1971

Validation Studies at Tucson, Arizona

David Hendricks

A. Neil Macgregor

E. Lendell Cockrum

et al

IBP

DESERT BIOME

US/IBP ANALYSIS OF ECOSYSTEMS

1970

PROGRESS REPORT

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VALIDATION STUDY

Validation Studies at Tucson, Arizona

David Hendricks and A. Neil Macgregor, Department of Agriculatural Chemistry and Soils; E. Lendell Cockrum, T. C. Vaughan, Charles Lowe, S. M. Russell, and G. T. Austin Department of Biological Sciences; Floyd G. Werner, and William I. Nutting, Department of Entomology; E. T. Bartlett, John L. Thames and E. B. Fish, Department of Watershed Management, University of Arizona, Tucson, Arizona

Objectives

The objectives of the validation measurements are four-fold:

1. To conduct an initial inventory (standing-crop measurements) of energy, nitrogen, phosphorus, carbon, and water in as many as possible of the biotic (species) and abiotic components of the site.
2. To make periodic standing-crop estimates of the major biotic and abiotic components of the system.
3. To make periodic measurements of the physical factors and inputs in the site.
4. To develop equipment and facilities to accomplish the above.

Methods

The following project list enumerates the specific methods being used for the site.

Project: Inventory Bird Populations (DSCODE = A3URJ _ _)

Data recorded. -- Density (individuals per 100 acres) and biomass (grams per 100 acres).

Experimental methods. -- Censuses were conducted using the Emlen census technique. William's spot map census technique was used as check during the breeding season.

Experimental design. -- 50 acre plot with coordinate lines on each site (as noted as A3UCE _ _).

Project: Soil Survey (DSCODE A3UHD _ _)

Data recorded. -- Soil series of Santa Rita site and their characteristics.

Experimental methods. -- Survey was contracted to Soil Conservation Service (SCS).

Experimental design. -- Survey contracted to SCS.

Project: Nitrogen-fixation by desert algal crusts (DSCODE = A3UMA01)

Data recorded. -- Capacity of algal crusts to produce ethylene (nitrogen fixed) in nanomoles of ethylene produced per cm^2 per hour of incubation.

Experimental methods. -- 18 cm^2 samples of intact algal crust were moistened and incubated in presence of acetylene in gas-tight tubes. Light supplied at 1.1 lumens/cm^2. Ethylene production was determined by standard gas chromatographic procedure.

Experimental design. -- Random sampling of 1 hectare in destruct area.

Project: Microbial content of semi-arid soils (DSCODE = A3UMA02)

Data recorded. -- Nanograms of ATP per gram of soil; ≠ 10% as low as 20 nanograms of ATP measured per gram of soil.

Experimental method. -- Samples of the soil profile were collected from a freshly dug trench. The soil samples were extracted with butanol-octanol mixture and the laciferin-laciferase reaction. Current research suggests that for microorganisms each gram of microbial biomass is associated with 200 ug of ATP.

Experimental design. -- Sampling of two sites in destruct area: one with grass cover, the other with no grass cover.

Project: Surveys of terrestrial invertebrates, mainly arthropods, as related to the area sampled (DSCODE = A3UWH01)

Data recorded. -- Number of organisms, dry weight of large individuals, combined dry weight of sample for inventory period.

Experimental methods. -- The method is dependent on class of invertebrate.

Expermental design. -- Random sampling of invertebrate fauna.

Project: Surveys of invertebrates associated with plant species (DSCODE = A3UWH02)

Data recorded. -- Numbers of organisms, dry weight of large individuals, combined dry weights for inventory period.

Experimental methods. -- The method is dependent on class of invertebrate, but most samples taken from plant with D-Vac sampler, with opening 20 cm in diameter, and related to area covered by plant part sampled.

Experimental design. -- Random sampling of invertebrate fauna.

Project: Surveys of ant colonies (DSCODE = A3UWH03)

Data recorded. -- Colonies per unit area: precision high for large species, lower for small species; precision highest on fixed quadrats, which can be examined repeatedly. Workers per colony: precision low (estimates based partly on extrapolation and comparison).

Experimental methods. -- Count of numbers of colonies per unit area, either on a measured strip, a fixed quadrat, or a moving quadrat. Estimate of numbers in colony by mark-recapture and other methods.

Experimental design. -- Count of colonies per unit area. Estimate of number of workers per colony.

Project: Surveys of termite activity and distribution related to host plant availability. (DSCODE = A3UNE _ _)

Data recorded. -- Species of each item of host wood or dead plant material, its position, exposure, length, diameter and weight; the presence or absence of termites in each item; and the colony or group size and composition, including caste, sex, number of individuals and dry weight of samples from each category.

Experimental methods -- (1) Activity of specific termites is determined by visual examination of superficial dead plant material in small (sq. yard) quadrats spaced 50 ft. apart on transects across the study areas. (2) All superficial dead wood within 50-m^2 circles is plotted, measured, weighed and examined for termites. (3) All dead wood (branches 2 cm diam. and larger) on individual trees is plotted, removed with a chain saw, measured, weighed and examined for termites. Entire colonies, or foraging groups of termites, are extracted by hand or trapped in damp paper, sorted, counted, and samples of each caste are weighed.

Experimental design. -- (1) Rapid, transect sampling of termite activity in all types of superficial dead plant material. (2) Detailed sampling of termites in superficial dead wood in randomly selected small areas. (3) Detailed sampling of termites in standing dead wood on individual trees.

Project: Monitering small mammal populations (DSCODE = A3UCE06)

Data recorded. -- Location and weight (to nearest gram) of small mammals taken in the sample quadrat.

Experimental design. -- Live trap, toe clip, weigh, release. The general techniques of marking, grid placement, etc., are those that have been utilized by a large number of previous investigators. The specific modifications of these techniques that are utilized in this study are given in some detail in the file A3UCE _ _.

Project: Air temperature (DSCODE = A3UTC01)

Data recorded. -- Air temperature in degrees F.

Experimental methods. Continuous recording hygrothermograph with seven day clock located at trailer on Santa Rita Validation Site (see map A3U#009).

Experimental design. -- One instrument in standard instrument shelter.

Availability of data. Listings available from central office on request.

Project: Air relative humidity (DSCODE = A3UTC02)

Data recorded. -- Air, relative humidity.

Experimental methods. -- Continuous recording hygrothermograph with seven day clock located at trailer on Santa Rita validation site (see map A3U#009).

Experimental design. -- One instrument in standard instrument shelter.

Availability of data. -- Listings available from central office on request.

Project: Precipitation (DSCODE = a3UTC03)

Data recorded. Time rain started, stopped, and amount (inches) will be recorded for each storm.

Experimental methods. Standard recording raingage with 7 day clock at trailer on Santa Rita experimental range.

Availability of data. -- Listings available from central office on request.

Project: Vegetation inventory for major perennial species (DSCODE = A3UFI _ _)

Data recorded. Density, cover and frequency of major perennial species.

Experimental methods.- Samples are made with aerial photography and checked with ground truth data.

Experimental design. -- Random sampling stratified between major vegetative communities.

Site Development

Santa Rita Experimental Range

Site development at the Santa Rita Experimental Range, a primary objective of 1970, was completed. The area was divided into 4 subsites (Figure 1) and in order to provide a wider variety of desert ecosystems with which to test the predictive model, each was subjected to manipulation. These were:

Subsite 1: an ungrazed area
Subsite 2: an area where mesquite has been treated with deisel fuel
Subsite 3: a grazed area
Subsite 4: a chained area

Originally, subsite 4 was to be sprayed with 2,4D, or 2,4,5-T; however, because of the recent controversy concerning herbicide use, it was decided to chain the area. Subsite 2 was to be burned during the summer, and this manipulation was attempted June 29. However, the burn was unsuccessful due to lack of fuel to carry the fire. The oiling of the mesquite was then conducted in the event that burning is attempted in 1971.

The actual validation areas were to include the entire fenced areas, but as investigators initiated studies, it was discovered that some of the inventory methods disturbed the site. Consequently, the actual validation area on the subsites was reduced by 50 acres on the western border. Limited destructive sampling is practiced on these areas.

Manipulation (grazing) on subsite 3 has not yet been initiated. During 1970, the U.S. Forest Service was in the process of changing private cooperators who would graze cattle on the Santa Rita Experimental Range. The new cooperator will have his stock on the area in 1971. At this time it seems very likely that cattle will be on the site in the future.

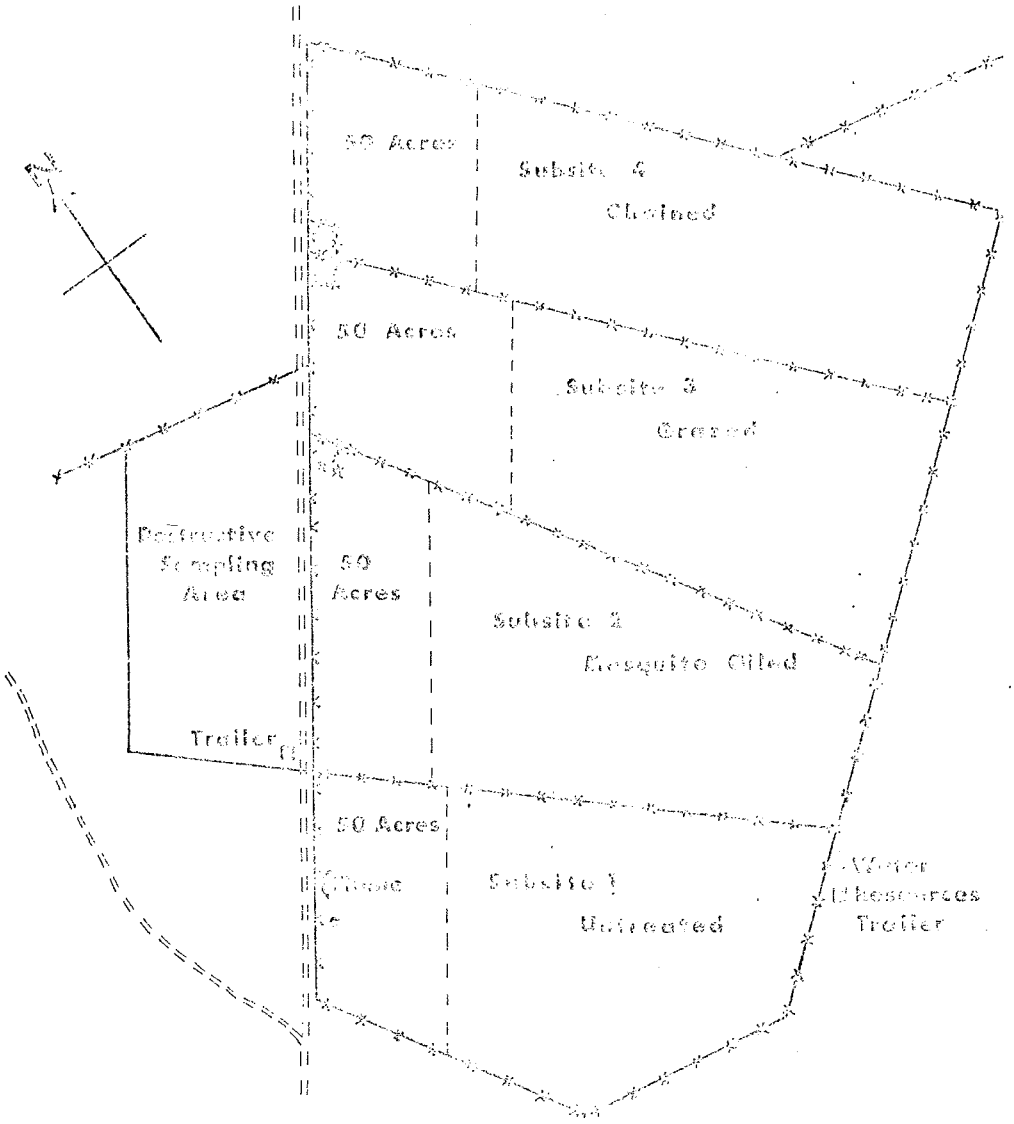


Figure 1. Santa Rita Validation Site.

Most physical structures at Santa Rita have been completed. This includes:

1. Fencing around all subsites (9 miles 4-strand).
2. Corrals and watering troughs in pastures to be grazed.
3. Pipeline from old corral in subsite 4 to a new corral outside of the site to replace the watering facility of the U.S. Forest Service.
4. Flume in Subsite 1 that was installed by the Hydrology and Water Resources Office, University of Arizona.

Silver Bell Site

Early in the study it became apparent that an additional site, more typical of the Sonoran Desert was needed in the program; a site under the control of the Biome where a perturbation treatment might be imposed. The original Saguaro Monument site and the surrounding Tucson Mountain Park was closed to any type of disturbance, including live trapping. Land near the park was not available.

A new Sonoran site was selected in the spring of 1970 by David Goodall, Charles Lowe, Robert Chew, and John Thames on Bureau of Land Management lands on the Silver Bell mountain bajada. A land-use agreement was made with the BLM for removing the site from the grazing lease. Although one clause in the agreement required re-working before final approval, the arrangement was sufficiently firm to begin work on the site.

The American Smelting and Refining Company staked mining claims on the area in July. We were told that some mining exploratory work would be done but prospects were not promising. The exploratory work did not appear to conflict with IBP objectives. However, with the exception of some small mammal studies, most validation work was halted.

By mid-October, it was apparent that the mining company wished to expand exploratory drilling to an extent which would render the site unsuitable for IBP purposes. ASRCO promised to bear most of the expense of relocating the site.

A new site, 10 km NW and very similar to the old Silver Bell site was selected. The present grazing lease on the land has been cancelled by BLM and mining will be excluded. Negotiations are underway with the ASRCO to establish the new site. A work plan proposed for site treatment will be executed as soon as negotiations with ASRCO are completed.

Findings

Avifauna

Studies of the avifauna on the Santa Rita site were initiated in March 1970 when a fifty-acre study area was established on the untreated plot. Censuses were conducted four to seven times per month using the Emlen census technique (Emlen, unpubl. manuscript). The William's spot map census technique (Kendeigh, 1944) was used as a check during the breeding season. All nests located on the study area were checked every two or three days and data on success and growth of nestlings and nest placement were obtained. Similar data were obtained for nests located in surrounding areas. There were a total of 158 nestlings banded. Data on foraging method and station were obtained for foliage gleaning insectivorous birds using techniques modified after Sturman (1968).

Population and Biomass: Data on population size are presented in Table 1. Numbers declined from April to June after which they rose to an October high. More than 50% of the birds present in April and from August through November were sparrows. The increases in July and August were due to birds of the year joining the population and to the arrival of species which breed after the rains start (Mockingbird, Blue Grosbeak, Cassins Sparrow, Black-throated Sparrow). The increase in September and October is due to the arrival of transients and winter residents.

Biomass exhibited a similar pattern of increase and decrease (Table 2). Sparrows are consistently important members of the avifauna, amounting to 10-20 percent of the biomass from April to July and more than 35 percent from August through November. Other important species are quail, doves, Cactus Wren, and Curve-billed Thrasher. Although quail account for a substantial portion of the total biomass, they apparently did not nest on the fifty-acre study plot. Weights of individual birds were obtained from the literature and from specimen lables. Thus, biomass figures are approximations and more accurate figures will be devised from process studies in 1971.

Nesting Activity: The intensity of nesting activity on the study areas is presented in Figure 2. Mourning Dove, Cactus Wren, and Curve-billed Thrasher were the principal (58% of nests constructed) breeding species before the rains started. Peak activity occurred after the rains. Within a week of the first rain, nearly all pairs of Rufous-winged Sparrows and Brown Towhees had initiated breeding activity. Concurrently, Mockingbird, Blue Grosbeak, Cassin's Sparrow, and Black-throated Sparrow arrived, established territories, and initiated nest construction. These latter six species built 79 percent of the nests built in July and August.

The breeding season varied in length for the several species breeding in the Santa Ritas (Figure 3). Mourning Doves built nests in all months from March to September. Cactus Wrens and Curve-billed Thrashers initiated nests from May to August. Other common species had shorter breeding seasons.

Table 1. Density (individuals per 100 acres) on the Santa Rita Experimental Range (untreated area).

	April	May	June	July	August	Sept.	Oct.	Nov.
Sparrow Hawk	--	--	--	--	--	--	--	--
Scaled Quail	35	13	8	--	4	7	12	--
Gambel's Quail	4	6	3	6	--	3	9	--
White-winged Dove	--	3	2	4	2	--	--	--
Mourning Dove	13	8	10	8	10	3	--	--
Roadrunner	--	--	--	--	--	--	2	--
Poor-will	--	--	--	--	2	2	--	--
Broad-tail Hummingbird	--	1	--	--	--	--	--	--
Gilded Flicker	1	--	1	1	1	2	2	1
Gila Woodpecker	3	3	1	2	2	1	1	--
Ladder-b. Woodpecker	6	2	3	3	3	3	4	3
Western Kingbird	--	--	--	--	4	2	--	--
Ash-th. Flycatcher	8	2	8	9	8	3	--	--
Verdin	7	11	9	12	13	14	9	10
House Wren	--	--	--	--	--	--	2	--
Cactus Wren	11	19	26	28	24	20	19	14
Mockingbird	--	--	--	12	13	7	--	--
Curve-b. Thrasher	16	10	11	9	14	16	14	6
Black-Thr. Gnatcatcher	8	2	4	5	4	5	8	6
Ruby-Cr. Kinglet	--	--	--	--	--	--	--	2
Phainopepla	--	--	--	--	2	6	--	--
Loggerhead Shrike	--	--	--	--	2	--	--	--
Bell's Vireo	--	--	--	--	2	--	--	--
Orange-cr. Warbler	--	--	--	--	--	2	--	--
Lucy's Warbler	5	10	4	6	2	--	--	--
Yellow Warbler	--	--	--	--	6	--	--	--
Aubudon's Warbler	--	--	--	--	--	--	3	--
MacGillivray's Warbler	--	--	--	--	--	5	--	--
Wilson's Warbler	--	2	--	--	--	--	--	--
Hooded Oriole	--	--	--	--	4	--	--	--
Bullock's Oriole	--	--	--	2	2	2	--	--
Brown-head Cowbird	2	1	4	3	--	1	--	--
Western Tanager	--	1	--	--	--	--	--	--
Pyrrholoxia	--	1	1	--	--	2	--	2
Blue Grosbeak	--	--	--	2	6	5	--	--
Lazuli Bunting	--	1	--	--	2	6	2	--
House Finch	2	5	3	6	17	5	2	--
Lesser Goldfinch	--	--	--	--	--	2	--	--
Green-tail Towhee	--	--	--	--	--	7	2	--
Brown Towhee	22	13	4	8	14	12	3	7
Lark Bunting	--	--	--	--	24	2	3	--
Vesper Sparrow	--	--	--	--	--	--	--	4
Lark Sparrow	2	--	--	--	4	2	--	--
Rufous-winged Sparrow	30	24	28	45	49	58	56	35
Cassin's Sparrow	18	--	--	30	40	73	29	9
Black-thr. Sparrow	2	--	--	11	49	65	85	45
Chipping Sparrow	--	--	--	--	--	6	--	--
Brewer's Sparrow	65	5	--	--	--	18	99	104
TOTAL	262	143	130	212	329	367	369	248

Table 2. Biomass (per 100 acres) on the Santa Rita Experimental Range (untreated area).

