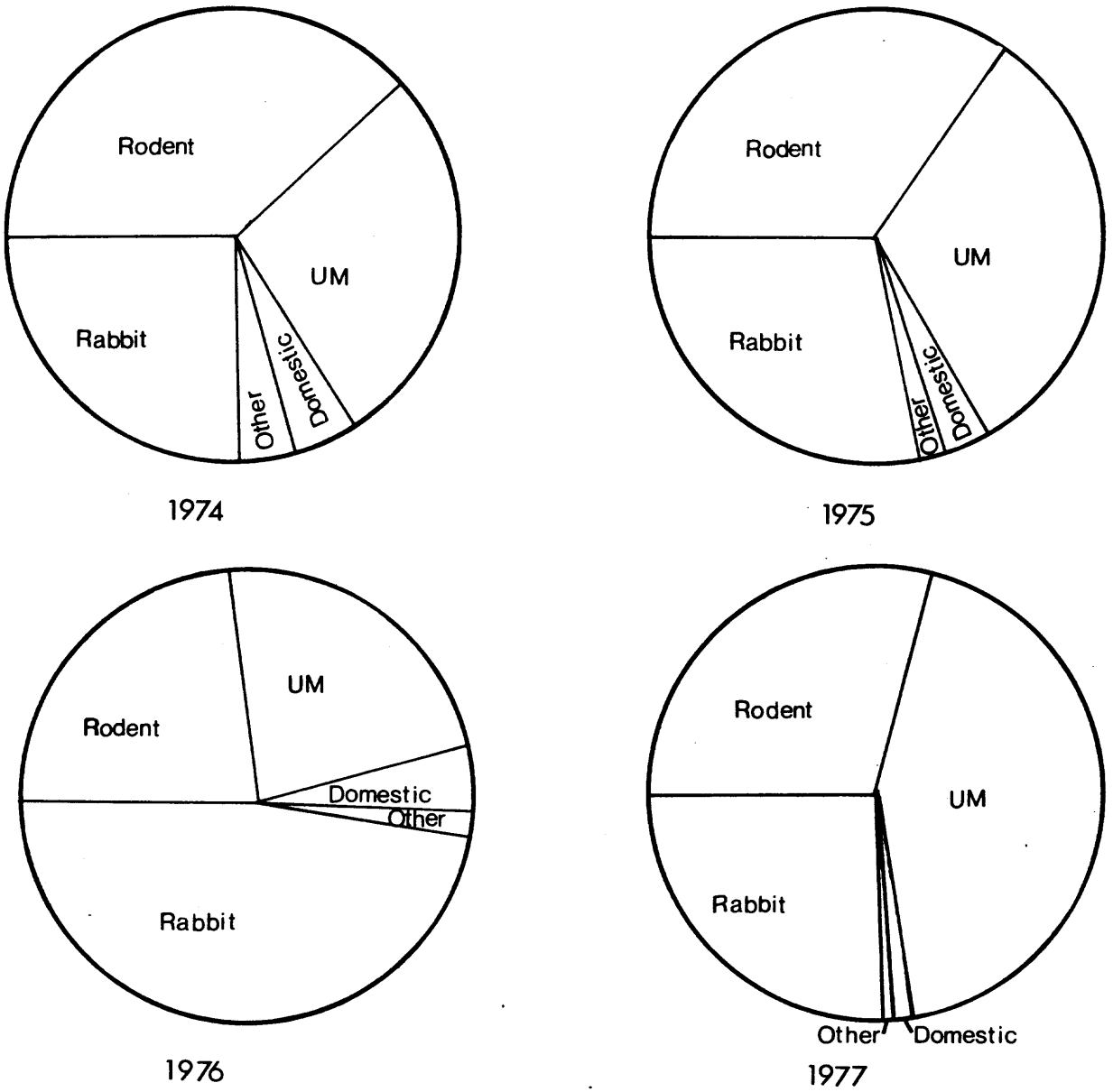

Figure 12-2. Proportion of the volume displaced by mammal foods in coyote scats (1974-1977). Categories are explained in Figure 12-1.

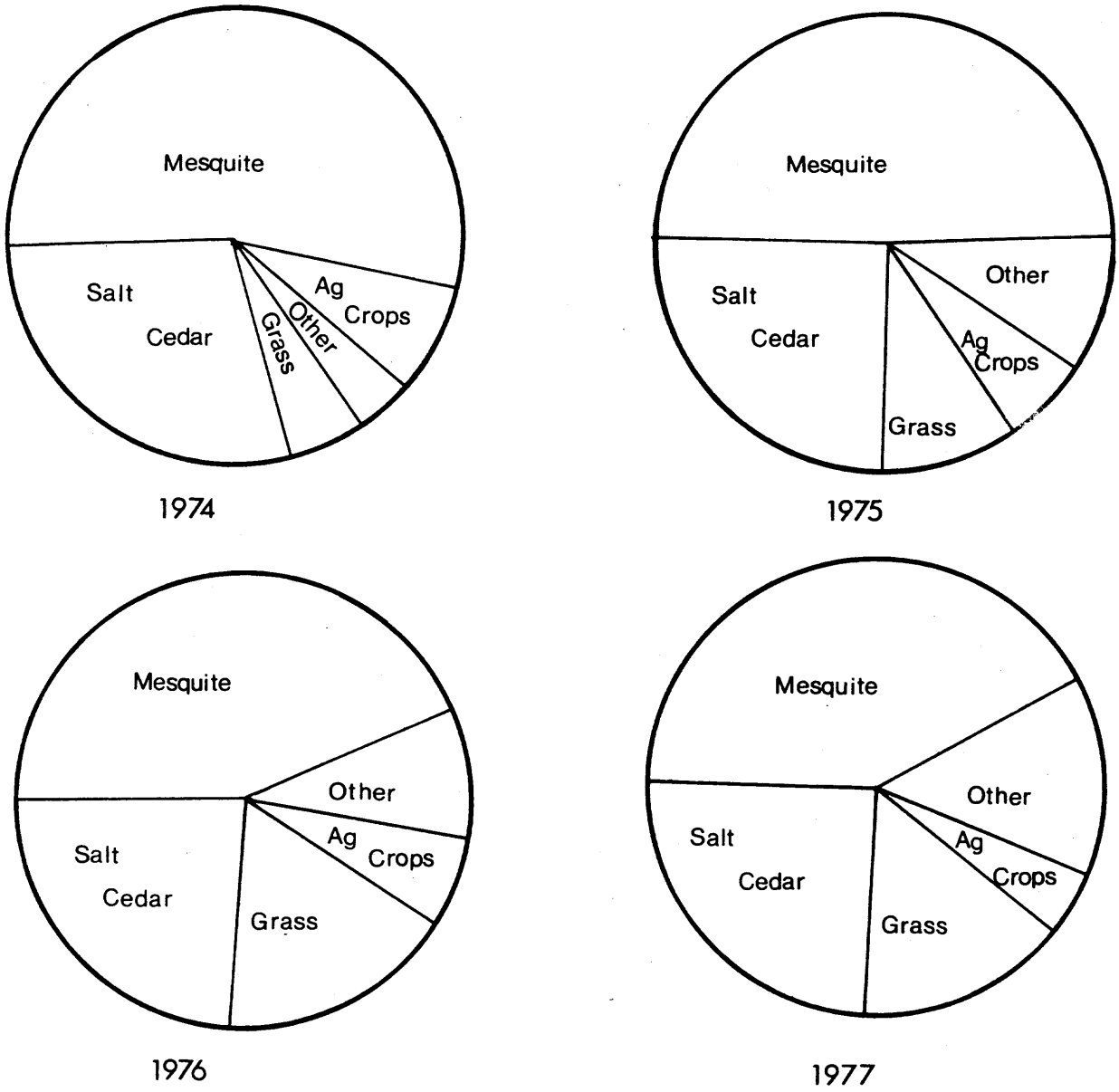

Figure 12-3. Proportion of plant foods occurring in coyote scats (1974-1977). Mesquite = honey, screwbean, and unidentified mesquite; Ag crops = date palm, grape seed, melon, orange fruit, sorghum, wheat; Other = unidentified plant and seeds, shrubs.

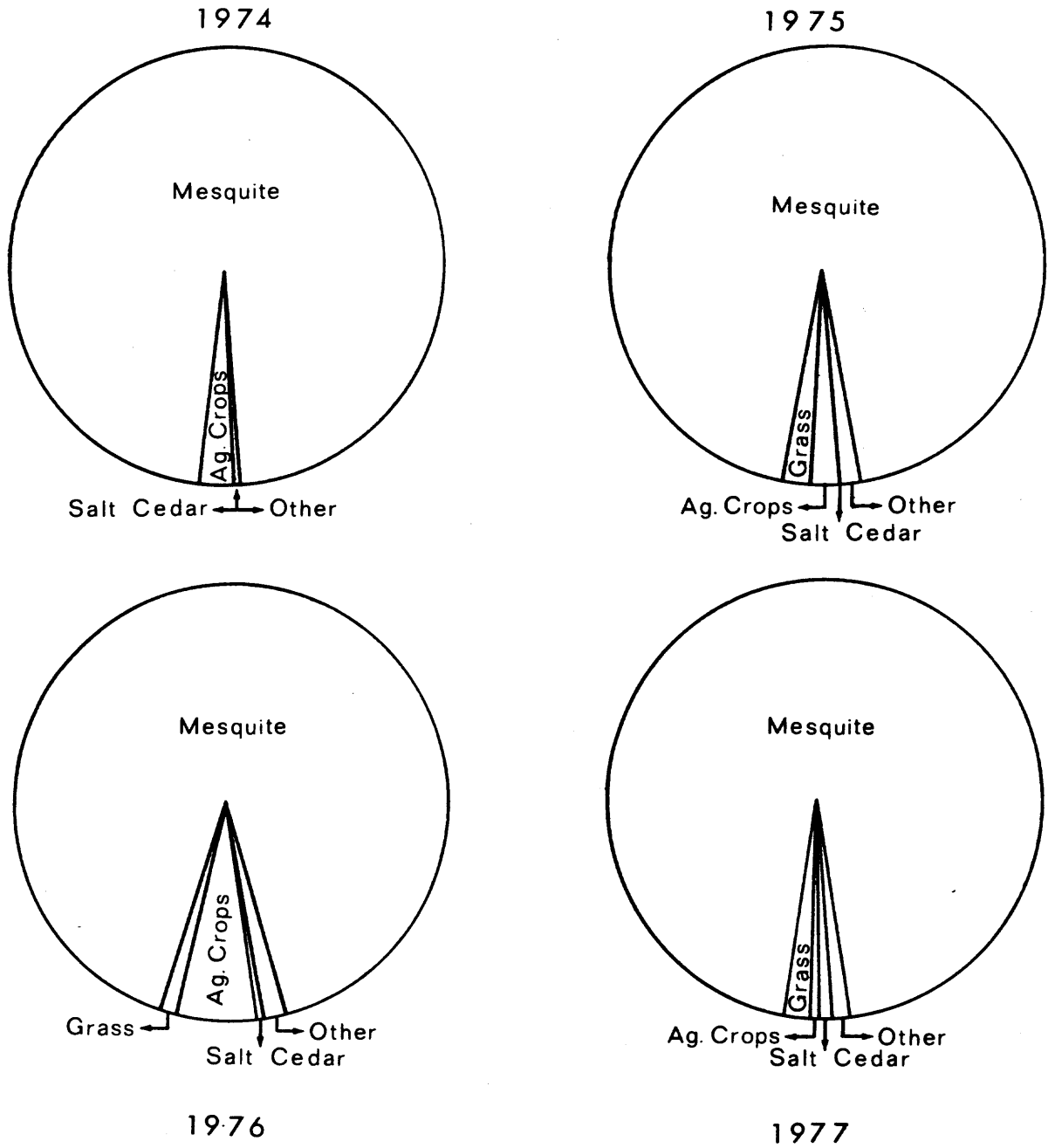

Figure 12-4. Proportion of the volume displaced by plant foods in coyote scats (1974-1977). Categories are the same as in Figure 12-3.

Table 12-3. Volume/frequency (V/F) values for food groups found in coyote scats (1974-1977). Percent frequencies are in parentheses.

Food group	1974	1975	1976	1977
Rabbit	1.0 (8.7)	1.1 (11.7)	1.3 (22.3)	1.3 (8.7)
Rodent	0.59 (22.2)	0.74 (21.5)	0.69 (19.2)	0.76(16.3)
Other	1.4 (1.0)	0.8 (1.0)	0.92 (1.2)	0.43 (0.7)
Livestock	0.38 (3.9)	0.73 (2.2)	1.0 (2.7)	0.25 (2.4)
Unidentified mammal	0.36 (26.9)	0.50 (30.4)	0.46 (28.0)	0.40(46.5)
Mesquite	0.56(104.8)	0.48 (92.6)	0.38 (86.5)	0.59(80.0)
Agricultural crops	0.11 (14.6)	0.09 (10.9)	0.19 (11.4)	0.04 (8.0)
Grass	0.0 (10.6)	0.05 (18.5)	0.01 (35.2)	0.04(28.2)
Salt cedar	0.004(56.7)	0.004(46.9)	0.004(49.7)	0.01(47.5)

Mammals	Plants	Arthropods
Hispid cotton rat	Grass	Beetle
Desert cottontail rabbit	Honey mesquite	Botfly
Domestic cattle	Melon	Crayfish
Domestic sheep	Salt Cedar	
Kangaroo rat	Screwbean mesquite	
Muskrat	Wheat	
White-throated woodrat	Unidentified plant	
Valley pocket gopher		
Unidentified rodent		
Unidentified mammals		

Eggshell remains, unidentified bird, unidentified fish, and spiny lizard were also found.

Principal Foods

Comparing V/F among typical coyote food items with similar frequencies (Table 12-4) showed that mammalian species had higher values than any other category of foods such as bird, fish, arthropod, plant, and reptile. Bird, fish, arthropod, and plant, except mesquite, had similar values. Mesquite had higher values than other plants. All values for mammals were $\geq$0.3 in 26 of 28 cases. The only items of 14 others with 0.3 or greater V/F were screwbean and honey mesquite, spiny lizard, beetle and crayfish. In only one of three cases did the latter three exceed 0.3.

In summary, only mammals, screwbean mesquite, and honey mesquite, showed consistently high relative V/F ratios in coyote scats. Among mammals, the white-throated woodrat, rabbit, unidentified rodent, and mammalian categories had frequencies over 5%. All mesquite frequencies each year exceeded 5%. Based on V/F and percent frequency of occurrence, we considered white-throated woodrat, rabbit, and screwbean and honey mesquite as principal foods in coyote diets. Unidentified rodents and mammals made up a large proportion of the diet of coyotes, but this category provides little information on specific food items. The role of other mammalian species in the coyote diet may be masked in the unidentified categories.

