ECOLOGICAL RELATIONS OF THE BREEDING BIRD POPULATION OF THE DESERT BIOME IN ARIZONA

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INTRODUCTION

Bird populations of the lower Sonoran deserts have been long neglected, due primarily to the hardships encountered and the inaccessibility of most areas that are relatively undamaged by human intervention. Few areas remain with unspoiled desert flora and fauna so characteristic of the "old southwest." In this hard climate, overgrazing, overshooting, fires, and other catastrophes leave scars for long periods of time. Recovery is slow, because there is little rainfall to invigorate plant successions. Accessible bodies of permanent natural water are usually surrounded by extensive, barren areas due to trampling by cattle.

The Organ Pipe Cactus National Monument, Pima County, Arizona, was selected as the site for the present study. It contains 330,687 ac. or 516 sq. mi. of luxuriant growth. About one thousand head of cattle inhabit the area, but only in the vicinity of water holes is their presence noticeable to any extent. The Monument is situated 15 miles south of Ajo, Arizona, and is crossed by an improved road which leads south to Sonoyta, Mexico, thence on to Punta

Penasco, Sonora, Mexico. The Gulf of Lower California lies within 50 miles of the southern boundary of the Monument. Only one additional graded road is maintained and this runs along the southern border from the Monument Headquarters to Quitobaquito in the southwestern corner of the area, a distance of about 20 mi. Numerous unimproved desert roads lead to most sections of the Monument but are traversable only with proper equipment and then sometimes with difficulty.

The field study was initiated in July, 1948, and concluded the following season (February-August, 1949). The study was made possible through the courtesy of the National Park Service and with the generous cooperation of the local officials, William R. Supernaugh, Monument Superintendent and Ranger Glen L. Bean.

The writer is indebted to Dr. A. A. Allen, Department of Conservation, Cornell University and to Dr. S. Charles Kendeigh, Department of Zoology, University of Illinois, for their supervision of the research program and critical examination of the manuscript. Any errors are entirely the responsibility of the author.

TOPOGRAPHY AND GEOLOGY

Organ Pipe Cactus National Monument is a flat, level plain, interrupted by several ranges or groups of low mountains (Fig. 1). Most of the ranges extend in a north-south direction, which is the general pattern for northern Sonora, southeastern California, southern Arizona, and southern New Mexico (Gould 1938).

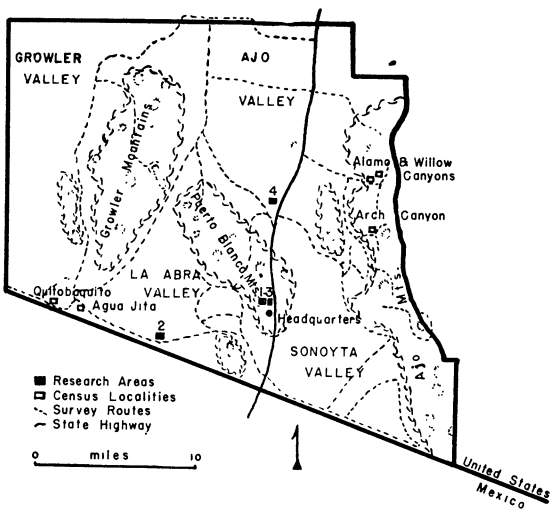

FIG. 1. Organ Pipe Cactus National Monument.

Two prominent mountain ranges are present within the boundaries of the Monument, the Ajo and the Growler Mountains. Several smaller groups are also included as well as four main valleys, the Ajo, Sonoita, La Abra, and Growler. For the most part the mountains are relatively low, and the entire Monument lies almost completely within the Lower Sonoran Life Zone. Only in the canyons of the Ajo Mountains does one approach Upper Sonoran conditions (Phillips & Pulich 1948). Santa Rosa, the highest peak of the range, rises to 4829 ft. Kino Peak, in the Growler range, has an elevation of 3057 ft. while Twin Peaks, highest of the Puerto Blancos, is 2600 ft.

The southern boundary of the Monument coincides with the northern boundary of the State of Sonora, Mexico, for its full length of approximately 32 mi. The eastern boundary extends for about 25 mi. along the crest of the Ajo Mountains where it contacts the Papago Indian Reservation. The western edge is a common boundary with the Agua Prieta Wildlife Refuge. The southern and northern boundaries have been almost completely fenced and the western border partly so. Fencing will eventually completely surround the Monument, with the exception of the Ajo Mountain sector, in order to prevent the ingress of cattle from adjoining range lands bordering on the north and south sides.

Most of the rocks within the Monument are of three general kinds; old pre-Cambrian schist, gneiss, and granite; Tertiary volcanic lava and tuff, and recent alluvium and valley wash (Gould 1938). The pre-Cambrian element is chiefly gray and red granite and schist. The greater part of the rocks which form the mountains are of volcanic origin for the region contained many volcanoes during the late northern Sonoran geologic period (Gould 1938). As the molten lava cooled it formed black basalt which is now exposed on the mountain tops. Lighter colored volcanic ash was compacted and hardened to form tuff. Layer after layer of these accumulated until thicknesses of 2000 ft. or more are attained as in the Ajo Mountains.

Large deposits of alluvium occupy the valleys. Rock debris and other materials washed from the mountains have filled the lower reaches to depths of hundreds of feet in some cases. This alluvium is sometimes cemented by lime or other materials to form a conglomerate, but most often in this region it is loose and unconsolidated. Caliche (hardpan) is formed in this region as a mixture of uncemented material (Breaziale & Smith 1950).

NATURAL WATER SUPPLY

Gould (1938) reported three springs on the Monument, namely: Bull Pasture Spring (Ajo Mountains), Dropping Springs (Puerto Blanco Mountains), and Quitobaquito. At least three additional sources of semi-permanent tinajas (pot-holes) have been recently located and two other permanent springs. The latter may have been included by Gould as part of the Quitobaquito Spring as Agua Jita is a seep of about 30 yd. approximately a half mile east of Quitobaquito and Rincon Spring is approximately three mi. north. The flow at Quitobaquito, estimated at about 43 gallons per minute by Gould, was impounded several years back by a Papago Indian who settled nearby and planted a few fruit trees in the vicinity. The pond now covers

about one-quarter of an acre in area and comprises a veritable oasis in the desert. The spot was formerly one of the major water holes along the old "Camino del Diablo" which ran from Sonoyta to Yuma during the early mining era of the southwest country.

During the current study several exploratory excursions were taken into the canyons of the Ajo Mountains where several semi-permanent shaded tinajas were discovered. Upper Alamo, "Willow," Arch, "Mammosa," and Canyon Diablo all contained pools of water that were with the exceptions of Diablo and Alamo accessible to the mammals and birds of the region. The names "Willow" and "Mammosa" are terms utilized by the writer as a temporary means of distinguishing the canyons for no names have been permanently applied.

In addition to these natural water sources, a total of at least six active wells are present. These are all fenced and are available only to the cattle and the smaller vertebrates.

CLIMATE

Latitude, altitude, interfering mountain ranges, and remoteness from any large body of water are the principal factors which influence the climate of the region. Temperatures are high and the rainfall low which accounts for an extremely low relative humidity. Temperature ranges between diurnal and nocturnal periods are great and generally speaking, the summers are usually long.

Temperature. Two weather stations, located near the Monument, present a reasonably accurate appraisal of conditions at the study areas. Ajo is ap-

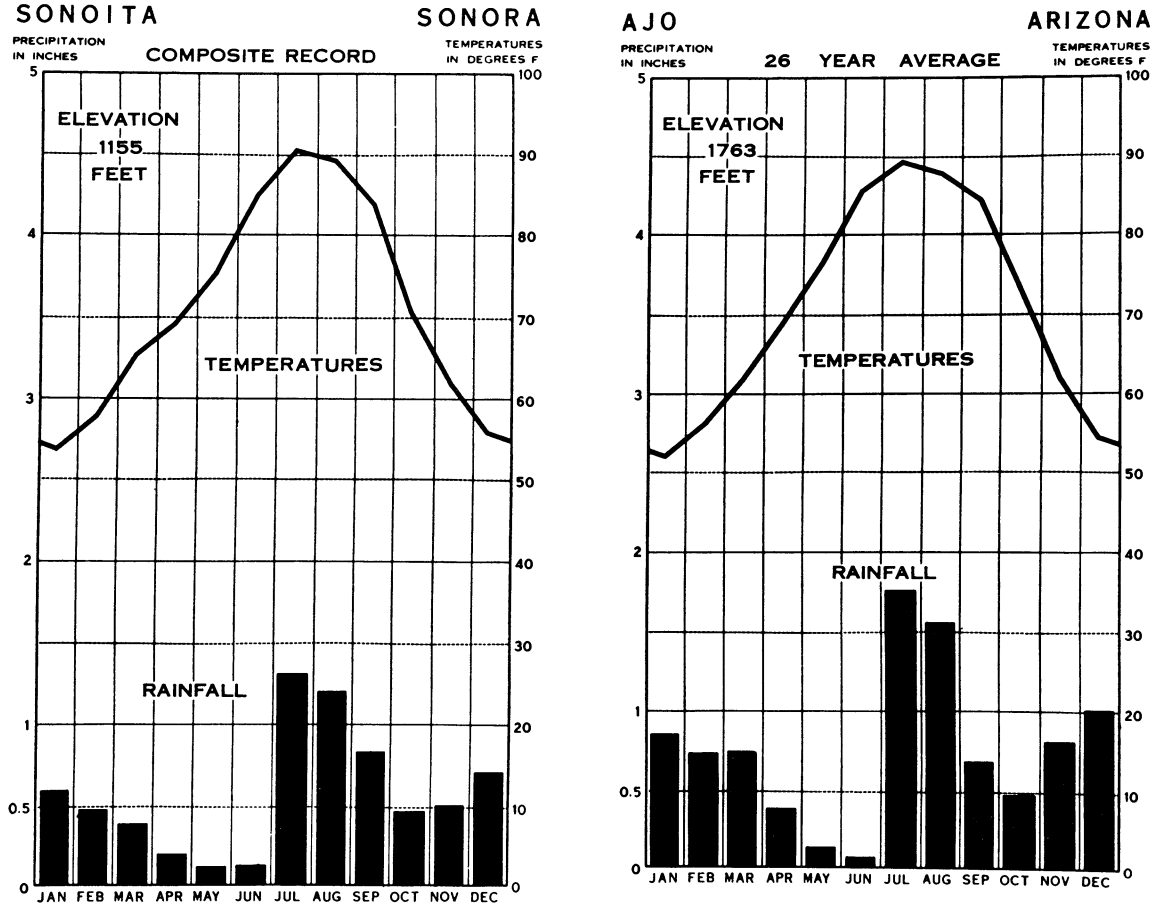

FIG. 2. Composite record of temperatures and rainfall at Sonoita, Mexico and Ajo, Arizona.

TABLE 1. Mean monthly maximum and minimum temperatures during the study period in 1948-49.

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July
Mean Maximum.....	102.6	99.5	86.4	72.6	64.5	55	62	75.5	85.9	89.1	95.5	101.2
Mean Minimum.....	72.5	66.8	57.7	38.3	37.8	31.5	33.5	41	50.2	52.9	62.4	73
Mean Monthly.....	87.6	83.2	72	55.5	51.2	43.3	47.7	58.3	68.2	71	78.9	87.1

proximately 30 mi. northwest of Monument headquarters while Sonoyta, Sonora, Mexico, is only about 5 mi. to the south. Figure 2 shows composite records for several years at these stations.

Daily temperature readings were also taken at Monument Headquarters. These data are shown in Table 1 for the months during which the current study was conducted.

The average date of the last spring frost at Ajo falls on January 22 and the average date of the first autumn frost comes on December 20. There is thus an average growing season of 332 days. Extreme frost dates are March 13 and November 11.

Precipitation. Two distinct rainy seasons are characteristic for the state as a whole with the most important season occurring during July, August, and September. According to Smith (1945) the state receives about 43% of the entire year's supply during this period. During the current study at Organ Pipe Cactus National Monument the summer rainfall came chiefly during the month of October, somewhat later than the mean season. These summer rains are spotty in distribution and spontaneous in nature, usually short-lived and accompanied by wind, thunder, and lightning. A total high for the month of October at Monument Headquarters amounted to 2.6 in.

The second rainfall period takes place from December to March and is of considerably longer duration but produces less water (35%) of the annual precipitation of the state. These rains are mostly gentle showers which may last for hours. Normal monthly and annual precipitation for Ajo and Organ Pipe Cactus National Monument is shown in Table 2.

Miscellaneous Climatic Phenomena. The Sonoran region lies in a belt of lower relative humidity than most other parts of the United States. On hot summer days the relative humidity may go as low as 5% or less. As to be expected the winter months may have quite high humidity records due to the lower temperatures and the occurrence of the winter rainy season. Highest humidity may be expected just before sunrise during the normal daily fluctuating cycle and a low point is usually reached just after noon, depending on the temperature.

The southwestern sector of Arizona receives more sunshine than does any other part of the country. Here approximately 85% of the possible sunshine is recorded. The winter months of November, December, and January produce the lowest number of sunny days as a rule.