	April	May	June	July	August	Sept.	Oct.	Nov.
Sparrow Hawk	---	---	---	---	---	---	290	---
Scaled Quail	6703	2490	1532	---	766	1341	2298	---
Gambel's Quail	678	1018	509	1018	---	509	1526	---
White-winged Dove	---	438	292	584	292	---	---	---
Mourning Dove	1707	1050	1313	1050	1313	394	---	---
Roadrunner	---	---	---	---	---	---	479	---
Poor-will	---	---	---	---	92	92	---	---
Broad-t. Hummingbird	---	3	---	---	---	---	---	---
Gilded Flicker	104	---	104	104	104	208	208	104
Gila Woodpecker	210	210	70	140	140	70	70	---
Ladder-b. Woodpecker	183	61	92	92	92	92	122	92
Western Kingbird	---	---	---	---	149	74	---	---
Ash-th. Flycatcher	224	56	224	252	224	84	---	---
Verdin	57	81	67	89	96	104	67	70
House Wren	---	---	---	---	---	---	20	---
Cactus Wren	421	728	996	1072	919	766	728	536
Mockingbird	---	---	---	596	646	347	---	---
Curve-b. Thrasher	1312	820	902	738	1148	1312	1148	492
Black-t. Gnatcatcher	44	11	22	28	22	28	44	33
Ruby-cr. Kinglet	---	---	---	---	---	---	---	12
Phainopopla	---	---	---	---	53	159	---	---
Loggerhead Shrike	---	---	---	---	95	---	---	---
Bell's Vireo	---	---	---	---	18	---	---	---
Orange-cr. Warbler	---	---	---	---	---	17	---	---
Lucy's Warbler	32	64	26	28	13	---	---	---
Yellow Warbler	---	---	---	---	56	---	---	---
Audubon's Warbler	---	---	---	---	---	---	38	---
MacGillivary's Warbler	---	---	---	---	---	53	---	---
Wilson's Warbler	---	15	---	---	---	---	---	---
Hooded Oriole	---	---	---	---	94	---	---	---
Bullock's Oriole	---	---	---	67	67	67	---	---
Brown-h. Cowbird	78	39	156	117	---	39	---	---
Western Tanager	---	29	---	---	---	---	---	---
Pyrrhuloxia	---	36	36	---	---	71	---	71
Blue Grosbeak	---	---	---	66	199	166	---	---
Lazuli Bunting	---	14	---	---	28	83	28	---
House Finch	38	95	57	114	323	95	38	---
Lesser Goldfinch	---	---	---	---	---	18	---	---
Green-tail Towhee	---	---	---	---	---	195	56	---
Brown Towhee	990	585	180	360	630	540	135	315
Lark Bunting	---	---	---	---	941	78	118	---
Vesper Sparrow	---	---	---	---	---	---	---	98
Lark Sparrow	60	---	---	---	121	60	---	---
Rufuous-wing. Sparrow	459	367	428	689	750	887	857	536
Cassin's Sparrow	326	---	---	543	724	1321	525	163
Black Thr. Sparrow	26	---	---	144	642	852	1114	590
Chipping Sparrow	---	---	---	---	---	73	---	---
Brewer's Sparrow	697	52	---	---	---	187	1029	1082
TOTAL	14351	8262	7006	7901	10767	10382	10938	4194

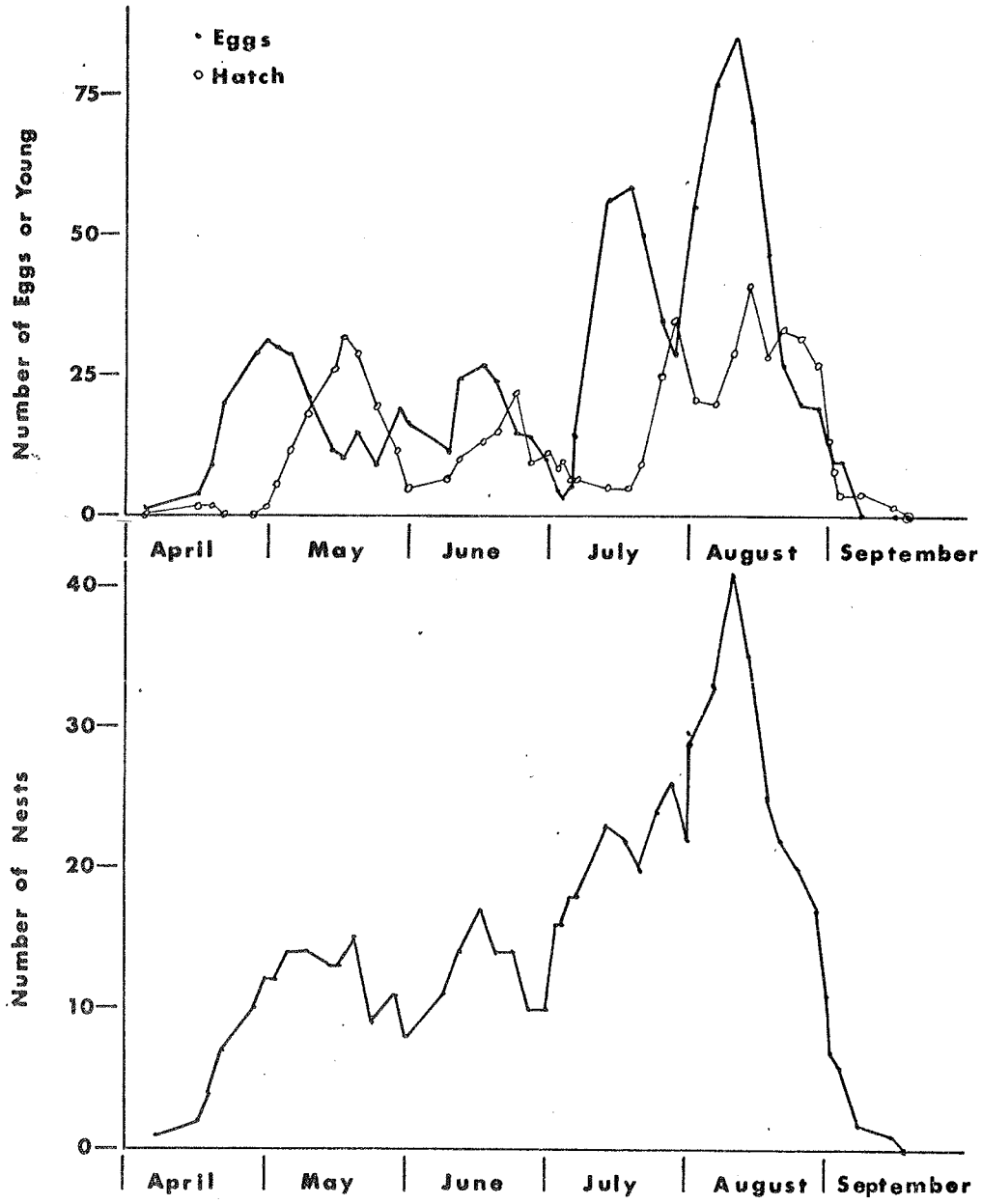


Figure 2: Number of eggs, young and nests on a 50 acre study area on the Santa Rita Experital Range (untreated plot).

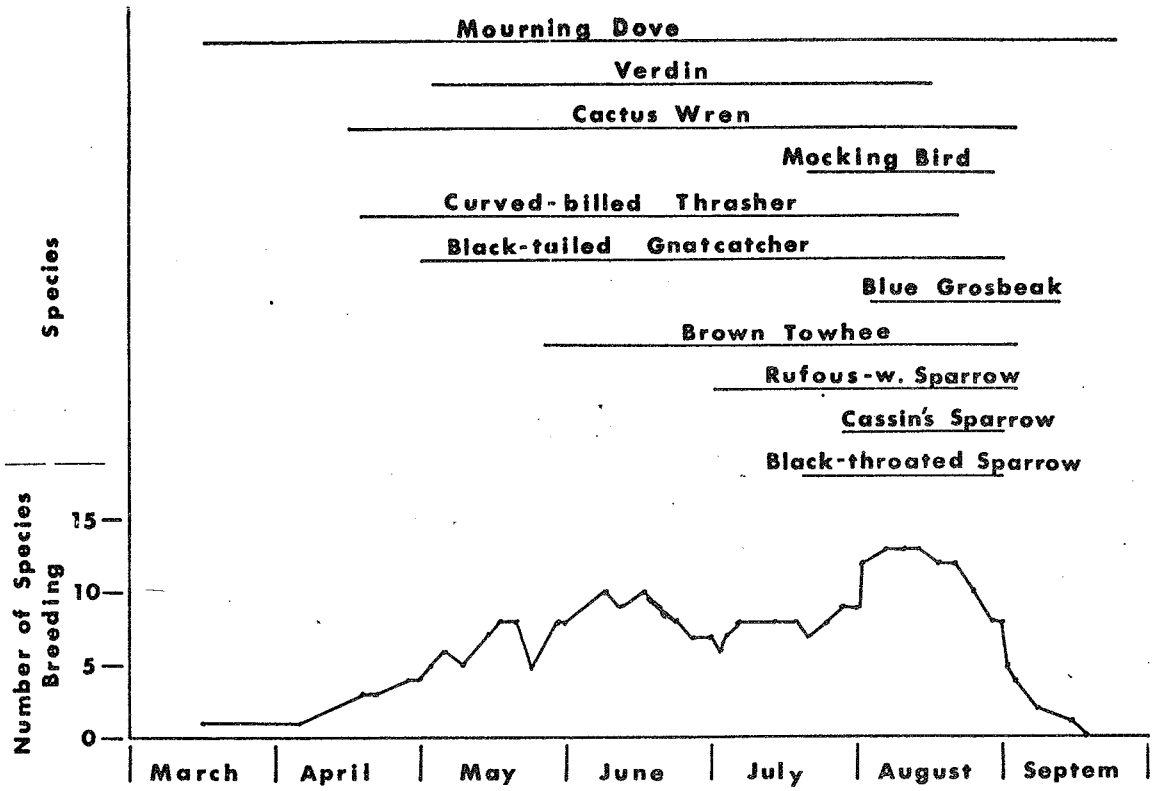


Figure 3: Extent of breeding season for several species (above) and number of species breeding on the 50 acre study (below).

Breeding Success: Breeding success was obtained for 234 nests and their contents of 20 species (Table 3). The probability for any egg to fledge a young was 0.36; if an egg hatched, there was a 0.60 probability of fledging. Success was greater after the rains, declining from an April high to a June low. July and August success approximated that in April. Eleven of 18 young in nests during the late June heat were lost (10 were Cactus Wrens). June was the only period when the number of nestlings lost exceeded those fledged (Table 4). Species which bred entirely (or nearly so) after the rains (Mockingbird, Blue Grosbeak, Brown Towhee, Cassin's Sparrow, Rufous-winged Sparrow, and Black-throated Sparrow) tended to be more successful than those species which did not.

Nest success data are presented in Figure 4. Thirty-nine percent of the nests constructed fledged at least one young. Greatest losses were in the incubation and nestling stages.

Table 3. Breeding success of birds on the untreated Santa Rita Experimental Range plot (in percent).

Species	Eggs Hatched	Eggs Fledged	Hatched Fledged	Nests Successful	No. Eggs	No. Nests
White-winged Dove	75.0	0.0	0.0	0.0	4	3
Mourning Dove	40.4	40.4	100.0	37.0	47	27
Roadrunner	58.3	58.3	100.0	66.7	12	3
Gilded Flicker	--	--	--	100.0	--	1
Ladder-back Woodpecker	--	--	--	100.0	--	1
Ash-throat Flycatcher	--	--	--	66.7	--	3
Verdin	58.2	36.7	63.0	62.0	79	25
Cactus Wren	69.5	44.7	63.4	56.3	118	32
Mockingbird	51.4	21.6	42.1	21.4	37	14
Curve-billed Thrasher	65.1	23.3	35.7	29.4	43	17
Black-tailed Gnatcatcher	0.0	0.0	0.0	37.5	13	8
Lucy's Warbler	0.0	0.0	0.0	0.0	6	3
Hooded Oriole	100.0	100.0	100.0	100.0	3	1
Brown-headed Cowbird	42.3	30.8	72.7	--	26	--
Blue Grosbeak	88.9	55.6	62.5	40.0	9	5
House Finch	81.8	45.5	55.6	75.0	11	4
Brown Towhee	77.6	44.9	57.9	38.1	49	21
Rufous-winged Sparrow	53.4	41.4	77.5	44.0	133	50
Cassin's Sparrow	82.5	62.5	75.8	63.6	40	11
Black-throated Sparrow	78.6	78.6	100.0	80.0	14	5
TOTAL (50 acres)	60.0	36.1	60.1	38.6	380	145
Pre-rain	59.4	30.4	51.2	40.4	138	52
Post-rain	60.3	39.3	65.1	37.6	242	93
March	0.0	0.0	0.0	0.0	4	2
April	68.8	43.8	63.6	47.1	48	17
May	51.3	25.6	50.0	46.7	39	15
June	61.7	23.4	37.9	33.3	47	18
July	60.5	41.4	68.4	42.1	162	57
August	60.8	35.4	58.3	31.4	79	35
September	0.0	0.0	0.0	0.0	1	1

Table 4. Extent of reproductive success and failure as a function of time of year for the 50 acre study area.

	March	April	May	June	July	August	Sept.	Total
No. eggs lost	4	4	22	23	23	54	14	144
No. young lost	0	0	17	20	5	40	8	90
No. young fledged	0	2	19	11	21	75	9	137
No. nests lost	2	1	12	10	15	34	7	81
No. nests fledged	0	1	7	8	9	25	5	55
Percent units* fail	100.0	67.7	67.2	79.6	57.1	55.6	71.0	63.1
Percent nests* fail	100.0	50.0	63.2	55.6	62.5	57.6	58.3	59.6

*units = no. eggs losts, young lost, and young fledged.

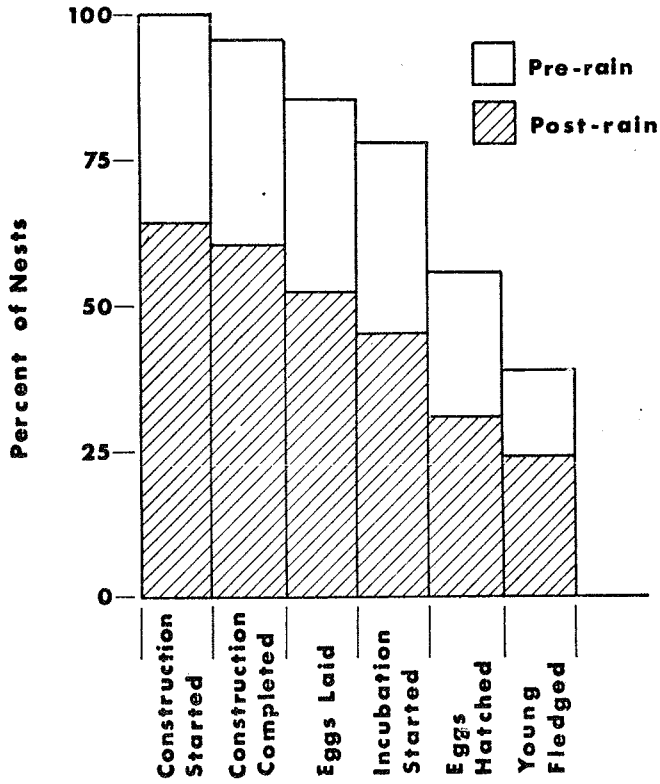


Figure 4: Fate of nests built on the 50 acre study area on the Santa Rita Experimental Range.

Productivity: Based on the fifty-acre study area, the breeding population produced 274 fledged young per 100 acres (Table 5). This amounted to a biomass production (based on adult weight) of 12.6 kg per 100 acres. Four species (Roadrunner, Mourning Dove, Cactus Wren and Rufous-winged Sparrow) produced a total of more than 8.8 kg (70 percent) per 100 acres.

A pair of roadrunners was successful in fledging seven young on the study plot, but they did most of their foraging outside the untreated area. Consequently they rarely appeared on censuses.

Nest Placement and Height: Nearly 64 percent of the nests constructed on the study area were in three species of plants: jumping cholla (Opuntia fulgida), Palo Verde (Cercidium floridum) and honey mesquite (Prosopis juliflora). All Curve-billed Thrasher and House Finch nests and most Cactus Wren nests were placed in the cholla (Table 6). Mesquite was preferred by Mourning Dove and Mockingbrid. Black-tailed Gnatcher, Brown Towhee and Verdin preferred Palo Verde. Can cholla (O. spinosior) was utilized heavily by Rufous-winged Sparrows. The four Mourning Dove nests on the ground were build in March and early April. All subsequent nests of this species were built off the ground. Nest placement and height varied amoung the species (Tables 6, and 7). However, Curve-billed Thrasher and Cactus Wren nests were placed in almost identical situations.

Table 5. Reproduction by birds on the Santa Rita Experimental Range, based on data for 50 acre untreated study plot.

Species	Number per 100 acres	Biomass (g) per 100 acres
Mourning Dove	22	2889
Roadrunner	14	3354
Verdin	10	74
Cactus Wren	40	1532
Mockingbird	6	298
Curve-billed Thrasher	10	820
Brown-headed Cowbird	10	389
Blue Grosbeack	10	332
House Finch	10	190
Brown Towhee	18	810
Rufous-winged Sparrow	70	1071
Cassin's Sparrow	34	615
Black-throated Sparrow	20	262
TOTAL	274	12636

Table 6. Nest sites of birds on the untreated Santa Rita Experimental Range Plot (in percent).

	Prosopis	Acacia	Corcidium	Celtis	Opuntia fulgida	Opuntia spinosior	Saguaro	Grass	Ground	Other	Nests
White-winged Dove	33.3	---	---	---	66.7	---	---	---	---	---	3
Mourning Dove	59.3	---	---	---	14.8	11.1	---	---	14.9	---	27
Roadrunner	33.3	---	---	---	66.7	---	---	---	---	---	3
Gilded Flicker	---	---	---	---	---	---	100.0	---	---	---	1
Gila Woodpecker	---	---	---	---	---	---	100.0	---	---	---	1
Ladder-b. Woodpecker	100.0	---	---	---	---	---	---	---	---	---	1
Western Kingbird	50.0	---	50.0	---	---	---	---	---	---	---	2
Ash-th. Flycatcher	66.7	---	---	---	---	---	33.3	---	---	---	3
White-necked Raven	---	---	100.0	---	---	---	---	---	---	---	1
Verdin	14.6	2.4	68.3	9.8	---	4.9	---	---	---	---	41
Cactus Wren	---	---	3.6	---	82.1	14.3	---	---	---	---	28
Mockingbird	50.0	---	7.1	7.1	21.4	14.3	---	---	---	---	14
Curve-b. Thrasher	---	---	---	---	100.0	---	---	---	---	---	16
Black-t. Gnatchatcher	11.1	---	77.8	11.1	---	---	---	---	---	---	9
Lucy's Warbler	100.0	---	---	---	---	---	---	---	---	---	3
Hooded Oriole	100.0	---	---	---	---	---	---	---	---	---	1
Blue Grosbeak	40.0	40.0	20.0	---	---	---	---	---	---	---	5
House Finch	---	---	---	---	100.0	---	---	---	---	---	4
Brown Towhee	18.2	22.7	45.5	4.5	9.1	---	---	---	---	---	22
Rufous-winged Sparrow	---	7.7	30.8	21.2	1.9	36.5	---	---	---	1.9	52
Cassin's Sparrow	---	8.3	---	---	---	---	---	83.3	---	8.3	12
Black-th. Sparrow	---	20.0	---	---	20.0	---	---	40.0	---	20.0	5
Study Area	16.4	6.2	20.5	4.8	26.7	13.7	2.1	6.2	2.1	1.4	146

Table 7. Nest height of nests on the untreated Santa Rita Experimenal Range plot (in inches).