Year-to-Year Variation of Principal Foods

Mammals

Among mammalian remains, rodent proportions in coyote scats decreased in 1976 from 1974-1975 levels (Figs. 12-1 and 12-2). Percent frequency of occurrence dropped again in 1977 (Fig. 12-1), but percent volume increased (Fig. 12-2). Rabbit proportion of percent frequency of occurrence and percent volume increased in 1976 from 1974-1975 levels (Figs. 12-1 and 12-2). These levels decreased in 1977. Proportions of unidentified mammals found in coyote scats in 1974 were similar to those found in 1975; they decreased in 1976 and increased in 1977.

Table 12-4. Volume/frequency ratios of typical foods found in coyote scats along the lower Colorado River (1974-1977). Items are grouped according to similar frequencies.

1974		1975		1976		1977	
Sheep	0.30	Muskrat	0.96	Cattle	1.13	Pocket gopher	1.33
Pocket gopher	0.50	Eggshell	0.04	Sheep	0.92	Cotton rat	0.75
Cotton rat	1.00	Botfly	0.03	Pocket gopher	1.75	Kangaroo rat	0.67
Spiny lizard	0.50			Cotton rat	0.92	Woodrat	0.78
Crayfish	0.00	Kangaroo rat	0.56	Spiny lizard	0.06	Rodent*	0.66
Beetle	0.00	Fish*	0.06			Spiny lizard	0.25
Botfly	0.00			Muskrat	0.89	Crayfish	0.00
Fish*	0.10	Woodrat	0.80	Crayfish	0.66	Bird*	0.08
Eggshell	0.00	Wheat	0.08			Grass	0.04
				Woodrat	0.68	Screwbean mesquite	0.67
Woodrat	0.86	Beetle	0.10	Rabbit	1.26	Honey mesquite	0.62
Wheat	0.05	Melon	0.15	Mammal*	0.46		
				Botfly	0.03	Sheep	0.33
Rodent*	0.61	Bird*	0.16	Fish*	0.04	Beetle	0.31
Plant*	0.03	Screwbean mesquite	0.54	Bird*	0.10	Eggshell	0.00
		Mammal*	0.50	Wheat	0.05		

Table 12-4. (cont.)

1974		1975		1976		1977	
Rabbit	1.00			Eggshell	0.07	Mammal*	0.40
Grass	0.00					Salt cedar	0.01
				Grass	0.01		
Mammal*	0.36			Screwbean mesquite	0.58	Botfly	0.04
Bird*	0.14			Honey mesquite	0.37	Melon	0.08
Screwbean mesquite	0.60			Kangaroo rat	0.52		
Salt cedar	<0.01			Melon	0.00		

*Unidentified to species.

Rodent Abundance

Rodent trapping totaled 189,000 trap nights from 1974-1977. Population analyses dealing with five numerically dominant rodent species yielded sample sizes of: (1) desert pocket mouse -- 1,095; (2) cactus mouse -- 7,504; (3) deer mouse -- 1,048; (4) white-throated woodrat -- 1,114; (5) Merriam kangaroo rat -- 2,507.

Numbers of each species declined from 1974 through 1976, although their patterns differed. Annual population changes of rodent species are reported in Chapter 11. The desert pocket mouse and cactus mouse declined annually (Figs. 12-5 and 12-6). Numbers of deer mice and Merriam kangaroo rats did not decrease until 1976; white-throated woodrats decreased in winter 1975 (Figs. 12-5 and 12-7). Their numbers showed a rise in winter 1977.

Mesquite

The mesquite proportion of plants in coyote scats was the same in 1976 and 1977 (Fig. 12-3) but slightly below the 1975 level, which was slightly below that in 1974. Mesquite proportion of percent volume in coyote scats was similar in all four years except for a small decrease in 1976 (Fig. 12-4).

Mesquite Abundance

Numbers and biomasss of screwbean and honey mesquite pods on the ground were greater each month in 1976 than in 1977 (Table 12-5). There was a larger number of screwbean than honey mesquite pods on the ground each month both years, and greater biomass except in the peak month in honey mesquite. (Honey mesquite and screwbean mesquite peaks were offset a month.) The number of screwbean mesquite pods on the ground was greatest in August; the number of honey mesquite pods on the ground was greatest in September. By December virtually all honey mesquite pods had been removed, while screwbean mesquite pods were still present on the ground.

Number of Species Consumed

The number of different foods in coyote scats increased from 1974 to 1977, with greatest diversity in 1976 (Table 12-6). This does not appear to be a function of sample size (Table 12-1), since largest sample sizes do not correspond with greatest diversity of foods.

Seasonal Consumption of Food

The percent frequency of mammalian items occurring in coyote scats peaked in spring each year (Fig. 12-9). Percent frequency of occurrence of these items remained high in summer, declined in fall, and remained near the fall level throughout the winter months each year. Percent frequency of occurrence of bird remains found in coyote scats peaked in summer each year, decreased in fall, and remained at that level throughout winter and spring. Percent frequency of occurrence of screwbean mesquite pods in coyote scats peaked in fall 1975, 1976, 1977,

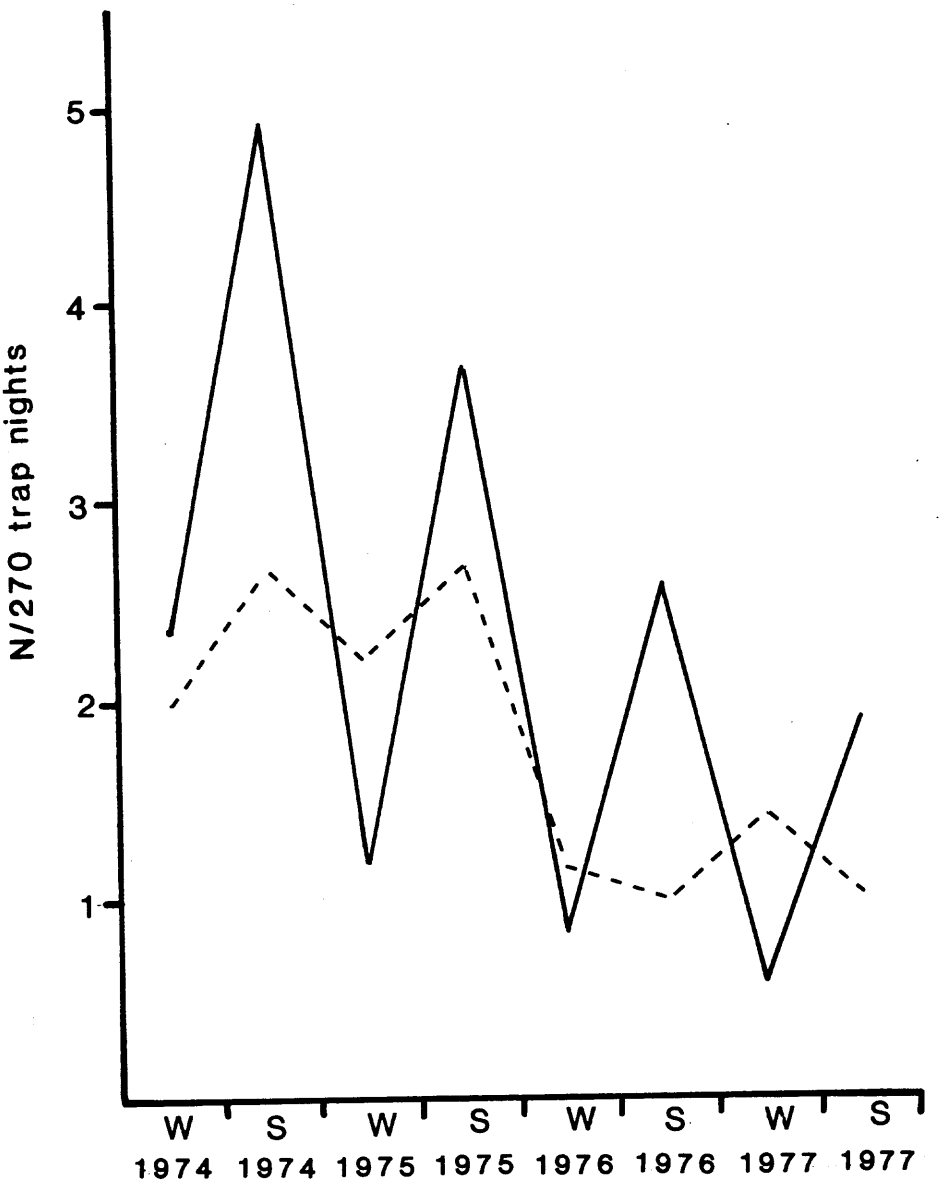

Figure 12-5. Seasonal densities (N/270 trap nights) of the desert pocket mouse (——) and Merriam kangaroo rat (----) in the lower Colorado River valley. W = winter; S = summer.

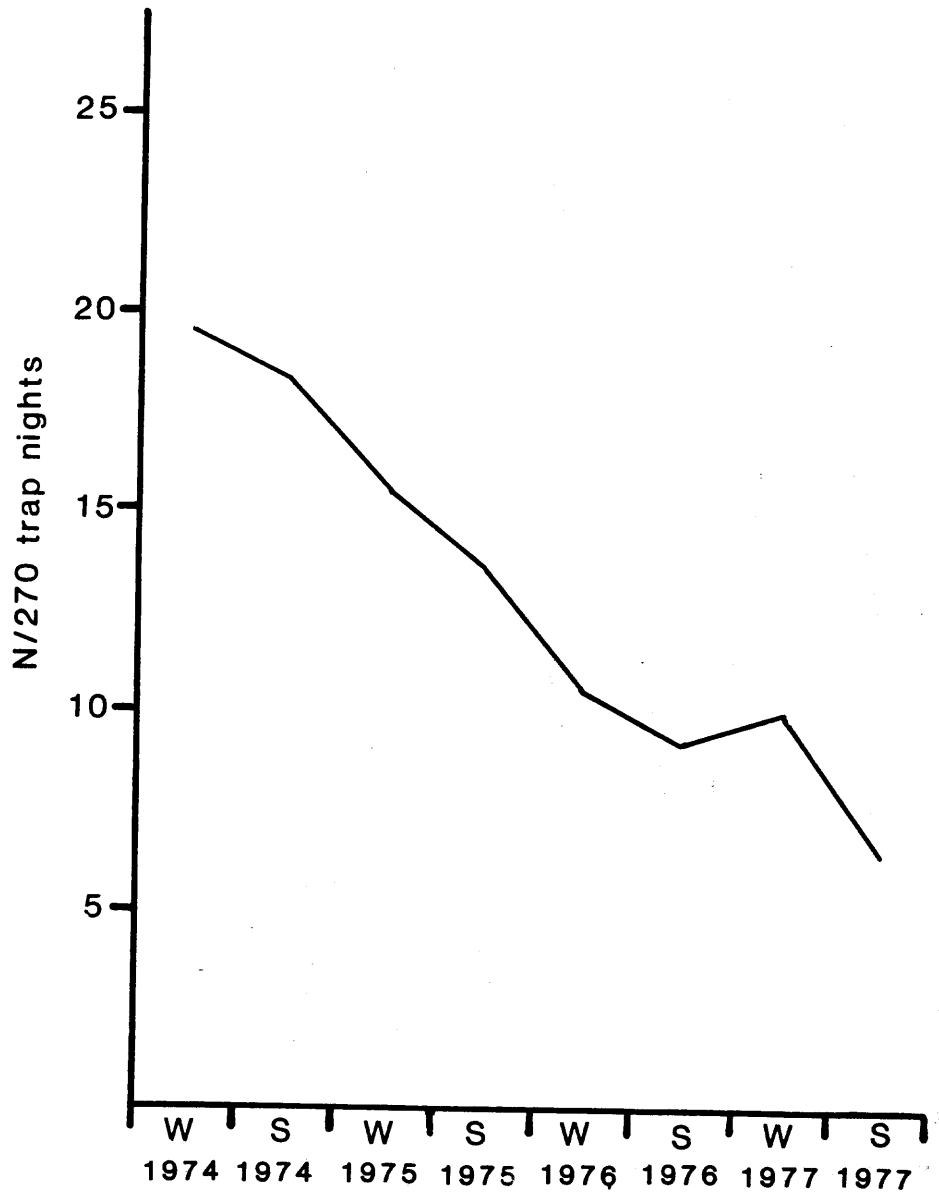

Figure 12-6. Seasonal densities (N/270 trap nights) of the cactus mouse in the lower Colorado River valley. W = winter; S = summer.

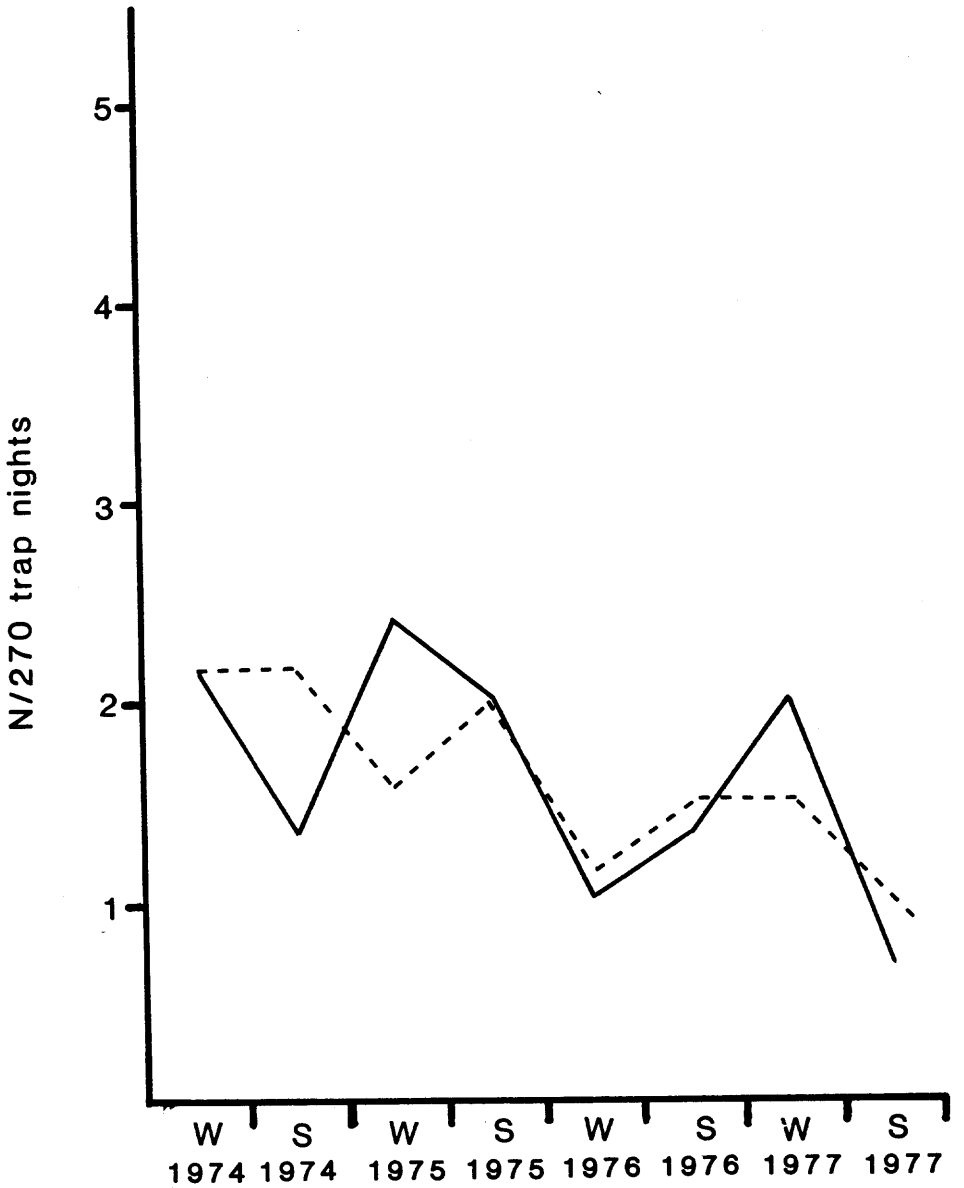

Figure 12-7. Seasonal densities (N/270 trap nights) of the deer mouse (——) and white-throated woodrat (----) in the lower Colorado River valley. W = winter; S = summer.