Wind velocities are mild, usually ranging from 5 to 8 mi. per hour, depending on the local topography, while extreme velocities seldom reach fifty miles per hour. The prevailing winds are from the southwest. Ajo records prevailing winds from the south for January and November.

VEGETATIONAL ASPECT OF ORGAN PIPE CACTUS NATIONAL MONUMENT

Benson & Darrow (1944) place the southwestern creosote bush deserts into three categories (Mojave, Sonoran, and Chiuahuan) arranged according to species composition and general structure of the vegetation. According to these workers the Arizona Desert differs from the other southwestern deserts in the richness of its arboreal and succulent plants, being partially isolated from the other deserts by the low elevations of the Colorado River on the western border and by the higher elevations of the Mexican Plateau between southeastern Arizona and southwestern New Mexico.

The term biome is used as a synonym of biotic formation which essentially is a complex of fully developed and developing communities, characterized by uniformity of the plant climaxes. The biome (Clements 1946), is based upon both plants and animals.

Although covered primarily by such characteristic desert plants as creosote bush, bur sages, etc., many minor variations in the vegetation exist within the Monument due to differences in soil composition, texture, available moisture, shade, and altitude. The lowest elevation (1000 ft.) on the Monument is found in the extreme southwestern sector around Quitobaquito and Agua Jita. Only here are found such plants as arrow weed (*Pluchea sericea*) and smoketree (*Dalea spinosa*). On the other hand, the shaded canyon floors of the Ajo Mountains may exceed 4000 ft. in elevation and support a host of plant species entirely restricted to such specific situations. Juniper and oak trees are common in the canyons and such herbs as the gooseberry (*Ribes quercetorum*) and *Penstemon microphyllus* may be found in association with the Vauquelina.

A total of 398 species of plants have been recorded by the local officials to date (1950) on the Monument and represent 72 families.

Many of the plants are of unusual interest for they represent new locality records and include range extensions of considerable distances. Few professional botanists have visited the region and, as a result, the flora of the Ajo Mountain canyons, in particular, is not well known. Many plants of more than causal interest are certain to be found once the hardships of

TABLE 2. Normal monthly and annual precipitation for Ajo and Organ Pipe Cactus National Monument.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Ajo (27 yrs.)	.84	.71	.66	.30	.11	.11	1.48	1.85	.97	.50	.70	1.06	9.29
Organ Pipe (5 yrs.)	.45	.56	.55	.12	.01	0	.66	1.81	2.11	.70	.65	.89	7.69
Organ Pipe (1948-49)	2.19	.06	.37	.22	0	T	.65	.90	.07	2.64	0	1.14	8.24

desert remoteness and discomforts are braved by some interested scientists. *Agave schottii* var. *treleasei,* known only from one station on the southern slopes of the Santa Catalina Mountains and the bush penstemon, *Penstemon antirrhinoides* var. *microphyllus* (nearest locality 150 mi. to the northeast) are two of the unusual plants found in the canyons of the Ajos. The elephant plant, *Bursera microphylla,* occurs along the foothill slopes near Sweetwater Pass in the south central part of the Monument. Colonies of *Dalea pringlei* and *Jatropha angustidens* were found in Arch Canyon in 1947 by C. L. Fouts but have since disappeared so their inclusion in the flora of the Monument is questionable at this time.

The small pond at Quitobaquito supports a fine stand of sedge, *Cyperus laevigatus,* which was first collected by Mearns during the early expeditions of the International Boundary Survey. Four miles to the north at Rincon Springs is another small water hole (mentioned earlier) that has a flourishing stand of cattails.

Two major eco-systems or soil-vegetation complexes are found in the Monument, namely: (1) alluvial fill and (2) the lava-granite composition of the mountains.

INTERMOUNTAIN ALLUVIAL FILL COMPLEX

Most of the valleys or intermountain plains are composed chiefly of silt and rocks washed down from the adjoining mountain ranges. Varying degrees of consistency and composition of the alluvial fill are present and may influence the vegetation type growing on them depending on the exposure, available moisture, altitude, and other factors (Fig. 3).

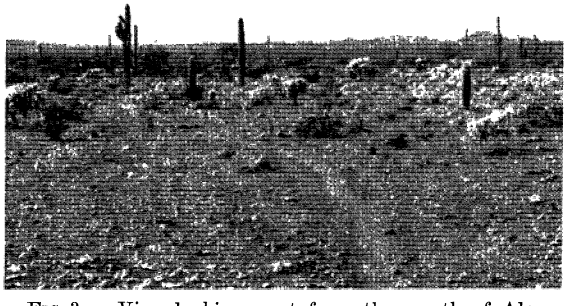

FIG 3a. View looking west from the mouth of Alamo Canyon.

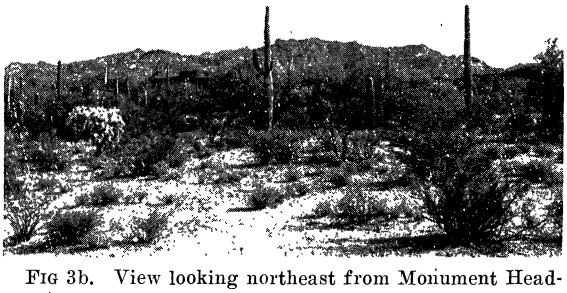

FIG 3b. View looking northeast from Monument Headquarters.

Photos by courtesy of Wm. R. Supernaugh

On the western edge of the Monument, west of the Growler Mountains and in the eastern extremity of the Colorado Desert, the soil apparently has a larger gravel content, and is generally more arid. Plants are widely spaced, the vegetation is less luxuriant, and competition for water is obviously keen. There are few saguaros (*Cereus giganteus*) and large trees. Three chollas are present: *Opuntia acanthocarpa, O. arbuscula,* and *O. ramasissima.* The barrel cactus, *Echinocactus wislinzenii* occurs only in this area. Creosote bush (*Larrea divericata*) is the dominant plant. Within this area, stands of Hilaria are present.

Where the silt is fine and sandy, such as the Ajo Valley and along the northern portion of the Monument, several species have reduced numbers. Saguaro, iron-wood, and palo verde trees occur only in scatterred regions. Creosote bush occurs in large pure stands that reach their maximum development on the Monument. Also an extensive mesquite bosque (forest) is found in the northern sector of this silty soil-type. The crucifixion thorn (*Holacantha emoryi*) and the showy Ajo lily (*Hesperocallis undulata*) are common.

South of the Puerto Blancos on the eastern edge of La Abra Valley lies quite a different faciation. Here are concentrated the large stands of mature saguaros. The alluvium is liberally sprinkled with granite particles from the adjoining mountains and this provides a heavier, more stable soil for the roots of the giant cacti. Along the southern slopes of washes and foothills are also found the prominent and conspicuous organ pipe cactus, (*Cereus thurberi*), and in the lower wash floodplains an occasional specimen of the rare senita (*Cereus schottii*) may be encountered. In the northeastern portion of the Monument of the same general soil type but at a somewhat higher elevation such plants as yucca (*Agave schotti*), desert willow (*Chilopsis linearis*), desert honeysuckle (*Anisacanthus thurberi*), and *Opuntia kunzii* are found.

Most of the remaining alluvial fill soils may be classed as caliche or conglomerate and comprise the larger part of the intermountain plains, including the Sonoyta Valley. Covered by the everpresent Larrea and Franseria they also support a great variety of chollas, as well as ironweed, desert hackberry, palo verde, catclaw, and many other species.

Where permanent standing water is present, such as the situation at Quitobaquito and Agua Jita, a great variety of plants may be found immediately surrounding the periphery of the area. Black willow (*Salix nigra*) and several large mature specimens of the cottonwood (*Populus fremontii*) grow around the small pond at Quitobaquito. A few specimens of the screwbean mesquite, *Prosopis odorata,* may also be found here. The seepage at Agua Jita supports a fine stand of honey mesquite, *Prosopis juliflora;*

catclaw, *Acacia greggii* and the conspicuous annual jackass clover, *Wislizenia refracta.*

MOUNTAIN LAVA-GRANITE COMPLEX

The Ajo Mountain range provides one of the most distinctive vegetational units on the Monument. Numerous species are found only in the shaded canyons and along protected ledges of the higher elevations. Such tree species as juniper (*Juniperus monosperma*), desert olive (*Forestiera phillyreoides*), Arizona rosewood (*Vauquelinia californica*), and Palmer's oak (*Quercus palmeri*) grow in the canyons. A host of shrubs grow profusely on the canyon floor and around the occasional water-seepage areas. Saguaros, organ pipe cactus, prickly pears, creosote bush, palo verde, and many other species are found over most of the mountain slopes and often extend to the tops when enough soil is available to hold the roots.

DESCRIPTION OF THE STUDY AREAS

TOPOGRAPHY AND LOCATION

Four typical lower Sonoran desert areas were studied intensively in so far as the plant composition and bird populations were concerned. During the course of the initial survey of the Monument, and in conducting the censuses throughout the summer, some 1800 miles were traveled by auto, truck, and on foot in the process of accumulating the data. Many of the isolated mountain ranges were reached only by extensive hikes and the necessity of packing water and food made frequent trips impractical. However, two canyons (Alamo and its adjoining branch "Willow") were readily accessible and frequent bird censuses were conducted in them during the breeding season. Three extended exploratory surveys to the more remote canyons in the Ajos were made with Monument officials and an opportunity was thus available for a general appraisal of the plant and avian constituents. These trips marked the first exploration of the canyons since the Monument was established in 1937.

The primary objective of the study was to determine the breeding-bird composition of the desert floor. An attempt was made to select accessible study areas containing as many of the habitat-niches as possible that were present in the extensive intermountain plains of the desert. Special consideration was therefore directed toward the dry washes or arroyos. their adjoining "outwashes," and intervening desert country. These intermountain alluvial plains are dissected by innumerable dry washes running from the mountains and their foothills to the larger washes at lower elevations. It is difficult to find any large area devoid of the typical thin belt of mesquite, ironwoods, and associated plants that accompany even the smaller washes. At least one study plot was located in each of three major valleys of the region namely: the Ajo, Sonoyta, and La Abra (Fig. 1).

Of the four areas finally selected two (1 and 2) represent examples of the larger dry washes and two (3 and 4) of areas with only small tributaries, being, primarily, sections of the flat desert floor.

Area 1. Located a quarter mile north of headquarters in the Sonoyta Valley, this 70 ac. rectangular tract embraced a typical dry wash and its adjoining low hinterland. A narrow fringe of mature mesquites and ironwoods paralleled the bed of the ten to fifteen foot-wide sandy wash. The adjoining region was sprinkled with saguaro, chain cholla, creosote bush, and bur sages, common constituents of the desert floor. The trees along the wash ranged in height from 15-35 ft.

Area 2. This 40 ac. plot is the second wash area and is located in the La Abra Valley south of the Puerto Blanco Mountains approximately 10 mi. from headquarters along the desert road to Quitobaquito. Its southern boundary parallels the Mexican border 300 yds. to the the south. Floristically it is similar to the first area discussed. It contains a sizable dry wash lined with mature trees. Being in the belt of the mature saguaro stands along the southern boundary it contains a substantially larger and more mature giant cactus component.

Area 3. In contrast to the above study plots this area is a 100 ac. expanse of the typical general desert floor. Located immediately to the west and bordering Area 1, it provides an excellent comparative relationship to the wash situation. The remaining three sides (north, west, and south) are bordered by hills of the Puerto Blanco Range thus creating a more or less natural boundary. The topography is that of a gentle slope from the hill on the west boundary eastward to the wash in Area 1. No one large wash occurs within the area, but it is traversed by a series of small drainage channels all running to the eastward.

Area 4. In the Ajo Valley some eight miles to the north of Monument Headquarters lies a 50 ac. tract of pure creosote bush. No drainage wash crossed the area. It is typical of the large flat reaches characteristic of the fine sandy silt of the Ajo Valley. A few straggly mesquites line the northern boundary and a small wash runs a few hundred feet south of the southern border line. Only one dead mesquite stump lies within the area.