	$\bar{x}$ Height of Nest	$\bar{x}$ Height of Nest Tree	Number of Nests
White-winged Dove	80.7	144.7	3
Mourning Dove	51.8	119.1	27
Roadrunner	53.0	114.7	3
Gilded Flicker	125.0	228.0	1
Gila Woodpecker	142.0	228.0	1
Ladderbacked Woodpecker	59.0	163.0	1
Western Kingbird	130.0	190.0	2
Ash-throated Flycatcher	96.7	198.7	3
White-necked Raven	195.0	233.0	1
Verdin	78.2	186.4	41
Cactus Wren	68.1	81.2	33
Mockingbird	69.1	135.6	14
Curve-b. Thrasher	63.0	82.4	17
Black-tail Gnatchatcher	99.7	190.7	9
Lucy's Warbler	48.8	166.8	4
Hooded Oriole	184.0	256.0	1
Blue Grosbeak	89.2	139.4	5
House Finch	52.0	65.8	4
Brown Towhee	72.9	151.6	22
Rufous-w. Sparrow	45.0	103.3	52
Cassin's Sparrow	10.0	28.4	11

Clutch Size: Cassin's Sparrow had the largest cluth size and largest number of fledged young per nest built and per successful nest among species for which ten or more nests were examined (Table 8). The clutch sizes presented are those which are known to be complete and were not disturbed by cowbird parisitism.

Table 8. Clutch size of birds on the untreated Santa Rita Experimental Range plot (no. of nests in parentheses).

	$\bar{x}$ Clutch Size	$\bar{x}$ No. of Young Fledging (successful nests)	$\bar{x}$ No. Fledged Per Nest Puilt
White-winged Dove	2.00(2)	----	0.00(3)
Mourning Dove	2.00(20)	1.90(10)	0.70(27)
Roadrunner	4.00(3)	3.50(2)	2.33(3)
Verdin	3.16(25)	2.62(13)	1.36(25)
Cactus Wren	3.66(29)	2.89(18)	1.63(32)
Mockingbird	3.50(10)	2.67(3)	0.57(14)
Curve-b. Thrasher	2.67(15)	2.00(5)	0.59(17)
Black-t. Gnatcatcher	4.00(1)	----	0.00(8)
Lucy's Warbler	3.00(2)	----	0.00(3)
Hooded Oriole	3.00(1)	3.00(1)	3.00(1)
Blue Grosbeak	3.00(3)	2.50(2)	1.00(5)
House Finch	3.67(3)	1.67(3)	1.25(4)
Brown Towhee	3.06(16)	2.78(9)	1.25(20)
Rufous-winged Sparrow	3.53(34)	2.50(22)	1.10(50)
Cassin's Sparrow	4.00(10)	3.57(7)	2.27(11)
Black-thr. Sparrow	3.50(4)	2.75(4)	2.20(5)

Comparison of Census Techniques: Table 9 gives sample comparisons for the two census techniques used. The results are comparable. Some of the differences may be due to small sample sizes for deriving coefficients of detectibility for the Emlen technique. These will be defined as more data becomes available. The value of the Emlen method is that it is applicable at all seasons, gives an estimate for nonterritorial species, and takes into account fledglings entering the population. Also, for some species, such as Mourning Dove, only one of a pair is on the study area at a particular instant (the brooding bird). Thus, based on the number of active nests in May (three), the population would be estimated at six. Emlen's method gives an estimate of 3.3 (per 40 acres) which is closer to the true average.

Foraging Behavior: Foraging behavior data were obtained for several species; most data are for Verdin and Black-tailed Gnatcatcher. Nearly 2000 observations have been obtained to date. Data reduction is now in progress.

Table 9. Comparisons of densities by two census techniques on the same study area. 40 acre density (individuals).

Species	Month	William's	Emlen's
Verdin	May	4	5
Cactus Wren	May	7	8
Curve-b. Thrasher	April	6	6
Black-t. Gnatcatcher	June	2	2
Lucy's Warbler	May	3	4
Blue Grosbeak	August	3	3
House Finch	May	2	2
Brown Towhee	August	7	6
Rufous-wing Sparrow	June	13	12
Rufous-wing Sparrow	July	21	18
Cassin's Sparrow	August	16	16

Note: Comparison made in period preceeding fleding of young.

Table 10. Density and biomass (per 100 acres) on the chained plot, Santa Rita Experimental Range in November.

Species	Density (Individuals)	Biomass (grams)
Cactus Wren	14	536.2
Curve-billed Thrasher	7	574.0
Logger-head Shrike	4	190.8
House Finch	18	342.0
Brown Towhee	17	765.0
Lark Bunting	15	588.0
Vesper Sparrow	15	366.0
Cassin's Sparrow	36	651.6
Black-thr. Sparrow	6	78.6
Brewer's Sparrow	353	3,671.2
Chestnut-collared Longspur	45	868.5
TOTAL	530	8,631.9

Table 11. Estimated population densities (in individuals per 100 acres) for the Avra Valley IBP site. Data for May are based on the Emlen method; data for June-July are for a fifty acre plot in the East portion of the area and are based on the Williams map plot method. Biomass figures shown in parentheses for June-July.

Species	May East	May West	June-July	
White-winged Dove	1.0	5.0	2	(292)
Mourning Dove	6.0	6.0	8	(1050)
Screech Owl	-	-	4	(514)
Gila Woodpecker	2.0	3.4	4	(280)
Gilded Flicker	-	-	6	(623)
Ladder-b. Woodpecker	-	-	2	(61)
Ash-th. Flycatcher	0.8	8.2	20	(560)
Verdin	3.4	10.1	18	(133)
Cactus Wren	5.6	8.6	26	(996)
Curve-billed Thrasher	1.7	3.0	16	(1312)
Black-t. Gnatcatcher	3.2	3.8	12	(66)
Lucy's Warbler	1.7	3.4	--	--
Wilson's Warbler	2.0	5.0	--	--
Brown-headed Cowbird	1.0	3.0	12	(467)
House Finch	1.5	1.5	12	(218)
Brown Towhee	1.5	1.5	4	(180)
Brewer's Sparrow	3.0	1.0	--	--
Rufous-winged Sparrow	-	-	4	(61)
Black-th. Sparrow	-	-	36	(472)
Omers	16.9	13.4	--	--
TOTAL	51.3	76.9	186	(7286)

Small Mammals

The details of objectives and procedures involved in establishing and operating live trap grids are outlined in Non-Program Informative Abstracts A3UCE04, A3UCE05, and A3UCE06 developed as part of the small mammal validation study.

Species Observed: The following is a checklist of mammals actually captured or sighted on, or adjacent to the validation sites. The data for the Old Silver Bell site is included since it is quite similar to the new Silver Bell site.

Order Chioptera

Various bats have been detected as they passed over the sites on feeding flights. However, none appear to be numerous enough to warrant further consideration.

	Santa Rita	Silver Bell
Order Lagomorpha		
Family Leporidae		
*Lepus alleni (Antelope Jackrabbit)	S-3	S-0
*Lepus californicus (Black-tailed Jackrabbit)	S-2	S-3
*Sylvilagus audubonii (Desert Cottontail)	S-1	S-0
Order Rodentia		
Family Sciuridae		
Spermophilus tereticaudus (Roundtail Ground Squirrel)	T-2	T-2
Ammospermophilus harrisi (Harris ground squirrel)	T-2	T-2

	Santa Rita	Silver Bell
Family Heteromyidae		
Perognathus flavus (Silky Pocket mouse)	T-2	T-0
*Perognathus amplus (Arizona Pocket mouse)	T-4	T-4
Perognathus penicillatus (Desert Pocket mouse)	T-4	T-3
Perognathus intermedius (Rock Pocket mouse)	T-0	T-2
Perognathus baileyi (Bailey's Pocket mouse)	T-3	T-4
Dipodomys spectabilis (Banner-tailed Kangeroo rat)	T-2	T-0
Dipodomys merriami (Merriam's Kangeroo rat)	T-4	T-4
Family Cricetidae		
Onychomystorridus (Southern grasshopper mouse)	T-4	T-1
Reithrodontomys megalotis (Western Harvest mouse)	T-1	T-0
Reithrodontomys fulvescens (Fulvous Harvest mouse)	T-1	T-0
Reithrodontomys montanus (Plains Harvest moust)	T-1	T-0
Peromyscus maniculatus (Deer mouse)	T-2	T-1
Peromyscus eremicus (Cactus mouse)	T-2	T-0
Sigmodon hispidus (Cotton rat)	T-1	T-0
Neotoma albigula (White-throated wood rat)	T-2	T-2
Family Muridae		
Mus musculus (House mouse)	T-2	T-0
Family Erethizontidae		
Erethizon dorsatum (Porcupine)	S-2	S-0
Order Carnivora		
Family Canidae		
Canis latrans (Coyote)	S-3	S-3
Vulpes macrotis (Kit fox)		
Family Mustelidae		
Taxidae taxus (Badger)	S-1	S-3
Mephitis (Skunk)	S-0	S-2
Family Felidae		
Lynx rufus (Bobcat)	S-1	S-0
Order Artiodactyla		
Family Tayassuidae		
Peccari tajacu (Javelina)	S-3	S-2
Family Cervidae		
Odocoileus hemionus (Mule deer)	S-3	S-0

S-Sighted
0-No evidence of presence
1-Only a single time. Total evidence (sightings, tracks, etc.) such that judged relatively unimportant.
2-A few sightings.
3-Several sightings. Total evidence indicates may be significant component of biomass.

T-Livetrapped on grids or captured in kill-traps near grids.
0-No evidence of presence.
1-Only a single individual taken.
2-Only a few (2-10).
3-Several to many taken.
4. One of 3 or 4 most common species in area.

*Observations and trapping results obtained so far clearly indicate major seasonal shifts in the importance of some species in the area. For example, at the Santa Rita site rabbits, mostly Lepus alleni and some Lepus californicus, were frequently observed from July 24 until the first week in September on the site, as well as along approximately 15 miles of dirt road surrounding the area. During this period it was not uncommon to see 25-30 jackrabbits in the time it took to drive the 15 miles. On the nights of September 25-26 the same road was driven, but no rabbits were seen, and none were seen on either of the plots being trapped. Two weeks later on October 9, one Lepus alleni was seen on the raod; the following night none were seen. The week end of October 24, five Lepus alleni were seen, three in the chained area and two while driving the roads. Since this time the frequency of sightings has remained about the same, much lower than in late July to mid-September.

The number of silky pocket mice (Perognathus amplus) increased markedly at both sites in late April and early May, and they remained active throughout the summer. By late October most were again inactive. Note, for example, the dominance of Perognathus amplus on Silver Bell #1 grid from August 29 through September 11, its reduction on October 9-10, and its absence October 30-31 and November 20-21 (Appendix I).

Identification of Species Present. Cockrum has concerned himself in part with the determination of the specific identification of the silky pocket mice in the areas. Two morphologically distinct groups probably with slightly different micro-environmental requirements and seasons on activity -- apparently live in the area. In the past these appear to have both been identified as Perognathus amplus.

Comparative material of silky pocket mice from Arizona and adjacent parts of Sonora and California have been borrowed from other institutions. Most have been measured. Other material already in the collection of the University of Arizona has also been measured. Currently awaited is the large number of silky pocket mice taken in the Silver Bell area this past summer by Drs. Bateman and Vaughan (of Northern Arizona University). This material, taken during a process study, will be cleaned and measured after which the data will be analyzed statistically -- by sex and age group, as well as geographically -- in an effort to clarify the taxonomic status of the silky pocket mice herein reported as Perognathus flavus.

Inventories: Before inventories could be made it was necessary to obtain a sufficient number of traps. By buying materials, borrowing equipment, and utilizing work-study and volunteer help and a graduate assistant (Tommy Vaughan, 2 months at 1/2 time), we managed to get 1,000 live traps for $1,250 (plus Vaughan's time). the lowest bid obtained from a commercial organization to make the traps was $4.50 per trap in lots of 500 or more. Trap grids were measured off on the following sites.

a) Santa Rita: Untreated
b) Santa Rita: Treated
c) Silver Bell: West
d) Silver Bell: East

Four assistants were required for six hours to place traps; 196 grid. The grids were oriented as follows:

a) Initially, for a period of 14 successive nights, baiting at sundown and running at 11 p.m. and at day break
b) Thereafter, each operated for two successive nights every second (Santa Rita) or third (Silver Bell) week

Grids Santa Rita #1 and Santa Rita #4 were operated by Tommy Vaughan and one unpaid assistant. Grid #1 is on the untreated area and Grid #4 is on the treated (chained) area. Vaughan's preliminary comments follow:

"The number of active Perognathus amplus started to decline on both plots at Santa Rita by late October. At the same time the number of Onychomys torridus being captured tended to increase. The first Perognathus flavus was taken on October 10. Since that time 5 more have been marked, all from the chained area."

"As of November 20-22, juvenile Onychomys and Dipodomys merriami were taken. Also lactating female Dipodomys were taken, but none of the females of the other species appeared to be nursing young."

Grids Silver Bell #1 and Silver Bell #2 were operated by Dennis Massion and one assistant. Grid #1 west edge and #2 is the east edge of the former validation sites. The two differ markedly in vegetation cover and soil type. Massion's preliminary comments follow.

"Site #1"

Changes in site:	28 August	Traps set out day before. Ants and snakes very concentrated.
	3-6 September	Rains heavily.
	11 September	End of two week trap period
	9 October	Drill operating
	30 October	No drilling
	20 November	Scrapped center of plot and a light generator was run for 5 nights

a) P. amplus was dominant species until September 11 (end of 14 day trap period). Six amplus were caught 3 weeks latter and none since. The majority of amplus were marked by the 5th day and by the 7th day 52/57 were marked.

b) P. baileyi and D. merriami assumed dominant species after P. amplus disappeared: (1) New P. baileyi have been trapped throughout the trap period: (2) most D. merriami (11/16) were marked by the 7th day and the half in the 1st 2 days.

c) An Onychomys torridus was first trapped on October 10. Three weeks later this and 2 juveniles were captured consistently.

d) N. albigula -- an occasional capture: (3) S. tereticaudus and A. harrisi both diurnal and caught late in the morning or during periods of intense heat.

Site #2

Changes in site:
10 October — Large concentration of snakes and ants
22 September — Hog-nosed skunk turning over many traps
27 September — End of second week trap-period

a) P. amplus was the dominant species until the end of the two week trap period (September 13-27). The majority of individuals were marked by the end of the 9th day (24/27). There was no increase in the number of other species captured after P. amplus disappeared.

b) D. merriami is the most widely distributed species captured and has continued to be caught at the same frequency until the 31st of October.

c) P. baileyi and P. penicillatus were not caught until the 5th day of trapping and became very scarce after the end of the 10 day trap period.

d) It is belived that the nightly raids (from September 22 until October 31) of what appears to be a hog-nosed skunk has influenced the behavior of a number of animals towards traps. The skunk has either released or eaten a number of animals.

The numbers of individuals of various species taken on the various plots are summarized in Table 11. Note that the totals for the end of the initial 14 day trapping period and the total taken for all trapping periods are shown. Further note that the diurnal ground squirrels are not included. Trapping experience in July revealed that these died in the traps before they could be removed. Resultantly, all traps were closed at daybreak.

Table 11 is a summary of data presented in Tables 12 through 15.

Table 11. Summary of number of individuals taken on the plots at SRER and Silver Bell.

	SANTA RITA				SILVER BELL			
	Untreated		Chained		West		East	
	14 days	26 days	14 days	24 days	14 days	20 days	14 days	20 days
Perognathus flavus	0	0	0	0	0	0	0	0
Perognathus amplus	20	29	14	16	56	57	27	27
Perognathus baileyi	2	6	8	10	20	23	12	12
Perognathus penicillatus	35	41	38	45	5	6	7	8
Dipodomys spectabillis	1	1	0	0	0	0	0	0
Dipodomys merriami	52	83	20	38	12	16	20	23
Onychomys torridus	11	24	3	12	0	3	0	0
Reithrodontomys montanus	0	0	0	1	0	0	0	0
Peromyscus maniculatus	0	1	0	1	0	0	0	0
Peromyscus eremicus	0	0	0	2	0	0	0	0
Sigmodon hispidus	0	1	0	0	0	0	0	0
Neotoma albigula	3	5	2	3	2	3	2	2
TOTALS	124	191	85	134	96	109	68	72

Table 12. Number of individuals trapped on the untreated site (Subsite 1) at Santa Rita. (Data indicates number of animals trapped/number trapped that had been trapped previously.)

	July														
	24 P	25 A	25 P	26 A	26 P	27 A	27 P	28 A	28 P	29 A	29 P	30 A	30 P	31 A	31 P
D. merriami	9/9	11/0	7/1	11/0	12/1	12/2	17/2	20/2	19/2	18/1	17/2	16/2	16/3	14/0	18/1
P. penicillatus	2/2	3/2	2/2	1/0	2/2	5/2	6/2	5/1	12/7	5/1	7/2	10/2	9/3	8/2	8/2
P. amplus	5/5	5/4	1/0	1/0	3/0	4/0	7/1	6/2	6/1	5/0	4/0	8/1	5/0	7/1	7/0
P. baileyi	---	---	---	---	---	---	---	1/1	---	---	---	---	---	---	---
P. flavus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
O. torridus	---	1/1	1/1	--	2/2	1/1	1/0	---	1/0	---	---	---	---	---	1/0
N. albigula	---	---	1/1	---	---	---	---	---	---	---	---	---	---	---	---
P. maniculatus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
D. spectabilis	---	---	---	---	---	---	---	1/1	---	---	---	---	---	---	---
S. hispidus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

	AUGUST												
	1 A	1 P	2 A	2 P	3 A	3 P	4 A	4 P	5 A	5 P	6 A	6 P	7 A
D. merriami	20/0	17/0	12/0	18/0	19/5	17/0	15/0	14/1	13/0	13/0	11/0	11/0	15/6
P. penicillatus	5/0	9/1	6/0	8/0	5/0	8/1	3/1	5/0	6/0	7/0	5/0	8/0	5/0
P. amplus	3/0	4/0	3/1	8/0	7/0	4/0	5/1	4/0	4/0	6/1	4/0	5/0	8/2
P. baileyi	---	---	---	---	---	---	---	---	---	---	---	---	1/1
P. flavus	---	---	---	---	---	---	---	---	---	---	---	---	---
O. torridus	---	1/0	2/1	---	2/1	1/1	2/0	1/0	1/1	2/1	2/0	1/0	2/1
N. albigula	---	---	---	---	1/1	1/1	---	---	1/0	---	---	---	---
P. maniculatus	---	---	---	---	---	---	---	---	---	---	---	---	---
D. spectabilis	1/0	---	1/0	---	---	---	---	---	---	1/0	---	---	---
S. hispidus	---	---	---	---	---	---	---	---	---	---	---	---	---

	SEPTEMBER								OCTOBER (1st half)			
	5 P	6 A	6 P	7 A	25 P	26 A	26 P	27 A	9 P	10 A	10 P	11 A
D. merriami	4/1	7/3	5/0	3/0	9/0	11/5	4/1	5/0	2/0	9/1	1/0	14/1
P. penicillatus	6/1	7/0	4/0	3/0	1/0	3/1	2/0	4/2	1/0	1/0	1/1	2/0
P. amplus	4/0	3/1	2/0	1/0	7/3	3/1	3/0	3/2	---	3/0	1/0	2/1
P. baileyi	1/1	1/1	---	---	---	---	1/1	---	1/1	---	1/0	---
P. flavus	---	---	---	---	---	---	---	---	---	---	---	---
O. torridus	1/0	1/0	4/0	3/0	3/1	3/0	2/0	3/0	4/2	5/1	3/2	4/0
N. albigula	---	1/1	---	1/1	2/0	---	---	---	1/0	---	1/0	1/0
P. maniculatus	---	---	---	---	---	---	---	---	---	---	---	---
D. spectabilis	---	---	1/0	---	---	---	---	---	---	---	---	---
S. hispidus	---	1/1	---	---	---	---	---	---	---	---	---	---

	OCTOBER (2nd half)								NOVEMBER			
	23 P	24 A	24 P	25 A	6 P	7 A	7 P	8 A	20 P	21 A	21 P	22 A
D. merriami	12/0	5/0	10/3	6/1	14/4	9/1	1/0	9/0	17/4	1/0	20/6	4/0
P. penicillatus	2/0	2/0	2/1	3/0	1/0	1/0	---	1/0	2/0	2/0	2/0	1/0
P. amplus	2/0	1/0	1/1	2/0	1/0	---	---	---	---	---	---	---
P. baileyi	---	---	---	---	---	---	---	---	---	---	---	---
P. flavus	---	---	---	---	---	---	---	---	---	---	---	---
O. torridus	6/1	3/1	5/2	2/0	7/1	7/2	3/0	8/0	10/0	3/0	8/0	5/0
N. albigula	1/0	---	---	---	---	---	---	---	---	---	1/0	---
P. maniculatus	---	---	---	---	---	---	1/1	---	---	---	---	---
S. spectabilis	---	---	---	---	---	---	---	---	---	---	---	---
S. hispidus	---	---	---	---	---	---	---	---	---	---	---	---

Table 13. Number of individuals trapped on the chained site (Subsite 4) at Santa Rita. (Data indicates number of animals trapped/number trapped that had been previously trapped).