Table 12-5. Numbers and weight of screwbean and honey mesquite pods on the ground, August through December, 1976-1977.

	Number of pods X 10^6 per 40 ha			
	1976		1977	
	Screwbean mesquite	Honey mesquite	Screwbean mesquite	Honey mesquite
August	45.7	1.02	38.2	1.0
September	24.4	8.7	19.9	6.6
October	13.7	0.30	11.6	0.32
November	2.2	0.55	5.7	0.18
December	14.8	-	0.7	-
TOTAL	100.8	10.67	76.1	8.10

	Kg X 10^3 per 40 ha			
	1976		1977	
	Screwbean mesquite	Honey mesquite	Screwbean mesquite	Honey mesquite
August	26.8	2.8	22.5	2.7
September	14.3	23.7	11.7	18.0
October	8.1	0.8	6.8	0.9
November	1.3	1.5	3.4	0.5
December	8.7	-	0.5	-
TOTAL	59.2	28.8	44.9	22.1

Table 12-6. Annual diversity of food items found in coyote scats (1974-1977). Numbers include only those items having measurable frequency and volume.

Group	1974	1975	1976	1977
Mammal	12	15	15	14
Plant	7	9	11	9
Bird	1	2	2	2
Reptile	1	0	3	3
Fish	1	1	1	1
Arthropod	1	3	4	4
TOTAL	23	30	36	32

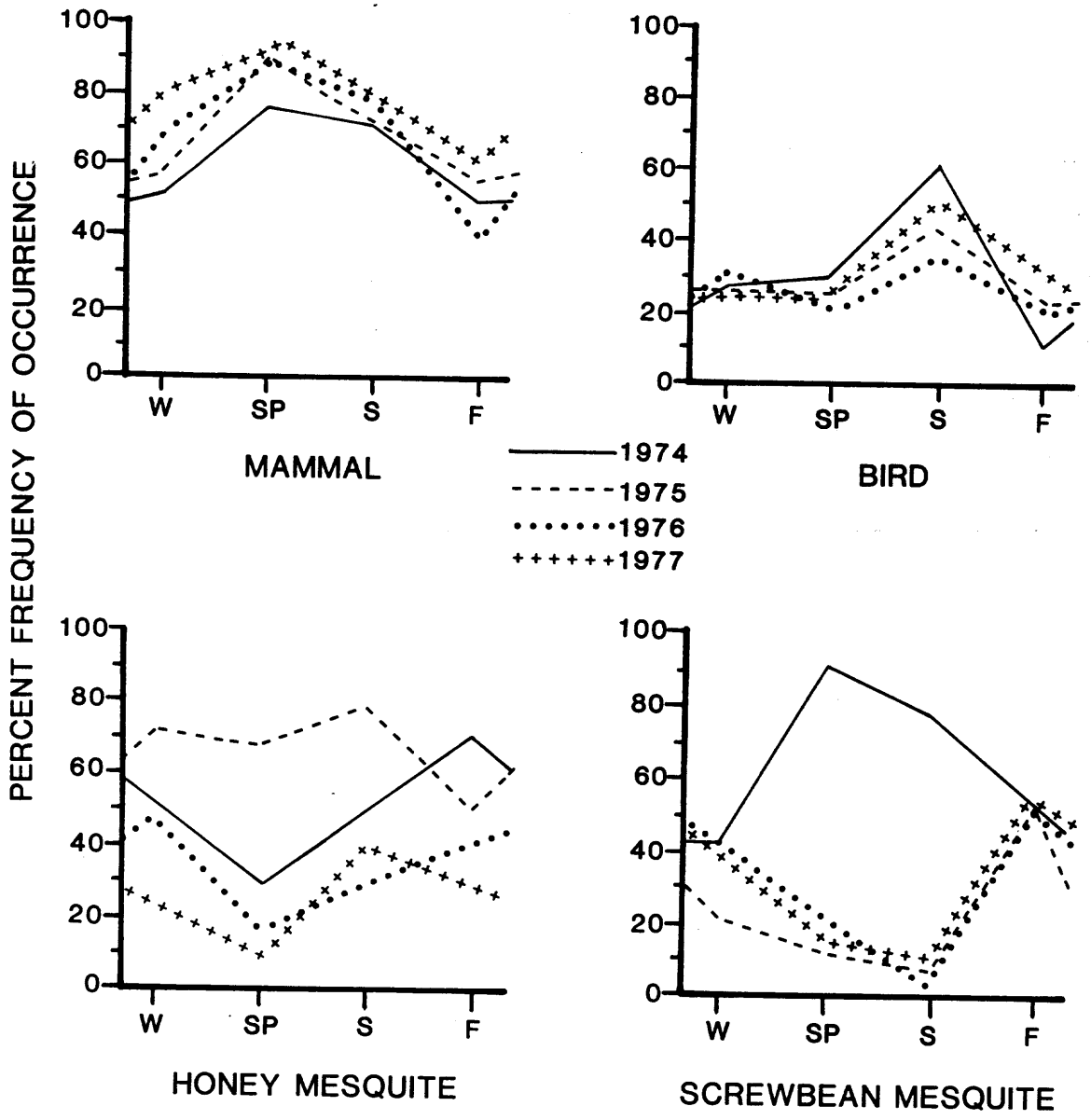

Figure 12-9. Seasonal variations in percent frequency of occurrence of food types found in coyote scats from 1974-1977. W = winter; SP = spring; S = summer; F = fall.

then declined steadily from fall through summer, except in 1974. Honey mesquite showed inconsistent peaks in percent frequency of occurrence, declining to the lowest level by spring each year except 1975.

Mammals displaced the most percent volume in coyote scats in spring of 1975, 1976, and 1977, and in summer 1974 (Fig. 12-9). The lowest percent volume was recorded in fall. Mesquite pod percent volumes in scats peaked or were at similar levels in fall and winter (Fig. 12-10). Screwbean mesquite representation in scats was lowest in summer; honey mesquite had the lowest percent volume in spring.

Seasonal Abundance of Foods

Mammals

Rodent population analysis was divided into two seasons, whereas scat analysis dealt with four seasons. Differences in defining seasons rendered difficult the task of relating peak rodent consumption by coyotes to rodent population analysis. Reproductive output of rodents was measured each month, and we assumed that rodent densities were higher in the breeding than in the nonbreeding period. Peak rodent consumption by coyotes corresponded to the rodent reproductive period (Figs. 12-8 and 12-9).

Breeding activity of rodent species in the valley is reported in Chapter 10. Highest proportions of pregnant females occurred in: (1) cactus mouse, March through July or August; (2) deer mouse, March through July or August; (3) white-throated woodrat, insufficient data; (4) Merriam kangaroo rat, February or March through May or July; (5) desert pocket mouse, April or May through July or August (Fig. 12-10). The cottontail rabbit reproduced year round in 1974 in the lower Colorado River valley (Anderson and Ohmart 1982). Peak reproduction occurred from March to August. Rodent and rabbit peak reproduction extended through spring and summer, the time of year corresponding to highest percent frequency of occurrence and percent volume of mammals in coyote scats (Fig. 12-9).

Birds

Avian densities peaked in summer in all five habitat types each year, 1975 through 1977 (Table 12-7). This corresponded to peak percent frequency of occurrence of birds in coyote scats in 1975 through 1977 (Fig. 12-8).

Mesquite

Screwbean mesquite pods were most abundant on the ground in August and were found on the ground in high numbers in September (Table 12-5). Honey mesquite pods were most abundant on the ground in September. This did not correspond to the season of highest percent frequency of occurrence and percent volume of mesquite pods in coyote scats (Fig. 12-8).

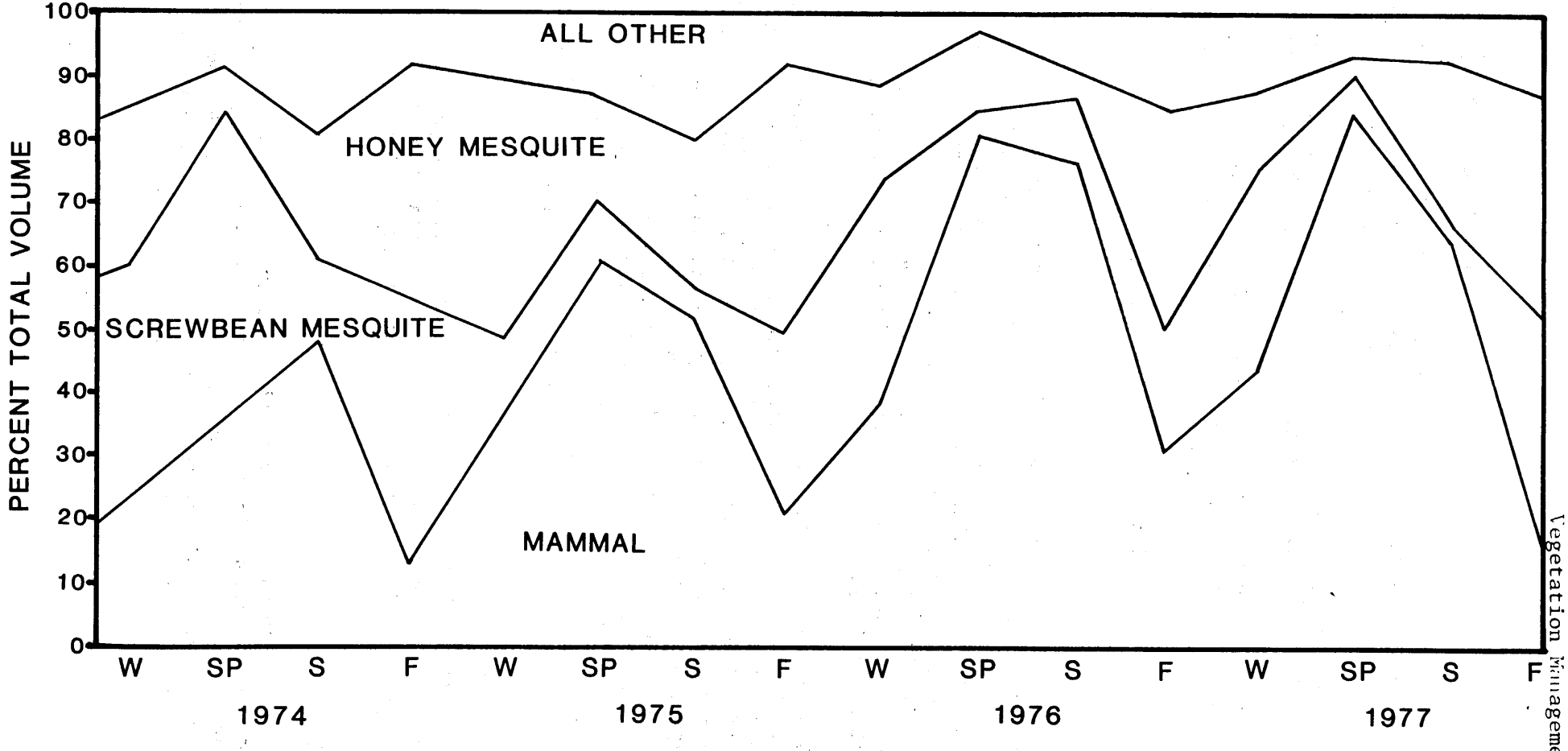

Figure 12-10. Seasonal variations in percent total volume of coyote foods found in scats in 1974-1977. For a given season, the total percentages (on the left) are a cumulative figure such that for all seasons, mammal + screwbean and honey mesquite + "other" equals 100%. W = winter; SP = spring; S = summer; F = fall.

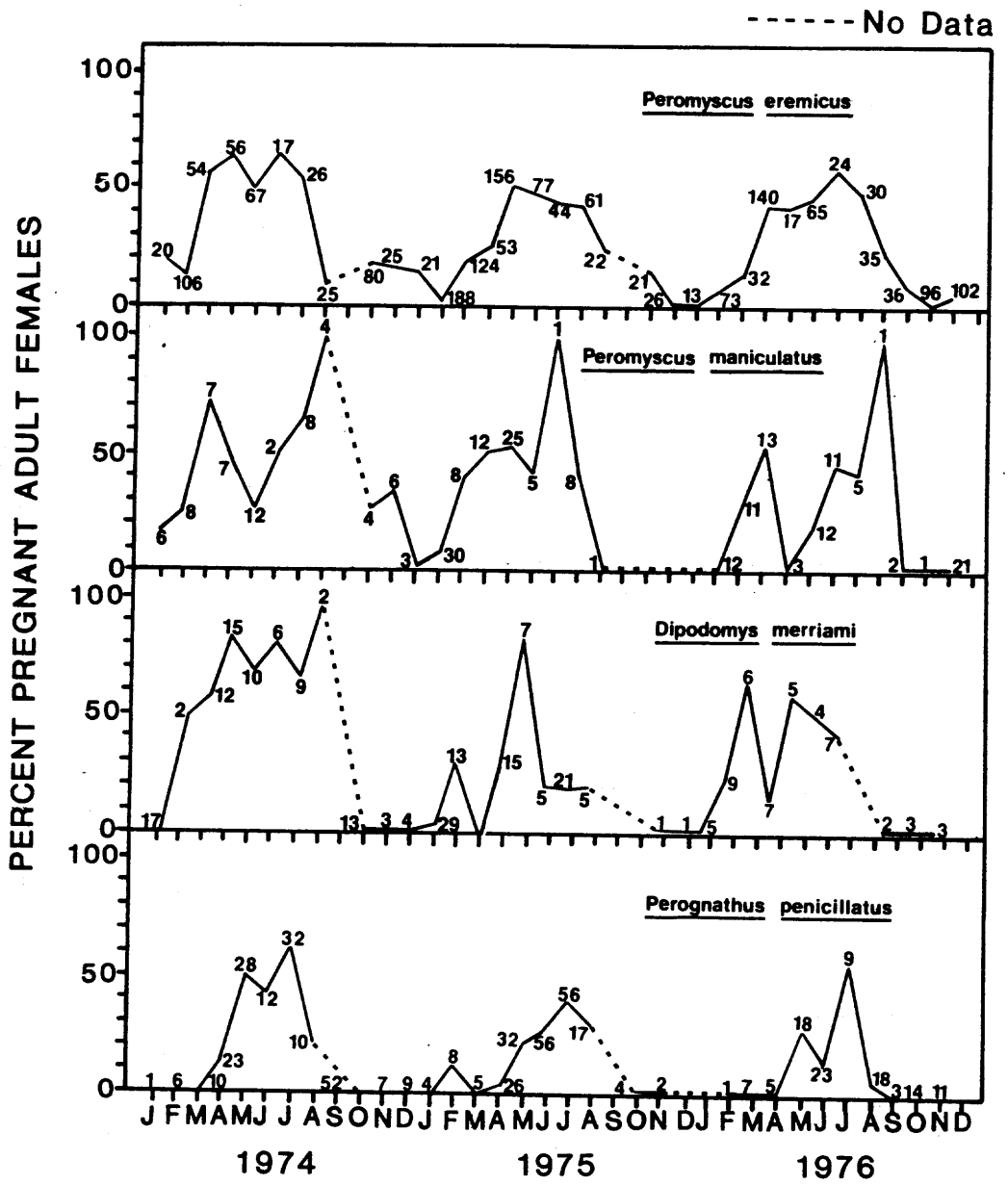

Figure 12-8. Proportion of pregnant females of four numerically dominant rodent species in the lower Colorado River valley each month in 1974-1977. (1) Cactus mouse (Peromyscus eremicus); (2) deer mouse (Peromyscus maniculatus); (3) Merriam kangaroo rat (Dipodomys merriami); (4) pocket mouse (Perognathus penicillatus). The horizontal axis abbreviates the months.