FLORA

Considerable study was made of the species composition of plants on the four areas under consideration for they are of basic importance in considering the ecological relationships of the faunal components of a community. An analysis of the flora was attempted by counting and recording each individual of the species encountered. In the case of the wash areas (1 and 2) the main bed was followed and every plant along both sides recorded. Percentages derived from such data are for practical purposes almost absolute. A somewhat different procedure was used in Area 3. Here a series of three transects were laid out across the area and on each of these was located three plots measuring 100 ft. on a side. These plots were selected at random in order to

TABLE 3. Plant species composition of four selected Lower Sonoran Desert areas.*

Species	Combined total No. Counted	%	Area 1 Number Counted	%	Area 2 Number Counted	%	Area 3 Number Counted	%
Franseria deltoidea (Bur-sage)	1096	19.0	175	10	72	5	849	30
Larrea divericata (Creosotebush)	763	13.0	281	16	132	10	350	13
Cercidium microphylium (Yellow Palo-verde)	594	10.1	31	2	70	5	493	18
Cereus giganteus (Saguaro)	497	9.0	208	12	255	20	34	1
Franseria ambrosioides (Bur-sage)	363	6.0	289	16	74	6	—	—
Lycium parishii (Desert Thorn)	350	6.0	146	8	168	13	36	1
Acacia greggii (Catclaw)	269	4.6	151	9	108	8	10	.5
Olneya tesota (Ironwood)	251	4.2	23	1	84	7	144	5
Opuntia fulgida (Chain Cholla)	195	3.3	174	10	+	+	21	1
Acacia constricta (White-thorn)	182	3.0	43	2	—	—	139	5
Celtis pallida (Desert Hackberry)	137	2.3	94	5	11	1	32	1
Hymenoclea pentalepis (Burro-bush)	131	2.2	—	—	131	10	—	—
Sapium biloculare (Jumping Bean)	130	2.2	—	—	—	—	130	5
Encelia farninos (Encelia)	127	2.1	—	—	15	2	112	4
Opuntia bigelovii (Teddy Bear Cactus)	119	2.0	—	—	—	—	119	4
Cercidium torreyanum (Blue Palo-verde)	91	1.5	46	2	43	4	2	+
Condalia globosa (Bitter Condalia)	86	1.5	50	3	34	3	2	+
Prosopia juliflcra (Mesquite)	68	1.1	17	1	48	4	3	+
Opuntia acanthocarpa (Staghorn Cholla)	66	1.1	—	—	—	—	66	3
Jatropha cardiophylla	66	1.1	—	—	—	—	66	3
Lycium berlandiere (Lycium)	52	1.0	—	—	—	—	52	2
Fouquieria splendens (Ocotillo)	49	.8	—	—	—	—	49	2
Bebbia juncea	38	.6	36	2	2	—	—	—
Krameri grayi	333	.5	—	—	—	—	33	1
Calliandra eriophylla	31	.5	—	—	—	—	31	.5
Anisacanthus thurberi (Desert Honeysuckle)	23	.4	23	1	—	—	—	—
Condalia lycioides (Sweet Condalia)	21	.4	—	—	19	1	2	—
Jatropha spathulata	14	.2	—	—	—	—	14	1
Jatrcpha canescens (Dragon-blood)	9	.1	—	—	9	1	—	—
Opuntia arbyscula (Pencil Cholla)	6	.1	—	—	—	—	6	.5
Krameria parvifolia	5	+	—	—	—	—	5	+
Atriplex canescens (Fourwing Saltbush)	4	+	—	—	4	+	—	—
Funastrum heterophyllum (Trailing Milkweed)	4	+	2	+	2	+	—	—
Cereus thurberi (Organ Pipe Cactus)	4	+	—	—	—	—	4	+
Echinocereus Engelmanii (Hedge-hog Cactus)	3	+	—	—	—	—	3	+
Echinocactus Wislizenii (Barrel Cactus)	2	+	—	—	—	—	2	+
Total No. of plants recorded	5879		1789		1281		2809	
Total No. of species recorded	36		17		20		29	

*Area 4 composed of 100% creosotebush (*Larrea divericata*).

represent as unbiased an appraisal as possible. All plants were counted within each of the 0.23-ac. plots and from the composite total of the nine plots the percentage of occurrence of each species was recorded. In addition short randomly selected sections of three of the larger drainages were checked in order to get a representative portion of the wash species. Two plot counts were also made in Area 1.

Thirty-six species of plants comprise the major part of the vegetation on the areas under consideration (Table 3). Bur sage, creosote bush, yellow palo verde, and the saguaro are the most abundant species ranking in the order listed. It is apparent that this region falls into the Larrea sub-type of the Larrea-Atriplex association as defined by Nichol (1943). The conspicuous occurrence of the saguaro and chain cholla (*Opuntia fulgida*) further defines the area as part of the Arizona Succulent Desert as described by Kearney & Peebles (1951).

Examination of Table 3 provides one a clear idea of the vegetation of each research area. The common creosote bush and bur sage (*Franseria deltoida*) make up the "matrix" of the vegetation pattern, being well represented in all three localities. Of the tree species, catclaw, and bitter condalia (*Condalia globosa*) are about equally represented in the two wash areas. The abundance of other trees varies considerably.

The two species of palo verde present an interesting correlation. The blue palo verde (*Cercidium torreyanum*) is quite sensitive to the moisture factor. Area 2 being almost completely an out-wash situation has twice the percentage of this species as does Area 1, which is somewhat higher and drier. This species is almost exclusively a wash inhabitant. The yellow palo verde (*C. microphyllum*), on the contrary, is found on the uplands where its greatest numbers are recorded in abundance in the upland research area (3). Other predominately wash plants are *Franseria ambrosioides* and *Lycium parishii*.

Most conspicuous is the difference in abundance of the saguaro. Scattered sparingly, but still being

a prominent feature of the landscape in Area 3, they reach a peak in the low wash situations (Area 2) comprising 20% of the total species composition and being the most abundant species. Making up 12% of the total in Area 1, the saguaro ranked third in abundance.

The chain cholla was, by far, more abundant in Area 1 than in either Areas 2 or 3 (Table 3).

BREEDING BIRD POPULATIONS OF THE RESEARCH AREAS

METHODS OF STUDY

The major part of the field research was devoted to determining the breeding bird populations of the desert floor or intermountain plains. Owing to their significance, limited time was also spent in censuing areas around sources of natural permanent water and, to some extent, in the more accessible mountain canyons of the Ajos. Ninety six censuses were conducted on the four research areas, at Quitobaquito, and in Alamo and "Willow" Canyons (Table 4). In addition a single census was taken in three remote canyons (Arch, April; Diablo, May 6; and "Mammosa," June 12) and four others at Aqua Jita (April 7 through July 24). A total of 102 censuses was made involving 348 man-hours. During the time spent on the areas 132 nests were located, which when added to the 52 additional ones found while traveling about the Monument and to the study areas, makes a total of 184 active nests. Of this number approximately 125 were examined periodically and detailed information recorded.

Following the census trips about 300 man-hours were spent in searching for nests and data gathered concerning the nest building, attentiveness of the nesting individuals, incubation, care of the young, and territorial behavior of the various species.

Censusing of the four intermountain areas was accomplished by the combination of the strip, plot, and nest counting techniques described by Kendeigh (1944). Census lines were marked out across the study areas and by alternately following the lines and the areas between a thorough coverage was guaranteed. Chances of recounting individuals over sections already covered were thereby minimized. The census lines, ranging from 120 to 250 ft. apart, depending on the terrain and vegetation, were marked by colored cards (3 x 6) which were tied to conspicuous plants. Each card bore a letter which denoted the census line and a number indicating the position on the line. Scaled field maps of the areas were then mimeographed with the check points included, thereby making it possible to locate exactly any individual recorded during the census trips. Particular effort was made to plot all singing males and nests located.

Composite maps were made for each species from these data and by merely encircling the clustered recorded locations of the individuals it was relatively simple to determine the number of territories present for each one. By combining the various species one could then determine the total breeding density for the area concerned. The sizes of the various territories were determined by the use of a planimeter. For those species not exhibiting territorial behavior the presence of nests, young, and other criteria were necessarily considered in evaluating their population density.

The canyon censuses were made primarily to record the species and all nests possible. An attempt was made to determine the relative breeding density for comparison with other canyon studies. Approximate densities were derived from the accumulated data. Usually only one passable trail was present in the canyons. Consequently, all recordings of species and numbers were made while progressing up the canyon while the downward trek was devoted primarily to searching for nests and observations.

At Quitobaquito and Agua Jita one merely had to traverse the circumference of the pools and record the birds as they came in to drink or bathe. No particular concentration of nests or territories was evident around these areas.

The breeding populations of the various study plots are treated in the following categories.

NESTING SPECIES AROUND PERMANENT NATURAL WATER SOURCES

As would be expected a source of available water in such an arid region attracts great numbers of individuals. Due probably to such constant influxes of birds seeking relief from the heat and thirst few

TABLE 4. Compilation of census data on the research areas.

Research Area	Total Number Census Trips	Total Number Census hours	Total Number Breeding Species	Total Number Trans. or Visit.*	Total Number Nests Found	Extreme Census Dates
Area 1	25	100	16	27	48	Mar. 6 - July 27
Area 2	15	45	17	17	33	Mar. 16 - July 19
Area 3	21	126	15	4	22	Mar. 7 - July 27
Area 4	10	20	0	14	0	April 1 - July 2
Alamo Canyon	6	18	20	19	15	Mar. 17 - July 28
Willow Canyon	4	12	16	14	4	May 15 - June 30
Quitobaquito	15	15	15	45	10	Feb. 28 - Aug. 24
Totals	96	336	..	..	132	....

(*) Transients or visitants.

TABLE 5. Species and numbers of birds recorded at Quitobaquito from February through June (1949) and August (1948).

Species	Feb. 28	Mar. 26-29	April 7-17-29	May 4- 9-13- 25- 27	June 7- 16	Aug. 24
Pied-billed Grebe	....	.. ..	1 1	.. ..	.. ..	....
Treganza's Heron	....	.. ..	.. .. ..	.. ..	1 ..	....
Anthony's Green Heron	1	1 1	1	.. 1 1	.. ..	....
Wood Ibis	....	.. ..	.. .. ..	.. ..	.. 1	1
Mallard	....	.. ..	.. 1 ..	.. ..	.. ..	....
Green-winged Teal	2	.. ..	1	.. ..	.. ..	....
Blue-winged Teal	....	.. ..	2	.. 2	.. ..	....
Cinnamon Teal	....	.. ..	.. .. ..	.. 1 1	.. ..	....
Red-head	....	.. ..	1	.. ..	.. ..	....
Greater Scaup	....	1 ..	.. .. ..	.. ..	.. ..	....
Turkey Vulture	....	.. 1	.. .. ..	.. .. 1	.. ..	1
Black Vulture	....	1 ..	.. .. ..	.. ..	.. ..	....
Cooper's Hawk	....	.. ..	1	.. ..	.. ..	....
Red-tailed Hawk	....	.. ..	.. .. ..	.. 1	.. ..	....
Gambel's Quail	....	.. ..	1 .. 4	.. 1 2	10 ..	....
Sora	....	.. ..	 1	.. 1	.. ..	....
Coot	....	.. ..	 1	.. ..	.. ..	....
Killdeer	15	6 6	8 6 6	8 1 4 1 2	2 ..	5
Wilson's Snipe	4	.. 2	2	.. ..	.. ..	....
Spotted Sandpiper	....	.. ..	.. .. ..	.. 1	.. ..	....
Solitary Sandpiper	....	.. ..	1 .. 1	.. 1	.. ..	....
Western Sandpiper	....	.. ..	2 8 ..	.. ..	.. ..	....
Western Mourning Dove	....	8 6	7 6 4	10 12 3 15 10	4 2	....
White-winged Dove	....	.. ..	 1	6 10 2 100 400	400 200	....
Texas Nighthawk	....	.. ..	.. .. ..	.. .. 1 ..	2 1	....
Belted Kingfisher	....	.. ..	.. 1 ..	.. ..	.. ..	1
Gila Woodpecker	1	1 1	.. .. ..	.. 1 1	.. ..	....
Western Kingbird	....	.. ..	.. .. ..	.. 4 2	.. ..	....
Ash-throated Flycatcher	....	.. ..	 2	2 1 .. 2 ..	.. ..	....
Western Flycatcher	....	.. ..	.. .. ..	.. 1	.. ..	....
Black Phoebe	2	1 ..	 1	 1	.. ..	2
Vermilion Flycatcher	....	1 2	1	1 1 1 2 ..	.. 2	....
Violet-green Swallow	....	2 ..	.. .. ..	.. .. .. 1 1	.. ..	....
Tree Swallow	....	4 ..	.. .. ..	.. ..	.. ..	....
Cliff Swallow	....	.. ..	.. .. ..	.. .. .. 2 ..	.. 8	....
Rough-winged Swallow	....	.. ..	.. .. ..	.. ..	.. ..	28
Barn Swallow	....	.. ..	.. .. ..	.. .. .. 2 ..	.. ..	....
Verdin	....	.. ..	.. .. ..	.. .. .. 1 1	1 ..	....
Mockingbird	1	2 1	2 2 ..	.. 4 1 2 ..	.. ..	....
Palmer's Thrasher	1	.. 2	.. .. ..	.. .. .. 1 2	1 ..	....
Crissal's Thrasher	....	.. ..	.. .. ..	.. .. .. 2 1	.. ..	....
Robin	1	1 ..	.. .. ..	.. ..	.. ..	....
Phainopepla	2	.. 4	5 4 ..	3 6 2 4 4	1 ..	....
Least Vireo	....	.. ..	 2	1 1 1 3 1	1 1	....
Solitary Vireo	1	.. ..	.. .. ..	.. ..	.. ..	....
Yellow Warbler	....	.. ..	1 2 2	.. .. .. 1 ..	.. ..	....
Audubon's Warbler	....	1 ..	.. .. ..	.. ..	.. ..	....
Yellowthroat	....	1 ..	.. .. ..	.. ..	.. ..	....
Pileolated Warbler	....	2 4	1 4 8	4 2 .. 2 ..	.. ..	8
Western Meadowlark	....	.. ..	4	.. ..	.. ..	....
Yellow-headed Blackbird	....	.. ..	.. .. ..	.. 1	.. ..	....
Hooded Oriole	....	2 1	4 2 4	3 2 2 2 4	.. 1	2
Dwarf Cowbird	....	2 ..	 25	.. 25 25 50 40	25 50	....
Black-headed Grosbeak	....	.. ..	.. .. ..	.. ..	.. 1	....
House Finch	....	.. ..	.. .. ..	.. 5 .. 25 ..	6 ..	....
White-crowned Sparrow	10	12 15	.. .. ..	.. .. 2	.. ..	....
Gambel's Sparrow	....	.. ..	.. .. ..	.. .. 2	.. ..	....
Total Numbers	63	66 65	96 37 62	38 83 52 221 477	444 265	54
Total Species	14	18 13	20 11 14	9 22 16 21 13	11 8	9