	AUGUST														
	24 P	25 A	25 P	26 A	26 P	27 A	27 P	28 A	28 P	29 A	29 P	30 A	30 P	31 A	31 P
D. merriami	2/2	2/2	3/3	---	2/1	3/2	---	5/4	4/2	2/0	---	4/1	1/1	2/0	1/1
P. penicillatus	2/2	1/1	---	3/2	3/1	3/2	3/3	2/0	3/2	2/1	3/2	4/4	1/1	2/0	4/0
P. amplus	1/1	---	1/1	3/3	1/1	1/0	2/1	---	3/2	1/0	4/3	---	1/0	1/0	3/1
P. baileyi	1/1	1/1	1/0	1/1	1/0	---	---	---	1/0	1/0	1/1	2/0	1/1	---	1/0
P. flavus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
O. torridus	---	---	---	---	---	---	---	1/1	---	---	---	1/1	---	---	---
N. albigula	---	1/1	1/0	1/0	1/1	---	---	---	1/1	---	---	1/1	---	---	---
P. maniculatus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
P. eremicus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
P. montanus	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

	SEPTEMBER												
	1 A	1 P	2 A	2 P	3 A	3 P	4 A	4 P	5 A	5 P	6 A	6 P	7 A
D. merriami	4/1	2/0	3/0	1/0	2/1	---	---	5/0	2/0	1/0	5/0	3/0	2/0
P. penicillatus	6/4	4/2	5/2	4/1	5/4	4/0	1/0	5/0	4/1	10/1	11/1	10/1	2/0
P. amplus	1/0	1/0	2/0	3/0	2/0	1/0	---	---	---	1/0	2/1	---	---
P. baileyi	1/0	1/1	1/1	1/0	3/1	1/0	---	1/0	1/0	1/0	1/0	1/0	1/0
P. flavus	---	---	---	---	---	---	---	---	---	---	---	---	---
O. torridus	---	---	---	---	---	---	1/1	1/0	1/0	1/0	1/0	---	1/0
N. albigula	---	---	---	1/0	---	1/0	---	---	---	---	---	---	---
P. maniculatus	---	---	---	---	---	---	---	---	---	---	---	---	---
P. eremicus	---	---	---	---	---	---	---	---	---	---	---	---	---
P. montanus	---	---	---	---	---	---	---	---	---	---	---	---	---

	SEPTEMBER				OCTOBER							
	25 P	26 A	26 P	17 A	9 P	10 A	10 P	11 A	23 P	24 A	24 P	25 A
D. merriami	8/2	11/1	2/0	4/0	7/0	14/2	5/2	4/0	7/0	7/1	2/0	3/0
P. penicillatus	9/2	8/2	5/0	2/1	6/0	3/0	4/0	4/0	9/0	2/0	5/1	6/0
P. amplus	2/0	3/1	1/0	2/0	---	2/0	---	2/0	---	1/1	---	---
P. baileyi	---	1/1	---	1/0	---	---	---	1/0	---	---	---	---
P. flavus	---	---	---	---	---	1/1	---	---	---	---	---	---
O. torridus	---	1/1	---	---	---	1/0	---	2/1	1/0	2/1	2/0	---
N. albigula	---	1/1	---	---	---	---	---	---	---	1/0	1/0	---
P. maniculatus	---	---	---	---	---	---	---	---	---	---	---	---
P. eremicus	---	---	---	---	---	---	---	1/1	---	---	---	1/1
P. montanus	---	---	---	---	---	---	---	---	---	---	---	---

	NOVEMBER							
	6 P	7 A	7 P	8 A	20 P	21 A	21 P	22 A
D. merriami	5/2	8/2	2/0	4/1	7/3	4/2	4/1	2/1
P. penicillatus	4/0	3/0	3/1	5/0	7/0	3/0	6/0	---
P. amplus	---	---	---	---	2/0	---	---	---
P. baileyi	---	---	---	3/0	---	1/0	1/0	1/0
P. flavus	1/1	1/1	---	---	4/3	---	1/0	---
O. torridus	3/2	5/3	4/0	3/0	5/0	2/0	3/0	2/1
N. albigula	1/0	1/0	---	---	---	2/0	1/0	---
P. maniculatus	---	---	---	---	---	---	1/1	---
P. eremicus	---	1/0	1/0	---	---	1/0	---	---
P. montanus	---	---	---	---	---	---	---	1/1

Table 14. Number of individuals trapped on grid 1 at Silver Bell. (Data indicates number of animals trapped/number trapped that had previously be trapped).

	AUGUST							SEPTEMBER					
	28 P	29 A	29 P	30 A	30 P	31 A	31 P	1 A	1 P	2 A	2 P	3 A	3 P
P. amplus	10/10	7/3	12/7	11/5	17/7	4/1	17/8	6/4	13/2	7/0	10/1	9/1	---
P. baileyi	---	---	2/2	2/2	4/2	1/0	4/2	2/1	4/1	2/0	2/0	2/2	---
P. penicillatus	1/1	---	---	---	---	---	---	---	---	---	3/1	2/1	---
D. merriami	5/5	---	2/2	1/1	---	---	---	1/0	1/0	3/1	2/1	---	
N. albigula	---	---	---	---	---	1/1	---	---	---	---	---	---	---

	SEPTEMBER (Cont.)														
	4 A	4 P	5 A	5 P	6 A	6 P	7 A	7 P	8 A	8 P	9 A	9 P	10 A	10 A	11 A
P. amplus	7/3	6/0	3/0	4/1	5/0	12/1	7/0	12/1	11/0	11/0	9/0	9/0	8/0	10/0	20/1
P. baileyi	---	---	1/1	---	1/1	5/2	---	---	2/2	3/1	1/0	3/1	2/0	6/1	2/0
P. penicillatus	---	2/1	2/0	2/1	---	3/0	2/0	3/0	3/0	2/0	1/0	2/0	3/1	3/0	3/0
D. merriami	4/1	2/0	2/0	1/0	2/0	1/0	2/1	1/0	1/0	1/0	---	1/0	---	---	---
N. albigula	---	---	1/1	---	---	---	---	---	---	---	---	---	---	---	---

	WEEKENDS					
	9-10 OCTOBER 9	10-11 OCTOBER 10	30-31 OCTOBER 30	31-1 OCTOBER 31	20-21 NOVEMBER 20	21-22 NOVEMBER 21
P. amplus	2/0	4/1	---	---	---	---
P. baileyi	11/0	11/0	7/1	8/0	4/0	4/1
P. panicillatus	4/0	2/0	2/0	3/1	---	---
D. merriami	6/2	7/0	7/0	5/0	5/2	3/0
N. albigula	---	1/1	---	---	---	---

Table 15. Number of individuals trapped on grid 2 at Silver Bell. (Data indicates number of animals trapped/number trapped that had previously been trapped).

	SEPTEMBER														
	13 P	14 A	14 P	15 A	15 P	16 A	16 P	16 A	17 P	17 A	18 P	19 A	19 P		
P. amplus	1/1	---	2/2	1/1	3/0	3/1	5/2	1/0	6/2	4/1	6/1	4/1	6/1		
P. baileyi	---	---	---	---	---	---	---	---	---	---	1/1	---	4/3		
P. penicillatus	---	---	---	---	---	---	---	---	3/3	---	1/1	2/1	2/0		
D. merriami	---	---	2/2	---	1/0	---	---	1/1	1/1	1/1	3/1	2/0	5/2		
N. albigula	---	---	---	---	---	---	---	---	---	---	1/1	---	---		
	SEPTEMBER (Cont.)														
	20 A	20 P	31 A	31 P	22 A	22 P	23 A	23 P	24 A	24 P	25 A	25 P	26 A	26 P	27 A
P. amplus	4/2	11/5	5/0	14/3	7/1	10/0	6/0	9/0	4/0	9/0	4/0	10/0	3/0	---	13/3
P. baileyi	2/1	2/1	/10	4/2	2/0	4/0	2/0	---	1/0	1/1	---	1/1	1/0	---	3/2
P. penicillatus	2/0	1/0	1/0	---	1/0	1/1	---	2/1	1/0	1/0	---	1/0	1/0	---	1/0
D. merriami	2/0	3/0	3/0	6/1	---	3/2	3/0	4/1	1/0	7/1	3/1	6/3	2/0	---	5/4
N. albigula	---	---	---	---	---	---	---	---	---	1/0	---	1/1	---	---	---
	WEEKENDS														
	9-10 OCTOBER 9	10-11 OCTOBER 10		30-31 OCTOBER 30	31-1 OCTOBER 31		20-21 NOVEMBER 20	21-22 NOVEMBER 21							
P. amplus	3/0	6/0		2/0	---		---	---							
P. baileyi	---	---		---	---		---	---							
P. penicillatus	---	---		---	---		---	1/1							
D. merriami	5/1	4/1		4/0	---		1/0	3/1							
N. albigula	---	---		---	---		---	1/0							

Herpetofauna

The design of the investigation for validation was originally, and is at present directed to standing crop, with measurement of two population parameters:(1)species density and (2) species biomass in terms of wet weight. The data are corrected to standing crop at March 1. Density calibration is anticipated in 1971, and results on standing crop for 1970 are regarded tentative until that time (see Table 17).

The species that were encountered (captured or observed) on or near the validation sites are listed in Table 16. Included are 3 species on the rock slope habitats on Silver Bell Bajada that are adjacent to but not directly on the site. While a large number of species in the herpetofauna are shared by both sites, there is an important set of ten Sonoran Desert species that reach their easternmost distributional limits in the Avra Valley system (including Silver Bell Bajada area) and do not occur on the more highly elevated and colder Santa Rita Experimental Range southeast of Tucson. These desert species are:

Gopherus agassizi
Dipsosaurus dorsalis
Sauromalus obesus
Phrynosoma platyrhinos
Urosaurus graciosus
Phyllorynchus browni
Phyllorynchus decurtatus
Crotalus cerastes
Chilomeniscus cinctus
Chionactis occipitalis

Table 16. The herpetofauna on and adjacent to the Tucson validation sites, the Santa Rita Experimental Range (SRR) and Silver Bell Bajada (SBB), determined to date. Vouchers deposited at University of Arizona.

	SRR	SBB
Testudinata		
Testudinidae		
1. *Gopherus agassizi* (desert tortoise)		x
Sauria		
Helodermatidae		
2. *Heloderma suspectum* (Gila monster)	x	x
Gekkonidae		
3. *Coleonyx variegatus* (banded gecko)	x	x
Iguanidae		
4. *Dipsosaurus dorsalis* (desert iguana)		x
5. *Sauromalus obesus* (chuckwalla)		x
6. *Crotaphytus collaris* (collared lizard)		x
7. *Crotaphytus* (*Gambelia*) *wislizeni* (leopard lizard)	x	x
8. *Callisaurus draconoides* (zebra-tailed lizard)	x	x
9. *Sceloporus clarki* (Clark's spiny lizard)	x	x
10. *Sceloporus magister* (desert spiny lizard)	x	x
11. *Uta stansburiana* (side-blotched lizard)	x	x
12. *Urosaurus graciosus* (long-tailed brush lizard)		x
13. *Urosaurus ornatus* (tree lizard)	x	x
14. *Phrynosoma platyrhinos* (desert horned lizard)		x
15. *Phrynosoma solare* (regal horned lizard)	x	x
Teiidae		
16. *Cnemidophorus tigris* (western whiptail	x	x
17. *Cnemidophorus sonorae* (Sonoran whiptail	x	
18. *Cnemidophorus uniparens* (desert-grassland whiptail)	x	
Serpentes		
Leptotyphlopidae		
19. *Leptotyphlops humilis* (western worm snake)	x	x
Colubridae		
20. *Arizona elegans* (glossy snake)	x	x
21. *Chilomeniscus cinctus* (banded burrowing snake)	x	x
22. *Chionactis occipitalis* (shovel-nose snake)		x
23. *Hypsiglena torquata* (spotted night snake)	x	x
24. *Lampropeltis getulus* (king snake)		x
25. *Masticophis flagellus* (red whipsnake)	x	x
26. *Phyllorhynchus browni* (saddled leafnose snake)		x
27. *Phyllorhynchus decurtatus* (spotted leafnose snake)		x

Table 16. (Cont.) The herpetofauna on and adjacent to the Tucson validation sites, the Santa Rita Experimental Range (SRR) (and Silver Bell Bajada (SBB), determined to date. Vouchers deposited at University of Arizona.

	SRR	SBB
29. Rhinocheilus lecontei (longnose snake)	x	x
30. Salvadora hexalepis (patchnose snake)		x
31. Sonora semiannulata (ground snake)	x	x
32. Trimorphodon lyrophanes (lyre snake)		x
Elapidae		
33. Micruroides euryxanthus (Arizona coral snake)	x	x
Crotalidae		
34. Crotalus atrox (western diamondback)	x	x
35. Crotalus cerastes (sidewinder)		x
36. Crotalus scutulatus (Mohave rattlesnake)	x	x
37. Crotalus tigris (tiger rattlesnake)		x
Salientia		
Pelobatidae		
38. Scaphiopus couchi (Couch spadefoot toad)	x	x
39. Scaphiopus hammondi (Hammond spadefoot toad)	x	x
Bufonidae		
40 Bufo alvarius (Colorado River toad)	x	x
41. Bufo cognatus (Great Plains toad)	x	x

Methods and Results: Work was conducted at both of the Tucson validation sites, viz., (1) Santa Rita range (SRR), and (2) Silver Bell Bajada (SBB)/ This discussion refers to the operations with the herpetofauna on both sites and on similar areas near both sites. Considerably more data on herpetofauna were obtained from the greater amount of field work conducted on and adjacent to the Silver Bell site. The reason for the larger data from Silver Bell is that the major effort during the period reported was on development of adequate field census methods (appropriate to the species encountered, the data required, and the size of the budget), which were largely worked out on that desert site (SBB) where generic and species diversity are greater than on the Santa Rita range (Table 16).

The work was in part an experimental field study and analysis directed to methods of population census. It should be noted that there is not wide-spread agreement on what constitutes an adequate (much less, a "best") sampling for density and other parameters of the terrestrial herpetofauna. These animals are not bait-trap susceptible in the sense of mammal trapping, nor are they pair-nested in the sense of bird-pair counting. The herpetofauna in this case involves 41 species (Table 16) of vertebrates in these desert-scrub communities, constituting a major community component of primary and secondary consumers for which we seek accurate rapid-sensing. Many persons contributed to this phase of the project work and, in particular, we are indebted to Frederick B. Turner and Philip B. Medica for discussions on measurement and analysis and to John K. Cross and Michael D. Robinson for assistance in the field. Grids at both sites were operated by R. Blake, T. Van Devender, C. Lowe, and J. Cross.

Permanent grid plots (80 m X 135 m) of 2.43 hectares (6.0 acres) were established at each site (Figure 5). Density counts were made by observers walking grid lines. On other areas off-site, live and/or fresh field weights were established for other series of these species which were noosed or shot. Mettler balances were used. Length-weight regressions (wet weight on snout-vent length, and wet weight on total length) are being obtained for each of the reptilian and amphibian species occurring on site. From these data, species standing crop (biomass, kg/ha) can be obtained as the simple product of mean density and mean wet weight, but more accurately and with greater demographic value when calculated as the sum of the partitioned biomass per age-size class (Table 17). The data for 1970 are for untreated plots. Data for treated plots are incomplete at both sites.

Circadian and seasonal rhythms sharply affect the activity behavior of all species in the herpetofauna, whether they are diurnal, crepuscular, nocturnal, or facultative species. As there is great variation in the time of the maximum diel activity in the species represented, and as this seriously affects the data obtained on grid runs for estimating density, techniques were developed to ensure that the grid counts were made for each species at the time of its maximum activity period (circadian and seasonal) on the surface. From the age structure of the samples, species density and biomass were calculated back to March 1, 1970 for each species on

As the determinations for period of maximum surface activity at the population level are essential for meaningful census data for the herpetofauna, and as the critical time of day involved for each species shifts significantly with season, the determination and its verification for each of the species required more project time (>50%) than anticipated during the first year. Accordingly, from this necessity, byproduct data are obtained for species on daily and seasonal time and extent of surface activity and the behavioral themoregulation involved.