Table 12-7. Average bird densities (n/40 ha) in five community types (1975-1977). Winter = December, January, February; Spring = March, April; Summer = May, June, July; Late summer = August, September; and Fall = October, November.

Community type	1975	1976	1977
Honey mesquite			
Winter	143	154	200
Spring	145	185	260
Summer	232	313	284
Late summer	171	193	179
Fall	130	231	217
Screwbean mesquite			
Winter	51	78	117
Spring	126	120	147
Summer	588	559	441
Late summer	270	315	28
Fall	136	185	189
Cottonwood-willow			
Winter	108	183	256
Spring	141	175	276
Summer	268	369	430
Late summer	256	250	430
Fall	185	225	388

Table 12-7. (cont.)

Community type	1975	1976	1977
Salt cedar			
Winter	98	97	138
Spring	92	86	133
Summer	225	278	291
Late summer	169	235	161
Fall	151	159	207
Salt cedar-honey mesquite			
Winter	58	40	80
Spring	68	115	157
Summer	138	292	250
Late summer	216	181	198
Fall	151	176	174

Abundance of Coyote Scats in Different Habitat Types

In 1975 honey mesquite habitat showed the highest number of coyote scats per km of community (Table 12-8). In 1976 and 1977 coyote scats were most numerous per km in screwbean mesquite. Coyote scats were more numerous on roads than on chopped paths except in salt cedar-honey mesquite (Table 12-9). There were only four transects in this habitat type, compared to 17 to 22 in each of the other habitat types. The small sample size in salt cedar-honey mesquite prohibited determining the difference between scat numbers on roads and paths; therefore a correction factor was not determined for this habitat.

When coyote scats/km values were multiplied by the correction factor for road bias (Table 12-9), the resulting adjustment had only a minor effect. Honey mesquite values remained highest in 1975 and screwbean mesquite values were highest in 1976 and 1977 (Table 12-10).

Rodent Populations Among Habitat Types

Associations of rodent species to habitat types are reported in Chapters 10 and 11. In brief summary, analyses of a five-year trapping period showed highest numbers of: (1) cactus mice in salt cedar, salt cedar-honey mesquite, and arrowweed; (2) deer mice in salt cedar; (3) white-throated woodrats in screwbean mesquite, honey mesquite, and cottonwood-willow; (4) Merriam kangaroo rats in screwbean mesquite and honey mesquite; and (5) desert pocket mice in screwbean mesquite, honey mesquite, and salt cedar-honey mesquite (Figs. 12-11 to 12-15).

DISCUSSION

Diet Evaluation

Scat analysis compared to other methods of food habit evaluation has certain advantages: (1) it affords a more complete insight into diet if the area and number of coyotes investigated is small; (2) samples are relatively large and are readily collected; (3) it is a more random sampling technique; and (4) it presumably does not affect the organism studied. Certain disadvantages of scat analysis, dealing mainly with frequency of occurrence analysis, have been pointed out. Lockie (1959), Clark (1972), and Mech (1970, from empirical evidence) suggested that because animals of smaller size possess a higher proportion of undigestible to digestible matter, they are over-represented in percent frequency of occurrence analyses. Scott (1941, also from empirical evidence) suggested this was not the case. But he argued that food groups with a higher diversity of members may be over-represented in percent frequency of occurrence analyses because they have a higher "scoring power." For example, because three mice species are noticeably different, they are each recorded as a new occurrence, whereas three chickens would receive only one record of occurrence; thus, mice are judged as being three times more frequent in scats than are chickens. Group diversity and/or prey size may bias percent frequency of occurrence analysis, which could lead to an unrealistic evaluation of the importance of different foods in the coyote diet.

Table 12-8. Number of coyote scats per km in five habitat types (1975-1977).

Habitat type	1975	1976	1977	Total
Honey mesquite	7.8	2.8	9.6	20.2
Screwbean mesquite	5.3	5.4	16.3	27.0
Salt cedar	3.4	3.7	6.6	13.7
Cottonwood-willow	3.8	2.8	4.3	10.9
Salt cedar-honey mesquite	2.1	4.2	9.4	15.7

Table 12-9. Derivation of the correction factor for the bias in coyote scat abundance attributed to the presence of roads. Correction factor equals (% difference) X (% road).

Habitat type/ Year	No. of scats per km road	No. of scats per km path	Percent difference	Sample	Km of transect	Percent road	Correction factor (percent)
Screwbean mesquite							
1975	7.5	4.9	21.0	74	13.9	17.4	3.7
1976	3.8	5.7	20.0	82	15.2	16.0	3.2
1977	18.8	15.6	9.3	257	15.8	20.0	1.9
Salt cedar							
1975	7.4	2.2	54.2	26	7.7	23.5	12.7
1976	10.3	2.3	63.5	36	9.8	18.8	11.9
1977	13.1	6.0	37.2	88	13.3	14.3	5.3
Cottonwood-willow*							
1976	3.3	2.8	8.2	33	12.0	5.1	0.42
1977	9.9	4.0	42.4	57	13.3	4.5	1.9

*No road transects were established in 1975.

Table 12-10. Adjusted values for the number of coyote scats per km in the three habitat types in which there was an adequate sample of road and path transects.

Habitat type	1975	1976	1977	Total
Screwbean mesquite	5.1	5.8	16.0	26.9
Salt cedar	3.0	3.3	6.3	12.6
Cottonwood-willow	3.8	2.8	4.2	10.8

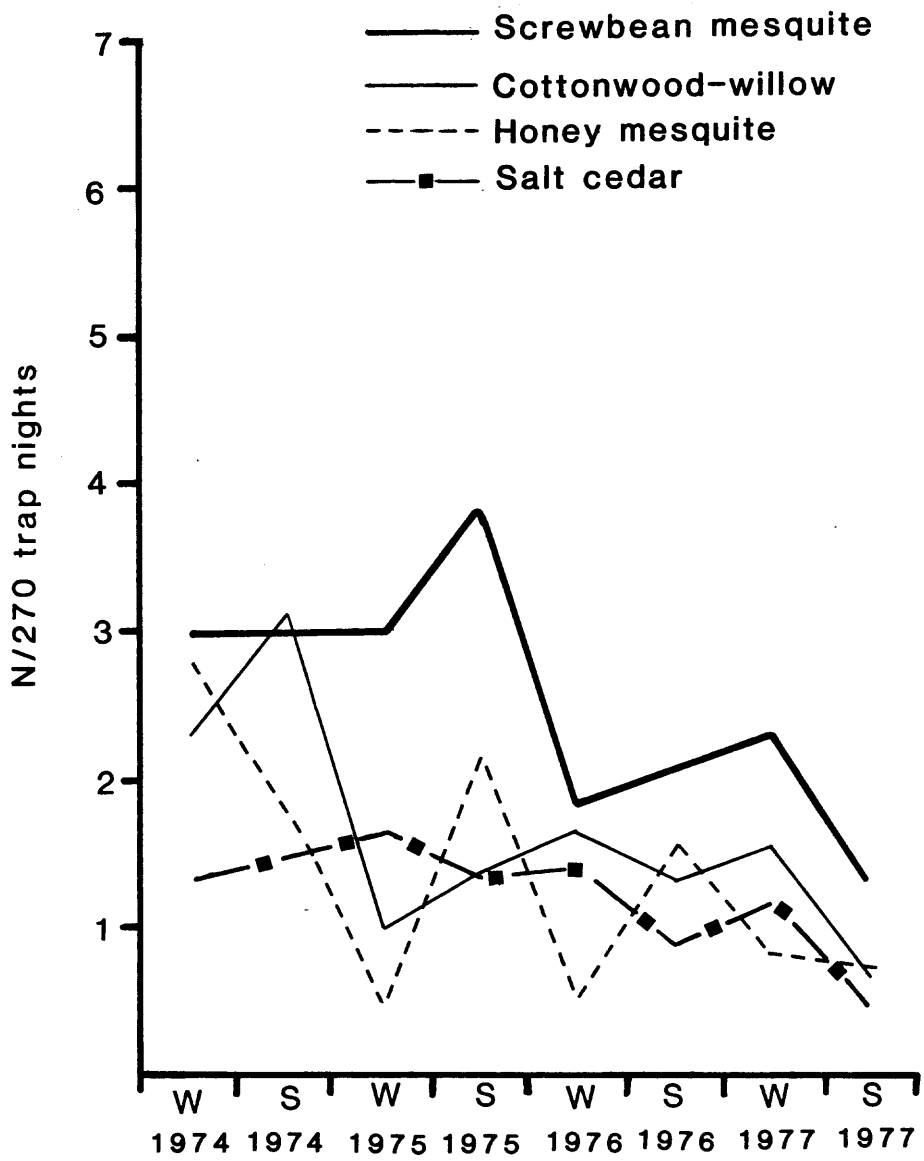

Figure 12-11. Seasonal densities (N/270 trap nights) of the white-throated woodrat in four habitat types. W = winter; S = summer.

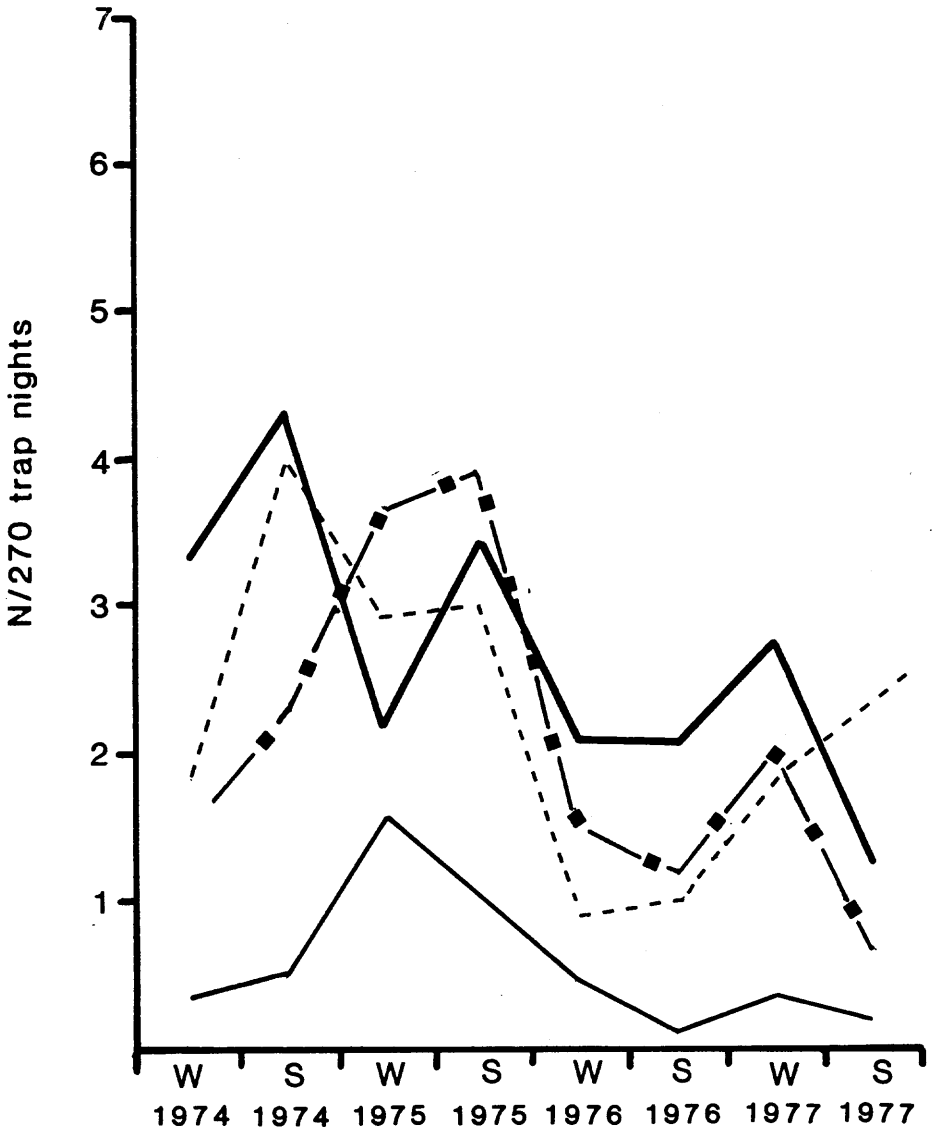

Figure 12-12. Seasonal densities (N/270 trap nights) of the Merriam kangaroo rat in four habitat types. Habitat types and abbreviations as in Figure 12-11.