birds nest in the immediate vicinity of the pond at Quitobaquito. Only about 15 species of the 59 recorded were found to be nesting nearby (Table 5) and only one pair of each species usually was the case, with the exception of the two dove species (white-winged and mourning doves), hooded oriole, and killdeer. The spring supplying the flow of water emerges to the surface about 100 yds. away from the pond and flows down a slight incline to the impoundment. The tiny stream is only about a foot wide for most of its length but around the spring and along the flow a rather luxuriant growth of condalia and mesquite flourish, as well as, stands of arrow weed, lycium, and other smaller plants. These furnished a suitable cover for white-winged and western mourning doves to congregate by the hundreds in some cases. Many of these birds nested in the surrounding hinterland and came in regularly for water but most of the individuals were migrants. Concentrations of white-winged doves on four censuses during latter May and early July (Table 5) numbered 100, 400, 400, and 200, respectively. Mesquite and condalia trees on such occasions would be crowded with resting birds while new arrivals constantly dropped in while others were leaving for their nesting or feeding sites. Western mourning doves were not so numerous as its relative, discussed above, but on occasions as many as 15 would be seen during one observation at this spot.

Two pairs of hooded orioles nested in the cottonwoods bordering the pond. One pair had a nest about 7 ft. from the ground on the north side while the nest of the second pair was placed 12 ft. up in a cottonwood on the west side of the pond. Chasing by the males was observed only on two occasions. Both pairs nested successfully.

Huey (1942) stated "About a dozen Killdeer lived about Quitobaquito where conditions were ideal for them." During the current study, only six individuals were regularly recorded and only one pair was observed with young.

A single pair of vermilion flycatchers evidently controlled all nesting rights for this species around the pond. The adults were often seen flying low over the water or darting out for insects from favorite perching sites atop a dead mesquite tree. Both adults were seen feeding three fledglings on May 25.

One verdin nest was found along the little steam and apparently was the only nesting pair in the vicinity.

Gambel's quail came to water regularly and on one occasion (May 27) five pairs were recorded. One female was observed on May 4 in the process of shaping a nesting cavity under a small bush along the small stream but deserted the site after being flushed. A pair with 12 young chicks was feeding near the pond on May 9, evidently having nested in the near vicinity.

Young mockingbirds and Crissal's thrashers were recorded on May 25. This pair of Crissal's thrashers and the three fledglings marks the only nesting observation of this species during the study. Huey found a nest containing one fresh egg on March 25 at this location and collected a fully feathered bird of the year at Bates well on April 25.

Four censuses were taken at nearby Agua Jita. The short seepage here did not afford such an im-

portant source of food as did the pond at Quitobaquito but was utilized extensively for drinking and bathing purposes. The accompanying stand of mesquite, catclaw, and condalia was much denser and afforded well protected nesting sites. The same situation existed here as was found at the other water locality. Concentrations of birds were high while nests were again not in evidence. Only three nests (western mourning dove, Gambel's quail, and Arizona crested flycatcher) were observed. The single nest of the Gambel's quail, which contained 21 eggs, was the only one located for the species during the study. At least eight pairs of these birds apparently nested in the vicinity for four pairs were seen at the seepage on April 29, including a brood of several young chicks, while as many more were calling nearby.

A single nest of the western mourning dove was located deep within the thicket, 8 ft. high in a mesquite while the pair of crested flycatchers occupied a woodpecker hole in a saguaro nearby.

A total of 21 species was recorded at Aqua Jita from April 7 through July 24. Of this number, five species were found here but not seen at nearby Quitobaquito (Arizona crested flycatcher, cactus wren, Sonora gnatcatcher, Arizona Bell's vireo, western warbling vireo, bronzed cowbird).

The greatest concentrations were noted on the June 16 (12 species, 192 individuals) and July 24 (10 species, 189 individuals) visits.

SPECIES COMPOSITION AND RELATIVE POPULATION DENSITY OF THE MOUNTAIN CANYONS

Six censuses were conducted in Alamo Canyon (Table 6) during which time a total of 38 species of birds were recorded. Of this number at least 20 are known to constitute the breeding component. An area about 25 by 800 yds. in width constituted the accessible census area of the canyon. During the previous summer (July, 1948) an exploratory hike was made into upper Alamo Canyon and here was recorded the first positive nesting record for the pyrrhuloxia on the Monument. Two adults and three feathered fledglings were observed in dense brush that lined the banks of the wash along the canyon floor. This species was not recorded during the following season (1949) but their niche was apparently occupied by a pair of cardinals which were recorded on each census in the same locality. Rock and canyon wrens were present and a pair of each species was observed carrying nesting material into crevices of the steep rocky walls.

On July 28 an adult ferruginous pygmy owl with two fully grown young was observed midway up the canyon. This record with the pair that nested on Area 1 also constitutes a new nesting species for the Monument. Two pairs of hooded orioles occupied territories in Alamo and both reared young.

TABLE 6. Species composition and relative population density of Alamo Canyon.

Species	March 17	March 24	April 10	May 21	June 30	July 28
Turkey Vulture	..	..	..	1	..	..
Harris's Hawk	1	..	..	..	..	..
Sparrow Hawk	..	..	..	1	..	..
Gambel's Quail	8	5	4	8	8	30
W. Mourning Dove	1	4	20	100	50	20
White-winged Dove	..	..	..	44	13	10
Roadrunner	..	..	..	1	..	..
Ferruginous Pygmy Owl	..	..	..	..	..	1
Costa's Hummingbird	1	2	..	5	..	..
Gilded Flicker	2	2	..	..	..	..
Gila Woodpecker	..	.	..	..	..	1
Ladder-backed Woodpecker	1	1	..	..	2	1
Arizona Crested Flycatcher	1	2	..	4	10	..
Western Flycatcher	1	2	..	1	..	..
Black Phoebe	1	..	..	..	..	..
Raven	2	..	..	..	..	2
Verdin	3	3	1	14	3	3
Cactus Wren	1	2	..	..	..	..
Canyon Wren	3	1	..	..	3	2
Rock Wren	1	8	2	..	..	2
Palmer's Thrasher	1	4	3	9	..	3
Sonora Gnatcatcher	2	4	..	6	2	.
Ruby-crowned Kinglet	6	6	..	.	..	..
Cedar Waxwing	..	.	..	1	..	..
Phainopepla	1	5	4	6	..	..
Orange-crowned Warbler	4	..	..	..	..	..
Calaveras Warbler	..	3	..	..	..	..
Black-throated Gray Warbler	..	4	..	..	..	..
Hooded Oriole	..	3	..	..	..	..
Scott's Oriole	..	..	.	..	..	1
Cardinal	1	4	2	2	1	2
House Finch	13	3	20	50	10	4
Green-backed Goldfinch	..	2	..	2	..	..
Brown Towhee	..	1	..	..	..	..
Desert Sparrow	..	4	4	.	..	..
Sage Sparrow	..	1	..	..	..	..
Pink-sided Junco	1	..	..	..	..	..
Brewer's Sparrow	..	..	2	..	..	..
Total Number Individuals	56	76	62	255	107	85
Total Number Species	22	24	10	17	11	15

Large contingents of western mourning and white-winged doves were also recorded here during the May and June trips. The majority of individuals were probably transients but many were inhabiting the surrounding hinterland. No nest of the former species was located and only three of the latter were found in the canyon. The cattle trough at the mouth of the canyon was undoubtedy the factor responsible for the large numbers of these species.

The Palmer's thrasher nests in the canyon were in chollas and regularly located along the length of the canyon.

Four pairs of Gambel's quail apparently comprised the breeding population of that species.

The breeding component of "Willow" Canyon was made of largely the same species as were found in Alamo. It was in this area that the first Grinnell's water thrush was recorded on the Monument. Of particular significance is the large numbers of doves of both the species discussed earlier. Highest densities were, as before, recorded during the May and June trips.

SPECIES COMPOSITION AND BREEDING DENSITY OF THE INTER-MOUNTAIN PLAINS

WASH AREAS (1 AND 2)

Thin lines of trees edging the widespread network of washes over the desert floor provide habitats for a great number of bird species. Utilized by the larger percentage of breeding individuals, these dry washes are also well marked migratory avenues for the transient species (Table 7). A total of 295 transient individuals through the two wash areas were recorded during the 78 day migration period. These individuals represented some 18 different species.

Two species (ferruginous pygmy owl and desert sparrow hawk) appeared as breeding species in Area 1 but not in the second area, although the sparrow hawk was a frequent visitant. Conversely four species (ash-throated flycatcher, western mourning dove, Sonora white-rumped shrike, and Mexican ground dove) were nesting in Area 2 but were not found to be inhabiting Area 1. Two additional species (western red-tailed hawk and western horned owl) had nests along the opposite boundaries of Area 2, on the east and west sides, respectively.

The difference in the population density of the two areas is largely due to the preponderance of white-winged and mourning doves nesting in Area 2 (Table 8). The density per 100 ac. of the first mentioned species in the second area was over twice that of Area 1. Furthermore no western mourning doves nested in the first area as contrasted to the 13 pairs per 100 ac. in the second study plot.

INTER-WASH AREAS (3 AND 4)

Considering first the migrant species as found on these types it is apparent that the absence of the wash vegetation is expressed by the numbers of species utilizing the open desert. A total of six species migrated through Area 3 while only three traversed the creosote bush area (Table 9). A total number of 165 transients recorded is also considerably smaller than the 295 found in the wash areas although the total area considered is at least 40 acres larger. Brewer's sparrows are by far the most abundant species for the dry creosote flats afforded by these areas are preferred by these birds. The nine records of violet-green swallows are individuals flying overhead in Area 3.

As is to be expected the breeding density of the open desert regions are not as high as the wash situations. Only 37 pairs per 100 ac. were present in Area 3 (Table 8) while the creosote flat was entirely devoid of nesting species. The occurrence of the three species (rock wren, canyon wren, and canyon towhee), are due to the presence of the surrounding hills of the Puerto Blanco Mountains as explained earlier. Actually, therefore, 23 species util-

TABLE 7. Migrant species showing periods recorded on the Wash Areas (1 and 2).

Species	Date first recorded	Date last recorded	Total period recorded	Total number recorded
Sage Thrasher	March 3	March 3	1 day	1
Cassin's Vireo	" 6	" 6	1 day	1
White-crowned Sparrow	" 6	April 13	38 "	160
Brewer's Sparrow	" 8	" 30	53 "	88
Pileolated Warbler	" 10	" 30	51 "	11
Western Flycatcher	" 27	July 27	122 "	7
Western House Wren	April 1	April 1	1 "	1
Gambel's Sparrow	" 1	" 1	1 "	1
Black-throated Gray Warbler	" 5	" 16	11 "	5
Yellow Warbler	" 5	" 24	19 "	5
Least Flycatcher	" 6	" 19	13 "	2
Scott Oriole	" 8	July 28	111 "	4
Clay-colored Sparrow	May 4	May 4	1 "	1
Lark Bunting	" 4	" 4	1 "	1
Western Tanager	" 4	" 12	8 "	2
Bullock's Oriole	" 5	" 12	7 "	3
Willow Thrush	" 20	" 20	1 "	1
Macgillivary's Warbler	" 20	" 20	1 "	1

Total migration period recorded March 3 - May 20 - 78 days*
Total number migrating species recorded - 18
Total number of migrating individuals - 295

(*) Last recorded dates of Western Flycatcher and Scott's Oriole not included.