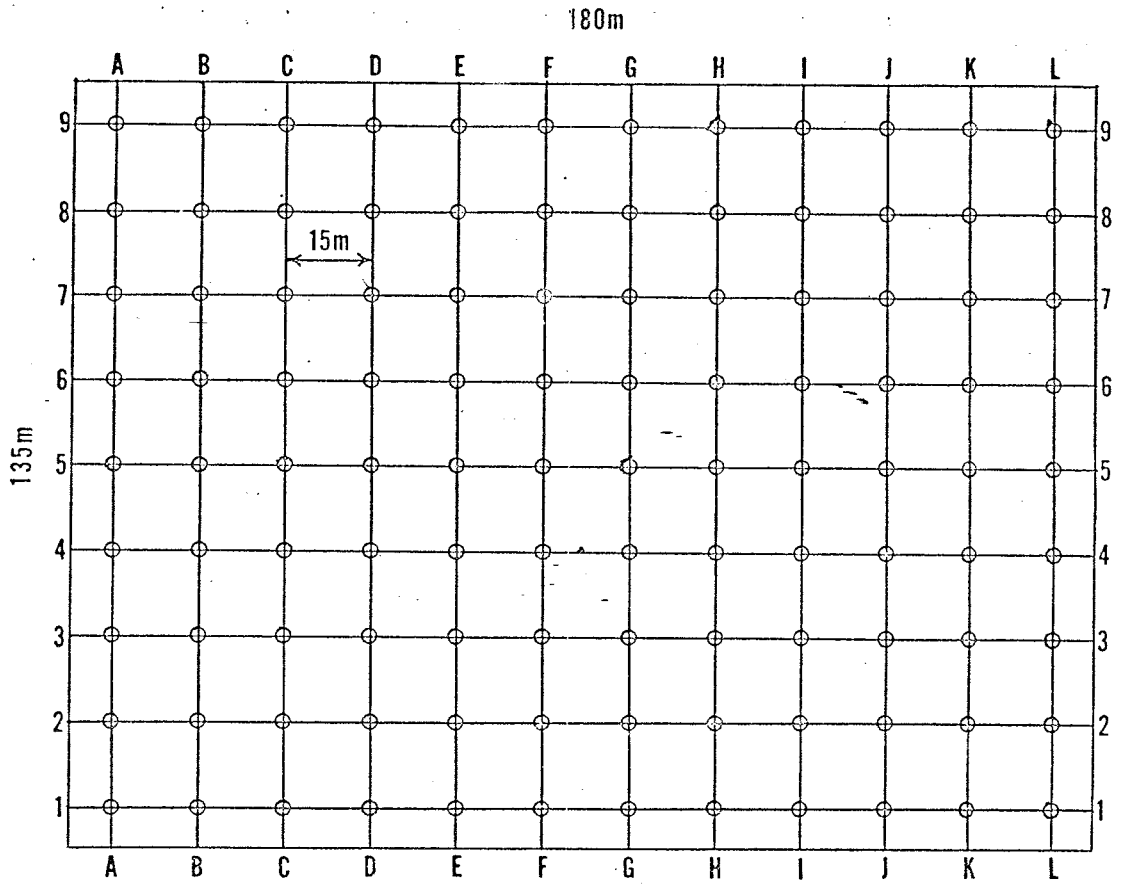


Figure 5. Rectangular grid (135m x 180m) for estimating population density, et al. Area is 24,300m^2 (2.43 hectares; 6.0 acres), with 15m distance between rows. Grid stakes (circles) shown, A1 through L9.

The date March 1, our first census point for population structure (Table 17), is used for several important reasons: (1) At latitude 32°N, populations of poikilotherms undergo a fall-winter attrition caused periodically and in important measure by winter freeze-kill and other contributing factors. Accordingly, an autumn or winter population reference point is not realistic as a reliable estimator for population density for the subsequent spring poikilotherm surface activity, which is followed immediately or later by adult reproductive behavior; (2) In the populations concerning us directly in the desert biome, some individuals of some species are surface-active in March when predation both above surface and underground is underway; (3) March 1 has been used previously in other studies in the North American Desert (for example in the Sonoran Desert in Arizona and on the Mohave Desert with Turner's UCLA group at Mercury, Nevada) and thus this date provides a point for reliable comparative analysis.

Table 17. Data reduction for species standing crop (kg/ha) with estimate for population density and biomass at March 1. Cnemidophorus tigris on Santa Rita Experimental Range, Arizona; grid area 2.43 ha (6.0 acres).

	Cnemidophorus tigris Mean Number on Grid					
	Adult	Subadult	Juvenile	Total	Species Density (n/ha)	Species Standing Crop (kg/ha)
March 1, 1970	8.7[1] $\bar{x}$ of May-June	3.8[1] $\bar{x}$ of April-May	0 $\bar{x}$ of April-May	12.7	5.2	.062
April	3.0	4.0	0	7.0	2.9	.028
May	8.3	3.7	0	12.0	4.9	.060
June	9.0	3.3	0	12.3	5.1	.063
July	8.5	3.5	1.0	13.0	5.4	.062
August	10.0	2.0	6.0	18.0	7.4	.072
September	0	8.0	41.0	49.0	20.2	.079
Mean field weight (gm)	14.4	7.0	3.3			

[1] An individual active on the grid after March 1, during the Spring and early Summer, was in the population on March 1 (underground) if old enough when observed active above ground to have been in the population before March 1.

Each individual of these species observed after March 1, during the spring and early summer, was in the population on March 1 if old enough when observed above ground to have been in the population on or before March 1. At Tucson and vicinity, one small species only (Uta stansburiana)is surface active and sexually competent during all winter months, and one other small species (Urosaurus ornatus)is active during some winter months but is not a winter breeder (see Asplund and Lowe, 1964, Jour. Morph., 115(1): 27-33).

Data for our second census point, which varies with the reproductive and post-reproductive patterns of the species, is obtained during the period August 1 - September 30 according to species. The situation is more complex in this post-summer census than for the post-winter (March 1) census, and we are presently working on an experimental design for obtaining data only on the most abundant or otherwise prominent species of community importance for post-summer census. It should be noted for these organisms, that, with the exception of one or more exceptional species, it is not possible to sample for equally meaningful data or to sample at all for total population density after September of the calendar year.

Invertebrates

An original objective of the invertebrate studies on the Tucson validation sites was to make a regular inventory of the species and populations present. While this objective was not entirely accomplished, one incomplete inventory was made in November as well as a number of separate studies that should enable us to proceed with a better knowledge of the species present than was possible before the study.

The Nov. 1 Invertebrate Inventory On The Santa Rita Sites: The first general inventory of the Santa Rita sites was called for the two-week period with Nov. 1, 1970 as the mid-date. While we had had some experience in sampling before this date, this was the first time we were called on to inventory all of the invertebrates in any one period. We feel that we were partially successful.

The modus operandi that was developed was the result of an attempt to reconcile the use of various sampling techniques for different kinds of animals; one is justified in using any method for any one taxon that relates the population to area, and may use various methods for sampling as long as the same taxon is not counted in more than one method. For purposes of this sampling, the taxon may be chosen at the level of phylum, order, species, or even stage of a species. If, for any reason, one wishes to count the same taxon in two habitats, he must make the counts simultaneously. The choice of sampling method should be the one that yields the highest count per unit area, and the time of sampling should be chosen for the same reason.

It can be argued that thereare no methods of proven reliability for many of the invertebrates. In the present context, it is felt that it is preferable to use a method that results in a short estimate instead of omitting a group entirely.

Because some of the methods used for the Nov. 1 inventory would be affected by weather, an advance plan was worked out as to which methods to use on warm, clear days (if there were any) and which could be used on cloudy or cold days. As it turned out the weather was good during the entire inventory period so there was no need to change the pattern. The sampling was divided so that one unit could be completed on all 4 sites in one day. The various groups and methods used to sample them were as follows:

It must be assumed that ants are primarily subterranean creatures and that the workers above ground are there only temporarily. Since our aim was to measure populations and not just surface activity, we used our best estimate of the number of colonies per unit area of various ant taxa, obtained the previous month by counting colonies on strips 5 m wide, multiplying the number of colonies by a conservative estimate of the number of workers in a "typical" colony of that taxon, and dry weight of workers taken on the surface during the inventory period. The weakest part of this estimate is the rather arbitrary assignment of a number for the size of the colony. Despite numerous efforts to obtain estimates of colony size by mark-recapture and other methods, there seems to be no way to obtain colony size without digging the colony out. Our own efforts at estimating during the summer were no more fruitful than many others. A rough figure of no more than 10% of a colony's workers being involved in the gathering force during any one period seems to hold for harvester ants, PORU. We started on the basis of 10,000 workers per colony for this species, a figure less than half that obtained in a PORU dig in the spring and in line with numbers obtained for another species of Pogonomyrmex by Lavigne. Other species were gauged in relation to PORU. Ants were not included in counts or weights when they were obtained in other kinds of samples.

Grasshoppers are highly mobile and likely to be disturbed by the presence of the observer, making it necessary to design survey methods around moving to new locations and getting the sample from a small area before the individuals can move away. The method used was that of the USDA, with modification. Two people worked as a team, one walking ahead for 50 steps in a straight line, then being directed to a position on a predetermined line by the second person, who was 50 steps back. The front person then examined a patch of ground ca. 1 m ahead of him and ca. 0.1 m^2 in area, counting any grasshoppers or other visible invertebrates present or leaving the plot at the time. The second person helped to prevent an almost inevitable tendency for an observer to move toward what he is looking for if he sees it. As it turned out, only grasshoppers were found by this method. On the small plots individuals (or a substitute of the same species if the individual escaped) were captured and used in dry-weight figures.

This procedure seemed very slow and tedious, and may not be precise enough for inventory use. A number of premarked and randomly distributed larger plots would probably be preferable. We counted one grasshopper species in the plant-centered samples. This one is a specific feeder on the plant sampled. It was not encountered in the general grasshopper count. There was a substantial difference in grasshopper numbers on different plots. This was evident in the field, but we cannot say whether the differences indicated in the dry weight figures would hold up in a longer sampling period, or with a more rigorous method. It happened that our sampling period was not preceded by a killing frost. We therefore had a fairly large population to sample.

The D-Vac suction sampler was used to obtain samples from 4 shrubby dominants, ACGR, APTE, CEPA, and PRJU, as had been done during the summer season. During the inventory period and for several samples before, the samples taken were related to area of cover represented. The openning of the sampler is a circle of 20 cm in diameter. If it was pushed 20 cm into a bush and took in all of the bush in that vertical column, it was counted as sampling 400 cm^2. If it sampled only 1/3 of the vertical column, it was counted as 1/3 of 400 cm^2. Bushes chosen were those closest to the randomly selected sampling points. The figures obtained are expressed as number and dry weight per m^2 of cover. When plant cover figures are in, the measures can be extrapolated to total area. The APTE plants sampled were all small enough that the sampler came down on them so that no plant height correction was necessary.

Visual samples were also made on CEPA and PRJU. On CEPA, psyllid galls were collected and nymphs removed in the lab. The nymph count and weight was added to the D-Vac estimate, because the D-Vac did not pick up nymphs. On PRJU a count of branches girdled was made and related to plant area. This count cannot be given a dry weight because no girdling beetles were found. However, several larger insects not taken with the D-Vac were encountered. These were added to the D-Vac figures.

Visual sampling was the only method used on CEFL and 3 cacti, OPEN, OPFU, and OPSP.

Among the most conspicuous insects were butterflies, bees, etc. on a few plants in bloom. These were not included because the randomly selected plants we sampled did not have them. They did turn up to some extent in an aerial sample taken with a truck-mounted net moved at 25-30 mph along the main road. Runs of ca. 5 mi were made every 30 min. from mid-afternoon into early evening on one sampling day. The catch consisted almost entirely of insects that we did not pick up with the plant-centered sampling. The highest diurnal and the highest nocturnal catch together yielded a dry-weight figure of ca. 0.2 g/Ha. This is probably a low figure and may even be low for the number in flight at any one time. The method is very useful for determining the time periods of insect flight, but it is probably not extremely useful in inventory. If every insect flew a certain distance at some time during every day, it would be a useful method.

Counts of termites active at the surface were made along with other measurements. These are being related to area. We feel that we have made a solid start on a method to handle this group, but the problems of estimation are probably more severe than they are in most insect groups.

Except for ants and termites, invertebrates that were in the soil or inside of trunks and branches were not measured. Sampling problems for these could be formidable, especially if one suspected clustered distribution. They have yet to be worked out. The modus operandi adopted for the November 1 inventory might be expanded one step farther and used to obtain figures for any species that spends part of its life cycle in hidden places. The only time during the year that such animals can be counted easily is when they are active and above ground. Usually this is when they are in the adult stage. The adult population the following season must be represented by some hidden stage. If we had a figure for the adult population and a weight per individual at the stage represented during the desired sampling period, we could produce a minimum count and weight for the sampling period. Secondary studies of mortality factors and factors that determine distribution of these hidden stages would make it possible to refine the figures obtained and relate them more closely to individual plots. The initial figures would have to be on a "not-less-than" basis, without indication of where the hidden stages were.

The most obvious omissions were larvae and pupae of scarab beetles, woodboring larvae, and probably even adults not yet emerged, grasshopper eggs, and spiders and other arthropods with holes and lairs. A check on nocturnal activity just before the inventory period indicated little if any surface activity of this group at the time. Since we had no counts to fall back on, we had to ignore this group.

On the basis of simple extrapolation with all 4 sites grouped for ants, aerial, and plant-centered samples, the dry weight biomass of the invertebrates on the 4 sites was as follows:

	Site 1	Site 2	Site 3	Site 4	
Ants	1150.	1150.	1150.	1150.	
Aerial	0.2	0.2	0.2	0.2	
Grasshoppers	343.	776.	890.	3696.	
	1493.2	1926.2	2040.2	4846.2	g/Ha

PLUS

the following, based on the area covered by the major shrubby species and cacti:

ACGR	0.1944 g/m^2 of cover	Acacia greggii
APTE	0.2245	Aplopappus tenuisectus
CEPA	0.4282	Celtis pallida
CEFL	0.1317	Cercidium floridum
PRJU	0.0845	Prosopis juliflora
OPEN	0.0086	Opuntia engelmannii
OPFU	0.1212	Opuntia fulgida
OPSP	0.1307	Opuntia spinosior

To these figures should be added those for termites from W. L. Nutting's work. The grasshopper biomass figure for site 4 may be high; this and the adjacent site (3) did have much more grass than the others, and visibly larger and more diverse grasshopper populations at the time.

Inventory of species associated with dominant plants: Regular samples of invertebrates on 4 dominant shrubby plant species were taken with a D-Vac suction sampler, beginning in May and continuing until the November 1 inventory period. The species so sampled were APTE, ACGR, CEPA, and PRJU. As the season progressed, the clumps of APTE became more and more intermixed with grasses and other plants. Other dominant shrubs and cacti were sampled visually, for the most part. From the start, an attempt was made to keep the volume of plants sampled uniform from week to week so that there could be a general measure of the waxing and waning of populations.

The samples taken before mid-September have now been mounted for study, labeled, and sorted to group. They are being scrutinized for species that maintained high populations for more than brief periods. As these species are noted, the course of their populations during the summer and such things as plant specificity will be extracted from the samples. These same species will then be traced through the subsequent samples, which are either in alcohol storage or dry.

Discussion: At the present time, it appears that several species of psyllids and leafhoppers in the other Homoptera, and mirids in the Hemiptera, will be the main ones to qualify for special study. An attempt will be made to see whether any of the Diptera and Hymenoptera taken can be associated with them as parasitoids or predators.

In a few instances, species were found to be on the plants only at night. In general, however, nocturnal D-Vac samples were very similar to those taken during the day. Some rearing of immature stages was accomplished, the resulting information helps to tie individual species to host plants.

Other sampling: Periodic counts and samples of grasshoppers were taken by the USDA method of counting the individuals in or leaving ft^2 plots selected every so many steps. The populations became moderate by late summer, and continued into the November 1 inventory period, with some reduction.

Ant colonies were counted, first in 3 square acre plots on the untreated site in the Santa Rita sites, then on 5 m wide strips along or across all of the sites. Some of these counts were used in the November 1 inventory. A variety of attempts to work out an easy method to estimate the number of workers in a colony of large ants was made in August and September. The results were not encouraging. A mark-recapture method used on harvester ants, PORU, gave a very low figure for the ants foraging on the surface, certainly no more than 10% of the total. Obtaining a large number of ants by disturbing them and catching them as they came out of the entrance, then counting the marked ants in the foraging force on succeeding days, gave a higher estimate. We had apparently induced ants to come out that were not involved in the foraging force. These later stayed in the nest or about the entrance.

In anticipation of problems with ant sampling, a start was made on excavating PORU nests in the spring. One nest was carefully assessed by the mark-recapture of foragers method and an estimate of the size of its worker force arrived at. Then it was dug out. The undertaking turned out to be much larger than had been anticipated. By the time further digging yielded no more ants, the hole was more than 11 ft. deep and a back hoe had been used twice in the digging process. This colony contained more than 22,000 workers. The need to start other kinds of sampling precluded going on to digging other nests in the spring. It is obvious that obtaining hard figures on colony size of the larger ants is going to be a time-consuming process. Lavigne, writing of another species of harvester ant, indicated that he could find no correlation between mound size, nest opening, or other surface indications and the size of the colony. Our pre-dig estimate was only ca. 10% of the number found in PORU. There is a process study on harvester ants for 1971. The need for hard figures on colony size, storage, and activity becomes apparent when one compares our estimates of the ant biomass with that of other invertebrates during the November 1 inventory period.

Most of the sampling was done on the Santa Rita sites. A very preliminary sample of invertebrates associated with shrub dominants on the Silverbell sites indicated that there would be some differences, partly because the plants were different, but that midsummer populations were quite low. These samples, and a count of ant colonies on strips across the 2 ends, were made on the original Silverbell site.

The new Silverbell site was examined for general invertebrate activity in November. In about 3 mi of walking it became obvious that the ant situation is quite different from what it was on the old site, and on the Santa Rita sites. No nests of PORU were found, and only one of ACVE, the leaf-cutting ant. The most abundant large ant is Novomessor, one that is fairly abundant at the Santa Rita sites. This ant is usually not regarded as primarily a seed-gatherer. One seed-gatherer, Vermessor pergandei seems to be present only in small numbers. It is likely that the site does not support a very large population of seed-gathers. Very few grasshoppers were seen, but it is likely that the species associated with Larrea are well represented in the area.

Vegetation

Because of the requirement for a vegetative inventory which creates a minimum amount of disturbance to the study site, the use of aerial photography to extrapolate ground truth data obtained outside the study sites to the interior of the sites is a critical portion of the inventory procedures. Due to the physical relocation of the Silverbell study site in November, 1970, no further reference was made to that site except to note that comparable data had been collected on the original site.

The study site was initially typed into the two vegetation units by use of small scale aerial photography. Within each treatment area and within each vegetation unit large scale aerial photographic transects were obtained. Each transect provided 4 - 5 plots of approximately one-third acre in size. From these plots data were obtained on cover, density and frequency of major perennial species. To assess the accuracy of the photo interpretation ground truth was also collected on the same factors. Table 18 gives a summary of photographic coverage in 1970.

TABLE 18. Aerial Photographic Coverage Tucson Validation Sites

The following aerial photographic coverage was obtained on the Santa Rita and Silverbell sites of the Desert Biome.

a. Black and white aerial photography at an approximate scale of 1:9000; taken in late spring 1970.

b. Color infrared aerial photography at an approximate scale of 1:6000; taken in late spring 1970.

c. Color infrared aerial photography of 10 transects; 30 meters by 150 meters at an approximate scale of 1:6000 taken in late spring 1970.

d. Ecktachrome 35 mm slides low oblique aerial, taken in late spring 1970.

e. Black and white low oblique aerial, taken in late spring 1970.

f. Black and white aerial photography at an approximate scale of 1:144,0-0 taken in late spring 1970.

g. Black and white aerial photography at an approximate scale of 1:10,000 taken in mid-summer 1970.

h. Color infrared aerial photography at an approximate scale of 1:50,000 taken in mid-summer 1970.

i. Color infrared aerial photography at an approximate scale of 1:6000 taken in mid-summer 1970.