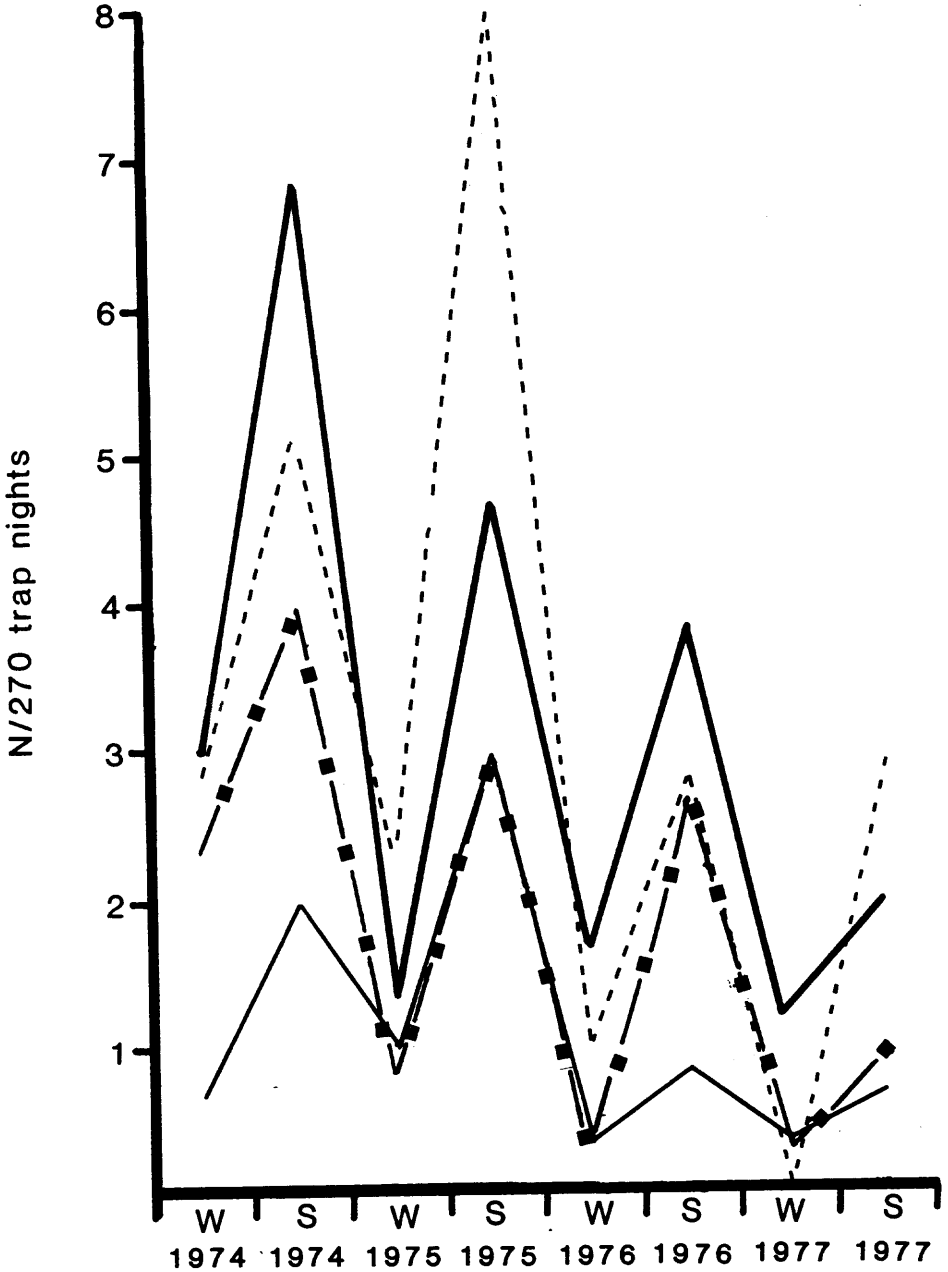

Figure 12-13. Seasonal densities (N/270 trap nights) of the desert pocket mouse in four habitat types. Habitat types and abbreviations as in Figure 12-11.

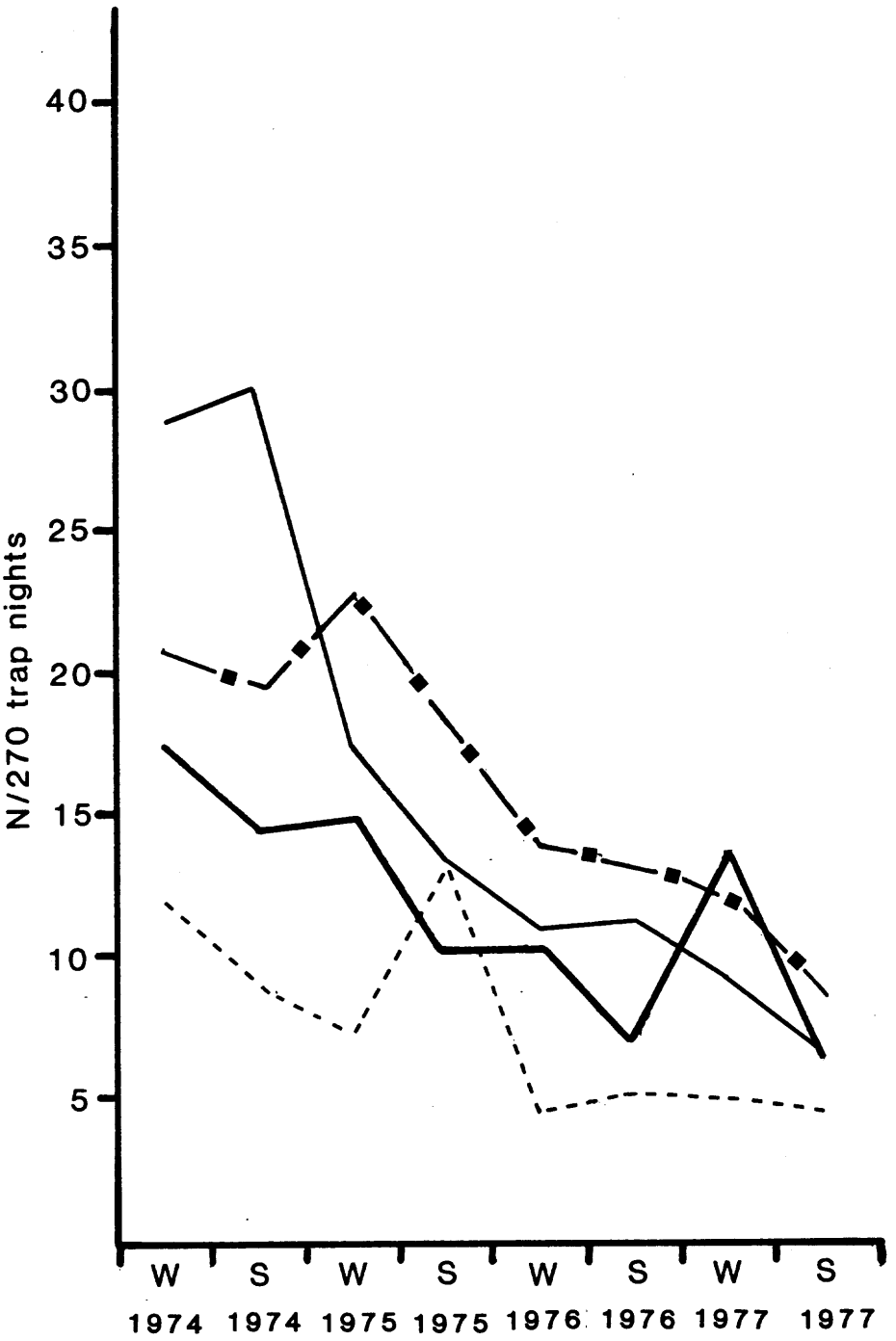

Figure 12-14. Seasonal densities (N/270 trap nights) of the cactus mouse in four habitat types. Habitat types and abbreviations as in Figure 12-11.

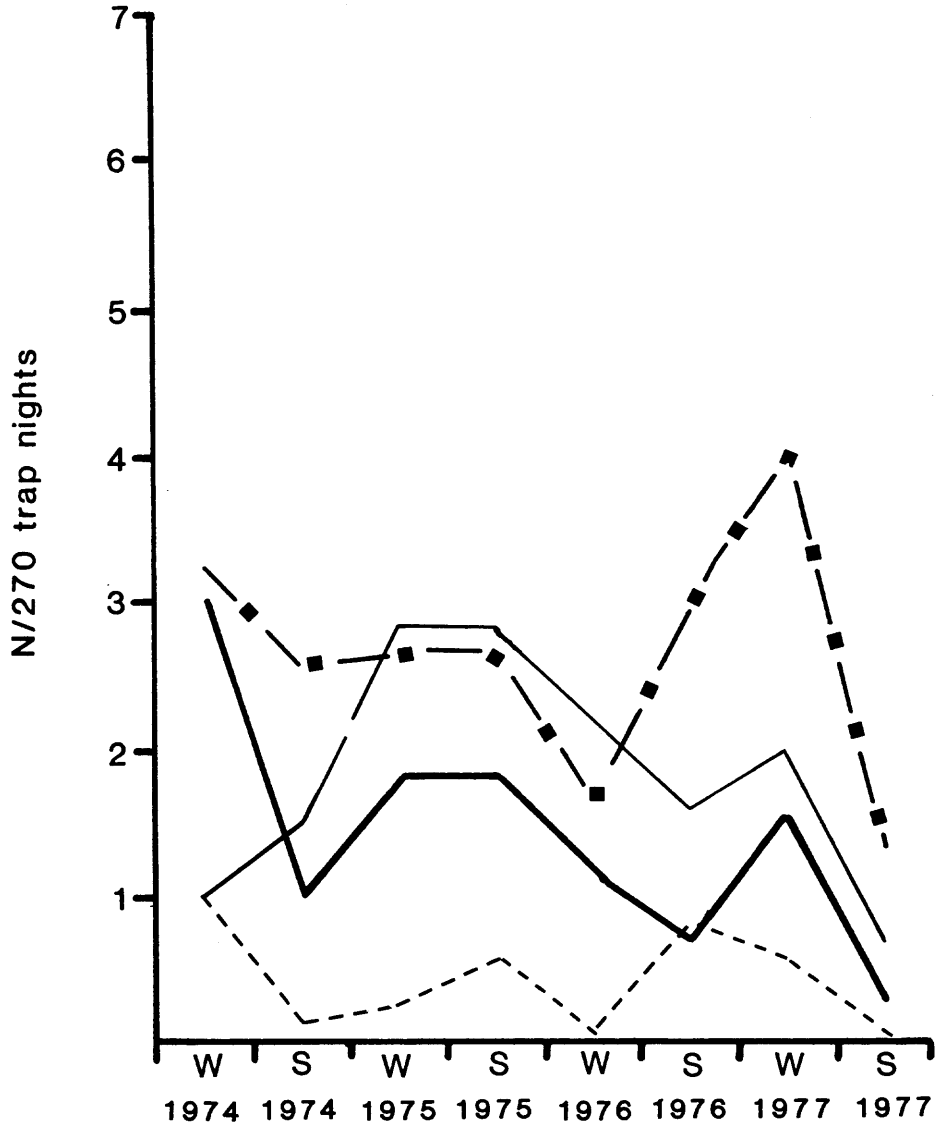

Figure 12-15. Seasonal densities (N/270 trap nights) of the deer mouse in four habitat types. Habitat types and abbreviations as in Figure 12-11.

If percent frequency of occurrence and percent volume are measured, these potential biases can be reduced by using a percent volume-to-percent frequency of occurrence index. If a prey item occurs more frequently as the result of a disproportionate quantity of undigestible matter or higher "scoring power," the denominator of the index increases. This lowers the index value unless there is a proportionate volume increase from consumption of more of the same item. Those prey items with proportionately less undigestible matter or lower "scoring power" would have a relatively greater percent volume than percent frequency of occurrence; therefore, their V/F index would increase. Overrated items would have a decreased index value and underrated items would have an increased index value; the V/F ratio reduces both biases.

Percent frequency of occurrence and percent volume measurements demonstrated contradictory conclusions about relative importance of food types when using these measurements independently. Proportions of rabbit, rodent, and unidentified mammals were inconsistent between measurements. Salt cedar changed rank entirely between measurements. One could observe the variations from year to year in percent frequency of occurrence and percent volume together instead of percent frequency of occurrence and percent volume independently. The fluctuations were inconsistent. For some items, percent frequency of occurrence increased one year, whereas percent volume did not. In another year both increased. The third year percent volume increased, whereas percent frequency of occurrence decreased. What conclusion can be reached concerning the relative importance of a food based on such a complex fluctuation? The V/F index incorporates both analyses, and the values were consistent among years for foods that occurred with relatively high frequency. The index was inconsistent among years for foods that occurred with low frequency (domestic, other). This may be because foods that occurred in low frequency in coyote scats were inconsistently available (e.g., livestock, deer, and carrion).

To discern principal foods, a number of criteria should be used along with V/F values. This ratio assigns a value to the relationship between two numbers. The relationship could be the same for foods consumed infrequently compared to foods consumed frequently. Comparisons of V/F should be drawn among foods that occur in similar frequencies. Logically, foods consumed often and with high V/F values would be those foods upon which coyotes were most dependent for energy.

We compared V/F values only among foods which occurred in scats all four years and showed some volume displacement. Other foods added to the diversity of diet but probably were not significant energy sources to the coyote. Among typical foods, most plants, invertebrates, fish, and birds had similar V/F ratios; these values were overshadowed by the V/F figures of mammals and mesquites. We considered rabbits and small rodents the mainstay mammalian component of the coyote diet. Although domestic and other categories had high V/F values, they composed a low proportion of percent frequency of occurrence and percent volume.

Diet and Prey Abundance

Other workers have suggested that coyotes showed a functional response to prey abundance (Korschgen 1957, Clark 1972, Nellis and Keith 1976). Our analyses suggest that coyotes showed a response to rodent population levels which reflected availability of this resource. Mouse (Cricetidae) populations decreased from 1974 to 1976. Rat (Cricetidae and Heteromyidae) populations declined in 1976. Therefore, 1976 had the more extreme decrease in rodent populations. Rodents were shown to constitute a major portion of the coyote diet. In fact, the white-throated woodrat composed a substantial proportion of rodent consumption by coyotes. Rodent consumption decreased slightly in 1975 and more severely in 1976. This decrease appeared to be offset by increased rabbit consumption. Annual variations in percent volume and percent frequency of occurrence of rodents and rabbits, although small, except in 1975 to 1976, were consistently inverse. Population data on rabbits over the study period were unavailable. Without such data we cannot definitely determine that rodent consumption by coyotes showed a functional response. Rabbit populations may have increased, whereas rodent populations declined. The drop in rodent consumption may then have been associated with increased numbers of rabbits and not decreased numbers of rodents. Errington (1937) reported this in the red fox. This suggests that an investigator requires knowledge of the interaction of all principal prey population levels in relation to food consumption analyses to actually demonstrate a functional response.

In 1976 rodent populations declined to lowest levels during the study and coyote diet diversity was highest. Dixon (1925) reported that the greatest use of "other mammals" as food occurred when rabbit and mice abundances were low. The increased diet diversity in 1976 may be related to the depressed rodent densities.

Dixon (1925) also noted that livestock consumption by coyotes was low when rabbit and rodent consumption was high and vice versa. In the present study, consumption of domestic species was slight, nowhere near the level of rabbit and rodent consumption, and this changed very little between years. What slight changes there were, were not consistent with low rabbit and rodent consumption. Highest proportions of livestock consumption occurred in 1974 and 1976 when rodent or rabbit consumption was also highest.