TABLE 8. Breeding bird populations in four areas of typical Lower Sonoran Desert.*

Species	Area 1 (Wash) 70 acres	Area 2 (Wash) 40 acres	Area 3 (Open Desert) 100 acres	Area 4 (Creosote) 50 acres
Turkey Vulture	V	V	V	V
W. Red-tailed Hawk	V	.5 (1)	V	V
Harris's Hawk	V	V	V	—
Desert Sparrow Hawk	1 (1)	V	V	—
Gambel Quail	8.5 (12)	3 (8)	— (—)	V
W. Mourning Dove	V	5 (13)	V	V
White-winged Dove	9 (13)	11 (28)	7 (7)	—
Mexican Ground Dove	—	1 (3)	—	—
Saguaro Screech Owl	—	—	V	—
Western Horned Owl	—	.5 (1)	—	—
Ferruginous Pygmy Owl	1 (1)	—	V	—
Elf Owl	V	—	—	—
Costa's Hummingbird	V	V	V	—
Mearn's Gilded Flicker	+ (—)	— (—)	— (—)	—
Gila Woodpecker	2.5 (3)	2 (5)	2 (2)	—
Cactus Woodpecker	V	V	V	—
Ariz. Crested Flycatcher	2.5 (3)	2 (5)	2.5 (3)	V
Ash-throated Flycatcher	+ (—)	.5 (1)	1 (1)	—
Say's Phoebe	—	—	V	—
Purple Martin	—	V	—	—
Raven	—	V	—	—
Verdin	8 (11)	5 (13)	4.5 (5)	V
Cactus Wren	7 (10)	2 (5)	8 (8)	—
Canyon Wren	—	—	+ (+)	—
Rock Wren	—	—	+ (+)	—
Western Mockingbird	+ (—)	—	V	V
Palmer's Thrasher	6	1.5 (4)	2 (2)	V
Plumbeous Gnatcatcher	5 (7)	2.5 (6)	6 (6)	—
Phainopepla	6.5 (9)	4.5 (11)	.5 (1)	V
Son. White-rumped Shrike	V	.5 (1)	—	V
Lucy Warbler	—	V	—	—
Hooded Oriole	V	V	—	—
Dwarf Cowbird	V	V	—	—
Pyrrhuloxia	V	—	—	—
House Finch	7 (10)	1 (3)	2 (2)	—
Canyon Towhee	—	—	V	—
Desert Sparrow	+ (—)	+ (—)	+ (—)	V
Total Populations	64 (88)	42.5 (108)	35.5 (37)	0
Total Species	28	29	26	12

*Figures in parentheses indicate pairs per 100 acres while those species marked (V) are visitants.

TABLE 9. Migrant species showing periods recorded on the Inter-wash Areas (3 and 4).

Species	Date first recorded	Date last recorded	Total period recorded	Total number recorded
Violet-green Swallow	Feb. 27	March 20	24 days	9
Western Gnatcatcher	" 27	Feb. 27	1 "	1
Western Flycatcher	" 27	" 27	1 "	1
White-crowned Sparrow	March 7	April 21	45 "	24
Brewer's Sparrow	" 16	" 21	35 "	127
Cooper's Hawk	April 14	April 14	1 "	1
Western Tanager	May 3	May 3	1 "	2

Total migration period recorded - February 27 to May 3 - 68 days
Total number of migrating species - 7
Total number of migrating individuals - 165

ized the area proper for nesting and feeding purposes.

The dozen species observed in the creosote bush tract (Area 3) are doubtlessly breeding species nesting in the near vicinity and appeared on the area in search of food. It is generally known that extensive pure stands of creosote bush in the southwest deserts seldom attract many birds. However, when it occurs intermixed in or at the fringes of cacti, mesquite, and catclaw associations it has been observed that a number of birds make use of it (Anderson & Anderson 1946).

During the course of the study the nest sites of eight pairs of western red-tailed hawks, two pairs of Harris's hawks and two pairs of western horned owls were discovered. It is noteworthy that only two of the total nests observed were located outside of the "cruised area" although considerably more miles were covered in the remaining part of the Monument. The cruised area is a 5 by 15 mi. tract extending along the International Boundary Line which acts as its southern border. This tract embracing about 75 sq. mi. contained the nesting and hunting territories of ten pairs of the three species mentioned above, six of which were western red-tailed hawks and two each of Harris's hawks and western horned owls. Within the tract then each pair could control about 7.5 sq. mi. of hunting territory provided the niche requirements were similar. This figure appears to embrace considerable territory for a single species but, on occasion, members of the pairs of red-tailed hawks under observation were recorded at least three miles from their assumed nesting locality.

The greatest distance between two nests of the red-tailed hawk was approximately 6 mi. On the other hand only about 3 mi. separated the two closest nests. Considering only this species each pair could theoretically maintain a hunting territory of about 12.5 sq. mi.

THE COMPARATIVE POPULATIONS AND NESTING ACTIVITIES OF THE RESEARCH AREAS

COMPARATIVE POPULATION DENSITY

The monthly density of recorded individuals (Figure 4) presents a more graphic illustration of the

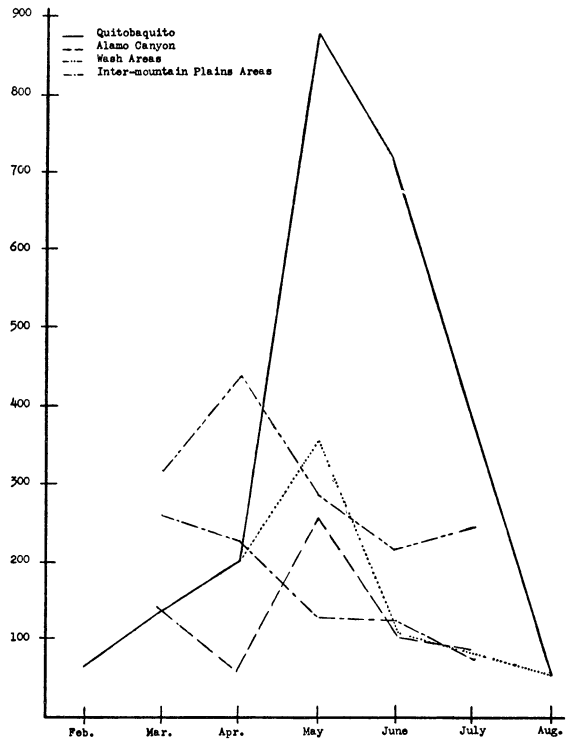

FIG. 4. Graph showing population density of individual birds on the study areas.

population distribution than is evident by the tables. As can be seen each study area presents a different population tendency.

From the data presented (Figs. 4 and 5) it appears that April and May are possibly the periods of peak migration through the areas, however, a more intensive analysis will introduce several other factors that have to be considered. The curve for Quitobaquito is greatly exaggerated during the months of May and June by the immense numbers of white-winged doves that frequented the place. If these individuals are subtracted (518 and 600, respectively) from the total number of individuals the curve approximates that of the other areas (Fig. 4). With 32 species recorded in May, this month appears to be the period of peak concentration at this area with April next. The heavy concentrations of white-winged doves are largely composed of transient individuals as well as a few early nesters in the vicinity. The first appearance of the species was on April 19 while the first active nest located was under construction on May 25. Following this a sudden splurge of nesting activity occurred. Neff (1940) noted that in 1939 the migration was normal with unusually heavy populations observed during late May and early June within the Arizona range of the species. By mid-June the summer population was distributed to the normal nesting grounds.

The wash areas (1 and 2) exhibited the next highest concentration of individuals. The peak popula-

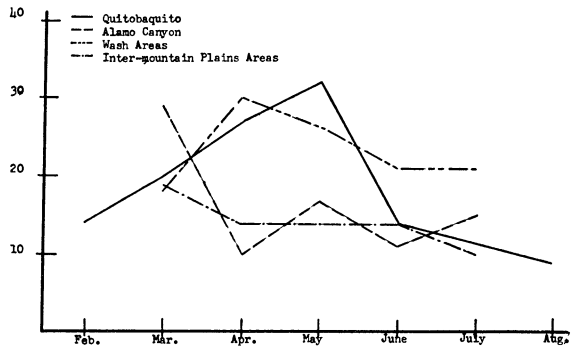

FIG. 5. Bird species density on the study areas.

tion density occurred during April and tapered off to a constant level by June. A total of 30 species, as compared to the 32 at Quitobaquito in the May peak, was recorded. Significantly, white-winged doves were in much lesser numbers in the washes preferring the vicinity of water sources and as a result did not greatly influence the population trend.

In the intermountain plains (Areas 3 and 4) the tendency was still somewhat different for the peak appeared in March, earlier than either of the areas discussed above. Congregations of white-crowned, Gambel's, and desert sparrows contributed heavily to the total numbers of individuals recorded. As would be expected the species tendency (Fig. 5) closely followed that of the total populations. Whether or not the earlier peak experienced here is due to the more open and therefore less attractive nature of the terrain, which would expose the birds to the elements, is suppositional but highly probable. Earlier seasonal movements through habitats of this nature may be customary before heat and water conditions became critical.

Most controversial is the picture portrayed by the population trend of the canyons. It is unlikely that two widely separated population peaks exist (March and May) as indicated in Figs. 4 and 5. It must be considered that the April figure is based on data from only one census and thereby is likely to introduce factors which might be changed by additional data. In view of the fact that the highest peak is in May it seems logical to assume that the same general tendency exists here that is apparent at Quitobaquito, namely that of a later peak population period than indicated by the remaining intermountain areas. This condition could be influenced by two primary factors: (1) sources of water are still present at this time in the canyons by virtue of numerous shaded tinajas, or pot-holes, in the rocks which have preserved remnants of the spring rains. As a result the need of additional water during the warm later seasons is not an inhibiting factor, and (2) sufficient shade and cover exists around permanent waterholes, such as Quitobaquito, and reaches a maximum in the more or less shaded mountain canyons. Thus shade, water, cover and food therefore are all available at these later dates.

On the basis of these data, then, the seasonal peaks of abundance for both numbers of individuals and of species during the current study were recorded in the following sequences: 1. March (open desert), 2. April (washes), and 3. May (mountain canyons and permanent water sources).

COMPARATIVE NESTING ACTIVITY

Active nests of 15 species of birds were located on the research areas that were intensively studied. Extreme nesting dates recorded were March 6 (Palmer's thrasher nest containing eggs) and July 27, when nests of both the Palmer's thrasher and white-winged dove were found with fresh eggs. The approximate total nesting season then extended at least from about February 28 to August 15. The final censuses were conducted on July 27 and 28. The Palmer's thrasher exhibited the most prolonged nesting period of all the species under observation for approximately 170 days (February 28-August 15) of nesting activity were recorded for the species. In contrast the total period of nesting activity for the one pair of Sonoran white-rumped shrikes amounted to only about 35 days.

The nesting components are predominately composed of permanent residents which are represented by ten species while the summer residents number only five species. As a rule the first mentioned group appear to be the earlier nesters, for seven of the ten species listed were actively nesting by March. The three exceptions (gila woodpecker, ash-throated flycatcher, and Sonoran white-rumped shrike) delayed until April. Only one species of the summer residents, phainopepla, was recorded actively nesting in March. Western mourning doves had started nests by the middle of April while the remaining three species delayed until May before commencing nest operations.

Eight of the tabulated species apparently raised two broods during the breeding season. Of these only the three species of doves (white-winged, mourning, and Mexican ground doves) are summer residents. The remaining five species are permanent residents. The species rearing two broods are: western mourning dove, white-winged dove, Mexican ground dove, gila woodpecker, verdin, cactus wren, Palmer's thrasher, and house finch.

COMPARISON WITH SIMILAR DESERT BIRD POPULATION STUDIES

Two breeding bird population studies were conducted by Hutchinson & Hutchinson (1941, 1942) in the Colorado Desert of California. Being in the western aspect of the Sonoran desert these studies provide a direct and interesting correlation with the breeding birds found in the Arizona aspect as determined in the intermountain study areas of the current project. This desert area encompassed 37 ac. of typical Colorado desert. Creosote bush, desert lavender (*Hyptis emoryi*), burrow-weed, (*Franseria dumosa*), Encelia (*Encelia farinosa*), cat's claw and buckthorn cholla (*Opuntia acanthocarpa*) were the

predominant plant species sparsely scattered on sandy gravel strewn with rocks. Along a stream that crossed the area the vegetation was dense and high with the mesquite forming impenetrable thickets in some cases. These plant species are prominent constituents of the flora in the study areas established during the current study (Table 3).

Table 10 lists the species and comparative densities of the breeding populations for the two areas. The Colorado desert areas were censused during two consecutive breeding seasons by the same workers. A total of 26 breeding species was recorded during the three seasons on the two areas mentioned, of which ten were common to both (Table 10). For comparative purposes data from the four intermountain plains areas (Areas 1, 2, 3 and 4) were combined to present the same wash and hinterland conditions as did the California study. The breeding density per 100 ac. is relatively consistent during the three seasons represented with the slightly higher figures for the Colorado desert areas being due in large part to the high concentration of the Costa's hummingbird. The number of species recorded on the two areas during the seasons studied is also remarkably constant.

TABLE 10. Comparison of the breeding bird density (pairs per 100 ac.) of two areas in the Colorado and Arizona sub-divisions of the Sonoran Desert.