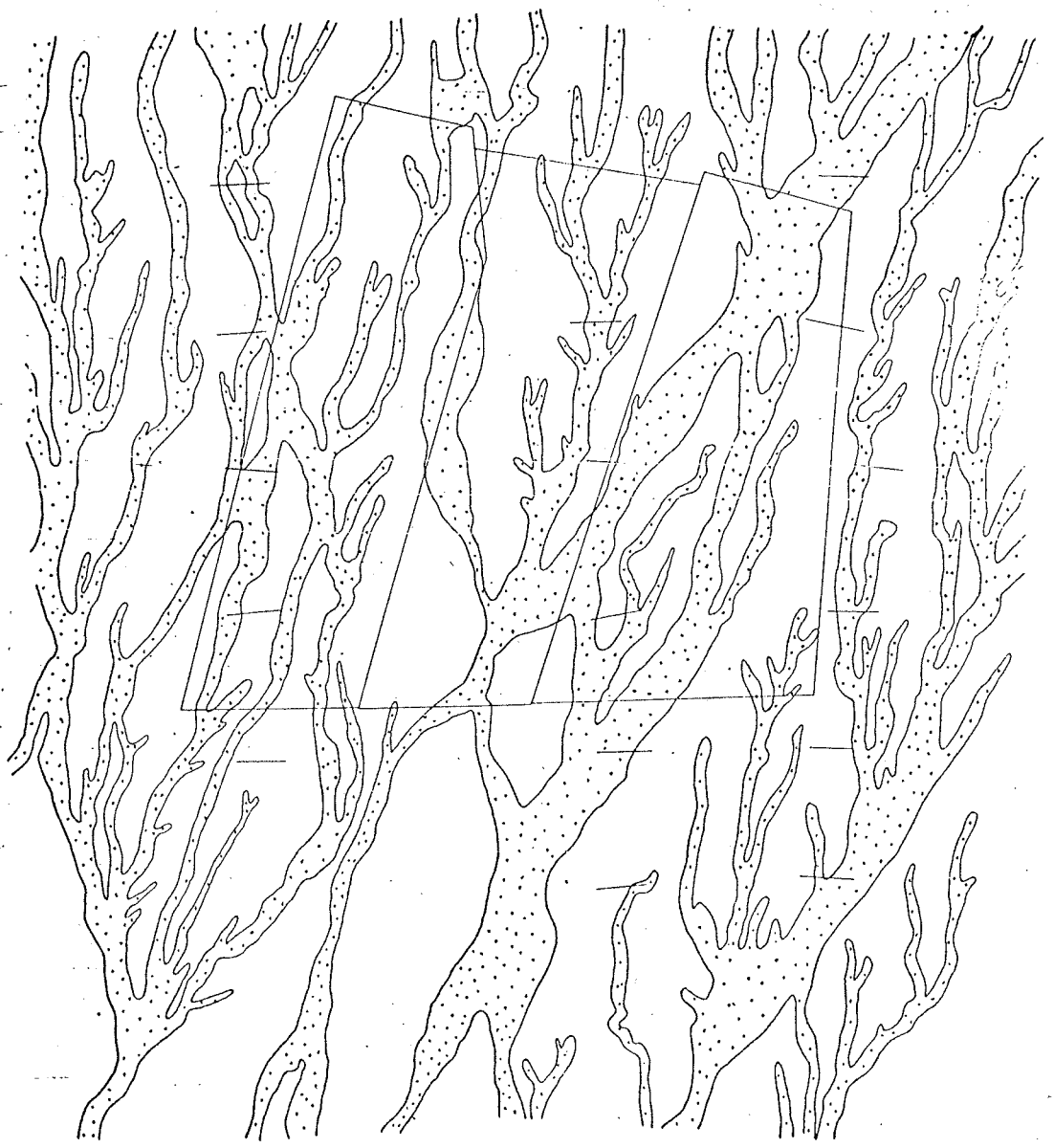
j. Color infrared aerial photography of 10 transects; 30 meters by 150 meters at an approximate scale of 1:6000, taken in mid-summer 1970.

k. Black and white aerial photography at an approximate scale of 1:10,000 taken in early fall 1970.

Biomass samples were taken on individuals outside the study area but which were also covered by imagery.

Additional data was collected by ground quadrats on each transect to collect data on species which could not be distinguished from the photography. These consisted of 150, 1 meter square quadrats per transect.

There are primarily two vegetation types on the Santa Rita site (Figure 6). These are closely tied to the microrelief and drainage patterns at the site. The types have been labeled Upland and Braided channel. The upland type is characterized by an open scattered stand of desert trees dominated by Mesquite (Prosopis juliflora var. velutina)with Foothills paloverde (Cercidium microphyllum) a species of secondary importance. Below the tree layer is a characteristic cacti stratum dominated by Opuntia fulgida and Opuntia versicolor. Burroweed (Aplopappus tenvisectus) dominates the low shrum layer nearly to the complete exclusion of other species. The herbaceous layer is primarily composed of annual grasses and forbs. Bush muhly (Muhlenbergia porteri), tanglehead (Heteropogon contortus), Arizona cottontop (Trichachne californica) three awns (Aristida spp.) and Lovegrasses (Eragrostis spp.) predominate in the perennial grass portion of this layer.



The braided channel site includes that area within the normal flood lines of the drainage pattern. Approximately 20 percent of this type is barren sandy channel. The type is characterized by a heavier stand of mequite and paloverde than in found on the upland site. The cacti strata is essentially non-existent being replaced by catclaw (Acacia greggi). The general aspect of this type is best characterized by increased over-all density and a change in composition. No species were found which were exclusively located in one type or the other.

Over-all, the Santa Rita site is approximately 60 percent upland type and 40 percent braided channel type. Biomass of principal shrubs and trees for the two types is presented in Table 19.

TABLE 19. Biomass of Principal Shrubs and Trees
Santa Rita Site in Kg/hn

	Chained		Untreated	
	Channel	Upland	Channel	Upland
Aplopappus spinulosus	0.56	0.53	0.58	0.61
Aplopappus tenuisectus	1.15	2.95	1.28	1.60
Baccharis brachyphylla	0.0	0.0	0.0	0.71
Prosopis juliflora	0.0	0.0	40694.58	29792.76
Zinnia pumila	0.0	0.14	0.09	1.08

Data: Ground truth data collected to date on photographic transects has included crown cover, frequency and density of the major perennial species in each strata except the herbaceous layer. Density is summarized in Table 20. The field portion of this data is currently on punched cards. The photographic data is in raw data form for the majority of the area with three transects yet to be evaluated.

TABLE 20. Density per hectare of major perennial species
Santa Rita Site.

Chained Area	Braided Channel Site	Upland Site
Prosopis juliflora	0.0	0.0
Cercidium microphyllum	0.0	0.0
Celtis pallida	9.1	22.2
Acacia greggii	4.4	0.0
Opuntia fulgida	0.0	0.0
Opuntia versicolor	0.0	0.0
Opuntia phaeacantha	5.7	22.2
Ferocactus wislizenii	0.0	0.0
Ephedra trifurca	0.0	22.2
Aplopappus tenuisectus	820.3	1109.5
Aplopappus spinulosus	299.8	279.8
Zinnia pumila	0.0	20.0
Untreated Area		
Prosopis juliflora	48.9	35.8
Cercidium microphyllum	15.5	6.4
Celtis pallida	24.9	12.6
Acacia greggii	30.6	8.4
Opuntia fulgida	32.1	118.8
Opuntia versicolor	26.7	21.5
Opuntia phaeacnatha	23.7	20.2
Ferocactus wislizenii	9.4	10.6
Ephedra trifurca	2.5	2.0
Aplopappus tenuisectus	914.4	1141.4
Aplopappus spinulosus	309.5	321.0
Zinnia pumila	1.2	14.8
Baccharis brachyphylla	0.0	50.3

Biomass determination efforts to date have been confined to one tree (Prosopis juliflora var. velutina) (Table 21) and one low shrub (Aplopappus tenuisectus). Samples are currently being dried. Portions of these samples will be retained for use by other investigators for possible future analysis.

TABLE 21. Biomass, Prosopis juliflora velutina, Santa Rita

Plant part	Kilograms/plant
Leaves	36.9
Branches less than 4" diam.	495.4
Branches greater than 4" diam.	399.1
Dead branches	161.3

Data for the control and grazing exclosures is most complete at this time. The effect of the spraying treatment on vegetation in that exclosure cannot be fully evaluated until active growth begins in the spring of 1971. However, preliminary evaluation in the late fall of 1970 indicated that approximately 95 percent of the mesquite trees were experiencing some effect from the treatment as evidenced by leaf discoloration and defoliation.

The chaining treatment effectively removed the tree and cacti layers as they previsouly existed and seriously altered the low shrub layer. Complete evaluation of the remaining vegetation will be possible in the late spring of 1971. Initial indications are that many of the Opuntia joints which were scattered extensively during the treatment are rooting. If these survive, the density of these species will be considerably higher in this exclosure compared to all others.

Currently the emphasis in the vegetation inventory work is on photo interpretation. The extensive coverage which is available is requiring a great deal of time for proper evaluation. It is expected that this effort will fully occupy the investigator for another 90 to 120 days.

D. Cable of the United States Forest Service provided production and intercept data for grasses and shrubs on the Santa Rita Site. The data are presented in Table 22.

TABLE 22. Production and Intercept for Santa Rita
(developed from data supplied by D. Cable, USFS)

Species	Production[1/]			Intercept[2/]		
	10 Yr. Avg. 1957-1966	1966	1970	10 Yr. Avg. 1957-1966	1966	1970
Aristida glabrata	3.6	6.7	6.9	.01	.01	.05
Aristida sp.	2.5	5.8	17.6	.01	.01	.01
Bouteloua eriopoda	2.6			.01		
B. rothrockii	1.2			T		
Cottea pappophoroides		.9			T	T
Enne pogon devauxii						.01
Muhlenbergia porteri	11.5	27.9	22.5	.01	.02	.05
Setaria mactostachya		.7	.2			
Sporobolus spp.			.2			
Tirchachne california	6.8	7.1	8.0	.01	.03	
Other perennial grasses	3.9					
Total perennial grasses	32.1	49.1	56.3	.01	.07	.12
Annual grasses	119.7	143.9	83.7			
Shrubs						
Acacia greggii					.33	.44
Aplopappus tenuisectus				3.71	14.16	1.79
Buccharis brach.					1.92	.12
Culliandra erisphylla				.13		
Cercidium mierophyllum					.57	.37
Celtis palida					2.01	1.37
Ephedra trifurea					.34	.25
Opuntia engelmannii				.63	.44	.92
O. fulgida				.14		
O. spinosior				.31		
Prosopis juliflora vel.				7.02	5.60	5.92
Zinnia pumila						.28
Others				3.30		
				15.23	25.37	11.46
	151.8	193.4	140.0	15.30	25.44	11.58

Soils

High intensity detailed soil surveys were made of the Santa Rita and Silver Bell(old) sites. A soil map of the sites is presently being prepared by the Cartographic Service, SCS, Washington. The following are descriptions of the soil series and mapping units.

Anthony Series. The Anthony series consists of well-drained soils. They formed in moderately coarse textured alluvium from granite, rhyolite, andesite, and limestone on alluvial fans. Slopes are 1 to 3 percent. Elevation is 3100 to 3300 feet. Vegetation is desert shrub, cacti, and grass, lovegrass, spike dropseed, and bush muhly. Precipitation is 10 to 12 inches. Mean annual air temperature is 60 to 70° F. and the frost free period is 170 to 300 days.

Typically the surface layer is yellowish brown sandy loam about 3 inches thick. The underlying material is brown stratified sandy loam and gravelly sandy loam to 44 inches and more. The soil is mildly alkaline and lime may occur at depths below 30 inches.

The soil is moderately rapidly permeable. Water supplying capacity is 4 to 6 inches. Effective rooting depth is 40 inches or more.

These soils are used for range.

A representative profile is located 350 feet westerly along fence and 75 feet south of the SE corner of the control plot #1 of the Santa Rita Validation site.

Anthony sandy loam
(Colors are for dry soils unless otherwise noted)

A1 0-1" -- Light yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 3/4) moist; weak platy structure, slightly hard; very friable; many fine roots; many fine interstitial pores; 10% fine and medium subrounded gravels; mildly alkaline (pH 7.5); abrupt wavy boundary.

C1 3-27" -- Brown (7.5YR 4/4) dry and moist sandy loam; massive; slightly hard, very friable; many fine roots; many fine interstitial pores; common cylindrical biological casts, 5 to 1 cm in diameter, 18 percent fine and medium subrounded gravels; mildly alkaline (pH 7.6); abrupt wavy boundary.

C2 27-44" -- Brown (7.5YR 5/4) gravelly sandy loam, brown (7.5YR 4/4) moist; massive; very friable; common fine roots; many fine interstitial pores; common fine cylindrical biological casts, 5 to 1 cm in diameter; 25 percent subrounded gravel; weakly effervescent; mildly alkaline (pH 7.8).

Anthony sandy loam, 1 to 3 percent slopes A1

This soil is on alluvial fans. Bodies are large, 40 to more than 100 acres in size and occur between drainageways. The soil has the profile described as representative for the series. Inclusions of Valencia sandy loam make up to 10 to 15 percent of this unit and occur as narrow bodies between mapped bodies of Anthony and Sonoita sandy loams or at random as much of the Anthony series is underlain by a buried subsoil layer at depths of 40to 60 inches.

Anthony gravelly sandy loam, 1 to 3 percent slopes A2

This soil is on fans and stabilized areas adjacent to large washes. It differs from the profile representative for the series in having more gravel, 15 to 35 percent, throughout profile. Inclusions of Gravelly alluvial land and Valencia gravelly sandy make up less than 15 percent of this unit.

A representative profile is located 350 feet easterly along fence and 30 feet south of the SW corner of plot #2 of the Santa Rita Validation site.

Anthony gravelly sandy loam, 1 to 3 percent slopes
(Color for dry soil unless otherwise noted)

A1 0-2" -- Dark yellowish brown (7.5YR 4/4) gravelly sandy loam, dark yellowish brown (7.5YR 3/4) moist; very weak thick platy structure; slightly hard, very friable; many fine roots; many fine interstitial pores; 15 percent fine subrounded gravels; neutral (pH 7.2); abrupt wavy boundary.

C1 2-24" -- Dark yellowish brown (7.5YR 3/4) dry and moist; gravelly sandy loam; massive; slightly hard, very friable; common fine roots; many fine interstitial pores; 15 percent fine subrounded gravels; mildly alkaline (pH 7.6); clear wavy boundary.

C2 24-38" -- Reddish brown (5YR 4/4) light gravelly sandy loam, reddish brown (5YR 4/3) moist; massive; slightly hard, friable; few medium and fine roots; many fine and medium interstitial pores; 45 percent fine and medium subrounded gravels; mildly alkaline (pH 7.8); abrupt wavy boundary.

C3 38-44" -- Reddish brown (5YR 4/4) dry and moist gravelly sandy loam; massive; slightly hard, friable; few medium and fine roots; many fine and medium interstitial pores; 20 percent fine subrounded gravels; mildly alkaline (pH 7.8)

Sonoita Series. The Sonoita soils are well-drained. They formed in moderately coarse textured alluvium from granite, rhyolite, andesite, and limestone on alluvial fans. Slopes are 1 to 8 percent. Elevation is 3100 to 3300 feet. Vegetation is desert shrum, cacti and grasses, burrow-weed, threeawn, bush muhly, grama and annuals. Precipitation is 10 to 12 inches. Mean annual air temperature is 60° to 70° F. and the frost free period is 170 to 300 days.

Typically the surface layer is brown loam. It has a surface crust, has week granular to fine subangular blocky structure, and is about 5 inches thick. The subsoil is reddish brown subangular blocky sandy loam or light sandy clay loam. Reaction is neutral or mildly alkaline and a small amount of lime may occur at depths below 25 inches.

The soil is moderately permeable. Water supplying capacity is 4 to 6 inches. Effective rooting depth is 45 inches and more.

These soils are used as range.

A representative profile is located 650 feet easterly along fence from the NW corner of plot #2 of the Santa Rita Validation site.

Sonoita sandy loam
(Color for dry soil unless otherwise noted)

A1 0-5" -- Brown (7.5YR 5/4) sandy loam, brown (7.5YR 4/4) moist; weak thick platy to weak fine subangular blocky structure; hard, very friable; common fine and medium roots, many fine interstitial pores; neutral (pH 6.8) abrupt wavy boundary.

B1t 5-18" -- Reddish brown (5YR 4/4) sandy loam; weak medium and fine subangular blocky; slightly sticky; common fine and medium roots; many fine interstitial and few tubular pores; few thin clay films on sand grains and in tubular pores; few fine gravels; neutral (pH 6.8), clear wavy boundary.

B22t 13-28" -- Reddish brown (7.5YR 4/4) heavy sandy loam; dark reddish brown (7.5YR 3/4) moist; weak medium and fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and medium roots, few tubular and common fine and medium interstitial pores; common thin clay films on ped faces and in tubular pores; few fine gravels; mildly alkaline (pH 7.5) clear wavy boundary.

B3tca 28-45" -- Light brown (7.5YR 6/4) light sandy clay loam; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, plastic; few medium and fine roots; common fine interstitial pores; very few clay films on ped faces; few fine gravels; strongly effervescent; common faint soft lime segregations; mildly alkaline (pH 7.8).

Sonoita sandy loam, 1 to 3 percent slopes S-1

This soil is on alluvial fans. Bodies are large, 40 to more than 100 acres in size and occur between drainageways. The soil has profile described as representative for the series. Inclusions of Valencia sandy loam make up 5 to 10 percent of this unit and occur as narrow bodies between mapped bodies of Sonoita and Anthony sandy loams.

Sonoita sandy loam, eroded, 3 to 5% slopes S2

This soil occurs on alluvial fans. Bodies are 5 to 50 acres and more in size. The profile of this soil is the same as the profile described under the series heading except it has been truncated, has more surface gravel and cobble, no or a very thin surface layer that is developing from the subsoil and has lime at shallower depth. The drainageways are more deeply entrenched, have active headcuts and adjacent areas of sheet erosion cutting back into included areas of Sonoita sandy loam, 1 to 3 percent slopes that occur as narrow ridge topes and make up 30 to 50 percent of this unit. Topography is undulating with short 3 to 5 percent slopes. Vegetation is sparse desert shrub and cacti and only scattered grass plants.

Sonoita sandy loam, eroded, 5 to 8% slopes S3

This unit occurs on alluvial fans adjacent to the more deeply entrenched drainageways. Bodies are long and narrow on 5 to 20 acres in size. The profile of this soil is the same as that described under the series except it has been truncated, has more surface gravel and cobble, no or a very thin surface horizon that is developing the subsoil and has lime at shallower depths. Topography is moderately sloping or rolling with 5 to 8 percent slopes. Vegetation is sparse desert shrub on cacti with little grass except on area in the NW part of plot #2 that has stabilized and revegetated with grass.

Gravelly Alluvial Land A3

This land type consists of unconsolidated stratified gravelly and sandy recently deposited alluvium along stream channels. It is subject to overflow and change by shifting stream channels. Topography is undulating and slopes are 1 to 3 percent. Vegetation is desert shrub, grass and cacti, ironwood, mesquite, palo verde, barrel cacti, threeawn, bush muhly and annual forbs and grasses are common. Precipitation is 10 to 12 inches. Mean annual air temperature is 60 to 70°F. and the frost free period is 170 to 300 days.

Samples representative of the mapping units of the Santa Rita Site were calibrated, processed and are presently being analyzed.

Soil Microorganisms

Studies involving soil microorganisms were initiated in mid-February of this year. In keeping with the funds available, two semi-independent investigations were initiated, one involving nitrogen fixation by leguminous plants and algal crusts, the other to estimate the microbial biomass content of desert soil. Both investigations used material from the "destruct" area at the Santa Rita Site.