Mesquite

The percent volume and percent frequency of occurrence of mesquite in coyote scats exceeded the percent volume and percent frequency of occurrence of each mammal, and the V/F ratio approached some of the lower mammalian ratios. No other plant types approached these values. Mesquites appear to be an important food for coyotes. One difficulty in using a V/F index, and particularly in using it to compare plant foods to animal foods, is that there are differences in degree of digestibility of these food classes. Differences should not be so extreme within animal or plant categories as those between plant and animal categories. Plant matter was less easily digested than animal matter; consequently plants would show volumes (and therefore V/F)

greater than those of mammals. N. Dodd (unpubl. data) quantified the degree of digestibility of different foods by coyotes. He determined, on the basis of the volume of preingested food compared to postingested food, that there was no significant difference ($P>0.05$) in the average percent of digestibility of cottontail rabbit, jackrabbit, and quail by coyotes ($83.4 \pm 5.7, 88.9 \pm 0.9, 87.8 \pm 1.3\%$, respectively), but there was a significant difference between the percent of digestibility of honey mesquite pods ($6.8 \pm 1.9\%$) and percent of digestibility of each of these animal foods.

Following these data, the importance of mesquite in the coyote diet should drop relative to mammalian foods. Mesquite volumes are biased high, the bulk being undigested and unutilized. Although digestion of honey mesquite pods by coyotes seldom exceeded partial breakdown of the pod itself, the pod is a rich carbohydrate source (Catlin 1925, Benson 1941). According to Walton (1923), the pods contain 31% sugar and 9.5% protein. Percent frequency of occurrence and percent volume measures indicated that coyotes consumed a great number of mesquite pods. In the coyote diet mesquite pods may serve a different function than does mammalian protein; that is, they provide a carbohydrate fuel reserve. Pod consumption by coyotes was greatest in fall and winter, periods of lower ambient temperatures and higher metabolic heat costs, rather than during August and September, the period of peak pod abundance.

Seasonal Consumption

Peak consumption of mammals and birds by coyotes corresponded to the seasonal population peaks of these prey. It also corresponded to the coyote breeding season. From the examination of reproductive tracts of coyotes collected in 13 western states, including Arizona, Hamlett (1938) found that the coyote breeding season was under way by February. Observations of a small captive coyote population in a desert-vegetated enclosure at Arizona State University indicated that breeding begins in late January or early February. Gestation is 60-63 days (Gier 1957, Kennelly 1978). Litters were born to the captive coyotes in early April.

Coyote reproductive success depends on favorable environmental conditions, including food availability (Murie 1940, Gier 1957 and 1975, Clark 1972, Nellis and Keith 1976). Clark (1972) found that the coyote reproductive rate was correlated with jackrabbit density--a major food item for those coyotes. He suggested a possible effect of food availability on ovulation. Rodents and rabbits were mainstay foods for coyotes on the lower Colorado River. Peak abundance and consumption of mammals (and birds) corresponded to the coyote breeding season when food availability was of critical importance to reproductive success.

Habitat Association

We have examined the importance of mammals and mesquite fruits in the coyote diet and discussed a potential functional response by coyotes to rodent abundance. Rodent trapping data and mesquite pod counts identified abundances of these foods among different habitat types. Rodent species showed associations to particular habitats. Rats and

pocket mice were more numerous in screwbean and honey mesquite; mice were less numerous in mesquite habitats. The white-throated woodrat rated as a principal food. There were more screwbean mesquite pods on the ground than honey mesquite pods, and screwbean mesquite pods were available to a later date than were honey mesquite pods.

Using the above data, we predicted screwbean mesquite stands, and secondarily honey mesquite stands, to be preferred forage habitats. We expected coyotes to frequent mesquite habitats more than cottonwood-willow or salt cedar habitats. Pellet counts have been used as relative density estimates for many organisms (Taylor 1930, rodents; Taylor et al. 1935, rabbits; McClure 1945, pheasants; Emlen et al. 1957, rodents; Overton and Davis 1969, a review of many animal types; Bennett et al. 1940, deer; Clark 1972, coyotes). Taylor (1930) noted that rabbits deposited pellets almost immediately after feeding. Bennett et al. (1940:401) stated that "deer deposited a great proportion of their pellet groups near where they fed so that the distribution of pellet groups becomes a useful key to forage preferences." They found that population estimates by pellet counts agreed with figures obtained by other census methods. Coyotes drop scats almost immediately after they feed (Bekoff pers. comm.). (This does not mean, however, that these scats contained remains of material most recently consumed.) Coyote scats were most numerous in screwbean mesquite in two of three years and in honey mesquite one year. We judged relative scat abundance as indicative of relative visitation by coyotes in habitat types. Screwbean and honey mesquite appeared to be preferred foraging habitats.

Management Implications

These food habit analyses suggest: (1) native riparian habitats should be maintained as forage and cover area for the coyote in the lower Colorado River valley; (2) livestock was not a major food item for the coyote; (3) coyote food habits, i.e., the dependence on small rodents and rabbits, may be an asset to farmers in the valley. Screwbean and honey mesquite habitat afford the greatest abundance of major foods for the coyote, and the number of coyote scats among habitat types indicated that coyotes frequented mesquite habitats most often. Therefore, mesquite habitats should be preserved.

Coyotes consumed livestock and agricultural crops, but these appeared as items adding to the diversity of foods consumed and did not rank as principal foods upon which coyotes appear to be energetically dependent. Other studies have reported that coyotes resort to livestock consumption when abundances of other major foods, such as rabbits and/or rodents, are low. Livestock consumption by coyotes in this region did not correspond to (and therefore did not offset) decreased rodent consumption. During decreased rodent abundance coyotes ate more mesquite pods, preyed more heavily on rabbits, and consumed a greater diversity of foods, such as arthropods, reptiles and plants. This suggests that coyotes in this region did not prey heavily on livestock, that is, sheep that grazed in the valley during winter months. This is not to say that some coyotes did not kill and eat sheep, but generally the coyote population relied most heavily on natural foods.

Cottontail rabbits, small rodents, and mesquite fruits were the most important components in the coyote diet. Rabbits and rodents are to some degree pests to agriculture. Eadie (1954) and Gier (1957) reported the economic benefits of potential coyote predation of pest rodents. Coyote food habits, i.e., dependence on rabbits and rodents, may be a benefit to farmers in the valley. Although rodent densities other than pocket gophers are small in agricultural land, rabbit populations are large (Anderson and Ohmart 1982).

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 per 40 ha) in the lower Colorado River valley, 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.

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CHAPTER 13

INTEGRATION AND CONCLUSIONS

We initially stated that the major objective of our work was to explore the possibility of managing riparian vegetation for the enhancement of wildlife in order to (1) reduce water loss caused by evapotranspiration, (2) reduce total floodplain vegetation at heights of 0.5-3 m (5-10 ft) so that flood flows could pass relatively unimpeded by the damming effect of dense vegetation, and (3) explore the economic and technical feasibility of revegetating areas. These objectives were to blend with wildlife enhancement. The purpose of this final chapter is to indicate the degree to which these objectives can be met, in the light of data presented in the preceding chapters.

METHODS

Summary Assessment of Wildlife Use of Riparian Habitats

An estimation of the value of various riparian habitats to wildlife should be quantitative and should include all wildlife categories studied. This is difficult because different population units were used for assessing each category, e.g., bird numbers were expressed as N per 40 ha, rodent numbers as N per 270 trap nights, and coyote numbers as scats per transect. We circumvented this difficulty by tabulating the number of times each of the 23 habitat types ranked among the top three for a given wildlife category. Summing this number across all wildlife categories yielded a rough index to the value of each habitat type. Fifty-six different wildlife categories (Table 13-1) were included. These represent all of the variables we studied. Clearly birds contributed to a far greater extent than mammals. We would argue that collectively birds contribute more in terms of numbers of species and numbers of individuals than mammals. They are also important economically because of their aesthetic value and importance as game birds. The disparity in the contribution was evened to some degree by lumping several bird species into each of several categories and by considering each of eight mammals species separately. With this procedure the scarce harvest mouse counted as much in the final evaluation as the density of visiting insectivorous birds in a given season. Thus birds, even though they contributed nearly three times as much to the analysis as mammals, are not grossly overrepresented. We emphasize, however, that conclusions would be altered little even if mammals contributed equally as much as birds or even if they contributed twice as much as birds. The reader is welcome to test this with the data presented in Appendix 13-1. Adding insects to the evaluation would make only minor, if any, changes in conclusions. We have found that insect densities and diversities are closely correlated with densities of insectivorous birds (Anderson and Ohmart unpubl. data).

Table 13-1. Variables used in assessing wildlife use of various riparian habitats along the lower Colorado River. Sp = spring, Su = summer, LS = late summer, F = fall, and W = winter.

Variables	Total number of categories	Percent of total
BIRDS	41	73.2
Total species - Sp, Su, LS, F, W	5	8.9
Number of species:		
Permanent resident insectivores - Sp, Su, LS, F, W	5	8.9
Visiting insectivores - Sp, Su, LS, F, W	5	8.9
Density of:		
Permanent resident insectivores - Sp, Su, LS, F, W	5	8.9
Visiting insectivores - Sp, Su, LS, F, W	5	8.9
Gambel Quail - Sp, Su, LS, F, W	5	8.9
Doves - Sp, Su, LS, F, W	5	8.9
Granivores - Sp, F, W	3	5.4
Frugivores - Sp, F, W	3	5.4
MAMMALS	15	26.8
N/270 trap nights:		
Cactus mouse - two seasons	2	3.6
White-throated woodrat - two seasons	2	3.6
Merriam kangaroo rat - two seasons	2	3.6
Desert pocket mouse - two seasons	2	3.6
Deer mouse - two seasons	2	3.6
Harvest mouse - annual total	1	1.8
Southern grasshopper mouse - annual total	1	1.8
Coyote scats/transect - annual total for each of three years	3	5.4

Developing Predictive Capabilities

Wildlife

The procedure described above allows one to discriminate habitats of low wildlife use values from those of high wildlife use. We developed predictive capabilities by correlating the total number of times each habitat ranked in the top three (across all wildlife categories) with the number of cottonwood, willow, and honey mesquite trees. However, all vegetation types were considered for each wildlife group. These tree species were chosen because they were by far the variables most frequently significantly associated with wildlife densities and diversities (Fig. 5-3). These species would be among those most often included in revegetation projects. The extent to which they preferred some other habitats is clearly presented in Appendix 13-1. The predictive regression equation is expressed as:

$$NWC = B_1 S_{CW} + B_2 S_H + B_0 \text{ (Equation 1)},$$

where NWC is the number of wildlife categories ranking in the top three, B_1 and B_2 are regression coefficients for slope, S_{CW} and S_H are the number of cottonwood-willow or honey mesquite per acre, and B_0 is the intercept coefficient.

Nearly all habitats, even those called honey mesquite or cottonwood-willow, have several variables sharing in any explanation of why wildlife use the area. For example, frugivorous birds are associated with honey mesquite because mistletoe, the fruit of which is eaten by frugivorous birds, happens to infest honey mesquite much more often than any other tree species. Similarly, many birds are attracted to quail bush, wolfberry, and other shrubs. Using equations developed earlier in this report, we first attempted to subtract all groups from the total number in the top three ranks in any habitat type if their rank in that habitat was due to some environmental variable other than cottonwood, willow, or honey mesquite. Thus frugivores, even though they always had their highest ranks in honey mesquite, were subtracted from the total number of top three ranks in that habitat type. In salt cedar habitats, where cottonwood, willow, or honey mesquite, by definition, did not occur, the contribution to wildlife use by cottonwood, willow, and honey mesquite was, of course, zero.

Foliage Density

In estimating potential reduction in water loss due to evapotranspiration we assume that there is a linear relationship between foliage density and total evapotranspiration. This assumption is based on the finding that honey mesquite, which has the lowest foliage density per unit area has an ET rate of about 0.22 mm/hr (Gay and Sammis 1977). Salt cedar has the densest foliage per unit area and has an ET rate of about 0.47 mm/hr (Gay et al. 1976). Cottonwood and willow have somewhat less foliage density per unit area than salt cedar and have an ET rate about as high or a little lower than salt cedar (Cunningham et al. 1973). Atriplex, with foliage density somewhat greater than honey mesquite has an estimated ET of 0.24 mm/hr (McDonald and Hughes 1968).

For purposes of making predictions about changes in total foliage density and foliage density at 1.5 and 3.0 m, we developed regression equations for the relationship between number of trees present and total foliage density and foliage density at 1.5-3.0 m. In making this determination we subtracted all foliage density contributed by vegetation other than cottonwood and willow trees in cottonwood-willow habitats and by other than honey mesquite in honey mesquite habitats. Since a given number of honey mesquite trees does not have the same foliage density as an equal number of cottonwood or willow trees, separate regression equations had to be developed for honey mesquite and cottonwood-willow.

Habitat Improvement

In preceding chapters we have demonstrated the low habitat quality of salt cedar so the following examples involve clearing of salt cedar habitats. These data are summarized in Appendix 13-1. However, any habitat could have been used. We also assume that areas to be cleared and revegetated encompass at least 40 ha (100 a). Problems of scaling render our data less appropriate as the size of the area decreases, until they become completely inappropriate at about 10 ha. Since cottonwood-willow and honey mesquite were both among the best wildlife habitats, they are both potential candidates for revegetation projects. In fact, because each of these habitats is attractive to somewhat different categories of wildlife, we assume that all revegetation efforts will include both of these native tree species (cottonwood and willow are considered one species).

Enhancement of an area can be predicted from:

$$E = \frac{(\text{Equation 1}) \times P_C}{W_C} - 1 \times 100 \quad \text{(Equation 2)}$$

where E represents enhancement, P_C is the proportion of the cleared area to be revegetated, and W_C is the number of wildlife categories ranked among the top three in the cleared area before clearing.

Evaluation of Habitat Use by Wildlife Category

The habitats in which each of various faunal components was ranked in the top three are presented in detail in Appendix 13-1. A summary of this information clearly indicates that peak wildlife use over several years (three for coyotes, five for rodents, four for birds) for which data are presented occurred in CW I-IV and HM III and IV habitats (Table 13-2). Even after correcting for the possible contribution of other vegetation such as shrubs and mistletoe, these habitats remain the premiere riparian habitats along the lower Colorado River. Details (Appendix 13-1) show that these two habitats were the "best" or were among the "best" for all of the categories listed except perhaps the Merriam kangaroo rat. But even for this species our regression analysis (Chapter 11) indicated that honey mesquite habitats were important, even though this final analysis indicates that honey mesquite habitats were

Table 13-2. Wildlife and vegetation characteristics for 23 riparian habitat types found in the lower Colorado River valley. CW = cottonwood-willow, HM = honey mesquite, SC = salt cedar, SB = screwbean mesquite, SH = salt cedar-honey mesquite, AW = arrowweed.