Species	Colorado Desert (37 acres)		Arizona Desert (210 acres)
	1941	1942	1949
Gambel's Quail	3	3	6
Phainopepla	3	3	6
Red-shafted Flicker	3	—	—
Costa's Hummingbird	35	38	+
Dwarf Cowbird	3	—	—
Desert Sparrow	16	16	+
Cactus Wren	3	11	8
Arizona Verdin	14	8	9
Sonora Gnatcatcher	8	16	7
Abert's Towhee	3	—	—
Rock Wren	5	8	+
Western Mourning Dove	—	3	2
Black Phoebe	—	3	—
Bewicks Wren	—	5	—
House Finch	—	5	5
Green-backed Goldfinch	—	5	—
California Towhee	—	3	—
White-winged Dove	—	—	13
Palmer's Thrasher	—	—	5
Gila Woodpecker	—	—	3
Arizona Crested Flycatcher	—	—	3
Ferruginous Pygmy Owl	—	—	.5
Sparrow Hawk	—	—	.5
Ash-throated Flycatcher	—	—	1
Sonoran White-rumped Shrike	—	—	.5
Mexican Ground Dove	—	—	.5
Total number of species	11	14	16
Breeding density per 100 acres	96	127	70

The species composition and densities of the non-breeding birds recorded on these two areas are tabulated in Table 11. Transients, wintering residents still lingering in the areas, unmated males, and casual visitors comprised this category. As indicated in the table (11) the final density of individuals (breeding plus non-breeding) is also slightly less than that recorded in both the breeding and non-breeding categories in the California study and could feasibly be due to the presence of the stream running through the area. It is not recorded as to whether the stream contained water or was a dry arroyo, as was the case in the Arizona study plots. The presence of water would undoubtedly account for large numbers of individuals such as the Costa's hummingbird.

In an analysis of the ecological components of the northern desert shrub biome in western Utah, Fautin (1946) noted that the bird populations in all communities were relatively low. From actual counts of 4 hectare (10 ac.) plots, the average summer populations varied from 10.6 / 10 hectares (25 ac.) in the shadscale, *Atriplex confertifolla,* 12.6 in the tetradymia, *Tetradymia glabrata,* to 27.0 in the greasewood, *Sarcobatus vermiculatus,* communities. In terms of individuals per 100 ac. these figures are 42.4, 50.4 and 108 respectively. Populations were greatest in the tetradymia and shadscale communities during spring and early summer.

FAMILY ORIGINS OF THE BREEDING SPECIES

An analysis of the zoogeographic origin of the populations indicate a difference between those of the Arizona desert plains and those of the Colorado desert (Table 12). The region of origin for the various groups is taken from Mayr (1946) and for most species is based on the origin of the family, except in the Fringillidae where the sub-families are used. In some cases the genus is considered. Due to the fact that the analysis by pairs is based only on the birds as found on specific community censuses while the analysis by species includes all the breeding

TABLE 11. Comparison of the non-breeding bird densities of two areas in the Colorado and Arizona sub-division of the Sonoran Desert, including final density of the total avian population.

Areas	No. of censuses taken	Total no. species recorded	Total no. individuals recorded	Ave. no. recorded per census	No. of breeding individuals	Final density (per 100 ac.)
Colorado Desert (1941)	17	37	149	8.7	190	199
Colorado Desert (1942)	—	—	—	20.6	248	269
Arizona Desert (1949)	71	21	460	6.5	138	145

TABLE 12. Zoogeographic origin of the breeding birds in two southwestern desert areas.

Areas	SOUTH AMERICAN		NORTH AMERICAN		OLD WORLD		UNANALYZED	
	Species	Pairs	Species	Pairs	Species	Pairs	Species	Pairs
Colorado Desert (California)..	11.1	37.1	77.8	48.6	11.1	14.3	—	—
Arizona Desert (OPCNM)....	21.6	6.1	35	53.0	26.7	39.4	16.6	—

species occurring on the Monument, the data are, therefore, not entirely comparable.

Considering first the species analysis as listed in Table 12 it is apparent that the North American element is, by far, the more important in so far as the two desert areas are concerned. The considerably higher figure listed for the Colorado desert is due to the fact that seven of the nine families represented are of North American origin. In the Arizona area only 11 of 60 families come in this category. Had a larger area been studied in the former region where more species would likely have been encountered these figures would no doubt be more comparable.

The South American and Old World categories apparently are about equally represented in the Colorado region while in the Arizona study the latter center of origin presents a slighly larger percentage of species and pairs than does the South American.

The families Trochillidae, Tyrannidae, and Icteridae, which Mayr lists as belonging to the Pan-American element but probably originally South American, are included under the latter category herein.

Comparison of the pairs analysis presents some interesting observations. In the Old World element, the same general tendency as the species is expressed. On the other hand the reverse situation occurs in the South American element for the pairs analysis as is expected by the expressed species tendency. The large percentage of pairs in this category recorded in the California region is due to the large density of breeding Costa's hummingbird, the single family of South American origin. Thirty-seven per cent of the breeding pairs were members of this species, for 13 nests were located of the total 35 breeding pairs of birds recorded.

HABITAT NICHES OCCUPIED BY THE BREEDING SPECIES

Contrary to many popular opinions desert habitats are varied and numerous. There is as much difference between habitats in the desert as in any other region and the relative sharpness of demarcation forms one of the most striking and characteristic features of arid regions (Spaulding 1909).

Turnage (1939) in his analysis of desert subsoil temperatures notes that the minimum temperature periods at three depths (3, 6, and 12 ft.) occurred just before and during the spring growing season when leaf and stem growth of plants was rather active. Maximum temperature periods came during the summer rainy season when plant growth was at a maximum.

Gambel's quail, the only ground nesting species recorded on the reseach areas brought off young during the month of May with the first brood of very young chicks observed on May 12. Such species as Palmer's thrasher, verdin, and Sonora gnatcatcher who nest above the soil surface where air currents have a moderating effect on the temperature may extend the nesting season into July when temperatures are much higher.

Different types of nests are utilized as well as choice of location by many species. On the three study areas (1, 2, and 3) four nest types were apparent, namely; (a) the conventional open-top form of the house finch, phainopepla, Palmer's thrasher, Sonora gnatcatcher, white-rumped shrike, red-tailed hawk, and western horned owl, (b) close-roofed nests of the cactus wren and verdin, (c) platform nests built by the Mexican ground, white-winged, and western mourning doves, and (d) hole nests in saguaros, built by the gila woodpecker, and utilized by the Arizona crested and ash-throated flycatchers after abandonment by the woodpeckers.

Temperatures were taken in 13 nests of four species of birds included in the first two categories above (Table 13). The nest temperatures were determined by inserting a small thermometer into the nest chamber and checked after a suitable time had elapsed. As a rule, the two species building covered nests, cactus wren and verdin, had nest temperatures slightly lower than those found in the open-topped structures of the phainopepla and Sonora gnatcatcher. However, they were inclined to place them in more exposed situations and thus were subjected to greater temperatures. That is particularly true of the cactus wren which frequents the exposed interwash areas

TABLE 13. Nest environment data for four species of desert birds.

Species	Plant utilized	Height from ground (in.)	Exposure	Nest temperature in degrees F.
Cactus Wren.....	Cholla	60	SW	76
" "	Cholla	63	E	88
" "	Cholla	66	N	94
Verdin.....	Palo verde	56	W	81
"	Condalia	64	E	92
"	Cholla	70	E	94
"	Condalia	100	W	102
"	Condalia	64	E	98
"	Palo verde	65	N	101
Phainopepla	Palo verde	72	N	98
"	Catclaw	50	E	98
"	Palo verde	72	W	90
Sonora Gnatcatcher....	Condalia	55	Center	94

and nests primarily in the chain cholla. Although well protected nest sites may be available in these plants this species is in direct competition for them with the larger, more aggressive Palmer's thrasher which also inhabits the same upland situations. Huey (1942) states: "their choice habitat amongst the chollas cactus was occupied commonly by Palmer's thrashers and the competition appeared to be too much for the wrens." As a result the denser more luxuriant chollas were usually taken by the thrashers which needed considerable protection for their open nests. Verdin nests, usually placed on the periphery of the tree or cholla, and varying in height from 3-20 ft., were commonly fully exposed but, as was the case with the cactus wren, always kept the nest in full repair at all seasons.

The species building open-topped nests, on the other hand, placed them in well protected spots usually or where circulation of cooling breezes occurred. The Sonora gnatcatcher invariably used dense condalia or other shrubs as nest sites and located the structure deep within the interior of the plant. Those species included under group (c) above (the three dove species) usually placed their sparsely constructed nests on the horizontal branches in such trees as the palo verde, ironwood, and condalia. One white-winged dove nest was placed on a broken vertical stump of a saguaro which was fully exposed to the June sun. The pair of Mexican ground doves built a nest on a slanting, almost horizontal trunk of a dead ironwood five feet above the ground. This site, used for successfully rearing two broods of young, was also fully exposed to the sun.

The hole-nesting species and the larger birds of prey, whose nests were all located in saguaros were apparently less affected by the temperatures than were the other species concerned. The red-tailed and Harris's hawk, as well as the western horned owls, commenced nesting activities well in advance of most of the other species and had young fledged or well developed by the time extreme temperatures occurred.

Locations of the nests varied with the availability of suitable sites. The higher nesting species such as the three birds of prey, the two flycatchers, and the gila woodpecker utilized the saguaro extensively, with the ash-throated and Arizona crested flycatchers being dependent upon the abandoned nesting cavities of the gila woodpecker in large part. The two hawk species (red-tailed and Harris's) usually placed their nests in the giant cactus on specimens where supporting arms were noticeably higher than the surrounding plants. The white-winged and western mourning dove, and the phainopepla utilized the higher wash plants as the condalia, mesquite and ironwood trees, for the most part, and exhibited a wide range of nest heights as a result. Conversely, those birds which preferred the cholla cactus (cactus wren, Palmer's thrasher, house finch) were necessarily content with little height variation but had the excellent protection of the spiny branches which surrounded the nest. The relatively low nesting verdin utilized both the cholla and several plant species along the washes. In turn the cleverly constructed nests, without fail, always had several spiny catclaw twigs incorporated around the entrance hole and often formed a short protecting porch-like projection over the entrance with this same material. As a result, even though the nest was rather low and placed in an open-branched wash tree it presented quite a challenge to most predators. Only one nest of the desert sparrow was found (Alamo Canyon) and was located in the interior of a thick bushy bur sage. Completely invisible from all sides of the nest plant, it was discovered only by the actions of the adults and the presence of a fledgling in a neighboring shrub.

Ground nesting species are not so common in such areas where the sparsely scattered bushes afford little cover. Only in the vicinity of water holes and along the more thickly vegetated washes, with the exception of the canyons, does the ground cover afford suitable nesting niches. Only a single nest of the Gambel's quail was located during the study. The nest site was under a thick two-foot high bur sage along the south periphery of a large condalia tree at Agua Jita. In the case of the turkey vultures, however, vegetative cover was not a contributing factor to nesting success. The one nest found of this species, was situated in the center of a large rock pile on the open desert. The boulders were so arranged as to form a cairn with a single small opening into a sizeable room within the pile. The entrance was just large enough to permit the birds to enter into the nesting cavity which was some 10 ft. in diameter and 3.5 ft. high.

PLANT UTILIZATION AS RELATED TO THE FOOD, WATER AND NESTING REQUIREMENTS

Water requirements of desert animals have long been a subject of interest to many scientists. Most work to date has been concerned with desert mammals. Bailey (1923), Sumner (1925), and Vorhies (1928, 1945) have made outstanding contributions to our scant knowledge of the water problem of these animals thriving in arid regions. The problem has been considered in the old world deserts by Buxton (1923) and Feniuk & Kazantzera (1937).

Animals living in desert country are commonly thought to derive moisture from two chief sources when free water is not available. These are succulent foods and metabolic processes. Many mammals have been successfully kept in captivity for months, even years, subsisting on diets of air dried foods as rolled oats and dry grain.

Table 14 indicates some common sources of food and water. As a result, the critical hot summer seasons. Throughout the nesting period various plants are producing flowers, which attract large numbers of insects, or fruits which supply both food and water. As a result, the critical hot summer months are endured with relative ease by most of

TABLE 14. Approximate seasons of common food and water sources available to the desert fauna during the current study (1949).

Source	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Precipitation	XXXX						XX	XX	XX	XXXX		XXXX
Winter Annuals	XX										XX	XXXX
Spring Annuals			XXXX	XX								
Mesquite (*Prosopis juliflora*)			XX	XXXX	XXXX	XXXX	XXXX	XX				
Mistletoe (*Phoradendron californicum*)				XXXX	XXXX							
Hedgehog Cactus (*Echinocereus*)				XX	XXXX	XX						
Indian Wheat (*Plantago*)				XX	XXXX	XXX						
Condalia (*Condalia lycioides*)				XX	XXXX	XXXX						
Saguaro (*Cereus giganteus*)				X	XXXX	XXXX	XXXX					
Lycium (*Lycium berlandieri*)					XXXX							
Catclaw (*Acacia greggii*)					XXXX	XXXX	XXXX	X				
Organ Pipe Cactus (*Cereus thurberi*)					XXXX	XXXX	XXXX	XX				
Prickly Pear Cactus (*Opuntia engelmanii*)					XXXX	XXXX	XXXX	XXX				
Ironwood (*Olneya tesota*)					XX	XXXX	XXXX	X				
Palo verde (*Circidium*)						XXXX						
Barrel Cactus (*Echinocactus*)							XX	XXXX	XXX			
Hackberry (*Celtis reticulata*)						XXXX			XXXX			

the birds. Only the permanent residents and winter visitants would seemingly have the most difficulty and that would be during the cooler winter season. Rains occurred in September, October, December, and January which alleviated most of the water difficulty, temporarily, for it is not so important during this period of cooler weather and higher humidity (Table 14). Invertebrates, seeds, winter buds, and other foods are available most of this time, and even these groups experience few unfavorable periods.