Nitrogen Fixation Studies. The method chosen for routine examination of possible nitrogen fixing systems was based on the now commonly accepted acetylene-reduction test. Acetylene is a competitive inhibitor of the nitrogen fixing enzyme, nitrogenase. Nitrogenase has been found to be the only nitrogen reducing enzyme in all the biological nitrogen-fixing systems so far examined. Ethylene, product of the reduction of acetylene, is quantitatively detected by a gas chromatographic procedure. Since very small amounts of ethylene can be detected using a hydrogen flame detector, low rates of nitrogen fixation can be detected with ease. This seems a highly appropriate technique for the detection of low levels of nitrogen fixation by desert legumes and algal crusts.

The months of March, April and May were devoted to developing the methodology required for successful detection of nitrogen fixation. The conditions ultimately selected, including details of the gas chromatographic procedure, are as follows:

1. Root-nodules or samples of algal crusts were placed in gas-tight containers, flushed with a gas mixture containing 20% oxygen, 0.04% carbon dioxide and 80% argon. Finally, acetylene to 5% (gas phase) was added.

2. Algal crusts were incubated at 38°C under 1.1 lumens per $c,^2$ illumination; nodules were incubated in the dark at 22°C.

3. The gas chromatograph column was 2.7 m long by 3 mm I.D. aluminum tubing filled with 90-100 mesh Poropak-R. The carrier gas was argon flowing at 50 ml/min; normal column operating temperature was 100°C. Ethylene had a retention time of 2 min 25 sec and acetylene, 2 min 45 sec.

4. Calculation of nitrogen fixation was based on: 3 moles of ethylene produced = one mole of N_2 fixed.

Symbiotic nitrogen fixation. The first nodule study was done on plant material from greenhouse-reared legumes and legumes reared in the open at the Plant Materials Center, Soil Conservation Service, Tucson. Except for material from an Astragalus sp., none of the material would be found at the Santa Rita Site. Table 23 gives ethylene formation by root nodules from a variety of leguminous plants.

Table 23. Ethylene formation by root nodules of leguminous plants.

Plant	mμ moles C_2H_4/mg nodules/24 hr	Comments and Source
Glycine max (soybean)	220	Published data
Medicago sativa (alfalfa)	161	Published data
Alnus species (alder)	24	Published data
Astragalus species	107	Greenhouse experiment
Calliandra eriophylla (fairy-duster)	36	Greenhouse experiment
Lotus tennuis (narrow leaf birds foot trefoil)	750	Plant Material Center-Tucson
Astragalus cicer (cicer milk vetch)	69	Plant Material Center-Tucson
Coronilla varia (crown vetch)	55	Plant Material Center-Tucson

A search was made for native-legumes growing under natural conditions and which had root-nodules. This included mesquite (Prosopis juliflora) which is probably the dominant legume at the Santa Rita Site. The on-site legumes, mesquite and Astragalus spp., and off-site legumes of the genera Krameria, Coursetia, Lupinus and Cassia were examined and found, at least at the time of sampling, to be devoid of root nodules.

The apparent scarcity of root-nodules on the desert legumes examined may reflect the preceding dry winter and early spring. However, an examination of both Astragalus spp., and mesquite in August (after the onset of summer rains) also failed to reveal root-nodules even though there was noticeable growth of new root tissue. It was considered that any attempt at an estimation of nitrogen fixation

by nodulated legumes would be thwarted by difficulties in procuring root nodules.

Nitrogen fixation by algal crusts. Preliminary experiments determined that samples of algal crust, once moistened and allowed to incubate in the light, were capable of nitrogen fixation. Put on a more quantitative basis, 18 cm^2-portions of intact algal crusts were incubated in the presence of acetylene. Both the moistened crusts incubated in the dark, and dry crusts incubated in the light failed to produce detectable levels of ethylene. Moistened algal crusts incubated in the light had the following characteristics:

1. Detectable levels of ethylene were found 3 hours after the algal crusts were moistened and incubated in the presence of acetylene.

2. Based on the first hour of incubation (crusts were premoistened the night before) algal crusts produced 78 ± 5 nanomoles of ethylene per cm^2 of crust per hour.

3. Moistened crusts when first incubated in the light for at least a 4 hour period, continued to produce ethylene (in the presence of acetylene) for at least one hour after being placed in total darkness.

Table 24 summarizes these results.

Table 24. Nitrogen fixation capability of algal crusts.

Treatment	Acetylene added	Ethylene produced
1. Dry algal crust	-	-
2. Dry algal crust	+	-
3. Moist algal crust incubated in the dark	+	-
4. Moist algal crust incubated in the light	+	+
5. Moist algal crust incubated in the light	-	-

The samples were taken at Santa Rita on August 15, 1970. Based on these results, it is calculated that algal crusts have the capacity of fixing 26 nanomoles of N_2, or 0.7 µg or N, per cm^2 per hour.

In an attempt to relate the above results to field conditions, it was first necessary to have some idea of the percent surface area of the study site covered with algal crusts. Belt-transects (50xlm) were conducted at random over one hectare and mean value of 4% (0.0% to 17.5%) was obtained. It is estimated that following a rainfall, the algal crusts of one hectare of desert grassland may be capable of fixing nitrogen (N) at a rate approximating 3 to 4 grams/hour. Based on forty years of meteorological records for the area, algal crusts may be moist enough for an average of 168 days in every year for nitrogen fixation to occur. Assuming an average day-length of 12 hours, nitrogen fixation by algal crusts alone may total 6 kg of N per hectare per year.

Microbial Biomass Studies: Just as in other Biomes, soil of the Desert Biome must be expected to have a "normal" complement of soil microorganisms. Estimations of the microbial content of soil are of intrinsic value and partly give insight into the extent and possible activities of a minute but living portion of the total soil organic matter. In semi-arid soils (usually low in organic matter), the microbial content probably assumes greater significance than for other soils since not only are microorganisms involved in the normal soil transformation of inorganic and organic matter but are a significant portion of the total organic matter. Inasmuch as all cells experience turnover of their constituent molecules, the "live" portion of organic matter in semi-arid soils probably influences the dynamic nature of organic matter to a significant degree. Part of this influence is probably manifest as productivity in the form of microbial tissues. How important microbial productivity is to an ecosystem (in terms of energy-flow, nitrogen-flow and so on) has yet to be determined. The first stage of such an assessment is an estimation of the microbial biomass content of the soil in question.

Without going into an appraisal of methods currently being used it is probably sufficient to say that with a few exceptions (including the following) most methods used in determining microbial biomass content of soil are inadequate. The method used here is based on the extraction of ATP from whole-soil and relating the ATP to microbial biomass.

Briefly, the method is as follows:

1. ATP is extracted from soil using a butanol/octanol procedure; the ATP is taken up in arsenate buffer. In calcareous soils, weakly polar-solvents are preferred dur to Ca^{2+}-interference of ATP-assay.

2. Although minute amounts of ATP (from only live microbial cells) are extracted, the ATP can be accurately assayed using the luciferin-luciferase reaction during which light is emitted as one product of the biological reaction.

3. An ATP-containing soil extract is injected into a small amount of firefly "cocktail" and the light emitted measured in a scintillation spectrometer.

4. From figures given in the literature and from our own experiments, bacteria, actinomycetes, algae, fungi and even nematodes seem to average 200 µg ATP per gram of live biomass (range 40 µg to 1000 µg).

Although the quantitation of extraction of microbial ATP from soil is not fully determined, first indications are that 80% of total ATP (theoretical) is made available for assay.

A preliminary microbial analysis of two profiles on Sonoita sandy loan (to a depth of 100 cm) was conducted on October 15, 1970. One profile was grass covered while one was not. The results are given in Table 25.

Table 25. Microbial biomass.

	Grass Cover		No Grass Cover	
Soil depth	Microbial biomass	Soil organic matter	Microbial biomass	Soil organic matter
cm	µg/g soil	%	µg/g soil	%
0	65	0.7	700	0.5
40	600	0.5	170	0.2
60	500	0.6	11	0.3
100	95	NA	5	trace

NA - not attempted

Meteorological Data

During 1970, temperature, relative humidity and precipitation were measured using standard recording gauges. Rainfall is shown in Table 26; daily temperatures and relative humidity are illustrated in Figures 7 and 8, respectively.

Table 26. Rainfall amount and storm duration at Santa Rita.

Date	Storm Duration	Rainfall
July 11, 1970	:30	.18
July 20, 1970	1:40	.85
July 20-21, 1970	6:03	.11
July 25-26, 1970	9:47	.48
July 26, 1970	1:35	.85
July 27, 1970	1:19	.17
Aug. 1-2, 1970	5:30	.48
Aug. 14-15, 1970	7:25	.48
Sept. 3, 1970	:58	.40
Sept. 3-4, 1970	6:20	.37
Sept. 4, 1970	3:48	.93
Sept. 4, 1970	2:45	.79
Oct. 10, 1970	--	.14

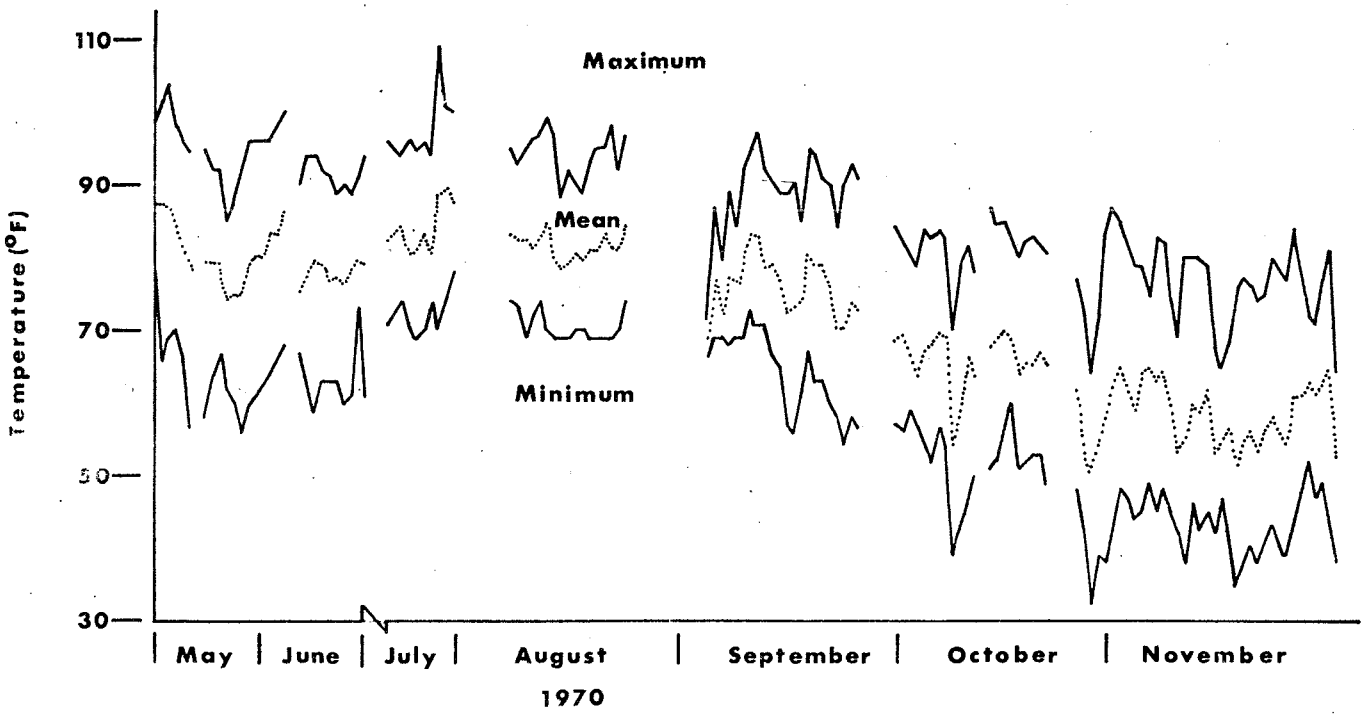
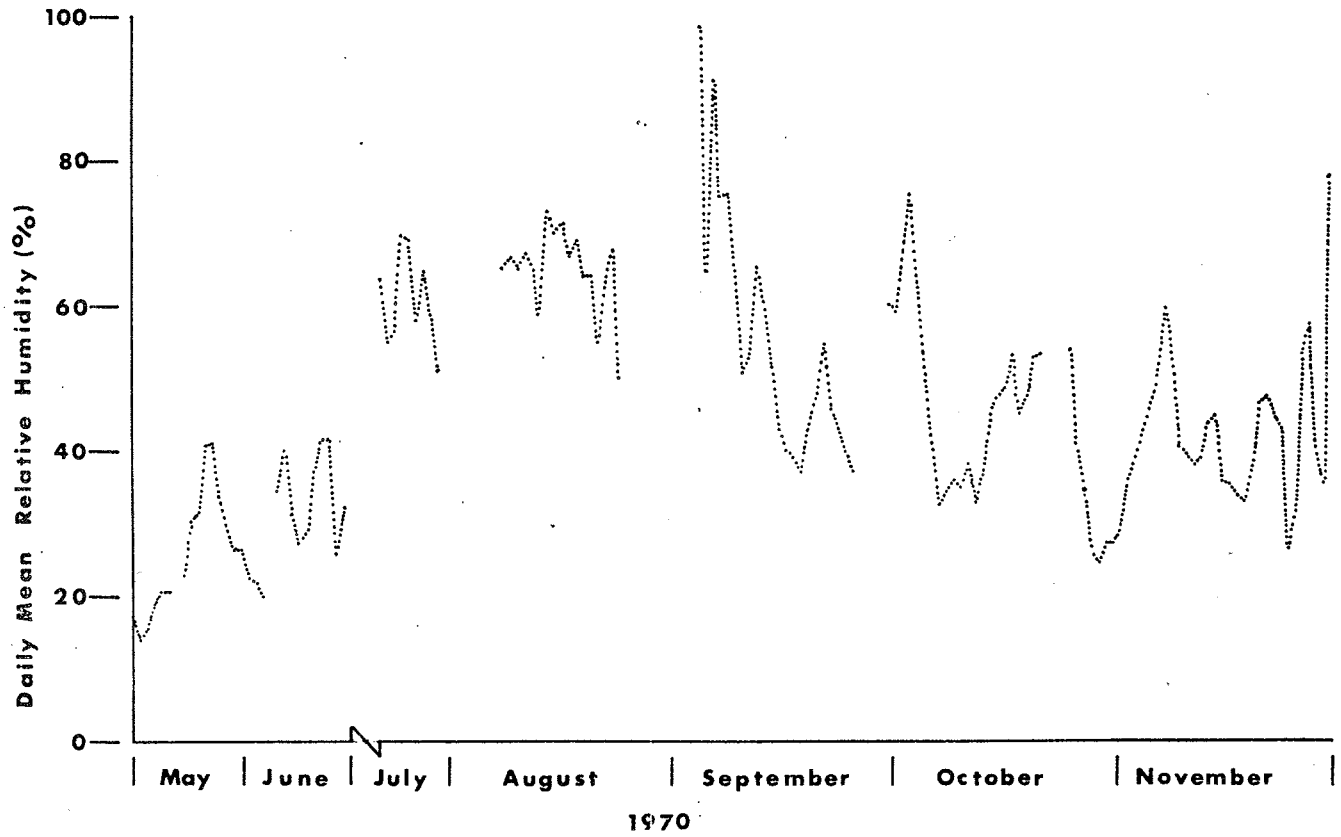


Figure 7. Mean, maximum, and minimum daily temperatures for Santa Rita site.



Meteorological Station:

A meteorological station with a complete set of sensors as specified in the Research Design has been installed on the Santa Rita site. Data collection from the station is controlled remotely and automatically from a central station located on campus. The central station hardware includes a small 8 K computer, high speed paper tape recorder, TTY and magnetic tape transport.

The entire facility is one of the most sophisticated data aquisition systems in existence. It allows complete flexibility in data collection, reduction and storage. Human error and effort is reduced to a minimum and costs of adding additional field stations are low. Considerable effort has gone into its development. A description of the installation and the associated software follows.

DATA ACQUISITION SYSTEM

The BIOME computer controlled ELEP system consists of a central station and up to 3 remote stations with VHF radio transmission, and telephone lines, used as the communications medium. The VHF radio transmission is FM with four-state tone modulation for data and auxiliary voice modulation for maintenance.

The data formats are divided into three groups: Central station to remote station address, hereafter referred to as "Address", remote station to central station data, hereafter referred to as "Data", and remote station to central station precipitation data, hereafter referred to as "Precip Data".

The central station computer generates remote station addresses, check all addresses and incoming data for message validity, and logs all addresses and data. Selected channels may be logged. The computer stores all data as received on the magnetic tape unit; converts the data from these channels into engineering terms, e.g., wind direction in degrees, wind velocity in miles per hour, air temperature in degrees "C", etc; restores the data on magnetic tape; and prints the formatted data on the TTY. Data conversion occurs at two specified times (by the user) or when the raw data file on magnetic tape is filled (whichever occurs first). Data conversion also takes place by manual command.

Computer Control Panel

The computer control panel consists of sixteen sense switches which have pre-assigned functions for preprogrammed computer operation. Function assignments and descriptions are as follows:

Interrogation Interval					Sta. Sel.			Rem	Cal	Prnt	Srch	Enter Date		Proc Tape	New Cmd
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	3 Min	15 Min	30 Min	60 Min	1	2	3	10%	90%						

Sense Switch Functions

1. Manual Interrogation: The computer generates address codes to interrogate all selected remote stations. Data is stored on magnetic tape and printed on the TTY if sense switch 10 is depressed.

2. 3 minute, 15 minute, 30 minute, and 60 minute interrogations: All selected remote stations may be interrogated at the preselected time interval. (Time intervals are additive.)

3. Station Select 1, 2 and 3: Sequential interrogations are performed on the stations selected by these switches.

4. Remote Cal: These switches select a 10% or 90% of full scale calibration reading in the analog channels of any stations selected by the Station Select Switches.

5. Print: Formats and prints data during each automatic interrogation.

6. Search: Enters starting date, time and number of records for records to be searched. Data is converted and printed out on TTY.

7. Enter Date: Enters times at which computer will convert raw data into engineering terms.

8. Process Tape: The raw data, stored on magnetic tape, is processed, formatted, restored

9. New Command: Halts the computer so that new commands can be entered on the sense switches. Only required for switches 1 thru 13.

10. Spare: Switch 13 is a spare, for future use.

Computer Timing

Incorporated in the central station is a master clock for presentation of real time data to the computer. This data is a 20 bit BCD format for hours, minutes, and seconds presented on 20 parallel lines. Time update occurs once each second in coincidence with a separate interrupt signal presented to the computer. For presentation of month, day, and year, the computer is capable of receiving operator instructions via teletype keyboard for current date, and automatically updates when the time code reaches 23 hours, 59 minutes, and 59 seconds. The central station master clock has provisions for battery operation for a four-hour period to provide for power failure.

Computer Input/Output Signals

Data format for "Address", "Data", and "Precip Data" has been established and these data will be sent to, or received from, the computer via the following input-output signals.

1. Input bus bit 0 - Sync bit. This line goes low for the first 15 ms of the first bit in each word in the message.

2. Input bus bit 1 - Data "1". This line goes low for the first 15 ms of the bit period if the bit is to be a data "1".

3. Input bus bit 2 = Clock. This line goes low to define each data read time to the computer. When the clock bit occurs, the computer shall sample data, and wait until the clock bit has disappeared and reoccurs for the next sample, i.e.

Clock 1	Computer sample 1st bit
Clock 2	No sample
Clock 1	Computer sample 2nd bit
etc.	

4. Input buses bits 3 through 22 = Time Code Data. These lines will present the BCD time code to the computer.

5. Input FLAG 1 = Precipitation FLAG. This line goes low when precipitation data is received from the remote stations.

6. Input FLAG 2 = Time Code FLAG. This line goes low once each second when the central station master clock updates.

7. Output bus bit 0 = Time On Transmitter. This line must be low 2 seconds before output of address and remain low during output of the address.