Vegetation type	Average number of wildlife categories ranking in top three	Approximate contribution by vegetation other than CW or HM	Contribution by CW or HM	Trees/acre (0.4 ha)		Foliage density of CW or HM	
				CW	HM	1.5-3.0 m	Total
CW I	17	0	17	146	0	0.22	1.39
II	23	0	23	87	0	0.21	0.85
III	26	5	21	83	0	0.17	0.79
IV	19	7	12	29	0	0.05	0.20
V	5	5	0	17	0	0.05	0.20
VI	6	6	0	2	0	0.00	0.00
SC I	4	4	0	0	0	0.42	1.21
II	8	8	0	0	0	0.26	0.96
III	5	5	0	0	0	0.39	0.61
IV	3	3	0	0	0	0.33	0.65
V	5	5	0	0	0	0.19	0.47
VI	7	7	0	0	0	0.42	1.10

Table 13-2. (cont.)

Vegetation type	Average number of wildlife categories ranking in top three	Approximate contribution by vegetation other than CW or HM	Contribution by CW or HM	Trees/acre (0.4 ha)		Foliage density of CW or HM	
				CW	HM	1.5-3.0 m	Total
SB II	8	8	0	0	0	0.36	1.08
III	15	15	0	0	0	0.22	0.48
IV	9	9	0	0	0	0.28	0.64
V	9	9	0	0	0	0.20	0.64
VI	4	4	0	0	0	0.09	0.38
SH IV	8	7	1	0	35	0.33	0.62
AW VI	1	1	0	0	0	0.16	0.53
HM III	20	0	20	0	93	0.45	0.71
IV	21	9	12	0	31	0.10	0.29
V	10	9	1	0	12	0.28	0.30
VI	9	9	0	0	9	0.04	0.19

not consistently among the top three across the five years of study. In contrast, salt cedar habitats were consistently among the best habitats only for doves (SC II), cactus mouse (SC II), Merriam kangaroo rat (SC VI), southern grasshopper mouse (SC V), desert pocket mouse (SC III and V), and deer mouse (SC I and VI).

Peak Use-Habitat Correlation

The relationship between the number of high ranks for the various faunal components and the number of cottonwood-willow and honey mesquite trees per acre was highly significant ($F = 28.2$, df 2,20, $P<0.0001$) and is expressed as:

$$NWC = 9.3\log_{10} CW/acre + 6.3\log_{10} HM/acre + (-0.9) \text{ (Equation 3).}$$

If 100 a (40 ha) of salt cedar IV habitat were cleared and if cottonwood-willow trees were planted at densities of 10 trees per acre (25/ha) and honey mesquite at 80 trees per acre in just 30% of the total area, there would be a theoretical enhancement in the area of about 80% (Table 13-3). At these tree densities the values of the area to wildlife would triple if 60% of the cleared area was revegetated. At tree densities of 10 cottonwood-willow and 80 honey mesquite per acre we would predict that several species of visiting insectivores would not be enhanced as much as permanent resident insectivores because the former tended to be associated with greater numbers of cottonwood-willow. For this reason a more even ratio of cottonwood-willow:honey mesquite is probably preferable. Certainly no realistic revegetation plan should ignore these two groups. It can be determined (Appendix 13-1) that if honey mesquite and cottonwood-willow are planted in about equal numbers many diverse wildlife categores would be enhanced, varying from rodents to coyotes to birds in various groups. If species low on the food pyramid (rodents) are benefited, higher order consumers, including some snakes, birds of prey, foxes, bobcats, etc., will also benefit.

Even if honey mesquite is planted in large numbers, we would not predict the presence of frugivorous species such as Phainopepla, whose presence depends on the presence of mistletoe berries. A study of ways to artificially infest honey mesquite with mistletoe should be initiated. Until then we cannot predict the presence of mistletoe and therefore the presence of frugivores. Planting of shrubs in plots of 2-4 ha (5-10 a) would help insure that enhancement would occur, as it would add vertical and horizontal diversity to the vegetation. Several bird species are known to be attracted to shrubs of various species (see Chapter 5 this study, Anderson et al. 1978, Meents et al. 1982).

Predicting Foliage Densities

Total foliage density and number of cottonwood-willow trees per acre (0.4 ha) is predicted by:

$$\text{Total foliage density} = -0.02 + 0.01 \text{ CW/acre}, r = 0.99, r^2 = 0.99, P<0.01 \text{ (Equation 4).}$$

Table 13-3. Wildlife enhancement to be expected if 40 ha (100 a) of salt cedar Type IV habitat were cleared and replaced by cottonwood-willow (CW) and honey mesquite (HM) trees. The numbers in the matrix are the percent enhancement expected.

Number of CW and HM per acre in revegetated portion		Percent of cleared area to be revegetated									
CW	HM	10	20	30	40	50	60	70	80	90	100
10	80	0	12	83	154	225	296	368	438	509	580
20	70	0	28	107	186	266	345	424	503	582	661
30	60	0	36	119	203	286	369	452	536	619	702
40	50	0	41	126	211	297	382	468	553	639	724
50	40	0	43	129	215	302	388	475	561	647	734
60	30	0	42	128	215	301	387	473	560	646	732
70	20	0	39	124	208	293	377	462	547	631	716
80	10	0	30	110	190	270	350	430	510	590	671

At 1.5-3.0 m the relationship was:

Foliage density 1.5-3.0 m = 0.02 + 0.002 CW/acre, $r = 0.94$, $r^2 = 0.89$, $P<0.05$ (Equation 5).

For honey mesquite the equations were:

Total foliage density = 0.16 + 0.006 HM/acre, $r = 0.98$, $r^2 = 0.96$, $P<0.10$ (Equation 6)

and

Foliage density 1.5-3.0 m = 0.08 + 0.004 HM/acre, $r = 0.80$, $r^2 = 0.64$, $P<0.20$ (Equation 7).

Although the equations for honey mesquite are not significant at the 0.05 level, this primarily reflects the small samples used in making the calculations. The consistently high correlation coefficients (r) lend credence to their use. Data used in these calculations are found in Table 13-2.

If 40 ha (100 a) of salt cedar Type IV habitat is cleared and replaced with densities of 10 cottonwood-willow and 80 honey mesquite per acre over 40% of the area, there would be a net decrease in the total foliage density in the area of 55% at maturity of the revegetated portions (Table 13-4). If vegetation removal salvages ground water, then this revegetation plan should result in a significant water savings. It would also have a 154% enhancement effect on wildlife (Table 13-3). Foliage at 1.5-3.0 m, which is likely to inhibit passage of floodwater would be reduced by 47%. As stated above, a more even ratio of cottonwood-willow:honey mesquite is preferrable. If the ratio were 50 cottonwood-willow to 40 honey mesquite, there would be a 45% reduction in total foliage density. As the number of cottonwood-willow increases, foliage density at 1.5-3.0 m decreases; thus in this example, there would be a 57% decrease in foliage at this level relative to the amount typically found in salt cedar Type IV vegetation.

Testing Predicted Wildlife Enhancement Values

About 44% of our 30-ha (75-a) dredge-spoil revegetation site was revegetated. In predicting wildlife use of this area for 1982 with Equation 3 we considered honey mesquite and palo verde trees to be at least rough ecological equivalents (Anderson and Ohmart unpubl. data), so their numbers were combined. The ratio of cottonwood-willow to honey mesquite + palo verde was 40:13. Using Equation 2, wildlife enhancement is predicted to be:

$$NWC = \frac{9.3 \times \log_{10}40 + 6.3 \times \log_{10}13 + -0.9 \times 0.44}{3} = 3.08$$

The 0.44 on the right end of the numerator is the proportion being cleared, and the denominator is the wildlife value for salt cedar Type IV habitat (Appendix 13-1).

Table 13-4. Predicted percent reduction in total foliage density and density at 1.5-3.0 m assuming that 40 ha of salt cedar Type III habitat was cleared and replaced in varying amounts by cottonwood-willow (CW) or honey mesquite (HM). The numbers in the matrix represent the percentage by which the foliage density before clearing would be reduced when the revegetated area is mature.

	Tree densities in revegetated portion		Percent of area being revegetated						
	CW	HM	20	30	40	50	60	70	80
Total foliage density	10	80	78	67	55	44	33	22	11
	20	70	76	65	53	41	29	18	6
	30	60	75	63	50	38	26	13	1
	40	50	74	61	48	35	22	9	0
	50	40	73	59	45	32	18	4	0
	60	30	71	57	43	29	14	2	0
	70	20	70	55	40	26	11	0	0
	80	10	69	53	38	7	0	0	0
Foliage density 1.5-3.0 m	10	80	73	60	47	34	20	7	0
	20	70	75	62	49	37	24	11	0
	30	60	76	64	52	40	28	16	4
	40	50	77	66	54	43	31	20	8
	50	40	78	67	57	46	35	24	13
	60	30	80	69	59	49	39	28	18
	70	20	81	71	61	52	42	33	23
	80	10	82	73	64	55	46	37	28

The revegetated area was not trapped enough to evaluate possible enhancement of rodents. The value for coyotes was not determined. Therefore, the test of predicted improvement lies exclusively with the outcome for birds (Table 13-5). In making this determination we first calculated the four-year average for the third-ranked value for each of the components (total species, densities of visiting insectivores, etc.). If the respective value for the dredge spoil was equal to or greater than the average for a given category we concluded that it would probably have ranked in the top three for all the habitat types in riparian vegetation.

Over the five seasons in 1982 there was a total of 15 categories judged to have ranked among the top three in riparian vegetation. Since the area also had shrubs present, some adjustment must be made to account for birds attracted to the area because of shrubs (Rice et al. 1983). In our judgment, shrubs merely increased densities of species that would have been on the site even in the absence of shrubs. After adjustment, the number of categories judged to rank in the top three as a result of the presence of cottonwood, willow, and honey mesquite was reduced to seven (Table 13-5). Salt cedar Type IV had three total faunal components among the top three; thus the revegetated area represents an improvement of 7/3 or 2.33. This is 76% of the predicted value of 3.08. The inclusion of shrubs boosted the observed to five times the value of SC IV (Table 13-5).

Values and means for several avian components for each season for several years are presented in Appendix 13-2. We divided the mean value in salt cedar IV habitats by the value for the revegetated site. Using this procedure we can see precisely what categories were enhanced and during which seasons the enhancements occurred on the revegetated area (Table 13-6). The number of doves was much lower on the revegetated site than typically found in salt cedar IV habitat. The number of species of permanent resident insectivores on the revegetated site was about equal to the number in salt cedar IV habitat. All other components showed an increase on the revegetated area.

Our prediction concerning wildlife use is probably somewhat low because in our young stand there are very few cavity-nesting species because of the absence of dead trees or snags. As the stand matures, dead snags will increase in number as will cavity-nesting species. Also, had rodents and coyotes been included the actual value would probably have exceeded the predicted value.

Testing Foliage Density Predictions

Using Equations 4 and 6, the predicted total foliage density is $-0.02 + 0.01(42\ CW) + [0.16 + 0.006(24\ HM)]0.44 = 0.31$. Foliage density in salt cedar Type IV averages about 0.65; thus we predict a reduction in total foliage density of $0.65-0.31/0.65 = 0.52(100) = 52\%$. The observed foliage density was $0.93(0.44) = 0.41$, which represents a reduction of $0.65 - 0.41/0.65 = 0.37(100) = 37\%$. Thus there was an apparent error in estimation of about 15%. In view of the inherent inaccuracies in measuring foliage density, some error is not overly disturbing (Chapter 2). Another point worthy of mention is that our predictive equations

Table 13-5. Numbers associated with various avian categories on a revegetated plot and the average value for the third ranking value for all riparian habitats in the lower Colorado River valley (parentheses). The revegetated area would rank in the top three if the number for a given category is equal to or greater than the number in parentheses.

Category	Spring	Summer	Late summer	Fall	Winter	Total in top three	Approximate number in top three as a result of shrubs	New total
Total species	31(31)	28(26)	26(30)	29(26)	32(29)	4	0	4
Species of permanent resident insectivores	7(11)	9(12)	9(12)	7(11)	7(13)	0	0	0
Species of visiting insectivores	14(13)	12(12)	11(11)	10(12)	9(16)	3	0	3
Density of visiting insectivores	93(103)	66(114)	38(81)	228(136)	49(285)	1	1	0
Density of permanent resident insectivores	36(72)	40(95)	34(134)	54(68)	77(72)	1	1	0
Density of doves	8(34)	67(198)	24(113)	---	---	0	0	0
Density of Gambel Quail	57(19)	16(55)	29(69)	144(42)	15(11)	3	3	0
Density of granivores	57(30)	---	---	144(54)	284(68)	3	3	0
Totals in top three	4	2	1	4	4	15	10	7

Table 13-6. Ratio resulting from the number of each category (listed on left) found on revegetation plot:number for salt cedar IV habitats. Ratios >1.0 indicate enhancement relative to salt cedar.

Category	Spring	Summer	Late summer	Fall	Winter	Mean
Total species	1.53	1.40	1.44	1.41	1.19	1.39
Species of permanent resident insectivores	1.00	1.00	1.07	0.92	0.85	0.97
Species of visiting insectivores	1.77	1.46	1.90	1.35	1.36	1.57
Density of permanent resident insectivores	1.24	0.80	0.45	1.50	3.63	1.52
Density of visiting insectivores	3.00	1.08	1.42	5.35	2.13	2.60
Density of doves	0.44	0.34	0.31	--	--	0.36
Density of Gambel Quail	4.79	1.01	3.54	4.34	0.67	2.87
Density of granivores	9.05	--	--	9.00	49.00	22.35
MEAN	2.85	1.01	1.45	3.41	8.40	4.20

are for mature stands; the trees on our revegetation site are only four years old. At present the trees on the revegetation site have leaves at low levels. As the trees continue to grow, sunlight to low levels will be blocked and limbs and leaves will become fewer. Foliage density at $\leq$3 m will be reduced, thus decreasing total foliage density at <3 m as growth gradually attenuates.

Using Equations 5 and 7, predicted total foliage density at 1.5-3.0 m is: 0.02 + [0.002(42)] + [0.08 + 0.004(24)]0.44 = 0.123. Foliage density at this level in salt cedar IV habitats averages about 0.33; thus we predict a reduction in foliage density of 0.33 - 0.12/0.35 = 0.64(100) = 64%. The observed foliage density of 0.42(0.44) = 0.18. The observed foliage reduction would have been 0.33 - 0.18/0.33 = 0.45(100) = 45%. At 1.5-3.0 m our prediction is high by 19%. Our above comments relative to foliage density apply here as well.

CONCLUSIONS AND RECOMMENDATIONS

In addition to the quantified data presented in this and other chapters in this volume we have many notebooks filled with ancedotal data concerning wildlife use of our revegetated sites. It seems appropriate to very briefly summarize some of this data at this point in order to strengthen conclusions drawn from the quantifiable data.

Rodent and Audubon cottontail (Sylvilagus audubonii) populations became so high on the revegetation site that they began to do severe damage to the planted vegetation. To relieve this pressure 40 line traps were set out by our laborers. For 10 consecutive nights they caught and removed 30-40 rodents, including many cotton rats. Five rabbit traps caught 3-5 rabbits every night for the same period. This indicates huge populations of these species.