An examination of the winter and permanent residents will reveal the following four food-preference categories of birds: (a) Carnivorous, 19%; (b) Insectivorous, 43%; (c) Seed eaters, 30%; (d) and Miscellaneous, 8%.

(a) *Carnivorous species.* Rodents and smaller birds play the predominant role in the food habits of hawks and owls and are available the year around. Least difficulty for survival should be experienced by these birds.

(b) *Insectivorous species.* Sixteen species are listed as primarily insectivorous. These include the gnatcatchers, shrikes, vireos, flycatchers, wrens, thrashers, woodpeckers, phainopepla, and verdin. The food habits of these species vary with the seasons and during the summer when the mistletoe is in fruit it comprises almost 100% of the food of the phainopepla. Cactus wrens and Palmer's thrashers were often seen pecking at the unopen fruits of the saguaro to get at the seeds and sweet juicy pulp within. The woodpeckers were somewhat independent of the surrounding conditions for water was accessible to them by merely piercing the tough outer covering of the saguaro which exposed the watery pulp beneath. This trait undoubtedy benefited other species seeking water for considerable time may elapse before the juices hardened to seal the wound from further water loss. One instance of this procedure was recorded on March 16. A gila woodpecker was observed pecking on the extreme top of an 18 ft. saguaro. The purpose of his efforts was unknown but evidently the outer covering of the plant was pierced for chips could be seen falling to the ground. After working for some 15 min. the woodpecker departed and his place was soon taken by a Palmer's thrasher who discovered the wound and commenced picking at the spot, accompanied by an occasional raising of the head in the characteristic fashion of a drinking bird. After satisfying his thirst the thrasher departed and in turn the spot was utilized by one of a pair of cactus wrens that was building nearby. The purpose of the wren's visit was apparently to sing from the elevated perch for several minutes of singing were concluded before this bird also was noticed picking and drinking from the same spot.

Insects are apparently abundant during the winter season, as well, for Huey (1942) observed hundreds of white-throated swifts capturing insects that had been carried up from Alamo Canyon by an updraught of wind during his study in the canyon on December 14.

(c) *Seed eaters.* This group is composed mostly of Fringillids, with the exception the Gambel's quail. Food is obtained during the winter seasons from the many minor plant species as well as mesquite and other seed bearing trees. Insects are no doubt utilized as well when they are chanced upon. Gambel's quail uses both vegetable and animal foods depending on the season. Vegetable food reaches its maximum in

February, its minimum in June, at which time animal matter reaches its peak (Gorsuch 1934). Mesquite far surpasses any other species in both frequency of occurrence and quantity and furnishes food throughout the year. Large quantities of buds and flowers are taken in the spring by many species of birds while during the fall and winter the seeds are eaten in vast numbers. Most small birds cannot break the hard tough pod of the mesquite but many become available after coyotes, cattle, and other animals have eaten pods which are digested and the beans passed out entirely and thus made available to quail and other species. Various cacti furnish a constant source of food to most species of wildlife on the desert. Gorsuch (1934) mentions that during the hot dry season it is not uncommon to find quail with beaks and faces stained a deep red from the juices of the prickly pear fruits upon which they have been gorging. Cholla fruits are apparently less attractive to the quail but the seeds are readily utilized as recorded by the above writer. New leaves of the composites (Compositae) are taken during winter months while budding flowers are eaten in the spring.

The desert hackberry serves a dual purpose of both food and cover and is one of the prime importance to quail according to Gorsuch. The orange-colored berries are produced from mid-summer through the fall months and are greatly relished by birds.

(d) *Miscellaneous species.* Three species include the killdeer, roadrunner, and raven. In the case of the killdeer, food and water are no problem for it is restricted to permanent water sites where these natural requirements are abundant.

Especial mention should be made of the importance of the saguaro in its effect on the desert wildlife. Utilized by a majority of the mammal and bird species it is one of the most important components of the desert flora, ranking high with such plants as mesquite and hackberry. The flowers appearing in April are a source of both food and water for the bird species. The large flowers have the typical waxy gloss of the cactus blossoms and are persistent for a few days even during the hot seasons. Having a deep bell-shaped form the numerous yellow stamens completely cover the slightly elongated hypanthium which is filled with a sweet thick nectar. Many observations were made of birds digging deep into these flowers for the insects and apparently to sip the juice. The doves, both white-winged and western mourning, were exceptionally fond of this source of nourishment.

It is probable that the presence of the larger numbers of saguaros on Area 2 partly accounted for the considerably higher dove populations which occurred there. By counting the total number of individual saguaros present, it was found that 638 (15.8 / ac.) mature, producing plants were found in Area 2 as contrasted to 261 (3.7 / ac.) in the other area. Expressing these data in terms of percentages in Area 2, 118% more saguaros were present, 23% more birds of all species comprised the population and a difference of 215% more doves were recorded in the same area.

By crudely weighing several lots of saguaro fruits an average of approximately one ounce of juicy pulp was found to be available in each fruit. Being rather tender when ripening and finally popping open at maturity those fruits were available to the birds and scores were knocked off the plants to be eaten by cattle, deer, coyotes, and myriads of other desert animals. Up to a hundred blossoms have been counted on a single young plant while four or five arms, each producing blossoms and fruits, are found on many saguaros. As a result, a tremendous amount of food and juice is available during the hot critical summer period when this plant is bearing.

An interesting correlation may be drawn between the flowering of the saguaro and the presence of the white-winged dove. The date of the first dove recorded on the Monument was April 19 and two days later (April 21), the first saguaro blossom was seen. The breeding period of this species and the flowering and fruiting season of the saguaro both occur from April to August, approximately. Wetmore (1920) stated that the favorite food of the white-wings along the Gila River during the summer period was the purple drupe borne by *Condalia spatulata* and the fruits of the giant cactus, which they ate as rapidly as they ripened. Gilman (1911) noted that their coming was coincident with the ripening of the berries of the wild jujube, *Zizyphus lycioides,* upon which they fed greedily as long as the fruit lasted, consuming both ripe and green. Gilman adds that the giant cactus furnishes them (white-winged doves) a large amount of food and noted that: "They may be seen on top of the giant columns as soon as the first blossoms appear, thrusting their bills into the trumpet-shaped flowers, but whether for insects, pollen, or nectar was not learned. As soon as the fruit ripens, however, there is no doubt as to what they are seeking. Their actions are a sufficient index even without the telltale red stain around their mouths. They frequent the cactus groves as long as any fruit is left, flying a long distance to reach this delicacy."

Anderson & Anderson (1946) recorded, near Tucson, instances of English sparrows (*Passer domesticus*) eating the buds of the creosote bush and house finches crushing the fuzzy fruits with their bills to get at the seeds inside. Another instance of the green-backed goldfinch (*Spinus psaltria*) sampling the fruit was also made. Although the creosote bush fruits ripen in enormous numbers each year, and are easily accessible, none of the desert birds apparently feeds on them regularly. Only one observation of a bird feeding from this species was made during the current study, that being a cactus wren which may have been eating the flowers or more likely snaring insects from the blossoms.

An attempt was made to determine what plants were commonly utilized in the nest construction of the various species of birds. One verdin nest was

completely analyzed as to plant species involved and produced some interesting facts of construction and utilization of various plant twigs. The globular structure had a depth and breadth of about nine by seven in. while the nesting cavity measured about five by three in. The nest was divided into three distinct layers (1) an outer rough layer of larger twigs which made up about 25% of the bulk, (2) a middle layer comprising most of the structure (70%) and made of short twigs and leaves of softer composition, and (3) an inner layer of feathers which made up the remaining 5% of the total bulk.

(1). This layer was composed of five species of plants: Lycium, 45%; ironwood, 21%; hackberry, 14%; Condalia, 4% and Acacia 1%. A remaining 15% was unidentified. The catclaw was represented by the lowest per cent of occurrence (1%) but also the twigs were strategically placed over the entrance hole. A count of 40 twigs revealed an average of 3.8 in. in length, the longest and shortest being 7 and 1 in., respectively.

(2). The middle layer was chiefly made up of shorter finer twigs of the species listed above, with the exception of the catclaw. No thorns were found here. A considerable proportion of leaves were added in this layer to provide insulation and softness to the chamber. These were principally ironwood and mesquite.

(3). The lining of the nesting chamber proper was made completely of feathers, all of small size and of undetermined origin. Breast feathers of the cactus wren and Gambel's quail were most common.

TERRITORIAL BEHAVIOR AND NESTING ACTIVITY OF THE BREEDING SPECIES

Comparative Sizes of the Territories

During the current study a more or less consistent size of territories was evident, particularly in the wash areas, where the habitats of both plots were similar, regardless of the population density. In Area 1 twice the number of Gambel's quail was present than were in Area 2 yet the average nesting territorial sizes were surprisingly similar (Table 15). Other species (gila woodpecker, verdin, Palmer's thrasher, Sonora gnatcatcher) exhibited the same tendency. On the other hand, where the same number of birds was present on each area the sizes of the territories may vary, such as shown by the phainopepla and Arizona crested flycatcher. The one pair of cactus wrens nesting in Area 2 maintained a considerably larger territory than those of the first wash plot.

Comparison of these wash territory sizes, however, to the open desert typified by Area 3 reveals quite a different tendency. Here all of the average territory sizes are larger than those maintained by the same species in the wash situation. Extreme cases are provided by four species; the gila woodpecker, ash-throated flycatcher, Palmer's thrasher, and phainopepla (Table 15). Every species, with the exception of the cactus wren, at least doubled their territory sizes. In the case of the exception cited, it is interesting to note that the seven open desert territories averaged less than an ac. (.7) larger than the single territory maintained by the species in Area 2. Perhaps these sizes recorded may be the optimum desired under unmolested and uncrowded conditions. Also the presence of a richer food supply along the washes might have accounted for the smaller territories in those areas. In the open desert area a considerable amount of additional suitable habitat was available had the individuals desired to extend their territories.

Both the ferruginous pygmy owl and sparrow hawk maintained a hunting territory over Area 1 and the portions in which they were observed were plotted mostly along the wash. The hunting territory of each was determined and listed in the table. Young of the owl species were recorded on several occasions along the wash. Two mockingbirds established territories but so far as could be ascertained, these males did not mate. One male maintained his territory from March 8 to April 25 and the other remained from March 19 to April 25. No evidence of territorial

TABLE 15. Comparative territorial sizes (in acres) for the common nesting species on the three study areas.

Species	Area 1				Area 2				Area 3			
	Number of territories	Max.	Min.	Ave.	Number of territories	Max.	Min.	Ave.	Number of territories	Max.	Min.	Ave.
Cactus Wren	7	6.3	3.1	4.6	1	—	—	8.9	7	13.0	6.6	9.6
Gambel's Quail	6	4.5	1.7	3.4	3	3.8	3.2	3.1	+	+	+	+
Verdin	6	1.9	1.0	1.3	4	1.7	.9	1.3	4	6.6	5.2	5.7
Phainopepla	5	3.1	1.7	2.4	5	1.9	1.2	1.4	1	—	—	10.5
Sonora Gnatcatcher	4	2.6	2.0	2.4	2	2.3	2.3	2.3	6	6.6	4.2	5.2
Palmer's Thrasher	3	11.5	9.9	10.5	1	—	—	9.2	2	48.3	29.4	38.9
Gila Woodpecker	2	11.6	11.3	11.5	1	—	—	11.0	2	24.7	24.1	24.4
Arizona Crested Flycatcher	2	12.7	9.4	11.0	2	10.4	6.3	8.4	2	20.9	18.8	19.9
Western Mockingbird	2	8.2	7.1	7.7	—	—	—	—	—	—	—	—
Ash-throated Flycatcher	1	—	—	7.3	+	+	+	+	1	—	—	24.7
Ferruginous Pygmy Owl	1	—	—	20.8	—	—	—	—	—	—	—	—
Sparrow Hawk	1	—	—	22.6	—	—	—	—	—	—	—	—
House Finch	+	+	+	+	+	+	+	+	+	—	—	8.2

behavior was noted for any of the pairs of house finches recorded in Area 1. Active nests were sometimes within 100 ft. of each other and no competition was evident. The one pair of this species nesting in Area 3 was recorded during the period of nesting over an area embracing some 8.2 ac.

No territorial behavior was noted for either of the common breeding dove species.

Nesting Success of the Breeding Species

Considering first the larger common birds of prey 100% nest success was recorded for eight nests of the western red-tailed hawk that were observed. Five of the eight nests contained two eggs each while the remainder had three each. One of the two nests located of the Harris's hawk did not produce its full clutch. In this case one of the two day-old young was either pushed or fell from the nest and was found dead at the base of the saguaro that provided the nest-site. The other nest contained three eggs. For the two hawk species listed all the eggs hatched that were laid. In the case of the western horned owl, the sizes of the original clutches were not known, however, both the nests located were found while the young were quite undeveloped and it is reasonable to assume that if a mate had been present it would not have fledged prior to the discovery of the nest-site. Bent (1938) states that two eggs form a set and sometimes three may be found.