8. Output bus bit 1 = Data "1". This line goes low for the first 15 ms of each 20 ms bit period if the bit is to be a "1".

9. Output bus bit 2 = Data "0". This line goes low for the first 15 ms of each 20 ms bit period if the bit is to be a "0".

10. Output bus bit 3 = Turn On TTY. This line must be low 2 seconds before output of data and remain low during output of data.

11. Output bus bit 4 = Turn On Mag Tape. This line goes low to turn on the mag tape transport.

12. Output bus bit 5 = "SYNC". This line goes low for the first 15 ms of each 20 ms bit period if the bit is to be a "SYNC" bit. A sync bit is generated followed by the 12 information bits (calibration and address) which are followed by a sync bit.

Remote Station Calibration

The computer generated remote station address contains four control bits. These specific bits are used in this system to command a self-calibration mode in all of the station's analog

Control

1. 0 0 0 0 0 0/ = Normal station interrogation

2. 1 0 0 1/ = Calibration, 10% full scale

3. 1 0 1 0/ = Calibration, 90% full scale

Data Computations

1. Wind Direction

Wind direction is derived from the four wind direction words, N, S, E, W. The computation is as follows:

Find the algebraic sum of the N, S, (A) direction components and the E, W, (B) direction components.

Find the arc tangent of B/A. This number will be an angle between 0° and 45°.

Determine the angle in the 360° circle by the following computation:

If; N > E Print the arc tangent B/A
N < E Subtract arc tangent B/A from 90° and print difference.

S < E Add arc tangent B/A to 90° and print sum
S > E Subtract arc tangent B/A from 180° and print difference.

S > W Add arc tangent B/A to 180° and print sum
S < W Subtract arc tangent B/A from 270° and print difference.

N < W Add arc tangent B/A to 270° and print sum
N > W Subtract arc tangent B/A from 360° and print difference.

2. Total Wind

Each count received represents 528 ft. of wind. To compute, multiply the data value times 528 and divide the resultant number by the elapsed time in minutes since the last scan. The final data is in tenths of miles/hour.

3. Air Temperature

Convert data value to decimal form and subtract 400 to get temperature in tenths of degrees C. Final printout should be in tenths of degrees C.

4. Soil Temperature

Same as air temperature.

5. Soil Surface Temperature

Conversion scale not available at this time. It is anticipated that two data channels will be used for this measurement. One channel will contain the uncorrected data value, and the other channel will contain the correction factor. The computer will be required to apply the correction factor and convert the data for print out.

6. Relative Humidity

Received data reads directly in tenths of a percent. Print out is to the nearest whole percentage.

7. Pyranometers

Received data is divided by 500 to scale for a range of 0 to +2 Langleys. Print out is to the nearest tenth of one Langley.

8. Net Radiation

Received data for 250 subtracted and the difference divided by 500 to scale for a range of -.5 to +1.5 Langleys. Print out is to the nearest tenth of one Langley, and has the appropriate polarity sign.

SOFTWARE SPECIFICATIONS

The software consists of the following seven programs:

1. Initiator Program (INIT)
2. Data Acquisition Program (DACQ)
3. Data Search Program (DATAS)
4. Data Process Program (DPROC)
5. Print Program (PRINT)
6. Precipitation Interrupt Program (RAIN)
7. Executive (EXEC)

Initiator Program

The Initiator Program loads in the switch sense functions, sets up the proper commands and linkages to perform the selected functions, and requests the date and data conversion times. After initiation is complete the program automatically loads and gives control to the "Run and New Command Loop" program.

Data Acquisition Program

The data acquisition program resides in high core and operates under the interrupt system. Upon receipt of a clock service request, the data acquisition program assumes control, address the selected remote station, tests for valid data, records the data on magnetic tape, and then returns control to the program which was running before the interrupt occurred. All working registers return to the program without loss of data in either the programming running at the time of interrupt or the data acquisition program.

Station interrogation is initiated by a clock interrupt, or by a manual interrogation command. A clock interrupt occurs once each second. The computer will update the time interrogation counter (preselected interrogation time intervals set by the sense switches) and interrogate the remote station(s) if the interval has expired.

The interrogation sequence is as follows:

1. The computer reads the time of day from the central station master clock and stores it and the date as the first data items in the core data buffer.
2. Generates the address and command code of the first selected station to be interrogated. If the station is energized it will transmit data back according to the attached data format. The computer will then check data validity. If verification is positive, the computer stores the data as the next item in the core data buffer and generates the address code of the next selected station.
3. The computer checks data validity by checking:
   A. Sync bit at beginning of each word.
   B. Correct parity bit at end of each word.
   C. Correct number of bit periods followed by a minimum of 60 ms gap length.
   D. Bit by bit comparison of the first 18 bits of each word to the last 18 bits.
4. If verification of any word is negative, the computer stores the data that is most closely correct and indicates correct/incorrect data by the code shown below:
   A. ϕ = All validity checks positive.
   B. 1 = First 18 bits selected, second 18 bits incorrect.
   C. 2 = Second 18 bits selected, first 18 bits incorrect.

E. 4 = All validity checks positive except bit by bit comparison, first 18 bits selected.

These codes are stored in the data buffer core preceding each data word.

5. If after step four, one or more of the words has all validity checks negative, the TTY is turned on and type date, time, station #, and the message "Validity Neg".

6. If no data is received within 4 seconds after the address has been transmitted, regenerated the address and command codes. If data is then received, steps two through five are followed.

7. If after step six, no data is received, all zeros are stored in the data buffer after the station I.D. word, TTY is turned on and date, time and station #, and the message "No Response" is typed.

8. After step seven, address code is generated of the next selected station to be interrogated. Sequentially all stations in the system are interrogated. Steps two through seven are repeated as required.

9. After all stations have been interrogated, the magnetic tape is positioned to the end of file three and the entire data buffer is stored as one magnetic data record. An end of file mark is written, to reclose file three, and rewind the tape deck.

10. Control is returned to the program running prior to interrupt.

Data Search Program

A search process is initiated when sense switch 11 is depressed during a new command period. Depressing this switch allows entry of a start date and time, and the number of records to be searched. The selected data is converted to engineering terms and printed out on the TTY.

Data Process Program

The data process program at specified times (twice a day or when the magnetic tape unit's file three is filled) automatically retrieves the data from file three of the magnetic tape. The computer then converts the data into engineering terms, e.g., wind direction in degrees, wind velocity in miles per hour, air temperature in degrees "C", etc. The converted data is then restored on the magnetic tape unit, file five, and printed on the TTY.

The data process program is also manually initiated whenever sense switch 14 is depressed.

Print Program

Whenever the data process program is initiated, the raw data is converted into engineering terms and printed out on the TTY. The print out format is as follows:

	Soil Temp Deg C	Air Temp Deg C	RH %	PYR Lang	Wind Speed MPH	Wind Dir Deg	Soil Surt Deg C	Net Rad Lang
STA #1	YXX.X	*2YXX.X	XX	X.X	XX.X	XXX	YXX.X	YX.X
	YXX.X	YXX.X	XX	X.X	XX.X			
11/20/70	*1YXX.X	YXX.X	XX	X.X	*3---	**BAT 12.5**		
	YXX.X							
14:22	YXX.X							
	YXX.X							
STA #2	YXX.X	YXX.X	XX	X.X	XX.X	XXX	YXX.X	YX.X
	*3.....	YXX.X	XX	X.X	XX.X			
11/20/70	YXX.X	YXX.X	XX	X.X	XX.X	**BAT 12.4**		
	YXX.X							
14:22	YXX.X							
	YXX.X							
STA #1	YXX.X	YXX.X	XX	X.X	XX.X	XXX	YXX.X	YX.X
	YXX.X	YXX.X	XX	X.X	XX.X			
11/20/70	YXX.X	YXX.X	XX	X.X	XX.X	**BAT 12.5**		
	YXX.X							
15:22	YXX.X							
	YXX.X							

Y = Positive = Blank
Negative = -

During an automatic data process routine, after all the data from File three has been converted and listed, the precipitation data is listed on the TTY. The precipitation printout format it as follows:

```
10/21/70
14:45
1006      1004      1002      3002      3001
14:46                                                          Station I.D.
2002      2001      1004      1003      1002      3001      2001      3004
14:47
1006                                                           Sensor I.D.

10/21/70
16:22
3002      3004

10/25/70
11:31
1004      1005
11:35
2006      2001      2003      3005
```

Precipitation Interrupt Program

Once the system has been interrupted by a precipitation signal, the precipitation routine takes priority and holds up the computer for precipitation processing. This hold up continues until 5 minutes has elapsed without a precipitation signal, at which time it will revert to the normal program.

If clock service request occurs while the computer is in the precipitation routine, a flag is set and the clock service request processed as soon as the precipitation routine releases the computer. If more than one clock service request is generated during the precipitate routine, only one will be processed.

Each time a precipate interrupt occurs the date, time (in hours and minutes only), station I.D. and sensor I.D. is stored.

While normally the precipitate interrupt has priority, if the computer is processing a clock service request, the precipitate interrupt will be ignored until the clock service routine has been completed.

The computer shall receive a precipitation interrupt signal and serial data which identifies the station I.D. and precipitation sensor at that station. The serial data will be sent twice for computer verification as outlined.

Executive

This program loads the switch sense commands. These commands will be used to initiate all data acquisition functions per page seven of the BIOME COMPUTER CONTROLLED ELEP SYSTEM specifications. The program will then wait in a loop until either a new command is entered from the sense switches or a service request interrupt is received from the central station.

Thus, this program serves two purposes:

1. As a communications link between the user and the computer.

2. As a dummy program to maintain the interrupt capability of the system if a user's program is not being executed.

The following software is provided in addition to the seven data acquisition programs.

1. A subroutine to be added to user written programs which automatically loads and returns control to the data acquisition software upon completion of the user's program. (EXIT)

2. A configure BCS tape to allow the user to produce absolute tapes from programs written in FORTRAN, ALGOL or Assembly languages. User written programs may then be added to the system and executed without interferring with the data acquisition process.

3. A configured SIO TAPE.

4. Configured FORTRAN Compiler.
5. Configured ALGOL Compiler.
6. Configured Assembler.
7. Configured BASIC Compiler.
8. All standard HP supplied software.

MAGNETIC TAPE SYSTEM

The magnetic tape will be divided into seven files.

1. File 1 contains the four data acquisition programs and any user written absolute programs.
2. File 2 is a dummy file to permit expansion of File 1 by the user.
3. File 3 is the "raw" data file.
4. File 4 is a dummy file to permit expansion of File 3.
5. File 5 is the formatted data file.
6. File 6 is a dummy file to permit expansion of File 5.
7. File 7 is the precipitation data file.

DISCUSSION

Invertebrates

Infrared Photography: Eric Erickson spent some time early in the study assessing the possibilities of the use of infrared photography. The most important thing he discovered was that it was very easy to distinguish soil recently added to the surface of nest mounds of ants from that which had been there for some time. The photographs used were 34 mm. color slides. Best results were obtained with slight underexposure; slides which show most of the soil surface and dry grass as blue-green, show the active nest of Veromessor pergandei as yellowish green. The reason for the difference in soil color has not been investigated. IR photography has been used extensively for distinguishing living from moribund or dead plant tissue, and even to distinguish plant species. Erickson's preliminary studies indicate that it may be useful for keeping track of the activity of any animal that brings soil to the surface from below. Among the invertebrates, some spiders and many solitary wasps, as well as ants, regularly add fresh soil to the surface in the course of their activities. Rodents and other mammals also do so. If IR photography provides a rapid and easy way to distinguish recently added soil from old soil, it should be useful in keeping track of activity.

Termite studies. Several approaches for gathering information on termite distribution, activity and biology have been devised and field tested. Three have proven to be practical and were used for the fall census on the Santa Rita site.

The first method involves quick visual examination of surface dead wood and other plant material in small quadrats spaced 50 ft. apart on transects across the study areas. It provides a fairly rapid survey of termite activity on dead grass, annuals, woody perennials, miscellaneous wood, cow chips and under stones. The fact that specific termites have attacked a particular host can usually be determined whether the termites are present or not. The species detected by this method so far are all subterranean: Heterotermes aureus, Gnathamitermes perplexus, Tenuirostritermes tenuirostris and Amitermes, probably wheeleri.

The other two methods were designed to relate termite distribution to available dead wood, both on the ground and in trees. The second method is considerably more time consuming but generates more information. All of the superficial dead wood within 50-m^2 circles is plotted, measured and weighed. Other dead plant material has not been considered. Each item containing a termite colony or foraging group is bagged, and the termites later extracted for sorting, counting, and weighing. Foraging groups of the following termites have been taken in this way: one dry-wood species, Paraneotermes simplicicornis, and three subterranean species, Heterotermes aureus, Gnathamitermes perplexus, and Amitermes wheeleri.

The third procedure involves plotting, removing, measuring, and weighing nearly all of the dead wood (branches ca. 2 cm. diam. and larger) on individual trees. Termite colonies or foraging groups are extracted later for sorting, counting and weighing. Several representatives of Acacia Greggii, Cercidium floridum, and Prosopis juliflora have been examined. Dead cholla cacti (Opuntia sp.) are examined under the second procedure. The following termites have been found in standing dead wood: the dry-wood species, Pterotermes occidentis (complete colonies) and Paraneotermes simplicicornis, and the subterranean species Heterotermes aureus (foraging groups).

Activity surveys will probably be continued at various times of the day and night and, perhaps as often as once a month, through at least one year. Superficial and standing dead wood on more species of individual trees will be sampled several times during the next year.

These methods have provided information pertinent to both the validation and process studies. Although the data have not yet been analyzed, a few general statements can be made on the basis of the field work to date. Among the dry-wood termites, Pterotermes is probably restricted to the larger dead branches on Cercidium, while Paraneotermes attacks dead wood, on or in the ground, of several species including Acacia greggii, Cercidium floridum and one or more species of cholla (Opuntia). Neither termite appears to be very abundant although much more dead wood needs to be examined.

Of the subterranean species, foraging groups of Gnathamitermes are extremely active and common: during the summer and fall on the Santa Rita Site hardly a square yard could be found without some evidence of its activity. It scrapes dead cellulose from the surfaces of nearly all plant materials including grasses, annuals, woody perennials, miscellaneous wood, seed pods, and a variety of living plants. Although it tunnels within cow chips, it does not bore into solid wood. Heterotermes is also common, and foraging groups must reduce large amounts of wood of at least the following plants: Prosopis, Cercidium, Acacia, Celtis pallida, several species of Opuntia, and undoubtedly several others. A few foraging groups of Amitermes wheeleri have been found attacking buried stumps of Acacia and one or more species of Opuntia. A practical method of sampling subterranean dead wood might well show it to be much more common. A few small groups of Tenuirostritermes have been found on and near the Santa Rita Site. It forages on the soil surface, probably in the daytime, for grass and tender vegetation, both living and dead. Field experiments concerned with food preferences and perhaps even food

consumption can probably be used to advantage in connection with these types of simple data collection.

Detailed data on absolute colony size and composition are avaialble for several species of dry-wood termite species in the Tucson Basin. Colonies of Pterotermes contain up to 3000 individuals, and 10 to 30% of a colony, depending on its size, may transform into winged formes, or alates, which fly from the colony from July into September each year. Foraging groups of Paraneotermes may contain at least 2000 individuals, and somewhat smaller groups have produced about 15% alates which fly between May and September.

No data are available on absolute colony size and composition, or on the size of foraging territories, for any of the subterranean species. Foraging groups of Heterotermes range from a few to over 10,000 individuals. Mature colony size may be expected to reach several tens of thousands. On the basis of a few reports on related groups, a colony might produce between 5 and 10% alates between June and September. Foraging groups of Gnathamitermes have been found containing from a few to over 1000 individuals. Colony size might reach between 10 and 20 thousand, with an annual crop of alates of 5% or less flying between June and September. Foraging groups of somewhat over 100 have been found of Amitermes wheeleri. Colonies might contain a few thousand individuals and produce no more than 5% alates during July and August each year. Tenuirostritermes colonies are probably comparable to those of Amitermes wheeleri, or slightly larger. It should be possible to refine these estimates during the next year or two, perhaps by digging or, more likely, by a combination of indirect methods. Only a few random galleries, probably of Gnathamitermes, were found in three 14-ft-deep trenches dug by another group in the destructive sampling area earlier this year.

More information was collected in Tucson on the flight patterns of 13 species of termites, including 5 of the 6 species thus far found on the Santa Rita Site. This data collection, which has been continuing for the last 15 years, includes notes on the number and size of flights together with temperature, relative humidity, evaporation, rainfall, and time of day. Observations have also been made on two dry-wood species in large saran screen cages. This information should provide a good basis for predicting the availability of the alates as food for a variety of predators which include many arthropods as well as members of all major vertebrate groups. Field observations and stomach-content analyses will be needed to complete this picture.

Where a rather high percentage of the bits of plant material on the surface shows evidence of termite attack, it is striking that there should be such an accumulation of dead cellulose which is not, and may never be, used by them. This is a problem which can be more hopefully approached by a multidisciplinary team, such as the Desert Biome group, than by a few lone individuals. It is undoubtedly very complex and certainly involves several factors which limit termite feeding or actually prevent them from utilizing more of this potential food. These factors must include temperature, moisture content of both wood and soil, and the presence of absence of fungi and feeding inhibitors or deterrents within the food materials. Production rates of dead plant materials will be needed for any approach to the problem.

Vegetation

Experience with biomass determinations on Prosopis juliflora at the Santa Rita site indicates that a tremendous amount of time is required to sample even one individual when the collections are made by organ groups. Therefore, all biomass sampling will be done on a time available basis following the collections of other data. Biomass data on herbaceous vegetation will be collected on a total weight basis per plant. Biomass sampling will be conducted in designated destructive sampling areas at both locations and will be projected into the treatment areas. Herbaceous biomass determinations will be conducted at two seasons if possible, following winter growth and following summer growth.

The following work will be conducted during 1971 on the validation sites:

Santa Rita

1. Collection of biomass data on Opuntia fulgida for the categories of: fruiting structures, branching joints, and main trunks.

2. Collection of data for herbaceous vegetation to include for each species an estimate of density, cover, height and above ground biomass. Samples will be taken using nested quadrats on a stratified random basis.

Silverbell

1. The area will be typed into major communities for stratification of sampling.

2. Flight planning for aerial photography missions which includes layout and marking of flight lines location and marking of photographic transects prior to each flight.

3. From the photography, estimates of density and cover will be made for major woody species and cacti. These samples will be ground checked as required.

4. Collection of data for herbaceous vegetation to include for each species an estimate of density, cover, height and above-ground biomass. Samples will be taken using nested quadrats on a stratified random basis.

Soils

Harith Loqa has collected samples of Anthony from under mesquite and paloverde trees in the destructive sampling area near the Santa Rita site. He will also be collecting samples of Sonoita under trees of these species. To determine the influence of different species of desert plants on the chemical properties of soils is part of Mr. Loqa's Ph.D. dissertation.

Plans for 1971. A high intensity detailed soil survey will be made of the new Silverbell site. Soil characterization samples will be collected that are representative of the soils of the new site. Characterization analyses will be performed on these samples together with those collected from the Santa Rita site. Mr. Loqa will continue his study of the influence of paloverde and mesquite on the chemical properties of the Anthony and Sonoita soils. He may also expand his study to include one or more soils from the new Silver Bell site.