In spite of the heavy trapping by our laborers to remove rodents damaging trees we put out snap-trap grids. This data is, of course, of little value because of the massive removal effort. Nonetheless, four snap-trap grids set out in the fall averaged 11.2 rodents per 270 trap nights. This is remarkable considering that it took place after intensive removal over most of the summer. The catch averaged 6 cactus mice, 4 pocket mice, and 1.2 Merriam kangaroo rats per 270 trap nights.

Rodent trapping on the revegetation site which has been cleared had enormous rodent populations, including 28 cactus mice per 270 trap nights, by the first fall after planting (Anderson and Ohmart 1982). Catches in fall 1983 included 41 cactus mice per 270 trap nights. This exceeds the average per 270 trap nights for all habitat types (Anderson and Ohmart 1977). In fall 1982 the catch included 31 cactus mice per 270 trap nights. Thus even though the habitat analysis revealed salt cedar II to be the preferred habitat of the cactus mouse by managing for maximum wildlife values to the fullest extent possible we were able to create a habitat which supported a sustained population of cactus mice larger than was found in almost all riparian habitats. SC IV averaged 20 cactus mice per 270 trap nights in fall (Anderson and Ohmart 1977).

In addition to rodents, bird censusers frequently encountered live coyotes and the scats of coyotes and bobcats. Skunks were abundant on the dredge-spoil site. Deer use the area regularly and two bucks were taken there during the 1983 deer hunting season. Deer pellets and tracks are frequently seen. Deer shedding velvet rub their antlers on trees and can do considerable damage to limbs. We also have photographic evidence of this as well as photographs of the deer, deer tracks, and deer pellet groups.

Rattlesnakes (Crotalus atrox) are as abundant on the dredge-spoil site as any place in the lower Colorado River valley. High boots must be worn and a great deal of care taken when working on the site every day from mid-April through October. Gopher snakes (Pituophis melanoleucus) are also abundant on the revegetation site. A total of 16 species of reptiles were observed on the revegetation site in 1980. A discussion of lizard numbers is found in Anderson and Ohmart (1982).

We have shown that it is possible to clear dense stands of salt cedar and to replace these stands with smaller amounts of native vegetation that will attract more wildlife and still allow a significant overall net reduction in foliage density. This reduction may lead to salvage of ground water and would also reduce the damming effect that dense vegetation has on passage of flood waters. Our predictive equations have been developed on the basis of a very large data base and have been proven to have high predictive capabilities through tests of field data from an experimental plot.

Earlier in this report (see Chapter 5) we showed that shrubs and foliage diversity in the horizontal plane are important to attracting wildlife. We would recommend planting a patch of about 2 or 3 ha (5 or 7.5 a) of shrubs for every 20 ha of vegetation to be planted. This would increase both vertical and horizontal foliage diversity and would attract certain wildlife species. It would probably also lead to a mature stand consisting of less total foliage density than if only trees were planted.

We also recommend that honey mesquite and cottonwood-willow trees be planted in patches of about 1 or 2 ha rather than alternating individual cottonwood-willow and honey mesquite trees. This would also increase patchiness at a scale at which birds seem to respond. We also recommend that revegetation efforts be initiated only on plots of 20 acres or more. Accurate predictions of the outcome are not possible on smaller plots. Also wildlife enhancement can be expected to be less on smaller plots (Ambuel and Temple 1983).

The rate at which a revegetated area develops is a very important feature of revegetation projects. Done properly, revegetated areas can be expected to develop at an astonishingly rapid rate. But what constitutes "proper" procedure? We have summarized these steps elsewhere (Anderson and Ohmart 1982), but it seems worthwhile to emphasize here that a careful soil salinity analysis prior to planting anything is of profound importance. Such an analysis allows wise decisions to be made concerning what species of vegetation to plant and where to plant them on the site. Failure to conduct this crucial

preliminary step will lead inexorably from moderately high to very high mortality rates, slow growth rates, and low wildlife use values.

Why, we have asked, do well-meaning individuals omit this critical step? The most frequently given reason is that money was in short supply, and for this reason steps had to be omitted. Including a soil analysis would have raised the cost per tree to such a high level that the project could not have been undertaken. In reality the opposite is true. It costs as much to plant a tree that dies as it does to plant one that survives, thus, haphazard planting increases the cost per survivor.

We have also shown that value to wildlife (at least for birds, rodents, coyotes, and insects) is almost a straight-line relationship with the number of trees which survive (Anderson and Ohmart unpubl. data; Table 13-2, equation 3 this chapter). Therefore wildlife use where soil factors are studied will pay off in terms of increased tree survival and increased benefit to wildlife. Also, there is another important consideration. When trees are planted in an area so unsuitable that one-third of the trees die, it means that there will be a slow average growth rate of the survivors. Thus at the end of two years not only will one-third of the trees be dead, but those still living will be stunted; in other words the area will not be much better than bare soil in its value to wildlife. Perhaps in 10 or 20 years this area may become a habitat of modest wildlife value, but the road to that stage will be punctuated with low wildlife use.

Aside from soil salinity analyses, tillage to an adequate depth and preventing invasion by weed competitors are additional keys to success. Some may argue that assuming one-third mortality rate without a preliminary soil factor analysis is unreasonably high. In reality such an estimate may be somewhat above average. According to data we have on file, failure to do a preliminary soil factor study could be expected to add about 25% mortality on the average. Rates are lowest for blue palo verde ($7\pm8\%$), followed by honey mesquite ($11\pm5\%$), willow ($37\pm28\%$) and cottonwood ($32\pm30\%$). With inappropriate tillage (e.g., halfway to permanently wet soil), it is reasonable to expect another 10% mortality. If competition from weeds is allowed to develop, it is reasonable to add another 10-15% mortality (Anderson and Ohmart unpubl. data).

However, consequences other than mortality are associated with inappropriate procedures. When mortality of 10% is associated with honey mesquite and cottonwood-willow, it means that growth rates are so slow that biomass (= foliage density) is reduced by about 50% (Anderson and Ohmart unpubl. data). Wildlife use of such an area can be deduced by using Equation 2.

Assume that a hypothetical project involved clearing 40 ha of salt cedar IV habitat. Twenty percent of the area was to be planted with a ratio of 30 honey mesquite:30 cottonwood-willow. The predicted wildlife value would be 1.5 times that of the salt cedar IV habitat. But because inappropriate planting procedures were followed, the planting must be considered to be only 15 cottonwood-willow:15 honey mesquite. The resulting habitat would not be as good as the salt cedar it was to replace.

Proper procedures give revegetation efforts the predictability of success necessary for an effective management tool. Without being able to predict plant growth and survival, wildlife use cannot be predicted. This would confine revegetation efforts to bare areas. Projects involving clearing could not be done.

Since this volume was prepared several papers from it have been published. In an effort to make the volume as current as possible we have included the titles of these papers as well as titles of other papers which have resulted from "vegetation management" studies.

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Appendix 13-1. Evaluation of habitat use by wildlife of 23 riparian habitats along the lower Colorado River. An x indicates each variable ranked among the top three habitats. For example, if the density of visiting insectivores was greatest in cottonwood-willow II habitat in spring, an x was placed under CW II. This was repeated for each of the top three ranks. More than three habitats occurred when there were ties. CW = cottonwood-willow, SB = screwbean mesquite, SC = salt cedar, SC-HM = salt cedar-honey mesquite, AW = arrowweed, HM = honey mesquite.

	CW						SB					SC						SC-HM	AW	HM			
Variable	I	II	III	IV	V	VI	II	III	IV	V	VI	I	II	III	IV	V	VI	IV	VI	III	IV	V	VI
Birds - total species																							
Spring		x	x	x																			
Summer	x	x	x	x																x	x		
Late summer			x	x				x		x										x			
Fall			x	x				x	x								x			x	x		
Winter		x	x	x										x				x			x		
Species of permanent resident insectivores																							
Spring				x																			
Summer		x	x	x				x		x										x	x		
Late summer				x														x		x	x		
Fall			x	x		x														x	x		x
Winter			x			x															x		
Species of visiting insectivores																							
Spring	x	x		x																			
Summer	x		x	x	x																		
Late summer	x	x	x	x										x			x			x			
Fall	x	x	x																				
Winter			x	x	x																		

Appendix 13-1. (cont.)

Variable	CW						SB					SC						SC-HM	AW	HM			
	I	II	III	IV	V	VI	II	III	IV	V	VI	I	II	III	IV	V	VI	IV	VI	III	IV	V	VI
Density of permanent resident insectivores																							
Spring	x	x	x																				
Summer	x	x	x					x	x											x			
Late summer	x	x																		x			
Fall	x	x	x											x									
Winter	x	x	x						x								x			x	x		
Density of visiting insectivores																							
Spring	x	x	x																				
Summer	x	x	x	x		x		x															
Late summer	x	x	x	x																			
Fall	x	x	x								x												
Winter	x	x	x																				
Density of Gambel Quail																							
Spring			x					x							x					x	x	x	
Summer				x	x	x		x									x			x	x		
Late summer			x				x	x				x						x		x			
Fall								x	x	x								x		x			x
Winter																				x	x	x	
Density of doves																							
Spring							x	x					x							x			
Summer			x	x			x	x					x							x			

Appendix 13-1. (cont.)

Variable	CW						SB					SC						SC-HM	AW	HM			
	I	II	III	IV	V	VI	II	III	IV	V	VI	I	II	III	IV	V	VI	IV	VI	III	IV	V	VI
Density of doves (cont.)																							
Late summer							x	x					x							x			
Density of granivores																							
Fall																					x	x	x
Winter																					x	x	x
Spring																					x	x	x
Density of frugivores																							
Fall																					x	x	x
Winter																					x	x	x
Spring																					x	x	x
Bird totals	15	17	24	17	3	4	4	12	4	3	1	1	3	3	1	0	4	4	0	18	17	8	8
Cactus mouse																							
Summer		x						x					x										
Winter		x					x						x										
White-throated woodrat																							
Summer		x							x				x										
Winter		x					x						x										

Appendix 13-1. (cont.)

Variable	CW						SB					SC						SC-HM	AW	HM			
	I	II	III	IV	V	VI	II	III	IV	V	VI	I	II	III	IV	V	VI	IV	VI	III	IV	V	VI
Merriam kangaroo rat																							
Summer									x	x							x						
Winter										x							x						x
Harvest mouse	x		x	x																			
Southern grasshopper mouse										x						x					x		
Desert pocket mouse																							
Summer									x	x	x			x		x		x			x		x
Winter									x									x					x
White-footed mouse																							
Summer		x				x									x								
Winter					x	x						x							x				
Coyote																							
Year 1	x	x	x	x	x	x	x	x	x	x	x									x	x	x	x
Year 2							x	x	x	x	x	x	x	x	x	x	x	x					
Year 3	x	x	x	x	x	x	x	x	x	x	x							x		x	x	x	x
Mammal totals	3	7	3	3	3	4	5	4	7	7	4	2	5	2	2	3	3	4	1	2	4	2	5
Mammal + bird totals	18	24	27	20	6	4	9	16	7	11	7	3	8	5	3	3	7	8	1	20	21	10	13

Appendix 13-2. Numbers per 40 ha for nine bird variables for salt cedar Type IV habitats in the lower Colorado River valley. For each year there was an average of three transects each censused three times per month. No censusing was done in fall and late summer 1979 or in winter 1979-80.

SPRING

Variable	1975	1976	1977	1978	1979	1980	1981	Mean	Standard deviation
Total species	17	12	23	25	22	19	24	20.3	4.6
Species of permanent resident insectivores	5	4	8	8	9	8	7	7.0	1.8
Species of visiting insectivores	5	3	8	11	10	6	12	7.9	3.3
Density of visiting insectivores	27	9	19	50	39	33	40	31.0	13.9
Density of permanent resident insectivores	41	16	20	31	33	34	29	29.1	8.6
Density of doves	15	5	15	37	7	29	20	18.3	11.5
Density of Gambel Quail	17	11	10	2	19	23	1	11.9	8.4
Density of granivores	23	8	7	3	4	0	5	6.3	5.4
Density of frugivores	1	0	0	0	0	2	0	0.4	--

Appendix 13-2. (cont.)

SUMMER								
Variable	1975	1976	1977	1978	1979	1980	Mean	Standard deviation
Total species	19	17	18	19	23	24	20.0	2.82
Species of permanent resident insectivores	12	9	8	8	10	7	9.0	1.8
Species of visiting insectivores	7	8	6	8	10	10	8.2	1.6
Density of visiting insectivores	30	31	32	54	105	108	61.2	36.1
Density of permanent resident insectivores	33	34	31	64	54	85	50.2	21.6
Density of doves	53	159	159	182	259	377	198.0	109.6
Density of Gambel Quail	10	6	12	41	10	16	15.8	12.8
Density of granivores	0	0	0	x	x	x	--	--
Density of frugivores	0	0	0	x	x	x	--	--

Appendix 13-2. (cont.)

LATE SUMMER								
Variable	1975	1976	1977	1978	1979	1980	Mean	Standard deviation
Total species	13	13	19	23	--	22	18.0	4.8
Species of permanent resident insectivores	7	10	8	9	--	8	8.4	1.1
Species of visiting insectivores	2	6	5	8	--	8	5.8	2.5
Density of visiting insectivores	18	19	12	36	--	49	26.8	15.3
Density of permanent resident insectivores	51	62	48	85	--	132	75.6	34.7
Density of doves	27	37	21	73	--	226	76.8	85.8
Density of Gambel Quail	2	31	9	22	--	102	33.2	40.1
Density of granivores	0	2	5	0	--	--	--	--
Density of frugivores	0	0	0	0	--	--	--	--

Appendix 13-2. (cont.)

	FALL							
Variable	1975	1976	1977	1978	1979	1980	Mean	Standard deviation
Total species	14	21	24	27	--	17	20.6	5.2
Species of permanent resident insectivores	6	8	6	11	--	7	7.6	2.1
Species of visiting insectivores	4	8	10	11	--	4	7.4	3.3
Density of visiting insectivores	14	43	83	41	--	32	42.6	25.3
Density of permanent resident insectivores	18	39	25	43	--	55	36.0	14.7
Density of doves	1	3	5	3	--	3	3.0	1.4
Density of Gambel Quail	0	1	4	3	--	33	8.2	14.0
Density of granivores	9	20	24	14	--	13	16.0	6.0
Density of frugivores	0	0	0	0	--	1	--	--

Appendix 13-2. (cont.)

	WINTER							
Variable	1975-1976	1976-1977	1977-1978	1978-1979	1979-1980	1980-1981	Mean	Standard deviation
Total species	11	14	17	27	--	15	16.8	6.1
Species of permanent resident insectivores	5	10	7	13	--	6	8.2	3.3
Species of visiting insectivores	3	4	7	14	--	5	6.6	4.4
Density of permanent resident insectivores	8	18	14	33	--	33	21.2	11.3
Density of visiting insectivores	4	27	37	21	--	26	23.0	12.1
Density of doves	5	2	1	2	--	70	16.0	30.2
Density of Gambel Quail	2	1	0	7	--	102	22.4	44.6
Density of granivores	4	3	8	12	--	2	5.8	4.1
Density of frugivores	1	0	0	0	--	0	--	--

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