A more significant appraisal of the nesting success can be derived from Table 16 where the data are presented in terms of percentages. The two dove species which are common nesters, build the typical flat platform type of nest and are not so particular concerning the exposure of the nest site. As a result they exhibit the lowest per cent of nesting success of any of the species studied. The period of greatest mortality appeared to be during the incubation phase. In a study of 56 white-winged dove nests in a southern Arizona survey, Arnold (1943) recorded a 75% success in 1942. The same area, according to Arnold, produced a 53% success in 1941. This figure was compiled on the basis of 60 nests. The 1941 figure did not include the probably more successful early season nests.

It is interesting to note the close similarity in the per cent of successful nests of the cactus wren, verdin, Palmer's thrasher, and house finch. With the exception of the verdin, all utilized chollas exclusively as nesting sites. Palo verde trees were used most frequently (7 out of 15) by verdins.

In the Tuscon Mountain Park area Arnold (1943) found that birds (white-winged doves) nesting in low open sites on cholla cactus have a high percentage of success. The current study seems to bear out this observation for species other than the doves mentioned above.

As a whole, 70% of the total number of active nests were successful, fledging at least one young. Table 16 lists the hatching and fledging data for these successful nests thereby providing an index to the fertility and viability of the eggs, as well as to the rearing efficiency of the adults.

A total of 30 nests failed to produce fledglings successfully on the study areas. The factors apparently responsible for the unsuccessfulness of the attempts are summarized in Table 17. Six nests were raided during the egg stage. In all cases the nests appeared to be undisturbed with only the eggs missing. In one instance noted both eggs of the phainopepla nest were punctured. A Sonora gnatcatcher was surprised at or near the nest on the observers' approach and rapidly flew from the vicinity.

A known cause for desertion by incubating house finches was due to parasitization by the dwarf cowbird. A pair of white-winged doves deserted their nest after the eggs were punctured similarly to those of the phainopeplas mentioned above.

Table 16. Nesting success of the common species of birds on three Lower Sonoran Desert areas.

Species	Total no. nest active	Total no. eggs laid	% eggs laid that hatched	% young hatched that fledged	% eggs laid that fledged	% nest with at least one young fledged	No. eggs laid in successful nests	% eggs hatched in successful nests	% eggs hatched that fledged in successful nests
White-winged Dove	24	44	45	90	41	42	18	100	100
Cactus Wren	20	69	86	97	83	80	56	100	100
Verdin	15	56	96	85	82	80	48	96	100
Palmer's Thrasher	15	40	92	78	72	80	31	97	97
House Finch	10	41	80	100	80	80	33	100	100
Phainopepla	8	18	78	93	72	75	14	100	93
W. Mourning Dove	4	8	50	100	50	50	4	100	100
Mexican Ground Dove	2	4	100	100	100	100	4	100	100
W. Red-tailed Ha. k	1	2	100	100	100	100	2	100	100
W. Horned Owl	1	1	100	100	100	100	1	100	100
Son. White-rumped Shrike	1	6	100	100	100	100	6	100	100
Sonora Gnatcatcher	1	5	20	100	20	100	5	40	50
Fledged broods seen	(5)	—	—	—	—	—	—	—	—
Gambel Quail	—	—	—	—	—	—	—	—	—
Fledged broods seen	(6)	—	—	—	—	—	—	—	—
Totals	102	294	81	91	72	70	222	97	99

TABLE 17. Factors responsible for nest losses on the three study areas.

Species	No. nests unsuccessful	RAIDED		ABANDONED		Nest tipped	Undetermined
		egg stage	nestling stage	egg stage	nestling stage		
White-winged Dove	14	3	1	2	..	..	8
Cactus Wren	4	..	3	..	1		
Verdin	3	..	1	1	1		
Palmer's Thrasher	3	1	1	..	..	1	
House Finch	2	..	..	2			
Phainopepla	2	1	..	1			
Western Mourning Dove	2	1	1				
Totals	30	6	7	6	2	1	8

Two cases are listed of birds deserting the nest with young still unfledged. A cactus wren nest was checked on April 25 at which time the young were vigorous and just commencing to develop pin feathers. Five days later all three young were dead and completely dehydrated. The pin feathers were well developed at the time of death. No evidence of parasites was present and adult birds were in the area. Factors causing the deaths of the fledglings are undetermined. The other case was of a similar nature involving a nest of verdins. This nest was placed about 2½ ft. up in a cholla and was found on April 5 with four eggs. By April 21 all were dead and completely dehydrated. The adults were not in the vicinity. No traces of tracks were visible beneath the nest nor was the structure itself damaged. No parasites were found on the young or in the nest. It is known that direct rays of a bright sun can readily have a disastrous effect upon nestlings within a few minutes (Willford 1925) and perhaps could feasibly have raised the temperature within such closed structures, under certain conditions, to a lethal threshold. However, it seems more likely that either parasites or the death of the adults was the responsible factor.

One nest of the Palmer's thrasher was the victim of strong winds which so loosened its attachments that it tipped over, spilling the fully feathered young into the chollas. Two of the three fledglings were impaled on the thorns of the cactus while the third was missing. Both were dehydrated.

Several factors may be attributed to the large number of raided nests. In addition to the egg puncturing, probably by some bird, the area abounds with predators, as the coyote, ground squirrels, bobcat, birds of prey, and several species of snakes that no doubt take their toll of nestlings and eggs. One white-winged dove nest was unquestionably destroyed by a coyote who consumed both the eggs and the incubating bird. A few scattered feathers were found on the ground as well as several distinct tracks of the predator. The nest was about five feet high in an acacia, growing along the wash in Area 1. On one occasion, a gray-tailed antelope ground squirrel (*Citellus h. harrisii*) was found in an old nest of the Palmer's thrasher which was placed up in a cholla. As to their ability to negotiate the hazardous chollas Huey (1942) states: "At times they were seen atop bristling-spined cholla cactus, where they sat erect to view the surrounding area. How they could negotiate the climb over the vicious thorns was always a question, for the soft pads of the feet on specimens taken in such positions never contained spines nor were there scars to indicate former difficulties."

On July 28, a large Arizona bull snake (*Pituophis sayi affinis*) was discovered 4 ft. up in a large ironwood tree in Area 2. Although the tree contained no active nest, so far as was known, the presence of this potential enemy had aroused a good number of birds. Eleven individuals of six species were present in the tree: three verdins, one white-winged dove, two Sonora gnatcatchers, two cactus wrens, two gila woodpeckers, and a Scott's oriole. Instances of eggs failing to hatch were recorded on four occasions. In two cases one egg of the clutch failed to hatch in verdin's nests and a pair of Palmer's thrashers fledged two young while leaving an egg in the nest. The Sonora gnatcatcher, already mentioned, was the remaining species who failed to hatch the complete clutch for only two of the five eggs hatched and only one of these fledged.

Young birds sometimes experienced considerable difficulty with the thorns of the cholla. On April 30, the nest of a Palmer's thrasher was found with a fully feathered young bird perched on the rim of the structure with one wing firmly held by the thorns. The bird was dead, being completely dehydrated, while the nest contained two eggs of the second brood. The incubating bird was flushed from the nest. Similar instances of young birds jumping from the nest during advanced nestling stages and becoming entangled with the thorns were recorded. Twice the fledglings became so securely fastened that only after considerable effort, were they freed by the writer.

SUMMARY AND CONCLUSIONS

Four areas exhibiting typical lower Sonoran desert vegetation were intensively studied in Organ Pipe Cactus National Monument, Arizona, during June and July of 1948 and from February through August 1949. Of these, two represented wash situations

and two were located in the intermountain plains. A total of 398 species of plants were recorded on the Monument. Many represent new locality records and include range extensions of considerable distances.

Two major eco-systems are found in the Monument being (1) the alluvial fill of the intermountain valley regions and (2) the mountain lava-granite complex.

By means of plot, transect, and continuous line counts of the wash plants, the plant species composition and relative abundance of each species was determined. The wash plots were predominately tree areas with mesquite, palo verde, ironwood, and saguaros particularly abundant. Another area was typical open desert with creosote bush, bur sages, chain cholla, and palo verde trees most common while another was 100% creosote bush.

Censusing of the breeding birds was done by strip, plot, and nest counting methods and territorial maps were determined for each species. In all 96 censuses were conducted on the study areas, and approximately 648 man-hours were spent on the areas. During the study 200 active nests were located of which 125 were periodically examined. Most of the work was confined to the desert floor but a few canyon censuses were made.

No concentrations of nests were apparent in the vicinity of water holes although such species as killdeer and vermilion flycatcher were found only in the vicinity of the small pond at Quitobaquito. These areas were utilized by large numbers of individuals of several species for drinking and bathing purposes.

The white-winged doves were by far the most abundant. Twenty species of birds composed the breeding population of Alamo Canyon.

The four research plots located in the intermountain plains, were divided into two habitat phases: (1) wash and (2) inter-wash areas.

(1) *Wash areas.* A total of 295 transient individuals, representing 18 species were observed on these two areas. Members of the sparrow genus Zonotrichia were the most numerous with the Brewer's sparrow second in abundance during the 78-day migration period (March 3 to May 20).

Breeding populations of the two areas were similar in species concerned, 28 in Area 1 and 29 in Area 2, while the density was considerably higher in the second area (88 to 108 pairs per hundred acres, respectively). The difference in the population density is due to the greater numbers of white-winged and mourning doves nesting in Area 2.

(2) *Inter-wash areas.* Seven species utilized these open areas while migrating. A total of 165 individuals were noted during the 68 day period from February 27 to May 3, with the Brewer's sparrow being the most abundant.

The breeding population of the open desert was considerably lower than in the washes for only 37 pairs per 100 ac. were present in Area 3 while the creosote flat of Area 4 was devoid of nesting birds. A total of 25 species utilized Area 3 for nesting and feeding activities.

Eight nests of the western red-tailed hawk, two of the Harris's hawk and two western horned owl nests were found during the study. All but two were confined to a 75 sq. mi. tract in the south-central part of the Monument. Distances between nests of the red-tailed hawk ranged from 3-6 mi.

April and May appear to be the peak migratory periods through the region with the earlier movements being apparent on the open exposed deserts. As the season advances, the cooler canyons and water holes attract the transient individuals.

The over-all nesting season extended from February 28 to August 15, at least, with the Palmer's thrasher having the most prolonged nesting period (170 days). Active nests of 15 species were found on the four areas, of which five were resident species. About 1.0 breeding birds were sustained per acre in the washes while the open desert supported only .24 individuals per acre.

The Arizona study exhibited a lower bird population per 100 ac. than was the case in studies conducted in the Colorado desert of California. During two seasons the California workers recorded 95 and 124 pairs per 100 ac. while the current study found only 69 pairs for the three areas combined. The data were not closely comparable, however, for the Arizona figure was derived from a compilation of all the study areas (210 ac.) while the California project was a selected plot of 37 ac.

An analysis of the zoogeographic origin of the populations supports, when compared with other desert areas, the tendency to an increase from north to south in the South American element and a decrease in the Old World element is presented by Mayr (1946).

Most available habitats have been utilized by the bird species with the cholla cactus, saguaro, palo verde, ironwood, and mesquite being the favored nest plants. Four types of nests were recorded, namely: (1) conventional open-topped bowl, (2) closed-roofed nests, (3) platform type, and (4) hole nests. In general those species building closed nests were not as selective in choosing nest sites as were those whose open-topped structures needed protection.

Heat and humidity may be more critical factors than drinking water during the hot summer nesting season for the bird species. Water is usually obtainable from the food sources throughout the warmer seasons in the form of the various flowers and fruits of the cactus species, particularly the saguaro.

Territory sizes of the various species were quite uniform for the particular species when the two wash areas were examined but differed widely when contrasted to the open desert. Here all species, with the exception of the cactus wrens maintained territories just slightly larger in open desert than was exhibited, in the wash situations.

The large birds of prey produced the highest nesting success with the red-tailed hawk and western

horned owl having a 100% fledging. One of the Harris's hawk nests fledged only one of the two chicks hatched and marked the only fatality in this group.

A total of 294 eggs were laid of which 235 hatched and 214 fledged from 102 nests on the three areas. Expressed in percentages, 80% of the eggs laid hatched, 72% fledged, 91% of the young hatched fledged, and 70% of the nests were successful. White-winged and mourning doves exhibited the lowest nest success being 42% and 50%, respectively. The phainopepla fledged young from 75% of the nests while the remaining four common nesters (cactus wren, verdin, Palmer's thrasher, and house finch) indicated an 80% success.

Factors responsible for nest losses were primarily predators during the egg and nestling stages and desertions during the egg stage. Coyotes, snakes, ground squirrels, and birds of prey probably account for many of the raided nests. Two cases (verdin and cactus wren) of the fully feathered nestlings dying were recorded but no causes could be determined. At least one fledging (Palmer's thrasher) was known to have perished as a result of being entangled in cholla thorns. Instances of eggs failing to hatch were recorded in four cases, twice in verdin nests and once each in Palmer's thrasher and Sonora gnatcatcher nests.

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